

# APPENDIX E

## Additional BMP Design Requirements

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City of Seattle | Stormwater Manual



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Appendix E includes additional design requirements for the following:

- Flow Control Structures (*Section E-1*)
- Flow Splitters (*Section E-2*)
- Flow Spreaders (*Section E-3*)
- Level Spreaders (*Section E-4*)
- Pipe Slope Drains (*Section E-5*)
- Outlet Protection (*Section E-6*)
- Liners (*Section E-7*)
- Geotextiles (*Section E-8*)
- Drywell Sizing Tables (*Section E-9*)

## E-1. Flow Control Structures

Flow control structures are catch basins or maintenance holes with a restrictor device for controlling outflow from a BMP to meet the desired performance.

The flow control device usually consists of two or more orifices and/or a weir section sized to meet performance requirements. Standard flow control device details are shown in Figures E.1, E.2, and E.3 and in City of Seattle Standard Plan 272a.

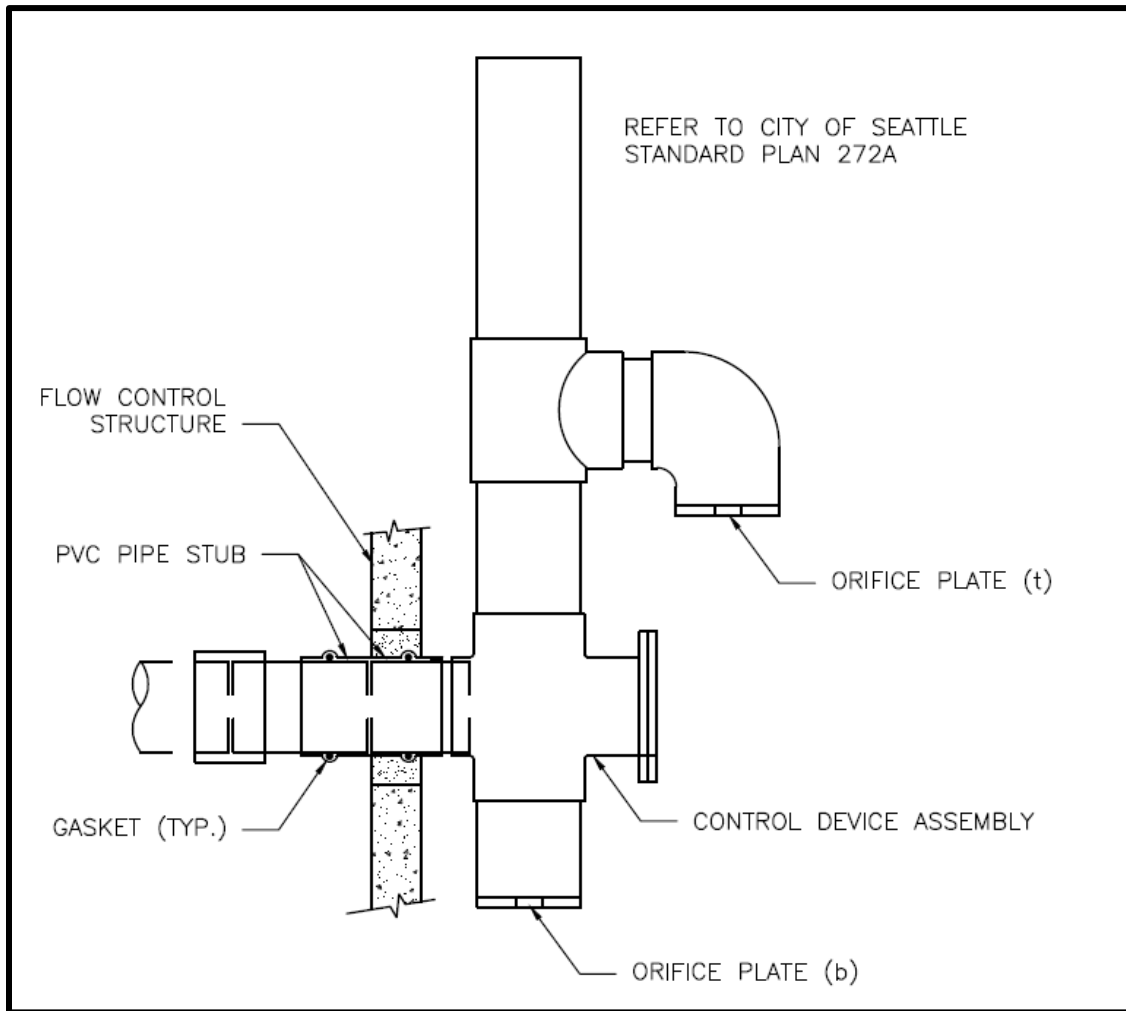


Figure E.1. Simple Orifice.

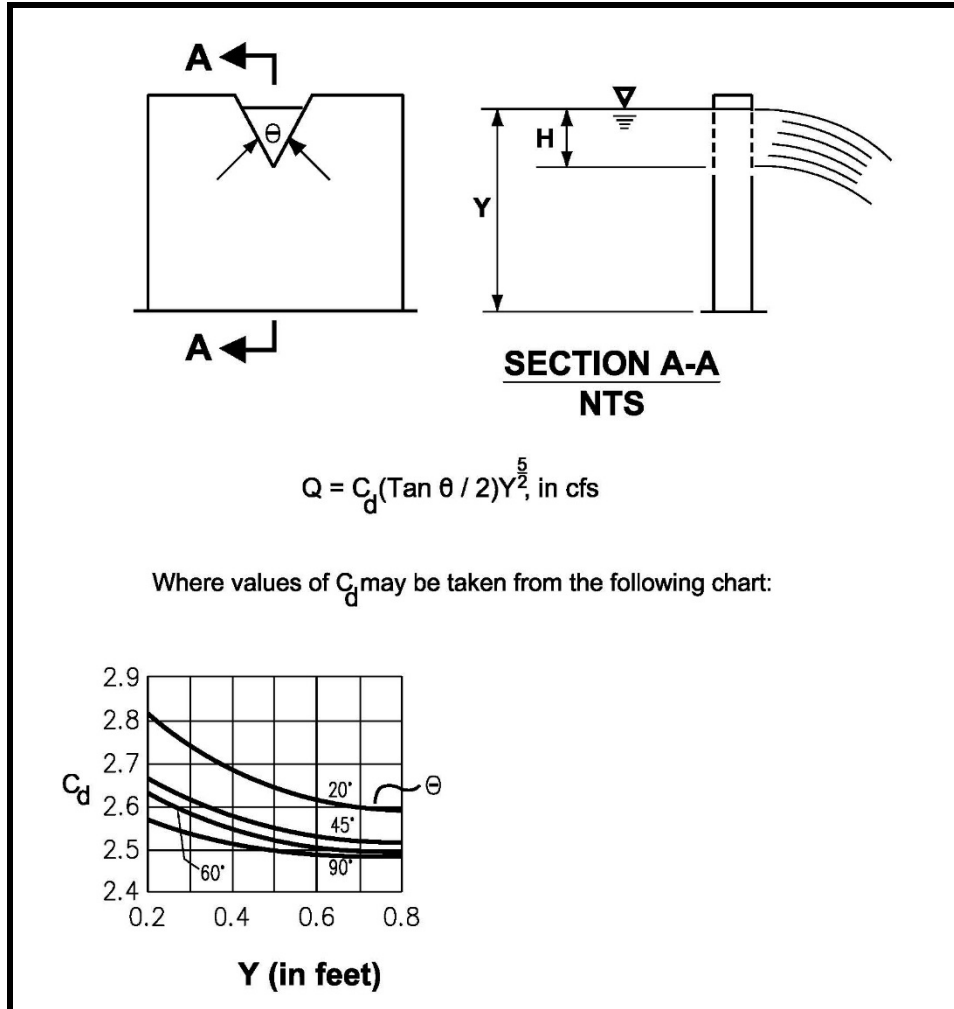
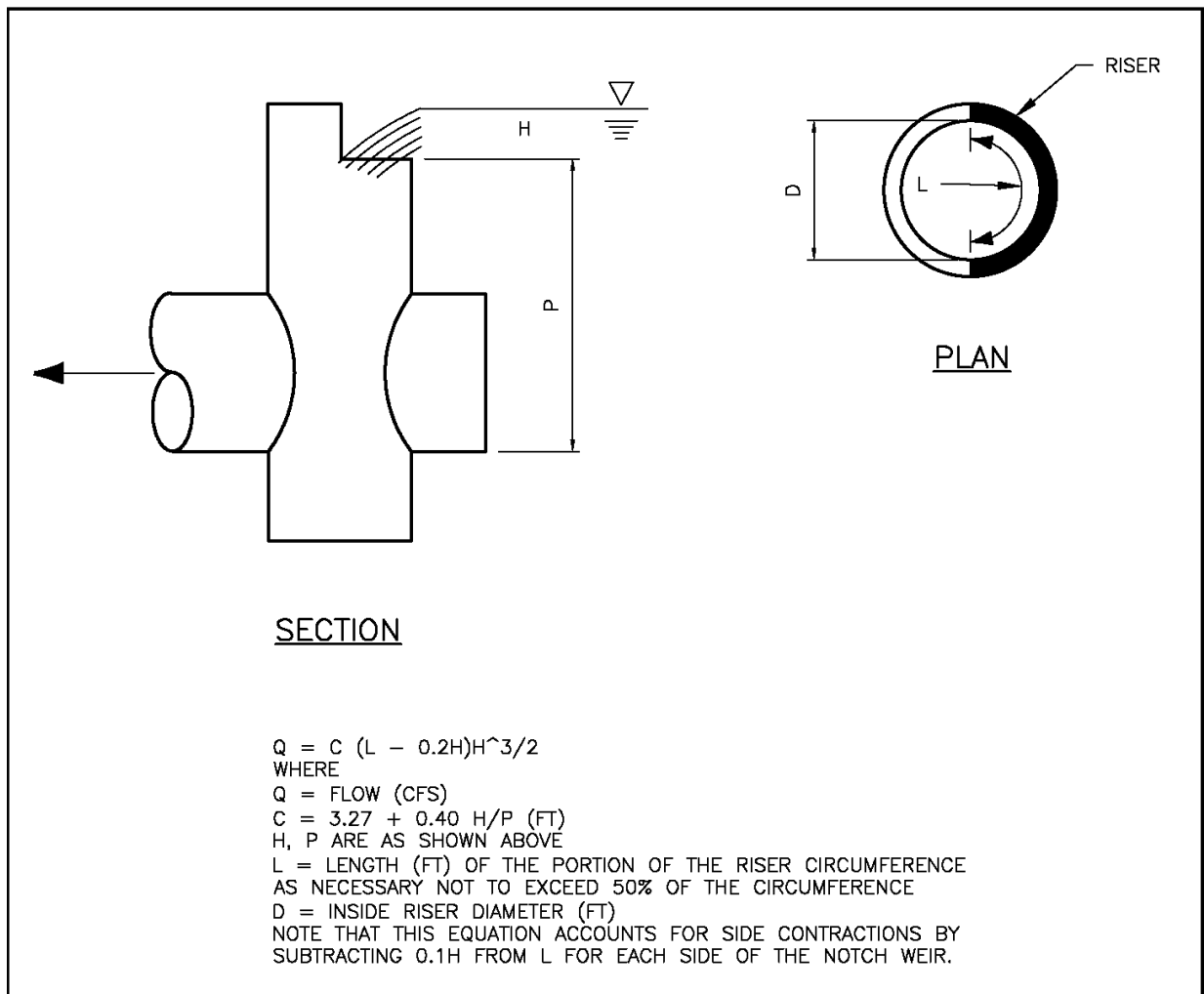


Figure E.2. V-Notch, Sharp-Crested Weir.



**Figure E.3. Rectangular Notch, Sharp-Crested Weir.**

### *E-1.1. General Requirements*

Flow control structures shall comply with the specifications outlined in the City of Seattle’s Standard Plans No. 270 and 272A. Additional general requirements are presented below.

Plans submitted for a permit shall include:

- Flow control structure rim elevation
- Storage pipe invert elevation
- Outlet pipe invert elevation
- Elevation at the top of the storage pipe
- Elevation at the top of the overflow pipe
- Orifice diameter(s)
- Orifice elevation(s)

For ponding BMPs, backwater effects shall be included in designing the height of the downstream conveyance system. High tailwater elevations may affect performance of the restrictor system and reduce live storage volumes.

For regionally sized detention BMPs, non-standard orifice orientation and orifice/weir and gate combinations for flow throttling may be used to meet both stormwater and operational requirements. These general requirements are not meant to be restrictive when a flow control need beyond what is discussed here can be demonstrated.

### *E-1.2. Access*

The following access requirements apply to control structures:

- Access shall be provided to the flow control structure from the ground surface with a three-bolt locking maintenance hole ring and cover (refer to SDCI Director’s Rule 4-2011, Requirements for Design & Construction of Side Sewers). Rim elevations shall match proposed finish grade. A rectangular cover, or a cover that allows water to enter through the top of the flow control structure, shall not be used. The ring and cover shall be set so the flow control device or the ladder is visible at the edge of the access opening.
- The inside diameter of the flow control structure shall be at least 4 feet to allow maintenance and repair access, and to accommodate stormwater overflow.
- Maintenance holes and catch basins shall meet the OSHA and WISHA confined space requirements, which include, but are not limited to, clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser under the access lid.
- The flow control device shall not be Corrugated Metal Pipe (CMP). The mounting straps and the outlet adapter shall be installed in a manner that will make the flow control device easily removable for maintenance, repair, or replacement. The flow control device shall be designed and located under the maintenance hole ring and cover for inspection from the surface. The outlet pipe adapter may be a plastic, bell-end pipe, or a plastic coupling with rubber gaskets. The outside of the pipe or coupling shall be sanded, epoxy coated, and sand impacted to bond with the flow control structure.

### *E-1.3. Design Criteria*

#### *E-1.3.1. Multiple Orifice Restrictor*

In most cases, control structures only need two orifices: one at the bottom and one near the top of the riser, oriented horizontally. Additional orifices may best utilize detention storage volume in a few cases.

Design requirements for multiple orifice flow restrictors are presented below.

- The minimum allowable orifice diameter is 0.5 inch for underground tanks or vaults and 0.25 inch for aboveground cisterns. In some instances, a 0.5-inch bottom orifice will be too large to meet target release rates, even with minimal head. In these cases, the live storage depth need not be reduced to less than 3 feet in an attempt to meet the performance standards. Also, underground weirs or orifices shall not be reduced to

less than 0.5-inch length or diameter in an attempt to meet the performance standards. See Volume 3, Section 4.1.3.2 for additional guidance when a 0.5-inch orifice is too large.

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

### *E-1.3.2. Weir Restrictor*

Design requirements for weir flow restrictors are presented below.

- A sharp crested overflow weir shall be used to provide for overflow of the detention BMP and should be analyzed for the developed 100-year peak flow discharge (Figure E.4).
- A notch weir may be used to restrict flows and replace a top orifice.
- The minimum allowable weir length is 0.25 inch.

## *E-1.4. Flow Control Device Sizing*

### *E-1.4.1. Orifices*

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

$$Q = C A \sqrt{2gh}$$

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

Figure E.4 illustrates this simplified application of the orifice equation.

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

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

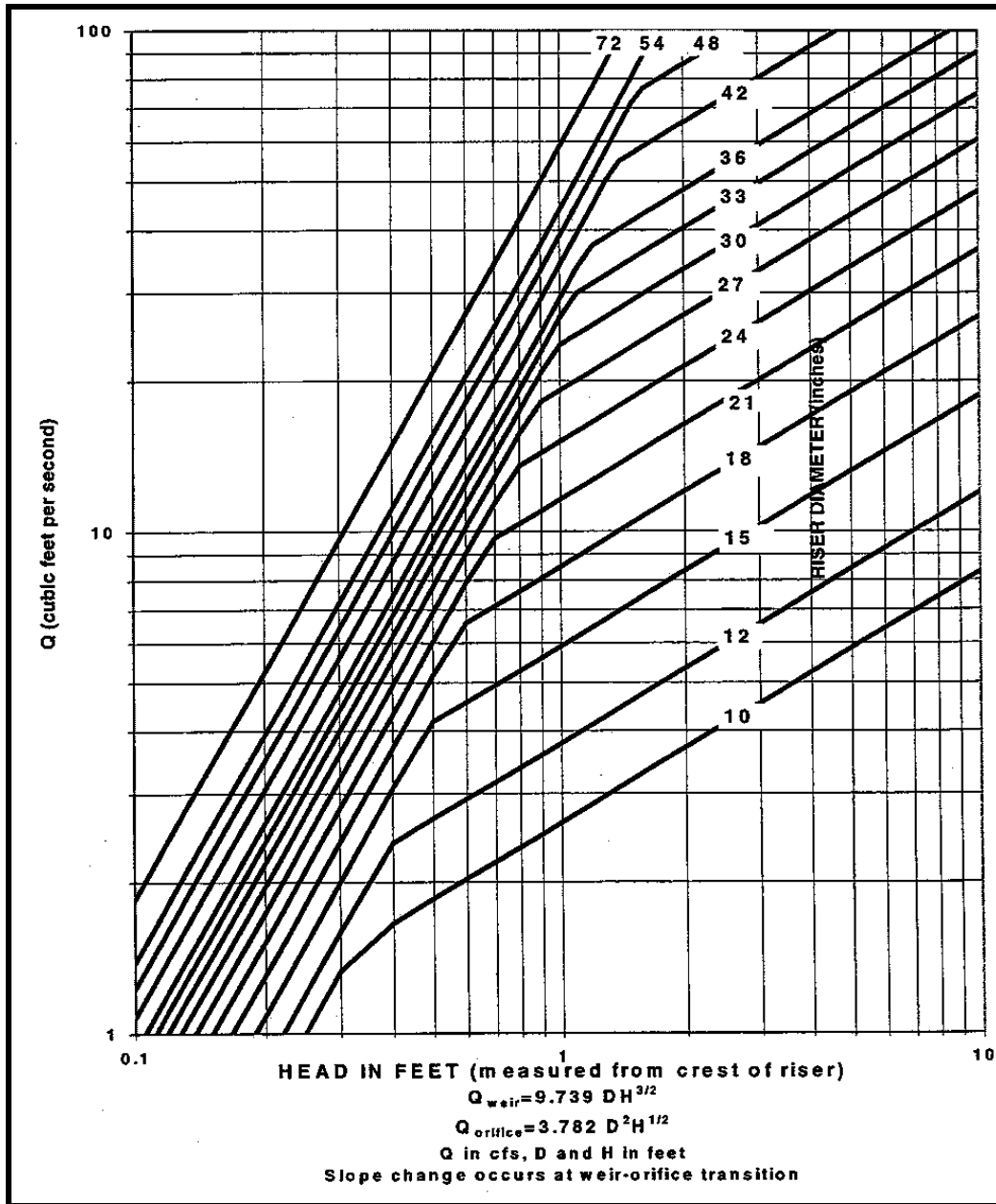


Figure E.4. Riser Inflow Curves.

#### E-1.4.2. Riser Overflow

The combined orifice and riser (or weir) overflow may be used to meet performance requirements; however, the design shall still provide for overflow of the developed 100-year peak flow assuming all orifices are plugged. The nomograph in Figure E.4 can be used to determine the head (in feet) above a riser of given diameter and for a given flow. For design requirements on overflows, refer to *Volume 3, Section 4.3.3*.

## E-2. Flow Splitters

Flow splitters are typically structures with baffles, weirs, or orifice controls. Two examples of maintenance hole flow splitters are shown in Figure E.5 and Figure E.6. Other equivalent designs for splitting flows may also be acceptable.

### *E-2.1. General Design Criteria*

The top of the weir shall be located at the water surface for the design flow. Flows modeled using a continuous simulation model shall be at a 15-minute time step or less.

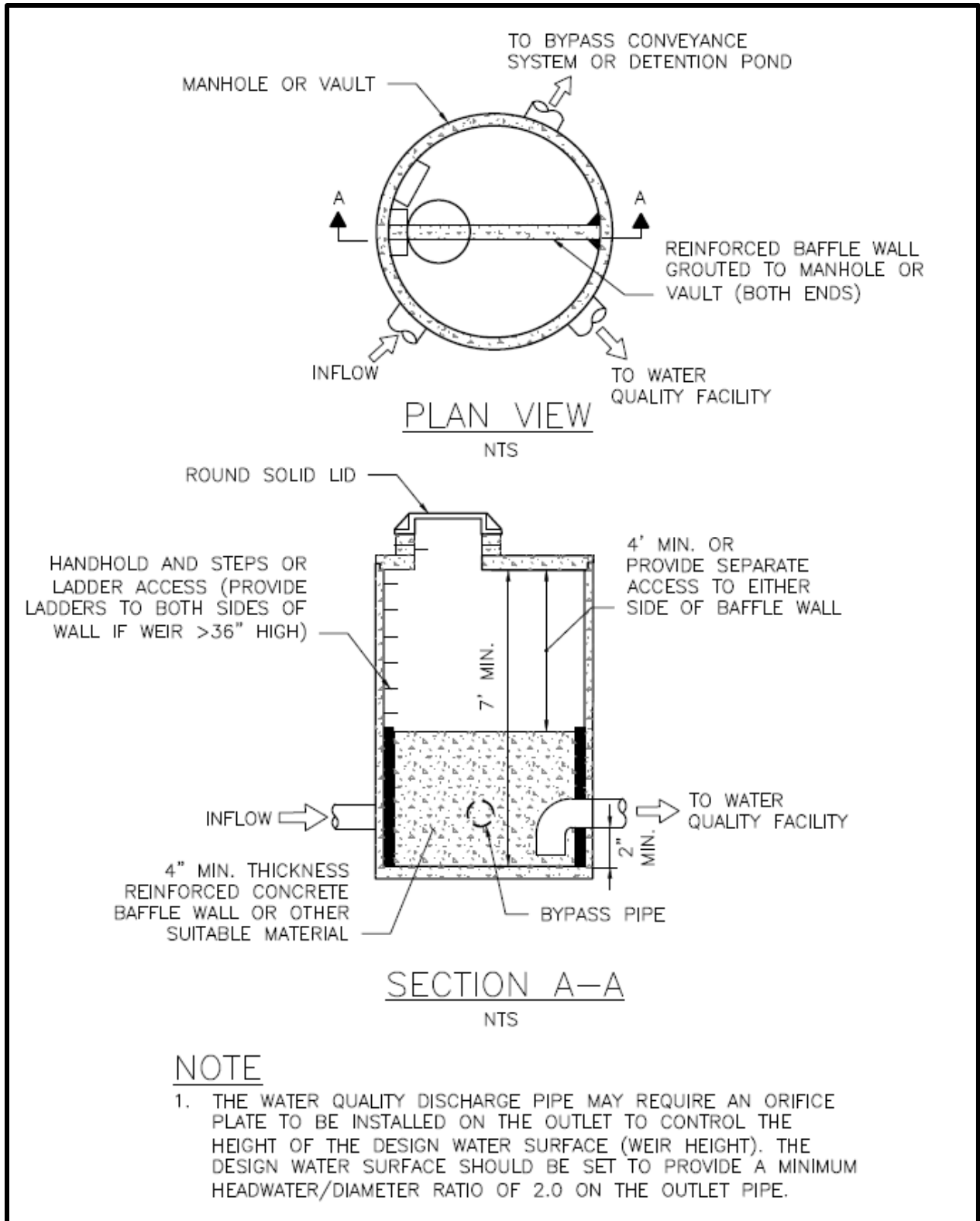
The maximum head shall be minimized for flow in excess of the water quality design flow. Specifically, flow to the treatment BMP at the 100-year water surface shall not increase the design water quality flow by more than 10 percent.

As an alternative to using a solid top plate in Figure E.6, a full tee section may be used with the top of the tee at the 100-year water surface. This alternative would route emergency overflows (if the overflow pipe were plugged) through the treatment BMP rather than generate back up from the maintenance hole.

Backwater effects shall be included in the design of standpipe height in the maintenance hole.

### *E-2.2. Materials*

- The splitter baffle may be installed in a maintenance hole or vault.
- The baffle wall shall be made of reinforced concrete or another suitable material resistant to corrosion and have a minimum 4-inch thickness.
- All metal parts shall be corrosion resistant. Examples of required materials include aluminum, stainless steel, and plastic. Zinc and galvanized materials are prohibited because of aquatic toxicity. Painted metal parts shall not be used because of poor longevity.



**Figure E.5. Flow Splitter Example A.**

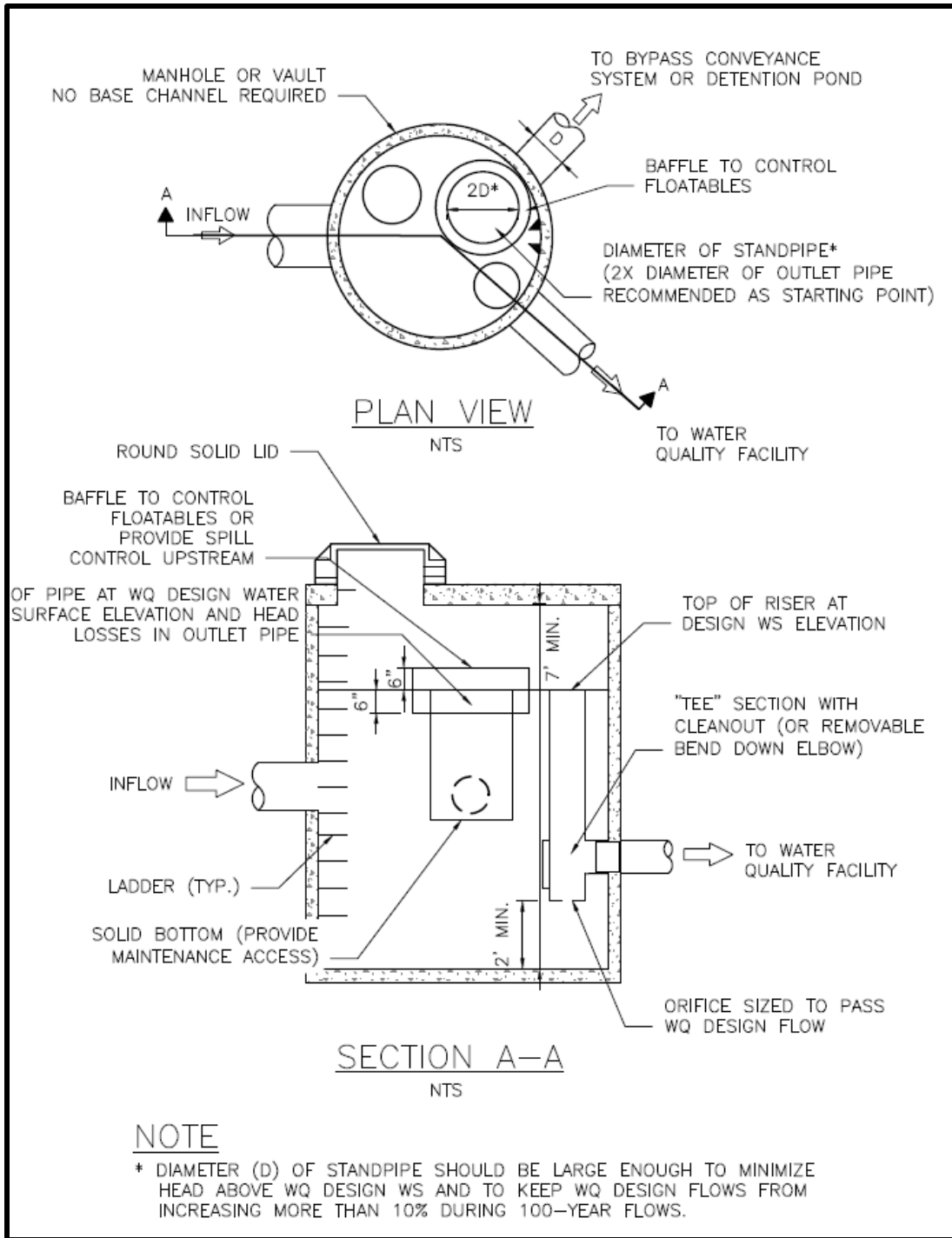


Figure E.6. Flow Splitter Example B.

## E-3. Flow Spreaders

Flow spreaders uniformly spread flows across the inflow portion of non-infiltrating BMPs (e.g., sand filter, biofiltration swale, or filter strip). There are five flow spreader options presented in this section:

- Option A – Anchored plate
- Option B – Concrete sump box
- Option C – Notched curb spreader
- Option D – Through-curb ports
- Option E – Interrupted curb

Options A through C can be used for spreading flows that are concentrated. Any one of these options can be used when spreading is required by the BMP design criteria. Options A through C can also be used for unconcentrated flows, and in some cases shall be used, such as to correct for moderate grade changes along a filter strip.

Options D and E can only be used for flows that are already unconcentrated and enter a filter strip or continuous inflow biofiltration swale. Other flow spreader options are possible with prior approval by the Director.

### E-3.1. General Design Criteria

- Where flow enters the flow spreader through a pipe, it is recommended that the pipe be submerged to the extent practical to dissipate energy as much as possible.
- For higher inflows (greater than 5 cfs for the 100-year 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 of the catch basin. The top of the grate should be lower than the flow spreader plate, or if a notched spreader is used, lower than the bottom of the v-notches.

### E-3.2. Option A – Anchored Plate

- An anchored plate flow spreader shall be preceded by a sump having a minimum depth of 8 inches and minimum width of 24 inches. If not otherwise stabilized, the sump area shall be lined to reduce erosion and to provide energy dissipation.
- The top surface of the flow spreader plate shall be level, projecting a minimum of 2 inches above the ground surface of the treatment BMP, or v-notched with notches 6 to 10 inches on center and 1 to 6 inches deep (use shallower notches with closer spacing). Alternative designs may also be considered.
- A flow spreader plate shall extend horizontally beyond the bottom width of the BMP to prevent water from eroding the side slope. The horizontal extent shall be such that the bank is protected for all flows up to the 100-year flow, or the maximum flow that will enter the treatment BMP.
- Flow spreader plates shall be securely fixed in place.

- Flow spreader plates may be made of either wood, metal, fiberglass reinforced plastic, or other durable material. If wood, pressure treated 4- by 10-inch lumber or landscape timbers are acceptable.
- Anchor posts shall be 4-inch square concrete, tubular stainless steel, or other material resistant to decay. Refer to Volume V of the Stormwater Management Manual for Western Washington (SWMMWW) for an example of an anchored plate flow spreader.

### ***E-3.3. Option B – Concrete Sump Box***

- The wall of the downstream side of a rectangular concrete sump box shall be level and shall extend a minimum of 2 inches above the inlet to the treatment BMP. This serves as a weir to spread the flows uniformly across the BMP inlet.
- The downstream wall of a sump box shall have “wing walls” at both ends. Side walls and returns shall 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 shall be reinforced with wire mesh for cast-in-place sump boxes.
- Sump boxes shall be placed over bases that consist of 4 inches of crushed rock, 5/8-inch minus to help assure the sump box remains level. Refer to Volume V of the SWMMWW for an example of a concrete sump box flow spreader.

### ***E-3.4. Option C – Notched Curb Spreader***

Notched curb spreader sections shall be made of extruded concrete laid side-by-side and level. Typically, five “teeth” per 4-foot section provides good spacing. The space between adjacent teeth forms a v-notch.

### ***E-3.5. Option D – Through-Curb Ports***

Unconcentrated flows from paved areas entering filter strips or continuous inflow biofiltration swales can use through-curb ports (Option D) or interrupted curbs (Option E) to allow flows to enter the BMP. Through-curb ports use fabricated openings that allow concrete curbing to be poured or extruded while still providing an opening through the curb to admit water to the BMP.

Openings in the curb shall be at regular intervals and at least every 6 feet. The width of each opening shall be a minimum of 8 inches for non-right-of-way applications and a minimum of 10 inches in the right-of-way. Approximately 15 percent or more of the curb section length should be in open ports, and no port should discharge more than about 10 percent of the flow. Refer to Volume V of the SWMMWW for an example of a through-curb port flow spreader.

### *E-3.6. Option E – Interrupted Curb*

Interrupted curbs are sections of curb placed to have gaps spaced at regular intervals along the total width (or length, depending on the BMP) of the treatment area. At a minimum, gaps shall be every 6 feet to allow distribution of flows into the treatment BMP before they become too concentrated. The opening shall be a minimum of 8 inches for non-right-of-way applications and a minimum of 10 inches in the right-of-way. As a general rule, no opening should discharge more than 10 percent of the overall flow entering the BMP.

## E-4. Level Spreaders

### *E-4.1. Definition*

A level spreader is constructed at zero percent grade and can be used to distribute concentrated runoff to sheet flow. Level spreaders can be used as either a temporary or a permanent BMP.

### *E-4.2. Purpose*

To convert concentrated runoff to a thin layer of sheet flow to promote release onto a stable receiving area. For example, an existing vegetated area or a vegetated strip.

### *E-4.3. Condition Where Practice Applies*

None identified for this BMP.

### *E-4.4. Planning Considerations*

When properly constructed, the level spreader will significantly reduce the velocity of concentrated stormwater and spread it uniformly over a stabilized or undisturbed area.

Particular care shall be taken to ensure that the lower downslope side (or the lip) of the structure is level and on grade. If there are any depressions in the lip, flow will tend to concentrate at these points and erosion will occur, resulting in failure of the outlet. This problem may be avoided by using a grade board or a gravel lip over which the runoff shall flow when exiting the spreader. Regular maintenance is essential for this practice.

Level spreaders shall be constructed on undisturbed areas that are stabilized by existing vegetation, or areas that have been properly stabilized in accordance with the requirements of the Construction Stormwater Control section of this manual (*Volume 2*), and where concentrated flows will be dissipated at zero percent grade (Figure E.7).

### *E-4.5. Design Criteria*

- The grade of the pipe and/or ditch for the last 20 feet before entering the level spreader shall be less than or equal to 1 percent, if feasible. If the grade is steeper, provide a flow dissipation device. The grade of the level spreader shall be zero percent to ensure uniform spreading of stormwater runoff.
- An 8-inch high gravel berm placed across the level lip shall consist of washed crushed rock, 2- to 4-inch or 0.75-inch to 1.5-inch size.
- The temporary level spreader length shall be calculated by one of the following methods:
  - Single Event Hydrograph Method: The peak volumetric flow rate from a 10-year, 24-hour design storm with a 10-minute time step or the 10-year recurrence flow, and selecting the appropriate length from Table E.1.

- Continuous Simulation Method:
  - The 10-year peak flow rate as determined by an approved continuous runoff model with a 15-minute time step or less.
  - If the level spreader will be permanent, level spreader length will be determined by estimating the flow expected from the 25-year, 24-hour design storm (Q25). Alternatively, an approved continuous runoff model should be used to model the 25-year recurrence interval.
- Use multiple spreaders for higher flows.
- The depth of the spreader as measured from the lip should be at least 8 inches and should be uniform across the entire length.
- The area below the level spreader outlet shall be stabilized and have a slope of less than 11 percent.



**Figure E.7. Level Spreader Prior to Backfill and Downstream Stabilization.**

**Table E.1. Spreader Length Based on 10-Year, 24-Hour Storm.**

<b>Q<sub>10</sub> or Q<sub>25</sub> in cfs*</b>	<b>Minimum Length (in feet)</b>
0 to 0.1	15
0.1 to 0.2	25
0.2 to 0.3	35
0.3 to 0.4	45
0.4 to 0.5	55

\*Use Q10 for temporary level spreaders. Use Q25 for permanent level spreaders.

cfs= cubic feet per second

Q10 = 10-year, 24-hour design storm or peak flowrate for the 10-year recurrence flow

Q25 = 25-year, 24-hour design storm or peak flowrate for the 25-year recurrence flow

### ***E-4.6. Maintenance***

The spreader should be inspected regularly to ensure that it is functioning correctly. Do not place any material on the level spreader and prevent traffic from crossing over the level spreader. If the level spreader is damaged, it shall be immediately repaired.

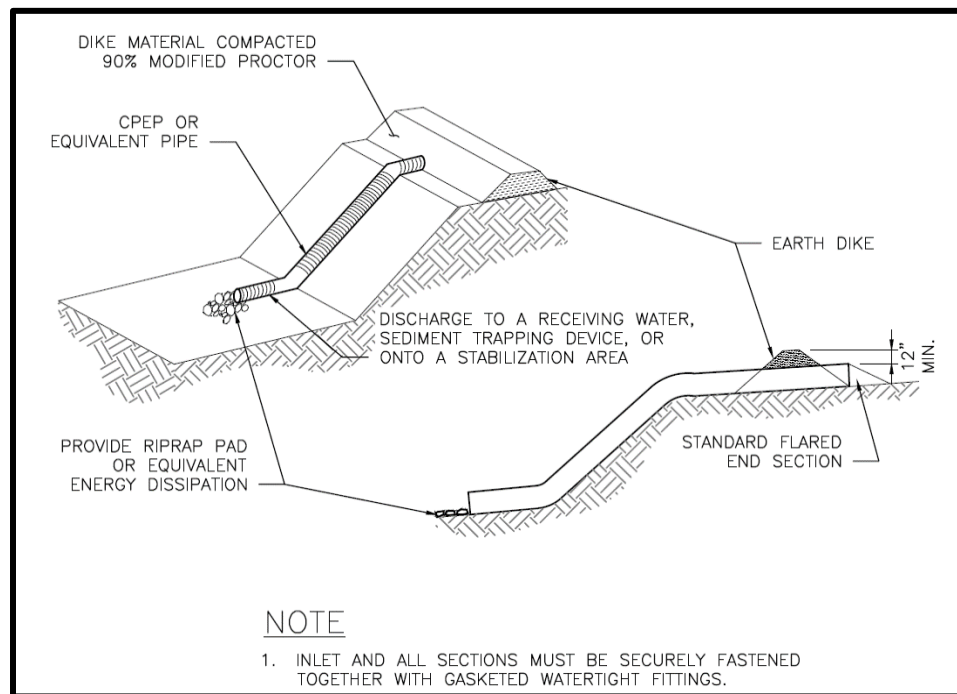
## E-5. Pipe Slope Drains

### E-5.1. Definition

A slope drain consists of a pipe extending from the top to the bottom of a cut or fill slope and discharging into a stabilized watercourse or a sediment trapping device or onto a stabilization area. It can also be used for water discharging from a flow control or treatment BMP, or to safely convey water past the toe of the slope. Pipe slope drains can be used as a temporary BMP.

### E-5.2. Purpose

To convey concentrated runoff down steep slopes without causing gullies, channel erosion, or saturation of landslide-prone soils (Figure E.8).



**Figure E.8. Pipe Slope Drain Details.**

### E-5.3. Conditions Where Practice Applies

Pipe slope drains shall be used when conveying concentrated runoff down a steep slope has the potential to cause erosion.

### E-5.4. Planning Considerations

There is often a lag between the time a cut or fill slope is completed and the time a permanent drainage system can be installed. During this period, the slope is usually not stabilized and is particularly vulnerable to erosion. Temporary slope drains can provide valuable protection of exposed slopes until permanent drainage structures can be installed.

The entrance section shall be securely entrenched, all connections shall be watertight, and the conduit shall be staked securely.

Additional protection requirements for steep slopes are included in the Environmentally Critical Area Ordinance (SMC, Section 25.09.090).

### ***E-5.5. Design Criteria***

- Permanent slope drains shall be designed by a licensed engineer and may have additional criteria for flow and water quality treatment requirements. Variations or alterations to the minimum BMP requirements outlined below require a licensed engineer's approval.
- Size the pipe to convey the projected flow. The capacity for temporary drains shall be sufficient to handle the flows calculated by one of the following methods:
  - Single Event Hydrograph Method: The peak volumetric flow rate calculated using a 10-year, 24-hour design storm with a 10-minute time step.
  - Continuous Simulation Method: The 10 percent annual probability flow (10-year peak flow rate) using a 15-minute time step or less, indicated by an approved continuous runoff model.

The hydrologic analysis shall use the existing land cover condition for predicting flow rates from tributary areas outside the project limits. For tributary areas on the project site, the analysis shall use the temporary or permanent project land cover condition, whichever will produce the highest flow rates. If using WWHM, bare soil areas should be modeled as "landscaped area." Refer to *Appendix F* for additional information on stormwater modeling.

- Re-establish cover immediately on areas disturbed by installation.
- Ensure that the entrance area is stable and large enough to direct flow into the pipe.
- The entrance shall consist of a standard flared end section for culverts 12 inches and larger with a minimum 6-inch metal toe plate to prevent runoff from undercutting the pipe inlet. The slope of the entrance shall be at least 3 percent.
- Pipe slope drain size should be no greater than 6 inches. Intercept flow frequently by using multiple pipe slope drains. Multiple pipes should be no closer than 10 feet.
- The soil around and under the pipe and entrance section shall be thoroughly compacted to prevent undercutting.
- The flared inlet section shall be securely connected to the slope drain and have watertight connecting bands.
- Slope drain sections shall be securely fastened together and have gasketed watertight fittings, and be securely anchored into the soil.
- Thrust blocks should be installed any time 90 degree bends are utilized. Depending on size of pipe and flow, these can be constructed with sand bags, straw bales staked in place, "t" posts and wire, or ecology blocks.
- Pipe needs to be secured along its full length to prevent movement. This can be done with steel "t" posts and wire. Install a post on each side of the pipe and wire the pipe

to them. This should be done every 10 to 20 feet of pipe length, depending on the size of the pipe and quantity of water diverted.

- Earth dikes shall be used to direct runoff into a pipe slope drain. The height of the dike shall be at least 12 inches higher at all points than the top of the inlet pipe.
- The area below the outlet shall be stabilized with a riprap apron (refer to *Section E-6* for outlet protection).
- If the pipe slope drain is conveying sediment-laden water, direct all flows into a sediment trapping BMP.
- Refer to the City of Seattle Standard Specifications for all material specifications (<https://www.seattle.gov/utilities/construction-resources/standards-and-guidelines/standard-specs-and-plans>).

### *E-5.6. Maintenance*

- Check inlet and outlet points regularly, especially after heavy storms. The inlet should be free of undercutting, and no water should be going around the point of entry. If there are problems, reinforce the headwall with compacted earth or sand bags. The outlet point should be free of erosion and installed with appropriate outlet protection.
- For permanent installations, inspect the pipe periodically for vandalism and physical distress such as slides and wind-throw. Clean the pipe and outlet structure at the completion of construction.
- Normally the pipe slope is so steep that clogging is not a problem with smooth wall pipe; however, debris may become lodged in the pipe or at the inlet.

## E-6. Outlet Protection

### *E-6.1. Definition*

Energy dissipating materials or devices placed at concentrated flow outlets, such as the outlets of pipes or paved channel sections. Outlet protection can be used as either a temporary or a permanent BMP.

### *E-6.2. Purpose*

To prevent scour at stormwater outlets, and to minimize the potential for downstream erosion by reducing the velocity of concentrated stormwater flows.

### *E-6.3. Condition Where Practice Applies*

Outlet protection is required wherever concentrated runoff could cause scour or erosion.

### *E-6.4. Planning Considerations*

None identified for this BMP.

### *E-6.5. Design Criteria*

- Permanent BMPs shall be designed by a licensed engineer and may have additional criteria for flow and water quality treatment requirements. Variations and/or alterations to the minimum BMP requirements require a licensed engineer's approval.
- Protect culvert outlets from erosion by rock lining the downstream and extending up the channel sides above the maximum tailwater elevation.
- Standard wing walls, tapered outlets, and paved channels should also be considered when appropriate for permanent outlet protection.
- With low flows, grass-lined channels (refer to Ecology BMP C201) can be an effective alternative for lining material.
- Blankets (refer to BMP E1.15: Mulching, Matting, and Compost Blankets in *Volume 2*) or riprap channel lining (refer to Ecology BMP C202) provide suitable options for lining materials.
- The following guidelines shall be used for outlet protection with riprap:
  - For outlets at the base of steep slope pipes (pipe slope greater than 10 percent), use an engineered energy dissipater
  - Filter fabric or erosion control blankets should be used under riprap to prevent scour and channel erosion. Refer to BMP E1.15: Mulching, Matting, and Compost Blankets in *Volume 2*.

### *E-6.6. Maintenance*

Check for evidence of erosion, scour, or channeling. Rock may need to be added if sediment builds up in the pore spaces of the outlet pad. Vegetation, erosion control blankets, or rock pads may need replacement. Partial blocking of an outlet with a protective measure is not allowed unless designed by a licensed engineer.

## E-7. Liners

Liners discussed in this section are intended to reduce the likelihood that pollutants in stormwater will reach groundwater when treatment BMPs are constructed or protect surrounding areas from seepage when necessary. In addition to groundwater protection considerations, some facility types require permanent standing water for proper functioning. An example is the first cell of a wet pond.

There are three types of liners:

1. **Treatment liners** amend the soil with materials that treat stormwater before it reaches more freely draining soils. They have slow rates of infiltration, generally less than 2.4 inches per hour, but not as slow as low permeability liners. Treatment liners may use in-place native soils or imported soils, provided that the design criteria outlined below are met.
2. **Low permeability liners** reduce infiltration to a very slow rate, generally less than 0.02 inch per hour. These types of liners are often used for industrial or commercial sites with a potential for high pollutant loading in the stormwater runoff. Low permeability liners may be constructed from compacted till, clay, or concrete. Till liners are preferred because of their general resilience and ease of maintenance.
3. **Impermeable liners** prevent the transmission of water between the BMP and native soils. Impermeable liners shall be used when BMPs are constructed in areas where infiltration is not permitted or is discouraged (e.g., landslide-prone areas or in contaminated soils). Impermeable liners shall be constructed from geomembrane.

Table E.2 shows the type of liner required for use with various treatment BMPs (detention, non-infiltrating, and pretreatment BMPs). Other liner configurations may be used with prior approval from the Director.

Liners shall be placed over the bottom and/or sides of the BMP as indicated in Table E.2.

When placing a liner for water quality treatment, areas above the treatment volume that are required to pass flows greater than the water quality treatment flow (or volume) need not be lined. However, the lining shall be extended to the top of the interior side slope and be anchored if it cannot be permanently secured by other means.

**Table E.2. Lining Types Required by BMP Type.**

<b>BMP</b>	<b>Area to be Lined</b>	<b>Type of Liner Required</b>
Presettling basin	Bottom and sides	Low permeability liner, treatment liner, or impermeable liner
Wet pond	First cell: bottom and sides to WQ design water surface	Low permeability liner, treatment liner, or impermeable liner
	Second cell: bottom and sides to WQ design water surface	Treatment liner
Combined detention/non-infiltrating BMP	First cell: bottom and sides to WQ design water surface	Low permeability liner, treatment liner, or impermeable liner
	Second cell: bottom and sides to WQ design water surface	Treatment liner
Stormwater wetland	Bottom and sides, both cells	Low permeability liner or impermeable liner
Sand filter basin	Required if over a critical aquifer recharge area, otherwise not required. Refer to <i>Volume 3, Section 5.8.5.</i>	Low permeability line, treatment liner, or impermeable liner
Sand filter vault	Not applicable	No liner needed
Linear sand filter	Not applicable if in vault	No liner needed
	Bottom and sides of presettling cell if not in vault	Low permeability liner, treatment liner, or impermeable liner
Media filter (in vault)	Not applicable	No liner needed
Wet vault	Not applicable	No liner needed
Non-infiltrating bioretention	Bottom and sides	Low permeability liner or impermeable liner
Open bottom or open sided detention products (e.g., arch pipe, modular plastic tanks, etc.)	Bottom and sides	Low permeability liner or impermeable liner

## Notes

<sup>a</sup> The Director may approve native soils as a low permeability liner based on measured infiltration rates and the recommendation of a licensed professional.

<sup>b</sup> The Director may also require impermeable liner based on infiltration setbacks or site constraints.

### ***E-7.1. Design Criteria for Treatment Liners***

This section presents the design criteria for treatment liners.

- A 2-foot-thick layer of soil with a minimum organic content of 1 percent AND a minimum cation exchange capacity (CEC) of 5 milliequivalents/100 grams can be used as a treatment layer beneath a water quality or detention BMP.
- To demonstrate that in-place soils meet the above criteria, one sample per 1,000 square feet of BMP area shall be tested. Each sample shall be a composite of subsamples collected throughout the depth of the treatment layer (usually 2 to 6 feet below the expected BMP invert).

- Typically, side wall seepage is not a concern if the seepage flows through the same stratum as the bottom of the treatment BMP. However, if the treatment soil is an engineered soil or has very low permeability, the potential to bypass the treatment soil through the side walls may be significant. In those cases, the treatment BMP side walls should be lined with at least 18 inches of treatment soil, as described above, to prevent untreated seepage. This lesser soil thickness is based on unsaturated flow as a result of alternating wet-dry periods. Approved continuous simulation models must be run using the “No infiltration” option through the sidewalls if one sidewall is impervious unless the model can limit infiltration only to the unlined portion of the perimeter.
- Organic content shall be measured on a dry weight basis using ASTM D2974.
- Cation exchange capacity (CEC) shall be tested using EPA laboratory method 9081.
- Certification by a soils testing laboratory that imported soil meets the organic content and CEC criteria above shall be provided to the City.
- The liner shall extend vertically to the water quality design water surface elevation plus 6 inches at the minimum.

### *E-7.2. Design Criteria for Low Permeability Liners*

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

- Where the seasonal high groundwater elevation is likely to contact a low permeability liner, liner buoyancy may be a concern. In these instances, use of a low permeability liner shall be designed by a geotechnical engineer.
- Where grass is planted over a low permeability liner per the BMP design, a minimum of 6 inches of topsoil of sufficient organic content and depth or compost-amended native soil shall be placed over the liner in the area to be planted. Native underlying soils may be suitable for planting if amended per Soil Amendment BMP requirements in *Volume 3, Section 5.1*. Twelve inches of cover is preferred.
- Low permeability liners shall extend vertically to the design water surface elevation plus 6 inches at a minimum. For bioretention, the design water surface elevation shall be the 25-year water surface elevation.

#### *E-7.2.1. Compacted Till Liners*

- Liner thickness shall be 18 inches after compaction.
- Soil shall be compacted to 95 percent minimum dry density, modified proctor method (ASTM D-1557).
- A different depth and density sufficient to slow the infiltration rate to  $2.4 \times 10^{-5}$  inches per minute may also be used instead of the above criteria if designed by a geotechnical engineer.
- Soil shall be placed in maximum 6-inch lifts.
- Soils shall meet the gradation outlined in Table E.3 unless otherwise designed by a geotechnical engineer.

**Table E.3. Compacted Till Liners.**

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

**E-7.2.2. Clay Liners**

- Liner thickness shall be 12 inches after compaction.
- Clay shall be compacted to 95 percent minimum dry density, modified proctor method (ASTM D-1557).
- A different depth and density sufficient to slow the infiltration rate to  $2.4 \times 10^{-5}$  inches per minute may also be used instead of the above criteria, if designed by a geotechnical engineer and approved by the Director.
- Plasticity index shall not be less than 15 percent (ASTM D-423, D-424).
- Liquid limit of clay shall not be less than 30 percent (ASTM D-2216).
- Clay particles passing shall not be less than 30 percent (ASTM D-422).
- The slope of clay liners shall be restricted to 3H:1V for all areas requiring soil cover; otherwise, the soil layer shall be stabilized by another method so that soil slippage into the BMP does not occur. Any alternative soil stabilization method shall take maintenance access into consideration.

**E-7.2.3. Concrete Liners**

- Concrete liners may also be used for sedimentation chambers, for sedimentation and filtration basins less than 1,000 square feet in area, and non-infiltrating bioretention. Concrete shall be 5-inch thick Class 3000 or better and shall be reinforced by steel wire mesh. The steel wire mesh shall be 6 gage wire or larger and 6-inch by 6-inch mesh or smaller. An "Ordinary Surface Finish" is required per City of Seattle Standard Specification 6-02.3(14). When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton per square foot or less, the concrete shall have a minimum 6-inch compacted aggregate base consisting of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75 to 1 inch. Where visible, the concrete shall be inspected annually and all cracks shall be sealed.
- Portland cement liners are allowed irrespective of BMP size, and shotcrete may be used on slopes. However, specifications shall be designed by a licensed engineer who certifies the liner against cracking or losing water retention ability under expected conditions of operation, including BMP maintenance operations. Weight of maintenance equipment can be up to 80,000 pounds when fully loaded.
- Asphalt concrete may not be used for liners due to its permeability to many organic pollutants.
- If grass is to be grown over a concrete liner, slopes shall be no steeper than 5H:1V to prevent the top-dressing material from slipping. Textured liners may be used on slopes up to 3H:1V upon recommended design by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.

### *E-7.3. Design Criteria for Impermeable Liners*

#### *E-7.3.1. 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 will be operated over the membrane.
- The geomembrane fabric shall be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top of and beneath the geomembrane. The geotextile fabric shall have a high survivability per the WSDOT Standard Specifications Section 9-33 Construction Geotextile. Equivalent methods for protecting the geomembrane liner may be permitted, subject to approval by Director. Equivalency will be based on the ability of the fabric to protect the geomembrane from puncture, tearing, and abrasion.
- Geomembranes shall be bedded according to the manufacturer's recommendations.
- Liners shall be covered with minimum of 12 inches of top dressing. Top dressing shall include 6 inches of crushed rock immediately over the liner to mark the location of the liner for future maintenance operations. As an alternative to crushed rock, orange plastic "safety fencing" or another highly visible, continuous marker may be embedded 6 inches above the membrane to alert maintenance workers of the liner below.
- If possible, liners should be of a contrasting color so that maintenance workers are aware of any areas where a liner may have become exposed when maintaining the BMP.
- Non-textured 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 design by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.
- Geomembrane liners used to control seepage shall be joined using heat-fusion or equivalent and include boots around all pipe and structure penetrations.
- Geomembrane liners shall extend vertically to the design water surface elevation plus 6 inches at a minimum. For bioretention, the design water surface elevation shall be the 25-year water surface elevation.

## E-8. Geotextiles

The following recommended applications are provided courtesy of Tony Allen (Geotechnical Engineer-WSDOT) with references provided to the relevant tables in the City of Seattle Standard Specifications:

- For sand filter drain strip between the sand and the drain rock or gravel layers, use Geotextile Properties for Underground Drainage, moderate survivability, Class A, from Tables 1 and 2 in the City of Seattle Standard Specifications 9-37.
- 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 in Table 4 in the City of Seattle Standard Specifications 9-37 shall be used to specify survivability properties for the liner protection application. Table 2 in the City of Seattle Standard Specifications 9-37, Class C shall be used for filtration properties. Only nonwoven geotextiles are appropriate for- the liner protection application.
- For infiltration BMPs, use Geotextile for Underground Drainage, low survivability, Class C, from Tables 1 and 2 in the City of Seattle Standard Specifications 9-37.
- For a sand bed cover, a geotextile fabric is placed exposed on top of the sand layer to trap debris brought in by the stormwater and to protect the sand, facilitating easy cleaning of the surface of the sand layer. A polyethylene or polypropylene geonet shall be used in lieu of geotextile fabric. The geonet material shall have high UV resistance (90 percent or more strength retained after 500 hours in the weatherometer, ASTM D-4355), and high permittivity (ASTM D-4491,  $0.8 \text{ sec}^{-1}$  or more) and percent open area (CWO22125, 10 percent or more). Tensile strength shall be on the order of- 200 pounds grab (ASTM D-4632) or more.
- For above and below a geomembrane liner, the geotextile fabric shall be Geotextile for Separation per the COS Standard Specifications Section 9-37 Construction Geotextile.

## E-9. Drywell Sizing Tables

For small projects with no approved off-site point of discharge (refer to *Volume 3, Section 4.3.2*), Table E.4, Table E.5, and Table E.6 specify the required area for drywells of 4-foot and 6-foot depths to be used as overflow/point of discharge downstream of a bioretention cell or a permeable pavement facility sized for the water quality treatment standard, pre-developed pasture standard, and the on-site stormwater management standard, respectively.

The minimum measured infiltration rate from a Small or Large Pilot Infiltration Test (PIT) that is required to use these tables is 0.25 inch per hour (in/hr).

**Table E.4. Drywell Sizing Downstream of Bioretention Sized for Water Quality Treatment Standard or Permeable Pavement Facility.<sup>c</sup>**

<b>Contributing Area (sf)</b>	<b>Drywell Area (sf)<sup>a, b, c</sup> Drywell Depth = 4 ft</b>	<b>Drywell Area (sf)<sup>a, b, c</sup> Drywell Depth = 6 ft</b>
500	27	19
1,000	98	67
1,500	164	115
2,000	240	169
2,500	314	222
3,000	390	278
3,500	468	336
4,000	548	396
4,500	630	459
5,000	713	524

<sup>a</sup> Sizing was performed using a 5-minute computational time-step and the “Seattle 38” 158-year synthetic precipitation series.

<sup>b</sup> Drywell was sized to minimize the 25-year peak flow target to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a variable length and width.

<sup>c</sup> Bioretention and permeable pavement facilities must be sized per the pre-sized requirements in *Volume 3, Chapter 5* based on the amount of contributing area.

**Table E.5. Drywell Sizing Downstream of Bioretention Sized for the Pre-Developed Pasture Standard.<sup>c</sup>**

Contributing Area (sf)	Drywell Area (sf) <sup>a, b, c</sup> Drywell Depth = 4 ft	Drywell Area (sf) <sup>a, b, c</sup> Drywell Depth = 6 ft
500	14	9
1,000	71	49
1,500	130	90
2,000	200	137
2,500	260	184
3,000	326	234
3,500	393	286
4,000	462	341
4,500	532	399
5,000	605	458

<sup>a</sup> Sizing was performed using a 5-minute computational time-step and the "Seattle 38" 158-year synthetic precipitation series.

<sup>b</sup> Drywell was sized to minimize the 25-year peak flow target to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a variable length and width.

<sup>c</sup> Bioretention and permeable pavement facilities must be sized per the pre-sized requirements in *Volume 3* based on the amount of contributing area.

**Table E.6. Drywell Sizing Downstream of Bioretention Sized for the On-Site Stormwater Management Standard.**

Contributing Area (sf)	Bioretention Bottom Area (sf) <sup>a, b</sup>	Drywell Area (sf) <sup>b, c</sup> Drywell Depth = 4 ft	Drywell Area (sf) <sup>b, c</sup> Drywell Depth = 6 ft
500	9	56	39
1,000	17	99	68
1,500	30	170	119
2,000	44	249	178
2,500	60	332	238
3,000	76	417	299
3,500	94	501	361
4,000	112	587	424
4,500	131	665	488
5,000	151	753	544

<sup>a</sup> Bioretention design/modeling representation included 6 inches of ponding, 0.25 in/hr measured soil infiltration rate, 3H:1V BMP side slopes, a square bottom area, 12-inch bioretention soil thickness, 40 percent porosity, 3 in/hr bioretention soil infiltration rate, and a 12-inch overflow structure diameter.

<sup>b</sup> Sizing was performed using a 5-minute computational time-step and the "Seattle 38" 158-year synthetic precipitation series.

<sup>c</sup> Drywell was sized to reduce the 25-year peak discharge rate to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a square bottom area.

Table E.7 specifies the required area for drywells of 4-foot and 6-foot depths that are not located downstream of a bioretention cell or permeable pavement facility.

**Table E.7. Drywell Sizing Without Bioretention or Permeable Pavement Facility Upstream.**

<b>Contributing Area (sf)</b>	<b>Drywell Area (sf)<sup>a, b</sup> Drywell Depth = 4 ft</b>	<b>Drywell Area (sf)<sup>a, b</sup> Drywell Depth = 6 ft</b>
500	125	88
1,000	249	175
1,500	347	263
2,000	498	350
2,500	623	438
3,000	747	526
3,500	872	613
4,000	996	701
4,500	1,121	788
5,000	1,245	876

<sup>a</sup> Sizing was performed using a 5-minute computational time-step and the “Seattle 38” 158-year synthetic precipitation series.

<sup>b</sup> Drywell was sized to minimize the 25-year peak flow target to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a variable length and width.

Drywells that do not meet the above design criteria and assumptions shall be sized to meet the requirements for projects with no offsite point of discharge per *Volume 3, Section 4.3.2*.

## E-10. Additional Presettling BMPs For Bioretention Owned or Maintained by Phase 1 Municipal Stormwater Permittees

The following presettling BMPs are described below: Manufactured Treatment Devices (MTDs) and “fat pipes”.

### *E-10.1. Manufactured Treatment Devices*

The MTDs included on the TAPE Pretreatment GULD list include systems that remove sediment using screening and/or settling of particles. A typical Pretreatment MTD provides residence time to allow particles to settle along with enhanced features to optimize settling and/or prevent resuspension during higher flows. **For use as presettling prior to bioretention, the MTD must be selected based on the normalized performance noted in Table E.8. A discussion of how and why the performance of the BMPs were normalized is provided below.**

The design flow rates for MTDs are provided in the manufacturers’ literature and are often based on testing of one selected size and design flow rate of each system as part of a regulatory certification process (i.e., New Jersey Corporation for Advanced Technology (NJCAT) and Washington State Technology Assessment Protocol - Ecology (TAPE)). The design flow rates for the other sizes of each system appear to be determined using an extrapolation/estimation process performed by the manufacturers and then endorsed by regulatory agency, typically based on a hydraulic loading rate (gallons per minute per square foot [gpm/sf] of presettling area).

To normalize the performance of these selected MTDs so they can be compared to each other, Herrera reviewed the dimensions and design flow rates for the selected presettling MTDs. To better compare them to other types of BMPs, we evaluated them solely on the settling volume provided (as measured from overflow to top of dedicated sediment storage zone). From the design flow rate and the volume provided, a hydraulic residence time was derived. From the hydraulic residence time and the available settling depth, a particle size that would fully settle was derived. This particle size is reported below as “Particle Size Captured by MTD (micron)” in Table E.8.

Next, the hydraulic residence time that would equate to a capture of the 80micron particle size given the settling depth available was derived. The flow rate that corresponds to this residence time was then derived based on the volume provided in the device. This particle size is reported below as “Design Flow Rate Normalized to 80 microns (cfs)” in Table E.8. This design concept is supported using the Peclet Number to assess the performance of standard sumps as BMPs for stormwater treatment (McIntire et al. 2012). In this study, the researchers established that settling of particles in stormwater sumps can be estimated by scaling using the Peclet Number:  $Pe = (d \cdot h \cdot V_s) / Q$  where  $d$  = horizontal flow dimension in feet,  $h$  = vertical flow dimension in feet,  $V_s$  = particle settling velocity in ft/s, and  $Q$  = flow rate in cfs. For similar performance, the flow rate  $Q$  can be scaled based on the relationship between settling velocities for different particle sizes.

As seen in the results in Table E.8, the relationship between the design flow rate and the target particle size is highly variable between MTDs and between different models of the same MTD. Additionally, none of the MTDs capture a particle size of 80 microns at their design flow rates; the captured particle size ranges from 122 percent to over 700 percent of the target 80micron particle size. MTDs used for presettling prior to bioretention must be sized based on the design flow rate normalized on 80 microns.

**Table E.8. Adjusted Target Particles and Design Flow Rates for Selected Approved Pretreatment Manufactured Treatment Devices.**

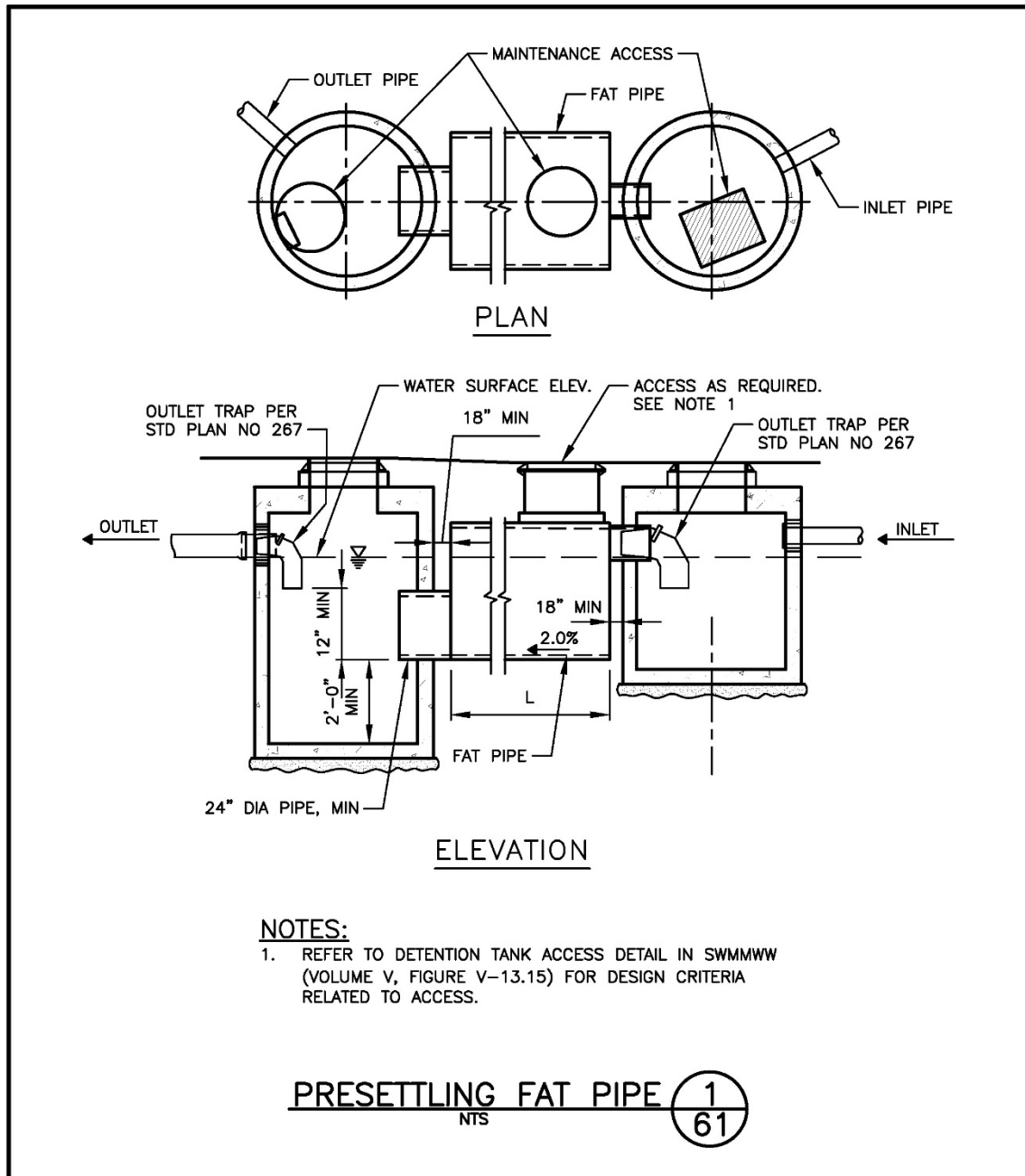
<b>Device Name (manufacturer)</b>	<b>Model</b>	<b>Published Design Flow Rate (cfs)</b>	<b>Particle Size Captured by MTD (micron)</b>	<b>Design Flow Rate Normalized to 80 Microns (cfs)</b>
Vortechs System (Contech)	1000	0.55	111	0.31
	2000	1.00	126	0.45
	3000	1.50	136	0.60
	4000	2.20	147	0.79
	5000	3.00	157	0.97
	7000	3.90	162	1.20
	9000	5.00	168	1.46
	11000	6.10	170	1.75
	16000	8.80	173	2.45
Downstream Defender (Hydro International)	4 foot	1.30	192	0.31
	6 foot	4.10	259	0.66
	8 foot	9.40	311	1.21
	10 foot	17.70	357	1.93
Stormceptor (Imbrium Systems)	STC 450i	0.32	114	0.17
	STC 900	0.63	108	0.38
	STC 1200	0.63	104	0.40
	STC 1800	0.63	101	0.43
	STC 2400	1.06	98	0.75
	STC 3600	1.06	95	0.78
	STC 4800	1.77	100	1.21
	STC 6000	1.77	99	1.23
	STC 7200	2.47	98	1.75
	STC 11000	3.53	151	1.21
	STC 13000	3.53	150	1.23
	STC 16000	4.95	148	1.75
CDS Stormwater Treatment Systems (Contech)	CDS 2015-4	0.70	127	0.31
	CDS 2015-5	0.70	101	0.47
	CDS 2020-5	1.10	133	0.46

**Table E.8 (continued). Adjusted Target Particles and Design Flow Rates for Selected Approved Pretreatment Manufactured Treatment Devices.**

<b>Device Name (manufacturer)</b>	<b>Model</b>	<b>Published Design Flow Rate (cfs)</b>	<b>Particle Size Captured by MTD (micron)</b>	<b>Design Flow Rate Normalized to 80 Microns (cfs)</b>
CDS Stormwater Treatment Systems (Contech)	CDS2025-5	1.60	172	0.45
	CDS3020-6	2.00	155	0.66
	CDS 3030-6	3.00	210	0.64
	CDS 3035-6	3.80	256	0.62
	CDS 4030-8	4.50	207	0.97
	CDS 4040-8	6.00	261	0.96
	CDS 4045-8	7.50	314	0.95
	CDS 5640-10	9.00	219	1.80
	CDS 5653-10	14.00	319	1.74
	CDS 5668-10	19.00	427	1.68
Nutrient Separating Baffle Box (Oldcastle Infrastructure, Inc.)	CDS 5678-10	25.00	567	1.65
	NSBB-48	4.60	180	1.22
	NSBB-510	8.03	201	1.80
	NSBB-612	12.70	231	2.37
	NSBB-816	26.00	263	4.11
	NSBB-1020	45.40	274	6.82
	NSBB-1224	71.70	300	9.62

### *E-10.2. Presettling Vault/“Fat Pipe”*

A presettling vault is a below-grade vault or tank located inline as part of the upstream conveyance system. The volume provided slows down the water quality flow rate and allows settling to occur. The vaults can be constructed of precast or cast-in-place concrete or can be constructed as a length of oversized pipe with smaller diameter inlet and outlet pipe connections that match at the crowns. This configuration is commonly called a “fat pipe” and is recognized as being a simple and cost-efficient type of presettling vault because the facility utilizes standard materials, and its cylindrical shape is very material efficient. A fat pipe presettling vault is shown in Figure E.9.



**Figure E.9. "Fat Pipe" Presettling Vault.**

BMP T6.10 of the 2024 *Stormwater Management Manual for Western Washington* provides design guidance for presettling vaults and recommends that they have a 3:1 (minimum) length-to-width ratio and a minimum depth of 4 feet. When designing a fat pipe, increasing either the diameter or the length of the pipe (while maintaining the minimum length-to-width ratio) improves the settling capability.

To compare the performance of different fat pipe configurations, several small-diameter pipe options were evaluated, each with the lower 12 inches reserved for sediment storage. Once that storage volume is filled, maintenance is required and the sediment must be removed.

The resulting cross-sectional areas and volumes were determined and the settling velocities of particles per modified Stokes' Law (Ferguson and Church 2004) were considered.

Table E.9 shows the design water quality flow rate for fat pipes of various diameters and a constant length of 10 feet that settle 80micron particles. Table E-10 shows the water quality flow rate for fat pipes of varying lengths and a constant diameter of 4 feet which settle the target 80-micron particle. Note that several of the configurations presented in the tables below do not meet the recommended minimum length to diameter ratio but have been included to illustrate how settling performance changes as pipe length and diameter change.

The analysis in Table E.9 and Table E-10 focuses on smaller-diameter storage pipes. Although larger diameter pipe (such as 6-foot diameter) could provide similar performance, a longer pipe would be recommended to maintain the minimum length to diameter ratio.

**Table E.9. 10-Foot-Long Fat Pipe Sizing for Various WQ Flow Rates to Settle 80 Micron Particles.**

Fat Pipe Diameter (feet)	Design WQ Flow Rate (cfs)
3	0.489
4 <sup>a</sup>	0.636
5 <sup>a</sup>	0.779

<sup>a</sup> Configuration does not meet the recommended minimum length to width ratio (3:1). Length of these options would need to be adjusted to meet this requirement to be used as a presettling BMP.

**Table E-10. 4-Foot-Diameter Fat Pipe Sizing for Various WQ Flow Rates to Settle 80 Micron Particles.**

Fat Pipe Length (feet)	Design WQ Flow Rate (cfs)
5 <sup>a,b</sup>	0.318
10 <sup>a</sup>	0.636
15	0.954
20	1.272
25	1.590

<sup>a</sup> Configuration does not meet the recommended minimum length to width ratio (3:1). Length would need to be adjusted to meet this requirement to be used as a presettling BMP.

<sup>b</sup> A 5-foot-long fat pipe is shown for informational purposes only; the minimum recommended fat pipe length is 10 feet.

To illustrate the expected sizing of a fat pipe for a 6acre residential basin, consisting of 25 percent impervious cover, with generally flat topography and underlain by till soils, MGSFlood was used to estimate the water quality flow rate for the subject basin. The resulting online water quality flow rate is 0.2200 cfs. Per the sizing in Tables E.9 and E.10, presettling requirements could be satisfied using a 3-foot-diameter, 10-foot-long fat pipe.

### E-10.3. Extended Sump with Baffle Presetting BMP

Extended sumps help improve the effectiveness of sediment capture in catch basins or maintenance holes by providing additional volume and residence time by deepening the sump. See Figure E.10. Baffles will necessarily inhibit the conveyance capacity of the structure and introduce additional head loss. These losses should be considered during design to verify sufficient conveyance capacity of the proposed drainage system.

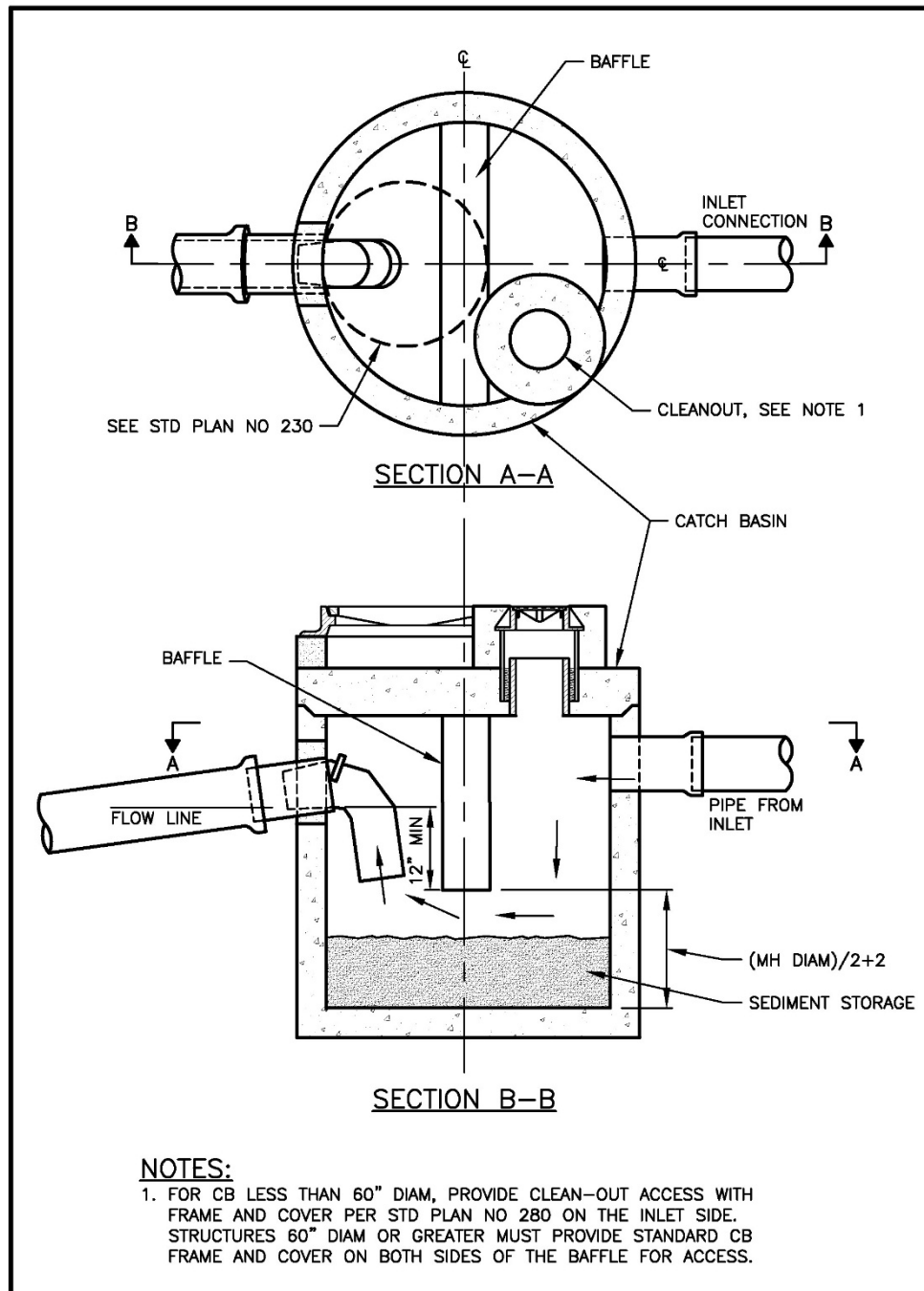


Figure E.10. Catch Basin/Maintenance Hole with an Extended Sump and a Baffle.

Extended sump manholes with various diameters and an extended sump of 4 feet were evaluated for settling 80micron particles; the results are shown in Table E.11. It is intended that the 1 foot of the extended sump would be available for sediment storage. Once the 1 foot is filled, the BMP must be maintained and the sediment removed.

Table E.11 shows the water quality design flow rate that would settle an 80micron particle considering the geometry shown in Figure E.10. Due to the small design water quality flow rate capacity of Extended Sumps, these are only expected to be applicable for smaller basins.

**Table E.11. Particle Settling Effectiveness for 4-Foot Extended Sumps to Settle 80 Micron Particles.**

<b>Catch Basin Diameter (feet)</b>	<b>Design WQ Flow Rate (cfs)</b>
4	0.2871
5	0.3872
6	0.4986
7	0.6214
8	0.7555

To illustrate the expected sizing of an extended sump for a 6acre residential basin, consisting of 25 percent impervious cover, with generally flat topography and underlain by till soils, MGSFlood was used to estimate the water quality flow rate for the subject basin. The resulting online water quality flow rate is 0.2200 cfs. Per the sizing in Table E.11, presettling requirements could be satisfied using a 4-foot-diameter, 4-foot-deep extended sump.