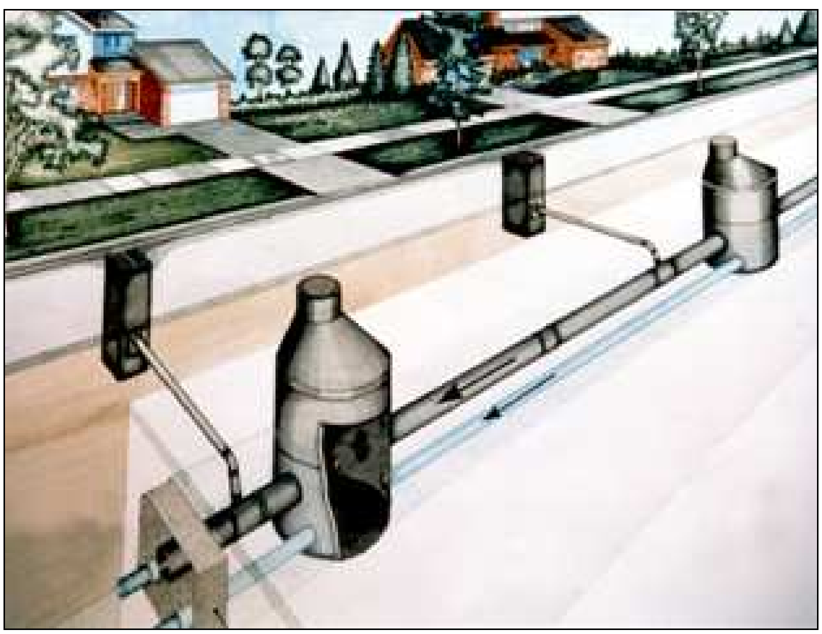
4.10 Perforated Pipe Systems

4.10.1 Overview

Description

Perforated pipe systems can be thought of as long infiltration trenches or linear soakaways that are designed for both conveyance and infiltration of stormwater runoff. They are underground stormwater conveyance systems designed to attenuate runoff volume and thereby, reduce contaminant loads to receiving waters. 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. A design variation can include perforated catchbasins, where the catchbasin sump is perforated to allow runoff to infiltrate into the underlying native soil. Perforated pipe systems can also be referred to as pervious pipe systems, exfiltration systems, clean water collector systems and percolation drainage systems.

Figure 4.10.1 Conceptual drawing of a perforated pipe system



Common Concerns

If properly located, designed and maintained, perforated pipe systems can greatly reduce runoff volume while having little or no surface footprint, which helps to conserve highly valued developable land. Some common concerns associated with their use that should be addressed through siting and design include:

- *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 (Pitt *et al.*, 1999). Chloride and sodium from de-icing salts applied to roads and parking areas during winter are not well attenuated in soil and can easily travel to shallow groundwater. Infiltration of de-icing salt constituents is also known to increase the mobility of certain heavy metals in soil (*e.g.*, lead, copper and cadmium), thereby raising the potential for elevated concentrations in underlying groundwater (Amrhein *et al.*, 1992; Bauske and Goetz, 1993). However, very few studies that have sampled groundwater below infiltration facilities or roadside ditches receiving de-icing salt laden runoff have found concentrations of heavy metals that exceed drinking water standards (*e.g.*, Howard and Beck, 1993; Granato *et al.*, 1995). To minimize risk of groundwater contamination the following management approaches are recommended (Pitt *et al.*, 1999; TRCA, 2009b):
    - stormwater 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 (*e.g.*, source areas where land uses or activities have the potential to generate highly contaminated runoff such as vehicle fuelling, servicing or demolition areas, outdoor storage or handling areas for hazardous materials and some heavy industry sites);
    - 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 more than 10 years of operation (TRCA, 2008).

- *Maintenance*: With proper location and adequate pretreatment, perforated pipe systems can continue to function effectively with very low levels of maintenance activities (J.F. Saborin and Associates, 2008a). 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.

- *Standing Water and Mosquitoes*: The detention of water in a perforated pipe system should be solely underground.

- *Foundations and Seepage*: Perforated pipe systems 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 (MTO, 2005).

Physical Suitability and Constraints
Key constraints to locating perforated pipe systems include:

- *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:* Perforated pipe systems should be located below shoulders of roadways, pervious boulevards or grass swales where they can be readily excavated for servicing. An adequate subsurface area outside of the four (4) metre setback from building foundations and suitable distance from other underground utilities must be available.

- *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%.

- *Water Table:* Designers should ensure that the bottom of the gravel bed is separated from the seasonally high water table or top of bedrock elevation by at least one (1) metre to prevent groundwater contamination.

- *Soils:* Underlying native soil conditions do not constrain the use of perforated pipe systems but greatly influence their runoff reduction performance. In order to predict facility performance so that downstream end-of-pipe facility designs can be adjusted accordingly, designers should verify the site-specific soil infiltration rates at the proposed facility locations and depths using the methods described in Appendix C.

- *Drainage Area:* Systems typically receive foundation drain water and runoff from roofs, walkways, roads and parking lots from multiple lots. They are typically designed with an impervious drainage area to treatment facility area ratio of between 5:1 to 10:1 (SWAMP, 2005).

- *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.
- *Setbacks 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 perforated pipe systems near other underground utilities.

Typical Performance

Table 4.10.1 Ability of perforated pipe systems 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

Water Balance

The degree to which water balance objectives are met will depend on the underlying native soil type on which the system is located. Several Ontario studies have assessed the performance of perforated pipe systems in cold climates. Table 4.10.2 summarizes the runoff reduction benefits achieved.

Table 4.10.2 Volumetric runoff reduction[1] achieved by perforated pipe systems

LID Practice	Location	Native Soil Type	Runoff Reduction[1]	Reference
Grass swale/ Perforated pipe system	Nepean, Ontario	Silty till	73%	J.F. Sabourin and Associates (2008a)
Grass swale/ Perforated pipe system	Nepean, Ontario	Sandy Silty till	86%	J.F. Sabourin and Associates (2008a)
Perforated pipe system	Etobicoke, Ontario	Clay to clayey silt till over silty sand	95%	SWAMP (2005)
Perforated pipe system	North York, Ontario	Silty sand	89%	SWAMP (2005)
Runoff Reduction Estimate[2]		**85% on HSG A and B soils; 45% on HSG C and D soils.**		

Notes:
1. Runoff reduction estimates are based on differences in runoff volume between the practice and a conventional catchbasin and storm sewer system over the period of monitoring.
2. This estimate is provided only for the purpose of initial screening of LID practices suitable for achieving stormwater management objectives and targets. Performance of individual facilities will vary depending on site specific contexts and facility design parameters and should be estimated as part of the design process and submitted with other documentation for review by the approval authority.

Water Quality – Pollutant Removal Capacity

Performance results from a limited number of field studies indicate that subsurface stormwater infiltration practices are effective BMPs for pollutant removal (TRCA, 2009b). These types of practices provide effective removal for many pollutants as a result of sedimentation, filtering, and soil adsorption. It is also important to note that there is a relationship between the water balance and water quality functions. If an infiltration practice infiltrates and evaporates 100% of the runoff from a site, then there is essentially no pollution leaving the site in surface runoff. Furthermore, treatment of infiltrated runoff continues to occur as it leaves the facility and moves through the native soil. The performance of perforated pipe systems would be expected to reduce pollutants in runoff in a manner similar to infiltration trenches. Table 4.4.3 summarizes pollutant removal results from performance studies of infiltration trenches and perforated pipe systems.

Several studies of perforated pipe systems in Ontario have examined their water quality benefits (Table 4.10.3). Seasonal contaminant load reductions in the order of 80% were observed for most constituents, with the exception of chloride, in the study of the system installed in a low density residential neighbourhood in Etobicoke (SWAMP, 2002; SWAMP, 2005). Perforated pipe systems that incorporate grassed swales as pretreatment have been observed to reduce loads of suspended sediment, phosphorus, nitrogen copper, lead and zinc in runoff flowing from the system between 75 to 90% in comparison to a similar catchment with conventional catchbasins and storm sewers (J.F. Sabourin and Associates, 1999; and 2008a). The Nepean systems were shown to release significantly less pollutants than the conventional sewer system, even after 20 years of operation (J.F. Sabourin and Associates, 2008a).

Table 4.10.3 Pollutant removal efficiencies[1] for soakaways, infiltration trenches and perforated pipe systems (in percent)

BMP	Reference	Location	Lead	Copper	Zinc	TSS[2]	TP[3]	TKN[4]
Soakaway	Barraud *et al.* (1999)	Valence, France	98	NT	54 to 88	NT	NT	NT
Infiltration trench	ASCE (2000)[5]	Various	70 to 90	70 to 90	70 to 90	70 to 90	50 to 70	40 to 70
Grass swale/ perforated pipe system	SWAMP (2002)	North York, Ontario	75	96	93	24	84	84
Grass swale/ perforated pipe system	J.F. Sabourin & Associates (2008a)	Nepean, Ontario	>99[6]	66	0	81	81	72
Grass swale/ perforated pipe system	J.F. Sabourin & Associates (2008a)	Nepean, Ontario	>99[6]	>99[6]	90	96	93	93

Notes:

NT = not tested

1. Pollutant removal efficiency refers to the pollutant load reduction from the inflow to the outflow (from an underdrain) of the practice, over the period of monitoring.
2. Total suspended solids (TSS)
3. Total phosphorus (TP)
4. Total Kjeldahl nitrogen (TKN)
5. Pollutant removal efficiencies are reported as ranges because they are based on a synthesis of several performance monitoring studies that were available as of 2000.
6. Concentrations at the outlet were below the detection limit.

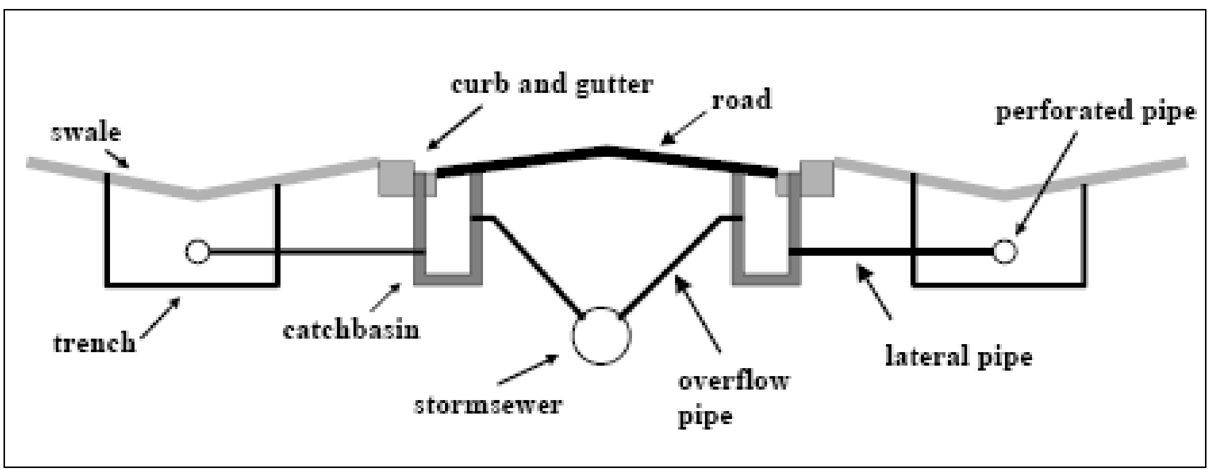
Stream Channel Erosion Control
While perforated pipe systems are not specifically designed to store the channel erosion control volume, their ability to reduce runoff volume should help protect downstream channels from erosion. The Nepean grass swale/perforated pipe systems were observed to reduce peak flow rates by 90% in 1998 (J.F. Sabourin and Associates, 1999) and by 47% and 86% in 2006 (J.F. Sabourin and Associates, 2008a).

4.10.2 Design Template

Applications
Like a conventional catchbasin and storm sewer pipe systems, perforated pipe systems typically receive foundation drain water and runoff from roofs, walkways, road and parking lots from multiple lots. They should not receive runoff from pollutant hot spots nor high traffic roads where large quantities of de-icing salts are spread during winter. Pretreatment of road runoff, which may contain high levels of suspended sediment, is necessary before it reaches the pervious pipes to reduce the risk of clogging and groundwater contamination. Like other subsurface SWM practices, (*e.g.*, soakaways, infiltration trenches and chambers), the majority of components associated with perforated pipe systems are located underground resulting in very small surface footprints. This makes them highly suited to high density development contexts (*i.e.*, ultra-urban areas) when being designed for new developments. Opportunities to retrofit high density development areas with perforated pipe systems will likely be highly constrained by proximity to building foundations and other underground utilities.

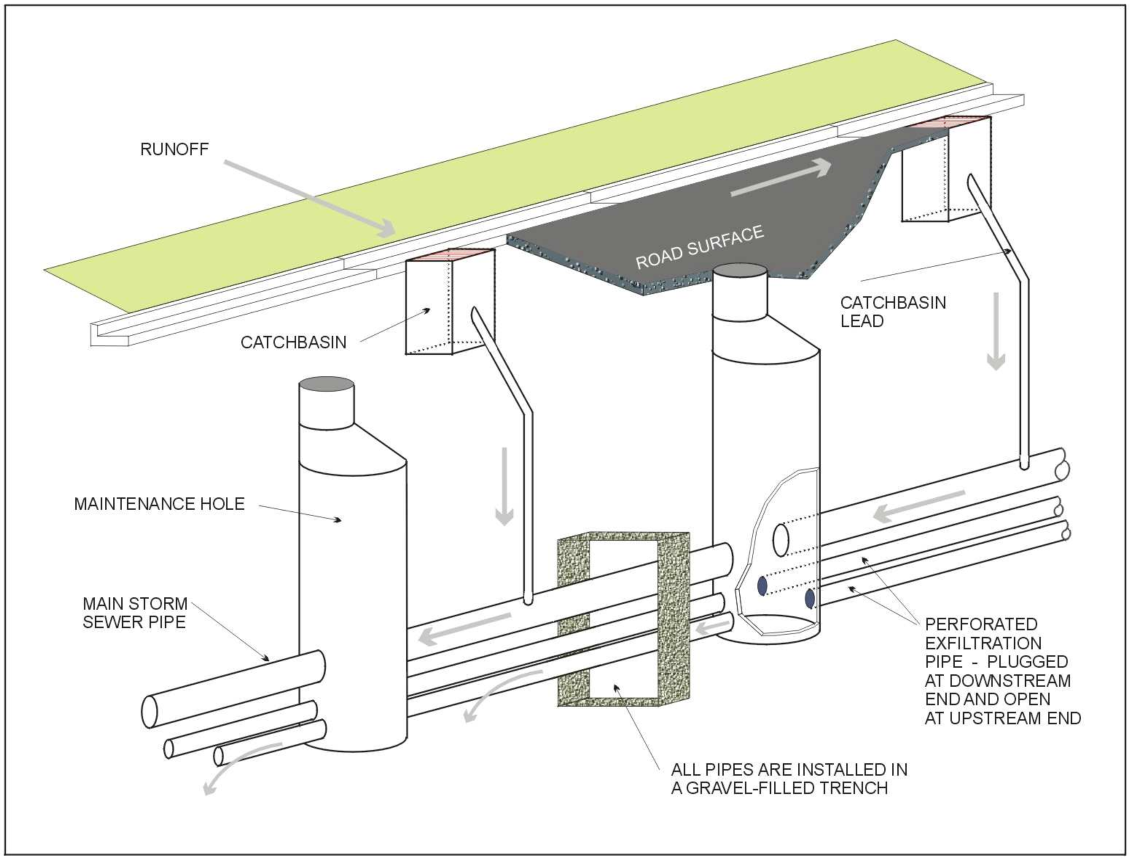
Typical Details
Schematics of different types of perforated pipe systems are provided in Figures 4.10.2 to 4.10.5. Planners should also refer to Figures 4.11 to 4.13 in the OMOE Stormwater Management Planning and Design Guideline (OMOE, 2003).

Figure 4.10.2 Simplified schematic of a perforated pipe system integrated with a grass swale



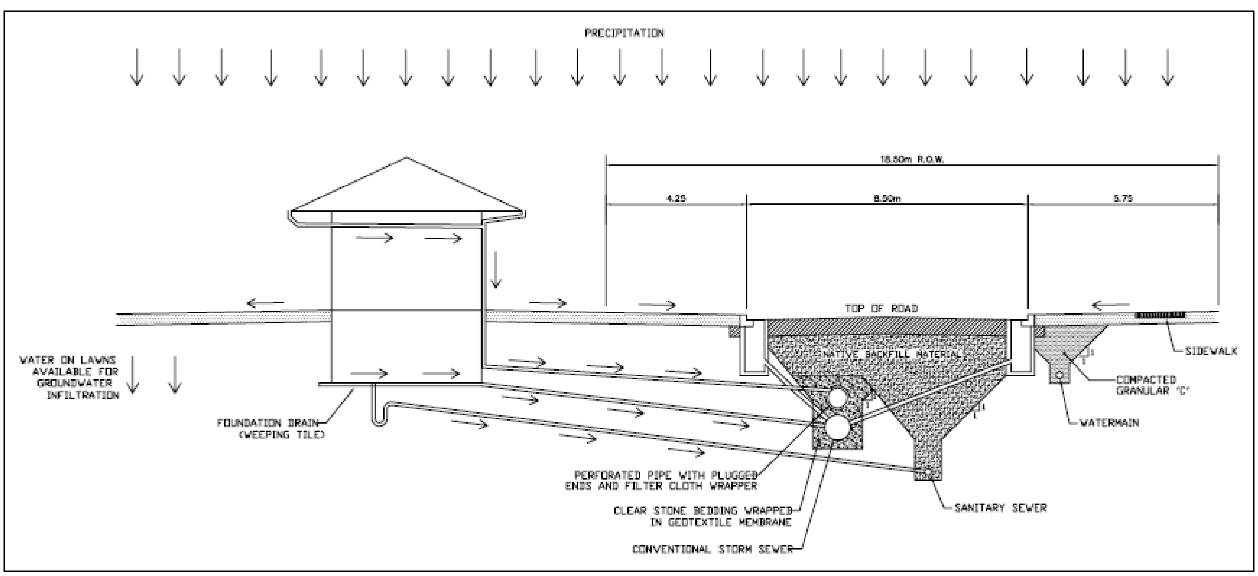
Source: SWAMP, 2005

Figure 4.10.3 Schematic of a perforated pipe system connected to catchbasins



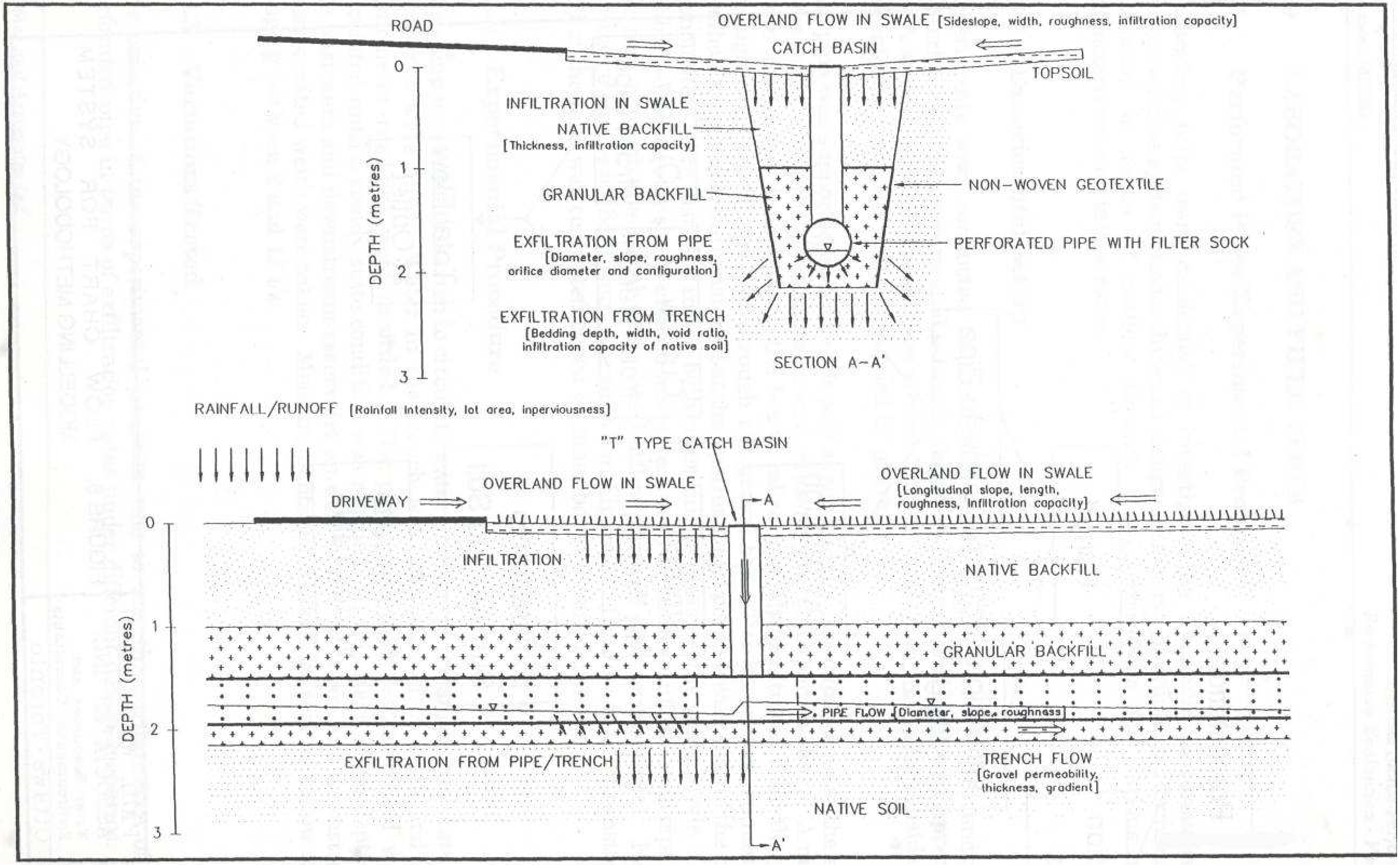
Source: SWAMP, 2005

Figure 4.10.4 Schematic of a perforated pipe system receiving roof runoff only



Source: Clarifica and Schaeffers, 2005

Figure 4.10.5 Schematic of perforated pipe system integrated with a grass swale



Source: Paul Wisner and Associates, 1994

Design Guidance

Soil Characteristics
Perforated pipe systems can be constructed over any soil type, but HSG 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 site-specific soil infiltration rate at the proposed location and depth using the methods for on-site investigation presented in Appendix C.

Geometry and Site Layout
Gravel beds in which perforated pipe systems are installed are typically rectangular excavations with a bottom width between 600 and 2400 mm (GVRD, 2005). The gravel beds should have gentle slopes between 0.5 to 1%.

Pretreatment
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:

- *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. Leaf screens must be regularly cleaned to be effective; if not maintained, they can become clogged and prevent rainwater from flowing into the facility.

- *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. Like leaf screens, they require regular cleaning to ensure they do not become clogged.

- *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 perforated pipe system (*e.g.*, Figures 4.10.4 and 4.10.5). The swale could be designed as a simple grass channel, an enhanced grass swale (section 4.8) or dry swale (section 4.9).

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. Smooth walled interior pipe is recommended because it reduces the potential for clogging and facilitates clean out in the event of excessive sediment accumulation (OMOE, 2003). A minimum diameter of 200 mm should be used to facilitate maintenance. The gravel filled trench should be 75 to 150 mm deep above the perforated pipe (OMOE, 2003). The depth of the gravel trench below the pipe is

dependent on the volume of runoff to be infiltrated and the infiltration rate of the native soil material (see BMP Sizing section). 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 retention volume and the potential for infiltration (J.F. Sabourin and Associates, 2008b). Overflows from the granular filled trench should either back up into manholes that are also connected to a conventional storm sewer (*e.g.*, Figures 4.10.2 and 4.10.5) or conveyed to a receiving waterbody by overland flow.

Filter Media

- *Gravel filled trench:* 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 perforated pipe systems 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. The primary function of the geotextile is separation between two dissimilar soils. When a finer grained soil overlies a coarser grained soil or aggregate layer (*e.g.*, stone reservoir), the geotextile prevents clogging of the void spaces from downward migration of soil particles. When a coarser grained aggregate layer (*e.g.*, stone reservoir) overlies a finer grained native soil, the geotextile prevents slumping from downward migration of the aggregate into the underlying soil. Geotextile may also enhance the capacity of the facility to reduce petroleum hydrocarbons in runoff, as microbial communities responsible for their decomposition tend to concentrate in geotextile fabrics (Newman *et al.*, 2006a). Specification of geotextile fabrics in perforated pipe systems 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. Table 4.10.4 provides further detail regarding geotextile specifications.

Other Details

As in conventional storm sewer systems, manholes should be must be installed to provide access to the system of pipes for inspection and maintenance activities.

Other Design Resources

Clarifica Incorporated and Schaeffers Consulting Engineers. 2005. *Clean Water Collector System Implementation Report - Block 12 Development Lands*, City of Vaughan. Ontario.

Greater Vancouver Regional District. 2005. *Stormwater Source Control Design Guidelines 2005*. Prepared by Lanarc Consultants Limited, Kerr Wood Leidal Associates Limited and Goya Ngan

J.F. Sabourin and Associates. 2008b. *Grass Swale and Perforated Pipe Drainage Systems Design Manual and Design Tool*. Prepared for the City of Ottawa, Infrastructure Management Division. Project No. 524 (01).

Ontario Ministry of the Environment. 2003. Stormwater Management Planning and Design Manual.

BMP Sizing

The gravel trench should be 75 to 150 mm deep above the perforated pipe. The depth of the trench below the pipe is dependent on the native soil infiltration rate, porosity (void space ratio) of the gravel storage layer media (i.e, aggregate material used in the stone reservoir) and the targeted time period to achieve complete drainage between storm events. The maximum allowable depth below the pipe can be calculated using the following equation:

$$d_{r\ max} = i * t_s / V_r$$

Where:

- $d_{r\ max}$ = Maximum stone trench depth below pipe (mm)
- i = Infiltration rate for native soils (mm/hr)
- V_r = Void space ratio for aggregate used (typically 0.4 for 50 mm clear stone)
- t_s = Time to drain (design for 48 hour time to drain is recommended)

The value for native soil infiltration rate (i) used in the above equation should be the design infiltration rate that incorporates a safety correction factor based on the ratio of the mean value at the proposed bottom elevation of the practice to the mean value in the least permeable soil horizon within 1.5 metres of the proposed bottom elevation (see Appendix C, Table C2). On highly permeable soils, a maximum stone reservoir depth of 2 metres is recommended to prevent soil compaction and loss of permeability from the mass of overlying stone and stored water.

Once the depth of the stone reservoir has been determined the water quality volume, computed using the methods in the relevant CVC and TRCA stormwater management criteria documents (CVC, 2010; TRCA, 2010), can be used to determine the footprint needed using the following equation:

$$A_f = WQV / (d_r * V_r)$$

Where:

- A_f = Footprint surface area (m^2)
- WQV = Water quality volume (m^3)
- d_r = Stone reservoir depth (m)
- V_r = Void space ratio for aggregate used (typically 0.4 for 50 mm clear stone)

Further guidance regarding sizing of perforated pipe systems is provided in sections 4.5.10 and 4.9.4 of the OMOE *Stormwater Management Planning and Design Manual* (OMOE, 2003).

Design Specifications

Recommended design specifications for perforated pipe systems are provided in Table 4.10.4 below.

Table 4.10.4 Design specifications for perforated pipe systems

Component	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 50 mm clear stone with a 40% void ratio.	Volume of the facility is calculated by methods referenced in the previous section of this guide.
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. The following geotextile fabric selection criteria are suggested (adapted from AASHTO, 2002; Smith, 2006; and U.S. Dept. of Defense, 2004): <u>Apparent Opening Size (AOS; max. average roll value) or Percent Open Area (POA)</u> For fine grained soils with more than 85% of	Around the gravel filled trench (stone reservoir)

Component	Specification	Quantity
	particles smaller than 0.075 mm (passing a No. 200 sieve): AOS ≤ 0.3 mm (non-woven fabrics) For fine grained soils with 50 to 85% of particles smaller than 0.075 mm (passing a No. 200 sieve): AOS ≤ 0.3 mm (non-woven fabrics) POA ≥ 4% (woven fabrics) For coarser grained soils with 5 to 50% of particles smaller than 0.075 mm (passing a No. 200 sieve): AOS ≤ 0.6 mm (non-woven fabrics) POA ≥ 4% (woven fabrics) For coarse grained soils with less than 5% of particles smaller than 0.075 mm (passing a No. 200 sieve): AOS ≤ 0.6 mm (non-woven fabrics) POA ≥ 10% (woven fabrics) <u>Hydraulic Conductivity (k, in cm/sec)</u> k (fabric) > k (soil) <u>Permittivity (in sec^{-1})</u> Where, Permittivity = k (fabric)/thickness (fabric): For fine grained soils with more than 50% of particles smaller than 0.075 mm (passing a No. 200 sieve), Permittivity should be 0.1 sec^{-1} For coarser grained soils with 15 to 50% of particles smaller than 0.075 mm (passing a No. 200 sieve), Permittivity should be 0.2 sec^{-1}. For coarse grained soil with less than 15% of particles smaller than 0.075 mm (passing a No. 200 sieve), Permittivity should be 0.5 sec^{-1}.	

Construction Considerations

Erosion and sediment control and compaction are the main construction concerns.

- *Soil Disturbance and Compaction:* Before site work begins, locations of facilities should be clearly marked. Only vehicular traffic used for construction 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, to the extent possible. After the site is vegetated, erosion and sediment control structures can be removed and the system brought online. If catchbasins draining to the perforated pipe system must be used for flood flow conveyance during construction, an engineer approved erosion and sediment control plan must be implemented.

Sequencing
Infiltration facilities are particularly vulnerable to failure during the construction phase for two reasons. First, if the construction sequence is not followed correctly, construction sediment can clog the pit. In addition, heavy construction can result in compaction of the soil, which can then reduce the soil's infiltration rate. For this reason, a careful construction sequence needs to be followed. This includes:

1. Heavy equipment and traffic should avoid traveling over the proposed location of the facility to minimize compaction of the soil.

2. Facilities should be kept "off-line" until construction is complete. They should never serve as a sediment control device during site construction. Sediment should be prevented from entering the infiltration facility using super silt fence, diversion berms or other means

3. Upland drainage areas need to be properly stabilized with a thick layer of vegetation, particularly immediately following construction, to reduce sediment loads.

4. The facility should be excavated to design dimensions from the side using a backhoe or excavator. The base of the facility should be level or nearly level.

5. Geotextile filter fabric should be correctly installed in the infiltration trench excavation. Large tree roots should be trimmed flush with the sides of the facility to prevent puncturing or tearing of the filter fabric during subsequent installation procedures. When laying out the geotextile, the width should include sufficient material to compensate for perimeter irregularities in the facility and for a 150 mm minimum top overlap. Voids may occur between the fabric and the excavated sides of the facility. Natural soils should be placed in any voids to ensure fabric conformity to the excavation sides.

4.4.3 Maintenance and Construction Costs

Inspection and Maintenance
As with all infiltration practices, these facilities require regular inspection to ensure continued functioning. 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. The expected lifespan of infiltration practices is not well understood, however, it can be expected that it will vary depending on pretreatment practice maintenance frequency, and the sediment texture and load coming from the catchment. Perforated pipe systems with grass swales as pretreatment have been observed to continue to function well after 20 years of operation (J.F. Sabourin and Associates, 2008).

Installation and Operation Costs

Very limited information is available regarding construction costs for perforated pipe systems. Due to similarities in design components, base construction costs would likely be similar to infiltration trenches or dry swales.

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