7.6 Green Roofs

7.6.1 BMP Overview

Green roofs are specially engineered rooftops designed to support the growth of vegetation while protecting the structural integrity of the roof. They can also be referred to as vegetated roofs, rooftop gardens or eco-roofs. A green roof acts like a lawn, meadow or garden by intercepting and absorbing a portion of the rain or snow that falls on it. The typical layers of a green roof (in order from the roof surface) include insulation layer, water-proofing membrane, root barrier, drainage layer, geotextile, lightweight growing medium layer and the vegetation. Excess water that is not absorbed by the vegetation, growing medium, or geotextile is collected by the underlying drainage layer, directed to outlet structures and conveyed via the roof drainage system to another stormwater BMP or the municipal storm sewer system. A large portion of the water absorbed by green roofs is returned to the atmosphere by evaporation and transpiration by plants. Green roofs are typically designed to retain precipitation from small to medium-sized storm events. Overflow outlets are necessary to safely convey flows from major storm events. Key components of green roofs for inspection and maintenance are described in Table 7.32 and Figure 7.6.

Properly functioning green roofs reduce the quantity of runoff and pollutants being discharged to municipal storm sewers and receiving waters (i.e., rivers, lakes and wetlands). The growing medium and plants retain pollutants deposited from the atmosphere and reduce metals and other pollutants from conventional roof materials transported by runoff. In addition to their SWM benefits, green roofs can improve the energy efficiency of the building due to their insulating properties, reduce the urban heat island effect, provide food and shelter for pollinators and have aesthetic value as attractive landscaped features.

There are two types of green roofs: intensive and extensive. Intensive green roofs contain greater than 15 cm depth of growing medium, can be planted with deeply rooted plants and can be designed to handle pedestrian traffic. Extensive green roofs consist of a thinner growing medium layer (15 cm depth or less) and are typically planted with drought-tolerant, shallow rooting, low maintenance herbaceous vegetation.

Ontario Occupational Health and Safety training standards for individuals working at heights must be adhered to during installation, inspection and maintenance of green roofs. Individuals working on rooftops should be adequately trained on the use and maintenance of fall prevention and arrest equipment and review hazards and safety plans regularly. Further information about Ontario's training standard for working at heights can be accessed at the following location:

- http://www.labour.gov.on.ca/english/hs/pubs/wah/

Table 7.32: *Key Components of Green Roofs for Inspection and Maintenance.*

Component	Description
Perimeter	Inspection of the perimeter is done to confirm the dimensions of the BMP are acceptable, check for wind uplift of green roof layers or other types of structural damage (e.g. failing edge restraint). A vegetation-free zone that separates the green roof perimeter from the roof perimeter and other structures on the roof (e.g., vents), that is kept devoid of vegetation and natural debris should be maintained as a fire prevention measure. Parapets or other wind break structures may also be present around the green roof perimeter to help prevent wind scour of growing medium, and should be routinely inspected for damage.
Filter bed/ Growing media area	The green roof surface that is composed of filter bed (i.e., growing medium area) covered by a mixture of vegetation and either flat or gently sloping. Growing media will vary according to the green roof system/product installed but is generally designed to be porous and lightweight with adequate fertility and drainage capacity to support plant growth and allow for absorption and infiltration of water. Growing media may be covered by matting or another erosion control measure to prevent surface erosion from rain or wind scour while plantings are becoming established. Green roofs are designed to drain all excess water within a few hours after the end of a storm. The filter bed should be routinely checked for presence of standing water. Trash should be removed from the filter bed regularly. Repair of animal burrows or damage from foot traffic, wind scour or uplift may also be needed periodically.
Vegetation	Green roofs rely on vegetation (i.e., sedums/succulents, grasses, herbs, wildflowers and for intensive green roofs, shrubs and trees) to intercept, absorb and evapo-transpire stormwater. Plantings should be adapted to the harsh conditions (i.e., minimal soil depth, seasonal drought, high winds and strong sun exposure) prevalent on rooftops. A wider variety of vegetation types may be used on intensive green roofs, but these typically require additional maintenance. In the first 2 months of establishment, plantings need to be irrigated frequently (e.g., bi-weekly). Routine maintenance of vegetation is similar to a conventional planting bed (i.e., weeding, pruning, watering during droughts, fertilization as needed).
Overflow outlets	Flows exceeding the storage capacity of the BMP are conveyed to an adjacent drainage system via an overflow outlet structure and the roof drainage system. Overflow outlet structures must be kept free of obstructions to ensure stormwater is safely conveyed during major storm events.
Irrigation system	Most green roofs will require periodic irrigation, especially during the first 2 months of the establishment period. Inspection and testing of the irrigation system should be done regularly to ensure it is functioning properly. Irrigation systems need to be disconnected from the water supply and drained prior to winter and re-connected in the spring.
Protective layers	Green roofs typically contain one or more layers designed to protect the roof deck and insulation from water damage, including a water-proofing membrane layer, a root barrier layer that protects the water-proofing membrane from root penetration and degradation by microbial activity, or a single protective layer that provides both functions. Inspection work should include checking for any portions of the green roof where protective layers are exposed and thereby at risk of damage.
Leak detection system	Where present, leak detection systems should be used to periodically check for the presence of leaks in the water-proofing membrane.

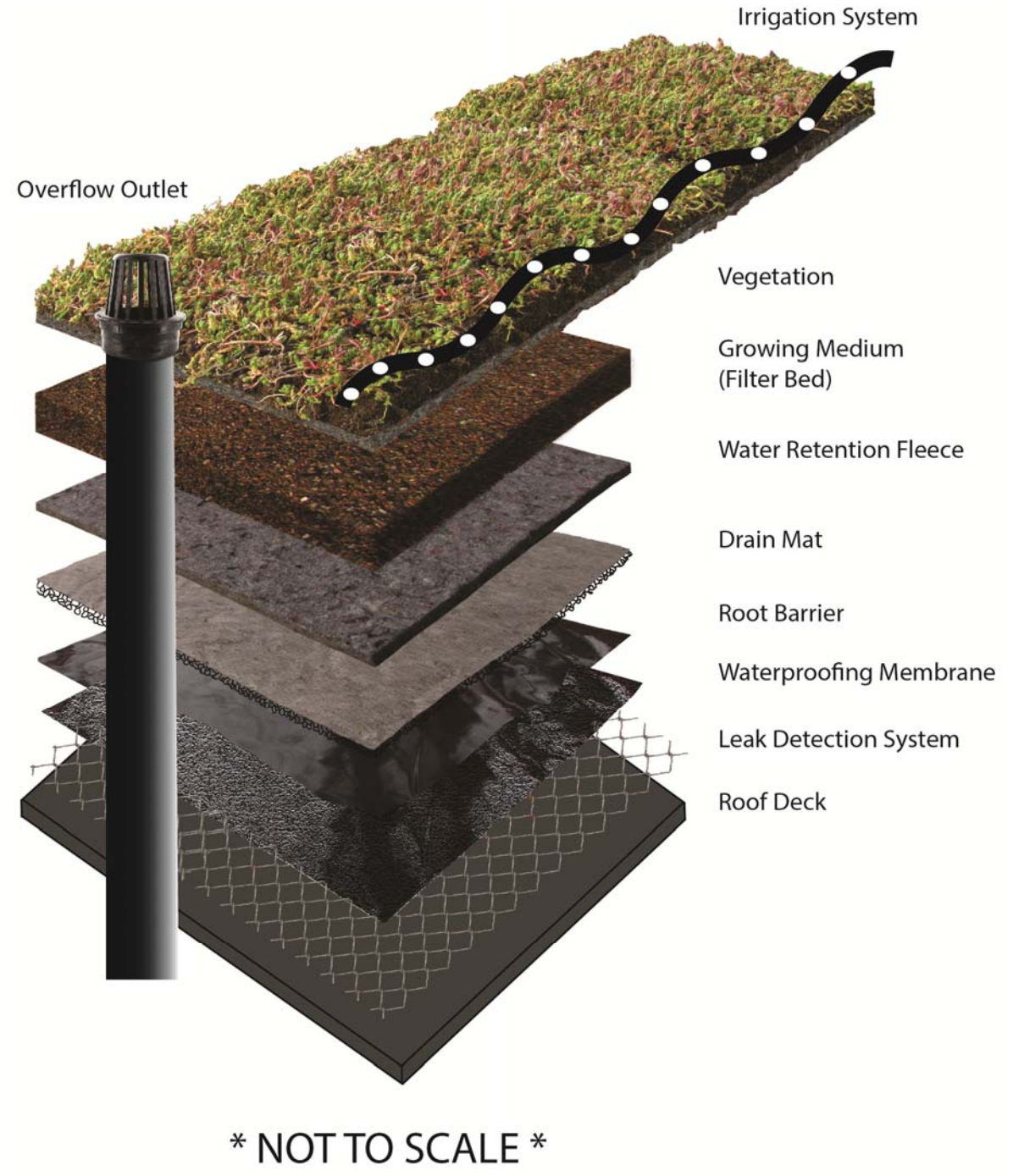

Figure 7.6: *Generalized plan and cross-section views of a green roof showing key components.*

7.6.2 Inspection and Testing Framework

Table 7.33 describes what visual and testing indicators should be used during each type of inspection for green roofs 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.

7.6.3 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 installation to ensure the roof structure is ready for green roof construction work and confirm that BMP layout area matches approved design drawings and that construction materials meet design specifications;
2. After installation of leak detection system (if applicable) to ensure it was done properly.
3. At installation of water-proofing membrane, prior to installation of root barrier, drainage layer and overflow outlets to ensure it was done properly and to confirm that slopes are acceptable;
4. After installation of root barrier, drainage layer (including filter fabric/layer) and overflow outlets, prior to installation of growing medium and plants to ensure it was done properly and confirm that depth and slopes are acceptable;
5. After installation of growing medium layer and plants to ensure it was done properly and to confirm depth, slopes and elevations at overflow outlets are acceptable;
6. After installation of irrigation system to confirm system is functioning;
7. Prior to hand-off points in the construction sequence when the contractor responsible for the work changes (i.e., hand-offs between the building and green roof installation contractors);
8. After every large storm event (e.g., 15 mm rainfall depth or greater) to ensure roof drainage or flow diversion devices are functioning and adequately maintained.

Additional inspections may be needed depending on the number of layers in the green roof design (e.g., insulation, root barrier, and growing medium structural support layers) and may be required to comply with product warranty conditions. The green roof product vendor or designer should provide further guidance in this regard, specific to the system or product being installed.

Table 7.34 describes some critical points during the construction sequence when inspections should be performed prior to proceeding further. Table 7.34 can also be used as a checklist during Construction inspections, in addition to the Inspection Field Data Forms provided in Appendix C.

Table 7.33: *Inspection and testing indicators framework for green roofs.*

INSPECTION AND TESTING FRAMEWORK					
GREEN ROOFS		**Inspection Type**			
Section	Indicator	Construction	Assumption	Routine Operation	Verification
Visual indicators					
C.6	BMP dimensions	x	x		x
C.27	Green roof structural integrity		x	x	x
C.9	Standing water		x	x	x
C.10	Trash		x	x	
C.11	Filter bed erosion		x	x	
C.17	Vegetation cover	x	x	x	x
C.18	Vegetation condition		x	x	
C.19	Vegetation composition	x	x	x	
C.22	Overflow outlet obstruction	x	x	x	x
Testing indicators					
8.2	Soil characterization testing	x	x		(x)
8.7	Green roof irrigation system testing	x	x	x	
8.8	Green roof leak detection testing		x		x

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

Table 7.34: *Critical timing of construction inspections - green roofs.*

Construction Sequence Step and Timing	Inspection Item	Observations [1]
During site preparation, prior to BMP installation	Ensure the roof structure is ready for green roof construction work	
	BMP layout area and dimensions match approved design drawings	
	Construction materials have been confirmed to meet design specifications	
After installation of leak detection system (if applicable), prior to installation of water-proofing membrane	Quality control check leak detection system installation	
After installation of water-proofing membrane, prior to installation of root barrier, drainage layer and overflow outlets	Quality control check membrane installation	
	Confirm that slopes conform with approved design drawings	
After installation of root barrier, drainage layer (including filter fabric) and overflow outlets, prior to installation of growing medium layer and plants	Quality control check root barrier and drainage layer installations	
	Installation of drainage layer (e.g., depth and slope) is acceptable	
	Installations of overflow outlets (e.g., elevation and slope) are acceptable	
After installation of filter bed (growing medium layer and plants)	Quality control check installation of any structural components of growing medium layer (if applicable)	
	Installation of growing medium (e.g., depth, elevations at overflow outlets) is acceptable	
	Growing medium is free of ruts, local depressions	
	Planting material meets approved planting plan specifications (plant types and quantities)	
	Quality control check installation of erosion matting/protection (if applicable)	
After installation of irrigation system	Confirm installation is acceptable and system is functioning (through testing)	

Notes:

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

7.6.4 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.

7.6.5 Routine Maintenance

Table 7.35 describes routine maintenance tasks for green roofs, 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 or high pedestrian traffic locations or intensive green roofs featuring shrubs, trees and a wider variety of vegetation types. Tasks involving removal of trash, debris and weeding/trimming or replacement of dead plants may need to be done more frequently in such contexts. For further guidance on maintenance of vegetation cover on green roofs, refer to ASTM D2400/E2400M-06 Standard Guide for Selection, Installation and Maintenance of Plants for Green Roof Systems (ASTM International, 2015).

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
- 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 7.35: *Routine maintenance tasks for green roofs.*

Component	Routine Maintenance Task	Frequency[1]	
		Minimum[2]	High[3]
Perimeter	◖ Remove any vegetation or natural debris from the vegetation-free zones between the green roof perimeter and the roof edge and other rooftop structures	A	BA
Filter bed	◖ Remove trash and natural debris	A	BA
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
	◖ Remove undesirable vegetation (e.g., weeds or invasive species, tree or shrub seedlings/saplings)	BA	Q
	◖ Replace dead/diseased plants to maintain a minimum of 80% vegetation cover[4] ◖ Prune shrubs and trees ◖ Cut back spent plants	A	BA
Overflow outlets	◖ Remove trash, natural debris and clippings	BA	Q
	◖ Flush out accumulated sediment with hose or pressure washer	A	BA
Irrigation system	◖ In the Spring, reconnect all parts to the water supply, flush lines to clear out any debris or sediment and test (i.e., run each zone for a few minutes) to confirm that the system is undamaged and functioning well ◖ In the late Fall/early Winter, disconnect the system from the water supply, connect it to an air compressor and blow air through it to remove water and ensure the lines and parts are dry, shut off water supply to the roof, and drain all hose bibs	A	A
	◖ Remove any debris or sediment accumulated on main assembly filter (if present)	BA	BA
Protective layers	◖ Repair isolated leaks in the water-proofing membrane through deconstruction of a small portion of the green roof, patching with new material, and reconstruction.	1 m^2 patch at 10 years & every 5 years thereafter	2 m^2 patch at 10 years & every 5 years thereafter

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 or in highly visible locations, may warrant a higher frequency of routine maintenance tasks involving weeding and replacing dead plants.
4. 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 growing medium soil is saturated, any maintenance tasks involving foot traffic on the filter bed should not be performed during wet weather;
- Pavers or walkways should be placed at roof access locations and in primary paths to facilitate ease of access and help avoid having to walk on planted portions of the green roof during inspection and maintenance work.;
- During maintenance and any other type of installation or repair work over the green roof, use of sharp tools, lawn staples and stakes should be avoided to prevent damage to the drainage layer, root barrier and water-proofing membrane. All sharp pieces of metal and fasteners should be removed from the filter bed area with care;
- For green roofs with sedum as vegetation cover, trim off top stems annually in the spring during the first two years of establishment and leave on the growing medium surface to encourage colonization or purchase and spread fresh cuttings;
- Transplant vegetation that is established in the vegetation-free zone between the green roof perimeter and roof edge or other rooftop structures to supplement plantings on the filter bed if species are appropriate;
- Pruning of mature trees should be performed under the guidance of a Certified Arborist;
- Establish procedures and timing for irrigation system start-up and winterization to avoid damage to system components from freezing (e.g., start-up in the spring, once minimum air temperatures are above freezing and shutdown/winterize in late fall, prior to on-set of freezing weather);
- Routinely check that the irrigation system is free of damage and delivering water evenly to vegetated areas;
- For green roofs with automated irrigation systems using municipal/drinking water, schedule watering to occur at night or early in the morning to minimize the loss of water to evaporation; and
- For green roofs with automated irrigation systems using cistern water, irrigating during the day when evaporation rate is high will make greater use of stored rainwater between storm events, thereby freeing up more storage in the system for the next event and helping to reduce site runoff volume.

7.6.6 Rehabilitation and Repair

Table 7.36 provides guidance on rehabilitation and repair work specific to green roofs organized according to BMP component.

Table 7.36: *Rehabilitation and repair guidance for green roofs.*

BMP Component	Problem	Task
Filter bed/ Growing medium area	Eroded growing media area ≥ 30 cm in length or other damage is present	Restore growing media to required depth with material that meets design specifications, replant and irrigate bi-weekly or as needed until plantings are established. If problems persist, consider covering with matting or other erosion control measure until plantings are established or adding parapets or other wind break structures.
	Growing medium texture is out of specification range	Consult with medium manufacturer or product vendor to determine corrective actions.
	Growing medium organic matter or phosphorus content too low AND vegetation not thriving	Amendment or fertilizer application should be prescribed by the medium manufacturer or product vendor.
	Growing medium pH is out of specification range (6.0 to 7.8) AND vegetation not thriving	Consult with media manufacturer or product vendor to determine corrective actions.
	Growing medium soluble salts content exceeds 2.0 mS/cm AND vegetation not thriving	Consult with media manufacturer or product vendor to determine corrective actions.
	Surface ponding remains for > 3 hours after the end of a storm event because water does not infiltrate through the growing medium	Aerate (i.e., rake) or replace growing medium in problem areas taking care not to damage the drainage layer, root barrier or water-proofing membrane.
	Surface ponding remains for > 3 hours after the end of a storm event because water does not infiltrate through the drainage layer	Consult with green roof designer or product manufacturer/vendor to determine corrective actions.
Overflow outlets	Surface ponding remains for > 3 hours after the end of a storm event because overflow outlet is obstructed	Remove the obstruction which may require the use of a pressure washer or drain-snaking service.
Irrigation system	Distribution line, fitting or drip emitter/spray head is leaking, damaged or misaligned.	Identify the location of the damaged system component through testing (i.e., running the system in each zone while making observations). Turn off the system and schedule the repair work.

Protective layers	Water-proofing membrane has reached 40 years of age and is due for replacement.[1]	Deconstruct the green roof (re-using materials where possible), replace the water-proofing membrane with new material, and reconstruct with materials that meet design or product specifications.

Notes:

1. The expected lifespan of typical water-proofing membrane materials used below a green roof is estimated to be 40 years (TRCA & U of T, 2013a).

7.6.7 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 four design variations 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 & U of T, 2013a).

For green roofs it is assumed that replacement of the water-proofing membrane protecting the roof structure will be needed once the roof has been in place for 40 years (TRCA & U of T, 2013a). Rehabilitation costs are those related to deconstruction, replacement of most materials (assumes 2/3 of cuttings needed to replant the 10 cm deep growing media bed design can be harvested from the previous roof), and reconstruction including (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 7.35. As part of these costs, it is assumed that a minor leak is detected in the waterproofing membrane when the roof reaches 10 years of age, and that the leak can be isolated through leak detection tests and repaired through patching. It is also assumed that one minor leak is detected and repaired every 5 years thereafter, until it reaches 40 years of age, when the entire membrane is replaced with new material.

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.

The design variations examined are as follows:

1. Extensive, 10 cm deep growing media bed, no irrigation system, no waterproof membrane;
2. Extensive, 10 cm deep growing media bed, no irrigation system, with waterproof membrane;
3. Extensive, 15 cm deep growing media bed with irrigation system, no waterproof membrane;
4. Extensive, 15 cm deep growing media bed with irrigation system and waterproof membrane;

The costing presented in this section is specific to extensive green roofs only, which are more common than intensive green roofs. Extensive green roofs support low growing plants and have substrate depths ranging from 5-15 cm, while intensive green roofs have growing media deeper than 15 cm (Permeable Pavement Task Committee, 2015). The no waterproof membrane scenarios assume that the membrane has already been installed as part of building roof construction and that waterproof membrane leak detection testing is performed by flood tests.

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 7.33 and Table 7.35 "Minimum Frequency" column), and a high frequency scenario (i.e., Table 7.33 and Table 7.35 "High Frequency" column) to provide an indication of the potential ranges.

For all scenarios, the CDA (i.e., green roof area) is 2,000 m^2 and cost estimates include crane mobilization and demobilization to install, deconstruct and reconstruct the green roof. The 10 cm deep growing media bed is planted with cuttings and the "with water-proofing membrane" design is installed with a thermoplastic polyolefin (TPO) membrane and no membrane leak detection system. The 15 cm deep growing media bed is planted with pre-grown sedum mats, includes an irrigation system, and the "with waterproof membrane" design is installed with a synthetic rubber, ethylene propylene diene terpolymer (EPDM) membrane and an Electric Field Vector Mapping (EFVM) leak detection system.

Estimates of the life cycle costs for all green roof design variations and maintenance scenarios in Canadian dollars per unit CDA ($/$m^2$) are presented in Table 7.37. 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 replacement of the water-proofing membrane is needed at 40 years of age (TRCA & U of T, 2013a). Where a green roof is in place, replacement of the water-proofing membrane is assumed to typically involve the following tasks and associated costs:

- Deconstruction of all green roof components and layers;
- For 10 cm growing media bed designs, harvesting 2/3 of the plant material needed to replant by cuttings;
- For 15 cm growing media bed designs planted with pre-grown sedum mats, it is assumed that all mats and associated growing media and plants are replaced with new ones;
- Replacement of the water-proofing membrane with new material that meets design specifications;
- Reconstruction of the green roof layers up to and including the growing media bed with new material that meets design specifications;

- Leak detection testing to confirm membrane installation is acceptable;
- Planting or installation of new plant material;
- Reconstruction of the irrigation system (where applicable) with new materials that meet design specifications;
- Green roof irrigation system testing to confirm installation is acceptable (where applicable);
- Construction and Assumption inspection work as part of reconstruction work at year 40;
- Routine inspection and vegetation maintenance work over a two (2) year establishment period for the plantings;
- Replace plants that don't survive the initial establishment period (assumes 10% and 20% of transplanted plant material does not survive the first year for Minimum Recommended and High Frequency maintenance scenarios, respectively).

Table 7.37: *Life cycle cost estimates for extensive green roofs.*

Green Roofs	Minimum Frequency				High Frequency			
Design Variation	**10 cm bed, no irrig., w membr.**	**10 cm bed, no irrig., w/o memb.**	**15 cm bed, w irrig. & memb.**	**15 cm bed, w irrig., w/o memb.**	**10 cm bed, no irrig., w membr.**	**10 cm bed, no irrig., w/o memb.**	**15 cm bed, w irrig. & memb.**	**15 cm bed, w irrig., w/o memb.**
Construction Costs	$126.40	$60.50	$244.75	$158.50	$126.40	$60.50	$244.75	$158.50
Rehabilitation Costs	$133.00	$84.45	$232.85	$169.35	$131.65	$83.10	$231.60	$168.10
Rehabilitation Period (years in service)	40	40	40	40	40	40	40	40
50 YEAR EVALUATION PERIOD								
Average Annual Maintenance	$2.50	$2.50	$2.60	$2.60	$4.65	$4.65	$4.65	$4.65
Maintenance and Rehabilitation	$257.55	$209.00	$362.45	$298.95	$363.00	$314.45	$464.25	$400.75
25 YEAR EVALUATION PERIOD								
Average Annual Maintenance	$2.80	$2.80	$2.85	$2.85	$5.15	$5.15	$5.15	$5.15
Maintenance and Rehabilitation	$69.55	$69.55	$71.85	$71.85	$128.70	$128.70	$129.05	$129.05

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 rehabilitative maintenance work assumed to be needed within the first 40 years of operation, including those associated with inspection and maintenance over a two (2) year establishment period for the plantings.

4. Average annual maintenance cost estimates for the High Frequency maintenance program scenario are approximately 1.82 times the costs for the Minimum Recommended Frequency scenario over the 50 year evaluation period.
5. Rehabilitation costs for the 10 cm deep filter bed, no irrigation system, with membrane are estimated to be between 1.04 and 1.05 times the original construction costs for High and Minimum Recommended Frequency maintenance program scenarios, respectively.
6. Rehabilitation costs for the 15 cm deep filter bed, with irrigation system, with membrane are estimated to be 95% of the original construction costs for both High and Minimum Recommended Frequency maintenance program scenarios.
7. Maintenance and rehabilitation costs over a 25 year time period for the High Frequency maintenance scenario are estimated to be 1.01 and 0.53 times the original construction costs for the 10 cm and 15 cm with membrane designs, respectively.
8. Maintenance and rehabilitation costs over a 25 year time period for the Minimum Frequency maintenance scenario are estimated to be 0.55 and 0.30 times the original construction costs for the 10 cm and 15 cm with membrane designs, respectively.
9. Maintenance and rehabilitation costs over a 50 year time period for the High Frequency maintenance scenario are estimated to be 2.87 and 1.90 times the original construction costs for the 10 cm and 15 cm with membrane designs, respectively.
10. Maintenance and rehabilitation costs over a 50 year time period for the Minimum Frequency maintenance scenario are estimated to be 2.04 and 1.48 times the original construction costs for the 10 cm and 15 cm with membrane designs, respectively.