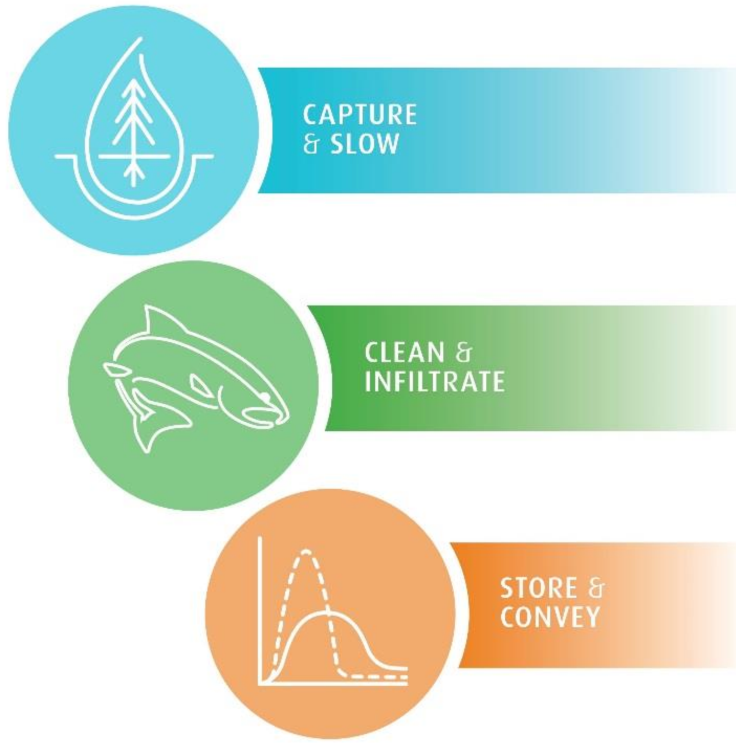


APPENDIX C - VEGETATED & GRASSY INFILTRATION SWALE SYSTEMS

Green Stormwater Infrastructure Design Guidelines for the Capital Region

SPRING 2019

Vegetated & Grassy Infiltration Swale Systems[1]

Description

Swales are graded and engineered landscape features which generally have a linear open channel. Vegetated and grassy bioretention and infiltration swales are designed to collect, safely convey stormwater while reducing runoff (though infiltration), delaying peak flows and providing treatment. Swales can remove low concentrations and quantities of total suspended solids, heavy metals, petroleum hydrocarbons, and/or nutrients from stormwater.

Figure 1 Flat curbs with swale at South Valley Estates, District of Saanich

Simple grass channels or ditches have long been used for stormwater conveyance, particularly for roadway drainage. Vegetated and grassy swales incorporate design features such as modified geometry and check dams that improve the contaminant removal and runoff reduction functions of simple grass channel and roadside ditch designs.

Grassy swales promote the conveyance of stormwater at a slower, controlled rate and allow infiltration along its entire length. A vegetated swale has the same features as grassy swales, however, the presence of additional vegetation provides additional pollutant removal. Vegetated swales are essentially multiple rain gardens connected together with only the downstream rain garden having an overflow drain.

The surface component of an infiltration swale (also known as biofiltration swale, bioswale, dry swale with underdrain, swale/trench element) is a shallow channel, accepting flows from small areas of adjacent paved surfaces such as roads and parking. The swale is designed to hold the stormwater behind a weir, and then allow it to infiltrate slowly through a soil bed to an underlying drain rock reservoir system. The surface soils and drain

[1] **Adapted with permission from Metro Vancouver.**
Original document: Metro Vancouver's Stormwater Source Control Design Guidelines 2012, primary author Kerr Wood Leidal Associates Ltd. with Lanarc Consultants Ltd and Goya Ngan, http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/StormwaterSourceControlDesignGuidelines2012StormwaterSourceControlDesignGuidelines2012.pdf
Adaptations authored by: Opus International Consultants (Canada) Limited
Design guidelines drawings by: Kerr Wood Leidal Associates Ltd. and/or as noted in figures.

rock reservoir are sized to store the design storm event, and to allow it to infiltrate slowly into underlying soils. A perforated drain placed near the top of the drain rock reservoir provides an underground overflow, which also maintains drainage of adjacent road base courses. The surface swale and weir structures provide conveyance for larger storm events to a surface outlet.

Where infiltration is not possible, consider a sunken or above ground Flow-Through Planter (see Appendix F) as an optimal alternative in an ultra-urban setting.

Selection, Application and Limitations

- Design may need to be adapted to address levels of phosphorus or nitrogen entering and leaving the facility.
- Swales can be used for contaminated stormwater runoff from roadways, driveways, parking lots, and highly impervious ultra-urban areas.
- An infiltration or bioswale is designed to provide conveyance, contaminant removal, as well as infiltrate the design volumetric capture target, and treat the design water quality volume.
- A rain garden and infiltration swale have similar design and functions; however, a swale provides conveyance of flows, but may provide less capture of peak flows than a rain garden (due to ponding).
- A grassy swale is generally less expensive to install than a vegetated swale (per unit area), but may require a larger area to meet the same capture targets.
- When lower capture targets are used such that a higher degree of surface conveyance is required, a grassy infiltration swale is advisable due to its lower susceptibility to erosion, compared to a mulched and planted swale or rain garden.

Figure 2 Grassy Swale, View Royal. Note: Flat over-flow drain may get blocked by debris, beehive style is recommended. Photo Credit: Town of View Royal

- Suitable for most development situations – residential areas, municipal office complexes, rooftop runoff, parking and roadway runoff, parks and greenspace, golf courses.
- With proper weir spacing, practical for profiles up to 10% slope.
- Maximum contributing area 2 ha.
- Standard minimum separation from base of drain rock reservoir to water table is 610 mm.

- ❑ Identify pollutant sources, particularly in industrial/commercial hotspots, that require pre-treatment or source control upstream of this GSI facility (infiltration swale system).

Design Guidelines

1. Detailed design requirements should be evaluated for each individual application based on site-specific constraints and objectives.
2. Follow all applicable federal, provincial and municipal regulations.
3. Geo-technical investigations are recommended with soil permeability testing being the minimum requirement for design. Advice from a professional engineer for design is recommended.
4. An infiltration swale should be designed with a trapezoidal cross-section. Swale bottom width: 600 mm minimum, 2,400 mm maximum (recommended), flat, in cross section.
5. The infiltration swale should be sized based on infiltration area, or base area of the swale, as the effective area for infiltration occurring in the swale.
6. Flow to the swale should ideally be distributed sheet flow. Provide non-erodible material for erosion and scour protection, sediment cleanout basins, and weir flow spreaders at point-source inlets.
7. Provide erosion control, vegetated or otherwise, along all sides of weirs and at drainage inlets.
8. Pavement edge at the swale may be wheel stop, flush curb, or reverse curb. Provide a 50 mm drop at the edge of paving to the swale soil surface, to allow for positive drainage and buildup of road sanding/organic materials at this edge.

Figure 3 Vegetated Swale, Victoria Airport

9. Integrated mowing strip is desirable in lawn areas.
10. Swale planting is typically sodded lawn. Low volume swales can be finished with a combination of grasses, shrub, groundcover and tree planting to provide a 100% vegetated cover within 2 years of planting.

11. Footprint of Infiltration Swale = Base Area + Side Slope Area. Add additional area for side slopes according to the shape of the swale and the chosen side slopes; e.g., add [2 x slope x swale depth (m)] to each dimension of the base area to determine total footprint area.
12. Swale surface side slopes – 3 (horizontal):1 (vertical) maximum, 4:1 preferred for maintenance.
13. Design stormwater conveyance using Manning's formula, with attention to erosion of soils and vegetation and channel stability during maximum flows.
14. Longitudinal slope of the swale should be between 1%-2%.
15. For slopes of 2%-10%, the swale length may be broken up by terraces (steps) or weirs of up to 300 mm height to reduce the slope; 200 mm or less is preferred. Splash pads of cobble-sized rock (or similar) must be included below each step or weir to prevent erosion.
16. Where weirs are used to reduce the longitudinal slope, swale longitudinal slope should be 1%-2%, or dished, between weirs.
17. Weirs to have level top to spread flows and avoid channelization, keyed in 100 mm minimum.

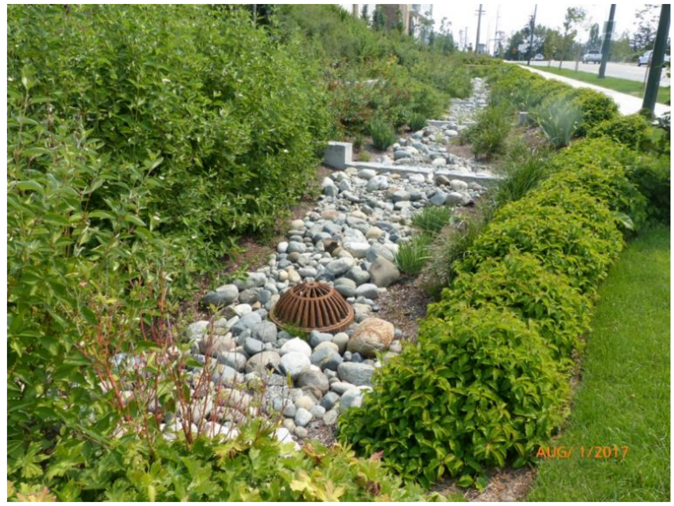


Figure 4 Swale, Watkiss Way, Eagle Creek, View Royal. Photo Credit: Town of View Royal

18. Maximum ponded level at weirs: 150 mm
19. Drawdown time for the maximum surface ponded volume – 48 hours maximum.
20. Minimum freeboard to adjacent paving: 100 mm or in accordance with swale conveyance design.
21. Treatment soil or Bioretention Soil Mix (BMS) depth: 450 mm minimum. Minimum can be decreased if design professional calculates adequate pollutant removal, or 100 mm minimum growing medium over 100 mm minimum washed sand. A standard value of 300 mm soil depth is common. BSM must be well aged organics, weed free, preferably manure free and biosolid free.
22. Drain rock reservoir bottom to be level.
23. Underground weirs of undisturbed native material or constructed trench dams to be provided to create underground pooling in the reservoir sufficient for infiltration performance.
24. A non-erodible outlet or spillway must be established to discharge overflow.
25. Avoid utility or other crossings of the swale. Where utility trenches must be constructed crossing below the swale, install trench dams to avoid infiltration water following the utility trench.
26. Refer to Figures 17-19 for curbing, inlet and flow dissipator detail options.
27. See Table 1 for setbacks for infiltration swales.

Table 1 Infiltration Swale Setbacks

Setback From	Distance (m)
Up-gradient of building foundations	3
Property Line	Site dependent
Drinking Water Well	30
Up-gradient of septic field	3
Seasonal High Water Table	1
Up-gradient of active or inactive landfill or contaminated site	30
Existing trees	Outside root protection zone

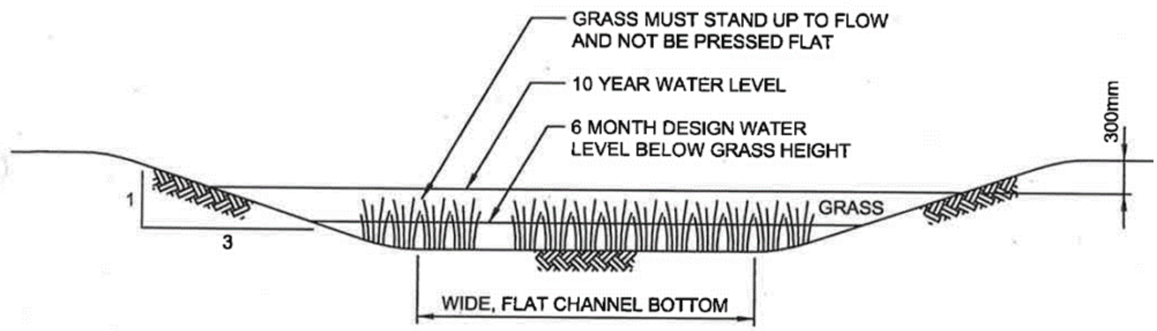


Figure 5 Grassy Infiltration Swale Section

Source: Saanich Engineering Specifications, 2003

Design Options

Drain rock reservoir and underdrain may be deleted where infiltration tests, by the design professional taken at the level of the base of the proposed construction, show an infiltration rate that exceeds the maximum inflow rate for the design storm (approximately rainfall intensity x (I/P ratio + 1); I/P ratio is defined below as part of Sizing).

Infiltration Swale Sizing

Infiltration swales may be sized using a simplified sizing approach that does not require water balance modelling or continuous simulation. The sizing approach presented below uses a depth capture criteria of X mm in 24 hours.

1. In general, the infiltration swale area is sized based on the upstream impervious area that it serves. This relationship can be defined by the ratio of impervious area to pervious area (e.g., I/P ratio). For the simplified sizing approaches here, this represents the ratio of upstream impervious area (also called catchment area) to the base area of the swale. I/P ratio to achieve the target capture criteria will be calculated by the 2 sizing methods below for various maximum allowable I/P ratio for given surface types is shown in Table 2. This maximum is based on ability of the vegetation to handle flows and pollutants and is not related to capture. Regardless of sizing calculation below, maximum I/P ratio for a given surface type should not be exceeded. The table shows maximum allowed I/P ratios, not recommended I/P ratios. I/P ratios must be calculated in order to achieve rainfall capture targets.

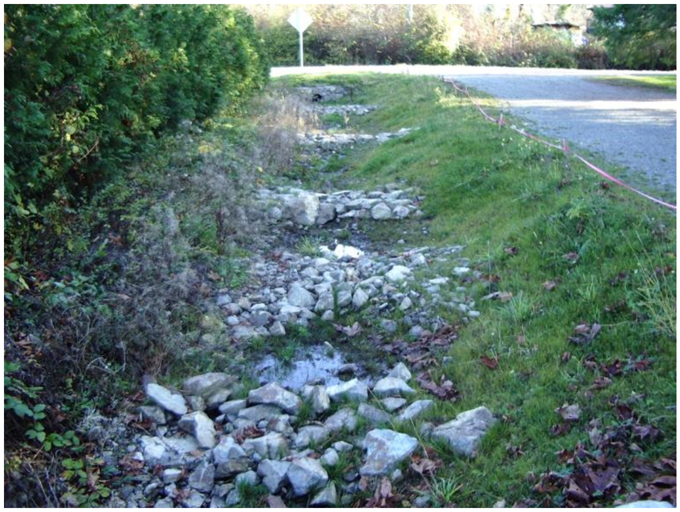


Figure 6 Swale Ditch, North Saanich

2. The simplified sizing process provides the base area of the swale which is the flat area at the bottom with uniform layers of topsoil and drain rock. Sizing by these methods does not account for any infiltration benefit provided by the sloped sides of the infiltration swale.
3. The base area of the infiltration swale will always be smaller than the total footprint of the facility, so the footprint must be calculated (see Design Guideline Item 8, above) in order to understand the actual site area required.

4. Sizing presented here is for infiltration of rainwater for "capture" and prevention of site runoff. Sizing and design according to this guidance will generally provide water quality treatment for the volume of water infiltrated. If "water quality" criteria volumes are larger than "capture" volumes, additional sizing may be required and a professional engineer should be consulted.

Figure 7 Swale at Railyards, Victoria

5. Sizing the swale for conveyance is not covered here but should be done by standard methods. The simplified methods here may define the width of swale needed, but the depth and overall footprint should be based on the flow conveyance required.

Table 2 Swale Maximum I/P Ratios by Surface Type

Surface Type	Max. I/P Ratio
General/Industrial Storage/Loading Areas	20:1
Divided or Undivided Major Road (Expressway or Highway)	20:1
Collector Road	20:1
Parking >1 car/day/parking space	20:1
Local Road	30:1
Parking <1 car/day/parking space	40:1
Low traffic areas, no parking	50:1
Single Family Residential, Lot and Roof	50:1

Sizing for Depth Capture Criteria: R mm in 24 hrs

To determine R mm of rain in 24 hrs see Appendix A, Table 1 for area-specific typical GSI facility design guideline rainfall capture targets and confirm with respective municipality.

1. Determine the maximum rock depth according to the drain time (4 days max.) and round down to the nearest 50 mm increment for constructability; allowable depth range is 300 to 2,000 mm:

   $$D_R = \frac{Ks \times T \times 24}{n}$$

   Where:

   D_R = Depth (thickness) of rock reservoir (mm)

   Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr), as measured during winter saturated soil conditions

   T = allowable drain time (days)

   n = porosity of drain rock in reservoir (unitless, e.g., 0.35)

2. Use the following equation to determine the base (bottom) area of the swale and rock reservoir required by finding the I/P ratio for the site:

   $$I/P = \frac{24 \times Ks + D_R \times n + 0.2 \times D_S}{R} - 1$$

   Where:

   I/P = Ratio of impervious tributary area to swale base area (unitless)

   R = Rainfall capture depth (mm)

   Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr),

   D_R = Depth (thickness) of rock reservoir (mm)

   n = porosity of drain rock in reservoir (unitless, e.g., 0.35)

   D_S = Soil layer depth (thickness); standard value = 300 (mm)

3. Check that the I/P ratio calculated is less than the maximum allowed (Table 2). If it is not, use the maximum allowed I/P ratio. This may mean that the infiltration swale will exceed the % capture desired.

4. To find the swale base area:

   $$BaseArea = \frac{\text{Impervious } TributaryArea}{I/P}$$

5. Calculate the footprint of the facility based on the base area and side slopes as described in Item 11 of Design Guidelines above.

6. If the site cannot accommodate the I/P ratio required to provide the target capture, a partial-infiltration swale with flow restrictor design may be used.

7. A 0.25 L/s/ha (or 0.09 mm/hr) unit discharge is the recommended flow restrictor at the downstream end of the swale underdrain.

8. Calculate the allowable discharge through the orifice:

$$Q = \frac{0.25 \times A_{SITE}}{1000}$$

   Where:
   Q = Allowable discharge through orifice (m^3/s)
   0.25 = Recommended unit discharge (L/s/ha)
   A_{SITE} = Total site area draining to the swale, including the swale area (ha)

Figure 8 Vegetated Swale, Tattersal Drive, Saanich

9. Solving the orifice equation for area of the orifice (AO):

$$A_O = \frac{Q}{K \times \sqrt{2gh}}$$

   Where:
   Q = Allowable discharge through orifice (m^3/s)
   K = Orifice Coefficient (typical value 0.6)
   g = gravitational constant (m/s^2)
   h = head on the orifice when trench is 0.3 m full of water (typical value 0.3 m)
   A_O = Area of the orifice opening (m^2) – generally assumed to be circular for calculation of orifice diameter.

10. The size of the swale is then determined by the available area on the site up to the maximum I/P ratio for the surface type as shown in Table 2.

$$I/P = \frac{\text{Impervious } TributaryArea}{BaseArea}$$

11. The depth of the rock reservoir above the orifice outlet is calculated as:

$$D_R = \frac{R \times (I/P+1) - 0.09mm/hr \times 24hrs \times (I/P+1) - 24 \times Ks - 0.2 \times D_S}{n}$$

Where:
D_R = Depth (thickness) of rock reservoir (mm)
R = Rainfall capture depth (mm)
I/P = Ratio of impervious tributary area to swale base area (unitless)
0.09 = Recommended unit discharge through orifice (mm/hr)
Ks = Saturated hydraulic conductivity of subsurface soil (mm/hr), as measured during winter saturated soil conditions
D_S = Soil layer depth (thickness); standard value = 300 (mm)
n = porosity of drain rock in reservoir (unitless, e.g., 0.35)

Guideline Specifications

Materials shall meet Master Municipal Construction Document (MMCD) 2009 requirements, and:

1. Infiltration Drain Rock: clean round stone or crushed rock, 75 mm max, 38 mm min, 40% porosity or MMCD Section 31 05 17 Part 2.6 – Drain Rock, Coarse.
2. Pipe: PVC, DR 35, 150 mm min. dia. with cleanouts, certified to CSA B182.1 as per MMCD.
3. Geosynthetics: as per Section 31 32 19, select for filter criteria or from approved local government product lists.
4. Sand: Pit Run Sand as per Section 31 05 17.
5. Growing Medium: Bioretention Soil Mix: As per Tables 3a and 3b, with required minimum saturated hydraulic conductivity of 70 mm/hr.

Figure 9 Vegetated Swale receiving runoff directly from road, Saanich

6. Seeding: to Section 32 92 20 Seeding or 32 92 19 Hydraulic Seeding (note – sodding will be required for erosion control in most instances).
7. Sodding: to Section 31 92 23 Sodding.
8. Planting: see Supplemental 1, Planting Templates & Plant Lists.

Construction Practices shall meet Master Municipal Construction Document 2009 requirements, and:

1. Isolate the swale site from sedimentation during construction, either by use of effective erosion and sediment control measures upstream, or by delaying the excavation of 300 mm of material over the final subgrade of the swale until after all sediment-producing construction in the drainage area has been completed.

2. Prevent natural or fill soils from intermixing with the Infiltration Drain Rock. All contaminated stone aggregate must be removed and replaced.

3. Infiltration Drain Rock shall be installed in 300 mm lifts and compacted to eliminate voids between the geotextile and surrounding soils.

Figure 10 Swale under construction at Oak Bay High School parking. Raised or beehive style grates are recommend.

4. Maintain grass areas to mowed height between 50 mm and 150 mm, but not below the design water level. Landscape Maintenance standards shall be to the Canada Landscape Standard, 1st Edition, Maintenance Level 4: Open Space / Play Area.

Bioretention Soil Medium

Composition of Bioretention Soil Medium (BSM) is an important factor in the performance of GSI facilities. Soil mixes for bioretention and vegetated infiltration facilities need to balance 3 primary design objectives for optimum performance:

- ✓ High enough infiltration rates to meet desired surface water drawdown and system dewatering.
- ✓ A growth media to support long term plant and soil health and water quality treatment capability.
- ✓ Infiltration rates that are not too high in order to optimize pollutant removal capability.

For the latest information on bioretention soil research see the Department of Ecology, State of Washington Stormwater Action Monitoring webpage on Effectiveness studies (https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring/SAM-effectiveness-studies).

Minimum infiltration rate (lab tested) of 70 mm/hr for BSM. Below are 2 local BSM suggested mixes.

Table 3.a Vegetated and Grassy Swale Bioretention Soil Mediums Mix 1[2]

<table>
<tr><td colspan="2">Vegetated and Grassy Swale
Bioretention Soil Medium (BSM) Mix 1
Recommended depth: minimum of 450 mm
Minimum required saturated hydraulic conductivity of 70 mm/hr.</td></tr>
<tr><th>Component (partial size classes)</th><th>Percentage by Weight</th></tr>
<tr><td>Gravel (greater than 2.5 mm)</td><td>0</td></tr>
<tr><td>Sand (greater than 0.05 mm and less than 2.5 mm)
• Sand to be hard, granular sharp sand well washed and free of impurities, chemicals or organic matter; and
• Particle size in sand to be:
a) 90-100% passing a 2.50 mm sieve,
b) 0-65% passing a 0.500 mm sieve,
c) 0-5% passing a 0.0500 mm sieve</td><td>70-80</td></tr>
<tr><td>Silt (greater than 0.002 mm and less than 0.05 mm)</td><td>5-15</td></tr>
<tr><td>Clay (less than 0.002 mm)</td><td>2-5</td></tr>
<tr><td>Organic Content (%dry weight)
• must be well aged organics, weed free, preferably manure free and biosolid free.</td><td>10-15</td></tr>
<tr><th colspan="2">Other Soil Considerations</th></tr>
<tr><td colspan="2">• pH of mixed materials between 6-8.5
• Phosphorus (P) and Nitrogen (N) Management Recommendations: In some cases, bioretention facilities have the potential to export P and N at a higher rate than contained in the stormwater they are receiving. See Low Impact Development Technical Guidance Manual for Puget Sound 2012 (chapter 6.1.2 Bioretention Design) for nutrient management suggestions.
http://www.psp.wa.gov/downloads/LID/20121221_LIDmanual_FINAL_secure.pdf
• Safe Soils: The spread and proliferation of invasive species through many regions of the province comes from the re-distribution of invasive species laden soils. In 2016, a Soils and Invasive Species Sub-Working Group was developed to explore province-wide solutions regarding the movement of soil and related materials that may contain invasive species. This Sub-Working Group involves provincial and local government representation. Learn more: Provincial Response to the Resolutions of the 2016 Union of British Columbia Municipalities Convention FEBRUARY 2017
B113 SAFE SOILS PROGRAM (page 111)
http://www.ubcm.ca/assets/Resolutions~and~Policy/Resolutions/Provincial_Responses-2016_UBCM_Resolutions.pdf</td></tr>
</table>

[2] Modified from Vegetated Swale, Stormwater Best Management Practices, District of Saanich
http://www.saanich.ca/assets/Community/Documents/Vegetated%20Swale.pdf

Table 3.b Grassy and Vegetated Swale Bioretention Soil Mediums Mix 2[3]

<table>
<tr><td colspan="2">Grassy or Vegetated Swale
Bioretention Soil Medium (BSM) Mix 2*
Recommended depth: minimum of 450 mm
Minimum required saturated hydraulic conductivity of 70 mm/hr.</td></tr>
<tr><th>Component (partial size classes)</th><th>Percentage by Weight</th></tr>
<tr><td>Coarse Gravel (particles greater than 19 mm and less than 40 mm)</td><td>0 to 1</td></tr>
<tr><td>All Gravels (particles greater than 2 mm and less than 40 mm)</td><td>10 to 25</td></tr>
<tr><td colspan="2">Sand, Silt, Clay & Organic components measured from remaining non gravel portion of sample (% dry weight)</td></tr>
<tr><td>Sand (greater than 0.05 mm and less than 2.5 mm)
• Sand to be hard, granular sharp sand well washed and free of impurities, chemicals or organic matter.
• Note: Growing medium/BSM to be manufactured with ‘2 mm minus’ sand to reduce gravel content in the soil. 2 mm minus sand is available from most local quarries upon request.</td><td>60-70</td></tr>
<tr><td>Combined Silt and Clays (less than 0.05 mm)</td><td>10-20</td></tr>
<tr><td>Organics (% dry weight)
• must be well aged organics, weed free, preferably manure free and biosolid free.</td><td>15-20</td></tr>
<tr><td colspan="2">Other Soil Considerations</td></tr>
<tr><td colspan="2">• pH of mixed materials between 6-8.5
• Phosphorus (P) and Nitrogen (N) Management Recommendations: In some cases, bioretention facilities have the potential to export P and N at a higher rate than contained in the stormwater they are receiving. See Low Impact Development Technical Guidance Manual for Puget Sound 2012 (chapter 6.1.2 Bioretention Design) for nutrient management suggestions. http://www.psp.wa.gov/downloads/LID/20121221_LIDmanual_FINAL_secure.pdf
• Safe Soils: The spread and proliferation of invasive species through many regions of the province comes from the re-distribution of invasive species laden soils. In 2016, a Soils and Invasive Species Sub-Working Group was developed to explore province-wide solutions regarding the movement of soil and related materials that may contain invasive species. This Sub-Working Group involves provincial and local government representation. Learn more: Provincial Response to the Resolutions of the 2016 Union of British Columbia Municipalities Convention FEBRUARY 2017, page 111 for B113 SAFE SOILS PROGRAM. http://www.ubcm.ca/assets/Resolutions~and~Policy/Resolutions/Provincial_Responses-2016_UBCM_Resolutions.pdf</td></tr>
</table>

[3] Modified from City of Victoria, Rainwater Management Standards – Professional Edition (June 2015) http://www.victoria.ca/assets/Departments/Engineering~Public~Works/Documents/SWVictoria_Professional_Rainwater_Mgmt_Stds_June2015.pdf

Infiltration Swale Design Example for Capture of R mm/24-hour Criteria

Scenario Description

An Infiltration Swale is proposed to capture a portion of the runoff from a paved parking area (see illustration below).

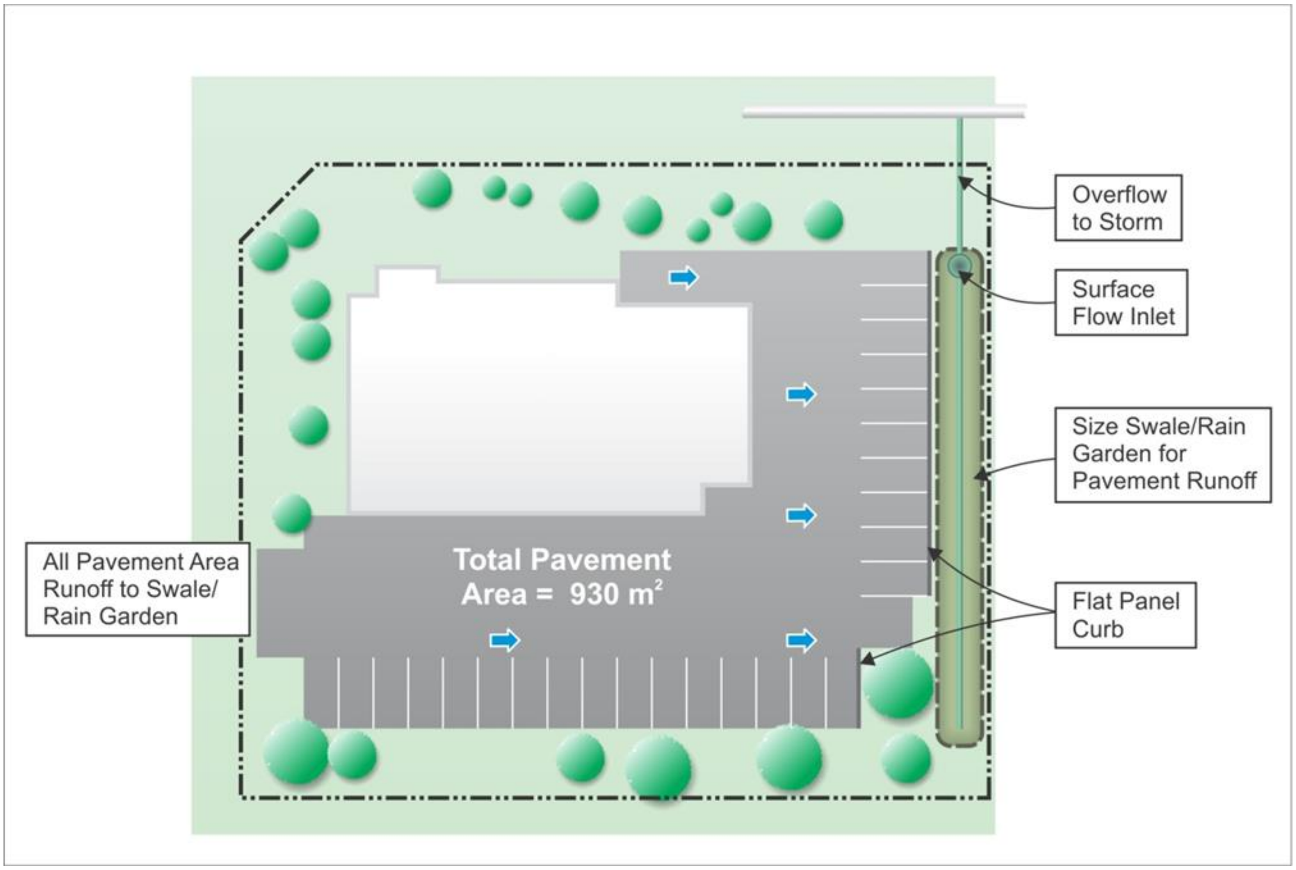


Figure 11 Example – Parking Area Draining To Infiltration Swale

The following parameters are known:

- Total pavement area = 930 m^2
- Available site area for swale = 90 m^2
- 2-year 24-hour rain depth = 92 mm
- Native soil infiltration rate = 1.5 mm/hr
- Parking use is more than 1 car per day
- Capture target is 72% of 2-year 24-hour rain = 66 mm

Determine the infiltration swale footprint area and rock trench depth. Also, estimate the annual percent capture of rainfall for the calculated infiltration swale size.

Sizing

Determine the maximum rock depth based on the 4-day maximum drain time:

$$D_R = \frac{Ks \times T \times 24}{n} = \frac{1.5mm/hr \times 4days \times 24hr/day}{0.35} = 411mm$$

Use 400 mm rock depth (see Table 2). Parking use of more than 1 car per day yields a maximum I/P ratio of 20.

Determine the base (bottom) area of swale and rock reservoir required by calculating the required I/P ratio:

$$I/P = \frac{24 \times Ks + D_R \times n + 0.2 \times D_S}{R} - 1$$

$$I/P = \frac{24 \times 1.5mm/hr + 400mm \times 0.35 + 0.2 \times 300mm}{66mm} - 1$$

$$I/P = 2.6$$

Check that the I/P ratio is less than the maximum (2.6 < 20, therefore, OK). However, with an I/P ratio of 2.6, the swale would need to be 358 m^2 in size and would not fit on the site. A partial-infiltration swale with flow restrictor is required to meet the capture target.

GSI Driver Effectiveness – Runoff Reduction and Contaminant Removal

International Stormwater BMP Database http://www.bmpdatabase.org/ is a recommended resource for performance summaries of GSI facilities and latest research.

Vegetated swales act as both a stormwater conveyance and treatment system. Pollutant removal in swales is the result of filtration, infiltration, and microbial activity. The effectiveness of pollutant removal can vary greatly depending on swale geometry and soils. Swales often collect sediments and other gross particulate matter that may be exported during large rainfall events. This can result in an increase in effluent phosphorus concentrations. Long, shallow sloped, sandy soiled and densely grassed swales have the highest pollutant removal rates. Check dams can be added to slow conveyance and increase infiltration. The following table shows the effectiveness of vegetated swales for GSI drivers.

Table 4 Runoff Reduction and Contaminant Removal

Bioretention and Vegetated Infiltration GSI Facilities (rain gardens, swales, planters, curb extensions)	
GSI Driver	***Estimated Effectiveness or typical % Reduction or Removal**
Capture & Slow – Volume Runoff Reduction	85% without underdrain 45% with underdrain
Store & Convey – Rate Control Delay Peak	Medium to high without under drain Medium with underdrain
Clean & Infiltrate – Water Quality Treatment	Highly variable with design, BSM, native soil and depth, plant type. Below are typical results. Research has observed good retention and at times production and export. Export is more likely with an underdrain.
Heavy Metals (Copper, Lead, Zinc)	35 to >90
Oil and Grease	>70 (higher with mulch)
Phosphorus	(-70) to >85
Nitrogen	20 to > 30
Total Suspended Solids (TSS)	60 to > 95
Bacteria (Fecal coliform bacteria or E. coli)	>70

Note: *Performance of individual facilities will vary depending on site-specific contexts and facility design. Negative numbers indicate contaminant loading from the given GSI facility producing a higher export of a given contaminant.

Sources:

http://www.psp.wa.gov/downloads/LID/20121221_LIDmanual_FINAL_secure.pdf
http://www.creditvalleyca.ca/wp-content/uploads/2012/02/lid-swm-guide-chapter4-4.5-bioretention.pdf
http://roads.maryland.gov/OPR_Research/MD-05-SP208B4E-Grassed-Swale-Pollutant-Efficiency-Study-Report.pdf
http://www.lid-stormwater.net/bio_benefits.htm
http://www.deq.virginia.gov/fileshare/wps/2013_DRAFT_BMP_Specs/
https://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
http://your.kingcounty.gov/dnrp/library/water-and-land/stormwater/juanita-retrofit/appendix-d-removal-rates.pdf
http://www.bmpdatabase.org/

Maintenance of Infiltration Swales

The useful life of an infiltration swale system is directly proportional to its level of maintenance. With proper design and regular maintenance, infiltration swales can last indefinitely. The routine maintenance objectives are to maintain a dense healthy grass cover to ensure efficient hydraulics and pollutant removal. Routine maintenance includes spring clean-up, regular mowing, and pruning of trees and shrubs. The following is a table showing Operation, Maintenance, and Replacement Schedules for Infiltration Swales:

OPERATION ACTIVITY	SCHEDULE
Inspect for sedimentation, erosion, plant health, and mulch condition	Semi-annually (spring and fall) quarterly first 2 years
Irrigation	As needed
Street sweeping to reduce sedimentation	Semi-annually (spring and fall)
Soil infiltration testing	Bi-annually
MAINTENANCE ACTIVITY	**SCHEDULE**
Weed control	Bi-monthly
Mowing and clipping removal no shorter than maximum flow depth	Monthly (March-October)
Prune vegetation	As needed
Litter and debris removal	Bi-monthly
Tilling or deep raking	Bi-annually
Sand and sediment removal	Annually (spring)
Erosion repair	As needed
REPLACEMENT ACTIVITIES	**SCHEDULE**
Grass/plants	As needed(1-10 years)
Mulch	As needed(1-3 years)
Soils	As indicated by infiltration testing (2-20 years)
Gravel drainage layer	As indicated by infiltration testing (25-50 years)
Under drain	As indicated by flushing (25-50 years)

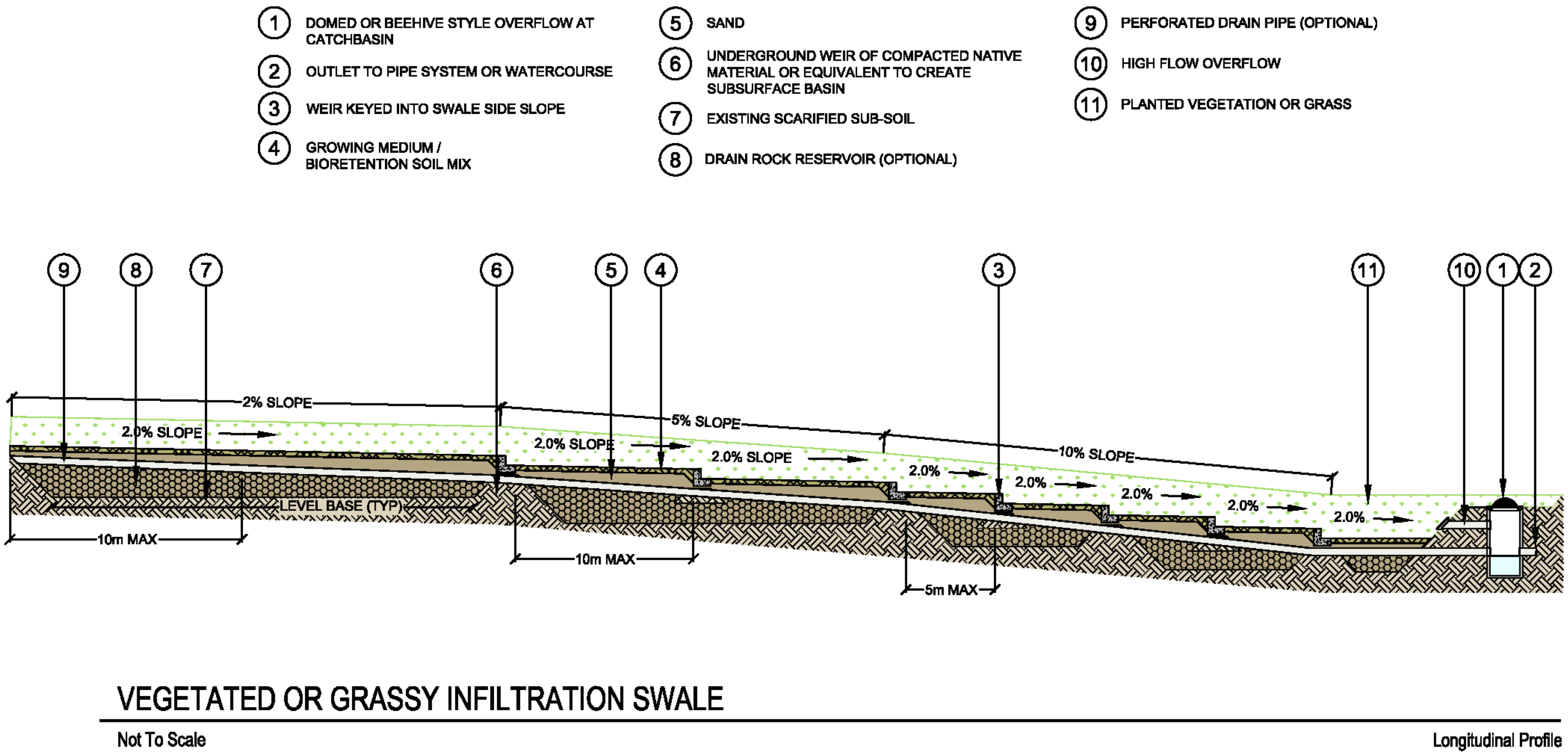


Figure 12 Vegetated or Grassy Infiltration Swale – No Flow Restrictor (Not to scale, Longitudinal Profile)

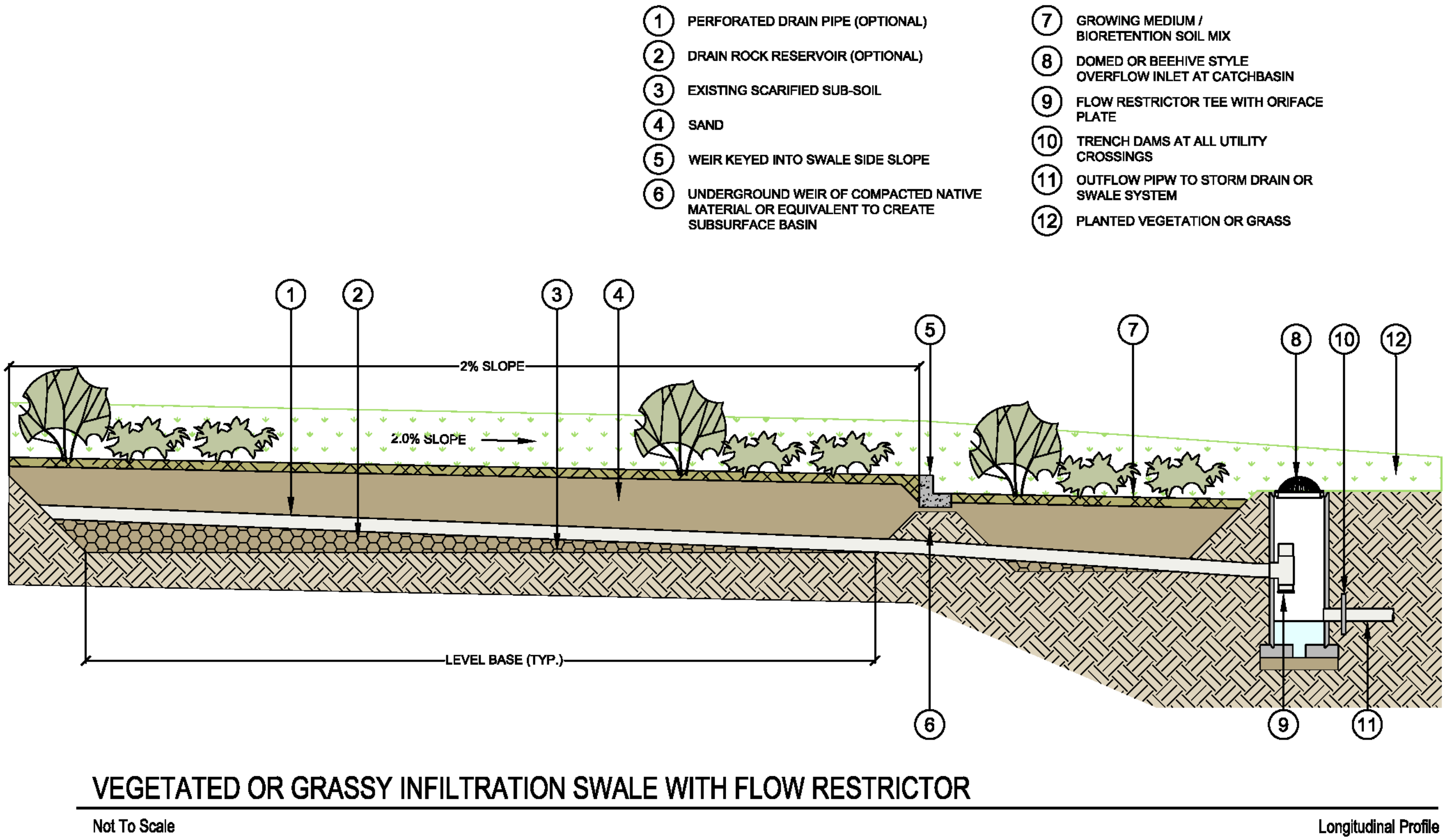


Figure 13 Vegetated or Grassy Infiltration Swale with Flow Restrictor (Not to scale, Longitudinal Profile)

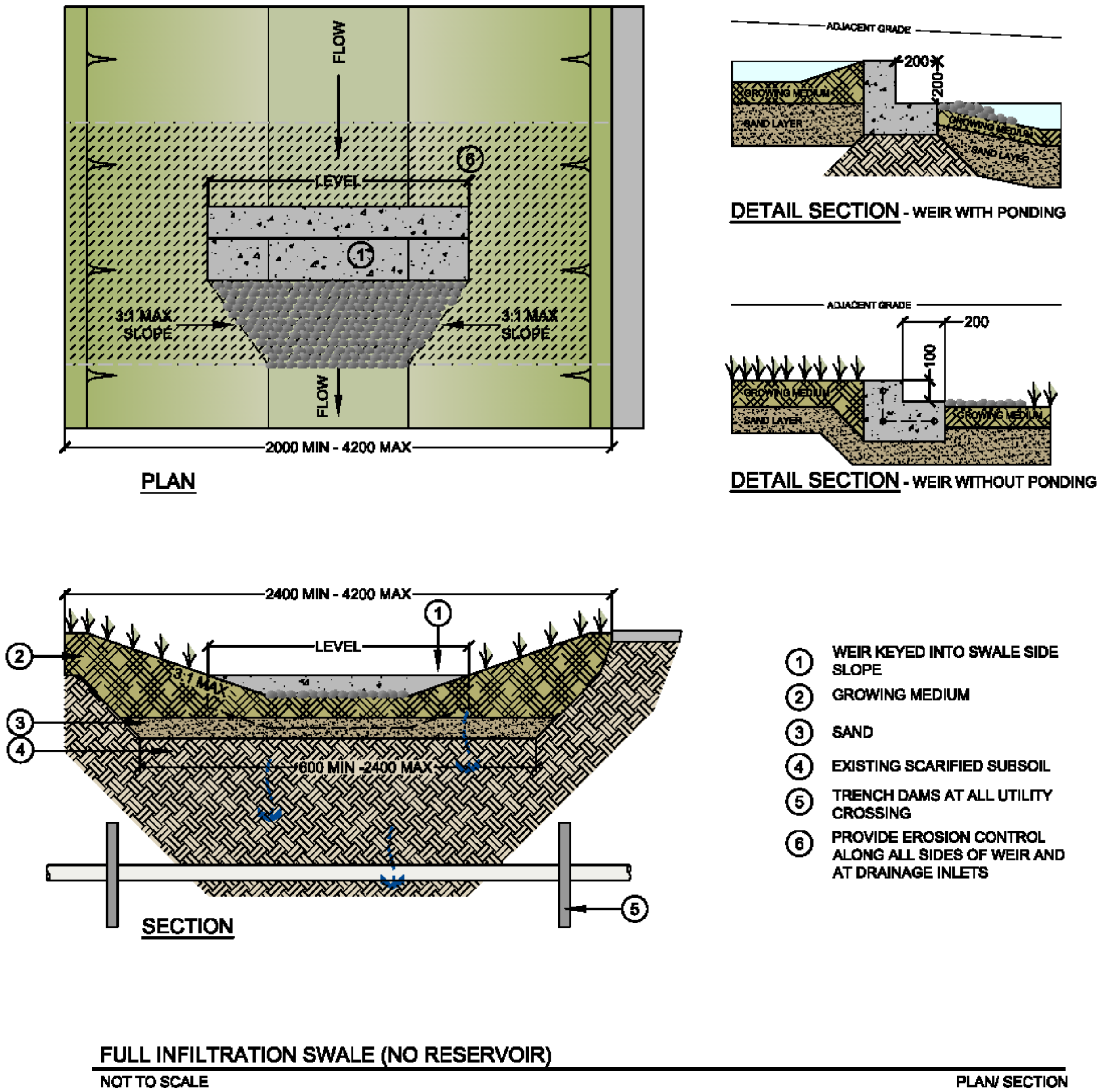


Figure 14 Full Infiltration Swale (No Reservoir) (Not to scale, Plan/Section)

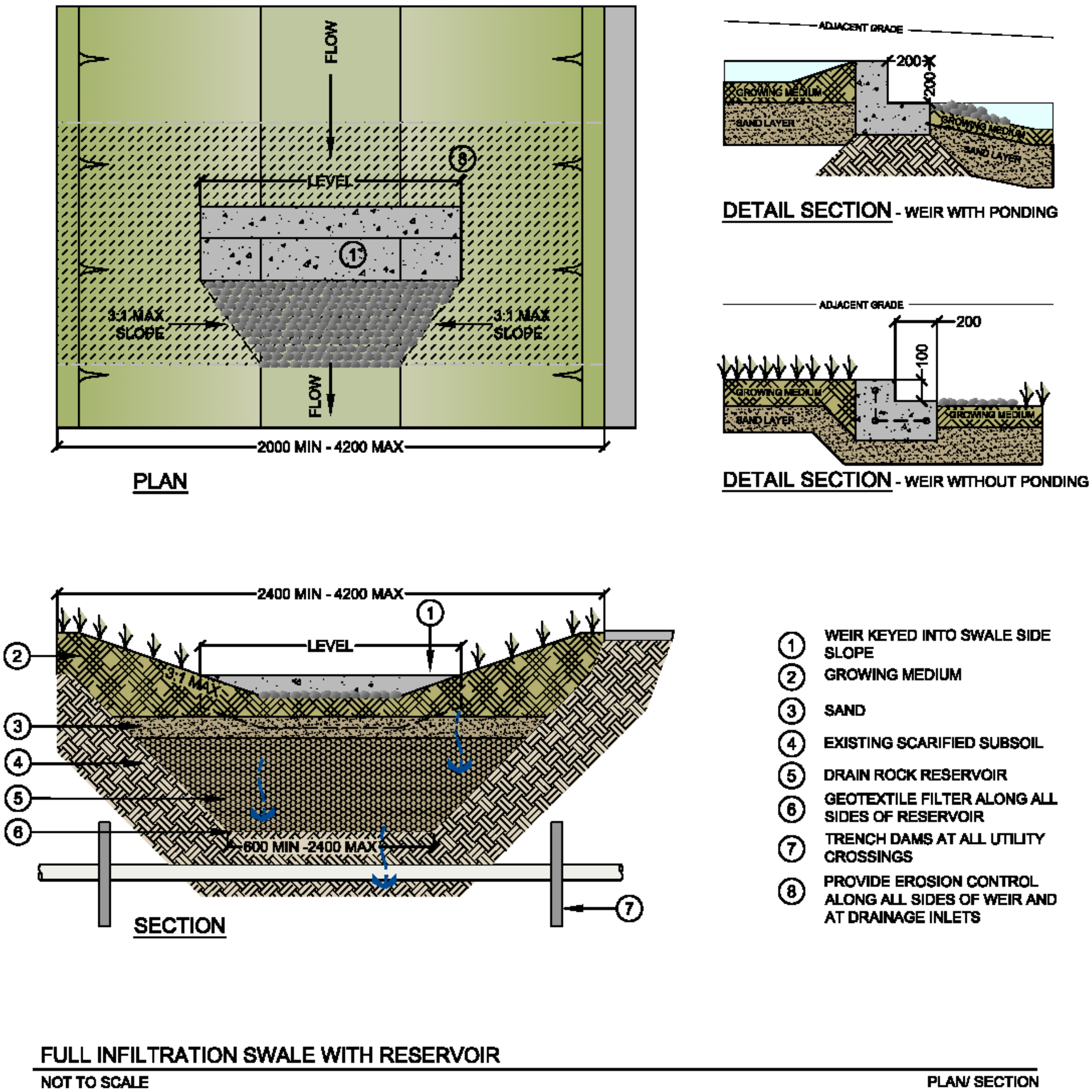


Figure 15 Full Infiltration Swale with Reservoir (Not to scale, Plan/Section)

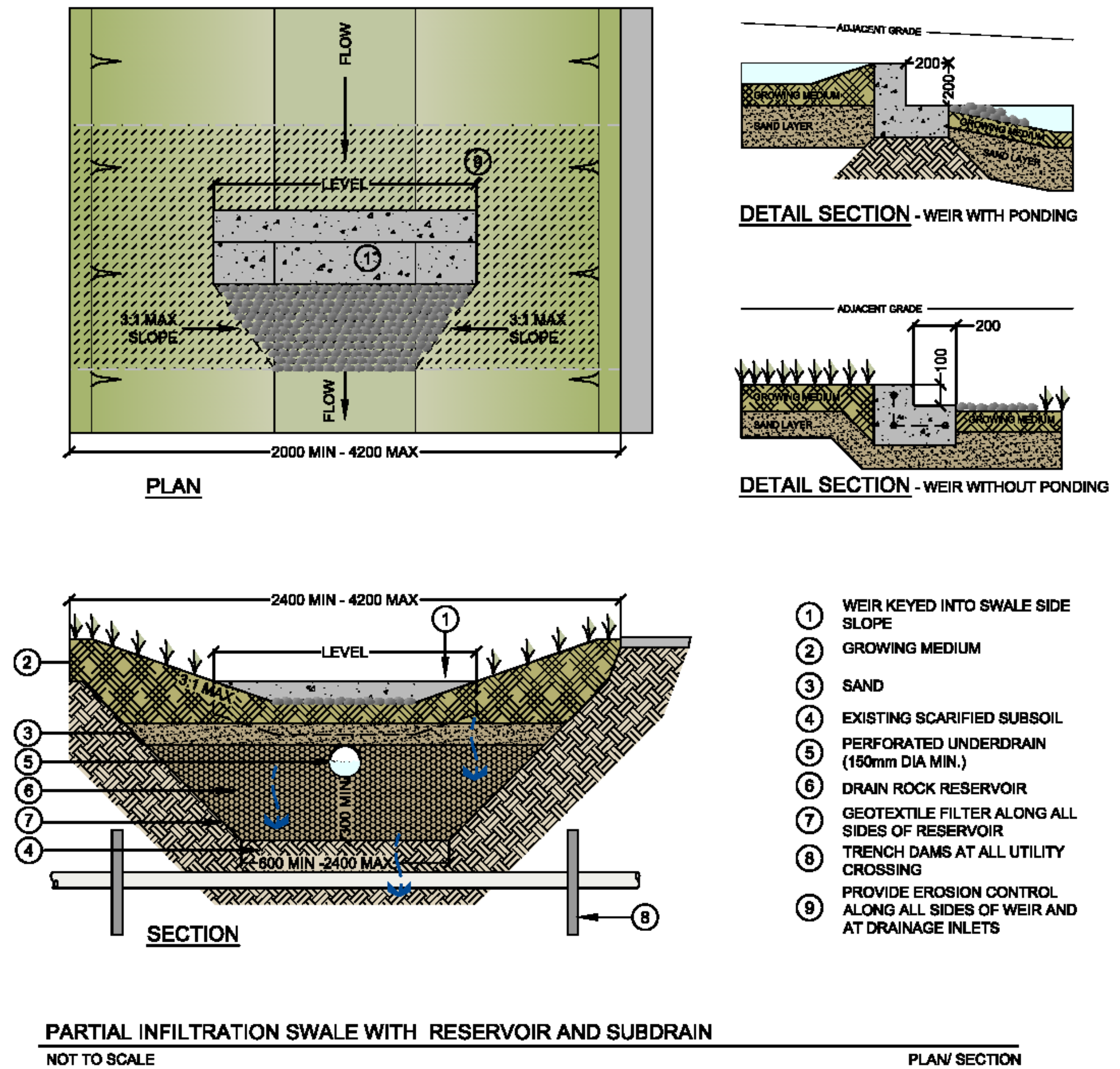


Figure 16 Partial Infiltration Swale with Reservoir and Subdrain (Not to scale, Plan/Section)

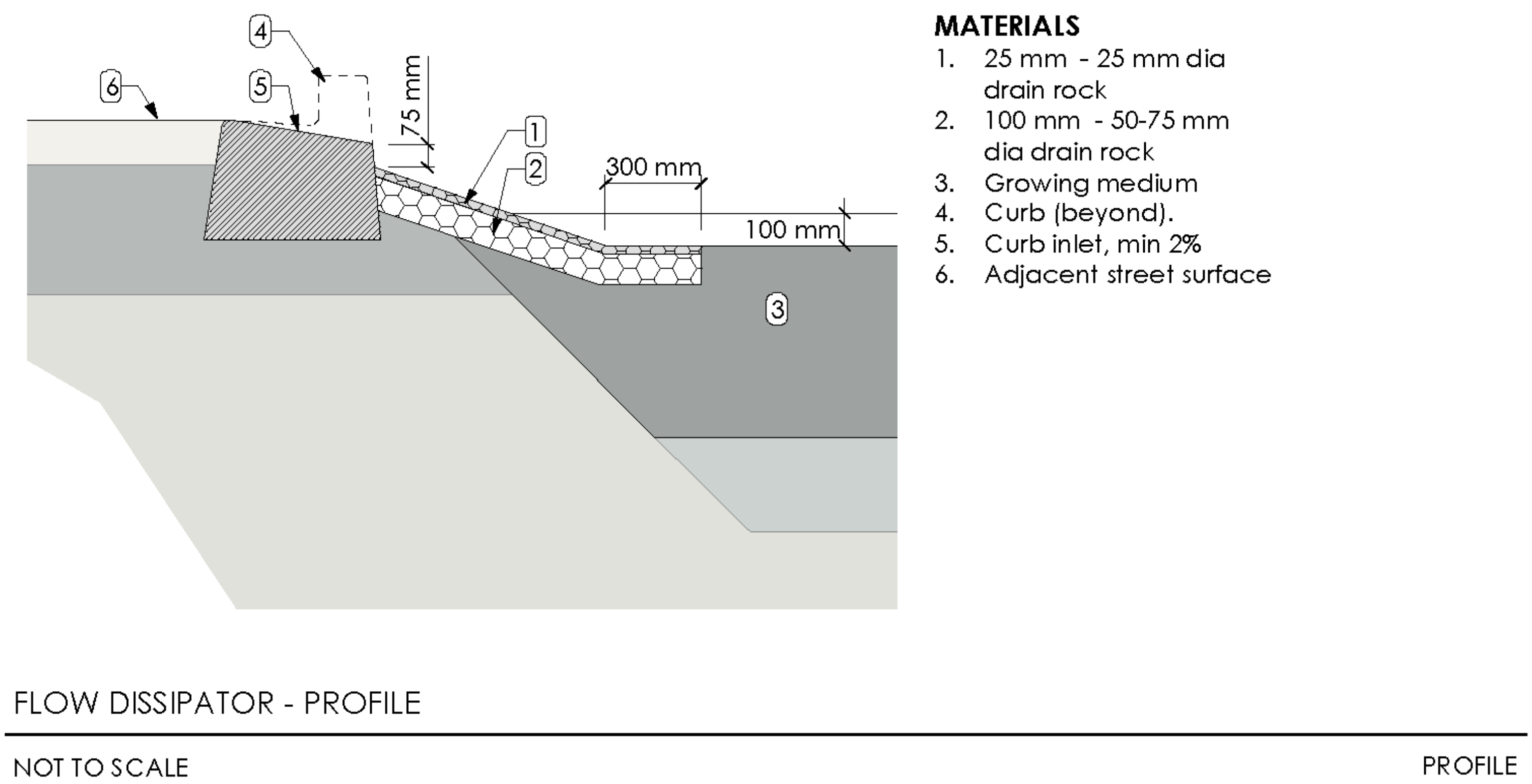
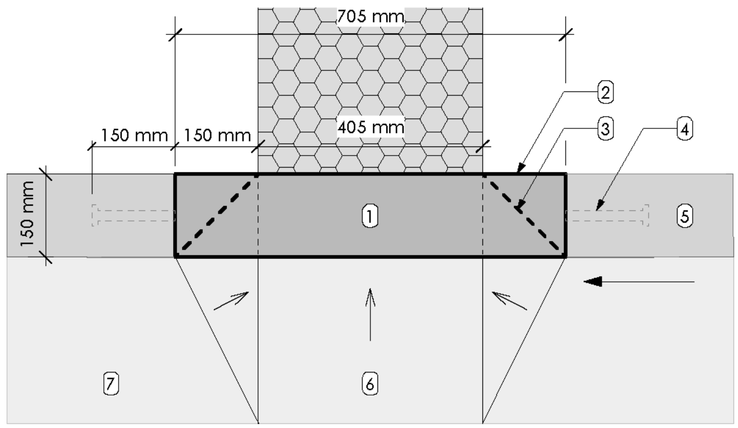


Figure 17 Flow Dissipator Options (Not to scale, Section)[4]

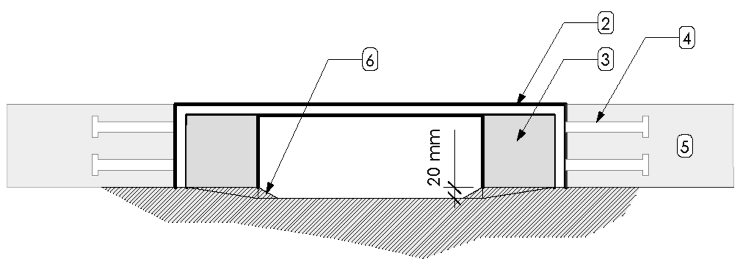
[4] Modified from: District of Saanich Stormwater Management Guidebook (2011, Unpublished Draft), written by Kerr Wood Leidal Associates Ltd. and Murdoch de Greeff Inc.



MATERIALS
1. Steel inlet structure
2. Steel rear wall
3. Steel baffle, angled 45 degrees towards rear wall.
4. Steel anchor, welded to inlet structure (2 each side)
5. Cast in place concrete curb
6. Hand trowel gutter to meet inlet base. Ensure positive drainage towards inlet.
7. Concrete gutter

STEEL CURB INLET

NOT TO SCALE
PLAN

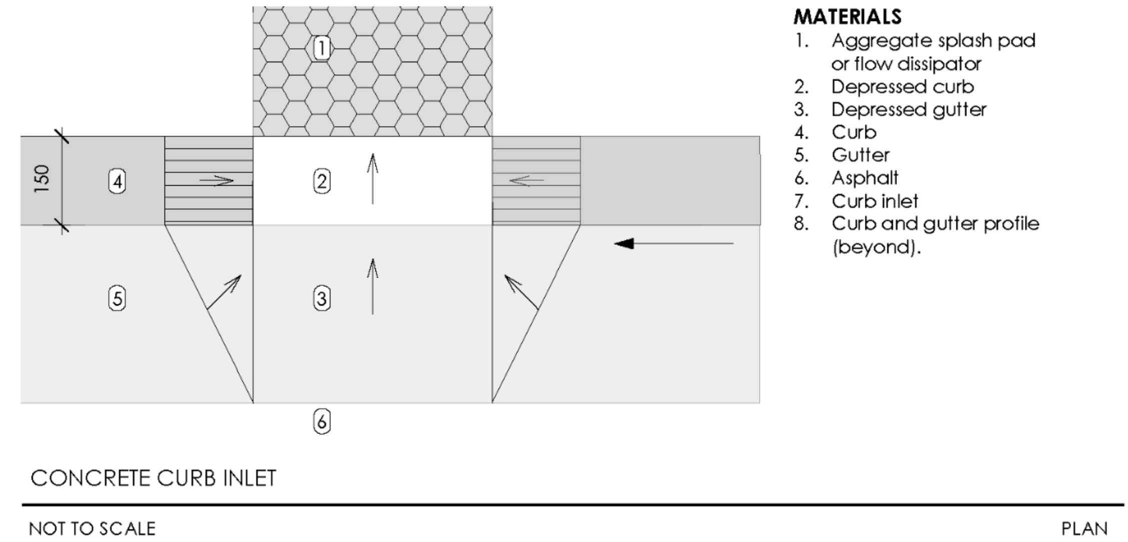


STEEL CURB INLET

NOT TO SCALE
FRONT SECTION/ELEVATION DETAIL

Figure 18 Steel Curb Inlet Option[5]

[5] Modified from: District of Saanich Stormwater Management Guidebook (2011, Unpublished Draft), written by Kerr Wood Leidal Associates Ltd. and Murdoch de Greeff Inc.



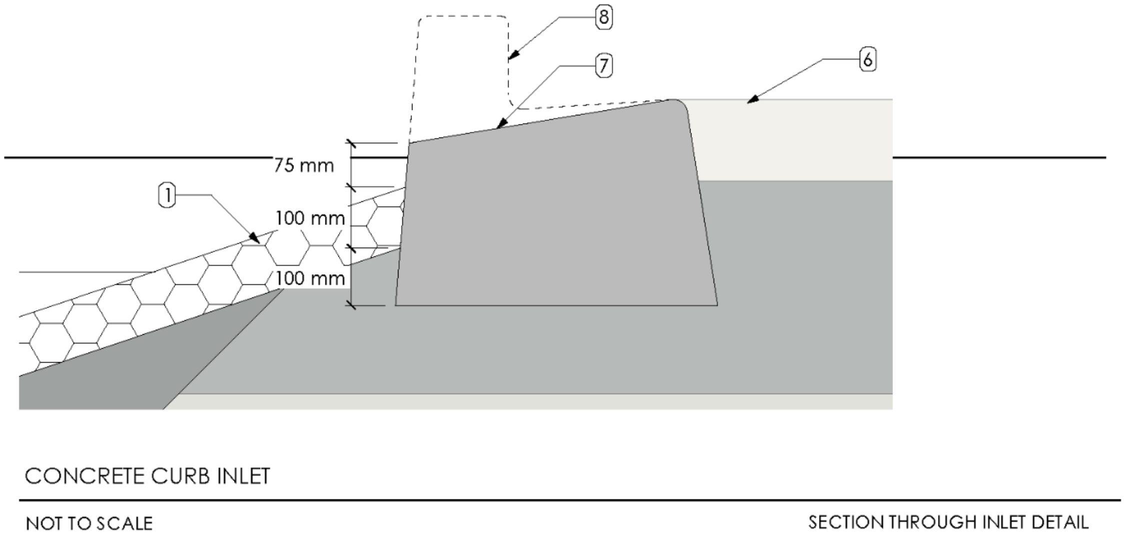


Figure 19 Concrete Curb Inlet Option[6]

[6] Modified from: District of Saanich Stormwater Management Guidebook (2011, Unpublished Draft), written by Kerr Wood Leidal Associates Ltd. and Murdoch de Greeff Inc.