7.5 Underground Infiltration Systems

7.5.1 BMP Overview

Underground infiltration systems is a general term that refers to stormwater treatment practices that temporarily store runoff below ground in geotextile-lined excavations filled with clear stone (i.e., washed gravel) or other void space forming structures and treat it by sedimentation and filtration through the geotextile and underlying sub-soil. Runoff water is delivered to the practice through inlets such as curb-cuts or other concrete structures and pipes connected to other stormwater conveyances (e.g., catchbasins, roof downspouts). They are most often installed to a depth below the maximum frost penetration depth to ensure they continue to drain year-round. Water that is in excess of the storage capacity overflows to an adjacent drainage system (e.g., municipal storm sewer or other BMP), typically via a manhole containing a control structure, to safely convey flows from major storm events. Depending on the permeability of the underlying native sub-soil, such practices may be designed without a sub-drain for full infiltration or with a sub-drain for partial infiltration. Captured water is either infiltrated or collected by the sub-drain and discharged to the municipal storm sewer system. The sub-drain pipe may feature a flow restrictor (e.g., orificed cap, ball valve) for BMPs designed to control the peak flow rate. Key components of underground infiltration systems for inspection and maintenance are described in Table 7.25 and Figure 7.5.

Properly functioning underground infiltration systems reduce the quantity of runoff and pollutants being discharged to municipal storm sewers and receiving waters (i.e., rivers, lakes and wetlands) and can help replenish groundwater resources. An advantage of underground infiltration systems is that they can be located below parking lots, roads, parkland or other landscaped areas. In densely developed urban areas, where the value of land is very high, this often makes them preferable to surface practices.

Underground infiltration systems include soakaways, infiltration trenches, infiltration chamber systems and perforated pipe storm sewer systems. Soakaways typically service individual lots and receive only roof and walkway runoff but can also be designed to receive overflows from other LID BMPs (e.g., rain barrels or cisterns). Soakaways can also be referred to as infiltration galleries, dry wells or soakaway pits. Infiltration trenches are linear oriented soakaways designed to fit into narrow strips of land between buildings or properties, or along road rights-of-way and can also receive road runoff with an adequate pretreatment device upstream. Infiltration chamber systems include a range of proprietary manufactured modular structures installed underground that create large void spaces for temporary storage of stormwater (CSA, 2011). Structures may be plastic or concrete and typically have an open bottom and are wrapped with clear stone and geotextile. They can be installed individually or in series in trench or bed configurations. They can also be referred to as infiltration tanks. Perforated pipe storm sewer systems can be thought of as long infiltration trenches or linear soakaways that are installed parallel with conventional storm sewer pipes that receive stormwater from them (i.e., roof, walkway and road runoff). Perforated pipe systems can also be referred to as exfiltration systems, percolation drainage systems, and clean water collector systems (i.e., those receiving flows from roofs and foundation drains only).

Requirements of the Ontario Occupational Health and Safety Act regulation for individuals working in confined spaces (O. Reg. 632/05) must be adhered to during any inspection or maintenance work on underground infiltration systems that involves entry into confined spaces (e.g., catchbasins, manholes, access hatches). Individuals working in such environments should be adequately trained on the use and maintenance of the necessary safety equipment and review hazards and safety plans regularly. Further information about Ontario's Confined Spaces Regulation and Guideline can be accessed at the following location:

- http://www.labour.gov.on.ca/english/hs/pubs/confined/cs_4.php

Table 7.25: *Key components of underground infiltration systems for inspection and maintenance.*

Component	Description
Contributing Drainage Area	The area from which runoff directed to the BMP originates. CDAs include impervious and pervious areas draining to the BMP. CDAs should be free of point sources of pollutants (e.g., leaking waste containers, spills, failing ESCs). Trash, sediment and debris should be removed regularly from pavements and other stormwater conveyances (e.g., gutters, eavestroughs) draining to the BMP.
Inlets	Inlets can be curb-cuts, pipes or other engineered structures. Inlets must remain unobstructed to ensure that stormwater enters the BMP as designed. Pipe inlets typically include a perforated section that distributes flow throughout the practice and may be wrapped with geotextile.
Pretreatment	Pretreatment refers to techniques or devices used to slow down concentrated stormwater flow and retain coarse materials suspended in runoff, either through filtration or settling, before it enters the BMP. Proper pretreatment extends the operating life cycle of the BMP by reducing the rate of accumulation of coarse sediment in the BMP. Common pretreatment devices include geotextile-lined stone inlets, eavestrough screens or filters, oil and grit separators (i.e., hydrodynamic separators), manholes containing baffles and sumps, in-line filters or chamber structures that are isolated from the main portion of infiltration chamber systems (a.k.a. isolator or containment row). Pretreatment devices require frequent (e.g., annual or bi-annual) trash, sediment and debris removal maintenance.
Filter bed	The clear stone bed on which infiltration chamber systems are installed. When accessible by a maintenance hatch or manhole, filter beds should be routinely checked for sediment accumulation which may require the use of a closed circuit camera. Accumulated sediment may need to be periodically removed by a hydro-vac truck to maintain infiltration function (e.g., once over a 50 year life cycle).
Overflow outlets	Flows exceeding the storage capacity of the BMP are conveyed to an adjacent drainage system via an overflow outlet structure (e.g., control manhole containing a weir wall and outlet pipe). Overflow outlet structures must be kept free of obstructions to ensure stormwater is safely conveyed during major storm events.

Sub-drain	Sub-drains are optional components that may be included where the permeabililty of the underlying native sub-soil is low. They are installed in the clear stone fill or bedding to collect and convey filtered water to an adjacent drainage system. Sub-drains are comprised of perforated pipes and may be wrapped in geotextile filter fabric. A maintenance port standpipe or manhole may be connected to the perforated pipe to provide a means of flushing and inspecting it. The perforated pipe must be kept free of obstructions to ensure that the subsurface water storage capacity of the BMP drains within a specified time period. Perforated pipes should be routinely flushed with water to remove sediment. If the sub-drain is equipped with a flow-restrictor (e.g., orifice plate, ball valve) to attenuate flow rates, the flow restrictor must be inspected and cleaned regularly.
Monitoring well	Standpipes that extend from the surface to the bottom of the excavation and contain perforations or slots to allow observation and measurement of subsurface water level in the BMP. Monitoring wells are needed to determine if the BMP drains within an acceptable time period and to track drainage performance over its operating lifespan. Standpipes should be securely capped on both ends and remain undamaged and free of sediment which may require periodic flushing.
Control structure	The manhole or catchbasin that contains the overflow control structure and outlet pipe and is connected to the sub-drain pipe that provides access to the outlet, sub-drain and flow restrictor device, if present. Inspect for damage, obstruction and sediment accumulation.

7.5.2 Inspection and Testing Framework

Table 7.26 describes what visual and testing indicators should be used during each type of inspection for underground infiltration systems and provides a basis for planning field work. Numbers in the first column refer to the section of Section 8.0 and Appendix C that provides detailed guidance on standard protocols and test methods for assessing the respective indicator.

7.5.3 Critical Timing of Construction Inspections

Construction inspections take place during several points in the construction sequence, specific to the type of LID BMP, but at a minimum should be done weekly and include the following:

1. During site preparation, prior to BMP excavation and grading to ensure the CDA is stabilized or that adequate ESCs or flow diversion devices are in place and confirm that construction materials meet design specifications;
2. At completion of excavation and grading, prior to backfilling and installation of geotextile/pipes to ensure depths, slopes and elevations are acceptable;
3. At completion of installation of geotextile/pipes, prior to completion of backfilling to ensure slopes and elevations are acceptable;
4. Prior to hand-off points in the construction sequence when the contractor responsible for the work changes (i.e., hand-offs between the storm sewer servicing, paving, building and landscaping contractors);

5. After every large storm event (e.g., 15 mm rainfall depth or greater) to ensure ESCs and pretreatment or flow diversion devices are functioning and adequately maintained.

Table 7.27 describes critical points during the construction sequence when inspections should be performed prior to proceeding further. Table 7.27 can also be used as a checklist during Construction inspections, in addition to the Inspection Field Data Forms provided in Appendix C. Additional inspection points may be warranted for infiltration chamber systems. Refer to the installation instructions provided by the product vendor/manufacturer for further guidance on construction sequence and critical timing of inspections.

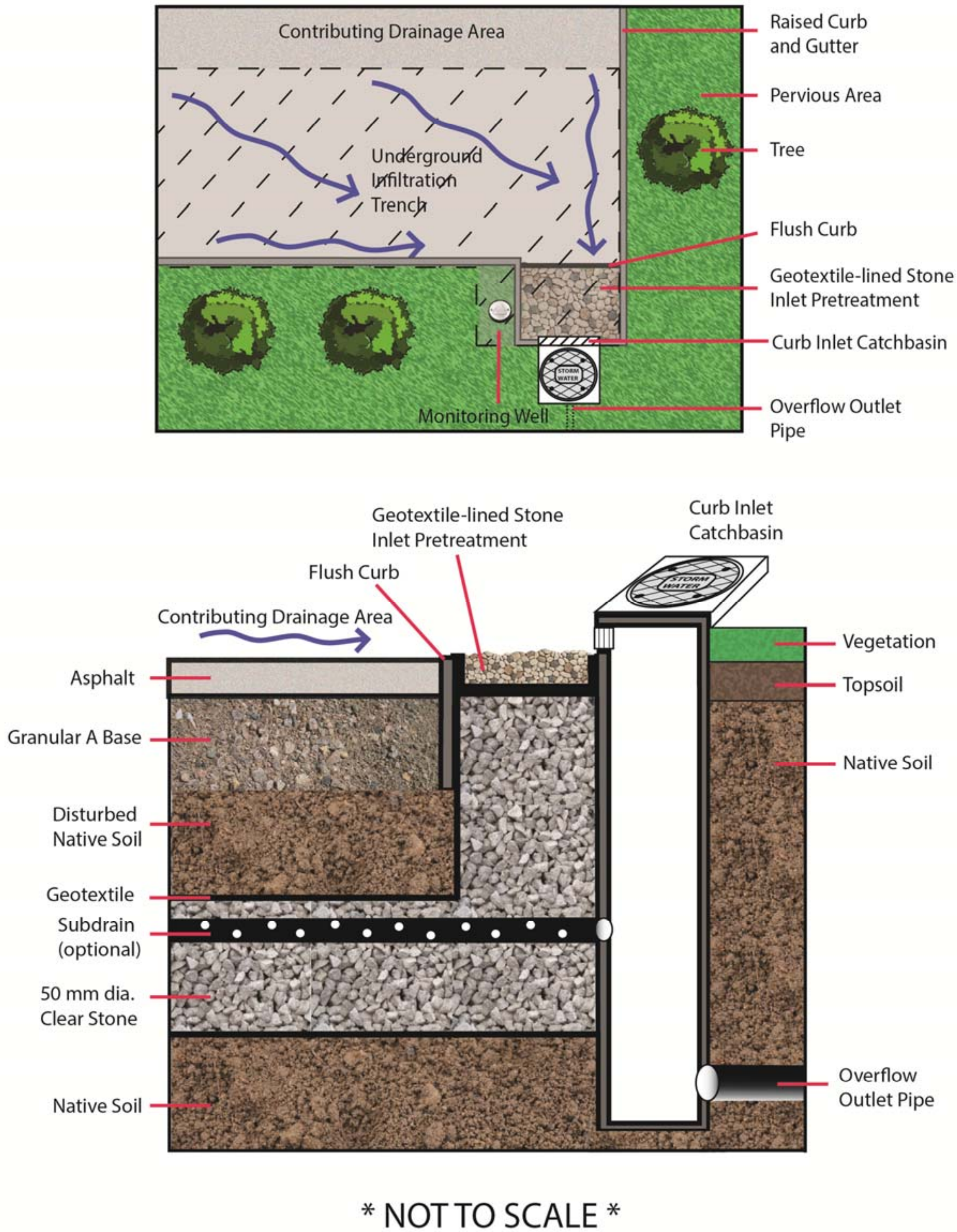

Figure 7.5: *Generalized cross-section view of an infiltration trench showing key components.*

Table 7.26: *Inspection and testing indicators framework for underground infiltration systems.*

INSPECTION AND TESTING FRAMEWORK					
UNDERGROUND INFILTRATION SYSTEMS		Inspection Type			
Section	**Indicator**	**Construction**	**Assumption**	**Routine Operation**	**Verification**
Visual indicators					
C.1	CDA condition	x	x	x	x
C.2	Inlet//Flow spreader structural integrity		x	x	x
C.3	Inlet/Flow spreader obstruction	x	x	x	x
C.4	Pretreatment sediment accumulation	x	x	x	
C.6	BMP dimensions	x	x		x
C.13	Filter bed sediment accumulation		x	x	x
C.20	Monitoring well condition	x	x	x	x
C.21	Sub-drain/Perforated pipe obstruction		x		x
C.22	Overflow outlet obstruction	x	x	x	x
C.25	Control structure condition	x	x	x	x
C.26	Control structure sediment accumulation	x	x	x	x
Testing indicators					
8.3	Sediment accumulation testing	x	x	x	x
8.5	Natural or simulated storm event testing		x		(x)
8.6	Continuous monitoring		x		(x)

(x) denotes indicators to be used for Performance Verification inspections only (i.e., not for Maintenance Verification inspections)

Table 7.27: *Critical timing of construction inspections - underground Infiltration Systems.*

Construction Sequence Step and Timing	Inspection Item	Observations [1]
Site Preparation – after site clearing and grading, prior to BMP excavation and grading	Natural heritage system and tree protection areas remain fenced off	
	ESCs protecting BMP layout area are installed properly	
	CDA is stabilized or runoff is diverted around BMP layout area	
	BMP layout area has been cleared and is staked/delineated	
	Benchmark elevation(s) are established nearby	
	Construction materials have been confirmed to meet design specifications	
BMP Excavation and Grading - prior to backfilling and installation of geotextile/pipes	Excavation location, footprint, depth and slope are acceptable	
	Excavated soil is stockpiled outside the CDA	
	Compaction of subsoil where load-bearing portions of the system will be installed is acceptable	
	Excavation bottom and sides roughened to reduce smearing and compaction	
BMP Installation – after installation of geotextile/ pipes/structures, prior to completion of backfilling	Installation of structural components (e.g., control manhole, maintenance hatches) is acceptable	
	Installations of sub-drain pipes (e.g., locations, elevations, slopes) & maintenance access hatches are acceptable	
	Sub-drain trench dams installed correctly (location, elevation)	

Notes:

1. S = Satisfactory; U= Unsatisfactory; NA = Not Applicable

7.5.4 Inspection Field Data Forms

Template forms for recording inspection observations, measurements, sampling location details and follow-up actions have been prepared for each LID BMP type and can be found in Appendix C.

7.5.5 Routine Maintenance

Table 7.28 describes routine maintenance tasks for underground infiltration systems, organized by BMP component, along with recommended minimum frequencies. It also suggests higher frequencies for certain tasks that may be warranted for BMPs located in highly visible locations or those receiving flow from large or high traffic (vehicle or pedestrian) drainage areas. Tasks involving removal of trash, debris and sediment for BMPs in such contexts may need to be done more frequently (i.e., higher standards may be warranted).

Table 7.28: *Routine maintenance tasks for underground infiltration systems.*

Component	Routine Maintenance Task	Frequency[1]	
		Minimum[2]	High[3]
Contributing Drainage Area	Remove trash, natural debris, clippings and sediment	BA	Q
	Re-plant or seed bare soil areas	A	BA
Inlets and Outlets	Remove trash, natural debris and clippings	BA	Q
	Remove accumulated sediment	A	BA
Pretreatment Devices	Remove trash, natural debris, clippings and sediment	A	BA
Filter bed	Remove accumulated sediment when ≥ 8 cm depth (requires BMP to be fully drained first)	AN	AN
Overflow Outlets	Remove trash, natural debris and clippings	BA	Q
	Remove accumulated sediment	A	BA
Sub-drain & Monitoring well	Flush out accumulated sediment with hose or pressure washer	A	A
Control structure	Remove accumulated sediment when ≥ 10 cm depth	AN	AN

Notes:

1. A = Annually; AN = As needed based on Routine Operation inspections; BA = Bi-annually or twice per year, ideally in the spring and late fall/early winter; BM = Bi-monthly; BW = Bi-weekly or twice per week; Q = Quarterly or four times per year, ideally in the spring, summer, early fall and late fall/early winter.
2. These frequencies are recommended as the minimum necessary to ensure the BMP functions adequately over its expected lifespan.
3. High priority BMPs such as or those draining to a sensitive receiving waterbody, those receiving drainage from high traffic areas, or those designed with larger than recommended impervious drainage area to pervious BMP footprint area ratios (i.e., I:P ratios), may warrant a higher frequency of routine maintenance tasks involving removal of trash/debris/sediment.

Tips to help preserve BMP function

- Prohibit stockpiling of soil, sand, compost or unwashed gravel within the CDA and inlets to prevent clogging with sediment;
- For BMPs with sub-drains and flow restrictors, pretreatment devices that prevent floating trash and debris from entering the practice should be used to prevent obstruction of the sub-drain pipe/flow restrictor;

- For BMPs equipped with pretreatment that detains floating contaminants (e.g., oil and grease, trash and debris), such as hydrodynamic separators or forebays with baffle walls, remove trash and debris first using a bucket strainer. Floating oils and grease should then be removed off the top of the water using a vacuum truck;
- Provide a means of draining infiltration chamber systems by gravity (e.g., pipe and valve through the control structure weir wall) to make inspection and maintenance work that requires drainage of the BMP (e.g., filter bed and control structure inspection and sediment removal, repairs to control structure) easier to perform; and
- To remove accumulated sediment from sub-drain pipes and chamber system units, a hydro-vac truck equipped with a JetVac nozzle should be employed that uses pressured jets of water to propel itself through the structure while scouring and directing suspending sediments to a collection point. As the nozzle is retrieved, the sediment is flushed into the manhole or catchbasin sump for removal by vacuuming. Selecting an appropriate JetVac nozzle will depend on the structure being cleaned. For chamber system units, fixed nozzles designed for culverts or large diameter pipe cleaning with rear-facing jets are preferable (consult product manufacturer for further guidance).

7.5.6 Rehabilitation and Repair

Table 7.29 provides guidance on rehabilitation and repair work specific to underground infiltration systems organized according to BMP component.

Table 7.29: *Rehabilitation and Repair Guidance for Underground Infiltration Systems.*

BMP Component	Problem	Task
Sub-drain	Sub-drain perforated pipe is obstructed by trash, debris, sediment or roots	Schedule hydro-vac truck or drain-snaking service to remove the obstruction.
	Pipe caps are missing or damaged	Replace missing or damaged caps.
Filter bed (for chamber systems only)	Average sediment accumulation ≥ 8 cm in depth or drainage performance is unacceptable	Schedule work to fully drain the system and remove accumulated sediment through use of a hydro-vac truck equipped with JetVac nozzle.
Control structure	Structure or pipe connection is leaking and impairing the water storage capacity or function of the BMP	Schedule work to repair cracks or seal leaking components. The BMP may need to be fully drained to make such repairs.

7.5.7 Life Cycle Costs of Inspection and Maintenance

Estimates of the life cycle costs of inspection and maintenance have been produced using the latest version of the LID Life Cycle Costing Tool (STEP, 2016) to assist stormwater infrastructure planners, designers and asset managers with planning and preparing budgets. For more details of the Tool's assumption, see Section 7.1.7 and refer to the project report (TRCA and U of T, 2013a).

For underground infiltration systems it is assumed that no rehabilitation work will be needed to maintain drainage performance at an acceptable level over a 50 year period of operation, given that pretreatment devices are in place upstream and are being adequately maintained. The annual average maintenance cost value represents an average of routine maintenance tasks, as outlined in Table 7.28. All cost value estimates represent the NPV as the calculation takes into account average annual interest (2%) and discount (3%) rates over the evaluation time periods.

Life cycle cost estimates have been generated for two types of underground infiltration systems: infiltration trenches and infiltration chamber systems. For each type, two design variations have been examined: BMPs designed to receive roof runoff only; and BMPs designed to receive a combination of roof and road runoff. For each system type and design variation, life cycle cost estimates have been calculated for two level-of-service scenarios: the minimum recommended frequency of inspection and maintenance tasks (i.e., Table 7.26 and Table 7.28 "Minimum Frequency" column), and a high frequency scenario (i.e., Table 7.26 and Table 7.28 "High Frequency" column) to provide an indication of the potential range.

For all design variations, the CDA is assumed to be composed of a 2,000 m^2 roof for the roof runoff only design variation, and a 500 m^2 roof and 1,500 m^2 impermeable pavement area for the roof and road runoff design. All are sized to retain runoff from a 34 mm rain event and assumed to have a native sub-soil infiltration rate of 34 mm/h. An impervious drainage area to pervious area ratio (I:P ratio) of 20:1 is used to size the BMP footprint area, in accordance with the LID SWM Planning and Design Guide recommendations (CVC & TRCA, 2010). The infiltration trench is assumed to be 1.630 m deep, 2.0 m wide and 50.0 m long. The infiltration chamber system is assumed to be 1.067 m deep, 8.0 m wide and 12.5 m long.

For all design variations, the invert of the overflow outlet pipe is located 1.2 m below the surface to protect against frost. Monitoring wells are provided to facilitate inspections. In the roof runoff only design, there is no pretreatment other than a sump in the control manhole which allows for some settling of coarse sediment and debris. In the roof and road runoff design, pretreatment is provided by a hydrodynamic (i.e., oil and grit) separator for the impermeable pavement portion of the CDA.

Estimates of the life cycle costs of infiltration trenches and chamber systems in Canadian dollars per unit CDA ($/$m^2$) are presented in Tables 7.30 and 7.31, respectively. The LID Life Cycle Costing Tool allows users to select what BMP type and design variation applies, and to use the default assumptions to generate planning level cost estimates. Users can also input their own values relating to a site or area, design, unit costs, and inspection and maintenance task frequencies to generate customized cost estimates, specific to a certain project, context or stormwater infrastructure program.

Table 7.30: *Life cycle cost estimates for infiltration trenches.*

Infiltration Trenches	Minimum Frequency		High Frequency	
Design Variation	**Roof only**	**Road & Roof**	**Roof only**	**Road & Roof**
Construction Costs	$18.25	$27.55	$18.25	$27.55
Rehabilitation Costs	$0.00	$0.00	$0.00	$0.00
Rehabilitation Period (years in service)	n/a	n/a	n/a	n/a
50 YEAR EVALUATION PERIOD				
Average Annual Maintenance	$0.20	$0.70	$0.25	$1.20
Maintenance and Rehabilitation	$10.75	$34.20	$13.50	$60.50
25 YEAR EVALUATION PERIOD				
Average Annual Maintenance	$0.20	$0.75	$0.30	$1.30
Maintenance and Rehabilitation	$5.55	$18.45	$7.10	$32.90

Notes:

1. Estimated life cycle costs represent NPV of associated costs in Canadian dollars per square metre of CDA ($/m2).
2. Average annual maintenance cost estimates represent NPV of all costs incurred over the time period and do not include rehabilitation costs.
3. Life cycle costs are higher for BMPs designed to receive roof and road runoff due to additional costs associated with the hydrodynamic (i.e., oil and grit) separator and associated inspection and routine maintenance.
4. Life cycle cost estimates are similar between infiltration trench and infiltration chamber system designs, and predicted to be slightly higher for infiltration trenches compared to chamber systems (construction and maintenance costs).
5. Maintenance costs over a 25 year time period for roof runoff only infiltration trenches are estimated to be 30.4% of the original construction cost for the Minimum Recommended Frequency maintenance scenario, and 38.9% for the High Frequency maintenance scenario.
6. Maintenance costs over a 25 year time period for roof and road runoff infiltration trenches are estimated to be 67.0% of the original construction cost for the Minimum Recommended Frequency maintenance scenario, and 1.19 times the original construction cost for the High Frequency maintenance scenario.
7. Maintenance costs over a 50 year time period for roof runoff only infiltration trenches are estimated to be 58.9% of the original construction cost for the Minimum Recommended Frequency maintenance scenario, and 74.0% for the High Frequency maintenance scenario.
8. Maintenance costs over a 50 year time period for roof and road runoff infiltration trenches are estimated to be 1.24 times the original construction cost for the Minimum Recommended Frequency maintenance scenario, and 2.20 times for the High Frequency maintenance scenario.

Table 7.31: *Life cycle cost estimates for infiltration chamber systems.*

Infiltration Chambers	**MINIMUM RECOMMENDED FREQUENCY**		**HIGH FREQUENCY**	
Design Variation	**Roof only**	**Road & Roof**	**Roof only**	**Road & Roof**
Construction Costs	$13.95	$23.80	$13.95	$23.80
Rehabilitation Costs	$0.00	$0.00	$0.00	$0.00
Rehabilitation Period (years in service)	n/a	n/a	n/a	n/a
50 YEAR EVALUATION PERIOD				
Average Annual Maintenance	$0.15	$0.65	$0.20	$1.15
Maintenance and Rehabilitation	$7.85	$32.10	$10.00	$58.50
25 YEAR EVALUATION PERIOD				
Average Annual Maintenance	$0.15	$0.70	$0.20	$1.25
Maintenance and Rehabilitation	$3.90	$16.70	$5.10	$30.75

Notes:

1. Estimated life cycle costs represent NPV of associated costs in Canadian dollars per square metre of CDA ($/m2).
2. Average annual maintenance cost estimates represent NPV of all costs incurred over the time period and do not include rehabilitation costs.
3. Life cycle costs are higher for BMPs designed to receive roof and road runoff due to additional costs associated with the hydrodynamic (i.e., oil and grit) separator and associated inspection and routine maintenance.
4. Maintenance costs over a 25 year time period for roof runoff only infiltration chamber system are estimated to be 28.0% of the original construction cost for the Minimum Recommended Frequency maintenance scenario, and 36.6% for the High Frequency maintenance scenario.
5. Maintenance costs over a 25 year time period for roof and road runoff infiltration chamber system are estimated to be 70.2% of the original construction cost for the Minimum Recommended Frequency maintenance scenario, and 1.29 times the original construction cost for the High Frequency maintenance scenario.
6. Maintenance costs over a 50 year time period for roof runoff only infiltration chamber system are estimated to be 56.3% of the original construction cost for the Minimum Recommended Frequency maintenance scenario, and 71.7% for the High Frequency maintenance scenario.
7. Maintenance costs over a 50 year time period for roof and road runoff infiltration chamber system are estimated to be 1.35 times the original construction cost for the Minimum Recommended Frequency maintenance scenario, and 2.46 times for the High Frequency maintenance scenario.