PART 2 – INSPECTION AND MAINTENANCE OF LID PRACTICES

OVERVIEW

With the realization that conventional stormwater detention ponds do not address all the potential impacts of urbanization on our rivers, lakes and wetlands, regulators have begun to require that Low Impact Development (LID) best management practices (BMPs) be integrated into municipal stormwater management (SWM) systems. An LID approach to SWM system design involves smaller-scale BMPs distributed throughout the drainage areas upstream of end-of-pipe practices, potentially on both publicly and privately owned land.

Implementing such an approach to system design has implications on municipalities and property managers with respect to stormwater infrastructure asset management as it increases the number and types of BMPs that need to be inspected, tracked and maintained. Operationalizing an LID approach to SWM requires municipalities and property managers to develop their capacity to inspect and maintain BMPs that most have little or no experience with.

To assist with this challenge, Part 2 of this guide provides detailed guidance on inspection, testing and maintenance of seven (7) types of LID BMPs including the following topics:

- A recommended framework of inspection types that should be performed over the life cycle of SWM BMPs, and the LID BMP specific indicators and tests to use during each type of inspection (Section 6.0);
- BMP specific inspection, testing and maintenance tasks, recommended frequencies, structural repair procedural options and estimates of life cycle costs (Section 7.0);
- Standard inspection and testing protocols for twenty-nine (29) visual indicators and eight (8) types of testing including quantitative triggers for follow-up actions (Section 8.0 and Appendix C) and inspection field data forms for documenting results (Appendix C).

The recommended inspection and testing framework focuses on visual indicators and simple tests to identify potential problems or deficiencies with LID BMPs during construction, before assumption by the property owner and over their operating life cycle. Taking a proactive approach to inspection will avoid assuming BMPs that are already in need of maintenance or repair. Feedback from routine inspections can be used to optimize the frequency of maintenance tasks, avoid more costly repair work, extend the BMPs operating life cycle and save money over the long-term. Utilizing visual indicators for routine inspections, which represent the majority of inspection work over the lifespan of an LID BMP, makes them easier, faster and cheaper to perform. It also limits the need for involving highly trained professionals and technicians to more detailed inspections during construction, prior to assumption and periodic intervals to verify that the BMPs are being maintained and performing adequately.

6.0 INSPECTION AND TESTING FRAMEWORK

6.1 Types of Inspections

The recommended framework for LID stormwater infrastructure inspection and testing programs is organized according to the two main phases in the life cycle of a BMP, construction and routine operation, and involve five types of inspections:

1. Construction inspections
2. Assumption inspections
3. Routine Operation inspections
4. Verification inspections
5. Forensic Inspection and Testing (FIT)

Figure 6.1 describes the inspection framework in terms of BMP life cycle phase, sequence and responsible parties and Table 6.1 summarizes details regarding objectives, timing/frequency and inspector qualifications. Figure 6.2 illustrates a typical inspection timeline for an LID BMP over a 50 year life cycle.

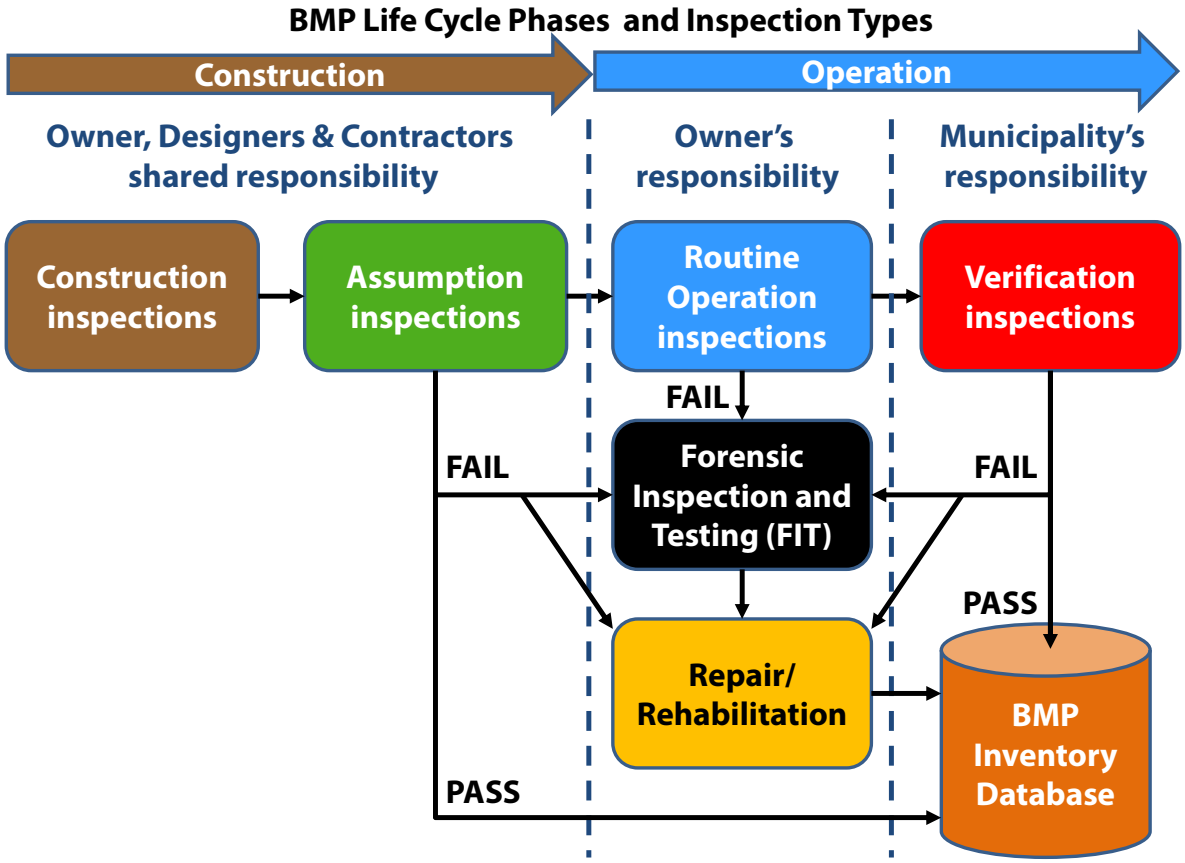

Figure 6.1: *Stormwater BMP life cycle phases, inspection types and responsibilities.*

Table 6.1: *Summary of stormwater BMP inspection types.*

Inspection Type	Objectives	Parties Involved	Timing or Frequency	Inspector Qualifications
Construction inspections	Ensure adequate ESCs are in place and BMP is installed at an appropriate time, as designed with specified materials	Construction contractors, design consultants & project manager	Several points in the construction sequence specific to BMP type; weekly and after any large storm event (e.g., 15 mm rainfall depth)	Certified design professionals (engineers and landscape architects) or technologists (engineering or environmental technologists)
Assumption inspections	Confirm BMP was installed as designed with specified materials, is functioning properly, and determine if BMP is ready to be assumed	Construction contractors, design consultants & project manager	After construction is completed, prior to termination of contracts and warranty or establishment periods	Certified design professionals (engineers and landscape architects) or technologists (engineering or environmental technologists)
Routine Operation inspections	Identify/address minor maintenance needs and determine when structural repair or further investigation into BMP function is needed	Property owner and their contractors	Annually, in the spring at a minimum. Bi-annually (twice per year) in spring and fall for vegetated BMPs	Operations or maintenance crew leaders trained and experienced in road, drainage and landscaping inspections, maintenance and record keeping
Verification inspections	Ensure compliance with inspection and maintenance plan conditions and determine if BMP functional performance remains acceptable	Municipality (property owner and their consultants may also be involved)	Maintenance Verification inspections every 5 yrs.; Performance Verification inspections every 15 yrs.	Certified design professionals (engineers and landscape architects) or technologists (engineering or environmental technologists)
Forensic Inspection and Testing (FIT)	Investigate/diagnose suspected problems with BMP function and determine corrective actions	Property owner and their consultants (municipalities may also be involved)	As needed, triggered by results from other types of inspections	Certified design professionals (engineers and landscape architects) or technologists (engineering or environmental technologists)

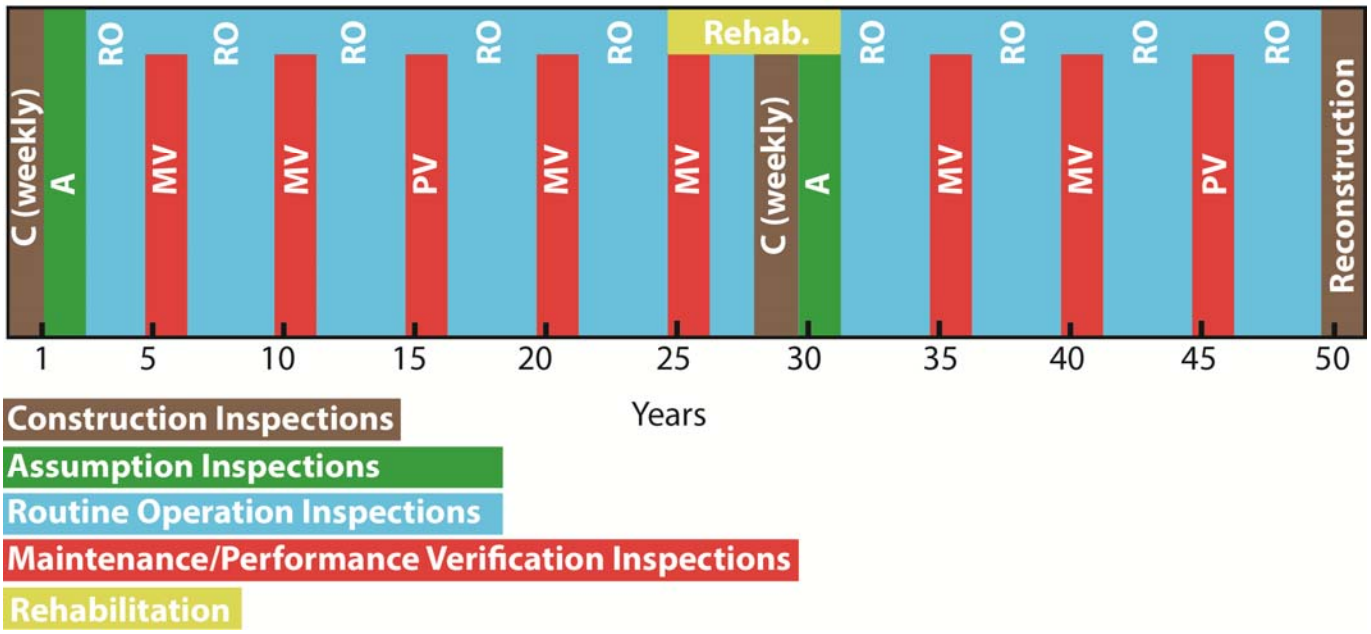

Figure 6.2: *Typical inspection timeline for LID BMPs over a 50 year life cycle.*

The objectives of inspection and testing work and the indicators and tests performed differ for each type of inspection. The following sections describe in greater detail the objectives of each type of inspection, the recommended timing or frequency of inspection and testing work, and the training or specific skills required for staff involved in performing the work.

6.1.1 Construction Inspections

Inspections during construction are done to ensure the following:

1. BMP layout (i.e., location and footprint dimensions) is acceptable;
2. Construction materials meet design specifications;
3. CDA (CDA) is stabilized or erosion and sediment controls (ESCs) or flow diversion devices are in place and adequately maintained;
4. Fencing to restrict heavy vehicle traffic from sensitive areas (e.g., natural heritage features, locations of infiltration BMPs) is in place and adequately maintained;
5. BMPs are installed as designed (i.e., within acceptable tolerances), at an appropriate time in the overall site construction sequence and with suitable equipment and procedures; and
6. Pretreatment and flow diversion devices are functioning and adequately maintained.

Construction inspections take place during several points in the construction sequence, specific to the type of LID BMP (see Section 7.0 for detailed guidance for each BMP type), 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 certify 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 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.

Construction inspections should be performed by trained professionals that are experienced with interpreting construction drawings and the use of surveying equipment (e.g., professional engineer, landscape architect or certified engineering/environmental technologist) and are accredited inspectors of ESCs. Individuals involved in performing or reviewing inspection work during construction should include design professionals and construction contractors at a minimum, and may also include representatives of the property owner (e.g., municipality or project manager) at critical milestones.

Figure 6.3 illustrates a recommended process for conducting Construction inspections. Table 6.2 provides guidance on each step of the process.

Further guidance on conducting inspections of LID BMPs during construction, and tips regarding common pitfalls and ways of avoiding them are provided in Credit Valley Conservation's Low Impact Development Construction Guide (CVC, 2012).

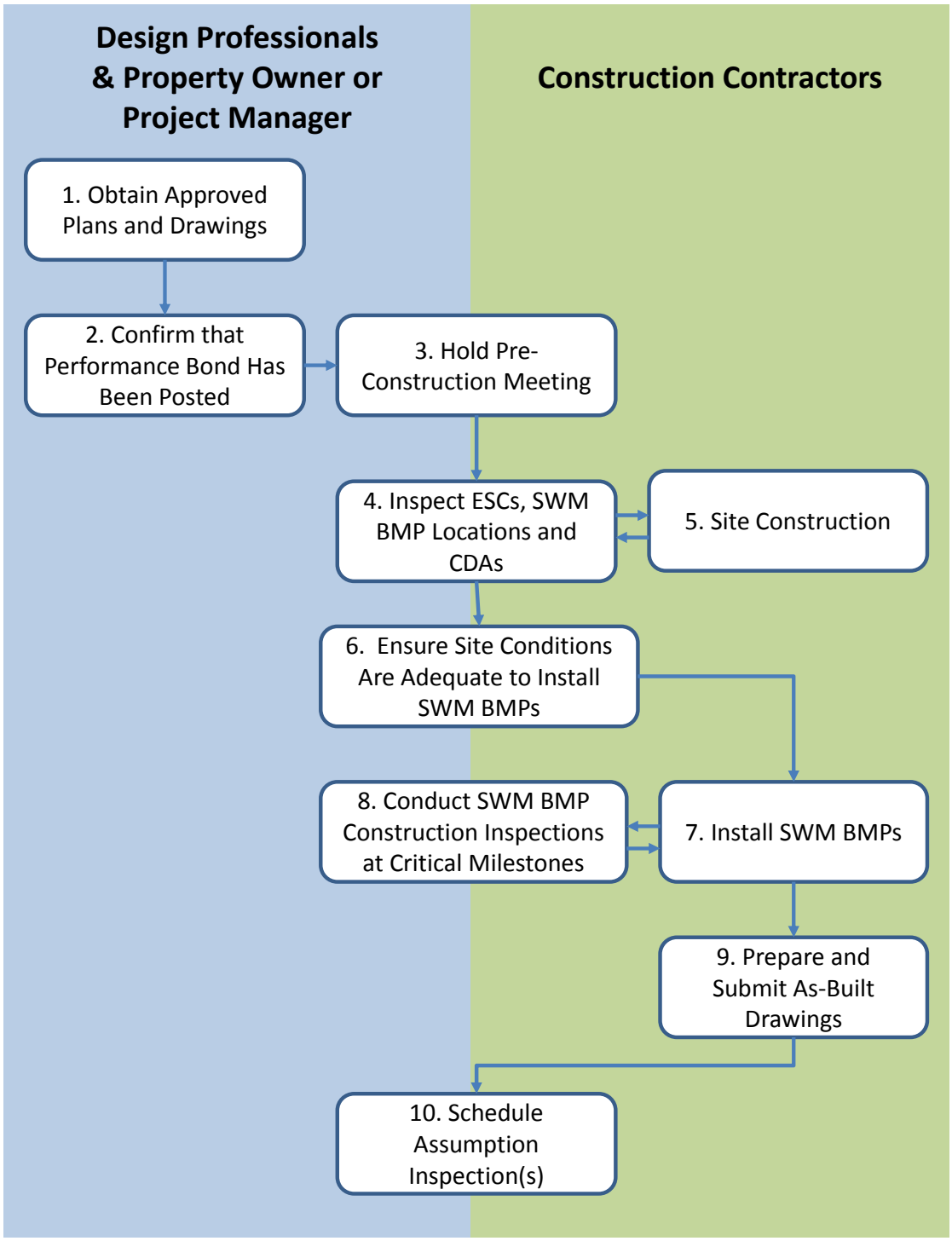

Figure 6.3: *Recommended process for conducting inspections during construction (Adapted from CWP, 2008).*

Table 6.2: *Description of tasks involved in the inspection process during construction. (Adapted from CWP, 2008).*

Process Step	Description
1. Obtain approved plans and drawings	Copies of approved plans, final construction and landscaping plan drawings and contracts are needed. Other information needed by inspectors includes the following: ◖ Summary of how the SWM system meets regulatory requirements; ◖ List of all SWM BMPs to be used at the site; ◖ Set of drawings and details illustrating the types, locations and specifications of SWM BMPs to be used at the site; ◖ Permits; ◖ Contact information for designers and construction contractors; ◖ Construction schedule.
2. Confirm performance bond has been posted (where applicable)	The contractors should post adequate performance bonds or other sureties to ensure costs incurred to address any deficiencies revealed through inspections can be covered. Inspectors should ensure that the bond has been posted before any construction activities begin.
3. Hold pre-construction meeting	A pre-construction meeting should be held prior to any construction activity. The meeting should review the stormwater BMPs to be installed, installation procedures and construction sequence. Critical milestones in the construction sequence, when inspections are needed before proceeding further, should be established. It is recommended that the following parties attend the meeting: ◖ Design professionals (e.g., engineer & landscape architect); ◖ Construction site foreman; ◖ Representatives of relevant construction contractors (e.g., servicing, paving, landscaping); ◖ (Optional) Property owner or their representatives (e.g., project manager or municipal inspector).
4. Inspect ESCs, SWM BMP locations and CDAs	Project site visits and inspections should be conducted according to an established schedule. These inspections can be conducted on a regular basis (e.g., weekly) or at critical milestones in the construction sequence. Such inspection work should focus on the following; ◖ Ensure ESCs remain in place and continue to function; ◖ Fencing around protected natural heritage features and stormwater infiltration BMP locations (where possible), remains in place throughout the construction process; ◖ Track construction sequence and progress towards critical milestones; ◖ Ensure permanent LID BMPs are not placed on-line prematurely during grading or before the CDA has been stabilized and conveyances have been cleaned out.
5. Site construction	Contractors should be made aware of locations of sensitive natural heritage features that should not be disturbed, locations of infiltration BMPs that should not be subject to heavy vehicle traffic or material storage to avoid excessive soil compaction, and critical milestones in the construction sequence when inspections are needed.

6. Ensure site conditions are adequate to install SWM BMPs	Construction of some types of BMPs should not be completed until the CDA is stabilized to help avoid contamination or clogging of inlets, pretreatment devices, and filter beds. Inspectors should ensure that the procedures and sequence of activities detailed on construction drawings and in contracts or tender documents is followed and that the condition of ESCs and the CDA, including conveyances are adequate to complete installation of permanent BMPs. This might take place at several points in the construction sequence as different phases of the project are stabilized.
7. Install SWM BMPs	Installation of permanent BMPs should commence only once verbal or written notice from the inspector has been received indicating that site conditions are adequate to do so.
8. Conduct SWM BMP construction inspections at critical milestones	Although inspectors cannot be on-site during the entire construction sequence, it is critical that inspections take place at critical milestones such as: ◖ 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; ◖ Prior to hand-off points in the construction sequence when the contractor responsible for the work changes (i.e., hand-offs between the grading, servicing, paving, building and landscaping contractors); ◖ At completion of rough grading and excavation of permanent BMPs, prior to installation of pipes/sewers and backfilling to ensure elevations, depths and grades are acceptable; ◖ Inspection of test results/quality assurance documents for construction materials prior to delivery; ◖ After placement of sub-drain system pipes and downstream conveyances (e.g., catchbasins, manholes), prior to backfilling to ensure elevations, depths and grades are acceptable; ◖ After final grading but prior to planting to ensure elevations, depths and grades are acceptable; ◖ After planting to ensure the right type of plants have been installed in appropriate locations and acceptable quantities.
9. Prepare and submit as-built drawings	Once installation is complete, the designers and construction contractors must prepare as-built drawings for each permanent SWM BMP that describe all approved change orders and any other deviations from the final design drawings that occurred during construction. Design consultants should certify that the BMP has been constructed in accordance with the as-built drawings. Information on as-built drawings should include: ◖ Routes for inspection and maintenance access; ◖ Dimensions (horizontal and vertical) and orientation; ◖ Invert elevations and grades of inlets, outlets, risers, embankments; ◖ Plant material installed (common name, species name & quantity).
10. Schedule Assumption inspection(s)	Upon completion of as-built drawings, the inspector schedules the Assumption inspections. Assumption inspections completed to the satisfaction of the property owner or their design consultants must be done prior to the termination of construction contracts and release of the performance bond.

6.1.2 Assumption Inspections

Assumption inspections are done as a condition of assumption of ownership and maintenance responsibilities for a BMP by the property owner, prior to the termination of construction contracts and warranty or establishment periods for plantings. Other terms for such inspections include deficiency, project acceptance or certification inspections. This type of inspection represents the last opportunity that the property owner has to confirm that the BMP was installed as designed, with the specified materials and is functioning properly. Therefore, Assumption inspections must be both timely and thorough and involve the most comprehensive set of indicators and test procedures. For stormwater infiltration BMPs (i.e., bioretention, permeable pavement, underground infiltration systems), testing may include continuous monitoring of drainage and treatment performance during natural or simulated storm events (Section 8.6). Completion of Assumption inspections to the satisfaction of the property owner or their design consultants prior to the termination of construction contracts and release of the contractor's performance bond should be a required condition included in all contracts involving construction of stormwater BMPs.

Assumption inspection and testing work is done to ensure the following:

- BMPs are installed in accordance with as-built construction and landscaping drawings with materials that meet design specifications;
- Any sediment, trash or debris accumulated on the CDA, in conveyances to the BMP and in pretreatment devices during construction has been removed;
- BMPs are functioning properly;
- Plantings match specifications on the as-built landscaping plan drawing, have been adequately maintained during their warranty period and have become established (i.e., indicators for vegetation cover, composition and condition are within acceptable ranges);
- The BMP is ready for inspection and maintenance responsibilities to be assumed by the property owner.

At a minimum, Assumption inspections should be performed:

- Immediately after site construction (including landscaping) ends (i.e., the deficiency inspection) prior to substantial completion of construction, release of performance bonds (if applicable) and beginning of the warranty or establishment period, and;
- Prior to termination of the warranty or establishment period (e.g., 2 years after substantial completion of construction), release of any maintenance holdbacks (if applicable) and assumption by the property owner.

Prior to conducting Assumption inspections, the property owner or their project manager must receive as-built drawings signed by the design professionals that describe all approved change orders and any other deviations from the final design drawings/plans that occurred during construction. The results of Assumption inspection and testing work should be compared to as-built drawings and

planting plans to determine if the BMP was constructed properly and is ready to be assumed. Municipalities will have their own standards for as-built drawings but they can be as simple as electronic copies of the final design drawings legibly marked up with all change orders, deviations or substitutions that were necessary during construction.

Ideally, Assumption inspections should be performed by individuals involved in the design and construction of the BMP being inspected and may also involve the property owner or their representative (e.g., project manager, municipal inspector). At a minimum they should be performed by trained professionals that are experienced with interpreting construction drawings and the use of surveying, soil sampling and testing and environmental monitoring equipment (e.g., professional engineer or certified engineering or environmental technologist). To confirm that plantings match those specified in planting plans, inspectors should include individuals experienced in plant identification that are able to distinguish plantings from weeds (e.g., landscape architect, landscaping technician). It is a good idea to also include individuals that will be responsible for performing Routine Operation inspections as well, to provide an opportunity to familiarize them with the BMP features and their condition at assumption. Further guidance regarding contractual and administrative approaches to ensuring thorough and satisfactory Assumption inspections of stormwater BMPs are completed prior to assumption by the property owner are provided in Section 3.4.2.

Documentation of the results of Assumption inspections should include photographs for each visual indicator relevant to the BMP, which can be used to train individuals responsible for Routine Operation inspections on what features to inspect and maintain.

Upon completion of Assumption inspections to the satisfaction of the property owner or their consultants that confirm the BMP is properly installed and in good working order, the performance bond can be released and construction contracts can be terminated. Upon release of the bond, it is a good idea for the design consultants to issue a certificate of completion, which provides good documentation for the property owner that is assuming the BMP, and the construction contractors regarding this transfer of responsibilities.

6.1.3 Routine Operation Inspections

As part of regularly scheduled visits to the BMP for routine maintenance (e.g., trimming vegetation, weeding, trash and sediment removal, clearing of inlets and outlets) over the operating phase of the BMP life cycle, inspections involving a sub-set of visual indicators and simple sediment accumulation tests should be performed. Routine Operation inspections are done to ensure the following:

- Any routine maintenance needs are identified and immediately addressed before they affect BMP function/performance or require more costly structural repair work;
- Determine if the preset schedule of routine maintenance tasks specified in the inspection and maintenance plan is adequate or needs adjustment;

- Identify when structural repairs are needed or investigations into suspected problems with BMP function are warranted.

At a minimum, Routine Operation inspections should be performed annually in the spring or early summer, prior to the on-set of summer thunder storms. For vegetated BMPs, inspections should be performed every time maintenance crews visit the site to maintain vegetation, which is typically a minimum of twice annually in the spring and fall seasons. 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. The minimum frequency of Routine Operation inspections, the indicators and test to be used, and record keeping/reporting requirements must be specified in the BMP specific inspection and maintenance plan.

Records describing the routine maintenance tasks performed and/or the results of Routine Operation inspections must be documented and tracked over the operating life cycle of the BMP by the property owner so that they can be reviewed as part of Maintenance Verification inspections to confirm compliance with ECA or maintenance agreement conditions and inspection and maintenance plans.

Routine Operation inspections should be performed by individuals trained in road, drainage and landscaping inspection, maintenance and associated record keeping (e.g., operations or maintenance crew leaders). Further suggestions regarding options for delegating responsibilities for Routine Operation inspections are provided in Section 3.4.3. The first Routine Operation inspection a BMP receives should involve all parties that will be responsible for routine inspection and maintenance tasks at the same time to serve as a training exercise. Documentation from Assumption inspections (e.g., completed field data forms and photographs for each visual inspection indicator) should be referred to during the first Routine Operation inspection to help train individuals on what BMP features to inspect and maintain.

The following documents should be provided to property owners taking on responsibility for routine inspection and maintenance of LID BMP, following the satisfactory completion of Assumption inspections:

- As-built drawings signed by the design professionals;
- ECA or maintenance agreement and BMP specific inspection and maintenance plan(s);
- Records from Assumption inspections, including any Forensic Inspection and Testing work completed and photographs of components to be routinely inspected and maintained; and
- Records describing maintenance tasks performed by contractors over the warranty or establishment period.

6.1.4 Verification Inspections

For a permanent BMP designed and installed to meet regulatory or municipal program requirements, periodic inspection and testing over the operating phase of its life cycle is needed to verify property owner compliance with ECA or maintenance agreement conditions and inspection and maintenance plans, and to determine if functional performance remains acceptable. Feedback from Verification inspections should be used to initiate compliance enforcement actions if warranted and schedule structural repairs or further investigations into observed problems with BMP function.

Verification inspections should be the responsibility of the municipality or be a shared responsibility between the property owner (e.g., hires consultant to perform and document the inspections) and municipality (e.g., approves and tracks documentation). These types of inspections can be further classified into Maintenance Verification inspections and Performance Verification inspections.

Maintenance Verification Inspections

Maintenance Verification inspections are performed to verify the following:

- The BMP continues to exist;
- The BMP has been maintained in accordance with the conditions of the ECA or maintenance agreement and inspection and maintenance plan;
- Identify when structural repairs are needed or investigation into suspected problems with BMP function are warranted.

Maintenance Verification inspections should be conducted on five (5) year intervals beginning after the date of assumption and involve review of documentation from Routine Operation inspections, selected visual inspection indicators and simple sediment accumulation tests. They should also be performed when property ownership changes to ensure the new owner is not assuming a BMP that has been neglected by the previous owner, and help educate the owner about their inspection and maintenance and record keeping responsibilities. The minimum frequency of Maintenance Verification inspections, the indicators and test to be used, and record keeping/reporting requirements must be specified in the BMP specific inspection and maintenance plan.

Inspections should be performed by individuals familiar with the contents and conditions of the ECA or maintenance agreements and associated inspection and maintenance plan. Inspectors should be experienced in the inspection of road and drainage infrastructure and landscaping. A Maintenance Verification inspection could replace the need for one Routine Operation inspection that the property owner is responsible for that year and may be conducted as co-inspections with the property owner or their contractor where feasible.

If the Maintenance Verification inspection reveals any failing conditions for visual indicators or if test results do not meet Acceptance Criteria or trigger the need for follow up tasks (e.g., routine maintenance; Forensic Inspection and Testing work; structural repairs; rehabilitation), the municipality

sends a letter to the property owner informing them that the BMP has been found to not be in compliance with the maintenance agreement and plan (and the reasons why) and gives them a timeframe for completing follow-up tasks. If the property owner fails to complete follow-up tasks within the timeframe specified by the municipality, enforcement actions are warranted. The nature and severity of enforcement actions will differ depending on the municipality but may include loss of stormwater utility fee credits, billing of the property owner for necessary maintenance or repair work performed by the municipality or third party, or fines.

Performance Verification Inspections

Performance Verification inspections are performed to verify the following;

- The BMP continues to exist;
- The BMP is being maintained in accordance with the conditions of the ECA or maintenance agreement and associated inspection and maintenance plan;
- Function performance remains acceptable or when further investigation into observed problems with BMP function is warranted;
- Identify when structural repair, rehabilitation or replacement is needed.

Performance Verification inspections should, at a minimum, be conducted on fifteen (15) year intervals beginning after the date of assumption and involve the use of the same visual and testing indicators used for Maintenance Verification inspections, plus functional performance testing indicators specific to the BMP type. For infiltration BMPs, continuous monitoring of drainage performance during natural or simulated storm events may also be undertaken. More frequent Performance Verification inspections and/or inclusion of continuous monitoring of water treatment performance during natural storm events may be warranted in the following scenarios:

- When the BMP is a new or hybrid technology for which limited treatment performance evaluation results are available;
- When the BMP is being applied in a certain context for the first time;
- Where the receiving water is highly sensitive; or
- Where the receiving water is habitat for a species at risk.

The minimum frequency of Performance Verification inspections, the indicators and test to be used, and record keeping/reporting requirements must be specified in the BMP specific inspection and maintenance plan.

Performance Verification inspections should be performed by individuals familiar with the contents and conditions of ECAs, maintenance agreements and BMP-specific inspection and maintenance plans and be trained in, and experienced with inspecting LID SWM BMPs. Individuals must also be trained in the use of soil sampling and testing and environmental monitoring equipment (e.g., engineer, engineering or environmental technologist). A Performance Verification inspection also serves as the Maintenance Verification inspection for that year.

The results of Performance Verification inspections should be provided to the property owner along with any recommendations for follow-up tasks or corrective actions that arise from them and timeframes for completing them. If the property owner fails to complete follow-up tasks within the timeframe specified by the municipality, enforcement actions are warranted. The nature and severity of enforcement actions will differ depending on the municipality but may include loss of stormwater utility fee credit, billing the property owner for necessary maintenance or repair work completed by the municipality or their contractors, or fines.

6.1.5 Forensic Inspection and Testing

When results from other types of inspections identify a potential problem with BMP function, Forensic Inspection and Testing (FIT) work is undertaken as a follow-up task to investigate the situation and come up with a plan to address any confirmed problems. FIT work involves the application of a similar set of inspection and testing indicators as those used in Performance Verification inspections, but focuses on diagnosing suspected problems with the following objectives in mind:

- Confirm whether or not problems with BMP function exist;
- Identify the causes of confirmed problems;
- Determine corrective actions needed.

Forensic Inspection and Testing is done on an as-needed basis, as follow-up from other types of inspections where potential problems with BMP function are suspected. Instances when FIT work is warranted include the following:

- Visual inspections reveal potential problems with standing water, vegetation cover/condition (i.e., widespread failure of plantings), control structure condition or cistern structural integrity (Section 8.1 and Appendix C);
- Soil characterization testing indicates soil texture, organic matter, cationic exchange capacity, phosphorus or soluble salts is not within Acceptance Criteria ranges (Section 8.2);
- Surface infiltration rate testing indicates surface drainage rate is less than trigger values for follow-up/corrective action (Section 8.4);
- Results from natural or simulated storm event testing indicate problems with site grading or drainage function of the BMP or conveyances to it (Section 8.5);
- Results from continuous monitoring indicate problems with BMP functional or water treatment performance (Section 8.6).

These specialized inspections must be a shared responsibility of the property owner (e.g., hires consultant to perform and document the inspections) and municipality (e.g., approves and tracks documentation), as they will determine what corrective actions are needed, which could involve structural repairs, rehabilitation or replacement of the BMP. Results of FIT work and any corrective actions that follow it should be recorded in BMP inventory and tracking databases maintained by the municipality. FIT work should be performed by individuals trained in, and experienced with

inspecting LID SWM BMPs, landscaping, and diagnosing the causes of observed problems with function. Individuals must also be trained in the use of soil sampling and testing and environmental monitoring equipment (e.g., engineer, engineering or environmental technologist). The results of FIT work should be provided to the property owner along with any recommendations for follow-up tasks that arise from them and timeframes for completing them. If the property owner fails to complete follow-up tasks within the timeframe specified by the municipality, enforcement actions are warranted. The nature and severity of enforcement actions will differ depending on the municipality but may include loss of stormwater utility fee credit, billing the property owner for necessary maintenance or repair work completed by the municipality or their contractors, or fines.

6.2 Inspection and Testing Indicators

The recommended framework for inspection of LID BMPs relies on a set of twenty-nine (29) visual indicators and eight (8) types of tests to rapidly determine if they are ready to be put into service, assumed by the property owner, to assess their maintenance condition, and to periodically evaluate their functional performance. To the greatest extent possible, quantitative triggers have been established for each indicator and test to determine when routine maintenance, structural repair or rehabilitation or other follow-up tasks (e.g., further investigation) are warranted. The set of visual and testing indicators to be used for a given LID BMP will vary depending on the type of inspection and BMP and must be described in the BMP specific inspection and maintenance plan. For Routine Operation inspections, which will be the most frequent type of inspection over the operating life cycle of the BMP (once or twice annually), the focus is on simple visual indicators that can be rapidly assessed by leaders or supervisors of field crews that perform routine maintenance work . This limits the need to involve highly trained design professionals and technicians to Construction, Assumption and Verification inspections and FIT work that require inspectors to be experienced with a variety of environmental sampling, testing and monitoring equipment and data analysis and interpretation.

Table 6.3 describes the recommended framework of inspection and testing indicators that should be used as part of each type of inspection. Table 6.4 describes the recommended inspection and testing framework according to LID BMP Type, showing what visual indicators and tests apply to each. Individual tables for each type of LID BMP are provided in Section 7.0, that describe the visual inspection and testing indicators that should be used during each type of inspection for that type of BMP.

Section 8 and Appendix C describe each type of indicator in detail and provides guidance on sampling protocols, test methods, acceptance criteria, triggers for follow up actions and suggestions for follow-up tasks specific to each indicator.

6.2.1 Visual Indicators

The visual indicators approach allows for a rapid assessment of an LID BMP within a few hours by visually examining the condition of key components in a logical sequence. The observed condition for each indicator is recorded on an inspection field data form, documented by photographs (ideally

georeferenced photos) and compared to quantitative or qualitative triggers to determine if follow-up tasks are warranted (e.g., routine maintenance, structural repair, further investigation).

Table 6.3: *Matrix of inspection and testing indicators by inspection type.*

INSPECTION AND TESTING FRAMEWORK		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
C.23	Pavement surface condition		x	x	
C.24	Pavement surface sediment accumulation	x	x	x	x
C.25	Control structure condition	x	x	x	x
C.26	Control structure sediment accumulation	x	x	x	x
C.27	Green roof structural integrity		x	x	x
C.28	Cistern structural integrity	x	x	x	x
C.29	Cistern sediment accumulation		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)
8.7	Green roof irrigation system testing	x	x	x	
8.8	Green roof leak detection testing	x	x		x
8.9	Cistern pump testing		x	x	(x)

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

Table 6.4: *Matrix of inspection and testing indicators by BMP type.*

INSPECTION AND TESTING FRAMEWORK		BMP TYPE						
Section	**Indicator**	**Bioretention & Dry Swales**	**Enhanced Swales**	**Vegetated Filter Strips & Soil Amendments**	**Permeable Pavements**	**Underground Infiltration Systems**	**Green Roofs**	**Rainwater Cisterns**
Visual indicators								
C.1	CDA condition	x	x	x	x	x		x
C.2	Inlet//Flow spreader structural integ.	x	x	x		x		x
C.3	Inlet/Flow spreader obstruction	x	x	x		x		x
C.4	Pretreatment sediment accumulation	x	x			x		x
C.5	Inlet erosion	x	x					
C.6	BMP dimensions	x	x	x	x	x	x	x
C.7	Side slope erosion	x	x					
C.8	Surface ponding area	x	x					
C.9	Standing water	x	x	x	x		x	
C.10	Trash	x	x	x	x		x	
C.11	Filter bed erosion	x	x	x			x	
C.12	Mulch depth	x						
C.13	Filter bed sediment accumulation	x	x			x		
C.14	Surface ponding depth	x	x					
C.15	Filter bed surface sinking	x	x	x				
C.16	Check dams	x	x					
C.17	Vegetation cover	x	x	x	x		x	
C.18	Vegetation condition	x	x	x	x		x	
C.19	Vegetation composition	x	x	x	x		x	
C.20	Monitoring well condition	x			x	x		
C.21	Sub-drain/Perforated pipe obstruction	x			x	x		
C.22	Overflow outlet obstruction	x	x		x	x	x	x
C.23	Pavement surface condition				x			
C.24	Pavement surface sediment accum.				x			
C.25	Control structure condition				x	x		x
C.26	Control structure sediment accum.				x	x		
C.27	Green roof structural integrity						x	
(continues on the following page)								

INSPECTION AND TESTING FRAMEWORK		BMP TYPE						
Section	**Indicator**	**Bioretention & Dry Swales**	**Enhanced Swales**	**Vegetated Filter Strips & Soil Amendments**	**Permeable Pavements**	**Underground Infiltration Systems**	**Green Roofs**	**Rainwater Cisterns**
C.28	Cistern structural integrity							x
C.29	Cistern sediment accumulation							x
Testing								
8.2	Soil characterization testing	x	x	x			x	
8.3	Sediment accumulation testing	x	x	x		x		x
8.4	Surface infiltration rate testing	x	x	x	x			
8.5	Natural or simulated storm event testing	x	x		x	x		
8.6	Continuous monitoring	x			x	x		
8.7	Green roof irrigation system test						x	
8.8	Green roof leak detection system test						x	
8.9	Cistern pump test							x

In Appendix C, visual indicators are organized by BMP component (e.g., CDA Condition; Inlet Obstruction; Inlet Erosion; etc.). It is recommended that the components relevant to the BMP under inspection be examined in the order they appear as they follow a logical progression that mirrors how water is delivered to and flows through the BMP. Following this sequence will reinforce the inspector's understanding of the function of the BMP while helping to hone in on the cause of any observed issues with its condition or function.

6.2.2 Testing Indicators

In addition to visual indicators, which are used during all types of inspections, a set of testing indicators are also recommended for use in the more rigorous inspection work involved in Construction, Assumption and Verification inspections. The tests can involve collection of both soil and water samples and may involve submitting samples to analytical laboratories for testing. They can also involve the use of specialized field instruments or devices to conduct in-situ field testing of soil characteristics, sediment depth, BMP water levels, and outflow rates and volumes. Notes and sketches describing the sampling approach (i.e., number of samples collected, locations and depths) along with test results should be recorded on inspection field data forms. Test results should be compared to quantitative acceptance criteria or trigger values for follow-up to determine if further testing/investigation, routine maintenance, or repair/rehabilitative tasks are warranted.

In Section 8.0, testing indicators are organized according to the following eight (8) types of tests:

1. Soil Characterization Testing;
2. Sediment Accumulation Testing;
3. Surface Infiltration Rate Testing;
4. Natural or Simulated Storm Event Testing;
5. Continuous Monitoring;
6. Green Roof Irrigation System Testing;
7. Green Roof Leak Detection Testing;
8. Cistern Pump Testing.