7.0 BMP SPECIFIC INSPECTION, TESTING AND MAINTENANCE

7.1 Bioretention and Dry Swales

7.1.1 BMP Overview

Bioretention is a general term that refers to stormwater treatment practices that temporarily store runoff in shallow, depressed planting beds or other structures (e.g., concrete planters) and treat it by sedimentation, filtration through highly permeable soil (i.e., filter media) and the root zones of plants, infiltration into underlying sub-soil and evaporation back to the atmosphere. Runoff water is delivered to the practice through inlets such as curb-cuts or other concrete structures, sheet flow from paved areas, or pipes connected to other stormwater conveyances (e.g., catchbasins, roof downspouts). The planting bed and side slopes are typically covered with a mixture of vegetation, mulch and stone. Water that is in excess of the surface ponding or storage capacity overflows to an adjacent drainage system (e.g., municipal storm sewer or other BMP). Bioretention is typically designed to capture runoff from small to medium-sized storm events. An overflow outlet or bypass is necessary to safely convey flows from major storm events. Filtered water is either infiltrated into the underlying native sub-soil or collected by a sub-drain and discharged to the municipal storm sewer system. Key components of bioretention practices for inspection and maintenance are described in Table 7.1 and Figure 7.1.

Properly functioning bioretention practices 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. In addition to their SWM benefits, bioretention areas provide aesthetic value as attractive landscaped features.

A variety of terms can be used to describe design variations for the practice of bioretention. Rain gardens or bioretention cells are depressed planting beds located on individual lots that receive drainage from small to medium-sized areas. Depending on the permeability of the underlying native sub-soil and other constraints, bioretention practices may be designed without a sub-drain for full infiltration, with a sub-drain for partial infiltration, or with an impermeable liner and sub-drain for filtration only. The sub-drain pipe may feature a flow restrictor (e.g., orificed cap, ball valve) in BMPs designed to control peak flow rate. Bio-filters are another name for lined, filtration only bioretention practices. A linearly oriented bioretention practice may be referred to as a bioretention swale (i.e., bio-swale) or dry swale. When contained within engineered structures they may be referred to as stormwater planters or soil cells. Bioretention practices can be adapted to fit into many different contexts and provide a convenient area for snow storage and treatment.

Table 7.1: *Key Components of Bioretention and Dry Swales 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 and the BMP itself. 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 conveyances (e.g., gutters, catchbasins, eavestroughs) draining to the BMP.
Inlets	Inlets can be pavement edges (for BMPs receiving sheet flow), curb-cuts, pipes or other engineered structures. Inlets must remain unobstructed to ensure that stormwater enters the BMP as designed. Scour protection features (e.g., stone cover, flow spreader) may also be needed for curb-cut or pipe inlets to prevent erosion of the filter bed from concentrated flow.
Pretreatment	Pretreatment refers to techniques or devices used to slow down and spread out concentrated stormwater flow and retain coarse materials suspended in runoff 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 vegetated filter strips, geotextile-lined stone inlets, gravel diaphragms, forebays, check dams, eavestrough screens or filters, oil and grit separators (i.e., hydrodynamic separators) and manholes containing baffles or filters and sumps. Pretreatment devices require frequent (e.g., annual or bi-annual) trash, sediment and debris removal.
Perimeter	Side slopes of the BMP, covered by a mixture of vegetation, mulch and stone with slopes of 2:1 (H:V) or less that surround the filter bed and allow for surface ponding. For stormwater planters the perimeter may be a concrete or masonry structure with vertical walls. Inspection of the perimeter is done to confirm the dimensions of the BMP are acceptable, ensure the structural integrity of side slopes or vertical walls is maintained and confirm that the BMP continues to provide the designed surface ponding water storage capacity. Periodic maintenance of side slopes may be needed to repair erosion rills or damage from vehicle or foot traffic.
Filter bed	Flat or gently sloping area composed of a 0.5 to 1 metre deep layer of filter media soil covered by a mixture of vegetation, mulch and stone where surface ponding and infiltration of runoff occurs. Bioretention practices are designed to infiltrate all water ponded on the surface within 24 hours of the end of a storm to prevent conditions supportive of mosquito breeding. Filter beds should be checked for presence of standing water. Trash should be removed from the filter bed regularly. Mulch or stone cover should be maintained on non-vegetated areas to prevent weed growth and soil erosion. Accumulated sediment should be periodically removed to maintain infiltration function. Repair of animal burrows, sunken areas, erosion rills or damage from vehicle or foot traffic may also be needed to prevent short circuiting of flow through the filter media soil. Maximum ponding depth should be checked to ensure designed water storage capacity is maintained.
Vegetation	Bioretention practices rely on vegetation to intercept, uptake and evapotranspire stormwater and provide habitat for soil organisms that break down pollutants. Plant roots also help to maintain soil structure and permeability. Routine maintenance of vegetation is the same as a conventional planting bed (i.e., weeding, mowing, pruning, irrigation during droughts). In the first 2 months of

	establishment, plantings need to be irrigated frequently (e.g., bi-weekly). As bioretention practices are intended to retain nutrients from inflowing stormwater, applying fertilizer to the filter bed should not be a part of routine maintenance.
Overflow Outlets	Flows exceeding the storage capacity of the BMP are conveyed to an adjacent drainage system via an overflow outlet structure (e.g., pipe, standpipe, curb-cut, swale, catchbasin). 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 or, due to other constraints, an impermeable liner is required. They are installed below the filter media soil layer to collect and convey treated water to an adjacent drainage system. Sub-drains are comprised of perforated pipes wrapped in a gravel blanket and in some cases geotextile filter fabric. 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. A maintenance port standpipe may be connected to the perforated pipe to provide a means of flushing and inspecting it. Perforated pipes should be routinely flushed with water to remove sediment. Trimming of plant roots that have penetrated the perforated pipes may be warranted periodically. If the sub-drain is equipped with a flow-restrictor (e.g., orificed cap, ball valve) to attenuate flow rates, the flow restrictor must be inspected and cleaned regularly.
Monitoring well	Standpipes that extend from above the surface of the filter bed 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.

7.1.2 Inspection and Testing Framework

Table 7.2 describes what visual and testing indicators should be used for bioretention practices during each type of inspection and provides a basis for planning field work. Numbers in the first column refer to the part of Section 8.0 and Appendix C that provides detailed guidance on standard protocols and test methods for assessing the respective indicator.

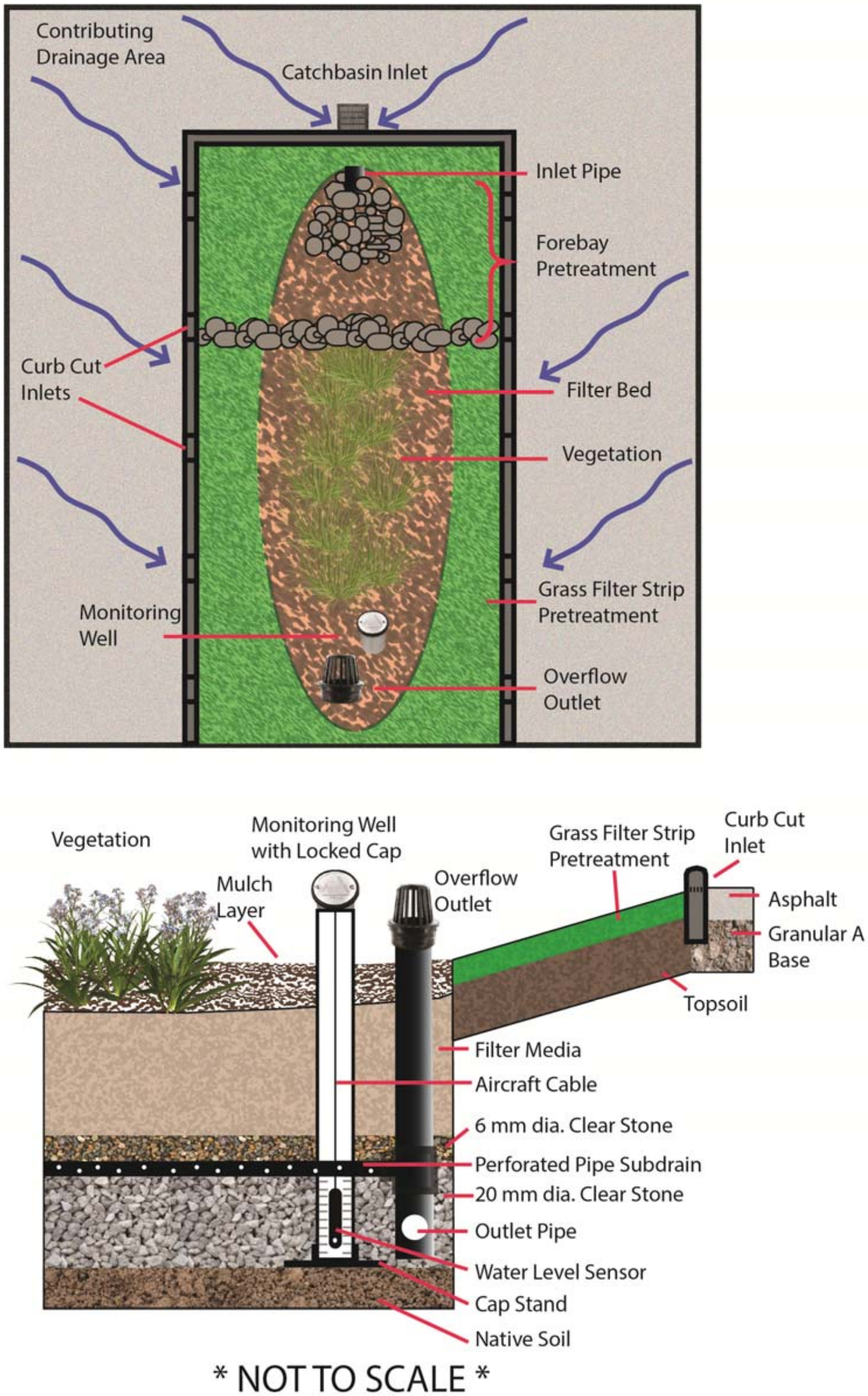

Figure 7.1: *Generalized plan and cross-section views of a bioretention cell showing key components.*

Table 7.2: *Inspection and testing indicators framework for bioretention and dry swales.*

INSPECTION AND TESTING FRAMEWORK					
BIORETENTION & DRY SWALES		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.5	Inlet erosion		x	x	
C.6	BMP dimensions	x	x		x
C.7	Side slope erosion		x	x	
C.8	Surface ponding area	x	x		x
C.9	Standing water		x	x	x
C.10	Trash		x	x	
C.11	Filter bed erosion		x	x	
C.12	Mulch depth	x	x	x	x
C.13	Filter bed sediment accumulation		x	x	x
C.14	Surface ponding depth	x	x		x
C.15	Filter bed surface sinking		x	x	x
C.16	Check dams	x	x	x	x
C.17	Vegetation cover	x	x	x	x
C.18	Vegetation condition		x	x	
C.19	Vegetation composition	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
Testing Indicators					
8.2	Soil characterization testing	x	x		(x)
8.3	Sediment accumulation testing	x	x	x	x
8.4	Surface infiltration rate testing		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)

7.1.3 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 installation of pipes/sewers and backfilling to ensure depths, slopes and elevations are acceptable;
3. At completion of installation of pipes/sewers, prior to backfilling to ensure slopes and elevations are acceptable;
4. After final grading, prior to planting to ensure depths, slopes and elevations are acceptable;
5. 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);
6. 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 7.3 describes critical points during the construction sequence when inspections should be performed prior to proceeding further. Table 7.3 can also be used as a checklist during Construction inspections, in addition to the Inspection Field Data Forms provided in Appendix C.

7.1.4 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.

Table 7.3: *Critical timing of construction inspections - bioretention and dry swales.*

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 installation of pipes/sewers and backfilling	Excavation location, footprint, depth and slopes are acceptable	
	Excavated soil is stockpiled outside the CDA	
	Embankments/berms (elevations, slopes, compaction) are acceptable	
	Excavation bottom and sides roughened to reduce smearing and compaction	
BMP Installation – after installation of pipes/sewers, prior to backfilling	Structural components (e.g., foundation, walls) installed according to plans, if applicable	
	Impermeable liner installed correctly, if applicable	
	Installations of sub-drain pipes (e.g., locations, elevations, slopes), standpipes/monitoring wells are acceptable	
	Sub-drain trench dams installed correctly (location, elevation)	
Landscaping – after final grading, prior to planting	Filter bed depth and surface elevations at inlets are acceptable	
	Maximum surface ponding depth is acceptable	
	Filter bed is free of ruts, local depressions and not overly compacted	
	Planting material meets approved planting plan specifications (plant types and quantities)	

Notes:

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

7.1.5 Routine Maintenance

Table 7.4 describes routine maintenance tasks for bioretention practices, 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 high traffic areas (vehicle or pedestrian). Tasks involving removal of trash, debris and sediment and weeding/trimming of vegetation for BMPs in such contexts may need to be done more frequently (i.e., higher standards may be warranted).

Individuals conducting vegetation maintenance and in particular, weeding (i.e., removal of undesirable vegetation), should be familiar with the species of plants specified in the planting plan and experienced in plant identification and methods of removing/controlling noxious weeds. Key resources on these topics are provided below:

- Agriculture and Agri-food Canada's WeedInfo database, http://www.weedinfo.ca/en/
- Ontario Ministry of Agriculture, Food and Rural Affairs' Ontario Weed Gallery, http://www.omafra.gov.on.ca/english/crops/facts/ontweeds/weedgal.htm
- Ontario Ministry of Agriculture, Food and Rural Affairs' Noxious Weeds In Ontario list, http://www.omafra.gov.on.ca/english/crops/facts/noxious_weeds.htm
- Ontario Invasive Plant Council's Quick Reference Guide to Invasive Plant Species, http://www.ontarioinvasiveplants.ca/files/Invasives_booklet_2.pdf
- Oregon State University Stormwater Solutions, 2013, Field Guide: Maintaining Rain Gardens, Swales and Stormwater Planters, Corvallis, OR.
- Plants of Southern Ontario (book), 2014, by Richard Dickinson and France Royer, Lone Pine Publishing, 528 pgs.
- Weeds of North America (book), 2014, by Richard Dickinson and France Royer, University of Chicago Press, 656 pgs.

Table 7.4: *Routine Maintenance Tasks for Bioretention and Dry Swales.*

Component	Routine Maintenance Task	Frequency[1] Minimum[2]	Frequency[1] High[3]
Contributing Drainage Area	• Remove trash, natural debris, clippings and sediment	BA	Q
	• Remove accumulated sediment. • Re-plant or seed bare soil areas	A	BA
Inlets and Outlets	• Remove trash, natural debris and clippings	BA	Q
	• Remove accumulated sediment • Remove woody vegetation at inflow points	A	BA
Pretreatment & Flow spreaders	• Remove trash, natural debris, clippings	BA	Q
	• Remove accumulated sediment	A	BA
	• Re-grade and re-plant eroded areas when ≥30 cm in length	AN	AN
Perimeter	• Add stone or mulch to maintain 5 to 10 cm depth on non-vegetated areas	Every 2 years	Every 2 years
	• Re-grade and re-plant eroded areas when ≥30 cm in length	AN	AN
Filter bed	• Remove trash • Re-distribute mulch or stone cover to maintain 5 to 10 cm depth on non-vegetated areas	BA	Q
	• Remove accumulated sediment when ≥ 5 cm depth • Re-grade and restore cover over any animal burrows, sunken areas when ≥ 10 cm in depth and erosion rills when ≥ 30 cm in length	AN	AN
	• Add mulch or stone cover to maintain 5 to 10 cm depth where specified in the planting plan	Every 2 years	Every 2 years
Vegetation	• Watering during first two months after planting	BW	BW
	• Watering for the remainder of the first two (2) growing seasons (i.e., May to September) after planting or until vegetation is established	AN	AN
	• Watering for the remainder of the BMP lifespan	D	AN
	• Mow grass to maintain height between 10 to 15 cm.	M	BM
	• Remove undesirable vegetation (e.g., tree seedlings, invasives/weeds)	BA	Q
	• Replace dead/diseased plants to maintain a minimum of 80% vegetation cover[4]	A	BA
	• Prune shrubs and trees • Cut back spent plants • Divide or thin out overcrowded plants	A	A
Sub-drain & Monitoring well	• Flush out accumulated sediment with hose or pressure washer	A	A

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; M = Monthly; D = During drought conditions classified by Agriculture and Agri-Food Canada's Canadian Drought Monitor as severe (D2) or higher (AAC, 2015); Q = Quarterly or four times per year, ideally in the spring, summer, early fall and late fall/early winter; W = Weekly.
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 and mowing/weeding/trimming of vegetation.
4. More frequent inspections may be warranted for highly visible BMPs, those receiving drainage from high traffic areas (vehicle or pedestrian), or those designed with larger than recommended impervious drainage area to pervious BMP footprint area ratio (i.e., I:P ratio), which will be more prone to accumulation of trash and sediment.
5. Aim to achieve 80% vegetation cover in planting areas by the end of the establishment/warranty period for the original plantings (e.g., two years after planting).

Tips to help preserve BMP function

- Because the risk of compaction is higher when filter media soil is saturated, any maintenance tasks involving vehicle (e.g., ride mower) or foot traffic on the filter bed should not be performed during wet weather;
- Use push mower to maintain bioretention practices with grass as vegetation cover or the lightest ride mower equipment available to minimize compaction of the filter bed;
- Use a mulching mower to maintain bioretention practices with grass as vegetation cover or leave clippings on the surface to help maintain organic matter and nutrients in the filter media;
- Pruning of mature trees should be performed under the guidance of a Certified Arborist;
- Woody vegetation should not be planted or allowed to become established where snow will be piled/stored during winter; and
- Removal of sediment accumulated on the filter bed surface should be performed by hand with rake and shovel, or vacuum equipment where feasible. If a small excavator is the chosen method, keep the excavator off the BMP footprint to avoid damage to side slopes/embankments and compaction of the filter media.

7.1.6 Rehabilitation and Repair

Table 7.5 provides guidance on rehabilitation and repair work specific to bioretention and dry swales organized according to BMP component.

Table 7.5: *Rehabilitation and repair guidance for bioretention and dry swales.*

BMP Component	Problem	Tasks
Inlets	Inlet or flow spreading device is producing concentrated flow and causing filter bed erosion	Add flow spreading device or re-grade existing device back to level to promote sheet flow to the filter bed. Regrade damaged portion of the filter bed and replant or restore mulch/stone cover. If problem persists, replace filter bed vegetation/mulch cover with stone at inlets.
Filter bed	Filter media is overly compacted	Core aerate; or remove stone, mulch and vegetation cover and till filter media to a depth of 20 cm; or remove and replace with uncompacted material that meets design specifications. Replace stone, mulch and vegetation cover (re-use/transplant where possible).
	Filter media texture is too fine (i.e., % silt and clay-sized particles too high)	Remove stone, mulch and vegetation cover and till filter media to a depth of 20 cm; or remove and replace all or the uppermost 15 cm of material with filter media that meets design specifications. Replace stone, mulch and vegetation cover (re-use/transplant where possible).
	Filter media organic matter or phosphorus content too low AND vegetation not thriving	Remove stone, mulch and vegetation cover and uppermost 5 cm of filter media, spread 5 cm compost, incorporate into filter media to 20 cm depth by tilling. Replace stone, mulch and vegetation cover (re-use/transplant where possible).
	Filter media pH is out of specification range (6.0 to 7.8) AND vegetation not thriving	If soil pH is lower than 6.0, amend with ground limestone to raise the pH back to neutrality. If soil pH is higher than 7.8, amend with compost or sulphur to lower the pH back to neutrality.
	Filter media cationic exchange capacity is <10 meq/100 g	Remove stone, mulch and vegetation cover and uppermost 5 cm of filter media, spread 5 cm compost, incorporate into filter media to 20 cm depth by tilling; or replace all or the uppermost 15 cm of material with filter media that meets design specifications. Replace stone, mulch and vegetation cover (re-use/transplant where possible).
	Filter media soluble salts content exceeds 2.0 mS/cm	Flush the affected area thoroughly with fresh water.
Filter bed	Local or average sediment accumulation ≥ 5 cm in depth	For local accumulation areas (e.g., at inlets) remove stone and use vacuum equipment to remove accumulated sediment/mulch, or to minimize disturbance of vegetation cover. Sediment from local areas can be removed with hand tools (e.g., rake and shovel). For large BMPs, use of a small excavator may be preferable. Restore grades with filter media that meets design specifications. Replace stone, mulch and vegetation cover (re-use/transplant where possible).

	Surface ponding remains for > 24 hours or surface infiltration rate is out of acceptable range	Remove stone, accumulated sediment/mulch, and vegetation cover. Till the exposed filter media to a depth of 20 cm to eliminate surface crusting or macropores and reduce compaction, or remove and replace the uppermost 15 cm of material with filter media that meets design specifications. Replace stone, mulch and vegetation cover (re-use/transplant where possible).
	Damage to filter bed or slide slope is present (e.g., erosion rills, animal burrows, local sinking, ruts)	Regrade damaged portion by shovel and replant or restore mulch/stone cover. Animal burrows, local sinking and compacted areas should be tilled to 20 cm depth prior to re-grading.
Sub-drain	Sub-drain perforated pipe is obstructed by sediment or roots	Schedule hydro-vac truck or drain-snaking service to remove the obstruction.

7.1.7 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; TRCA & U of T, 2013b) for three design variations (full infiltration, partial infiltration and no infiltration) to assist stormwater infrastructure planners, designers and asset managers with planning and preparing budgets. For each 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 7.2 and Table 7.4 "Minimum Frequency" column), and a high frequency scenario (i.e., Table 7.2 and Table 7.4 "High Frequency" column) to provide an indication of the potential range.

The general assumptions used in developing version 1.1 of the LID Life Cycle Costing Tool (TRCA & U of T, 2013b) are outlined in detail in the report titled "Assessment of the Life Cycle Costs of Low Impact Development Stormwater Management Practices" (TRCA and U of T, 2013a). Assumptions for the Minimum Maintenance Frequency scenario can be viewed in the latest version of the spreadsheet tool (STEP, 2016) using the default values and a CDA of 2,000 m^2, and are briefly summarized here. Assumptions regarding design and material specifications are based on guidance provided in the LID SWM Planning and Design Guide (CVC & TRCA, 2010).

Capital costs included within the category of construction include those related to site assessment, and conceptual and detailed design related tasks such as borehole analysis and soil testing. All material, delivery, labour, equipment (rental, operation, operator), hauling and disposal costs are accounted for within the construction costs of the facility. Standard union costs were derived from the RSMeans database in 2010 and have been adjusted for 5 year inflation of 8.79% (2010 to June, 2015). Costs include overhead and inflation to represent contractor pricing. It was assumed the practice is part of a new development (i.e., not a retrofit), thereby excluding (de)mobilization costs unless a particular piece of equipment would not normally have been present at the site. Additionally, it was assumed that excavated soil associated with construction of the BMP would be reused elsewhere on site. Overhead costs were presumed to consist of construction management (4.5%), design (2.5%), small tools (0.5%), clean up (0.3%) and other (2.2%).

Assumptions regarding maintenance frequencies and requirements and the life span of each practice are based on both literature and practical experience. Life cycle and associated maintenance costs are evaluated over a 50 year timeframe, which is the typical period over which infrastructure decisions are made.

For bioretention it is assumed that some rehabilitation (e.g., rehabilitative maintenance) work will be needed on the filter bed surface once the BMP reaches 25 and 50 years of age in order to maintain functional drainage performance at an acceptable level. Included in the rehabilitation costs are (de)mobilization costs, as equipment would not have been present on site. Design costs were not included in the rehabilitation as it was assumed that the original LID practice design would be used to inform this work. The annual average maintenance cost does not include rehabilitation costs and therefore represents an average of routine maintenance tasks, as outlined in Table 7.4. All cost value estimates represent the net present value (NPV) as the calculation takes into account average annual interest (2%) and discount (3%) rates over the evaluation time periods.

For all bioretention design variations, the CDA has been defined as a 2,000 m^2 impervious pavement area plus the footprint area of a bioretention cell that is 133 m^2 in size, as per design recommendations. The impervious area to pervious area ratio (I:P ratio) used to size the BMP footprint is 15:1, which is the maximum ratio recommended in the LID SWM Planning and Design Guide (CVC & TRCA, 2010). It is assumed that water drains to the cell through curb inlets spaced 6 m apart with stone cover on the filter bed at the inlets to dissipate the energy of the flowing water.

While orientation (i.e., cell versus swale) and choice of components (e.g., inlet/outlet structures etc.) can vary widely, design variations for bioretention practices can be broken down into three main categories. They can be designed to drain through infiltration into the underlying subsoil alone (i.e., Full Infiltration design, no sub-drain), through the combination of a sub-drain and infiltration into the underlying subsoil (i.e., Partial Infiltration design, with a sub-drain), or through a sub-drain alone (i.e., No Infiltration or “filtration only” design, with a sub-drain and impermeable liner). For Full Infiltration systems, an overflow is provided for storms up to 37 mm based on a subsoil infiltration rate of 20 mm/hour. Two standpipe wells are part of the design (one subdrain inspection/flushing port at the upstream end and one sub-surface water storage reservoir monitoring well at the downstream end). Partial Infiltration systems have a sub-surface water storage reservoir with a perforated pipe sub-drain within it. The depth of the reservoir is sized to store flow from a 25 mm rain event over the CDA based on native soil infiltration rate of 10 mm/hour. The No Infiltration system includes an impermeable liner between the base and sides of the BMP and surrounding native sub-soil, to prevent infiltration.

Estimates of the life cycle costs of bioretention and dry swales in Canadian dollars per unit CDA ($\$/m^2$) are presented in Table 7.6. 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.

For all BMP design variations and maintenance scenarios, it is assumed that rehabilitation of part or all of the filter bed surface will be necessary once the BMP reaches 25 and 50 years of age to maintain acceptable surface drainage performance (e.g., surface ponding drainage time). Filter bed rehabilitation for bioretention and dry swales is assumed to typically involve the following tasks and associated costs:

- Remove mulch, stone and vegetation cover, separating and re-using existing materials and plants to greatest extent feasible (all stone is re-used, 2/3 of vegetation is transplanted);
- Remove uppermost 15 cm of soil from the filter bed surface;
- Spread 15 cm of filter media that meets design specifications, thoroughly wet the material, allow time to settle, and rake to restore grade;
- Construction and Assumption inspection and testing work, including soil characterization testing to confirm that filter media meets design specifications;
- Surface infiltration rate testing, to confirm that acceptable drainage performance has been restored;
- Restore mulch or stone cover and transplant/plant vegetation;
- Perform routine vegetation maintenance tasks (i.e., watering, weeding, trimming) at recommended frequencies over the two (2) year establishment period for the plantings; and
- Replace plants that don't survive the initial establishment period (assumes 10% and 20% of plant material does not survive the first year for Minimum Recommended and High Frequency maintenance scenarios, respectively).

Table 7.6: *Life cycle cost estimates for bioretention and dry swales.*

Bioretention & Dry Swales	Minimum Frequency			High Frequency		
Design Variation	**Full Infiltr.**	**Partial Infiltr.**	**No Infiltr.**	**Full Infiltr.**	**Partial Infiltr.**	**No Infiltr.**
Construction Costs	\$17.02	\$22.17	\$21.80	\$17.02	\$22.17	\$21.80
Rehabilitation Costs	\$4.83	\$4.78	\$4.78	\$4.50	\$4.41	\$4.41
Rehabilitation Period (years in service)	25	25	25	25	25	25
50 YEAR EVALUATION PERIOD						
Average Annual Maintenance	\$0.66	\$0.70	\$0.70	\$0.94	\$0.98	\$0.98
Maintenance and Rehabilitation	\$37.59	\$39.09	\$39.09	\$51.75	\$53.25	\$53.25
25 YEAR EVALUATION PERIOD						
Average Annual Maintenance	\$0.70	\$0.75	\$0.75	\$1.03	\$1.08	\$1.08
Maintenance and Rehabilitation	\$20.53	\$21.33	\$21.33	\$28.36	\$29.16	\$29.16

Notes:

1. Estimated life cycle costs represent NPV of associated costs in Canadian dollars per square metre of CDA (\$/m^2).
2. Average annual maintenance cost estimates represent NPV of all costs incurred over the time period and do not include rehabilitation costs.
3. Rehabilitation cost estimates represent NPV of all costs related to repair work assumed to occur every 25 years, including those associated with inspection and maintenance over a two (2) year establishment period for the plantings.
4. Full Infiltration design life cycle costs are lower than Partial and No Infiltration designs due to the absence of a sub-drain to construct, inspect and routinely flush.
5. Rehabilitation costs for Full Infiltration designs are estimated to be 26.4 to 28.4% of the original construction costs for High and Minimum Recommended Frequency maintenance program scenarios, respectively.
6. Rehabilitation costs for Partial Infiltration designs are estimated to be 19.9 to 21.6% of the original construction costs for High and Minimum Recommended Frequency maintenance program scenarios, respectively.
7. Rehabilitation costs for No Infiltration designs are estimated to be 20.2 to 21.9% of the original construction costs for High and Minimum Recommended Frequency maintenance program scenarios, respectively.
8. Maintenance and rehabilitation costs over a 25 year time period for the Minimum Recommended maintenance scenario are estimated to be roughly equivalent to the original construction cost for Partial Infiltration and No Infiltration designs (96.2% and 97.8%, respectively), and 1.21 times the original construction cost for Full Infiltration design.

9. Maintenance and rehabilitation costs over a 25 year time period for the High Frequency maintenance scenario are estimated to be 1.32 times the original construction costs for Partial Infiltration, 1.34 times for No Infiltration designs, and 1.67 times for Full Infiltration designs.
10. Maintenance and rehabilitation costs over a 50 year time period for the Minimum Recommended Frequency maintenance scenario are estimated to be approximately 1.76 times the original construction cost for Partial Infiltration designs, 1.79 times the original construction cost for No Infiltration designs, and 2.21 times the original construction cost for Full Infiltration designs.
11. Maintenance and rehabilitation costs over a 50 year time period for the High Frequency maintenance scenario are estimated to be approximately 2.40 times the original construction cost for Partial Infiltration designs, 2.44 times the original construction cost for No Infiltration designs, and 3.04 times the original construction cost for Full Infiltration designs.