Mature stands
Reduce the building footprint by using taller

7.
The location and configuration of elements, such as streets, sidewalks, driveways, and walkways, needed to service a development. Municipal zoning regulations often require specified setbacks and frontages that are a determinant for the area of pavement, street, driveways, and walkways. These layouts by themselves may not achieve the many goals of urban design. However, used in a hybrid form together or with other street network designs, they provide more ancillary benefits.

Avoid development on permeable soils. Where avoiding development on permeable soils is not possible, stormwater management should focus on mitigation of reduced groundwater infiltration capacity (and treatment capacity) of soils. During construction, natural heritage features and locations where stormwater infiltration practices will be used should be delineated and not subject to construction equipment or other vehicular traffic, nor stockpiling of topsoil.

Preserve areas of undisturbed soil and vegetation cover. Typical construction processes, such as excavation, site grading, and compaction by construction equipment, can considerably reduce the infiltration capacity (and treatment capacity) of soils. During construction, natural heritage features and locations where stormwater infiltration practices will be used should be delineated and not subject to construction equipment or other vehicular traffic, nor stockpiling of topsoil.

3. Avoid development on permeable soils. Highly permeable soils (i.e., hydrologic soil groups A and B) function as important groundwater recharge areas. To the greatest extent possible, these areas should be preserved in an undisturbed condition or set aside for stormwater infiltration practices. Where avoiding development on permeable soils is not possible, stormwater management should focus on mitigation of reduced groundwater infiltration capacity through application of stormwater infiltration practices.

4. Preserve existing trees and shrubs. Mature stands of deciduous trees will intercept 10 to 20% of annual precipitation falling on them and a stand of evergreens will intercept 15 to 40%. Preserving mature trees will provide immediate and long-term benefits. Whereas newly planted trees will take 10 years or more to provide equivalent benefits. These layouts by themselves may not achieve the many goals of urban design. However, used in a hybrid form together or with other street network designs, they provide more ancillary benefits.

6. Use open space or clustered development. Clustering development increases the development density in sensitive areas of the site while leaving the rest of the site as protected community open space. Some features of open space or clustered development are smaller lots, curvilinear streets, and shared driveways, and shared parking. Clustered development also reduces the amount of impervious surfaces and stormwater runoff that will need to be managed, reduces pressure on buffer areas, reduces the construction footprint, and provides more area and options for stormwater controls.

7. Use innovative street network designs. Certain roadway network designs (e.g., loops, cul-de-sacs, frontage roads, frontage roads less important than others. These layouts by themselves may not achieve the many goals of urban design. However, used in a hybrid form together or with other street patterns, they can meet multiple urban design objectives and reduce the necessary green space area thereby reducing the amount of impervious surfaces and stormwater runoff to be managed.

8. Reduce roadway setbacks and lot frontages. The lengths of setbacks and frontages are often a result of both functional pavement, street, driveways, and walkways, needed to service a development. Municipal zoning regulations for setbacks and frontages have been found to be a significant influence on the production of stormwater runoff.

Soil Amendment Guidelines

Soil amendment sizing criteria:

- impervious area / soil area = 1
- use 100 mm compost, till to 300 - 450 mm depth
- impervious area / soil area = 2
- use 200 mm compost, till to 300 - 450 mm depth
- impervious area / soil area = 3
- use 300 mm compost, till to 450 - 600 mm depth

Compacted soil should consist of well-aged (at least one year) leaf compost. Amended soil should have an organic content of 8-15% by weight or 30-40% by volume.

Source: Soils for Salmon, 2005

Using Natural Drainage Systems

Rather than collect and move stormwater rapidly to a centralized location for detention and removal, stormwater management strategies are designed to take advantage of undisturbed vegetated areas and natural drainage patterns (e.g., small headwater drainage features). Using these strategies will extend runoff flow paths and slow down flow of the soils and vegetation, allowing it to seep into and stay in the soil. Using natural systems or green infrastructure is often more cost effective than traditional engineering approaches, and they provide more ancillary benefits.

14. “Disconnect” impervious areas. Road building, modification of street networks, sidewalks, and patios should be disconnected from impervious areas and directed towards stabilized permeable areas as storm water flow paths. In areas of concentration, the use of permeable paving or pavers with a high void content should be used. In places where a high void content is not possible, permeable soil should be placed under the pavement in addition to using unpaved end-of-stall overhangs, setting aside smaller stalls for compact vehicles, and configuring or overlapping common areas like fire lanes, collectors, catch basins, and drop off areas.

- More costly approaches to reducing the parking footprint include parking structures or underground parking.

12. Consider alternative cul-de-sac designs. Using alternatives to the standard 15 metre radius cul-de-sac can further reduce the impervious areas required to service each dwelling. Ways to reduce the impervious areas of cul-de-sacs include a landscaped or bioretention centre island, T-shaped turnaround, or by using a loop road instead.

13. Eliminate unnecessary streets and driveways. A flexible design standard for sidewalks is recommended to allow for unnecessary sidewalks to be eliminated. Sidewalks that are not needed for pedestrian circulation or connectivity should be removed. Often sidewalks are only necessary on one side of the street. Driveways where impervious area can be reduced through the use of shared driveways or alley accessed garages.

Using Drainage Open Applied in a Medium Density Neighborhood

Open Drainage Applied in a Medium Density Neighborhood

CVC/TRCA LOW IMPACT DEVELOPMENT SITE DESIGN GUIDELINES - FACT SHEET
GENERAL DESCRIPTION
Rainwater harvesting systems are designed to capture, store, and treat rainwater for future use. The systems are typically found on roofs, eaves, or in-ground gutters, allowing rainwater to be captured and directed into a storage tank. The tank serves as a reservoir for treated rainwater, which can then be used for various purposes, such as irrigation, toilet flushing, or other non-potable uses. This helps to delay expansion of treatment and distribution systems, reduce water usage, and improve water conservation.

CATCHMENT AREA
The catchment area is the surface area from which rainfall is collected. Generally, roofs are the catchment area, as this helps to capture rainwater from low-flow parking lots and rain gardens. The size of the catchment area may vary depending on the type of setting, such as a commercial or residential area. The quality of the harvested water will vary according to the type of catchment area and material from which it is constructed.

COLLECTION AND CONVEYANCE SYSTEM
The collection and conveyance system consists of the eaves, downspouts, and pipe that channel rainwater into the storage tank. Eaves, downspouts, and gutters should be designed with screens to prevent large debris from entering the storage tank. For dual-use systems (used for both outdoor and indoor use), the conveying system leading to the catchment should be buried at a depth no less than the local maximum frost penetration depth and have a minimum 1% slope. If this is not possible, conveyance pipes should be located in a heated indoor environment (e.g., garage).

PRE-TREATMENT
Pre-treatment is needed to remove debris, dust, debris, and other contaminants that may affect the performance of the rainwater harvesting system. For dual-use systems with supply water for irrigation and toilet flushing, only rainwater on the first flush diverter is recommended. For rainwater harvesting systems designed only for outdoor uses, filtration or first-flush diversion treatment is recommended. To prevent mosquito breeding, first-flush diveters or in-ground Screens should be placed on inlets above-ground systems should be disconnected and drained. For below-ground systems, downspouts and overflow components should be checked and cleaned regularly inspections every six months during the spring and fall seasons to keep leaf and mosquito screens (1 mm mesh size). The swimming pool and any associated filtration (including ponds) should be screened to prevent small animals and insects from entering the storage tank.

STORAGE TANKS
The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. The size of the storage tank is determined by several variables: rainfall and snowfall frequencies and totals, the capacity of the conveyance pipe, ground frost penetration depth or indoors, the type of growth to be treated, the size and budget. In the Greater Toronto Area, an initial target for sizing the storage tank is determined by the following factors:

- The size of the storage tank is determined during the design calculations.
- The storage tank is the most important and typically the most expensive component of a rainwater harvesting system.
- The storage tank is designed to hold the collected rainwater and distribute it to the points of use.
- The size of the storage tank is determined by the volume of collected rainwater and the system's needs.

OPERATION AND MAINTENANCE
Maintenance requirements for rainwater harvesting systems vary according to use. Systems designed for indoor use have higher maintenance requirements than those designed for outdoor use. For dual-use systems designed for both indoor and outdoor use, maintenance requirements should be higher than those for systems designed for indoor use only. The maintenance tasks include:

- Regular inspections every six months during the spring and fall seasons to keep leaf and mosquito screens (1 mm mesh size).
- First-flush diverter maintenance to prevent contamination with debris, dirt, and other contaminants.
- Cleaning and maintaining first-flush diveters and filters, especially in systems where native soils or building materials are used.
- Cleaning and maintaining eaves, downspouts, and gutters to prevent clogging and contamination.
- Cleaning and maintaining storage tanks to prevent contamination.
- Cleaning and maintaining conveyance pipes to prevent clogging and contamination.
- Cleaning and maintaining overflow components to prevent contamination.

MOSQUITO CONTROL
If screening is not sufficient to deter mosquitoes, vegetable oil can be used to treat the water, but systems require installation of barrier screens to prevent entry.

WINTER OPERATION
Rainwater harvesting systems have a number of components that can be affected by freezing temperatures. For above-ground systems, winter operation requires the following steps to prevent damage:

- Prior to the start of freezing temperature, the above-ground systems should be disconnected and drained.
- For below-ground and indoor systems, downstreams and overflow components should be checked for frost heave during snowmelt events.

SITE CONSIDERATIONS
Storage tanks can be placed underground in areas adjacent to buildings on non-potable water uses such as irrigation and toilet flushing due to potential for contamination with toxic compounds.
GENERAL DESCRIPTION
Green roofs, also known as "living roofs" or "roof gardens", consist of a thin layer of vegetation and growing medium installed on top of a conventional flat or sloped roof. Green roofs are protected for their beauty, as they improve energy efficiency, reduce urban heat island effects, and create habitats for passive recreation or aesthetic enjoyment. They are also attractive for their water quality, water balance, and air flow control benefits. The green roof acts like a lawn or meadow by storing rainwater in the growing medium and ponding at the desired ponding elevation. Alternately, roof drain flow restrictors can be used. Excess runoff can be directed through roof leaders to another stormwater BMP such as a rain barrel, soakaway, bioretention area, or storm sewer. They can also reduce energy demand by as much as 75%, and may be subject to a legally binding maintenance agreement. An incentive program such as a storm sewer user fee based on the area of impervious coverage.

CONSTRUCTION CONSIDERATIONS
An experienced professional green roof installer is needed. The installer must work with the construction contractor to design and build a green roof assembly that is appropriate for the specific roof type. A green roof assembly should be constructed in sections for easier inspection and maintenance access to the roof drainage system. Green roofs can be purchased at competitive prices from specialized suppliers who distribute all the assembly components, including the waterproofing membrane. Alternatively, a green roof designer can design a custom green roof and specify suppliers for each component of the system.

SITE CONSIDERATIONS
Green roofs may be installed on rooftops with slopes up to 10%. During installation, care should be taken to avoid damage to the roof structure and selected building components, including the waterproofing, insulation, and structural support. Excess runoff from the green roof should be directed to other stormwater BMPs such as rain barrels, soakaways, or bioretention areas to prevent water damage to the roof structure. An incentive program such as a storm sewer user fee based on the area of impervious coverage can also be used to support the weight of the soil, vegetation, and accumulated water on the roof surface. A green roof may be installed under a green roof assembly. Conventional membrane installed is appropriate for use under a green roof assembly. Green roofs should be constructed in sections for easier inspection and maintenance access to the roof drainage system. Green roofs can be purchased at competitive prices from specialized suppliers who distribute all the assembly components, including the waterproofing membrane.

COST
As an incentive to determine cost effectiveness for a given site should include the roof lifespan, energy savings, stormwater management requirements, aesthetics, market value, tax and other municipal incentives. It is important to note that green roofs can extend the life of a roof structure by as long as 25 years by reducing exposure of the materials to sun and precipitation. They can also reduce energy demand by as much as 70%.

Aesthetic
Green roofs can be used to support the weight of the soil, vegetation, and accumulated water on the roof surface. They can be used to support sustainable, concrete pavers, etc.

Vegetation
Green roofs are designed to support a variety of plant species, including grasses, perennials, and annuals. They can also be used to support a variety of plant species, including grasses, perennials, and annuals.
GENERAL DESCRIPTION
Simple downspout disconnection involves directing flow from roof downspouts to a pervious area that drains away from the building. This prevents stormwater from directly entering the storm sewer system or flowing across a "connected" impervious surface, such as a driveway, that drains to a storm sewer. Simple downspout disconnection requires a minimum flow path length across the pervious area of 5 metres.

DESIGN GUIDANCE
Roof downspout disconnections should meet the following criteria:
- Pervious areas used for downspout disconnection should be graded to have a slope of between 1 to 5%.
- Pervious areas should slope away from the building.
- The flow path length across the pervious area should be 5 metres or greater.
- The infiltration rate of soils in the pervious area should be 15 mm/hr or greater (i.e. hydraulic conductivity of 1x10⁻⁶ cm/s or greater).
- If infiltration rate of the soil in the pervious area is less than 15 mm/hr, it should be tilled to a depth of 300 mm and amended with compost to achieve a ratio of 8 to 15% organic content by weight or 30 to 40% by volume.
- If the flow path length across the pervious area is less than 5 metres and the soils are hydrologic soil group C or D, roof runoff should be directed to another LID practice (e.g. rainwater harvesting system, bioretention area, soakaway, aerated or perforated pipe system).
- The total roof area contributing drainage to any single downspout discharge location should not exceed 100 square metres, and:
  - A level spreading device (e.g., pea gravel diaphragm) or energy dissipating device (e.g., splash pad) should be placed at the downspout discharge location to distribute runoff as evenly as possible over the pervious area.

APPLICATIONS
There are many options for keeping roof runoff out of the storm sewer system. Some of the options are as follows:
- Simple roof downspout disconnection to a pervious area or vegetated filter strip, where sufficient flow path length across the pervious area and suitable soil conditions exist;
- Downspout disconnection to a pervious area or vegetated filter strip that has been tailored and amended with compost to improve soil infiltration rate and moisture storage capacity;
- Directing roof runoff to an enhanced grass swale, dry swale, bioretention area, soakaway or perforated pipe system;
- Directing roof runoff to a rainwater harvesting system (e.g., rain barrel or cistern) with overflow to a pervious area, vegetated filter strip, dry swale, bioretention area, soakaway or permeable pavement.

CONSTRUCTION CONSIDERATIONS
SOIL DISTURBANCE AND COMPACTION
Only vehicular traffic necessary for construction should be allowed on the pervious area to which roof downspouts will be discharged. If vehicle traffic is unavoidable, then the pervious area should be tilted to a depth of 300 mm to loosen the compacted soil.

EROSION AND SEDIMENT CONTROL
If possible, construction of a pervious area should be directed away from the proposed downspout discharge location. After the contributing drainage area and the downspout discharge location are stabilized and vegetated, erosion and sediment control structures can be removed.

ABILITY TO MEET SWM OBJECTIVES

<table>
<thead>
<tr>
<th>BMP</th>
<th>Water Balance Benefit</th>
<th>Water Quality Improvement</th>
<th>Stream Channel Erosion Control Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downspout Disconnection</td>
<td>Partial – depends on soil infiltration rate and length of flow path over the pervious area</td>
<td>Partial – depends on soil infiltration rate and length of flow path over the pervious area</td>
<td>Partial depends on combination with other practices</td>
</tr>
</tbody>
</table>

Downspout disconnection is primarily a practice used to help achieve water balance benefits, although it can also contribute to water quality improvement. Very limited research has been conducted on the runoff reduction benefits of downspout disconnection, so initial estimates are drawn from research on filter strips, which operate in a similar manner. The research indicates that runoff reduction is a function of soil type, slope, vegetative cover and filtering distance. A conservative runoff reduction rate is 25% for hydrologic soil group (HSG) C and D soils and 50% for HSG A and B soils.

OVERVIEW

OPERATION AND MAINTENANCE
Maintenance of disconnected downspouts will generally be no different than for lawns or landscaped areas. Maintenance agreements with property owners or managers to maintain existing practices.

SITE CONSIDERATIONS

COMMON CONCERNS

ON PRIVATE PROPERTY
Property owners or managers will need to be educated on its function and maintenance needs, and may be subject to a legally binding maintenance agreement. An incentive program such as a storm sewer user fee based on the area of impervious cover or a property that is directly connected to a storm sewer could be used to encourage property owners or managers to maintain existing practices.

STANDING WATER AND POLY, AGRICULTURE
Downspout disconnection is not intended to replace water to any standing water that should be infiltrated or removed within 24 hours of the end of each runoff event. If ponding for longer than 24 hours occurs, mitigation actions noted under Operation and Maintenance should be undertaken.

FOR FURTHER DETAILS SEE SECTION 4.3 OF THE CVC/TRCA LID SWM GUIDE

CVC/TC/GALOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET
GENERAL DESCRIPTION
Soakaways are rectangular trenches lined with geosynthetic fabric and filled with clean granular stone or other void forming material that receives runoff from a perforated pipe inlet and allows it to infiltrate into the underlying native soil. Structures typically have open bottoms, perforated side walls and optional underlying granular stone reservoirs. They can be installed individually or in匆匆 spaced configurations. They can also be referred to as infiltration galleries or linear soakaways.

Infiltration chambers are another design variation on soakaways. They include a range of proprietary manufactured modular structures installed underground, typically under parking or landscaped areas that create large void spaces for temporary storage of stormwater, allowing it to infiltrate into the underlying native soil. Structures typically have open bottoms, perforated side walls and optional underlying granular stone reservoirs. They can be installed individually or in匆匆 spaced configurations. They can also be referred to as infiltration galleries or linear soakaways.

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DESIGN GUIDANCE

• MOISTURIZING WELLS
  Capped vertical non-perforated pipes connected to the inlet and outlet of soakaways are recommended to provide a means of moisturizing and flushing them out as part of routine maintenance. A capped vertical standpipe consisting of an anchored 100 to 150 mm diameter perforated pipe with a turf cap installed to the top of the facility is also recommended for monitoring the length of time required to fully drain the facility between maintenance. Monitoring and inspection pipes should be installed in infiltration chambers to provide access for monitoring and maintenance activities.

• PRE-TREATMENT
  It is important to prevent sediment and debris from entering infiltration facilities because they could contribute to clogging and failure of the system. The following pretreatment devices are options:

  • Leaf screens. Leaf screens are mesh screens installed either on the building eavestroughs or roof downspouts and are used to remove leaves and other large debris from runoff.

  • In-ground devices. Devices placed between a conveyance pipe and the facility (e.g., oil and grit separators, sedimentation chamber or goss filters). These can be installed to remove both large and fine particulates from runoff. A number of proprietary stormwater filter devices are available.

  • Vegetated filter strips or grass swales. Road and parking lot runoff can be protected with vegetated filter strips or grass swales prior to entering the infiltration practice.

• FILTER MEDIA
  • Stone reservoir. Soakaways and infiltration chambers should be filled with uniformly graded, washed stone that provides 30 to 40% void space. Granular material should be 50 mm clear stone.
  • Geostat. A non-woven needle punched or woven monofilament geosynthetic fabric should be installed around the stone reservoir of soakaways and infiltration chambers to prevent migration of non-woven fabrics, or percent open area (POA) for woven fabrics, which over 1-50% to allow for water flow. Other factors that need consideration include maximum forces to be exerted on the fabric, and the load bearing capacity, textural (e.g., grain size distribution) and permeability of the native soil in which they will be installed.

ABILITY TO MEET SWM OBJECTIVES

<table>
<thead>
<tr>
<th>BMP</th>
<th>Water Balance Benefit</th>
<th>Water Quality Improvement</th>
<th>Stream Channel Erosion Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soakaways, Infiltration Trenches and Chambers</td>
<td>Yes</td>
<td>Yes</td>
<td>Partial, depends on soil infiltration rate</td>
</tr>
</tbody>
</table>

CONSTRUCTION CONSIDERATIONS

SOIL DISTURBANCE AND COMPACTATION: Before site work begins, locations of facilities should be reviewed with building owners or managers to maintain existing practices. Alternatively, infiltration practices should be considered in portions of the site with the highest runoff generation. Designers should verify the soil in the site area meets the compaction and flow through depth under field measured water infiltration or conductivity under field saturated conditions.

MONITORING WELLS
• Monitoring wells are recommended to provide a means of inspecting and flushing the facility area ratio of between 5:1 pervious drainage area to treatment area.
  • Monitoring and inspection wells should be installed in infiltration chambers to provide access for monitoring and maintenance activities.

MONITORING WELLS
• Monitoring wells are recommended to provide a means of inspecting and flushing the facility area ratio of between 5:1 pervious drainage area to treatment area.
  • Monitoring and inspection wells should be installed in infiltration chambers to provide access for monitoring and maintenance activities.

PARTICLE SIZE DISTRIBUTION
The effectiveness of infiltration practices is dependent on the particle size distribution of the native soil in which they will be installed. High clay soils are not recommended because they can contribute to clogging of infiltration structures. The particle size distribution of the native soil should be determined by a soil survey or using field test procedures. The soil should be tested for its ability to infiltrate at least 100 mm of water per hour under field saturated conditions.

SITE CONSIDERATIONS

Wellhead Protection
Facilities receiving road or parking lot runoff should be located within two (2) years of travel without protection areas.

Sewer User Fee
• Facilities cannot be located on natural strips greater than 15%.
• The bottom of the facility should be between two and five times the depth above the ground surface.

Soil Erosion
Soakaways, infiltration trenches and chambers can be constructed over any soil type, but hydraulic conductivity of the soil should be considered in the selection of the device. Designers should verify the soil in the site area meets the compaction and flow through depth under field measured water infiltration or conductivity under field saturated conditions.

INFILTRATION CHAMBER SYSTEM UNDER A PARKING LOT

CONSIDERATIONS

Soil Erosion Control
Infiltation practices should be considered in portions of the site with the highest runoff generation. Designers should verify the soil in the site area meets the compaction and flow through depth under field measured water infiltration or conductivity under field saturated conditions.

MONITORING WELLS
• Monitoring wells are recommended to provide a means of inspecting and flushing the facility area ratio of between 5:1 pervious drainage area to treatment area.
  • Monitoring and inspection wells should be installed in infiltration chambers to provide access for monitoring and maintenance activities.

Soil Erosion Control
Infiltation practices should be considered in portions of the site with the highest runoff generation. Designers should verify the soil in the site area meets the compaction and flow through depth under field measured water infiltration or conductivity under field saturated conditions.
### GENERAL DESCRIPTION

As a stormwater filter and infiltration practice, bioretention temporarily stores, treats and infiltrates runoff. Depending on native soil infiltration rate and physical constraints, the facility may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain (filtration only, i.e. a biobarrel). The primary component of the practice is the filter bed which is a mixture of soil, fines and organic materials. Other filter elements include multi-grid growing areas and plants adapted to the conditions of a stormwater practice. Bioretention is designed to manage small storm events to the same quality as a storm drain system. An overflow is necessary to pass large storm event flows. Bioretention can be adapted to fit many different development contexts and can provide a convenient area for snow storage and treatment.

### DESIGN GUIDANCE

#### SOIL CHARACTERISTICS

Bioretention can be constructed on any soil type, but hydric soil group A and B or fine to sandy soils are preferred. Bioretention should be sited in the areas of the development with the highest native soil infiltration rates.

**Water Balance**

Suitable for small bioretention systems when it is necessary to infiltrate runoff. Depending on native soil infiltration rate and physical constraints, the facility may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain (filtration only, i.e. a biobarrel). The primary component of the practice is the filter bed which is a mixture of soil, fines and organic materials. Other filter elements include multi-grid growing areas and plants adapted to the conditions of a stormwater practice. Bioretention is designed to manage small storm events to the same quality as a storm drain system. An overflow is necessary to pass large storm event flows. Bioretention can be adapted to fit many different development contexts and can provide a convenient area for snow storage and treatment.

### GEOMETRY & SITE LAYOUT

Key Bioretention Design Parameters

- **Minimum footprint of the filter bed area is the drainage area.**
- **Typical drainage areas to bioretention are between 100 m2 to 0.5 hectares.**
- **Maximum recommended drainage area is 1.3 hectares.**
- **Infiltration rate location and depth should be confirmed through measurement of hydraulic conductivity.**
- **Typical drainage areas to bioretention are between 100 m2 to 0.5 hectares.**
- **Bioretention can be designed for full or partial infiltration. Facilities designed for full infiltration are not recommended.**
- **SWM Planning and Design Guide, Table 4.5.5.**

### GENERAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter Media Soil Mixture to contain:</td>
<td>1.0 to 1.25 metres</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 85 to 95% sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 8 to 12% soil fines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 3 to 5% organic matter (leaf compost)</td>
<td></td>
</tr>
<tr>
<td>Other Crisp</td>
<td>- Phosphorus soil test Index (Pb-value) between 10-30 ppm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Cationic exchange capacity (CEC) greater than 10 meq/100g</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Fine of stones, stumps, and other large debris</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- pe between 5 to 7.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Infiltration rate greater than 25 mm/hr</td>
<td></td>
</tr>
</tbody>
</table>

### CONSTRUCTION CONSIDERATIONS

Ideally, bioretention sites should remain outside the limit of disturbance until construction of the bioretention facility is completed. Bioretention is considered to be a sediment trap for small events and can be designed to accommodate large events. Overflow points should be designed to divert stormwater from the facility to prevent erosion and also to reduce the impact on the bioretention area. Overflow points should be designed to divert stormwater from the facility to prevent erosion and also to reduce the impact on the bioretention area.

### OPERATION AND MAINTENANCE

Bioretention requires routine inspection and maintenance of the landscape as well as periodic inspection for less frequent maintenance or remediation. Generally, routine maintenance should be conducted on a quarterly basis, while more frequent inspections are recommended for the first year after construction. Facilities should be inspected at least every other year to determine if the facility still meets the intended goals. Facilities should be inspected at least every other year to determine if the facility still meets the intended goals. Facilities should be inspected at least every other year to determine if the facility still meets the intended goals.

### SITE CONSIDERATIONS

- **Pollution Hot Spot Runoff**
  - To protect groundwater from possible contamination, storm drains should not enter bioretention.
  - Bioretention should not be used as sediment basins during construction, as the concentration of fines will prevent infiltration of runoff. The facility should be designed to convey runoff to a storm drain or other method of conveyance and the availability of space include:
- **Bioretention in soils with infiltration rates less than 15 mm/hr will require an underdrain.**
  - For further guidance see CYC/CTVC LID SWM Planning and Design Guide, Section 4.5.2 - Construction Considerations.

### ABILITY TO MEET SWM OBJECTIVES

<table>
<thead>
<tr>
<th>IMP</th>
<th>Water Balance</th>
<th>Water Quality Improvement</th>
<th>Stream Channel Erosion Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope with no underdrain</td>
<td>Yes</td>
<td>Yes</td>
<td>Partial based on available storage and soil infiltration rate</td>
</tr>
<tr>
<td>Slope with underdrain</td>
<td>Partial based on available storage and soil infiltration rate</td>
<td>Yes</td>
<td>Partial based on available storage and soil infiltration rate</td>
</tr>
<tr>
<td>Slope with underdrain and impermeable filter</td>
<td>Partial</td>
<td>Partial</td>
<td>Partial</td>
</tr>
</tbody>
</table>

### UNDERDRAIN

- Only needed where native soil infiltration rate is less than 15 mm/hr (hydraulic conductivity of less than 0.006).  
- Should consist of perforated pipe embedded in the coarse gravel storage layer at least 100 mm below the filter bed.
- A strip of geotextile filter fabric placed between the filter media and pea gravel shall protect the perforated pipe to prevent fine wastewater particles from entering the underdrain.
- A vertical stream connected to the underdrain can be used as a cleanout and monitoring well.

### MONITORING WELLS

A properly sized soil sample consisting of an anchored 100 to 150 mm diameter perforated pipe with a lockable cap installed to the bottom of the facility is recommended for monitoring drainage between storms times.  

### GENERAL DESCRIPTION

As a stormwater filter and infiltration practice, bioretention temporarily stores, treats and infiltrates runoff. Depending on native soil infiltration rate and physical constraints, the facility may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain (filtration only, i.e. a biobarrel). The primary component of the practice is the filter bed which is a mixture of soil, fines and organic materials. Other filter elements include multi-grid growing areas and plants adapted to the conditions of a stormwater practice. Bioretention is designed to manage small storm events to the same quality as a storm drain system. An overflow is necessary to pass large storm event flows. Bioretention can be adapted to fit many different development contexts and can provide a convenient area for snow storage and treatment.
GENERAL DESCRIPTION

Vegetated filter strips (e.g., buffer strips and grassed filter strips) are gently sloping, densely vegetated areas that treat runoff as sheet flow from adjacent impervious areas. They allow runoff velocity and filter out sediment and associated pollutants, and provide some infiltration into underlying soils. Originally used as an agricultural treatment practice, filter strips have evolved into an urban SWM practice. Vegetation may be comprised of a variety of trees, shrubs, and native plants, each with aesthetic value as well as water quality benefits. With proper design and maintenance, filter strips can provide relatively high pollutant removal benefits. Maintaining sheet flow into the filter strip through the use of a level spreading device (e.g., pea gravel diaphragm) is essential. Using vegetated filter strips as pretreatment practices to other best management practices is highly recommended. They also provide a convenient area for snow storage and treatment, and are particularly valuable due to their capacity for snowmelt infiltration.

DESIGN GUIDANCE

GEOMETRY AND SITE PLANNING

The maximum contributing flow path length across adjacent impervious surfaces should not exceed 25 metres. The impervious areas draining to a filter strip should not have slopes greater than 3%. The filter strip should have a flow path length of at least five (5) metres to provide substantial water quality benefits; however, some pollutant removal benefits are realized with three (3) metres of flow path length.

PRETREATMENT

A pea gravel diaphragm at the top of the slope is recommended to act as a pretreatment device and level spreader to maintain sheet flow into the filter strip.

CONVEYANCE AND OVERFLOW

Level spreaders are recommended to ensure runoff draining into the filter strip does so as sheet flow (e.g., pea gravel diaphragms, concrete curbs with curbing). When filter strip areas are greater than 5%, a series of level spreaders should be used to help maintain sheet flow.

When designed as a stand-alone water quality BMP (i.e., not pretreatment to another BMP), the vegetated filter strip should be designed with a pervious berm at the toe of the slope for shallow ponding of runoff. The berm should be 150 to 300 millimetres in height above the bottom of the depression and should contain a perforated pipe drain, which is connected to the storm sewer. The volume ponded behind the berm should be equal to the water quality storage requirements. During larger storms, runoff overtops the berm and flows directly into a storm sewer Claire.

SOIL AMENDMENTS

If soils on the filter strip site are highly compacted, or of such low fertility that vegetation cannot become established, they should be tilled to a depth of 300 mm and amended with compost to achieve an organic content of 8% to 15% by weight or 30 to 40% by volume.

OPERATION AND MAINTENANCE

Generally, routine maintenance will be the same for any other landscaped area, weeding, pruning, and filter removal. Regular watering may be required during the first two years until vegetation is established. Routine inspection is very important to ensure that dense vegetation cover is maintained and following runoff does not become concentrated and short circuit the practice. Vegetation should not be parted or driven on filter strips. For routine mowing of grassed filter strips, the lightest possible mowing equipment should be used to prevent soil compaction.

For the first two years following construction, the filter strip should be inspected at least quarterly and after each major storm event (> 25 mm). Subsequently, inspections should be conducted in the spring and fall of each year and after major storm events. Inspect for vegetation density (at least 80% coverage), damage by foot or vehicular traffic, channelization, accumulation of debris, trash and sediments, and structural damage to pretreatment devices.

Trash and debris should be removed from pretreatment devices and the filter strip surface at least twice annually. Other maintenance activities include weeding, replacing dead vegetation, repairing eroded areas, detaching and adjusting curbs, applying fertilizers to the filter strip surface when dry and exceeding 25 mm depth.

VEGETATED FILTER STRIPS

CONSTRUCTION CONSIDERATIONS

Soil Disturbance and Compaction

The limits of disturbance should be clearly shown on all construction drawings. Before site work begins, areas for filter strips should be clearly marked and protected by acceptable signage and turf fencing. Only vehicular traffic for construction should be allowed within three metres of the filter strip.

Erosion and Sediment Control

Construction runoff should be directed away from the proposed filter strip through the use of a level spreading device (e.g., pea gravel diaphragm) to prevent soil compaction.

SITE CONSIDERATIONS

Available Space

The flow path length across the vegetated filter strip should be at least 5 metres to provide substantial water quality benefits. Vegetated filter strips incorporated as pretreatment to another BMP may be designed with shorter flow path lengths.

Site Topography

Filter strips are best used to treat runoff from ground-level impervious surfaces that generate sheet flow (e.g., roads and parking areas). The recommended filter strip slope is between 1 to 5%.

Flow Path Length Across Impermeable Surface

The maximum flow path length across the contributing impermeable surface should be less than 25 metres.

Filter Strips are a suitable practice on all soil types. If soils are rocky, if used for sediment control, or of such low fertility that vegetation cannot be established, they should be amended to a depth of 300 mm and amended with compost to achieve an organic content of 8% to 15% by weight or 30 to 40% by volume.

Pollution Hot Spot Runoff

To protect groundwater from pollution, especially during storms when land uses or human activities have the potential to generate highly contaminated runoff (e.g., vehicle fueling, servicing and demolition areas, sudden runoff and handling areas for hazardous materials), low-traffic activity areas with heavy pedestrian traffic should not be treated by vegetated filter strips.

Water table

Filter strips should only be used where depth to the water table (i.e., high water table at least one (1) metre below the ground surface).
GENERAL DESCRIPTION
Permeable pavement, an alternative to conventional pavement, allow stormwater to drain through the pavement and into a stone reservoir where it is infiltrated into the underlying native soil or temporarily detained. It can be used for low traffic roads, parking lots, driveways, pedestrian plazas and walkways. Permeable pavement is ideal when there is an impermeable liner and underdrain for a no infiltration or detention only application.

GEOMETRY & SITE LAYOUT

Permeable pavement systems can be used for entire parking lot areas or drive lanes. Site layout is determined by traffic volumes and stormwater considerations. For example, the parking spaces of a parking lot or road can be permeable pavements while the driveways and sidewalks are impermeable asphalt pavement. Typically, the permeable area should comprise 70% or less of the area of the permeable pavement that receives the runoff (GVRD, 2006).

SITE TREATMENT
In most permeable pavement designs, the pavement building layer acts as a reservoir to store stormwater. In regions of intense precipitation, protective measures like not starting snow or other materials on the pavement is critical to ensure that the runoff does not percolate through the pavement above the surface. Another design option is an open gravel, which has a slightly greater ability to infiltrate than a closed gravel reservoir.

CONVEYANCE AND OVERFLOW
All designs require an impermeable liner to be installed to a storm drain with capacity to convey larger storms. One option is to set storm drain pipe alongside the roadway to convey water to a stone reservoir where it is infiltrated into the underlying soil.

STONE RESERVOIR
The stone reservoir must be designed to maintain both runoff storage and structural support requirements. Drainage Area & Runoff Volume calculations are recommended for determining the length of time required to fully drain the backing between storms.

CONSTRUCTION

PERMEABLE PAVEMENT

The stone reservoir should be installed between the stone reservoir and permeable pavement. The reservoir should be full for a maximum of 50% of its total volume.

STONE RESERVOIR

The stone reservoir should be full for a maximum of 50% of its total volume.

SITING

Permeable pavement should be situated on native soil or temporarily detained. They can be used for low traffic roads or parking lots, driveways, pedestrian plazas and walkways. Permeable pavement is ideal when there is an impermeable liner and underdrain for a no infiltration or detention only application.

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PERMEABLE PAVEMENT

The stone reservoir should be installed between the stone reservoir and permeable pavement. The reservoir should be full for a maximum of 50% of its total volume.

STONE RESERVOIR

The stone reservoir should be full for a maximum of 50% of its total volume.

SITING

Permeable pavement should be situated on native soil or temporarily detained. They can be used for low traffic roads or parking lots, driveways, pedestrian plazas and walkways. Permeable pavement is ideal when there is an impermeable liner and underdrain for a no infiltration or detention only application.
GENERAL DESCRIPTION

Enhanced grass swales are vegetated open channels designed to convey, treat and attenuate stormwater runoff (also referred to as enhanced vegetated swales). Check dams and vegetation in the swale slows the water to allow sedimentation, filtration through the root zone and soil matrix, evapotranspiration, and infiltration into the underlying native soil. Simple grass swales or ditches have long been used for stormwater conveyance, particularly for roadway drainage. Enhanced grass 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 roadbed ditch designs.

Where development density, topography and depth to water table permit, enhanced grass swales are a preferred alternative to both curb and gutter and storm drains as a stormwater conveyance system. When incorporated into a site design, they can reduce impervious cover, accent the natural landscape, and provide aesthetic benefits.

DESIGN GUIDANCE

GEOMETRY AND SITE LAYOUT

- Shape: Should be designed with a trapezoidal or parabolic cross section. Trapezoidal swales will generally evolve into parabolic swales over time. To aid in proper longitudinal and cross-sectional design, check dams should be placed at a consistent distance downstream and at intersections. Check dams should be placed at a consistent distance downstream and at intersections. Check dams should be placed according to the cross-sectional design. Check dams should be spaced at intervals of 25 to 100 m apart depending on the length of the swale.
- Bottom Width: Should be designed with a bottom width between 0.75 and 3.0 m. Should allow for shallow flows and adequate water quality treatment, while preventing flows from concentrating and creating gullies.
- Longitudinal Slopes: Should be between 0.5% and 4%. Check dams should be incorporated on slopes greater than 3%.
- Length: When used to convey and treat road runoff, the length simply parallels the road, and therefore should be equal to, or greater than the contributing roadway length.
- Flow Depth: A maximum flow depth of 100 mm is recommended during a 4 hour, 25 mm Chicago storm event.
- Side Slopes: Should be as flat as possible to aid in providing pre-treatment for severe incoming flows and to minimize the swale filtering surface. Steeper side slopes are likely to have erosion gullying from incoming lateral flows. A maximum slope of 2:1 (H:V) is recommended and a 1:4 slope is preferred where space permits.

PRE-TREATMENT

A pea gravel drainband located along the top of each bank can be used to provide pre-treatment of any runoff entering the swale laterally along its length. Vegetated filter strips or mild side slopes (3:2) also provide pre-treatment for any lateral sheet flow entering the swale. Sedimentation basins in inlets to the swale are also a pre-treatment option.

CONVEYANCE AND OVERFLOW

Grass swales must be designed for a minimum velocity of 0.5 m/s or less for the 4 hour 25 mm Chicago storm event. The swale should also convey the locally required design storm (usually the 10 year storm) at non-erosive velocities.

SOIL AMENDMENTS

It is recommended to deeply till the swale soil. The soil should be tilled to a depth of 300 mm and amended with compost to achieve an organic content of 8 to 15% by weight or 30 to 40% by volume.

OPERATION AND MAINTENANCE

Generally, routine maintenance will be the same as for any other landscaped area: weeding, mowing, and leaf removal. Grassed swales should be mowed at least twice yearly to maintain grass height between 75 and 150 mm. The highest possible mowing equipment should be used to prevent soil compaction. Routine roadside ditch maintenance practices such as scraping and re-grading should be avoided. Regular mowing may be required during the first two years until vegetation is established. Routine inspection is very important to ensure that dense vegetation cover is maintained and inlets and pre-treatment devices are free of debris.

CONSTRUCTION CONSIDERATIONS

Grass swales should be clearly marked before site work begins to avoid disturbance during construction. No vehicular traffic, except that specifically used to construct the facility, should be allowed within the swale site. Any accumulation of sediment that does occur within the swale must be removed during the final stages of grading to achieve the design cross-section. Final grading and planting should not occur until the adjoining areas draining into the swale are stabilized. Flow should not be diverted into the swale until the swale unit has been stabilized.

Preferably, the swale should be planted in the spring so that the vegetation can become established with minimal irrigation. Installation of erosion control matting or blanketing to stabilize soil during establishment of vegetation is highly recommended. If sod is used, it should be placed with staggered ends and secured by rolling the sod. This helps to prevent gullies.

For the first two years following construction the swale should be inspected at least quarterly and after every major storm event (> 25 mm). Subsequently, inspections should be conducted in the spring and fall of each year and after major storm events. inspector for vegetation density (at least 80% coverage, damage by foot or vehicular traffic, accumulation of debris, trash and sediment, and structural damage to pre-treatment devices). Trash and debris should be removed from pre-treatment devices and the surface of the swale at least twice annually. Other maintenance activities include weeding, replacing dead vegetation, removing eroded areas, disturbing and compacting as needed. Remove accumulated sediment from the swale surface when dry and exceeding 25 mm depth.

ABLE TO MEET SWM OBJECTIVES

<table>
<thead>
<tr>
<th>BMP</th>
<th>Water Balance Benefit</th>
<th>Water Quality Improvement</th>
<th>Stream Channel Erosion Control Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced Grass Swale</td>
<td>Partial - depends on soil infiltration rate</td>
<td>Yes, if design velocity is 0.5 m/s or less for 4-hour, 25 mm Chicago storm</td>
<td>Partial - depends on soil infiltration rate</td>
</tr>
</tbody>
</table>

GENERAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check Dams</td>
<td>Constructed of a non-erosive material such as suitably sized aggregate, wood, gabions, riprap, or concrete. All check dams should be underlain with geosynthetic filter fabric.</td>
<td></td>
</tr>
<tr>
<td>Wood used for check dams should consist of pressure treated logs, timbers, or water-resistant tree species such as cedars, hemlock, larch, oak or balsam.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel</td>
<td>Washed stone between 3 and 10 mm in diameter.</td>
<td>Minimum of 300 mm wide and 800 mm deep</td>
</tr>
</tbody>
</table>

SITE CONSIDERATIONS

Available Space

Available space usually cannot accommodate about 1 to 2% of the contributing drainage area. A width of at least 2 metres is required.

Site Topography

Geometric constraints the application of grass swales. Local slope ratios between 5:1 and 6:1 are allowable. This prevents problems with providing resistance time and preventing erosion. On slopes greater than 2%, check dams should be used.

Drainage Area & Runoff

The conveyance capacity should match the drainage area. Drain flow to the grass swale is preferential, with flows generally greater than 10 m wide. High discharge through the swale may result after grading and sedimentation, and the swale may require additions of rippled, riprap, and errosion control structures. Typical ratios of rippled drain swales to facility areas range from 0.5:1 to 1:1.

Soil

Grass swales can be applied on soils with any type of soils.

Pollution Hot Spot Runoff

Grass swales can be used for absolute prevention or detention of runoff resulting from industrial and commercial activities. Grass swales can be used for absolute protection of areas that are not underlain with geosynthetic filter fabric.

Proximity to Underground Utilities

Utilities running parallel to the swale should be either offset from the centerline of the swale. Under unusual conditions before the bottom of the swale are not a problem.

Water Table

The bottom of the swale should be separated from the weathered water table by at least 1 metre.

Setback from Buildings

The swale should be treated a minimum of four (4) metres from building foundations to prevent washout damage.
A dry swale can be thought of as an enhanced grass swale that incorporates an engineered filter media bed and pre-treated, treated wastewater from a bioswale cell configured as a linear open channel. They can also be referred to as infiltration basins or bioswales. Dry swales are constructed in enhanced grass swales in terms of the design of their surface geometry, slope, check dams and pretreatment devices. They are similar to infiltration basins in that they use coarse gravel storage layer and optional underdrain. In general, they are open channels designed to convey, treat and infiltrate stormwater runoff. Vegetation on or adjacent material on the surface of the swale allows runoff water to allow sedimentation, infiltration through the root zone and engineered soil bed, evapotranspiration, and infiltration into the underlying native soil. They are similar to infiltration basins in that they use coarse gravel storage layer and optional underdrain. In general, they are open channels designed to convey, treat and infiltrate stormwater runoff. Vegetation on or adjacent

**GENERAL DESCRIPTION**

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**DESIGN GUIDANCE**

**SHAPE:** A parabolic shape is preferable for aesthetic maintenance and hydraulic reasons. A trapezoidal cross-section is commonly used with a trapezoidal cross-section as long as the engineered soil (filter media) bed boundaries lay in the flat bottom areas. Swale length between culverts should be 5 meters or greater.

**BOTTOM WIDTH:** For the trapezoidal cross section, the bottom width should be between 7.5 and 2 meters. For greater widths more, box cross sections should be designed.

**LONGITUDINAL SLOPE:** Should be as gradual as possible to permit the temporary ponding of the water quality stormwater. The swale should be designed with longitudinal slopes generally ranging from 0.5 to 4%, and no greater than 6%. On slopes steeper than 3%, check dams should be used. Check dams should be located on the base and back slopes. A check dam should be spaced far enough apart to allow for access for maintenance equipment.

**PRE-TREATMENT**

Pretreatment systems are a prerequisite to capture sediments before they reach the filter bed. Where runoff source areas produce little sediment, such as roads, dry swales can function effectively without pretreatment. To treat park area or road runoff, a treatment system is recommended. Pretreatment practices that may be feasible, depending on conveyance method and availability of space include:

- **SEDIMENTATION FOBAY (TWO-CELL DESIGN):** Forebay ponding volume should account for 25% of the water quality storage requirement and be designed with a 2:1 length to width ratio.

- **VEGETATED FILTER STRIP (SHEET FLOW):** Ideally, a minimum of 3 meters in width, more frequent maintenance of the filter bed can be anticipated.

- **GAS PERCOLATION FOBAY:** A gravel trench filled with pea gravel which is perpendicular to the flood path between the edge of the pavement and the dry swale will form a permeable gravel drainage pipe to convey flow into the facility. A drop of 50-150 mm into the gravel drainpipe can be used to disperse flow.

- **RIP RAP AND/OR DENSE VEGETATION (CHANNEL FLOW):** Suitable for small dry swales with drainage areas less than 100 square metres.

**DRAINAGE STORAGE**

**DEPTH:** Should be a minimum of 300 mm deep and sized to provide the required storage volume. Granular material should be 50 mm diameter clear drain rock.

**GRAVEL LAYING:** A 100 mm deep layer of pea gravel (3 to 10 mm) prior to installation of additional gravel storage layer as a layering separator it separating from the overlying filter media bed.

**FILTER MEDIA**

**CATEGORIES:**

- **Coarse gravel:** To ensure a consistent and homogeneous bed, filter media should come pre-mixed from an approved vendor.

- **DEPTH:** Ranges from 0.5 to 15 m. The depth must be at least 1.0 m.

- **Filter Media - 30 mm layer of coarse gravel:** A 30 mm layer of coarse gravel is required on the surface of the filter bed to enhance plant survival, suppress weed growth and pretreat runoff before it reaches the filter bed.

**UNDERDRAIN**

- **Only needed where native soil infiltration rate is less than 15 mm/hr (hydraulic conductivity of less than 10-3 cm/s).**

- **Should consist of a perforated pipe embedded in the coarse gravel storage layer at least 100 mm below the surface.**

- **A strip of geotextile filter fabric placed between the filter media and pea gravel check dam layer is optional to help prevent fine soil particles from entering the underdrain.**

- **A vertical standpipe connected to the underdrain at the furthest downstream end of the swale can be used as a cleanout and monitoring well.**

**CONSEQUENCE AND OVERFLOW**

Should be designed for a maximum velocity of 0.5 mm or less for a 4-25 cm Chicago storm event. The swale should also convey the locally required drainable flood volume and depth. Facilities should be designed with adequate capacity and depth used in design computations.

**MONITORING WELLS**

A vertical standpipe connected to the underdrain at the furthest downstream end of the swale can be used as a cleanout and monitoring well.

**ABILITY TO MEET SWM OBJECTIVES**

<table>
<thead>
<tr>
<th>BMP</th>
<th>Water Balance Benefit</th>
<th>Water Quality Improvement</th>
<th>Stream Channel Erosion Control Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry swale with no underdrain or full infiltration</td>
<td>Yes</td>
<td>Yes - for water quality storage requirement</td>
<td>Partial - based on available storage volume and soil infiltration rate</td>
</tr>
<tr>
<td>Dry swale with underdrain or partial infiltration</td>
<td>Partial - based on available storage volume beneath the underdrain and soil infiltration rate</td>
<td>Yes - for water quality storage requirement</td>
<td>Partial - based on available storage volume beneath the underdrain and soil infiltration rate</td>
</tr>
<tr>
<td>Dry swale with underdrain and impermeable drain line or infiltration</td>
<td>Partial - some volume reduction through evapotranspiration</td>
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<td>Partial - some volume reduction through evapotranspiration</td>
</tr>
</tbody>
</table>

**OPERATION AND MAINTENANCE**

Dry swales require routine inspection and maintenance of the landscaping as well as periodic inspection for less frequent maintenance needs or remedial maintenance. Generally, routine maintenance will be the same for any other landscaped area; weeding, mowing and other Criteria:

- **Filter media Soil Mixture to contain:**
  - pH between 5.5 to 7.5
  - Infiltration rate greater than 25 mm/hr.
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**SPECIFICATIONS**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Filter Media Composition</td>
<td>Filter Media Soil Mixture to contain: 85% to 88% sand; 8% to 12% silt fines; 3% to 5% organic matter (leaf compost)</td>
<td>Volumetric computation based on dry and depth used in design computations.</td>
</tr>
</tbody>
</table>
GENERAL DESCRIPTION

Perforated pipe systems can be thought of as long infiltration trenches or linear soak-aways that are designed for both conveyance and infiltration of stormwater runoff. They are composed of perforated pipes installed in gently sloping granular stone beds that are backfilled with geosynthetics that allow infiltration of runoff into the gravel bed and underlying native soil while it is being conveyed from source areas or other BMPs to an end-of-pipe facility or receiving water systems. Pipe systems can be used in place of conventional storm sewer systems, where topography, water table depth, and rainfall quality conditions are suitable. The benefits include treating runoff from roads, parking lots, and low-volume drainage areas. Perforated pipe systems can also be referred to as permissive pipe systems, infiltration systems, clean water collector systems and percolation drainage systems.

DESIGN GUIDANCE

SOIL CHARACTERISTICS

Perforated pipe systems can be constructed over any soil type, but hydraulic soil groups A or B are best for achieving water balance objectives. If feasible, facilities should be located in portions of the site with the highest native soil infiltration rates. Designers should work with the native soil infiltration rate at all the proposed location and depth through measurement of hydraulic conductivity under field saturated conditions.

GEOMETRY AND SITE LAYOUT

Gravel beds in which the perforated pipes are installed are typically rectangular excavations with a bottom width of 600 and 2,500 mm. The gravel beds should have gentle slopes between 0.5 to 1.5.

PRE-TREATMENT

It is important to prevent sediment and debris from entering infiltration facilities because they could contribute to clogging and failure of the system. The following pre-treatment devices are suggested:

- In-ground devises: Devices placed between a conveyance pipe and the facility (e.g., oil and grit separators, sedimentation chambers, grass traps), that can be designed to remove both large and fine particulate from runoff. A number of proprietary filter designs are also available.
- Vegetated filter strips or grass swales: Road and parking lot runoff can be pretreated with vegetated filter strips or grass swales prior to entering the infiltration process.

CONVEYANCE AND OVERFLOW

Collection and conveyance of runoff into the perforated pipe system can be accom-
mplished through conventional catchbasin and non-perforated pipes heading from foundation drain and roof downspouts. Perforated pipes should be smooth-walled to reduce the potential for clogging and facilitate clean out. The gravel filled trench should be at least 75 to 150 mm deep above the perforated pipe. On-few concrete, clay or plastic trench bottoms can be installed across the gravel filled trench to reduce flow along the system, thereby increasing the capacity for infiltration. Overflow from the gravel filled trench should either back up into manholes that are connected to conventional storm sewers or be conveyed to a storm sewer or receiving waterbody by overland flow.

FILTER MEDIA

- Gravel filled trench: Should be filled with uniformly-sized, washed, 50 mm clear stone that provides 40% void space.
- Geotextile: A non-woven needle punched or woven monofilament geotextile fabric should be installed around the stone reservoir of perforated pipe systems with a minimum overlap at the top of 300 mm.

COMMON CONCERNS

Risk of Groundwater Contamination

Most pollutants in urban runoff are well retained by infiltration practices and soils and therefore, have a low to moderate potential for groundwater contamination. To minimize risk of groundwater contamination, the following conditions are recommended:

- Infiltration practices should not receive runoff from high traffic areas where large amounts of de-icing salts are applied (e.g., busy highways), nor from pollution hot spots.
- Porous infiltration of runoff from source areas that are comparatively less con-
maminated such as roads, low traffic roads and parking areas, and.
- Apply sedimentation pretreatment practices (e.g., oil and grit separation) before infiltration of road or parking area runoff.

Standing Water and Mosquitoes

Complete dryout should occur within 72 hours after a storm event, before mosquito-
izes have an opportunity to breed.

Foundations and Seepage

Should be setback at least four metres from building foundations to prevent base-
mement flooding and damage during freeze/thaw cycles.

Winter Operation

Perforated pipe systems will continue to function during winter months if the inlet pipe is cleared of ice by a variety of means. For winter maintenance, the facility should not be closed to the public.

OPERATION AND MAINTENANCE

Maintenance typically consists of cleaning out leaves, debris and accumulated sedi-
mant in a timely manner. Maintenance practices for perforated pipe systems should be designed to ensure the facility remains within the maximum acceptable length of time (typically 72 hours) at least annually and following major storm events (i.e., 25 mm). If the time required to obtain adequate 72-hour cleanout is greater than 72 hours, drain via pumping or chemical cleanout of the perforated pipe by flushing. If slow drainage persists, the system may need removal of gravel fill and replacement of perforated pipes. Perforated pipe systems should be located below shoulders of roadways, previous boulevards or grass swales where they can be readily evacuated for servicing.

SITEx CONSIDERATIONS

Soil Characterization

Before site work begins, locations of facilities should be clearly marked. Only vehicular traffic used for construction of the infiltration facility should be allowed close to the facility location.

Soil and Sediment Control

Infiltration practices should never serve as a sediment control device during construc-
tion. Construction activity should be directed away from the proposed facility location. After the site is erosion-vegetated, erosion and sediment control structures can be removed.

GENERAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perforated pipe systems</td>
<td>Should be continuously perforated, smooth-walled with a minimum inside diameter of 200mm.</td>
<td></td>
</tr>
<tr>
<td>Pipe</td>
<td>Should be filled with washed 50 mm clear stone with a 40% void ratio.</td>
<td></td>
</tr>
<tr>
<td>Stone</td>
<td>The trench in which perforated pipes are installed should be filled with washed 50 mm clear stone with a 40% void ratio.</td>
<td></td>
</tr>
<tr>
<td>Geotextile</td>
<td>Material specifications should conform to Ontario Provincial Standard Specification (OPSS) 1880 for Class I geotextile fabrics.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Should be woven monofilament or non-woven needle punched fabrics. Woven slit film and non-woven heat bonded fabrics should not be used as they are prone to clogging.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Around the gravel filled trench (stone reservoir).</td>
<td></td>
</tr>
</tbody>
</table>

SBMP

<table>
<thead>
<tr>
<th>BMP</th>
<th>Water Balance Benefit</th>
<th>Water Quality Improvement</th>
<th>Stream Channel Erosion Control Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perforated pipe systems</td>
<td>Yes</td>
<td>Yes</td>
<td>Partial, depends on soil infiltration rate</td>
</tr>
</tbody>
</table>