LOW IMPACT DEVELOPMENT SITE DESIGN STRATEGIES

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

PRESERVING IMPORTANT HYDROLOGIC FEATURES AND FUNCTION

There are many features in the natural landscape that provide the important hydrologic functions of retention, detention, infiltration, and filtering of stormwater. These features include, but are not limited to; highly permeable soils, pocket wetlands, significant small (headwater) drainage features, riparian buffers, floodplains, undisturbed natural vegetation, and tree clusters. All areas of hydrologic importance should be delineated at the earliest stage in the development planning process.

STRATEGIES

1. ***Buffers provide filtration, infiltration, flood management, and bank stability benefits.*** Unlike stormwater ponds and other structural infrastructure, buffers are essentially a no capital cost and low maintenance form of "green" infrastructure. The benefits of buffers diminish when slopes are greater than 25%; therefore steep slopes should not be counted as buffer.
2. ***Preserve areas of undisturbed soil and vegetation cover.*** Typical construction practices, such as topsoil stripping and stockpiling, and 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 constructed 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 recharge through application of stormwater infiltration practices.
4. ***Preserve existing trees and, where possible, tree clusters.*** 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 benefits in new developments, whereas newly planted trees will take 10 years or more to provide equivalent benefits. Tree clusters can be incorporated into parking lot interiors or perimeters, private lawns, open space areas, road buffers, and median strips. An uncompacted soil volume of 15 to 28 m3 is recommended to achieve a healthy mature tree with a long lifespan.

SITING AND LAYOUT OF DEVELOPMENT

The location and configuration of elements, such as streets, sidewalks, driveways, and buildings, within the framework of the natural heritage system provides many opportunities to reduce stormwater runoff.

STRATEGIES

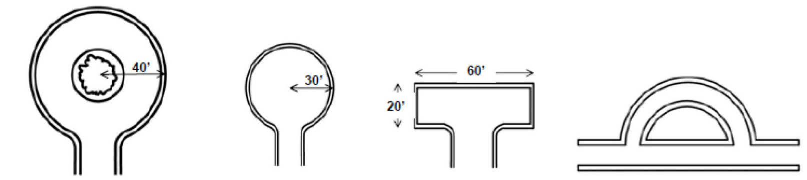
5. ***Fit the design to the terrain.*** Using the terrain and natural drainage as a design element will reduce the amount of clearing and grading required and the extent of necessary underground drainage infrastructure. This helps to preserve predevelopment drainage boundaries.
6. ***Use open space or clustered development.*** Clustering development increases the development density in less 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, shared driveways, and shared parking. Clustered development also reduces the amount of impervious surfaces and stormwater runoff 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, fused grids) create less impervious area 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 street 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 a determinant for the area of 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.

REDUCING IMPERVIOUS AREA

Many of the strategies described previously are primarily for the purpose of reducing impervious area on a macro scale. The following strategies provide examples of how to reduce impervious area on a micro or lot level scale.

STRATEGIES

9. ***Reduce street width.*** Streets constitute the largest percentage of impervious area and contribute proportionally to the urban runoff. Streets widths are sized for the free flow of traffic and movements of large emergency vehicles. In many cases, such as low density residential, these widths are oversized for the typical function of the street. Amending urban design standards to allow alternative, narrower street widths might be appropriate in some situations. There are a variety of ways to accommodate emergency vehicle movements and traffic flow on narrower streets, including alternative street parking configurations, vehicle pullout space, connected street networks, prohibiting parking near intersections, and reinforced turf or gravel edges.
10. ***Reduce building footprints.*** Reduce the building footprint by using taller multi-story buildings and taking advantage of opportunities to consolidate services into the same space.
11. ***Reduce parking footprints.*** Excess parking not only results in greater stormwater impacts and greater stormwater management costs but also adds unnecessary construction and maintenance costs and uses space that could be used for a revenue generating purpose.
    - Keep the number of parking spaces to the minimum required. Parking ratio requirements are often set to meet the highest hourly parking demand during the peak season. The parking space requirement should instead consider an average parking demand and other factors influencing demand like access to mass transit.
    - Take advantage of opportunities for shared parking. For example, businesses with daytime parking peaks can be paired with evening parking peaks, such as offices and a theatre, or land uses with weekday peak demand can be paired with weekend peak demand land uses, such as a school and church.
    - Reductions in impervious surface can also be found in the geometry of the parking lot. One way aisles when paired with angled parking will require less space than a two way aisle. Other reductions can be found in using unpaved end-of-stall overhangs, setting aside smaller stalls for compact vehicles, and configuring or overlapping common areas like fire lanes, collectors, loading, 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 area 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 sidewalks 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. Driveway impervious area can be reduced through the use of shared driveways or alley accessed garages



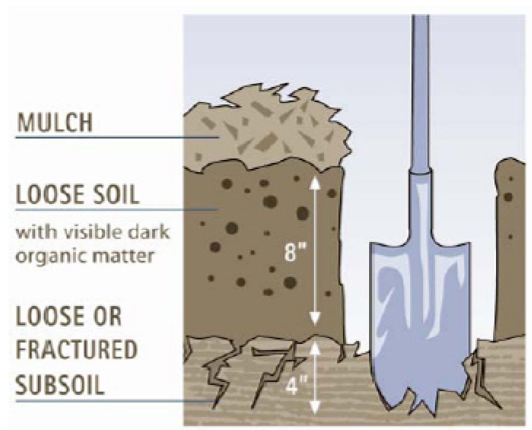
40 ft cul-de sac with landscaped island | 30 ft radius cul-de-sac | 60 by 20 ft T-shaped turnaround | Loop road

Source: CWP, 1998

	Square grid (Miletus, Houston, Portland, etc.)	Oblong grid (most cities with a grid)	Oblong grid 2 (some cities or in certain areas)	Loops (Subdivisions – 1950 to now)	Culs-de-sac (Radburn – 1932 to now)
Percentage of area for streets	36.0%	35.0%	31.4%	27.4%	23.7%
Percentage of buildable area	64.0%	65.0%	68.6%	72.6%	76.3%

Source: CMHC, 2002

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

Compost 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

Open Drainage Applied in a Medium Density Neighbourhood

Source: U.S. EPA

USING NATURAL DRAINAGE SYSTEMS

Rather than collect and move stormwater rapidly to a centralized location for detention and treatment, the goal of these strategies is to take advantage of undisturbed vegetated areas and natural drainage patterns (e.g., small headwater drainage features). These strategies will extend runoff flow paths and slow down flow to allow soils and vegetation to treat and retain it. Using natural systems or green infrastructure is often more cost effective than traditional drainage systems, and they provide more ancillary benefits.

STRATEGIES

14. ***"Disconnect" impervious areas.*** Roof leaders or downspouts, parking lots, driveways, sidewalks, and patios should be disconnected from the storm sewer and directed towards stabilized pervious areas as sheet flow where possible. In cases of concentrated flow, the flow can be broken up with level spreaders or flow dissipating riprap. With the proper treatment, the landscaped areas of a site can accept runoff from impervious areas. Deep tilling or soil aeration is recommended for topsoil that has been replaced or compacted by construction equipment. Soil amendments can be applied to hydrologic soil group C and D soils to encourage runoff absorption. Use deep rooting vegetation in landscaped areas when possible which will maintain and possibly improve soil infiltration rate over time:
    - ***Undisturbed densely vegetated areas and buffers*** - A hydrologist and/or ecologist should be consulted before designing a site to drain to sensitive natural heritage features like pocket wetlands.
    - ***Landscaped and disturbed areas*** - With the proper treatment, the landscaped areas of the site can accept runoff from impervious areas. Deep tilling or soil aeration is recommended for topsoil that has been replaced or compacted by construction equipment. Soil amendments can be applied to hydrologic soil group C and D soils to encourage runoff absorption. Use deep rooting vegetation in landscaped areas when possible which will maintain and possibly improve the infiltration rates over time.
15. ***Preserve or create micro-topography.*** Undisturbed lands have a micro-topography of dips, hummocks and mounds which slow and retain runoff. Site grading smoothes out these topographic features. Micro-topography can be restored in areas of ornamental landscaping or naturalization.
16. ***Extend drainage flow paths.*** Slowing down flows and lengthening flow paths allow more opportunities for stormwater to be filtered and infiltrated. Extending the travel time can also delay and lower peak flows. Where suitable, flows should be conveyed using vegetated open channels (e.g., enhanced grass swales).

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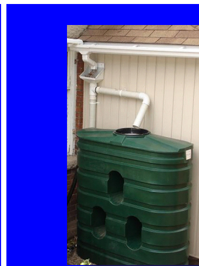
RAINWATER HARVESTING

GENERAL DESCRIPTION

Rainwater harvesting is the process of intercepting, conveying and storing rainfall for future use. The rain that falls upon a catchment surface, such as a roof, is collected and conveyed into a storage tank. Storage tanks range in size from rain barrels for residential land uses (typically 190 to 400 litres in size), to large cisterns for industrial, commercial and institutional land uses. A typical pre-fabricated cistern can range from 750 to 40,000 litres in size.

With minimal pretreatment (e.g., gravity filtration or first-flush diversion), the captured rainwater can be used for outdoor non-potable water uses such as irrigation and pressure washing, or in the building to flush toilets or urinals. It is estimated that these applications alone can reduce household municipal water consumption by up to 55%. The capture and use of rainwater can, in turn, significantly reduce stormwater runoff volume and pollutant load. By providing a reliable and renewable source of water to end users, rainwater harvesting systems can also help reduce demand on municipal treated water supplies. This helps to delay expansion of treatment and distribution systems, conserve energy used for pumping and treating water and lower consumer water bills.



DESIGN GUIDANCE

CATCHMENT AREA

The catchment area is simply the surface from which rainfall is collected. Generally, roofs are the catchment area, although rainwater from low traffic parking lots and walkways, may be suitable for some non-potable uses (e.g., outdoor washing). The quality of the harvested water will vary according to the type of catchment area and material from which it is constructed. Water harvested from parking lots, walkways and certain types of roofs, such as asphalt shingle, tar and gravel, and wood shingle roofs, should only be used for irrigation or toilet flushing due to potential for contamination with toxic compounds.

COLLECTION AND CONVEYANCE SYSTEM

The collection and conveyance system consists of the eavestroughs, downspouts and pipes that channel runoff into the storage tank. Eavestroughs and downspouts should be designed with screens to prevent large debris from entering the storage tank. For dual use cisterns (used year-round for both outdoor and indoor uses), the conveyance pipe leading to the cistern 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 either be located in a heated indoor environment (e.g., garage, basement) or be insulated or equipped with heat tracing to prevent freezing. All connections between downspouts, conveyance pipes and the storage tank must prevent entry of small animals or insects into the storage tank.

PRE-TREATMENT

Pretreatment is needed to remove debris, dust, leaves, and other debris that accumulates on roofs and prevents clogging within the rainwater harvesting system. For dual use cisterns that supply water for irrigation and toilet flushing only, filtration or first-flush diversion pretreatment is recommended. To prevent ice accumulation and damage during winter, first-flush diverters or in-ground filters should be in a temperature controlled environment, buried below the local frost penetration depth, insulated or equipped with heat tracing.

STORAGE TANKS

The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. The required size of storage tank is dictated by several variables: rainfall and snowfall frequencies and totals, the intended use of the harvested water, the catchment surface area, aesthetics, and budget. In the Greater Toronto Area, an initial target for sizing the storage tank could be the predicted rainwater usage over a 10 to 12 day period.

DISTRIBUTION SYSTEM

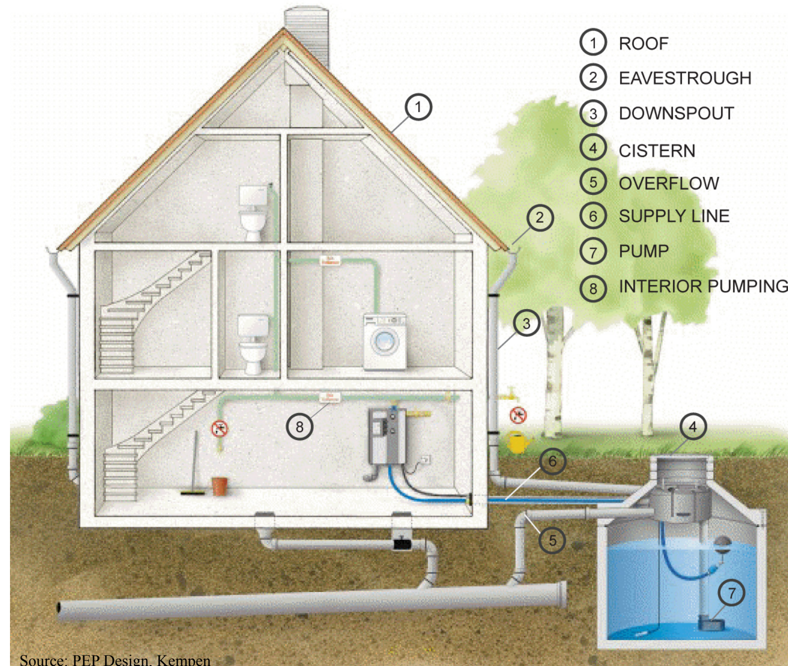
Most distribution systems are gravity fed or operated using pumps to convey harvested rainwater from the storage tank to its final destination. Typical outdoor systems use gravity to feed hoses via a tap and spigot. For underground cisterns, a water pump is needed. Indoor systems usually require a pump, pressure tank, back-up water supply line and backflow preventer. The typical pump and pressure tank arrangement consists of a multistage centrifugal pump, which draws water out of the storage tank into the pressure tank, where it is stored for distribution.

OVERFLOW SYSTEM

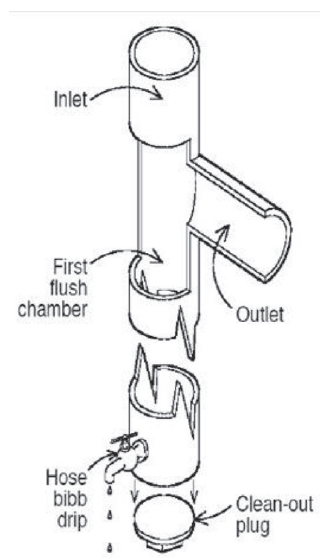
An overflow system must be included in the design. Overflow pipes should have a capacity equal to or greater than the inflow pipe(s). The overflow system may consist of a conveyance pipe from the top of the cistern to a pervious area down gradient of the storage tank, where suitable grading exists. The overflow discharge location should be designed as simple downspout disconnection to a pervious area, vegetated filter strip, or grass swale. The overflow conveyance pipe should be screened to prevent small animals and insects from entering. Where site grading does not permit overflow discharge to a pervious area, the conveyance pipe may either be indirectly connected to a storm sewer (discharge to an impervious area connected to a storm sewer inlet) or directly connected to a storm sewer with incorporation of a backflow preventer.

ACCESS AND MAINTENANCE

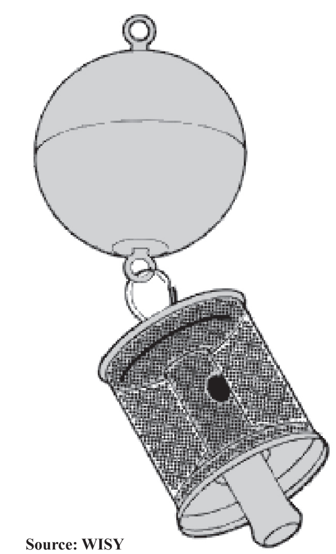
For underground cisterns, a standard size manhole opening should be provided for maintenance purposes. This access point should be secured with a lock to prevent unwanted access.



OVERVIEW



FIRST FLUSH DIVERTER



FLOATING SUCTION FILTER

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Rainwater Harvesting	Yes - magnitude depends on water usage	Yes - size for the water quality storage requirement	Partial - can be used in series with other practices

GENERAL SPECIFICATIONS

Component	Specification	Quantity
Eavestroughs and Downspouts	Materials commonly used for eavestroughs and downspouts include polyvinylchloride (PVC) pipe, vinyl, aluminum and galvanized steel. Lead should not be used as solder as rainwater can dissolve the lead and contaminate the water supply.	Length of eavestroughs and downspouts is determined by the size and layout of the catchment and the location of the storage tanks.
Pretreatment	At least one of the following: • leaf and mosquito screens (1 mm mesh size); • first-flush diverter; • in-ground filter; • in-tank filter. Large tanks (10 m3 or larger) should have a settling compartment for removal of sediments.	1 per inlet to the collection system
Storage Tanks	• Materials used to construct storage tanks should be structurally sound. • Tanks should be installed in locations where native soils or building structures can support the load associated with the volume of stored water. • Storage tanks should be water tight and sealed using a water safe, non-toxic substance. • Tanks should be opaque to prevent the growth of algae • Previously used containers to be converted to rainwater storage tanks should be fit for potable water or food-grade products. • Cisterns above- or below ground must have a lockable opening of at least 450 mm diameter.	The size of the cistern(s) is determined during the design calculations.

Note: This table does not address indoor systems or pumps.

SITE CONSIDERATIONS

Available Space
Storage tanks can be placed underground, indoors, on roofs, or adjacent to buildings depending on intended uses of the rainwater.

Site Topography
Influences the placement of the storage tank and design of the distribution and overflow systems.

Soil
Underground cisterns should be placed on or in native, rather than fill soil.

Head
Rain barrels or above ground cisterns with gravity distribution systems should be sited up-gradient from landscaping areas to which rainwater is to be applied.

Pollution Hot Spot Runoff
Can be an effective BMP for roof runoff from sites where land uses or activities at ground level have the potential to generate highly contaminated runoff.

Winter Operation
Can be used throughout the winter if tanks are located below the local frost penetration depth or indoors.

Underground Utilities
Presence of underground utilities may constrain the location of underground storage tanks.

Plumbing Code
Code allows the use of harvested rainwater for toilet and urinal flushing, but systems require installation of backflow prevention devices.

Standing Water and Mosquitoes
If improperly managed, tanks can create habitat suitable for mosquito breeding, so screens should be placed on inlets and outlets to prevent entry.

Child Safety
Above and below ground cisterns with openings large enough for children to enter must have lockable covers.

Setback
Tanks should be water tight to avoid ponding or saturation of soils within 4 metres of building foundations.

Vehicle Loading
Underground tanks should be sited in areas without vehicular traffic.

Drawdown Between Storms
A suggested target for sizing the storage tank to ensure drawdown between storms is the predicted rainwater demand over a 10 to 12 day period.

OPERATION AND MAINTENANCE

Maintenance requirements for rainwater harvesting systems vary according to use. Systems that are used to provide supplemental irrigation water have relatively low maintenance requirements, while systems designed for indoor uses have much higher maintenance requirements. All rainwater harvesting system components should undergo regular inspections every six months during the spring and fall seasons to keep leaf screens, eavestroughs and downspouts free of leaves and other debris; check screens and patch holes or gaps; clean and maintain first flush diverters and filters, especially those on drip irrigation systems; inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots; and replace damaged system components as needed.

MOSQUITO CONTROL

If screening is not sufficient to deter mosquitoes, vegetable oil can be used to smother larvae. Alternatively mosquito dunks or pellets containing larvicide can be used.

WINTER OPERATION

Rainwater harvesting systems have a number of components that can be affected by freezing winter temperatures. For above-ground systems, winter-time operation may not be possible. Prior to the onset of freezing temperatures, above-ground systems should be disconnected and drained. For below-ground and indoor systems, downspouts and overflow components should be checked for ice blockages during snowmelt events.

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FOR FURTHER DETAILS SEE SECTION 4.1 OF THE CVC/TRCA LID SWM GUIDE

GREEN ROOFS

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

GENERAL DESCRIPTION

Green roofs, also known as "living roofs" or "rooftop gardens", consist of a thin layer of vegetation and growing medium installed on top of a conventional flat or sloped roof. Green roofs are touted for their benefits to cities, as they improve energy efficiency, reduce urban heat island effects, and create greenspace for passive recreation or aesthetic enjoyment. They are also attractive for their water quality, water balance, and peak flow control benefits. The green roof acts like a lawn or meadow by storing rainwater in the growing medium and ponding areas. Excess rainfall enters underdrains and overflow points and is conveyed in the building drainage system. After the storm, a large portion of the stored water is evapotranspired by the plants, evaporates or slowly drains away.

There are two types of green roofs: intensive and extensive. Intensive green roofs contain greater than 15 cm depth of growing medium, can be planted with deeply rooted plants and are designed to handle pedestrian traffic. Extensive green roofs consist of a thinner growing medium layer (15 cm depth or less) with herbaceous vegetative cover. Guidance here focuses on extensive green roofs.

DESIGN GUIDANCE

ROOF STRUCTURE

The load bearing capacity of the roof structure must be sufficient to support the soil and plants of the green roof assembly, as well as the live load associated with maintenance staff accessing the roof. A green roof assembly weighing more than 80 kg per square metre, when saturated, requires consultation with a structural engineer. Green roofs may be installed on roofs with slopes up to 10%. As a fire resistance measure, non-vegetative materials, such as stone or pavers should be installed around all roof openings and at the base of all walls that contain openings.

WATERPROOFING SYSTEM

The first layer above the roof surface is a waterproofing membrane. Two common waterproofing techniques are monolithic and thermoplastic sheet membranes. Another option is a liquid-applied inverted roofing membrane assembly system in which the insulation is placed over the waterproofing, which adheres to the roof structure. An additional protective layer is generally placed on top of the membrane followed by a physical or chemical root barrier. Once the waterproofing system has been installed it should be fully tested prior to construction of the drainage system. Electronic leak detection systems should also be installed at this time if desired.

DRAINAGE LAYER

The drainage system includes a porous drainage layer and a geosynthetic filter mat to prevent fine growing medium particles from clogging the porous media. The drainage layer can be made up of gravels or recycled-polyethylene materials that are capable of water retention and efficient drainage. The depth of the drainage layer depends on the load bearing capacity of the roof structure and the stormwater retention requirements. The porosity of the drainage layer should be greater than or equal to 25%.

CONVEYANCE AND OVERFLOW

Once the porous media is saturated, all runoff (infiltrate or overland flow) should be directed to a traditional roof storm drain system. Landscaping style catch basins should be installed with the elevation raised to 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, swale or simply drain to a pervious area.

GROWING MEDIUM

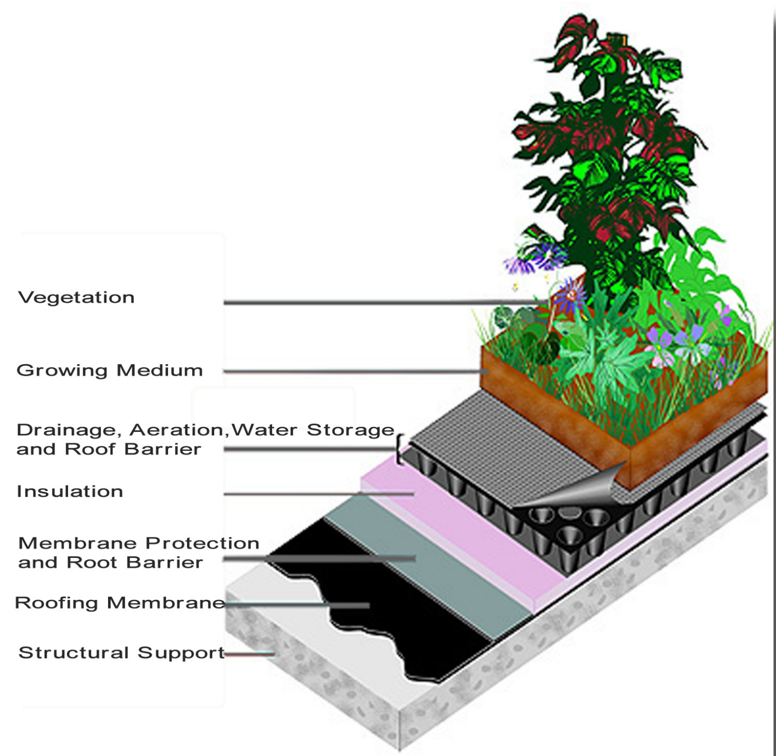
The growing medium is usually a mixture of sand, gravel, crushed brick, compost, or organic matter combined with soil. The medium ranges between 40 and 150 mm in depth and increases the roof load by 80 to 170 kg per square metre when fully saturated. The sensitivity of the receiving water to which the green roof ultimately drains should be taken into consideration when selecting the growing medium mix. Green roof growing media with less compost in the mix will leach less nitrogen and phosphorus. Low nutrient growing media also promotes the dominance of stress-tolerant native plants. Fertilizer applied to the growing medium during production and the period during which vegetation is becoming established should be coated controlled release fertilizer to reduce the risk of damage to vegetation and leaching of nutrients into overflowing runoff. Fertilizer applications should not exceed 5 g of nitrogen per square metre.

MODULAR SYSTEMS

Modular systems are trays of vegetation in a growing medium that are prepared and grown off-site and placed on the roof for complete coverage. There are also pre-cultivated vegetation blankets that are grown in flexible growing media structures, allowing them to be rolled out onto the green roof assembly. The advantage of these systems is that they can be removed for maintenance.

Green Rooftops are composed of:

- A roof structure capable of supporting the weight of a green roof system;
- A waterproofing system designed to protect the building and roof structure;
- A drainage layer that consists of a porous medium capable of water storage for plant uptake;
- A geosynthetic layer to prevent fine soil media from clogging the porous media;
- Soil with appropriate characteristics to support selected green roof plants;
- Plants with appropriate tolerance for harsh rooftop conditions and shallow rooting depths.



GREEN ROOF LAYERS
(Source: Great Lakes Water Institute)

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Green Rooftops	Yes	Yes	Yes

GENERAL SPECIFICATIONS

ASTM International released the following Green Roof standards in 2005:

- E2396-05 Standard Test Method for Saturated Water Permeability of Granular Drainage Media;
- E2397-05 Standard Determination of Dead Loads and Live Loads associated with Green Roof Systems;
- E2398-05 Standard test method for water capture and media retention of geocomposite drain layers for green roof systems;
- E2399-05 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems; and
- E2400-06 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems.

Although the Ontario Building Code (2006) does not specifically address the construction of green roofs, requirements from the Building Code Act and Division B may apply to components of the construction. Further requirements from sections 2.4 and 2.11 of the 1997 Ontario Fire Code also require consideration.

COMMON CONCERNS

WATER DAMAGE TO ROOF

While failure of waterproofing elements may present a risk of water damage, a warranty can ensure that any damage to the waterproofing system will be repaired. Leak detection systems can also be installed to minimize or prevent water damage.

VEGETATION MAINTENANCE

Extreme weather conditions can have an impact on plant survival. Appropriate plant selection will help to ensure plant survival during weather extremes. Irrigation during the first year may be necessary in order to establish vegetation. Vegetation maintenance costs decrease substantially after the first two years.

COLD CLIMATE

Green roofs are a feasible BMP for cold climates. Snow can protect the vegetation layer and once thawed, will percolate into the growing medium and is either absorbed or drained away just as it would during a rain event. No seasonal adjustments in operation are needed.

COST

An analysis 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 estimated that green roofs can extend the life of a roof structure by as long as 20 years by reducing exposure of the materials to sun and precipitation. They can also reduce energy demand by as much as 75% .

ON PRIVATE PROPERTY

Property owners or managers will need to be educated on their routine operation and maintenance needs, understand the long-term maintenance plan, 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 on a property that is directly connected to a storm sewer could be used to encourage property owners or managers to maintain existing practices.

CONSTRUCTION CONSIDERATIONS

An experienced professional green roof installer should install the green roof. The installer must work with the construction contractor to ensure that the waterproofing membrane installed is appropriate for use under a green roof assembly. Conventional green roof assemblies should be constructed in sections for easier inspection and maintenance access to the membrane and roof drains. Green roofs can be purchased as complete systems from specialized suppliers who distribute all the assembly components, including the waterproofing membrane. Alternatively, a green roof designer can design a customized green roof and specify suppliers for each component of the system.

OPERATION AND MAINTENANCE

- Green roof maintenance is typically greatest in the first two years as plants are becoming established. Vegetation should be monitored to ensure dense coverage. A warranty on the vegetation should be included in the construction contract.
- Regular operation of a green roof includes irrigation and leak detection. Watering should be based on actual soil moisture conditions as plants are designed to be drought tolerant. Electronic leak detection is recommended. This system, also used with traditional roofs, must be installed prior to the green roof.
- Ongoing maintenance should occur at least twice per year and should include weeding to remove volunteer seedlings of trees and shrubs and debris removal. In particular, the overflow conveyance system should be kept clear.

SITE CONSIDERATIONS

Roof Slope
Green roofs may be installed on roofs with slopes up to 10%.

Drainage Area & Runoff Volume
Green roofs are designed to capture precipitation falling directly onto the roof surface. They are not designed to receive runoff diverted from other source areas.

Structural Requirements
Load bearing capacity of the building structure and selected roof deck need to be sufficient to support the weight of the soil, vegetation and accumulated water or snow, and may also need to support pedestrians, concrete pavers, etc.

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FOR FURTHER DETAILS SEE SECTION 4.2 OF THE CVC/TRCA LID SWM GUIDE

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

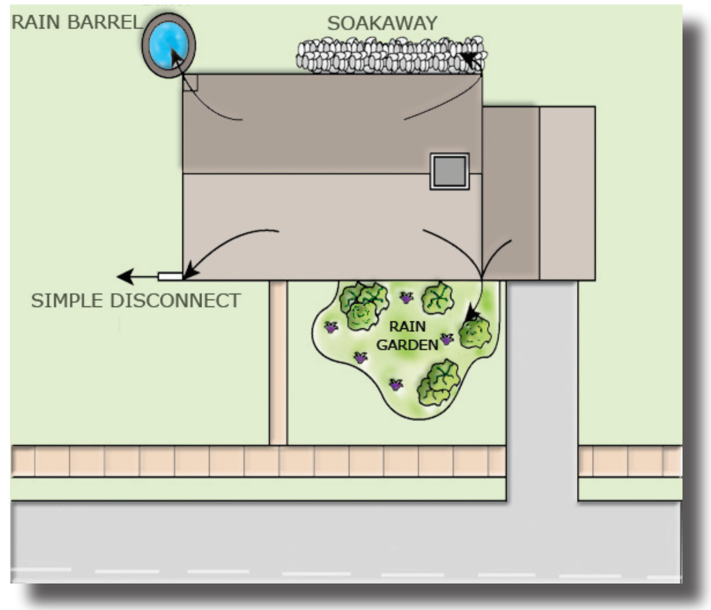
Roof downspout disconnections should meet the following criteria:

- 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, swale, soakaway, 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;
- Roof downspout disconnection to a pervious area or vegetated filter strip that has been tilled 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, swale, bioretention area, soakaway or permeable pavement.



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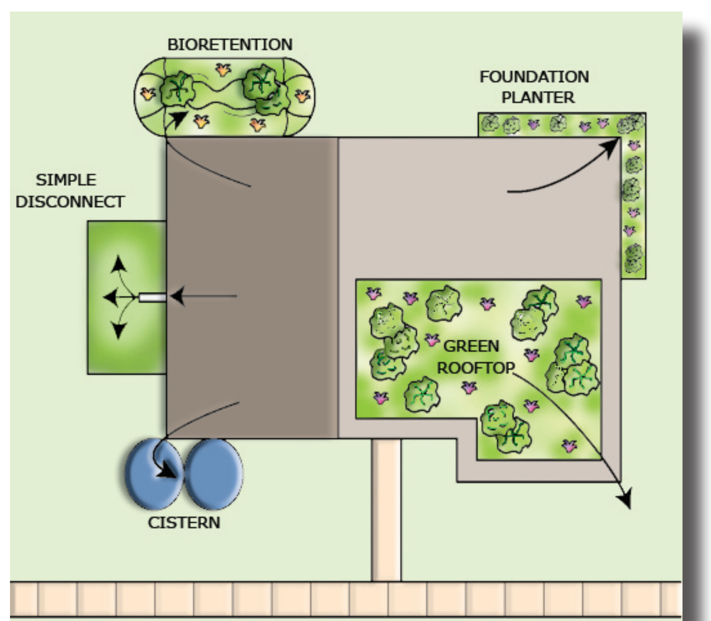


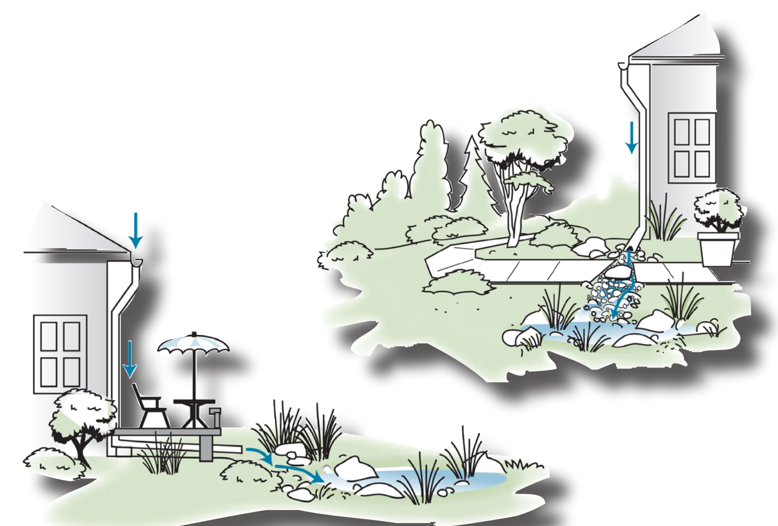
COMMERCIAL

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benfit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Downspout Disconnection	Partial - depends on soil infiltration rate and length of flow path over the pervious area	Partial - depends on soil infiltration rate and length of flow path over the pervious area	Partial - depends on combination with other practices

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.* These values apply to disconnections that meet the feasibility criteria outlined in this section, and do not include any further runoff reduction due to the use of compost amendments along the filter path.

*Hydrologic soil group (HSG) classifications are based on the ability of the soil to transmit water. Soil groups are ranked from A to D. Group A soils are sandy, loamy sand, or sandy loam types. Group B soils are silt loam or loam types, Group C soils are sandy clay loam types. Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay types



OVERVIEW

SITE CONSIDERATIONS

Site Topography
Disconnected downspouts should discharge to a gradual slope that conveys runoff away from the building. The slope should be between 1% and 5%. Grading should discourage flow from reconnecting with adjacent impervious surfaces.

Water Table
Roof downspouts should only be disconnected where the minimum depth to the seasonally high water table is at least one (1) metre below the surface.

Pollution Hot Spot Runoff
Downspout disconnection can be used where land uses or activities at ground-level have the potential to generate highly contaminated runoff (e.g., vehicle fueling, servicing and demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites) as long as the roof runoff is kept separate from runoff from ground-level impervious surfaces.

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 on 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 PONDING
Downspout disconnection is not intended to pond water, so any standing water should be infiltrated or evaporated 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.

CONSTRUCTION CONSIDERATIONS

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

EROSION AND SEDIMENT CONTROL
If possible, construction runoff 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.

OPERATION AND MAINTENANCE

Maintenance of disconnected downspouts will generally be no different than for lawns or landscaped areas. A maintenance agreement with property owners or managers may be required to ensure that downspouts remain disconnected and the pervious area remains pervious. For long-term efficacy, the pervious area should be protected from compaction. One method is to plant shrubs or trees along the perimeter of the pervious area to prevent traffic. On commercial sites, the pervious area should not be an area with high foot traffic. If ponding of water for longer than 24 hours occurs, the pervious area should be dethatched and aerated. If ponding persists, regrading or tilling to reverse compaction and/or addition of compost to improve soil moisture retention may be required.

DOWNSPOUT DISCONNECTION

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

TORONTO AND REGION Conservation for The Living City

CVC CREDIT VALLEY CONSERVATION

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

SOAKAWAYS, INFILTRATION TRENCHES AND CHAMBERS

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

GENERAL DESCRIPTION

Soakaways are rectangular or circular excavations lined with geotextile fabric and filled with clean granular stone or other void forming material that receive runoff from a perforated pipe inlet and allow it to infiltrate into the native soil. They typically service individual lots and receive only roof and walkway runoff but can also be designed to receive overflows from rainwater harvesting systems. Soakaways can also be referred to as infiltration galleries, dry wells or soakaway pits.

Infiltration trenches are rectangular trenches lined with geotextile fabric and filled with clean granular stone or other void forming material. Like soakaways, they typically service an individual lot and receive only roof and walkway runoff. This design variation on soakaways is well suited to sites where available space for infiltration is limited to narrow strips of land between buildings or properties, or along road rights-of-way. 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 series in trench or bed configurations. They can infiltrate roof, walkway, parking lot and road runoff with adequate pretreatment. Due to the large volume of underground void space they create in comparison to a soakaway of the same dimensions, and the modular nature of their design, they are well suited to sites where available space for other types of BMPs is limited, or where it is desirable for the facility to have little or no surface footprint (e.g., high density development contexts). They can also be referred to as infiltration tanks.

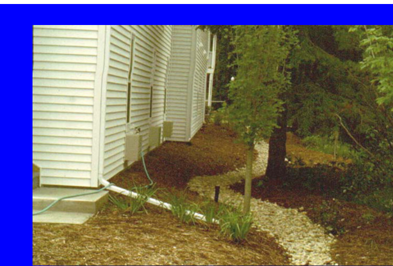
DESIGN GUIDANCE

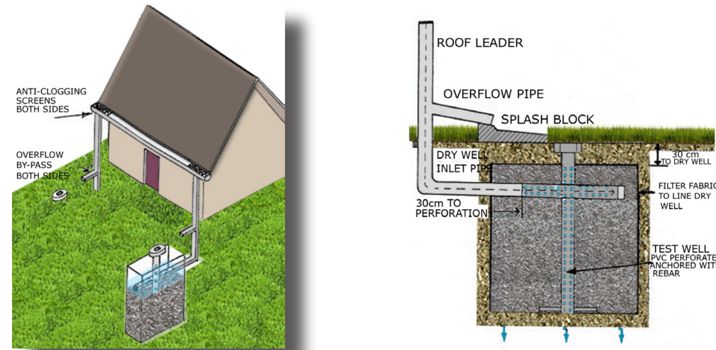
MONITORING WELLS
Capped vertical non-perforated pipes are recommended to the inlet and outlet pipes to provide a means of inspecting and flushing them out as part of routine maintenance. A capped vertical standpipe consisting of an anchored 100 to 150 mm diameter perforated pipe with a lockable cap installed to the bottom of the facility is also recommended for monitoring the length of time required to fully drain the facility between storms. Manholes and inspection ports 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:

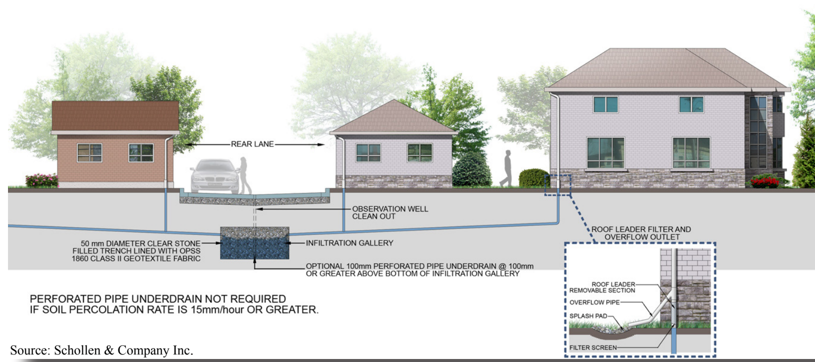
- Leaf screens: Leaf screens are mesh screens installed either on the building eavestroughs or roof downspouts and are used to remove leaves and other large debris from roof runoff.
- In-ground devices: Devices placed between a conveyance pipe and the facility (e.g., oil and grit separators, sedimentation chamber or goss traps), that can be designed to remove both large and fine particulate from runoff. A number of proprietary stormwater filter designs are 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 practice

FILTER MEDIA
- Stone reservoir: Soakaways and infiltration trenches should be filled with uniformly-graded, washed stone that provides 30 to 40% void space. Granular material should be 50 mm clear stone
- Geotextile: A non-woven needle punched, or woven monofilament geotextile fabric should be installed around the stone reservoir of soakaways and infiltration trenches with a minimum overlap at the top of 300 mm. Woven slit film and non-woven heat bonded fabrics should not be used as they are prone to clogging. Specification of geotextile fabrics should consider the apparent opening size (AOS) for non-woven fabrics, or percent open area (POA) for woven fabrics, which affect the long term ability to maintain water flow. Other factors that need consideration include maximum forces to be exerted on the fabric, and the load bearing ratio, texture (i.e., grain size distribution) and permeability of the native soil in which they will be installed.





DRY WELL SYSTEM



INFILTRATION TRENCH BELOW A LANEWAY

INFILTRATION CHAMBER SYSTEM UNDER A PARKING LOT

GEOMETRY AND SITE LAYOUT
Soakaways and infiltration chambers can be designed in a variety of shapes, while infiltration trenches are typically rectangular excavations with a bottom width generally between 600 and 2400 mm. Facilities should have level or nearly level bed bottoms.

CONVEYANCE AND OVERFLOW
Inlet pipes to soakaways and infiltration trenches are typically perforated pipe connected to a standard non-perforated pipe or eavestrough that conveys runoff from the source area to the facility. The inlet and overflow outlet to the facility should be installed below the maximum frost penetration depth to prevent freezing. The overflow outlet can simply be the perforated pipe inlet that backs up when the facility is at capacity and discharges to a splash pad and pervious area at grade or can be a pipe that is at the top of the gravel layer and is connected to a storm sewer. Outlet pipes must have capacity equal to or greater than the inlet.

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Soakaways, Infiltration Trenches and Chambers	Yes	Yes	Partial, depends on soil infiltration rate

CONSTRUCTION CONSIDERATIONS

SOIL DISTURBANCE AND COMPACTION: 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.

EROSION AND SEDIMENT CONTROL: Infiltration practices should never serve as a sediment control device during construction. Construction runoff should be directed away from the proposed facility location. After the site is vegetated, erosion and sediment control structures can be removed.

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 management approaches 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;
- prioritize infiltration of runoff from source areas that are comparatively less contaminated such as roofs, low traffic roads and parking areas; and,
- apply sedimentation pretreatment practices (e.g., oil and grit separators) before infiltration of road or parking area runoff.

RISK OF SOIL CONTAMINATION
Available evidence from monitoring studies indicates that small distributed stormwater infiltration practices do not contaminate underlying soils, even after 10 years of operation.

ON PRIVATE PROPERTY
Property owners or managers will need to be educated on their routine maintenance needs, understand the long-term maintenance plan, and 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 on a property that is directly connected to a storm sewer could be used to encourage property owners or managers to maintain existing practices. Alternatively, infiltration practices could be located in an expanded road right-of-way or "stormwater easement" so that municipal staff can access the facility in the event it fails to function properly.

WINTER OPERATION
Soakaways, infiltration trenches and chambers will continue to function during winter months if the inlet pipe and top of the facility is located below the local maximum frost penetration depth.

OPERATION AND MAINTENANCE

Maintenance typically consists of cleaning out leaves, debris and accumulated sediment caught in pretreatment devices, inlets and outlets annually or as needed. Inspection via an monitoring well should be performed to ensure the facility drains within the maximum acceptable length of time (typically 72 hours) at least annually and following every major storm event (>25 mm). If the time required to fully drain exceeds 72 hours, drain via pumping and clean out the perforated pipe underdrain, if present. If slow drainage persists, the system may need removal and replacement of granular material and/or geotextile fabric.

SITE CONSIDERATIONS

Wellhead Protection
Facilities receiving road or parking lot runoff should not be located within two (2) year time-of-travel wellhead protection areas.

Site Topography
Facilities cannot be located on natural slopes greater than 15%.

Water Table
The bottom of the facility should be vertically separated by one (1) metre from the seasonally high water table or top of bedrock elevation.

Soil
Soakaways, infiltration trenches and chambers can be constructed over any soil type, but hydrologic soil group A or B soils are best for achieving water balance and channel erosion control objectives. If possible, facilities should be located in portions of the site with the highest native soil infiltration rates. Designers should verify the soil infiltration rate at the proposed location and depth through field measurement of hydraulic conductivity under field saturated conditions.

Drainage Area
Typically are designed with an impervious drainage area to treatment facility area ratio of between 5:1 and 20:1. A maximum ratio of 10:1 is recommended for facilities receiving road or parking lot runoff.

Pollution Hot Spot Runoff
To protect groundwater from possible contamination, runoff from pollution hot spots should not be treated by soakaways, infiltration trenches or chambers.

Setback from Buildings
Facilities should be setback a minimum of four (4) metres from building foundations.

Proximity to Underground Utilities
Local utility design guidance should be consulted to define the horizontal and vertical offsets. Generally, requirements for underground utilities passing near the practice will be no different than for utilities in other pervious areas. However, the designer should consider the need for long term maintenance when locating infiltration facilities near other underground utilities.

TORONTO AND REGION Conservation for The Living City

CVC CREDIT VALLEY CONSERVATION

FOR FURTHER DETAILS SEE SECTION 4.4 OF THE CVC/TRCA LID SWM GUIDE



Source: Minnesota Businesses for Clean Water

Source: City of Portland


BIORETENTION

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

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 system may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain for filtration only (i.e., a biofilter). The primary component of the practice is the filter bed which is a mixture of sand, fines and organic material. Other elements include a mulch ground cover and plants adapted to the conditions of a stormwater practice. Bioretention is designed to capture small storm events or the water quality storage requirement. An overflow or bypass is necessary to pass large storm event flows. Bioretention can be adapted to fit into many different development contexts and provide a convenient area for snow storage and treatment.

DESIGN GUIDANCE

SOIL CHARACTERISTICS

Bioretention can be constructed over any soil type, but hydrologic soil group A and B are best for achieving water balance goals. If possible, bioretention should be sited in the areas of the development with the highest native soil infiltration rates. Bioretention in soils with infiltration rates less than 15 mm/hr will require an underdrain. Designers should verify the native soil infiltration rate at the proposed location and depth through measurement of hydraulic conductivity under field saturated conditions.

GEOMETRY & SITE LAYOUT

Key geometry and site layout factors include:

- The minimum footprint of the filter bed area is based on the drainage area. Typical drainage areas to bioretention are between 100 m2 to 0.5 hectares. The maximum recommended drainage area is 0.8 hectares. Typical ratios of impervious drainage area to treatment facility area range from 5:1 to 15:1.
- Bioretention can be configured to fit into many locations and shapes. However, cells that are narrow may concentrate flow as it spreads throughout the cell and result in erosion.
- The filter bed surface should be level to encourage stormwater to spread out evenly over the surface.

PRE-TREATMENT

Pretreatment prevents premature clogging by capturing coarse sediment particles before they reach the filter bed. Where the runoff source area produces little sediment, such as roofs, bioretention can function effectively without pretreatment. To treat parking area or road runoff, a two-cell design that incorporates a forebay is recommended. Pretreatment practices that may be feasible, depending on the method of conveyance and the availability of space include:

- *Two-cell design (channel flow):* 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):* Should be a minimum of three (3) metres in width. If smaller strips are used, more frequent maintenance of the filter bed can be anticipated.
- *Gravel diaphragm (sheet flow):* A small trench filled with pea gravel, which is perpendicular to the flow path between the edge of the pavement and the bioretention practice will promote settling out of sediment and maintain sheet flow into the facility. A drop of 50-150 mm into the gravel diaphragm can be used to dissipate energy and promote settling.
- *Rip rap and/or dense vegetation (channel flow):* Suitable for small bioretention cells with drainage areas less than 100 square metres.

GRAVEL STORAGE LAYER

- 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 stone.
- PEA GRAVEL CHOKING LAYER: A 100 mm deep layer of pea gravel (3 to 10 mm diameter clear stone) should be placed on top of the coarse gravel storage layer as a choking layer separating it from the overlying filter media bed.

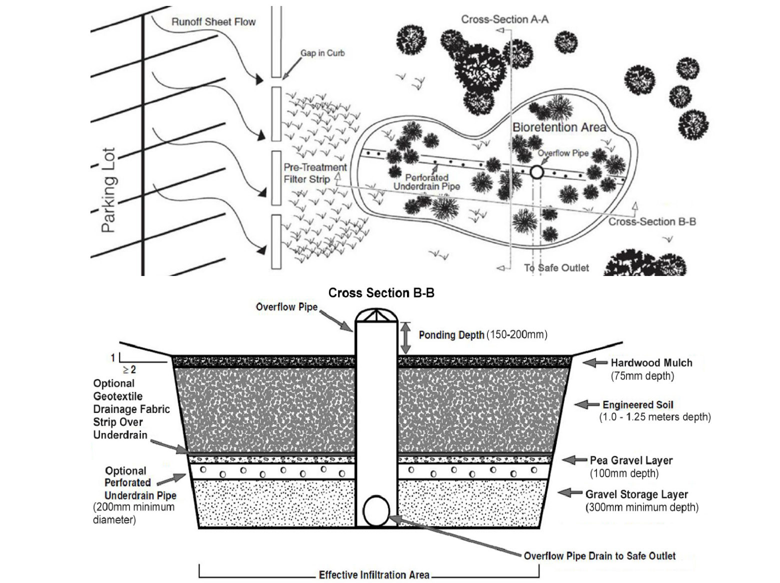
FILTER MEDIA

- COMPOSITION: To ensure a consistent and homogeneous bed, filter media should come pre-mixed from an approved vendor.
- DEPTH: Recommended depth is between 1.0 and 1.25 m. However in constrained applications, pollutant removal benefits may be achieved in beds as shallow as 500 mm. If trees are to be included in the design, bed depth must be at least 1.0 m.
- MULCH: A 75 mm layer of mulch on the surface of the filter bed enhances plant survival, suppresses weed growth and pretreats runoff before it reaches the filter bed.

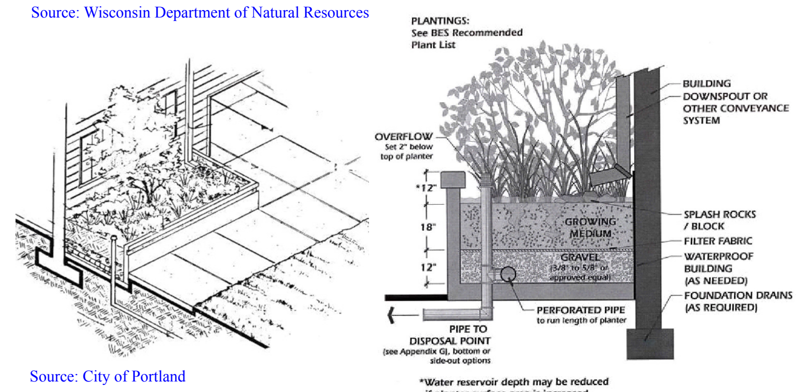
CONVEYANCE AND OVERFLOW

Bioretention can be designed to be inline or offline from the drainage system. Inline bioretention accepts all flow from a drainage area and conveys larger event flows through an overflow outlet. Overflow structures must be sized to safely convey larger storm events out of the facility. The invert of the overflow should be placed at the maximum water surface elevation of the bioretention area, which is typically 150-250 mm above the filter bed surface.

Offline bioretention practices use flow splitters or bypass channels that only allow the required water quality storage volume to enter the facility. This may be achieved with a pipe, weir, or curb opening sized for the target flow, but in conjunction, create a bypass channel so that higher flows do not pass over the surface of the filter bed. Using a weir or curb opening minimizes clogging and reduces maintenance frequency.



Source: Wisconsin Department of Natural Resources



Source: City of Portland

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefits
Bioretention with no underdrain	Yes	Yes - size for water quality storage requirement	Partial - based on available storage volume and infiltration rates
Bioretention with underdrain	Partial - based on available storage volume beneath the underdrain and soil infiltration rate	Yes - size for water quality storage requirement	Partial - based on available storage volume beneath the underdrain and soil infiltration rate
Bioretention with underdrain and impermeable liner	Partial - some volume reduction through evapo-transpiration	Yes - size for water quality storage requirement	Partial - some volume reduction through evapotranspiration

UNDERDRAIN

- Only needed where native soil infiltration rate is less than 15 mm/hr (hydraulic conductivity of less than 1x10-6 cm/s).
- Should consist of a perforated pipe embedded in the coarse gravel storage layer at least 100 mm above the bottom.
- A strip of geotextile filter fabric placed between the filter media and pea gravel choking layer over the perforated pipe is optional to help prevent fine soil particles from entering the underdrain.
- A vertical standpipe connected to the underdrain can be used as a cleanout and monitoring well.

MONITORING WELLS

A capped vertical stand pipe 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 time between storms.

GENERAL SPECIFICATIONS

Material	Specification	Quantity
Filter Media Composition	Filter Media Soil Mixture to contain: • 85 to 88% sand • 8 to 12% soil fines • 3 to 5% organic matter (leaf compost) Other Criteria: • Phosphorus soil test index (P-Index) value between 10 to 30 ppm • Cationic exchange capacity (CEC) greater than 10 meq/100 g • Free of stones, stumps, roots and other large debris • pH between 5.5 to 7.5 • Infiltration rate greater than 25 mm/hr	Recommended depth is between 1.0 and 1.25 metres.
Mulch Layer	Shredded hardwood bark mulch	A 75 mm layer on the surface of the filter bed
Geotextile	Material specifications should conform to Ontario Provincial Standard Specification (OPSS) 1860 for Class II geotextile fabrics. 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. For further guidance see CVC/TRCA LID SWM Planning and Design Guide, Table 4.5.5.	Strip over the perforated pipe underdrain (if present) between the filter media bed and gravel storage layer (stone reservoir)
Gravel	Washed 50 mm diameter clear stone should be used to surround the underdrain and for the gravel storage layer Washed 3 to 10 mm diameter clear stone should be used for pea gravel choking layer.	Volume based on dimensions, assuming a void space ratio of 0.4.
Underdrain	Perforated HDPE or equivalent, minimum 100 mm diameter, 200 mm recommended.	• Perforated pipe for length of cell. • Non-perforated pipe as needed to connect with storm drain system. • One or more caps. • T's for underdrain configuration

CONSTRUCTION CONSIDERATIONS

Ideally, bioretention sites should remain outside the limit of disturbance until construction of the bioretention begins to prevent soil compaction by heavy equipment. Locations should not be used as sediment basins during construction, as the concentration of fines will prevent post-construction infiltration. To prevent sediment from clogging the surface of a bioretention cell, stormwater should be diverted away from the bioretention until the drainage area is fully stabilized.

For further guidance regarding key steps during construction, see the CVC/TRCA LID SWM Planning and Design Guide, Section 4.5.2 - Construction Considerations)

OPERATION AND MAINTENANCE

Bioretention requires 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 as for any other landscaped area; weeding, pruning, and litter removal. Regular watering may be required during the first two years until vegetation is established.

For the first two years following construction the facility 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. Inspect for vegetation density (at least 80% coverage), damage by foot or vehicular traffic, channelization, accumulation of debris, trash and sediment, and structural damage to pretreatment devices.

Trash and debris should be removed from pretreatment devices, the bioretention area surface and inlet and outlets at least twice annually. Other maintenance activities include reapplying mulch, pruning, weeding replacing dead vegetation and repairing eroded areas as needed. Remove accumulated sediment on the bioretention area surface when dry and exceeding 25 mm depth.

SITE CONSIDERATIONS

Wellhead Protection
Facilities receiving road or parking lot runoff should not be located within two (2) year time-of-travel wellhead protection areas.

Available Space
Reserve open areas of about 10 to 20% of the size of the contributing drainage area.

Site Topography
Contributing slopes should be between 1 to 5%. The surface of the filter bed should be flat to allow flow to spread out. A stepped multi-cell design can also be used.

Available Head
If an underdrain is used, then 1 to 1.5 metres elevation difference is needed between the inflow point and the downstream storm drain invert.

Water Table
A minimum of one (1) metre separating the seasonally high water table or top of bedrock elevation and the bottom of the practice is necessary.

Soils
Bioretention can be located over any soil type, but hydrologic soil group A and B soils are best for achieving water balance benefits. Facilities should be located in portions of the site with the highest native soil infiltration rates. Where infiltration rates are less than 15 mm/hr (hydraulic conductivity less than 1x10-6 cm/s) an underdrain is required. Native soil infiltration rate at the proposed facility location and depth should be confirmed through measurement of hydraulic conductivity under field saturated conditions.

Drainage Area & Runoff Volume
Typical contributing drainage areas are between 100 m2 to 0.5 hectares. The maximum recommended contributing drainage area is 0.8 hectares. Typical ratios of impervious drainage area to treatment facility area range from 5:1 to 15:1.

Pollution Hot Spot Runoff
To protect groundwater from possible contamination, runoff from pollution hot spots should not be treated by bioretention facilities designed for full or partial infiltration. Facilities designed with an impermeable liner (filtration only facilities) can be used to treat runoff from pollution hot spots.

Proximity to Underground Utilities
Designers should consult local utility design guidance for the horizontal and vertical clearances required between storm drains, ditches, and surface water bodies.

Overhead Wires
Check whether the future tree canopy height in the bioretention area will interfere with existing overhead phone and power lines.

Setback from Buildings
If an impermeable liner is used, no setback is needed. If not, a four (4) metre setback from building foundations should be applied.

TORONTO AND REGION Conservation for The Living City
CVC CREDIT VALLEY CONSERVATION

FOR FURTHER DETAILS SEE SECTION 4.5 OF THE CVC/TRCA LID SWM GUIDE

VEGETATED FILTER STRIPS

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

GENERAL DESCRIPTION

Vegetated filter strips (a.k.a. buffer strips and grassed filter strips) are gently sloping, densely vegetated areas that treat runoff as sheet flow from adjacent impervious areas. They slow runoff velocity and filter out suspended 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 to add 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.

Source: Trinkaus Engineering

Source: Wisconsin Department of Natural Resources

Source: Wisconsin Department of Natural Resources

Source: Washington State Department of Transportation

DESIGN GUIDANCE

GEOMETRY AND SITE LAYOUT

The maximum contributing flow path length across adjacent impervious surfaces should not exceed 25 metres. The impervious surfaces 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.

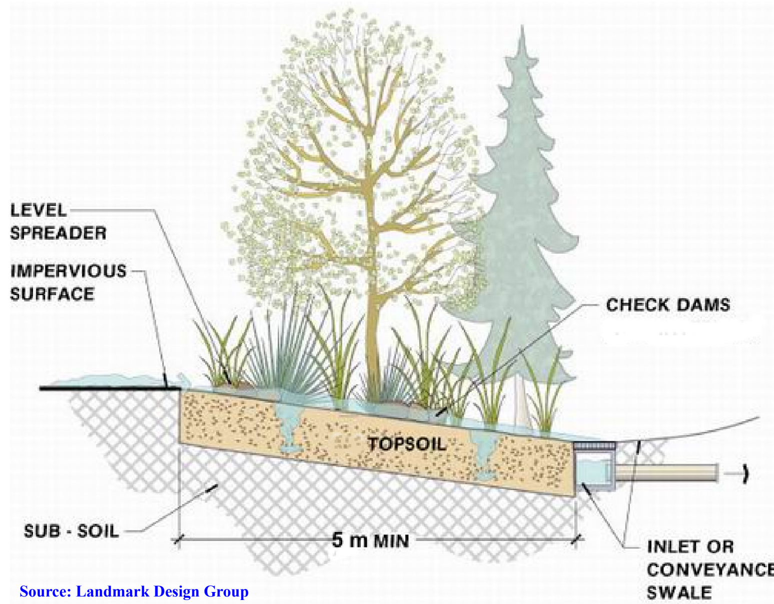
CONVEYANCE AND OVERFLOW

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 cutouts). When filter strip slopes 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 underdrain connected to the storm sewer. The volume ponded behind the berm should be equal to the water quality storage requirement. During larger storms, runoff overtops the berm and flows directly into a storm sewer inlet.

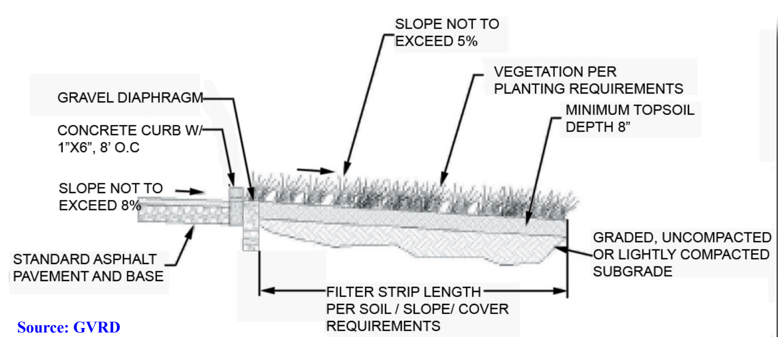
SOIL AMENDMENTS

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.



Source: Landmark Design Group

VEGETATED FILTER STRIPS



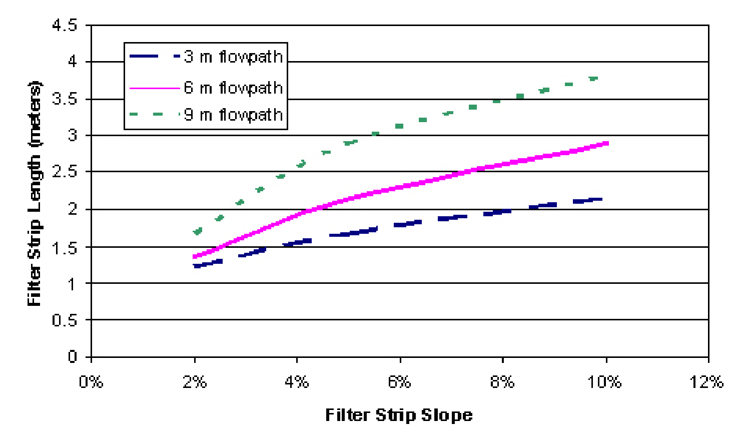
Source: GVRD

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Vegetated Filter Strips	Partial - depends on soil infiltration rate	Partial - depends on soil infiltration rate and flow path length	Partial - depends on soil infiltration rate

GENERAL SPECIFICATIONS

Material	Specification	Quantity
Gravel Diaphragm	Washed 3 to 10 mm diameter stone	Diaphragm should be a minimum of 300 mm wide and 600 mm deep (MDE, 2000).
Gravel/ Earthen Berm	Berm should be composed of sand (35 to 60%), silt (30 to 55%), and gravel (10 to 25%) (MDE, 2000) Gravel should be 15 to 25 mm in diameter.	N/A



Source: Pennsylvania Department of Environmental Protection

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.

Soil

Filter strips are a suitable practice on all soil types. If soils 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.

Pollution Hot Spot Runoff

To protect groundwater from possible contamination, source areas where land uses or human activities have the potential to generate highly contaminated runoff (e.g., vehicle fueling, servicing and demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites) should not be treated by vegetated filter strips.

Water table

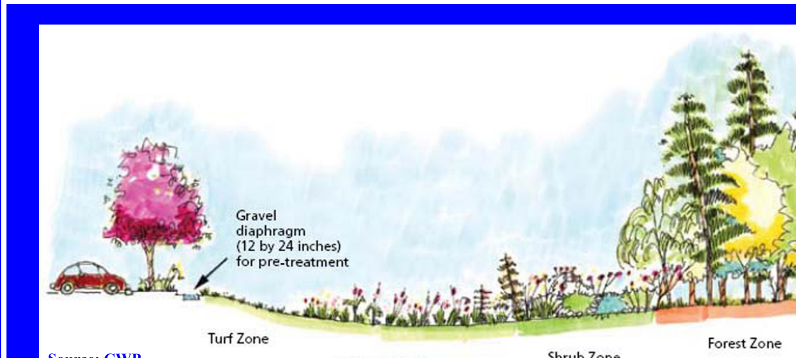
Filter strips should only be used where depth to the seasonally high water table is at least one (1) metre below the ground surface.

OPERATION AND MAINTENANCE

Generally, routine maintenance will be the same as for any other landscaped area; weeding, pruning, and litter 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 inflowing runoff does not become concentrated and short circuit the practice. Vehicles should not be parked 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 every 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 sediment, 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, dethatching and aerating as needed. Remove accumulated sediment on the filter strip surface when dry and exceeding 25 mm depth



Source: CWP

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 silt fencing. Only vehicular traffic used 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 site. If used for sediment control during construction, it should be regraded and revegetated after construction is finished.

TORONTO AND REGION Conservation for The Living City

CVC CREDIT VALLEY CONSERVATION

FOR FURTHER DETAILS SEE SECTION 4.6 OF THE CVC/TRCA LID SWM GUIDE

PERMEABLE PAVEMENT

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

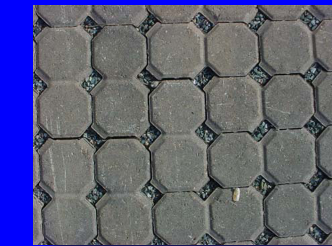
GENERAL DESCRIPTION

Permeable pavements, an alternative to traditional impervious pavement, allow stormwater to drain through them and into a stone reservoir where it is infiltrated into the underlying native soil or temporarily detained. They can be used for low traffic roads, parking lots, driveways, pedestrian plazas and walkways. Permeable pavement is ideal for sites with limited space for other surface stormwater BMPs. Examples of permeable pavement types include:

- permeable interlocking concrete pavers (i.e., block pavers);
- plastic or concrete grid systems (i.e., grid pavers);
- pervious concrete; and
- porous asphalt.

Depending on the native soils and physical constraints, the system may be designed with no underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain for a no infiltration or detention and filtration only practice.




DESIGN GUIDANCE

GEOMETRY & SITE LAYOUT

Permeable pavement systems can be used for entire parking lot areas or driveways or can be designed to receive runoff from adjacent impervious pavement. For example, the parking spaces of a parking lot or road can be permeable pavers while the drive lanes are impervious asphalt. In general, the impervious area should not exceed 1.2 times the area of the permeable pavement which receives the runoff (GVRD, 2005).

PRE-TREATMENT

In most permeable pavement designs, the pavement bedding layer acts as pretreatment to the stone reservoir below. Periodic vacuum sweeping and preventative measures like not storing snow or other materials on the pavement are critical to prevent clogging. An optional pretreatment element can be a pea gravel choking layer above the coarse gravel storage reservoir.

CONVEYANCE AND OVERFLOW

All designs require an overflow outlet connected to a storm sewer with capacity to convey larger storms. One option is to set storm drain inlets slightly above the surface elevation of the pavement, which allows for temporary shallow ponding above the surface. Another design option is an overflow edge, which is a gravel trench along the downgradient edge of the pavement surface that drains to the stone reservoir below.

Pavements designed for full infiltration, where native soil infiltration rate is 15 mm/hr or greater, do not require incorporation of a perforated pipe underdrain. Pavements designed for partial infiltration, where native soil infiltration rate is less than 15 mm/hr, should incorporate a perforated pipe underdrain placed near the top of the granular stone reservoir. Partial infiltration designs can also include a flow restrictor assembly on the underdrain to optimize infiltration with desired drawdown time between storm events.

MONITORING WELLS

A capped vertical standpipe 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 the length of time required to fully drain the facility between storms.

STONE RESERVOIR

The stone reservoir must be designed to meet both runoff storage and structural support requirements. Clean washed stone is recommended as any fines in the aggregate material will migrate to the bottom and may prematurely clog the native soil. The bottom of the reservoir should be flat so that runoff will be able to infiltrate evenly through the entire surface. If the system is not designed for infiltration, the bottom should be sloped at 1 to 5% toward the underdrain.

GEOTEXTILE

A non-woven needle punched, or woven monofilament geotextile fabric should be installed between the stone reservoir and native soil to maintain separation.

EDGE RESTRAINTS

Pavers must abut tightly against the restraints to prevent rotation under load and any consequent spreading of joints. The restraints must be able to withstand the impact of temperature changes, vehicular traffic and snow removal equipment. Metal or plastic stripping is acceptable in some cases, but concrete edges are preferred. Concrete edge restraints should be supported on a minimum base of 150 mm of aggregate.

LANDSCAPING

Adjacent landscaping areas should drain away from permeable pavement to prevent sediments from running onto the surface. Urban trees also benefit from being surrounded by permeable pavement rather than impervious cover, because their roots receive more air and water.

OPERATION AND MAINTENANCE

Annual inspections of permeable pavement should be conducted in the spring to ensure continued infiltration performance. Check for deterioration and whether water is draining between storms. The pavement reservoir should drain completely within 72 hours of the end of the storm event. The following maintenance procedures and preventative measures should be incorporated into a maintenance plan:

Surface Sweeping: Sweeping should occur once or twice a year with a commercial vacuum sweeping unit. Permeable pavement should not be washed with high pressure water systems or compressed air units.

Inlet Structures: Drainage pipes and structures within or draining to the subsurface bedding beneath permeable pavement should be cleaned out on regular intervals.

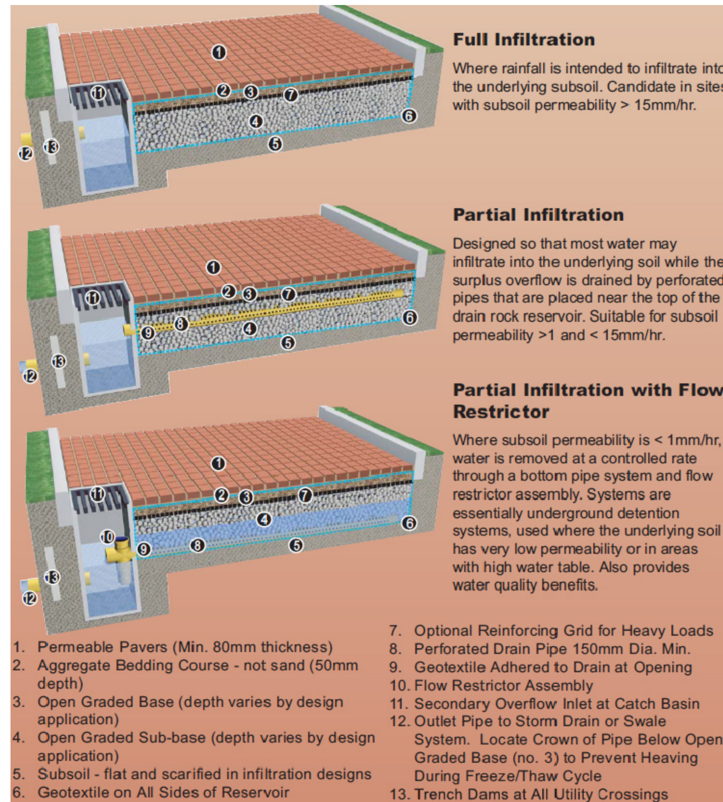
Heavy Vehicles: Trucks and other heavy vehicles should be prevented from tracking or spilling dirt onto the permeable pavement.

Construction and Hazardous Materials: Due to the potential for groundwater contamination, all construction or hazardous material carriers should be prohibited from entering a permeable pavement site.

Drainage Areas: Impervious areas contributing to the permeable pavement should be regularly swept and kept clear of litter and debris. Flows from any landscaped areas should be diverted away from thepavement or be well stabilized with vegetation.

Grid Pavers: Grid paver systems that have been planted with grass should be mowed regularly with the clippings removed. Grassed grid pavers may require periodic watering and fertilization to establish and maintain healthy vegetation.

Winter Maintenance: Sand should not be spread on permeable pavement as it can quickly lead to clogging. Deicers should only be used in moderation and only when needed. Pilot studies have found that permeable pavement requires 75% less de-icing salt than conventional pavement over the course of a typical winter season. Permeable pavement is plowed for snow removal like any other pavement. Plowed snow piles should not be stored on permeable pavement systems.



Source: GVRD

ABILTY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Permeable pavement with no underdrain	Yes	Yes - size for water quality storage requirement	Partial - based on available storage volume and soil infiltration rate
Permeable pavement with underdrain	Moderate - based on native soil infiltration rates and storage beneath the underdrain	Yes - size for water quality storage requirement	Partial - based on available storage volume and soil infiltration rate
Permeable pavement with underdrain and liner	No - some volume reduction occurs through evapotranspiration	Moderate - limited filtering and settling of sediments	Partial - based on available storage volume and soil infiltration rate

GENERAL SPECIFICATIONS

Material	Specification	Quantity
Pervious Concrete	• NO4-RG-S7 mix with air entrainment proven to have the best freeze-thaw durability after 300 freeze-thaw cycles. • 28 day compressive strength = 5.5 to 20 MPa • Void ratio = 14% - 31% • Permeability = 900 to 21,500 mm/hr	Thickness will range from 100mm - 150 mm depending on the expected loads
Porous Asphalt	• Open-graded asphalt mix with a minimum of 16% air voids • Polymers can be added to provide additional strength for heavy loads • The University of New Hampshire Stormwater Center has detailed design specifications for porous asphalt on their webpage: http://www.unh.edu/erg/cstev/pubs_specs_info	Thickness will range from 50 mm to 100 mm depending on the expected loads.
Permeable Pavers	• Permeable pavers should conform to manufacturer specifications. • ASTM No. 8 (5 mm dia.) crushed aggregate is recommended for fill material in the paver openings. For narrow joints between interlocking shapes, a smaller sized aggregate may be used (Smith, 2006). • Pavers shall meet the minimum material and physical properties set forth in CAN 3-A231.2, Standard Specification for Precast Concrete Pavers. • Pigment in concrete pavers shall conform to ASTM C 979. • Maximum allowable breakage of product is 5%.	For vehicular applications, the minimum paver thickness is 80 mm and for pedestrian applications is 60 mm. Joint widths should be no greater than 15 mm for pedestrian applications.
Stone Reservoir	All aggregates should meet the following criteria: • Maximum wash loss of 0.5% • Minimum durability index of 35 • Maximum abrasion of 10% for 100 revolutions and maximum of 50% for 500 revolutions Granular Subbase The granular subbase material shall consist of granular material graded in accordance with ASTM D 2940. Material should be clear crushed 50 mm diameter stone with void space ratio of 0.4. Granular Base The granular base material shall be crushed stone conforming to ASTM C 33 No 57. Material should be clear crushed 20 mm diameter stone. Bedding The granular bedding material shall be graded in accordance with the requirements of ASTM C 33 No 8. The typical bedding thickness is between 40 mm and 75 mm. Material should be 5 mm diameter stone or as determined by the Design Engineer (Smith, 2006).	See BMP Sizing section for aggregate bed depth and multiply by application are to get total volume.
Geotextile	Material specifications should conform to Ontario Provincial Standard Specification (OPSS) 1860 for Class II geotextile fabrics. 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. Primary considerations are: • Suitable apparent opening size (AOS) for non-woven fabrics, or percent open area (POA) for woven fabrics, to maintain water flow even with sediment and microbial film build-up; • Maximum forces that will be exerted on the fabric (i.e., what tensile, tear and puncture strength ratings are required?); • Load bearing ratio of the underlying native soil (i.e., is geotextile needed to prevent downward migration of aggregate into the native soil?); • Texture (i.e., grain size distribution) of the overlying aggregate material; and • Permeability of the native soil. For further guidance see CVC/TRCA LID SWM Planning and Design Guide, Table 4.7.3.	Between stone reservoir and native soil.
Underdrain (optional)	• HDPE or equivalent material, continuously perforated with smooth interior and a minimum inside diameter of 100 mm. • Perforations in pipes should be 10 mm in diameter. • A standpipe from the underdrain to the pavement surface can be used for monitoring and maintenance of the underdrain. The top of the standpipe should be covered with a screw cap and a vandal-proof lock.	Pipes should terminate 0.3 m short from the sides of the base.

SITE CONSIDERATIONS

Wellhead Protection

Permeable pavement should not be used for road or parking surfaces within two (2) year time-of-travel wellhead protection areas.

Site Topography

Permeable pavement surface should be at least 1% and no greater than 5%.

Water Table

The base of permeable pavement stone reservoir should be at least one (1) metre above the seasonally high water table or top of bedrock elevation.

Soil

Systems located in native soils with an infiltration rate of less than 15 mm/hr (i.e., hydraulic conductivity of less than 1x10-6 cm/s) require a perforated pipe underdrain. Native soil infiltration rate at the proposed location and depth should be confirmed through measurement of hydraulic conductivity under field saturated conditions.

Drainage Area & Runoff Volume

In general, the impervious area treated should not exceed 1.2 times the area of permeable pavement which receives the runoff.

Setback from Buildings

Should be located downslope from building foundations. If the pavement does not receive runoff from other surfaces, no setback is required. If the pavement receives runoff from other surfaces a minimum setback of four (4) metres down-gradient is recommended.

Pollution Hot Spot Runoff

To protect groundwater from possible contamination, runoff from pollution hot spots should not be treated by permeable pavement.

CONSTRUCTION CONSIDERATIONS

SEDIMENT CONTROL

The treatment area should be fully protected during construction so that no sediment reaches the permeable pavement system. Construction traffic should be blocked from the permeable pavement and its drainage areas once the pavement has been installed.

BASE CONSTRUCTION

In parking lots, the stone aggregate should be placed in 100 mm to 150 mm lifts and compacted with a minimum 9,070 kg (10 ton) steel drum roller.

WEATHER

Porous asphalt and pervious concrete will not properly pour and set in extremely high and low temperatures.

PAVEMENT PLACEMENT

Properly installed permeable pavement requires trained and experienced producers and construction contractors.

TORONTO AND REGION Conservation for The Living City

CVC CREDIT VALLEY CONSERVATION

FOR FURTHER DETAILS SEE SECTION 4.7 OF THE CVC/TRCA LID SWM GUIDE

ENHANCED GRASS SWALES

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

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 channels 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 roadside 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, so the initial trapezoidal cross-section design should be checked for capacity and conveyance assuming it is a parabolic cross-section. Swale length between culverts should be 5 metres or greater.
- Bottom Width: Should be designed with a bottom width between 0.75 and 3.0 metres. Should allow for shallow flows and adequate water quality treatment, while preventing flows from concentrating and creating gullies.
- Longitudinal Slope: 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 pretreatment for lateral incoming flows and to maximize the swale filtering surface. Steeper side slopes are likely to have erosion gullying from incoming lateral flows. A maximum slope of 2.5:1 (H:V) is recommended and a 4:1 slope is preferred where space permits.

PRE-TREATMENT

A pea gravel diaphragm located along the top of each bank can be used to provide pretreatment of any runoff entering the swale laterally along its length. Vegetated filter strips or mild side slopes (3:1) also provide pretreatment for any lateral sheet flow entering the swale. Sedimentation forebays at inlets to the swale are also a pretreatment option.

CONVEYANCE AND OVERFLOW

Grass swales must be designed for a maximum 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

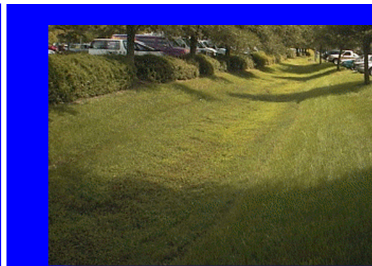
If soils along the location of the swale are highly compacted, or of such low fertility that vegetation cannot become established, they should be tilled to a depth of 300 mm and amended with compost to achieve an organic content of 8 to 15% by weight or 30 to 40% by volume.


Source: Delaware Department of Transportation

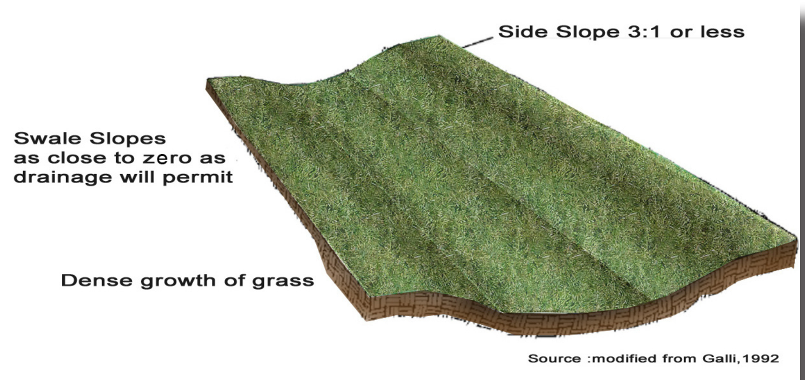

Source: Seattle Public Utilities


Source: Thomas Engineering

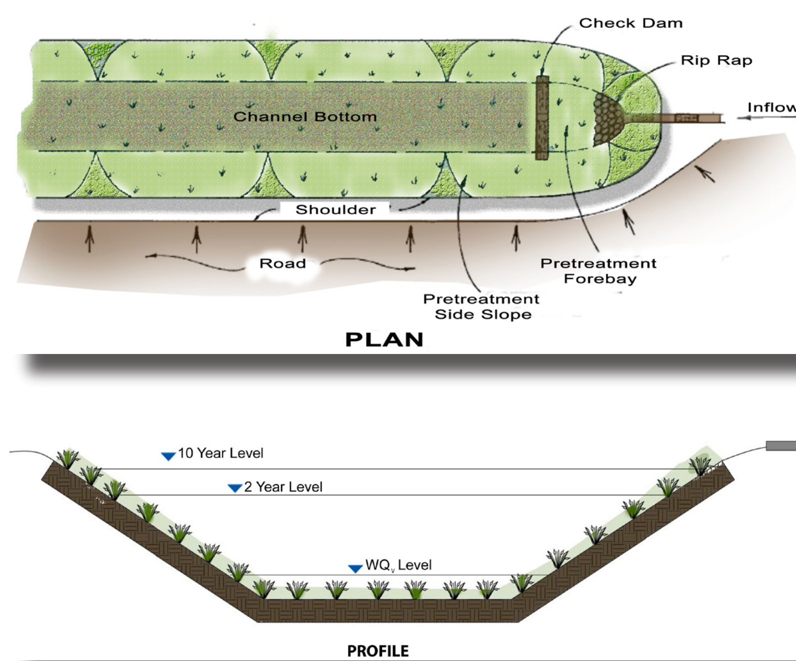

Source: Sue Donaldson




Source: CWP



PLAN VIEW OF A GRASS SWALE



PLAN AND PROFILE VIEWS

ABILITY TO MEET SWM OBJECTIVES

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

GENERAL SPECIFICATIONS

Component	Specification	Quantity
Check Dams	Constructed of a non-erosive material such as suitably sized aggregate, wood, gabions, riprap, or concrete. All check dams should be underlain with geotextile filter fabric. Wood used for check dams should consist of pressure treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak or locust.	Spacing should be based on the longitudinal slope and desired ponding volume.
Gravel Diaphragm	Washed stone between 3 and 10 mm in diameter.	Minimum of 300 mm wide and 600 mm deep.

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 banks are 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.

OPERATION AND MAINTENANCE

Generally, routine maintenance will be the same as for any other landscaped area; weeding, pruning, and litter removal. Grassed swales should be mown at least twice yearly to maintain grass height between 75 and 150 mm. The lightest 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 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 inlets and pretreatment devices are free of debris.

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. Inspect for vegetation density (at least 80% coverage), damage by foot or vehicular traffic, accumulation of debris, trash and sediment, and structural damage to pretreatment devices.

Trash and debris should be removed from pretreatment devices and the surface of the swale at least twice annually. Other maintenance activities include weeding, replacing dead vegetation, repairing eroded areas, dethatching and aerating as needed. Remove accumulated sediment on the swale surface when dry and exceeding 25 mm depth.

SITE CONSIDERATIONS

Available Space
Grass swales usually consume about 5 to 15% of their contributing drainage area. A width of at least 2 metres is needed.

Site Topography
Site topography constrains the application of grass swales. Longitudinal slopes between 0.5 and 6% are allowable. This prevents ponding while providing residence time and preventing erosion. On slopes steeper than 3%, check dams should be used.

Drainage Area & Runoff Volume
The conveyance capacity should match the drainage area. Sheet flow to the grass swale is preferable. If drainage areas are greater than 2 hectares, high discharge through the swale may not allow for filtering and infiltration, and may create erosive conditions. Typical ratios of impervious drainage area to treatment facility area range from 5:1 to 10:1.

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

Pollution Hot Spot Runoff
To protect groundwater from possible contamination, source areas where land uses or human activities have the potential to generate highly contaminated runoff (e.g., vehicle fueling, servicing and demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites) should not be treated by grass swales.

Proximity to Underground Utilities
Utilities running parallel to the grass swale should be offset from the centerline of the swale. Underground utilities below the bottom of the swale are not a problem.

Water Table
The bottom of the swale should be separated from the seasonally high water table or top of bedrock elevation by at least one (1) metre.

Setback from Buildings
Should be located a minimum of four (4) metres from building foundations to prevent water damage.

TORONTO AND REGION Conservation for The Living City

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FOR FURTHER DETAILS SEE SECTION 4.8 OF THE CVC/TRCA LID SWM GUIDE

DRY SWALES

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

GENERAL DESCRIPTION

A dry swale can be thought of as an enhanced grass swale that incorporates an engineered filter media bed and optional perforated pipe underdrain or a bioretention cell configured as a linear open channel. They can also be referred to as infiltration swales or bio-swales. Dry swales are similar to enhanced grass swales in terms of the design of their surface geometry, slope, check dams and pretreatment devices. They are similar to bioretention cells in terms of the design of the filter media bed, gravel storage layer and optional underdrain. In general, they are open channels designed to convey, treat and attenuate stormwater runoff. Vegetation or aggregate material on the surface of the swale slows the runoff water to allow sedimentation, filtration through the root zone and engineered soil bed, evapotranspiration, and infiltration into the underlying native soil.

DESIGN GUIDANCE

GEOMETRY AND SITE LAYOUT

- SHAPE: A parabolic shape is preferable for aesthetic, maintenance and hydraulic reasons. However, design may be simplified 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 metres or greater.
- BOTTOM WIDTH: For the trapezoidal cross section, the bottom width should be between 0.75 and 2 metres. When greater widths are desired, bioretention cell designs should be used.
- SIDE SLOPES: Should be no steeper than 3:1 for maintenance considerations (mowing). Flatter slopes are encouraged where adequate space is available to provide pretreatment for sheet flows entering the swale.
- LONGITUDINAL SLOPE: Should be as gradual as possible to permit the temporary ponding of the water quality storage requirement. 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 dam spacing should be based on the slope and desired ponding volume. They should be spaced far enough apart to allow access for maintenance equipment (e.g., mowers).

PRE-TREATMENT

Pretreatment prevents premature clogging by capturing coarse sediments before they reach the filter bed. Where runoff source areas produce little sediment, such as roofs, dry swales can function effectively without pretreatment. To treat parking area or road runoff, a two-cell design that incorporates a forebay is recommended. Pretreatment practices that may be feasible, depending on conveyance method and availability of space include:

- SEDIMENTATION FOREBAY (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): Should ideally be a minimum of three (3) metres in width. If smaller strips are used, more frequent maintenance of the filter bed can be anticipated.
- GRAVEL DIAPHRAGM (SHEET FLOW): A small trench filled with pea gravel, which is perpendicular to the flow path between the edge of the pavement and the dry swale will promote settling out of sediment and maintain sheet flow into the facility. A drop of 50-150 mm into the gravel diaphragm can be used to dissipate energy and promote settling.
- RIP RAP AND/OR DENSE VEGETATION (CHANNEL FLOW): Suitable for small dry swales with drainage areas less than 100 square metres.

GRAVEL STORAGE LAYER

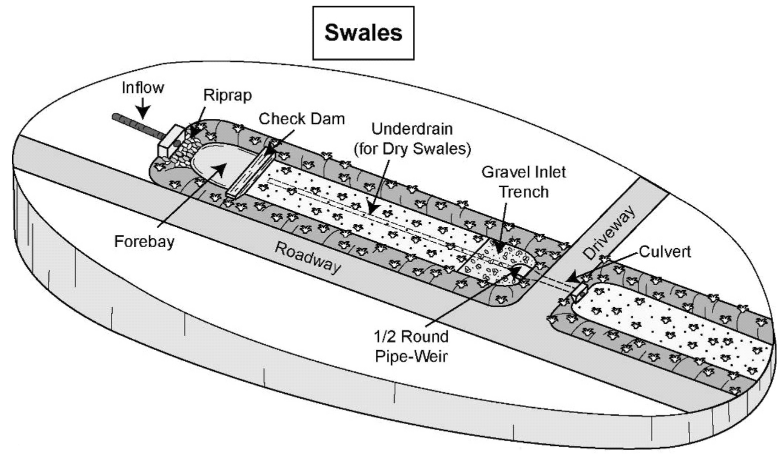
- DEPTH: Should be a minimum of 300 mm deep and sized to provide the required storage volume. Granular material should be 50 mm diameter clear stone.
- PEA GRAVEL CHOKING LAYER: A 100 mm deep layer of pea gravel (3 to 10 mm diameter clear stone) should be placed on top of the coarse gravel storage layer as a choking layer separating it from the overlying filter media bed.

FILTER MEDIA

- COMPOSITION: To ensure a consistent and homogeneous bed, filter media should come pre-mixed from an approved vendor.
- DEPTH: Recommended depth is between 1.0 and 1.25 m. However in constrained applications, pollutant removal benefits may be achieved in beds as shallow as 500 mm. If trees are to be included in the design, bed depth must be at least 1.0 m.
- MULCH: A 75 mm layer of mulch on the surface of the filter bed enhances plant survival, suppresses weed growth and pretreats 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 1x10-6 cm/s).
- Should consist of a perforated pipe embedded in the coarse gravel storage layer at least 100 mm above the bottom.
- A strip of geotextile filter fabric placed between the filter media and pea gravel choking layer over the perforated pipe 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.



ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Dry swale with no underdrain or full infiltration	Yes	Yes - size for water quality storage requirement	Partial - based on available storage volume and soil infiltration rate
Dry swale with underdrain or partial infiltration	Partial - based on available storage volume beneath the underdrain and soil infiltration rate	Yes - size for water quality storage requirement	Partial - based on available storage volume beneath the underdrain and soil infiltration rate
Dry swale with underdrain and impermeable liner or no infiltration	Partial - some volume reduction through evapotranspiration	Yes - size for water quality storage requirement	Partial - some volume reduction through evapotranspiration

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 as for any other landscaped area; weeding, pruning, and litter removal. Regular watering may be required during the first two years until vegetation is established.

For the first two years following construction the facility 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. Inspect for vegetation density (at least 80% coverage), damage by foot or vehicular traffic, channelization, accumulation of debris, trash and sediment, and structural damage to pretreatment devices.

Trash and debris should be removed from pretreatment devices, the dry swale surface and inlet and outlets at least twice annually. Other maintenance activities include reapplying mulch, pruning, weeding replacing dead vegetation and repairing eroded areas as needed. Remove accumulated sediment on the dry swale surface when dry and exceeding 25 mm depth.

CONVEYANCE AND OVERFLOW

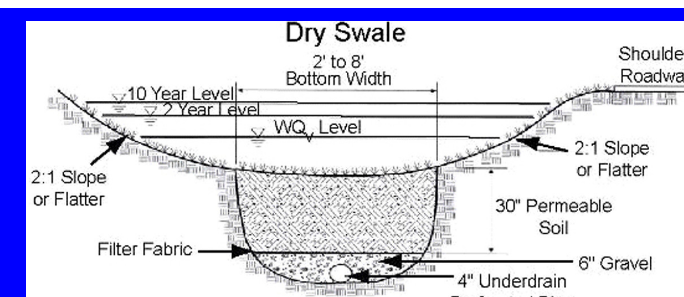
Should be designed for a maximum velocity of 0.5 m/s or less for a 4 hour 25 mm Chicago storm event. The swale should also convey the locally required design storm (usually the 10 year storm) at non-erosive velocities with freeboard provided above the required design storm water level.

MONITORING WELLS

A capped vertical standpipe consisting of an anchored 100 to 150 millimetre diameter perforated pipe with a lockable cap installed to the bottom of the facility at the furthest downgradient end is recommended for monitoring the length of time required to fully drain the facility between storms.

GENERAL SPECIFICATIONS

Material	Specification	Quantity
Filter Media Composition	Filter Media Soil Mixture to contain: • 85 to 88% sand • 8 to 12% soil fines • 3 to 5% organic matter (leaf compost) Other Criteria: • Phosphorus soil test index (P-Index) value between 10 to 30 ppm • Cationic exchange capacity (CEC) greater than 10 meq/100 g • Free of stones, stumps, roots and other large debris • pH between 5.5 to 7.5 • Infiltration rate greater than 25 mm/hr.	Volumetric computation based on surface area and depth used in design computations
Geotextile	Material specifications should conform to Ontario Provincial Standard Specification (OPSS) 1860 for Class II geotextile fabrics. 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. For further guidance see CVC/TRCA LID SWM Planning and Design Guide, Table 4.9.4.	Strip over the perforated pipe underdrain (if present) between the filter media bed and gravel storage layer (stone reservoir).
Gravel	Washed 50 mm diameter clear stone with void space ratio of 0.4 should be used to surround the underdrain.	Volumetric computation based on depth.
Underdrain (optional)	Perforated HDPE or equivalent material, minimum 100 mm dia., 200 mm dia. recommended. Set pipe invert at least 100 mm above bottom of the gravel layer.	• Perforated pipe for length of dry swale. • Non-perforated pipe to connect with storm drain system. • One or more caps. • T's for underdrain
Check Dams	• Should be constructed of a non-erosive material such as wood, gabions, riprap, or concrete and underlain with filter fabric. • Wood used should consist of pressure treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak or locust.	Computation of check dam material needed based on surface area and depth used in design computations
Mulch or Matting	• Shredded hardwood bark mulch • Where flow velocities dictate, use erosion and sediment control matting - coconut fiber or equivalent.	Mulch - A 75 mm layer on the surface of the filter bed. Matting - based on filter bed area.



SITE CONSIDERATIONS

Available Space

Footprints are 5 to 15% of their contributing drainage area. Swale length between culverts should be 5m or greater.

Site Topography

Longitudinal slopes ranging from 0.5 to 4%. On slopes steeper than 3%, check dams should be used.

Drainage Area and Runoff Volume to Site

Typically treat drainage areas of two hectares or less. Typical ratios of impervious drainage area to treatment facility area range from 5:1 to 15:1.

Soil

Dry swales can be located over any soil type, but hydrologic soil group A and B soils are best for achieving water balance benefits. Facilities should be located in portions of the site with the highest native soil infiltration rates. Where infiltration rates are less than 15 mm/hr (hydraulic conductivity less than 1x10-6 cm/s) an underdrain is required. Native soil infiltration rate at the proposed facility location and depth should be confirmed through measurement of hydraulic conductivity under field saturated conditions.

Wellhead Protection

Facilities receiving road or parking lot runoff should not be located within two (2) year time-of-travel wellhead protection areas.

Water Table

The bottom of the swale should be separated from the seasonally high water table or top of bedrock elevation by at least one (1) metre to prevent groundwater contamination.

Pollution Hot Spot Runoff

To protect groundwater from possible contamination, runoff from pollution hot spots should not be treated dry swales designed for full or partial infiltration. Facilities designed with an impermeable liner (filtration only facilities) can be used to treat runoff from pollution hot spots.

Setback from Buildings

Should be set back four (4) metres from building foundations unless an impermeable liner and underdrain system is used.

Proximity to Underground Utilities

Designers should consult local utility design guidance for the horizontal and vertical clearance between storm drains, ditches, and surface water bodies.

CONSTRUCTION CONSIDERATIONS

Ideally, dry swale sites should remain outside the limit of disturbance until construction of the swale begins to prevent soil compaction by heavy equipment. Dry swale locations should never be used as the site of sediment basins during construction, as the concentration of fines will prevent post-construction infiltration. To prevent clogging, stormwater should be diverted away from the practice until the drainage area is fully stabilized.

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FOR FURTHER DETAILS SEE SECTION 4.9 OF THE CVC/TRCA LID SWM GUIDE

PERFORATED PIPE SYSTEMS

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

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 lined with geotextile fabric 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 waterbody. Perforated pipe systems can be used in place of conventional storm sewer pipes, where topography, water table depth, and runoff quality conditions are suitable. They are suitable for treating runoff from roofs, walkways, parking lots and low to medium traffic roads, with adequate pretreatment. Perforated pipe systems can also be referred to as pervious pipe systems, exfiltration systems, clean water collector systems and percolation drainage systems.

DESIGN GUIDANCE

SOIL CHARACTERISTICS

Perforated pipe systems can be constructed over any soil type, but hydrologic soil group A or B soils are best for achieving water balance objectives. If possible, facilities should be located in portions of the site with the highest native soil infiltration rates. Designers should verify the native soil infiltration rate at 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 between 600 and 2400 mm. The gravel beds should have gentle slopes between 0.5 to 1%.

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 options:

- *In-ground devices:* Devices placed between a conveyance pipe and the facility (e.g., oil and grit separators, sedimentation chambers, goss 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 practice.

CONVEYANCE AND OVERFLOW

Collection and conveyance of runoff into the perforated pipe system can be accomplished through conventional catchbasins and non-perforated pipes leading from foundation drains 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 75 to 150 mm deep above the perforated pipe. On-line concrete, clay or plastic trench baffles or other barriers can be installed across the granular filled trench to reduce flow along the system, thereby increasing the potential for infiltration. Overflows from the granular filled trench should either back up into manholes that are also 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-graded, 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 management approaches 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;
- prioritize infiltration of runoff from source areas that are comparatively less contaminated such as roofs, low traffic roads and parking areas; and,
- apply sedimentation pretreatment practices (e.g., oil and grit separators) before infiltration of road or parking area runoff.

Standing Water and Mosquitoes

Complete drawdown should occur within 72 hours after a storm event, before mosquitoes have an opportunity to breed.

Foundations and Seepage

Should be setback at least four (4) metres from building foundations to prevent basement flooding and damage during freeze/thaw cycles.

Winter Operation

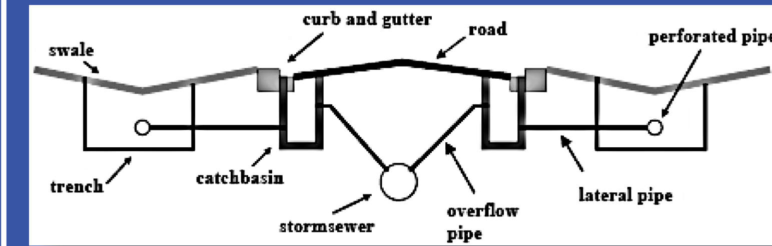
Perforated pipe systems will continue to function during winter months if the inlet pipe and top of the gravel bed is located below the local maximum frost penetration depth.

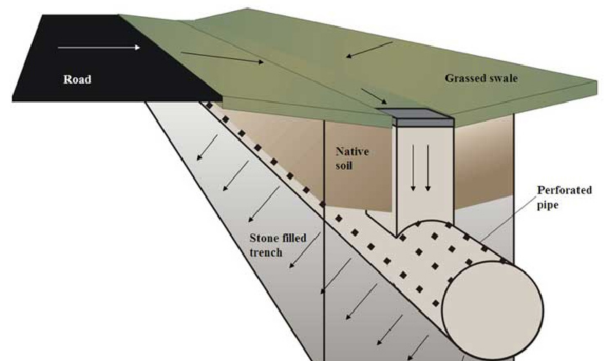
Risk of Soil Contamination

Available evidence from monitoring studies indicates that small distributed stormwater infiltration practices do not contaminate underlying soils, even after 10 years of operation.

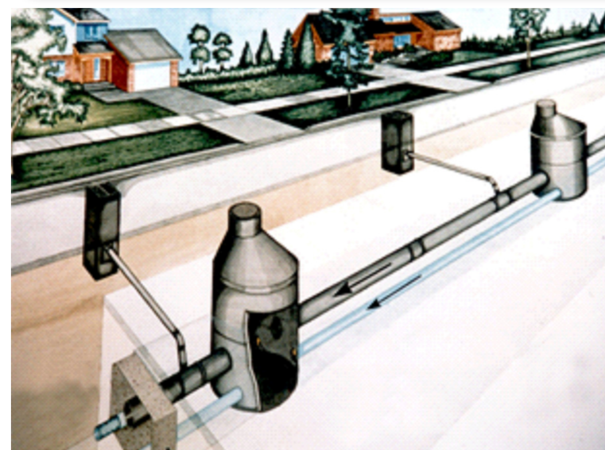
Maintenance

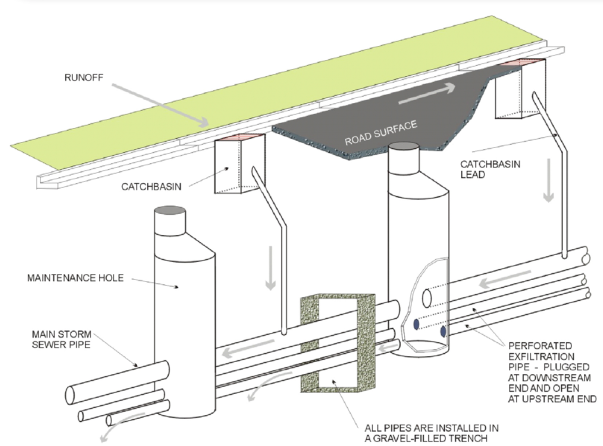
With proper location and adequate pretreatment, perforated pipe systems can continue to function effectively with very low levels of maintenance activities. Like conventional stormwater conveyance infrastructure (i.e., catchbasins and storm sewers), perforated pipe systems are typically located on public property (e.g., within road rights-of-way). An advantage to incorporating these systems in stormwater management systems is that legal agreements with property owners or managers, to ensure long term operation and maintenance, are not needed.





Source: STEP





CONSTRUCTION CONSIDERATIONS

Soil Disturbance and Compaction

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.

Erosion and Sediment Control

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

GENERAL SPECIFICATIONS

Material	Specification	Quantity
Perforated pipe	Pipe should be continuously perforated, smooth interior, with a minimum inside diameter of 200 millimetres.	Perforated pipe should run lengthwise through the facility at least 100 mm above the bottom of the gravel filled trench. Non-perforated pipe should be used for conveyance to the facility.
Stone	The trench in which perforated pipes are installed should be filled with washed 50 mm clear stone with a 40% void ratio.	Volume is based on trench dimensions and a void ratio of 40%.
Geotextile	Material specifications should conform to Ontario Provincial Standard Specification (OPSS) 1860 for Class II geotextile fabrics. 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. Primary considerations are: • Suitable apparent opening size (AOS) for non-woven fabrics, or percent open area (POA) for woven fabrics, to maintain water flow even with sediment and microbial film build-up; • Maximum forces that will be exerted on the fabric (i.e., what tensile, tear and puncture strength ratings are required?); • Load bearing ratio of the underlying native soil (i.e., is geotextile needed to prevent downward migration of aggregate into the native soil?); • Texture (i.e., grain size distribution) of the overlying native soil, filter media soil or aggregate material; and • Permeability of the native soil. For further guidance see CVC/TRCA LID SWM Planning and Design Guide, Table 4.10.4	Around the gravel filled trench (stone reservoir).

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Perforated Pipe Systems	Yes	Yes	Partial, depends on soil infiltration rate

OPERATION AND MAINTENANCE

Maintenance typically consists of cleaning out leaves, debris and accumulated sediment caught in pretreatment devices annually or as needed. Inspection via manholes should be performed to ensure the facility drains within the maximum acceptable length of time (typically 72 hours) at least annually and following every major storm event (>25 mm). If the time required to fully drain exceeds 72 hours, drain via pumping and clean out the perforated pipe by flushing. If slow drainage persists, the system may need removal and replacement of granular material and/or geotextile liner. Perforated pipe systems should be located below shoulders of roadways, pervious boulevards or grass swales where they can be readily excavated for servicing.


Source: STEP


Source: Plastream

SITE CONSIDERATIONS

Site Topography
Systems cannot be located on natural slopes greater than 15%. The gravel bed should be designed with gentle slopes between 0.5. to 1%.

Drainage Area
Typically designed with an impervious drainage area to treatment facility area ratio of between 5:1 to 10:1.

Soil
Perforated pipe systems can be located over any soil type, but hydrologic soil group A and B soils are best for achieving water balance benefits. Facilities should be located in portions of the site with the highest native soil infiltration rates. Native soil infiltration rate at the proposed facility location and depth should be confirmed through measurement of hydraulic conductivity under field saturated conditions.

Wellhead Protection
Facilities receiving road or parking lot runoff should not be located within two (2) year time-of-travel wellhead protection areas.

Water Table
The bottom of the gravel bed should be separated from the seasonally high water table or top of bedrock elevation by at least one (1) metre to prevent groundwater contamination.

Pollution Hot Spot Runoff
To protect groundwater from possible contamination, source areas where land uses or human activities have the potential to generate highly contaminated runoff (e.g., vehicle fueling, servicing and demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites) should not be treated by perforated pipe systems.

Setback from Buildings
Facilities should be setback a minimum of four (4) metres from building foundations.

Proximity to Underground Utilities
Local utility design guidance should be consulted to define the horizontal and vertical offsets. Generally, requirements for underground utilities passing near the practice will be no different than for utilities in other pervious areas.

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FOR FURTHER DETAILS SEE SECTION 4.10 OF THE CVC/TRCA LID SWM GUIDE