# Green Infrastructure Construction Guide for Capital Works

November 2025 (v1.0)

TORONTO

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# Definitions

**Asphalt Binder:** Means the asphalt cement that holds the aggregates together.

**Bioretention Growing medium:** A special mix composed of topsoil, sand, and organic soil components, designed to manage stormwater runoff, and support healthy vegetation in GI systems, Type 4 growing medium as per TS 5.10.

**Contributing drainage area:** The total land area that drains water into a specific point, in this case, the inlet of a GI system.

**Edge Restraint:** means a curb, edging, or other appurtenance that is intended to confine the bedding layer / choker course so that the permeable pavement is separated from other impervious streetscape features.

**Filter bed:** A layer in the GI system typically consisting of growing medium used to filter pollutants from stormwater runoff and to grow vegetation.

**Granular Base:** Means a layer of compacted aggregate that is placed above the granular subbase.

**Granular Subbase:** Means a layer of compacted aggregate that is placed above the subgrade.

**Gray Infrastructure:** Refers to traditional infrastructure systems such as pipes that convey water directly to waterways or ponds, often using hard materials.

**Green Infrastructure (GI):** In this guide, GI is an engineered system that mimics nature, designed to capture and filter stormwater close to where it falls, reducing the volume of stormwater that enters the City's sewer system and improving the quality of runoff before it makes its way into local waterways.

**Growing Medium:** the material in which plants grow, providing support for the roots and acting as a reservoir for water, nutrients, and oxygen.

**Hard Surface Green Infrastructure (or permeable pavement):** Hard surface GI or permeable pavement is an alternative to conventional pavements that allows rainwater to drain through the surface and into a stone reservoir, where it infiltrates into the underlying native soil or is temporarily detained and filtrated. In this guide hard surface GI refers to porous asphalt, pervious concrete and permeable pavers.

**Infiltration:** the process by which water enters the soil from the ground's surface

**Joint:** Means a vertical contact between the proposed permeable pavement and other pavement or rigid object that exists at the time the permeable pavement is laid.

**Native soil:** Native soil is soil that occurs naturally in a specific area. It's made up of clay, silt, and sand

**Pervious Concrete Pavement:** means a rigid pavement structure that allows water flow into and through the pavement structure.

**Porous Asphalt:** means the hot mix asphalt prepared to mix standards to allow for permeability and is placed on the bedding layer / choker course to create a traversable pavement surface.

**Rain gauge:** A device for collecting and measuring the amount of rain which falls.

**Runoff:** The portion of rain or snow that falls on land and flows across the surface as water, instead of soaking into the soil.

**Soil Fracture:** Breaking of soil via mechanical or erosive processes.

**Soil Ped**: soil aggregates built over time via natural processes – air, water, microorganisms – that give the soil its structure

**Surface Ravelling** means the loss of coarse aggregate from the surface of the pervious concrete pavement.

**Temporary sediment basins:** small ponds that are sometimes required during construction to capture and settle sediments, and prevent them from entering a near by waterway.

**Till:** The mechanical process by which soil is broken up. Various means can be used to till ranging from hand equipment such as a spade/rake to intensive mechanized equipment. The term is used here to refer to the process of loosening the surface of the native soil so that it mixes with the growing medium.

**Topsoil**: A nutrient-rich layer of soil that is naturally occurring and characterized by a high concentration of organic matter and microorganisms. Topsoil, sand and compost are the components of growing medium.

# Acknowledgements

A significant portion of this guide is based on information from the Sustainable Technologies Evaluation Program https://sustainabletechnologies.ca/ (STEP), applied to the City of Toronto's Right of Way context.

# Chapter 1: Use of this Guide

This guide has been developed to provide guidance for Contract Administrators and Inspectors during construction of GI features installed within the road right of way.

**Chapter 2** “Green Infrastructure and Green Streets” provides an overview of the main types of green infrastructure that can be implemented within the right-of-way.

**Chapter 3** “Key Factors to Consider During Construction” provides a summary of key factors that the inspector should consider during all phases of the construction to guarantee the proper installation of GI facilities.

**Chapter 4** “GI Construction Phases Inspection” provides inspection tasks for each GI construction phase, and the technical rationale behind those tasks. At the end of Chapter 4, practical resources, such as checklists and graphs are provided to facilitate the inspection process after the full guide has been studied.

**Appendix A** “Growing Medium Requirements: Testing, Handling and Installation” includes a summary of key requirements for verification of growing medium, including testing requirements and instructions, guidelines for handling and installation, and relevant specifications.

**Appendix B** “Drainage and Infiltration Testing Requirements” provides instructions for infiltration testing, and natural or simulated storm testing, required to verify that the system is absorbing water as intended, and that storm runoff from adjacent areas is flowing in the right direction, and is being captured by the GI system.

**Appendix C** “Examples of Failures” provides photographs of examples of failures.

**Appendix D** “Weed Identification Resources” provides resources to identify (invasive) weeds in vegetated GI systems.

# Chapter 2: Green Infrastructure and Green Streets

Green infrastructure (GI) is designed to capture and filter stormwater close to where it falls, reducing the volume of stormwater that enters the City's sewer system and improving the quality of runoff before it makes its way into local waterways.

Green Streets are road rights-of-way that incorporate green infrastructure to complement or replace grey infrastructure. Green Streets help to build a city that is resilient to climate change and contributes to an improved quality of life.

There are two (2) main GI categories implementable within the right-of-way (ROW):

1. The vegetated or soft surface GI, comprised of growing medium and granular storage layer, and
2. Permeable pavements or hard surface GI, which doesn't have growing medium or vegetation and instead has a porous hard surface allowing for rainwater to infiltrate into the ground.

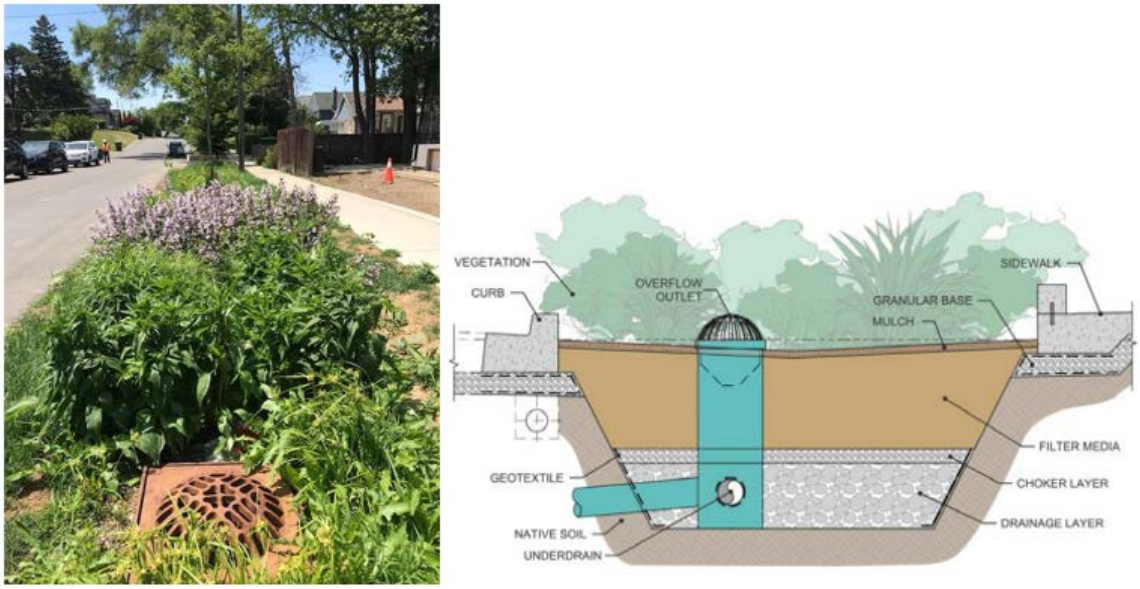



*Figure 1: Vegetated Green Infrastructure / Soft Surface GI*

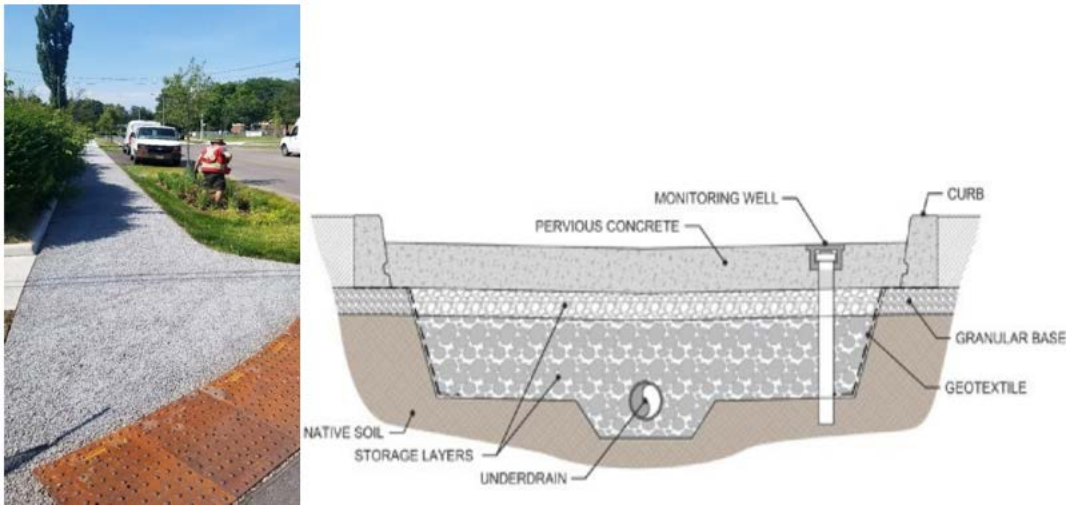



*Figure 2: Permeable Pavement / Hard Surface GI*

The City has developed GI standard drawings, construction specifications, design criteria and life-cycle activities guidelines.

The GI standard drawings are comprised of GI facilities implementable within the ROW, and includes plan view and cross section details of various GI types along with components such as inlets, monitoring wells, plantings, etc.

Construction specifications were developed for common GI components. TS 5.10 Construction Specification for Growing Medium and TS 5.30 Construction Specification for Planting were revised to incorporate GI growing medium and planting, respectively. TS 859, TS 860 and TS 861 are permeable pavement construction specifications suitable for installation within the ROW.

A series of special specifications are under development to supplement standard specifications and assist the CA and Inspectors for proper installation of GI within the ROW.

# Chapter 3: Key Factors to Consider During Construction

The installation of GI facilities is fairly simple but extremely sensitive to errors in construction. Attention to detail is fundamental. The key factors that should be considered throughout the construction, and require careful attention are described below.

The installation of GI facilities shall be according to the contract drawings and specifications that cover phasing plans and clear criteria to ensure proper implementation, functionality, and long-term success. Measures such as site assessment, soil testing, drainage patterns, erosion and sediment control plans, temporary measures to redirect runoff, installation of underdrains, etc. to be specified by the Contract Administrator during Pre-Construction Meeting. GI locations, dimensions and tie-ins to the existing drainage; cross-sections, inlets and outlet locations, catch basin and underdrain connections, erosion and sediment control measures and planting details shall be included in the drawings and installations shall be according to the drawing's details.

## 3.1. Communications

At the pre-construction meeting, ensure that the General Contractor understands the following communication guidelines to be followed during the entire construction process:

- GI installation phasing and sequencing specified on the drawings shall be followed during construction.
- Subcontractors working in all areas of the project, including adjacent construction, should be made aware of the significance, and intended functions of the GI facility.
- It is critical that key information about the GI construction approach and the sensitivity of the system be passed along between sub-contractors at hand-off points (where contractor responsibilities of work change such as between servicing, paving and landscaping) and as the construction process moves from phase to phase.
- Key communication between subcontractors should include all aspects listed herein.

Extra attention must be paid to the following elements which are critical to the success of the system:

## 3.2. Erosion and Sediment Control

Protecting the GI feature from sediment accumulation and compaction during construction is extremely important for the functionality of the constructed system.

Erosion and Sediment Control (ESC) measures are imperative to the functionality of the GI system, and its ability to manage stormwater. Compaction of native soil/ sub grade or growing media with heavy equipment can impede infiltration of water. Sediments or construction contaminants can impact adequate drainage of stormwater runoff as well as stormwater filtration (Source: Erosion and Sediment Control Guide for Urban Construction, Toronto and Region Conservation Authority, 2020.)

Repairs of GI systems are expensive and time consuming. During construction ESC measures shall be inspected to ensure that the GI is protected as per an approved ESC plan.

Best Practices for the Protection of GI Systems and Related Inspection Tasks:

- Marking the Area:  Verify that GI areas are properly identified and marked, ideally with signage.
- Perimeter Controls:  Verify that perimeter controls to protect the GI system are installed early and are in working order throughout construction. Even short-term failure of perimeter controls can result in significant sediment deposition and impacts to the GI system functionality. Examples of perimeter controls are filter socks, sand or pea gravel bags, natural fibre logs and wattles, and sediment fence.
- Temporary Runoff Diversion/ Inlet Protection: Verify that during construction water runoff is temporarily diverted away from the GI system with well-maintained impermeable physical barriers at the inlets such as sandbags or wood.
- If for some reason the design establishes that the system should receive runoff during construction, verify that permeable barriers, such as geotextiles are installed at the inlets, to protect the system from sediments.
- Construction vehicles should not be permitted on the permeable pavement and its drainage areas once the pavement has been installed for up to 7 days.
- Cleaning of Sediments: Verify that construction sediments accumulated in underdrains are cleaned before and after they are installed. Verify that sediments in inlets are cleaned on a regular basis, and especially before the temporary runoff diversion measures are removed.
- Frequency of Inspections: Carry out ESC site inspections weekly and before and after rain or snowmelt events to verify that ESC measures are in good

working order and functioning as intended. The post-construction efforts shall be coordinated with Transportation Services Operation and Maintenance.

- Stockpiles: Verify that stockpiles of construction materials are stored down stream of the GI system (≥ 30 m recommended).
  - Verify that the stockpiles do not exceed a height of 1.4m.
  - Verify that sediment controls (e.g. filter socks) are adequately installed around all stockpiles.
  - Ensure that sediment controls are applied to temporarily stored landscaping materials (including boulders, etc.), on finished surfaces, as (i.e. typically via tarps, etc.).
- ESC measures should be maintained from the start of construction until construction is complete, surrounding area is stabilized, and construction vehicle mud tracking has ceased.
  - Verify that concrete washout areas are located away from the GI system.
  - Verify that the GI system will not be used as a temporary sediment basin, unless specified in the tender package, with special directions.
  - Ensure that nearby drainage areas, and the GI footprint, do not contain trash, debris, and other pollutants

## 3.3. Construction Materials

- Supplied material samples to be taken for testing prior to delivery on site. It is the responsibility of the General Contractor to supply materials as per contract documents.
- Provide testing frequency/acceptable limits and sample collection/testing by the contracted testing company. Ensure testing of materials is included in the material testing contract
- At pre-construction meeting, remind the contractor that quality assurance material testing should be arranged for growing medium, crushed aggregate and washed stones. Delivery of materials and the use of the materials is the GC’s responsibility. Plant/supplier samples are to be taken prior to delivery for testing.
- Before the materials are delivered, verify that all submittals from the contractor, related to material testing, have been approved by the Contract Administrator. Submittals shall include product information, samples, test results, etc. Delivery of materials and the use of the materials is the GC’s responsibility.
- Ensure that materials do not arrive before the specified construction stage and that they are stored appropriately before they are installed to avoid contamination.

## 3.4. Water Runoff Flow

During construction, ensure that water runoff is temporarily diverted away from the GI system as per contract documents.

Following construction completion ensure that the adjacent areas are stabilized before allowing runoff into the system. Verify that site gradings allow stormwater runoff to flow into the system, and that there are no obstructions to enter the system through the inlets.

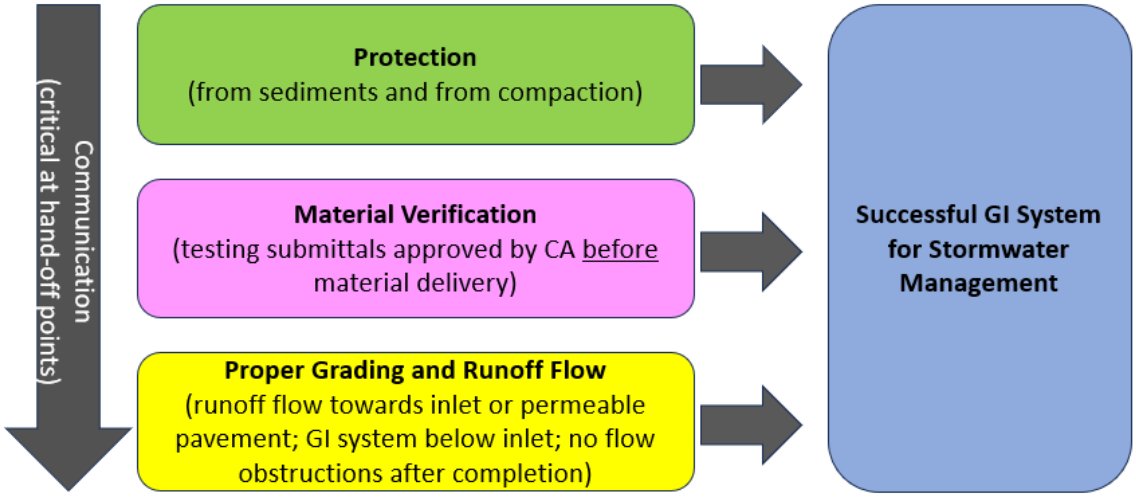



*Figure 3: Key Principles of Successful GI Construction*

# Chapter 4: GI Construction Phases Inspection

Special attention must be given at key construction stages and following rain events to ensure that the GI facility is being installed properly. This chapter provides inspection tasks for each GI construction phase, and the technical rationale behind those tasks. The various phases of GI installation phases are illustrated in Figure 4 below. A full-page version of this chart is available in Appendix E.

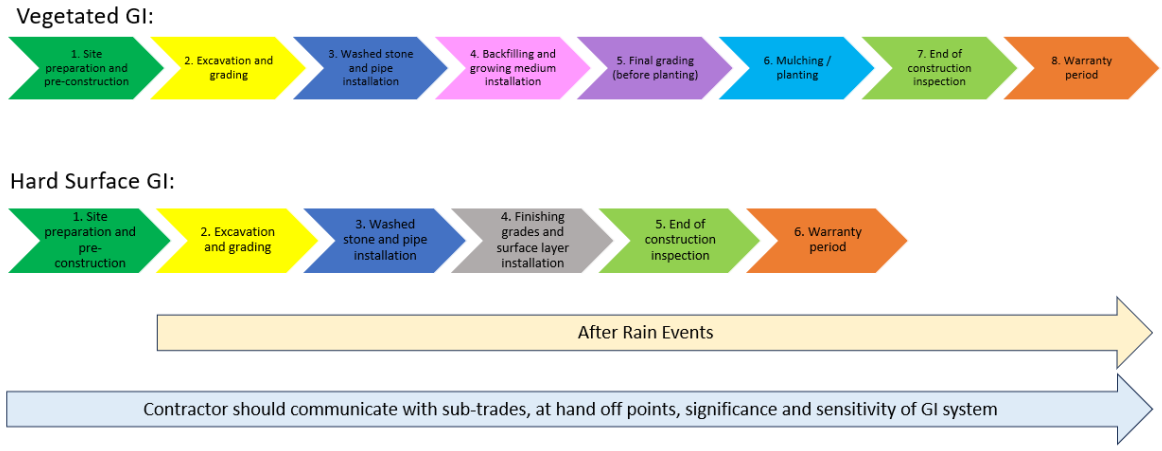



*Figure 4: GI Installation Phases*

## 4.1. Site Preparation and Pre-Construction

See Appendix F for checklists itemizing inspection tasks for this phase for both vegetated and hard surface GI.

- Assist the Contract Administrator (CA) to:
  a. Ensure the contractor has included a detailed schedule of the installation of GI amongst other construction scope components per contract requirement.
  b. Ensure that the contractor arranges for all material testing at project commencement. For quality control testing the CA and/or inspector to arrange for QA testing by the contracted testing company as per contractor's schedule.
  c. For vegetated systems, ensure that 45 days before installation of growing medium, the contractor submits all required submittals to the CA as per TS 5.10. Submittals include product information, samples and test results.

   d. For permeable pavement, verify that a detailed paving plan showing edge constraints, equipment and workforce has been submitted by the contractor.
   e. For porous asphalt, verify that the contractor has submitted a porous asphalt concrete mix design and trial mix test results to the Contract Administrator for review at least two weeks prior to commencing work.
   f. For porous concrete, ensure that the contractor has submitted all data on proposed concrete admixtures and proposed fibres to the CA for review.
- Confirm that installed Erosion and Sediment control measures are in place and functional as per the approved Erosion and Sediment control Plan, and that any sediments generated during construction are promptly removed from the GI construction area and elements such as pipes.
- If the proposed permeable pavement is adjacent to conventional pavement, ensure the impermeable pavement is installed to at least the base course prior to pervious pavement construction.
- Ensure the contractor has Emergency Erosion and Sediment Control measures in place, to protect the system during a major storm event as per the approved Erosion and Sediment Control plan.
- Ensure that runoff from adjacent areas has been temporarily diverted from the GI construction area until the construction is completed as per the approved Erosion and Sediment Control plan.
- Confirm that designated concrete washout areas are away from the GI feature
- Confirm that the contractor is not planning to use the GI feature as a sediment basin for adjacent construction, unless this has been specified in the tender package with directions for special controls.
- Verify that natural heritage features, including mature trees and sensitive areas, have been clearly marked for protection as per the contract documents and CA's direction.
- Ensure that only the (minimum) necessary area will be cleared from vegetation and that it's clearly marked.

## 4.2. Excavation and Grading

See Appendix F for checklists itemizing inspection tasks for this phase for both vegetated and hard surface GI.

- Verify the excavation limits of the feature are marked as per the drawings.
- Verify that all utilities are clearly marked.
- Verify that excavation is completed during dry conditions and that subgrade is free from standing water to avoid dewatering of the systems afterwards.

- Verify that excavation is done from the outside reaching in, when possible, using a backhoe or bucket with extension arm. A toothed bucket should be used so compaction caused by excavation can be broken up by scarifying the finished surface.
- If equipment is needed inside the facility, verify that low pressure-rated or marsh track equipment is used to minimize compaction.
- Verify that the CA has approved density results provided by the Contractor.
- If compaction is required in the tender package, make sure that it is as per specifications.
- Verify that the contractor has received written confirmation that the subgrade preparation is sufficient, prior to further installation. Excavation elevations should be within +/- 3cm.
- Confirm that excavated materials are controlled using temporary perimeter controls and stockpile management. Stockpiles must not be adjacent to excavation area.
- Confirm that unexpected contamination has not been uncovered during site excavation (if this is the case, the design may need to be modified).
- Confirm that the GI dimensions, and all depths, slopes and elevations are as per design specifications.
- Ensure that sufficient perimeter controls are in place to protect the GI feature.
- Areas of subgrade contaminated by the accumulation of silty material following rains or other debris or contamination shall be removed and disposed at the Contractor’s expense.
- Ensure the contractor has notified the CA a minimum of 24 hours prior to all base and sub-base work.
- If required by the specification, ensure that the contractor has written confirmation from the CA that the subgrade preparation is sufficient prior to further installation.
- Remind the contractor that materials brought in for next phase need to be approved by the CA before they are delivered (see Appendix A for details).
- Before backfilling, ensure that the subsoil of the subgrade is loosened or tilled to a depth of 50 to 75 mm with a backhoe or other suitable device.
- Ensure that the tilled area is protected. The tilled area should not become compacted or wet.
- Confirm that appropriate placing sequence for all materials is used during backfilling, and that the depths are as per the tender package. Typical sequencing is: 1. Gravel for drainage layer (at the bottom), 2. Stone for chocker layer; 3. Growing Medium; 4. Mulch and Vegetation (see typical cross section in Figure 5).
- Verify that the geotextile, if required, is installed as per the tender documents.

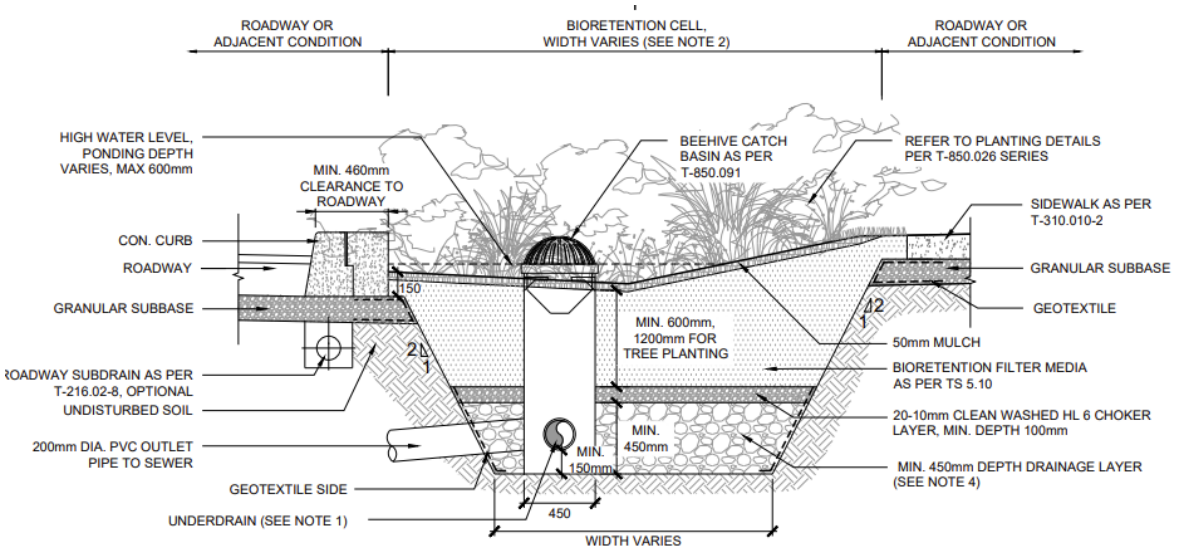



*Figure 5: Material Sequencing in Typical Cross Section of a Bioretention*

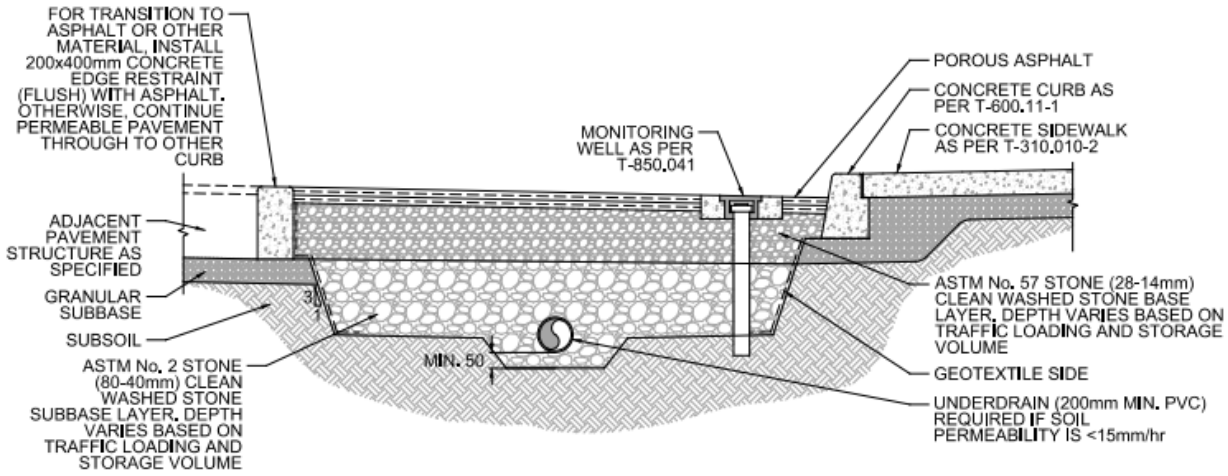



*Figure 6: Material Sequencing in Typical Cross Section of Porous Asphalt Pavement*

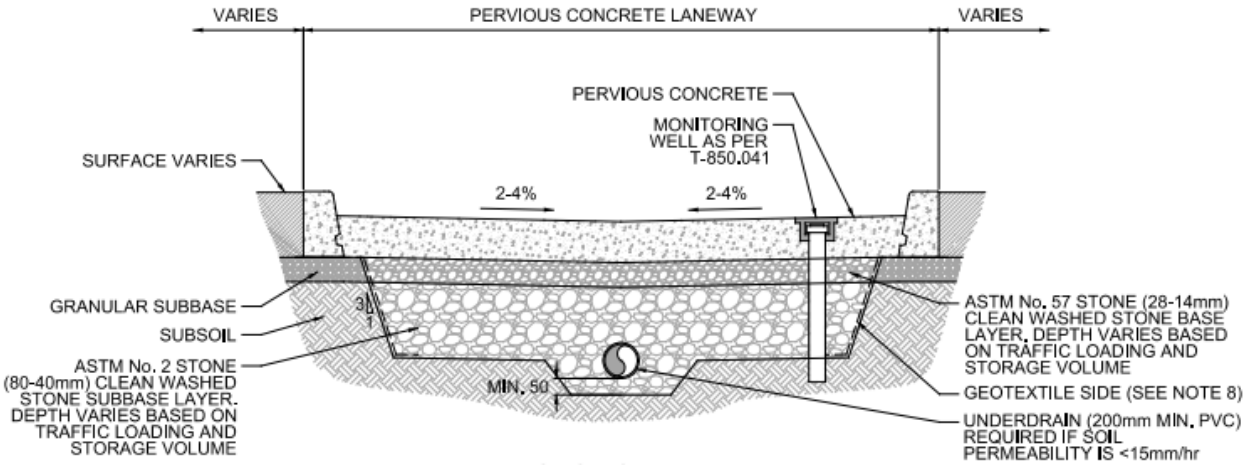



*Figure 7: Material Sequencing in Typical Cross Section of Pervious Concrete Pavement*

## 4.3. Washed Stone and Underdrain Pipe Installation

See Appendix F for checklists itemizing inspection tasks for this phase for both vegetated and hard surface GI.

- Verify that pipes are cleaned from sediments before installation.
- Ensure that the bioretention growing medium is delivered after underdrain systems are in place (See Appendix A).
- Ensure that perforated pipe is as per specifications included in the contract documents, and that proper procedures are followed for installation. The pipe gradient shall be as per the drawings and verified.
- Ensure that the CA approved aggregates and stones, and associated growing medium lab tests before the delivery.
- Ensure that installation does not take place in heavy rain, on frozen aggregate or on frozen soil subgrade.
- If work is taking place during cold weather, make sure that the contractor protects sub grades from freezing using covers or heated tenting as needed.
- Ensure that monitoring wells are installed as per the contract documents and City of Toronto construction specification TS 858 and that they have a cap. Monitoring wells serve as a place where monitoring equipment can be installed. They can also be an access point for maintenance.
- Verify that Granular subbase and granular base material are as per construction specifications and that test results have been approved by the CA.

- Verify leveling of the subbase and base by testing with a 3m long straightedge, placed in any direction on the surface:
    - Subbase: the gap between the straightedge and the (compacted) surface shall not be greater than 25 mm, at any point.
    - Base: the gap between the straightedge and the (compacted) surface shall not be greater than 65 mm, at any point.
- Verify that washed stone for the sub-base and base layers, is installed compacting in lifts per specifications and creating a smooth surface. Use only specified equipment.
- Ensure that aggregate is not crushed with the vibratory roller or other equipment during compaction.
- Verify that the subbase and the base are compacted to the level specified in the tender package.
- Verify that the base and the subbase courses have the density specified in the tender package.
- A light weight deflectometer may be used to test compaction level of open graded stone, to compare with specifications.
- Ensure the contractor folds the extra geotextile fabric over the top of the last aggregate layer, to serve as a backup sediment protection until permeable pavement is placed.

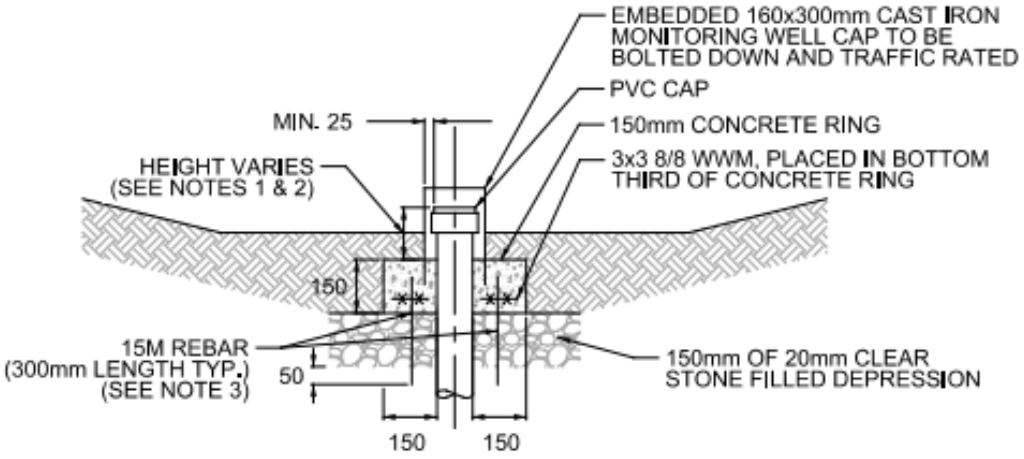



*Figure 8: Cross section of Monitoring Well (City of Toronto Specification)*

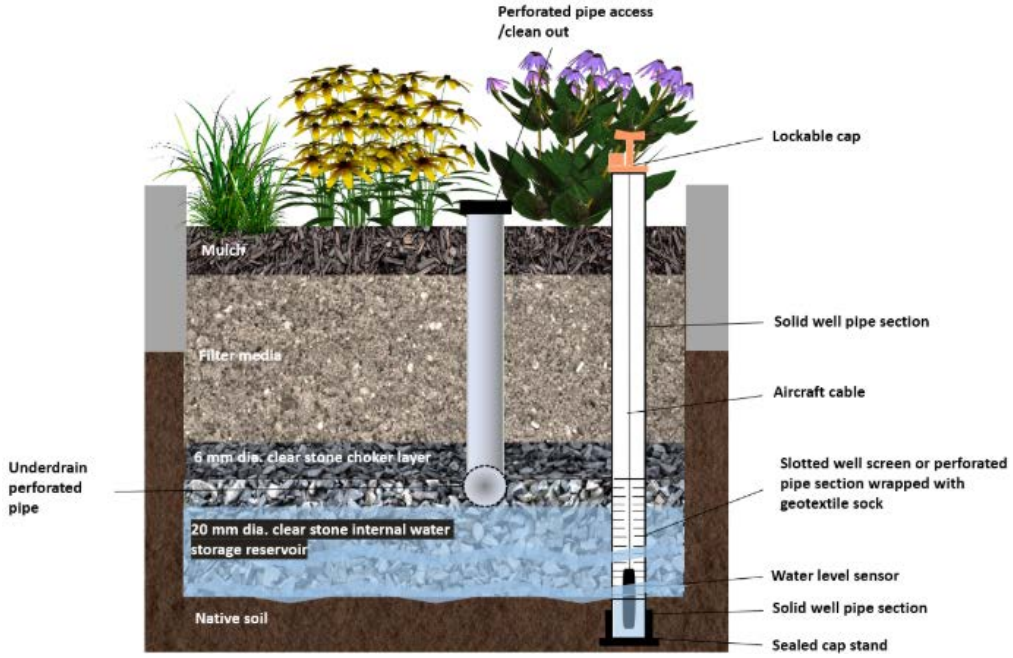



*Figure 9: Typical cross section of bioretention cell with monitoring well. Source: https://wiki.sustainabletechnologies.ca/wiki/Wells*

## 4.4. Backfilling and Growing Medium Installation (for Vegetated GI)

See Appendix F for checklists itemizing inspection tasks for this phase for both vegetated and hard surface GI.

- Ensure the updated TS 5.10 Growing Medium is being referenced and the growing medium meets the construction specification of the growing medium type.
- Before growing medium is offloaded from the trucks, collect tickets and verify that they have been approved by the Contract Administrator
- See testing requirements in Appendix A.
- Verify that the contractor does not mix, deliver, or place growing medium in frozen, wet, or muddy weather conditions.
- Verify that stockpiles of topsoil and growing medium are protected from freezing and saturation.
- If working in cold weather, verify that growing medium is removed from within the interior of the stockpile where it is not frozen. At the end of each day, the exposed working face of the stockpile should be covered to keep from freezing.

- Confirm that stockpiles have been protected from rain and washing that can separate fines and coarse material, and from wind erosion.
- Verify that stockpiles have been covered with plastic sheeting at the end of each workday and ensure covering is secured in case of windy conditions.
- Verify that, whenever possible, stockpiles are uncovered daily during warm dry conditions, to ensure breathability.
- Sub grades that are sufficiently well drained to preclude the buildup of ice may be installed and built upon during freezing weather provided the surface is cleared of snow and any ice bound material.
- Before aggregates are offloaded from the truck, verify that all tickets show that the product meets specifications.
- Observe the offloading of aggregates and sands to watch for dust clouds. Aggregates or sand for GI construction should not give rise to clouds of dust when dumped.
- Before the growing medium is offloaded from the truck, collect tickets, and verify that all testing submittals have been approved by the Contract Administrator.
- Before the growing medium is installed verify that the choker layer is clean, free of debris, concrete/ cement residues, or any sediments. This will not only impair the stormwater functionality of the system but will also contaminate the growing medium impacting the health of the future plants.
- Verify that the contractor doesn't use delivery or installation methods that overly mix the growing medium. Soil blowing shall not be permitted.
- Verify that the growing medium is installed in a manner that avoids compaction:
    - If soil slingers are used for delivery/installation; ensure that it is used as specified in Appendix A.
    - Ensure that the growing medium is installed in thin layers. First layer should be 50-75mm deep. The remaining growing medium should be installed in 300-400mm lifts to the required depth.
- Ensure that the work is performed outward so that the equipment does not have to pass over the installed growing medium.
- Ensure that the growing medium is installed above the finished grades, as specified in the contract drawings to anticipate for settling (typically, it should be installed at a level of 50mm above finished grade, assuming a 10-15% settlement of the installed depth during the first 12 months).
- Ensure that all finish grading activities in the GI are performed during dry conditions to prevent soil smearing and compaction.
- Ensure that all dips in the growing medium have been filled and that any bumps have been removed.
- Ensure there's no structural damage to monitoring well, perforated pipes and trench drain.

## 4.5. Finishing Grades and Surface Layer Installation (Permeable Hard Surfaces)

See Appendix F for a checklist itemizing inspection tasks for this phase.

While the initial phases of construction are similar for the different types of hard surface GI/ permeable pavements, different inspection tasks are required for each type, when implementing finishing grades and installing the surface layer. The following section describes inspection tasks in this construction phase, for the installation of different types of hard surface GI/ permeable pavement.

Weather: Note that porous asphalt and concrete have tighter climate considerations for installation than typical pavement.

Ensure that porous asphalt and pervious concrete are installed under the right weather conditions, as per the specifications (including air temperature, rain restrictions, forecast considerations, etc.)

### 4.5.1. Pervious Concrete

Before installations the CA must:

- sign off on concrete producer certification.
- approve data on proposed concrete admixtures and proposed fibres.
- sign off on all results of trial section tests.
- verify that washout areas are provided for concrete trucks and other equipment, and that they are located away, downstream, from the GI.
- verify that a Pervious Concrete Certified Person is responsible for the supervision of the concrete placement.
- verify that all equipment used for the concrete installation is as per the specifications.
- verify that the contractor has cleaned all surfaces of loose and foreign material.
- verify that edge restraints are as per the tender package.
- verify that the moisture of the ready mix is certified on site by a product expert prior to placement. Note that the placement process must often be stopped so the moisture content of the ready mix can be brought back up to specification before proceeding.

During installation the inspector must:

- ensure that granular base material is not disturbed or displaced during the concrete placing operations.

- ensure that the upper layer of the washed stone is wetted prior to placement of the pervious concrete
- verify that during placement pervious concrete is uniform in consistency and that placement is continuous.
- verify that the ready mix is pre-leveled with rakes.
- verify that individual loads of concrete are completed within 90 minutes of the introduction of mix water to the cement. If there is an interruption, pervious concrete shall be covered with a moisture vapour barrier. If the interruption is longer than 20 minutes, verify that a construction joint is made.
- ensure that the contractor uses a pressure mister to put a fog of moisture over the surface of the concrete while awaiting the plastic cover.
- ensure that the hose of the ready-mix truck is **not** used to spray the surface.
- verify that compaction is done as per the specification.
- ensure that moisture vapour barrier is placed on the surface of the pervious concrete immediately after compacting the pervious concrete surface as per specifications.
- Note that concrete should be wetted to avoid sticking of the plastic. Note that the plastic should be white to reduce solar load on the pavement.
- ensure that the cover plastic is not weighted down with dirt or other material which can fill the voids of the concrete. Instead, the plastic can be nailed down.
- verify that the curing continues for a minimum period of 7 Days in which concrete is kept covered.
- ensure that joints are implemented as per the specifications and have the right width and depth.
- verify that the pavement surface is mechanically swept, prior to testing for compliance to tolerances.

The CA must:

- sign off on all aspects of sampling and testing of pervious concrete, including management and testing of cores.
- verify that the overall concrete placement is certified by a product representative.

### 4.5.2. Permeable Pavers (Interlock)

- Permeable pavers require a bedding layer which consists of a crushed aggregate and provides a level medium onto which paved surfaces are installed. The following should be inspected for the bedding layer:
  - Before the bedding aggregate is downloaded from the truck, verify that the ticket confirms that the material meets the approved specifications.

  - Verify that the aggregate does not have fines. There should be no dust clouds when downloaded from the truck.
  - Verify that the bedding depth conforms to design, and it is uniform across the GI feature. A vibratory screed is recommended to level the material.
  - To verify leveling: When a 3-metre straightedge is placed on the surface of the bedding material, gaps between the straightedge and bedding surface should not be greater than 10 mm at any point.
  - Ensure that plate vibrators are **not** used for levelling as they can crush the bedding material.
  - Ensure that that the bedding layer is **not** compacted.
- Verify that sizes/ type of pavers and joints width conform to the tender documents
- Verify that cracked/ broken pavers are discarded and replaced prior to filling void spaces
- Verify that edges of pavers are set into concrete or other abutment as per the design.
- Ensure that edge pavers are cut with a wet saw, in a designated area, away form the GI area to avoid clogging with fines and dust.
- Ensure that cut pavers are installed to edges of the practice before compaction of completed sections takes place.
- Ensure that tampering is performed after the installation of the pavers.
- Verify that pavers elevation is exactly as per the tender documents to avoid drainage issues.
- Verify that the paver pattern conforms to the tender documents (and directions from manufacturer).
- Before the joint aggregate is downloaded from the truck, ensure that it meets contract specifications.
- Ensure that the joint aggregate is free of debris and fines. There should be no dust clouds when downloading it from the truck.
- Ensure that rock chips, as per specifications, are installed between surface voids. Note that sand or finer gradations will clog the system.
- Ensure that material is tamp vibrated into the joint.
- Ensure that permeable pavers are compacted at least twice with a plate compactor.
- For tampering, verify that a rubber pad is attached beneath the metal tamper plate to avoid damage on the surface of the pavers

### 4.5.3. Porous Asphalt

Before installations the CA must:

- approve the job-mix formula submitted by the contractor.
- approve the choker course prior to placing porous asphalt mix.

The inspector must:

- ensure that the contractor follows specifications in the tender for transport of mix, including:
  - Using vehicles cleaned from foreign material
  - Scheduling delivery of material during daylight (unless approved otherwise)
  - Delivering material to paver at uniform rate and in an amount within capacity of paving and compacting equipment
  - Delivering loads continuously in covered vehicles and immediately spread on prepared base.
- verify that tack coat material and the application rate is as per the tender package.
- verify that asphalt mix is not placed on wet surface.
- verify that asphalt thickness, grades and lines are as specified on the contract drawings.
- verify that joints are as per specifications.
- ensure that only binders and oils specified in the tender package are being used for porous asphalt.
- verify that there is enough rollers of type and weight, as per specifications.
- verify that compaction of the asphalt is as per specification. Over compaction can cause reduction in pavement porosity.
- verify that irregularities are corrected before completion of rolling. If irregularities remain after final compaction, the contractor shall remove surface course and lay new material to specified density.

Additional Inspection Activities that apply to all Permeable Pavement Types:

- If curbs are being built, ensure granular base (A) does not spill over into the GI infiltration area.
- If there is construction taking place adjacent to the permeable pavement, ensure the permeable hard surface, is properly marked and protected from construction traffic and sedimentation, with jersey barriers, fences or filter socks. Compaction of the surface material will prevent water from reaching the stone beds beneath the pavement and can cause water to pond on the surface generating dangerous conditions in the winter. Also, dirty tires from construction traffic are often a major source of sediment.
- Remind the contractor to communicate and coordinate with sub-contractors, to protect the GI feature

## 4.6. Final Grading (Before Planting Vegetated GI)

See Appendix F for a checklist itemizing inspection tasks for this phase.

- Ensure that slopes, pre-treatment features, inlets, outlets and overflow pipe elevations and dimensions are as per the design drawings.
- Ensure that pre-treatment measures have been installed as per the design drawings.
- Confirm that geotextiles (if any) are as per the design drawings and that they are installed properly.
- Ensure that monitoring wells are installed as per the contract documents and/or TS 858 and that they have a cap. Monitoring wells serve as a place where monitoring equipment can be installed. They can also be an access point for maintenance (see figure 6).
- Ensure that final stabilization and protection including mulch, additional erosion control and vegetation is installed immediately after final grading, and as per the design drawings.
- Confirm that all depths, slopes and elevations are as per the design drawings. Estimate that after soil settlement, the finish grade of the GI feature is below the surrounding hard surface and the elevation of the inlet in order for the runoff to enter the facility.
- Ensure that the following components (if they apply to the specific system) are not obstructed or clogged by sediment/ trash/ debris and that water flow is not impaired:
    - Inlet
    - pre-treatment device
    - outflow and overflow structures (check that the structure is not full of water)
    - underdrains/ perforated pipes (where visible)
    - stormwater trenches
- Ensure that all dips in the growing medium have been filled and that any bumps have been removed.
- Verify that all installed material is protected from compaction, contamination and erosion, with fences; mulch, mats and geo-fabrics over the surface of the soil as required.
- Remind the contractor to communicate and coordinate with sub-contractors, to protect the installed growing medium from compaction.
- If the soil becomes compacted, contaminated, or eroded, ensure that the damage is repaired by removing and reinstalling the compacted material.
- Ensure that plant material is not delivered to site until areas have been prepared for planting.

- Ensure that in-situ compaction testing for growing medium is performed by the contractor as specified in TS 5.10 (section TS 5.10.04.01.07) and Appendix A. The compaction log should be submitted to CA for approval.

## 4.7. Mulching and Planting (Vegetated GI)

See Appendix F for a checklist itemizing inspection tasks for this phase.

- Ensure that grates are installed in overflow/outlet structures.
- Ensure curb inlet's width is as per the design drawing.
- Ensure that plantings take place during the season/ months specified in the design. Plantings should typically be done during the spring months, except for some species which can be planted in the fall.
- Ensure that water is removed, and soils allowed to dry before mulch placement and planting.
- Ensure that plants look healthy before and after planting.
- The CA is responsible for approving the plant species supplied on site.
- Ensure the planting location and spacing is as per the planting plan.
- If plant substitutions are needed due to availability challenges, the CA should sign off on new species and planting plan.
- Ensure that mulch is free of bark, soil, green material, and debris.
- Ensure that mulch depth is as per specifications.
- If runoff is directed to turf grass, verify that sod is installed 5cm below the top of adjacent hard surface.
- Confirm that all depths, slopes and elevations are as per the design drawings. Estimate that after soil settlement, the finish grade of the GI feature will be below the surrounding surface and the elevation of the inlet for the runoff to enter the facility.
- Grade verification should be done before and after planting.
- Ensure that all grades are restored after the installation of plants and that any excess soil is removed during the planting process.

## 4.8. End of GI Construction and Verification of Substantial Completion

See Appendix F for checklists itemizing inspection tasks for this phase for both vegetated and hard surface GI.

### 4.8.1. Vegetated GI

- Verify that growing medium test results for post-installation samples have been approved by the CA.
- Ensure that temporary runoff diversion measures are removed, and runoff can flow into the system without obstruction.
- Make sure that surrounding area is stabilized before temporary flow diversion measures are removed.
- If indicated in the design, ensure that level loggers have been installed in the monitoring wells, as per contract documents. The water loggers should be left in place after end of construction. Self-contained water level loggers are devices that automatically and continuously measure water level inside a monitoring well to determine the depth and fluctuation of water levels in a GI system.
- Some GIs will be designed with water level loggers to monitor functionality.
- Confirm that the system has been constructed as per design specifications and drawings and that as-built drawings reflect any approved deviations. Inspector to provide red-line drawings.
- Check that all components including inlets, pre-treatment measures, outflow and overflow structures, monitoring well and trench drains are in good state without structural damage, that construction sediment/ trash/ debris, has been removed, and that water flow is not obstructed.
- Ensure that the monitoring well has a cap.
- Ensure that check dam structures are not missing, and that any sediment has been removed.
- Verify grading once more. Ensure that slopes are correct and that inflow, pre-treatment structures, riprap, gravel diaphragms, splash pads, etc. are installed at the correct elevation so that water can flow into the GI feature.
- Ensure that there are no settlement, cracking, or other grade abnormalities, and that there's no erosion gullies or bare soli areas.
- For Stormwater Tree Trenches, check the pavement surface condition. Ensure that there's no differential settlement, cracking or other grade abnormalities at tree opening or over covered soil trenches.
    - Ensure that any overflow/outflow structures are not full of water and have grates.
    - Ensure plantings are in healthy condition.
    - To verify that the GI system is functional at the end of construction, it is fundamental that the infiltration testing is performed by the contractor, and witnessed by the CA. For details on how to conduct infiltration testing see Appendix C. The CA should confirm that the system is working as per the design. Refer to standard and special specifications for permeable pavements.

### 4.8.2. Permeable Pavement

- Verify that there is no standing water on the permeable pavement or visual evidence of frequent ponding, such sediment accumulation or staining on the surface.
- Verify that there are no damaged, missing or displaced pavers, ruts or local sinking present, if applicable.
- Verify that there is no structural damage in the overflow/outlet structure, that the grate is not missing, and that there is no sediment/ trash/ debris obstructing the outflow.
- Verify that the overflow/outlet structure is not full of water.
- Ensure that temporary runoff diversion measures are removed, and runoff can flow into the system without obstruction
- Make sure that surrounding area is stabilized before temporary flow diversion measures are removed.
- Verify that monitoring well is in good condition. If indicated in the design, ensure that level loggers have been installed in the monitoring wells, as per contract documents. The water loggers should be left in place after end of construction. Self-contained water level loggers are devices that automatically and continuously measure water level inside a monitoring well to determine the depth and fluctuation of water levels in a GI system.
- Some GIs will be designed with water level loggers to monitor functionality.
- Ensure that the monitoring well has a cap.
- Confirm that the system has been constructed as per design specifications and drawings and that as-built drawings reflect any approved deviations.
- Check that all components including pre-treatment measures, outflow and overflow structures, monitoring well and trench drains are in good state without structural damage, that construction sediment/ trash/ debris, has been removed, and that water flow is not obstructed.
- For porous asphalt and pervious concrete, verify leveling with straightedge. The surface of the asphalt and concrete shall be such that when tested with a 3 m long straightedge, placed in any direction on the surface, the gap between the straightedge and the surface profile shall not be greater than 6 mm for the porous asphalt, and 10mm for the pervious concrete, at any point.
- Verify that transition to adjacent impervious asphalt pavement is merged neatly with flush, clean lines. Verify that finished pavement is even, without pockets, and graded to elevations shown on the Contract Drawings.
- For porous concrete, acceptance should be based on QA testing and visual inspection by the CA, as per the specification. QA testing for acceptance should include verification of thickness, void content and density, and core

compressive strength. Visual inspection should include surface appearance, surface tolerance, and surface ravelling.

- For QA, ensure that infiltration testing is performed by the contractor, and witnessed by the CA, as per permeable pavement standard and special specifications referenced in the tender documents. Details on how to conduct infiltration testing in Permeable Pavement are in Appendix B.
- If permeable pavement voids are contaminated with soils or debris, it should be cleaned at the expense of the contractor and to the satisfaction of the CA. If permeable pavement cannot be unclogged, it shall be removed and replaced at the Contractor's expense and to the satisfaction of the Contract Administrator.

## 4.9. Warranty Period in Collaboration with Transportation Services Operation and Maintenance

See Appendix F for checklists itemizing inspection tasks for this phase for both vegetated and hard surface GI.

Take photographs of the GI facility to document the condition of the following main GI components:

- GI Surrounding Area:
  - Verify that excessive trash, debris and sediment is not present in the surrounding area, or impairing function of the GI.
- Inlets:
  - Verify that there is no damage to inlet or sediment pad structure impairing function of the GI.
  - Verify that sediment/ trash/ debris/ vegetation is not blocking the inflow.
  - Verify that there are no visible gullies or bare soil areas ≥ 30cm in length.
- Perimeter:
  - Verify that the GI dimensions do not differ by >10% of as-built drawings.
  - Verify that there are no visible gullies or bare soil areas ≥ 30cm in length.
- Filter Bed (Growing Medium/Soil) Surface:
  - Verify that standing water is not ponded on filter bed surface for more than 24 hours after the end of a storm event.
  - Verify that there is no trash impairing aesthetics or function of the GI.
  - Verify that there are no visible gullies or bare soil areas ≥ 30cm in length.

  - Verify that average mulch depth is not less than 5cm, or greater than 15cm, and that there are no bare soil areas visible.
  - Verify that filter bed surface has not sinked significantly, and that animal burrows are not visible.
  - Verify that check dams' structures (if applicable) are not missing or buried in sediment.
- Planting Area:
  - Verify that no less than 80% of planting area is covered by living, healthy vegetation
  - Verify that vegetation is not over-grown or over-crowded and that it is not impairing aesthetics or obstructing sight lines needed for safety.
  - Verify that the plantings are in healthy condition and look for weeds or invasive plants or any species not identified in the planting details. For weed identification resources see Appendix D
- Outlet:
  - Verify that there is no structural damage of the monitoring well, and that sediment clog is not visible and impairing its function.
  - Verify that the monitoring well is not missing the cap.
  - Verify that there is no structural damage to the overflow outlet structure and that there is no sediment/trash/ debris obstructing outflow.
  - Verify that overflow outlet structure is not full of water and that the grate is not missing.
- Permeable Pavement Layer:
  - Verify that there is no standing water on the permeable pavement or visual evidence of frequent ponding, such sediment accumulation or staining on the surface
  - Verify that there are no damaged, missing or displaced pavers (if applicable), ruts or local sinking present
  - Verify that paver joint fill (if applicable) is not missing or low and that there is now weed growth between pavers which is extensive or impairing aesthetic value.
  - For pervious concrete, assess surface appearance by a visual survey as per the specifications (TS 356.07.09).
  - If repairs are required, verify that:
    - Non-porous materials are not used to seal or repave.
    - Portions of the surface that are below acceptable infiltration rates are reconstructed.
    - Potholes and cracks repaired using conventional, non-porous patching mixes do not exceed a cumulative area of 10% of the permeable paved area.

# Appendices

# Appendix A: Growing Medium Requirements: Testing, Handling and Installation

This Appendix includes a summary of key requirements for verification of growing medium in GI. It is meant to be used as a guide to support the inspectors in GI construction. It is NOT intended to supplant or modify the requirements of contract drawings and specifications, or the Field Services Manual.

**Note: This Appendix does not include requirements for re-using existing native site soil** as growing medium as it is not a typical approach. If the design recommends this approach, the CA and the inspector should further review TS 5.10 for details.

## 1. The Importance of Growing Medium in GI Facilities

Growing medium is a fundamental element in the performance of GI systems. The growing medium filters and infiltrates the stormwater runoff and supports the plants growth. If the growing medium utilized for the facility is not handled correctly or is not as per the design specifications, the GI facility will not function properly.

It is most important to sample and test soil characteristics to make sure that it meets specifications, and that handling storage and installation is done correctly:

## 2. Construction Specification for Growing Medium TS 5.10, September 2021:

Inspectors should familiarize themselves with TS 5.10, which, provides a detailed description of the requirements for growing medium, including:

- Reuse of existing site soil (if the design recommends this approach)
- Mixing and testing to create different types of growing medium, for different applications (see table A.1 (below))
- Installation
- Compacting and grading
- Adding organic material to the surface layer (when required)

Table A.1. Types of Growing Medium for Different Applications

| **Type** | **Application** |
|---|---|
| Type 1 | Standard Mix, for seeding, sodding and trees planted in turf |
| Type 2 | Planting Bed Mix, for planting of shrubs and perennials |
| Type 3 | Boulevard Mix, for trees planted in hardscaped boulevards |
| **Type 4** | **Bioretention mix, for bioretention and rain gardens requiring high infiltration or pre-treatment.** |
| Type 4 is typically used for GI systems for stormwater management. However, the design will confirm the type to be used in the specific facility.<br>The mix for Type 4 should have the following proportions: 2 parts topsoil, 3 parts sand, 1-part organic soil components (leaf and yard waste compost, and/or pine bark fines). | |

Please refer also to FSM-SOP-17, “Growing Medium: Material Verification and Testing Requirements”, available on the ECS intranet (http://insideto.toronto.ca/ecs/ess/fsm/index.htm).

Table A.2. Contractor's Submittal Checklist

| ✓ | Section # | Item |
|---|---|---|
| | | **Certificates** |
| | TS 5.10.04.01.02 | Certification that all growing medium components and the growing medium meet all environmental standards |
| | | **Product Data** |
| | TS 5.10.04.01.03 | *Product data: Coarse sand* |
| | TS 5.10.04.01.03 | Product data: Pine bark compost |
| | TS 5.10.04.01.03 | Product data: Yard waste compost |
| | | **Material Source Locations** |
| | TS 5.10.04.01.04 | Location of all topsoil and growing medium components sources |
| | | **Samples** |
| | TS 5.10.04.01.05 | Duplicate 4L samples: Topsoil / submitted with required testing results |
| | TS 5.10.04.01.05 | Duplicate 1L samples: Coarse sand / submitted with required testing results |
| | TS 5.10.04.01.05 | Duplicate 1L samples: Pine bark compost / submitted with required testing results |
| | TS 5.10.04.01.05 | Duplicate 1L samples: Yard waste compost / submitted with required testing results |
| | TS 5.10.04.01.05 | Duplicate 4L samples: Growing medium / submitted with required testing results |
| | | **Testing Reports** |
| | TS 5.10.04.01.06 | Particle size analysis: Topsoil including sand fractions |
| | TS 5.10.04.01.06 | Particle size analysis: Growing medium including sand fractions |
| | TS 5.10.04.01.06 | Chemical analysis: Topsoil |
| | TS 5.10.04.01.06 | Chemical analysis: Growing medium with lab recommendations for fertilizer applications and amendments. |
| | TS 5.10.04.01.07 | In-Situ Compaction Testing: Installed growing medium |
| | TS 5.10.04.01.06 | Infiltration Rate Testing: Installed growing medium |
| | | **Contractor's Qualifications** |
| | TS 5.10.04.01.08 | Documentation of contractor's qualifications |

2.1. Growing Medium Ticket:

- Verify that the contractor has submitted to the CA the following documents, and that the CA has approved:
  - **Certificates/tickets** that the growing medium, and all its components meet environmental standards
  - **Product data and literature** from the manufacturer (for growing medium components, including coarse sand, pine bark compost, and yard waste compost)
  - **Material source locations**, including all crops grown on the soil and any herbicides and pesticide applied over the previous three years.
  - **Duplicate samples of each material (**including coarse sand, pine bark compost, a yard waste compost, and the mixed growing medium) which shall be submitted at the same time as the product data of that material, within 45 days prior to installation. TS 5.10 provides details of the volume that each sample should have, pending on material.
  - **Testing Reports** for each sample. Testing reports should include: particle size distribution, chemical analysis, nutrient test, report of the suitability of the soil for applicable plants, and recommendations for amendments.
  - Documentation of Contractor Qualifications
- Verify that all pipes/ sewer systems have been installed in the GI system before the growing medium is delivered.

2.2. Growing Medium Material Testing

- Details of requirements for all submittals from the contractor to the CA are provided in TS 5.10
- The testing lab should be approved by the CA prior to starting the testing process
- Samples of growing medium should not be submitted for approval until all mix component testing has been reviewed and approved by the Contract Administrator.
- Certified reports shall be from samples taken within four months of the date of the sample submission.
- Samples of the growing medium shall be submitted no les than 14 days after the approval of mix components.
- Laboratory comments on recommendations regarding soil amendment requirements or procedures shall be approved by the Contract Administrator.

2.3. In-Situ Compaction Testing

- Verify that the contractor undertakes in-situ compaction testing of the growing medium as per tender documents:
  - Verify that the contractor uses a cone penetrometer and a soil moisture meter, as per American Society of Agricultural Engineers' Standard EP542.
  - Verify that the contractor performs cone penetration tests after wetting the growing media, and after allowing a minimum of one week settling.
  - Verify that penetration resistance is to the full depth of the installed soil profile, or 750mm, whichever is less.
  - Confirm that the soil moisture (measured in situ with a soil moisture meter) has acceptable ranges (see table A.2)
  - Verify that the contractor maintains a record log of all compaction testing for submission and approval, including date, location, depth and pressure reading of each test, and that the test location data is plotted on a site plan.
  - Require the contractor to submit the compaction log to the City at the end of installation period.
  - Verify that the compaction record log is kept current and available at the site for review at all times
  - Remind the contractor to communicate and coordinate with other trades, to protect the installed growing medium from compaction.
- Verify that post installation test results are approved by the CA.
- Verify that all installed material is protected from compaction, contamination and erosion, with fences; mulch, mats and geo-fabrics over the surface of the soil as required.
- If the soil becomes compacted, contaminated or eroded, ensure that the damage is repaired by removing and reinstalling the compacted material.

2.4. Site Soil Compaction Around Existing Trees:

When the compaction test results exceed the required specification within the Tree Protection Zone (TPZ):

- Verify that the that the contractor engages a qualified professional approved by the CA to determine the most appropriate procedure. Typical remediation procedures include:
  - Core aeration: Pore space in compacted soil may be increased by removing small soil cores to a depth of about 75 mm.

- Vertical mulching: Holes 25-50 mm in diameter may be drilled in the compacted soil and filled with perlite, vermiculite, or other amendment material.
- Radial trenching: Trenches 150-200 mm wide and no deeper than the root system or depth of compaction can be dug with trenching equipment.
- The trenches are dug around the trunk of an existing tree in a bicycle spoke pattern, extending from the trunk and backfilled with a mixture of soil and amendments.
- Air excavation: Alternating pie-shaped wedges of soil around an existing tree can be decompacted by “tilling” compost into surface soil around roots with an air excavation tool. Air excavation can damage roots if high pressure is used, so soil should be decompacted in no more than 50 per cent of the root system at a time.

Table A.3. Required soil moisture to apply in-situ compacting testing with cone penetrometer

| **Soil texture** | **Soil moisture** |
|---|---|
| sand, loamy sand, sandy loam | 12–18% |
| loam, sandy clay, sandy clay loam | 27–36% |
| clay loam, silt loam | 31–36% |
| silty clay, silty clay loam | 38–41 |

Table A.4. Key timelines / sequencing:

| **Action** | **Timeline** |
|---|---|
| • CA arranges for QC testing<br>• Contractor has a detailed schedule of the installation of growing medium and the CA has approved it | Construction kick-off |
| Contractor sends to CA samples and analysis of topsoil, and growing medium. Samples of each material shall be submitted at the same time as the product data and testing data of that material | Within 45 days prior to installation |
| Samples of growing medium submitted | No less than 14 days after the approval of the mix components. |
| Certified Reports | Should be from samples taken within 4 months of the date of the sample submission. |
| • Pipes and sewers are installed.<br>• CA has approved certificates, product data, material source location, samples and test results | Before growing medium is delivered to the construction site |
| • Collect tickets approved by the CA<br>• Soil texture tested by hand with ribboning technique | Before growing medium is offloaded from the trucks |
| • Compaction testing is performed, and test results are approved by the CA.<br>• Samples of installed growing medium are collected from locations indicated by the CA, and test results are approved by the CA.<br>• In-situ infiltration is conducted by contractor in the presence of the CA (See next section of this Appendix) | After the growing medium is installed |

# Appendix B: Drainage and Infiltration Testing Requirements

To confirm that the GI system is functioning well, from a stormwater management perspective, the contractor should verify the following under the supervision of the CA:

1. That infiltration of stormwater in the GI system is working as intended in the design. Infiltration is the downward entry of water into the soil, or in other words, it is the process of water being absorbed into the soil; and
2. **That runoff from adjacent areas is flowing** in the right direction **towards the GI inlets or permeable pavement**, and that it is being **captured by the GI system without obstructions (such as curbs)**

The infiltration testing shall be done by the Contractor while the Contract Administrator witnesses the procedure.

This Appendix includes procedures and tests to verify these points.

## 1. Infiltration testing

### 1.1. Infiltration rate: what it is and why is it important?

GI facilities are designed with a specific infiltration rate to function properly. The surface infiltration rate is the velocity at which water enters the native soil. It is typically expressed in mm/hr. If the surface infiltration rate is too low, the stormwater that enters the GI system will quickly begin to pond on the surface and, once the overflow outlet elevation is reached, it will by-pass the GI facility, without getting any treatment. If water ponds in the GI system for more than 24 hours, the vegetation will suffer, it will become an ideal mosquito breeding habitat, and in the winter, there will be ice formation.

### 1.2. Typical causes of low infiltration rate:

- Vegetated GI
  - using a growing medium that does not meet specifications,
  - accumulation of sediments which can clog the pores of the soil,
  - over-compaction
- Permeable Pavement
  - Using aggregate that do not meet specifications
  - Accumulation of sediments which can clog the pores of the permeable pavement and aggregate
  - Over-compaction

## 2. Testing Methods: Vegetated GI:

The TS 5.10 specification for growing media states that, for Type 4, bioretention mix, infiltration testing shall be done using ASTM D2434 or ASTM F1815.

Two methods are recommended: the Guelph permeameter, and the double ring infiltrometer. Both methods are explained below. The contractor should document the measurements in the presence of the CA. The CA will apply some formulas to calculate the final infiltration rate of the system, and will verify that it is according to the design.

### 2.1. Method 1-Guelph Permeameter:

A Guelph Permeameter is a portable device to measure how water is infiltrated into the soil. It involves directing water to a “tension disc”, from an inner and outer Mariotte reservoir or bottle, and monitoring how the water level drops until a steady state is approached.

A Mariotte reservoir or bottle is a device that allows you to deliver water at a constant (adjustable) pressure.

*Figure 10: Photograph and Illustration of a Guelph Permeameter. Source: https://wiki.sustainabletechnologies.ca/wiki/Permeameters*

### 2.1.1. Key Steps for Using a Guelph Permeameter:

*Make sure to read carefully the manufacturer's specific recommendations for assembly and use*. Below is a high-level list of key steps. Also, the 5 minute video below describes the assembling and using the system**:** Permeameters - LID SWM Planning and Design Guide

a) Site selection and preparation:

- Measurements should be taken in at least 3 locations for areas of up to 500 m2, and one additional location for each additional 500 m2 of filter bed surface area, or fraction thereof, including inlet and lowest elevation areas.
- The Contract Administrator should choose representative locations based on the design and site conditions.
- Excavate a borehole to the desired depth using an appropriate auger (which comes with the permeameter).
- Clean the borehole walls to remove any loose debris (with special device, that comes with the permeameter

b) Assembling the Guelph permeameter:

- Attach the appropriate air tube to the reservoir based on the desired hydraulic head (see instructions below)
- Fill the reservoir with water.

c) Inserting the permeameter:

- Carefully lower the permeameter into the borehole, ensuring the base of the support tube rests on the bottom of the hole.
- Check for a good seal between the borehole walls and the permeameter.

d) Starting the test:

- Raise the air tube to the desired height, creating a constant water level within the borehole.
- Begin monitoring the water level decline in the reservoir over time.

e) Data collection and analysis:

- Record water level measurements at regular intervals in the forms provided below.
- Use the measured data and soil properties to calculate the soil permeability (hydraulic conductivity) using appropriate formulas.

### 2.1.2. Guelph Permeameter Parts and Assembly:

The order in which the parts are assembled will be dictated by which connectors can fit through which holes within the connecting plates. It is easiest to connect up the thinnest tubes first. Find a clear flat piece of ground (or a picnic table) and assemble all of the parts horizontally to reduce strain on the connectors.

There are three thin inner tubes:

- the central tube is the longest and sits within the reservoir assembly,
- the bottommost tube has a washer/seal apparatus on the end which does not attach to the central tube,
- the top tube is the shortest and has an open end where it does not attach to the central tube.

The reservoir assembly comprises two tubes of the same length:

- the outer is unmarked,
- and there is a mid-sized tube with graduations in millimeters,

There are two further mid-sized tubes:

- the longer of these has a cup-shaped, filter-like ‘foot’ and should have a funnel shaped bushing threaded on (shown semi-transparent); this tube goes onto the base of the reservoir,
- the shorter tube has graduations in millimeters and no other components attached; it slides onto the very top around the shortest thin tube.

At the top of the reservoir section there are three small but important components to note:

- a short flexible hose to regulate air going into the reservoir; this should have a plastic ring associated to close it off,
- a hole with a rubber plug; this is used to fill the reservoir with water

a moveable ‘indicator’ on the inner tube; it is a small cylinder of plastic threaded onto the tube which come directly from the reservoir.

2.2. Method 2-Double Ring Infiltrometer:

The double-ring infiltrometer (see photo below) is made of two concentric tubes typically of thin metal or hard plastic, that are both continuously filled with water such that a constant water level is maintained as water infiltrates into the soil.

Using a double ring infiltrometer is a simple method for infiltration testing. However, the accuracy is only moderate compared to the Guelph permeameter,

and results tend to be biased towards higher values. In addition, it may require a large volume of water and a significant length of time for each measurement.

*Figure 11: Photograph of a double ring infiltrometer. Source: https://wiki.sustainabletechnologies.ca/wiki/Double_ring_infiltrometers*

2.2.1. Key Steps for Using a Double Ring Infiltrometer:

a) Installation

- Measurements should be taken in at least 3 locations for areas of up to 500 m2, and one additional location for each additional 500 m2 of filter bed surface area, or fraction thereof, including inlet and lowest elevation areas.
- Choose or create clear, level ground at the desired test location.
- Work with minimal disturbance to the soil within the test area.
- Place the wooden block across the ring and use the sledgehammer to drive the ring into the ground by ≥ 5 cm.
- Check that the ring is level in all directions and correct as necessary.
- Repeat with the second ring (note that the order may vary if the rings are of differing heights.
- Both rings should be firm into the ground.
- Secure the metal rulers to the inside of the rings.

b) Measurements

- To begin measurements gently pour 5 – 10 cm of water into both the inner and outer rings.
- Measurement of the water depth should be made every 15 minutes for the first hour, 30 minutes in the second hour and then hourly up to 6 hours.
- The rings should be covered to reduce evaporation, particularly in hot weather

2.3. Notes on Guelph Permeameter and Double Ring Infiltrometer:

The Guelph permeameter and the double ring infiltrometer don't measure infiltration rate directly. They measure field saturated hydraulic conductivity, which need to be converted with formulas, to infiltration rate. This is done by the Contract Administrator, based on measurements taken in the field by the contractor. The saturated hydraulic conductivity represents how easily water can pass through saturated soil

For detailed guidance on how to perform double ring testing, refer to ASTM D3385-09 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer (ASTM International, 2018[17]) and ASTM D5093-15 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer with Sealed-Inner Ring (ASTM International, 2018[18]

2.4. Natural or Simulated Storm Event Testing

2.4.1. Why is it important?

For GI systems that receive stormwater via conveyances like gutters, concrete inlets and leader pipes from catchbasins (i.e., bioretention and dry swales, enhanced swales, underground infiltration systems), it is critically important to confirm that these conveyances have been designed and constructed properly. If the conveyances are obstructed or improperly graded or constructed, the GI system may not receive the amount of stormwater runoff that it was designed to treat.

To confirm that the GI system is functioning properly, construction completion inspections should be conducted during a natural or simulated storm event, as described below.

### *2.4.2. Testing During a Natural Storm Event*

The simplest approach to confirming that conveyances to the GI system have been constructed properly, that the site grading is correct, and that subdrains are working as intended, is through observations during a natural storm event.

- Observe the path of runoff and confirm that it is flowing towards the GI inlets.
- Confirm that the water is entering the system through the inlets, unobstructed (note that this is to be done at the end of construction, once the temporary barriers in the inlets are removed).
- If the system has sub-drains that can be accessed and visually inspected, confirm that water is flowing in the sub-drain pipe.
- Confirm that there is no ponding in the GI system 24 hours after the end of the storm.

### *2.4.3. Testing During a Simulated Storm Event*

If timelines for completing inspections cannot be coordinated to coincide with a natural storm event, an alternative approach is to simulate a storm event by directing water onto the GI via inlets, through the use of a water tanker truck or fire hydrant while observing conveyances and measuring drainage performance of the GI system.

If this approach is decided, the Contract Administration needs to design the simulated storm event, including:

- The decision to use a tanker truck vs. a fire hydrant, based on the size of the GI facility.
- The amount of water that is to be used for the test

Once the storm event is designed by the Contract Administrator, the inspector can undertake the same tasks as with a natural storm event (described above).

### *2.4.4. Continuous Monitoring*

Natural or simulated storm event testing can also be undertaken to confirm that GI system drains at an acceptable rate. Designing such tests is much more involved and requires the deployment of specialized field monitoring equipment like continuous water level loggers (i.e., pressure transducers) in monitoring wells, flow measurement apparatuses (e.g., area-velocity sensors) in sub-drain or outlet pipes and rain gauges, in addition to staff familiar with the use and calibration of such equipment and the processing and analysis of the data.

## 3. Testing Methods: Hard Surface GI

In hard surface GI/ permeable pavements, there are two methods that are recommended for infiltration testing, and explained below:

1. Single ring infiltrometer applied to several locations
2. Continuous monitoring, in the monitoring well, during several storm events

The CA may also require continued monitoring in certain projects.

3.1. Method 1- Single Ring Infiltrometer Test:

A single ring infiltrometer is a simple device used to measure the infiltration rate of water in hard surface GIs. It consists of a cylindrical metal ring, typically 12 inches in inside diameter and approximately 4 tall. **The test must be performed in several representative locations** of the permeable hard surface area.

For details about this test see:

- ASTM C1701, for pervious concrete and porous asphalt
- ASTM C1781, for interlocking

*Figure 12: Surface infiltration testing conducted with a simple single-ring infiltrometer and a timer on the technician's mobile phone. Source: https://wiki.sustainabletechnologies.ca/wiki/Inspection_and_Maintenance:_Permeable_Pavement*

3.1.1. Key Steps for Using a Single Ring Infiltrometer:

a) Site Preparation:

- Select representative areas of the pavement where the test will be performed and document these exact locations.
- Remove debris from the test area surface.
- Place the infiltration ring on the pavement, using a sealing material around the base (such as plumber's putty) to prevent leakage. Special attention is required for permeable pavers with uneven surfaces).

b) Pre-wetting the Test Area (Optional but Recommended):

- Pour a known volume of water (typically 8 liters) and let it fully infiltrate.
- This conditions the surface and saturates the underlying structure.

c) Measurements:

- The CA will determine the required volume of water to be used, pending on the type of permeable surface (typically 12 liters for permeable unit pavers, and 40 liters for permeable concrete).
- Pour water into the ring.
- Start timing the moment water is introduced.
- Record the time it takes for all the water to infiltrate through the surface (i.e., until there is no standing water visible)

d) Calculation:
The CA will use the times recorded in the field, to apply special formulas and calculate the infiltration rate. The result will be compared with design values, to confirm performance of the system.

## 4. Recording Measurements

The images below are examples of field forms used to record measurements taken with a Guelph Permeameter and a Single Ring Infiltrometer. Excel files to be provided by the Contract Administrator.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | **Date:** | | | **Prescence of Special Soil Conditions** | | |
| 2 | **Location:** | | | (mottling, water table depth, hardpan, induration, compacted layers, etc | | |
| 3 | **Reservoir Constants** | | | | | |
| 4 | Combined Reservoirs (X) | | **35.22 cm2** | | | |
| 5 | Inner Reservoir (Y) | | **2.15 cm2** | | | |
| 6 | Reservoir Constant Used (cm^2): | | | **Comments & Notes** | | |
| 7 | **Depth of Hole (cm):** | | | (topography, slope, vegetation, etc.): | | |
| 8 | | | | | | |
| 9 | **1st Set of Readings with height of** | | | | | |
| 10 | **water in well (H1) set at 5cm** | | | | | |
| 11 | **Reading** | **Time** | **Time** | **Water Level in** | **Water Level** | **Rate of Water Level** |
| 12 | **Number** | | **Interval (min)** | **Reservoir (cm)** | **Change (cm)** | **Change R1 (cm/min** |
| 13 | 1 | | | | | |
| 14 | 2 | | | | | |
| 15 | 3 | | | | | |
| 16 | 4 | | | | | |
| 17 | 5 | | | | | |
| 18 | 6 | | | | | |
| 19 | 7 | | | | | |
| 20 | 8 | | | | | |
| 21 | 9 | | | | | |
| 22 | 10 | | | | | |
| 23 | 11 | | | | | |
| 24 | 12 | | | | | |
| 25 | 13 | | | | | |
| 26 | 14 | | | | | |
| 27 | 15 | | | | | |

*Figure 13: Example of Field Form to Record Measurements with Guelph Permeameter*

| | |
|---|---|
| **Contract Number:** | |
| **Inspector:** | |
| **Contractor:** | |
| **Date and Time of Test:** | |
| **Project Site:** | |
| **Inside Diametre of Ring Used (cm)** | |
| **# of Representative Locations Tested:** | |
| **Did it rain within 24 hours before test (Y/N)** | |

| **1st Measurement- Representative Location #1** | |
|---|---|
| Time when measure was taken: | |
| Exact location within site/ street: | |
| Water Volume used for pre-wetting (L) | |
| Water volume used for measurement (L) | |
| Infiltration time** (minutes) | |
| **Comment/ Observations** | |
| | |

| **2nd Measurement- Representative Location #2** | |
|---|---|
| Time when measure was taken: | |
| Exact location within site/ street: | |
| Water Volume used for pre-wetting (L) | |
| Water volume used for measurement (L) | |
| **Comment/ Observations** | |
| | |

| **3rd Measurement- Representative Location #3** | |
|---|---|
| Time when measure was taken: | |
| Exact location within site/ street: | |
| Water Volume used for pre-wetting (L) | |
| Water volume used for measurement (L) | |
| **Comment/ Observations** | |
| | |

*from the time water first contacts the pavement to when it is fully infiltrated

*Figure 14: Example of Field form to record measurements from Single Ring Infiltrometer Testing*

# Appendix C: Examples of Failures

*Figure 15: Cement / concrete debris and sediment contamination of bioretention bed will impact stormwater management function and health of the plants.*

# Appendix D: Weed Identification Resources

This appendix provides resources to identify non-beneficial weeds that typically grow in Vegetated GI systems for stormwater management in Toronto.

## 1. Cellphone Applications:

The following cellphone applications (for both apple and android) are excellent, easy to use resources to identify plants, including weeds. It is highly advisable for inspectors to download the apps in their phones and use them to inspect the systems during warranty period.

https://plantnet.org/en/

https://www.inaturalist.org/

## 2. Invasive Species Guide:

"A quick reference guide to Invasive Plant Species", provides helpful graphs, photographs and descriptions to identify invasive weeds in Southern Ontario: Quick-Reference-guide-to-Invasive-plant-species-1.pdf

## 3. Most Common Weeds found in GI systems:

The following section includes the most common weeds found in GI vegetated systems for stormwater management.

The top 3 most common are (see pictures and ID resources below):

1. Dog-strangling vine - *Vincetoxicum rossicum / V. nigrum*
2. Garlic mustard - *Alliaria petiolate*
3. Common reed / Phragmites - *Phragmites australis ssp. Australis*

Other common weeds found in vegetated GIs in Toronto

1. Reed canary grass - *Phalaris arundinacea, invasive strains)* *OIPC_BMP_ReedCanaryGrass.pdf*
2. Canada thistle - *Cirsium arvense (L.)* Scop. [wind-dispersed seed and by horizontal roots].
3. Chickweed - *Stellaria media (L.) Vill.*
4. Quackgrass - *Elytrigia repens (L.) Gould* (ID features)

5. Coltsfoot - *Tussilago farfara L.*
6. Tufted Vetch - *Vicia cracca L.* [seed and by spreading underground roots]
7. Field bindweed - *Convolvulus arvensis L.* [seeds, roots and rhizomes]
8. Creeping bellflower - *Campanula rapunculoides* [seeds, roots and rhizomes

### 3.1. Dog-strangling vine - Vincetoxicum rossicum / V. nigrum

**Plant type**: Herb, twining vine.

**Arrangement**: Opposite.

**Leaf**: Lance shaped, smooth margin (edge)

**Bark**: n/a

**Seed/Flowers**: Bean shaped seed pod with seeds attached to downy ‘umbrellas. Flowers – pink (*C. rossicum*) or purple (*C. nigrum*) with five petals.

**Buds/Stem**: n/a.

**Habitat**: Dry to moist soils; more dominant in meadows and woodland edges.

**Similar native species**: Swamp milkweed (*Asclepias incarnata*), is an upright plant, typically found in wetland habitats.


*Figure 16: Photograph of dog-strangling vine*

### 3.2. Garlic mustard - *Alliaria petiolate*

**Plant type**: Herb

**Arrangement**: Alternate.

**Leaf**: Saw tooth like edge, elongated heart shape with prominent veins. Garlic/onion smell when crushed. Young (first year) leaves are kidney shaped.

**Bark**: n/a

**Seed/Flowers**: Cluster of small white flowers with four petals. Small black <1 mm rounded seed found in elongated ‘tube-like’ seed pods (similar to a bean pod).

**Buds/Stem**: n/a.

**Habitat**: Various – dry to moist soils, in all habitat types, less often in meadows.

**Similar native species**: n/a.


*Figure 17: Photograph of garlic mustard*

### *3.3.* Common reed / Phragmites - *Phragmites australis ssp. Australis*

**Plant type**: Grass

**Arrangement**: Alternate.

**Leaf**: Broad leaf > 1 cm wide.

**Bark**: n/a

**Seed/Flowers**: Dense cascading ‘broom-like’ flower head. ‘Cottony’ in appearance when mature.

**Buds/Stem**: Stems rough and ridged, ligule a densely hairy band. Hairy band less conspicuous later in season. Mature plants > 3 m tall.

**Habitat**: Moist to wet soils. Found in wetlands, water-courses and road side ditches.

**Similar native species**: Species of manna grass (*Glyceria sp.*) including tall northern, eastern and rattlesnake grass. A native common reed exists but has a smooth stem and the ligule is not hairy. It is also quote rare.

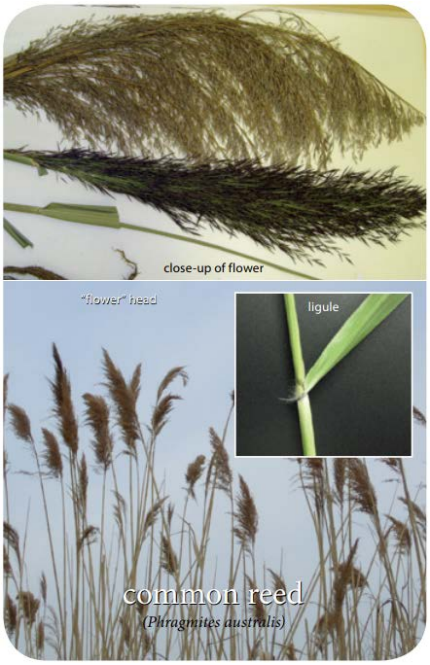



*Figure 18: Photograph of common reed*

# 4. Plant Recognition Terms

## 4.1. Leaf Shape

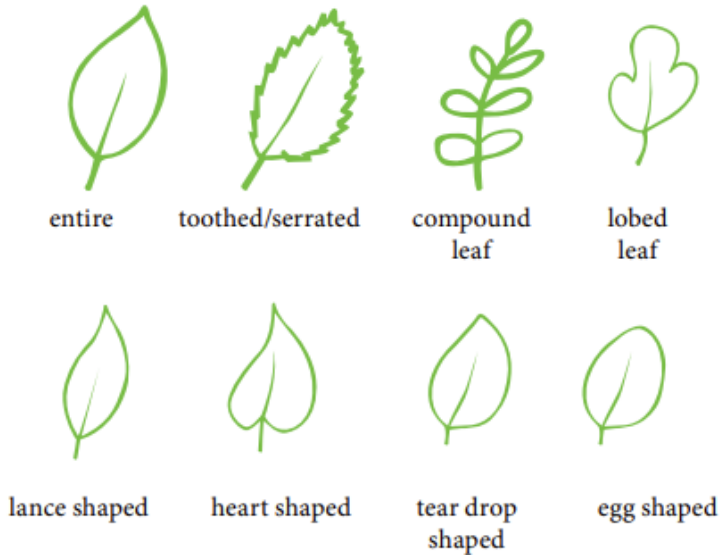



*Figure 19: Illustration of various leaf shapes: entire, toothed/serrated, compound leaf, lobed leaf, lance shaped, heart shaped, tear drop shaped, and egg shaped*

## 4.2. Arrangement

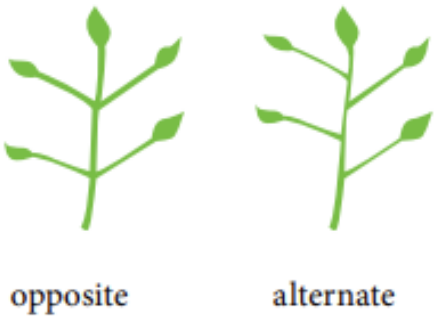



*Figure 20: Image of sample arrangements, opposite and alternate*

### 4.3. Buds

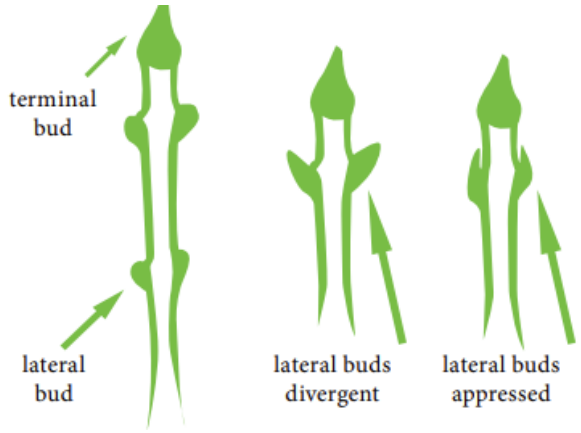



*Figure 21: Various types of buds - terminal, lateral, lateral buds divergent, and lateral buds appressed*

### 4.4. Stems / Bark

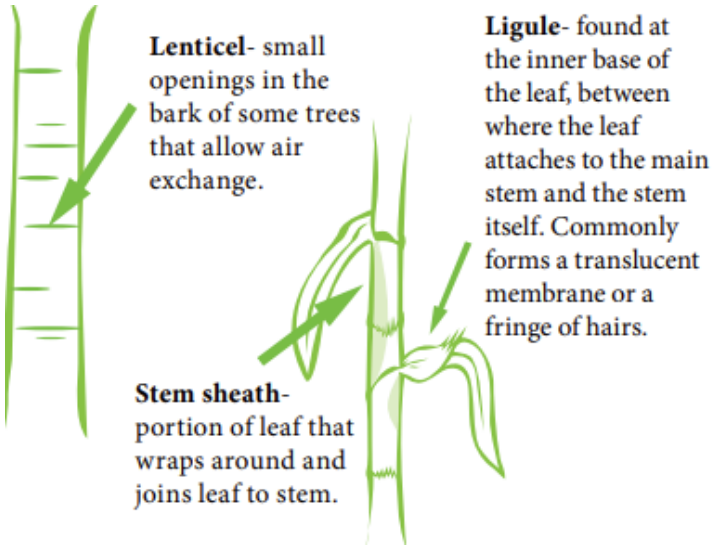


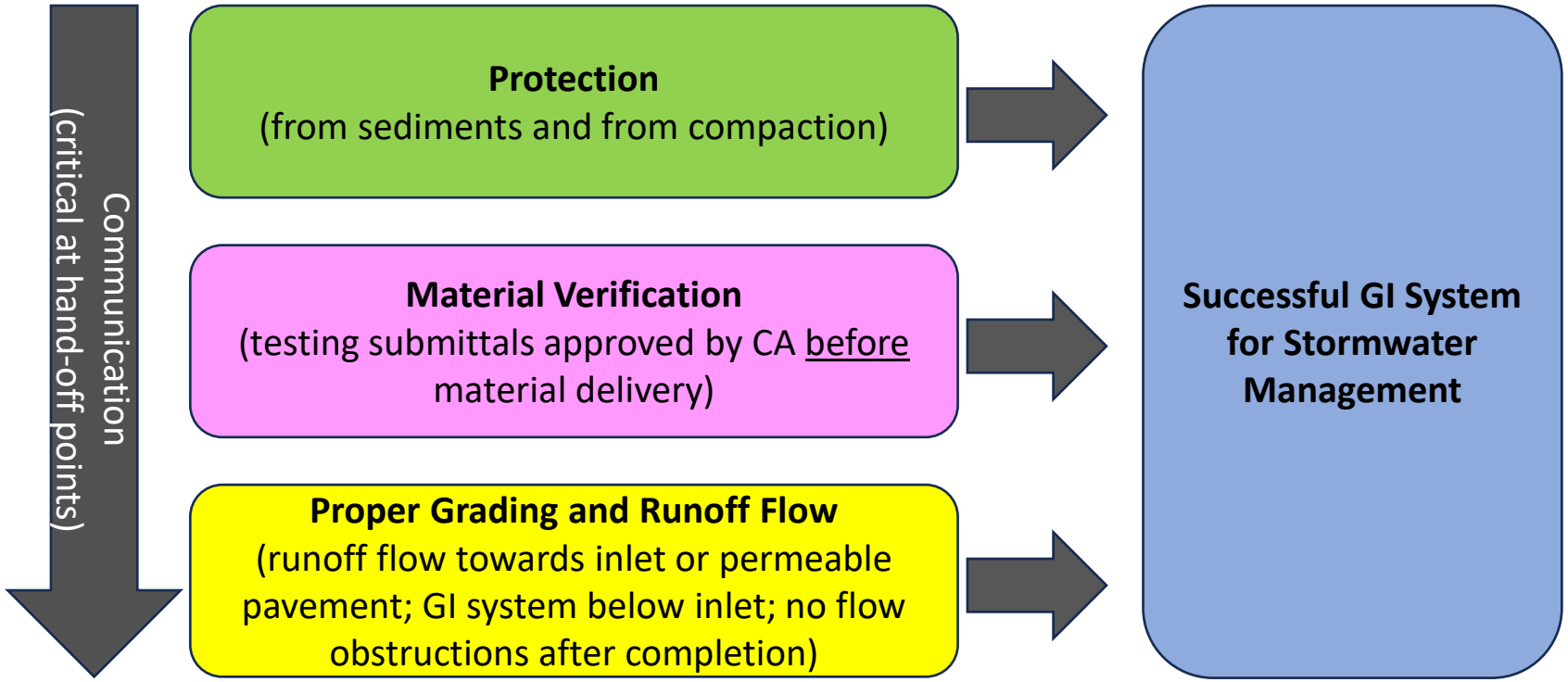

*Figure 22: Illustration of types of stems and barks: lenticel, stem sheath, and ligule*

# Appendix E: GI Construction Inspection Field Cards

*These cards represent a summary to support inspection activities. They don't supplement the GI Construction Inspection Guide, which contains important details that shall be addressed by the Inspector.*

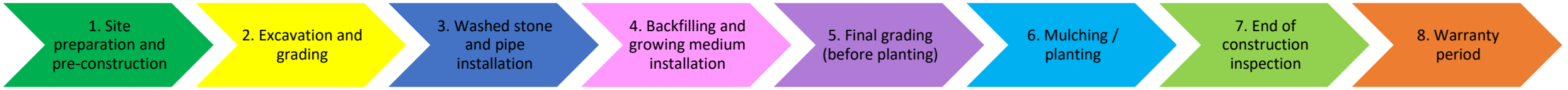
*These cards are generic. GI systems may not have all the elements that are listed here. Follow the designs and use these resources as applicable.*

# E1. Key principles for successful GI Construction

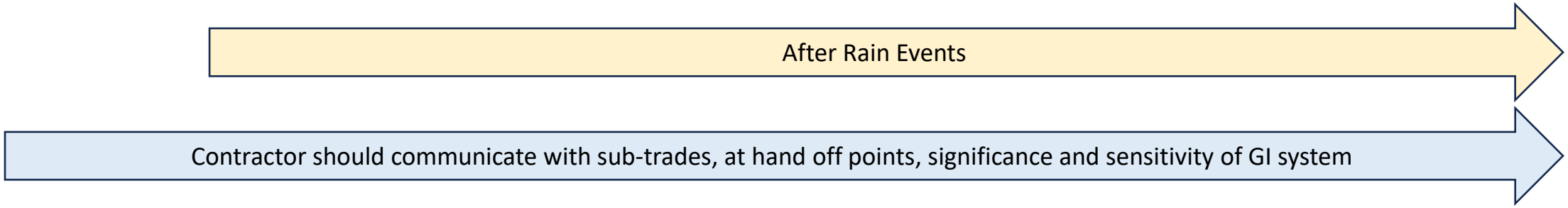


# E2. Vegetated and Hard Surface GI Construction Inspection Points

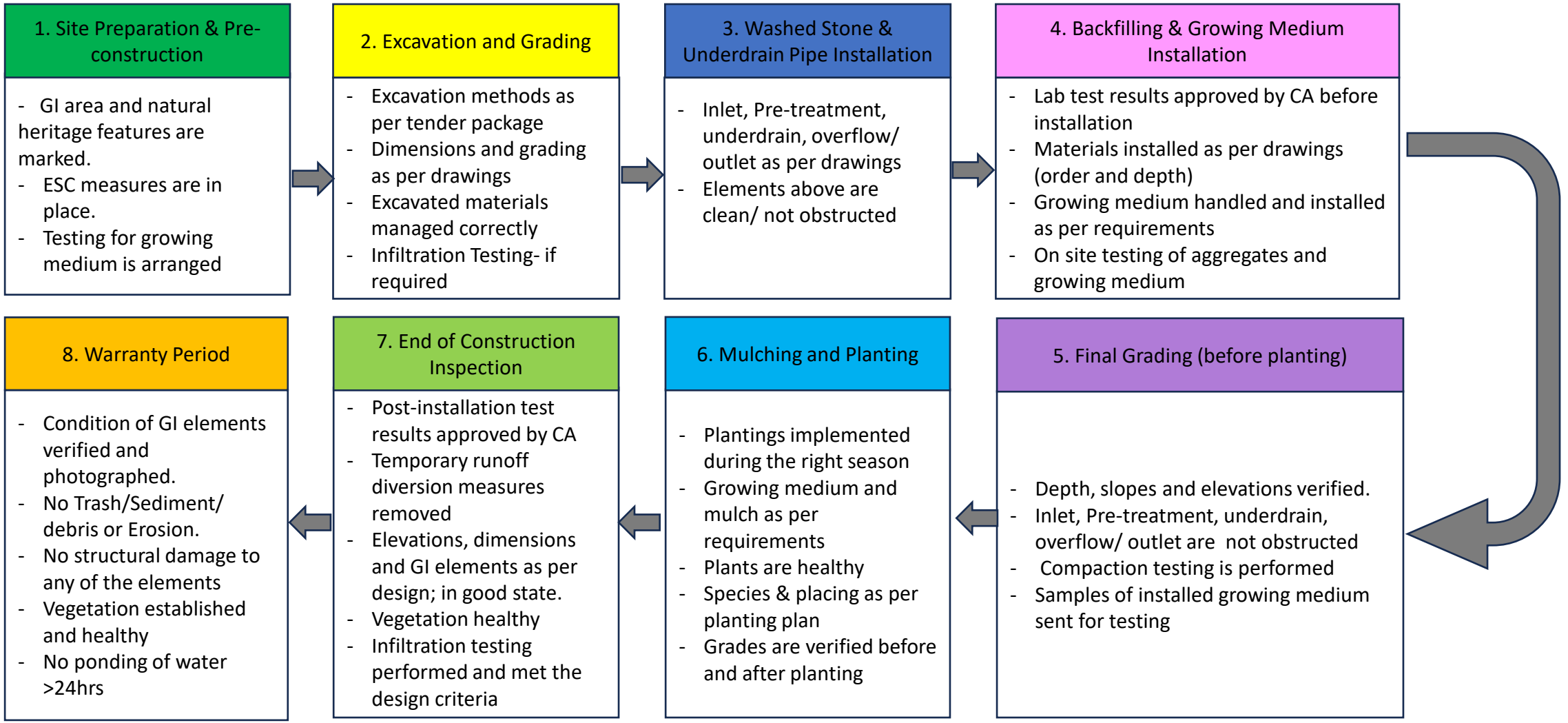
## Vegetated GI:



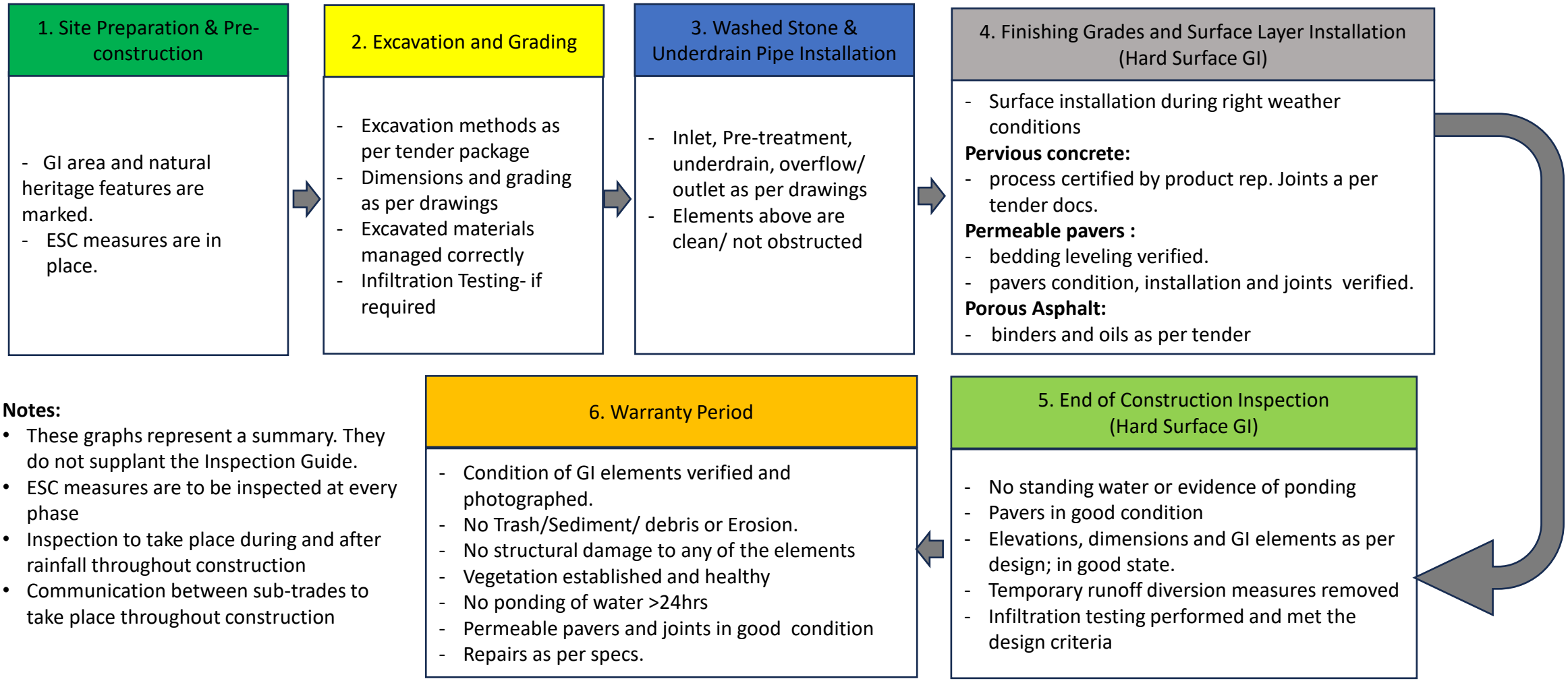

## Hard Surface GI:

# E3a. Summary of Inspection in Vegetated GI Construction Phases



# E3b. Summary of Inspection in Hard Surface GI Construction Phases




**Notes:**

- These graphs represent a summary. They do not supplant the Inspection Guide.
- ESC measures are to be inspected at every phase
- Inspection to take place during and after rainfall throughout construction
- Communication between sub-trades to take place throughout construction

# E4. Testing Required for Vegetated and Hard Surface Green Infrastructure

(See details in Appendix A of GI Construction Inspection Guide)

| At Project Start (Results approved by CA before growing medium is delivered) (Vegetated GI) | After Excavation, Before Backfilling (Vegetated and Hard Surface GI) | At Material Delivery for Backfilling (before offloading from the truck) (Vegetated and Hard Surface GI) | Surface Layer Installation (Hard Surface GI) | After Backfilling and Final Grading (Vegetated GI) | Before substantial completion (Vegetated and Hard Surface GI) |
|---|---|---|---|---|---|
| Growing medium and aggregate lab tests | In-situ infiltration testing (if required) | Aggregates on-site testing (no dust clouds seen during offloading). | **Pervious Concrete:**<br>- Ready mix moisture and overall concrete placement certified<br>**Permeable Pavers:**<br>- Joint Aggregate on-site testing (no dust clouds seen during offloading). | 1. Growing medium in-situ moisture and compaction testing<br><br>2. Growing medium lab tests from samples collected in-situ | On-site Infiltration Testing |

# Appendix F: GI Construction Inspection Checklists

## Checklist F1a: Site Preparation and Pre-Construction

Inspector to verify:

- ❑ Follow the Schedule of GI installation included by contractor and approved by the CA.
- ❑ Material testing arranged by contractor as per City's specifications.
- ❑ Growing medium submittals provided to CA by contractor (45 days before installation).
- ❑ Erosion & Sediment Control measures in place as per contract's requirement.
- ❑ Erosion & Sediment Control Emergency Plan in case of storm as per contract requirement.
- ❑ Runoff temporarily diverted from GI construction area.
- ❑ Concrete washout areas and sediment basins for adjacent construction away from GI footprint.
- ❑ Natural Heritage features marked for protection by the contractor and as per contract's requirement.
- ❑ Area to be cleared from vegetation marked (only the minimum necessary) by the contractor and as per contract's requirement.

End of Checklist

## Checklist F1b: Site Preparation and Pre-Construction

Inspector to verify:

- ❑ Follow the Schedule of GI installation included by contractor and approved by the CA.
- ❑ Material testing arranged by contractor as per City's specifications.
- ❑ Detailed paving plan submitted by contractor to the CA and approved by the CA.
- ❑ **For porous asphalt,** mix design and trial mix results submitted to CA two (2) weeks prior to commencing work.
- ❑ **For porous concrete**, admixtures and proposed fibers submitted to CA.
- ❑ Erosion & Sediment Control measures in place as per contract's requirement.
- ❑ Erosion & Sediment Control Emergency Plan in case of storm as per contract requirement.
- ❑ Runoff temporarily diverted from GI construction area.
- ❑ Concrete washout areas and sediment basins for adjacent construction away from GI footprint.
- ❑ Natural Heritage features marked for protection by the contractor and as per contract's requirement.
- ❑ Area to be cleared from vegetation marked (only the minimum necessary) by the contractor and as per contract's requirement.
- ❑ Conventional pavement adjacent to permeable pavement, installed to at least base course (if applicable)

End of Checklist

## Checklist F2a: Excavation and Grading

Inspector to verify:

- ❑ Finish grading activities performed during dry conditions (may need dewatering) as per contract's requirements.
- ❑ Excavation limits marked as per drawings.
- ❑ Excavation done from outside reaching in (with backhoe or bucket with extension arm).
- ❑ If equipment is needed inside the facility, it should be low pressure-rated or marsh track as per contract's requirements.
- ❑ Excavated materials/ stockpiles stored away from excavation area and controlled.
- ❑ Unexpected contamination (if uncovered) has been reported to CA.
- ❑ GI dimensions, depths, slopes, elevations are as per design.
- ❑ Perimeter controls are in place as per contract's requirements.
- ❑ Subsoil of subgrade is loosened or tilled, and tilled area is protected as per contract's requirements.
- ❑ Placing sequence for all materials and depth are correct as per contract's requirements.
- ❑ Infiltration testing may be required by the Contractor (pending findings during excavation) as per contract's requirements. CA to coordinate with the contractor and site inspector.

End of Checklist

## Checklist F2b: Excavation and Grading

Inspector to verify:

- ❑ Finish grading activities performed during dry conditions (may need dewatering) as per contract's requirements.
- ❑ Utilities are clearly marked by the contractor.
- ❑ Excavation limits marked as per drawings.
- ❑ Excavation done from outside reaching in (with backhoe or bucket with extension arm).
- ❑ If equipment is needed inside the facility, it should be low pressure-rated or marsh track as per contract's requirements.
- ❑ Material testing approved by CA
- ❑ Compaction is completed, if required, as per specifications.
- ❑ Contractor received written confirmation that subgrade work is sufficient
- ❑ Excavated materials/ stockpiles stored away from excavation area and controlled.
- ❑ Unexpected contamination (if uncovered) has been reported to CA.
- ❑ GI dimensions, depths, slopes, elevations are as per design.
- ❑ Perimeter controls are in place as per contract's requirements.
- ❑ Any contamination of subgrade removed by contractor.
- ❑ CA notified 24hrs prior to all base and subbase work
- ❑ Written confirmation from CA that subgrade work is sufficient (when required in spec)
- ❑ Subsoil of subgrade is loosened or tilled, and tilled area is protected as per contract's requirements.
- ❑ Placing sequence for all materials and depth are correct as per contract's requirements.
- ❑ Infiltration testing may be required by the Contractor (pending findings during excavation) as per contract's requirements. CA to coordinate with the contractor and site inspector.

End of Checklist

## Checklist F3a: Washed Stone and Underdrain Pipe Installation

Inspector to verify:

- ❑ Pipes cleaned from sediments before installation.
- ❑ Growing medium is delivered only after pipe installation.
- ❑ During cold weather, subgrades are protected from freezing.
- ❑ Slopes, pre-treatment, inlets, outlets, overflow pipe elevations and dimensions as per design.
- ❑ Perforated pipe as per specification; properly installed. Pipe gradient verified.
- ❑ Grates installed in overflow and outlet structures.
- ❑ Geotextiles are installed as per cross-section drawings.
- ❑ Monitoring well is as per specification and properly installed with a cap.
- ❑ Installation does not take place in heavy rain, on frozen aggregate or on frozen soil subgrade.
- ❑ Inlet, pretreatment, outflow/ overflow structures, underdrain, trench drains are not clogged.
- ❑ Overflow structure is not full of water.
- ❑ Granular subbase and granular base material are as per specification
- ❑ Aggregates and soil lab tests results approved by CA before delivery.
- ❑ Leveling of the subbase and base verified with straightedge
- ❑ Subbase and the base are compacted to the level specified in the tender package.
- ❑ Base and the subbase courses have the density specified in the tender package.

End of Checklist

## Checklist F3b: Washed Stone and Underdrain Pipe Installation

Inspector to verify:

- ❑ Pipes cleaned from sediments before installation.
- ❑ During cold weather, subgrades are protected from freezing.
- ❑ Slopes, outlets/overflow pipe elevations and dimensions as per design.
- ❑ Perforated pipe as per specification; properly installed. Pipe gradient verified.
- ❑ Grates installed in overflow and outlet structures.
- ❑ Geotextiles are installed as per cross-section drawings.
- ❑ Monitoring well is as per specification and properly installed with a cap.
- ❑ Installation does not take place in heavy rain, on frozen aggregate or on frozen soil subgrade.
- ❑ Outflow/ overflow structures, underdrain, trench drains are not clogged.
- ❑ Overflow structure is not full of water.
- ❑ Granular subbase and granular base material are as per specification
- ❑ Aggregates tests results approved by CA before delivery.
- ❑ Leveling of the subbase and base verified with straightedge
- ❑ Subbase and the base are compacted to the level specified in the tender package.
- ❑ Base and the subbase courses have the density specified in the tender package.

End of Checklist

## Checklist F4a: Backfilling and Growing Medium Installation

Inspector to verify:

- ❑ Soil and aggregates tickets show passed lab test results (signed off by CA), before offloading from truck.
- ❑ Aggregate doesn't generate dust clouds when downloaded during the delivery.
- ❑ Placing sequence of all materials as per specification.
- ❑ Installation of aggregates, including depth, as per tender documents.
- ❑ Choker layer is clean, free of debris or sediments before growing medium is installed.
- ❑ Growing medium is installed as per TS 5.10 (typically in even, thin layers).
- ❑ Sediment controls applied to temporarily stored topsoil and landscaping materials (including boulders).
- ❑ Whenever possible stockpiles are uncovered daily during warm dry conditions.
- ❑ Growing medium stockpiles protected from freezing and saturation.
- ❑ In cold weather, growing medium is removed from within the interior of the stockpile.
- ❑ Growing medium is not mixed, delivered or placed in frozen/wet/ muddy conditions.
- ❑ Contractor is not using delivery or installation methods that overly mix the growing medium.
- ❑ Growing medium is installed avoiding compaction.
- ❑ Finish grading activities in the GI are performed during dry conditions.
- ❑ All dips in the growing medium have been filled and any bumps have been removed by the contractor.
- ❑ Growing medium has the right elevation, as per design (to allow settling).
- ❑ No structural damage to monitoring well, perforated pipe, trench drain.

End of Checklist

## Checklist F4b: Backfilling and Growing Medium Installation – Hard Surface GI

Inspector to verify:

- ❑ Placing sequence of all materials as per specification.
- ❑ Installation of aggregates, including depth, as per tender documents.
- ❑ Sediment controls applied to temporarily stored landscaping materials (including boulders).
- ❑ No structural damage to monitoring well, perforated pipe, trench drain.

End of Checklist

## Checklist F5: Finishing Grades and Surface Layer Installation

Inspector to verify:

- ❑ Porous asphalt and pervious concrete installed under right weather, as per specifications
- ❑ If curbs are built, granular base (A) does not spill over into the GI infiltration area.
- ❑ If adjacent construction, permeable surface is properly protected.

**For Pervious Concrete:**

- ❑ CA has signed off on concrete producer certification.
- ❑ CA has approved proposed concrete admixtures and proposed fibres.
- ❑ Before installation, CA has signed off on results of trial section tests.
- ❑ CA has been notified in writing of the intent to place the pervious concrete pavement 3 Business Days prior to the start of the placing.
- ❑ Washout area for concrete trucks provided; located away, downstream, from the GI.
- ❑ Pervious Concrete Certified Person responsible for installation
- ❑ Installation equipment as per specifications
- ❑ Prior to any work, all surfaces cleaned of loose foreign material.
- ❑ Edge restraints as per the tender package
- ❑ Ready mix moisture certified on site, prior to placement, and verified frequently through installation process.
- ❑ Slump at time and point of discharge is 20-50mm
- ❑ Granular material is not disturbed or displaced during concrete placing.
- ❑ Upper layer of the washed stone wetted prior to placement of the pervious concrete.
- ❑ Pervious concrete is uniform in consistency and placement continuous.
- ❑ Ready mix pre-leveled with rakes.
- ❑ Individual loads of concrete completed/ managed as per specifications.

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- ❑ Fog moisture added with pressure mister over surface of concrete while awaiting the plastic cover (do not use ready mix truck hose).
- ❑ Moisture vapour barrier installed immediately after compaction.
- ❑ Concrete wetted to avoid sticking of the plastic.
- ❑ Cover plastic is nailed and not weighted down with dirt or other material.
- ❑ Curing during at least 7 days with concrete covered, without traffic.
- ❑ Joints implemented as per specifications with specified equipment.
- ❑ Joints have the right width and depth.
- ❑ Overall concrete placement is certified by a product representative.
- ❑ Surface swept, prior to testing for compliance
- ❑ CA signed off on all aspects of sampling and testing post installation.

**For Permeable Pavers:**

- ❑ Ticket verified before bedding aggregate is downloaded from the truck.
- ❑ Aggregate has no fines (i.e. no dust clouds when downloaded from the truck).
- ❑ Bedding depth conforms to design, and it is uniform across the GI feature.
- ❑ Leveling verified with 3-metre straightedge: gaps between straightedge and bedding surface are not greater than 10 mm at any point.
- ❑ Plate vibrators are not used for levelling.
- ❑ Bedding layer is not compacted.
- ❑ Sizes/ type of pavers and joints width conform to the tender documents.
- ❑ Cracked/ broken pavers discarded and replaced prior to filling void spaces.
- ❑ Edges of pavers set into concrete or other abutment as per design.
- ❑ Edge pavers cut with wet saw, in designated area, away from the GI area.
- ❑ Cut pavers installed to edges of the practice before compaction of completed sections takes place.
- ❑ Tampering performed after the installation of the pavers.
- ❑ Pavers' elevation exactly as per the tender documents.

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- ❑ Paver pattern conforms to the tender documents (and directions from manufacturer).
- ❑ Joint aggregate ticket verified before downloaded from the truck.
- ❑ Joint aggregate is free of debris and fines. There should be no dust clouds when downloading from the truck.
- ❑ Rock chips, as per specifications, installed between surface voids.
- ❑ Material tamp vibrated into the joint.
- ❑ Permeable pavers compacted at least twice with plate compactor.
- ❑ For tampering, rubber pad is attached beneath the metal tamper plate.

**For Porous Asphalt:**

- ❑ Only binders and oils specified in the tender package are used
- ❑ Job-mix formula approved by CA.
- ❑ Choker course approved by CA prior to placing of porous asphalt mix.
- ❑ Specifications for transport of mix followed by Contractor
- ❑ Tack coat material and the application rate as per the tender package.
- ❑ Asphalt mix is not placed on wet surface.
- ❑ Verify that asphalt thickness, grades and lines are as specified on the contract drawings.
- ❑ Joints are as per specifications.
- ❑ Only binders and oils specified in the tender package are used.
- ❑ Sufficient number of rollers of type and weight to obtain the necessary compaction of the porous asphalt mix, as per specifications.
- ❑ Compaction of the asphalt is as per specification.
- ❑ Irregularities are corrected before completion of rolling.

End of Checklist

## Checklist F6: Final Grading (before planting)

Inspector to verify:

- ❑ All depths, slopes and elevations as per the design drawings.
- ❑ Inlet elevation is below hard surface elevation for the stormwater to enter the GI.
- ❑ After soil settlement, finish grade of the GI feature is below the inlet.
- ❑ Inlet, pre-treatment device, outflow and overflow structures, underdrains/ perforated pipes, stormwater trenches are not obstructed.
- ❑ Outflow/Overflow structure is not full of water.
- ❑ Monitoring well is in good condition and has a cap.
- ❑ Installed material is protected from compaction.
- ❑ If the growing medium becomes compacted, contaminated or eroded, the damage is repaired.
- ❑ In-situ compaction testing of growing medium is conducted prior to planting
- ❑ Plant material is not delivered to site until areas have been prepared for planting.
- ❑ Mulch, additional erosion control and vegetation installed immediately after final grading (see next phase, “Checklist F7: Mulching and Planting – Vegetated GI”).

End of Checklist

## Checklist F7: Mulching and Planting

Inspector to verify:

- ❑ Plantings take place during season/ months specified in the design.
- ❑ Water removed and soils allowed to dry before mulch placement and planting.
- ❑ Plants look healthy before and after planting.
- ❑ Plant species, their location and spacing is as per design.
- ❑ CA signed off on any plant substitutions and new planting plan.
- ❑ Mulch free of bark, soil, green material and debris.
- ❑ Mulch depth is as per tender documents.
- ❑ Sod is installed 5cm below the top of adjacent hard surface.
- ❑ All depths, slopes and elevations as per the design drawings.
- ❑ After soil settlement, finish grade of the GI feature is below the inlet.
- ❑ Overwintering techniques implemented, if GI feature and adjacent construction not completed and stabilized by cold temperatures,

*Note: Grades to be verified before and after planting.*

End of Checklist

## Checklist F8a: End of Construction Inspection and Verification of Substantial Completion

Inspector to verify:

- ❑ Growing medium post-installation test results have been approved by CA.
- ❑ Temporary runoff diversion measures are removed, and runoff can flow into the system (the surrounding area has been stabilized before).
- ❑ Level loggers are installed in the monitoring wells, as per specifications.
- ❑ System has been constructed as per design; red-line/ as-built drawings reflect approved deviations.
- ❑ All components are in good state without structural damage. No construction sediment/ trash/ debris is obstructing flow.
- ❑ Monitoring well has a cap.
- ❑ Check dam structures are not missing, and sediment has been removed.
- ❑ Grading/ elevations verified once more. Water can flow into the GI feature.
- ❑ No differential settlement, cracking, or other grade abnormalities.
- ❑ No erosion gullies or bare soil areas.
- ❑ For Stormwater Trenches, pavement surface in good condition. No differential settlement, cracking or other grade abnormalities at tree opening or over covered soil trenches.
- ❑ Overflow/outflow structures are not full of water and have grates.
- ❑ Vegetation is healthy and watered thoroughly by the contractor.
- ❑ Photos are taken to document the constructed GI and vegetation state.
- ❑ Infiltration testing is conducted by contractor in the presence of the CA
- ❑ Contractor understands vegetation maintenance needs during warranty period.

End of Checklist

## Checklist F8b: End of Construction Inspection and Verification of Substantial Completion

Inspector to verify:

- ❑ No standing water on the permeable pavement or visual evidence of frequent ponding, such sediment accumulation or staining on the surface.
- ❑ No damaged, missing or displaced pavers, ruts or local sinking present.
- ❑ No structural damage in the overflow/outlet structure, grate is not missing, and no sediment/ trash/ debris obstructing the outflow.
- ❑ Overflow/outlet structure is not full of water.
- ❑ Surrounding area stabilized before temporary flow diversion measures are removed.
- ❑ Temporary runoff diversion measures removed. Runoff can flow into the system without obstruction
- ❑ Monitoring well in good condition.
- ❑ Level loggers installed in the monitoring wells, as per contract documents, if applicable.
- ❑ Monitoring well has a cap.
- ❑ Overall system constructed as per design specifications and drawings, and as-built drawings reflect any approved deviations.
- ❑ All components including pre-treatment measures, outflow and overflow structures, monitoring well and trench drains are in good state without structural damage. Construction sediment/ trash/ debris, has been removed, and water flow is not obstructed.
- ❑ Leveling of porous asphalt and pervious concrete, verified with straightedge, as per specifications.
- ❑ Transition to adjacent impervious asphalt pavement is merged neatly with flush, clean lines.
- ❑ Finished pavement is even, without pockets, and graded to elevations shown on the Contract Drawings.
- ❑ For porous concrete, acceptance should be based on QA testing and visual inspection by the CA, as per the specification.

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- ❑ Infiltration testing is conducted by contractor in the presence of the CA
- ❑ Any contamination of voids cleaned by contractor to CA's satisfaction.

End of Checklist

## Checklist F9: During / After Rain Events

Inspector to verify:

- ❑ No visible standing water in the GI feature after 24 hrs since rain event.
- ❑ Dewatering plan implemented after significant storms if the feature is still under construction.
- ❑ No differential settlement, cracking, or other grade abnormalities.
- ❑ No gullies equal or more than 30cm in length in and around the GI feature.
- ❑ Inlet, pre-treatment device, outflow and overflow structures, underdrains/ perforated pipes, stormwater trenches are not obstructed
- ❑ No sediment accumulated within the soil/ mulch.
- ❑ Runoff is draining towards the GI feature (inlets or permeable pavement)

End of Checklist

## Checklist F10a: Warranty Period

Inspector along with TS O&M staff to verify the following items.

The following GI components are verified and photographed:

**GI Surrounding Area:**

- ❑ No excessive trash, debris or sediment.

**Outlet:**

- ❑ No structural damage of the monitoring well, and sediment clog is not visible or impairing GI function.
- ❑ Monitoring well is not missing the cap.
- ❑ No structural damage to the overflow outlet structure and no sediment/trash/ debris obstructing outflow.
- ❑ Overflow outlet structure is not full of water, and the grate is not missing.

**Inlets:**

- ❑ No damage to inlet or pretreatment.
- ❑ No obstructions to inflow.
- ❑ No visible gullies or bare soil areas ≥ 30cm in length.

**Perimeter:**

- ❑ Dimensions do not differ by >10% of as-built drawings.
- ❑ No visible gullies or bare soil areas ≥ 30cm in length.

**Filter Bed (Growing medium/ soil) Surface**:

- ❑ Standing water is not ponded on the surface for more than 24 hours after the end of a storm.
- ❑ No trash impairing aesthetics or function.
- ❑ No visible gullies or bare soil areas ≥ 30cm in length.
- ❑ average mulch depth is not <5cm or >15cm, and there are no visible bare soil areas.
- ❑ Surface has not sinked significantly, and animal burrows are not visible.
- ❑ Check dams' structures (if applicable) are not missing or buried in sediment.

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**Planting Area**

- ❑ No less than 80% of planting area is covered by living, healthy vegetation.
- ❑ vegetation is not over-grown or over-crowded and it is not impairing aesthetics or obstructing sight lines.
- ❑ No more than 20% of the vegetation is undesirable (i.e. weed or not in planting plan).

End of Checklist

## Checklist F10b: Warranty Period – Hard Surface GI

Inspector along with TS O&M staff to verify the following items.

The following GI components are verified and photographed:

**GI Surrounding Area:**

- ❑ No excessive trash, debris or sediment.

**Outlet:**

- ❑ No structural damage of the monitoring well, and sediment clog is not visible or impairing GI function.
- ❑ Monitoring well is not missing the cap.
- ❑ No structural damage to the overflow outlet structure and no sediment/trash/ debris obstructing outflow.
- ❑ Overflow outlet structure is not full of water, and the grate is not missing.

**Surface Layer:**

- ❑ No standing water on the permeable pavement or visual evidence of frequent ponding, such sediment accumulation or staining on the surface.
- ❑ No damaged, missing or displaced pavers, ruts or local sinking present, if applicable.
- ❑ Paver joint fill not missing or low. No weed growth between pavers which is extensive or impairing aesthetic value.
- ❑ If repairs are required, :
- ❑ Non-porous materials are not used to seal or repave.
- ❑ Portions of the surface that are below acceptable infiltration rates are reconstructed.
- ❑ Potholes and cracks repaired using conventional, non-porous patching mixes do not exceed a cumulative area of 10% of the permeable paved area.

End of Checklist