Chapter 6 - Flow Control Design

This chapter presents methods, criteria, and details for design of flow control facilities and dispersion controls, including onsite stormwater management. *Flow control facilities* are detention or infiltration facilities engineered to meet the flow control standards specified in Core Requirement #7 and the onsite stormwater management standards in Core Requirement #5.

Section 6.1, *On-Site Stormwater Management*, describes *On-site Controls*, which are techniques and design methods intended to decrease the hydrologic impacts of new development, also referred to as *Low-Impact Development* (LID).

A subset of On-site Controls is *Dispersion Controls,* infiltration or dispersion systems required to be used to the maximum extent practical on individual lots, proposed plats, and short plats. Dispersion Controls are used in conjunction with, and in addition to, any flow control facilities that may be necessary. Implementation of dispersion controls may reduce the total effective impervious area and result in less runoff from these surfaces. The Western Washington Hydrology Model (WWHM) allows direct modeling of dispersion controls.

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

Section 6.2 describes *Detention Facilities*, while Section 6.3 includes *Infiltration Facilities* and criteria for site characterization and infiltration rate determination. Infiltration is the preferred method of stormwater management and shall be used to the maximum extent feasible.

See Table 7-1 (Chapter 7) for a listing of all Lacey-standard BMPs for flow control and treatment.

6.1 ON-SITE STORMWATER MANAGEMENT: LOW-IMPACT DEVELOPMENT

On-site low-impact development (LID) BMPs focus on minimization of impervious surface area, the use of infiltration, and dispersion through on-site vegetation for stormwater runoff treatment and flow control. LID emphasizes conservation and use of existing natural site features.

Some of the LID BMPs can be used to provide runoff treatment as well as flow control. Non-pollution generating surfaces, such as rooftops and patios, may use the flow control infiltration BMPs in Section 6.3. Pollution-generating surfaces, such as driveways, small parking lots, and landscaping, must use on-site BMPs to provide water quality treatment.

The LID Site Design BMPs in Section 6.1.1, Roof Downspout Controls in Section 6.1.2 and Soil Quality BMPs presented in Section 6.1.3 are required to be implemented to the maximum extent feasible without causing flooding or erosion impacts.

Additional LID measures are encouraged where appropriate, and in some cases may be necessary to meet the Core Requirements.

Additional information on LID techniques is available in the Thurston County 2009 *Drainage Design and Erosion Control Manual* and in the *Low Impact Development Technical Guidance Manual for Puget Sound,* available on-line at http://psat.wa.gov/Publications/Publication.htm. Measures described in those documents that are not listed in this Manual may be approved by the City of Lacey on a case-by-case basis.

Modeling credits (reductions in stormwater management facility size) are available when these techniques are used. Refer to the LID Flow Modeling Guidance referenced in Chapter 5.

6.1.1 LID Site Design BMPs

Reductions in impervious areas and maximizing on-site infiltration reduces the amount of runoff generated by a project site, thereby reducing stormwater management facility costs. The following BMPs are to be implemented to the maximum extent practicable:

- BMP LID-01 Protect and Restore Native Vegetation
- BMP LID-02 Reduce Effective Impervious Areas
- BMP LID-03 Full Dispersion
- BMP LID-09 Post-Construction Soil Quality and Depth

BMP LID-01 Protect and/or Restore Native Vegetation

Preserving native vegetation shall be the first priority wherever feasible. Native vegetation preservation and restoration areas shall be incorporated to the maximum extent practical and where most effective (i.e., where there is intact native vegetation and soils and/or unconcentrated flows from developed areas).

The goals for native vegetation preservation/retention are as follows:

- Large lot development: 65%
- Low density residential (0-4 dwelling units/acre): 50%
- Low-density residential (3-6 du/acre): 50%
- Medium density (6-12 du/acre): maximum practical extent
- High density (>6-20 du/acre): maximum practical extent.

At a minimum, requirements for native vegetation preservation and/or replacement as set forth in applicable sections of the Lacey Municipal Code, including critical areas, zoning, and grading shall be implemented.

Native soil and vegetation retention is the single most effective strategy to reduce stormwater impacts on-site, and has the added benefit of enhancing baseflow in streams and recharge of aquifers.

Native vegetation retention areas may be required for any of the following conditions:

- Areas reserved for stormwater dispersion for flow control or treatment
- Wetland or other critical area buffers required by the Lacey Municipal Code
- Riparian areas and buffers and habitat areas
- As required by the Lacey Municipal Code

Selection of areas for natural vegetation preservation shall be made in consultation with a landscape architect. Native vegetation and soil protection areas should be prioritized by location and type as follows:

1. Large tracts of riparian areas, that connect, create or maintain contiguous protected riparian areas
2. Large tracts of critical and wildlife habitat area , that connect, create or maintain contiguous protected areas
3. Tracts that create common open space areas among or within developed sites
4. Protection areas on individual lots
5. Protection areas on individual lots that connect to protection areas on adjacent lots

Design Criteria

During construction protect native tree preservation areas from disturbance.

Tree conservation areas should be designated for the site in areas not adjacent to or impacting structures (one tree height separation) or sight distance/clear area for roadways and shall be protected, or restored to follow natural successional patterns and to develop diverse multilayer canopy structure, snags, large woody debris, understory vegetation, and forest duff.

Vegetation restoration and planting methods shall conform to published standards. The following guidance documents are provided as an example:

For Riparian Areas

- *Restoring the Watershed A Citizen's Guide to Riparian Restoration in Western Washington*, Washington State Department of Fish and Wildlife, 1995

- *Streamside Planting Guide for Western Washington*, Cowlitz County Soil and Water Conservation District, *Plant It Right: Restoring Our Streams*, WSU Cooperative Extension, 2002

- *Integrated Streambank Protection Guidelines*, Washington State Department of Fish and Wildlife, 2000.

For Marine Bluffs

- *Surface Water and Groundwater on Coastal Bluffs: A Guide for Ecology*, Washington State Department of Ecology, Shorelands and Coastal Zone Management Program Publication No. 95-107, 1995

- *Vegetation Management: A Guide for Puget Sound Bluff Property Owners*, Washington State Department of Ecology, Shorelands and Coastal Zone Management Program Publication No. 93-31, 1993.

Conversion of Previously-Developed Surfaces to Native Vegetation

Conversion of a previously developed surface to native vegetated landscape or restoration of disturbed areas required to be native vegetation requires the removal of impervious surface and ornamental landscaping, de-compaction of soils, and the planting of native trees, shrubs, and ground cover in compost-amended soil according to all of the following specifications:

1. Existing impervious surface and any underlying base course (e.g., crushed rock, gravel, etc.) must be completely removed from the conversion area(s).

2. Underlying soils must be broken up to a depth of 18 inches. This can be accomplished by excavation or ripping with either a backhoe equipped with a bucket with teeth, or a ripper towed behind a tractor.

3. At least 4 inches of well-decomposed compost must be tilled into the broken up soil as deeply as possible. The finished surface should be gently undulating and must be only lightly compacted.

4. The area of native vegetated landscape must be planted with native species trees, shrubs, and ground cover. Species must be selected as appropriate for the site shade and moisture conditions, and in accordance with the following requirements:

   a. Trees: a minimum of two species of trees must be planted, one of which is a conifer. Conifer and other tree species must cover the entire landscape area.

   b. Shrubs: a minimum of two species of shrubs shall be planted. Space plants to cover the entire landscape area, excluding points where trees are planted.

   c. Groundcover: a minimum of two species of ground cover shall be planted. Space plants so as to cover the entire landscape area, excluding points where trees or shrubs are planted.

   Note: *For landscape areas larger than 10,000 square feet, planting a greater variety of species than the minimum suggested above is strongly encouraged. For example, an acre could easily accommodate three tree species, three species of shrubs, and two or three species of groundcover.*

5. At least 4 inches of hog fuel or other suitable mulch must be placed between plants as mulch for weed control. It is also possible to mulch the entire area before planting; however, an 18-inch diameter circle must be cleared for each plant when it is planted in the underlying amended soil.

   Note: *Plants and their root systems that come in contact with hog fuel or raw bark have a poor chance of survival.*

6. Plantings must be watered consistently once per week during the dry season for the first 3 years.
7. The plantings must be well established on at least 80 percent of the converted area after 2 years in order to be considered a native vegetated surface.

Materials

Developments shall use native trees for replacement in areas separate from residential lots, or storm drainage areas adjacent to roadway or parking lots. Species selection shall be based on the underlying soils and the historic, native indigenous plant community type for the site, if existing conditions can support the plant community.

Trees selected for replacement purposes must be free from injury, pests, diseases, and nutritional disorders. Trees must be fully branched and have a healthy root system. Coniferous and broad leaf evergreen trees shall be no less than 3 feet in height at time of planting. Deciduous trees shall be a minimum of 5 feet in height or have a minimum caliper size of 1 inch at time of planting.

Note: Avoid the use of a single species of tree for replacement purposes. No individual species of replacement tree should exceed 50 percent of the total, and no individual species should be less than 10 percent of the total.

Construction and Maintenance

Maintenance of native vegetation restoration areas shall include monitoring the survival of planted species, weed control and soil amendment as necessary to ensure the establishment of the native vegetation. A minimum 80 percent survival of all planted vegetation at the end of two years is required. Ongoing maintenance shall include weeding and watering for a minimum of three years from installation.

If during the 2-year period survival of planted vegetation falls below 80 percent, additional vegetation shall be installed as necessary to achieve the required survival percentage. The likely cause of the high rate of plant mortality shall also be determined and corrective actions taken to ensure plant survival. If it is determined that the original plant choices are not well suited to site conditions, these plants shall be replaced with plant species that are better suited to the site.

Native vegetation and soil protection areas serve as stormwater management facilities and should be managed as are other stormwater facilities. The Maintenance Plan for the stormwater facilities shall include a written vegetation management plan and protection mechanisms as necessary to maintain the benefit of these areas over time.

BMP LID-02 Reduce Effective Impervious Areas

Roads, shared accesses, alleys, sidewalk, driveways, and parking areas are a substantial portion of total urban impervious area and often have highly efficient drainage systems. Reducing the effective area of these surfaces (roofs excluded) is a key concept of LID.

The following design strategies are to be considered:

Roads

- Design using the minimum width permissible under applicable road design standards.
- Use of alternate paving materials, as described in BMP LID-11, is allowed adjacent to the traveled lane of private roads (e.g., for pull-out parking, shoulders, and sidewalks)
- For a cul-de-sac, the turnaround area can be disconnected from the drainage system by, for example, draining the cul-de-sac to a pervious area or bio-retention area.

Sidewalks

- Disconnected from road drainage systems where possible.
- Where feasible, sidewalks should be "reverse slope" or sloped away from the road and onto adjacent vegetated areas.
- Sidewalks and trails for private developments and private roadways may be constructed of porous materials. Porous materials must be ADA-compliant. See BMP LID-11 for guidance on these materials.

Parking Lots

- Use minimum off-street parking requirements for non-residential uses.
- Consider use of pervious pavement (BMP LID-11)
- Disconnect drainage, drain to landscaped area/bioretention facility

Driveways

- Minimize driveway width
- Reduce driveway length, where possible
- Design "clusters" of homes with shared driveway
- Consider use of pervious pavement (BMP LID-11)

BMP LID-03 Full Dispersion

Purpose and Definition

This BMP allows for "fully dispersing" runoff from impervious surfaces and cleared areas of development sites that preserve the equivalent of at least 65 percent of the site (or a threshold discharge area on the site) in a forest or native condition.

Fully dispersed runoff from impervious surfaces means that the area is "ineffective." Ineffective impervious areas are included in the Total Impervious Area thresholds when determining applicable Core Requirements, but are not included in the thresholds specific to the applicability of Core Requirement #6 (Runoff Treatment) and Core Requirement #7 (Flow Control).

Applicability

Full dispersion differs from other LID BMPs described previously in that if minimum native area preservation is adhered to, the limitations on how impervious surfaces are modeled and how concentrated flow can be dispersed are less restrictive. Additionally, if the minimum native area preservation requirements are met, on-site landscape area soils are not required to meet the minimum requirements of BMP LID-09 (Post-Construction Soil Quality and Depth) except as noted in Table 6.1 for landscape area equaling or exceeding 50 percent of the site on till soils.

Full dispersion would be most applicable to developments that desire to or can retain large portions of the site in native conditions such as for critical area buffers, or that concentrate development in a smaller area of a larger site to obtain some benefit from zoning codes (PRRD, Cluster Development, PRD, etc.).

Full dispersion can be used as long as the developed areas draining to the native vegetation do not have effective impervious surfaces that exceed 10 percent of the entire site. Low-density single-family residential developments should use this BMP wherever possible to minimize effective impervious surface to less than 10 percent of the development site.

Other types of development that retain 65 percent of the site (or a threshold discharge area on the site) in a forested or native condition may also use this BMP to avoid triggering the flow control facility requirement.

Full Dispersion for All or Part of the Development Site

Developments that cannot preserve 65 percent or more of the site in a forested or native condition may disperse runoff into a forested or native area in accordance with the elements of this BMP if:

- The effective impervious surface of the area draining into the native vegetation area is <10 percent; and

- The development maintains ratios proportional to the 65 percent forested or native condition and 10 percent effective impervious surface area. Examples of such ratios are shown in Table 6.1. Thus, if a development can preserve only 50% of the site on native vegetation, full dispersion can only be achieved if a maximum of 8% effective impervious surface is created.

Table 6.1 - Full Dispersion Ratios

% Native Vegetation Preserved	% Effective Impervious (max allowed)	% Lawn/Landscape (max allowed)
65	10	35
60	9	40
55	8.5	45
50	8	50*
45	7	55*
40	6	60*
35	5.5	65*

* Where lawn/landscape areas are established on till soils, and exceed 50 percent of the total site, they shall be developed using BMP LID.02 (Post- Construction Soil Quality and Depth).

Within the context of full dispersion for all or part of the development site the only impervious surfaces that are ineffective are those that are routed into a system designed for 100% infiltration (e.g. an appropriately-sized infiltration basin) that meets the flow control standard and does not overflow into the forested or native vegetation area.

Limitations

Runoff must be dispersed into native areas per the guidelines and limitations indicated in this BMP.

Additional impervious areas are allowed that exceed the 10 percent threshold, but should not drain to the native vegetation area and are subject to the thresholds, and treatment and flow control requirements of the stormwater manual.

Native vegetation areas must be protected from future development. Protection must be provided through legal documents on record with the local government. Examples of adequate documentation include a conservation easement, conservation parcel, and deed restriction.

All trees within the preserved area at the time of permit application shall be retained, aside from approved timber harvest activities and the removal of dangerous or diseased trees. Removal of dangerous or diseased trees will require acceptance of the City of Lacey and may require an arborist to make a written assessment of the trees' condition.

The preserved area may be used for passive recreation and related facilities, including pedestrian and bicycle trails, nature viewing areas, fishing and camping areas, and other similar activities that do not require permanent structures, provided that cleared areas and areas of compacted soil associated with these areas and facilities do not exceed eight percent of the preserved area.

Design Guidelines

Roof Downspouts

- Roof surfaces that comply with the downspout infiltration requirements of BMP LID-04 are considered to be "fully dispersed" (i.e., 0 percent effective imperviousness).
- All other roof surfaces are considered to be "fully dispersed" only if they are within a threshold discharge area that is or will be more than 65 percent forested (or native vegetative cover) and less than 10 percent effective impervious surface, and if they comply with the downspout dispersion requirements of BMP LID-05, and have vegetated flow paths through native vegetation exceeding 100 feet.

Driveway Dispersion

- Driveway surfaces are considered to be "fully dispersed" if they are within a threshold discharge area that is or will be more than 65 percent forested (or native vegetative cover) and less than 10 percent effective impervious surface (or meet the Full Dispersion Ratios in Table 6.1), and if they comply with the dispersion BMPs (BMP LID-07 and BMP LID-08) and have flow paths through native vegetation exceeding 100 feet.
- This also holds true for any driveway surfaces that comply with the roadway dispersion BMPs described below.

Roadway Dispersion BMPs

Roadway surfaces are considered to be "fully dispersed" if they are within a threshold discharge area that is or will be more than 65 percent forested (or native vegetative cover) and less than 10 percent effective impervious surface (or meet the Full Dispersion Ratios in Table 6.1), and if they comply with the following dispersion requirements:

- Roadway runoff dispersion is allowed only on rural neighborhood collectors and local access streets. To the extent feasible, disperse driveways to the same standards as roadways to ensure adequate water quality protection of downstream resources.
- Design the road section to minimize collection and concentration of roadway runoff. Use sheet flow over roadway fill slopes (i.e., where roadway subgrade is above adjacent right-of-way) wherever possible to avoid concentration.

- When it is necessary to collect and concentrate runoff from the roadway and adjacent upstream areas (e.g., in a ditch on a cut slope), concentrated flows shall be incrementally discharged from the ditch via cross culverts or at the ends of cut sections. These incremental discharges of newly concentrated flows shall not exceed 0.5 cfs at any one discharge point from a ditch for the 100-year runoff event (using approved continuous simulation model).

- Where flows at a particular ditch discharge point were already concentrated under existing site conditions (e.g., in a natural channel that crosses the roadway alignment), the 0.5-cfs limit would be in addition to the existing concentrated peak flows.

- Ditch discharge points with up to 0.2 cfs discharge for the peak 100-year flow shall use rock pads or dispersion trenches to disperse flows. Ditch discharge points with between 0.2 and 0.5 cfs discharge for the 100-year peak flow shall use only dispersion trenches to disperse flows.

- Dispersion trenches shall be designed to accept storm flows (free discharge) from a pipe, culvert, or ditch end, shall be aligned perpendicular to the flow path, and shall be minimum 2' x 2' in section, 50 feet in length, filled with 3/4-inch to 1-1/2-inch washed rock, and provided with a level notched anchor plate flow spreader (see Chapter 7, Figure 7.1). Manifolds may be used to split flows up to 2 cfs discharge for the 100-year peak flow between up to four trenches. Dispersion trenches shall have a minimum spacing of 50 feet.

- After being dispersed with rock pads or trenches, flows from ditch discharge points must traverse a minimum of 100 feet of undisturbed native vegetation before leaving the project site, or entering an existing onsite channel carrying existing concentrated flows across the road alignment.

- Flow paths from adjacent discharge points must not intersect within the 100-foot flow path lengths, and dispersed flow from a discharge point must not be intercepted by another discharge point. To enhance the flow control and water quality effects of dispersion, the flow path shall not exceed 15 percent slope, and shall be located within designated open space.

- Ditch discharge points shall be located a minimum of 100 feet upgradient of slopes steeper than 40 percent, wetlands, and streams.

- Where the City determines there is a potential for significant adverse impacts downstream (e.g., erosive steep slopes or existing downstream drainage problems), dispersion of roadway runoff may not be allowed, or other measures may be required.

Cleared Area Dispersion BMPs

The runoff from cleared areas that are comprised of bare soil, non-native landscaping, lawn, and/or pasture is considered to be "fully dispersed" if it is dispersed through at least 25 feet of native vegetation in accordance with the following criteria:

- The contributing flow path of cleared area being dispersed must be no more than 150 feet.
- Slopes within the 25-foot minimum flow path through native vegetation shall be no steeper than 8 percent. If this criterion cannot be met due to site constraints, the 25-foot flow path length must be increased 1.5 feet for each percent increase in slope above 8 percent.

6.1.2 Roof Downspout Controls

Roof downspout controls are simple pre-engineered designs for infiltrating and/or dispersing runoff from roof areas for the purposes of increasing opportunities for groundwater recharge and reduction of runoff volumes from new developments. Even if full dispersion is not feasible, roof downspout controls shall be used to provide partial flow control.

Infiltration (rather than dispersion) is the preferred method and must be used if feasible.

Roof downspout controls are not required if roof runoff is routed to a properly-sized infiltration facility.

The following BMPs are described in this section:

BMP LID-04 Downspout Infiltration
BMP LID-05 Downspout Dispersion
BMP LID-06 Perforated Stub-Out Connections
BMP LID-07 Concentrated Flow Dispersion
BMP LID-08 Sheet Flow Dispersion

BMP LID-04 Downspout Infiltration Systems

Downspout infiltration systems are trench designs intended only for use in infiltrating runoff from roof downspout drains. They are not designed to directly infiltrate runoff from pollutant-generating surfaces.

On lots or sites with more than 3 feet of permeable soil from the proposed final grade to the seasonal high groundwater table, downspout infiltration is considered feasible if the soils are outwash type soils and the infiltration trench can be designed to meet the minimum design criteria specified below. An engineer, soil scientist, or other licensed or certified professional with appropriate training shall evaluate soils to determine if they are suitable for infiltration.

Figure 6.1 shows a typical downspout infiltration trench system, and Figure 6.2 presents an alternative infiltration trench system for sites with coarse sand and cobble soils. Alternative designs and layouts may be acceptable if they meet the General Design Criteria below. In particular, typical setbacks from buildings and between inlet structures and a trench may be adjusted to fit a downspout infiltration system on a small lot, provided that an engineering report establishes that building foundations will not be negatively impacted (see the setback criteria described in Chapter 1).

General Design Criteria

1. The following minimum total infiltration trench lengths (linear feet), including rock backfill, are required per 1,000 square feet of roof area based on soil type may be used for sizing downspout infiltration trenches. For subdivisions, calculate sizes and provide a schedule, by lot number, with the engineered plans:
   - Coarse sands and cobbles 20 LF
   - Medium sand 30 LF
   - Fine sand, loamy sand 75 LF
   - Sandy loam 125 LF
   - Loam 190 LF
   - Hydrologic Group D soils (silts, clays, till soils with Group C or D surface soils, rock outcroppings, most fill materials) – infiltration trenches are generally prohibited.
2. Maximum length of trench should not exceed 100 feet from the inlet sump.
3. Minimum spacing between trench centerlines shall be 6 feet.
4. Filter fabric shall be placed over the drain rock as shown on Figure 6.1 prior to backfilling. Do not place fabric on trench bottom.
5. Minimum infiltration trench setbacks are as follows:
   - Water supply wells, building crawl spaces, or basements shall be at least 10 feet upgradient or 30 feet downgradient from the trench.
   - Infiltration trenches in till or layered soils must be located downgradient of crawl spaces or basements.
   - Top of slopes over 15 percent, 25 feet. May be increased if landslide hazards present.
   - Septic systems, per Thurston County Environmental Health Department requirements.
   - In case of conflict among setback requirements, the more stringent shall apply.

Note: Setbacks from buildings may be adjusted to fit a downspout infiltration system on a small lot provided an engineering report establishes that building foundations will not be negatively impacted.

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

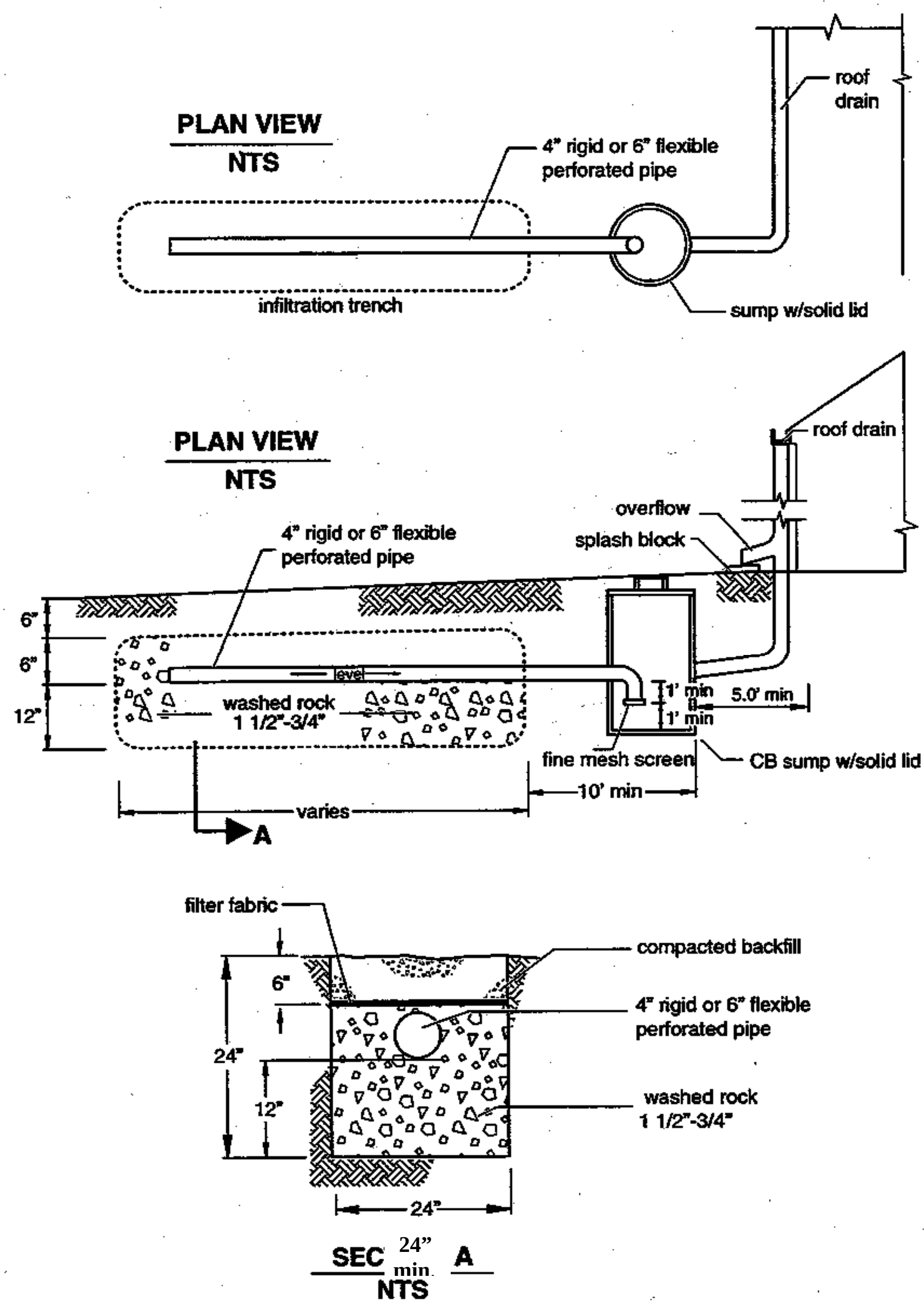


Figure 6.1 Typical Downspout Infiltration Trench

Source: King County. A filter basket may substitute for the fine mesh screen.

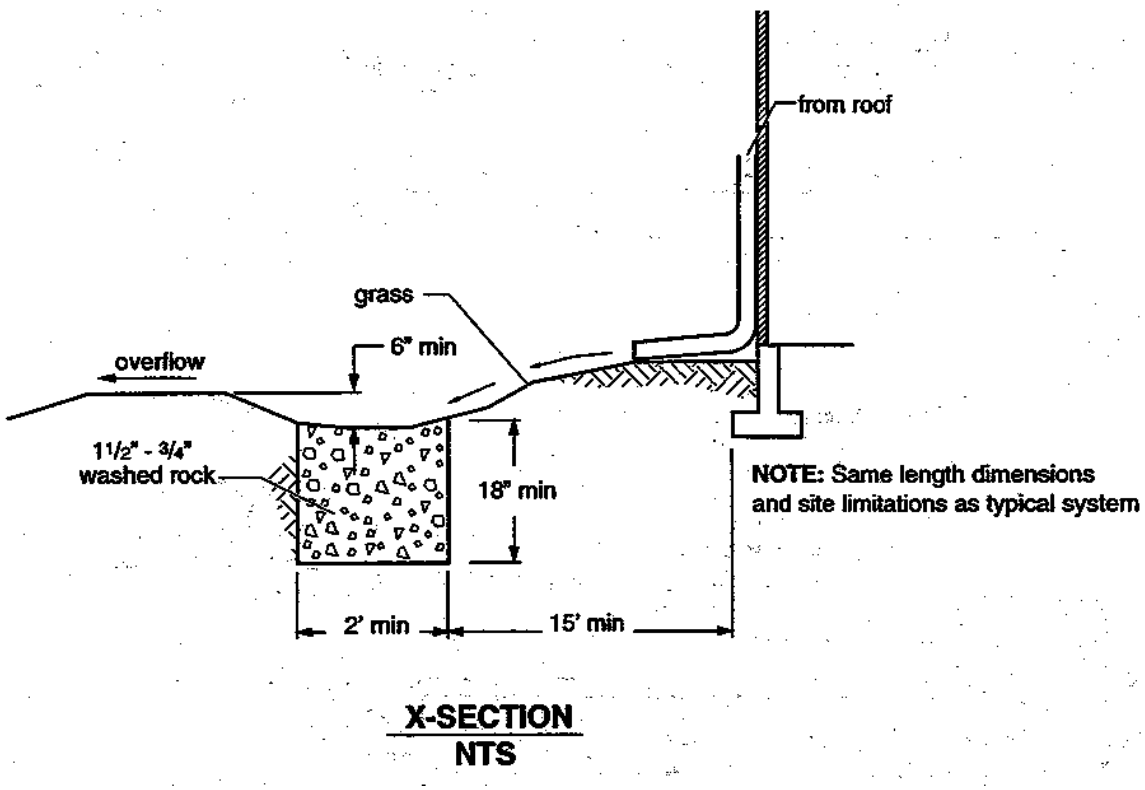


Figure 6.2 Alternative Downspout Infiltration Trench System (for coarse sand and gravel)

Source: King County

Sites that can fully disperse are not required to provide runoff treatment or flow control facilities. Full dispersion credit is limited to sites with a maximum of 10% impervious area that is dispersed through 65% of the site maintained in natural vegetation, and where maintenance needs of the BMPs are defined and provided.

Additional flow controls are required if modeling indicates that there will be a 0.1 cfs or greater increase in the 100-year return frequency flow. Also, a treatment facility is required if the thresholds in the Core Requirements are exceeded. Residential roofs or other impervious surfaces that are dispersed, modular grid pavements, and porous concrete and asphalt may be allowed a flow credit at local permitting authority discretion.

BMP LID-05 Downspout Dispersion – Trenches and Splash Blocks

Downspout dispersion BMPs are splashblocks or gravel-filled trenches that serve to spread roof runoff over vegetated pervious areas.

Applications and Limitations

Downspout dispersion is required on all subdivision single family lots where roof downspout infiltration is not feasible, and where the General Design Guidelines below can be met.

Downspout dispersion is not applicable to flat, poorly draining lawns subject to saturation.

General Design Guidelines

1. Dispersion trenches designed as shown in the Figures 6.3 and 6.4 shall be used for all downspout dispersion applications except where splashblocks are allowed below. See Figure 6.5 for a typical splashblock.

2. Splashblocks may be used for downspouts discharging to a vegetated flowpath at least 50 feet in length as measured from the downspout to the downstream property line, structure, sensitive steep slope, stream, wetland, or other impervious surface. Sensitive area buffers may count toward flowpath lengths. The vegetated flowpath must be covered with well-established lawn or pasture, landscaping with well-established groundcover, or native vegetation with natural groundcover. The groundcover shall be dense enough to help disperse and infiltrate flows and to prevent erosion.

3. If the vegetated flowpath is less than 25 feet on a subdivision single-family lot, a perforated stub-out connection may be used in lieu of downspout dispersion. A perforated stub-out may also be used where implementation of downspout dispersion might cause erosion or flooding problems, either on site or on adjacent lots.

If roof runoff is dispersed according to the requirements of this section and the *vegetative flow path* is 50 feet or longer through native landscape (including wetland buffers) and/or lawn/landscape area that meets BMP 6.5, the roof area may be modeled in WWHM as “grassed surface.”

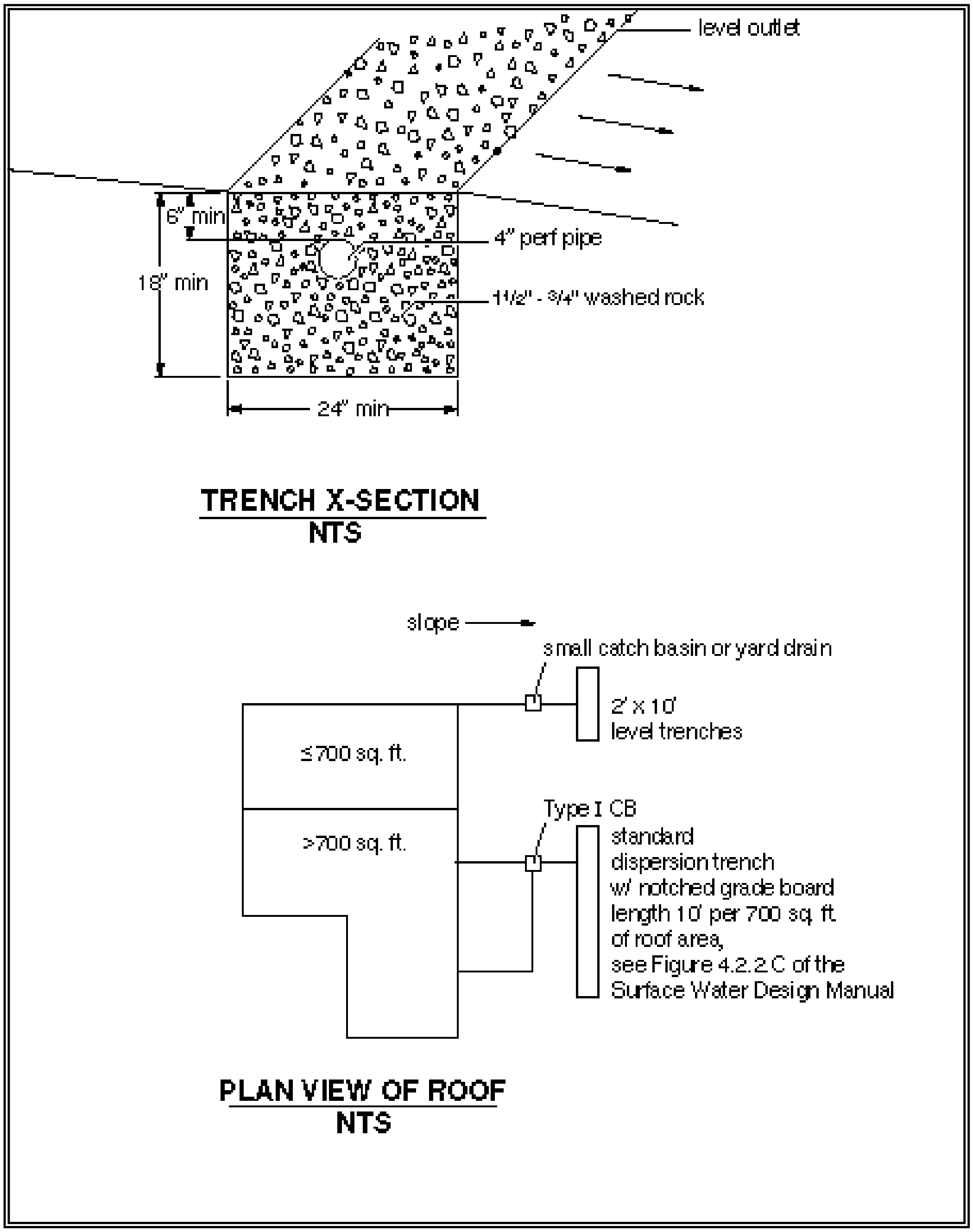


Figure 6.3 Typical Dispersion Trench

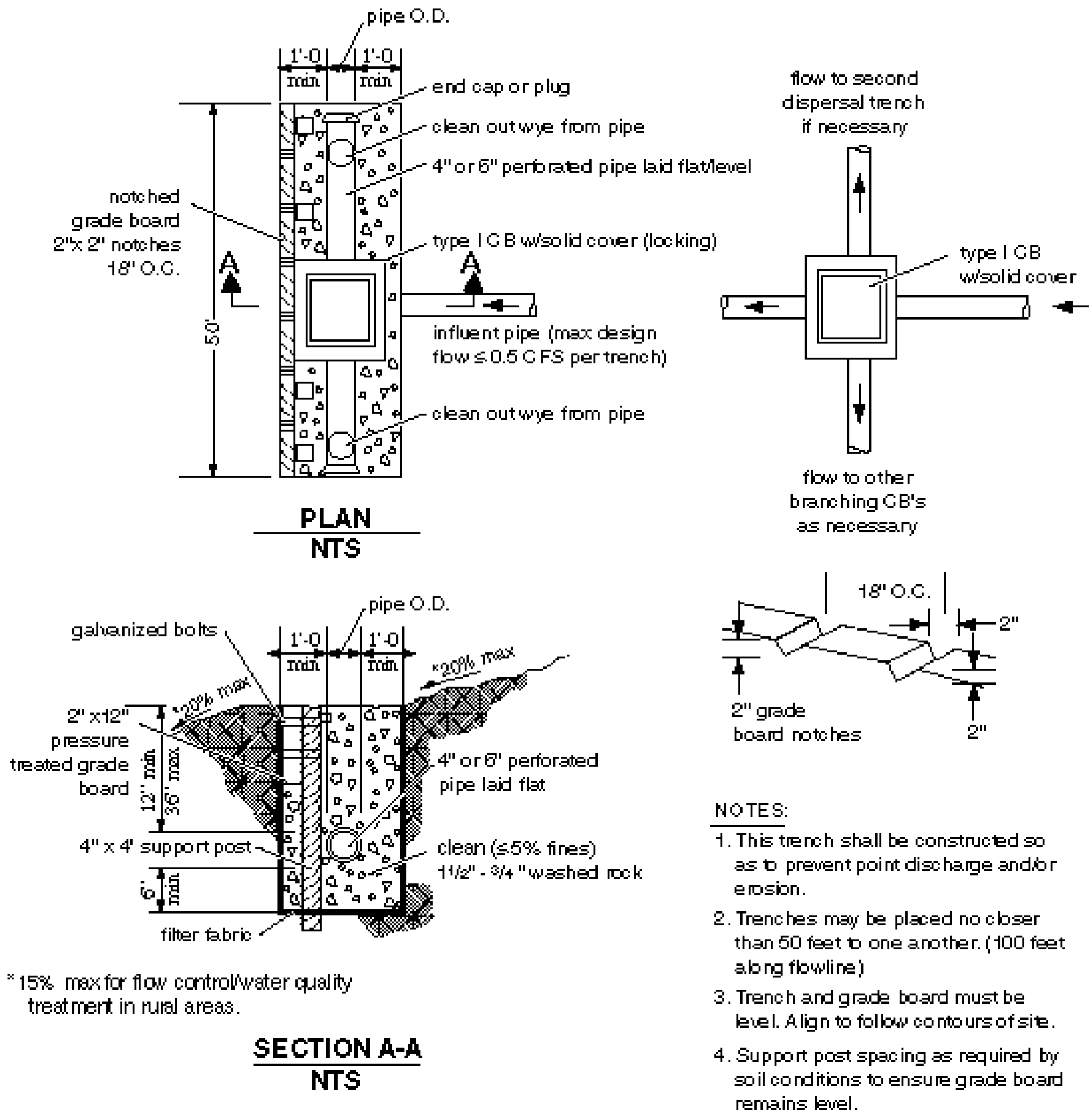


Figure 6.4 Standard Dispersion Trench with Notched Grade Board

Dispersion Trench Design Criteria

1. A vegetated flowpath of at least 25 feet in length must be maintained between the outlet of the trench and any property line, structure, stream, wetland, or impervious surface. A vegetated flowpath of at least 50 feet in length must be maintained between the outlet of the trench and any steep slope. Sensitive area buffers may count towards flowpath lengths.

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 6.3. For roof areas larger than 700 square feet, a dispersion trench with notched grade board as shown in Figure 6.4 may be used subject to approval by the City of Lacey. The total length of this design must provide at least 10 feet of trench per 700 square feet of roof area and not exceed 50 feet.

3. A setback of at least 5 feet shall be maintained between any edge of the trench and any structure or property line, except when trench is shared by parcels and approved by the Drainage Manual Administrator. See Chapter 1 for standard setbacks.

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

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

6. For sites with septic systems, the discharge point must be downgradient of the drainfield primary and reserve areas. This requirement can be waived by the jurisdiction's permit review staff if site topography will clearly prohibit flows from intersecting the drainfield.

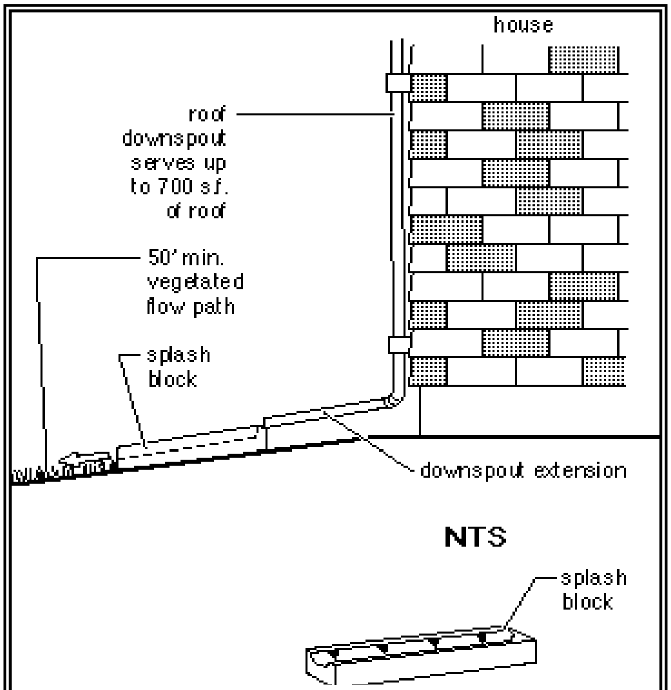


Figure 6.5 Typical Downspout Splashblock Dispersion

Splashblock Design Criteria

If the ground is sloped away from the foundation, and there is adequate vegetation and area for effective dispersion, splashblocks will adequately disperse storm runoff. If the ground is level, if the structure includes a basement, or if foundation drains are proposed, splashblocks with downspout extensions may be used.

In addition to the general design criteria, the following conditions must be met to use splashblocks, with or without extensions:

1. A maximum of 700 square feet of roof area may drain to each splashblock.
2. A splashblock or a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) shall be placed at each downspout discharge point.
3. Splashblocks may not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist.
4. For sites with septic systems, the discharge point must be downslope of the primary and reserve drainfield areas. This requirement may be waived if site topography clearly prohibits flows from intersecting the drainfield.

BMP LID-06 Perforated Stub-Out Connections

A perforated stub-out connection is a perforated pipe within a gravel-filled trench placed between a roof downspout and a stub-out to the storm drain system.

Applications and Limitations

1. Only allowed when downspout infiltration or dispersion (BMP LID-04 and BMP LID-05) is not feasible.
2. Used in poorly draining soils for limited flow control benefits.
3. Little or no flow control is expected during winter months.
4. Not allowed when seasonal water table is less than 1 foot below trench bottom.

Design Guidelines

1. Minimum 10 linear feet of trench for each 5,000 sf of contributing roof area.
2. Minimum 2-feet wide trench.
3. Backfill trench with ¾” to 1½” washed drain rock, minimum 12” depth.
4. Drain rock extends a minimum of 8 inches below bottom of pipe, and covers pipe.
5. Minimum 4”-diameter perforated pipe, level within trench.
6. Trench Cover: filter fabric and at least six inches of fill.
7. Perforated pipe shall not be located under impervious areas.
8. Perforated pipe must be located downgradient of septic systems.
9. Setbacks are the same as for infiltration trenches.

For flow control credit, pipe stub-out connections designed according to this section may be modeled in WWHM by considering the trench(es) as a detention pond. The stage-storage relation of the pond shall be computed using a void ratio of 0.3 (30%), with no infiltration and a single oversized orifice/overflow. Roof drainage to multiple pipe stub-out connections may be modeled as a single impervious basin to a single, combined detention pond.

BMP LID-07 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. See Figure 6.6.

Applications and Limitations

- Any situation where concentrated flow can be dispersed through vegetation.
- Applicable where driveway is at least 50 feet long.
- Dispersion for driveways will generally only be effective for single-family residences on large lots and in rural short plats.

Design Guidelines

1. A vegetated flowpath of at least 50 feet should 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 dispersion BMP.
3. A pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep, minimum) shall be placed at each discharge point.
4. Runoff discharged towards landslide hazard areas must be evaluated by a geotechnical engineer or qualified geologist. The discharge point shall not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and approval by the City of Lacey.
5. For sites with septic systems, the discharge point should be downgradient of the drainfield primary and reserve areas. Where BMP LID-03 is used to disperse runoff into an undisturbed native landscape area or an area that meets BMP LID-01, and the vegetated flow path is at least 50 feet, the impervious area may be modeled in WHMM as landscaped area.

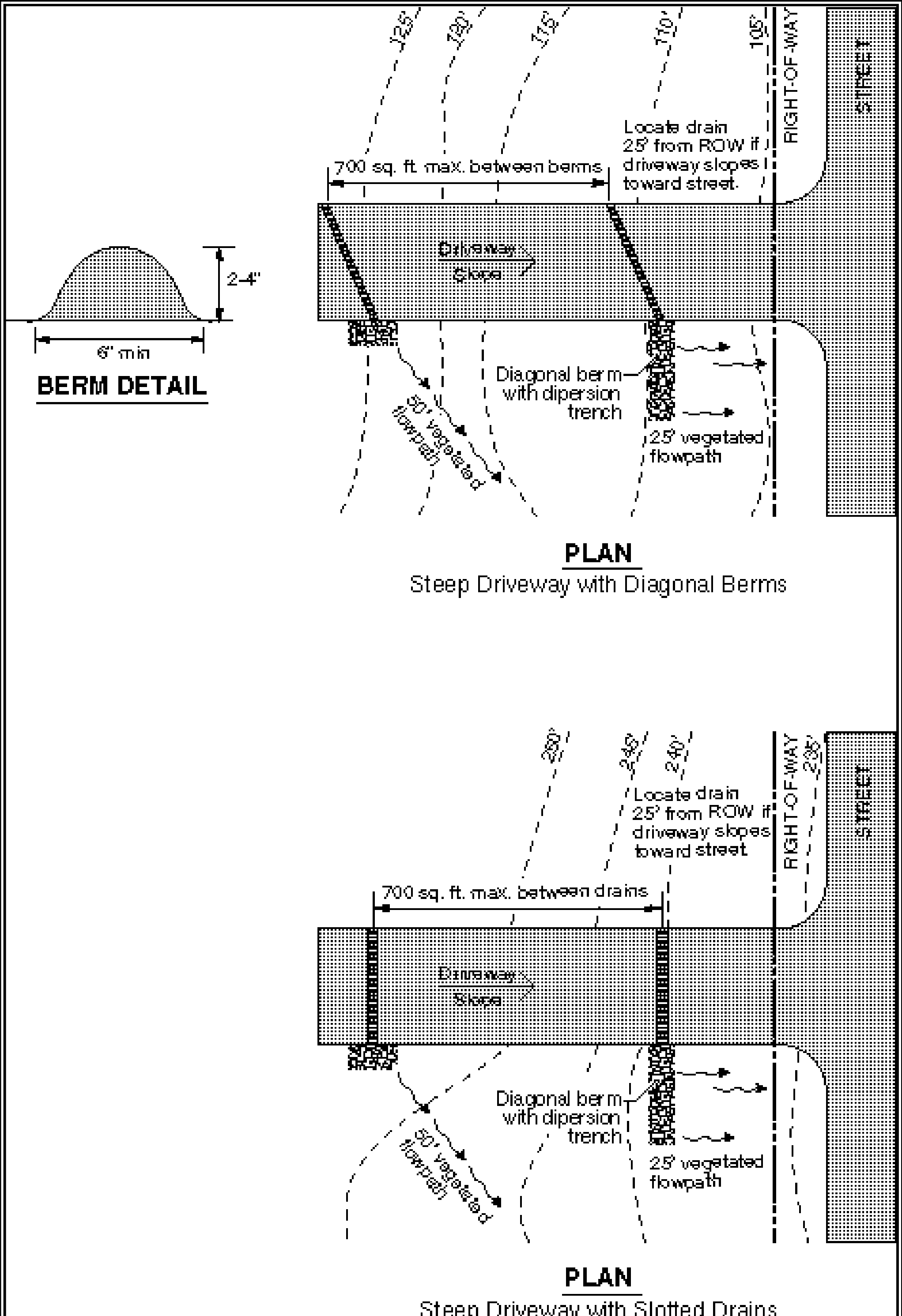


Figure 6.6 Typical Concentrated Flow Dispersion for Steep Driveways

BMP LID-08 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.

Applications and Limitations

Flat or moderately sloping (<15% 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 Guidelines

1. See Figure 6.7 for details for driveways.

2. A 2-foot-wide transition zone to discourage channeling shall 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, or drain rock.

3. 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 addition 20 feet of width or fraction thereof.

4. 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 should 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%.

5. Runoff discharge toward landslide hazard areas must be evaluated by a geotechnical engineer or a qualified geologist. The discharge point may not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and approval by the City.

6. For sites with septic systems, the discharge point must be downgradient of the drainfield primary and reserve areas. This requirement may be waived by the City if site topography clearly prohibits flows from intersecting the drainfield.

Flow Credits

Where BMP 6.4 is used to disperse runoff into an undisturbed native landscape area or an area that meets BMP 6.5, the impervious area may be modeled as landscaped area.

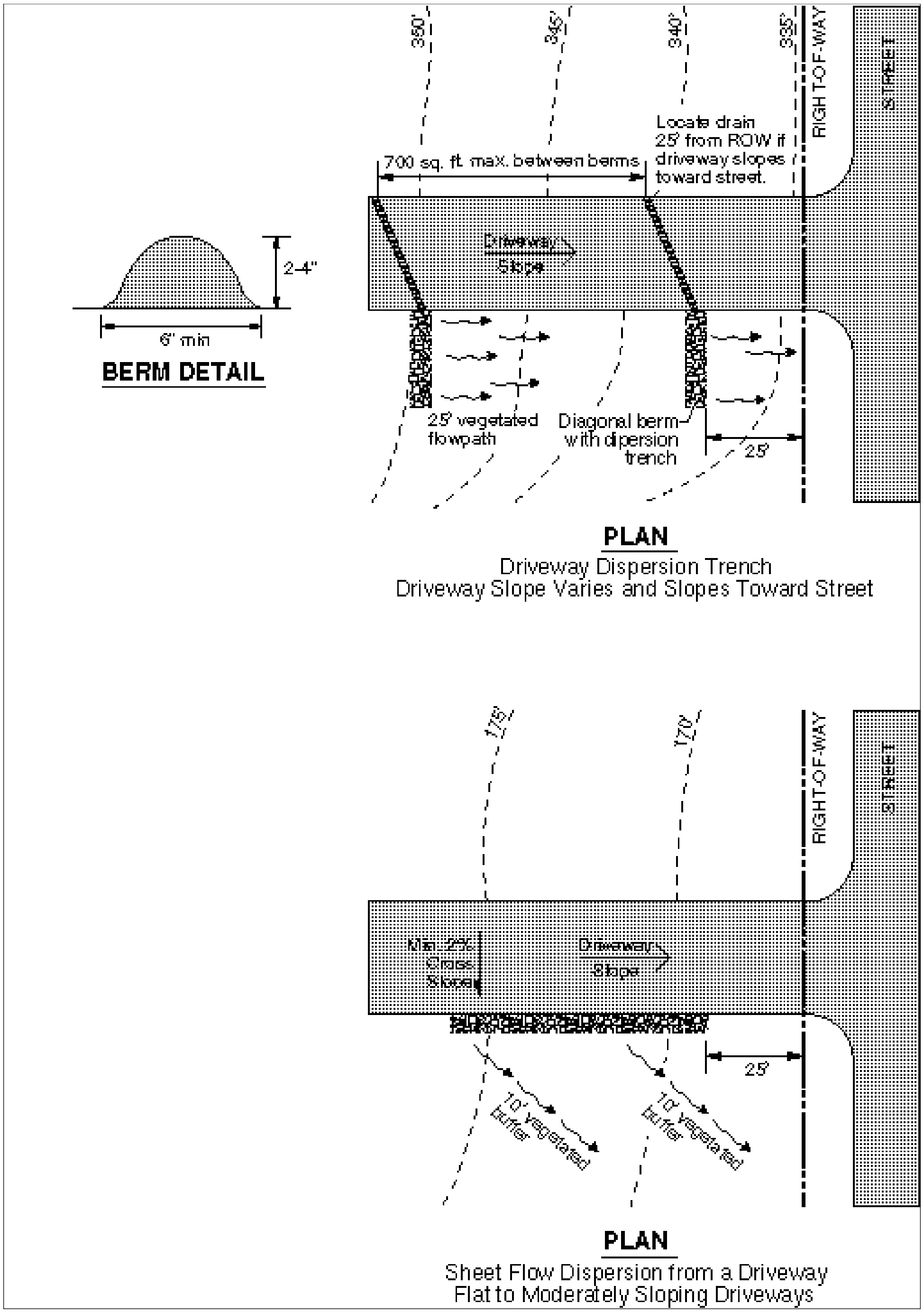


Figure 6.7 Sheet Flow Dispersion for Driveways

6.1.3 Soil Quality Enhancement

BMP LID-09 Post-Construction Soil Quality and Depth

Naturally occurring (undisturbed) soil and vegetation provide important stormwater functions. These functions are largely lost when development strips away native soil and vegetation and replaces it with minimal topsoil and sod.

Establishing minimum soil quality and depth requirements retains some stormwater infiltration functions in the post development landscape, provides increased treatment of pollutants and sediments that result from development and habitation, and minimizes the need for some landscaping chemicals.

Applicability

This BMP is required in projects subject to Core Requirement #5, On-site Stormwater Management. The following surfaces of a project site shall be required to implement this BMP:

- Areas that are to be incorporated into the stormwater drainage system such as surface BMPs. Note that BMP LID-10 (Bioretention) has alternate soil requirements.
- All new lawn and landscape areas. Except that the areas of the project implementing BMP LID-03, “Full Dispersion” are not required to implement this BMP, however, it is still recommended.
- Disturbed areas that are to be restored to native vegetation (See BMP LID-01).
- Existing lawn and landscape areas of a redevelopment project where the project is required to retrofit the entire site to current stormwater standards. Establishing minimum soil quality and depth is not the same as preservation of naturally occurring soil and vegetation. However, establishing a minimum soil quality and depth will provide improved onsite management of stormwater flow and water quality.

If soils must be amended to increase the organic content, several sources of organic matter (e.g., compost, composted woody material, biosolids, and forest product residuals) can be used. It is important that the materials used to meet the soil quality and depth requirements be appropriate and beneficial to the plant cover being established. It is also important that imported topsoils improve soil conditions and do not have an excessive percent of clay fines.

Limitations

Native soils with robust native landscapes must be protected from disturbance whenever possible, especially where no post-construction soil rehabilitation is planned.

In designated Well Head Protection Areas (WHPA) for public water systems with over 1,000 connections, compost used within the site shall be comprised entirely of vegetative materials only. Biosolids and animal manure components can result in large concentrations of nitrates leaching into groundwater aquifers and are consequently prohibited within the WHPA.

Poorly Draining Sites

If the site being considered for turf establishment does not drain well, consider an alternative to planting a lawn. 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 the region's extended saturated winter conditions may create water logging of the lawn. The landscape professional should also provide a drainage route or subsurface collection system as part of their design.

Existing Steep Slope Areas

Increasing soil moisture content may increase soil instability in areas with steep slopes. However, the Washington State Department of Transportation (WSDOT) has incorporated compost-amendment in almost all of its vegetated sites since 1992 without problems, even on the steepest sites (33 percent slope), as a result of the increased moisture holding capacity within the soils. (See design criteria below for requirements of steep slope soil amendment.)

- Onsite steep slope areas with native soils and robust native landscapes should be protected from disturbance, which is preferable to re-grading and augmenting the disturbed soil with soil amendment. Also, steep slope areas may be subject to critical area protection per TCC 17.15, which outlines criteria for classification of erosion and active landslide hazard areas.

- Where native soils and vegetation is sparse, steep slopes that remain on site that are not constructed as part of the development, should be amended by planting deep rooting vegetation. Soil amendments shall be applied with a pit application at least twice as wide as the root ball of the vegetation being planted, using a mix of 50 percent compost and 50 percent soil mixture.

Submittals and Approvals

A site specific Soil Management Plan (SMP) shall be submitted and must be approved as part of the permitting process for the project. The SMP shall be prepared per the Soils for Salmon guidance document (see Design Guidelines below) and includes:

- A scale-drawing (11" x 17" or larger) identifying area where native soil and vegetation will be retained undisturbed, and which soil treatments will be applied in landscape areas.

- Identified treatments and products to be used to meet the soil depth and organic content requirements for each area.

- Computations of compost or topsoil volumes to be imported (and/or site soil to be stockpiled) to meet "pre-approved" amendment rates; or calculations by a qualified professional to meet organic content requirements if using custom calculated rates. Qualified professionals include certified Agronomists, Soil Scientists or Crop Advisors; and licensed Landscape Architects, Civil Engineers or Geologists.

- Copies of laboratory analyses for compost and topsoil products to be used, documenting organic matter contents and carbon to nitrogen ratios.

The steps involved in preparing the SMP include the following:

Step 1: Review Site Landscape Plans and Grading Plans

- Assess how grading and construction will impact soil conditions

- Identify which areas are to receive which type of soil treatment options (1 through 4).

Step 2: Visit Site to Determine Soil Conditions

- Identify compaction of subgrade by digging down to a level 12 inches below finished grade and use a shovel or penetrometer to determine compaction.

- Assess condition of native areas that are to remain undisturbed.

- Assess soil conditions in each area to be cut, filled, or otherwise disturbed and establish scarification and amendment recommendations for each area.

Step 3: Select Amendment Options

- Identify areas where each amendment option will be applied and outline these areas on the SMP site plan and on the SMP form.

- Assign each area an identifying number or letter on the SMP site plan and on the SMP form

Step 4: Identify Compost, Topsoils, and Other Organic Materials for Amendment and Mulch.

- Products for soil amendment must be identified on the SMP form and recent product test results provided showing they meet the requirements of the Soil for Salmon guidance document (see Design Guidelines below).

- Compost shall meet requirements of WAC 173-3 50, Section 220 "Composted Materials".

Step 5: Calculate Amendment, Topsoil and Mulch Volumes on SMP Form

- Calculate required cubic yards of amendment for the pre- approved amendment areas.
- Compute custom calculated amendment rates to achieve the target Soil Organic Matter content (10 percent for landscape beds, 5 % for turf areas)

Design Guidelines

An applicant can demonstrate compliance with this BMP by following the guidance provided in the most current edition of *"Guidelines and Resources for Implementing Soil Quality and Depth,"* BMP T5.13 in Ecology's 2005 *Stormwater Management Manual for Western Washington.* This document is available at no charge from the following web sites: www.SoilsforSalmon.org and www.BuildingSoil.org

- Soil retention. The duff layer and native topsoil shall be retained in an undisturbed state to the maximum extent practicable. In any areas requiring grading, remove and stockpile the duff layer and topsoil on site in a designated, controlled area, not adjacent to public resources and critical areas, to be reapplied to other portions of the site where feasible.

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

    1. A topsoil layer with a minimum organic matter content of ten percent dry weight in planting beds, and 5% organic matter content in turf areas, and a pH from 6.0 to 8.0 or matching the pH of the original undisturbed soil. The topsoil layer shall have a minimum depth of eight inches except where tree roots limit the depth of incorporation of amendments needed to meet the criteria. Subsoils below the topsoil layer should be scarified at least 4 inches with some incorporation of the upper material to avoid stratified layers, where feasible.
    2. Planting beds must be mulched with 2 inches of organic material.
    3. Quality of compost and other materials used to meet the organic content requirements:

        a. The organic content for "pre-approved" amendment rates can be met only using compost that meets the definition of "composted materials" in WAC 173-350-220. This code is available online at: http://www.ecy.wa.gov/programs/swfa/facilities/350.html

        The compost must also have an organic matter content of 35% to 65%, 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.

        b. Calculated amendment rates may be met through use of composted materials as defined above; or other organic materials amended to meet the carbon to nitrogen ratio requirements, and meeting the contaminant standards of Grade A Compost.

- Implementation Options: The soil quality design guidelines listed above can be met by using one, or a combination, of the methods listed below
    1. Leave undisturbed native vegetation and soil, and protect from compaction during construction.
    2. Amend existing site topsoil or subsoil either at default "pre-approved" rates, or at custom calculated rates based on tests of the soil and amendment.
    3. Stockpile existing topsoil during grading, and replace it prior to planting. Stockpiled topsoil must also be amended if needed to meet the organic matter or depth requirements, either at a default "pre-approved" rate or at a custom calculated rate.
    4. Import topsoil mix of sufficient organic content and depth to meet the requirements.

Soil that already meets the depth and organic matter quality standards, and is not compacted, need not be amended.

Flow Modeling Credit

While hydrologic modeling credits cannot be applied for application of this BMP, credits can be taken in runoff modeling when the BMP is applied as part of a dispersion design under the conditions described in Section 5.1.1.

6.1.4 Additional LID Measures

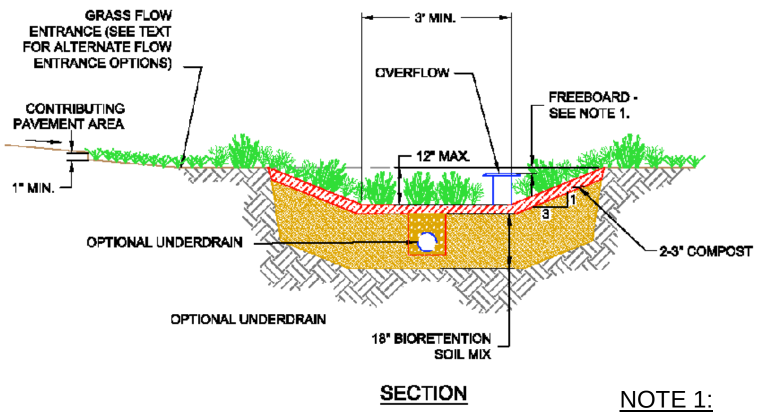
The LID measures described in this section are encouraged, and may be required to meet the Core Requirements.

Bioretention (BMP LID-10) is especially encouraged, and generally may be used to meet both flow control and water quality requirements. Note that the design criteria for LID BMPs is evolving and subject to revision; check with the Drainage Manual Administrator for updated design criteria.

BMP LID-10 Bioretention Facilities

Bioretention facilities are shallow stormwater retention systems designed to mimic forested systems by managing stormwater through detention, infiltration, and evapotranspiration. Bioretention areas also provide water quality treatment through sedimentation, filtration, adsorption, and phytoremediation. Compared to traditional stormwater pond designs, these facilities are typically smaller in scale and integrated into the landscape to better mimic natural hydrologic systems. They may be used for both flow control and water quality treatment.

Figure 6.8 illustrates a section view of a typical bioretention system.



NOTE 1:
Freeboard Depth shall be 2" min. for contributing areas < 1,000 SF, and 6" min. for contributing areas ≥ 1,000 SF

Figure 6.8 Typical Bioretention Facility

(courtesy of Thurston County)

Types of Bioretention Facilities

Bioretention facilities can be configured in many ways, including the following:

- Rain Gardens (Bioretention Cells): Shallow depressions with a designed planting soil mix and variety of plant material, including trees, shrubs, grasses, and/or other herbaceous plants. Bioretention cells may or may not have an under-drain and are not designed as a conveyance system. Bioretention cells can be configured as depressed landscape islands, larger basins, planters, or vegetated curb extensions. They are most appropriate for small (10,000 sf or less) contributing areas.

- Vegetated Curb Extensions: Bulb out areas along a road right-of-way containing a bioretention cell to accept roadway runoff.

- Bioretention Swales/In-line Bioretention: Long, linear facilities that incorporate the same design features as bioretention cells. Bioretention swales have relatively gentle side slopes and shallow flow depths.

Many other configurations of bioretention facilities are possible, but require different design methods than those described here. The following bioretention configurations require City acceptance, and are described in the *Low Impact Development: Technical Guidance Manual for Puget Sound* (PSAT 2005).

- Biodetention: a design that uses vegetative barriers arranged in hedgerows across a slope to disperse, infiltrate, and treat stormwater.

- Sloped Biodetention: uses vegetative barriers designed for a specific hydraulic capacity and placed along slope contours.

- Off-line Bioretention: the bioretention facility is placed next to a swale with a common flow entrance and flow exit.

- Sloped or Weep Garden bioretention areas: used for steeper gradients where a retaining wall is used for structural support and for allowing storm flows, directed to the facility, to seep out.

- Tree Box Filters: street tree plantings with an enlarged planting pit for additional storage, a storm flow inlet from the street or sidewalk, and an underdrain system.

Potential applications for bioretention facilities include the following:

- In parking lots, as concave landscaped areas (i.e., lower than the parking lot surface, so that stormwater runoff is directed as sheet flow into the bioretention area). This application, combined with porous surfaces in the parking lot, can greatly attenuate stormwater runoff.

- Areas within loop roads or cul-de-sacs, to collect runoff from adjacent areas and portions of the roadway.

- Along roads (linear bioretention cells or swales, vegetated curb extensions & planters)

- Within apartment complexes or other multifamily housing designs, in landscaped common areas.

- Shared facilities located in common areas within a subdivision.

- On individual lots, bioretention facilities should be used to receive rooftop runoff in areas where downspout infiltration systems (BMP LID-04) are not feasible and in preference to downspout dispersion systems (BMP LID-05), and may be integrated into the landscaped areas of the lot.

- On individual lots bioretention facilities can also be used to receive driveway and other on-lot impervious and pervious surfaces.

Limitations

- The maximum contributing area for any single bioretention facility is one-half acre, unless contributing area is 100% pervious, in which case contributing area may be up to ¾ acre.
- Bioretention facilities shall meet the same setback requirements as for infiltration facilities.
- Provide adequate separation from utilities, sidewalks, etc. for mature plants and roots.
- Situate the bioretention facility on slopes of less than 10% grade.
- Vertical separation from any restrictive layer (such as seasonally high groundwater level or glacial till) to the base of the amended soil mixture shall be as follows:

  A minimum clearance of 3 feet is necessary between the lowest elevation of the bioretention facility (i.e. base of soil mixture, or any underlying gravel layer) and the seasonal high groundwater elevation or other impermeable layer if the area tributary to the facility meets or exceeds any of the following limitations:

  - 5,000 square feet of pollution-generating impervious surface (PGIS)
  - 10,000 square feet of impervious area
  - Three-fourths of an acre (32,670 square feet) of lawn and landscape.

  For bioretention systems and rain gardens with a contributing area that is less than the above thresholds, or for a bioretention swale on a linear project (roadway) with continuous sheet flow runoff from the roadway surface, a minimum of 1 foot of vertical clearance above the seasonal high groundwater level or other impermeable layer (whichever is highest) is acceptable.

Hydrologic and Hydraulic Design Considerations

Bioretention Facility Sizing

The size of a bioretention facility is based mainly upon the size of the area contributing flow to the facility and the infiltration rate of the native soil below the facility. For hydrologic design, use the latest version of the Western Washington Hydrology Model (WWHM). Direct modeling of bioretention is available in the most recent version of WWHM (WWHM4). Note that a site with rain gardens or other bioretention facilities may also need a supplemental pond, infiltration trench and/or discharge system in lieu of other integrated L.I.D. practices.

A basic bioretention facility is considered to provide basic water quality treatment. To be considered an enhanced (metals) treatment BMP, the bioretention facility must infiltrate at least 91 percent of the total volume of runoff in the WWHM inflow runoff file.

Infiltration Rate Determination

The design infiltration rate for the bioretention facility must be the lower of:

(1) The estimated long-term rate of the imported soil, or

(2) The initial infiltration rate of the underlying soil profile.

Imported Soil

The infiltration rate of imported soils can be determined using ASTM D2434 Standard Test Method for Permeability of Granular Soils (Constant Head) with a compaction rate of 80 percent using ASTM D1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort. Alternately, the infiltration rate can be estimated from the proportion of fines (percent passing #200 sieve) in the aggregate portion of the imported soil. Refer to Figure 2.9 in Volume V of the Thurston County *Drainage Design and Erosion Control Manual* (2009) for a relationship between measured hydraulic conductivity and percent fines. If the design infiltration rate for the bioretention facility is determined by the imported soil, the quantitative method of determining the soil infiltration rate must be used.

The design infiltration rate for imported bioretention soil mix is estimated by applying a reduction factor to the measured value as discussed above. A reduction factor of 2 (multiply measured infiltration rate by 0.5) is applied where contributing areas are <5,000 sq. ft. of pollution generating surface, <10,000 sq. ft. of impervious area, and <3/4 acre of landscape area. Above these thresholds an infiltration reduction factor of 4 is applied.

Underlying Soil

See Section 6.3 (“Infiltration Facilities”) for determination of the design infiltration rate of the underlying soil.

Design Criteria

Cell Geometry

The surface of the bioretention facility must be lowest near the center to receive and contain inflow. This ponding area provides surface storage for storm flows, particulate settling, and the first stages of pollutant treatment within the facility. The bioretention cell ponding area shall have a level bottom area minimum 2 feet wide. The total width of the bioretention cell should be no less than 10 feet, with the length about two to three times the width.

Pretreatment

If the catchment area contains unvegetated exposed soils or steep slopes, a presettling system (e.g., a filter strip, presettling basin, or vault) is required.

Flow Entrance

Runoff water should flow slowly into the rain garden, to reduce the potential for erosion. Inflow should be spread-out rather than concentrated, to disperse the flow into the facility. Vegetated buffer strips are the preferred entrance type because they slow incoming flows and provide initial settling of particulates.

Flow velocity at any facility entrance should be no more than 1 ft. per second to minimize erosion potential. Where inflow is concentrated (from a pipe, channel or curb opening), provide flow dispersion and erosion protection at the transition into the bioretention facility.

Flows entering via a pipe should originate at a catch basin to trap sediment, while overland flows should pass through a vegetated buffer (e.g. a grass filter) and through a flow dissipater bordering the rain garden.

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

1. Dispersed, low velocity flow across a grass or landscape area; this is the preferred method of delivering flows into 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 roadway, driveway or parking lot areas; curb cuts shall include a concrete chute below the gutter grade to prevent material from building-up and backing flows into the roadway. Rock or other erosion protection material shall be installed at the outlet of the concrete gutter chute 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:

- If concentrated flows are entering the facility, engineered flow dissipation (e.g., rock pad or flow dispersion weir) must be incorporated.

- A minimum 2-inch grade change between the edge of a contributing impervious surface and the vegetated flow entrance is required.

- Until the upstream catchment area is thoroughly stabilized, flow diversion and erosion control measures must be installed to protect the bioretention area from sedimentation.

- Dispersed flow should not be concentrated for presettling purposes.

Slopes

Blend the rain garden slopes into the surrounding landscape for a smooth transition, and grade the surrounding area such that flow into the rain garden is spread-out and slowed-down as much as possible.

- The maximum interior side slopes within a bioretention cell shall be no steeper than 4H:1V. Steeper backslopes may be allowed for bioretention swales in roadway projects with limited right-of-way width, subject to City acceptance of the design.
- Vertical walls are not permitted except in bioretention planters.

Ponding Depth

The design ponding depth shall be a minimum of 6 inches and a maximum of 12 inches (unless optional detention storage is incorporated – see below), with a minimum freeboard of 6 inches above the ponding depth to the lowest point on the rim of the facility.

Overflow

Bioretention and rain garden facilities must include an overflow (unless designed for 100% infiltration of the entire continuous model runoff file). Facility overflow can be provided by an inlet grate or drain pipe installed at the designed maximum ponding depth and connected to a downstream BMP or an approved discharge point.

Overflow drainage facilities shall be designed to convey the 100-year recurrence interval flow. This assumes the facility will be full due to runoff rates far in excess of soil infiltration capacity. The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.

Drawdown Time

The rain garden should only hold surface water for brief periods if the facility infiltrates properly. The surface pool drawdown time shall be a maximum of 24 hours. This can be estimated by dividing the maximum ponded depth by the design (long-term) infiltration rate. Soils must be allowed to dry out periodically in order to restore the hydraulic capacity of the system and to maintain infiltration rates. Pooled water remaining for four days or longer may affect plant health, may promote the breeding of mosquitoes and other insects, and may indicate the need for rehabilitation of the facility.

The requirements for ponding depth and drawdown rate are intended to provide surface storage, adequate infiltration capability, and appropriate soil moisture conditions.

Optional Detention Storage

It is possible to design additional detention storage above the 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 meet the dewatering requirement of 24 hours, maximum.

If using this design, the plant selection must clearly reflect the additional proposed storage depth. This potential modified design is allowed only for large bioretention systems, not for facilities on individual lots. Care must be taken to still blend these larger and deeper facilities in with the surrounding landscape.

Bioretention Soil Mixture:

The planting soil mixture within the bioretention facility shall be a highly permeable, highly organic mixture of *sandy soil* mixed thoroughly with *compost amendment*. The soil mixture should never be compacted. The final Compost-Amended Soil Mixture shall be comprised of approximately 2/3 loamy sand and 1/3 compost amendment. Alternatively, the final soil mixture may be 30% sandy loam, 30% coarse sand, and 40% compost. The mixture should have about 10% organic content, with less than 5% clay. Soil mixture shall be clean (no man-made debris) and free of rocks, roots or other woody debris greater than 1”-diameter. The final bioretention soil mix shall have a CEC (cation exchange capacity) of at least 5 meq/100 grams of dry soil, 8% to 10% organic matter content, 2% to 5% fines, and a maximum of 12”/hour initial (measured) infiltration rate. A minimum of 18” soil depth shall have these properties.

Sandy Soil component:

The soil portion of amended soil mixtures for use in rain gardens shall consist of sand, loamy sand or sandy loam (with very little clay) per the USDA Textural Triangle. If on-site excavated soil is used to create the mixture, it must be tested and verified as suitable by the geotechnical engineer.

Compost Amendment component:

The compost used to amend soils for use in rain gardens must comply with Chapter 173-350 WAC (see www.ecy.wa.gov/programs/swfa/facilities/350.html). To meet the definition of composted material, it must be organic solid waste that has undergone biological degradation and transformation under controlled conditions designed to promote aerobic decomposition.

The compost should be stable and mature, dark brown in color, and earthy-smelling, with a crumbly texture. It should remain at a stable temperature (i.e. not heat-up when wetted), have mixed particle sizes, and shall meet the following criteria:

- Organic content 45% - 65%
- pH between 5.5 and 7.5
- Carbon to nitrogen ratio between 20:1 and 25:1 (30:1 to 35:1 preferred for native plants)
- Moisture content 35% to 50%
- No viable weed seeds present
- Less than 1% manufactured inert material (concrete, plastic, etc.)

Soil Testing shall be performed to verify that the soil mixture (or the sandy soil and compost amendment components) meets specifications. At least one soil test shall be performed for every 100 cubic yards of soil mixture, and all tests shall be certified by a testing laboratory or geotechnical engineer for approval by the City of Lacey prior to placement on the project site.

Soil Mixture Depth Requirements:

- For most applications (e.g. parking lots), amended soil mixture depth shall be 18” to 24”.
- For enhanced (metals and/or phosphorus) treatment and/or in sensitive locations, the soil mixture may be modified and/or the depth may be increased per the determination of the City of Lacey Public Works Department.
- For individual residential lots (e.g. roof drains), soil mixture depth shall be 18” min.

Note : The soil mixture depth and other potential requirements or restrictions for water resource protection (particularly in surface water or groundwater sensitive areas) shall be as specified by the City of Lacey. For nitrate removal, an underdrain system may be required to provide for anaerobic denitrification. Requirements for underdrains, rain garden components, and other factors are subject to revision at any time by the City of Lacey.

Mulch Layer

Cover the entire surface of the rain garden soil mixture with a layer of mulch. The mulch shall be the compost used in the soil mixture or a similar material, but shall not be bark or grass clippings within the bioretention facilities (compost is less likely to float and is a better source for organic materials). The mulch shall be free of weed seeds, soil and roots.

The mulch serves to retain soil moisture, discourage weed growth, prevent erosion and provide water quality improvement. The mulch layer filters pollutants and provides an environment conducive to the growth of microorganisms, which degrade oil-based substances and other organic materials. The compost mulch shall be maintained on the bottom and interior side slopes of the rain garden.

- Provide and maintain a 2” to 3”-deep layer of compost mulch over the entire soil mix surface.
- May use shredded or chipped hardwood or softwood in surrounding areas (beyond the rim of the facility).

Underdrain

In the event that the downstream pathway of infiltration and interflow cannot be maintained, 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 connected to a nearby vegetated channel, another stormwater facility, or dispersed into a natural protection area.

Underdrain systems should be installed only if the bioretention facility 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 the maximum pool drawdown time.

Only the area below the underdrain invert and the bottom of the bioretention facility can be used in the WWHM for flow control benefit. The area above an underdrain pipe in a bioretention facility provides attenuation and pollutant filtering.

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.

Underdrain pipe shall be per WSDOT Standard Specifications Section 9-05.2 for Perforated PVC Underdrain pipe, Perforated Corrugated Polyethylene Drainage Tubing Underdrain Pipe or Perforated Corrugated Polyethylene Underdrain Pipe.

The underdrain pipe diameter will depend on hydraulic capacity required (4 to 8 inches is common). Within the public right-of-way any underdrain shall have a minimum diameter of 12-inches with access to both ends. A geotextile fabric (see Appendix 6C) must be used between the soil layer and underdrain.

The underdrain should be sloped at 0.5 percent unless otherwise specified by the project engineer.

A minimum of 6 inches of granular filter material shall be placed over the top of the underdrain pipe. Wrapping with geotextile is not recommended.

A 6-inch rigid non-perforated observation pipe or other maintenance access shall be connected to the underdrain every 250 to 300 feet to provide a clean-out port, as well as an observation well to monitor dewatering rates.

Note: If a bioretention facility is designed with an underdrain, its ability to meet the flow control criteria of Minimum Requirement #7 is limited to that area beneath the underdrain that has stormwater holding capacity.

Gravel Filter Material

Gravel blankets and filter fabrics buffer the under-drain system from sediment input and clogging. Gravel Filter Material for underdrains shall be Gravel Backfill for Drains per WSDOT Standard Specifications 9-03.12(4).

Filter Fabric

Filter fabric for lining the underdrain (separation between gravel filter and native soil) shall be a non-woven geotextile fabric meeting WSDOT Standard Specifications Section 9-33 requirements for a “Separation” geotextile. See also Appendix 6C for geotextile specifications.

Alternative combinations of gravel filter material, underdrain pipe and filter fabric may be proposed if evaluated by a geotechnical or civil engineer for compatibility and suitability for the application.

Plants

The plants selected for a bioretention facility should ideally be hardy, drought-tolerant native species with good aesthetic qualities. Since this is more a functional garden than an ornamental one, the predominant plantings should generally be species that are adaptable to the varying wet and dry conditions that can be expected in a stormwater-receiving facility. The plants are a key component of the rain garden, and must be carefully selected, planted and cared-for.

Soil moisture and locational factors are the primary considerations, with landscaping considerations such as aesthetics, plant compatibility and blending into the adjacent setting also playing a role. Locational factors include sun exposure (sun/shade) and existing features, such as the presence of utilities. For example, the root systems of some plant species (such as willows) can potentially damage pavement and/or underground structures and should be selected and placed with consideration of this potential.

In terms of soil moisture, plants in a rain garden need to be tolerant of varying conditions including fluctuating water levels, saturated soils during rainy periods and summer dry spells. Plantings are arranged by zones within the rain garden, using appropriate plant varieties for the various moisture conditions and exposure to sun/shade present. Other considerations include such factors as plant growth, tree canopy, and tolerance of pollutants, insects and disease. A mix of several compatible species of various sizes will tend to resist devastation by infestation or disease, provide a healthy habitat, and provide functionality with a pleasing appearance. Weed growth can be limited by planting grasses and groundcovers.

Rain gardens generally have three planting zones, based on typical moisture conditions:

Zone 1: The low, wet zone at the bottom of the rain garden. Subject to periodic or frequent inundation or soil saturation. Plants suitable for this zone will also tolerate seasonal dry periods without additional watering, and may also survive in Zone 2 or 3.

Zone 2: Interior lower slopes, transitional between wet & dry zones, with periodic saturation. Plants suitable for this zone should also tolerate dry periods, and may be suitable for Zone 3.

Zone 3: The upper zone of generally dry soil, rarely inundated, on the upper slopes near the rim of the rain garden. Plants appropriate for this zone can survive with minimal watering once established, and may blend well into the surrounding landscape.

The predominant plantings should generally be facultative species (i.e. plant species that are equally likely to occur either in wetlands or non-wetlands) that are adapted to the stresses of varying wet and dry conditions. Planting in autumn is generally preferred, allowing for plant establishment before winter but without the higher watering needs of spring or summer plantings. The end result should include a dense plant community of compatible combinations of species.

The tables in Appendix 6D list some plant varieties that may be suitable for planting in bioretention facilities. The first table lists plants recommended for sunny sites, the second lists plants that are OK in the shade. Most of the plant varieties listed are native to the Puget Sound region, so they should be generally available and perform well under our local conditions. The lists are intended to provide some suggestions for potential plantings, and are not all-inclusive.

Planting Recommendations:

- Planting is best in autumn; it can be OK in winter & spring, but requires watering in summer.
- The rain garden should be planted with a minimum of 3 tree species, 3 shrub species, and 3 species from the emergent, herb and/or groundcover groups, in appropriate zones.
- More numerous/smaller plants are preferable to fewer/larger plantings. For example, in a span of 4 ft., five 6" pots spaced 12" on-center is preferable to three 2-gallon pots at 24" O.C. Smaller plant material provides several advantages and is recommended. Small plants require less careful handling and less initial irrigation, they experience less transplant shock, are less expensive, adapt more quickly to a site, and transplant more successfully than larger plants. Small trees or shrubs are generally supplied in pots of 3 gallons or less.
- Plants should conform to the standards of the current edition of *American Standard for Nursery Stock* as approved by the American Standards Institute, Inc. All plant grades shall be those established by said reference.
- All plant materials should have normal, well-developed branches and vigorous root systems, and be free from physical defects, plant diseases, and insect pests.
- All plants shall be tagged for identification when delivered.

Planting of bioretention areas should be designed by a landscape architect or landscaper, with reference to the plant recommendations in Appendix 6D and the detailed bioretention plant list in *Low Impact Development: Technical Guidance Manual for Puget Sound* (PSAT 2005).

Primary design considerations in plant selection include:

- *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.
- *Expected pollutant loadings*: Plants should tolerate the pollutants and loadings anticipated from the surrounding land uses.
- *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 should be selected to not damage underground utilities if present. Perforated pipe should be more than 5 feet from tree locations.
- *Adjacent plant communities and potential invasive species control.*
- *Site distances and setbacks for roadway applications.*
- *Visual buffering:* Plants can be used to buffer structures from roads, enhance privacy among residences, and provide an aesthetic amenity for the site.

- *Aesthetics:* Visually pleasing plant design adds value to the property and encourages community and homeowner acceptance. Homeowner education and participation in plant selection and design for residential projects should be encouraged to promote greater involvement in long-term care.

Signage and Fencing

Bioretention facilities (e.g. Rain Gardens) are stormwater management facilities and shall be identified as such with signage and fencing. Signs shall be installed identifying the facility and its purpose and not to disturb. Fencing should be considered to reduce public access through the facility, especially if located within a parking area or other area easily accessible to the public.

Maintenance

Regular maintenance is a basic necessity for any stormwater facility and for any landscaped area, and bioretention facilities are both. They will require a level of care similar to that required for any planting bed, plus attention to drainage features and structures such as overflow grates. They require annual plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. Plants will require watering, particularly during the first few years after planting and during prolonged dry spells. Weeds must be removed, and occasional pruning and removal of dead plant material may be necessary. Fertilizer and pesticide should be avoided, and should not be needed with appropriate plant selection and conditions. Watch for signs of erosion within and around the rain garden, particularly at the flow entrances and after intense storms. Repair areas where the mulch, plants or soil are displaced, and provide a means for flow dissipation and erosion protection to prevent damage from recurring. Replace or add mulch as needed to maintain approximately 2”-3”depth, generally once every year or two. In locations with potentially high pollutant loading, replace the mulch layer annually.

See the Stormwater Facility Maintenance Guide in Chapter 9 for bioretention maintenance checklists (routine and non-routine). The Maintenance Plan prepared for the owner should include suggestions such as those above, plus descriptions of the plants and other features of the bioretention facility, to aid in inspection and maintenance.

Construction of Bioretention Facilities

Pre-construction

All areas draining to the rain garden location must be stabilized prior to initiating rain garden excavation or construction. During site grading, direct flow away from the rain garden location by using temporary diversion swales or similar methods.

Bioretention facilities, as with all types of infiltration facilities, should generally not be used as temporary sediment traps during site work or construction. If a bioretention facility is to be used as a sediment trap, do not excavate to final grade until after the upgradient drainage area has been stabilized. Remove any accumulation of sediment from the facility before putting the facility into service.

Excavation

Minimizing compaction of native soils at the rain garden location is critical to avoid failure of the finished facility, so preserve uncompacted soil during construction activities. 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.

The excavated pit should be deep enough to allow for the prescribed depth of compost-amended soil mixture, 2"-3" of mulch, and about one foot of surface depression to contain collected rain water. The slopes of the exposed sidewalls above the soil mixture and mulch shall be no steeper than 4:1 (horiz:vert). The base of the excavated pit should be flat, and both the base and sidewalls of the excavation should be roughened where scraped smooth (and possibly sealed) by the excavation process. If the base area becomes compacted, it should be ripped to a depth of at least 12" below the base level to break-up the soil and restore permeability.

Soil Placement

The soil mixture should be placed when the excavated pit or trench is dry, by equipment operating adjacent to, but not within, the rain garden excavation. Place the soil in layers of not more than 12" per lift, and allow time for each lift to settle naturally. The soil mixture shall <u>not</u> be mechanically compacted. The soil may be lightly sprayed with water to speed the settling process, but do not saturate. The soil mixture must be approved by the City of Lacey prior to placement (see *Soil Testing*). Rain garden construction shall be supervised by the design engineer or landscape architect.

Submittals and Approval

The applicant should consult with the City at the pre-submittal meeting and the scoping report/meeting for the project to discuss the suitability of and requirements for a bioretention facility if one is proposed for the project.

Project submittal shall include the following in addition to the requirements of other sections:

- Source of bioretention soil mix and testing results of treatment soil.
- Description of method used and results of infiltration testing of base soils and bioretention soil mix.
- Hydrologic modeling results for the bioretention facility demonstrating that the water quality treatment design storm is handled by the facility and how volumes greater than the water quality design flow are managed.
- Project drawings shall include a typical cross-section of the facility and specifications for installation of treatment soils, seeding, sodding and other construction requirements.

- Maintenance Plan shall include a discussion of maintenance requirements, a planting plan and plant list, and plant care recommendations for the specific plants of the bioretention facility.
- The bioretention soils mix shall be tested for infiltration capacity using the following test method:
  - ASTM 2434 Standard Test Method for Permeability of Granular Soils (Constant Head) with a compaction rate of 80 percent using ASTM 1557 (Modified Proctor).
- Include in the Soils Management Plan prepared per BMP LID-09 the bioretention soils mix for any proposed bioretention facilities included in the project.

BMP LID-11 Alternative (Permeable) Paving Surfaces

Alternative (permeable) paving surfaces are designed to accommodate pedestrian, bicycle, and auto traffic while allowing infiltration and storage of stormwater. Alternative paving surfaces include:

- Permeable asphalt pavement
- Permeable concrete
- Grid or lattice rigid plastic or paving blocks where the holes are filled with soil, sand, or gravel
- Cast-in-place paver systems.

Alternative paving systems may be designed with an underdrain to collect stormwater or without an underdrain as an infiltration facility.

Applicability

Appropriate applications for alternative paving surfaces include parking overflow areas, parking stalls, low volume residential roads, alleys, driveways, sidewalks/pathways, patios, emergency access, and facility maintenance roads.

Permeable paving surfaces can provide some attenuation and uptake of stormwater runoff even on till soils while still providing the structural integrity required for a roadway surface to support heavy truck loads.

Permeable paving surfaces can be designed with aggregate storage to function as an infiltration facility with relatively low subgrade infiltration rates. Since the contributing flow is only the incident rainfall, the hydraulic loading rate of the infiltration area is low.

Limitations

The City of Lacey will not currently approve permeable pavement surfaces on City-maintained roads.

Permeable pavement is not intended to receive “run-on” stormwater from other areas.

Permeable paving surfaces are not appropriate for roads subject to high sediment loadings (such as roads that are sanded for deicing purposes in the winter). Application of sand and other gritty substances can clog the pavement, impeding the infiltration of stormwater and resulting in hazardous ponded water conditions.

Because of water quality concerns related to stormwater with high concentrations of oils or other contaminants infiltrating through the surface and contaminating groundwater, permeable pavement surfaces shall not be allowed with land uses that generate heavy loadings of these pollutants. These include, but are not limited to, gas stations, commercial fueling stations, auto body shops, automobile repair services, and automobile wash services.

Sidewalk designs incorporate scoring, or truncated domes, near the curb ramp to indicate an approaching traffic area for the blind. The rougher surface of some types of permeable paving may obscure this transition. Therefore standard concrete with scoring or truncated domes with pavers may be required for curb ramps (check with the City of Lacey for current requirements).

The aggregate within the cells of permeable pavers can settle or be displaced from vehicle use. As a result, paver installations for disabled parking spaces and walkways may require the use of solid pavers or standard concrete or asphalt (check with City of Lacey for current requirements).

Permeable pavement surfaces are suitable for use in Type A through C soils, but are not recommended for Type D soils. However, with adequate accommodation of potential runoff from the permeable paving surface over Type D soils, the application can be beneficial for encouraging infiltration.

Note: Permeable pavement is an evolving BMP with ongoing research and development. The City of Lacey’s specifications for permeable pavement are subject to change at any time. All proposed permeable pavements are subject to approval by the Lacey Public Works Department.

Hydrologic and Hydraulic Design Considerations

Permeable paving surfaces differ greatly in infiltration capacity. Base materials of permeable pavement systems can be designed to infiltrate vertically into outwash soils.

Where cemented till layers of soil exist under a parking lot, a permeable pavement system can potentially still be effective to attenuate peak flows. In small area applications, the subgrade of the parking lot can be built up with permeable base material and graded to direct runoff through this material to a controlled outfall, such as a bioretention area.

Flow Credit/Modeling of Alternative (Permeable) Paving Surfaces

Permeable pavement surfaces designed in accordance with this section for infiltration should be modeled as indicated in Table 5.3.   Note that permeable paving surfaces should not be receiving "run on" from other surfaces. Permeable paving surfaces are highly effective at infiltrating runoff, even with relatively low infiltration rates because the BMP surface area is the same as the contributing surface area. Installing an underdrain is typically unnecessary and greatly reduces the flow control benefit of this BMP.

Design Criteria

Manufacturer's recommendations on design, installation, and maintenance shall be followed for each application.

Drainage Conveyance

Design roads with adequate drainage conveyance facilities as if the road surface was impermeable.

Design drainage flow paths to safely move water away from the road prism and into the roadside drainage facility for roads with base courses that extend below the surrounding grade.

Runoff Treatment

The subgrade must have an infiltration rate of less than 2.4 inches per hour and a cation exchange capacity of 5 milliequivalents CEC/100 grams dry soil or greater to provide water quality treatment that satisfies Core Requirement #6. Runoff treatment does not apply to alternative paving surface facilities with an underdrain.

Geometry

Positive surface drainage shall be provided to eliminate risk of ponding on pavement surface (minimum surface slope of 1 percent).

- Unless approved in writing by the City of Lacey Department of Public Works, maximum slopes for alternative paving surfaces are 5% for permeable asphalt, 6 % for permeable concrete, 10% for interlocking pavers, and 5% to 6% for grid and lattice systems.

Materials

Figures 6.9 and 6.10 show examples of typical cross-sections of permeable paving sections. They typically consist of a top layer (permeable wearing course), an aggregate subbase, an optional leveling course and geo-textile fabric.

Porous Wearing Course

The wearing course or surface layer of the alternative paving surface may consist of permeable asphalt, permeable concrete, interlocking concrete pavers, or open-celled paving grid with vegetation or gravel. The wearing course must provide adequate porosity and permeability for stormwater infiltration.

Requirements for the wearing layer include the following:

- A minimum infiltration rate of 10 inches/hour is required, although higher infiltration rates are desirable.
- For permeable asphalt, products must have adequate void space, commonly 12 to 20 percent.
- For permeable concrete, products must have adequate void space, commonly 15 to 21 percent.
- For grid/lattice systems filled with gravel, sand or a soil of finer particles with or without grass, fill must be at least 2 inches. Fill shall be underlain with 6 inches or more of sand or gravel to provide an adequate base. Locate fill at or slightly below the top elevation of the grid/lattice structure. Modular grid openings must be at least 40 percent of the total surface area.
- For paving blocks, fill spaces between blocks with 6 inches of free draining sand or aggregate material. Provide a minimum of 12 inches of free-draining surface area.
- For a vegetated open-celled paving grid, topsoil shall have 4 percent minimum organic matter by dry weight.

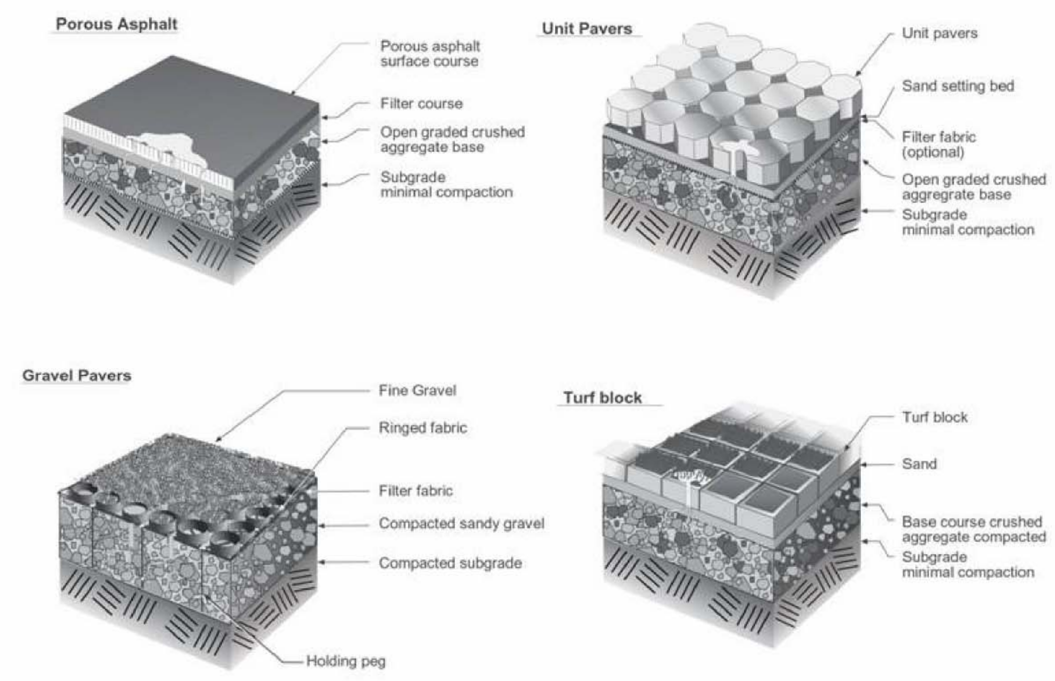


Figure 6.9 Typical Permeable Pavement Cross-Sections (source: Thurston County)

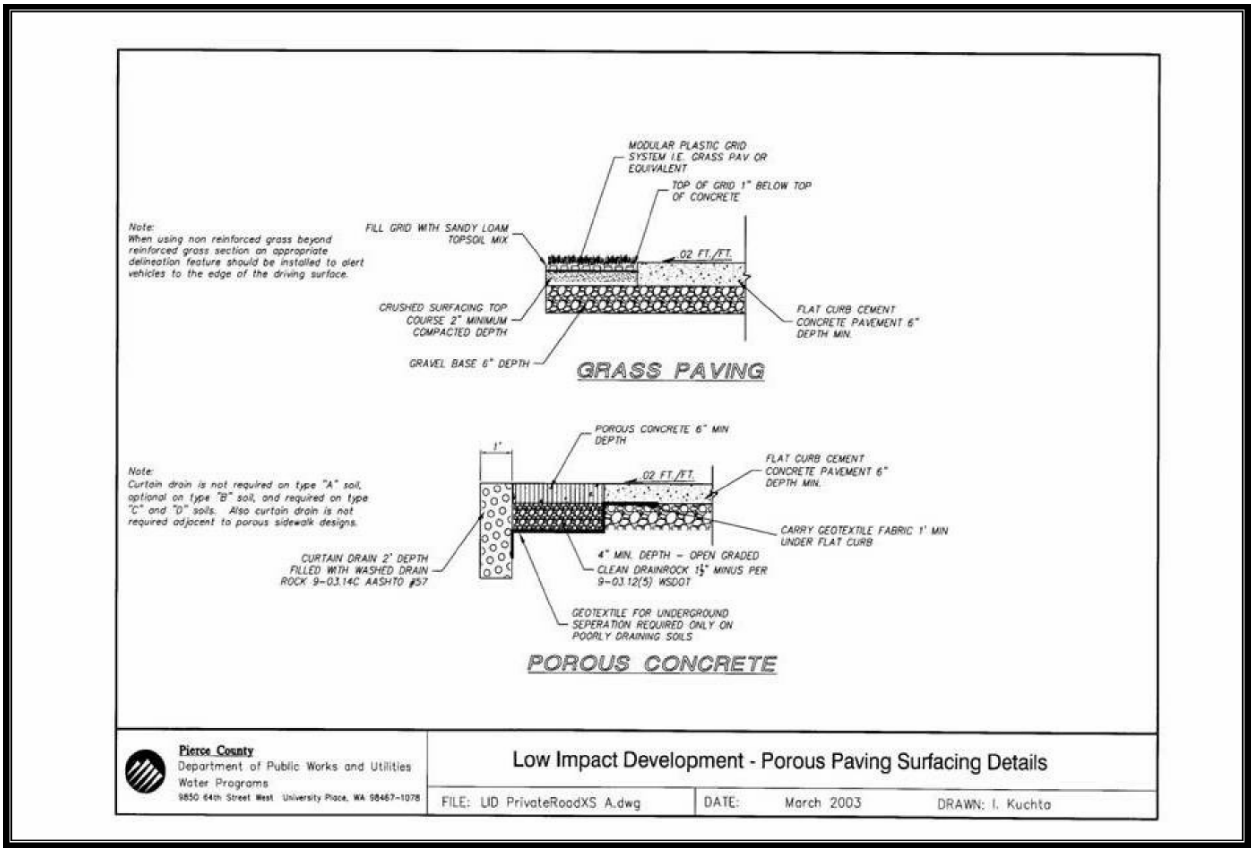


Figure 6.10 Typical Permeable Pavement Details (source: Pierce County)

Leveling Course

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

Aggregate Subbase

In a permeable paving surface, the aggregate subbase serves as the support base and must be designed to support the expected loads and be free draining. The subbase shall meet the following criteria:

- Material must be free draining.
- A 4 to 6-inch depth of aggregate subbase is recommended under the permeable wearing course and leveling course (if any).

- Aggregate subbase shall consist of larger rock at the bottom and smaller rock directly under the top surface (e.g. a gradient from 2 inches to 5/8 inch).

- Below are examples of possible base material specifications. See Chapter 6 of the "*Low Impact Development: Technical Guidance Manual for Puget Sound*" for more detailed information.

    - Driveway base material:

        - > 4-inch layer of free-draining crushed rock, screened gravel, or washed sand.
        - < 5 percent fines (material passing the #200 sieve) based on fraction passing the #4 sieve.

    - Roads and Parking Lots:

        - Follow the standard material and quantities used for asphalt roads.

Geotextile Fabric

As part of the pavement section design, the designer should review the existing native soil or subbase characteristics and determine if a nonwoven geotextile is needed for separation of subbase from underlying soils.

Where necessary, the bottom and sides of the aggregate subbase should be contained by a nonwoven geotextile. The fabric should allow water to infiltrate but restrict movement of other particles into the gravel. See Appendix 6C for geotextile specifications.

Separation or Bottom Filter Layer

A layer of sand or crushed stone graded flat is recommended to promote infiltration across the surface, stabilize the base layer, protect the underlying soil from compaction, and serve as a transition between the base coarse and the underlying geotextile. This layer is optional but recommended.

Subgrade

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

Structural Design Considerations

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

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

ADA compliance should be requested from the manufacturer and is a consideration in determining where to use alternative paving surfaces.

Construction and Maintenance

Installation Criteria

Proper installation is key to the success of permeable paving surfaces. As with any pavement system, permeable pavement systems require careful preparation of the subgrade and base course to ensure success in terms of strength and permeability. The compressive strength of a permeable paver system relies mainly on the strength of the underlying soils, particularly when using modular or plastic units where the pavement itself lacks rigidity. Alternative paving surfaces shall be designed and installed according to manufacturer recommendations.

Install appropriate source and erosion control BMPs to prevent sediment transport from construction activities onto the base material or top course when the permeable surface is applied prior to the completion of construction and stabilization of the entire site.

If possible, temporary roads should be used during construction and final construction of the base material, and the permeable surfacing completed after building construction is complete.

Acceptance Test

Test all permeable surfaces by throwing a bucket of water on the surface. If anything runs off the surface or puddles, additional testing is necessary prior to accepting the construction.

As directed by the Administrator or designee, test with a 6–inch ring Infiltrometer or sprinkle Infiltrometer. Wet the road surface continuously for 10 minutes. Test to determine compliance with the 10 inches per hour minimum infiltration rate.

For facilities designed to infiltrate, the bucket test shall be completed annually.

Test documentation shall be retained with maintenance records and submitted with the engineer's inspection report at project completion.

Maintenance Criteria

Some general maintenance considerations for alternative paving surfaces are as follows:

- Clogging is the primary mechanism that degrades infiltration rates. However, as discussed above, the surface design can have a significant influence on clogging of void space.
- Studies have indicated that infiltration rates on moderately degraded permeable asphalts and concrete can be partially restored by suctioning and sweeping of the surface. Highly degraded permeable asphalts and concrete require high pressure washing with suction.
- Maintenance frequencies of suctioning and sweeping shall be specified by the design engineer and included in the Stormwater Facilities Maintenance Plan.
- Permeable pavement systems designed with pavers have advantages of ease of disassembly when repairs or utility work is necessary. However, it is important to note that the paver removal area should be no greater than the area that can be replaced at the end of the day. If an area of pavers is removed, leaving remaining edges unconfined, it is likely that loading in nearby areas will create movement of the remaining pavers thereby unraveling significantly more area than intended.

BMP LID-12 Vegetated ("Green") Roofs

A vegetated roof, also known as a green roof, ecoroof or roof garden, is an area of living vegetation installed on top of a building. A vegetated roof can provide flow control via detention, attenuation, and soil storage, and can control losses to interception, evaporation and transpiration. It can also provide habitat, enhance aesthetics, reduce the urban heat island effect, and reduce rooftop degradation from UV exposure.

Vegetated roofs generally consist of a layered system on a flat or nearly-flat rooftop, designed to provide for plant growth and drainage characteristics. The layered system typically includes a waterproof membrane, a root barrier, a drainage system, a soil layer and the vegetation.

Criteria for vegetated rooftops is not provided in this manual. Refer to the publication "*Low Impact Development: Technical Guidance Manual for Puget Sound*" or other appropriate references for design information.

Approval of vegetated rooftops will be on a case-by-case basis, and may be subject to specific requirements of the City of Lacey Building Department and Fire Marshal.

6.2 DETENTION FACILITIES

Detention facilities provide for the temporary storage of increased surface water runoff resulting from development pursuant to the performance standards set forth in Core Requirement #7 for flow control.

Three categories of detention facilities are presented in this section: detention ponds, tanks, and vaults.

6.2.1 Detention Ponds

The design criteria in this section are for detention ponds. However, many of the criteria also apply to other pond-type BMPs (e.g., infiltration ponds and water quality wetponds).

Any stormwater facilities that can impound 10 acre-feet or more with the water level at the embankment crest are subject to the state's dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-020(1)).

BMP D-01 Detention Ponds

Design Criteria

Standard details for detention ponds are shown in Figure 6.11 through Figure 6.13.

General

1. Ponds must be designed as flow-through systems (however, parking lot storage may be utilized through a back-up system). Developed flows must enter through a conveyance system separate from the control structure and outflow conveyance system. Place inlets and outlets the maximum practicable distance apart.
2. Pond bottoms shall be level and include one foot of dead storage below the outlet.
3. A geotechnical analysis and report must be prepared for steep slopes (i.e., slopes over 15%), or if the pond is located within 200 feet of the top of a steep slope or landslide hazard area.

Side Slopes

1. Interior side slopes up to the emergency overflow water surface shall not be steeper than 3H:1V unless a retaining wall is used and a fence is provided in those areas..
2. Exterior side slopes shall not be steeper than 3H:1V unless analyzed for stability and erosion resistance by a geotechnical engineer.

3. Ponds may have vertical retaining walls, provided: (a) they are constructed of reinforced concrete per Section 6.2.3, Materials; (b) a safety fence is provided along the top of wall; (c) at least 25 percent of the pond perimeter is a vegetated soil slope not steeper than 3H:1V; and (d) the design is stamped by a licensed civil engineer with structural expertise.

   Other retaining walls such as rockeries, concrete, masonry unit walls, and keystone type walls may be used if designed by a geotechnical engineer or a civil engineer with structural expertise. If more than 50 percent of the pond perimeter is to be retaining walls, ladders shall be provided on the walls for safety reasons.

Embankments

1. Pond berm embankments higher than 6 feet must be designed by a professional engineer with geotechnical expertise.
2. Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical engineer) free of seepage plains, loose surface soil materials, roots, and other organic debris.
3. Pond berm embankments greater than 4 feet in height must be constructed by excavating a key equal to 50 percent of the berm embankment cross-sectional height and top width (minimum 3 feet) unless specified otherwise by a geotechnical engineer.
4. Embankment compaction shall be accomplished in such a manner as to produce a dense, low permeability engineered fill that can tolerate post-construction settlements with a minimum of cracking. The embankment fill shall be placed on a stable subgrade and compacted to a minimum of 95% of the Standard Proctor Maximum Density, ASTM Procedure D698. Placement moisture content should lie within 1% dry to 3% wet of the optimum moisture content.
5. 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.

Overflow

1. 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 developed peak flow. The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.
2. A secondary inlet to the control structure must be provided in ponds as additional protection against overtopping. A “birdcage” or “beehive” inlet is required (Figure 6.13) and a grated opening (“jailhouse window”) in the control structure manhole, which functions as a weir may also be included as a secondary inlet.

   Note: The maximum circumferential length of this grated opening must not exceed one-half the control structure circumference.

Emergency Overflow Spillway

1. In addition to the above overflow provisions, ponds must have an emergency overflow spillway. For impoundments under 10 acre-feet, ponds must have an emergency overflow spillway that is sized to pass the 100-year developed peak flow.

2. Emergency overflow spillways must be provided for ponds with constructed berms over 2 feet in height, or for ponds located on grades in excess of 5 percent. As an option for ponds with berms less than 2 feet in height and located at grades less than 5 percent, emergency overflow may be provided by an emergency overflow structure, such as a Type II manhole fitted with a birdcage as shown in Figure 6.13. The emergency overflow structure must be designed to pass the 100-year developed peak flow, with a minimum 10% overvolume (and in no case less than 6 inches of freeboard), directly to the downstream conveyance system or another acceptable discharge point.

3. The emergency overflow spillway must be armored.. 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.

4. Emergency overflow spillway designs must be analyzed as broad-crested trapezoidal weirs. Either one of the weir sections shown in Figure 6.13 may be used.

Access

1. Maintenance access road(s) shall be provided to the control structure and other drainage structures associated with the pond (e.g., inlet or bypass structures).

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

Design of Access Roads

Access road design requirements are given below:

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

Construction of Access Roads

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

Fencing

1. A fence is needed at the emergency overflow water surface elevation, or higher, where a pond interior side slope is steeper than 3H:1V, or where the impoundment is a wall greater than 24 inches in height.
2. Fences shall be a minimum of 42 inches high, of such materials that would effectively prevent entry by small children, and complying with City of Lacey permitting requirements (such as building codes).
3. Access road gates shall be a minimum of 16 feet wide, consisting of two swinging sections 8 feet in width. Additional vehicular access gates may be needed to facilitate maintenance access.
4. Pedestrian access gates (if needed) should be 4 feet in width.
5. Vertical metal balusters or 9 gauge galvanized steel fabric with bonded vinyl coating can be used as fence material. For steel fabric fences, the following aesthetic features may be considered:
    a) Vinyl coating that is compatible with surrounding environment (e.g., green in open, grassy areas and black or brown in wooded areas). All posts, cross bars, and gates may be painted or coated the same color as the vinyl clad fence fabric.
    b) Fence posts and rails that conform to WSDOT Standard Plan L-2 for Types 1, 3, or 4 chain link fence.
6. For metal baluster fences, Building Code standards apply.
7. Wood fences may be used in subdivisions where the fence will be maintained by homeowners associations or adjacent lot owners.
8. Wood fences shall have pressure treated posts (ground contact rated) either set in 24-inch deep concrete footings or attached to footings by galvanized brackets. Rails and fence boards may be cedar, pressure-treated fir, or hemlock.

Signage

Detention ponds, infiltration ponds, wetponds, and combined ponds shall have a sign placed for maximum visibility from adjacent streets, sidewalks, and paths. Signage shall be as specified in the City of Lacey Development Guidelines or as specified by the drainage manual administrator.

Right-of-Way

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

Setbacks

All facilities shall be a minimum of 50 feet from the top of any steep (greater than 15 percent) slope, unless a geotechnical analysis and report are prepared that justify a smaller setback.

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

Seeps and Springs

When continuous flows are intercepted and directed through flow control facilities, adjustments to the facility design shall be made to account for the additional base flow. Setbacks may be required for seeps that classify as critical (such as landslide hazard) areas.

Planting Requirements

Exposed earth on the pond bottom and interior side slopes shall be sodded or seeded with an appropriate seed mixture. All remaining areas of the tract should be planted with grass or be landscaped and mulched.

Landscaping

Landscaping is encouraged for most stormwater tract areas (see below for areas not to be landscaped). However, if provided, landscaping should adhere to the criteria that follow so as not to hinder maintenance operations. Landscaped stormwater tracts may, in some instances, provide a recreational space. In other instances, "naturalistic" stormwater facilities may be placed in open space tracts.

The following guidelines shall be followed if landscaping is proposed.

1. No trees or shrubs may be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways or flow spreaders. Species with roots that seek water, such as willow or poplar, should be avoided within 50 feet of pipes or manmade structures.

2. Planting shall be restricted on external berms that impound water either permanently or temporarily during storms. This restriction does not apply to cut slopes that form pond banks, only to berms.

   a) Trees or shrubs may not be planted on portions of water- impounding berms taller than four feet high. Only grasses may be planted on berms taller than four feet.

      Grasses allow unobstructed visibility of berm slopes for detecting potential dam safety problems such as animal burrows, slumping, or fractures in the berm.

   b) Trees planted on portions of water-impounding berms less than 4 feet high must be small, not higher than 20 feet mature height, and have a fibrous root system. Table 6.2 gives some examples of trees with these characteristics developed for the central Puget Sound.

      These trees reduce the likelihood of blow-down trees, or the possibility of channeling or piping of water through the root system, which may contribute to dam failure on berms that retain water.

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. Compost used shall meet specifications for Grade A compost quality as described in Ecology publication 94-38.

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

5. For a naturalistic effect as well as ease of maintenance, trees or shrubs should be planted in clumps to form *"landscape islands"* rather than evenly spaced.

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

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

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

9. Drought tolerant species are recommended.

Table 6.2
Small Trees and Shrubs with Fibrous Roots

Small Trees / High Shrubs	Low Shrubs
*Red twig dogwood *(Cornus stolonifera)*	*Snowberry *(Symporicarpus albus)*
*Serviceberry *(Amelanchier alnifolia)*	*Salmonberry *(Rubus spectabilis)*
*Filbert (*Corylus cornuta*, others)	Rosa rugosa (avoid spreading varieties)
Highbush cranberry *(Vaccinium opulus)*	Rock rose *(Cistus spp.)*
Blueberry *(Vaccinium spp.)*	Ceanothus spp. (choose hardier varieties)
Fruit trees on dwarf rootstock	New Zealand flax (Phormium penax)
Rhododendron (native and ornamental varieties)	Ornamental grasses (e.g., Miscanthis, Pennisetum)

*Native species

Guidelines for Naturalistic Planting

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

Open Woodland

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

1. Landscaped islands (when mature) should cover a minimum of 30 percent or more of the tract, exclusive of the pond area.
2. Tree clumps should be underplanted with shade-tolerant shrubs and groundcover plants. The goal is to provide a dense understory that need not be weeded or mowed.
3. Landscaped islands should be placed at several elevations rather than “ring” the pond, and the size of clumps should vary from small to large to create variety.
4. Not all islands need to have trees. Shrub or groundcover clumps are acceptable, but lack of shade should be considered in selecting vegetation.

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

Northwest Savannah or Meadow

In addition to the general landscape guidelines above, the following are recommended.

1. Landscape islands (when mature) should cover 10 percent or more of the site, exclusive of the pond area.
2. Planting groundcovers and understory shrubs is encouraged to eliminate the need for mowing under the trees when they are young.
3. Landscape islands should be placed at several elevations rather than “ring” the pond. The remaining site area should be planted with an appropriate grass seed mix, which may include meadow or wildflower species. Native or dwarf grass mixes are preferred. Table 6.3 below gives an example of dwarf grass mix developed for central Puget Sound. Grass seed should be applied at 2.5 to 3 pounds per 1,000 square feet.

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

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

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

Seed Mixes

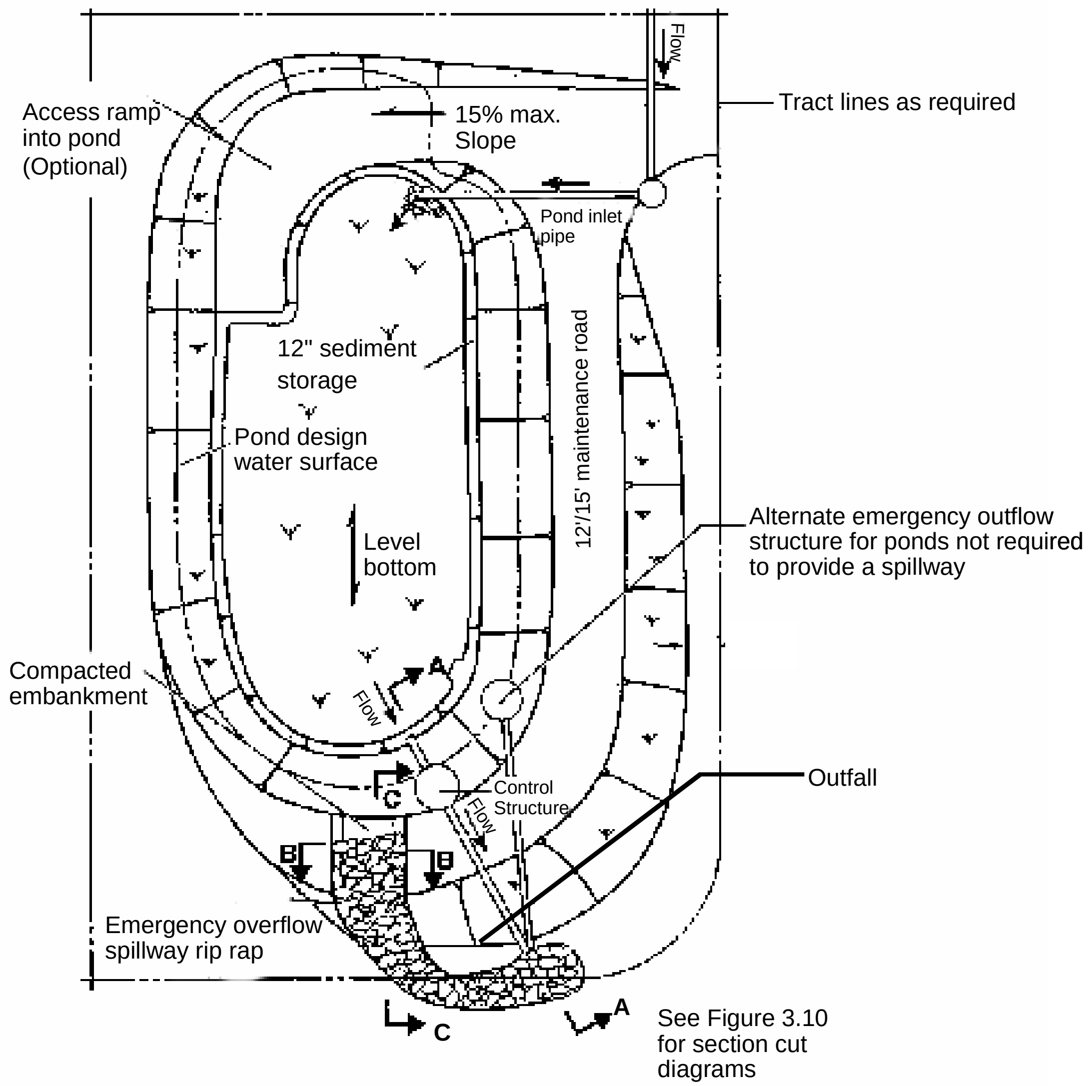
The seed mix listed in Table 6.3 below was developed for central Puget Sound.

Table 6.3

Stormwater Tract "Low Grow" Seed Mix

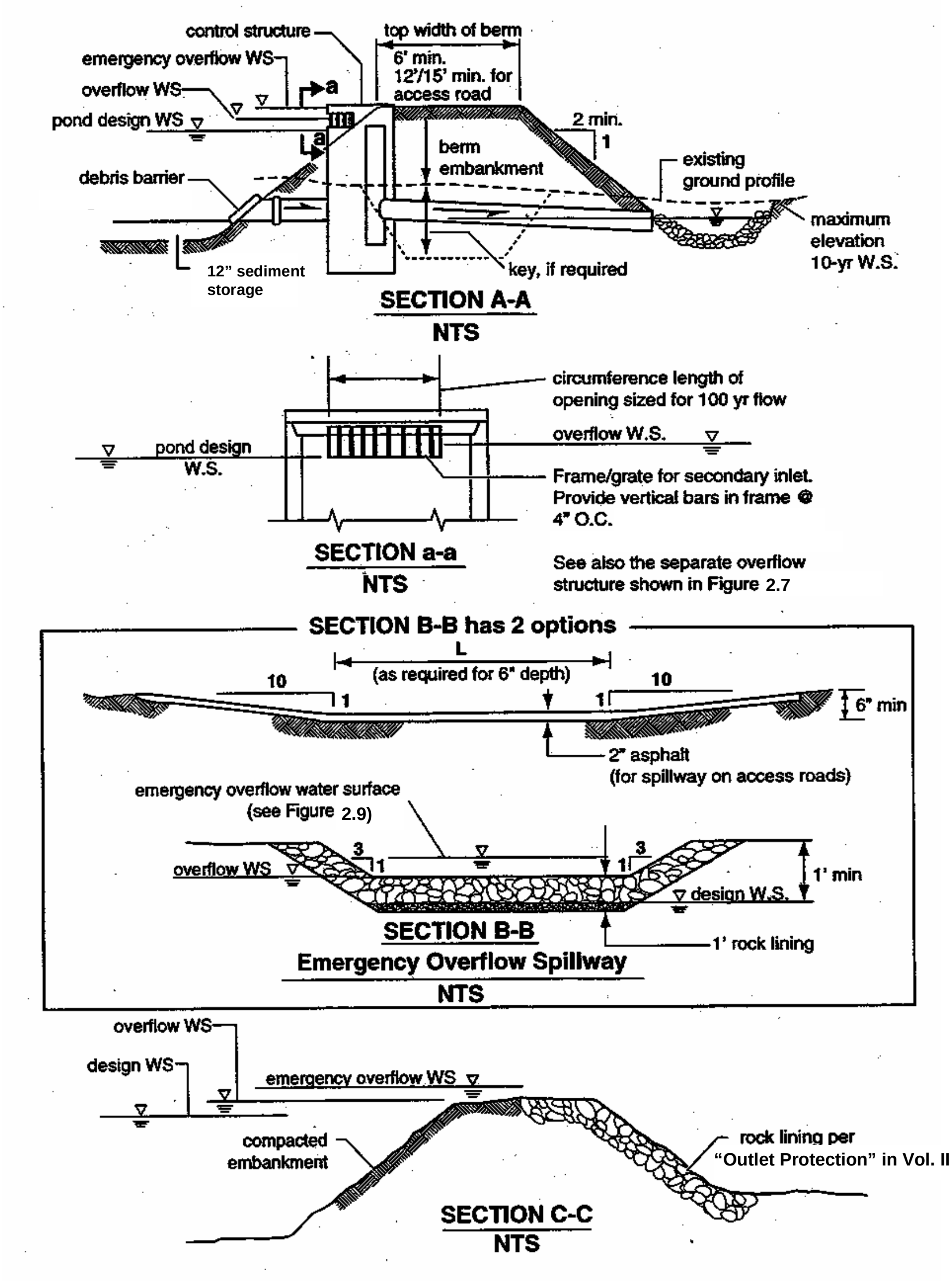
Seed Name	Percentage of Mix
Dwarf tall fescue	40%
Dwarf perennial rye "Barclay"*	30%
Red fescue	25%
Colonial bentgrass	5%

* 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.



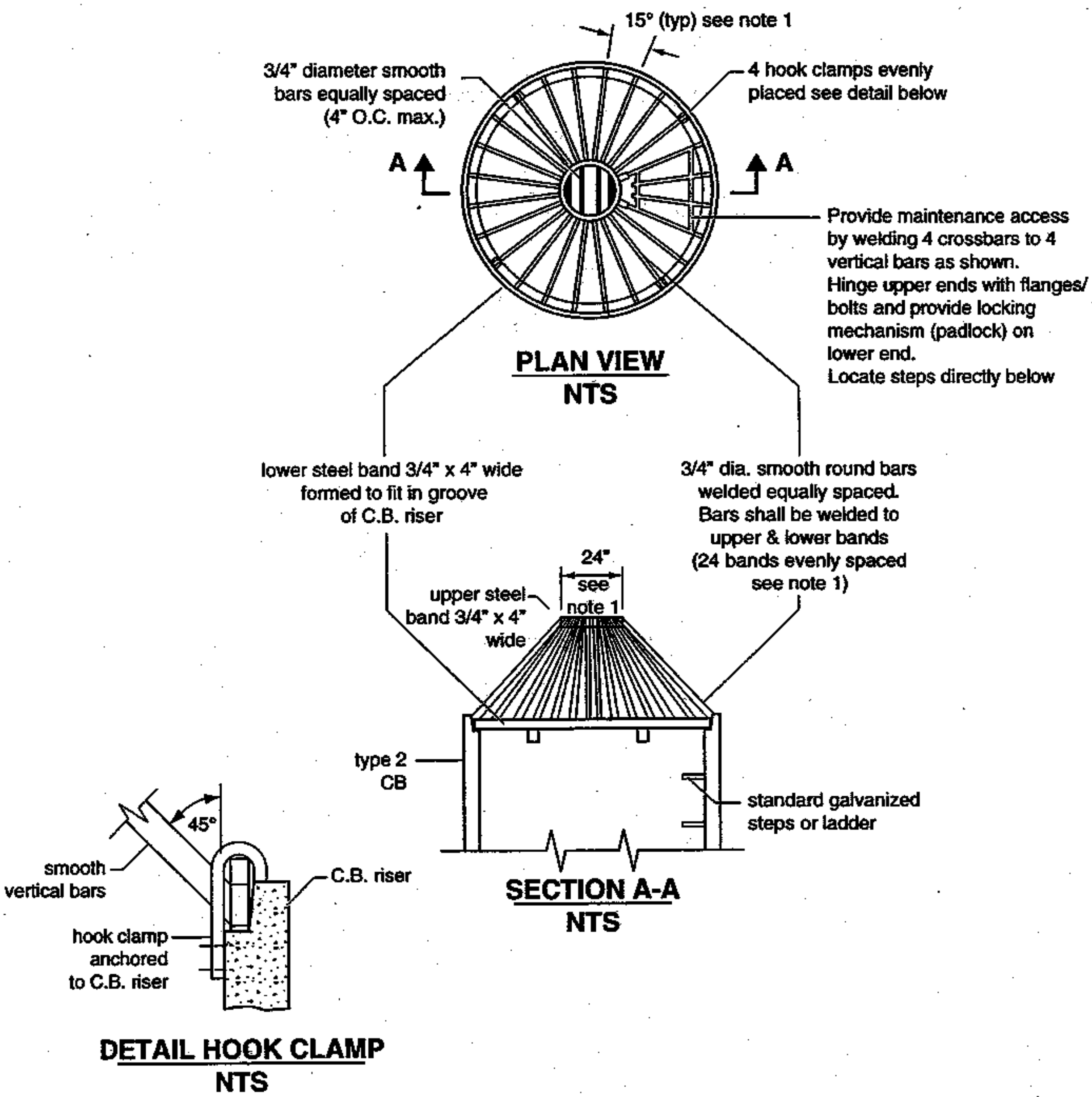
Note:
This detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

Figure 6.11 Typical Detention Pond



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

Figure 6.12 Typical Detention Pond Sections



NOTES:

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

Figure 6.13 Overflow Structure

Vegetation

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

Sediment

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

Detention Ponds in Infiltrative Soils

Detention ponds may occasionally be sited on till soils that are sufficiently permeable for a properly functioning infiltration system. These detention ponds have a surface discharge and may also utilize infiltration as a second pond outflow. Detention ponds sized with infiltration as a second outflow must meet all the requirements of Section 6.3 for infiltration ponds.

Emergency Overflow Spillway Capacity

For impoundments under 10-acre-feet, the emergency overflow spillway weir section must be designed to pass the 100-year runoff event for developed conditions assuming a broad-crested weir. The broad-crested weir equation for the spillway section in Figure 6.14, for example, would be:

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

Where
- Q_{100} = peak flow for the 100-year runoff event (cfs)
- C = discharge coefficient (0.6)
- g = gravity (32.2 ft/sec^2)
- L = length of weir (ft)
- H = height of water over weir (ft)
- θ = angle of side slopes

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 maximum):

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

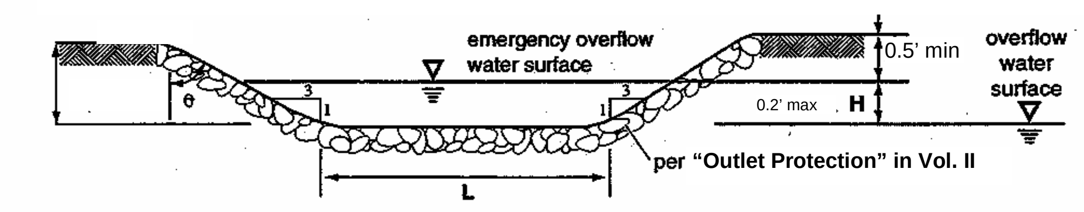


Figure 6.14 Weir Section for Emergency Overflow Spillway

6.2.2 Detention Tanks

Detention tanks are underground storage facilities typically constructed with large diameter corrugated metal or HDPE pipe. Standard detention tank typical details are shown in Figure 6.15 and Figure 6.16.

BMP D-02 Detention Tanks

Design Criteria

1. Tanks shall be designed as flow-through systems with manholes in line (see Figure 6.15) to promote sediment removal and facilitate maintenance. Tanks may be designed as back-up systems if preceded by water quality facilities, since little sediment should reach the inlet/control structure and low head losses can be expected because of the proximity of the inlet/control structure to the tank

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

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

4. Tanks larger than 36 inches may be connected to each adjoining structure with a short section (2-foot maximum length) of 36-inch minimum diameter pipe

5. If the tank has no access riser, provide an air vent (see Figure 6.15).

Materials

Use of galvanized materials in stormwater facilities and conveyance systems is prohibited.

Pipe material, joints, and protective treatment for tanks shall be in accordance with Section 9.05 of the *WSDOT/APWA Standard Specifications*.

Structural Stability

Tanks must meet structural requirements for overburden support and traffic loading if appropriate. H-20 live loads must be accommodated for tanks lying under parking areas and access roads. Metal tank end plates must be designed for structural stability at maximum hydrostatic loading conditions. Flat end plates generally require thicker gage material than the pipe and/or require reinforcing ribs. Tanks must be placed on stable, well consolidated native material with a suitable bedding. Tanks must not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

Buoyancy

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

Access

The following requirements apply:

1. Maximum depth from finished grade to tank invert shall be 12 feet.

2. Access openings shall be positioned a maximum of 50 feet from any location within the tank.

3. All tank access openings shall have round, solid locking lids (usually 1/2 to 5/8-inch diameter Allen-head cap screws).

4. Thirty-six-inch minimum diameter type manholes (see example, Figure 6.15) shall be used for access along the length of the tank and at the upstream terminus of the tank in a backup system. The top slab is separated (1-inch minimum gap) from the top of the riser to allow for deflections from vehicle loadings without damaging the riser tank.

5. All tank access openings must be readily accessible by maintenance vehicles.

6. Tanks must comply with the OSHA confined space requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

Access Roads

Access roads are needed to all detention tank control structures and risers. The access roads must be designed and constructed as specified for detention ponds in Section 6.2.1.

Right-of-Way

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

Setbacks

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

Other codes, such as Health or Building codes, should be consulted for setbacks from detention tanks.

Maintenance

Provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See the *Stormwater Facility Maintenance Guide* in Chapter 9 for specific maintenance requirements.

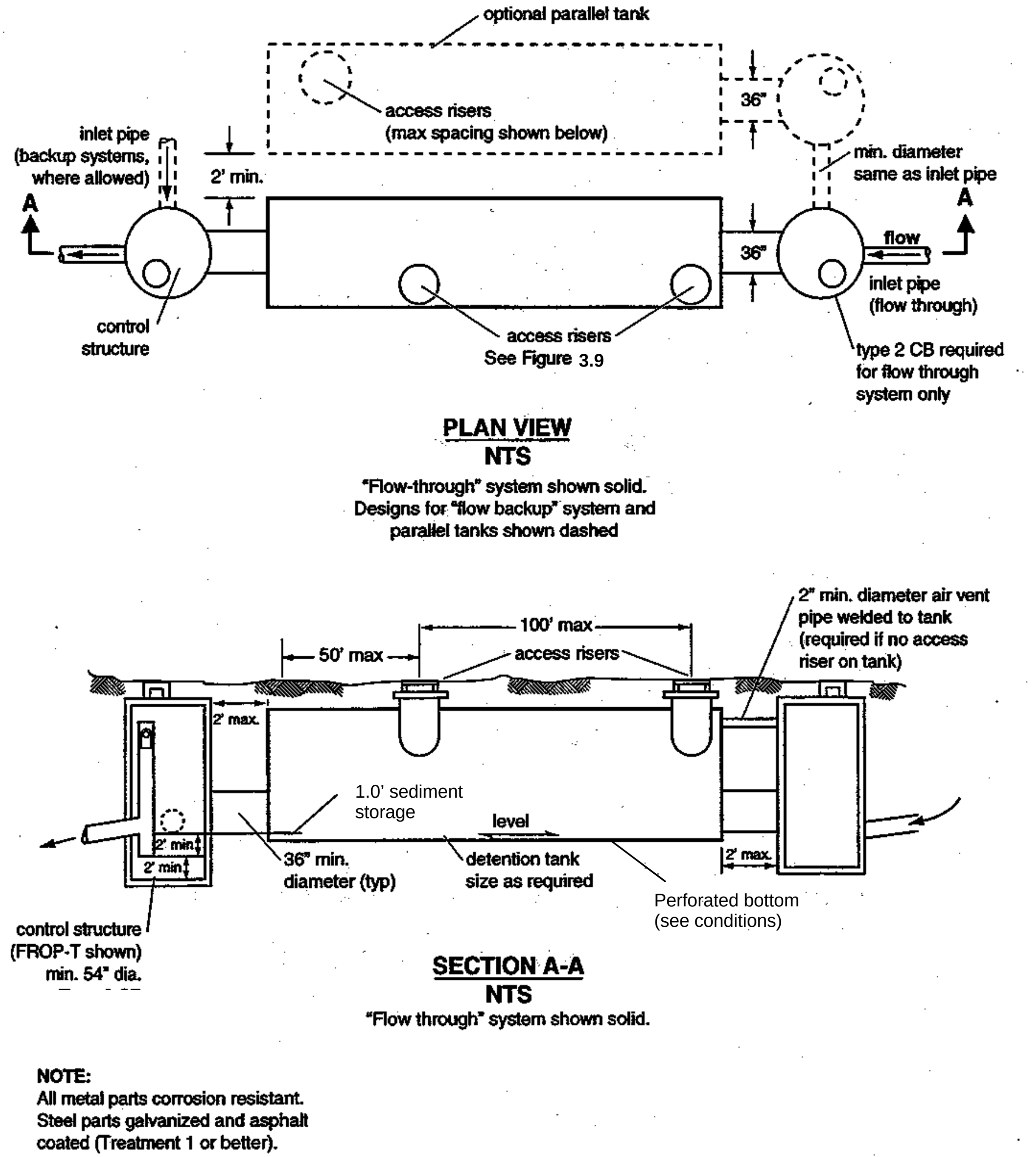
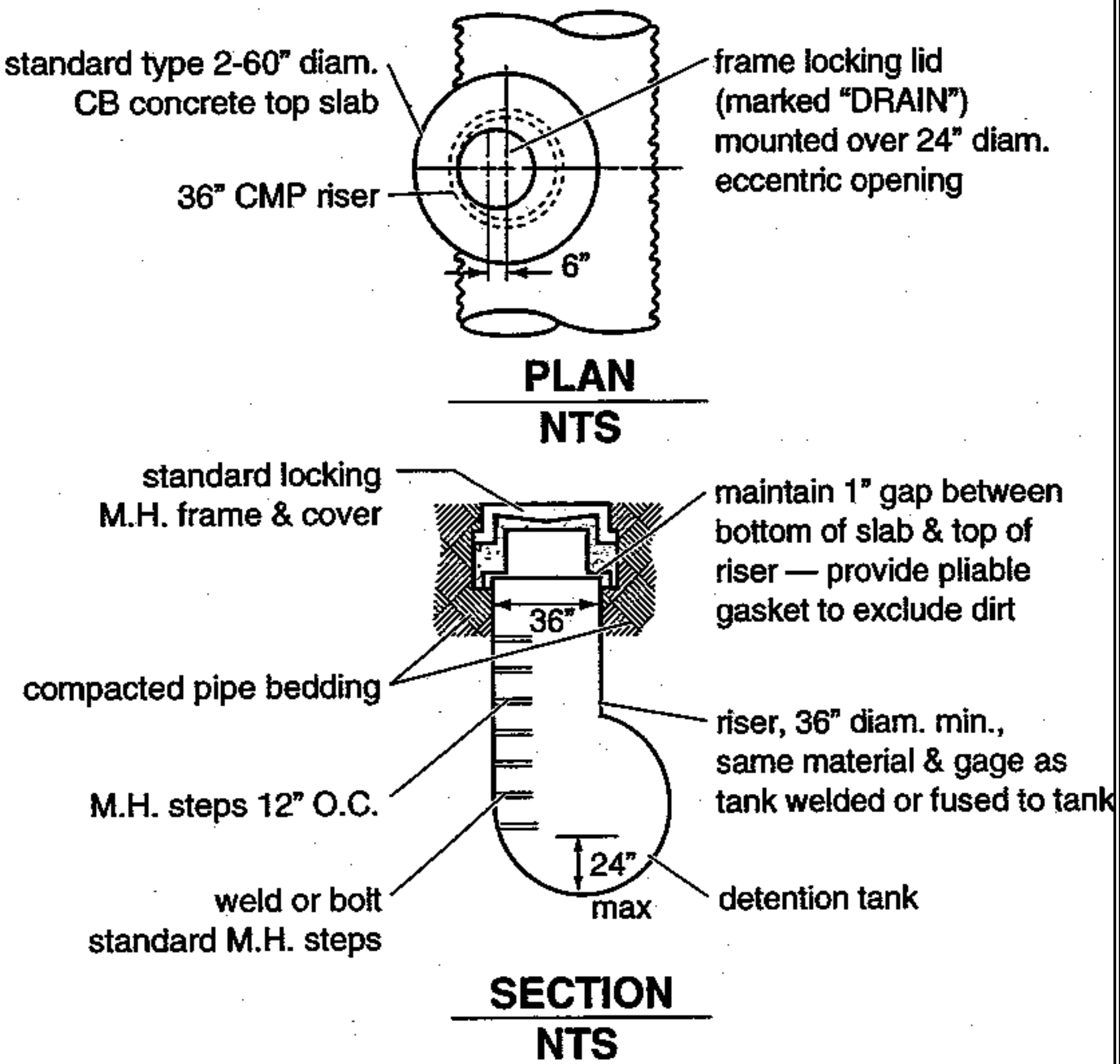


Figure 6.15 Typical Detention Tank



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

Figure 6.16 Detention Tank Access Detail

6.2.3 Detention Vaults

Detention vaults are underground storage facilities typically constructed with reinforced concrete. A standard typical detention vault detail is shown in Figure 6.17.

BMP D-03 Detention Vaults

Design Criteria

1. Detention vaults shall be designed as flow-through systems with bottoms level (longitudinally) or sloped toward the inlet to facilitate sediment removal. Distance between the inlet and outlet should be maximized (as feasible). Bottom shall be perforated, except in high water table areas.

2. The detention vault bottom may slope at least 5 percent from each side towards the center, forming a broad “v” one foot below the outlet to facilitate sediment removal. More than one “v” may be used to minimize vault depth. However, the vault bottom may be flat with 0.5 to 1 foot of sediment storage if removable panels are provided over the entire vault. The removable panels should be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.

3. The invert elevation of the outlet should be elevated above the bottom of the vault to provide an average 6 inches of sediment storage over the entire bottom. The outlet should also be elevated a minimum of 2 feet above the orifice to retain oil within the vault.

Materials

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

Structural Stability

All vaults must meet structural requirements for overburden support and HS20-44 traffic loading (See Standard Specifications for Highway Bridges, latest edition, American Association of State Highway and Transportation Officials). Vaults located under roadways must meet any live load requirements of the local government. Cast-in-place wall sections must be designed as retaining walls. Structural designs for cast-in-place vaults must be stamped by a licensed civil engineer with structural expertise. Vaults must be placed on stable, well-consolidated native material with suitable bedding. Vaults must not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

In addition to these requirements, vaults located within a fire apparatus access roadway (fire lane) location subject to the staging of fire fighting operations shall be designed for actual fire apparatus loads and stabilizer (outrigger) loads.

Access

Access must be provided over the inlet pipe and outlet structure. The following requirements apply:

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

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

3. For vaults under roadways, the removable panel must be located outside the travel lanes. Alternatively, multiple standard locking manhole covers may be provided. Ladders and hand-holds need only be provided at the outlet pipe and inlet pipe, and as needed to meet OSHA confined space requirements. Vaults providing manhole access at 12-foot spacing need not provide corner ventilation pipes as specified in Item 10 below.

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

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

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

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

8. The minimum internal height should be 7 feet from the highest point of the vault floor (not sump), and the minimum width should be 4 feet. However, concrete vaults may be a minimum 3 feet in height and width if used as tanks with access manholes at each end, and if the width is no larger than the height. Also the minimum internal height requirement may not be needed for any areas covered by removable panels.

9. Vaults must comply with the OSHA confined space requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

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

Access Roads

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

Right-of-Way

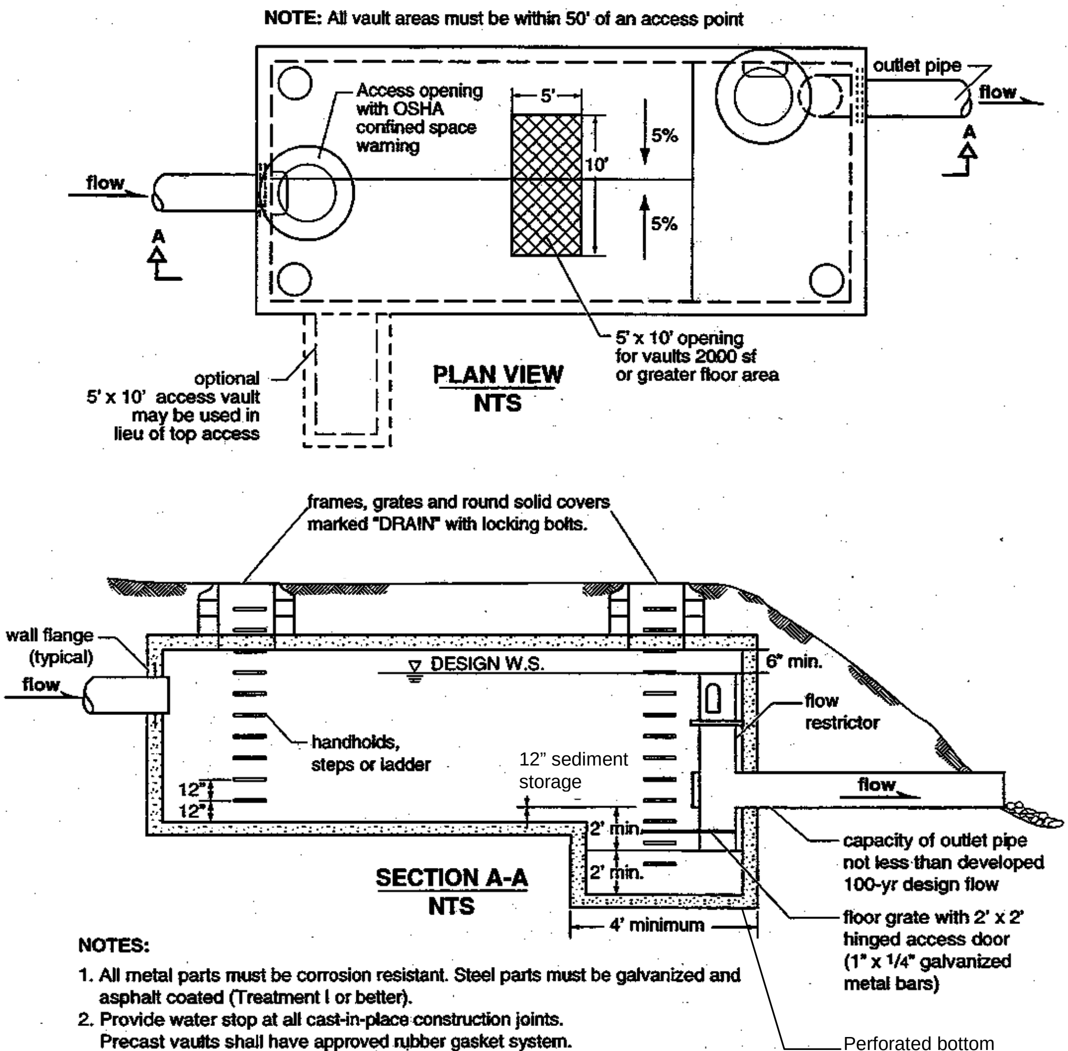
Right-of-way is needed for detention vaults maintenance. It is recommended that any tract not abutting public right-of-way should have a 15 to 20-foot wide extension of the tract to accommodate an access road to the facility.

Setbacks

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

Maintenance

Provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Appendix 9A for specific maintenance requirements.



NOTES:

1. All metal parts must be corrosion resistant. Steel parts must be galvanized and asphalt coated (Treatment I or better).
2. Provide water stop at all cast-in-place construction joints. Precast vaults shall have approved rubber gasket system.
3. Vaults ≤ 10' wide must use removable lids.
4. Prefabricated vault sections may require structural modifications to support 5' x 10' opening over main vault. Alternatively, access can be provided via a side vestibule as shown.

Figure 6.17 Typical Detention Vault

6.2.4 Control Structure Design

Allowable flow control structures are illustrated in Figures 6.18 through 6.20.

1. Properly designed weirs and/or orifices (see Section 6.2.6) may be used as flow restrictors. However, they must be designed to provide for primary overflow of the developed 100-year peak flow discharging to the detention facility.

2. The combined orifice and riser (or weir) overflow may be used to meet performance requirements; however, the design must still provide for primary overflow of the developed 100-year peak flow assuming all orifices are plugged.

Access

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

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

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

Information Plate

A brass or stainless steel plate shall be permanently attached inside each control structure with the following information engraved on the plate:

- Name and file number of project
- Name and company of (1) developer, (2) engineer, and (3) contractor
- Date constructed
- Date of manual used for design

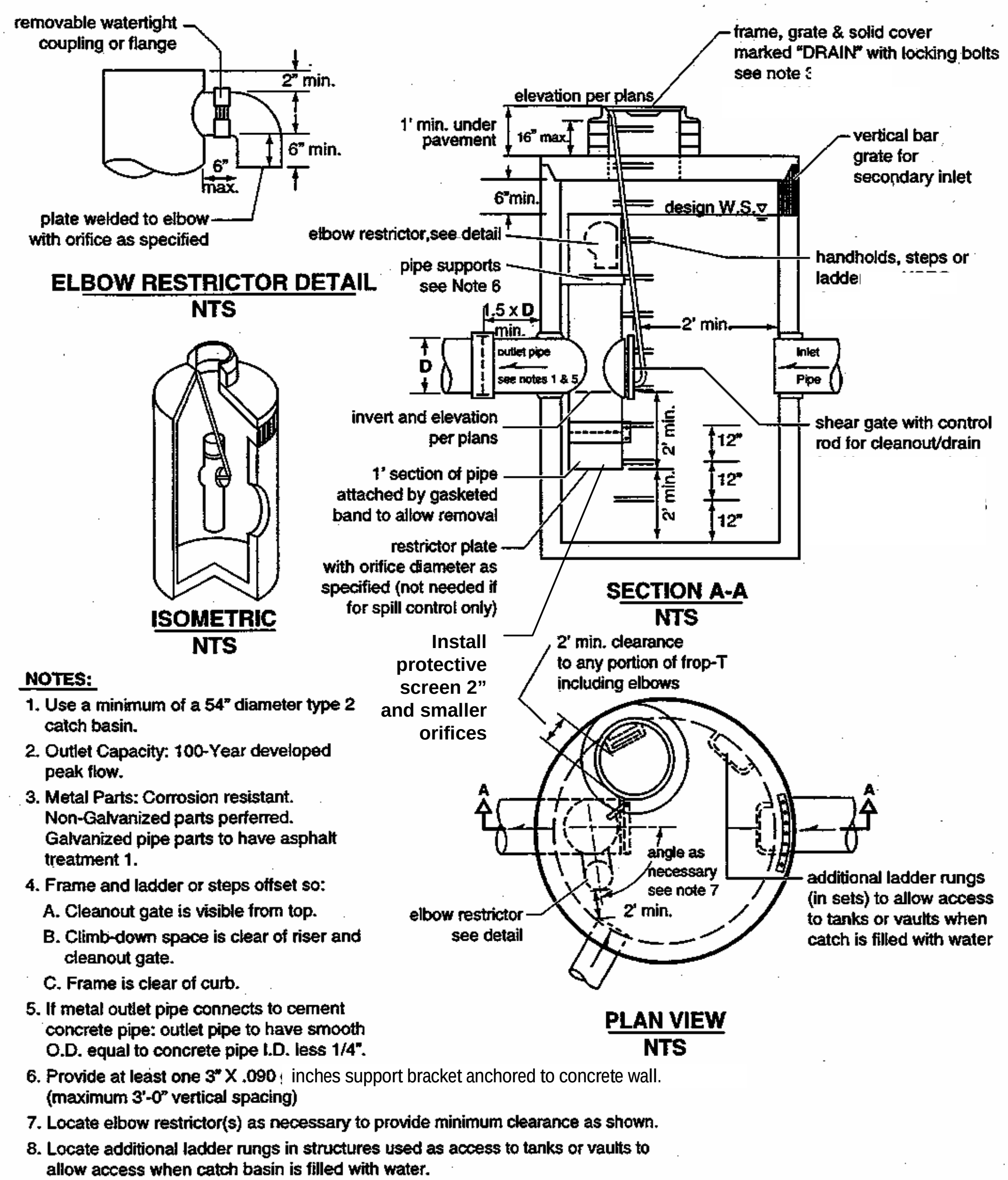


Figure 6.18 Flow Restrictor (Tee)

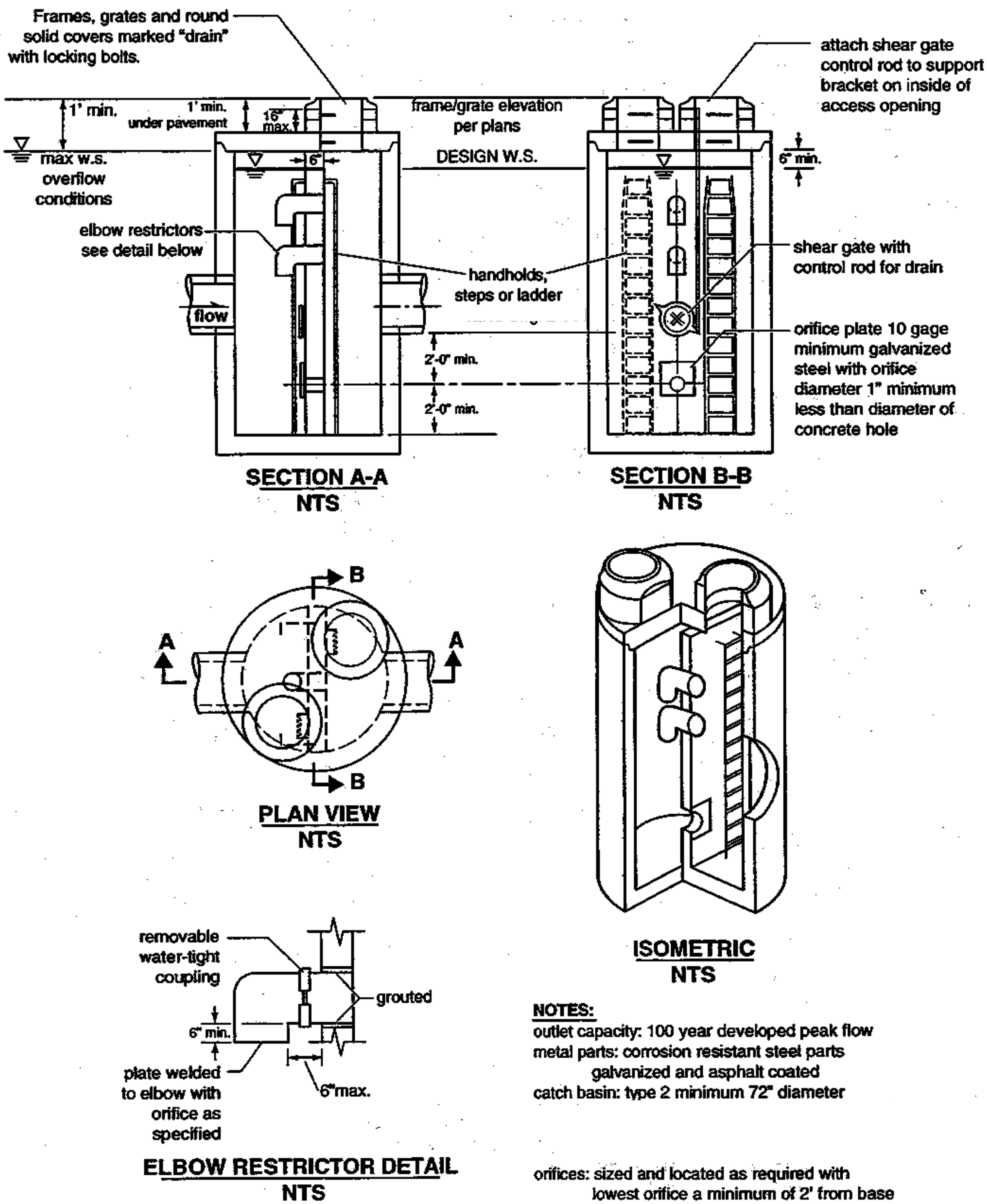
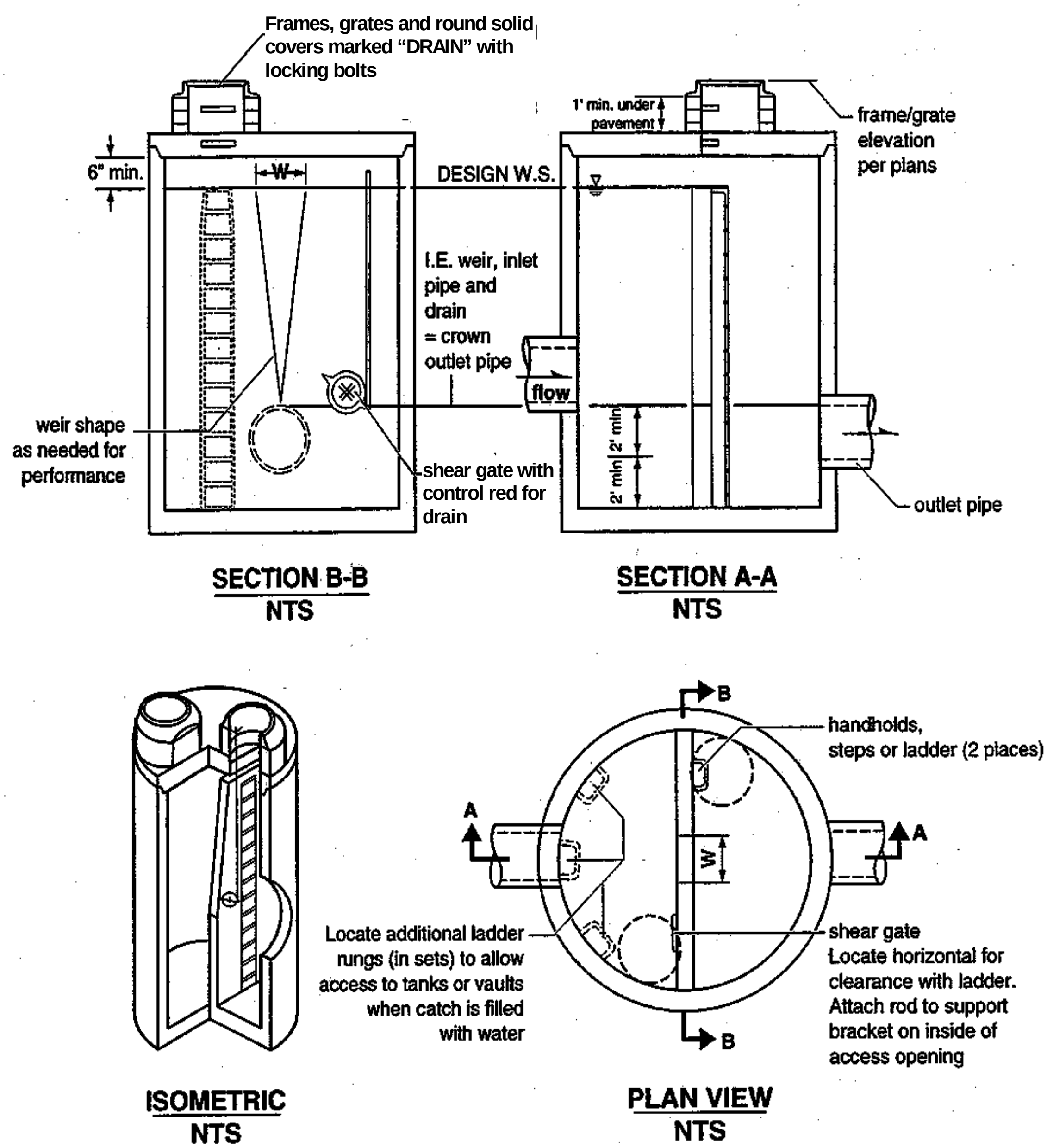


Figure 6.19 Flow Restrictor (Baffle)



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

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

Figure 6.20 Control Structure Details

6.2.5 Other Detention Options

This section presents another design option for detaining flows to meet flow control facility requirements.

BMP D-04 Parking Lot Detention

Private parking lots may be used to provide additional detention volume for runoff events greater than the 2-year runoff event provided all of the following are met:

1. The depth of water detained does not exceed 1 foot at any location in the parking lot for runoff events up to and including the 100-year event.

2. The gradient of the parking lot area subject to ponding is 1 percent or greater.

3. The detained water is completely contained on-site and does not impact other properties or the public right-of-way.

4. The emergency overflow path is identified and noted on the engineering plan. The overflow must not create a significant adverse impact to any properties or drainage systems.

5. Fire access requirements are met.

6.2.6 Methods of Analysis – Orifices and Weirs

6.2.6.1 Orifices

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

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

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

Figure 6.21 illustrates this simplified application of the orifice equation.

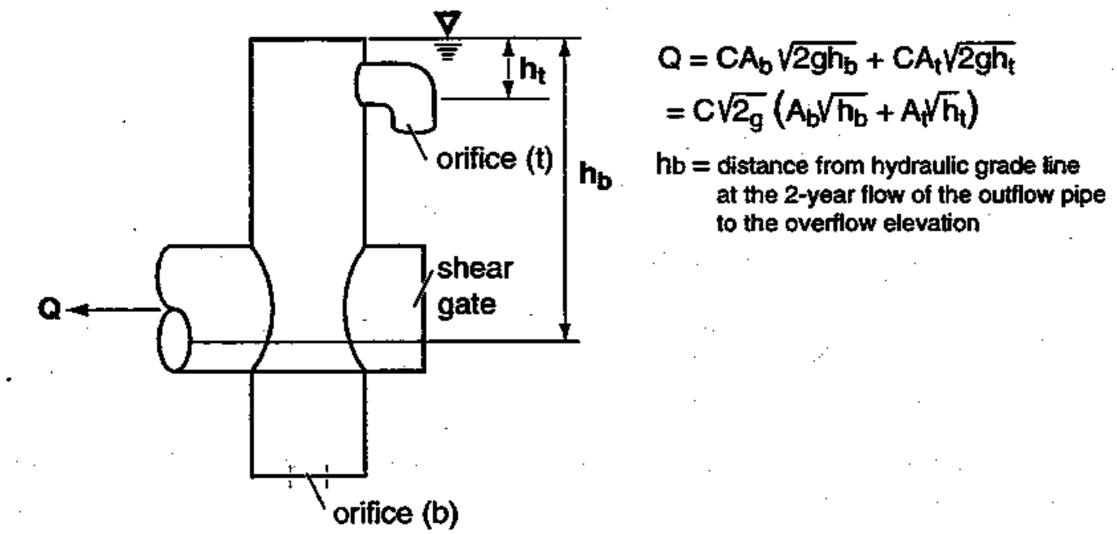


Figure 6.21 Simple Orifice

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

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

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

6.2.6.2 Rectangular Sharp-Crested Weir

The rectangular sharp-crested weir design shown in Figure 6.22 may be analyzed using standard weir equations for the fully contracted condition.

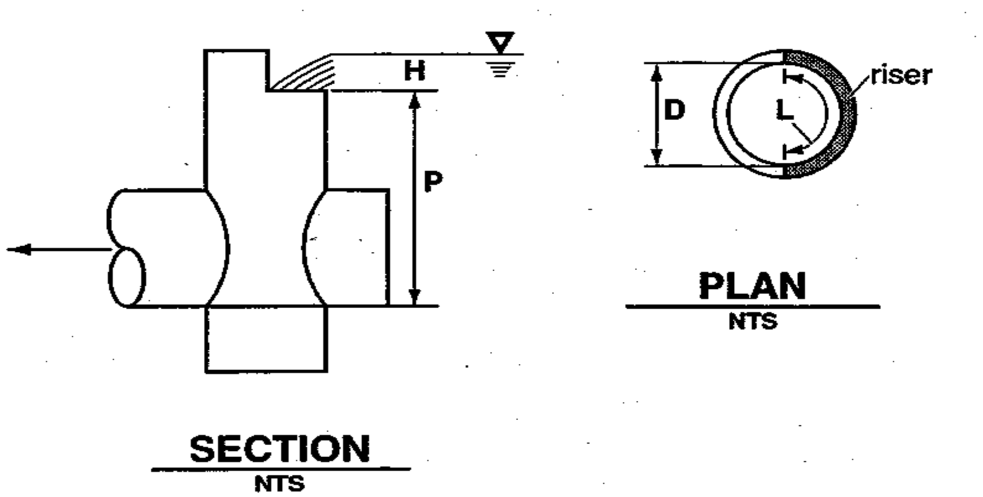


Figure 6.22 Rectangular, Sharp-Crested Weir

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

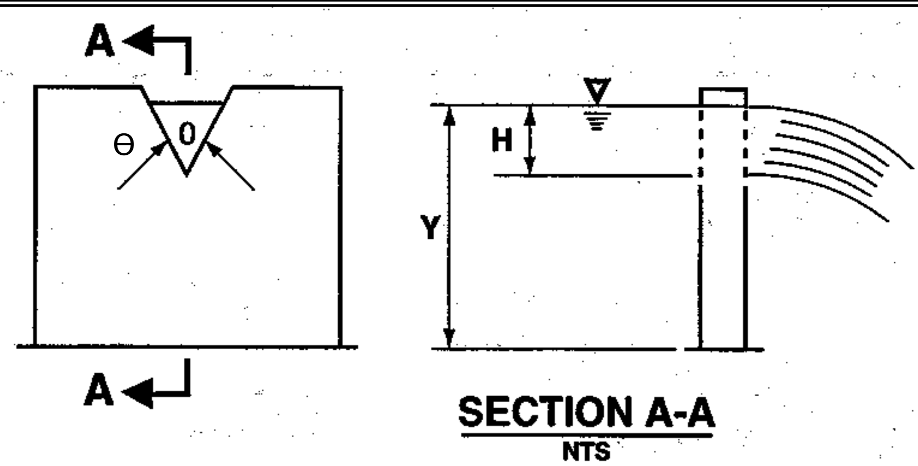
where

Q = flow (cfs)
C = 3.27 + 0.40 H/P (ft)
H, P are as shown above
L = length (ft) of the portion of the riser circumference as necessary not to exceed 50 percent of the circumference

D = inside riser diameter (ft)

6.2.6.3 V-Notch Sharp-Crested Weir

V-notch weirs as shown in Figure 6.23 may be analyzed using standard equations for the fully contracted condition.



$$Q = C_d(\text{Tan } \Theta/2)H^{5/2}, \text{ in cfs}$$

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

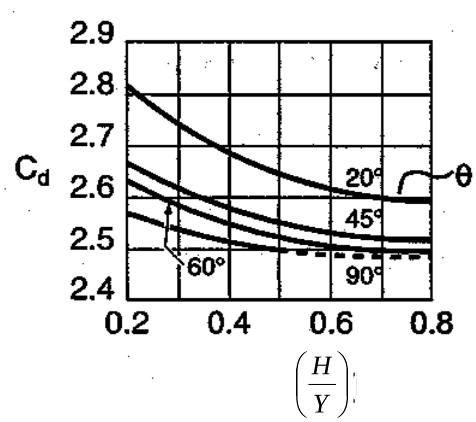


Figure 6.23 V-Notch, Sharp-Crested Weir

6.2.6.4 Proportional or Sutro Weir

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

The sutro weir consists of a rectangular section joined to a curved portion that provides proportionality for all heads above the line A-B in Figure 6.24.

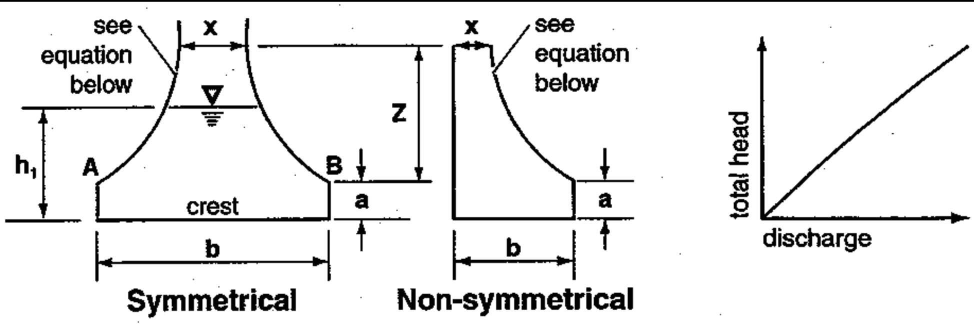


Figure 6.24 Sutro Weir

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

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

where a, b, x and Z are as shown in Figure 6.24. The head-discharge relationship is:

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

Values of *Cd* for both symmetrical and non-symmetrical sutro weirs are summarized below in Table 6.4. *(Note: When b > 1.50 or a > 0.30, use Cd = 0.6)*

.

Table 6.4
Values of C_d for Sutro Weirs

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

Riser Overflow

The nomograph in Figure 6.25 can be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 100-year peak flow for developed conditions).

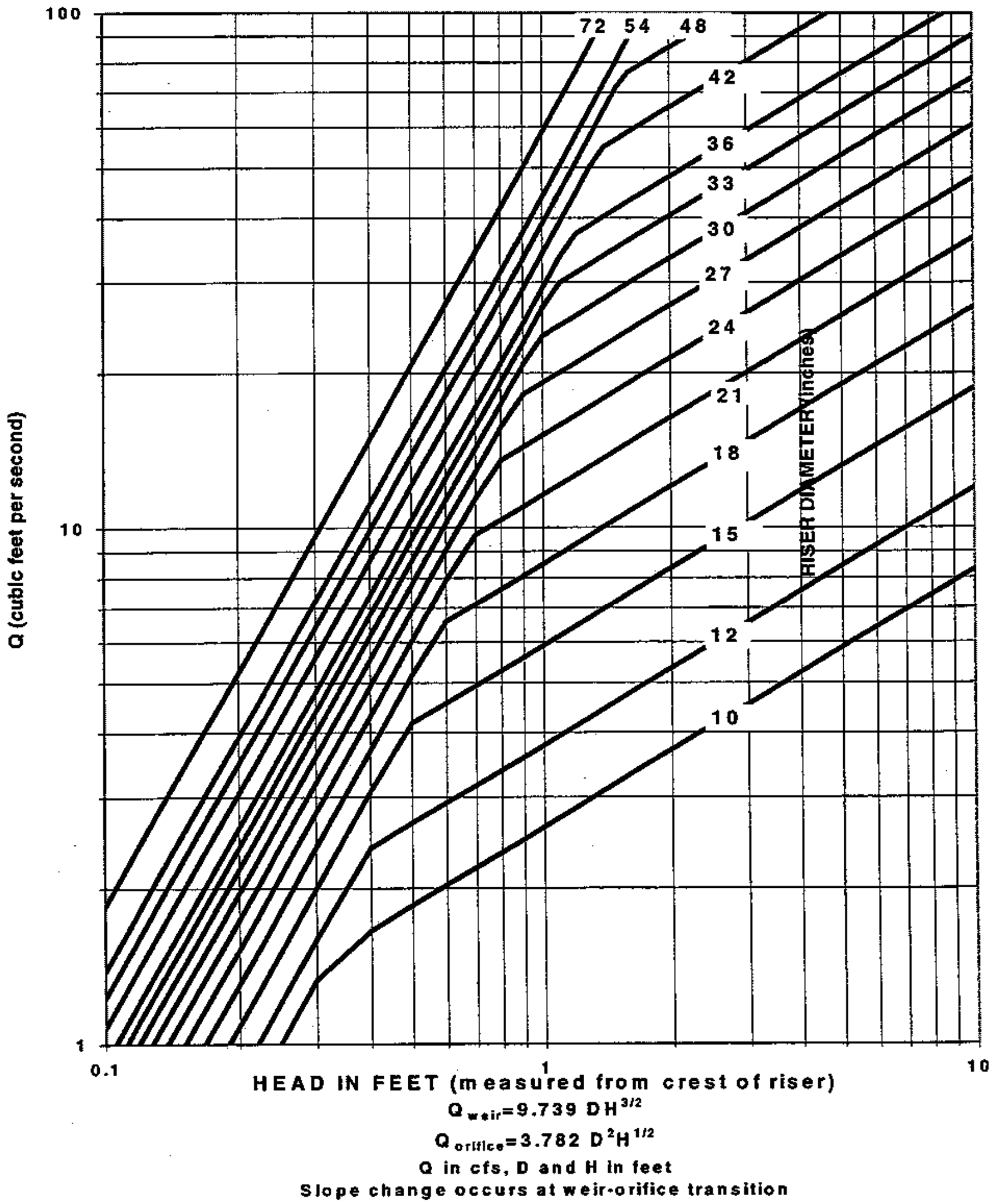


Figure 6.25 Riser Inflow Curves

6.3 INFILTRATION FACILITIES

An infiltration BMP is typically an open basin (pond), trench, or buried perforated pipe used for distributing the stormwater runoff into the underlying soil (See Figure 6.26). Stormwater dry-wells receiving uncontaminated or properly treated stormwater can also be considered as infiltration facilities. (See Underground Injection Control Program, Chapter 173-218 WAC).

Coarser more permeable soils can be used for quantity control provided that the stormwater discharge does not cause a violation of ground water quality criteria. Treatment for removal of TSS, oil, and/or soluble pollutants is necessary prior to conveyance to an infiltration BMP.

Use of the soil for treatment purposes is also an option as long as it is preceded by a pre-settling basin or a basic treatment BMP (see Chapter 7 for treatment design requirements).

6.3.1 General Site Suitability, Design and Construction Criteria

Site Suitability Criteria

1. **Setbacks**: Infiltration facilities (or detention facilities with partial discharge to groundwater) shall be a minimum of 50 feet from the top of any steep (greater than 15 percent) slope, a minimum of 20 feet from the downslope side of a building foundation, and a minimum of 100 feet from the upslope side of a building foundation, unless a geotechnical analysis and report are prepared that justify a smaller setback.

2. **Groundwater Protection Areas**: Infiltration is not suitable in wellhead protection areas or aquifer sensitive areas without adequate treatment, as described in Chapter 7. See maps in Appendix 6A.

3. **High Use Areas**: Commercial or industrial areas subject to oil control requirements can use infiltration only with adequate treatment. See Chapter 7.

4. **Depth to Bedrock, Water Table or Impermeable Layer**: The base of all infiltration facilities shall be at least 5 feet above the seasonal high water level, bedrock, glacial till or other low permeability layer. Smaller (3 ft. to 5 ft.) separations can be considered if a groundwater mounding analysis model (minimum technical standard model: MODRET) volumetric receptor capacity and design of overflow and/or bypass systems supports it. Note that groundwater mounding modeling requires a more detailed characterization of soil properties than infiltration rate determination.

5. **Soil Suitability for Treatment:** For infiltration treatment, the physical and chemical characteristics of the soil must be considered along with the soil texture and design infiltration rate. Refer to the Soil Suitability Criteria in Volume III, Section 3.3.7 of Ecology's 2005 *Stormwater Management Manual for Western Washington.*

Design Criteria

1. The size of the infiltration facility can be determined by routing the influent runoff file generated by the continuous runoff model (WWHM, HSPF) through the facility.

2. Overflows from an infiltration facility must comply with Core Requirement #7 for flow control. Infiltration facilities used for runoff treatment must not overflow more than 9% of the influent runoff file.

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

4. Less than 100% infiltration may be allowed as long as any overflows will meet the flow duration standard. Note that infiltration recharge to groundwater post-development must match or exceed the pre-development volume per Core Requirement #7, when applicable.

5. Slope of the base of the infiltration facility shall be less than 3 percent.

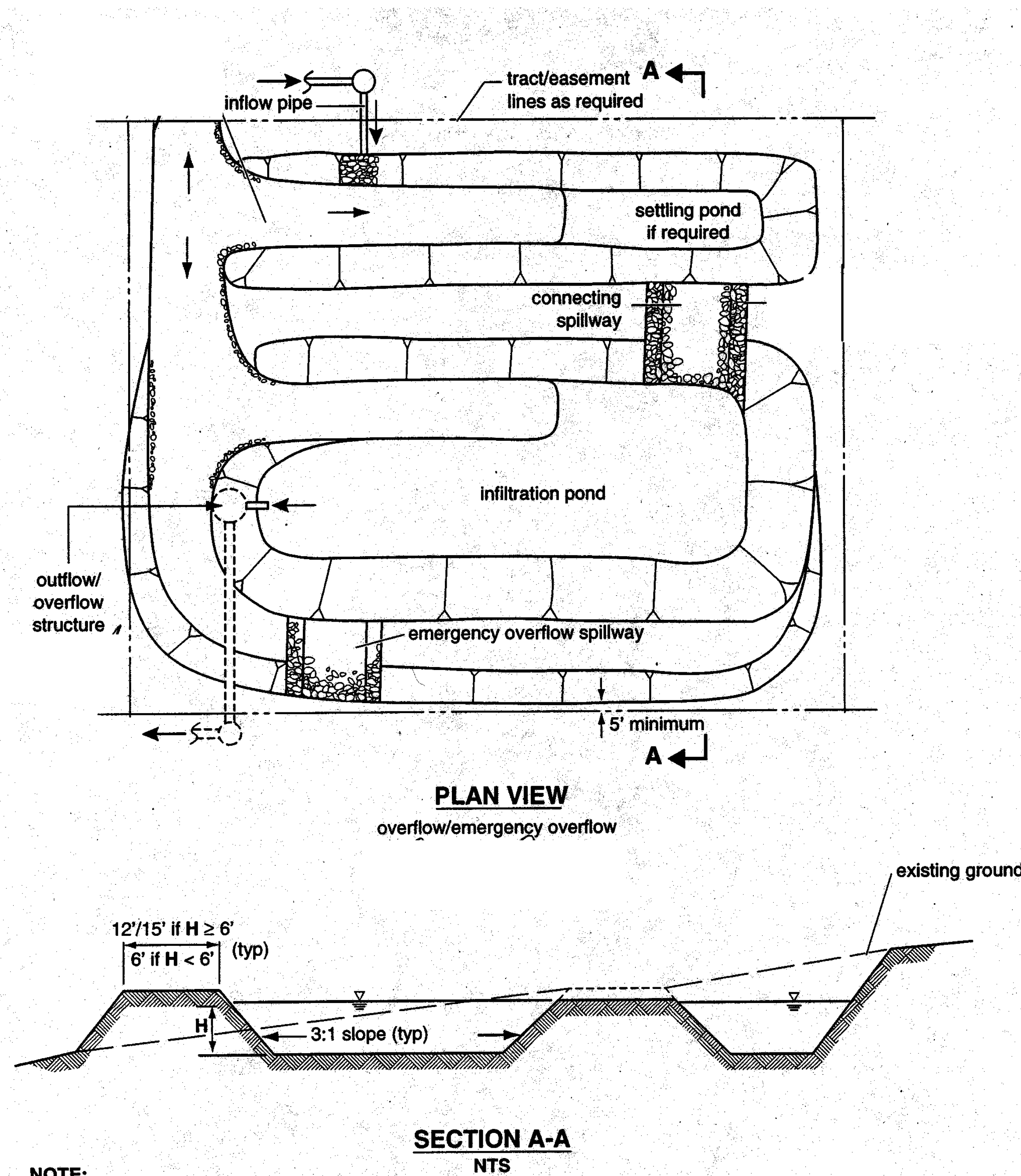
6. Spillways/Overflow structures - A non-erodible outlet or spillway with a firmly established elevation must be constructed to discharge overflow. Ponding depth, drawdown time, and storage volume are calculated from that reference point.

Construction Criteria

1. Initial basin excavation shall be conducted to within 1-foot of the final elevation of the basin floor. Excavate infiltration trenches and basins to final grade only after all disturbed areas in the upgradient project drainage area have been permanently stabilized. The final phase of excavation shall remove all accumulation of silt in the infiltration facility before putting it in service. After construction is completed, prevent sediment from entering the infiltration facility by first conveying the runoff water through an appropriate pretreatment system such as a pre-settling basin, wet pond, or sand filter.

2. Infiltration facilities should not be used as temporary sediment traps during construction, unless it is not excavated to final grade until after the contributing drainage area has been stabilized. Any accumulation of silt in the basin must be removed before putting it in service.

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



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

Figure 6.26 Typical Infiltration Pond/Basin

6.3.2 Site Characterization Criteria

This section describes the required basis of design for an infiltration facility for flow control.

Surface Features Characterization

1. Topography (City GIS contours) within 500 feet of the proposed facility.
2. Anticipated site use (street/highway, residential, commercial, high-use site).
3. Location of ground water protection areas and 1, 5 and 10-year time of travel zones for municipal well protection areas. See Appendix 6A for maps of Critical Aquifer Recharge Areas and Wellhead Protection Areas (showing time-of-travel for City wells).
4. Location of privately-owned public water supply wells.
5. A description of local site geology, including soil or rock units likely to be encountered, the groundwater regime, and geologic history of the site.

Subsurface Characterization

1. The applicant must demonstrate though infiltration testing, soil logs, and the written opinion of an engineer or geologist that sufficient permeable soil exists at the proposed facility location to allow construction of an infiltration facility that will properly function long-term.
2. The basic requirement is a minimum of three feet of permeable soil below the bottom of the infiltration facility, and at least five feet between the bottom of the facility and the maximum seasonal water table (see note #9) or restrictive soil layer (e.g., glacial till).
3. Test pits or borings shall extend to a depth at least five feet below the bottom of the infiltration facility. At least one pit or boring shall be extended to the water table or till layer. If the water table or till layer is deep, at least one pit or boring shall be extended below a proposed infiltration basin to a depth at least ¼ the maximum width of the basin.

   If the bottom of the proposed facility is in a restrictive layer that may be relatively thin, the exploration may be extended to potentially locate an infiltration receptor below that layer.
4. Representative samples from each soil type and/or unit encountered.
5. For basins, at least one test pit or test hole per 5,000 ft^2 of basin infiltrating surface (in no case less than two per basin).
6. For tanks, a minimum of two borings/pits.

7. For trenches, at least one test pit or test hole per 50 feet of trench length (in no case less than two per trench).

Note: The depth and number of test holes or test pits and samples may be modified if, in the judgment of a licensed engineer with geotechnical expertise (P.E.), a licensed geologist (L.G.), licensed engineering geologist (L.E.G.), or licensed hydrogeologist (L.H.G.), the conditions are highly variable or suffciently uniform. In high water table sites, the subsurface exploration sampling need not be conducted lower than two (2) feet below the ground water table.

8. The geotechnical engineer shall provide a report including detailed logs for each test pit or boring and a map showing the locations of the test pits or borings. Logs must include at a minimum, depth of pit or hole, description of each stratum, and depth to water.

9. Soil logs shall estimate and document evidence of the seasonal high groundwater level and the historic maximum groundwater level. If these levels cannot be estimated from pits or borings, they may be estimated from offsite or other local knowledge and verified by measurements during the period when the groundwater level is expected to be highest.

10. The geotechnical report shall state whether or not the location is suitable for the proposed infiltration facility and shall recommend a design infiltration rate (see Design Infiltration Rate below).

A detailed soils and hydrogeologic investigation may be required if potential pollutant impacts to ground water are a concern, or if the applicant is proposing to infiltrate in areas underlain by till or other impermeable layers.

Soil Testing:

Soil characterization for each soil unit (soils of the same texture, color, density, compaction, consolidation and permeability) encountered shall include:

1. Grain-size distribution (ASTM D422 or equivalent AASHTO specification)
2. Percent fines (passing #200 sieve)
3. Percent clay content (include type of clay, if known)
4. Color/mottling
5. Variations and nature of stratification

If the infiltration facility will be used to provide treatment as well as flow control, the soil characterization shall also include:

6. Organic matter content and pH for each soil type and stratum.

6.3.3 Design Infiltration Rate Determination

Infiltration rates can be determined using either a field method (in-situ field measurements) or a laboratory method (correlation to grain-size distribution from soil samples). The field method, using in-situ measurements, is the preferred method. By any method, the allowable long-term infiltration rate shall be limited to a maximum of 20 in/hr.

6.3.3.1. In-situ Infiltration Measurements

Lacey encourages in-situ infiltration measurements, using the Pilot Infiltration Test (PIT) described in Appendix 6B.

The infiltration rate obtained from the PIT test shall be considered a short-term rate. This short-term rate must be reduced through correction factors. The correction factors account for uncertainties in testing, depth to water table or impervious strata, infiltration receptor geometry, and long-term reductions in permeability due to biological activity and accumulation of fines.

The design infiltration (I_d) rate shall be computed based on the following equation:

$$I_d = I_m \times F_{testing} \times F_{geometry} \times F_{plugging}$$

where I_m is the measured infiltration rate and the F factors are the various corrections. Note that to use this method the design infiltration rate must not exceed 20 in./hr.

For pit tests, $F_{testing} = 0.5$

$F_{geometry}$ accounts for the influence of a shallow water table or impervious stratum, and is estimated using the following equation:

$$F_{geometry} = 4\,D/W + 0.05$$

Where: D = depth between bottom of facility and seasonal high groundwater or impervious stratum, whichever is less

W = width

$F_{geometry}$ is limited to the range 0.25 - 1.0. Computed values outside this range must be represented by the appropriate extreme of the range.

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

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

6.3.3.2. ASTM Gradation Testing

Table 6.5 and the procedure described here can be used to estimate long-term design infiltration rates directly from soil gradation data. The long-term rates provided in Table 6.5 represent a range of conditions regarding site variability, the degree of long-term maintenance and pretreatment for TSS control, and depth to a restrictive layer. A long-term infiltration rates less than the maximum in the range in Table 6.5 must be used if the site is highly variable, or if maintenance and influent characteristics are not well controlled, and/or if fine soil layering is present that is not captured by the soil gradation test. The data that form the basis for Table 6.5 were from sands or sandy gravel soils. Table 6.5 can not be used for soils with a d_{10} size (10% passing the size listed) less than 0.05 mm (U.S. Standard Sieve).

Table 6.5 – Design 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	3.5 - 9*
0.3	2.0 - 6.5*
0.2	0.75 - 3.5*
0.1	0.3 -2.0*
0.05	0.25 - 0.8

* Not recommended for treatment

Begin with the design rate value at the high end of the range for the appropriate soil D_{10} size.

If a restrictive layer or potential groundwater is present within 6 feet of the bottom of the proposed facility, the low end of the range must be used, and no further adjustments are required.

If no restrictive layer is present, apply site variability and maintenance correction factors as follows:

Site Variability:

The professional engineer, geologist, engineering geologist or hydrogeologist will assess site soil infiltration variability. Sufficient additional tests will be conducted, if deemed necessary, to develop confidence that the average soil D_{10} adequately characterizes the proposed infiltration location. The soils professional will adjust the design infiltration rate using professional judgment to account for variability.

Maintenance:

If any of the following conditions is present, a factor based on soil D_{10} shall be applied:

- maintenance plan not in conformance with Chapter 9,
- leaf or moss build-up is likely,
- pre-treatment for suspended solids does not meet standards in this manual

Table 6.6 - D_{10} Correction Factors

D_{10}, mm	Correction Factor
≥ 0.4	1.0
0.3	0.9
0.2	0.8
0.05 - 0.2	0.7

If fine layering of "fines" (silts and clays) is present, as determined by the soils professional, in-situ testing (Pilot Infiltration Test) must be performed.

Example:

> *D_{10} = 0.3 mm (based on average of 2 tests, 0.25 and 0.35 mm), no restrictive layer, water table greater than 6 feet below facility, no fine layering*
>
> *Beginning estimated infiltration rate = 6.5 in/hr (Table 6.4)*
>
> *Soil professional determines site is relatively homogenous, no correction factor applied.*
>
> *Site is subject to shading and leaf litter, CF of 0.9 applied: 0.9 x 6.5 =5.8 in/hr*

6.3.4 Operational Verification Testing

Prior to acceptance by the City, the design infiltration rate must be verified in operation through monitoring and/or testing. *This requirement can be ignored if an additional factor of safety of 2 is applied to the design rate as determined by either of the approved methods described above*.

Testing shall consist of automated continuous water level monitoring over a period containing two or more events in which 30% or more of the facility volume is exceeded, or one full wet season's (November 1 to March 30) data. Alternatively (for smaller systems) at least two events resulting in filling the facility volume over 30% may be simulated using available water.

A licensed civil engineer shall supervise the field work associated with the monitoring/testing, and shall prepare and seal a report documenting the operational infiltration rate. An operational rate less than 90% of the design rate shall result in remedial action (enhancement or expansion of the facility).

6.3.5 Contingency Planning

Soils, shallow geology, and groundwater conditions can be extremely complex and highly variable, which may cause inaccuracies in infiltration analysis. Therefore, it is necessary to have a plan for fixing under performance discovered after facilities are installed.

All projects using infiltration facilities shall provide a contingency plan for under performance. The plan shall include a reasonable "worst-case" projection of long-term infiltration performance and describe methods and costs for improving/restoring performance and/or expanding facility size. These costs shall provide one basis for required performance and/or operation and maintenance bonding (see Chapter 1).

6.3.6 Infiltration Basin and Trench BMPs

BMP IN-01 Infiltration Basins

Infiltration basins are earthen impoundments used for the collection, temporary storage and infiltration of incoming stormwater runoff. By meeting specific soil requirements, they may also be used for treatment (see BMP IN-01t, Infiltration Basins for Treatment, in Chapter 7).

Design Criteria Specific for Basins

1. Access shall 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 should not exceed 3% in any direction.
3. A minimum of one foot of freeboard is required when establishing the design ponded water depth. Freeboard is measured from the rim of the infiltration facility to the maximum ponding level or from the rim down to the overflow point if overflow or a spillway is included.
4. Infiltration basins must have sufficient vegetation established on the basin floor and side slopes to prevent erosion and sloughing and to provide additional pollutant removal. Erosion protection of inflow points to the basin must also be provided (e.g., riprap, flow spreaders, energy dissipators).
5. 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. The filter layer can be replaced or cleaned when/if it becomes clogged.
6. Vegetation - The embankment, emergency spillways, spoil and borrow areas, and other disturbed areas shall be stabilized and planted, preferably with grass.

Maintenance Criteria for Basins

1. Maintain basin floor and side slopes to promote dense turf with extensive root growth. This enhances infiltration, prevents erosion and consequent sedimentation of the basin floor, and prevents invasive weed growth. Bare spots are to be immediately stabilized and revegetated.
2. Vegetation growth shall not exceed 18 inches in height. Mow the slopes periodically and check for clogging, and erosion.
3. Fertilizers shall be applied only as necessary and in limited amounts to avoid contributing to ground water pollution.

BMP IN-02 Infiltration Trenches

Infiltration trenches are most appropriate for small contributing areas and retrofit situations where space is limited.

Infiltration trenches are at least 24 inches wide, and are backfilled with a coarse stone aggregate, allowing for temporary storage of stormwater runoff in the voids of the aggregate material. Stored runoff then gradually infiltrates into the surrounding soil. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or a grassed covered area with a surface inlet. Perforated rigid pipe of at least 8-inch diameter can also be used to distribute the stormwater in a stone trench. Note that infiltration trenches my be subject to the requirements of Underground Injection Control (UIC) regulations, particularly with perforated distribution pipe.

By meeting specific soil requirements, infiltration trenches may also be used for treatment (see BMP IN-02t, Infiltration Trenches for Treatment, in Chapter 7).

See Figure 6.27 for a schematic of an infiltration trench. See Figures 6.28, 6.29, 6.30, 6.31, and 6.32 for examples of trench designs. Infiltration galleries, consisting of manufactured detention structures within a broad trench, may be allowed on a case-by-case basis, and must be sized per the manufacturer's guidance using design infiltration rates developed per this manual.

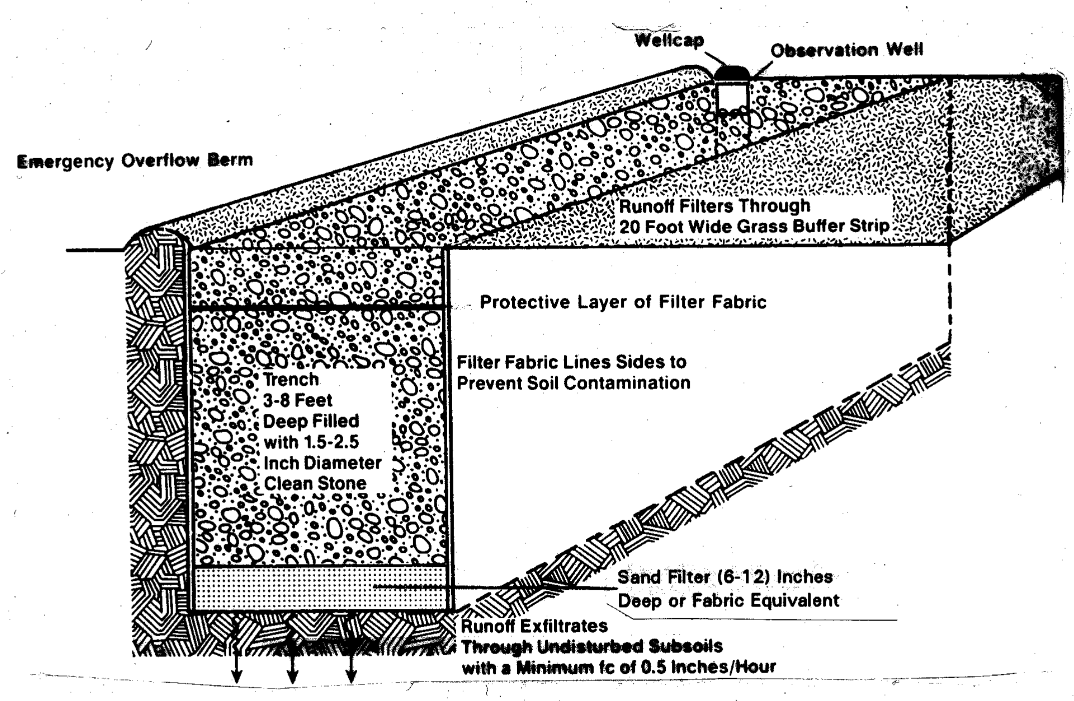


Figure 6.27 Schematic of an Infiltration Trench

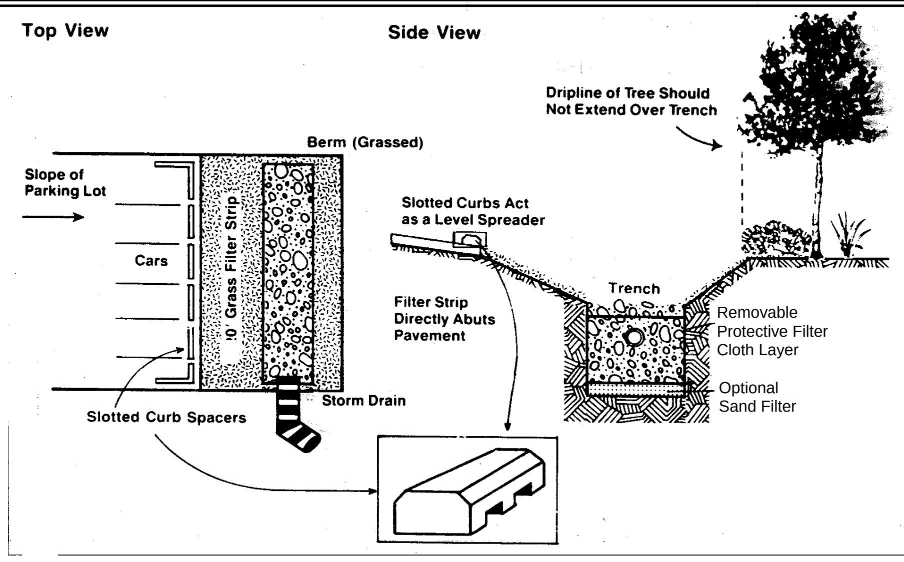


Figure 6.28 Parking Lot Perimeter Trench Design

Source: Schueler (reproduced with permission)

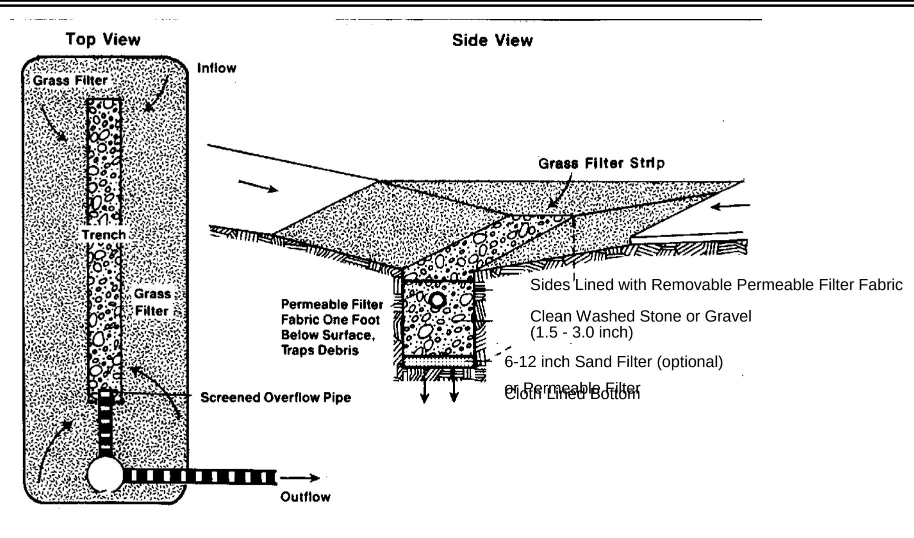


Figure 6.29 Median Strip Trench Design

Source: Schueler (reproduced with permission)

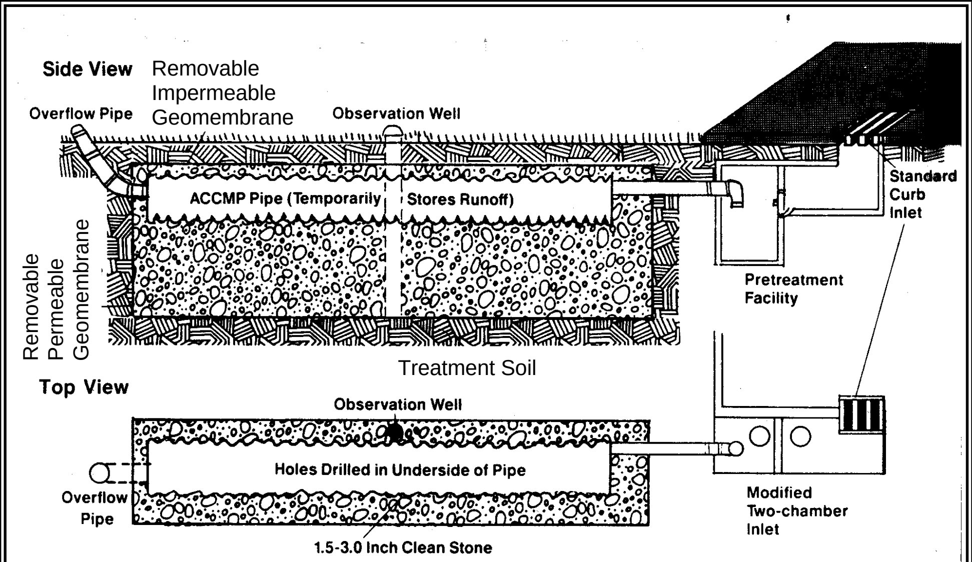


Figure 6.30 Oversized Pipe Trench Design

Source: Schueler (reproduced with permission)

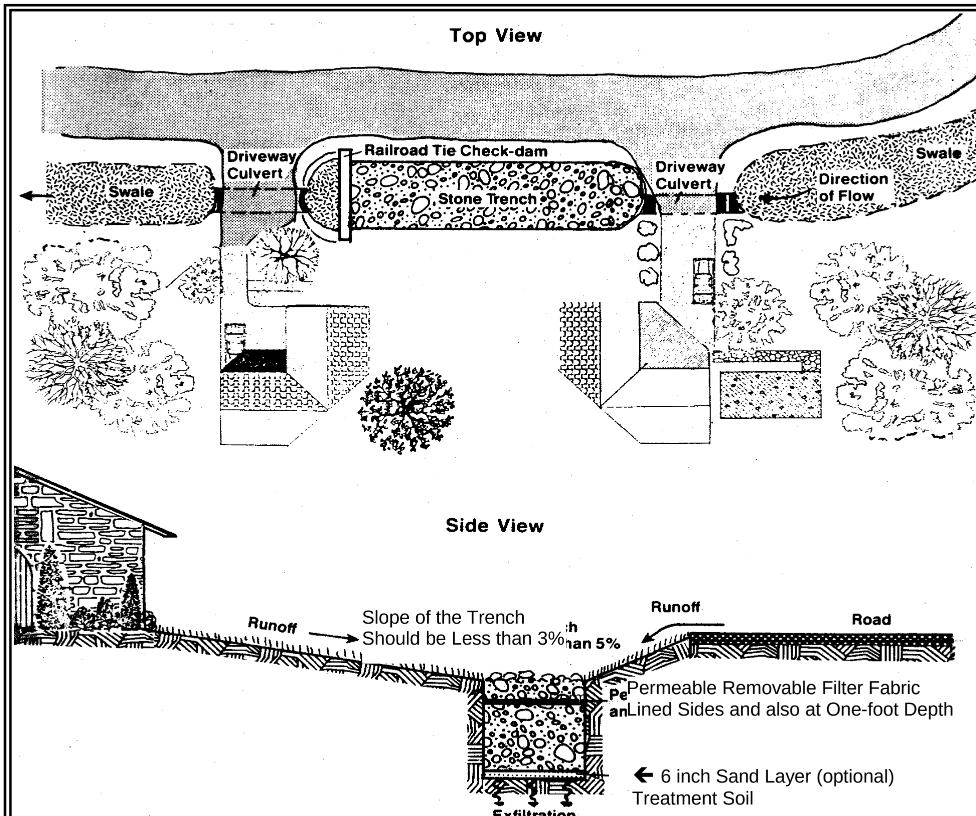


Figure 6.31 Swale/Trench

Source: Schueler (reproduced with permission)

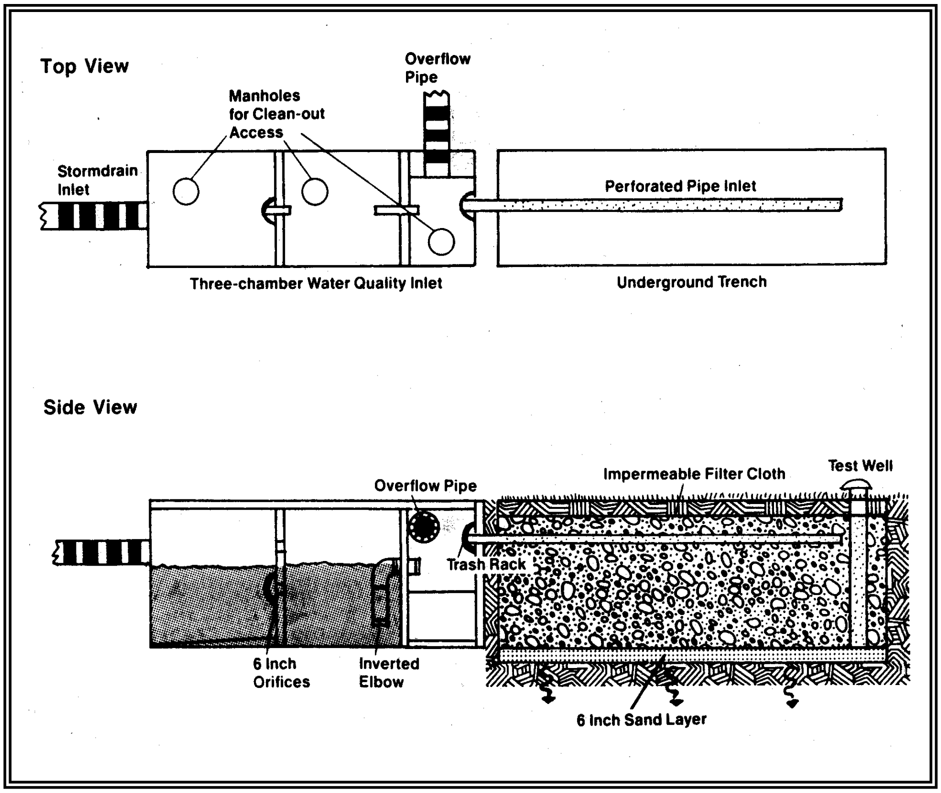


Figure 6.32 Underground Trench with Oil/Grit Chamber

Source: Schueler (reproduced with permission)

Design Criteria

1. An access port or open or grated top is required for accessibility to conduct inspections and maintenance.

2. Backfill Material - The aggregate material for the infiltration trench shall 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 shall be in the range of 30 to 40 percent.

3. Geotextile fabric liner - The aggregate fill material shall be completely encased in a geotextile material, except for the top one-foot, which is placed over the geotextile. Geotextile fabric with acceptable properties must be carefully selected to avoid plugging (see Appendix 6C).

4. The bottom sand or geotextile fabric as shown in the attached figures is optional.

5. Overflow Channel - An emergency spillway is not necessary. However, a non-erosive overflow channel leading to a stabilized watercourse shall be provided.

6. Surface Cover - A stone filled trench can be placed under a porous or impervious surface cover to conserve space. If located under pavement, the following are required:

- Observation wells must be placed no further than 100 feet apart.
- The plans, plan details, and the Stormwater Facilities Maintenance Plan must all clearly state that the pavement may have to be removed for trench maintenance.
- No infiltration facilities shall be allowed under any private or public streets.

7. Observation Well - 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. Figure 6.33 illustrates observation well details. It shall consist of a perforated PVC pipe which is 4 to 6 inches in diameter and it should be constructed flush with the ground elevation. For larger trenches a 12-36 inch diameter well can be installed to facilitate maintenance operations such as pumping out the sediment. The top of the well shall be capped.

8. Pre-treatment is required. With the exception of clean runoff water from non-pollution generating surfaces (e.g. roofs), all stormwater shall pass through a basic filter strip, a designed biofiltration swale system, or a pre-settling basin for water quality treatment prior to discharging to an infiltration trench.

9. Parallel trenches shall be spaced no closer than ten feet apart.

Construction Criteria

1. Trench Preparation - Excavated materials must be placed away from the trench sides to enhance trench wall stability. Care should also be taken to keep this material away from slopes, neighboring property, sidewalks and streets.
2. Stone Aggregate Placement and Compaction - The stone aggregate shall be placed in maximum 1-foot lifts and compacted using plate compactors.
3. Potential Contamination - Prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate must be removed and replaced with uncontaminated stone aggregate.
4. Overlapping and Covering - Following the stone aggregate placement, the geotextile must be folded over the stone aggregate to form a 12 inch minimum longitudinal overlap. When overlaps are required between rolls, the upstream roll shall overlap a minimum of 2 feet over the downstream roll in order to provide a shingled effect.
5. Voids behind Geotextile - Voids between the geotextile and excavation sides must be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure geotextile conformity to the excavation sides

Maintenance Criteria

Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well. Refer to the maintenance criteria in Appendix 9B.

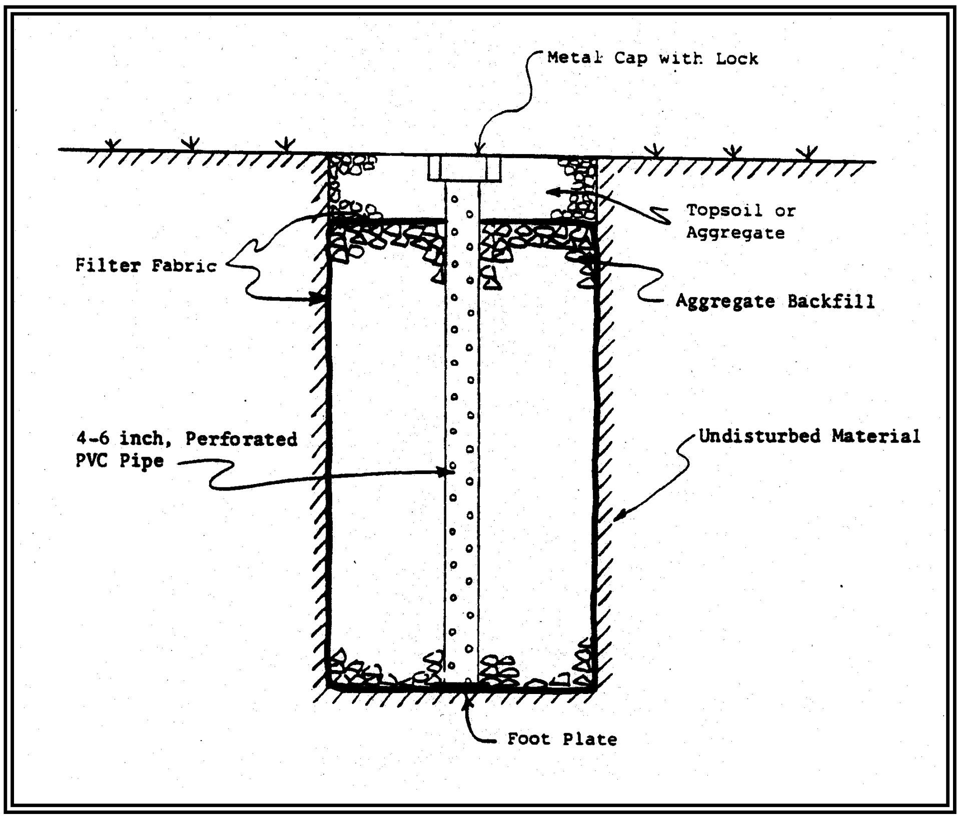


Figure 6.33 Observation Well Details

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Appendix 6A
Wellhead Protection Areas & Critical Aquifer Recharge Areas

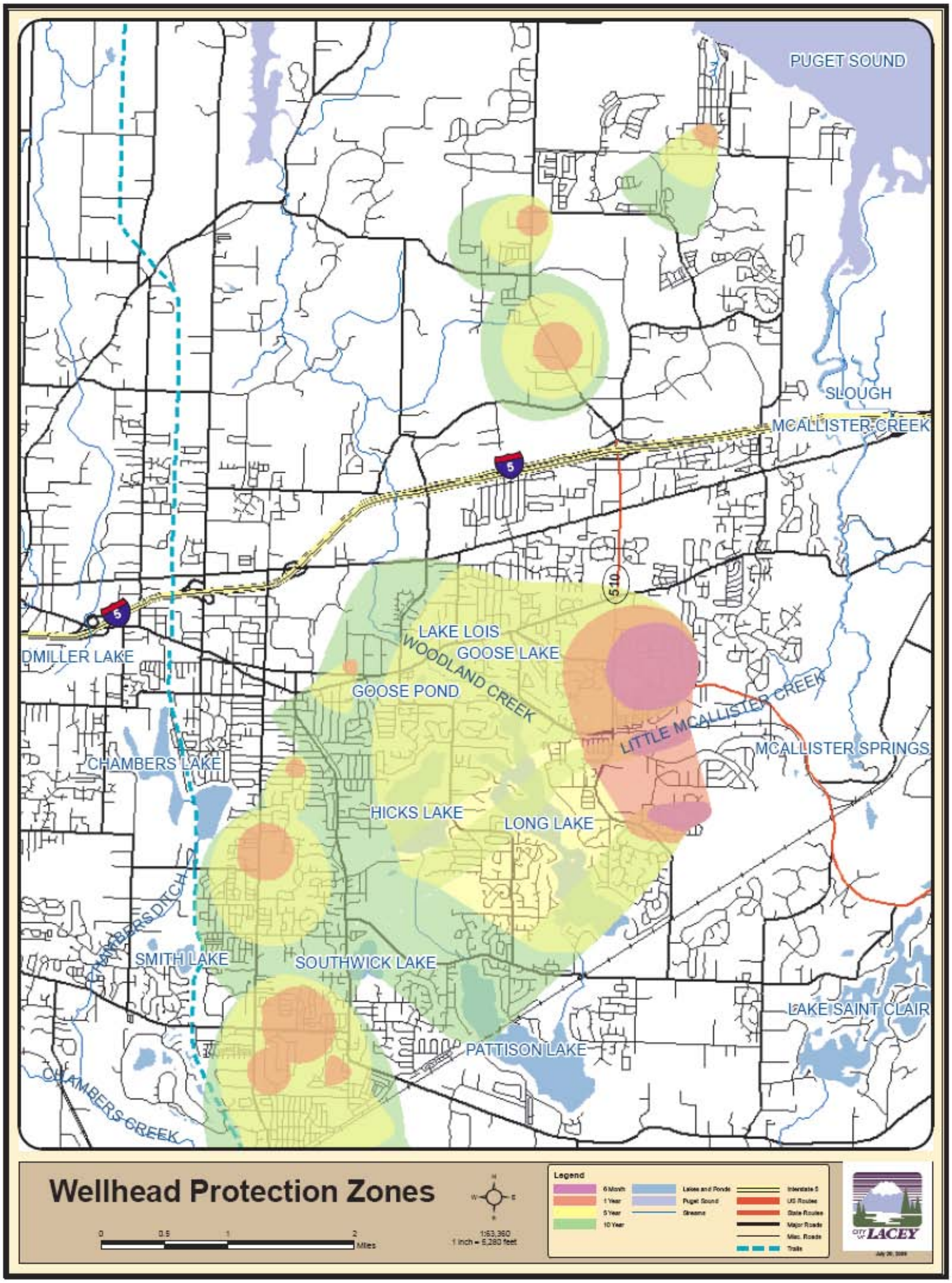

Figure 6A.1 Wellhead Protection Zones

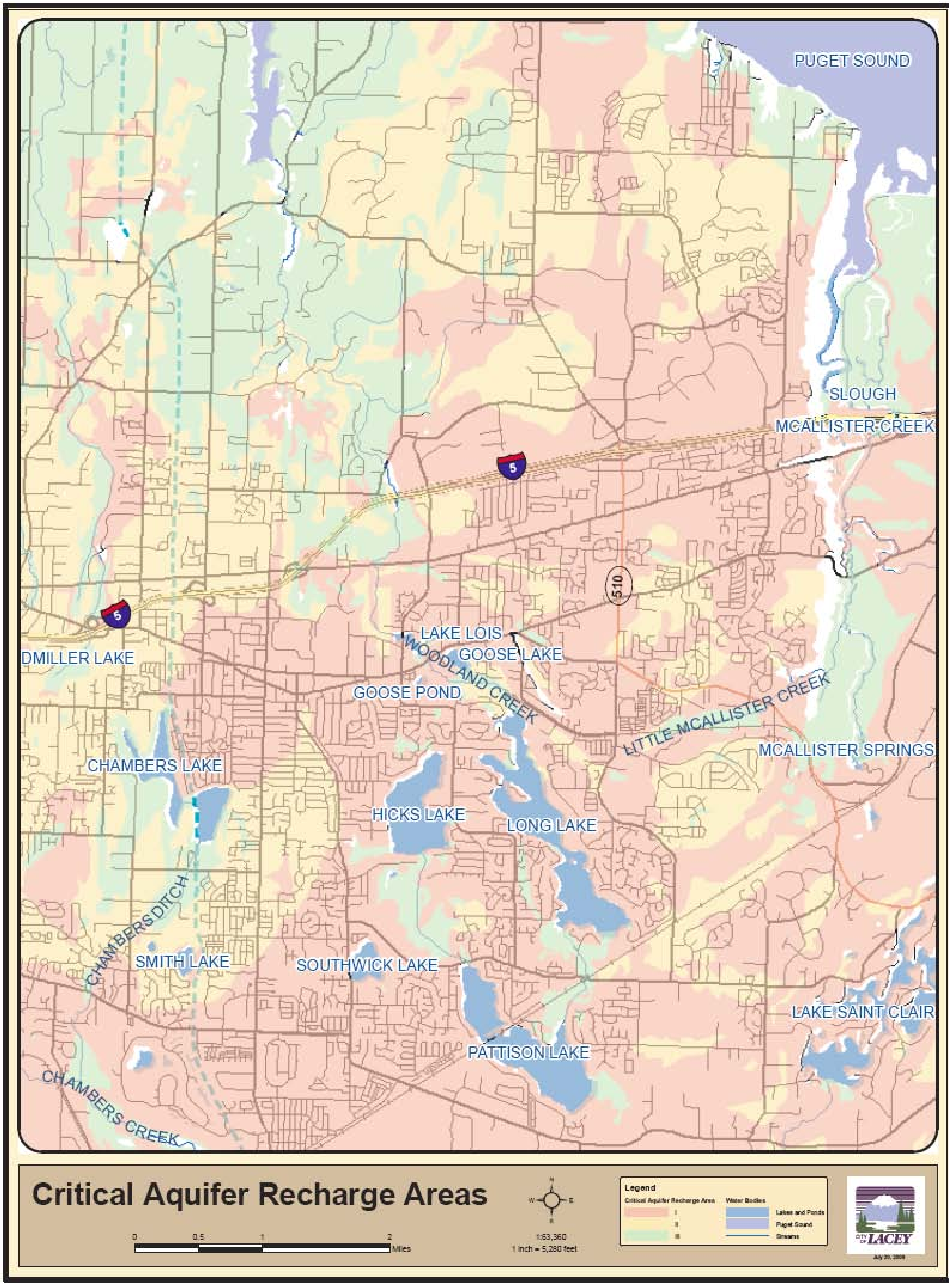

Figure 6A.2 Critical Aquifer Recharge Areas

Appendix 6B
Pilot Infiltration Test Procedure

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.

Infiltration Test Procedure

- 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.
- The horizontal surface area of the bottom of the test pit should be approximately 100 square feet. For small drainages and where water availability is a problem smaller areas may be considered as determined by the site professional.
- Accurately document the size and geometry of the test pit.
- Install a vertical measuring rod (minimum 5-ft. long) marked in half-inch increments in the center of the pit bottom.
- 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.
- 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.*

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.

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)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

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

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

Apply appropriate correction factors (see Section 6.3.3 to determine the site-specific design infiltration rate).

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Appendix 6C
Geotextile and Facility Liner Specifications

Table 6C.1
Geotextile Property Requirements
for Underground Drainage

		Low Survivability	**Moderate Survivability**
Geotextile Property	**Test Method**	**Woven/Nonwoven**	**Woven/Nonwoven**
Grab Tensile Strength, min. in machine and x-machine direction	ASTM D4632	180 lbs/115 lbs min.	250 lbs/160 lbs min.
Grab Failure Strain, in machine and x-machine direction	ASTM D4632	<50%/>50%	<50%/>50%
Seam Breaking Strength (if seams are present)	ASTM D4632 and ASTM D4884 (adapted for grab test)	160 lbs/100 lbs min.	220 lbs/140 lbs min.
Puncture Resistance	ASTM D4833	67 lbs/40 lbs min.	80 lbs/50 lbs min.
Tear Strength, min. in machine and x-machine direction	ASTM D4533	67 lbs/40 lbs min.	80 lbs/50 lbs min.
Ultraviolet (UV) Radiation stability	ASTM D4355	50% strength retained min., after 500 hrs. in weatherometer	50% strength retained min., after 500 hrs. in weatherometer

Note: 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).

Table 6C.2 Geotextile Property Requirements[1] for Underground Drainage Filtration				
Geotextile Property	**Test Method**	**Class A**	**Class B**	**Class C**
AOS[2]	ASTM D4751	.43 mm max. (#40 sieve)	.25 mm max. (#60 sieve)	.18 mm max. (#80 sieve)
Water Permittivity	ASTM D4491	.5 sec -1 min.	.4 sec -1 min.	.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).
[2] Apparent Opening Size (measure of diameter of the pores in the geotextile)

Table 6C.3
Geotextile Strength 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%
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% strength stability retained min., after 500 hrs. in weatherometer

[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).

Applications

1. For sand filter drain strip between the sand and the drain rock or gravel layers specify Geotextile Properties for Underground Drainage, moderate survivability, Class A, from Tables 1 and 2 in the Geotextile Specifications.

2. For sand filter matting located immediately above the impermeable liner and below the drains, the function of the geotextile is to protect the impermeable liner by acting as a cushion. The specification provided below in Table 3 should be used to specify survivability properties for the liner protection application. Table 2, Class C should be used for filtration properties. Only nonwoven geotextiles are appropriate for the liner protection application.

3. For an infiltration drain specify Geotextile for Underground Drainage, low survivability, Class C, from Tables 1 and 2 in the Geotextile Specifications.

4. For a sand bed cover a geotextile fabric is placed exposed on top of the sand layer to trap debris brought in by the storm water and to protect the sand, facilitating easy cleaning of the surface of the sand layer. However, a geotextile is not the best product for this application. A polyethylene or polypropylene geonet would be better. The geonet material should have high UV resistance (90% or more strength retained after 500 hours in the weatherometer, ASTM D4355), and high permittivity (ASTM D4491, 0.8 sec. -1 or more) and percent open area (CWO-22125, 10% or more). Tensile strength should be on the order of 200 lbs grab (ASTM D4632) or more.

Courtesy of Tony Allen, Geotechnical Engineer-WSDOT

Reference for Tables 1 and 2: Section 9-33.2 “Geotextile Properties,” 1998 Standard Specifications for Road, Bridge, and Municipal Construction

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Appendix 6D
Plant Lists for Bioretention Facilities

The following pages contain lists of suggested plant species for bioretention areas. Plant suggestions can also be found in the *Low Impact Development Technical Guidance Manual for Puget Sound* and in the Thurston County 2009 *Drainage Design and Erosion Control Manual*.

Table 6D.1 Plant Suggestions for Sunny Bioretention Facilities (Rain Gardens)

Zone	Type	Species Name	Common Name	Exposure	Notes
1	Emergent	Juncus ensifolius	**Daggerleaf Rush**	Full Sun	Likes wet soils; good soil binder
1	Emergent	Juncus effusus	**Common Rush**	Sun/Partial shade	Likes wet soils, but drought tolerant
1	Emergent	Carex aperta	**Columbia Sedge**	Full Sun	Tolerates water level fluctuations
1	Emergent	Scirpus acutus	**Hardstem Bulrush**	Full Sun	Must stay wet; can remove pathogens
1	Decid. Shrub	Cornus sericea	**Red-osier Dogwood**	Sun/Partial shade	Likes wet soils, but is adaptable
1	Decid. Shrub	Physocarpus capitatus	**Pacific Ninebark**	Sun/Partial shade	White showy flowers; drought tolerant
1	Decid. Shrub	Spiraea douglasii	**Douglas Spirea**	Sun/Partial shade	Tolerates inundation; spreads rapidly
1	Evergr. Shrub	Myrica californica	**Pacific Wax Myrtle**	Sun/Partial shade	Prefers moist soil; small flowers; tall
1	Decid. Tree	Alnus rubra	**Red Alder**	Sun/Partial shade	Adaptable; grows fast; fixes nitrogen
1	Decid. Tree	Fraxinus latifolia	**Oregon Ash**	Sun/Partial shade	Tolerates flooding; flowers
1	Decid. Tree	Malus fusca	**Pacific Crabapple**	Sun/Partial shade	Tolerates saturated soil; bears fruit; tall
2	Herb	Aquilegia formosa	**Western Columbine**	Sun/Partial shade	Tolerates flooding; red/yellow flowers
2	Herb	Aster subspicatus	**Douglas Aster**	Full Sun	Likes moist soils; blue/purple flowers
2	Herb	Camassia quamash	**Common Camas**	Sun/Partial shade	Keep moist while new; blue flowers
2	Herb	Iris douglasiana	**Pacific Coast Iris**	Sun/Partial shade	Tolerant; fast-growing; varied flowers
2	Evergr. Shrub	Mahonia aquifolia	**Tall Oregon Grape**	Sun/Partial shade	Tolerant; drought-resistant; dark fruit
2	Decid. Tree	Amelanchier alnifolia	**Western Serviceberry**	Sun/Partial shade	Drought tolerant; flowers/berries; birds
2	Decid. Tree	Corylus cornuta	**Beaked Hazelnut**	Sun/Partial shade	Moist, well-drained soil; edible nuts
3	Evergr. G.cover	Fragaria chiloensis	**Coastal Strawberry**	Sun/Partial shade	Well-drained soil; spreads; white flowers
3	Evergr. G.cover	Penstemon davidsonii	**Davidson's Penstemon**	Sun	Well-drained soil; low-growing; flowers
3	Evergr. Shrub	Arctostaphylos uva-ursi	**Kinnikinnik**	Sun/Partial shade	Well-drained soil; flowers; slow growing
3	Perennial	Achillea millefolium	**Western Yarrow**	Full Sun	Well-drained soils; varieties; flowers
3	Perennial	Lupinus polyphyllum	**Lupines**	Full Sun	Moist to dry soils; varieties; flowers
3	Evergr. Shrub	Arbutus unedo	**Dwarf Strawberry Tree**	Sun/Partial shade	Greenish-white flowers, red-orange fruit
3	Decid. Tree	Quercus garryana	**Oregon White Oak**	Full Sun	Tolerant; grows slowly; acorns
3	Evergr. Tree	Pseudotsuga menziesii	**Douglas-Fir**	Full Sun	Deep, moist soil; grows quickly, tall

Table 6D.2 Plant Suggestions for Shady Bioretention Facilities (Rain Gardens)

Zone	Type	Species Name	Common Name	Exposure	Notes
1	Emergent	Carex stipata	**Sawbeak Sedge**	Partial shade	Wet soils, shallow standing water
1	Emergent	Scirpus microcarpus	**Small-fruited Bulrush**	Sun/Shade	Wet soils; drought tolerant; soil binder
1	Emergent	Carex obnupta	**Slough Sedge**	Sun/Partial shade	Moist soil, drought tolerant, good soil binder
1	Fern	Blechnum spicant	**Deer Fern**	Partial/Full shade	Shallow flood tolerant; 1'-3' tall
1	Decid. Shrub	Lonicera involucrata	**Black Twinberry**	Partial/Full shade	Forest wetlands; yellow flowers; 2-8'
1	Decid. Shrub	Rubus spectabilis	**Salmonberry**	Partial/Full shade	Moist soil; forms thickets; flowers/fruit
1	Decid. Shrub	Ribes bracteosum	**Stink Currant**	Partial shade	Moist soil; flood-tolerant; big leaves
2	Herb	Tiarella trifoliate	**Foamflower**	Partial/Full shade	Likes moist soil; low, dense; white flowers
2	Herb	Viola, various species	**Violets**	Partial/Full shade	Likes moist soil; blue/yellow flowers
2	Herb	Asarum caudatum	**Wild Ginger**	Partial/Full shade	Likes moist soil; low; red-brown flowers
2	Herb	Tolmiea menziesii	**Piggyback Plant**	Partial/Full shade	Moist soil; groundcover; purple flowers
2	Decid. Shrub	Rosa nutkana	**Nootka Rose**	Sun/Partial shade	Tolerant; spreads; wildlife food/cover
2	Decid. Shrub	Rubus parviflorus	**Thimbleberry**	Sun/Partial shade	Tolerant; spreads; flowers/red berries
2	Decid. Shrub	Symphoricarpos albus	**Snowberry**	Sun/Shade	Tolerant; slope ctrl; flowers/white berries
2	Decid. Shrub	Vaccinium parvifolium	**Red Huckleberry**	Partial/Full shade	Dry, slightly acid soil; slow growing
2	Decid. Tree	Acer cirtinatum	**Vine Maple**	Filtered Sun/shade	Dry to moist soil; soil binder; fall color
2	Decid. Tree	Crataegus douglasii	**Black Hawthorn**	Sun/Partial shade	Well-drained soil; thorny thickets
2	Evergr. Tree	Thuja plicata	**Western Red Cedar**	Partial/Full shade	Likes moist, slightly acid soil; tall
3	Evergr. G.cover	Fragaria vesca	**Wood Strawberry**	Partial shade	Dry to moist soil; spreads; white flowers
3	Evergr. Shrub	Gaultheria shallon	**Salal**	Partial/Full shade	Tolerant of dry or moist; slow-growing
3	Evergr. Shrub	Mahonia nervosa	**Cascade Oregon Grape**	Partial/Full shade	Tolerant; drought-resistant; to 2' tall
3	Evergr. Shrub	Mahonia repens	**Creeping Mahonia**	Sun/Partial shade	Tolerant; drought-resistant; flowers
3	Perennial	Polystichum munitum	**Sword Fern**	Partial/Full shade	Moist soil; drought tolerant; slope control
3	Decid. Shrub	Holodiscus discolor	**Oceanspray**	Sun/Partial shade	Tolerates drought/some flooding
3	Decid. Shrub	Rosa gymnocarpa	**Baldhip Rose**	Partial shade	Drought tolerant; wildlife food/cover
3	Decid. Tree	Prunus emarginata	**Bitter Cherry**	Sun/Partial shade	Dry or moist soil; berries attract birds

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Chapter 7 – Water Quality Treatment

This chapter presents the City of Lacey approved methods and criteria for selection of stormwater BMPs (best management practices), and the analysis and design of water quality treatment facilities. The BMP selection process integrates both flow control (see Chapter 6 for analysis and design criteria) and water quality treatment, in order to facilitate the maximum practical use of LID measures.

Section 7.1 presents guidance for the selection of stormwater BMPs.

Section 7.2 presents General Design Requirements for Water Quality Facilities and details pertinent to all water quality facilities.

Sections 7.3 through 7.7 present details and requirements for categories of facilities, including Pre-treatment Facilities (Section 7.3), Infiltration Facilities (Section 7.4), Biofiltration Facilities (Section 7.5), Wetpool Designs (Section 7.6), Media Filtration Designs (Section 7.7), and Oil Control Facility Designs (Section 7.8).

The figures provided in Chapter 7 illustrate examples of how the design criteria might be applied. Other engineering solutions that meet the design criteria may be possible. The figures are not used to specify requirements unless they are referenced elsewhere in the Manual.

7.1 Stormwater BMP Selection

There are four main types of stormwater BMPs: (1) Water Quality Treatment, (2) Flow Control, (3) LID, which provide treatment and/or flow control benefits, and (4) Source Control. The first three are discussed in this section, and Source Control BMPs are addressed in Chapter 8.

This section presents a process for selecting LID, water quality treatment and flow control BMPs to help a project comply with Core Requirement #5 (On-site Stormwater Management), Core Requirement #6 (Runoff Water Quality Treatment) and Core Requirement #7 (Flow Control).

Section 7.1.1 describes the types of surfaces from which runoff flows require water quality treatment. Section 7.1.2 presents a general procedure for selecting stormwater BMPs, including LID BMPs, flow control BMPs and water quality treatment BMPs. The latter are chosen by using water quality treatment “menus,” which guide the selection of facilities based on conditions at a given project site. The Water Quality Treatment Menus are the following:

- Basic Water Quality Treatment Menu, Section 7.1.3
- Metals Control Treatment Menu, Section 7.1.4
- Phosphorus Control Menu, Section 7.1.5
- Oil Control Menu, Section 7.1.6

Table 7.1 presents a list of the BMPs described in this manual, to use as a quick reference.

Table 7.1 Lacey Stormwater Management BMPs

BMP No.	BMP Title	Type of BMP					
				Runoff Treatment			
		LID	Flow Control	Basic	Metals	Phosphorus	Oil Control
LID Stormwater Management BMPs							
LID-01	Protect and Restore Native Vegetation	√					
LID-02	Reduce Effective Impervious Area	√					
LID-03	Full Dispersion	√	√	√	√	√	
LID-04	Downspout Infiltration Systems	√					
LID-05	Downspout Dispersion Systems	√					
LID-06	Perforated Stub-out Connection	√					
LID-07	Concentrated Flow Dispersion	√					
LID-08	Sheet Flow Dispersion	√					
LID-09	Post Construction Soil Quality and Depth	√					
LID-10	Bioretention Facilities	√	√	√	√	*	
LID-11	Alternative (Permeable) Paving Surfaces	√					
LID-12	Vegetated ("Green") Roofs	√					
Infiltration BMPs							
IN-01	Infiltration Basins		√	*	*	*	
IN-02	Infiltration Trenches		√	*	*	*	
IN-03	Bio-Infiltration Swale		√	*	*	*	
IN-04	Bioretention Areas		√	√	√	*	
Detention BMPs							
D-01	Detention Ponds		√				
D-02	Detention Tanks		√				
D-03	Detention Vaults		√				
D-04	Parking Lot Detention		√				
Biofiltration BMPs							
BF-01	Basic Biofiltration Swale			√			
BF-02	Wet Biofiltration Swale			√			
BF-03	Continuous Inflow Biofiltration Swale			√			
BF-04	Vegetated or Compost-Amended Filter Strip			√	*		*
BF-05	Narrow Area Filter Strip			√			

BMP No.	BMP Title	Type of BMP					
		LID	Flow Control	Runoff Treatment			
				Basic	Metals	Phosphorus	Oil Control
Wet Pool BMPs							
WP-01	Wet Pond			√		*	
WP-02	Wet Vault			√			*
WP-03	Stormwater Treatment Wetland			√	√		
WP-04	Combined Detention/Wet Pool Facilities		√	√	*	*	
Media Filtration BMPs							
MF-01	Sand Filter Basin			√	*	*	
MF-02	Sand Filter Vault			√	*	*	
MF-03	Linear Sand Filter			√	*	*	√
MF-04	Commercial Media Filter			√	√	√	
MF-05	Media Filter Drain			√	√	√	
Oil and Water Separation BMPs							
OW-01	Catch Basin Inserts						√
OW-02	Oil/Water Separator						√
Pre-treatment BMPs							
PT-01	Pre-settling Basin						
PT-02	Pre-settling Vault						
PT-03	Hydrodynamic Settling Device						

√ Meets criteria

* Design option allows BMP to meet criteria

7.1.1 Flows Requiring Treatment

Flows that require treatment include runoff from pollution-generating surfaces, impervious or pervious (PGIS or PGPS) meeting the following area thresholds from Core Requirement #6, Chapter 1:

- **Projects in which the total of effective, pollution-generating impervious surfaces (PGIS) is 5,000 square feet or more in a threshold discharge area of the project, or**
- **Projects in which the total of pollution-generating pervious surfaces (PGPS) is three-quarters (3/4) of an acre or more in a threshold discharge area, and from which there is a surface discharge in a natural or man-made conveyance system from the site.**

Pollution-generating impervious surfaces (PGIS) include those surfaces which are subject to: vehicular use; industrial activities; or storage of erodible or leachable materials, wastes, or chemicals, and which receive direct rainfall or the run-on or blow-in of rainfall. Erodible or leachable materials, wastes, or chemicals are those substances which, when exposed to rainfall, measurably alter the physical or chemical characteristics of the rainfall runoff. Examples include erodible soils that are stockpiled, uncovered process wastes, manure, fertilizers, oily substances, ashes, kiln dust, and garbage dumpster leakage. Metal roofs are also considered to be PGIS unless they are coated with an inert, non-leachable material.

A surface, whether paved or not, shall be considered subject to vehicular use if it is regularly used by motor vehicles. The following are considered regularly-used surfaces: roads, driveways, parking lots, unfenced fire lanes, vehicular equipment storage yards, and airport runways.

The following are typically not considered regularly used surfaces: paved bike trails (separated from the traveled lanes), fenced fire lanes, and infrequently used maintenance access roads.

Pollution-generating pervious surfaces (PGPS) are any non-impervious surfaces subject to the use of pesticides and fertilizers or loss of soil. Typical PGPS include lawns, landscaped areas, golf courses, parks, cemeteries, and sports fields.

If combined with runoff from PGIS or PGPS, runoff from non-pollution-generating areas must be treated, and the facility (or facilities) must be sized accordingly.

7.1.2 Stormwater BMP Selection Procedure

Selection of BMPs shall follow the general procedure as described in Steps 1 – 6 below. The steps need not necessarily be followed in the order presented, but doing so ensures that all aspects of the selection process have been considered.

Step 1: Determine if the Project is Subject to an Implemented Basin Plan

If the project drains to a basin with an implemented basin plan, any requirements of the plan must be met as well as those specified in this Manual. In cases of inconsistency between the plan and this Manual, the more restrictive (protective) requirement applies. See the Thurston County basin planning website to determine whether any such plans and requirements apply to your project, at:

http://www.co.thurstoncounty.wa.us/stormwater/BasinPlans/Basin_Plans_home.htm

Step 2: Implement LID Site Design Measures

Site design can reduce the cost and land area required for both flow control and water quality treatment. The following site planning measures (described in Chapter 6) shall be considered and implemented to the maximum practical extent:

- BMP LID-01 Preserve and/or Restore Native Vegetation
- BMP LID-02 Reduce Effective Impervious Area
- BMP LID-03 Full Dispersion

If full dispersion is achievable, no further LID, flow control or water quality BMPs are required.

Step 3: Implement LID BMPs as Required and to the Maximum Extent Practicable

- BMP LID-04 Post-Construction Soil Quality and Depth
- BMP LID-05 Downspout Infiltration
- BMP LID-06 Downspout Dispersion

Some combination of the above LID BMPs are required to meet Core Requirements (if full dispersion is not practical). Lacey encourages the use of the other LID BMPs described in Chapter 6 as well.

Step 4: **Determine if Further Flow Control or Water Quality Treatment is Needed**

The implementation of LID BMPs will have reduced or perhaps eliminated the need for further stormwater BMPs. If further BMPs are needed, proceed to Step 5.

Step 5: Determine whether infiltration is feasible

Criteria for feasibility of infiltration for flow control are presented in Chapter 6.

Infiltration for water quality treatment is feasible if the soil suitability criteria in Section 7.4 can be met, either with native or engineered soils.

Additional restrictions on the use of infiltration apply if the project is in a Groundwater Protection Area. Location in a Wellhead Protection Area, a Critical Aquifer Recharge Area, nitrate hotspot area, or other area of known groundwater contamination. Refer to the maps of Wellhead Protection Areas and Critical Aquifer Recharge Areas in Appendix 6A, and check with the City of Lacey Public Works Department, Water Resources Division for the most up-to-date information.

If the project is in a **Wellhead Protection Area** the requirements and land use restrictions in Section 6.025 of the Design Guidelines and Lacey Municipal Code 14.36.215, 14.36.217 and 14.36.219 apply:

- All stormwater shall be directed away from the well's 100-foot sanitary setback.
- Stormwater shall not be discharged directly into the aquifer supplying the well within the well's 1-year time of travel zone.
- Integrated Pest Management (IPM) shall be used in choosing landscaping. Contact Thurston County Environmental Health for the most recent IPM standards.
- Within the 1-year time of travel zone, treatment shall be provided either by a treatment infiltration device (preceded by a pre-treatment BMP), or by providing metals and phosphorus removal prior to discharging to a flow control infiltration device.

If the project is in a **Category I Critical Aquifer Recharge Area**, the requirements and restrictions in Section 6.025 of the Design Guidelines and Lacey Municipal Code 14.36 apply.

- Stormwater shall not be discharged directly into an aquifer.
- Integrated Pest Management (IPM) shall be used in choosing landscaping. Contact Thurston County Environmental Health for the most recent IPM standards.
- Treatment shall be provided either by a treatment infiltration device (preceded by a pre-treatment BMP), or by providing metals and phosphorus removal prior to discharging to a flow control infiltration device.

If the project is located in a **nitrate hot spot:**

- Stormwater shall not be discharged directly into an aquifer.
- Integrated Pest Management (IPM) shall be used in choosing landscaping. Contact Thurston County Environmental Health for the most recent IPM standards.
- Treatment shall be provided either by a treatment infiltration device (preceded by a pre-treatment BMP), or by providing metals and phosphorus removal prior to discharging to a flow control infiltration device.

If infiltration is feasible and the project is not in a Groundwater Protection Area as described above, treatment may be provided using a flow control infiltration device preceded by a pre-treatment device.

Also, check Step 7A and apply oil control if necessary.

If infiltration is not feasible, surface discharge will be required. Steps 6 and 7 below apply to surface discharges. If infiltration is feasible, skip to Step 8.

Step 6: Select Flow Control BMP

If a combined treatment/flow control facility is feasible, select a combined wet/detention pond or a combined stormwater wetland/detention pond. Otherwise select any of the other flow control BMPs from Chapter 6.

Step 7: Select Runoff Treatment BMP

Any given project may be required to provide Oil Control, Phosphorus treatment, or Metals treatment, or any combination of the three, depending on project and receiving water characteristics. If neither Phosphorus nor Metals Treatment is required, treatment may be provided by a Basic Treatment BMP (Section 7.1.3).

Step 7A: Determine need for **Oil Control** BMP

If the project is a **High Use Site,** select treatment facilities from the **Oil Control Menu** (Section 7.1.6) in addition to any other required treatment**.**

A High Use Site is defined as follows:

- An area of a commercial or industrial site subject to an expected average daily traffic (ADT) count equal to or greater than 100 vehicles per 1,000 square feet of gross building area,
- An area of a commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year,

- An area of a commercial or industrial site subject to parking, storage or maintenance of 25 or more vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.),
- Vehicle-related businesses such as automotive parts, repair shops, oil-change services, vehicle storage, wrecking yards, etc,
- High-use road intersections as defined by the City of Lacey.

For high-use sites located within a larger commercial center, only the impervious surface associated with the high-use portion of the site is subject to treatment requirements. If common parking for multiple businesses is provided, treatment shall be applied to the number of parking stalls required for the high-use business only. However, if the treatment collection area also receives runoff from other areas, the treatment facility must be sized to treat all water passing through it.

High-use roadway intersections shall treat lanes where vehicles accumulate during the signal cycle, including left and right turn lanes and through lanes, from the beginning of the left turn pocket. If no left turn pocket exists, the treatable area shall begin at a distance equal to three car lengths from the stop line. If runoff from the intersection drains to more than two collection areas that do not combine within the intersection, treatment may be limited to any two of the collection areas.

Industrial sites in compliance with an NPDES permit that specifically addresses oil control for the target pollutant generating impervious surface are considered in compliance with Lacey's oil control requirement.

Step 7B: Determine Need for **Phosphorus Control** BMP

Phosphorus Control is required on projects that are a source of phosphorus, which include projects meeting the PGPS threshold, and any others determined to be a source. Phosphorus control can be provided by any of the BMPs in the phosphorus control menu (Section 7.1.5).

Project sites subject to Phosphorus Treatment requirements may also be subject to Metals Treatment requirements. In that event, select a facility or treatment train that provides both phosphorus and metals treatment.

Step 7C: Determine Need for **Metals Treatment** BMP

Metals treatment is required for the following project types throughout the City that discharge directly or indirectly via surface water to fish-bearing waters (all surface waters in Lacey):

a. Industrial project sites,
b. Commercial project sites,
c. Multi-family project sites,
d. Arterials and highways

If Metals Treatment is required, BMPs may be selected from the Metals Treatment Menu (Section 7.1.4), subject to consideration of the remaining menus.

Step 7D: Select **Runoff Treatment** BMPs

Based on the determination in Steps 7A through 7C of which types of treatment are required, select a BMP or set of BMPs from the appropriate menus that meet the treatment requirements and site conditions.

Step 8: Determine Need for and Select Pre-treatment BMP.

Pretreatment is intended to remove suspended sediments that would compromise the function of other treatment BMPs. Pretreatment is required in the following cases:

- On project sites using infiltration treatment.
- Where needed to ensure and extend performance of the other treatment facilities.

Select pre-treatment control measures from the menu in Section 7.1.7. Any BMP from the Basic Menu (Section 7.1.3) may also be used as pre-treatment.

Other Treatment Facility Selection Factors

The selection of a treatment facility should be based on site physical factors and pollutants of concern. The requirements for use of Metals Treatment or Phosphorus Treatment represent facility selection based on pollutants of concern. Even if the site is not subject to those requirements, try to choose a facility that is more likely to do a better job removing the types of pollutants generated on the site. The types of site physical factors that influence facility selection are summarized below.

Pollutants of Concern

The type of land use affects the types of pollutants that could be expected in stormwater. For example, oil and grease are the expected pollutants from an uncovered fueling station. Refer to Ecology's 2005 *Stormwater Management Manual for Western Washington,* Volume V, Chapter 2, for Tables 2.1 and 2.2. Table 2.1 summarizes the pollutants of concern and those land uses that are likely to generate pollutants. It also provides suggested treatment options for each land use. Using Table 2.1, a combination of an oil/water separator and a biofilter could be considered as the basic treatment for runoff from uncovered fueling stations. Table 2.2 is a general listing of the relative effectiveness of classes of treatment facilities in removing key stormwater pollutants.

Soil Type

The permeability of the soil underlying a treatment facility has a profound influence on its effectiveness. This is particularly true for infiltration treatment facilities that are best sited in sandy to loamy sand soils. They are not generally appropriate for sites that have final infiltration rates of less than 0.5 inches per hour. Wet pond facilities situated on coarser soils will need a synthetic liner or the soils amended to reduce the infiltration rate and provide treatment. Maintaining a permanent pool in the first cell is necessary to avoid resuspension of settled solids. Biofiltration swales in coarse soils can also be amended to reduce the infiltration rate.

High Sediment Input

High TSS loads can clog infiltration soil, sand filters and coalescing plate oil & water separators. Pretreatment with a presettling basin, wet vault, or another basic treatment facility would typically be necessary.

Other Physical Factors

Slope: Steep slopes restrict the use of several BMPs. For example, biofiltration swales are usually situated on sites with slopes of less than 6%, although greater slopes may be considered. Infiltration BMPs are not suitable when the slope exceeds 15%.

High Water Table: Unless there is sufficient horizontal hydraulic receptor capacity, the water table acts as an effective barrier to exfiltration and can sharply reduce the efficiency of an infiltration system. If the high water table extends to within five (5) feet of the bottom of an infiltration BMP, the site is seldom suitable.

Depth to Bedrock/ Hardpan/Till: The downward exfiltration of stormwater is also impeded if a bedrock or till layer lies too close to the surface. If the impervious layer lies within five feet below the bottom of the infiltration BMP the site is not suitable.

Proximity to Foundations and Wells: Since infiltration BMPs convey runoff back into the soil, some sites may experience problems with local seepage. This can be a real problem if the BMP is located too close to a building foundation. Another risk is ground water pollution; hence the requirement to site infiltration systems more than 100 feet away from drinking water wells.

Maximum Depth: Wet ponds are also subject to a maximum depth limit for the "permanent pool" volume. Deep ponds (greater than 8 feet) may stratify during summer and create low oxygen conditions near the bottom resulting in re-release of phosphorus and other pollutants back into the water.

7.1.3 Basic Water Quality Treatment Menu

The **Basic Treatment Menu** can be used for single-family residential project sites and as a source of components in a treatment train for Metals Treatment and/or Phosphorus Control, as described in those menus in Sections 7.1.4 and 7.1.5, respectively. Due to the surface water conditions in the City of Lacey, all projects considered sources of metals and discharging to surface waters require Metals Treatment (Section 7.1.4) and all projects considered sources of phosphorus discharging to surface waters are subject to Phosphorus Control as described in Section 7.1.5.

Subject to approval by the City of Lacey, the following options, or combinations thereof, may be chosen to satisfy the Basic Treatment requirement:

- **Basic WQ Option 1: Infiltration** (Section 7.4, page 7-23)

  Where feasible and soils are appropriate, infiltration of stormwater is the preferred method of basic treatment. Basic treatment soils are those with a measured infiltration rate of less than 2.4 inches per hour. Basic treatment can be achieved using various types of infiltration facilities, including basins and trenches similar to those described in Chapter 6 for flow control.

- **Basic WQ Option 2: Biofiltration Swale** (Section 7.5 page 7-29)

  A biofiltration swale is a long, gently-sloped vegetated ditch. Grass is the most common vegetation used. The biofiltration swale may be designed as a “wet” swale (BMP BF-02, page 7-35) for conditions where grass survivability is unlikely (slope less than 2%, high water table, or continuous base flow), or a continuous inflow swale (BMP BF-03, page 7-37).

- **Basic WQ Option 3: Filter Strip** (Section 7.5, page 7-29)

  A filter strip is a grassy area with gentle slopes which treats runoff before it concentrates in discrete channels. The narrow area filter strip (BMP BF-05, page 7-38) may be used along a roadway or parking lot in limited space situations.

- **Basic WQ Option 4: Wetpond** (Section 7.6, page 7-40)

  Wetponds are ponds that are designed to maintain a permanent pool of water for most of the year. Treatment is achieved through relatively long residence time in the pond.

- **Basic WQ Option 5: Wetvault** (Section 7.6, page 7-40)

  An underground vault, tank, or pipe system may be used to provide basic treatment, using the same permanent pool mechanism as a wetpond. **Note:** Lacey prohibits wetvaults for residential projects.

- **Basic WQ Option 6: Stormwater Treatment Wetland** (Section 7.6, page 7-40)

  A stormwater wetland uses biological processes of plant uptake and bacterial degradation as well as physical and chemical processes to remove pollutants. The footprint of the wetland is sized based on wetpond methods, but a portion (second cell) of the wetland is shallow to promote wetland plant growth.

- **Basic WQ Option 7: Combined Detention and Wetpool Facilities** (Section 7.6, page 7-40)

  This option allows the wetpond, vault or stormwater wetland volume to be placed underneath the live storage volume of a detention facility. Where site conditions allow, this option occupies less space than separate flow control and water quality facilities.

- **Basic WQ Option 8: Sand Filter** (Section 7.7.1, page 7-54)

  A sand filter is a depression or pond with a sand bottom layer, which treats stormwater as it percolates through the sand. Sand filters may be built as open ponds, underground vaults or linear perimeter trenches.

- **Basic WQ Option 9: Manufactured Treatment Systems** (Section 7.7.2, page 7-60)

  Three commercially-available treatment systems are currently approved by Ecology with General Use Level Designation (GULD) for basic treatment: (1) the Contech Stormwater Solutions Inc. StormFilter® using ZPG media, (2) the Contech Stormwater Solutions Inc. CDS® Media Filtration System, and (3) the Americast Filterra® Bioretention System.

  In addition to these current GULD systems, various other manufactured stormwater treatment systems are being developed and becoming available. These new systems may potentially be considered for use in Lacey where applicable and appropriate, subject to specific conditions of acceptance by the Lacey Drainage Manual Administrator. The use of <u>any</u> commercial treatment system will be determined by the City of Lacey on a case-by-case basis.

- **Basic WQ Option 10: Media Filter Drain** (Section 7.7.2, page 7-61)

  Another relatively new option for water quality treatment, particularly for long, linear applications such as along roadways, is the Media Filter Drain, formerly referred to as the Ecology Embankment. The Media Filter Drain (or MFD) has General Use Level Designation from Ecology for basic, metals and phosphorus treatment for roadways or similar sheet-flow applications. Media Filter Drains are typically sited on gentle side slopes along highways, and consist of four basic components: a gravel zone along the road edge, a grass strip, the MFD mix bed, and gravel-filled underdrain trench (with or without pipe) for infiltration and/or conveyance. See BMP MF-05, page 7-59.

7.1.4 Metals Control Treatment Menu

The **Metals Control Treatment Menu** is intended to provide improved metals removal and is required for all residential projects in the mapped Metals Treatment Area and the following project types throughout the City:

- Industrial project sites,
- Commercial project sites,
- Multi-family project sites,
- Arterials and highways

For developments with a mix of land use types, the Metals Treatment requirement applies when the area subject to the Metals Treatment requirement is 50% or more of total area within a threshold discharge area or if pollutants generated on-site are otherwise determined to warrant Metals Treatment.

Note that some Metals Treatment BMPs are not suitable for phosphorus control, required for all projects with Pollutant Generating Pervious Surfaces. If both Metals Treatment for metals removal and Phosphorus Control cannot be achieved with a single BMP, a combination of BMPs will be required. For example, a stormwater treatment wetland does not provide phosphorus control, and if used for Metals treatment it must be supplemented with a BMP that controls phosphorus.

Subject to approval by the City of Lacey, the following options may be chosen to satisfy the Metals treatment requirement:

- **Metals WQ Option 1: Infiltration Treatment** (Section 7.4, page 7-25)

  Infiltration is the preferred method of Metals treatment where site conditions allow and where soils are suitable. A Pretreatment BMP (Pretreatment Menu, Section 7.1.7) is required to protect the infiltration capacity of the facility.

  If the soils do not meet the soil suitability criteria **and** the infiltration site is within a wellhead protection area or groundwater protection area, treatment must be provided by one of the other treatment facility options listed below.

- **Metals WQ Option 2: Stormwater Treatment Wetland** (Section 7.6, page 7-40)

  A Stormwater Wetland, separate or combined with a detention facility, can be used for Basic or Metals Treatment.

- **Metals WQ Option 3: Bioretention (Rain Garden)** (Section 7.4, page 7-25)

  Rain gardens are designed to filter runoff through an amended soil medium.

- **Metals WQ Option 4: Media Filter Drain** (Section 7.7.2, Page 7-61)

  The Media Filter Drain (formerly Ecology Embankment) is acceptable for road or other narrow projects in Lacey that require metals treatment.

- **Metals WQ Option 5: Two-Facility Treatment Trains**

  This option is available where infiltration treatment is not feasible. A Basic Water Quality Treatment Option is followed by a Basic Sand Filter (basin, vault, or linear sand filter) or an approved media filter (Section 7.7).

Treatment train options for removal of dissolved metals are shown in Table 7.2:

Table 7.2 Treatment Trains for Metals Treatment

First Basic Treatment Facility	Second Treatment Facility
Biofiltration swale (Section 7.5)	Basic Sand Filter, Basic Sand Filter Vault, or Media Filter (Section 7.7)
Filter Strip (Section 7.5)	Linear Sand Filter, no pre-settling cell needed (Section 7.7)
Linear Sand Filter (Section 7.7)	Filter Strip (Section 7.5)
Wetpond (Section 7.6)	Basic Sand Filter, Basic Sand Filter Vault, or Media Filter (Section 7.7)
Wet Vault (Section 7.6)	Basic Sand Filter, Basic Sand Filter Vault, or Media Filter (Section 7.7)
Combined Detention/Wetpond (Section 7.6)	Basic Sand Filter, Basic Sand Filter Vault, or Media Filter (Section 7.7)
Sand Filter or Sand Filter Vault (Section 7.7) with pre-settling cell or preceded by detention	Media Filter (Section 7.7)
Note: approved media for Metals Treatment include StormFilter's™ leaf compost and zeolite media	

- **Metals WQ Option 6: Amended Sand Filter** (Section 7.7, page 7-54)

  Any of the Basic Treatment sand filter options, sand filter basin, linear sand filter, or sand filter vault can be used for Metals treatment if amended with appropriate metals-adsorbing materials. A pre-settling cell is required if the filter is not preceded by a detention facility.

7.1.5 Phosphorus Control Menu

Phosphorus Control is required on projects that are a source of phosphorous and are located within watersheds that have been determined to be sensitive to phosphorus (all surface waters in Lacey) and that are being managed to control phosphorus inputs from stormwater. This applies to all 303(d)-listed surface waters within Lacey's jurisdiction. This menu applies to stormwater conveyed to these waters by surface flow. Projects that may be considered a source of phosphorus are those that meet the treatment threshold.

Subject to approval by the City of Lacey, the following options may be chosen to satisfy the phosphorus treatment requirement.

- **Phosphorus Control Option 1: Infiltration Treatment** (Section 7.4)

  Infiltration is the preferred method of phosphorus control where site conditions allow and where soils are suitable. A Pretreatment BMP (Pretreatment Menu, Section 7.1.6) is required to protect the infiltration capacity of the facility.

  If infiltration treatment is not feasible, phosphorus control must be provided by one of the alternate treatment facility options listed below.

- **Phosphorus Control Option 2: Bioretention** (Section 7.7, page 7-54)

  Bioretention cells (or rain gardens) are designed to filter runoff through an amended soil mixture. In general, increased depth of the soil mixture increases phosphorus removal.

- **Phosphorus Control Option 3: Large Wetpond** (Section 7.6, page 7-40)

  A Wet Pond sized according to the procedures in Section 7.6 can be used to provide phosphorus control.

- **Phosphorus Control Option 4: Large or Amended Sand Filter** (Section 7.7, page 7-54)

  Sand filters (basins, vaults or linear) can be over-sized or amended as described in Section 7.7 to provide phosphorus control.

- **Phosphorus Control Option 5: Media Filter Drain** (Section 7.7, Page 7-61)

  The Media Filter Drain (formerly Ecology Embankment) is acceptable for road or other narrow projects in Lacey that require phosphorus treatment.

- **Phosphorus Control Option 6: Two-Facility Treatment Trains**

  This option is available where infiltration treatment is not feasible. A Basic Water Quality Treatment Option is followed by a Basic Sand Filter (basin, vault, or linear sand filter) or an approved media filter (Section 7.7.2). Treatment train options are shown in Table 7.3.

Table 7.3 Treatment Train Options for Phosphorus Control	
First Basic Treatment Facility	**Second Treatment Facility**
Biofiltration Swale (Section 7.5)	Basic Sand Filter, Basic Sand Filter Vault (Section 7.7)
Filter Strip (Section 7.5)	Linear Sand Filter, no pre-settling cell needed (Section 7.7)
Linear Sand Filter (Section 7.7)	Filter Strip (Section 7.5)
Wetpond (Section 7.6)	Basic Sand Filter, Basic Sand Filter Vault (Section 7.7)
Wet Vault (Section 7.6)	Basic Sand Filter, Basic Sand Filter Vault (Section 7.7)
Stormwater Treatment Wetland (Section 7.6)	Basic Sand Filter, Basic Sand Filter Vault (Section 7.7)
Combined Detention/Wetpond (Section 7.6)	Basic Sand Filter, Basic Sand Filter Vault, or Media Filter (Section 7.7)

7.1.6 Oil Control Menu

The following BMPs are available for Oil Control (see Section 7.8, page 7-70):

- **Oil Control Option 1: Catch Basin Inserts**

  Catch basin inserts as described in Section 7.8 may be used for Oil Control under certain circumstances.

- **Oil Control Option 2: Baffle-Type (API) Oil/Water Separators**
- **Oil Control Option 3: Coalescing Plate (CP) Separator**
- **Oil Control Option 4: Linear Sand Filter**
- **Media Filter targeted for oil removal, or other City-approved emerging technology**

7.1.7 Pretreatment Menu

Subject to approval by the City of Lacey, the following options may be chosen to satisfy the pretreatment requirement:

- **Pretreatment Option 1: Presettling Basin** (page 7-23)
- **Pretreatment Option 2: Presettling Wetvault** (page 7-23)
- **Pretreatment Option 3: Hydrodynamic settling devices/emerging technologies** (page 7-24)

  For pretreatment purposes, emerging technologies that have been approved by Lacey as capable of removing 50% of 50-micron-sized particles and 80% of 125-micron-sized particles shall be deemed acceptable for pretreatment.

7.2 General Requirements for Treatment Facilities

This chapter addresses general requirements for treatment facilities. Requirements discussed in this chapter include design volumes and flows, sequencing of facilities, liners, and hydraulic structures for splitting or dispersing flows.

7.2.1 Water Quality Design Storm Volume

The volume of runoff predicted from a 24-hour storm with a 6-month return frequency (a.k.a. 6-month, 24-hour storm) shall be calculated using the most current version of the Western Washington Hydrology Model (WWHM) with Thurston County enhancements.

7.2.2 Water Quality Design Flow Rate

***Downstream of Detention Facilities*: The full 2-year release rate from the detention facility, calculated using the most current version of the Western Washington Hydrology Model (WWHM) with Thurston County enhancements** to identify the 2-year return frequency flow rate discharged by a detention facility that is designed to meet the flow duration standard.

Treatment facilities that are located downstream of detention facilities must be designed as on-line facilities.

***Preceding Detention Facilities or when Detention Facilities are not required*: The flow rate at which 91% of the runoff volume, as estimated by WWHM, using long-term historical precipitation records, will be treated.** At the time of publication, all BMPs except wetpool-types should use the 15-minute time series from an approved continuous runoff model.

- *Off-line facilities*: For treatment facilities not preceded by detention, the treatment facility should continue to receive and treat the water quality design flow rate. Higher incremental portions of flow rates are bypassed around the treatment facility.

Treatment facilities preceded by a detention facility may identify a lower water quality design flow rate provided that at least 91 percent of the estimated runoff volume in the time series of a continuous runoff model is treated to the applicable performance goal.

- *On-line facilities*: Runoff flow rates in excess of the water quality design flow rate can be routed through the facility provided a net pollutant reduction is maintained, and the applicable annual average performance goal is likely to be met.

7.2.3 Sequence of Facilities

In general, any treatment BMP may be installed upstream of detention facilities, although presettling basins are needed for infiltration basins. However, not all treatment BMPs can function effectively if located downstream of detention facilities. Those facilities that treat unconcentrated flows, such as filter strips and narrow-area biofilters, shall not be used downstream of detention facilities, unless flow dispersion is provided.

Table 7.4 summarizes placement considerations of treatment facilities in relation to detention.

Table 7.4
Treatment facility placement in relation to detention

Water Quality Facility	Preceding Detention	Following Detention
Basic biofiltration swale	OK	OK. Prolonged flows may reduce grass survival. Consider wet biofiltration swale
Wet biofiltration swale	OK	OK
Filter strip	OK	Not allowed.
Basic or large wetpond	OK	OK—less water level fluctuation in ponds downstream of detention may improve aesthetic qualities and performance.
Basic or large combined detention and wetpond	Not applicable	Not applicable
Wetvault	OK	OK
Stormwater treatment wetland/pond	OK	OK—less water level fluctuation and better plant diversity are possible if the stormwater wetland is located downstream of the detention facility.
Emerging Technologies	Per Lacey-approved manufacturer's design	Per Lacey-approved manufacturer's design

7.2.4 Treatment BMP Liners

Treatment BMP liners may be a treatment liner where the material is intended to provide water quality treatment, or a low-permeability liner intended to retard infiltration thereby maintaining the water level in a wet-pool type BMP and/or protecting groundwater.

Treatment liners may consist of native soil if soil suitability criteria are met, or engineered soils meeting applicable suitability criteria. Treatment liners may use in-place native soils or imported/engineered soils. A two-foot thick layer of soil with a maximum infiltration rate of 2.4 inches per hour can be used as a treatment layer beneath a water quality or detention facility.

Low permeability liners reduce infiltration to a very slow rate, generally less than 0.02 inches per hour (1.4×10^{-5} cm/s). These types of liners must be used for industrial or commercial sites with a potential for high pollutant loading in the stormwater runoff, and in groundwater protection areas. Low permeability liners may be fashioned from compacted till, clay, geomembrane, or concrete.

Treatment liner construction shall be monitored, inspected and certified by a licensed civil or geotechnical engineer.

Table 7.5 summarizes liner types for various runoff treatment facilities

Table 7.5
Lining Types Recommended For Runoff Treatment Facilities

WQ Facility	Area to be Lined	Type of Liner Recommended
Presettling basin	Bottom and sides	Low permeability liner or Treatment liner (If the basin will intercept the seasonal high ground water table, a treatment liner is recommended.)
Wetpond	First cell: bottom and sides to WQ design water surface ---------------------------------- Second cell: bottom and sides to WQ design water surface	Low permeability liner or Treatment liner (If the wet pond will intercept the seasonal high ground water table, a treatment liner is recommended.) -------------------------------- No liner needed
Combined detention/WQ facility	First cell: bottom and sides to WQ design water surface ---------------------------------- Second cell: bottom and sides to WQ design water surface	Low permeability liner or Treatment liner (If the facility will intercept the seasonal high ground water table a treatment liner is recommended.) -------------------------------- No liner needed
Stormwater wetland	Bottom and sides, both cells	Low permeability liner (If the facility will intercept the seasonal high ground water table, a treatment liner is recommended.)

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Compacted Till Liners

- Liner thickness shall be 18 inches after compaction.
- Soil shall be compacted to 95% minimum dry density, modified proctor method (ASTM D-1557).
- A different depth and density sufficient to retard the infiltration rate to 0.02 inches per hour may also be used instead of Criteria 1 and 2.
- Soil should be placed in 6-inch lifts.
- Soils may be used that meet the gradation in Table 7.6.

Table 7.6 Gradation for Compacted Till Liners	
Sieve Size	**Percent Passing**
6-inch	100
4-inch	90
#4	70 – 100
#200	20

Clay Liners

- Liner thickness shall be 12 inches.
- Clay shall be compacted to 95% minimum dry density, modified proctor method (ASTM D-1557).
- A different depth and density sufficient to retard the infiltration rate to 0.02 inches per hour may also be used instead of the above criteria.
- 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.
- Where clay liners form the sides of ponds, the interior side slope should not be steeper than 3H: 1V, irrespective of fencing. This restriction is to ensure that anyone falling into the pond may safely climb out.

Geomembrane Liners

- 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.
- Geomembranes shall be bedded according to the manufacturer's recommendations.

- Liners shall be installed so that they can be covered with 12 inches of top dressing forming the bottom and sides of the water quality facility, except for liner 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.
- Liners shall 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.
- 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.

Concrete Liners

- 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 (must support weight of maintenance equipment, up to 80,000 pounds when fully loaded).
- 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.

7.2.5 Flow Spreading Options

Flow spreaders function to uniformly spread flows across the inflow portion of biofiltration swales. Two flow spreader options are presented in this section:

- Option A – Anchored plate
- Option B – Concrete sump box

These options can be used for spreading flows that are concentrated. They can be used when spreading is required by the facility design criteria or for unconcentrated flows.

Other flow spreader options are possible with approval from the City of Lacey.

General Design Criteria

- Where flow enters the flow spreader through a pipe, it is recommended that the pipe be submerged to dissipate energy.
- For higher inflows (greater than 5 cfs for the 100-yr storm), a Type 1 catch basin should be positioned in the spreader and the inflow pipe should enter the catch basin with flows exiting through the top grate. The top of the grate should be lower than the level spreader plate, or if a notched spreader is used, lower than the bottom of the v-notches.

Option A -- Anchored Plate (Figure 7.1)

- A sump having a minimum depth of 8 inches and minimum width of 24 inches must precede an anchored plate flow spreader. If not otherwise stabilized, the sump area must be lined to reduce erosion and to provide energy dissipation.
- The top surface of the flow spreader plate must be level, projecting 2 inches minimum above the ground surface of the water quality facility, or V-notched with notches 6 inches on center and 1 inch deep. Alternative designs may also be used.
- A flow spreader plate must extend horizontally beyond the bottom width of the facility to prevent water from eroding the side slope. The horizontal extent should be such that the bank is protected for all flows up to the 100-year flow or the maximum flow that will enter the Water Quality (WQ) facility.
- Flow spreader plates must be securely fixed in place.
- Flow spreader plates may be made of either metal, fiberglass reinforced plastic, or other durable material.
- Anchor posts must be 4-inch square concrete, tubular stainless steel, or other material resistant to decay.

Option B -- Concrete Sump Box (Figure 7.2)

- The wall of the downstream side of a rectangular concrete sump box must extend a minimum of 2 inches above the treatment bed. This serves as a weir to spread the flows uniformly across the bed.
- The downstream wall of a sump box must have “wing walls” at both ends. Sidewalls and returns must be slightly higher than the weir so that erosion of the side slope is minimized.
- Concrete for a sump box can be either cast-in-place or precast, but the bottom of the sump must be reinforced with wire mesh for cast-in-place sumps.
- Sump boxes must be placed over bases that consist of 4 inches of crushed rock, 5/8-inch minus to help assure the sump remains level.

7.3 Pre-Treatment BMPs

Pre-treatment maybe provided by any of the basic treatment BMPs (Section 7.1.3), by approved manufactured storm drain structures, or by a Pre-settling Basin.

Pretreatment must be provided in the following applications:

- for sand and media filtration and infiltration BMPs 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).

Any of the basic runoff treatment BMPs may also be used for pretreatment to reduce suspended solids. Catch basin inserts may be appropriate in some circumstances to provide oil or TSS control, depending on the type of insert.

BMP PT-01 Pre-settling Basin

A Pre-settling Basin is a small wet pond that provides pretreatment of runoff in order to remove suspended solids, which can impact other runoff treatment BMPs.

Design Criteria

1. The treatment volume shall be at least 30 percent of the design water quality volume
2. Liner requirements per Section 7.2.4.
3. The length-to-width ratio shall be at least 3:1. Berms or baffles may be used to lengthen the flowpath.
4. Pool depth shall be 4 to 6 feet.
5. Slopes shall be no steeper than 3H:1V. Refer to pond safety criteria in Section 6.2.1.
6. Inlets and outlets shall be designed to minimize velocity and reduce turbulence.

Site Constraints and Setbacks are similar to those for Wetponds.

BMP PT-02 Pre-settling Wetvault

Design criteria are similar to Basic Wetvault (BMP WP-02), except the treatment volume shall be at least 30 percent of the design water quality volume.

BMP PT-03 Hydrodynamic Settling Devices

Most of these types of systems are cylindrical in shape and are designed to fit into or adjacent to existing storm drainage systems or catch basins. The removal mechanisms include vortex-enhanced sedimentation, circular screening, and engineered designs of internal components, for large particle TSS and large oil droplets.

1. Vortex-enhanced Sedimentation

Vortex-enhanced Sedimentation consists of a cylindrical vessel with tangential inlet flow which spirals down the perimeter, thus causing the heavier particles to settle. It uses a vortex-enhanced settling mechanism (swirl-concentration) to capture settleable solids, floatables, and oil and grease. This system includes a wall to separate TSS from oil. An assessment of vortex technologies with designation levels is provided on Ecology's web site at http://www.ecy.wa.gov/programs/wq/stormwater/newtech/

2. Vortex-enhanced Sedimentation and Media Filtration

This system uses a two-stage approach which includes a Swirl Concentrator followed by a filtration chamber. See Figure 7.3.

Applications, Limitations, Design, Construction, and Maintenance Criteria
(See Ecology's web site)

3. Cylindrical Screening System

This system is comprised of a cylindrical screen and appropriate baffles and inlet/outlet structures to remove debris, large particle TSS, and large oil droplets. It includes an overflow for flows exceeding the design flow. Sorbents can be added to the separation chamber to increase pollutant removal efficiency. See Figure 7.4.

4. Engineered Cylindrical Sedimentation

This system is comprised of an engineered internal baffle arrangement and oil/TSS storage compartment designed to provide considerably better removals of large particle TSS and oil droplets than standard catch basins. It includes a bypass of flows higher than design flows, thus preventing scouring of collected solids and oils during the bigger storms. See Figure 7.5.

7.4 Infiltration and Bio-infiltration Treatment Facilities

A stormwater infiltration or bio-infiltration treatment facility is an impoundment, typically a basin, trench, vault or swale that releases stormwater into the ground, where the underlying soil removes pollutants. Infiltration is useful for both runoff water quality treatment and flow control, and is beneficial for wetlands and groundwater recharge, maintaining base flows in streams and reducing flood potential.

The infiltration BMPs described in this chapter include:

BMP IN-01 Infiltration basins

BMP IN-02 Infiltration trenches

BMP IN-03 Bio-infiltration swales

BMP IN-04 Bioretention Areas

Since infiltration facilities discharge stormwater into the soil, they must be located and designed to ensure groundwater drinking water sources or downstream surface waters are not contaminated. Infiltration provides runoff treatment by filtration, adsorption and biological decomposition within the soil, so soils providing runoff treatment must have the proper texture, organic content and sorption capacity to adequately remove pollutants. Coarse soils may infiltrate too rapidly to provide treatment, while compacted or fine-grained soils may not infiltrate rapidly enough to drain adequately.

Infiltration treatment soils must contain sufficient organic matter and/or clays to sorb, decompose, and/or filter stormwater pollutants. Pollutant/soil contact time, soil sorptive capacity, and soil aerobic conditions are important design considerations.

Infiltration treatment systems shall be installed as off-line systems, or on-line for small drainages and as part of a treatment train that includes a pretreatment device.

7.4.1 Site Suitability Criteria

The general site suitability and soil testing criteria for infiltration facilities (Chapter 6, Flow Control) apply to runoff treatment infiltration facilities, with the exception of the allowable design infiltration rates. Check the Wellhead Protection Areas map and the Critical Aquifer Recharge Areas (CARA) map in Appendix 6A to determine if the proposed project lies within a groundwater protection area.

Within Groundwater Protection Areas, if infiltration is allowed, the soil must meet the following criteria, to a depth at least 2 feet below the base of the infiltration facility:

- the short-term soil infiltration rate shall be 2.4 in./hour, or less
- organic matter content shall be greater than 0.5% (by weight)

Outside Groundwater Protection Areas, the soil must meet the following criteria to a depth of at least two feet below the base of the infiltration facility:

- the short-term soil infiltration rate shall be 9 in./hour, or less
- organic matter content shall be greater than 0.5% (by weight)

  OR

- soil is less than 25% gravel by weight with at least 75% passing the #4 sieve
- of the portion passing the #4 sieve,
  - at least 50% must pass the #40 sieve and at least 2% must pass the #100 sieve, OR
  - at least 25% must pass the #40 sieve and at least 5% must pass the #200 sieve.

Soil treatment properties may be provided by native or imported/amended soils. Where imported/amended soils are used to provide treatment, the minimum depth shall be three feet below the base of the treatment facility.

7.4.2 General Design, Construction and Maintenance Criteria

Side-Wall Seepage

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

Excavation

Final excavation to the finished grade shall be deferred until all disturbed areas in the upgradient watershed have been stabilized or protected. The final phase of excavation shall remove all accumulated sediment. After construction is completed, sediment shall be prevented from entering the infiltration facility through appropriate pretreatment.

Compaction

Use reasonable means (light tracked equipment, draglines, trackhoes) to avoid compaction of the floor of the infiltration facility. Flag or mark the infiltration area to keep equipment away.

Maintenance Criteria

Maintenance Criteria are addressed in Chapter 9.

7.4.3 Infiltration BMPs

BMP IN-01t Infiltration Basins (for water quality treatment)

Infiltration basins are typically earthen impoundments with a grass cover. Design and construction criteria for infiltration basins are provided in BMP IN-01, page 6-88. When used for treatment, the pond soils must meet the criteria in Section 7.4.1.

Design Criteria Specific for Infiltration Basins

- Pretreatment is required.
- The basin bottom shall have zero slope.
- Treatment infiltration basins must have sufficient vegetation established on the basin floor and side slopes to prevent erosion and sloughing of the sideslopes and to provide additional pollutant removal. Erosion protection of inflow points to the basin must also be provided (e.g., riprap, flow spreaders, energy dissipaters).
- A minimum of 1-foot of freeboard is required when establishing the design water depth at the long-term infiltration rate.
- A non-erodible outlet or spillway must be established at a proper elevation to discharge overflow.

BMP IN-02t Infiltration Trenches (for water quality treatment)

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

Design and construction criteria for infiltration trenches are provided in BMP IN-02, page 6-89 (see also Figures 6.27 through 6.32). When used for treatment, the trench subsoils must meet the criteria in Section 7.4.1. Infiltration trenches require a filter strip or other pre-treatment system.

BMP IN-03 Bio-infiltration Swales

Bio-infiltration swales, also known as Grass Percolation Areas, combine grassy vegetation and soils to remove stormwater pollutants by percolation into the ground.

In general, bio-infiltration swales are used for treating stormwater runoff from roofs, roads and parking lots. Flows greater than design flows are typically overflowed to the subsurface through an appropriate conveyance facility such as a drywell, or an overflow channel to surface water.

Additional Design Criteria Specific for Bio-infiltration Swales

- Pretreatment is required
- Drawdown time for the maximum ponded volume: 24 hours max.
- Swale bottom: flat with a longitudinal slope less than 1%.
- Maximum ponded depth: 6 inches.
- Treatment soil to be at least 18 inches thick with organic content of at least 1%. In lieu of testing, all soil textural classifications except “sand” shall be assumed to satisfy this requirement. The design soil thickness may be reduced to as low as 6 inches if the design infiltration rate does not exceed 1 inch per hour.
- Use native or adapted grass.

BMP IN-04 Bioretention Areas

Bioretention areas (e.g. Rain Gardens) designed in accordance with BMP LID-10 in Chapter 6 may be used for treatment and/or flow control. Where soils are not suitable for infiltration, Rain Gardens can be used for treatment provided that flows in excess of the water quality design flow is by-passed, and an underdrain is provided to ensure adequate drawdown.

7.5 Biofiltration Facilities

This section addresses five BMPs that are classified as biofiltration treatment facilities:

BMP	BF-01	Basic Biofiltration Swale
BMP	BF-02	Wet Biofiltration Swale
BMP	BF-03	Continuous Inflow Biofiltration Swale
BMP	BF-04	Basic Filter Strip & Compost-Amended Filter Strip
BMP	BF-05	Narrow Area Filter Strip

Biofilters are vegetated treatment systems (typically grass) that remove pollutants by means of sedimentation, filtration, soil sorption, and/or plant uptake. They are typically configured as swales or flat filter strips, to provide slow, shallow flow. Swales are narrow and long, to convey and treat concentrated runoff flows. Filter strips are broad with a relatively short flow path, to treat runoff as sheet flow.

Biofiltration BMPs are designed to remove low concentrations and quantities of total suspended solids (TSS), heavy metals, petroleum hydrocarbons, and/or nutrients from stormwater.

Applications

A biofilter can be used as a basic treatment BMP for contaminated stormwater runoff from roadways, driveways, parking lots, and highly impervious ultra-urban areas or as the first stage of a treatment train. In cases where hydrocarbons, high TSS, or debris would be present in the runoff, such as high-use sites, a pretreatment system for those pollutants is necessary. Off-line location is required to avoid flattening vegetation and the erosive effects of high flows.

Site Suitability

The following factors must be considered for determining site suitability:

- Target pollutants are amenable to biofilter treatment
- Accessibility for Operation and Maintenance
- Suitable growth environment (soil, sunlight, etc.) for the vegetation
- Adequate siting for a pre-treatment facility if high petroleum hydrocarbon levels (oil/grease) or high TSS loads could impair treatment capacity or efficiency.

Sizing criteria for Biofiltration BMPs are summarized in Table 7.7.

BMP BF-01 Basic Biofiltration Swale

Biofiltration swales are typically shaped as a triangle, parabola or trapezoid as shown in Figure 7.6. Figure 7.7 shows a typical biofiltration swale section.

Limitations

Data suggest that the performance of biofiltration swales is highly variable from storm to storm. Treatment methods providing more consistent performance, such as wet ponds, shall be considered first. Swales downstream of devices of equal or greater effectiveness can convey runoff but should not be expected to offer a treatment benefit.

Design Criteria:

- Design Criteria are specified Table 7.7.
- Check the hydraulic capacity/stability for inflows greater than design flows. Bypass high flows, or control release rates into the swale, if necessary.
- Install level spreaders (min. 1-inch gravel) at the head and every 50 feet in swales of ≥4 feet width. Include sediment cleanouts (weir, settling basin, or equivalent) at the head of the swale as needed.
- Use energy dissipators (riprap) for increased downslopes.
- May be on-line or off-line.

Construction Criteria

The biofiltration swale shall not be put into operation until areas of exposed soil in the contributing drainage catchment have been sufficiently stabilized. Deposition of eroded soils can impede the growth of grass in the swale and reduce swale treatment effectiveness. Thus, effective erosion and sediment control measures shall remain in place until the swale vegetation is established. Avoid compaction during construction. Grade biofilters to attain uniform longitudinal and lateral slopes

Maintenance Access

Maintenance access to a biofiltration swale inlet, outlet, and for mowing shall be provided (example, Figure 7.12).

Sizing Procedure for Biofiltration Swales

Step 1: Design Swale

The swale must be designed to meet the criteria in Table 7.7. Flow calculations shall be based on the Manning Equation for steady, uniform open channel flow:

$$Q = \frac{1.49AR^{0.67}s^{0.5}}{n}$$

Where:

Q = Water Quality Design Flow Rate in 15-minute time steps based on WWHM, (ft^3/s, cfs)
n = Manning's n (dimensionless)
s = Longitudinal slope (ft/ft)
A = Cross-sectional area (ft^2)
R = Hydraulic radius (ft)

Step 2: Check for Stability:

The stability check must be performed for the combination of highest expected flow and least vegetation coverage and height. A check is not required for biofiltration swales that are located off-line from the primary conveyance/detention system.

Perform the stability check for the 100-year, return frequency flow using 15-minute time steps using WWHM.

Select a trial Manning n-value for high flow conditions from Figure 7.8 considering the information in Table 7.8 and Table 7.9. Determine "VR" from Figure 7.8 and compute VR using the Manning equation. Iterate until "VR" from the stability check is within 5% of VR from the Manning equation. Minimum n-value allowed in the stability check is 0.033.

The maximum permissible velocity for erosion prevention (V_{max}) is 3 feet per second. If the computed 100-year velocity in the design swale exceeds 3 ft/sec using the Manning n from the stability check, an alternative design must be developed.

Table 7.7 – Biofiltration Sizing Criteria		
Design Parameter	**BMP BF.01, 02, 03 Biofiltration swale**	**BMP BF.04-Filter strip**
Longitudinal Slope	0.015 - 0.025[1]	0.01 - 0.15
Maximum velocity	1 ft / sec at WQ design flow rate ; for stability, 3 ft/sec max.	0.5 ft / sec
Maximum water depth[2]	2"- if mowed frequently; 4" if mowed infrequently	1-inch max.
Manning coefficient	(0.2 – 0.3)[3] (0.24 if mowed infrequently)	0.35 (0.45 if compost-amended, and mowed to maintain grass height ≤ 4")
Bed width (bottom)	(2 - 10 ft)[4]	---
Freeboard height	0.5 ft	---
Minimum hydraulic residence time at Water Quality Design Flow Rate	9 minutes (18 minutes)	9 minutes
Minimum length	100 ft	Sufficient to achieve hydraulic residence time in the filter strip
Maximum sideslope	3H : 1V 4H:1V preferred	Inlet edge ≥ 1" lower than contributing paved area
Max. tributary drainage flowpath	---	150 feet
Max. longitudinal slope of contributing area	---	0.05 (steeper than 0.05 need upslope flow spreading and energy dissipation)
Max. lateral slope of contributing area	---	0.02 (at the edge of the strip inlet)

Table 7.7 Notes:

1. For swales, if the slope is less than 1.5% install an underdrain using a perforated pipe, or equivalent. Amend the soil if necessary to allow effective percolation of water to the underdrain. Install the low-flow drain 6" deep in the soil. Slopes greater than 2.5% need check dams (riprap) at vertical drops of 12-15 inches. Underdrains can be made of 6 inch Schedule 40 PVC perforated pipe with 6" of drain gravel on the pipe. The gravel and pipe must be enclosed by geotextile fabric. (See Figures 7.9 and 7.10)

2 Below the design water depth install an erosion control blanket, at least 4" of topsoil, and the selected biofiltration mix. Above the water line use a straw mulch or sod.

3. This range of Manning's n can be used in the equation; $b = Qn/1.49y^{(1.67)} s^{(0.5)} - Zy$ with wider bottom width b, and lower depth, y, at the same flow. This provides the designer with the option of varying the bottom width of the swale depending on space limitations. Designing at the higher n within this range at the same flow decreases the hydraulic design depth, thus placing the pollutants in closer contact with the vegetation and the soil.

4. For swale widths up to 16 feet the cross-section can be divided with a berm (concrete, plastic, compacted earthfill) using a flow spreader at the inlet (Figure 7.11)

Table 7.8 -- Guide for Selecting Degree of Retardance for Stability Check[(a)]		
Coverage	**Average Grass Height (inches)**	**Degree of Retardance**
Good	<2	E. Very Low
	2-6	D. Low
	6-10	C. Moderate
	11-24	B. High
	>30	A. Very High
Fair	<2	E. Very Low
	2-6	D. Low
	6-10	D. Low
	11-24	C. Moderate
	>30	B. High

See Chow (1959). Recommended selection of retardance C for a grass-legume mixture 6-8 inches high and D for a mixture 4-5 inches high. No retardance recommendations have appeared for emergent wetland species. Therefore, judgment must be used. Since these species generally grow less densely than grasses, using a "fair" coverage would be a reasonable approach.

Table 7.9 -- Grass Seed Mixes suitable for Biofiltration Swale Treatment Areas			
Mix 1		**Mix 2**	
75-80 percent	tall or meadow fescue	60-70 percent	tall fescue
10-15 percent	seaside/colonial bentgrass	10-15 percent	seaside/colonial bentgrass
5-10 percent	Redtop	10-15 percent	meadow foxtail
		6-10 percent	alsike clover
		1-5 percent	marshfield big trefoil
		1-6 percent	Redtop

Note: *all percentages are by weight. * based on Briargreen, Inc.*

Table 7.10 -- Groundcovers and grasses suitable for the upper side slopes of a biofiltration swale in western Washington	
Groundcovers	
kinnikinnick*	*Arctostaphylos uva-ursi*
St. John's-wort	*Hypericum perforatum*
Epimedium	*Epimedium grandiflorum*
creeping forget-me-not	*Omphalodes verna*
--	*Euonymus lanceolata*
yellow-root	*Xanthorhiza simplissima*
--	*Genista*
white lawn clover	*Trifolium repens*
white sweet clover*	*Melilotus alba*
-------	*Rubus calycinoides*
strawberry*	*Fragaria chiloensis*
broadleaf lupine*	*Lupinus latifolius*
Grasses (drought-tolerant, minimum mowing)	
dwarf tall fescues	*Festuca* spp. (e.g., Many Mustang, Silverado)
hard fescue	*Festuca ovina duriuscula* (e.g., Reliant, Aurora)
tufted fescue	*Festuca amethystine*
buffalo grass	*Buchloe dactyloides*
red fescue*	*Festuca rubra*
tall fescue grass*	*Festuca arundinacea*
blue oatgrass	*Helictotrichon sempervirens*

BMP BF-02 Wet Biofiltration Swale

A *wet biofiltration swale* is a variation of a basic biofiltration swale for use where the longitudinal slope is slight, water tables are high, or continuous low base flow is likely to result in saturated soil conditions. Thus, vegetation specifically adapted to saturated soil conditions is needed. Different vegetation in turn requires modification of several of the design parameters for the basic biofiltration swale.

Applications/Limitations

Wet biofiltration swales are applied where a basic biofiltration swale is desired but not allowed or advisable because one or more of the following conditions exist:

- The swale is on till soils and is downstream of a detention pond providing flow control.
- Saturated soil conditions are likely because of seeps or base flows on the site.
- Longitudinal slopes are slight (generally less than 1.5 percent).

Design Criteria

Use the same design approach as for basic biofiltration swales except to add the following:

Off-line facility: A wet biofiltration swale must be designed with a high-flow bypass to protect the wetland plants. No slope stability check is required.

Adjust size for extended wet season flow. If the swale will be downstream of a detention pond providing flow control, multiply the treatment area (bottom width times length) of the swale by 2, and readjust the swale length, if desired. Maintain a 5:1 length to width ratio.

Swale Geometry: Same as specified for basic biofiltration swales except for the following modifications:

Criterion 1: The bottom width may be increased to 25 feet maximum, but a length-to-width ratio of 5:1 must be provided. No longitudinal dividing berm is needed.

Criterion 2: If longitudinal slopes are greater than 2 percent, the wet swale must be stepped so that the slope within the stepped sections averages 2 percent. Steps may be made of retaining walls, log check dams, or short riprap sections. **No underdrain or low-flow drain is required**.

Depth and Base Flow: Same as for basic biofiltration swales except the design water depth shall be 4 inches for all wetland vegetation selections, and **no underdrains or low-flow drains are required**.

Flow Velocity, Energy Dissipation, and Flow Spreading: Same as for basic biofiltration swales except no flow spreader is needed.

Access: Same as for basic biofiltration swales except access is only required to the inflow and the outflow of the swale; access along the length of the swale is not required. Also, wheel strips may not be used for access in the swale.

Soil Amendment: Same as for basic biofiltration swales.

Planting Requirements: Same as for basic biofiltration swales except for the following modifications:

1. A list of acceptable plants and recommended spacing is shown in Table 7.11. In general, it is best to plant several species to increase the likelihood that at least some of the selected species will find growing conditions favorable.

2. A wetland seed mix may be applied by hydroseeding, but if coverage is poor, planting of rootstock or nursery stock is required. Poor coverage is considered to be more than 30 percent bare area through the upper 2/3 of the swale after four weeks.

Maintenance Considerations: Mowing of wetland vegetation is not required. However, harvesting of very dense vegetation may be desirable in the fall after plant die-back to prevent the sloughing of excess organic material into receiving waters. Many native *Juncus* species remain green throughout the winter; therefore, fall harvesting of *Juncus* species is not recommended.

Table 7.11 Recommended plants for wet biofiltration swale

Common Name	Scientific Name	Spacing (on center)
Shortawn foxtail	*Alopecurus aequalis*	Seed
Water foxtail	*Alopecurus geniculatus*	seed
Spike rush	*Eleocharis spp.*	4 inches
Slough sedge*	*Carex obnupta*	6 inches or seed
Sawbeak sedge	*Carex stipata*	6 inches
Sedge	*Carex* spp.	6 inches
Western mannagrass	*Glyceria occidentalis*	seed
Velvetgrass	*Holcus mollis*	Seed
Slender rush	*Juncus tenuis*	6 inches
Watercress*	*Rorippa nasturtium-aquaticum*	12 inches
Water parsley*	*Oenanthe sarmentosa*	6 inches
Hardstem bulrush	*Scirpus acutus*	6 inches
Small-fruited bulrush	*Scirpus microcarpus*	12 inches

** Good choices for swales with significant periods of flow, such as those downstream of a detention facility.*

Note: Cattail (Typha latifolia) is not appropriate for most wet swales because of its very dense and clumping growth habit which prevents water from filtering through the clump.

BMP BF-03 Continuous Inflow Biofiltration Swale

In situations where water enters a biofiltration swale continuously along the side slope rather than discretely at the head, a continuous inflow biofiltration swale may be used. The basic swale design is modified by increasing swale length to achieve an equivalent average residence time.

Applications

A continuous inflow biofiltration swale is to be **used when inflows are not concentrated**, such as locations along the shoulder of a road without curbs. This design may also be **used where frequent, small point flows enter a swale**, such as through curb inlet ports spaced at intervals along a road, or from a parking lot with frequent curb cuts. In general, no inlet port should carry more than about 10 percent of the flow.

A continuous inflow swale is not appropriate for a situation in which significant lateral flows enter a swale at some point downstream from the head of the swale. In this situation, the swale width and length must be recalculated from the point of confluence to the discharge point in order to provide adequate treatment for the increased flows.

Design Criteria

Same as specified for **basic biofiltration swale** except for the following:

- The design flow for continuous inflow swales must include runoff from the pervious side slopes draining to the swale along the entire swale length. Therefore, they must be on-line facilities.
- Use the design flow rate at the swale outlet to size the swale.
- The required hydraulic residence time is 18 minutes, assuming an even distribution of inflow into the side of the swale.
- For continuous inflow biofiltration swales, interior side slopes above the WQ design treatment elevation shall be planted in grass. A typical lawn seed mix or the biofiltration seed mixes are acceptable. Landscape plants or groundcovers other than grass may not be used anywhere between the runoff inflow elevation and the bottom of the swale. **Intent:** The use of grass on interior side slopes reduces the chance of soil erosion and transfer of pollutants from landscape areas to the biofiltration treatment area.

BMP BF-04 Basic Vegetated Filter Strip and Compost-Amended Filter Strip

A basic filter strip is flat with no side slopes (Figure 7.13). Contaminated stormwater is distributed as sheet flow across the inlet width of a biofilter 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. Where a filter strip area is compost-amended to a minimum of 10% organic content in accordance with BMP LID.09; with hydroseeded grass maintained at 95% density and a 4-inch length by mowing and periodic re-seeding (possible landscaping with herbaceous shrubs), the filter strip serves as a Metals Treatment option.

Design Criteria for Filter strips:

- Use the Design Criteria specified in Table 7.7
- Filter strips should only receive sheet flow.
- Use curb cuts ≥ 12-inch wide and 1-inch above the filter strip inlet
- Depth computed from Manning's equation must not exceed 1 inch.
- Velocity must not exceed 0.5 ft./sec.
- Hydraulic residence time > 9 minutes.

BMP BF-05 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 can 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.

The treatment objectives, applications and limitations, design criteria, materials specifications, and construction and maintenance requirements set forth in the basic filter strip design apply to narrow filter strip applications.

Design Criteria

Design criteria for narrow area filter strips are the *same as specified for basic filter strips*. 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).

- Design length of narrow filter strip using Figure 7.14.
- Minimum filter length is 4 feet.
- The length of the flowpath from the upstream to the downstream edge of the impervious area draining sheet flow to the strip is the longest path perpendicular to the slope (along the direction of unconcentrated flow).
- The minimum slope for sizing purposes is 2 percent (if the actual 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.
- The filter strip must be designed to provide this minimum length obtained from Figure 7.14 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.

7.6 Wetpool Facilities

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

BMP WP-01 Wetponds - Basic and Large

BMP WP-02 Wetvaults

BMP WP-03 Stormwater Treatment Wetlands

BMP WP-04 Combined Detention and Wetpool Facilities

Wetpool facilities are generally constructed online, meaning that all storm flows are routed through them. Wetpool facilities may also be constructed off-line. Wetpools treat stormwater runoff by the processes of sedimentation (settling of particulates when the flow reaches the still water of the pool), vegetative filtration and biological uptake of dissolved pollutants.

BMP WP-01 Wetponds - Basic and Large

A wetpond is a constructed stormwater pond that retains a permanent pool of water ("wetpool") at least during the wet season. The effectiveness of the wetpool in settling particulates is related to the geometry (surface area and depth) of the pond. A shallow marsh area can be created within the permanent pool volume to provide additional treatment for nutrient removal. Peak flow control can be provided in the "live storage" area above the permanent pool. Figures 7.15a and 7.15b illustrate a typical wetpond BMP.

The basic wetpond can be used as a Pretreatment or Basic BMP, and the large wetpond can be used as a Phosphorus Control BMP.

Applications and Limitations

A wetpond typically requires a larger area than a biofiltration swale or a sand filter, but can usually be integrated to the contours of a site fairly easily. A wetpond can be an attractive aesthetic feature. Wet ponds in porous soils may need to be lined to maintain the permanent pool.

Wetponds may be designed with the permanent pool elevation below the groundwater level without lining, but if combined with a detention function, the live storage must be above the seasonal high groundwater level.

Design Criteria

For a basic wetpond, the wetpool volume provided shall be equal to or greater than the total volume of runoff from the water quality design storm - the 6-month, 24-hour storm event. A large wetpond requires a wetpool volume at least 1.5 times larger than the total volume of runoff from the 6-month, 24-hour storm event.

- Basic Wetpool volume = the 6-month, 24-hour runoff volume
- Large Wetpool volume ≥1.5 times the 6-month, 24-hour runoff volume
- Energy dissipation at the inlet(s) required.
- Minimum 3:1 flowpath length-to-width ratio. The ***flowpath length*** is defined as the distance from the inlet to the outlet, as measured at mid-depth. The ***width*** at mid-depth can be found as follows: width = (surface area at top width) / (flowpath length).
- Two cell design with broad-crested weir dividing cells preferred over other connections (such as a pipe).
- If the flowpath length-to-width ratio is 4:1 or greater, one-cell design may be used.
- The first cell shall contain between 25 to 35 percent of the total wetpool volume. The baffle or berm volume shall not count as part of the total wetpool volume.
- Sediment storage shall be provided in the first cell and shall have a minimum depth of 1-foot. A fixed sediment depth monitor or alternative gauging method shall be installed in the first cell to gauge sediment accumulation.
- The depth range of the first cell shall be 4 to 8 feet, exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell.
- The maximum depth of the second cell shall not exceed 8 feet (exclusive of sediment storage in the first cell). Second cell pool depths of 3 feet or shallower shall be planted with emergent wetland vegetation (see Planting Requirements).
- Wetponds with wetpool volumes less than or equal to 4,000 cubic feet may be single celled, but with flowpath length-to-width ratio at least 4:1 and minimum sediment storage of 0.5 feet.

Inlets and Outlet Criteria

- All inlets shall enter the first cell. If there are multiple inlets, the length-to-width ratio shall be based on the average flowpath length for all inlets.
- Inlets shall be submerged with the inlet pipe invert(s) a minimum of two feet from the pond bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1-foot, if possible.
- 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. No sump is required. The grate or birdcage openings provide an overflow route should the pond outlet pipe become clogged.

- The pond outlet pipe shall be back-sloped or have a turn-down elbow, and extend 1 foot below the WQ design water surface. Note: A floating outlet, set to draw water from 1-foot below the water surface, is also acceptable if vandalism concerns are adequately addressed.
- The overflow criteria for single-purpose (treatment only, not combined with flow control) wetponds are as follows:
  - 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.
  - The bottom of the grate opening in the outlet structure shall be set at or above the height needed to pass the WQ design flow through the pond outlet pipe.
  - In on-line ponds, the grated opening shall be sized to pass the 100-year design flow. The capacity of the outlet system shall be sized to pass the peak flow for the conveyance requirements.
- An emergency spillway shall be provided and designed according to the requirements for detention ponds (see Chapter 6).
- A gravity drain for maintenance is required if grade allows.
- The maintenance drain shall be at least 8 inches (minimum) diameter and shall be controlled by a valve. Use of a shear gate is allowed only at the inlet end of a pipe located within an approved structure.
- Operational access to the valve shall be provided to the finished ground surface.
- The valve location shall be accessible and well-marked with 1-foot of paving placed around the box. It must also be protected from damage and unauthorized operation.
- A valve box is allowed to a maximum depth of 5 feet without an access manhole. If over 5 feet deep, an access manhole or vault is required.
- All metal parts shall be corrosion-resistant. Galvanized materials shall not be used.

Planting Requirements

- Planting requirements for detention ponds (Chapter 6) also apply to wetponds.
- If the second cell of a basic wetpond is 3 feet or shallower, emergent wetland vegetation shall be established. See Table 7.12 for recommended emergent wetland plant species for wetponds.
- In Large Wetponds for Phosphorus Control, shrubs that form a dense cover shall be planted on slopes above the WQ design water surface elevation on at least three sides. No planting is allowed on berms regulated by dam safety requirements. The purpose of planting is to discourage waterfowl use of the pond and to provide shading. Some suitable trees and shrubs include vine maple (Acer circinatum), wild cherry (Prunus emarginata), red osier dogwood (Cornus stolonifera), California myrtle (Myrica californica), Indian plum (Oemleria cerasiformis), and Pacific yew (Taxus brevifolia) as well as numerous ornamental species.

Recommended Design Features

The following design features shall be incorporated into the wetpond design where site conditions allow:

- The method of construction of soil/landscape systems can cause natural selection of specific plant species. Consult a soil restoration or wetland soil scientist for site-specific recommendations. The soil formulation will impact the plant species that will flourish or suffer on the site, and the formulation should be such that it encourages desired species and discourages undesired species.
- For wetpool depths in excess of 6 feet, it is recommended that some form of recirculation be provided in the summer, such as a fountain or aerator, to prevent stagnation and low dissolved oxygen conditions.
- A tear-drop shape, with the inlet at the narrow end, rather than a rectangular pond is preferred since it minimizes dead zones caused by corners.
- Evergreen or columnar deciduous trees along the west and south sides of ponds are recommended to reduce thermal heating. In addition to shade, trees and shrubs also discourage waterfowl use and the attendant phosphorus enrichment problems they cause. Trees should be set back so that the branches will not extend over the pond.
- The access and maintenance road could be extended along the full length of the wetpond and could double as playcourts or picnic areas. Placing finely ground bark or other natural material over the road surface would render it more pedestrian friendly.
- The following design features should be incorporated to enhance aesthetics where possible:
  - Provide pedestrian access to shallow pool areas enhanced with emergent wetland vegetation. This allows the pond to be more accessible without incurring safety risks.
  - Provide side slopes that are sufficiently gentle to avoid the need for fencing (3:1 or flatter).
  - Create flat areas overlooking or adjoining the pond for picnic tables or seating that can be used by residents. Walking or jogging trails around the pond are easily integrated into site design.
  - Include fountains or integrated waterfall features for privately maintained facilities.
  - Provide visual enhancement with clusters of trees and shrubs. On most pond sites, it is important to amend the soil before planting since ponds are typically placed well below the native soil horizon in very poor soils. Make sure dam safety restrictions against planting do not apply.
  - Orient the pond length along the direction of prevailing summer winds (typically west or southwest) to enhance wind mixing.

Construction Criteria

- Sediment that has accumulated in the pond must be removed after construction in the drainage area of the pond is complete (unless used for a liner).

- Sediment that has accumulated in the pond at the end of construction may be used as a liner in excessively drained soils if the sediment meets the criteria for low permeability or treatment liners in keeping with guidance given in Section 7.2.4. Sediment used as a soil liner must be graded to provide uniform coverage and thickness.

Table 7.12 -- Emergent wetland plant species recommended for wetponds

Species	Common Name	Notes	Maximum Depth
INUNDATION TO 1-FOOT			
Agrostis exarata[1]	Spike bent grass	Prairie to coast	to 2 feet
Carex stipata	Sawbeak sedge	Wet ground	
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	to 2 feet
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	to 2 feet
Juncus tenuis	Slender rush	Wet soils, wetland margins	
Oenanthe sarmentosa	Water parsley	Shallow water along stream and pond margins; needs saturated soils all summer	
Scirpus atrocinctus (formerly S. cyperinus)	Woolgrass	Tolerates shallow water; tall clumps	
Scirpus microcarpus	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
Sagittaria latifolia	Arrowhead		
INUNDATION 1 TO 2 FEET			
Agrostis exarata[1]	Spike bent grass	Prairie to coast	
Alisma plantago-aquatica	Water plantain		
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	
Juncus effusus	Common (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 FEET			
Carex obnupta	Slough sedge	Wet ground or standing water	1.5 to 3 feet
Beckmania syzigachne[1]	Western sloughgrass	Wet prairie to pond margins	
Scirpus acutus[2]	Hardstem bulrush	Single tall stems, not clumping	to 3 feet
Scirpus validus[2]	Softstem bulrush		
INUNDATION GREATER THAN 3 FEET			
Nuphar polysepalum	Spatterdock	Deep water	3 to 7.5 feet
Nymphaea odorata[1]	White waterlily	Shallow to deep ponds	to 6 feet

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.

BMP WP-02 Wetvaults

A wetvault is an underground structure similar in appearance to a detention vault, except that a wetvault has a permanent pool of water (wetpool) which dissipates energy and improves the settling of particulate pollutants (see the wetvault details in Figure 7.16). A wetvault lacks the biological pollutant removal mechanisms, such as algae uptake, present in surface wetponds.

Applications and Limitations

A wetvault may be used for commercial, industrial, or roadway projects if there are space limitations precluding the use of other treatment BMPs. Combined detention and wetvaults are allowed. A wetvault may be used for Pretreatment or Basic Treatment. If oil control is required for a project, a wetvault may be combined with an API oil/water separator. A key limitation and design consideration is that below-ground structures like wetvaults are relatively difficult and expensive to maintain.

Design Criteria

- The wetpool volume for the wetvault shall be equal to or greater than the total volume of runoff from the 6-month, 24-hour storm event.
- The required depth of sediment storage is shown in the schedule below (interpolate for different vault widths):

Vault Width	Sediment Depth (from bottom of side wall)
15'	10"
20'	9"
40'	6"
60'	4"

- The second cell shall be a minimum of 3 feet deep.

Vault Structure

- The vault shall be separated into two cells by a wall or a removable baffle. If a wall is used, a 5-foot by 10-foot removable maintenance access must be provided for both cells. If a removable baffle is used, the following criteria apply:
  1) The baffle shall extend from a minimum of 1-foot above the WQ design water surface to a minimum of 1-foot below the invert elevation of the inlet pipe.
  2) The lowest point of the baffle shall be a minimum of 2 feet from the bottom of the vault, and greater if feasible.
- If the vault is less than 2,000 cubic feet (inside dimensions), or if the length-to-width ratio of the vault pool is 5:1 or greater, the baffle or wall may be omitted and the vault may be one-celled.

- The two cells of a wetvault shall not be divided into additional subcells by internal walls. If internal structural support is needed, post and pier construction shall be used to support the vault lid. Any walls used within cells must be positioned so as to lengthen, rather than divide, the flowpath.
- The bottom of the first cell shall be sloped toward the access opening. Slope shall be between 0.5 percent (minimum) and 2 percent (maximum). The second cell may be level (longitudinally) 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. Sloping the second cell towards the access opening for the first cell is also acceptable.
- 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. Note: More than one "v" may be used to minimize vault depth. The vault bottom may be flat if removable panels are provided over the entire vault. Removable panels shall be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.
- 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.
- Provision for passage of flows should the outlet plug shall be provided.
- Wetvaults may be constructed using arch culvert sections provided the top area at the WQ design water surface is, at a minimum, equal to that of a vault with vertical walls designed with an average depth of 6 feet.
- Wetvaults shall conform to the "Materials" and "Structural Stability" criteria specified for detention vaults in Chapter 6.
- Where pipes enter and leave the vault below the WQ design water surface, they shall be sealed using a non-porous, non-shrinking grout.

Inlet and Outlet

- The inlet to the wetvault shall be submerged with the inlet pipe invert a minimum of 3 feet from the vault bottom. The top of the inlet pipe should be submerged at least 1-foot, if possible.
- Unless designed as an off-line facility, the capacity of the outlet pipe and available head above the outlet pipe shall be designed to convey the 100-year design flow for developed site conditions without overtopping the vault. The available head above the outlet pipe must be a minimum of 6 inches.
- The outlet pipe shall be back-sloped or have tee section, the lower arm of which should extend 1 foot below the WQ design water surface to provide for trapping of oils and floatables in the vault.
- Provide a bypass/shutoff valve to enable the vault to be taken offline for maintenance.

Access Requirements

Access requirements are the same as for detention vaults (Chapter 6) except for the following additional requirement for wetvaults:

- A minimum of 50 square feet of grate shall be provided over the second cell. For vaults in which the surface area of the second cell is greater than 1,250 square feet, at least 4 percent of the top shall be grated. This requirement may be met by one grate or by many smaller grates distributed over the second cell area. Note: a grated access door can be used to meet this requirement. Screening may be needed to prevent vector entry.

Access Roads, Right of Way, and Setbacks

These requirements are the same as for detention vaults (Chapter 6).

Recommended Design Features

The following design features should be incorporated into wetvaults where feasible:

- Bottom or lower side area perforations are useful to draw down water levels, especially in summer, and may help reduce mosquito populations.
- The floor of the second cell should slope toward the outlet for ease of cleaning.
- The inlet and outlet should be at opposing corners of the vault to increase the flowpath.
- Lockable grates instead of solid manhole covers are recommended to increase air contact with the wetpool.
- Galvanized materials shall not be used unless unavoidable.
- The number of inlets to the wetvault should be limited, and the flowpath length should be maximized from inlet to outlet for all inlets to the vault.

Construction Criteria

Sediment that has accumulated in the vault must be removed after construction in the drainage area is complete. If no more than 12 inches of sediment have accumulated after the infrastructure is built, cleaning may be left until after building construction is complete

BMP WP-03 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 plants (see the stormwater wetland details in Figure 7.17 and Figure 7.18.

Wetlands created to mitigate disturbance impacts, such as filling, may not also be used as stormwater treatment facilities. Vegetation must occasionally be harvested and sediment dredged in stormwater treatment wetlands.

In general, stormwater wetlands perform well to remove sediment, metals, and pollutants that bind to humic or organic acids. Phosphorus/nutrient removal in stormwater wetlands is highly variable. Stormwater wetlands can be used for Metals Treatment.

Applications and Limitations

This stormwater wetland design occupies about the same surface area as wetponds, 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. Because water depths are shallower than in wetponds, water loss by evaporation is an important concern. Stormwater wetlands are a good WQ facility choice in areas with high winter groundwater levels.

Design Criteria

Stormwater treatment wetlands employ many of the same design features as wetponds

- The design volume is the total volume of runoff from the 6-month, 24-hour storm event, as determined by WWHM.

Wetland Geometry Criteria

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 design wetpool volume.
3. The depth of the presettling cell shall be between 4 feet (minimum) and 8 feet (maximum), excluding sediment storage.
4. One-foot of sediment storage shall be provided in the presettling cell.
5. The wetland (second) cell shall have an average water depth of about 1.5 feet (plus or minus 3 inches).

6. The "berm" separating the two cells shall be shaped such that its downstream side gradually slopes to form the second shallow wetland cell (see the section view in Figure 7.17). Alternatively, the second cell may be graded naturalistically from the top of the dividing berm (see Wetland Geometry Criterion 8 below).

7. The top of berm shall be either at the WQ design water surface or submerged 1-foot below the WQ design water surface, as with wetponds. Correspondingly, the side slopes of the berm must meet the following criteria:

   a. If the top of berm is at the WQ design water surface, the berm side slopes shall be no steeper than 3H:1V.

   b. If the top of berm is submerged 1-foot, the upstream side slope may be up to 2H:1V. If the berm is at the water surface, then for safety reasons, its slope should be not greater than 3:1, just as the pond banks should not be greater than 3:1 if the pond is not fenced. A steeper slope (2:1 rather than 3:1) is allowable if the berm is submerged in 1 foot of water. If submerged, the berm is not considered accessible, and the steeper slope is allowable.

8. Two examples are provided for grading the bottom of the wetland cell. One example is a shallow, evenly graded slope from the upstream to the downstream edge of the wetland cell (see Figure 7.17). The second example is a "naturalistic" alternative, with the specified range of depths intermixed throughout the second cell (see Figure 7.18). 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 7.13. below). The maximum depth is 2.5 feet in either configuration. Other configurations within the wetland geometry constraints listed above may be approved.

Design Procedure

<u>Step 1:</u> The design volume is the total volume of runoff from the 6-month, 24-hour storm event.

<u>Step 2:</u> Calculate the surface area of the stormwater wetland by using the volume from Step 1 and dividing by the average water depth (use 3 feet).

<u>Step 3:</u> Determine the surface area of the first cell of the stormwater wetland. Use the volume determined from Criterion 2 under "Wetland Geometry", and the design depth of the first cell.

<u>Step 4:</u> Determine the surface area of the wetland cell. Subtract the surface area of the first cell (Step 3) from the total surface area (Step 2).

<u>Step 5:</u> Determine 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 that determined in Step 1 above, but this is acceptable.

Step 6: Choose plants. See Table 7.12 for a list of plants recommended for wetpond water depth zones, or consult a wetland scientist.

Table 7.13 – Distribution of depths in wetland cell			
Dividing Berm at WQ Design Water Surface		**Dividing Berm Submerged 1-Foot**	
Depth Range (feet)	**Percent**	**Depth Range (feet)**	**Percent**
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

Lining Requirements

To determine whether a low-permeability liner or a treatment liner is required, determine whether the following conditions will be met. If soil permeability will allow sufficient water retention, lining may be waived.

1 The second cell must retain water for at least 10 months of the year.
2. The first cell must retain at least three feet of water year-round.
3. A complete precipitation record shall be used when establishing these conditions. Evapotranspiration losses shall be taken into account as well as infiltration losses.

If a low permeability liner is used, a minimum of 18 inches of native soil amended with good topsoil or compost (one part compost mixed with 3 parts native soil) must be placed over the liner. For geomembrane liners, a soil depth of 3 feet is required to prevent damage to the liner during planting. Hydric soils are not required.

The criteria for liners given in Section 7.2.4 must be observed.

Inlet and Outlet

Same as for wetponds (see BMP WP-01).

Planting Requirements

The wetland cell shall be planted with emergent wetland plants following the recommendations given in Table 7.12 or the recommendations of a wetland specialist.

Construction Criteria

Construction criteria are the same as for wetponds.

BMP WP-04 Combined Detention and Wetpool Facilities

Combined detention and WQ wetpool facilities have the appearance of a detention facility but contain a permanent pool of water as well, and thus provide the same level of treatment as wetpool facilities. All wetpool facilities can be designed as combined facilities.

Applications and Limitations

Combined detention and water quality facilities are very efficient for sites that also have detention requirements. The water quality facility may often be placed beneath the detention facility without increasing the facility surface area. However, the fluctuating water surface of the live storage will create unique challenges for plant growth and for aesthetics alike.

For the combined detention/stormwater wetland, criteria that limit the extent of water level fluctuation are specified to better ensure survival of the wetland plants.

Unlike the wetpool volume, the live storage component of the facility shall be provided above the seasonal high water table.

BMP WP-04a Combined Detention and Wetpond

Typical design details and concepts for a combined detention and wetpond are shown in Figures 7.19a and 7.19b**. The detention portion of the facility shall meet the design criteria and sizing procedures set forth in Chapter 6.**

Sizing Procedure

The sizing procedures for combined detention and wetponds are identical to those outlined for wetponds and for detention facilities.

Detention and Wetpool Geometry

- The wetpool and sediment storage volumes shall not be included in the required detention volume.
- The "Wetpool Geometry" criteria for wetponds (see BMP WP.01) 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. Note, however, that having the first wetpool cell at the inlet allows for more efficient sediment management than if the cell is moved away from the inlet. Wetpond criteria governing water depth must, however, still be met. See Figure 7.20 for two possibilities for wetpool cell placement.

This flexibility in positioning cells is provided to allow for multiple use options, such as volleyball courts in live storage areas in the drier months.

Criterion 2: The minimum sediment storage depth in both cells is 1-foot.

Inlet and Outlet

The "Inlet and Outlet" criteria for wetponds shall apply with the following modifications:

- A sump must be provided in the outlet structure of combined ponds.
- The detention flow restrictor and its outlet pipe shall be designed according to the requirements for detention ponds (see Chapter 6).

Access

Same as for wetponds.

Planting Requirements

Same as for wetponds.

BMP WP-04b Combined Detention and Wetvault

The sizing procedure for combined detention and wetvaults is identical to those outlined for wetvaults and for detention facilities.

The design criteria for detention vaults and wetvaults must both be met, except for the following modifications or clarifications:

- The minimum sediment storage depth in both cells shall average 1-foot.
- The oil retaining baffle shall extend a minimum of 2 feet below the WQ design water surface.
- The facility may not be modified to function as a baffle oil/water separator as allowed for wetvaults in BMP 7.14. This is because the added pool fluctuation in the combined vault does not allow for the quiescent conditions needed for oil separation.

BMP WP-04c Combined Detention and Stormwater Wetland

The sizing procedure for combined detention and stormwater wetlands is identical to those outlined for stormwater wetlands and for detention facilities.

The design criteria for detention ponds and stormwater wetlands must both be met, except for the following modifications or clarifications:

- Water Level Fluctuation Restrictions: The difference between the WQ design water surface and the maximum water surface associated with the 2-year 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 "Wetland Geometry" criteria for stormwater wetlands (BMP WP-03) are modified as follows:

  The minimum sediment storage depth in both cells is 1-foot. Intent: Since emergent plants are limited to shallower water depths, the deeper water created before sediments accumulate is considered detrimental to robust emergent growth. Therefore, sediment storage is confined to the first cell, which functions as a presettling cell.

The "Inlet and Outlet" criteria for wetponds shall apply with the following modifications:

- A sump must be provided in the outlet structure of combined facilities.
- The detention flow restrictor and its outlet pipe shall be designed according to the requirements for detention ponds (see Chapter 6).

The "Planting Requirements" for stormwater wetlands are modified to use the following plants that 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.

7.7 Media Filtration Treatment BMPs

This Chapter presents criteria for the design and construction of runoff treatment media filters, including sand filters and alternative media filters. Five Best Management Practices (BMPs) are discussed in this Section:

BMP MF-01 Sand Filter Basin
BMP MF-02 Sand Filter Vault
BMP MF-03 Linear Sand Filter
BMP MF-04 Commercial Media Filter
BMP MF-05 Media Filter Drain

7.7.1 Sand Filters

A typical sand filtration system consists of a pretreatment system, flow spreader(s), a sand bed, and underdrain piping. The sand filter bed includes a geotextile fabric between the sand bed and the bottom underdrain system.

An impermeable liner under the facility may also be needed if the filtered runoff requires additional treatment to remove soluble ground water pollutants, or in cases where additional ground water protection was mandated.

Applicability

Sand filtration can be used in most residential, commercial, and industrial developments where debris, heavy sediment loads, and oils and greases will not clog or prematurely overload the sand, or where adequate pretreatment is provided for these pollutants. Specific applications include residential subdivisions, parking lots for commercial and industrial establishments, gas stations, high-use sites, multi family housing, roadways, and bridge decks. Sand filters are suited for locations with space constraints.

General Design Criteria

- Sand filters shall be located off-line before or after detention.
- Pretreatment is required.
- In high water table areas adequate drainage of the sand filter may require additional engineering analysis and design considerations.
- Sufficient hydraulic head, at least 4 feet from inlet to outlet, is required
- 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.

- Underdrain piping shall be sized to handle the two-year return frequency flow indicated by the WWHM. There shall be at least one (1) foot of hydraulic head above the invert of the upstream end of the collector pipe.
- Internal diameters of underdrain pipes shall be a minimum of six (6) inches with two rows of ½-inch holes spaced 6 inches apart longitudinally (maximum), with rows 120 degrees apart (laid with holes downward). Maximum perpendicular distance between two feeder pipes is 15 feet. All piping is to be schedule 40 PVC or greater wall thickness.
- Main collector underdrain pipe shall be at a slope of 0.5 percent minimum.
- A geotextile fabric must be used between the sand layer and drain rock or gravel and placed so that 1-inch of drain rock/gravel is above the fabric. Drain rock shall be 0.75-1.5 inch rock or gravel backfill, washed free of clay and organic material.
- Cleanout wyes with caps or junction boxes must be provided at both ends of the collector pipes. Cleanouts must extend to the surface of the filter. A valve box must be provided for access to the cleanouts. Access for cleaning all underdrain piping shall be provided. This may consist of installing cleanout ports, which tee into the underdrain system and surface above the top of the sand bed. To facilitate maintenance of the sand filter an inlet shutoff/bypass valve is required.
- Sand specification: The sand in a filter must consist of a medium sand meeting the size gradation (by weight) given in Table 7.14 below. The contractor must obtain a grain size analysis from the supplier to certify that the No. 100 and No. 200 sieve requirements are met.

Table 7.14 Sand Medium 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, September 1998

- Impermeable Liners for Sand Bed Bottom: Impermeable liners are 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. Clay liners shall have a minimum thickness of 12 inches and meet the specifications given in Table 7.15:

Table 7.15 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 & 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% of Standard Proctor Density

Source: King County Surface Water Design Manual, September 1998

- If a geomembrane liner is used it shall have a minimum thickness of 30 mils and be ultraviolet resistant. The geomembrane liner shall be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top and bottom of the geomembrane.

- Concrete liners may be used for sedimentation chambers and for sedimentation and sand filtration basins less than 1,000 square feet in area. Concrete shall be 5 inches thick Class A or better and shall be reinforced by steel wire mesh. The steel wire mesh shall be 6 gauge 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. This base must consist of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75- to 1-inch.

- If an impermeable liner is not required then a geotextile fabric liner shall be installed that retains the sand unless the basin has been excavated to bedrock.

- If an impermeable liner is not provided, then an analysis shall be made of possible adverse effects of seepage zones on ground water, and near building foundations, basements, roads, parking lots and sloping sites. Sand filters without impermeable liners shall not be built on fill sites and shall be located at least 20-foot downslope and 100-foot upslope from building foundations.

- Include an access ramp with a slope not to exceed 7:1, or equivalent, for maintenance purposes at the inlet and the outlet of a surface filter.

- Side slopes for earthen/grass embankments shall not exceed 3:1.

- High groundwater may damage underground structures or affect the performance of filter underdrain systems. There shall be at least 2 feet between the seasonal high groundwater level and the bottom of the sand filter.

General Construction Criteria

- No runoff shall enter the sand filter prior to completion of construction and approval of site stabilization by the responsible inspector.

- Construction runoff routed to a pretreatment sedimentation facility, but discharge from sedimentation facilities shall by-pass downstream sand filters.

- 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. Over-compaction shall be avoided to ensure adequate filtration capacity.

- Sand in basins shall be placed using equipment (such as a low ground pressure bulldozer) that creates 4 psig or less ground pressure.

BMP MF-01 Sand Filter Basin

The basic Sand Filter Basin is shown in Figure 7.21. All general pond/basin design criteria apply. Figures 7.22 through 7.25 illustrate typical sand filter basin layouts and details, and Figure 7.26 illustrates an example of a diversion structure.

BMP MF-02 Sand Filter Vault

A sand filter vault (Figures 7.27a and 7.27b) is similar to an open sand filter except that the sand layer and underdrains are installed below grade in a vault. It consists of pre-settling and sand filtration cells.

Applications and Limitations

- Use where space limitations preclude above-ground facilities
- Not suitable where high water table and heavy sediment loads are expected

Additional Criteria Specific to Vaults

- Maximum of 8-inch distance between the top of the spreader and the top of the sand bed. Flows may enter the sand bed by spilling over the top of the wall into a flow spreader pad or alternatively a pipe and manifold system may be used. Any pipe and manifold system must retain the required dead storage volume in the first cell, minimize turbulence, and be readily maintainable.
- 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.

- Erosion protection must be provided along the first foot of the sand bed adjacent to the spreader. Geotextile fabric secured on the surface of the sand bed, or equivalent method, shall be used.
- The filter bed shall consist of a sand top layer, and a geotextile fabric second layer with an underdrain system.
- Design the pre-settling cell for sediment collection and removal. A V-shaped bottom, removable bottom panels, or equivalent sludge handling system shall be used. One-foot of sediment storage in the pre-settling cell must be provided.
- The pre-settling chamber must be sealed to trap oil and trash. This chamber is connected to the sand filtration chamber through an inverted elbow to protect the filter surface from oil and trash.
- If a retaining baffle is necessary for oil/floatables in the pre-settling 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. Access opening and ladder must be provided on both sides of the baffle.
- To prevent anoxic conditions, a minimum of 24 square feet of ventilation grate shall be provided for each 250 square feet of sand bed surface area. Placement at each end is preferred. Grates may also be dispersed over the entire sand bed area.
- Provision for access is the same as for wet vaults. Removable panels must be provided over the entire sand bed.
- Sand filter vaults must conform to the materials and structural suitability criteria specified for wet vaults.
- Provide a sand filter inlet shutoff/bypass valve for maintenance
- A geotextile fabric over the entire sand bed may be installed that is flexible, highly permeable, three-dimensional matrix, and adequately secured. This is useful in trapping trash and litter

BMP MF-03 Linear Sand Filter

Linear sand filters (Figure 7.28) are 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.

Application and Limitations

- Applicable in long narrow spaces such as the perimeter of a paved surface.
- As a part of a treatment train downstream of a filter strip, upstream of an infiltration system, or upstream of a wet pond or a biofilter for oil control.
- To treat small drainages (less than 2 acres of impervious area).
- To treat runoff from high-use sites for TSS and oil/grease removal, if applicable.

Additional Design Criteria for Linear Sand Filters

- The two cells shall be divided by a divider wall that is level and extends a minimum of 12 inches above the sand bed.
- Stormwater may enter the sediment cell by sheet flow or a piped inlet.
- The width of the sand cell must be 1-foot minimum to 15 feet maximum.
- 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.
- The drainpipe must be 6-inch diameter minimum and be wrapped in geotextile and sloped a minimum of 0.5 percent.
- Maximum sand bed ponding depth: 1-foot.
- Must be vented as for sand filter vaults
- Linear sand filters must conform to the materials and structural suitability criteria specified for wet vaults.
- Set sediment cell width as follows:

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

Sand Filter Amendments

Any of the sand filters (BMPs MF.01, MF.02, MF.03) may be amended to achieve treatment performance beyond "Basic" treatment. The following amendments may be used to achieve the indicated performance level:

- Processed steel fiber 5% by volume – Metals Treatment
- Crushed calcitic limestone 10% by volume – Phosphorus Treatment

All other design criteria for sand filters apply**.**

7.7.2 Media Filters

Media filter technology has been under development in the Pacific Northwest since the early 1990s. During the early stages of development, a leaf compost medium was used in fixed beds. Continued development of this technology is based on placing the media in filter cartridges (vertical media filters) instead of fixed beds, and amending the media with constituents that will improve effectiveness. The target pollutants for removal are TSS, total and soluble phosphorous, total nitrogen, soluble metals, oil & grease and other organics.

BMP MF-04 Commercial Media Filters

In manufactured media filters, the media can be housed in cartridges enclosed in concrete vaults, or in fixed beds such as the sand filters described above. An assortment of filter media are available including leaf compost, pleated fabric, activated charcoal, perlite, amended sand and perlite, and zeolite. The system functions by routing the stormwater through the filtering or sorbing medium, which traps particulates and/or soluble pollutants.

Media can be selected for removal of TSS, oil/grease or total petroleum hydrocarbons, soluble metals, nutrients and organics.

Pretreatment is required for high TSS and/or hydrocarbon loadings and debris that could cause premature failures due to clogging.

Media filtration, such as amended sand, should be considered for some Metals treatment applications to remove soluble metals and soluble phosphates.

These systems may be designed as on-line systems for small drainage areas, or as off-line systems. For off-line applications, flows greater than the design flow shall be bypassed.

Site Suitability

Consider:

- Space requirements
- Design flow characteristics
- Target pollutants
- O & M requirements
- Capital and annual costs

Design

- Determine TSS loading and peak design flow.
- TSS loading capacity per cartridge based on manufacturer's loading and flow design criteria to determine number and size of cartridges. Calculate maintenance frequency based on TSS loading and cartridge capacity.
- Evaluate for pre-treatment needs. Typically, roadways, single family dwellings, and developments with steep slopes and erodible soils need pretreatment for TSS. Developments producing sustained oil and grease loads should be evaluated for oil and grease pretreatment needs.
- Select media based on pollutants of concern which are typically based on land use and local agency guidelines.
- Use source control where feasible, including gross pollutant removal, sweeping, and spill containment.
- Maintain catch basins as needed to minimize inlet debris that could impair the operation of the filter media.

- Sedimentation vaults/ponds/tanks, innovative more-efficient catch basins, oil/water separators for oil > 25 ppm, or other appropriate pre-treatment systems are recommended to improve and maintain the operational efficiency of the filter media.
- Bypass flows above design flows.
- A precast or cast-in-place vault is typically installed over an underdrain manifold pipe system. This is followed by installation of the cartridges.
- Prior to cartridge installation, construction sites must be stabilized to prevent erosion and solids loading. Follow manufacturers O & M guidelines to maintain design flows and pollutant removals

Additional Applications, Limitations, Design, Construction, and Maintenance Criteria

Two commercially-available media filter treatment systems are currently approved by Ecology with General Use Level Designation (GULD) for basic treatment: (1) the Contech Stormwater Solutions Inc. StormFilter® using ZPG media (Figure 7.31), and (2) the Contech Stormwater Solutions Inc. CDS® Media Filtration System. In addition, the Americast Filterra® Bioretention System (Figure 7.32), which is similar to a bioretention cell, has General Use Level Designation (GULD) for basic, enhanced (metals) and oil treatment. See Section 7.9, and refer to Ecology's website for current information, approval status and conditions of use for manufactured "Emerging Technologies" at http://www.ecy.wa.gov/programs/wq/stormwater/newtech/

BMP MF-05 Media Filter Drain

The Media Filter Drain (MFD), previously referred to as the *ecology embankment*, is a linear flow-through stormwater runoff treatment device that was developed by the Washington State Department of Transportation (WSDOT). The MFD can be sited along roadway side slopes (conventional design) and within medians (dual media filter drains), borrow ditches, or other linear depressions.

MFDs have four basic components: a gravel no-vegetation zone, a grass strip, the MFD mix bed, and a conveyance system for flows leaving the MFD mix. This conveyance system usually consists of a gravel-filled underdrain trench or a layer of crushed surface base course (CSBC). This layer of CSBC must be porous enough to allow treated flows to freely drain away from the MFD mix.

Typical MFD configurations are shown in Figures 7.33, 7.34, and 7.35.

The MFD has a general use level designation (GULD) from the Department of Ecology for basic, phosphorus, and enhanced treatment. The MFD removes suspended solids, phosphorus, and metals from stormwater runoff through physical straining, biofiltration, ion exchange, and carbonate precipitation. For further information, see the most recent edition of the WSDOT Highway Runoff Manual.

Applicability

The MFD can be used where available right-of-way is limited, sheet flow is feasible (i.e., no curbs), lateral gradients are generally less than 25 percent (4H: 1V), and longitudinal gradients are less than 5 percent.

Media Filter Drains

Since maintaining sheet flow across the media filter drain is required for its proper function, the ideal locations for media filter drains are roadside embankments or other long, linear grades.

Dual Media Filter Drains

The dual media filter drain is fundamentally the same as the side-slope version. It differs in siting and is more constrained with regard to drainage options. Prime locations for dual media filter drains are medians, roadside drainage or borrow ditches, or other linear depressions. It is especially critical for water to sheet flow across the dual media filter drain.

Limitations

Flow Path

The longest flow path from the contributing area delivering sheet flow to the media filter drain shall not exceed 75 feet for impervious surfaces and 150 feet for pervious surfaces.

Channelized Flow

Media filter drains shall not be used where continuous off-site inflow may result in channelized flows or ditch flows running down the middle of the dual media filter drain.

Steep Slopes

- Avoid construction on longitudinal slopes steeper than 5 percent.
- Avoid construction on 3H:1V lateral slopes, and preferably use flatter than 4H:1V slopes. As slopes approach 3H:1V, without design modifications, sloughing may become a problem due to friction limitations between the separation geotextile and underlying soils. In areas where lateral slopes exceed 4H: 1V, it may be possible to construct terraces to create 4H: 1V slopes, or to otherwise stabilize up to 3H: 1V slopes.
- In areas where slope stability may be problematic, consult a geotechnical engineer.

Wetlands

- Do not construct in wetlands and wetland buffers.
- In many cases, a media filter drain (due to its small lateral footprint) can fit within the fill slopes adjacent to a wetland buffer. In those situations where the fill prism is located adjacent to wetlands, an interception trench or underdrain will need to be incorporated as a design element in the media filter drain.

Shallow Groundwater

- Mean high water table levels in the project area need to be determined to ensure that the MFD mix bed and the underdrain will not become saturated by shallow groundwater.
- There must be at least 1 foot of depth between the seasonal high groundwater table and the bottom of the facility.

Submittals and Approval

As part of the required submittals (see Chapter 2) include the following:

- Design information and calculations for the MFD including sizing criteria, assumptions for hydrologic modeling of the MFD and other data necessary to evaluate the suitability of the MFD in the proposed application.
- The Maintenance Plan shall include maintenance procedures for the MFD, frequency of maintenance and other information necessary for the ongoing maintenance of the MFD.
- The Drawings and Specifications for the project shall show the location of the MFD in the site plan, cross-sections and details of the MFD with all necessary information to construct it according to the plans, and specifications for all components of the MFD including seeding mix design, MFD bed design and testing requirements, and soil/material placement and compaction requirements.
- The Soils Management Plan required by BMP LID.02 shall include the area of the MFD and proposed soil amendments.

Pretreatment

No pretreatment is required. Sheet flow runoff from the roadway surface can be routed directly to the MFD.

Hydrologic and Hydraulic Design Considerations

The basic design concept behind the media filter drain and dual media filter drain is to fully filter all runoff through the MFD mix. Therefore, the infiltration capacity of the MFD mix and of the drainage below the MFD mix bed needs to match or exceed the hydraulic loading rate.

Infiltration Rate

The MFD mix has an estimated initial filtration rate of 50 inches per hour and a long-term filtration rate of 28 inches per hour, which accounts for siltation. With an additional safety factor, the rate used to size the length of the media filter drain should be 14 inches per hour.

Design Flow Rate

For western Washington, $Q_{Roadway}$ is the flow rate at or below which 91 percent of the runoff volume will be treated, based on a 15-minute time step, and can be determined using the water quality analysis feature in WWHM.

Sizing MFD Mix Bed

For runoff treatment, sizing the MFD mix bed is based on the requirement that the runoff treatment flow rate from the contributing roadway area $Q_{Roadway}$ cannot exceed the long-term infiltration capacity of the media filter drain, $Q_{Infiltration}$:

$$Q_{Roadway} \leq Q_{Infiltration}$$

$Q_{infiltration}$, the long-term infiltration capacity of the media filter drain is based on the following equation:

$$\frac{LTIR_{EM} * L_{EE} * W_{EE}}{C * SF} = Q_{Infiltration}$$

where:

$LTIR_{EM}$ = Long-term infiltration rate of the MFD mix (use 10 inches per hour for design) (in/hr)
L_{EE} = Length of media filter drain (parallel to contributing pavement) (ft)
W_{EE} = Width of the MFD mix bed (ft)
C = Conversion factor of 43,200 ((in/hr)/(ft/sec))
SF = Safety Factor (equal to 1.0, unless unusually heavy sediment loading is expected)

Assuming that the length of the media filter drain is the same as the length of the contributing pavement, solve for the width of the media filter drain:

$$W_{EE} = \frac{Q_{Roadway} * C * SF}{LTIR_{EM} * L_{EE}}.$$

Project applications of this design procedure have shown that, in almost every case, the calculated width of the media filter drain does not exceed 1.0 foot. Therefore, Table 7.16 was developed by WSDOT to simplify the design steps and should be used to establish an appropriate width.

Table 7.16 Design Widths for Media Filter Drains

Pavement Width that Contributes Runoff to the Media Filter Drain	Minimum Media Filter Drain Width*
< 20 feet	2 feet
≥ 20 and ≤ 35 feet	3 feet
> 35 feet	4 feet

Width does not include the required 1–3 foot gravel vegetation-free zone or the 3-foot filter strip width (see Figure 7.8).

Design Criteria

Media filter drains have four basic components: a gravel no-vegetation zone, a grass strip, the MFD mix bed, and a conveyance system for flows leaving the MFD mix.

Inflow

Runoff is always conveyed to a media filter drain using sheet flow from the pavement area. The longitudinal pavement slope contributing flow to a media filter drain should be less than 5 percent. Although there is no lateral pavement slope restriction for flows going to a media filter drain, the designer should ensure that flows remain as sheet flow.

No-Vegetation Zone

Stormwater runoff is conveyed to the MFD via sheet flow over a vegetation-free gravel zone to ensure sheet dispersion, and to provide some pollutant trapping. The no-vegetation zone is a shallow gravel trench located directly adjacent to the impervious surface to be treated. The no-vegetation zone is a crucial element in a properly functioning media filter drain or other BMPs that use sheet flow to convey runoff from the impervious surface to the BMP. The no-vegetation zone functions as: a level spreader to promote sheet flow, a deposition area for coarse sediments, and an infiltration area to reduce runoff volumes.

Grass Strip

Adjacent to the no-vegetation zone, a grass strip, which may be amended with compost, is incorporated into the top of the fill slope to provide pretreatment, further enhancing filtration and extending the life of the system.

Media Filter Drain Mix Bed

The runoff is then filtered through a bed of porous, alkalinity-generating granular medium—the MFD mix. Geotextile lines the underside of the MFD mix bed.

Conveyance System Below Media Filter Drain Mix

Treated water drains from the MFD mix bed into the conveyance system below the MFD mix. The conveyance system must be porous enough to allow treated flows to freely drain away from the MFD mix.

This conveyance system usually consists of a gravel-filled underdrain trench or a layer of crushed surfacing base course (CSBC).

Underdrain Trench

The gravel underdrain trench provides hydraulic conveyance when treated runoff needs to be conveyed to a desired location such as a downstream flow control facility or stormwater outfall.

The underdrain trench shall be a minimum of 2 feet wide for either the conventional or dual media filter drain. The gravel underdrain trench may be eliminated (see Figure 7.9) if there is evidence to support that flows can be conveyed laterally to an adjacent ditch or onto a fill slope that is properly vegetated to protect against erosion. The MFD mix shall drain freely, draining up to the 50-year storm event water surface elevation represented in the downstream ditch.

Underdrain Pipe

The trench's perforated underdrain pipe is a protective measure to ensure free flow through the MFD mix. It may be possible to omit the underdrain pipe if it can be demonstrated that the pipe is not necessary to maintain free flow through the MFD mix and underdrain trench.

In Group C and D soils, an underdrain pipe would help to ensure free flow of the treated runoff through the MFD mix bed. In some Group A and B soils, an underdrain pipe may be unnecessary if most water percolates into subsoil from the underdrain trench. The need for underdrain pipe should be evaluated in all cases.

Geometry

The no-vegetation zone should be between 1 foot and 3 feet wide. Depth will be a function of how the adjacent paved section is built from subgrade to finish grade; the resultant cross section will typically be triangular to trapezoidal.

The width of the vegetated filter strip is dependent on the availability of space within the sloped area where the media filter drain is to be constructed. The baseline design criterion for the grass strip within the media filter drain is a 3-foot-minimum-width, but wider grass strips are recommended if the additional space is available.

The MFD mix shall be a minimum of 12 inches deep, including the section on top of the underdrain trench. The MFD mix bed shall have a bottom width of at least 2 feet in contact with the conveyance system below the media filter drain mix.

In general, the length of a media filter drain or dual media filter drain is the same as that of the contributing pavement. Any length is acceptable as long as the surface area of the MFD mix bed is sufficient to fully infiltrate the runoff treatment design flow rate.

In profile, the surface of the media filter drain should preferably have a lateral slope less than 4H: 1V (<25 percent). On steeper terrain, it may be possible to construct terraces to create a 4H: 1V slope, or other engineering may be employed if approved by the City of Lacey and Ecology, to ensure slope stability up to 3H: 1V. If sloughing is a concern on steeper slopes, consideration should be given to incorporating permeable soil reinforcements, such as geotextiles, open-graded/permeable pavements, or commercially available ring and grid reinforcement structures, as top layer components to the MFD mix bed. Consultation with a geotechnical engineer is required.

Materials

WSDOT Standard Specifications should be consulted for the following:

- Gravel Backfill for Drains, 9-03.12(4)
- Underdrain Pipe, 7-01.3(2)
- Construction Geotextile for Underground Drainage, 9-33.1.

MFD Mix

The MFD mix is a mixture of crushed rock (screened to 3/8" to #10 sieve), dolomite, gypsum, and perlite. The crushed rock provides the support matrix of the medium. The dolomite and gypsum additives serve to buffer acidic pH conditions and exchange light metals for heavy metals. Perlite is incorporated to improve moisture retention, which is critical for the formation of biomass epilithic biofilm to assist in the removal of solids, metals, and nutrients.

The MFD mix used in the construction of media filter drains consists of the amendments listed in Table 7.17. Mixing and transportation must be done in a manner that ensures the materials are thoroughly mixed prior to pouring into the ground, and that separation does not occur during transportation or pouring.

Table 7.17 Media Filter Drain Mix

Amendment	Quantity
Mineral aggregate: Crushed screenings 3/8-inch to #10 sieve Crushed screenings shall be manufactured from ledge rock, talus, or gravel in accordance with Section 3-01 of the *Standard Specifications for Road, Bridge, and Municipal Construction* (2002), which meets the following test requirements: Los Angeles Wear, 500 Revolutions 35% max. Degradation Factor 30 min. Crushed screenings shall conform to the following requirements for grading and quality: Sieve Size — Percent Passing (by weight) 1/ 2" square — 100 3/8" square — 90 -100 U.S. No. 4 — 30 - 56 U.S. No. 10 — 0 -10 U.S. No. 200 — 0 -1.5 % fracture, by weight, min. — 75 Static stripping test — Pass The fracture requirement shall be at least one fractured face and will apply to material retained on the U.S. No. 10 if that sieve retains more than 4% of the total sample. The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials. Crushed screenings shall be substantially free from adherent coatings. The presence of a thin, firmly adhering film of weathered rock shall not be considered as coating unless it exists on more than 50% of the surface area of any size between successive laboratory sieves.	3 cubic yards
Perlite: Horticultural grade, free of any toxic materials 0-30% passing US No. 18 Sieve 0-10% passing U.S. No. 30 Sieve	1 cubic yard per 3 cubic yards of mineral aggregate.
Dolomite: CAMg(CO3)2 (calcium magnesium carbonate) Agricultural grade, free of any toxic materials 100% passing US No. 8 Sieve 0% passing U.S. No. 16 Sieve	10 pounds per cubic yard of perlite
Gypsum: Noncalcined, agricultural gypsum CaSO4+2H_2O (hydrated calcium sulfate) Agricultural grade, free of any toxic materials 100% passing US No. 8 Sieve 0% passing US No. 16 Sieve	1.5 pounds per cubic yard of perlite.

Crushed Surfacing Base Course (CSBC)

If the design is configured to allow the media filter drain to drain laterally into a ditch, the crushed surfacing base course below the media filter drain shall conform to Section 9-03.9(3) of the WSDOT *Standard Specifications*. The designer should consult with a professional to ensure that the CSBC will not impede the flow of water out of the media filter drain mix. If needed, a different gradation may be specified to ensure the free flow of water out of the media filter drain mix.

Soil Mix for Grass Strip

The designer should consult a landscape architect for soil mix recommendations. The designer may consider adding aggregate to the soil mix to help minimize rutting problems from errant vehicles. The soil mix should ensure grass growth for the design life of the MFD.

Site Design Elements

Landscaping (Planting Considerations)

Landscaping is the same as for biofiltration swales (see BMP BF.01) unless otherwise specified and approved by the City of Lacey.

Signing

Non-reflective guideposts shall be installed to delineate the MFD. The guideposts shall indicate that the area is a stormwater treatment facility and not to disturb without contacting the City of Lacey. This practice allows road maintenance personnel to identify where the system is installed and to make appropriate repairs should damage occur to the system. If the MFD is in a critical aquifer recharge area for drinking water supplies, signage prohibiting the use of pesticides must be provided.

Construction and Maintenance

Maintenance will consist of routine roadside management. While herbicides should not be applied directly over the MFD, it may be necessary to periodically control noxious weeds with herbicides in areas around the MFD as part of a roadside management program. The use of pesticides may be prohibited if the MFD is in a critical aquifer recharge area for drinking water supplies. The designer should check with the City of Lacey (or other local area water purveyor) and Thurston County Environmental Health. Areas of the MFD that show signs of physical damage will be replaced based on the original design which should be included in the Maintenance Plan.

7.8 Oil Control Facilities

Two types of facilities are available to meet the Oil Control requirement: catch basin inserts and oil/water separators.

BMP OC-01 Catch Basin Inserts (CBI)

CBIs have been under development for many years in the Puget Sound Basin. They function similarly to media filtration except that they are typically limited by the size of the catchbasin. They also are likely to be maintenance intensive.

Catch basin inserts typically consist of the following components:

- A structure (screened box, brackets, etc.) which contains a pollutant removal medium
- A means of suspending the structure in a catch basin
- A filter medium such as sand, carbon, fabric, etc.
- A primary inlet and outlet for the stormwater
- A secondary outlet for bypassing flows that exceed the design flow rate

Applications and Limitations

By treating runoff close to its source, the volume of flow is minimized and more effective pollutant removal is therefore possible. Depending on the insert medium, removals of TSS, organics (including oils), and metals can be achieved. The main drawbacks are the limited retention capacities and maintenance requirements on the order of once per month in the wet season to clean or replace the medium. The following are potential limitations and applications for CBIs:

- CBIs are not allowed as a substitute for basic BMPs such as wet ponds, vaults, constructed wetlands, grass swales, sand filters or related BMPs.
- CBIs can be used as temporary sediment control devices and pretreatment at construction sites.
- CBIs can be considered for oil control at small sites where the insert medium has sufficient hydrocarbon loading capacity and rate of removal, and the TSS and debris will not prematurely clog the insert.
- CBIs can be used in unpaved areas and are considered equivalent to currently accepted inlet protection BMPs.
- CBIs can be used when an existing catch basin lacks a sump or has an undersized sump.
- CBIs can cause flooding when plugged.
- CBIs may be considered in specialized small drainage applications for specific target pollutants where clogging of the medium will not be a problem.

BMP OC-02 Oil/Water Separators

Oil and water separators are typically the American Petroleum Institute (API) (also called baffle type) (American Petroleum Institute, 1990) or the coalescing plate (CP) type using a gravity mechanism for separation. See Figures 7.36 and 7.37. Oil removal separators typically consist of three bays; forebay, separator section, and the afterbay. The CP separators need considerably less space for separation of the floating oil due to the shorter travel distances between parallel plates.

Applications/Limitations

The following are potential applications of oil and water separators where free oil is expected to be present at treatable high concentrations and sediment will not overwhelm the separator. For low concentrations of oil, other treatments (e.g., sand filters, emerging technologies) may be more applicable.

- Commercial and industrial areas including petroleum storage yards, vehicle maintenance facilities, manufacturing areas, airports, utility areas (water, electric, gas), and fueling stations.
- Facilities that require oil control BMPs under the high-use site threshold including parking lots at convenience stores, fast food restaurants, grocery stores, shopping malls, discount warehouse stores, banks, truck fleets, auto and truck dealerships, and delivery services.

Without adequate maintenance, oil/water separators may not be sufficiently effective in achieving oil and TPH removal at required levels.

Pretreatment should be considered if the level of TSS in the inlet flow would cause clogging or otherwise impair the long-term efficiency of the separator.

For inflows from small drainage areas (fueling stations, maintenance shops, etc.) a coalescing plate (CP) type separator is typically considered, due to space limitations. However, if plugging of the plates is likely, then a new design basis for the baffle type API separator may be considered on an experimental basis. (See Design Criteria).

Design Criteria

If practicable, determine (or estimate) oil/grease (or TPH) and TSS concentrations, lowest temperature, pH; and empirical oil rise rates in the runoff, and the viscosity, and specific gravity of the oil. Also determine/assess whether the oil is emulsified or dissolved. (Washington State Department of Ecology, 1995) **Do not use oil/water separators for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.**

- Locate the separator off-line and bypass the incremental portion of flows that exceed the off-line 15-minute, Water Quality design flow rate as obtained from WWHM. If it is necessary to locate the separator on-line, try to minimize the size of the area needing oil control, and use the on-line water quality design flow rate from WWHM.
- To the maximum extent practicable, use only impervious conveyances for oil contaminated stormwater, or use pretreatment for TSS.
- Performance tests after installation and shakedown, and/or certification by a professional engineer that the separator is functioning in accordance with design objectives, are required. Corrective actions must be taken if it is determined the separator is not achieving acceptable performance levels.

Criteria for Separator Bays:

- Size the separator bay for the Water Quality design flow rate (15 minute time step, on-line or off-line).
- To collect floatables and settleable solids, design the surface area of the forebay at ≥ 20 ft^2 per 10,000 ft^2 of area draining to the separator. The length of the forebay should be 1/3-1/2 of the length of the entire separator. Include roughing screens for the forebay or upstream of the separator to remove debris, if needed.
- Include a submerged inlet pipe with a turn-down elbow in the first bay at least two 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.
- Include a shutoff mechanism at the separator outlet pipe.
- Use absorbents and/or skimmers in the afterbay as needed.

Criteria for Baffles:

- Oil retaining baffles (top baffles) should be located at least at 1/4 of the total separator length from the outlet and should extend down at least 50% of the water depth and at least 1 ft. from the separator bottom.
- Baffle height to water depth ratios should be 0.85 for top baffles and 0.15 for bottom baffles.

BMP OC-02a API (Baffle type) Separator (Figure 7.36)

Design Criteria

The criteria for small drainages is based on V_h, V_t, residence time, width, depth, and length considerations. As a correction factor API's turbulence criteria is applied to increase the length.

Ecology is modifying the API criteria for treating stormwater runoff from small drainage area (fueling stations, commercial parking lots, etc.) by using the design hydraulic horizontal velocity, V_h, for the design V_h/V_t ratio rather than the API minimum of $V_h/V_t = 15$. The API criteria appear applicable for greater than two acres of impervious drainage area. Performance verification of this design basis must be obtained during at least one wet season using the test protocol referenced in Section 7.9 for new technologies.

The following is the sizing procedure using modified API criteria:

- Determine the oil rise rate, V_t, in cm/sec, using Stokes Law (Water Pollution Control Federation, 1985), or empirical determination, or 0.033 ft./min for 60µ oil. The application of Stokes' Law to site-based oil droplet sizes and densities, or empirical rise rate determinations recognizes the need to consider actual site conditions. In those cases the design basis would not be the 60 micron droplet size and the 0.033 ft/min. rise rate.
- Stokes Law equation for rise rate, V_t (cm/sec):

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

Where:

g = gravitational constant (981 cm/sec²)
D = diameter of the oil particle in cm.

Use

oil particle size diameter, D = 60 microns (0.006 cm)

σ_w = 0.999 gm/cc. at 32° F

σ_o: Select conservatively high oil density

(For example, if diesel oil @ σ_o=0.85 gm/cc and motor oil @ σ_o = 0.90 can be present, then use σ_o = 0.90 gm/cc),

η_w = 0.017921 poise, gm/cm-sec. at T_w=32 °F, (See API Publication 421, February 1990)

Use the following separator dimension criteria:

- Separator water depth, $3 \leq d \leq 8$ feet (to minimize turbulence) (American Petroleum Institute, 1990; U.S. Army Corps of Engineers, 1994).
- Depth/width ratio of 0.3-0.5 (American Petroleum Institute, 1990)

For Stormwater Inflow from Drainages under 2 Acres:

1. Determine V_t and select depth and width of the separator section based on above criteria.
2. Calculate the minimum residence time (t_m) of the separator at depth d:

   $t_m = d/V_t$

3. Calculate the horizontal velocity of the bulk fluid, V_h, vertical cross-sectional area, A_v, and actual design V_h/V_t (American Petroleum Institute, 1990; U.S. Army Corps of Engineers, 1994).

   $V_h = Q/dw = Q/A_v$ (V_h maximum < 2.0 ft/min.)

   Q = 2 X the 15-minute Water Quality design flow rate in ft^3/min, at minimum residence time, t_m

   At V_h/V_t determine F, turbulence and short-circuiting factor. API F factors range from 1.28-1.74. (American Petroleum Institute, 1990)

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

   $l(s) = FQt_m/wd = F(V_h/V_t)d$
   $l(t) = l(f) + l(s) + l(a)$
   $l(t) = l(t)/3 + l(s) + l(t)/4$

   Where:

   l(t) = total length of 3 bays = "L" in Figure 7.33
   l(f) = length of forebay
   l(a) = length of afterbay

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

   V = minimum hydraulic design volume
   A_h = minimum horizontal area of the separator

For Stormwater Inflow from Drainages > 2 Acres:

Use $V_h = 15\ V_t$ and $d = (Q/2V_h)^{1/2}$ (with d/w = 0.5) and repeat above calculations 3- 5.

BMP OC-02b Coalescing Plate (CP) Separator (Figure 7.37)

Design Criteria

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 = 2 x the 15-minute water quality 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 32º F
σ_o = density of oil at 32º F
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 32º F

- Plate spacing should be a minimum of 3/4 inch (perpendicular distance between plates).
- Select a plate angle between 45° to 60° from the horizontal.
- Locate plate pack at least 6 inches from the bottom of the separator for sediment storage
- Add 12 inches minimum head space from the top of the plate pack and the bottom of the vault cover.
- 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 <500 (laminar flow).
- Include forebay for floatables and afterbay for collection of effluent.
- The sediment-retaining baffle must be upstream of the plate pack at a minimum height of 18 inches.
- Design plates for ease of removal, and cleaning with high-pressure rinse or equivalent.

Operation and Maintenance

- Prepare, regularly update, and implement an O & M Manual for the oil/water separators.
- Inspect oil/water separators monthly during the wet season of October 1-April 30 to ensure proper operation, and, during and immediately after a large storm event of ≥1 inch per 24 hours.
- Clean oil/water separators regularly to keep accumulated oil from escaping during storms. They must be cleaned by October 15 to remove material that has accumulated during the dry season, after all spills, and after a significant storm. Coalescing plates may be cleaned in-situ or after removal from the separator. An eductor truck may be used for oil, sludge, and washwater removal. Replace wash water in the separator with clean water before returning it to service.
- Remove the accumulated oil when the thickness reaches 1-inch. Also remove sludge deposits when the thickness reaches 6 inches.
- Replace oil absorbent pads before their sorbed oil content reaches capacity.
- Train designated employees on appropriate separator operation, inspection, record keeping, and maintenance procedures.

7.9 Emerging Technologies

The recognition of specific BMPs in this Manual is not intended to discourage the development of new and innovative BMPs that may provide better performance at reduced impact in cost and space. The City of Lacey encourages innovation in this regard. It will be the responsibility of the project proponent to demonstrate to the City's satisfaction that the proposed BMP meets or exceeds the performance standards of the conventional BMP that would apply to a given project.

Emerging technologies, as they are approved by Ecology, will generally be considered as potentially acceptable for use in Lacey, depending upon specific applications and conditions, and subject to approval by the Drainage Manual Administrator.

Lacey will employ an evaluation protocol similar to Ecology's Technology Assessment Protocol Ecology (TAPE) or Chemical TAPE (CTAPE) to determine acceptability of emerging technologies. The proponent will be required to monitor performance of the technology as a condition of acceptance. The project proponent or design engineer should consult with the Drainage Manual Administrator prior to preparing plans utilizing any stormwater technology that is not specifically included in this manual.

Refer to Ecology's website for current information, approval status and conditions of use for "Emerging Technologies"at http://www.ecy.wa.gov/programs/wq/stormwater/newtech/

7.10 Figures – Treatment Facilities

The following pages contain the figures for this chapter.

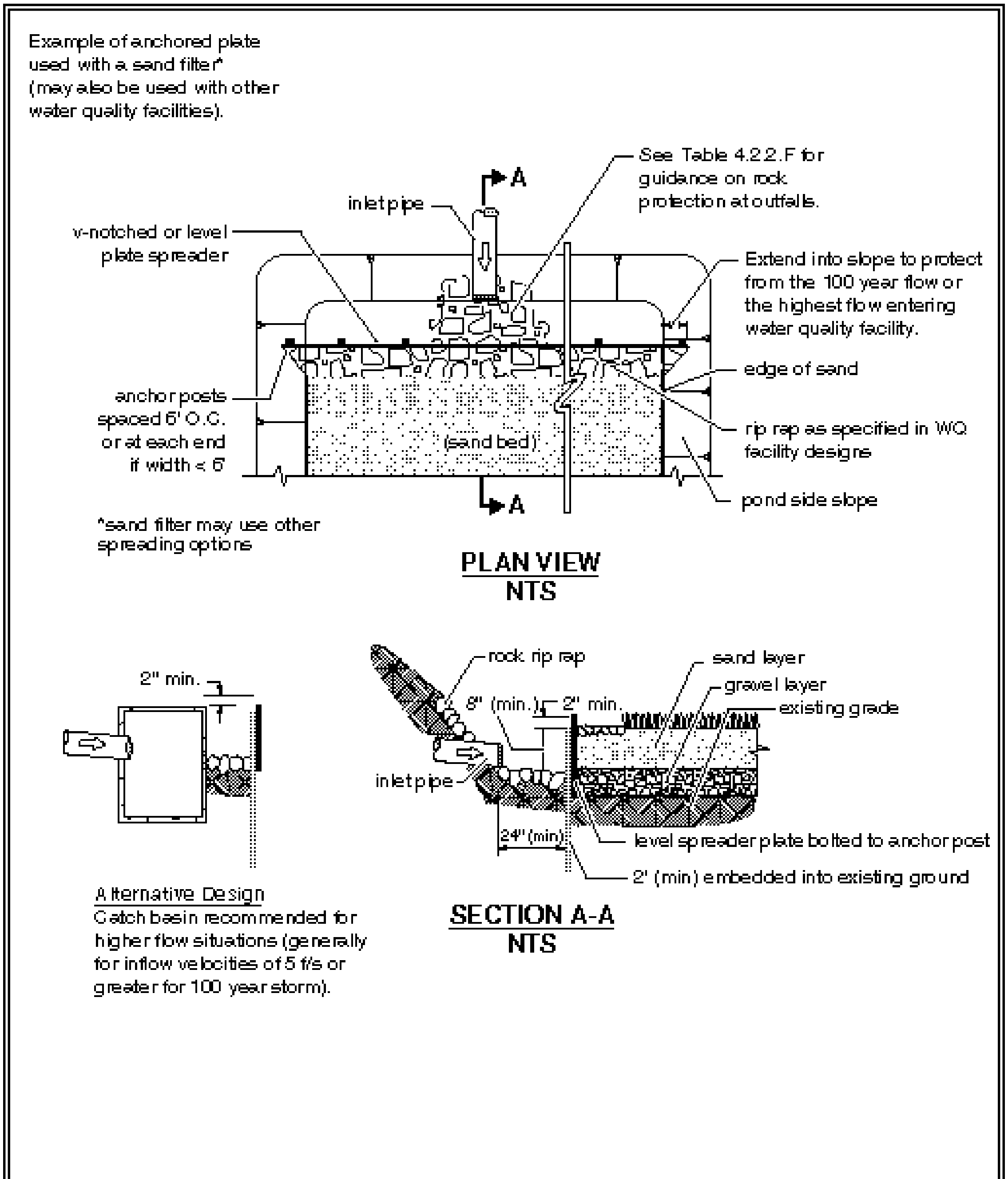


Figure 7.1 Flow Spreader Option A: Anchored Plate

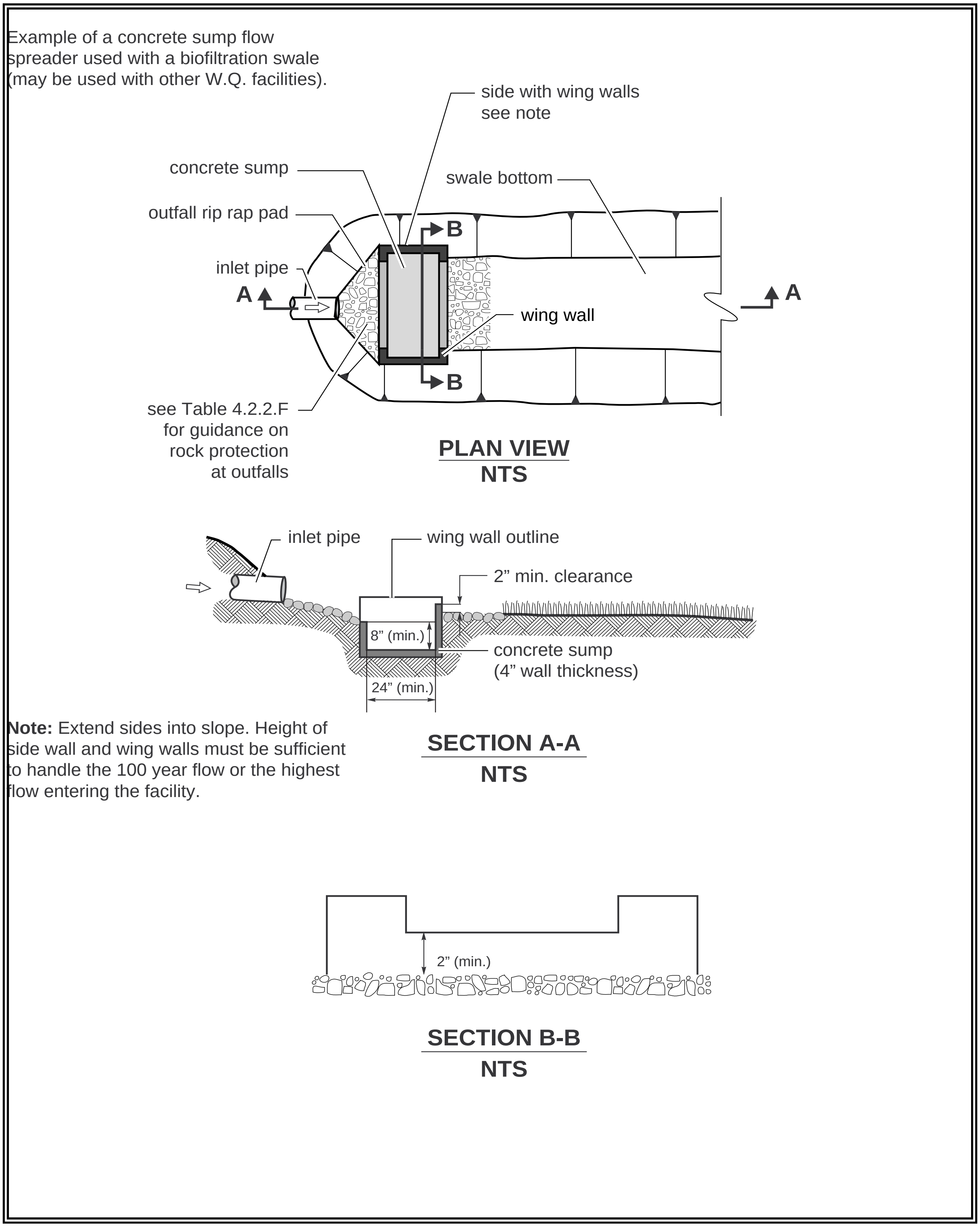


Figure 7.2 Flow Spreader Option B: Concrete Sump Box

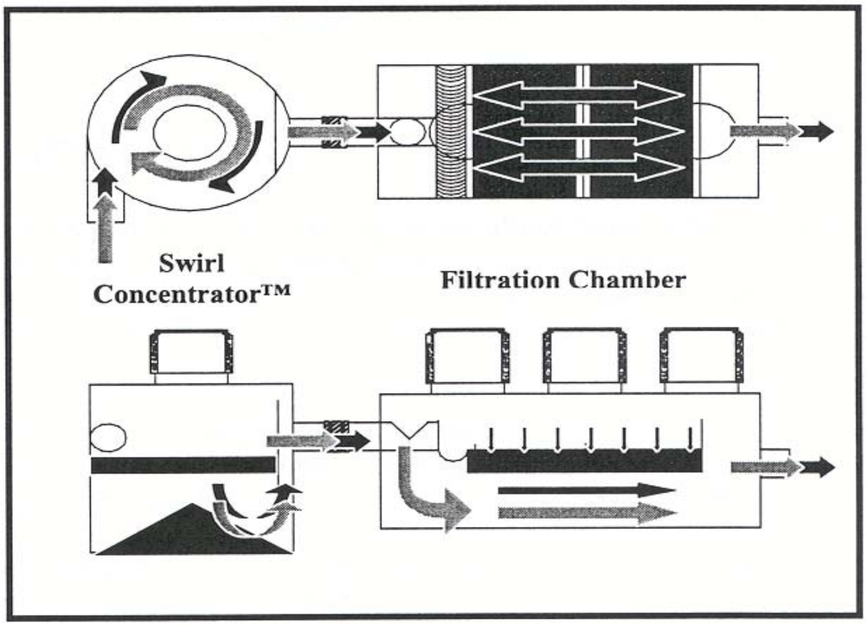


Figure 7.3 Vortex Enhanced Sedimentation and Media Filtration

(Courtesy of AquaShield, Inc.)

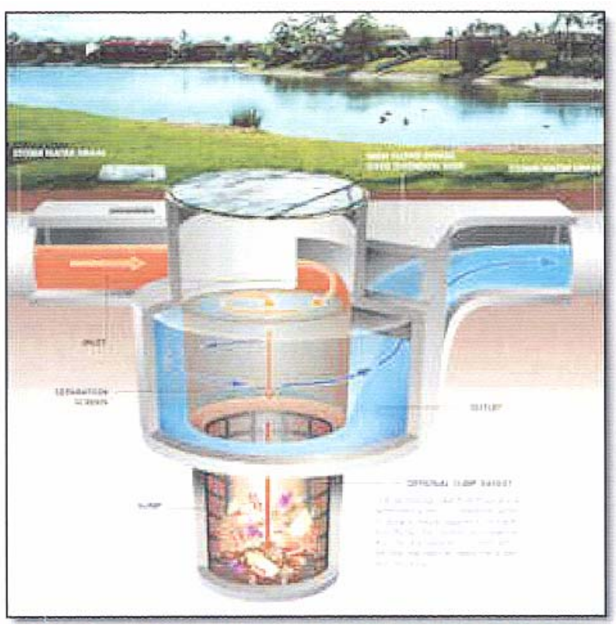


Figure 7.4 Screen Separator

(Courtesy of CDS, Inc)

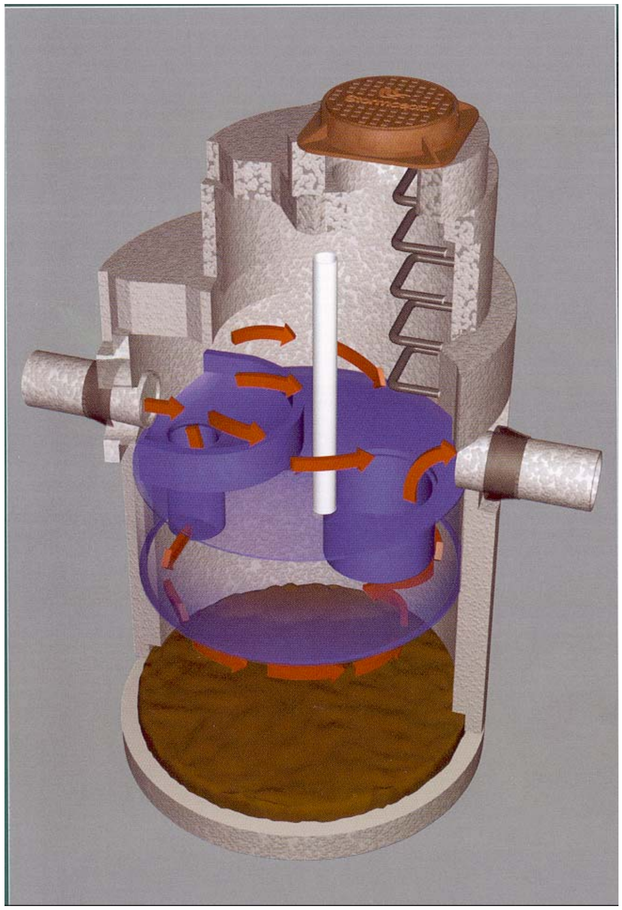


Figure 7.5 Engineered Cylindrical Sedimentation

Courtesy Rinker Materials

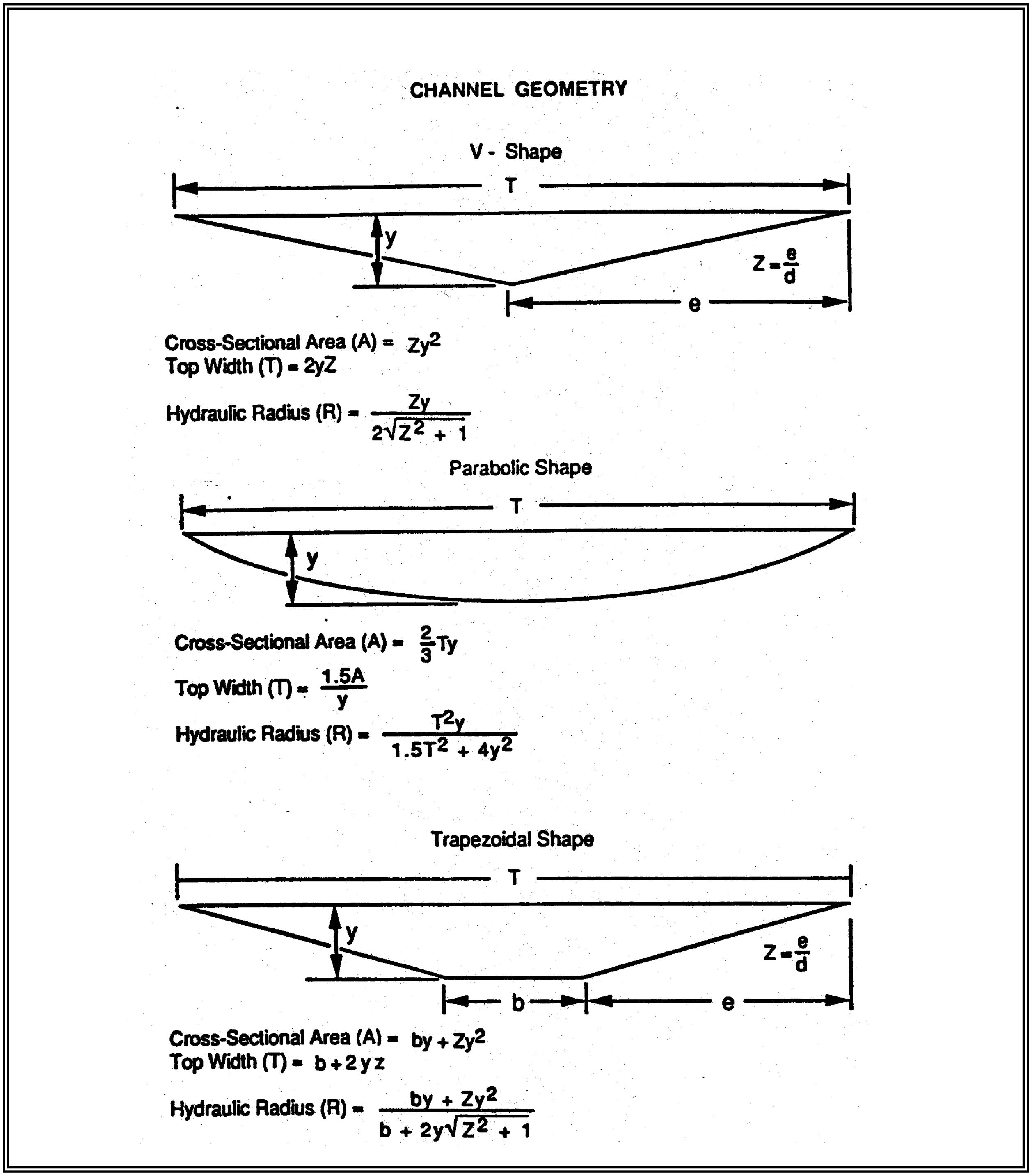


Figure 7.6 Geometric Formulas for Common Swale Shapes

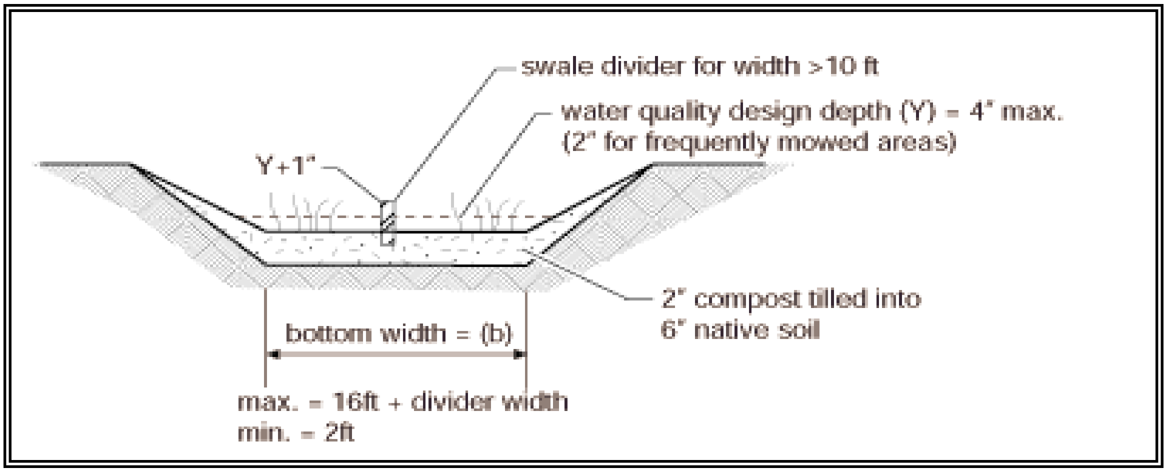


Figure 7.7 Typical Swale Section

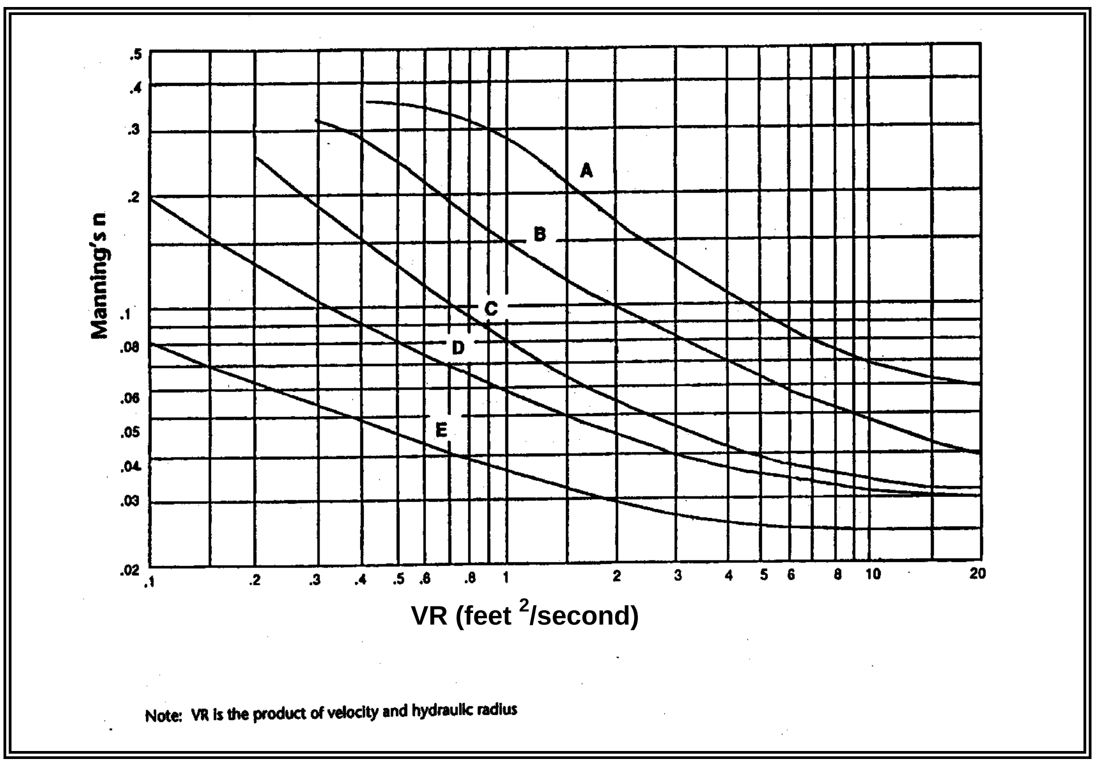


Figure 7.8 Relationship of Manning's n with VR for Degrees of Flow Retardance A-E

(*Source: Livingston, et al, 1984)*

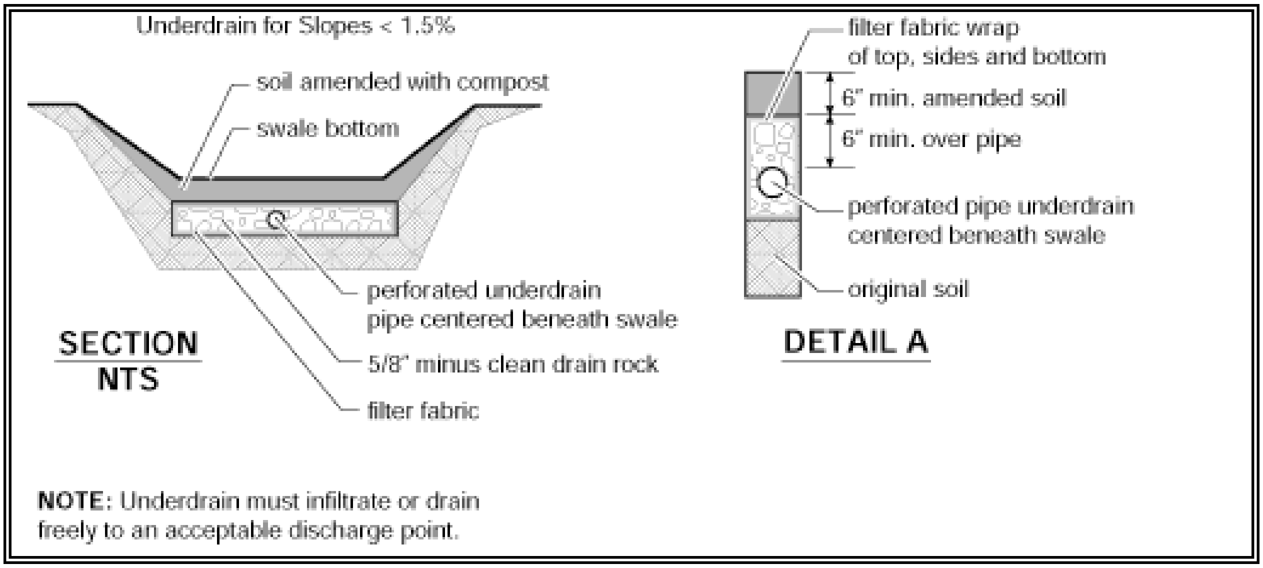


Figure 7.9 Biofiltration Swale Underdrain Detail

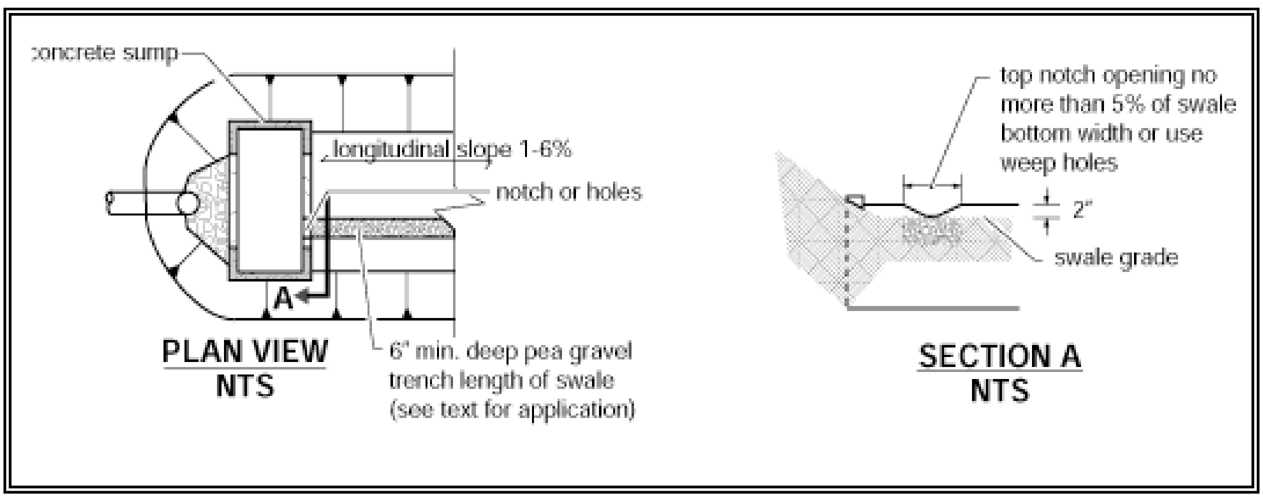
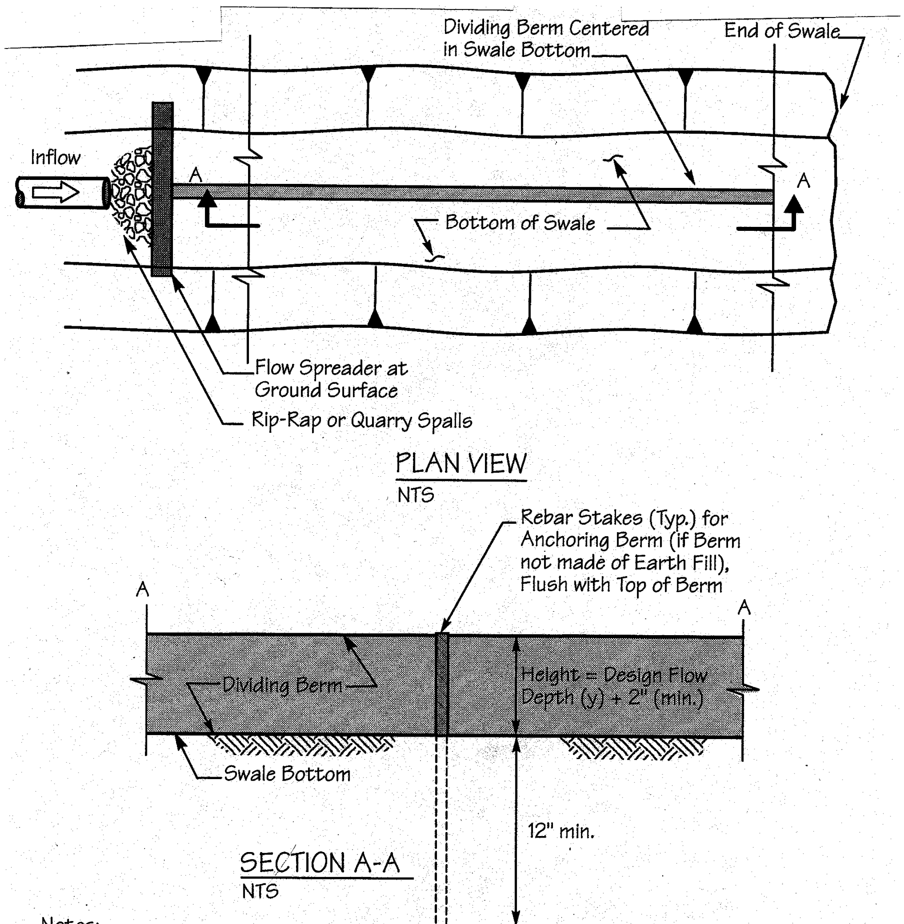


Figure 7.10 Biofiltration Swale Low-Flow Drain Detail



Notes:

1. Berm may be Made of Compacted Earthfill (seeded with grass), Timber, Concrete Plastic, or Similar Weather - Resistant Non - Erodible Material.
2. Rebar Stakes or Similar Berm Anchoring Materials Needed if Berm Made of Timber, Plastic, or Concrete Curbing - Stake Placement Required at Both Ends of Each Individual Member (at a minimum).

Figure 7.11 Swale Dividing Berm

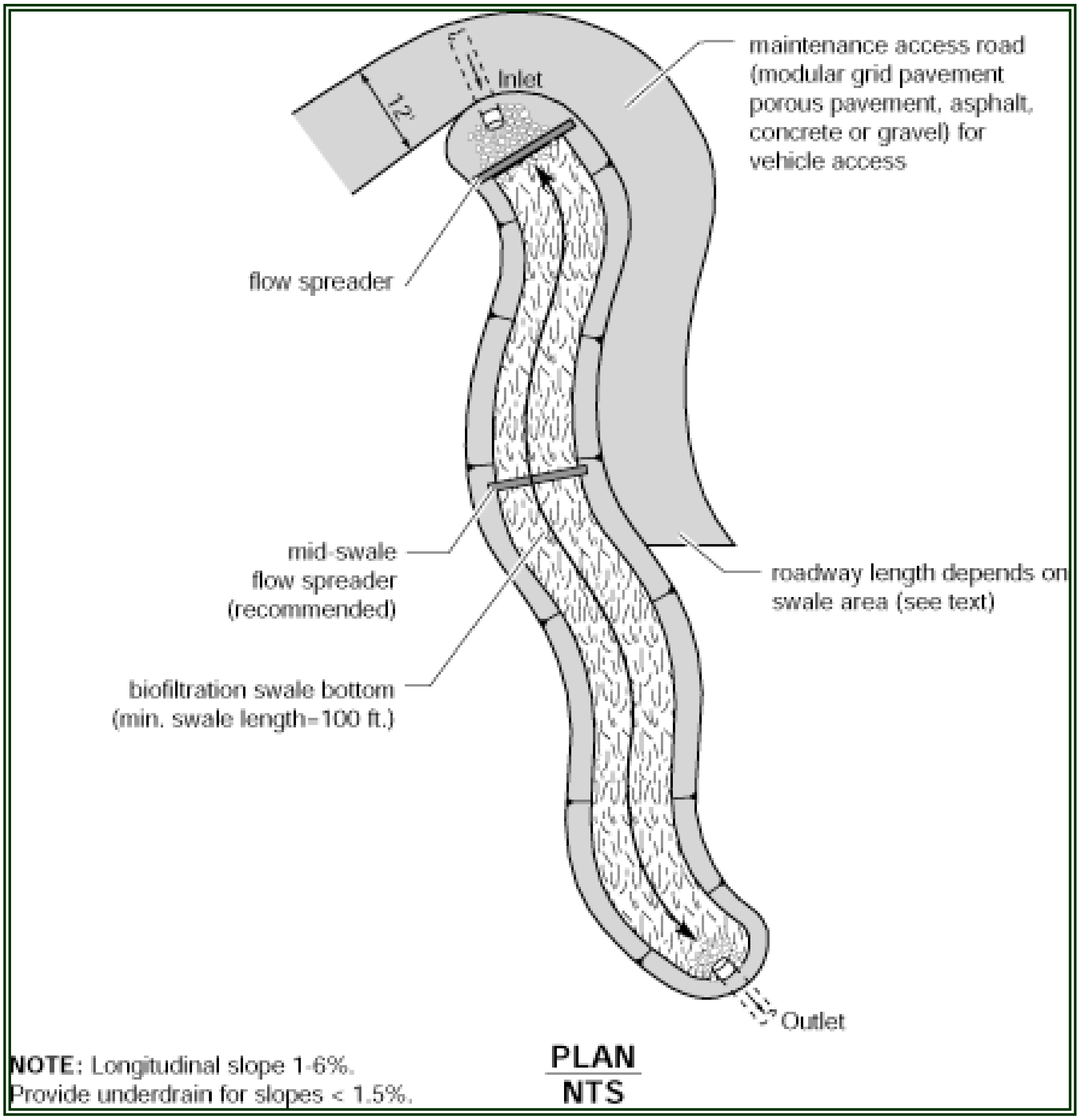


Figure 7.12 Typical Bioswale Maintenance Access

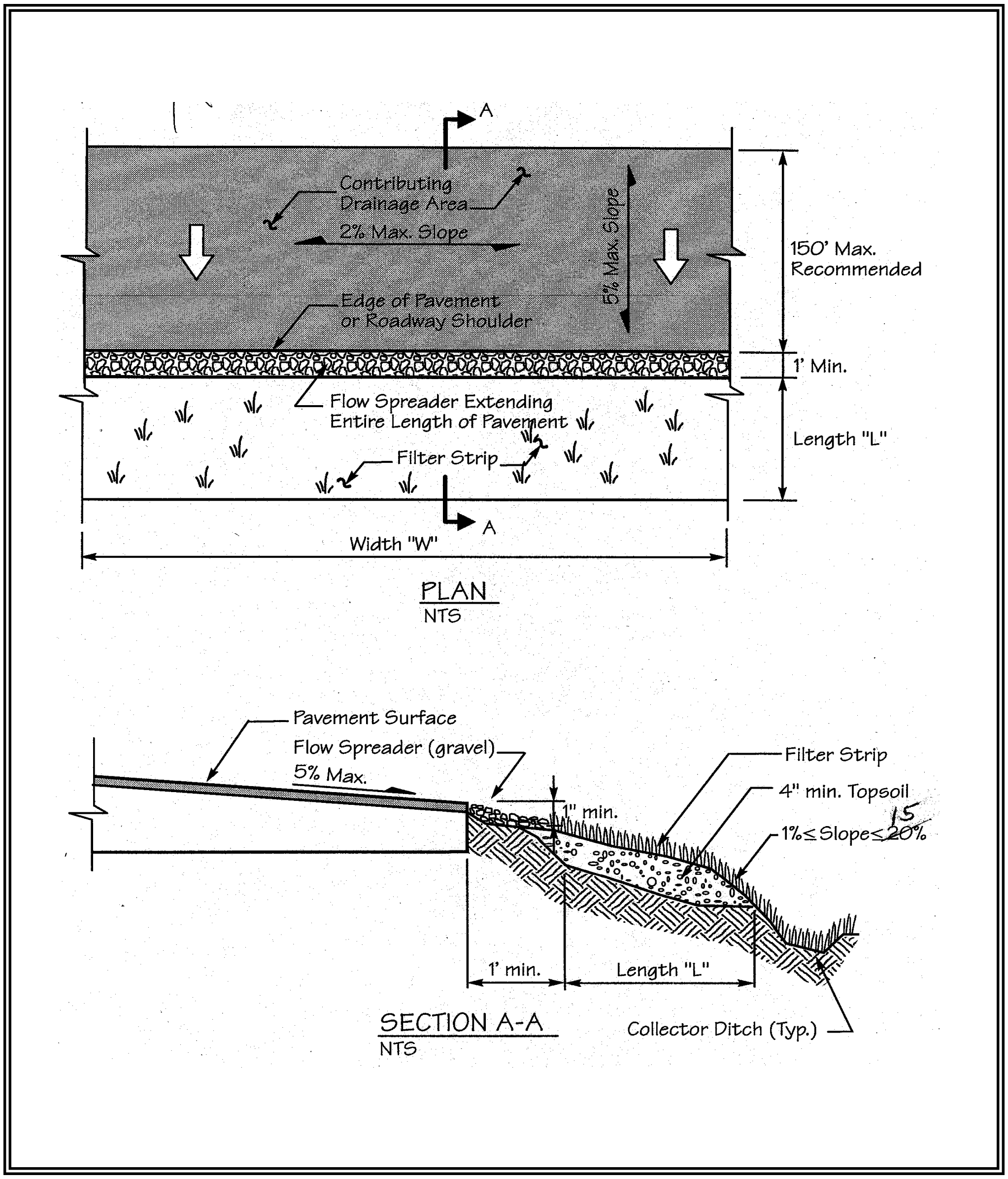
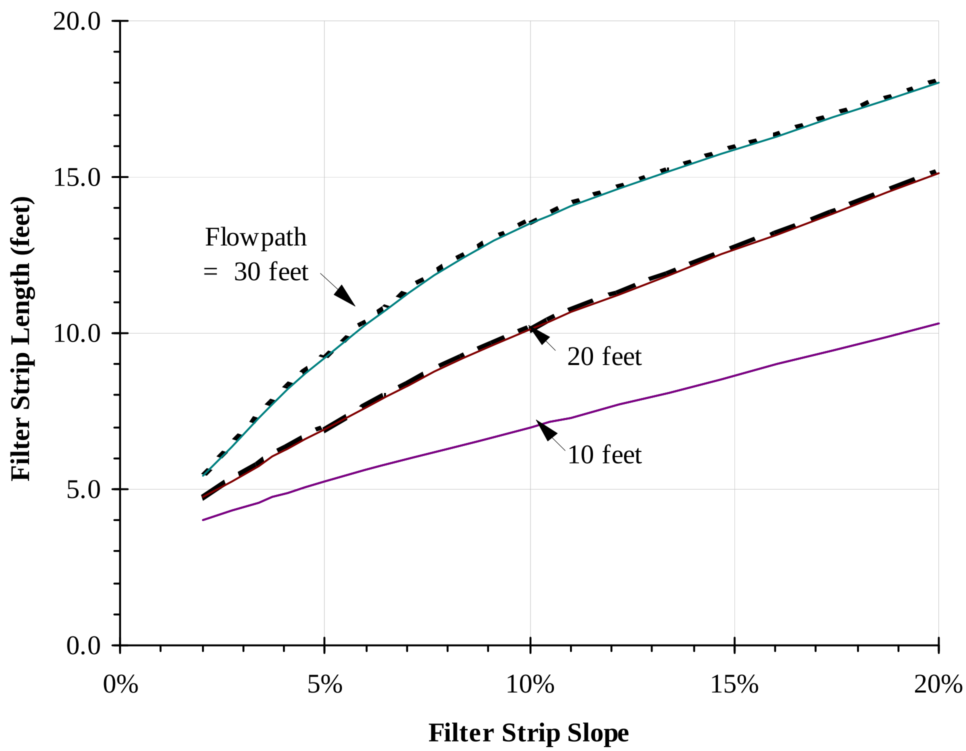


Figure 7.13 Typical Filter Strip



Note: minimum allowable filter strip length is 4 feet

Figure 7.14 Filter Strip Lengths for Narrow Right-of-Way

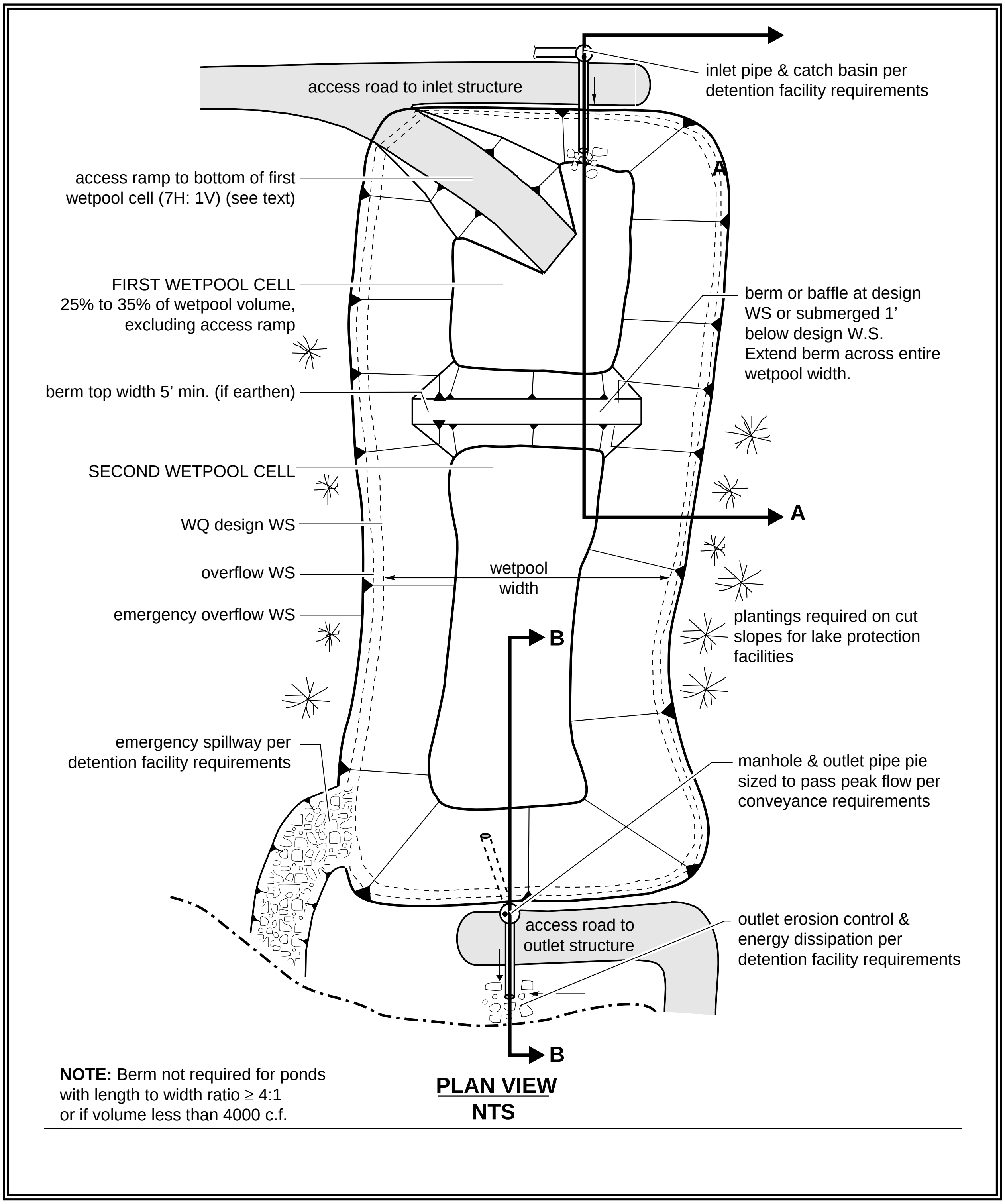


Figure 7.15a   Wetpond, Plan View

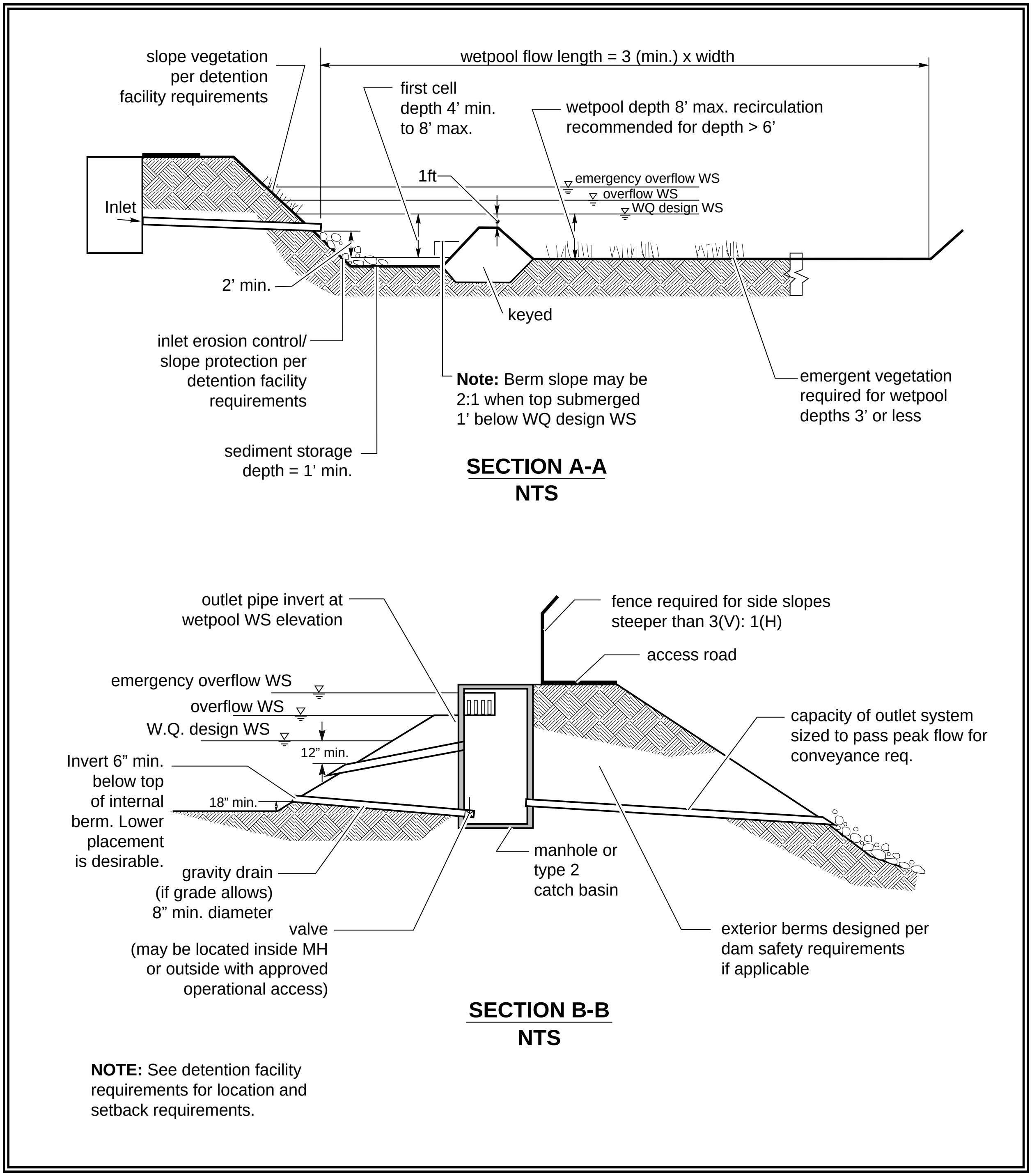


Figure 7.15b Wetpond, Section Views

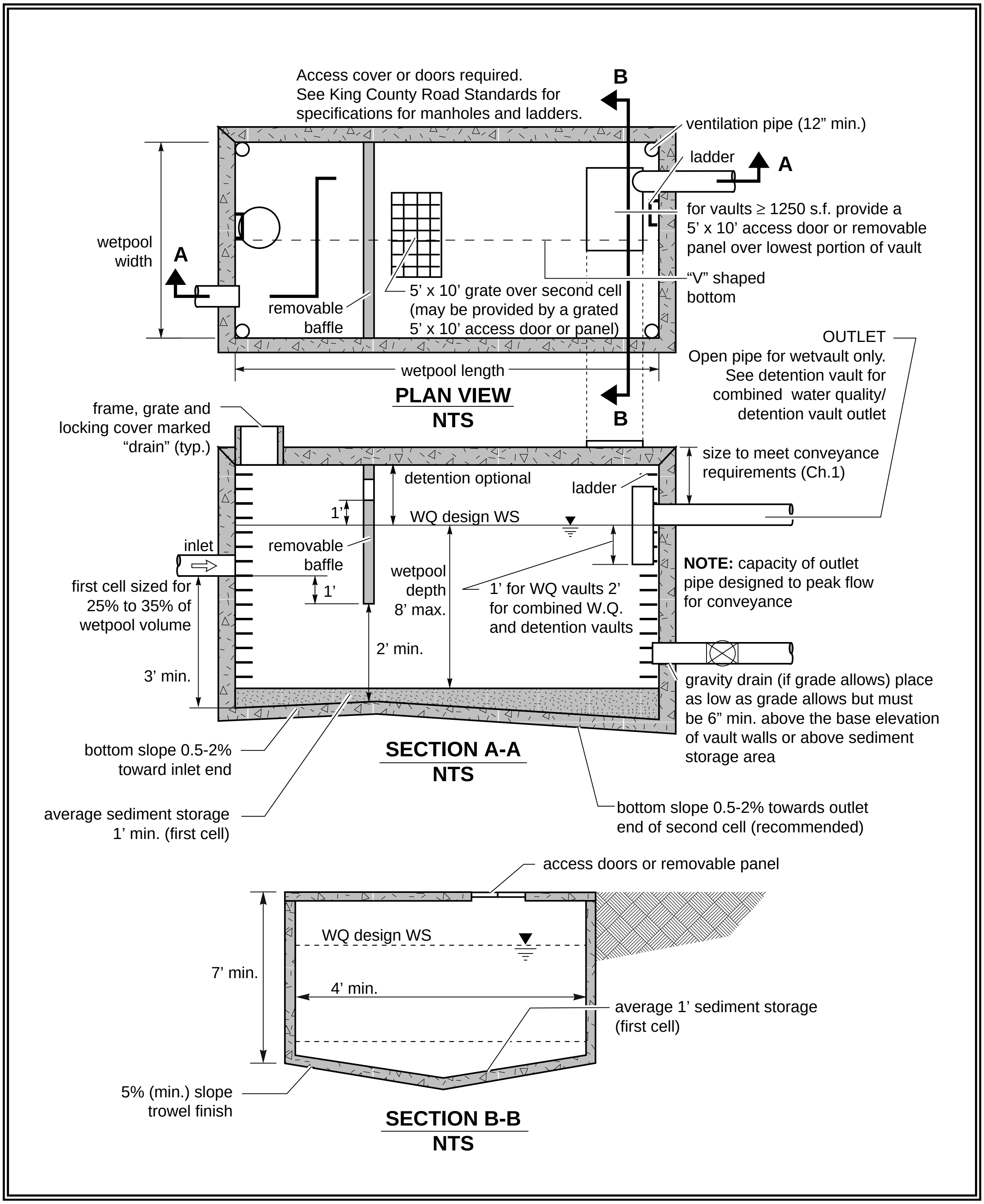


Figure 7.16 Wetvault

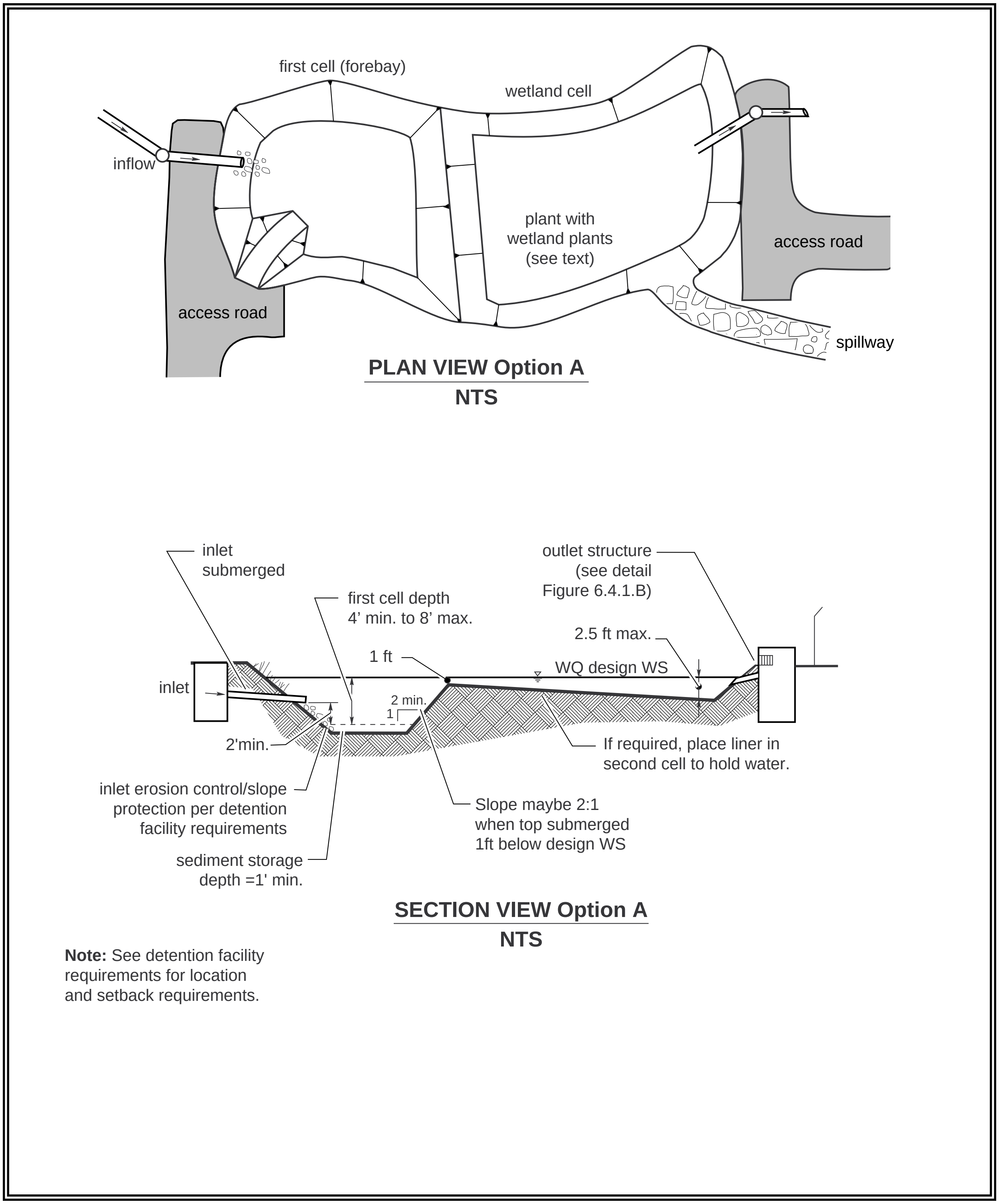


Figure 7.17 Stormwater Wetland — Option One

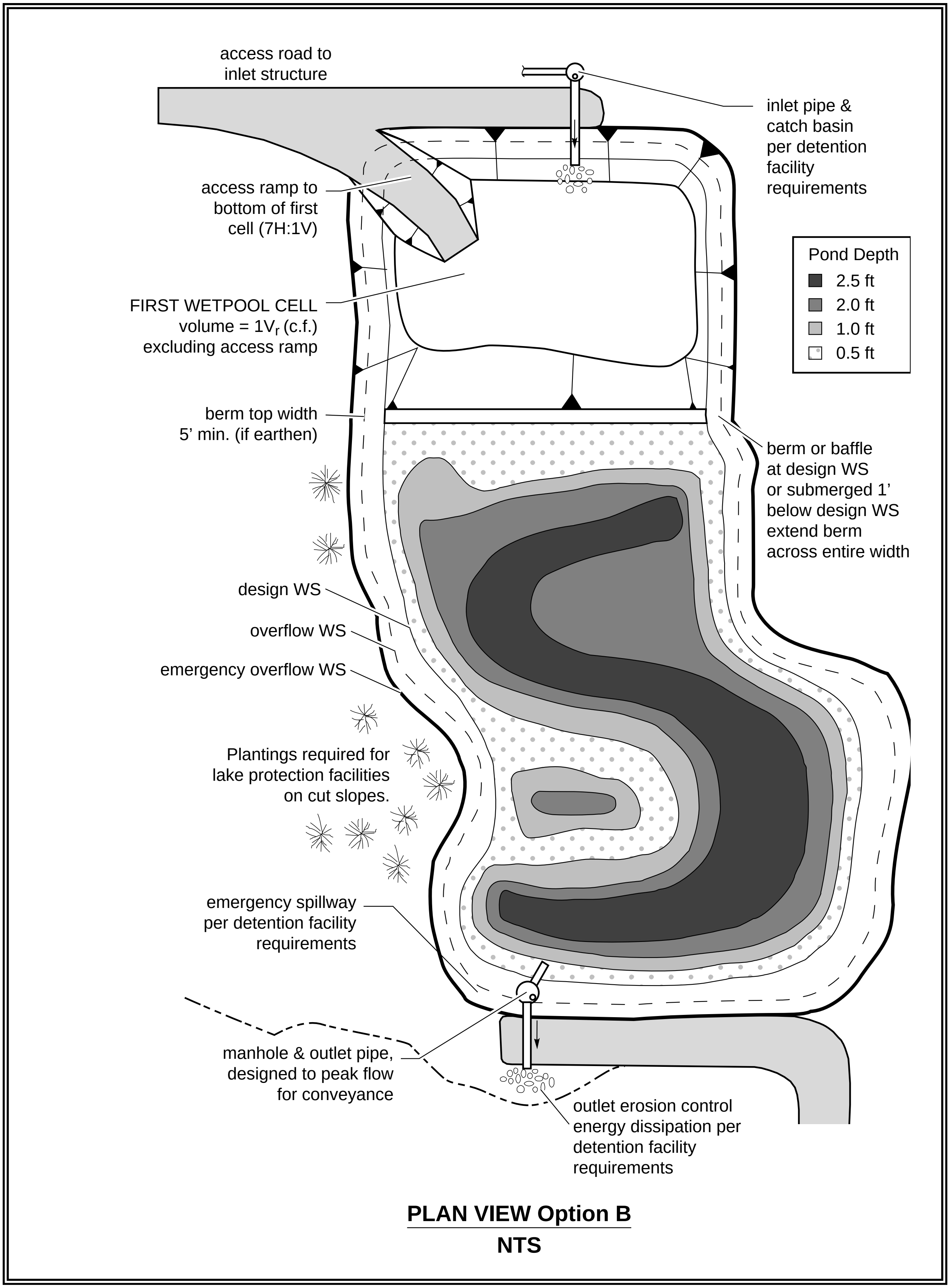


Figure 7.18 Stormwater Wetland — Option Two

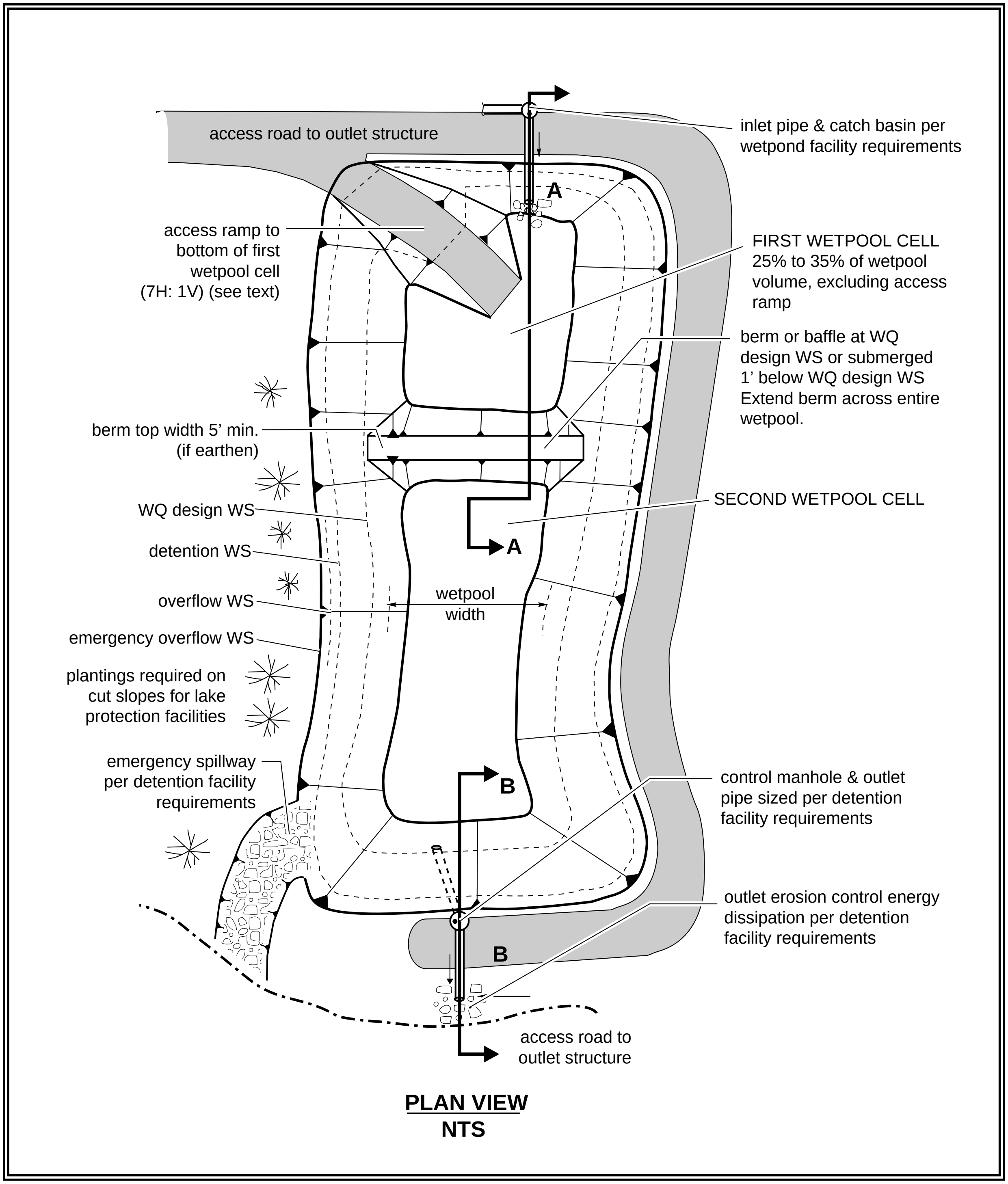


Figure 7.19a Combined Detention and Wetpond

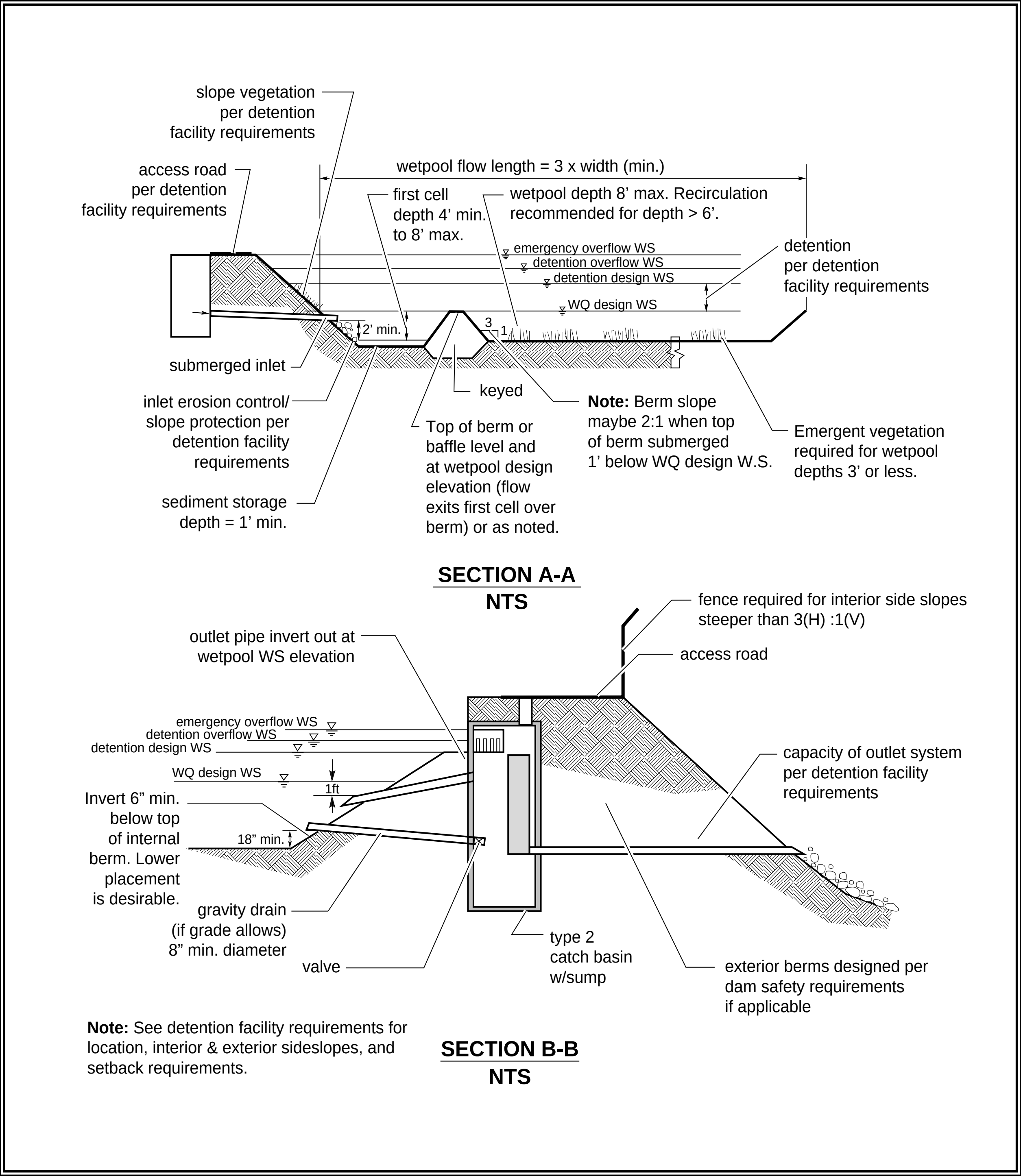
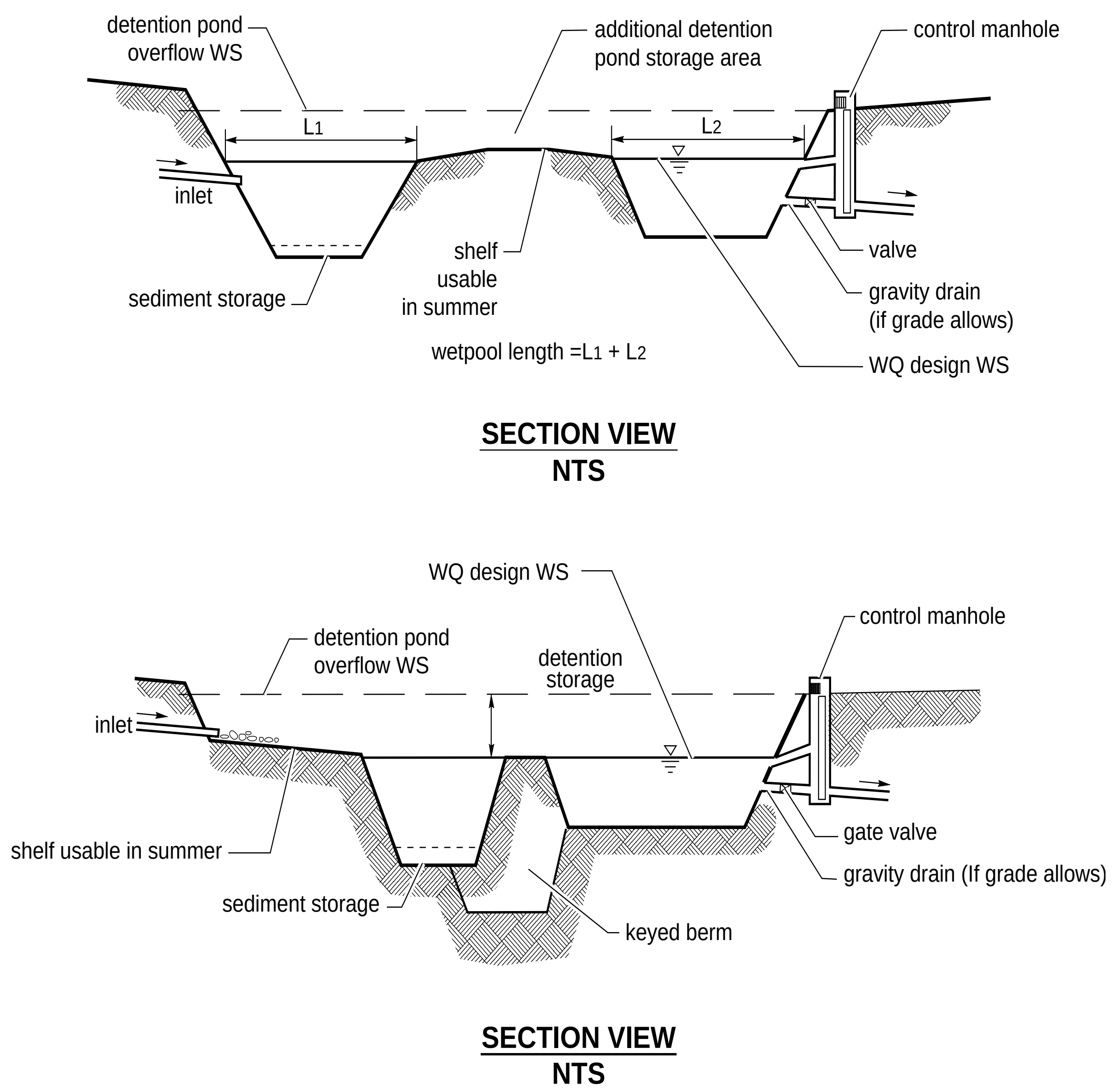


Figure 7.19b Combined Detention and Wetpond (continued)



Note: These examples show how the combined detention/wetpool can be configured to allow for "shelves" for joint use opportunities in dry weather. Other options may also be acceptable.

Figure 7.20 Alternative Configurations of Detention and Wetpool Areas

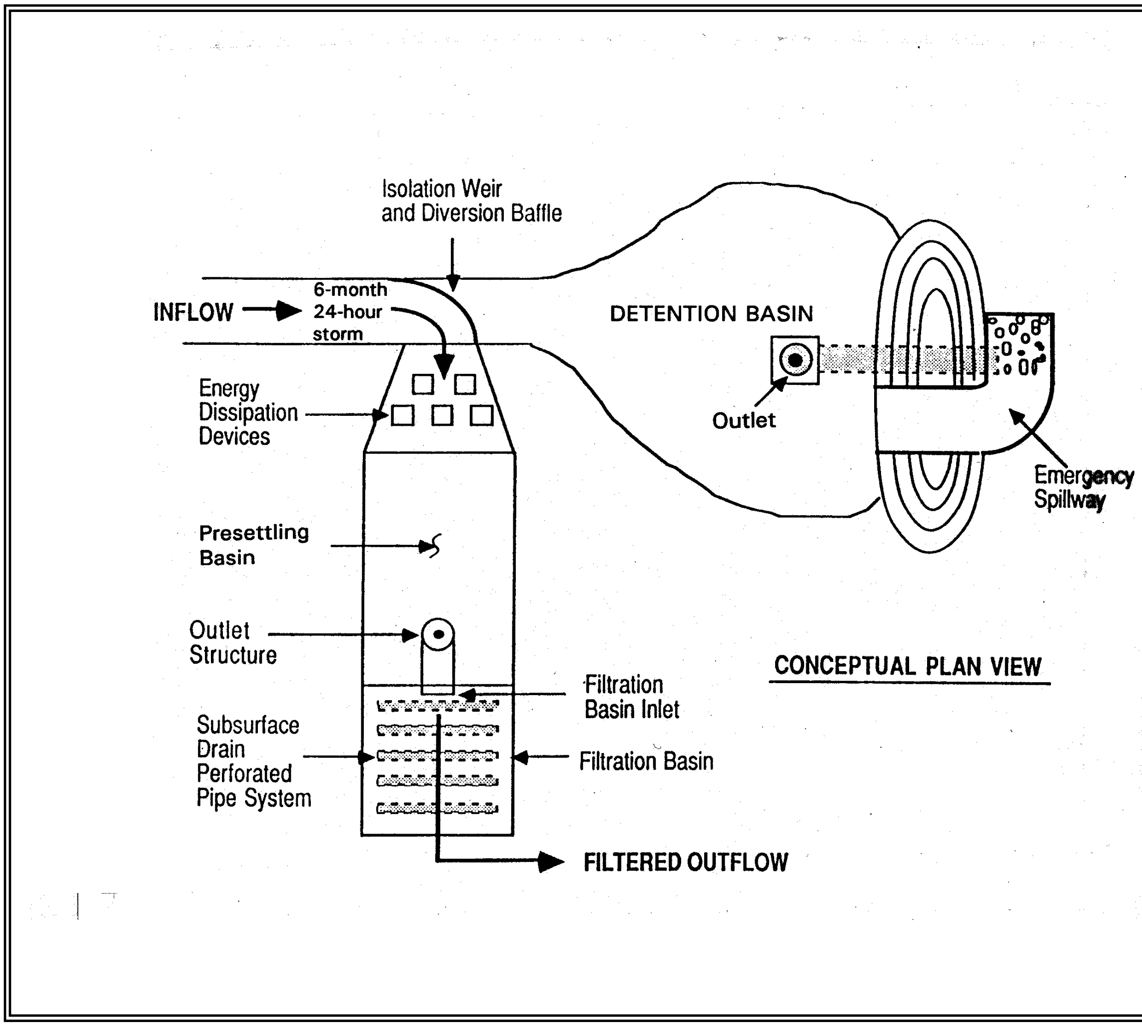


Figure 7.21 Basic Sand Filter with Pretreatment Cell

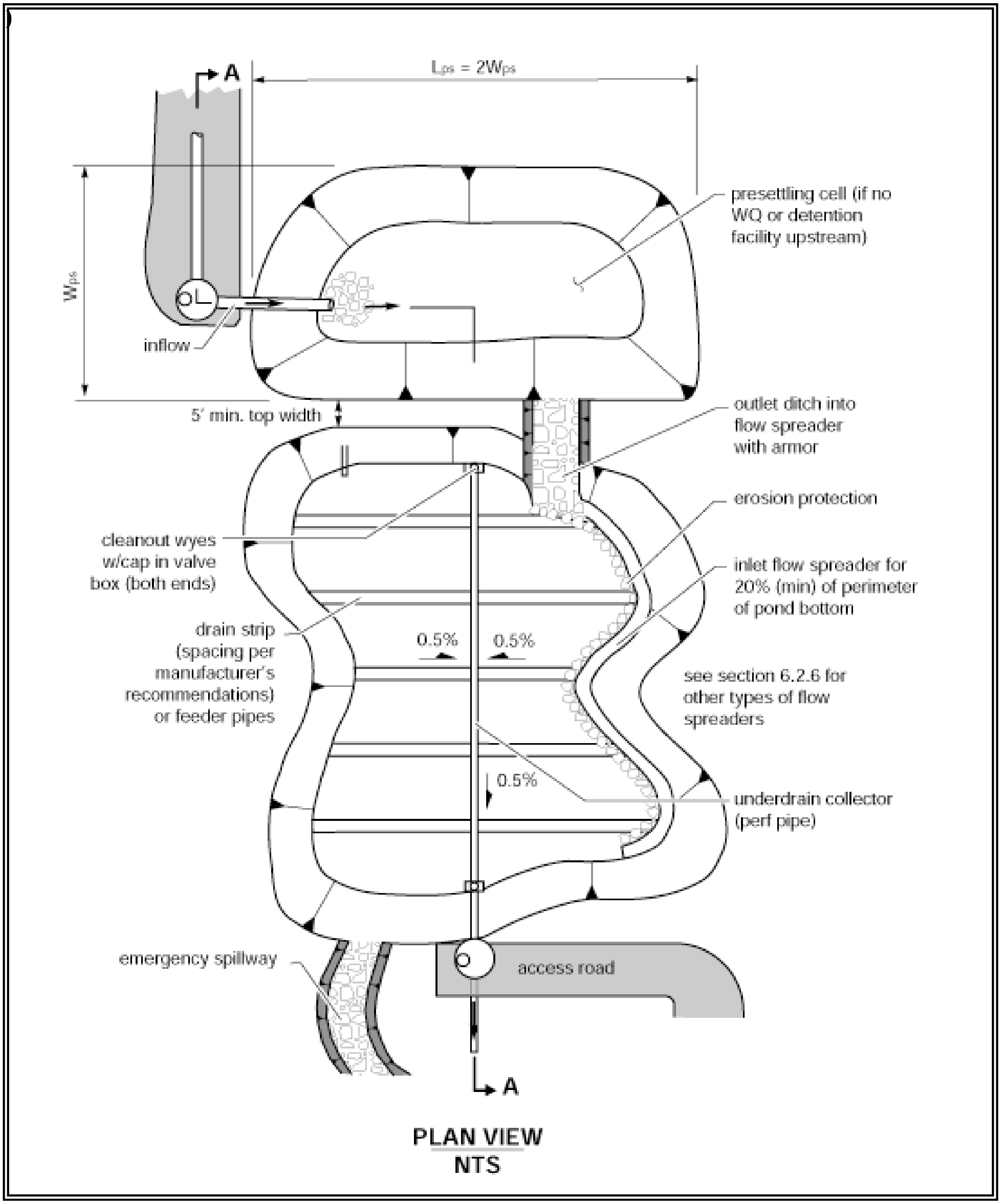


Figure 7.22 Sand Filtration Basin with Presettling Basin (Variation of a Basic Sand Filter)

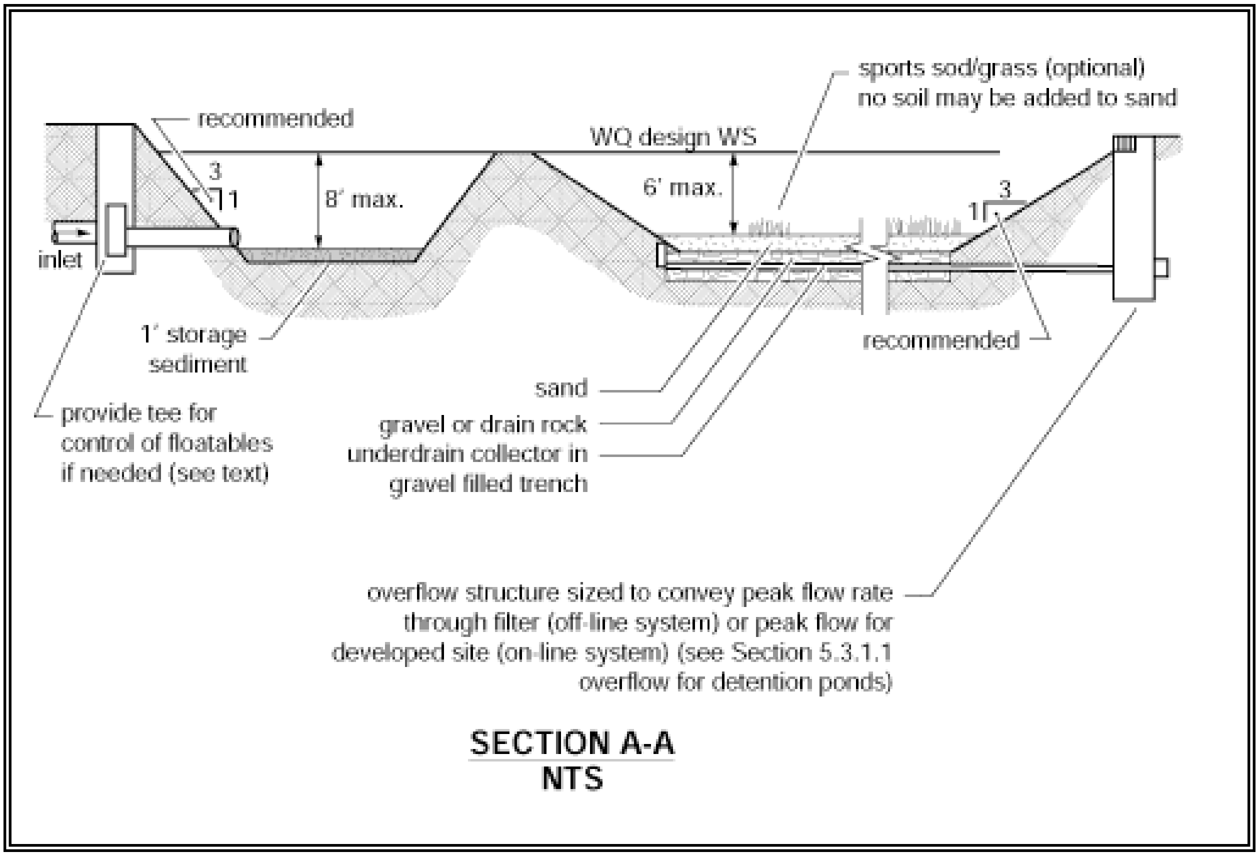


Figure 7.23 Sand Filter with Pretreatment Cell Section

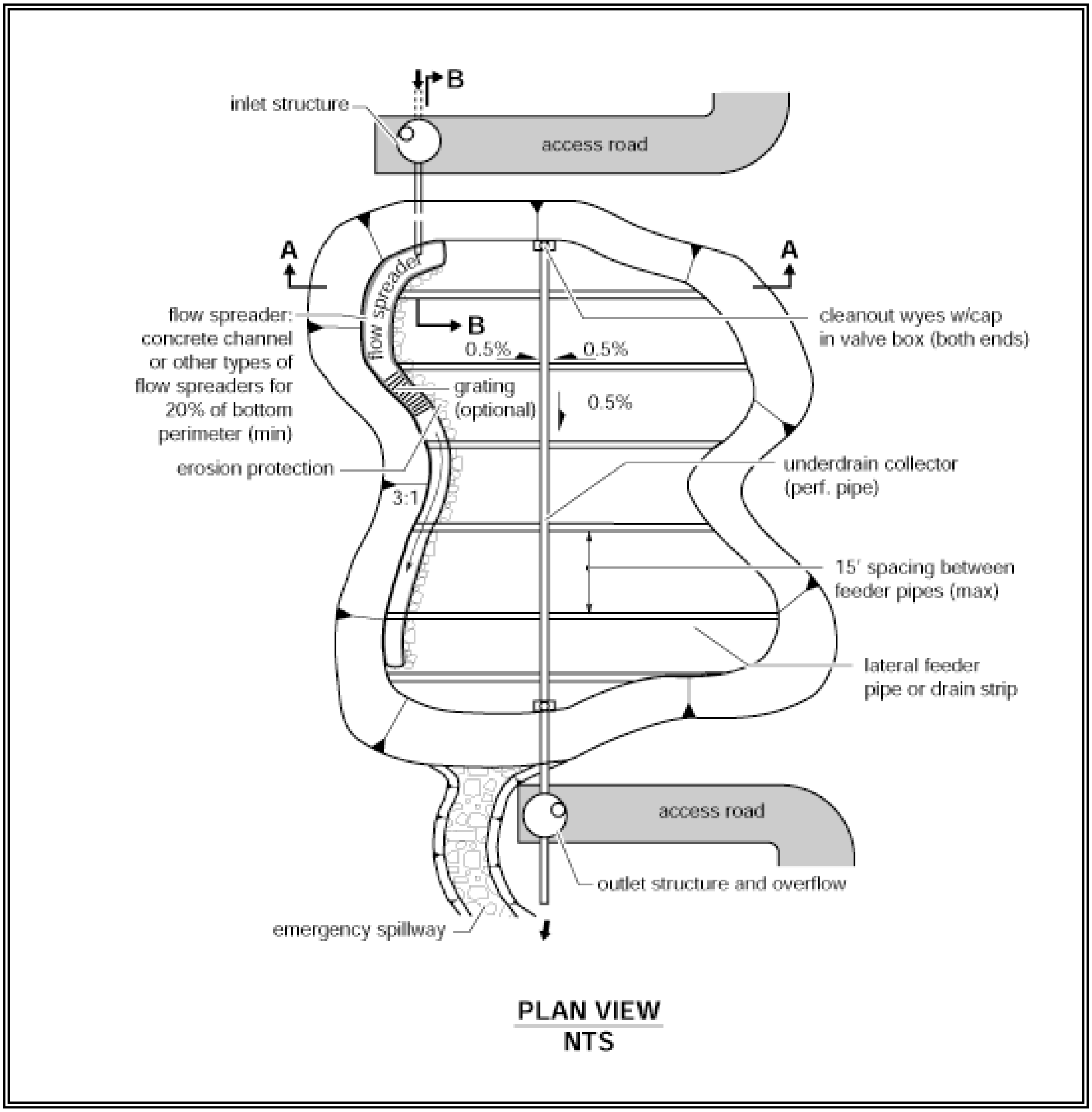


Figure 7.24 Sand Filter with Level Spreader

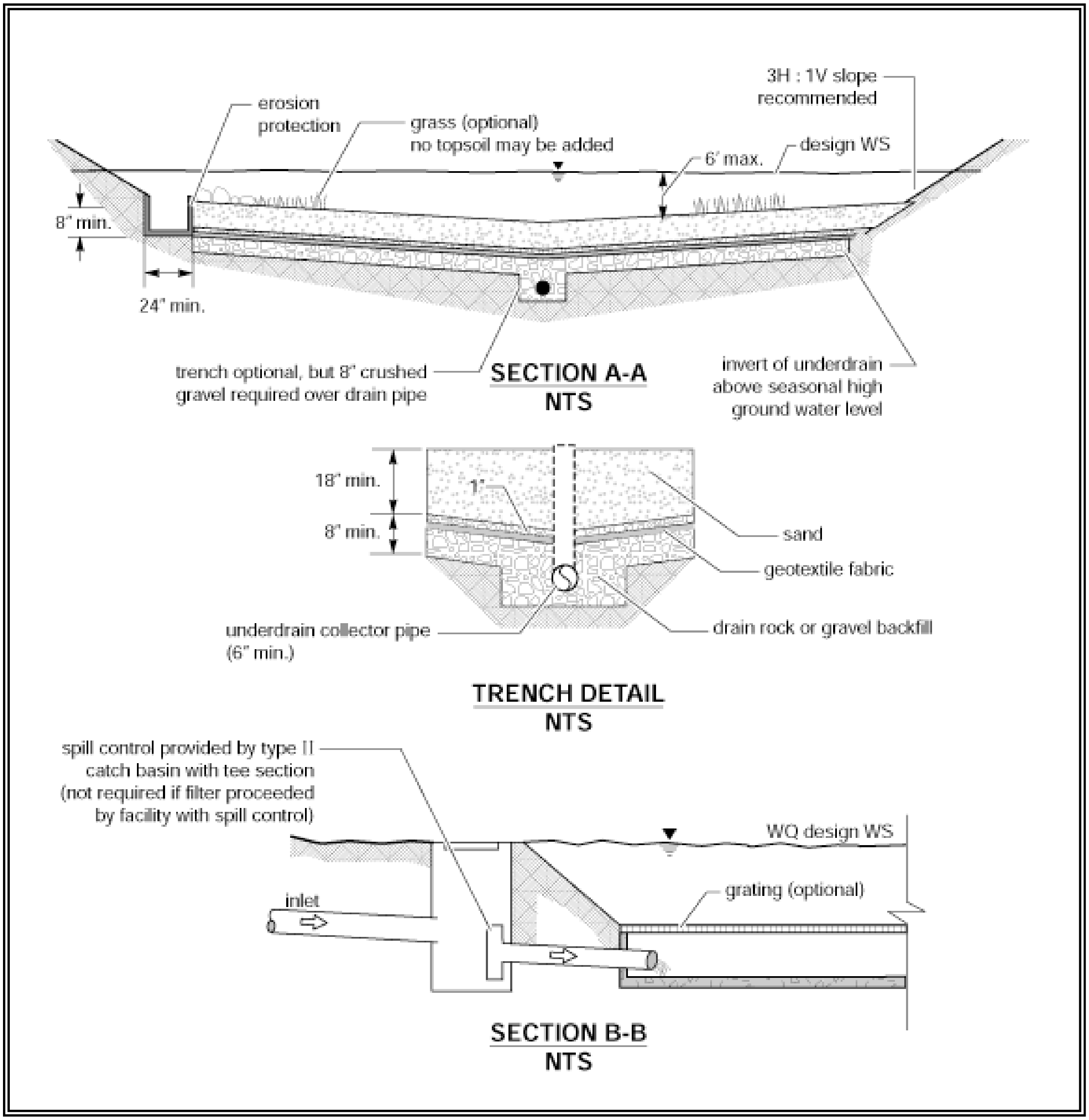


Figure 7.25 Sand Filter with Level Spreader Details

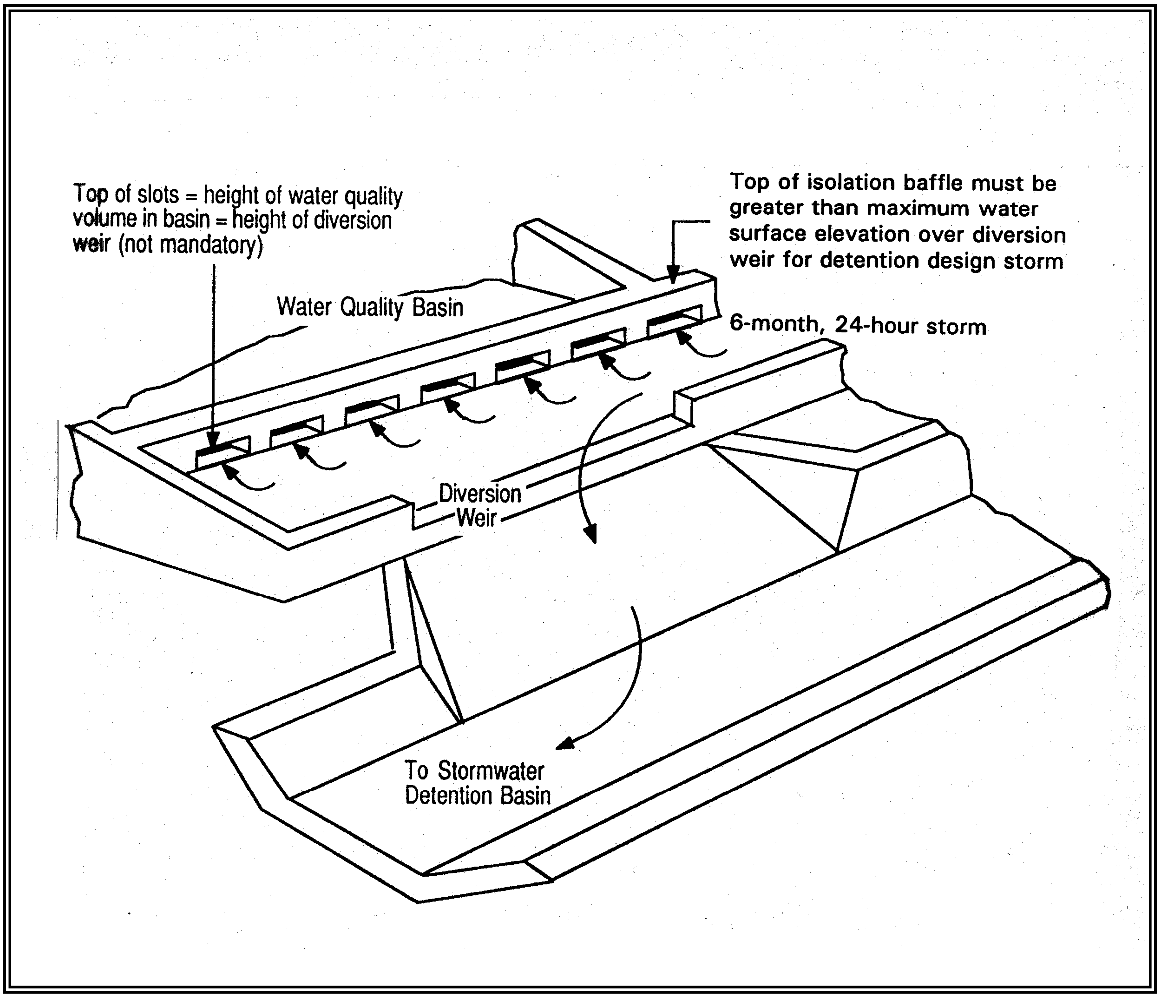


Figure 7.26 Example Isolation/Diversion Structure
(Source: City of Austin)

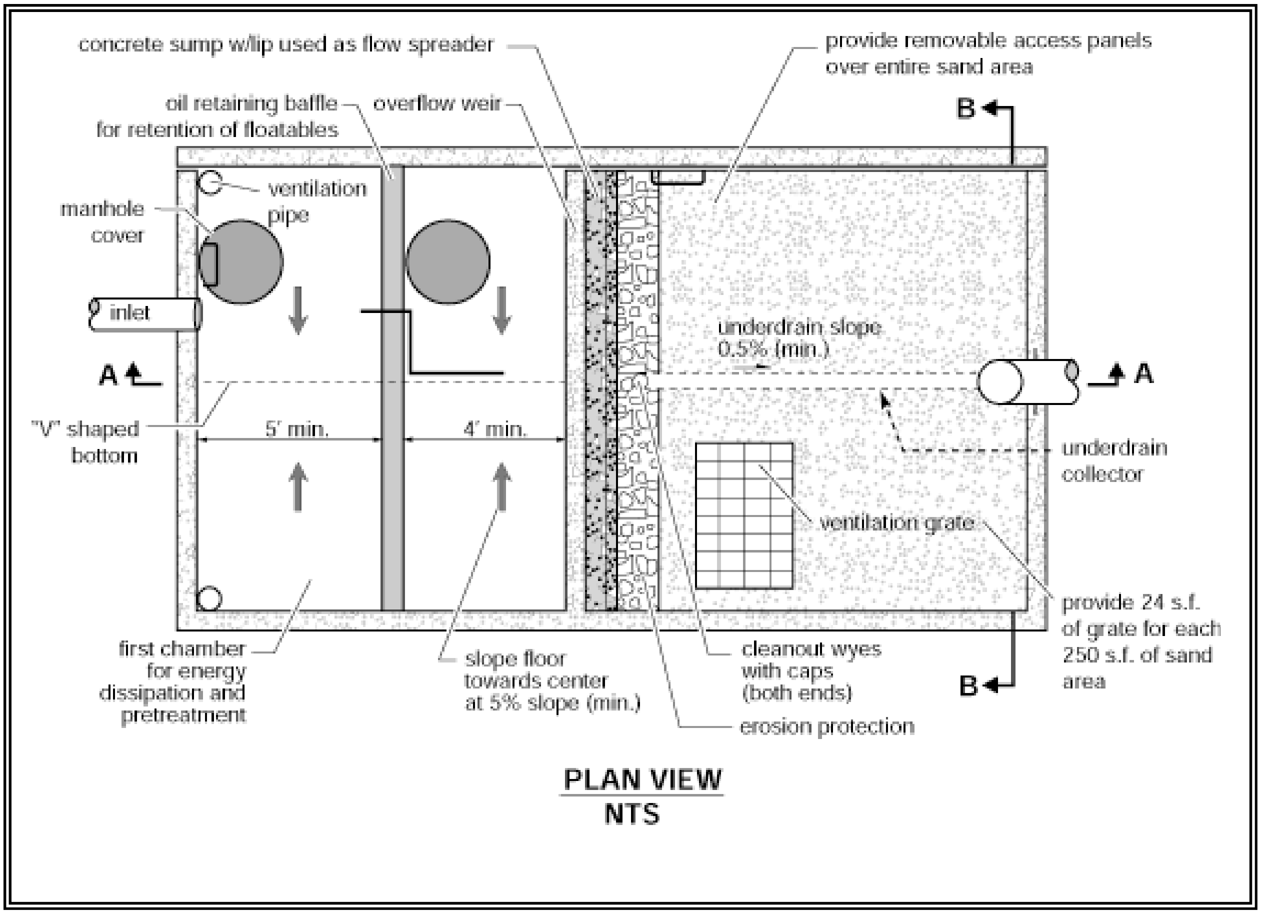


Figure 7.27a Sand Filter Vault

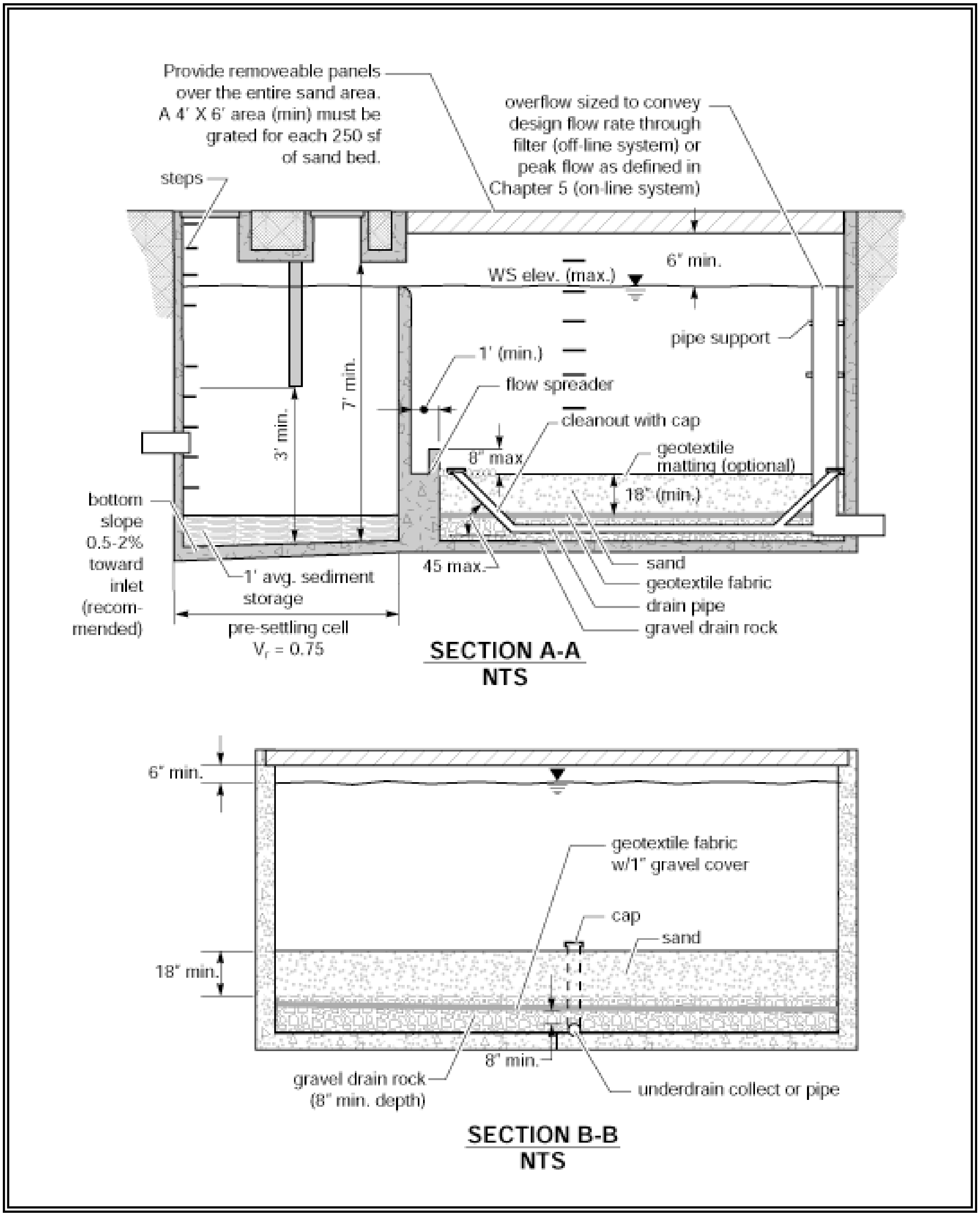


Figure 7.27b Sand Filter Vault (continued)

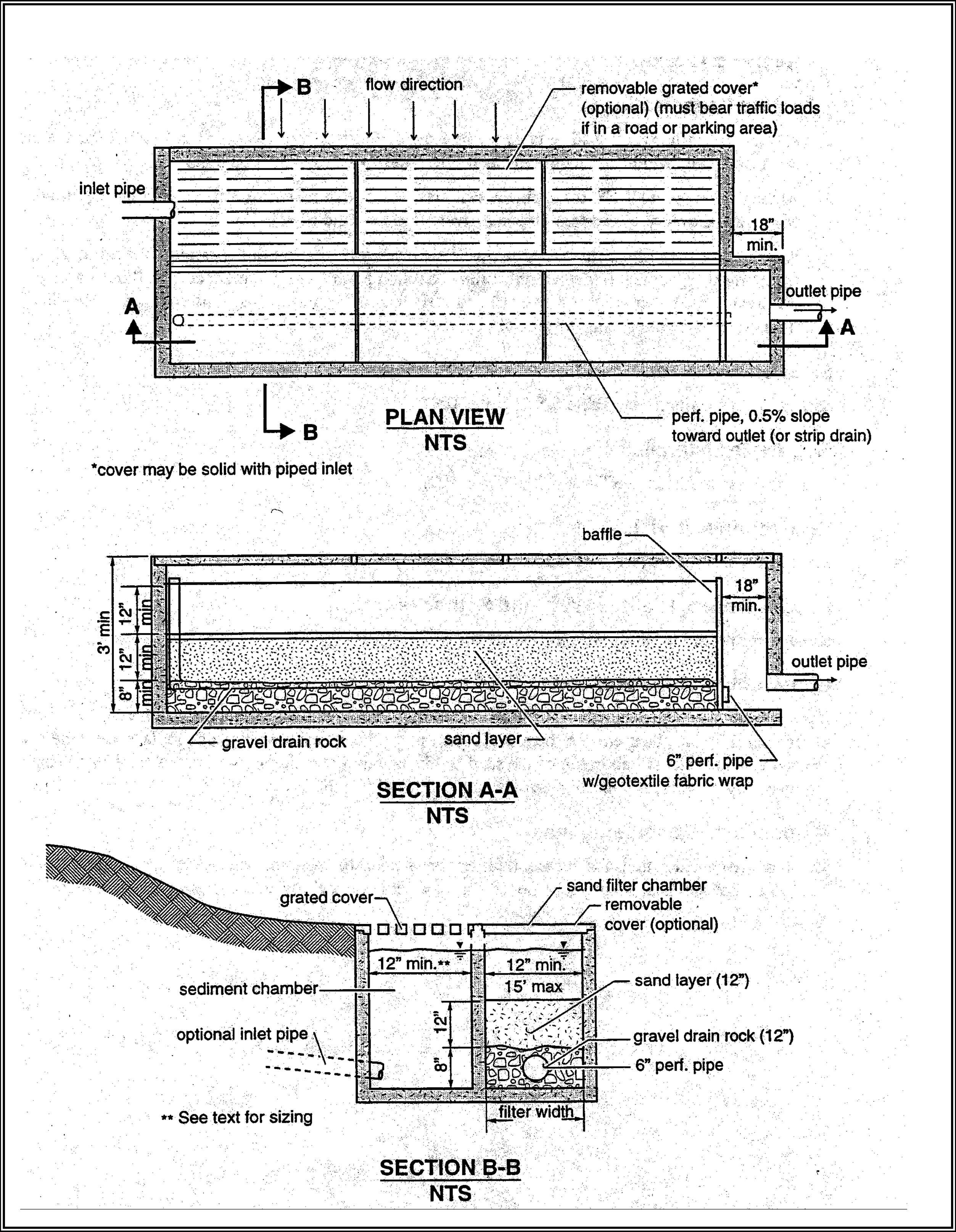


Figure 7.28 Linear Sand Filter

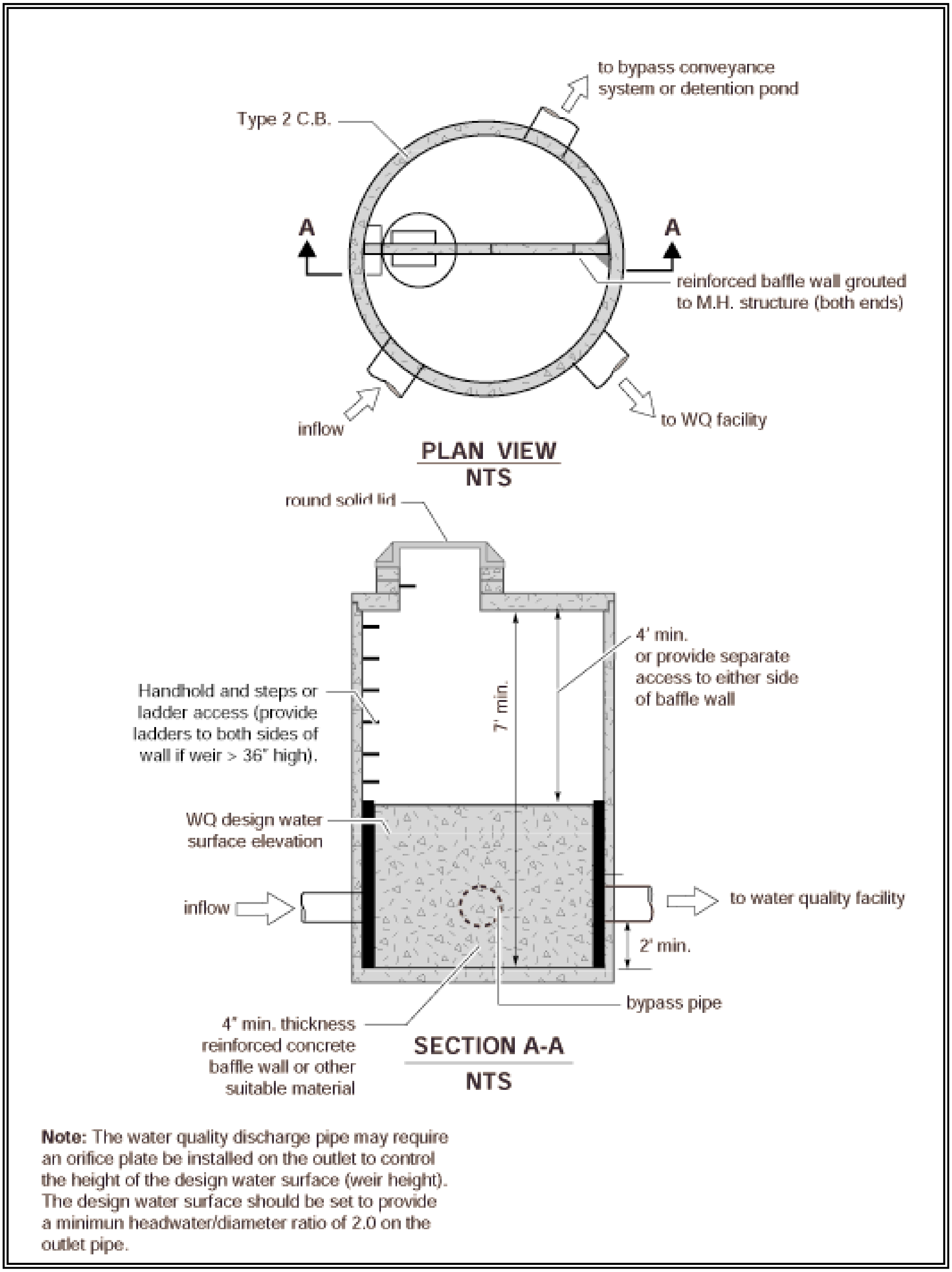


Figure 7.29 Flow Splitter Option A

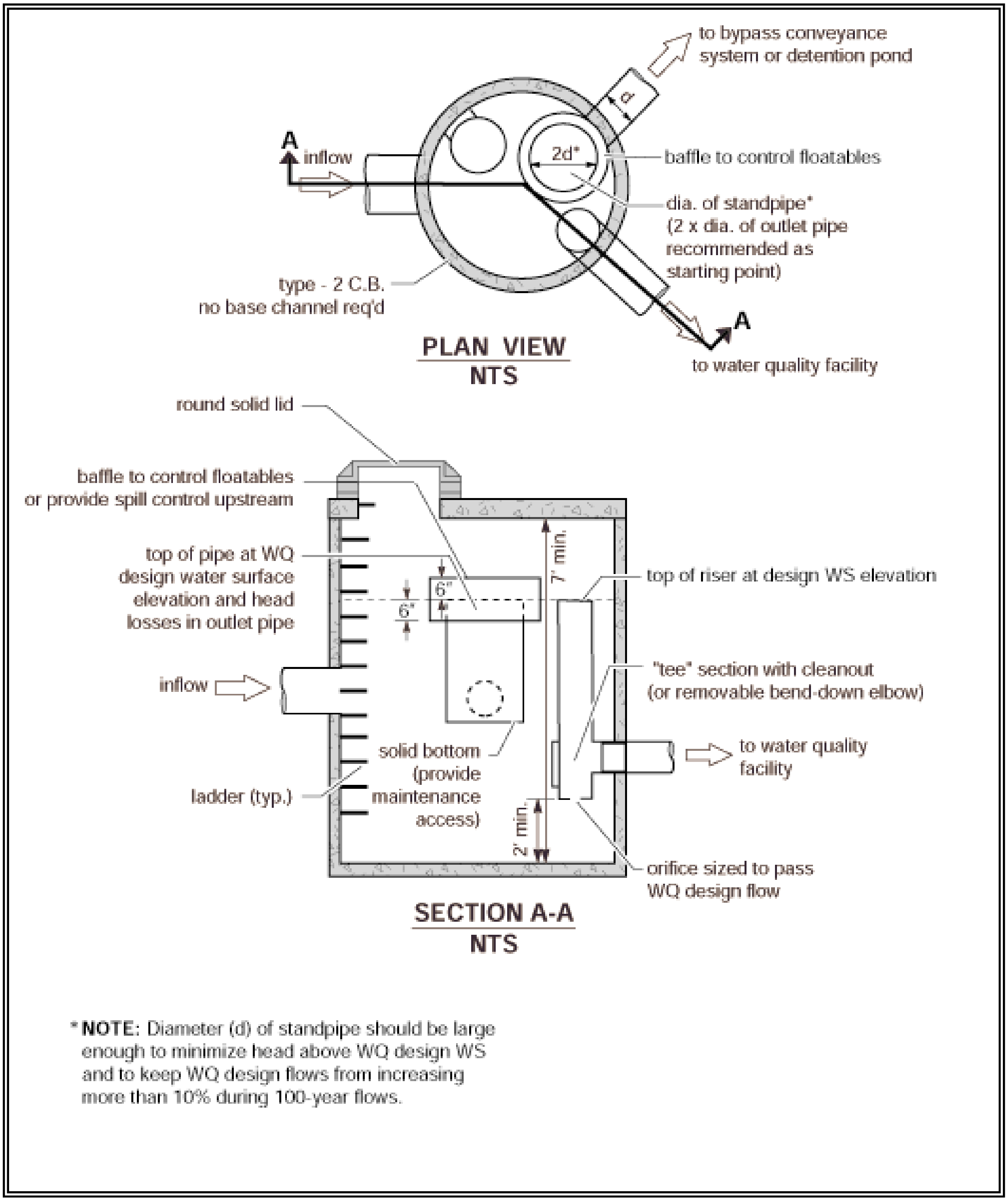


Figure 7.30 Flow Splitter Option B

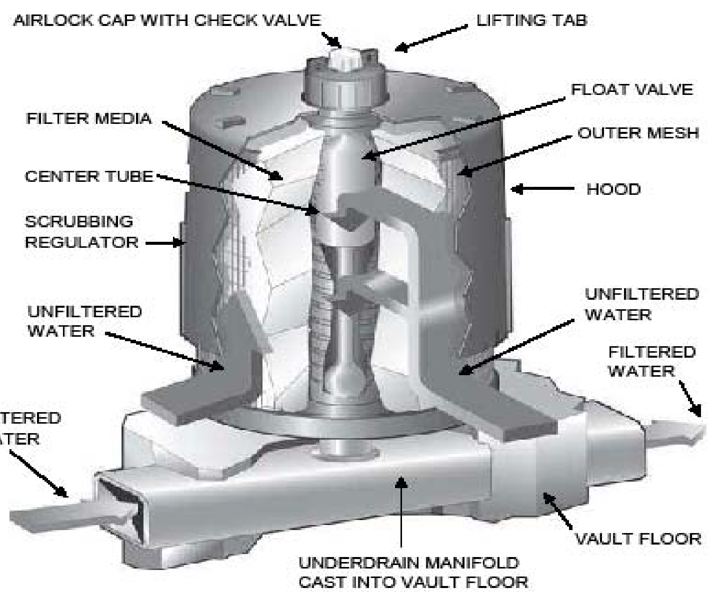


Figure 7.31 StormFilter Media Filter (courtesy of Contech Construction Products, Inc)

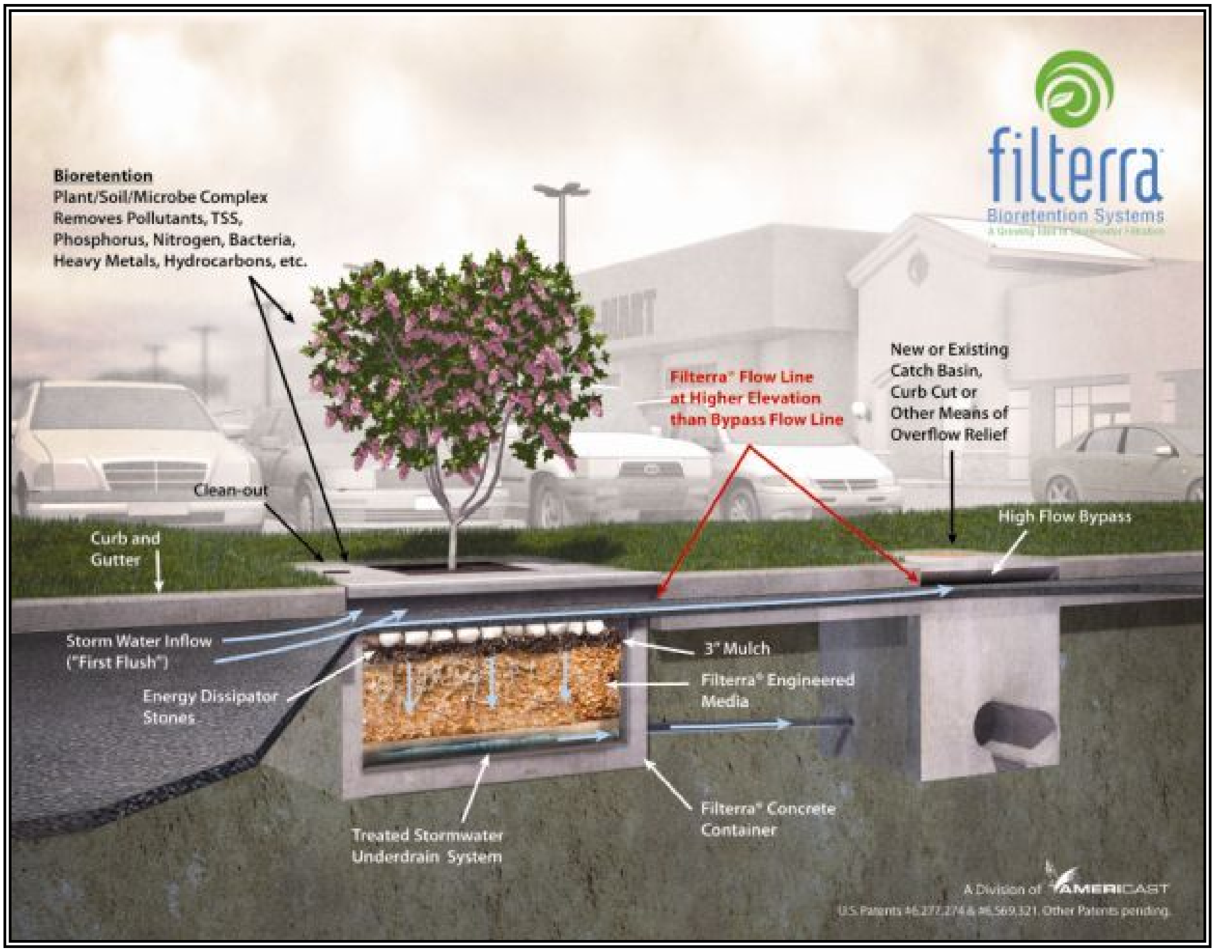


Figure 7.32 Filterra Bioretention System *(courtesy of Filterra, Inc)*

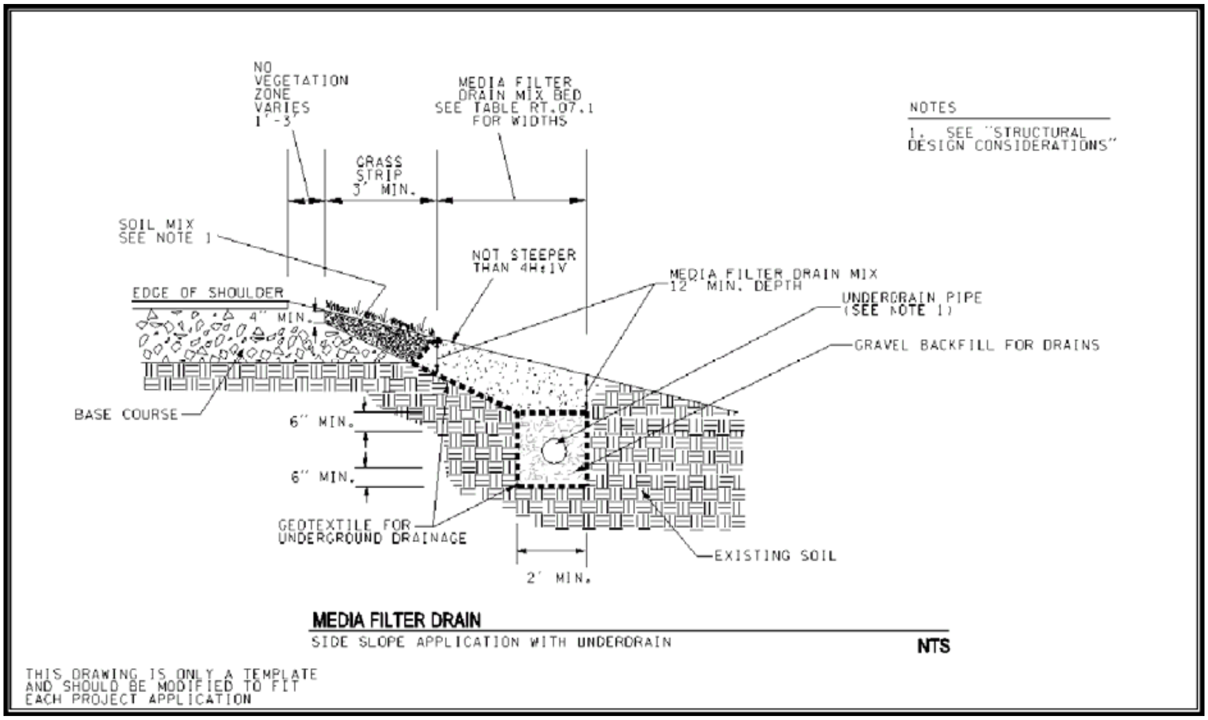


Figure 7.33. Media Filter Drain: Side Slope Application with Underdrain.

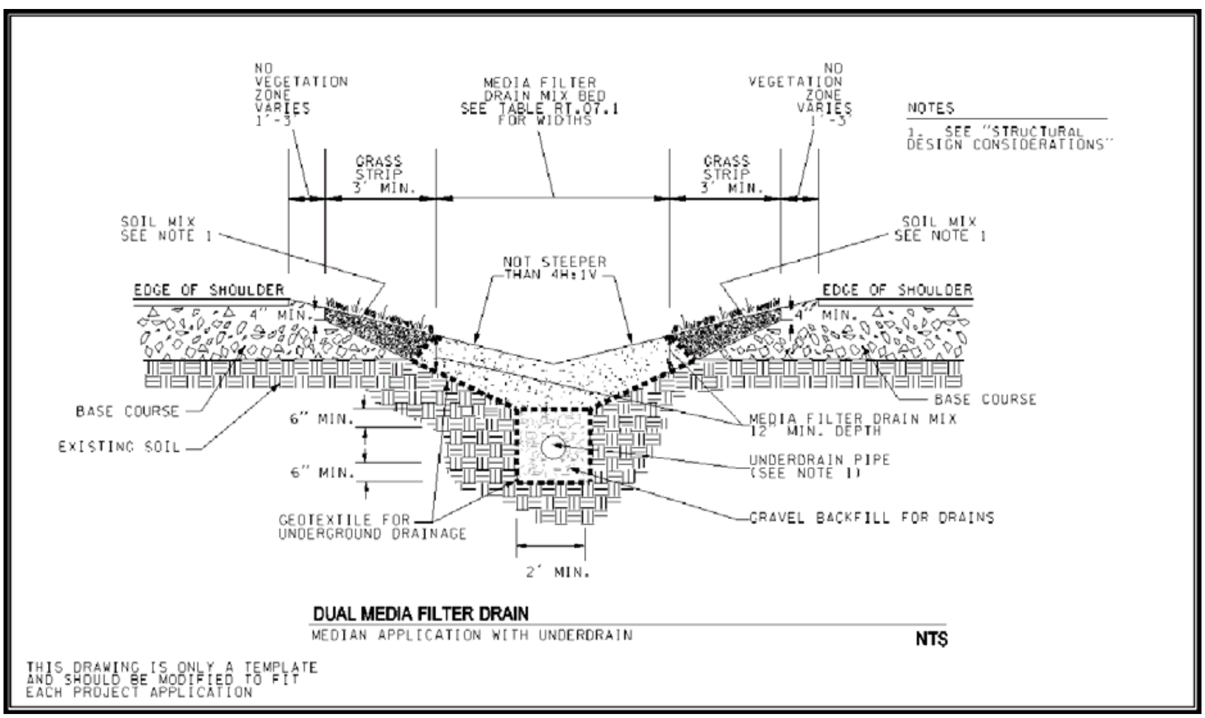


Figure 7.34. Dual Media Filter Drain: Median Application with Underdrain.

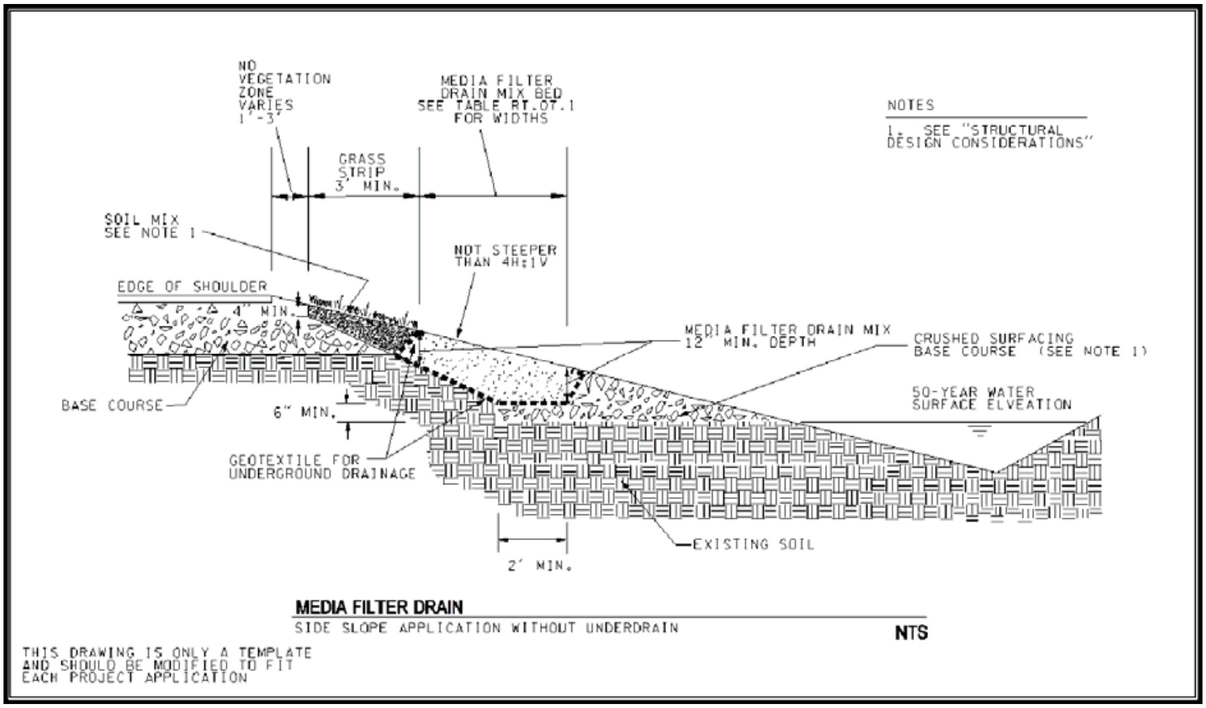


Figure 7.35. Media Filter Drain: Side Slope Application without Underdrain.

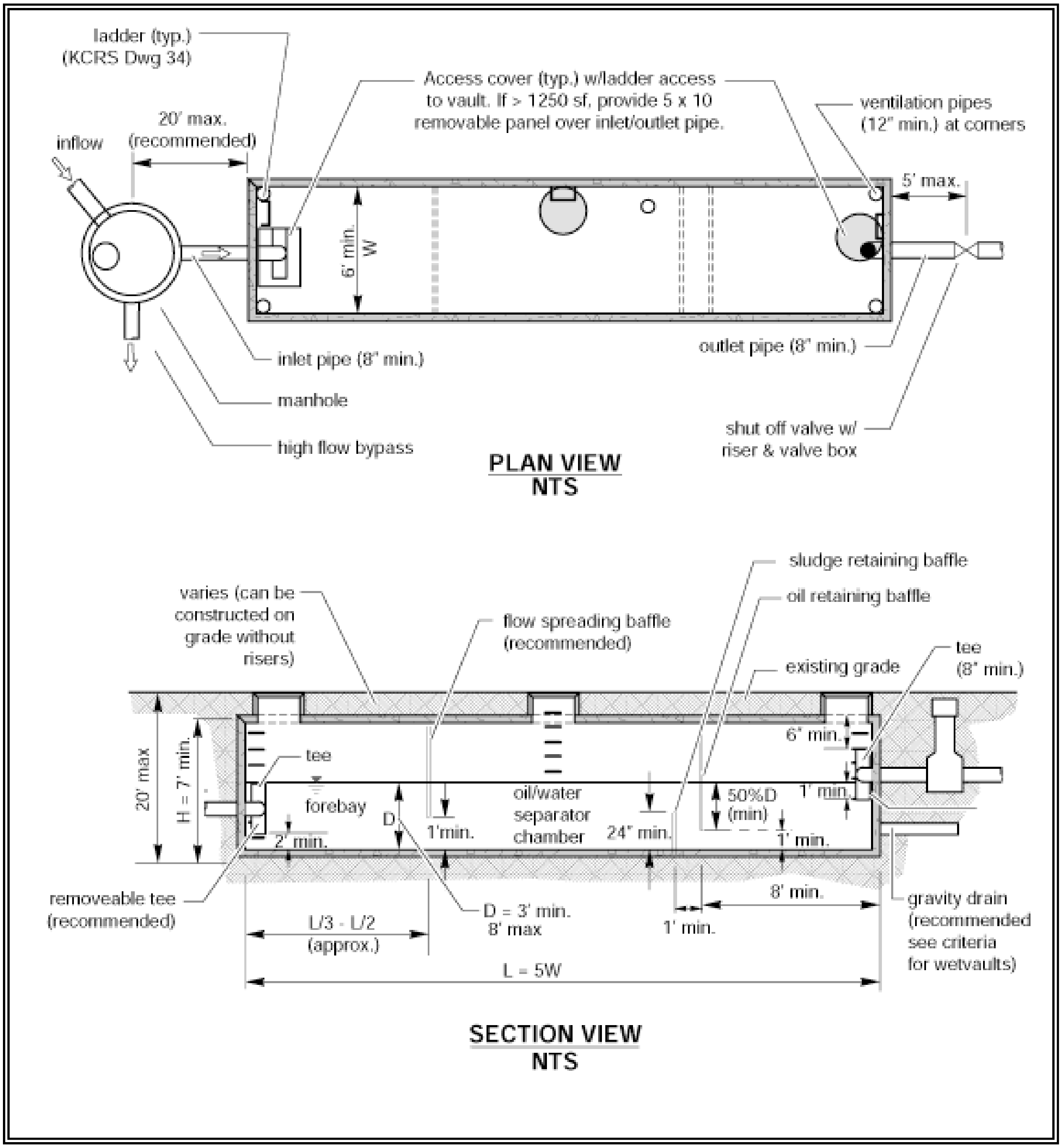
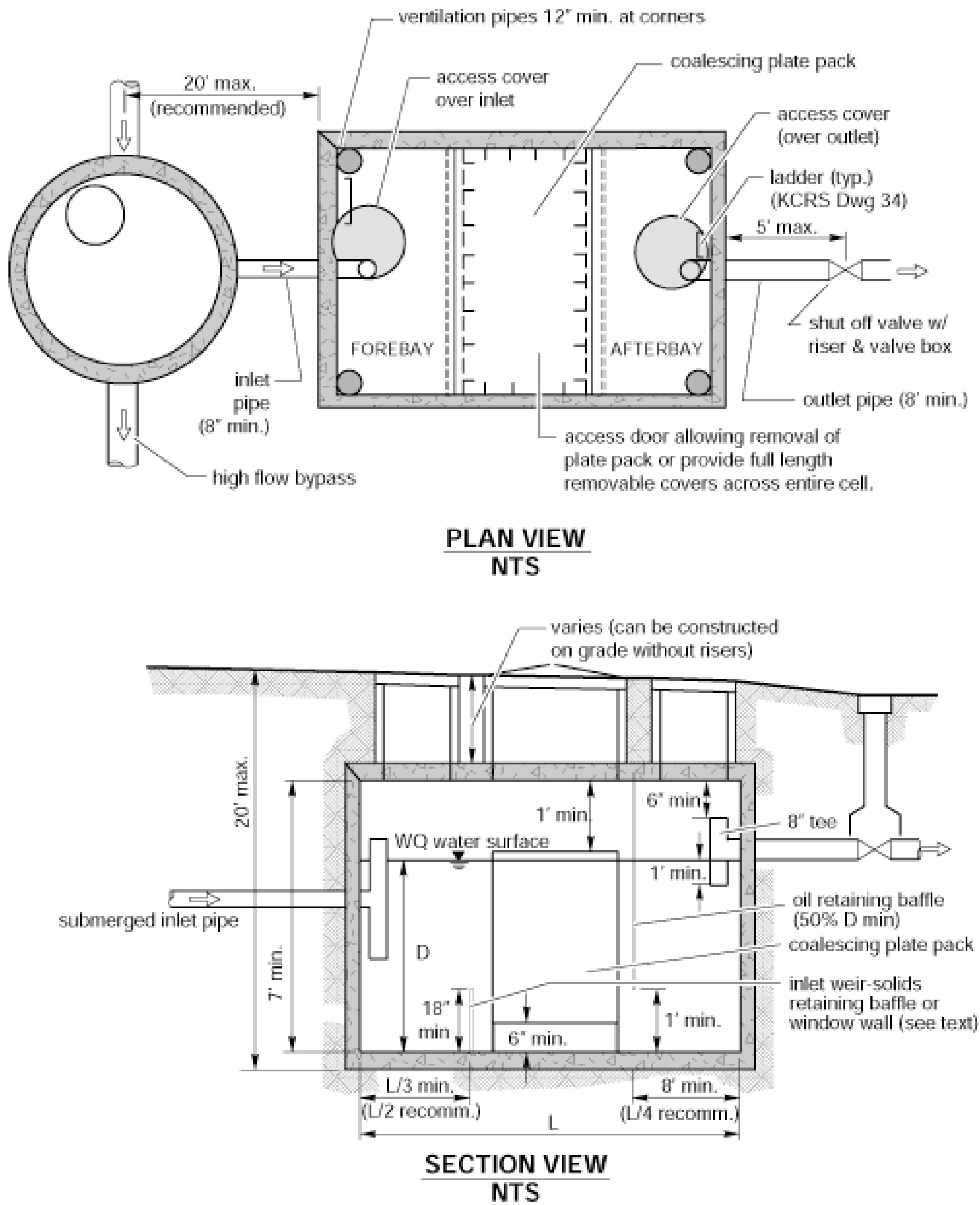


Figure 7.36 API Baffle Type Separator



Source: King County (reproduced with permission)

Figure 7.37 Coalescing Plate Separator

Appendix 7A
BMP Initial Selection Matrix

Site Constraint Screening for Selected BMPs

Legend:
- ✓ — Yes - BMP is generally suitable for this site
- Maybe - BMP might be feasible for this site
- No - BMP is generally not applicable to this site

Unit Process:	RUNOFF REDUCTION / ATTENUATION				INFILTRATION				FILTRATION			PRE-TREATMENT		DETENTION	
Operational BMP:	Protect & Restore Native Veg.	Dispersion	Post-Const. Soil Amendment	Green Roof	Bioretention	Permeable Pavement	Infiltration Trench/Gallery	Retention (Wetpond + Infilt. Basin)	Biofiltration Swale	Manufactured Media Filter	Media Filter Drain	Swale	Hydrodynamic Separator	Detention Pond/Basin	Detention Gallery/Vault
Site Constraints:															
Lack of Available Site Area	Maybe	✓	✓	✓	Maybe	✓	✓	No	No	✓	✓	Maybe	✓	No	✓
Low Permeability Soils/Layers	✓	✓	✓	✓	No	✓	No	No	✓	✓	✓	✓	✓	✓	✓
High Groundwater	✓	Maybe	✓	✓	No	No	No	No	✓	✓	Maybe	✓	✓	✓	✓
Sensitive Groundwater Zone	✓	✓	✓	✓	Maybe	Maybe	Maybe	Maybe	✓	✓	✓	✓	✓	✓	✓
Adjacent to Bldg. Foundation, Utilities	✓	✓	✓	No	Maybe	Maybe	Maybe	Maybe	✓	✓	✓	✓	✓	✓	✓
Near Steep Slopes	✓	Maybe	✓	✓	No	No	No	No	✓	✓	Maybe	✓	✓	✓	✓
Near Property Boundary	✓	Maybe	✓	✓	✓	✓	✓	Maybe	✓	✓	✓	✓	✓	✓	✓
Discharge/overflow to Surface Waters	✓	✓	✓	✓	✓	✓	✓	Maybe	Maybe	Maybe	✓	✓	Maybe	Maybe	Maybe
Spill Potential	✓	✓	✓	✓	Maybe	No	Maybe	Maybe	Maybe	Maybe	✓	Maybe	✓	Maybe	Maybe
Water Conservation/Minimize Use	✓	✓	✓	No	Maybe	✓	✓	Maybe	Maybe	✓	✓	Maybe	✓	✓	✓
Aesthetic or Safety Issues	✓	✓	✓	✓	✓	✓	✓	Maybe	✓	✓	✓	Maybe	✓	Maybe	✓
Reduce Fertilizer, Pest/Herbicides	✓	✓	✓	Maybe	Maybe	✓	✓	Maybe	Maybe	✓	✓	Maybe	✓	✓	✓
Maintenance Concerns	✓	✓	✓	Maybe	Maybe	Maybe	Maybe	✓	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe
TMDL Basin/Downstream (bacteria)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Maybe	Maybe	Maybe	✓
Subject to City Code/Conditional Use	✓	✓	✓	Maybe	✓	Maybe	✓	✓	✓	Maybe	✓	Maybe	Maybe	✓	Maybe

BMP Selection based on Proposed Land Surface

Legend:
- ✓ — Yes - BMP is generally suitable
- Conditional; potentially feasible
- No - BMP is not applicable

Unit Process:	RUNOFF REDUCTION / ATTENUATION				INFILTRATION				FILTRATION			PRE-TREATMENT		DETENTION	
Operational BMP:	Protect & Restore Native Veg.	Dispersion	Post-Const. Soil Amendment	Green Roof	Bioretention	Permeable Pavement	Infiltration Trench/Gallery	Retention (Wetpond + Infilt. Basin)	Biofiltration	Manufactured Media Filter	Media Filter Drain	Swale	Hydrodynamic Separator	Detention Pond/Basin	Detention Gallery/Vault
Identification of Land Surface Type as a Basis for BMP Selection:															
Roofs	✓	✓	✓	✓	✓	No	✓	✓	✓	✓	Conditional	✓	No	✓	✓
Streets	✓	✓	✓	No	✓	Conditional	Conditional	✓	✓	✓	✓	✓	✓	✓	✓
High-Use Parking Lots	✓	✓	✓	No	✓	Conditional	Conditional	✓	✓	✓	✓	✓	✓	✓	✓
Overflow Parking, Long-Term Parking	✓	✓	✓	No	✓	✓	Conditional	✓	✓	✓	✓	✓	✓	✓	✓
Landscaped Areas	✓	✓	✓	No	✓	No	No	✓	No	No	No	No	No	Conditional	Conditional

Note: These charts are intended as an initial filter for the general feasibility and suitability of various Best Management Practices for a range of situations and conditions.
These are not recommendations nor absolute prohibitions; refer to the drainage manual text for further information and design criteria.

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Chapter 8 – Source Control

Minimum Requirement #3, Source Control of Pollution, of the City of Lacey's NPDES Phase II Municipal Stormwater Permit states the following:

> **"All known, available and reasonable source control BMPs must be required for all projects approved by the Permittee. Source control BMPs must be selected, designed, and maintained in accordance with Volume IV of the (Department of Ecology's) *Stormwater Management Manual for Western Washington* (2005)**."

The purpose of source control BMPs is to prevent stormwater from coming in contact with pollutants. They can be a cost-effective means of reducing pollutants in stormwater, and, therefore, are to be a primary consideration in all projects.

The requirements in this Chapter apply to all multi-family housing, commercial and industrial projects in Lacey. Specific source control BMP requirements are based on the pollutants potentially generated at a particular category of project.

Source control BMPs can be either "operational" or "structural." Operational BMPs include practices such as inspections, maintenance, street sweeping, integrated pest/herbicide/fertilizer management and many others that reduce exposure of pollutants to stormwater. Structural source control BMPs prevent exposure of pollutants to stormwater by covering (e.g., roofing), grading (raising above grade), enclosing or other means that prevent contact of rain or runoff with potential pollutants. Reducing the area exposed to stormwater pollutants may result in a decrease in the required size of stormwater treatment facilities.

8. 1 Source Control BMP Selection

Source Control BMP selection is based on the types of activities to be conducted at a site and the potential stormwater pollutants associated with those activities.

The Source Control checklist in Appendix 8A shall be completed to document those activities/potential pollutant sources that will be present at a proposed project. All "Applicable BMPs" as listed in Volume IV, Chapter 2 of the Department of Ecology's *Stormwater Management Manual for Western Washington* (2005) for the activities present are required by the City of Lacey, while those described as "Recommended" are optional in Lacey. See below for the link to Ecology's Volume IV.

The source control BMP worksheet in Appendix 8A shall be used to document all of the source control BMPs (both required and otherwise) to be used at the site.

Note that satisfaction of the source control requirements of this section does not fulfill the requirements of any applicable State NPDES Industrial Stormwater Discharge Permit.

8.2 Source Control Submittals

The completed Stormwater Pollution Source Control Checklist and Worksheet shall be submitted with the initial permit application.

Structural source control BMPs shall be identified on the stormwater site plans submitted for City review.

8.3 Activity-Specific Water Quality Treatment BMPs

Some of the activities in the checklist have specific treatment BMP requirements. These requirements are also found in Volume IV, Chapter 2 of Ecology's 2005 stormwater manual. Any required BMPs shall be listed on the BMP worksheet and identified on stormwater site plans submitted for City review. Design information for water quality treatment facilities is presented in Chapter 7.

Ecology's Volume IV is on-line at http://www.ecy.wa.gov/biblio/0510032.html

8.4 General Principles of Pollution Prevention

This section describes the basic pollution prevention principles that every business and homeowner should consider. Most of these are common sense "housekeeping" types of solutions. With collective action by individuals and businesses throughout the region in implementing each of these principles, the improvement in water quality could be substantial. Although most of these principles are aimed at commercial or industrial activities, many items apply to individual residents as well.

1. Avoid the activity or reduce its occurrence

Avoid a potentially polluting activity or do it less frequently, especially if it takes place outdoors. Do a larger run of a process and reduce the number of times it needs to be repeated. Avoid one solvent-washing step altogether or have raw materials delivered closer to the time of use to avoid stockpiling and exposure to the weather. Apply lawn care chemicals following directions and only as needed. Many lawns are excessively fertilized. Do not apply herbicides right before it rains. Ecology or the Thurston County Department of Public Health and Social Services can provide pollution prevention assistance.

2. Move activities under shelter

Move a potentially polluting activity indoors or under cover out of the weather. This prevents runoff contamination, and you provides more control for a cleanup if a spill occurs. For example unload and store chemicals inside a garage area instead of outside. Be aware that moving storage areas indoors may require installation of fire suppression equipment or other building modifications as required by the International Building Code (IBC), applicable fire codes, or local ordinances.

3. Cleanup spills quickly

Promptly contain and cleanup solid and liquid pollutant leaks and spills on any exposed soil, vegetation, or paved area. Commercial spill kits are available, but readily available absorbent such as kitty litter also work well in many cases. Promptly repair or replace all leaking connections, pipes, hoses, valves, etc. which can contaminate stormwater.

4. Use less material

Don't buy or use more material than you really need. This not only helps keep potential disposal, storage, and pollution problems to a minimum, but will probably save money, too.

5. Use the least toxic materials available

Investigate the use of materials that are less toxic. For example, replace a caustic-type detergent or a solvent with a more environmentally friendly product. This might allow you to discharge process water to the sanitary sewer instead of paying for expensive disposal. Even if you do switch to a biodegradable product, only uncontaminated water is allowed to enter the stormwater drainage system.

6. Create and maintain vegetated areas near activity locations

Vegetation can filter pollutants out of stormwater. Route stormwater through vegetated areas located near your activity. Many low impact development (LID) stormwater BMPs can be used to manage stormwater from small source areas, like bioretention areas designed at depressions in parking lots. These BMPs are described in Chapter 6.

Wastewater other than stormwater runoff, such as wash water, must be discharged to a wastewater collection system, and may not be discharged to a storm drainage system.

High-use sites may require conveyance of runoff to an oil removal treatment system. For more information on high-use sites, refer to Chapter 7.

7. Locate activities as far as possible from surface drainage paths

Activities located as far as possible from known drainage paths, ditches, streams, other water bodies, and drains will be less likely to pollute, since it will take longer for material to reach the drainage feature. This gives more time to react to a spill, or if it is a “housekeeping” issue, may protect the local waters long enough for you to cleanup the area around the activity. Don't forget that groundwater protection is important throughout the region, no matter where the activity is located, so the actions taken on your site on a day-to-day basis are always important, even in dry weather.

8. Maintain stormwater drainage systems

Pollutants can concentrate over time in storm drainage facilities such as catch basins, vaults, ditches, and storm drains. When a large storm event occurs, turbulent runoff can mobilize these pollutants and carry them to receiving waters. Develop and implement maintenance practices, inspections, and schedules for treatment devices (e.g., detention ponds, oil/water separators, vegetated swales, etc.). Requirements for cleaning stormwater facilities are discussed in Chapter 9.

Repair or replace cracked or otherwise damaged pavement in areas used for secondary spill containment, high-intensity parking, and any other drainage areas that are subjected to pollutant material leaks or spills. Maintenance standards can be found in Chapter 9.

9. Reduce, reuse, and recycle as much as possible

Look for ways to recycle instead of just disposing. This saves money and keeps hazardous and non-hazardous materials out of landfills. You can learn more about other businesses that have made process changes allowing recycling of chemicals by calling Ecology at 1-800-RECYCLE and requesting publication No. 92-45 and No. 90-22.

Another unique recycling opportunity for businesses is available through the Industrial Materials Exchange, which covers the entire Pacific Northwest. This free service acts as a waste or surplus "matchmaker", turning one company's waste into another company's asset. For instance, waste vegetable oil can become biofuel for another business. Go to the Industrial Materials Exchange web site to list your potentially usable solid or chemical waste in their publication:

<http://www.govlink.org/hazwaste/business/imex/submit.cfm>

10. Be an advocate for stormwater pollution prevention

Help friends, neighbors, and business associates find ways to reduce stormwater pollution in their activities. Most people want clean water and do not pollute intentionally. Share your ideas and the BMPs in this volume to get them thinking about how their everyday activities affect water quality.

11. Report problems

We all must do our part to protect water, fish, wildlife, and our own health by implementing proper BMPs, and reporting water quality problems that we observe. In the City of Lacey, call the Department of Public Works at (360) 491-5644 to report dumping to sewers and to report spills and other incidents involving storm drains or ditches.

12. Provide oversight and training

Assign one or more individuals at your place of business to be responsible for stormwater pollution control. Hold regular meetings to review the overall operation of BMPs. Establish responsibilities for inspections, operation and maintenance (O&M), documentation, and availability for emergency situations. Train all team members in the operation, maintenance, and inspection of BMPs and reporting procedures.

13. Dust control

Sweep paved material handling and storage areas regularly as needed, to collect and dispose of dust and debris that could contaminate stormwater. Do not hose down pollutants from any area to the ground, storm drain, conveyance ditch, or receiving water unless necessary for dust control purposes to meet air quality regulations and unless the pollutants are conveyed to a treatment system approved by the City.

14. Eliminate illicit connections

A common problem with the stormwater drainage system for most communities is the existence of illicit connections of wastewater to the storm drainage system. Many businesses and residences have internal building drains, sump overflows, process wastewater discharges, and even sanitary sewer and septic system pipes that were connected to the nearby storm drainage system in the past as a matter of course.

All businesses and residences should examine their plumbing systems to determine if illicit connections exist. Any time it is found that toilets, sinks, appliances, showers and bathtubs, floor drains, industrial process waters, and/or other indoor activities are connected to the stormwater drainage system, these connections must be immediately rerouted to the sanitary or septic system, holding tanks, or a process treatment system.

15. Dispose of waste properly

Every business and residence in the City must dispose of solid and liquid wastes and contaminated stormwater properly. There are generally four options for disposal depending on the type of materials. These options include:

- Sanitary sewer and septic systems
- Recycling facilities
- Municipal solid waste disposal facilities
- Hazardous waste treatment, storage, and disposal facilities.

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Appendix 8A

Stormwater Pollution Source Control Checklist & Worksheet

CITY OF LACEY

STORMWATER POLLUTION SOURCE CONTROL CHECKLIST

Project Name:____

Check all activities that will occur at proposed project

☐	Boat/Ship Building, Repair or Maintenance
☐	Commercial Animal Handling
☐	Commercial Composting
☐	Commercial Printing
☐	De-icing and Anti-Icing
☐	Dust Control at Disturbed Land Areas and Unpaved Roadways and Parking Lots
☐	Dust Control at Manufacturing Areas
☐	Fueling at Dedicated Stations
☐	Landscaping and Lawn/Vegetation Maintenance
☐	Loading and Unloading of potential pollutants
☐	Maintenance and Repair of Vehicles and Equipment
☐	Maintenance of Utility Corridors and Facilities
☐	Maintenance of Roadside Ditches
☐	Maintenance of Stormwater Drainage and Treatment Systems
☐	Mobile Fueling of Vehicles and Heavy Equipment
☐	Painting/Finishing/Coating
☐	Parking and Storage of Vehicles and Equipment
☐	Railroad Yards
☐	Recyclers/Scrap Yards
☐	Roof/Building (floor) Drains
☐	Erosion and Sediment Control at Commercial or Industrial Sites
☐	Potential Spills of Oil or Hazardous Substances
☐	Storage of Liquids, Food Wastes or Dangerous Waste Containers
☐	Storage of Liquids in Permanent Above-ground Tanks
☐	Storage or Transfer (outside) of Solid Raw Materials, By-products or Finished
☐	Washing and Steam Cleaning Vehicles/Equipment/Buildings
☐	Wood Treatment Area

CITY OF LACEY

STORMWATER POLLUTION SOURCE CONTROL WORKSHEET

List All BMPs to be used at site. Use one worksheet for each activity from the checklist

Project:______________________________ Activity:____________________________

OPERATIONAL BMPs
STRUCTURAL BMPs
TREATMENT BMPs

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Chapter 9 – Operations and Maintenance

9.1 Operation and Maintenance Requirements

This chapter presents the requirements for operation and maintenance of privately-owned stormwater flow control and water quality treatment facilities. Proper O & M of drainage system components in conformance with standards is essential in keeping the drainage system functional over the long-term. Legal instruments attached to plats are required to identify the responsible party and ensure that facilities are maintained according to these standards. Operation and maintenance of private storm drain facilities are generally the responsibility of the facility owner(s).

9.2 Stormwater Facilities Maintenance Plan

For all projects subject to drainage review, a Stormwater Facilities Maintenance Plan shall be prepared by the Project Engineer. The Maintenance Plan shall be included in the submitted Drainage Report as part of the Stormwater Site Plan (as described in Chapter 2). The Maintenance Plan also shall be prepared as a stand-alone document (e.g. a separate binder) for the post-development facility owner(s), at the time of final project acceptance by the City. The Maintenance Plan shall include references to all on-site stormwater facilities (both pre-existing, if any, and new), and submitted for review and acceptance by the City with the Stormwater Site Plan for the project. Acceptance by the City of the Stormwater Facilities Maintenance Plan is required prior to final project acceptance.

The Stormwater Facilities Maintenance Plan shall contain five main sections:

Section 1: Owner Information
Section 2: Description of the Drainage System and Facilities serving the site
Section 3: Cost Estimate for long-term facilities maintenance, repair & rehabilitation
Section 4: Site and Facility Management
Section 5: Stormwater Facility Maintenance Guide

These Maintenance Plan sections shall include the following components:

Section 1: Owner Information

1a. Identification of the responsible maintenance organization or person. It is the City's policy that the property owner(s) shall maintain their stormwater drainage facilities. In the case of a subdivision, the Home Owners Association is responsible for maintenance of their jointly-owned facilities.

1b. A statement of who will keep the Maintenance Plan, the address where it will be kept, and that it must be made available for inspection by the City upon request. The Maintenance Plan shall be held by the property owner. For a subdivision, the Maintenance Plan shall be held by the Home Owners Association president, and shall be included by reference in the articles of incorporation of the Home Owners Association.

1c. A copy of the Maintenance Agreement (Commercial/Industrial or Residential) executed by the property owner and accepted as to form by the City of Lacey.

1d. A description of required recordkeeping and frequency of inspections and submittal of reports to the City (see "Annual Inspection & Maintenance Report" below)

Section 2: Description of the Drainage System and Facilities serving the site

2a. Descriptions

A written overview of the stormwater system for the site, describing where flows come from, how water moves through the site and facilities, and how and where the stormwater leaves the site. Provide a facilities inventory and a basic description of each flow control and treatment facility works. Explain the principles of facility operation and general maintenance requirements, and provide information from the Drainage Report that might be helpful for future maintenance of the stormwater facilities. This might include pipe and swale data, the design capacities of conveyance facilities, sizing and dimensions of infiltration and/or detention facilities and calculated release rates for various storm events.

2b. Drawings

A drawing showing all stormwater facilities, drainage easements, access easements, etc., with a key referencing the applicable maintenance checklists required to be used in performing routine inspection and maintenance for the facility

Engineering drawings of the stormwater facilities including details and specifications shall be included. Drawings may be 11" x 17" fold-outs, or full-size 22" x 34" sheets folded in a map pocket.

Section 3: Cost Estimate for long-term facilities maintenance, repair & rehabilitation

3a. An estimate of the average annual maintenance cost projected for 20 years, for owner awareness and budgeting (see Appendix 9A). The estimate shall include the annualized cost of both routine tasks (e.g. vegetation removal from wetponds, refurbishing media filter cartridges, etc.) and non-routine major tasks (e.g. wetpond sediment removal, infiltration enhancement, etc).

Section 4: Site and Facility Management

4a. Pollution Source Control Plan

Pollution source control is the application of pollution prevention practices on a developed site to reduce contamination of stormwater runoff **at its source.** Best management practices (BMPs) and resource management systems are designed to reduce the amount of contaminants used or discharged to the environment.

The Maintenance Plan shall contain language regarding pollution source control that is specifically developed for the type of site covered by the plan. The pollution source control section of the plan shall incorporate the relevant information referenced in Chapter 8 of this manual, unless otherwise accepted by the Administrator or designee.

4b. Vegetation Management Plan

A vegetation management plan shall be included in the Stormwater Facilities Maintenance Plan for the project and shall include descriptive information on the specified plantings for each stormwater facility, and recommendations for maintenance and replacement plantings. The effectiveness and functionality of most stormwater facilities will depend in part on the species planted in them and their proper management.

Section 5: Stormwater Facility Maintenance Guide

The Stormwater Facility Maintenance Guide (Appendix 9B) provides a tool to assist the facility owner to meet the inspection and maintenance requirements of this chapter for a variety of individual facilities. The checklists in the Stormwater Facility Maintenance Guide summarize maintenance requirements for various types of flow control, water quality, and related facilities approved by Lacey. Additional details are provided with the BMP descriptions in Chapter 6 or 7.

The Stormwater Facility Maintenance Guide shall include the following main elements:

5a. A general description of the Maintenance Guide, with safety information, instructions, and resources for maintenance assistance.

5b. Facility Summary Forms prepared for each stormwater facility as part of the drainage submittal requirements for final permitting

5c. Log Sheet of inspection observations and maintenance activities, in a tabular format that includes sufficient space to list maintenance activities completed as a result of inspections

5d. Maintenance Checklists applicable to all facilities included in the project. The applicant shall only include those checklists that apply to the project.

The checklists in the Stormwater Facility Maintenance Guide include a general description of the required maintenance frequency for each facility, and the facility conditions that indicate need for improvement to meet standards for functionality. At a minimum, facility inspections are required on an annual basis. An inspection report, indicating any follow-up actions taken, shall be retained by the responsible party, for review by the City upon request. Follow-up actions shall occur within the following time periods after inspections indicating the need for maintenance:

- Routine maintenance: within 6 months
- Capital project: within 1-2 years

9.3 Annual Inspection & Maintenance Report

The owner shall submit a brief annual Inspection & Maintenance Report to the City of Lacey Public Works Department by August 15th of each calendar year, to include the following:

- Name, address, and telephone number of the businesses, persons, or firms responsible for plan implementation, and the person completing the report.
- Time period covered by the report, generally the previous calendar year.
- A chronological summary of activities conducted to implement the Maintenance Plan. A photocopy of the log sheet and applicable checklists (with any additional explanation needed) should normally suffice. For any activities conducted by paid parties, include a description of tasks, name of service provider and costs, or include copies of the invoices for services.
- An outline of planned activities for the coming year.

9.4 Maintenance Standards

In general, the maintenance standards for each type of facility are embedded within the charts in the Guide. The maintenance standards are conditions used to indicate when maintenance is required, based on inspections. They are not standards that are to be met at all times between inspections. Exceeding these conditions between inspections does not necessarily constitute violation of these standards.

Appendix 9A
O&M Cost Estimate Calculations

The following is an example of a cost estimate to be prepared by the design engineer, to assist the post-development owners of stormwater facilities in budgeting for long-term facility operation and maintenance costs. The example below is for a Homeowners Association, where each lot owner is assumed to be an equal co-owner of the common facilities.

The initial value of the facilities, the annual maintenance costs (assuming all work is by hired workers), and factors such as inflation that occur over time are incorporated in the "sinking fund" calculation of future costs and the annual funding amount needed. The figures used are fictitious; the design engineer preparing the estimate will need to provide current, realistic figures for the calculations. This format does not need to be followed explicitly, but is provided as an example.

* * * * *

EXAMPLE:

Estimate of Annual Maintenance Costs

for the Stormwater Drainage Facilities at "Stormy Estates"

Introduction:

The following are assumptions, estimates and recommendations for funds to set-aside for annual maintenance costs and future replacement costs for the drainage facilities that are the responsibility of the *Stormy Estates* Homeowners' Association. The sinking fund estimate is an approximation of the annual funding needed over the next 20 years to keep the drainage system fully functional.

The fund reserve amount is computed with consideration for probable inflation over the life of the materials, structures, and facilities, and includes a summary of the amount of money to be set aside annually for the fund and the annual charge per lot owner to equal the annual set-aside.

Note that the sinking fund calculations are only an estimate, using approximated values. The Homeowners' Association should use these computations as a guide, and modify as needed to more accurately reflect actual costs.

Assumptions:

1. The drainage facilities are constructed properly, as per the approved plans and details.
2. Inspection and minor maintenance (e.g. debris removal) performed by HOA members/facility owners (no labor cost), but mowing and all other work is performed by hired workers.
3. Catch basins will be cleaned-out by hired vactor truck, once per year.
4. Catch basins and pipes should last at least 20 years, but assume replacement of 20% of the drainage system over the next 20 years.
5. Wetponds will need excavation/removal of accumulated sediment and muck every 15 years.
6. Infiltration facilities (basins, trenches, etc.) will need infiltration enhancement every 15 years.

EXAMPLE: Estimate of Annual Maintenance Costs – *continued*

Routine Operation & Maintenance - Estimated Costs:

Operation cost of the surface runoff drainage facilities is essentially zero, if there are no electric pumps or other devices serving the drainage system. Routine maintenance tasks and expenses, as detailed in the Stormwater Facilities Maintenance Plan, are as follows:

- **Ponding Basins** (2 total; one wetpond with an adjacent infiltration pond):

  Routine Tasks: remove excess vegetation from within wetpond, inspect/repair rock rip rap and stabilize slopes, conduct routine landscape maintenance and mowing of infiltration basin

  Once every 15 years: remove muck/debris from wetpond, and restore/enhance infiltration.

  Approximate annual maintenance cost for routine tasks = $400 per ponding basin, plus Capital expenses of $9,000 for pond/basin rehab. per 15-year cycle = $600 per year.

  Total approximate annual cost: 2 Ponds x $400 plus 1 x $600 = ($800 + $600) = $ 1,400.

- **Catch Basins** (8 total):

  Clear grates, remove vegetation, repair (grout) cracks at approximate annual cost of $20 per catch basin, plus vactoring-out sediment once per year at approximately $80 per catch basin;

  Total approximate annual cost: 8 Catch Basins at ($20 + $80) = 8 x $100 = $800.

- **Storm System Pipes** (approximately 400 lineal feet total):

  Manually clear pipe ends of sediment/debris, remove vegetation, repair/grout damaged pipe;

  Total approximate annual cost: 400 LF at $0.50 per LF = $200.

- **Surface Drainageways** (berms, swales, rip rap, etc., especially near the 2 ponding areas):

  Clear trash & debris, remove sediment & regrade, remove vegetation, repair erosion damage; Total approximate annual cost: 2 ponding areas at $100 each = $200.

- **Miscellaneous Facilities**:

  Maintain and repair various features such as maintenance access roads, energy dissipators, flow dispersion systems, filter strips, etc.; assume nominal cost for tools, supplies, labor

  Total approximate annual cost = $ 100.

Total Approximate Annual Operation & Maintenance Costs:

($1,400 + $800 + $200 + $200 + $100) = approximately $2,700 per year (before inflation)

Note: This total annual O&M cost amount is recorded under symbol "OM" on next page.

EXAMPLE:

Calculations for Stormwater Facilities O&M Fund Reserve Account

for routine annual Operation & Maintenance costs plus future Facility Replacement costs

Assumptions:

1. Assume the average inflation rate over the next 20 years will be about 4%.
   (The average inflation rate over the past 30 years has been approximately 4%)
2. Assume interest rates earned over the next 20 years will be about 3%.
   (Interest rates paid by banks currently, as of January 2010, are lower than 3%)
3. Assume 20% of storm system will need major repair/replacement during next 20 years
4. Assume the fictional plat of *Stormy Estates* has 22 individually-owned lots.

Symbol	Description	Cost
1. Routine O+M Funding:		
OM	Annual Operation & Maintenance costs (from previous page)	$ 2,700
2. Future Facility Replacement Funding:		
PV	Present Value of Storm Drainage Facilities (as per bid by *Storm Contractors, Inc*. for initial construction)	$ 150,000
PV/5	20% of PV for partial system repair/replacement in 20 years[3]	$ 30,000
FV	Future Value of portion of drainage system to replace in 20 years[1] assuming inflation = 4%, FV = PV/5 x (2.1911)	$ 65,733
A	Annual amount to Set-aside for future replacement costs[2] [@ 3% interest and n = 20, A/F = 0.03722; A = FV (A/F)]	$ 2,447

3. Total Funding Needed:

= Annual O&M Costs + Set-aside for Future = OM + A = (2,700 + 2,447) = $ 5,147

<u>Total Annual Funding Contribution per Lot Owner</u> [4] = $5,147 / 22 = <u>$ 233.96</u>

<u>Total Monthly Funding Contribution per Lot Owner = $233.96 / 12 = $ 19.50</u>

Note: Since O&M costs will vary and are also subject to inflation, they should also be adjusted over time. Facility owners should evaluate actual O&M needs and costs each year and adjust set-aside funds for the following year's cost projection.

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Appendix 9B

Stormwater Facility Maintenance Guide

CITY OF LACEY

Shaping Our Community Together

Maintaining Stormwater Facilities

All stormwater facilities need to be maintained. Regular maintenance ensures proper functioning and keeps the facility aesthetically appealing. This Stormwater Facility Maintenance Guide was designed to help explain how stormwater facilities work and provide user-friendly guidance on how to maintain them to keep them up to standards. As a facility owner or homeowner's association, you are responsible for regularly maintaining your privately-owned drainage facilities such as ponds, catch basins and pipes. Local governments maintain stormwater facilities located in public roadways.

Maintenance Checklists

The checklists in this guide are for you to use when inspecting and maintaining the stormwater facilities in your neighborhood. If you are missing a particular checklist, or if you have additional facilities not identified or addressed in this guide, please contact your developer or local jurisdiction.

The checklists are in table format for ease of use and brevity. Each checklist tells you what part of the feature to check, how often to check, what to check for, and what to do about it. Log sheets are included to help you keep track of when you last surveyed the storm drainage system.

Although it is not intended for the maintenance survey to involve anything too difficult or strenuous, there are a few tools that will make the job easier and safer. These tools include:

- Gloves.
- A flashlight (to look into catch basins, manholes or pipes).
- A long pole or broom handle (see below).
- Some kind of pry bar or lifting tool for pulling manhole and grate covers.

A listing of resources is also included within this packet (see next page). Here you will find the phone numbers of the agencies referred-to in the tables.

SAFETY WARNING:

Due to OSHA regulations, you should never stick your head or any part of your body into a manhole or other type of confined space. When looking into a manhole or catch basin, stand above it and use the flashlight to help you see. Use a pole or broom handle that is long enough when you are checking sediment depths in confined spaces. Always properly replace grates and lids.

NO PART OF YOUR BODY SHOULD BREAK THE PLANE OF THE OPEN HOLE.

Checklist Instructions

The following pages contain maintenance checklists covering most of the needs for the components of your drainage system, as well as for some components that you may not have (you can ignore those that don't apply to your system). Let us know if there are any components of your drainage system that you do not recognize or are missing from these pages.

You should plan to complete a check for all system components on the following schedule, as per the "How Often" column in the checklists:

> **Quarterly** – Plan to inspect the facility at least once per season, preferably during the following months – January, May, August, and November.
>
> **Annually** – The best time for an annual inspection is in the late summer, preferably August or September.
>
> **After Storms** – Also check all stormwater facilities after major storm events, defined as about 1 inch or more of precipitation in 24 hours.

Using photocopies of these checklists and the log sheet, check off the problems that you look for each time you do an inspection. Add comments regarding problems found and actions taken on the log sheet. Keep the completed forms in your files for future reference.

You may call the City of Lacey at (360) 491-5600 for technical guidance. Please do not hesitate to call, especially if you are unsure whether a situation you have discovered may be a problem.

Resource Listing

If you are unsure whether a problem exists, please contact the City at the number below and ask for technical assistance with your situation. Other resources are listed for your convenience and as references associated with the checklists.

Lacey Public Works Department
(360) 491-5600 www.ci.lacey.wa.us/

Thurston County Environmental Health
Hazardous Waste Disposal (oil, paint, pesticides, etc.)
(360) 754-4111 www.co.thurston.wa.us/health/ehhw/hwprevent

Solid Waste Disposal (yard waste, construction waste, contaminated soils, etc.)
(360) 786-5136 www.co.thurston.wa.us/health/ehhw/index

WSU Thurston Co. Extension (Water Resource Ed. Programs, Envir. Stewardship info.)
(360) 786-5445 http://thurston.wsu.edu/water/

Log Sheet

Use copies of this log sheet to keep track of when maintenance checks occur and what items, if any, are repaired or replaced. The completed sheets will serve as a record of past maintenance activities and will provide valuable information on how your facilities are operating. Keep all log sheets in a designated area so others can easily access them.

Location: _________________________________ **Date Checked:**
Checked By:
Name: _________________________________ ________/_______/20_____
Address: _________________________________ **Phone:**
City: _____________________ **Zip:** ___________ (______) __________________

Facility and Component Checked	Observations (List things that should be done)	Follow-up Actions Taken	Date Action Taken

Stormwater Facility Maintenance Checklists

Group 1: Ponds and Swales

- 1a Detention/Infiltration Ponds
- 1b Wetponds and Constructed Wetlands
- 1c Bio-Infiltration Swales (Grassed Percolation Areas)
- 1d Typical Bio-Swales
- 1e Wet Bio-Swales
- 1f Filter Strips
- 1g Open Sand Filters
- 1h Bioretention Cells (Rain Gardens)

Group 2: Underground Tanks, Vaults and Trenches

- 2a Detention Tanks and Vaults
- 2b Wetvaults
- 2c Enclosed Sand Filters
- 2d Dispersion Trenches

Group 3: Structures and Pre-Treatment

- 3a Control Structures/Flow Restrictors
- 3b Catch Basins
- 3c Debris Barriers (Trash Racks)
- 3d Energy Dissipators
- 3e API (Baffle) Oil/Water Separators
- 3f Coalescing Plate Oil/Water Separators
- 3g Catch Basin Inserts

Group 4: Miscellaneous Facilities and Features

- 4a Downspouts and Roof Drywells
- 4b Conveyance Pipes and Ditches
- 4c Access Roads

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Group 1

Ponds and Swales

1a Detention / Infiltration Ponds

There are essentially three types of storm ponds: detention ponds, infiltration ponds, and treatment wetponds. Detention ponds store water temporarily while releasing it gradually, while infiltration ponds percolate water into the ground. Wetponds improve water quality.

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Entire Facility	Quarterly	Trash & Debris	Dumping of yard wastes such as grass clippings and branches into pond. Presence of glass, plastic, metal, foam, or paper. There should be no visual evidence of dumping.		Remove and properly dispose all trash /debris.	
	Quarterly	Noxious or Poisonous Vegetation	Any invasive vegetation such as Scotch broom or blackberry vines, or any vegetation which may constitute a hazard to the public, such as poison oak, tansy ragwort, stinging nettles, or devil's club.		Completely remove invasive, noxious or non-native vegetation. Do not spray chemicals on vegetation without guidance or City approval.	
	Quarterly	Pollution or Fire Hazard	Presence of chemicals such as natural gas, oil, and gasoline, obnoxious color, odor, or sludge.		First, try to locate the source of the pollution. Then, call the Moderate Risk Waste Program at Thurston County Environmental Health to report the hazard.	
	Quarterly	Rodent Holes	Any evidence of rodent holes if facility is acting as a dam or berm. Water should not be able to flow through the rodent holes.		Destroy rodents and repair the dam or berm. Contact Thurston County Health Department for guidance.	
	Quarterly	Insects	Insects such as wasps and hornets interfering with maintenance activities, or mosquitoes becoming a nuisance.		Destroy or remove insects. For mosquito control, eliminate stagnant water.	
	Annually	Overgrown Vegetation around pond	Ensure trees/shrubs are not interfering with the facility function or maintenance (i.e. mowing, silt removal, or access).		Prune tree limbs to allow for maintenance. Trees should not be present within ponds.	
	Quarterly	Vegetation not growing or overgrown within pond	Sparse, weedy, or overgrown grass in grassy dry/infiltration ponds. Presence of invasive species or sparse/excessive growth of plants in wetland ponds.		For grassy ponds, selectively thatch, aerate, and re-seed ponds. Grass should be kept under 8" height. For wet ponds, Control cattail and unwanted vegetation to under 25% of pond bottom.	

1a Detention/ Infiltration Ponds (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Side Slopes	Annually	Erosion	Check around the inlets and outlets for signs of erosion. Check berms for signs of sliding or settling. Action is needed where eroded damage is over 2" deep and where there is potential for continued erosion.		Try to determine what has caused the erosion and fix it. Stabilize slopes by reinforcing the slope with rock, planting grass, or compacting the soil. Contact the City of Lacey for assistance.	
Pond Storage Area	Annually	Sediment Build-Up	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inlets or outlets of the facility. (If a percolation test pit or test of Infiltration facility indicates facility is only working at 90% of its designed capabilities. If two inches or more sediment is present.		Clean out sediment and re-seed the pond if deemed necessary to improve infiltration and control erosion.	
	Quarterly	PVC Pond Liner	Check to see if liner is visible and has more than three 1/4-inch holes, exposed and or torn. An indicator of a torn liner could be the pond no longer holds water. (during long dry periods the water may evaporate)		Repair or replace liner as needed.	
	Quarterly	Clay Liner	Check to see if pond is holding water. (during long dry periods the water may evaporate)		Repair liner to designed state.	
Dikes or Berms	Annually	Settlement	Any part of the dike or berm which has settled more than 4 inches lower than designed.		Build the dike or berm back to the original elevation. If there is significant settling a licensed Civil Engineer should be consulted.	
	Quarterly	Seepage	Check for water flowing through the pond berm.		Repair berm to stop seepage. (Consult a Geotechnical Engineer)	
Emergency Overflow Spillway	Annually	Rocks Missing	Check to see that the rip rap protective area in intact. If any native soil is exposed, cover soil with rock rip rap.		Replace rocks so that all native soil is covered.	

1a Detention/ Infiltration Ponds (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Side Slopes	Annually	Erosion	Check around the inlets and outlets for signs of erosion. Check berms for signs of sliding or settling. Action is needed where eroded damage is over 2" deep and where there is potential for continued erosion.		Try to determine what has caused the erosion and fix it. Stabilize slopes by reinforcing the slope with rock, planting grass, or compacting the soil. Contact the City of Lacey.	
Pond Storage Area	Annually	Sediment Build-Up	Accumulated sediment that exceeds 10% of the designed pond depth or affects inlets or outlets of the facility. (If a percolation test of infiltration facility indicates facility is only working at 90% of its designed capabilities, or if 2" or more sediment is present.		Clean out sediment and re-seed the pond if deemed necessary to improve infiltration and control erosion.	
	Quarterly	PVC Pond Liner	Check to see if liner is visible and has more than three 1/4-inch holes, exposed and or torn. An indicator of a torn liner could be the pond no longer holds water. (during long dry periods the water may evaporate)		Repair or replace liner as needed. Note: wetponds or detention ponds may have liners, but infiltration ponds do not have liners.	
	Quarterly	Clay Liner	Check to see if pond is holding water. (during long dry periods the water may evaporate)		Repair liner to designed state.	
Dikes or Berms	Annually	Settlement	Any part of the dike or berm which has settled more than 4 inches lower than designed.		Build the dike or berm back to the original elevation. If there is significant settling a licensed civil engineer should be consulted.	
	Quarterly	Seepage	Check for water flowing through the pond berm.		Repair berm to stop seepage. (Consult a Geotechnical Engineer)	
Emergency Overflow Spillway	Annually	Rocks Missing	Check to see that the rip rap protective area is intact. If any native soil is exposed, cover soil with rock rip rap.		Replace rocks so that all native soil is covered.	

1a Detention/ Infiltration Ponds (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Emergency Overflow Spillway (cont.)	Annually	Erosion	Make sure the riprap under the inlet pipe is intact and no native soil is exposed. Check for accumulations of sediment deeper than half the height of the rocks.		Replace rocks and/or clean out sediment.	
	Quarterly	Screen clogged or missing	The bar screen over the outlet should be intact and clear of debris. Water should flow freely through the outlet pipe.		Replace screen if it is not attached. Remove any trash or debris and dispose of properly. Clean out the end pipe if necessary.	
Sediment Trapping Area	Quarterly	Sediment and Debris Buildup	Ensure sediment and debris do not obstruct water flow into the infiltration area.		Clean out the sump area.	
	Annually	Inadequate Sediment Settling Area	Stormwater should not enter the infiltration area without some method of settling-out solids.		Add a sediment trapping area by constructing a sump or berm for settling of solids. This area should be separate from the rest of the facility. Contact City of Lacey for guidance.	

1b Wetponds and Constructed Wetlands

Wetponds and constructed wetlands are designed to improve water quality. They have a permanent pool of water, so incoming flows are slowed causing sediments and pollutants to settle-out. Plants provide biological treatment and filtering of runoff water.

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Entire Facility	Annually	Water Level	First cell is empty, doesn't hold water.		Line the first cell to maintain at least 4 feet of water. Although the second cell may drain, the first cell must remain full to control turbulence of the incoming flow and reduce sediment resuspension.	
	Quarterly	Trash and Debris	Accumulation that exceeds 1 cu. ft. per 1000 sq. ft. of pond area.		Trash and debris removed from pond.	
	Quarterly	Inlet/Outlet Pipe	Inlet/Outlet pipe clogged with sediment and/or debris material.		No clogging or blockage in the inlet and outlet piping.	
	Annually	Sediment Accumulation on Pond Bottom	Sediment accumulations in pond bottom that exceeds the depth of sediment zone plus 6-inches, usually in the first cell of the pond.		Sediment removed from pond bottom.	
	Quarterly	Oil Sheen on Water	Visible and prevalent oil sheen.		Oil removed from water using oil-absorbent pads or vactor truck. Source of oil located and corrected. If chronic low levels of oil persist, plant wetland plants such as Juncus effusus (soft rush) which can uptake small concentrations of oil.	
	Quarterly	Erosion	Erosion of the pond's side slopes and/or scouring of the pond bottom, that exceeds 6-inches, or where continued erosion is prevalent.		Slopes stabilized using proper erosion control measures and repair methods.	

1b Wetponds and Constructed Wetlands (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Entire Facility	Annually	Settlement of Pond Dike/Berm	Any part of these components that has settled 4-inches or lower than the design elevation, or inspector determines dike/berm is unsound.		Dike/berm is repaired to specifications.	
	Annually	Internal Berm	Berm dividing cells should be level.		Berm surface is leveled so that water flows evenly over entire length of berm.	
	Annually	Overflow Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.		Rocks replaced to specifications.	
	Quarterly	PVC Pond Liner	Check to see if liner is visible and has more than three 1/4-inch holes, exposed and or torn. An indicator of a torn liner could be the pond no longer holds water. (during long dry periods the water may evaporate)		Repair or replace liner as needed. Note: wetponds usually have liners	
	Quarterly	Clay Liner	Check to see if pond is holding water. (during long dry periods the water may evaporate)		Repair liner to designed state.	

1c Bio-Infiltration Swales (Grass Percolation Areas)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Swale	Quarterly	Sediment	Sediment depth on grass is 2" or deeper		Remove sediment deposits, re-seed as necessary	
Swale	Quarterly	Standing Water	Not freely draining between storms		Restore design grades, or convert facility to wet bio-swale	
Swale	Quarterly	Flow Spreader	Uneven or clogged, flows not uniformly distributed		Clean and level the spreader	
Swale	Quarterly	Vegetation	Vegetation causing hazard or nuisance; presence of noxious weeds		Remove problem vegetation	
Swale	Quarterly	Sparse Vegetation	Bare patches exceed 10% of swale bottom		Remove overhanging branches, shrubs if causing shading problem; reseed or plant	
Swale	Quarterly	Grass	Grass height exceeds 10 inches		Mow to 3" - 4" height	
Swale	Quarterly	Erosion or Scouring	Erosion damage in swale, channelization		Regrade and replant/ reseed, or repair ruts with gravel (< 12" wide)	
Swale	Quarterly	Sediment, Trash & Debris	Accumulation blocks inlet or outlet; trash/debris in swale		Unblock inlet/outlet; Remove trash/debris	

1d Typical Bio-Swales

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
General	Quarterly	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.		Remove sediment deposits on grass treatment area of the bio-swale. When finished, swale should be level from side to side and drain freely toward outlet. There should be no areas of standing water once inflow has ceased.	
	Quarterly	Standing Water	When water stands in the swale between storms and does not drain freely.		Any of the following may apply: remove sediment or trash blockages, improve grade from head to foot of swale, remove clogged check dams, add underdrains or convert to a wet biofiltration swale.	
	Quarterly	Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire swale width.		Level the spreader and clean so that flows are spread evenly over entire swale width.	
	Quarterly	Constant Baseflow	Small quantities of water continually flow through the swale, even when it has been dry for weeks, and an eroded, muddy channel has formed in the swale bottom.		Add a low-flow pea-gravel drain the length of the swale or by-pass the baseflow around the swale.	
	Quarterly	Poor Vegetation Coverage	Grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.		Determine why grass growth is poor and correct that condition. Re-plant with plugs of grass from the upper slope: plant in the swale bottom at 8-inch intervals. Or re-seed into loosened, fertile soil.	
	Quarterly	Vegetation	When the grass becomes excessively tall (greater than 10"); when nuisance weeds and other vegetation start to take over.		Mow vegetation or remove nuisance vegetation so that flow not impeded. Grass should be mowed to a height of 3 to 4 inches. Remove grass clippings.	
	Annually	Excessive Shading	Grass growth is poor because sunlight does not reach swale.		If possible, trim back over-hanging limbs and remove brushy vegetation on adjacent slopes.	

1d Typical Bio-Swales (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Swale	Quarterly	Inlet/Outlet	Inlet/outlet areas clogged with sediment and/or debris.		Remove material so that there is no clogging or blockage in the inlet and outlet area.	
	Quarterly	Trash and Debris Accumulation	Trash and debris accumulated in the bio-swale.		Remove trash and debris from bioswale.	
	Annually	Erosion/Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.		For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. If bare areas are large, generally greater than 12 inches wide, the swale should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident, or take plugs of grass from the upper slope and plant in the swale bottom at 8-inch intervals.	

1e Wet Bio-Swales

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Swale	Quarterly	Sediment Accumulation	Sediment depth exceeds 2-inches in 10% of the swale treatment area.		Remove sediment deposits in treatment area.	
Swale	Quarterly	Water Depth	Water not retained to a depth of about 4 inches during the wet season.		Build up or repair outlet berm so that water is retained in the wet swale.	
Swale	Quarterly	Wetland Vegetation	Vegetation becomes sparse and does not provide adequate filtration, OR vegetation is crowded out by very dense clumps of cattail, which do not allow water to flow through the clumps.		Determine cause of lack of vigor of vegetation and correct. Replant as needed. For excessive cattail growth, cut cattail shoots back and compost off-site. Note: normally wetland vegetation does not need to be harvested unless die-back is causing oxygen depletion in downstream waters.	
Swale	Quarterly	Inlet/Outlet	Inlet/outlet area clogged with sediment and/or debris.		Remove clogging or blockage in the inlet and outlet areas.	
Swale	Quarterly	Trash and Debris Accumulation	See "Detention Ponds".		Remove trash and debris from wet swale.	
Swale	Quarterly	Erosion/Scouring	Swale has eroded or scoured due to flow channelization, or higher flows.		Check design flows to assure swale is large enough to handle flows. By-pass excess flows or enlarge swale. Replant eroded areas with fibrous-rooted plants such as Juncus effusus (soft rush) in wet areas or snowberry (Symphoricarpos albus) in dryer areas.	

1f Filter Strips

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
General	Quarterly	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.		Remove sediment deposits, re-level so slope is even and flows pass evenly through strip.	
	Quarterly	Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.		Mow grass, control nuisance vegetation, such that flow not impeded. Grass should be mowed to a height between 3-4 inches.	
	Quarterly	Trash and Debris Accumulation	Trash and debris accumulated on the filter strip.		Remove trash and Debris from filter.	
	Quarterly	Erosion/Scouring	Eroded or scoured areas due to flow channelization, or higher flows.		For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the filter strip should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident.	
	Quarterly	Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.		Level the spreader and clean so that flows are spread evenly over entire filter width.	

1g Open Sand Filter

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Above Ground (open sand filter)	Quarterly	Sediment Accumulation on top layer	Sediment depth exceeds 1/2-inch.		No sediment deposit on grass layer of sand filter that would impede permeability of the filter section.	
	Quarterly	Trash and Debris Accumulations	Trash and debris accumulated on sand filter bed.		Trash and debris removed from sand filter bed.	
	Quarterly	Sediment/ Debris in Clean-Outs	When the clean-outs become full or partially plugged with sediment and/or debris.		Sediment removed from clean-outs.	
	Quarterly	Sand Filter Media	Drawdown of water through the sand filter media takes longer than 24-hours, and/or flow through the overflow pipes occurs frequently.		Top several inches of sand are scraped. May require replacement of entire sand filter depth depending on extent of plugging (a sieve analysis is helpful to determine if the lower sand has too high a proportion of fine material).	
	Quarterly	Prolonged Flows	Sand is saturated for prolonged periods of time (several weeks) and does not dry out between storms due to continuous base flow or prolonged flows from detention facilities.		Low, continuous flows are limited to a small portion of the facility by using a low wooden divider or slightly depressed sand surface.	
	Quarterly	Short Circuiting	When flows become concentrated over one section of the sand filter rather than dispersed.		Flow and percolation of water through sand filter is uniform and dispersed across the entire filter area.	
	Quarterly	Erosion Damage to Slopes	Erosion over 2-inches deep where cause of damage is prevalent or potential for continued erosion is evident.		Slopes stabilized using proper erosion control measures.	

1g Open Sand Filter (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Above Ground (open sand filter)	Quarterly	Rock Pad Missing or Out of Place	Soil beneath the rock is visible.		Rock pad replaced or rebuilt to design specifications.	
	Quarterly	Flow Spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed across sand filter.		Spreader leveled and cleaned so that flows are spread evenly over sand filter.	
	Annually	Damaged Pipes	Any part of the piping that is crushed or deformed more than 20% or any other failure to the piping.		Pipe repaired or replaced.	

1h Bioretention Cells (Rain Gardens)

Bioretention areas require annual plant, soil, and mulch maintenance to ensure optimum infiltration and pollutant removal capabilities. Most routine maintenance procedures are typical landscape care activities, but other tasks are more typical of drainage facilities.

1. Routine Maintenance

Activity	Schedule	Completed (Date/By)	Objective	What to do & Notes
Watering: Maintain irrigation system. Fix leaks & breaks, and clear blockages. Hand water as needed for specific plants.	Check system twice annually (such as, in May & July); water only as needed for plant health.		Establish vegetation with a minimum 80% survival rate.	Plants should be selected to be drought-tolerant and not require watering after establishment (2-3 years). Watering may be needed during prolonged dry periods after plants are established.
Weeding: Remove undesired vegetation by hand.	As needed, and especially prior to seed disbursement		Reduce competition for desired vegetation. Improve aesthetics. Exclude undesirable plants.	Periodic weeding is necessary until plants are established. Pull weeds by hand, if possible. Avoid using chemical weed controls. Avoid compacting soil in garden.
Prune/control vegetation: Trim excessive growth of branches and remove dead plant material.	Once or twice annually		Maintain plant health and adequate plant coverage. Reduce shading of under-story if species require sun. Maintain soil health and infiltration capability. Maintain clearances from utilities and sight distances.	Depending on aesthetic requirements, occasional pruning and removing dead plant material may be necessary. Remove and dispose of properly. Avoid compacting soil in rain garden.
Clean the entry: Remove any accumulation of debris from flow entrance to garden	Check at least twice annually (such as, in October and January)		Maintain proper flow of stormwater from paved and/or impervious areas to bioretention facility.	Remove debris from curb drops and gutters in flow path to the bioretention area.
Mulching: Replace or add mulch with hand tools to a depth of 2-4 inches.	Once annually, or every two years if runoff pollutant load is low.		Replenish organic material in soil, reduce erosion, prolong good soil moisture level, filter pollutants.	Use compost mulch on the rain garden bottom area and lower side slopes, and wood chips on the upper side slopes and rim (above typical water levels).
Trash, Litter & Debris Removal	As needed, check at least monthly		Maintain aesthetics and prevent clogging of infrastructure.	Remove paper, plastic and other deleterious material from garden
Maintain access to infrastructure: Clear vegetation within one foot of inlets and outfalls, maintain access pathways.	Annually		Prevent clogging of grates and pipes; prevent encroachment on utilities or other infrastructure; maintain sight lines for traffic; maintain access for inspections.	

1h Bioretention Cells (Rain Gardens) - continued

2. Non-routine Maintenance

Activity	Schedule	Completed (Date/By)	Objective	What to do & Notes
Erosion control: Prevent erosion and sediment movement. Replace soil, plant material, and/or mulch layer in areas where erosion has occurred.	Determined by inspection.		Reduce sediment transport and clogging of infrastructure. Maintain desired plant survival and appearance of facilities.	Properly designed facilities should not have erosion problems. If erosion problems persist, assess: (1) flow volumes vs. garden size, (2) flow velocities and gradients, (3) flow dissipation and erosion protection at the flow entrance.
Remove Sediment: Shovel or rake out sediment within vegetated areas. Vactor catch basins and sediment traps.	Determined by inspection.		Reduce sediment transport and clogging of infrastructure. Maintain plant survival and appearance of facilities. Maintain proper elevations and ponding depths.	If sediment is deposited in the bioretention area, determine the source within the contributing area and stabilize sediment source to prevent erosion.
Clean underdrains: Jet clean or rotary cut debris/roots from under-drains.	Determined by inspection of clean-outs.		Maintain proper subsurface drainage, ponding depths, and dewatering rates.	
Clear flow entry: Remove excess vegetation at garden edge with line trimmer, vacuum sweeper, rake and/or shovel.	Determined by inspection.		Prevent accumulation of vegetation at pavement edge and maintain proper sheet flow of stormwater from paved and/or impervious areas to rain garden.	Bioretention facilities should be designed with a proper elevation drop from pavement to vegetated area to prevent blockage of storm flows by vegetation into infiltration area.
Replace plants: Replant bare spots or poor-performing plants per original design or per City.	Determined by inspection.		Maintain dense vegetation cover to prevent erosion, encourage infiltration and exclude weeds.	If specific plants have a high mortality rate, assess the cause and replace with suitable species.
Replace soil: Remove vegetation and excavate soil.	Determined by inspection (visual) or tests (infiltration, pollutant, or soil fertility).		Maintain infiltration, soil fertility and pollutant removal capability. Save as much plant material as possible for replanting.	Soil mixes for bioretention facilities are designed to maintain long-term fertility and pollutant processing capability. Replacing mulch helps prolong performance & reduce pollutant accumulation.
Rebuild or reinforce structures: Various activities to maintain walls, intake and outfall pads, weirs, other hardscape elements	Determined by inspection.		Maintain proper drainage and aesthetics, and prevent erosion.	
Regrade or recontour slopes: Maintain proper slopes and replant exposed areas.	Determined by inspection.		Prevent erosion where side slopes have been disturbed by foot or auto traffic intrusion.	

Group 2

Underground Tanks, Vaults and Trenches

2a Detention Tanks and Vaults

These types of structures are usually underground and accessed via a manhole.

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Storage Area	Quarterly	Plugged Air Vents	One-half of the cross section of a vent is blocked at any point or the vent is damaged.		Vents open and functioning.	
	Quarterly	Debris and Sediment	Accumulated sediment depth exceeds 10% of the diameter of the storage area for 1/2 length of storage vault or any point depth exceeds 15% of diameter. (Example: 72-inch storage tank would require cleaning when sediment reaches depth of 7 inches for more than 1/2 length of tank.)		All sediment and debris removed from storage area.	
	Quarterly	Joints Between Tank/Pipe Section	Any openings or voids allowing material to be transported into facility. (Will require engineering analysis to determine structural stability).		All joint between tank/pipe sections are sealed.	
	Annually	Tank Pipe Bent Out of Shape	Any part of tank/pipe is bent out of shape more than 10% of its design shape. (Review required by engineer to determine structural stability).		Tank/pipe repaired or replaced to design.	
	Annually	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch and any evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determines that the vault is not structurally sound. Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or any evidence of soil particles entering the vault through the walls.		Vault replaced or repaired to design specifications and is structurally sound. No cracks more than 1/4-inch wide at the joint of the inlet/outlet pipe.	
Manhole	Quarterly	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.		Manhole is closed.	
	Quarterly	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread (may not apply to self-locking lids)		Mechanism opens with proper tools.	

2a Detention Tanks and Vaults (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Manhole	Quarterly	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. Intent is to keep cover from sealing off access to maintenance.		Cover can be removed and reinstalled by one maintenance person.	
	Quarterly	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, misalignment, not securely attached to structure wall, rust, or cracks.		Ladder meets design standards. Allows maintenance person safe access.	
Catch Basins		See "Catch Basins"	See "Catch Basins"		See "Catch Basins"	

2b Wet Vaults

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Vault	Quarterly	Trash/Debris Accumulation	Trash and debris accumulated in vault, pipe or inlet/outlet (includes floatables and non-floatables).		Remove trash and debris from vault.	
	Quarterly	Sediment Accumulation in Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6-inches.		Remove sediment from vault.	
	Quarterly	Damaged Pipes	Inlet/outlet piping damaged or broken and in need of repair.		Pipe repaired and/or replaced.	
	Quarterly	Access Cover Damaged/Not Working	Cover cannot be opened or removed, especially by one person.		Pipe repaired or replaced to proper working specifications.	
	Quarterly	Ventilation	Ventilation area blocked or plugged.		Blocking material removed or cleared from ventilation area. A specified % of the vault surface area must provide ventilation to the vault interior (see design specifications).	
	Annually	Vault Structure Damage - Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Maintenance/inspection personnel determine that the vault is not structurally sound.		Vault replaced or repairs made so that vault meets design specifications and is structurally sound.	
			Cracks wider than 1/2-inch at the joint of any inlet/ outlet pipe or evidence of soil particles entering through the cracks.		Vault repaired so no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.	
	Annually	Baffles	Baffles corroding, cracking warping and/or showing signs of failure as deemed by maintenance/ inspection staff.		Baffles repaired or replaced to specifications.	

2b Wet Vaults (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Vault	Annually	Access Ladder Damage	Ladder is corroded or deteriorated, not functioning properly, not attached to structure wall, missing rungs, has cracks and/or misaligned. Confined space warning sign missing.		Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel. Replace sign warning of confined space entry requirements. Ladder and entry notification complies with OSHA standards.	

2c Enclosed Sand Filter

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Vault	Quarterly	Sediment Accumulation on Sand Media Section	Sediment depth exceeds 1/2-inch.		No sediment deposits on sand filter section that would impede permeability of the filter section.	
Vault	Quarterly	Sediment Accumulation in Pre-Settling Portion of Vault	Sediment accumulation in vault bottom exceeds the depth of sediment zone plus 6-inches.		No sediment deposits in first chamber of vault.	
Vault	Quarterly	Trash/Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/ outlet, floatables and non-floatables.		Trash and debris removed from vault and inlet/outlet piping.	
Vault	Quarterly	Sediment in Drain Pipes/Cleanouts	When drain pipes, cleanouts become full with sediment and/or debris.		Sediment and debris removed.	
Vault	Quarterly	Short Circuiting	When seepage/flow occurs along the vault walls and corners. Sand eroding near inflow area.		Sand filter media section re-laid and compacted along perimeter of vault to form a semi-seal. Erosion protection added to dissipate force of incoming flow and curtail erosion.	
Pipes	Annually	Damaged Pipes	Inlet or outlet piping damaged or broken, in need of repair.		Pipe repaired and/or replaced.	
Vault	Quarterly	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/ deformation of cover. Maintenance person cannot remove cover using normal lifting pressure.		Cover repaired to proper working specifications or replaced.	
Vault	Quarterly	Ventilation	Ventilation area blocked or plugged		Blocking material removed/cleared from ventilation area. A specified % of the vault surface area must provide venting to the vault interior (per design)	

2c Enclosed Sand Filter (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Vault	Annually	Vault Structure Damaged; Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab.	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.		Vault replaced or repairs made so that vault meets design specifications and is structurally sound.	
Vault	Annually		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.		Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.	
Vault	Annually	Baffles/Internal walls	Baffles or walls corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.		Baffles repaired or replaced to specifications.	
Vault	Quarterly	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.		Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel.	

2d Dispersion Trenches

Dispersion trenches and pipes are designed to spread out the flow of water over a larger surface area, creating more of a sheet flow and less of an erosive point source. These structures are typically found at the outlet areas of ponds or swales.

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Dispersion Trench	Annually	Missing or Moved Rock	Trench should be full of rip rap.		Add large rocks (about 30 lb. each) so that rocks are visible above the edge of the trench.	
Dispersion Trench	Quarterly	Pipe Plugged	Accumulated sediment should not exceed 20% of the depth.		Clean and flush pipe. In severe cases, the rocks will have to be removed, cleaned, and then replaced.	
Dispersion Trench	Quarterly	Perforations Plugged	Ensure that at least half of the perforations in the pipe are not plugged with debris or sediment.		Clean or replace perforated pipe.	
Dispersion Trench	Semi-Annually & After Major Storms	Not Discharging Water Properly	The intent of the dispersion trench is to prevent erosion. Water should flow out of the trench in a uniform "sheet flow." Visually inspect the trench for evidence of water discharging at concentrated points and causing erosion.		If water is not being discharged correctly, the trench must be redesigned or rebuilt to standard. The elevation of the lip of the trench should be the same (level) at all points.	
Dispersion Trench	Semi-Annually & After Major Storms	Water flows out top of catch basin	Water should not flow out during storms smaller than the design storm. Also, ensure that it is not causing (and appears unlikely to cause) damage.		Facility must be rebuilt or redesigned to standards. Pipe is probably plugged or damaged and needs replacement.	
Dispersion Trench	Semi-Annually & After Major Storms	Receiving Area Over-Saturated	Ensure that the water in the receiving area is not causing, and does not have the potential to cause, a landslide.		Stabilize the slope with grass or other vegetation. You might need to use rock or other cover if the condition is severe.	

Group 3

Structures and Pre-Treatment

3a Control Structures and Flow Restrictors

These types of structures are usually placed within manholes, and could be locked. They typically consist of two pipes, one placed above the other. The lower pipe will typically have a cover and a small hole drilled in it to allow for slow release of water. The upper pipe is usually larger to provide for higher flows and emergency overflows.

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Structure	Quarterly	Trash and Debris (Includes Sediment)	Material exceeds 25% of sump depth or 1 foot below orifice plate.		Control structure orifice is not blocked. All trash & debris removed	
	Quarterly	Structural Damage	Structure is not securely attached to manhole wall.		Securely attach structure to wall and outlet pipe.	
			Structure is not in upright position (more than 10% from plumb)		Restore structure to correct position.	
			Connections to outlet pipe are not watertight and show signs of rust.		Pipe connections are water tight; structure repaired or replaced and works as designed.	
			Any holes in structure (other than designed holes).		Structure has no holes other than designed holes.	
Cleanout Gate	Quarterly	Damaged or Missing	Cleanout gate is not watertight or is missing.		Gate is watertight and works as designed.	
			Gate cannot be moved up and down by one maintenance person.		Gate moves up and down easily and is watertight.	
			Chain/rod leading to gate is missing or damaged.		Chain is in place and works as designed.	
			Gate is rusted over 50% of its surface area.		Gate is repaired or replaced to meet design standards.	
Orifice Plate	Quarterly	Damaged or Missing	Control device is not working properly due to missing, displaced, or bent orifice plate.		Plate is in place and works as designed.	
		Obstructions	Trash, debris, sediment or vegetation blocking the plate.		Plate is free of all obstructions and works as designed.	
Overflow Pipe	Quarterly	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.		Pipe is free of all obstructions and works as designed.	
Manhole			See “Closed Detention Systems”		See “Closed Detention Systems”	
Catch Basin			See “Catch Basins”		See “Catch Basins”	

3b Catch Basins

These structures are typically located in the streets. The City of Lacey is responsible for routine maintenance of the pipes and structures in the public rights-of-way, while the property owner or homeowners association is responsible for maintenance of pipes and catch basins in private areas and for keeping the grates clear of debris in all areas.

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Catch Basin	Quarterly	Trash & Debris	Trash or debris which is located immediately in front of the catch basin (CB) opening or is blocking inletting capacity of the basin by more than 10%.		Remove trash and debris located directly in front of CB or on grate	
			Trash or debris (in basin) that exceeds 60 percent of the sump depth as measured from bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6" clearance from the debris surface to the invert of the lowest pipe.		Remove all trash and debris from the catch basin.	
			Trash or debris in any inlet or outlet pipe blocking more than 1/3 of its height.		Inlet and outlet pipes free of trash or debris.	
			Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g. methane).		Remove dead animals, etc. present within the catch basin.	
	Quarterly	Sediment	Sediment (in basin) exceeds 60% of sump depth as measured from the bottom of basin to invert of lowest pipe into or out of basin, but in no case less than a minimum of 6" clearance from the sediment surface to the invert of lowest pipe.		No sediment in the catch basin	
	Annually	Structure Damage to Frame and/or Top Slab	Top slab has holes larger than 2 square inches or cracks wider than 1/4 inch (Intent is to make sure no material is running into basin).		Top slab is free of holes and cracks.	
			Frame not sitting flush on top slab, i.e., separation of more than 3/4 inch of the frame from the top slab. Frame not securely attached		Frame is sitting flush on the riser rings or top slab and firmly attached.	
	Annually	Fractures or Cracks in Basin Walls/ Bottom	Maintenance person determines structure is unsound.		Basin replaced or repaired to design standard	
			Grout fillet has separated or cracked wider than 1/2 inch and longer than 1 foot at the joint of any inlet/outlet pipe, or any evidence of soil entering basin.		Pipe regrouted and secure at basin wall.	

3b Catch Basins (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Catch Basin	Annually	Settlement/ Misalignment	If failure of basin has created a safety, function, or design problem.		Replaced or repair to design standards.	
	Quarterly	Vegetation	Vegetation growing across and blocking more than 10% of the basin opening.		Remove vegetation blocking opening to basin.	
			Vegetation growing in inlet/outlet pipe joints that is more than six inches tall and less than six inches apart.		No vegetation or root growth present.	
		Contamination and Pollution	See "Detention Ponds"		No pollution present.	
	Quarterly	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.		Catch basin cover is closed	
	Quarterly	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread.		Mechanism opens with proper tools.	
	Quarterly	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. (Intent is keep cover from sealing off access to maintenance.)		Cover can be removed by one maintenance person.	
Catch Basin Cover	Quarterly	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.		Catch basin cover is closed	
	Quarterly	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread.		Mechanism opens with proper tools.	
	Quarterly	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. (Intent is keep cover from sealing off access to maintenance.)		Cover can be removed by one maintenance person.	

3b Catch Basins (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Ladder	Quarterly	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, not securely attached to basin wall, misalignment, rust, cracks, or sharp edges.		Ladder meets design standards and allows maintenance person safe access.	
Metal Grates (If Applicable)	Quarterly	Grate opening Unsafe	Grate with opening wider than 7/8 inch.		Grate opening meets design standards.	
	Quarterly	Trash and Debris	Trash and debris that is blocking more than 20% of grate surface inletting capacity.		Grate free of trash and debris.	
	Quarterly	Damaged or Missing	Grate missing or broken member(s) of the grate.		Grate is in place and meets design standards.	

3c Debris Barriers (Trash Racks)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
General	Quarterly	Trash and Debris	Trash or debris that is plugging more than 20% of the openings in the barrier.		Barrier cleared to design flow capacity.	
Metal	Quarterly	Damaged/ Missing Bars	Bars are bent out of shape more than 3 inches.		Bars in place with no bends more than 3/4 inch.	
			Bars are missing or entire barrier missing.		Bars in place according to design.	
			Bars are loose and rust is causing 50% deterioration to any part of barrier.		Barrier replaced or repaired to design standards.	
	Quarterly	Inlet/Outlet Pipe	Debris barrier missing or not attached to pipe		Barrier firmly attached to pipe	

3d Energy Dissipaters

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Rock Pad	Quarterly	Missing or Moved Rock	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil.		Rock pad replaced to design standards.	
	Quarterly	Erosion	Soil erosion in or adjacent to rock pad.		Rock pad replaced to design standards.	
Dispersion Trench	Quarterly	Pipe Plugged with Sediment	Accumulated sediment that exceeds 20% of the design depth.		Pipe cleaned/ flushed so it matches design.	
	Quarterly	Not Discharging Water Properly	Visual evidence of water discharging at concentrated points along trench (normal condition is a "sheet flow" of water along trench). Intent is to prevent erosion damage.		Trench redesigned or rebuilt to standards.	
	Quarterly	Perforations Plugged.	Over 1/2 of perforations in pipe are plugged with debris and sediment.		Perforated pipe cleaned or replaced.	
	Quarterly	Water Flows Out Top of "Distributor" Catch Basin.	Maintenance person observes or receives credible report of water flowing out during any storm less than the design storm or its causing or appears likely to cause damage.		Facility rebuilt or redesigned to standards.	
	Quarterly	Receiving Area Over-Saturated	Water in receiving area is causing or has potential of causing landslide problems.		No danger of landslides.	
Manhole/Chamber	Annually	Worn or Damaged Post, Baffles, Side of Chamber	Structure dissipating flow deteriorates to 1/2 of original size or any concentrated worn spot exceeding one square foot which would make structure unsound.		Structure replaced to design standards.	
		Other Defects	See "Catch Basins"		See "Catch Basins"	

3e Baffle Oil/Water Separators (API Type)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
General	Quarterly	Dirty Discharge Water	Inspect discharge water for obvious signs of poor water quality.		Effluent discharge from vault should be clear without thick visible sheen.	
	Quarterly	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6-inches in depth.		Remove sediment deposits that would impede flow through the vault and reduce separation efficiency.	
	Quarterly	Trash and Debris Accumulation	Trash and debris accumulation in vault, or pipe inlet/outlet, floatables and non-floatables.		Remove trash and debris from vault and inlet/outlet piping.	
	Quarterly	Oil Accumulation	Oil accumulations that exceed 1-inch, at the surface of the water.		Extract oil from vault by vactoring. Disposal must be in accordance with state and local rules and regulations.	
	Quarterly	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.		Pipe repaired or replaced.	
	Quarterly	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover.		Cover repaired to proper working specifications or replaced.	
	Annually	Vault Structure Damage - Cracks in Walls or Bottom, Damage to Frame and/or Top Slab	See "Catch Basins"		Vault replaced or repairs made so that vault meets design specifications and is structurally sound.	
	Annually	Baffles	Baffles corroding, cracking, warping and/or show signs of failure as determined during inspection.		Baffles repaired or replaced to specifications.	
	Annually	Access Ladder Damaged	Ladder is corroded or deteriorated, not securely attached to structure wall, missing rungs, cracks, or misaligned.		Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection.	

3f Coalescing Plate Oil / Water Separators

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
General	Quarterly	Dirty Discharge Water	Inspect discharge water for obvious signs of poor water quality.		Effluent discharge from vault should be clear with no thick visible sheen.	
	Quarterly	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6-inches in depth and/or visible signs of sediment on plates.		No sediment on vault bottom and plate media, which would impede flow through the vault and reduce separation efficiency.	
	Quarterly	Trash and Debris	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables.		Trash and debris removed from vault.	
	Quarterly	Oil Accumulation	Oil accumulation that exceeds 1-inch at the water surface.		Oil is extracted from vault . Coalescing plates are cleaned. There should be no visible oil depth on water.	
	Annually	Damaged Coalescing Plates	Plate media broken, deformed, cracked and/or showing signs of failure.		Repaired or replaced.	
	Annually	Damaged Pipes	Inlet or outlet piping damaged or broken or in need of repair.		Pipe repaired and or replaced.	
	Annually	Baffles	Baffles showing signs of failure as determined during maintenance/inspection.		Baffles repaired or replaced to specifications.	
	Annually	Vault Structure Damage - Includes Cracks. Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.		Vault replaced or repairs made so that vault meets design specifications and is structurally sound.	
	Annually		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or soil particles entering through the cracks.		Vault repaired to designed condition.	
	Annually	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.		Replace or repair ladder so it meets specifications and is safe to use as determined by inspection.	

3g Catch Basin Inserts

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
General	Quarterly	Sediment Accumulation	When sediment forms a cap over the insert media of the insert and/or unit.		No sediment cap on the insert media and its unit.	
	Quarterly	Trash and Debris Accumulation	Trash and debris accumulates on insert unit creating a blockage/restriction.		Trash and debris removed from insert unit. Runoff freely flows into catch basin.	
	Quarterly	Media Insert Not Removing Oil	Effluent water from media insert has a visible sheen.		Effluent water from media insert is free of oils and has no visible sheen.	
	Quarterly	Media Insert Water Saturated	Catch basin insert is saturated with water and no longer has the capacity to absorb.		Remove and replace media insert	
	Quarterly	Media Insert-Oil Saturated	Media oil saturated due to petroleum spill that drains into catch basin.		Remove and replace media insert.	
	Quarterly	Media Insert Use Beyond Normal Product Life	Media has been used beyond the typical average life of media insert product.		Remove and replace media at regular intervals, depending on insert product.	

Group 4

Miscellaneous Facilities and Features

4a Downspouts and Roof Drywells

These facilities dispose of stormwater from roofs and clean impervious surfaces.

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Downspout	Annually	Overflow	Water overflows from the gutter or downspout during rain.		First try cleaning out the gutter and downspouts. If this doesn't solve the problem, a larger drywell may be needed.	
Roof	Annually	Moss	Moss and algae are taking over the shadier parts of the shingles.		Disconnect the flexible part of the downspout that leads to the drywell. Then perform moss removal as desired. Pressure wash or use fatty acid solutions instead of highly toxic pesticides or chlorine bleach. Install a zinc strip as a preventative.	

4b Conveyance Pipes, Ditches and Swales

These features contain and direct the flow of water from one location to another.

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Pipes	Annually	Sediment, Debris, & Vegetation	Accumulated sediment should not exceed 20% of the diameter of the pipe. Vegetation should not reduce free movement of water through pipes. Ensure that the protective coating is not damaged or rusted. Dents should not significantly impede flow. Pipe should not have major cracks or flaws allowing water to leak out.		Clean out pipes of all sediment and debris. Remove all vegetation so that water flows freely through pipes. Repair or replace pipe.	
Open Ditches	Quarterly	Trash & Debris	There should not be any yard waste or litter in the ditch.		Remove trash and debris and dispose of them properly.	
	Annually	Sediment Buildup	Accumulated sediment should not exceed 20% of the depth of the ditch.		Clean out ditch of all sediment and debris.	
Open Ditches and Swales	Annually	Overgrowth of Vegetation	Check for vegetation (e.g., weedy shrubs or saplings) that reduces the free movement of water through ditches or swales.		Clear blocking vegetation so that water moves freely through the ditches. Grassy vegetation should be left alone.	
	Quarterly	Erosion	Check around inlets and outlets for signs of erosion. Check slopes for signs of sloughing or settling. Action is needed where eroded damage is over 2" deep and where there is potential for continued erosion.		Eliminate causes of erosion. Stabilize slopes by using the appropriate erosion control procedure (e.g. compact the soil, plant grass, reinforce with rock).	
	Annually	Missing Rocks	Native soil beneath the rock splash pad, check dam, or lining should not be visible.		Replace rocks to design standard.	

4b Conveyance Pipes, Ditches and Swales (continued)

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
Swales	Quarterly	Vegetation	Grass cover is sparse and weedy, or areas are overgrown with woody vegetation.		Aerate soils and re-seed and mulch bare areas. Keep grass less than 8" high. Remove woody growth, re-contour & re-seed as necessary.	
	Quarterly	Homeowner Conversion	Swale has been filled in or blocked by shed, woodpile, shrubbery, etc.		Speak with the homeowner and request that the swale area be restored. Contact the City to report the problem if not rectified voluntarily.	
	Annually	Swale does not drain	Water stands in the swale, or flow velocity is very slow. Stagnation occurs.		A survey may be needed to check grades. Grades should be in 1-5% range if possible. If grade is less than 1%, under-drains may need to be installed.	

4c Access Roads & Easements

These features provide access to drainage facilities for inspection and/or maintenance.

What to Check	How Often	Problem or Defect	Conditions to Check For	√ Check	What to do for Desired Condition	√ Done
General	One Time	Access	Check to determine if there is adequate access to your stormwater facilities for maintenance vehicles.		If there is not adequate access, check with the City to determine whether an easement exists. If so, a maintenance road may need to be constructed there.	
Access Road	Quarterly	Blocked Roadway	Debris that could damage vehicle tires (glass or metal).		Clear all potentially damaging material.	
	Annually	Blocked Roadway	Any obstructions which reduce clearance above and along the road to less than 14 feet.		Clear above and along roadway so there is enough clearance.	
Road Surface	Annually	Bad Road Conditions	Check for potholes, ruts, mushy spots, or woody debris that limits access by maintenance vehicles.		Add gravel or remove wood as necessary.	
Shoulders and Ditches	Annually	Erosion	Check for erosion along roadway.		Repair erosion with additional soil or gravel.	

Glossary of Stormwater Terms

Best Management Practices (BMPs) – Structural features or procedures that reduce the adverse impacts of development on the quantity and/or quality of runoff water.

Biofilter (Swale) – A wider and flatter vegetated version of a ditch over which runoff flows at a uniform depth and velocity. Biofilters perform best when vegetation has a thick mat of roots, leaves, and stems at the soil interface (such as grass).

Biofiltration – The process through which pollutant concentrations in runoff water are reduced by filtering runoff through vegetation.

Buffer – The zone along a sensitive area that provides protection and stability for the area's functioning. As an integral part of a stream or wetland ecosystem, the buffer provides shading, slope and bank stabilization, and input of organic debris and coarse sediments to streams. It allows room for variation in aquatic system boundaries (due to hydrologic or climatic effects), attenuation of surface water flows from precipitation and stormwater runoff, habitat for wildlife, and protection from harmful disturbance or intrusion by humans or domestic animals.

Catch Basin – An inlet box set into the ground, usually rectangular and made of concrete, capped with a grate that allows stormwater to enter. A sump in the bottom catches sediment.

Check Dam – A dam (of rock, logs, etc.) built in a gully or drainage channel to reduce flow velocity, minimize erosive scouring, promote sediment deposition, and/or enhance infiltration.

Compost Stormwater Filter – A treatment facility that removes sediment and pollutants from stormwater by percolating water through a layer of specially-prepared Bigleaf maple compost. Clean water exits the bottom of the facility through a pipe, while stormwater flows in excess of the facility design overflow the compost bed and bypass the facility.

Constructed Wetland – A wet pond with dead storage at various depths and planted with wetland plants to enhance its treatment capabilities.

Control Structure or Flow Restrictor – A manhole and/or pipe structure with a flow-regulating or metering device such as a weir or plates with small holes known as orifices. The structure controls the rate at which water leaves the pond.

Conveyance – A mechanism or device for transporting water, including gutters, pipes, channels (natural or man-made), culverts, manholes, etc.

Critical Areas – Areas such as wetlands, streams, steep slopes, etc., as defined by ordinance or resolution by the jurisdiction. Also known as environmentally-sensitive areas.

Culvert – A conveyance device (e.g. concrete, metal or plastic pipe) which conveys water from a ditch, swale, or stream under (usually across) a roadway, driveway or embankment.

Dead Storage – The volume of storage in a pond below the outlet which does not drain after a storm event. This pool provides treatment of the stormwater by allowing sediments to settle out.

Detention Facility – A facility (e.g. a pond, vault, or pipe) in which surface water or stormwater is temporarily stored.

Detention Pond – A detention facility in the form of an open pond.

Dispersion Trench – An open-top trench filled with rip rap or gravel that takes the discharge from a pond, spreads it out, and spills (bubbles) the flow out along its entire length. Dispersion trenches are used to simulate "sheet flow" of stormwater from an area, and are often used to protect sensitive areas.

Drainage System – A combination of facilities for the collection, conveyance, containment, treatment, discharge and/or disposal of stormwater runoff.

Drop Structure – A structure for dropping water to a lower elevation and/or dissipating energy. A drop may be vertical or inclined.

Dry Pond – A detention facility that drains completely after a storm. This type of pond has a pipe outlet at the bottom.

Easement – A legal encumbrance placed against a property's title to reserve access. Drainage easements typically provide access to pipes and/or ponds, and are generally 15 to 20 feet wide.

Emergency Overflow or Spillway – An area on the top edge of a pond that is slightly lower in elevation than areas around it, and is normally lined with riprap for erosion protection. The emergency overflow is used only if the primary and secondary outlets of the pond fail, in the event of extreme storms, or if the infiltration capability of the pond becomes significantly diminished. If the emergency overflow ever comes into play, it may mean that the pond needs to be upgraded.

Energy Dissipater – A rock pad at an outlet (of a pipe, channel, etc.) designed to slow the flow velocity, spread out the water leaving the outlet, and reduce the potential for erosion.

Freeboard – The vertical distance between the design high water mark and the top of a pond (or other structure). Most ponds have one to two feet of freeboard to prevent them from overflowing.

Infiltration – The soaking of water through the soil surface into the ground (percolation is essentially the same thing). Many ponds are designed to infiltrate or retain stormwater, and thus do not have a regularly used discharge pipe.

Infiltration Facility (or Structure) – A facility (pond or trench) which retains and percolates stormwater into the ground, having no discharge (to any surface water) under normal operating conditions.

Junction – Point where two or more drainage pipes or channels converge (e.g. a manhole).

Jurisdiction – Lacey, Olympia, Tumwater, or Thurston County (as applicable).

Lined Pond or Conveyance – A facility, the bottom and sides of which have been made impervious (using, for example, a plastic liner or clay/silt soil layer) to the transmission of liquids.

Live Storage – The volume of storage in a pond above the outlet, which drains after a storm event. This storage capacity provides flood control and habitat protection for nearby streams.

Manhole – A larger version of the catch basin, often round with a solid lid. Manholes allow access to underground pipes (such as storm sewers) for maintenance.

Natural Channel – A stream, creek, river, lake, wetland, estuary, gully, swale, ravine, or any open conduit where water will concentrate and flow intermittently or continuously.

Oil-Water Separator – A structure or device used to remove oil and greasy solids from water. They operate by using gravity separation of liquids that have different densities. Many catch basins have a down-turned plastic elbow that provides some oil-water separation.

Outfall – The point where water flows from a man-made conduit, channel, or drain into a water body or other natural drainage feature.

Retention Facility – A facility that is designed to retain water and allow for infiltration.

Retention Pond – A retention facility that is an open basin or "pond."

Revetments – Materials such as rock or keystones used to sustain an embankment, such as in a retaining wall.

Riprap – Broken rock, cobbles, or boulders placed on earth surfaces, such as on top of a berm for the emergency overflow, along steep slopes, or at the outlet of a pipe, for protection against the erosive action of water. Also used for entrances to construction sites, to prevent sediment tracking.

Runoff – The portion of water originating as precipitation that becomes surface flow. See "stormwater" below.

Sand Filter – A treatment facility that removes pollutants and sediments from stormwater by percolating stormwater through a layer of sand. Clean water exits the bottom of the facility through a pipe.

Stormwater – The portion of precipitation that falls on property and that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes or other features into a defined surface water body or a constructed infiltration facility. Stormwater includes wash-down water and other wastewater that enters the drainage system.

Swale – A shallow surface drainage conveyance with relatively gentle side slopes, generally with flow depths less than 1 foot. Essentially a broad, flat-bottomed ditch. See "biofilter."

Trash Rack or Bar Screen – A device (usually a screen or bars) that fits over a pipe opening to prevent large debris such as rocks or branches from entering and partially blocking the pipe.

Wet Pond – A stormwater treatment pond designed with a "dead storage" volume to maintain a continuous or seasonal static water level below the pond outlet elevation.

Chapter 10 – Agreements and Guarantees

All drainage facilities constructed or modified must comply with the agreements and guarantees specified in this Chapter and in relevant portions of the City of Lacey *Development Guidelines and Public Works Standards* and the Lacey Municipal Code. These agreements and guarantees address financial responsibility for proper construction, operation and maintenance of drainage facilities.

10.1 FINANCIAL GUARANTEES

Financial guarantees may be required by the City to ensure the drainage facilities function according to the approved design, and are maintained and in proper condition after project construction. Bonding or other securities as specified by the Public Works Department shall be provided by the project proponent for the following types of guarantees:

A. Performance Guarantee

A performance financial guarantee shall be provided to the City in the amount equal to 150% of the estimated cost of the outstanding public works improvements, including the on-site drainage system (water, sewer, storm, frontage improvements), to ensure proper construction, functionality and operation of the improvements. The Certificate of Occupancy will not be issued until all public works improvements are completed and accepted by the City.

B. Storm Maintenance Guarantee

In addition to the General Public Works Maintenance Guarantee, a Storm Maintenance Guarantee shall be provided to the City prior to final Public Works approval in an amount equal to 20% of the estimated cost of the storm improvements. This guarantee is required for a period of two years after Final Public Works Approval is granted, to ensure satisfactory maintenance and repairs of drainage facilities in accordance with the Stormwater Facilities Maintenance Plan (as described in Chapter 9).

Maintenance shall include cleaning of the storm system at the end of the two-year period at the developer’s expense. The developer shall be responsible for cleaning the storm conveyance system, including treatment facilities, after one year.

If the stormwater system is dependent on a homeowners association (HOA) for maintenance, then the developer shall present evidence of a HOA being established and active before the financial guarantee is released. The developer shall establish a mechanism prior to sale of all or part of the project that ensures the legal right and ability to perform required stormwater system maintenance while the financial guarantee is in effect. Proof of same shall be provided to the City prior to acceptance of the financial guarantee.

10.2 AGREEMENTS

Drainage facilities may be privately operated and maintained according to the requirements addressed in Section 10.2.1, or may be turned over to the City for operation and maintenance under the conditions described in Section 10.2.2. The City retains the right, through easements to be granted for such purpose, to inspect privately operated facilities discharging to the public drainage system at is discretion, to perform maintenance determined by such an inspection to be needed, and to recover costs for such maintenance from the property owner or entity responsible for the maintenance.

10.2.1 Agreements Related To Facilities To Be Privately Maintained

Facilities to be privately operated and maintained must provide guarantees, as described in this chapter, to ensure adequate maintenance, as described in Chapter 9, such that stormwater facilities function properly and do not cause adverse impacts.

Stormwater facilities on private property, to be maintained by private associations, businesses or corporations, must demonstrate adequate commitment to maintaining the design function of such facilities, including flow control and water quality elements. Such commitment must be documented through the appropriate agreements:

- Residential Agreement to Maintain Stormwater Facilities and to Implement a Pollution Source Control Plan (Appendix Q of *Development Guidelines*)
- Commercial/Industrial Agreement to Maintain Stormwater Facilities and to Implement a Pollution Source Control Plan (Appendix Q of *Development Guidelines*)
- Adequate drainage easement is legally established and recorded (Utility Easement form, individual or corporate, Appendix B of *Development Guidelines*);

Maintenance of On-site Stormwater Management BMPs (e.g., roof downspout infiltration or dispersion) in Residential Developments must be provided for as part of the founding documents (Articles of Incorporation) of a Property Owners' Association, if applicable.

10.2.2 Agreements Related To Facilities To Be Maintained By The City

The City may consider acceptance of maintenance responsibility for private stormwater facilities under certain circumstances. Minimum requirements for such consideration are:

- An adequate drainage easement is legally established and recorded (Utility Easement form, individual or corporate, Appendix B, Development Guidelines);
- Final Plat Agreement to ensure maintenance/correction of drainage defects for a period of two years prior to final approval and turnover to City (Appendix I, Design Guidelines)

Note that facilities located on individual lots (e.g. lot-based biofiltration swales, rain gardens, etc.) will not be accepted for maintenance by the City.

Appendix 10A
Maintenance Covenants

10A.1 Maintenance Covenant

Whenever storm drainage facilities are to be maintained by a property owners' association within a subdivision, a covenant stating the property owners' specific maintenance responsibilities must be recorded on the plat and recorded against each lot in the subdivision. The covenant shall include the following or substantially similar language:

MAINTENANCE COVENANT

> Easements are hereby granted for the installation, inspection, and maintenance of utilities and drainage facilities as delineated on the plat for [subdivision name]. No encroachment will be placed within the easements shown on the plat which may damage or interfere with the installation, inspection, and maintenance of utilities. Maintenance and expense thereof of the utilities and drainage facilities shall be the responsibility of the property owners association as established by covenant recorded under Auditor's file number ____________________.

10A.2 Sanctions for Failure to Maintain

If a property owners' association is to maintain drainage facilities, then the following or substantially similar words shall appear in the document creating the property owners' association:

> In the event the Project Proponent (or successors or the Property Owners Association), in the judgment of the Jurisdiction, fails to maintain drainage facilities within the plat, or if the Proponent or successors willfully or accidentally reduces the capacity of the drainage system or renders any part of the drainage system unusable, the Proponent or successors agree to the following remedy: After 30 days notice by registered mail to the Proponent or successors, Jurisdiction may correct the problem or maintain facilities as necessary to restore the full design capacity of the drainage system. Jurisdiction will bill the Proponent or successors for all costs associated with the engineering and construction of the remedial work. Jurisdiction may charge interest as allowed by law from the date of completion of construction. Jurisdiction will place a lien on the property and/or on lots in the Property Owners Association for payments in arrears. Costs or fees incurred by the jurisdiction, should legal action be required to collect such payments, shall be borne by the Proponent or successors.

Glossary of Terms and Acronyms

The following definitions are provided for reference and use with this manual. They shall be superseded by any other definitions for these terms adopted by ordinance, unless defined in a Washington State WAC or RCW and/or used and defined as part of the Department of Ecology's Minimum Requirements for all new development and redevelopment.

AASHTO classification	The official classification of soil materials and soil aggregate mixtures for highway construction, used by the American Association of State Highway and Transportation Officials.
Absorption	The penetration of a substance into or through another, such as the dissolving of a soluble gas in a liquid.
Adjacent steep slope	A slope with a gradient of 15 percent or steeper within five hundred feet of the site.
Adjustment	A variation in the application of a Minimum Requirement to a particular project. Adjustments provide substantially equivalent environmental protection.
Adsorption	The adhesion of a substance to the surface of a solid or liquid; often used to extract pollutants by causing them to be attached to such adsorbents as activated carbon or silica gel. Hydrophobic, or water-repulsing adsorbents, are used to extract oil from waterways when oil spills occur. Heavy metals such as zinc and lead often adsorb onto sediment particles.
Aeration	The process of being supplied or impregnated with air. In waste treatment, the process used to foster biological and chemical purification. In soils, the process by which air in the soil is replenished by air from the atmosphere. In a well aerated soil, the soil air is similar in composition to the atmosphere above the soil. Poorly aerated soils usually contain a much higher percentage of carbon dioxide and a correspondingly lower percentage of oxygen.
Aerobic	Living or active only in the presence of free (dissolved or molecular) oxygen.
Aerobic bacteria	Bacteria that require the presence of free oxygen for their metabolic processes.
Aggressive plant species	Opportunistic species of inferior biological value that tend to out-compete more desirable forms and become dominant; applied to native species in this manual.

Algae	Primitive plants, many microscopic, containing chlorophyll and forming the base of the food chain in aquatic environments. Some species may create a nuisance when environmental conditions are suitable for prolific growth.
Algal bloom	Proliferation of living algae on the surface of lakes, streams or ponds; often stimulated by phosphate over-enrichment. Algal blooms reduce the oxygen available to other aquatic organisms.
American Public Works Association (APWA)	The Washington State Chapter of the American Public Works Association.
Anadromous	Fish that grow to maturity in the ocean and return to rivers for spawning.
Anaerobic	Living or active in the absence of oxygen.
Anaerobic bacteria	Bacteria that do not require the presence of free or dissolved oxygen for metabolism.
Annual flood	The highest peak discharge on average which can be expected in any given year.
Antecedent moisture conditions	The degree of wetness of a watershed or within the soil at the beginning of a storm.
Anti-seep collar	A device constructed around a pipe or other conduit and placed through a dam, levee, or dike for the purpose of reducing seepage losses and piping failures.
Anti-vortex device	A facility placed at the entrance to a pipe conduit structure such as a drop inlet spillway or hood inlet spillway to prevent air from entering the structure when the pipe is flowing full.
Applicable BMPs	As used in this manual and in Volume IV of Ecology's *Stormwater Management Manual for Western Washington*, applicable BMPs are those source control BMPs that are expected to be required by local governments at new development and redevelopment sites. Applicable BMPs will also be required if they are incorporated into NPDES permits, or are included by local governments in a stormwater program for existing facilities.
Applicant	The person who has applied for a development permit or approval.
Appurtenances	Machinery, appliances, or auxiliary structures attached to a main structure, but not considered an integral part thereof, for the purpose of enabling it to function.

Aquifer A geologic stratum containing groundwater that can be withdrawn and used for human purposes.

Aquifer, Perched A region in the unsaturated soil zone where the soil may be locally saturated because it overlies a low-permeability unit (e.g. glacial till).

Arterial A road or street primarily for through traffic. A major arterial connects an Interstate Highway to cities and counties. A minor arterial connects major arterials to collectors. A collector connects an arterial to a neighborhood. A collector is not an arterial. A local access road connects individual homes to a collector.

As-built drawings Engineering plans which have been revised to reflect all changes to the plans which occurred during construction.

As-graded The extent of surface conditions on completion of grading.

BSBL See Building setback line.

Background A description of pollutant levels arising from natural sources, and not because of man's immediate activities.

Backwater Water upstream from an obstruction which is deeper than it would normally be without the obstruction.

Baffle A device to check, deflect, or regulate flow.

Bankfull discharge A flow condition where streamflow completely fills the stream channel up to the top of the bank. In undisturbed watersheds, the discharge conditions occur on average every 1.5 to 2 years and controls the shape and form of natural channels.

Base flood A flood having a one percent chance of being equaled or exceeded in any given year. This is also referred to as the 100-year flood.

Base flood elevation The water surface elevation of the base flood. It shall be referenced to the National Geodetic Vertical Datum of 1929 (NGVD).

Baseline sample A sample collected during dry-weather flow (i.e., it does not consist of runoff from a specific precipitation event).

Basin plan A plan that assesses, evaluates, and proposes solutions to existing and potential future impacts to the beneficial uses of, and the physical, chemical, and biological properties of waters of the state within a basin. Basins typically range in size from 1 to 50 square miles. A plan should include but not be limited to recommendations for:

- Stormwater requirements for new development and redevelopment;
- Capital improvement projects;

- Land Use management through identification and protection of critical areas, comprehensive land use and transportation plans, zoning regulations, site development standards, and conservation areas;
- Source control activities including public education and involvement, and business programs;
- Other targeted stormwater programs and activities, such as maintenance, inspections and enforcement;
- Monitoring; and
- An implementation schedule and funding strategy.

A plan that is "adopted and implemented" must have the following characteristics:

- It must be adopted by legislative or regulatory action of jurisdictions with responsibilities under the plan;
- Ordinances, regulations, programs, and procedures recommended by the plan should be in effect or on schedule to be in effect; and,
- An implementation schedule and funding strategy that are in progress.

Bearing capacity The maximum load that a material can support before failing.

Bedrock The more or less solid rock in place either on or beneath the surface of the earth. It may be soft, medium, or hard and have a smooth or irregular surface.

Bench A relatively level step excavated into earth material on which fill is to be placed.

Berm A constructed barrier of compacted earth, rock, or gravel. In a stormwater facility, a berm may serve as a vertical divider typically built up from the bottom.

Best management practice (BMP) The schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices, that when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State.

Biochemical oxygen demand (BOD) An indirect measure of the concentration of biologically degradable materials present in organic wastes. The amount of free oxygen utilized by aerobic organisms when allowed to attack the organic material in an aerobically maintained environment at a specified temperature (20°C) for a specific time period (5 days), and thus stated as BOD5. It is expressed in milligrams of oxygen utilized per liter of liquid waste volume (mg/l) or in milligrams of oxygen per kilogram of waste solution (mg/kg = ppm = parts per million parts). Also called biological oxygen demand.

Biodegradable Capable of being readily broken down by biological means, especially by microbial action. Microbial action includes the combined effect of bacteria, fungus, flagellates, amoebae, ciliates, and nematodes. Degradation can be rapid or may take many years depending upon such factors as available oxygen and moisture.

Bioengineering The combination of biological, mechanical, and ecological concepts (and methods) to control erosion and stabilize soil through the use of vegetation or in combination with construction materials.

Biofilter A designed treatment facility using a combined soil and vegetation system for filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater when runoff flows over and through. Vegetation growing in these facilities acts as both a physical filter which causes gravity settling of particulates by regulating velocity of flow, and also as a biological sink when direct uptake of dissolved pollutants occurs. The former mechanism is probably the most important in western Washington where the period of major runoff coincides with the period of lowest biological activity.

Biofiltration The process of reducing pollutant concentrations in water by filtering the polluted water through biological materials.

Biological control A method of controlling pest organisms by means of introduced or naturally occurring predatory organisms, sterilization, the use of inhibiting hormones, or other means, rather than by mechanical or chemical means.

Biological magnification The increasing concentration of a substance along succeeding steps in a food chain. Also called biomagnification.

Bollard A post (which may or may not be removable) used to prevent vehicular access.

Bond A surety bond, cash deposit or escrow account, assignment of savings, irrevocable letter of credit or other means acceptable to or required by the manager to guarantee that work is completed in compliance with the project's drainage plan and in compliance with all local government requirements.

Borrow area A source of earth fill material used in the construction of embankments or other earth fill structures.

Buffer	The zone contiguous with a sensitive area that is required for the continued maintenance, function, and structural stability of the sensitive area. The critical functions of a riparian buffer (those associated with an aquatic system) include shading, input of organic debris and coarse sediments, uptake of nutrients, stabilization of banks, interception of fine sediments, overflow during high water events, protection from disturbance by humans and domestic animals, maintenance of wildlife habitat, and room for variation of aquatic system boundaries over time due to hydrologic or climatic effects. The critical functions of terrestrial buffers include protection of slope stability, attenuation of surface water flows from stormwater runoff and precipitation, and erosion control.
Building setback line (BSBL)	A line measured parallel to a property, easement, drainage facility, or buffer boundary, that delineates the area (defined by the distance of separation) where buildings or other obstructions are prohibited (including decks, patios, outbuildings, or overhangs beyond 18 inches). Wooden or chain link fences and landscaping are allowable within a building setback line. In this manual the minimum building setback line shall be 5 feet.
Capital Improvement Project or Program (CIP)	A project prioritized and scheduled as a part of an overall construction program, or the actual construction program.
Catch Basin	An inlet box set into the ground, usually rectangular and made of concrete, with a sump in the bottom to catch sediment, and capped with a grate that allows stormwater to enter; usually set at the curb line of a street, to admit surface runoff water to a sewer or subdrain.
Catchline	The point where a severe slope intercepts a different, more gentle slope.
Catchment	Surface drainage area.
Cation Exchange Capacity (CEC)	The amount of exchangeable cations that a soil can adsorb at pH 7.0.
CESCL	Certified Erosion and Sediment Control Lead. The person designated as the responsible representative in charge of erosion and sediment control and water quality protection during the construction period. The CESCL shall have a current certificate in construction site erosion and sediment control as per the requirements established by Ecology.
Channel	A feature that conveys surface water and is open to the air.
Channel, constructed	Channels or ditches constructed (or reconstructed natural channels) to convey surface water.

Channel, natural	Streams, creeks, or swales that convey surface/ground water and have existed long enough to establish a stable route and/or biological community.
Channel stabilization	Erosion prevention and stabilization of velocity distribution in a channel using vegetation, jetties, drops, revetments, and/or other measures.
Channel storage	Water temporarily stored in channels while enroute to an outlet.
Channelization	Alteration of a stream channel by widening, deepening, straightening, cleaning, or paving certain areas to change flow characteristics.
Check dam	Small dam constructed in a gully or other small watercourse to decrease the streamflow velocity, minimize channel scour, and promote deposition of sediment.
Chemical oxygen demand (COD)	A measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water. The COD test, like the BOD test, is used to determine the degree of pollution in water.
Civil engineer	A professional engineer licensed in the State of Washington in Civil Engineering.
Civil engineering	The application of the knowledge of the forces of nature, principles of mechanics and the properties of materials to the evaluation, design and construction of civil works for the beneficial uses of mankind.
Clay lens	A naturally occurring, localized area of clay which acts as an impermeable layer to runoff infiltration.
Clearing	The destruction and removal of vegetation by manual, mechanical, or chemical methods.
Closed depression	An area which is low-lying and either has no, or such a limited, surface water outlet that during storm events the area acts as a retention basin.
Cohesion	The capacity of a soil to resist shearing stress, exclusive of functional resistance.
Coliform bacteria	Microorganisms common in the intestinal tracts of man and other warm-blooded animals; all the aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C. Used as an indicator of bacterial pollution.

Commercial agriculture Those activities conducted on lands defined in RCW 84.34.020(2), and activities involved in the production of crops or livestock for wholesale trade. An activity ceases to be considered commercial agriculture when the area on which it is conducted is proposed for conversion to a nonagricultural use or has lain idle for more than five (5) years, unless the idle land is registered in a federal or state soils conservation program, or unless the activity is maintenance of irrigation ditches, laterals, canals, or drainage ditches related to an existing and ongoing agricultural activity.

Compaction The densification, settlement, or packing of soil in such a way that permeability of the soil is reduced. Compaction effectively shifts the performance of a hydrologic group to a lower permeability hydrologic group. For example, a group B hydrologic soil can be compacted and be effectively converted to a group C hydrologic soil in the way it performs in regard to runoff.

Compaction may also refer to the densification of a fill by mechanical means.

Compensatory storage New excavated storage volume equivalent to the flood storage capacity eliminated by filling or grading within the flood fringe. Equivalent shall mean that the storage removed shall be replaced by equal volume between corresponding one-foot contour intervals that are hydraulically connected to the floodway through their entire depth.

Compost Organic residue or a mixture of organic residues and soil, that has undergone biological decomposition until it has become relatively stable humus.

Reference note: The Department of Ecology Interim Guidelines for Compost Quality (1994) defines compost as “the product of composting; it has undergone an initial, rapid stage of decomposition and is in the process of humification (curing).” Compost used should meet specifications for grade A or AA compost in Ecology publication 94-038.

Composted Mulch Mulch prepared from decomposed organic materials that have undergone a controlled process to minimize weed seeds. Acceptable feedstocks include, but are not limited to, yard debris, wood waste, land clearing debris, brush, and branches.

Composting A controlled process of degrading organic matter by microorganisms. Present day composting is the aerobic, thermophilic decomposing of organic waste to relatively stable humus. Composting is the process of making usable, organic matter that is beneficial to plants and has converted nutrients into slow-release forms (versus mineralized water-soluble forms found in fertilizer).

Comprehensive planning	Planning that takes into account all aspects of water, air, and land resources and their uses and limits.
Conservation district	A public organization created under state enabling law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries, usually a subdivision of state government with a local governing body and always with limited authority. Often called a soil conservation district or a soil and water conservation district.
Constructed wetland	Those wetlands intentionally created on sites that are not wetlands for the primary purpose of wastewater or stormwater treatment and managed as such. Constructed wetlands are normally considered as part of the stormwater collection and treatment system.
Construction Stormwater Pollution Prevention Plan (C-SWPPP)	A document that describes the combination of best management practices designed to prevent surface water and ground water pollution from construction activities. The plan shall include a narrative and drawings that detail the pollution prevention practices implemented to prevent erosion, treat sediment-laden runoff, and limit pollution at its sources. Each of the 12 elements listed in Chapters 1 and 4 must be included in the Construction SWPPP unless an element is determined not to be applicable to the project and the exemption is justified in the narrative.
Contour	An imaginary line on the surface of the earth connecting points of the same elevation.
Conveyance	A mechanism for transporting water from one point to another, including pipes, ditches, and channels.
Conveyance system	The drainage facilities, both natural and man-made, which collect, contain, and provide for the flow of surface and stormwater from the highest points on the land down to a receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. The human-made elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/detention facilities.
Cover crop	A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of permanent vegetation.
CPESC	Certified Professional in Erosion and Sediment Control (see CESCL).
Created wetland	Means those wetlands intentionally created from non-wetland sites to produce or replace natural wetland habitat (e.g., compensatory mitigation projects).

Critical Areas	At a minimum, areas which include wetlands, areas with a critical recharging effect on aquifers used for potable water, fish and wildlife habitat conservation areas, frequently flooded areas, geologically hazardous areas, including unstable slopes, and associated areas and ecosystems.
Critical Drainage Area	An area with such severe flooding, drainage and/or erosion/sedimentation conditions that the area has been formally adopted as a Critical Drainage Area by rule under the procedures specified in an ordinance.
Critical reach	The point in a receiving stream below a discharge point at which the lowest dissolved oxygen level is reached and stream recovery begins.
Culvert	Pipe or concrete box structure that drains open channels, swales or ditches under a roadway or embankment. Typically, a culvert has no catch basins or manholes along its length.
Cut	Portion of land surface or area from which earth has been removed or will be removed by excavating; the depth below original ground surface to excavated surface.
Cut-and-fill	Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.
Cut slope	A slope formed by excavating overlying material to connect the original ground surface with a lower ground surface created by the excavation. A cut slope is distinguished from a bermed slope, which is constructed by importing soil to create the slope.
DNS	See Determination of Nonsignificance.
Dead storage	The volume available in a depression in the ground below any conveyance system, or surface drainage pathway, or outlet invert elevation that could allow the discharge of surface and stormwater runoff.
Dedication of land	Refers to setting aside a portion of a property for a specific use or function.
Degradation	(Biological or chemical) The breakdown of complex organic or other chemical compounds into simpler substances, usually less harmful than the original compound, as with the degradation of a persistent pesticide. (Geological) Wearing down by erosion. (Water) The lowering of the water quality of a watercourse by an increase in the pollutant loading.
Degraded (disturbed) wetland (community)	A wetland (community) in which the vegetation, soils, and/or hydrology have been adversely altered, resulting in lost or reduced functions and values; generally, implies topographic isolation;

hydrologic alterations such as hydroperiod alteration (increased or decreased quantity of water), diking, channelization, and/or outlet modification; soils alterations such as presence of fill, soil removal, and/or compaction; accumulation of toxicants in the biotic or abiotic components of the wetland; and/or low plant species richness with dominance by invasive weedy species.

Denitrification The biochemical reduction of nitrates or nitrites in the soil or organic deposits to ammonia or free nitrogen.

Depression storage The amount of precipitation that is trapped in depressions on the surface of the ground.

Design engineer The professional civil engineer licensed in the State of Washington who prepares the analysis, design, and engineering plans for an applicant's permit or approval submittal.

Design storm A prescribed hyetograph and total precipitation amount (for a specific duration recurrence frequency) used to estimate runoff for a hypothetical storm of interest or concern for the purposes of analyzing existing drainage, designing new drainage facilities or assessing other impacts of a proposed project on the flow of surface water. (A hyetograph is a graph of percentages of total precipitation for a series of time steps representing the total time during which the precipitation occurs.)

Detention The release of stormwater runoff from the site at a slower rate than it is collected by the stormwater facility system, the difference being held (detained) in temporary storage.

Detention facility An above or below ground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system. There is little or no infiltration of stored stormwater.

Detention time The theoretical time required to displace the contents of a stormwater treatment facility at a given rate of discharge (volume divided by rate of discharge).

Determination of Nonsignificance (DNS) The written decision by the responsible official of the lead agency that a proposal is not likely to have a significant adverse environmental impact, and therefore an EIS is not required.

Development **N**ew development, redevelopment, or both. See definitions for each.

Discharge Runoff leaving a new development or redevelopment site via overland flow, conveyance systems, or infiltration facilities. A hydraulic rate of flow, specifically fluid flow. The volume of fluid flowing past a specific point per unit of time, commonly expressed as cubic feet per second (cfs), gallons per minute (gpm), gallons per day (gpd), or millions of gallons per day (mgpd).

Dispersion Release of surface and stormwater runoff from a drainage facility system such that the flow spreads over a wide area and is located so as not to allow flow to concentrate anywhere upstream of a drainage channel with erodible underlying granular soils.

Ditch A long narrow excavation dug in the earth for drainage with its top width less than 10 feet at design flow.

Divide, Drainage The boundary between one drainage basin and another.

Drain A buried pipe or other conduit (closed drain). A ditch (open drain) for carrying off surplus surface water or ground water.

(To) Drain To provide channels, such as open ditches or closed drains, so that excess water can be removed by surface flow or by internal flow. To lose water (from the soil) by percolation.

Drainage Refers to the collection, conveyance, containment, and/or discharge of surface and stormwater runoff.

Drainage basin A geographic and hydrologic subunit of a watershed.

Drainage channel A drainage pathway with a well-defined bed and banks indicating frequent conveyance of surface and stormwater runoff.

Drainage course A pathway for watershed drainage characterized by wet soil vegetation; often intermittent in flow.

Drainage easement A legal encumbrance that is placed against a property's title to reserve specified privileges for the users and beneficiaries of the drainage facilities contained within the boundaries of the easement.

Drainage pathway The route that surface and stormwater runoff follows downslope as it leaves any part of the site.

Drainage review An evaluation by City of Lacey staff of a proposed project's compliance with the drainage requirements in this manual (or its technical equivalent) and other applicable criteria.

Drainage, Soil As a natural condition of the soil, soil drainage refers to the frequency and duration of periods when the soil is free of saturation; for example, in well-drained soils the water is removed readily but not rapidly; in poorly drained soils the root zone is waterlogged for long periods unless artificially drained, and the roots of ordinary crop plants cannot get enough oxygen; in excessively drained soils the water is removed so completely that most crop plants suffer from lack of water. Strictly speaking, excessively drained soils are a result of excessive runoff due to steep slopes or low available water-holding capacity due to small amounts of silt and clay in the soil material. The following classes are used to express soil drainage:

Well drained - Excess water drains away rapidly and no mottling occurs within 36 inches of the surface.

- Moderately well drained - Water is removed from the soil somewhat slowly, resulting in small but significant periods of wetness. Mottling occurs between 18 and 36 inches.
- Somewhat poorly drained - Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Mottling occurs between 8 and 18 inches.
- Poorly drained - Water is removed so slowly that the soil is wet for a large part of the time. Mottling occurs between 0 and 8 inches.
- Very poorly drained - Water is removed so slowly that the water table remains at or near the surface for the greater part of the time. There may also be periods of surface ponding. The soil has a black to gray surface layer with mottles up to the surface.

Drawdown Lowering of the water surface (in open channel flow), water table or piezometric surface (in ground water flow) resulting from a withdrawal of water.

Drop-inlet spillway Overall structure in which the water drops through a vertical riser connected to a discharge conduit.

Drop spillway Overall structure in which the water drops over a vertical wall onto an apron at a lower elevation.

Drop structure A structure for dropping water to a lower level and dissipating its surplus energy; a fall. A drop may be vertical or inclined.

Dry weather flow The combination of groundwater seepage and allowed non-stormwater flows found in storm sewers during dry weather.. Also that flow in streams during the dry season.

EIS See Environmental Impact Statement.

ESC Erosion and Sediment Control.

Earth material Any rock, natural soil or fill and/or any combination thereof. Earth material shall not be considered topsoil used for landscape purposes. Topsoil used for landscaped purposes shall comply with ASTM D 5268 specifications. Engineered soil/landscape systems are also defined independently.

Easement The legal right to use a parcel of land for a particular purpose. It does not include fee ownership, but may restrict the owners use of the land.

Effective Impervious Surface Those impervious surfaces that are connected via sheet flow or discrete conveyance to a drainage system. Impervious surfaces on residential development sites are considered ineffective if the runoff is dispersed through at least one hundred feet of native vegetation in accordance with BMP T5.30 - "Full Dispersion," as described in Chapter 5 of Volume V of Ecology's *Stormwater Management Manual for Western Washington*.

Embankment A structure of earth, gravel, or similar material raised to form a pond bank or foundation for a road.

Emergent plants Aquatic plants that are rooted in the sediment but whose leaves are at or above the water surface. These wetland plants often have high habitat value for wildlife and waterfowl, and can aid in pollutant uptake.

Emergency spillway A vegetated earth channel used to safely convey flood discharges in excess of the capacity of the principal spillway.

Emerging technology Treatment technologies that have not been evaluated with approved protocols, but for which preliminary data indicate that they may provide a necessary function(s) in a stormwater treatment system. Emerging technologies need additional evaluation to define design criteria to achieve, or to contribute to achieving, state performance goals, and to define the limits of their use.

Energy dissipator Any means by which the total energy of flowing water is reduced. In stormwater design, they are usually mechanisms that reduce velocity prior to, or at, the discharge from an outfall in order to prevent erosion. They include rock splash pads, drop manholes, concrete stilling basins or baffles, and check dams.

Energy gradient The slope of the specific energy line (i.e., the sum of the potential and velocity heads).

Engineered soil/ landscape system This is a self-sustaining soil and plant system that simultaneously supports plant growth, soil microbes, water infiltration, nutrient and pollutant adsorption, sediment and pollutant biofiltration, water interflow, and pollution decomposition. The system shall be protected from compaction and erosion. The system shall be planted and/or mulched as part of the installation.

The engineered soil/plant system shall have the following characteristics:

a. Be protected from compaction and erosion.

b. Have a plant system to support a sustained soil quality.

c. Possess permeability characteristics of not less than 6.0, 2.0, and 0.6 inches/hour for hydrologic soil groups A, B, and C, respectively (per ASTM D 3385). D is less than 0.6 inches/hour.

d. Possess minimum percent organic matter of 12, 14, 16, and 18 percent (dry-weight basis) for hydrologic soil groups A, B, C, and D, respectively (per ASTM D 2974).

Engineering geology The application of geologic knowledge and principles in the investigation and evaluation of naturally occurring rock and soil for use in the design of civil works.

Engineering plan A plan prepared and stamped by a professional civil engineer.

Enhancement To raise value, desirability, or attractiveness of an environment associated with surface water.

Environmental Impact Statement (EIS) A document that discusses the likely significant adverse impacts of a proposal, ways to lessen the impacts, and alternatives to the proposal. They are required by the national and state environmental policy acts when projects are determined to have significant environmental impact.

Erodible granular soils Soil materials that are easily eroded and transported by running water, typically fine or medium grained sand with minor gravel, silt, or clay content. Such soils are commonly described as Everett or Indianola series soil types in the SCS classification. Also included are any soils showing examples of existing severe stream channel incision as indicated by unvegetated streambanks standing over two feet high above the base of the channel.

Erosion The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Also, detachment and movement of soil or rock fragments by water, wind, ice, or gravity. The following terms are used to describe different types of water erosion:

Accelerated erosion - Erosion much more rapid than normal or geologic erosion, primarily as a result of the influence of the activities of man or, in some cases, of the animals or natural catastrophes that expose bare surfaces (e.g., fires).

- Geological erosion - The normal or natural erosion caused by geological processes acting over long geologic periods and resulting in the wearing away of mountains, the building up of floodplains, coastal plains, etc. Synonymous with natural erosion.

- Gully erosion - The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, ranging from 1 to 2 feet to as much as 75 to 100 feet.
- Natural erosion - Wearing away of the earth's surface by water, ice, or other natural agents under natural environmental conditions of climate, vegetation, etc., undisturbed by man. Synonymous with geological erosion.
- Normal erosion - The gradual erosion of land used by man which does not greatly exceed natural erosion.
- Rill erosion - An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently disturbed and exposed soils. See Rill.
- Sheet erosion - The removal of a fairly uniform layer of soil from the land surface by runoff.
- Splash erosion - The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.

Erosion classes (soil survey) A grouping of erosion conditions based on the degree of erosion or on characteristic patterns. Applied to accelerated erosion, not to normal, natural, or geological erosion. Four erosion classes are recognized for water erosion and three for wind erosion.

Erosion and sedimentation control Any temporary or permanent measures taken to reduce erosion; control siltation and sedimentation; and ensure that sediment-laden water does not leave the site.

Erosion and sediment control facility A type of drainage facility designed to hold water for a period of time to allow sediment contained in the surface and stormwater runoff directed to the facility to settle out so as to improve the quality of the runoff.

Escarpment A steep face or a ridge of high land.

Estuarine wetland Generally, an eelgrass bed; salt marsh; or rocky, sandflat, or mudflat intertidal area where fresh and salt water mix. (Specifically, a tidal wetland with salinity greater than 0.5 parts per thousand, usually semi-enclosed by land but with partially obstructed or sporadic access to the open ocean).

Estuary An area where fresh water meets salt water, or where the tide meets the river current (e.g., bays, mouths of rivers, salt marshes and lagoons). Estuaries serve as nurseries and spawning and feeding grounds for large groups of marine life and provide shelter and food for birds and wildlife.

Eutrophication Refers to the process where nutrient over-enrichment of water leads to excessive growth of aquatic plants, especially algae.

Evapotranspiration The collective term for the processes of evaporation and plant transpiration by which water is returned to the atmosphere.

Excavation The mechanical removal of earth material.

Exception Relief from the application of a Minimum Requirement to a project.

Exfiltration The downward movement of runoff through the bottom of an infiltration BMP into the soil layer or the downward movement of water through soil.

FIRM See Flood Insurance Rate Map.

Fertilizer Any material or mixture used to supply one or more of the essential plant nutrient elements.

Fill A deposit of earth material placed by artificial means.

Filter fabric A woven or nonwoven, water-permeable material generally made of synthetic products such as polypropylene and used in stormwater management and erosion and sediment control applications to trap sediment or prevent the clogging of aggregates by fine soil particles.

Filter fabric fence A temporary sediment barrier consisting of a filter fabric stretched across and attached to supporting posts and entrenched. The filter fence is constructed of stakes and synthetic filter fabric with a rigid wire fence backing where necessary for support. Also commonly referred to in the Washington Department of Transportation standard specifications as “construction geotextile for temporary silt fences.”

Filter strip A grassy area with gentle slopes that treats stormwater runoff from adjacent paved areas before it concentrates into a discrete channel.

Flocculation The process by which suspended colloidal or very fine particles are assembled into larger masses or floccules which eventually settle out of suspension. This process occurs naturally but can also be caused through the use of such chemicals as alum.

Flood	An overflow or inundation that comes from a river or any other source, including (but not limited to) streams, tides, wave action, storm drains, or excess rainfall. Any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream.
Flood control	Methods or facilities for reducing flood flows and the extent of flooding.
Flood control project	A structural system installed to protect land and improvements from floods by the construction of dikes, river embankments, channels, or dams.
Flood frequency	The frequency with which the flood of interest may be expected to occur at a site in any average interval of years. Frequency analysis defines the "n-year flood" as being the flood that will, over a long period of time, be equaled or exceeded on average once every "n" years.
Flood fringe	The portion of the floodplain outside of the floodway which is covered by floodwaters during the base flood; it is generally associated with slower moving or standing water rather than rapidly flowing water.
Flood hazard areas	Those areas subject to inundation by the base flood. Includes, but is not limited to streams, lakes, wetlands, and closed depressions.
Flood Insurance Rate Map (FIRM)	The official map on which the Federal Emergency Management Agency has delineated many areas of flood hazard, floodway, and the risk premium zones.
Flood Insurance Study	The official report provided by the Federal Emergency Management Agency that includes flood profiles and the FIRM.
Flood peak	The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge.
Floodplain	The total area subject to inundation by a flood including the flood fringe and floodway.
Flood-proofing	Adaptations that ensure a structure is substantially impermeable to the passage of water below the flood protection elevation that resists hydrostatic and hydrodynamic loads and effects of buoyancy.
Flood protection elevation	The base flood elevation or higher as defined by the local government.
Flood protection facility	Any levee, berm, wall, enclosure, raise bank, revetment, constructed bank stabilization, or armoring, that is commonly recognized by the community as providing significant protection to a property from inundation by flood waters.

Flood routing An analytical technique used to compute the effects of system storage dynamics on the shape and movement of flow represented by a hydrograph.

Flood stage The stage at which overflow of the natural banks of a stream begins.

Floodway The channel of the river or stream and those portions of the adjoining floodplains that are reasonably required to carry and discharge the base flood flow. The portions of the adjoining floodplains which are considered to be "reasonably required" are defined by flood hazard regulations.

Flow control facility A drainage facility designed to mitigate the impacts of increased surface and stormwater runoff flow rates generated by development. Flow control facilities are designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground, or to hold runoff for a short period of time, releasing it to the conveyance system at a controlled rate.

Flow duration The aggregate time that peak flows are at or above a particular flow rate of interest. For example, the amount of time that peak flows are at or above 50% of the 2-year peak flow rate for a period of record.

Flow frequency The inverse of the probability that a flow will be equaled or exceeded in any given year (the exceedance probability). For example, if the exceedance probability is 0.01 (or 1 in 100), that flow is referred to as the 100-year flow.

Flow path The route that stormwater runoff follows between two points of interest.

Forebay An easily maintained, extra storage area provided near an inlet of a BMP to trap incoming sediments before they accumulate in a pond or wetland BMP.

Forest practice Any activity conducted on or directly pertaining to forest land and relating to growing, harvesting, or processing timber, including but not limited to:

a. Road and trail construction.
b. Harvesting, final and intermediate.
c. Precommercial thinning.
d. Reforestation.
e. Fertilization.
f. Prevention and suppression of diseases and insects.
g. Salvage of trees.
h. Brush control.

Forested communities (wetlands)	In general terms, communities (wetlands) characterized by woody vegetation that is greater than or equal to 6 meters in height; in this manual the term applies to such communities (wetlands) that represent a significant amount of tree cover consisting of species that offer wildlife habitat and other values and advance the performance of wetland functions overall.
Freeboard	The vertical distance between the design water surface elevation and the elevation of the barrier that contains the water.
Frequently flooded areas	The 100-year floodplain designations of the Federal Emergency Management Agency and the National Flood Insurance Program or as defined by the local government.
Frost-heave	The upward movement of soil surface due to the expansion of water stored between particles in the first few feet of the soil profile as it freezes. May cause surface fracturing of asphalt or concrete.
Frequency of storm (design storm frequency)	The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus a 10-year storm can be expected to occur on the average once every 10 years. Sewers designed to handle flows that occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.
Functions	The ecological (physical, chemical, and biological) processes or attributes of a wetland without regard for their importance to society (see also values). Wetland functions include food chain support, provision of ecosystem diversity and fish and wildlife habitat, floodflow alteration, ground water recharge and discharge, water quality improvement, and soil stabilization.
Gabion	A rectangular or cylindrical wire mesh cage (a chicken wire basket) filled with rock and used as a protecting agent, revetment, etc., against erosion. Soft gabions, often used in streambank stabilization, are made of geotextiles filled with dirt, in between which cuttings are placed.
Gage or gauge	Device for registering precipitation, water level, discharge, velocity, pressure, temperature, etc. Also, a measure of the thickness of metal; e.g., diameter of wire or wall thickness of steel pipe.
Gaging station	A selected section of a stream channel equipped with a gage, recorder, or other facilities for determining stream discharge.
Geologist	A person who has earned a degree in geology from an accredited college or university or who has equivalent educational training and has at least five years of experience as a practicing geologist or four

years of experience and at least two years post-graduate study, research or teaching. The practical experience shall include at least three years work in applied geology and landslide evaluation, in close association with qualified practicing geologists or geotechnical professional/civil engineers.

Geologically hazardous areas Areas that because of their susceptibility to erosion, sliding, earthquake, or other geological events, are not suited to the siting of commercial, residential, or industrial development consistent with public health or safety concerns.

Geometrics The mathematical relationships between points, lines, angles, and surfaces used to measure and identify areas of land.

Geotechnical professional civil engineer A practicing, geotechnical/civil engineer licensed as a professional Civil Engineer with the State of Washington who has at least four years of professional employment as a geotechnical engineer in responsible charge, including experience with landslide evaluation.

Glacial Till A glacial deposit of poorly-sorted sand, silt, clay and cobbles that typically forms a subsurface layer having a very low infiltration rate.

Grade The slope of a road, channel, or natural ground. The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction such as paving or the laying of a conduit.

(To) Grade To finish the surface of a canal bed, roadbed, top of embankment or bottom of excavation.

Gradient terrace An earth embankment or a ridge-and-channel constructed with suitable spacing and an acceptable grade to reduce erosion damage by intercepting surface runoff and conducting it to a stable outlet at a stable nonerosive velocity.

Grassed waterway A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses, used to conduct surface water from an area at a reduced flow rate. See also biofilter.

Groundwater Water contained in interconnected pores in a saturated zone or stratum beneath the land surface.

Groundwater recharge Inflow to a groundwater reservoir.

Groundwater Table The free surface of the groundwater, that surface subject to atmospheric pressure under the ground, generally rising and falling with the season, the rate of withdrawal, the rate of restoration, and other conditions. It is seldom static.

Gully A channel caused by the concentrated flow of surface and stormwater runoff over unprotected erodible land.

Habitat The specific area or environment in which a particular type of plant or animal lives. An organism's habitat must provide all of the basic requirements for life and should be protected from harmful biological, chemical, and physical alterations.

Hardpan A cemented or compacted and often clay-like layer of soil that is impenetrable by roots. Also known as glacial till.

Harmful pollutant A substance that has adverse effects to an organism including immediate death, chronic poisoning, impaired reproduction, cancer or other effects.

Head (hydraulics) The height of water above any plane of reference. The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various compound terms such as pressure head, velocity head, and head loss.

Head loss Energy loss due to friction, eddies, changes in velocity, or direction of flow.

Heavy metals Metals of high specific gravity, present in municipal and industrial wastes, that pose long-term environmental hazards. Such metals include cadmium, chromium, cobalt, copper, lead, mercury, nickel, and zinc.

High-use site High-use sites are those that typically generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil. High-use sites include:

- An area of a commercial or industrial site subject to an expected average daily traffic (ADT) count equal to or greater than 100 vehicles per 1,000 square feet of gross building area;
- An area of a commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year, not including routinely delivered heating oil;
- An area of a commercial or industrial site subject to parking, storage or maintenance of 25 or more vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.);
- A road intersection with a measured ADT count of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway, excluding projects proposing primarily pedestrian or bicycle use improvements.

Highway	A main public road connecting towns and cities.
Hog fuel	See wood-based mulch.
Horton overland flow	A runoff process whereby the rainfall rate exceeds the infiltration rate, so that the precipitation that does not infiltrate flows downhill over the soil surface.
HSPF Hydrological Simulation Program-Fortran	A continuous simulation hydrologic model that transforms an uninterrupted rainfall record into a concurrent series of runoff or flow data by means of a set of mathematical algotrithms which represent the rainfall-runoff process at some conceptual level.
Humus	Organic matter in or on a soil, composed of partly or fully decomposed bits of plant tissue or from animal manure.
Hydraulic conductivity	The quality of saturated soil that enables water or air to move through it; a permeability coefficient, related to the fluid density and viscosity, describing the rate at which water can move through a permeable medium.
Hydraulic gradient	Slope of the potential head relative to a fixed datum. The change in total head with a change in distance.
Hydrodynamics	Means the dynamic energy, force, or motion of fluids as affected by the physical forces acting upon those fluids.
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Hydrograph	A graph of runoff rate, inflow rate or discharge rate, past a specific point, as a function of time.
Hydrologic cycle	The circuit of water movement from the atmosphere to the earth and returning to the atmosphere through various stages or processes as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.
Hydrologic Soil Groups (H.S.G.s)	A soil characteristic classification system defined by the U.S. Soil Conservation Service (SCS, now called the NRCS) in which a soil may be categorized into one of four soil groups (A, B, C, or D) based upon infiltration rate and other properties. <u>H.S.G. A:</u> Low runoff potential. Soils having high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep, well drained to excessively drained sands or gravels. These soils have a high rate of water transmission.

H.S.G. B: Moderately low runoff potential. Soils having moderate infiltration rates when thoroughly wetted, and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

H.S.G. C: Moderately high runoff potential. Soils having slow infiltration rates when thoroughly wetted, and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.

H.S.G. D: High runoff potential. Soils having very slow infiltration rates when thoroughly wetted, and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan, till, or clay layer at or near the surface, soils with a compacted subgrade at or near the surface, and shallow soils or nearly impervious material. These soils have a very slow rate of water transmission.[1]

[1] Vladimir Novotny and Harvey Olem. *Water Quality Prevention, Identification, and Management of Diffuse Pollution,* Van Nostrand Reinhold: New York, 1994, p. 109.

Hydrology The science of the behavior of water in the atmosphere, on the surface of the earth, and underground.

Hydroperiod A seasonal occurrence of flooding and/or soil saturation, generally used in reference to wetlands; it encompasses depth, frequency, duration, and seasonal pattern of inundation.

Hyetograph A graph of percentages of total precipitation for a series of time steps representing the total time in which precipitation occurs.

Illicit discharge All non-stormwater discharges to stormwater drainage systems that cause or contribute to a violation of state water quality, sediment quality or ground water quality standards, including but not limited to sanitary sewer connections, industrial process water, interior floor drains, car washing, and greywater systems.

Impact basin A device used to dissipate the energy of flowing water. Generally constructed of concrete in the form of a partially depressed or partially submerged vessel, it may utilize baffles to dissipate velocities.

Impermeable liner (or low-permeability liner) A layer of compacted till or clay, or a geomembrane, intended to restrict infiltration.

Impervious A surface which cannot be easily penetrated. For instance, rain does not readily penetrate paved surfaces.

Impervious surface A hard surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development. A hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater. Open, uncovered retention/detention facilities shall not be considered as impervious surfaces for the purposes of determining whether the thresholds for application of minimum requirements are exceeded. Open, uncovered retention/detention facilities shall be considered impervious surfaces for purposes of runoff modeling.

Impoundment A natural or man-made containment for surface water.

Improvement Streets (with or without curbs or gutters), sidewalks, crosswalks, parking lots, water mains, sanitary and storm sewers, drainage facilities, street trees and other appropriate items.

Industrial activities Material handling, transportation, or storage; manufacturing; maintenance; treatment; or disposal. Areas with industrial activities include plant yards, access roads and rail lines used by carriers of raw materials, manufactured products, waste material, or by-products; material handling sites; refuse sites; sites used for the application or disposal of process waste waters; sites used for the storage and maintenance of material handling equipment; sites used for residual treatment, storage, or disposal; shipping and receiving areas; manufacturing buildings; storage areas for raw materials, and intermediate and finished products; and areas where industrial activity has taken place in the past and significant materials remain and are exposed to stormwater.

Infiltration The downward movement of water from the surface into the subsoil.

Infiltration facility (or system) A drainage facility designed to use the hydrologic process of surface and stormwater runoff soaking into the ground, commonly referred to as a percolation, to dispose of surface and stormwater runoff.

Infiltration rate The rate, usually expressed in inches/hour, at which water moves downward (percolates) through the soil profile. Short-term infiltration rates may be inferred from soil analysis or texture or derived from field measurements. Long-term infiltration rates are affected by variability in soils and subsurface conditions at the site, the effectiveness of pretreatment or influent control, and the degree of long-term maintenance of the infiltration facility.

Ingress/egress The points of access to and from a property.

Inlet	A form of connection between surface of the ground and a drain or sewer for the admission of surface and stormwater runoff.
Insecticide	A substance, usually chemical, that is used to kill insects.
Interception (Hydraulics)	The process by which precipitation is caught and held by foliage, twigs, and branches of trees, shrubs, and other vegetation. Often used for "interception loss" or the amount of water evaporated from the precipitation intercepted.
Interflow	That portion of rainfall that infiltrates into the soil and moves laterally through the upper soil horizons until intercepted by a stream channel or until it returns to the surface for example, in a roadside ditch, wetland, spring or seep. Interflow is a function of the soil system depth, permeability, and water-holding capacity.
Intermittent stream	A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and no long-continued supply from melting snow or other sources. It is dry for a large part of the year, ordinarily more than three months.
Invasive weedy plant species	Opportunistic species of inferior biological value that tend to out-compete more desirable forms and become dominant; applied to non-native species in this manual.
Invert	The lowest point on the inside of a sewer or other conduit.
Invert elevation	The vertical elevation of a pipe or orifice in a pond that defines the water level.
Isopluvial map	A map with lines representing constant depth of total precipitation for a given return frequency.
Lag time	The interval between the center of mass of the storm precipitation and the peak flow of the resultant runoff.
Lake	An area permanently inundated by water in excess of two meters deep and greater than 20 acres in size as measured at the ordinary high water marks.
Land disturbing activity	Any activity that results in a movement of earth or a change in the existing soil cover (both vegetative and nonvegetative) and/or the existing soil topography. Land disturbing activities include, but are not limited to clearing, grading, filling, and excavation. Compaction that is associated with stabilization of structures and road construction shall also be considered a land disturbing activity. Vegetation maintenance practices are not considered land-disturbing activity.

Landslide	Episodic downslope movement of a mass of soil or rock that includes but is not limited to rockfalls, slumps, mudflows, and earthflows. For the purpose of these rules, snow avalanches are considered to be a special case of landsliding.
Landslide hazard areas	Those areas subject to a severe risk of landslide.
Leachable materials	Those substances that, when exposed to rainfall, measurably alter the physical or chemical characteristics of the rainfall runoff. Examples include erodible soils, uncovered process wastes, manure, fertilizers, oil substances, ashes, kiln dust, and garbage dumpster leakage.
Leachate	Liquid that has percolated through soil and contains substances in solution or suspension.
Leaching	Removal of the more soluble materials from the soil by percolating waters.
Legume	A member of the legume or pulse family, Leguminosae, one of the most important and widely distributed plant families. The fruit is a "legume" or pod. Includes many valuable food and forage species, such as peas, beans, clovers, alfalfas, sweet clovers, and vetches. Practically all legumes are nitrogen-fixing plants.
Level pool routing	The basic technique of storage routing used for sizing and analyzing detention storage and determining water levels for ponding water bodies. The level pool routing technique is based on the continuity equation: Inflow – Outflow = Change in storage.
Level spreader	A temporary ESC device used to spread out stormwater runoff uniformly over the ground surface as sheet flow (i.e., not through channels). The purpose of level spreaders is to prevent concentrated, erosive flows from occurring, and to enhance infiltration.
L.G.	Licensed Geologist in the State of Washington.
L.H.G.	Licensed Hydrogeologist in the State of Washington.
LID	See Low Impact Development.
LMC	Lacey Municipal Code, the codification of the ordinances of the City of Lacey.
Local government	Any county, city, town, or special purpose district having its own incorporated government for local affairs, such as the City of Lacey.
Low flow channel	An incised or paved channel from inlet to outlet in a dry basin which is designed to carry low runoff flows and/or baseflow, directly to the outlet without detention.

Low Impact Development A stormwater management strategy that emphasizes conservation and use of existing natural site features integrated with distributed, small-scale stormwater controls to more closely mimic natural hydrologic patterns in residential, commercial and industrial settings.

Lowest floor The lowest enclosed area (including basement) of a structure. An area used solely for parking of vehicles, building access, or storage, in an area other than a basement area, is not considered a building's lowest floor, provided that the enclosed area meets all of the structural requirements of the flood hazard standards.

MDNS A Mitigated Determination of Nonsignificance (See DNS and Mitigation).

Maintenance Repair and maintenance includes activities conducted on currently serviceable structures, facilities, and equipment that involves no expansion or use beyond that previously existing and resulting in no significant adverse hydrologic impact. It includes those usual activities taken to prevent a decline, lapse, or cessation in the use of structures and systems and includes replacement of malfunctioning facilities, including cases where environmental permits require replacing an existing structure with a different type structure, as long as the functioning characteristics of the original structure are not changed. For example, replacing a collapsed, fish blocking, round culvert with a new box culvert under the same span, or width, of roadway.

Manning's equation An equation used to predict the velocity of water flow in an open channel or pipelines:

$$V = \frac{1.486\, R^{2/3} S^{1/2}}{n}$$

where:

V is the mean velocity of flow in feet per second

R is the hydraulic radius in feet

S is the slope of the energy gradient or, for assumed uniform flow, the slope of the channel in feet per foot; and

n is Manning's roughness coefficient or retardance factor of the channel lining.

Mass wasting The movement of large volumes of earth material downslope.

Master drainage plan A comprehensive drainage control plan intended to prevent significant adverse impacts to the natural and manmade drainage system, both on and off-site.

Mean annual water level fluctuation

Derived as follows:

(1) Measure the maximum water level (e.g., with a crest stage gage, Reinelt and Horner 1990) and the existing water level at the time of the site visit (e.g., with a staff gage) on at least eight occasions spread through a year.

(2) Take the difference of the maximum and existing water level on each occasion and divide by the number of occasions.

Mean depth

Average depth; cross-sectional area of a stream or channel divided by its surface or top width.

Mean velocity

The average velocity of a stream flowing in a channel or conduit at a given cross-section or in a given reach. It is equal to the discharge divided by the cross-sectional area of the reach.

Measuring weir

A shaped notch through which water flows are measured. Common shapes are rectangular, trapezoidal, and triangular.

Mechanical analysis

The analytical procedure by which soil particles are separated to determine the particle size distribution.

Mechanical practices

Soil and water conservation practices that primarily change the surface of the land or that store, convey, regulate, or dispose of runoff water without excessive erosion.

Metals

Elements, such as mercury, lead, nickel, zinc and cadmium, which are of environmental concern because they do not degrade over time. Although many are necessary nutrients, they are sometimes magnified in the food chain, and they can be toxic to life in high enough concentrations. They are also referred to as heavy metals.

Microbes

The lower trophic levels of the soil food web. They are normally considered to include bacteria, fungi, flagellates, amoebae, ciliates, and nematodes. These in turn support the higher trophic levels, such as mites and earthworms. Together they are the basic life forms that are necessary for plant growth. Soil microbes also function to bioremediate pollutants such as petroleum, nutrients, and pathogens.

Mitigation

Means, in the following order of preference:

(a) Avoiding the impact altogether by not taking a certain action or part of an action;

(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts;

(c) Rectifying the impact by repairing, rehabilitating or restoring the affected environment;

(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and

(e) Compensating for the impact by replacing, enhancing, or providing substitute resources or environments.

Modification, modified (wetland) A wetland whose physical, hydrological, or water quality characteristics have been purposefully altered for a management purpose, such as by dredging, filling, forebay construction, and inlet or outlet control.

Monitor To systematically and repeatedly measure something in order to track changes.

Monitoring The collection of data by various methods for the purposes of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures imposed as conditions of development.

National Pollutant Discharge Elimination System (NPDES) The part of the federal Clean Water Act, which requires point source dischargers to obtain permits. These permits are referred to as NPDES permits and, in Washington State, are administered by the Washington State Department of Ecology.

Native Growth Protection Easement (NGPE) An easement granted for the protection of native vegetation within a sensitive area or its associated buffer. The NGPE shall be recorded on the appropriate documents of title and filed with the County Records Division.

Native vegetation Vegetation comprised of plant species, other than noxious weeds, that are indigenous to the coastal region of the Pacific Northwest and which reasonably could have been expected to naturally occur on the site. Examples include trees such as Douglas fir, Western Hemlock, Western Red Cedar, Alder, Big-leaf Maple, and Vine Maple; shrubs such as willow, elderberry, salmonberry and salal; and herbaceous plants such as sword fern, foam flower, and fireweed.

Natural location Means the location of those channels, swales, and other non-manmade conveyance systems as defined by the first documented topographic contours existing for the subject property, either from maps or photographs, or such other means as appropriate. In the case of outwash soils with relatively flat terrain, no natural location of surface discharge may exist.

New development Land disturbing activities, including Class IV -general forest practices that are conversions from timber land to other uses; structural development, including construction or installation of a building or other structure; creation of impervious surfaces; and subdivision, short subdivision and binding site plans, as defined and applied in Chapter 58.17 RCW. Projects meeting the definition of redevelopment shall not be considered new development.

NGPE See Native Growth Protection Easement.

NGVD National Geodetic Vertical Datum.

Nitrate (NO_3) A form of nitrogen which is an essential nutrient to plants. It can cause algal blooms in water if all other nutrients are present in sufficient quantities. It is a product of bacterial oxidation of other forms of nitrogen, from the atmosphere during electrical storms and from fertilizer manufacturing.

Nitrification The biochemical oxidation process by which ammonia is changed first to nitrites and then to nitrates by bacterial action, consuming oxygen in the water.

Nitrogen, Available Usually ammonium, nitrite, and nitrate ions, and certain simple amines available for plant growth. A small fraction of organic or total nitrogen in the soil is available at any time.

Nonpoint source pollution Pollution that enters a waterbody from diffuse origins on the watershed and does not result from discernible, confined, or discrete conveyances.

Normal depth The depth of uniform flow. This is a unique depth of flow for any combination of channel characteristics and flow conditions. Normal depth is calculated using Manning's Equation.

NPDES The National Pollutant Discharge Elimination System (see above) as established by the Federal Clean Water Act.

NRCS Method See SCS Method.

Nutrients Essential chemicals needed by plants or animals for growth. Excessive amounts of nutrients can lead to degradation of water quality and algal blooms. Some nutrients can be toxic at high concentrations.

Off-line facilities Water quality treatment facilities to which stormwater runoff is restricted to some maximum flow rate or volume by a flow-splitter.

Off-site Any area lying upstream of the site that drains onto the site and any area lying downstream of the site to which the site drains.

Off-system storage Facilities for holding or retaining excess flows over and above the carrying capacity of the stormwater conveyance system, in chambers, tanks, lagoons, ponds, or other basins that are not a part of the subsurface sewer system.

Oil/water separator A vault, usually underground, designed to provide a quiescent environment to separate oil from water.

On-line facilities Water quality treatment facilities which receive all of the stormwater runoff from a drainage area. Flows above the water quality design flow rate or volume are passed through at a lower percent removal efficiency.

On-site The entire property that includes the proposed development.

On-site Stormwater Management BMPs Site development techniques that serve to infiltrate, disperse, and retain stormwater runoff on-site.

Operational BMPs Operational BMPs are a type of Source Control BMP. They are schedules of activities, prohibition of practices, and other managerial practices to prevent or reduce pollutants from entering stormwater. Operational BMPs include formation of a pollution prevention team, good housekeeping, preventive maintenance procedures, spill prevention and clean-up, employee training, inspections of pollutant sources and BMPs, and record keeping. They can also include process changes, raw material/product changes, and recycling wastes.

Ordinary high water mark The term ordinary high water mark means the line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil destruction on terrestrial vegetation, or the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding area.

The ordinary high water mark will be found by examining the bed and banks of a stream and ascertaining where the presence and action of waters are so common and usual, and so long maintained in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland, in respect to vegetation. In any area where the ordinary high water mark cannot be found, the line of mean high water shall substitute. In any area where neither can be found, the channel bank shall be substituted. In braided channels and alluvial fans, the ordinary high water mark or substitute shall be measured so as to include the entire stream feature.

Organic matter Organic matter as decomposed animal or vegetable matter. It is measured by ASTM D 2974. Organic matter is an important reservoir of carbon and a dynamic component of soil and the carbon cycle. It improves soil and plant efficiency by improving soil physical properties including drainage, aeration, and other structural characteristics. It contains the nutrients, microbes, and higher-form soil food web organisms necessary for plant growth. The maturity of organic matter is a measure of its beneficial properties. Raw organic matter can release water-soluble nutrients (similar to chemical fertilizer). Beneficial organic matter has undergone a humification process either naturally in the environment or through a composting process.

Orifice An opening with closed perimeter, usually sharp-edged, and of regular form in a plate, wall, or partition through which water may flow, generally used for the purpose of measurement or control of water.

Outlet Point of water disposal from a stream, river, lake, tidewater, or artificial drain.

Outlet channel A waterway constructed or altered primarily to carry water from man-made structures, such as terraces, tile lines, and diversions.

Outwash soils Soils formed from highly permeable sands and gravels.

Overflow A pipeline or conduit device, together with an outlet pipe, that provides for the discharge of portions of combined sewer flows into receiving waters or other points of disposal, after a regular device has

allowed the portion of the flow which can be handled by interceptor sewer lines and pumping and treatment facilities to be carried by and to such water pollution control structures.

Overflow rate Detention basin release rate divided by the surface area of the basin. It can be thought of as an average flow rate through the basin.

Overtopping To flow over the limits of a containment or conveyance element.

Particle Size The effective diameter of a particle as measured by sedimentation, sieving, or micrometric methods.

P.E. Professional Engineer. As used in this manual, a P.E. is an engineer professionally licensed in the State of Washington.

Peak discharge The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Peak-shaving	Controlling post-development peak discharge rates to pre-development levels by providing temporary detention in a BMP.
Percolation	The movement of water through soil.
Percolation rate	The rate, often expressed in minutes/inch, at which clear water, maintained at a relatively constant depth, will seep out of a standardized test hole that has been previously saturated. The term percolation rate is often used synonymously with infiltration rate (short-term infiltration rate).
Permanent Stormwater Control (PSC) Plan	A plan which includes permanent BMPs for the control of pollution from stormwater runoff after construction and/or land disturbing activity has been completed
Permeable	Capable of being permeated. A material is permeable if the void spaces or interstices are large enough to pass liquid through. Note: the term "permeable pavement" is preferred over "porous pavement" since permeability is necessary for infiltration through the media, whereas a material can be porous without being very permeable.
Permeable soils	Soil materials with a sufficiently rapid infiltration rate so as to greatly reduce or eliminate surface and stormwater runoff. These soils are generally classified as SCS hydrologic soil types A and B.
Person	Any individual, partnership, corporation, association, organization, cooperative, public or municipal corporation, agency of the state, or local government unit, however designated.
Pervious	Open to passage or entrance; permeable. Related to the size and continuity of void spaces in soils, and to a soil's infiltration rate.
Pesticide	A general term used to describe any substance - usually chemical - used to destroy or control organisms; includes herbicides, insecticides, algicides, fungicides, and others. Many of these substances are manufactured and are not naturally found in the environment. Others, such as pyrethrum, are natural toxins that are extracted from plants and animals.
pH	A measure of the alkalinity or acidity of a substance which is conducted by measuring the concentration of hydrogen ions in the substance. A pH of 7.0 indicates neutral water. A 6.5 reading is slightly acid.
Physiographic	Characteristics of the natural physical environment (including hills).
Plan Approval Authority	The Plan Approval Authority is defined as that department within a local government that has been delegated authority to approve stormwater site plans.

Planned unit development (PUD) A special classification authorized in some zoning ordinances, where a unit of land under control of a single developer may be used for a variety of uses and densities, subject to review and approval by the local governing body. The locations of the zones are usually decided on a case-by-case basis.

Plat A map or representation of a subdivision showing the division of a tract or parcel of land into lots, blocks, streets, or other divisions and dedications.

P.L.S. Professional Land Surveyor. As used in this manual, a P.L.S. is a land surveyor professionally licensed in the State of Washington.

Plunge pool A device used to dissipate the energy of flowing water that may be constructed or made by the action of flowing. These facilities may be protected by various lining materials.

Point discharge The release of collected and/or concentrated surface and stormwater runoff from a pipe, culvert, or channel.

Point of compliance The location at which compliance with a discharge performance standard or a receiving water quality standard is measured.

Pollution Contamination or other alteration of the physical, chemical, or biological properties, of waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive or other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental or injurious to the public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life.

Pollution-generating impervious surface (PGIS) Those impervious surfaces considered to be a significant source of pollutants in stormwater runoff. Such surfaces include those which are subject to: vehicular use; industrial activities (as further defined in this glossary); or storage of erodible or leachable materials, wastes, or chemicals, and which receive direct rainfall or the run-on or blow-in of rainfall. Erodible or leachable materials, wastes, or chemicals are those substances which, when exposed to rainfall, measurably alter the physical or chemical characteristics of the rainfall runoff. Examples include erodible soils that are stockpiled, uncovered process wastes, manure, fertilizers, oily substances, ashes, kiln dust, and garbage dumpster leakage. Metal roofs are also considered to be PGIS unless they are coated with an inert, non-leachable material (e.g., baked-on enamel coating).

A surface, whether paved or not, shall be considered subject to vehicular use if it is regularly used by motor vehicles. The following are considered regularly-used surfaces: roads, driveways, parking lots, unvegetated road shoulders, unfenced fire lanes, vehicular equipment storage yards, and airport runways. The following are not considered regularly-used surfaces: paved bicycle pathways, road shoulders, fenced fire lanes, and infrequently used maintenance access roads.

Pollution-generating pervious surface (PGPS) Any non-impervious surface subject to use of pesticides and fertilizers or loss of soil. Typical PGPS include lawns, landscaped areas, golf courses, parks, cemeteries, and sports fields.

Predeveloped Condition The native vegetation and soils that existed at a site prior to the influence of Euro-American settlement. The pre-developed condition shall be assumed to be forested land cover unless reasonable, historic information is provided that indicates the site was prairie prior to settlement.

Prediction For the purposes of this document an expected outcome based on the results of hydrologic modelling and/or the judgment of a trained professional civil engineer or geologist.

Pretreatment The removal of material such as solids, grit, grease, and scum from flows prior to physical, biological, or physical treatment processes to improve treatability. Pretreatment may include screening, grit removal, settling, oil/water separation, or application of a Basic Treatment BMP prior to infiltration.

Priority peat systems Unique, irreplaceable fens that can exhibit water pH in a wide range from highly acidic to alkaline, including fens typified by Sphagnum species, Ledum groenlandicum (Labrador tea), Drosera rotundifolia (sundew), and Vaccinium oxycoccos (bog cranberry); marl fens; estuarine peat deposits; and other moss peat systems with relatively diverse, undisturbed flora and fauna. Bog is the common name for peat systems having the Sphagnum association described, but this term applies strictly only to systems that receive water income from precipitation exclusively.

Professional civil engineer A person registered with the state of Washington as a professional engineer in civil engineering.

Project Any proposed action to alter or develop a site. The proposed action of a permit application or an approval, which requires drainage review.

Project site That portion of a property, properties, or right of way subject to land disturbing activities, new impervious surfaces, or replaced impervious surfaces.

Properly Functioning Soil System (PFSS) Equivalent to engineered soil/landscape system. This can also be a natural system that has not been disturbed or modified.

Puget Sound basin	Puget Sound south of Admiralty Inlet (including Hood Canal); the waters north to the Canadian border, including portions of the Strait of Georgia; the Strait of Juan de Fuca south of the Canadian border; and all the lands draining into these waters as mapped in Water Resources Inventory Areas No. 1 through 19, set forth in WAC 173-500-040.
Rare, threatened, or endangered species	Plant or animal species that are regional relatively uncommon, are nearing endangered status, or whose existence is in immediate jeopardy and is usually restricted to highly specific habitats. Threatened and endangered species are officially listed by federal and state authorities, whereas rare species are unofficial species of concern that fit the above definitions.
Rational method	A means of computing storm drainage flow rates (Q) by use of the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the rainfall intensity and A is the area. This method is no longer used in the technical manual.
Reach	A length of channel with uniform characteristics.
Receiving waters	Bodies of water or surface water systems to which surface runoff is discharged via a point source of stormwater or via sheet flow.
Recharge	The addition of water to the zone of saturation (i.e., groundwater).
Recommended BMPs	As used in reference to Source Control (Chapter 8 of this manual, and Volume IV of Ecology's 2005 *Stormwater Management Manual for Western Washington*), recommended BMPs are those BMPs that are not expected to be mandatory by local governments at new development and redevelopment sites. However, they may improve pollutant control efficiency, and may provide a more comprehensive and environmentally effective stormwater management program.
Redevelopment	On a site that is already developed, the creation or addition of impervious surfaces; the expansion of a building footprint or addition or replacement of a structure; structural development including construction, installation or expansion of a building or other structure; replacement of impervious surface that is not part of a routine maintenance activity; and land disturbing activities.
Regional	An action (here, for stormwater management purposes) that involves more than one discrete property.
Regional detention facility	A stormwater quantity control structure designed to correct existing surface water runoff problems of a basin or subbasin. The area downstream has been previously identified as having existing or predicted significant and regional flooding and/or erosion problems.

	This term is also used when a detention facility is sited to detain stormwater runoff from a number of new developments or areas within a catchment.
Release rate	The computed peak rate of surface and stormwater runoff from a site.
Replaced impervious surface	For structures, the removal and replacement of any exterior impervious surfaces or foundation. For other impervious surfaces, the removal down to bare soil or base course and replacement.
Residential density	The number of dwelling units per unit of surface area. Net density includes only occupied land. Gross density includes unoccupied portions of residential areas, such as roads and open space.
Restoration	Actions performed to reestablish wetland functional characteristics and processes that have been lost by alterations, activities, or catastrophic events in an area that no longer meets the definition of a wetland.
Retention	The process of collecting and holding surface and stormwater runoff with no surface outflow.
Retention/detention facility (R/D)	A type of drainage facility designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground; or to hold surface and stormwater runoff for a short period of time and then release it to the surface and stormwater management system.
Retrofitting	The renovation of an existing structure or facility to meet changed conditions or to improve performance.
Return frequency	A statistical term for the average time of expected interval that an event of some kind will equal or exceed given conditions (e.g., a stormwater flow that occurs every 2 years).
Rhizome	A modified plant stem that grows horizontally underground.
Riffles	Fast sections of a stream where shallow water races over stones and gravel. Riffles usually support a wider variety of bottom organisms than other stream sections.
Rill	A small intermittent watercourse with steep sides, usually only a few inches deep. Often rills are caused by an increase in surface water flow when soil is cleared of vegetation.
Riprap	A facing layer or protective mound of rocks placed to prevent erosion or sloughing of a structure or embankment due to flow of surface and stormwater runoff.
Riparian	Pertaining to the banks of streams, wetlands, lakes, or tidewater.

Riser	A vertical pipe extending from the bottom of a pond BMP that is used to control the discharge rate from a BMP for a specified design storm.
Rodenticide	A substance used to destroy rodents.
Runoff	Water originating from rainfall and other precipitation that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes and wetlands as well as shallow ground water. As applied in this manual, it also means the portion of rainfall or other precipitation that becomes surface flow and interflow.
SBUH	Santa Barbara Unit Hydrograph, a hydrologic analysis method based upon the SCS Curve Number Method (see below), but generally yielding more consistent results for analysis of small subbasins.
SCS	Soil Conservation Service (now the Natural Resources Conservation Service), U.S. Department of Agriculture.
SCS Method	A single-event hydrologic analysis technique for estimating runoff based on the Curve Number method. Curve Numbers are published by NRCS in *Urban Hydrology for Small Watersheds, TR-55, June 1976*. With the name change above, may be referred to as the NRCS Method.
SEPA	See State Environmental Policy Act.
Salmonid	A member of the fish family Salmonidae. Chinook, coho, chum, pink and sockeye salmon; cutthroat, brook, brown, rainbow, and steelhead trout; Dolly Varden, kokanee, and char are examples of salmonid species.
Sand filter	A man-made depression or basin with a layer of sand that treats stormwater as it percolates through the sand and is discharged via a central collector pipe.
Saturation point	In soils, the point at which a soil or an aquifer will no longer absorb any amount of water without losing an equal amount.
Scour	Erosion of channel banks due to excessive velocity of the flow of surface and stormwater runoff.
Sediment	Fragmented material that originates from weathering and erosion of rocks or unconsolidated deposits, and is transported by, suspended in, or deposited by water.
Sedimentation	The depositing or formation of sediment.
Sensitive emergent vegetation communities	Assemblages of erect, rooted, herbaceous vegetation, excluding mosses and lichens, at least some of whose members have relatively narrow ranges of environmental requirements, such as hydroperiod, nutrition, temperature, and light. Examples include fen species such

as sundew and, as well as a number of species of Carex (sedges).

Sensitive life stages Stages during which organisms have limited mobility or alternatives in securing the necessities of life, especially including reproduction, rearing, and migration periods.

Sensitive scrub-shrub vegetation communities Assemblages of woody vegetation less than 6 meters in height, at least some of whose members have relatively narrow ranges of environmental requirements, such as hydroperiod, nutrition, temperature, and light. Examples include fen species such as Labrador tea, bog laurel, and cranberry.

Settleable solids Those suspended solids in stormwater that separate by settling when the stormwater is held in a quiescent condition for a specified time.

Sheet erosion The relatively uniform removal of soil from an area without the development of conspicuous water channels.

Sheet flow Runoff that flows over the ground surface as a thin, even layer, not concentrated in a channel.

Shoreline development The proposed project as regulated by the Shoreline Management Act. Usually the construction over water or within a shoreline zone (generally 200 feet landward of the water) of structures such as buildings, piers, bulkheads, and breakwaters, including environmental alterations such as dredging and filling, or any project which interferes with public navigational rights on the surface waters.

Short circuiting The passage of runoff through a BMP in less than the design treatment time.

Siltation The process by which a river, lake, or other waterbody becomes clogged with sediment. Silt can clog gravel beds and prevent successful salmon spawning.

Site The legal boundaries of a parcel or parcels of land that is (are) subject to new development or redevelopment. For road projects, the length of the project and the right-of-way boundaries define the site.

Slope Degree of deviation of a surface from the horizontal; measured as a numerical ratio, percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise), as 2:1. A 2:1 slope is a 50 percent slope. Expressed in degrees, the slope is the angle from the horizontal plane, with a 90° slope being vertical (maximum) and 45° being a 1:1 or 100 percent slope.

Sloughing The sliding of overlying material. It is the same effect as caving, but it usually occurs when the bank or an underlying stratum is saturated or scoured.

Soil The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. See also topsoil, engineered soil/landscape system, and properly functioning soil system.

Soil group, hydrologic A classification of soils by the Soil Conservation Service into four runoff potential groups. The groups range from A soils, which are very permeable and produce little or no runoff, to D soils, which are not very permeable and produce much more runoff.

Soil horizon A layer of soil, approximately parallel to the surface, which has distinct characteristics produced by soil-forming factors.

Soil profile A vertical section of the soil from the surface through all horizons, including C horizons.

Soil structure The relation of particles or groups of particles which impart to the whole soil a characteristic manner of breaking; some types are crumb structure, block structure, platy structure, and columnar structure.

Soil permeability The ease with which gases, liquids, or plant roots penetrate or pass through a layer of soil.

Soil stabilization The use of measures such as rock lining, vegetation or other engineering structures to prevent the movement of soil when loads are applied to the soil.

Soil Texture Class The relative proportion, by weight, of particle sizes, based on the USDA system, of individual soil grains less than 2 mm equivalent diameter in a mass of soil. The basic texture classes in the approximate order of increasing proportions of fine particles include: sand, loamy sand, sandy loam, loam, silt loam, silt, clay loam, sandy clay, silty clay, and clay.

Sorption The physical or chemical binding of pollutants to sediment or organic particles.

Source control BMP A structure or operation that is intended to prevent pollutants from coming into contact with stormwater through physical separation of areas or careful management of activities that are sources of pollutants. This manual separates source control BMPs into two types. *Structural source control BMPs* are physical, structural, or mechanical devices or facilities that are intended to prevent pollutants from entering stormwater. *Operational BMPs* are non-structural practices that prevent or reduce pollutants from entering stormwater. See Chapter 8 of this manual and Volume IV of Ecology's *Stormwater Management Manual for Western Washington* for details.

Spill control device A Tee section or turn down elbow designed to retain a limited volume of pollutant that floats on water, such as oil or antifreeze. Spill control devices are passive and must be cleaned-out for the spilled pollutant to actually be removed.

Spillway A passage such as a paved apron or channel for surplus water over or around a dam or similar obstruction. An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

State Environmental Policy Act (SEPA)

RCW 43.21C

The Washington State law intended to minimize environmental damage. SEPA requires that state agencies and local governments consider environmental factors when making decisions on activities, such as development proposals over a certain size and comprehensive plans. As part of this process, environmental documents are prepared and opportunities for public comment are provided.

Steep slope Slopes of 40 percent gradient or steeper within a vertical elevation change of at least ten feet. A slope is delineated by establishing its toe and top, and is measured by averaging the inclination over at least ten feet of vertical relief. For the purpose of this definition:

The toe of a slope is a distinct topographic break in slope that separates slopes inclined at less than 40% from slopes 40% or steeper. Where no distinct break exists, the toe of a steep slope is the lower-most limit of the area where the ground surface drops ten feet or more vertically within a horizontal distance of 25 feet; AND

The top of a slope is a distinct topographic break in slope that separates slopes inclined at less than 40% from slopes 40% or steeper. Where no distinct break exists, the top of a steep slope is the upper-most limit of the area where the ground surface drops ten feet or more vertically within a horizontal distance of 25 feet.

Storage routing A method to account for the attenuation of peak flows passing through a detention facility or other storage feature.

Storm drains The enclosed conduits that transport surface and stormwater runoff toward points of discharge (sometimes called storm sewers).

Storm frequency The time interval between major storms of predetermined intensity and volumes of runoff for which storm sewers and other structures are designed and constructed to handle hydraulically without surcharging and backflooding, e.g., a 2-year, 10-year or 100-year storm.

Storm sewer	A pipe system that carries stormwater and surface water, street wash and other wash waters or drainage, but excludes sewage and industrial wastes. Also called a storm drain.
Stormwater	That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes and other features of a stormwater drainage system into a defined surface waterbody, or a constructed infiltration facility.
Stormwater drainage system	Constructed and natural features which function together as a system to collect, convey, channel, hold, inhibit, retain, detain, infiltrate, divert, treat or filter stormwater.
Stormwater facility	A constructed component of a stormwater drainage system, designed or constructed to perform a particular function, or multiple functions. Stormwater facilities include, but are not limited to, pipes, swales, ditches, culverts, street gutters, detention ponds, retention ponds, constructed wetlands, infiltration devices, catch basins, oil/water separators, and biofiltration swales.
Stormwater Management Manual for Western Washington (SMMWW)	The manual, as prepared by Ecology, containing BMPs to prevent, control or treat pollution in stormwater and reduce other stormwater-related impacts to waters of the State. The SMMWW is intended to provide guidance on measures necessary in western Washington to control the quantity and quality of stormwater runoff from new development and redevelopment.
Stormwater Program	Either the Basic Stormwater Program or the Comprehensive Stormwater Program (as appropriate to the context of the reference) called for under the Puget Sound Water Quality Management Plan.
Stormwater Site Plan	The comprehensive report containing all of the technical information and analysis necessary for regulatory agencies to evaluate a proposed new development or redevelopment project for compliance with stormwater requirements. Contents of the Stormwater Site Plan will vary with the type and size of the project, and individual site characteristics. It includes a Construction Stormwater Pollution Prevention Plan (Construction SWPPP) and a Permanent Stormwater Control Plan (PSC Plan). Guidance on preparing a Stormwater Site Plan is contained in Chapter 2.
Stream gaging	The quantitative determination of stream flow using gages, current meters, weirs, or other measuring instruments at selected locations. See Gaging station.
Streambanks	The usual boundaries, not the flood boundaries, of a stream channel. Right and left banks are named facing downstream.

Streams — Those areas where surface waters flow sufficiently to produce a defined channel or bed. A defined channel or bed is an area that demonstrates clear evidence of the passage of water and includes, but is not limited to, indicated by hydraulically sorted sediments or the removal of vegetative litter or loosely rooted vegetation by the action of moving water. The channel or bed need not contain water year-round. This definition is not meant to include irrigation ditches, canals, stormwater runoff devices or other entirely artificial watercourses unless they are used to convey streams naturally occurring prior to construction. Those topographic features that resemble streams but have no defined channels (i.e. swales) shall be considered streams when hydrologic and hydraulic analyses done pursuant to a development proposal predict formation of a defined channel after development.

Structure — A catch basin or manhole in reference to a storm drainage system.

Structural source control BMPs — Physical, structural, or mechanical devices or facilities that are intended to prevent pollutants from entering stormwater. Structural source control BMPs typically include:

- Enclosing and/or covering the pollutant source (building or other enclosure, a roof over storage and working areas, temporary tarp, etc.).
- Segregating the pollutant source to prevent run-on of stormwater, and to direct only contaminated stormwater to appropriate treatment BMPs.

Stub-out — A short length of pipe provided for future connection to a storm drainage system.

Subbasin — A drainage area that drains to a water-course or waterbody named and noted on common maps and which is contained within a basin.

Subcatchment — A subdivision of a drainage basin (generally determined by topography and pipe network configuration).

Subdrain — A pervious backfilled trench containing stone or a pipe for intercepting ground water or seepage.

Subgrade — A layer of stone or soil used as the underlying base for a BMP.

Subsoil — The B horizons of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil), in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as the "subsoil."

Substrate	The natural soil base underlying a BMP.
Surcharge	The flow condition occurring in closed conduits when the hydraulic grade line is above the crown of the sewer.
Surface and stormwater	Water originating from rainfall and other precipitation that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes, and wetlands as well as shallow ground water.
Surface and stormwater management system	Drainage facilities and any other natural features that collect, store, control, treat and/or convey surface and stormwater.
Suspended solids	Organic or inorganic particles that are suspended in and carried by the water. The term includes sand, mud, and clay particles (and associated pollutants) as well as solids in stormwater.
Swale	A shallow drainage conveyance with relatively gentle side slopes, generally with flow depths less than one foot.
SWPPP	Stormwater Pollution Prevention Plan.
Terrace	An embankment or combination of an embankment and channel across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.
Threshold Discharge Area	An onsite area draining to a single natural discharge location or multiple natural discharge locations that combine within one-quarter mile downstream (as determined by the shortest flowpath). The examples in Figure 1.1 of Chapter 1 illustrate this definition. The purpose of this definition is to clarify how the thresholds of this manual are applied to project sites with multiple discharge points.
Tightline	A continuous length of pipe that conveys water from one point to another (typically down a steep slope) with no inlets or collection points in between.
Tile, Drain	Pipe made of burned clay, concrete, or similar material, in short lengths, usually laid with open joints to collect and carry excess water from the soil.
Tile drainage	Land drainage by means of a series of tile lines laid at a specified depth and grade.
Till	See Glacial Till.
Time of concentration	The time period necessary for surface runoff to reach the outlet of a subbasin from the hydraulically most remote point in the tributary drainage area.

Topography General term to include characteristics of the ground surface such as plains, hills, mountains, degree of relief, steepness of slopes, and other physiographic features.

Topsoil Topsoil shall be per ASTM D5268 standard specification, and water permeability shall be 0.6 inches per hour or greater. Organic matter shall have not more than 10 percent of nutrients in mineralized water-soluble forms. Topsoil shall not have phytotoxic characteristics.

Total dissolved solids The dissolved salt loading in surface and subsurface waters.

Total Petroleum Hydrocarbons (TPH) TPH-Gx: The qualitative and quantitative method (extended) for volatile ("gasoline") petroleum products in water; and TPH-Dx: The qualitative and quantitative method (extended) for semi-volatile ("diesel") petroleum products in water.

Total solids The solids in water, sewage, or other liquids, including the dissolved, filterable, and nonfilterable solids. The residue left when the moisture is evaporated and the remainder is dried at a specified temperature, usually 130°C.

Total suspended solids That portion of the solids carried by stormwater that can be captured on a standard glass filter.

Total Maximum Daily Load (TMDL) – Water Cleanup Plan A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. A TMDL (also known as a Water Cleanup Plan) is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the waterbody can be used for the purposes the State has designated. The calculation must also account for seasonable variation in water quality. Water quality standards are set by states, territories, and tribes. They identify the uses for each waterbody, for example, drinking water supply, contact recreation (swimming), and aquatic like support (fishing), and the scientific criteria to support that use. The Clean Water Act, section 303, establishes the water quality standards and TMDL programs.

Toxic Poisonous, carcinogenic, or otherwise directly harmful to life.

TR-55 Technical Release No. 55 of the U.S.D.A. Soil Conservation Service, Engineering Division, June 1986, titled "Urban Hydrology for Small Watersheds," which describes procedures for estimating runoff and peak discharges. See "SCS Method."

Tract A legally created parcel of property designated for special nonresidential and noncommercial uses.

Trash rack	A structural device used to prevent debris from entering a spillway or other hydraulic structure.
Travel time	The estimated time for surface water to flow between two points of interest.
Treatment BMP	A BMP that is intended to remove pollutants from stormwater. A few examples of treatment BMPs are wetponds, wetvaults, manufactured systems, oil/water separators, biofiltration swales, and constructed wetlands.
Treatment liner	A soil layer that is designed to slow the rate of infiltration and provide sufficient pollutant removal so as to protect groundwater quality.
Treatment train	A combination of two or more treatment facilities connected in series.
Turbidity	Dispersion or scattering of light in a liquid, caused by suspended solids and other factors; commonly used as a measure of suspended solids in a liquid.
Underdrain	Plastic pipes with holes drilled through, installed on the bottom of an infiltration BMP, which are used to collect and remove excess runoff.
Undisturbed buffer	A zone where development activity shall not occur, including logging, and/or the construction of utility trenches, roads, and/or surface and stormwater facilities.
Undisturbed low gradient uplands	Forested land, sufficiently large and flat to infiltrate surface and storm runoff without allowing the concentration of water on the surface of the ground.
Unstable slopes	Those sloping areas of land which have in the past exhibited, are currently exhibiting, or will likely in the future exhibit, mass movement of earth.
Unusual biological community types	Assemblages of interacting organisms that are relatively uncommon regionally.
Urbanized area	Areas designated and identified by the U.S. Bureau of Census according to the following criteria: an incorporated place and densely settled surrounding area that together have a maximum population of 50,000.
U.S. EPA	The United States Environmental Protection Agency.
Values	Wetland processes or attributes that are valuable or beneficial to society (also see Functions). Wetland values include support of commercial and sport fish and wildlife species, protection of life and property from flooding, recreation, education, and aesthetic enhancement of human communities.

Variance	See Exception.
Vegetation	All organic plant life growing on the surface of the earth.
Waterbody	Surface waters including rivers, streams, lakes, marine waters, estuaries, and wetlands.
Water Cleanup Plan	See Total Maximum Daily Load
Water quality	A term used to describe the chemical, physical, and biological characteristics off water, usually in respect to its suitability for a particular purpose.
Water quality design storm	The 24-hour rainfall amount with a 6-month return frequency. Commonly referred to as the 6-month, 24-hour storm.
Water quality standards	Minimum requirements of purity of water for various uses; for example, water for agricultural use in irrigation systems should not exceed specific levels of sodium bicarbonate, pH, total dissolved salts, etc. In Washington, the Department of Ecology sets water quality standards.
Watershed	A geographic region within which water drains into a particular river, stream, or body of water. Watersheds can be as large as those identified and numbered by the State of Washington Water Resource Inventory Areas (WRIAs) as defined in Chapter 173-500 WAC.
Water table	The upper surface or top of the saturated portion of the soil or bedrock layer, indicates the uppermost extent of groundwater.
Weir	Device for measuring or regulating the flow of water.
Weir notch	The opening in a weir for the passage of water.
Wetlands	Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands do not include those artificial wetlands intentionally created from nonwetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. Wetlands may include those artificial wetlands intentionally created from nonwetland areas to mitigate the conversion of wetlands. (Waterbodies not

included in the definition of wetlands as well as those mentioned in the definition are still waters of the state.)

Wetland edge	Delineation of the wetland edge shall be based on the U.S. Army Corps of Engineers Wetlands Delineation Manual, Technical Report Y-87-1, U.S. Army Engineers Waterways Experiment Station, Vicksburg, Miss. (1987)
Wetponds and wetvaults	Drainage facilities for water quality treatment that contain permanent pools of water that are filled during the initial runoff from a storm event. They are designed to optimize water quality by providing retention time in order to settle out particles of fine sediment to which pollutants such as heavy metals absorb, and to allow biologic activity to occur that metabolizes nutrients and organic pollutants.
Wetpool	In wet treatment facilities (such as wetponds, wetvaults, and constructed wetlands), the permanent water volume located below the discharge outlet.
WWHM	Western Washington Hydrology Model. A continuous simulation hydrologic model based on the EPA's HSPF software program. The WWHM was created for the purpose of sizing stormwater control facilities in western Washington.
Zoning ordinance	An ordinance based on the police power of government to protect the public health, safety, and general welfare. It may regulate the type of use and intensity of development of land and structures to the extent necessary for a public purpose. Requirements may vary among various geographically defined areas called zones. Regulations generally cover such items as height and bulk of buildings, density of dwelling units, off-street parking, control of signs, and use of land for residential, commercial, industrial, or agricultural purposes. A zoning ordinance is one of the major methods for implementation of a comprehensive plan.

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