LOW IMPACT DEVELOPMENT

CONSTRUCTION GUIDE

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Photo: Permeable pavement and bioretention planter retrofit to Elm Drive in the City of Mississauga.

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LISTS OF ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
BMP	Best management practice
CA	Conservation Authority
CSA	Canadian Standards Association
CVC	Credit Valley Conservation
CWP	Center for Watershed Protection
ESC	Erosion and Sediment Control
GGHA	Greater Golden Horseshoe Area
HSG	Hydrologic Soil Group
LID	Low Impact Development
MNR	Ontario Ministry of Natural Resources
MOE	Ontario Ministry of the Environment
OPSS	Ontario Provincial Standard Specification
SWMP	Stormwater Management Practice
SWM	Stormwater Management
TRCA	Toronto and Region Conservation Authority
U.S. EPA	United States Environmental Protection Agency

PREFACE

Some stormwater management professionals are now familiar with LID practices and have experienced barren bioretention cells containing stagnant water or an infiltration basin with an outlet installed incorrectly. These failed or diminished stormwater management practices can be the result of plans without sufficient construction details and instruction or contractors that do not understand the technology or function of certain procedures, materials, and erosion and sediment control.

Low Impact Development (LID) is a new approach in stormwater management and urban design for Ontario. In order to provide state-of-the-art information on construction of LID practices for engineers and contractors, Credit Valley Conservation (CVC) has teamed up with a U.S. consultant, Emmons & Olivier Resources, Inc. (EOR), to develop a *LID Construction Guide* and the *Contractor's and Inspector's Guide for LID (C&I Guide)*. This *LID Construction Guide*, in conjunction with the *C&I Guide,* is based on EOR's years of LID design and construction experience. The goal of this document is to guide the proper construction of LID designs, and, ultimately, the success of LID throughout Ontario.

Despite the fact that the engineering field has embraced LID over the last five years in Ontario, it is imperative that the design engineer understands and embraces the uniqueness of LID form and function in the eyes of the contractor.

The subject matter includes:

1. Overview and highlights of existing related guidance, common LID construction errors and considerations organized by construction stages and case studies.
2. Discussion of how construction procedures and sequencing of LID sites differs from conventional sites and how to protect LID practices through all phases of construction.
3. Recommendations on improving contracts, plans, specifications and communication to avoid construction errors.

Uneven settling caused failure of these pervious pavers that were used in a heavy traffic, urban setting.

1. INTRODUCTION

Early in 2010, Credit Valley Conservation (CVC) in partnership with the Toronto and Region Conservation Authority (TRCA) produced the Low *Impact Development Stormwater Management Planning and Design Guide*. The guide was developed to provide engineers, landscape architects, designers, ecologists and planners with up-to-date information and direction on the design of low impact development (LID) stormwater management (SWM) practices, and thereby help ensure the continued health of the streams, rivers, lakes, fisheries and terrestrial habitats in the CVC, TRCA watersheds and throughout Ontario.

LID is a comprehensive stormwater management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution by managing runoff as close to its source as possible. Unlike end-of-pipe controls, LID practices are an integral part of the urban form and require a different approach to construction. The Center for Watershed Protection survey in the James River watershed found in a survey of 72 BMPs approximately half (47%) deviated in one or more ways from the original design. Good designs can have poor specifications, and contractors and inspectors are often inexperienced in the construction of LID practices. Critical to success of sound LID designs is proper construction.

Developers have grown accustomed to practices such as site-wide mass grading, stormwater ponds and associated infrastructure, and using ponds for temporary sedimentation. This approach is rarely conducive to successful LID designs. Given LID is part of the urban form, implementation requires attentiveness throughout the construction process to LID practices, their location, intended function, and protection from sedimentation and compaction. The stabilization of the contributing sub-watersheds becomes critical to the success of LID features, as is their unique outlet configurations and specified materials.

Credit River flowing into Lake Ontario.

BMPs in construction:
Top - underground storage units
Middle - green roof installation
Lower - infiltration trench

1.1 ABOUT THIS DOCUMENT

The Low Impact Development (LID) Construction Guide and the *Contractor's and Inspector's Guide for Low Impact Development* (C&I Guide) were conceived in concert to target specific audiences and address the practical need for successful construction of LID SWM practices.

This effort complements the existing guidance documents in the region, *Greater Golden Horseshoe Erosion and Sediment Control Guidelines for Urban Construction* and the CVC/TRCA *Low Impact Development Stormwater Management Planning and Design Guide*. The *LID Construction Guide* will reference content in these documents, but will not restate that content. It is intended to build upon previously created materials.

The purpose of the *LID Construction Guide* is to alert design consultants, municipal engineers, plan reviewers, and construction project managers of the common LID construction failures and how to avoid them, to bridge the gap between the design and construction of LID. The sticking point for the designer is to understand and embrace the uniqueness/newness of LID form and function in the eyes of the contractor, and from this standpoint, to develop specifications that are clear and thorough so as to prevent construction error to the maximum extent possible.

Communication may be one of the most important tools in implementing LID plans into the landscape. Traditionally sub-contractors have been separate and isolated throughout the construction process. However, LID requires that critical information be passed along as the construction process moves from excavation, to utility construction, to street construction, to building construction, to final landscaping and stabilization. Key communication moments will be highlighted periodically throughout this document to alert designers and provide guidance on methods and content of communication strategies.

The *LID Construction Guide* will include:

- Chapter 1 Introduction: Introduces the *Designer's Guide* and the *C&I Guide* and presents the need for them.
- Chapter 2 Related Documents summarizes the content of existing related guidance documents for easy reference. Some of the following chapters in the *Designer's Guide* will reference content in these documents, but will not restate that content.
- Chapter 3-15 Common LID presents the LID construction process from Verification of Siting and Design to Certification and takes the designer through all phases of construction and identifies those activities most likely to result in failure. The DOs and DON'Ts of LID construction are identified based on LID implementation to date through use of photographs of actual construction projects, companion narratives, and sidebar notes highlights common mistakes and provides a quick overview for the designer.
- Appendix Case Studies provides an additional means of communicating the issues associated with LID construction. Additional case studies on LID construction and overcoming implementation barriers are posted to the CVC website (www.creditvalleyca.ca).

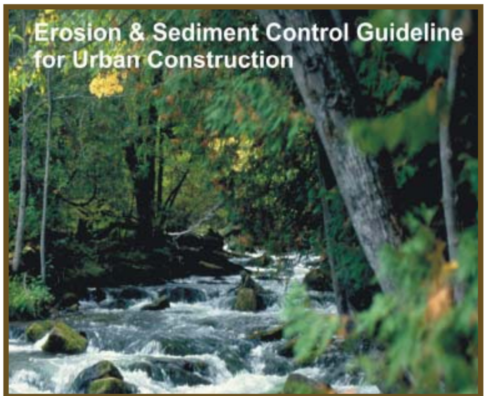
The companion *C&I Guide* targets contractors in the field, foremen, and construction site inspectors. The *C&I Guide* parallels this document, but is developed as a practical guide for the field in size and shape. Guidance is delevered through graphics and photographs illustrating the DOs and DON'Ts of construction techniques. The Field Guide also provides hands-on checklists to guide proper LID Construction.

Preparation of pedestrian, nature trail with proper erosion control established during construction.

2. RELATED RESOURCES

The following documents complement CVC's *LID Construction Guide* and *C&I Guide*. Practitioners are encouraged to review these guidance documents as companion tools for LID planning, design and implementation. These guides will be referenced throughout CVC's *LID Construction Guide* and *C&I Guide*. All of these resource documents can be downloaded at: http://www.creditvalleyca.ca/low-impact-development.

2.1 Greater Golden Horseshoe Erosion and Sediment Control Guideline for Urban Construction



Cover of the ESC Guidelines

The *Greater Golden Horseshoe Area Conservation Authorities Erosion and Sediment Control Guideline for Urban Construction* (*ESC Guidelines*) includes best management practices from all various erosion and sediment control (ESC) guidelines currently applied by municipal and provincial agencies within the Greater Golden Horseshoe Area (GGHA) with additional information from various sources. The guidelines are related solely to ESC at urban construction sites in the GGHA and provide a consistent approach to ESC in the GGHA that provides practitioners with greater certainty.

A key component of the *ESC Guidelines* is an ESC plan, which is as an integral part of the final detail design and approval submission for a project. The *ESC Guidelines* presents methods to develop dynamic ESC plans by combining environmental site conditions with all construction elements required for an undertaking.

The ***ESC Guidelines*** include the following:

- A review of erosion and sedimentation processes;
- An overview of the current regulatory framework in which ESC is reviewed including a consolidated statement of regulatory requirements and expectations regarding ESC;
- Clarification of the roles and responsibilities for all regulatory agencies, land owners, developers, builders, contractors and consultants involved in the construction process;
- Identification of the elements of an effective ESC plan;
- Methods to employ the routine ESC measures more effectively to protect natural environments within an urban construction project;
- Methods to prevent erosion and minimize sediment transport through the multi-barrier approach;
- Improved inspection, monitoring and maintenance protocols.

2.2 Greater Golden Horseshoe Erosion and Sediment Control Inspection Guide

The *Greater Golden Horseshoe Erosion and Sediment Control Inspection Guide* (*ESC Inspection Guide*) is intended for use as a quick reference to aid environmental inspectors in their day-to-day work. It is a brief companion document to the *ESC Guidelines* and should be used in conjunction with the *ESC Guidelines*.

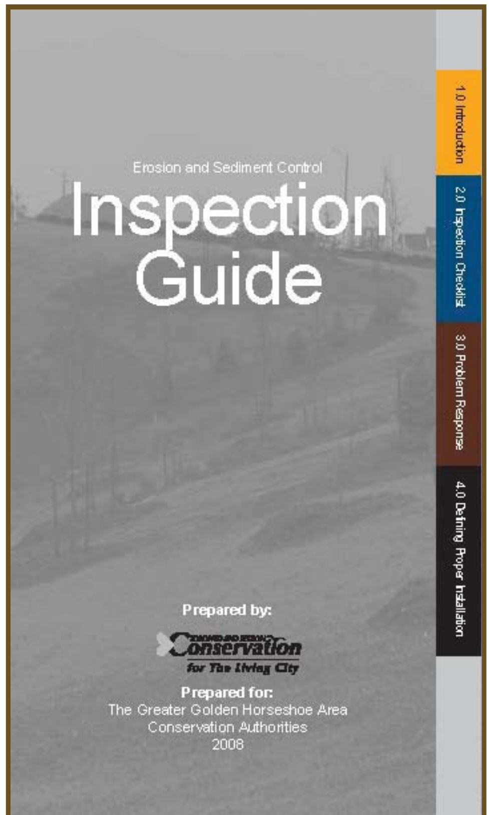
- An inspection checklist for each of the most common ESC practices.
- Discussion of roles and responsibilities and proper communication of findings.
- Brief problem response guidance and directory.
- A summary of proper installation of several ESC practices based on the ESC Guidelines.

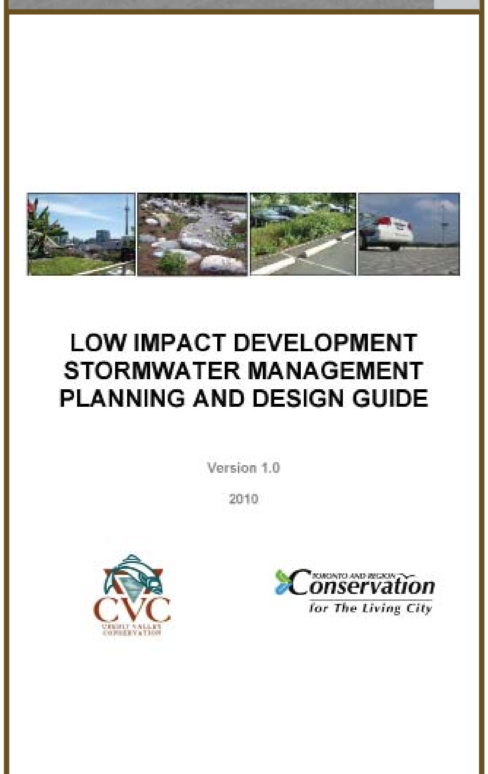
2.3 LID Stormwater Management Planning and Design Guide

The *Low Impact Development Stormwater Management Planning and Design Guide* (*LID SWM Guide*) provides engineers, ecologists and planners with up-to-date information and direction on the design of Low Impact Development (LID) stormwater management (SWM) practices. The *LID SWM Guide* is intended to augment the Ontario Ministry of the Environment's 2003 *Stormwater Management Planning and Design Manual*, which provides design criteria for conventional stormwater management practices such as wet ponds and constructed wetlands.

The ***LID SWM Guide*** includes the following:

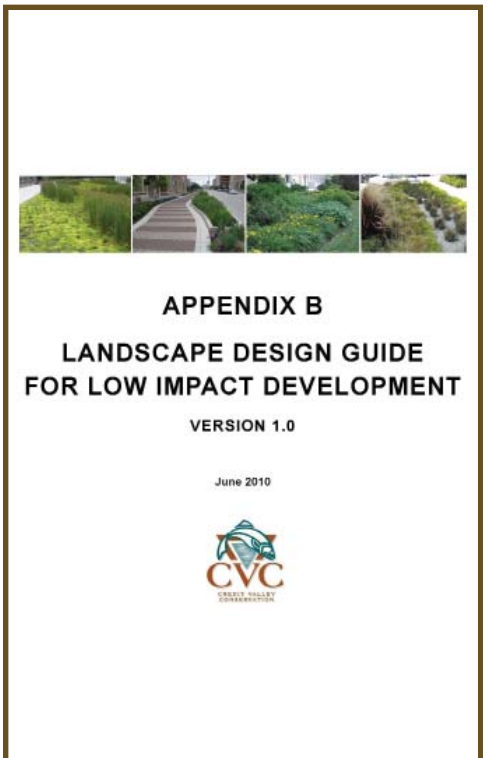
- an overview of why the guide has been developed, reviewing the environmental impacts of urbanization and the current planning framework for SWM in Ontario.
- SWM facility planning and design integration into the development planning process.





Covers of the CVC
ESC Inspection & LID Guides

- Examples of opportunities for integrating landscape-based stormwater management at various planning scales and stages in the process.
- Design of Structural Low Impact Development Practices for Stormwater Management
- Compliance, performance and environmental effects, and monitoring programs, as they relate to SWM systems.
- Useful references, fact sheets, guidelines, and protocols are found in the appendices.



Cover of the CVC Landscape Design Guide for LID

2.4 Landscape Design Guide for LID

The *Landscape Design Guide for Low Impact Development (LID Landscape Design Guide)* is presented as Appendix B of the *LID SWM Guide*, because of the unique importance of vegetation in LID. It provides support related to the plant selection and design of vegetated LID practices and provides land managers and professional practitioners with an understanding of the guiding principles of LID planting design, implementation and management including the following content:

- General guidance and principles of landscaping for LID.
- Individual LID practice planting guidance including plant species lists, discussions of site characteristics, construction guidance and maintenance guidance.
- A master plant list identifying individual species characteristics for each site's unique characteristics.

3. VERIFICATION OF SITING AND LID PRACTICE DESIGN

Working with the features of the site is the backbone of LID. If the designer has used the *LID SWM Guide* as the basis for stormwater design, they may have already reduced the risk of failure. However, one of the most commonly overlooked items in LID is physical site inspection to verify siting and design assumptions. Additionally, translation of design documents and transitioning to construction can provide new challenges that will require communication between the designers and contractors throughout the design and construction process.

Because of the inherent nature of LID that requires interactions between all aspects of the landscape, understanding the site is critical. Physical site inspection is one of the most overlooked aspects of LID design and construction but is a critical step in understanding aspects of a site that can't be learned from CAD or GIS applications. The following items represent some of the most commonly overlooked aspects of LID that have potentially led to failures in the past:

3.1 Site Evaluation and Analysis

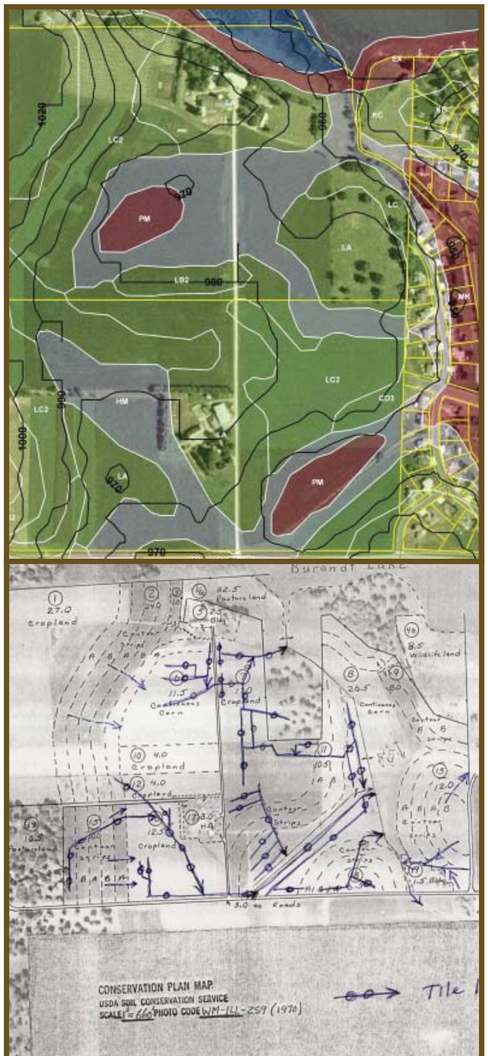
1. **Watershed Information**
   For watershed context, contact the conservation authority or check the conservation authority website for completed plans for the watershed or subwatershed in which your site is located. Understanding the contributing catchments to the site is a critical element that is often times overlooked. Too often designers get tunnel vision, focusing only on the site in question without looking at the big picture. Determination and evaluation of the contributing watershed through the use of aerial photography is another tool for identifying adjacent land uses, future development plans, contributing drainage areas, culverts coming to the site, and landscape signatures that aren't picked up in typical surveys.

2. **Topographic Information**
   Topographic contour surveys created by aerial photography and LIDAR should not be relied upon for design. Topographic surveys with contours of 0.1 m measured to an accuracy of 0.01 m accuracy are preferred.

THINGS TO REMEMBER:

Key aspects of field verification:

- Designer site visit
- Soil borings and test pits
- Understanding the site's context
- Knowing contributing watersheds
- Knowing the receiving waters of the site
- Preserving key landscape features
- Contact municipality and/or conservation authority for top of bank and natural feature boundaries



Mappings of hydrologic soil group above and drain tile location runs below

3. **Surficial Geology**
   Surficial geology mapping can many times give the designer a general indication of soil characteristics such as permeability and anticipated depth to seasonal high groundwater table. This information can guide the layout and placement of potential practices. However, detailed design should be based on soil borings or test pits, and not rely on information from soil geology mapping alone.

4. **Hydrologic Soils Groups (HSG)**
   The surficial geology mapping is complimented by the Hydrologic Soil Group mapping of the site which will give the designer a better idea of the soils that will be encountered at the surface. This information can be used for conceptual layout, but will need to be verified by BMP site-specific soil borings collected in the field and lab analyzed.

5. **Steep Slope/Erodible Soils Analysis**
   By combining the topographic and soils information the designer can begin to develop a strategy for protecting these areas during construction as well as knowing where to avoid placement of LID practices to minimize long term problems created by erosion and sedimentation. Contact the conservation authority to confirm any requirements pertaining to stable slope lines and setbacks.

6. **Wetland Inventory and Delineation**
   The HSG mapping and aerial photography can give the designer insight into existing and drained wetlands, but natural features should be determined and field verified with the appropriate agencies. A wetland boundary delineation may be required to establish development constraints and address permit requirements.

7. **Drain Tile Mapping**
   Many sites have wetlands that have been drained by using draintile. Many times these systems are linked together through natural drainage ways, which will create a domino effect if one link of the system is altered. A thorough understanding of these systems and their effect on the watershed is necessary to avoid problems during construction.

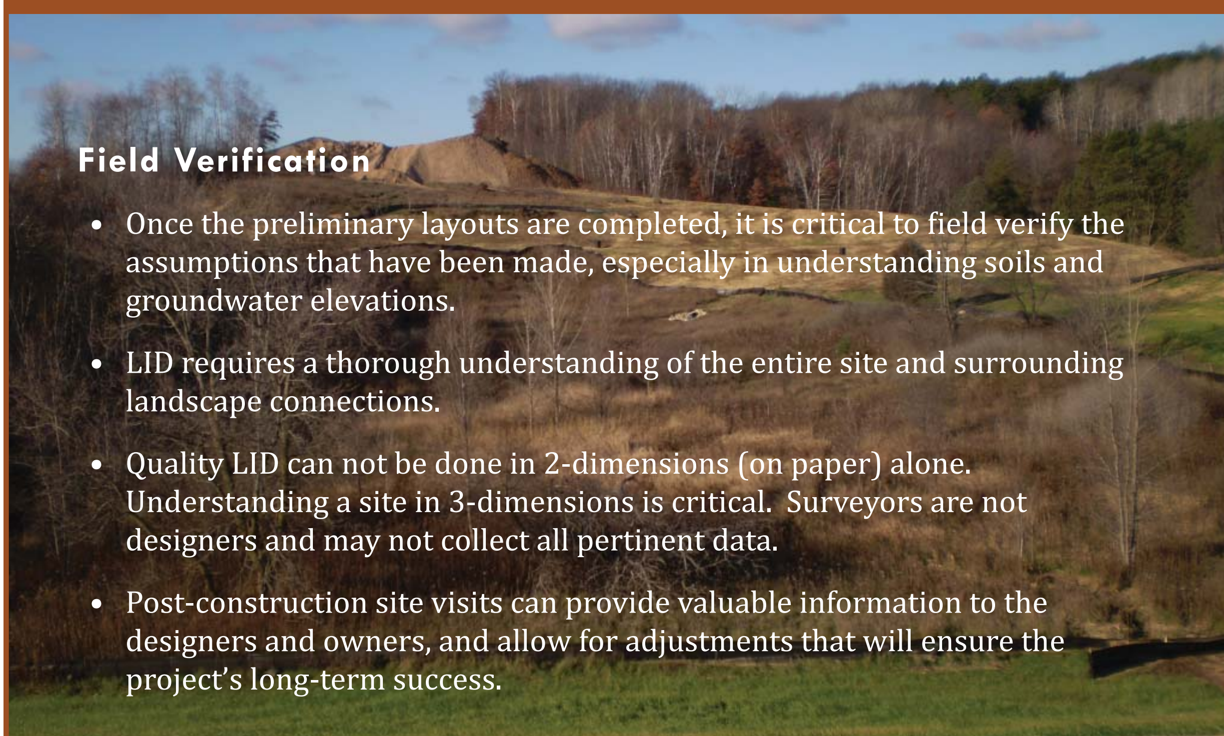
8. Stream and Receiving Waters Survey

If the site has stream or other water features, a field survey of their condition will reveal potential problem areas and help to develop protection strategies for the final design. Alterations to one site can have detrimental effects to downstream receiving waters. Understanding the characteristics of, and management targets for the watercourse or waterbody that will ultimately receive drainage from the site is also an important starting point. For example, if the receiving water provides habitat for cold-water or endangered species, special requirements for timing of construction and the types of SWM and ESC controls to be put in place may apply. Consultation with the Ministry of Natural Resources (MNR) may be required to address requirements under the Endangered Species Act.

9. Tree Inventory

Developers have said that one mature tree is worth thousands of dollars in property value. Many times projects are designed around mature vegetation and knowing where these trees are can help the designer implement their protection into the final design. A certified arborist and/or ecologist should be engaged to assist with establishing a tree protection plan. At a minimum, the dripline of the tree should be used as limit not only for grading, but to exclude all traffic including incidental machinery, parking of equipment and supplies. Compaction can readily occur from storing heavy equipment over the root zone, and often can be as detrimental to tree health as grading damage. The municipality or region may also have tree bylaws to be addressed.

IMPORTANT:



Field Verification

- Once the preliminary layouts are completed, it is critical to field verify the assumptions that have been made, especially in understanding soils and groundwater elevations.
- LID requires a thorough understanding of the entire site and surrounding landscape connections.
- Quality LID can not be done in 2-dimensions (on paper) alone. Understanding a site in 3-dimensions is critical. Surveyors are not designers and may not collect all pertinent data.
- Post-construction site visits can provide valuable information to the designers and owners, and allow for adjustments that will ensure the project's long-term success.

10. Hot Spots

Areas of past contamination should be investigated and addressed during design. However, unknown contamination may be uncovered during site excavation and the design may need to be modified to accommodate. Rerouting stormwater BMPs, scaling a BMP back in size, and modifying infiltration BMPs to filtration features may be needed.

3.2 Borings and Test Pits

As recommended in the Site Evaluation and Soil Testing Protocol for Stormwater Infiltration in Appendix C of the *LID SWM Guide*, more detailed soil investigations should be conducted following the development of a preliminary plan for the proposed development. Soil borings and/or test pits are one of the most important pieces of information to gather for LID infiltration practices, but are also one of the most prone to error or inadequate information. Soils information is critical to understanding infiltration potential which will, in-turn, influence the type and location of the practice used, its size, and final vegetation selection. Specifics regarding soil infiltration testing, including safety precautions, are described in detail in Appendix C of the *LID SWM Guide*. General guidelines for test pit and soil borings include:

1. Location and Number

Soil conditions can vary dramatically across a site test pit and borings should be located to provide representative coverage of the proposed practice area, collected from within the proposed feature footprint.

Infiltration BMP Area (m^2)	Number & Type
< 50	1 test pit and 1 soil boring
50 - 900	2 test pits or 1 test pit & 2 soil borings
> 900	(2 test pits or 1 test pit & 2 soil borings / 450 m^2) Conducted equidistantly
Linear	1 soil boring | 50 m 1 test pit | 450 m

2. Depth

Borings and test pits should be extended to a minimum depth of 1.5 metres below the subgrade elevation of LID practices that rely on infiltration. If larger scale infiltration features are being considered, (>900 sq. meters) deeper borings/ test pits from 2-6 metres should be considered.

3. Identification

Locations should be identified by GPS coordinates. All material penetrated by the boring or test pit should be identified, as follows:

- Description, logging, and sampling for the entire depth of the boring.

- At each test location, the following conditions should be noted and described:
  - → Soil horizons (upper and lower boundary);
  - → Soil texture and colour for each horizon;
  - → Any stains, odors, or other indications of environmental degradation;
  - → Depth to water table (including perched water table);
  - → Color patterns and observed depth (mottled or gley soils may indicate the seasonally high water table);
  - → Depth to bedrock (if encountered);
  - → Observations of pores or roots (size, depth);
  - → Estimated type and percent coarse fragments;
  - → Hardpan or other limiting layers; and
  - → Strike and dip of soil horizons.
- At the designer or geotechnical engineer's discretion, soil samples may be collected at various horizons for additional analyses. A grain size analysis, either alone or in conjunction with a hydrometer analysis, is recommended for the least permeable layer below the bottom of the proposed practice.
- Water levels in all borings should be taken at the time of completion and again 24 hours after completion. The boring should remain fully open to total depth of these measurements.

4. **Infiltration Testing**
Infiltration testing methods include the Guelph permeameter test, double-ring infiltrometer test, borehole permeameter test, and percolation test. At least one test should be conducted at the proposed bottom elevation of the infiltration BMP, plus additional tests at every other soil horizon encountered within 1.5 metres below the proposed

Drilling soil bores above, samples of drilled cores below.

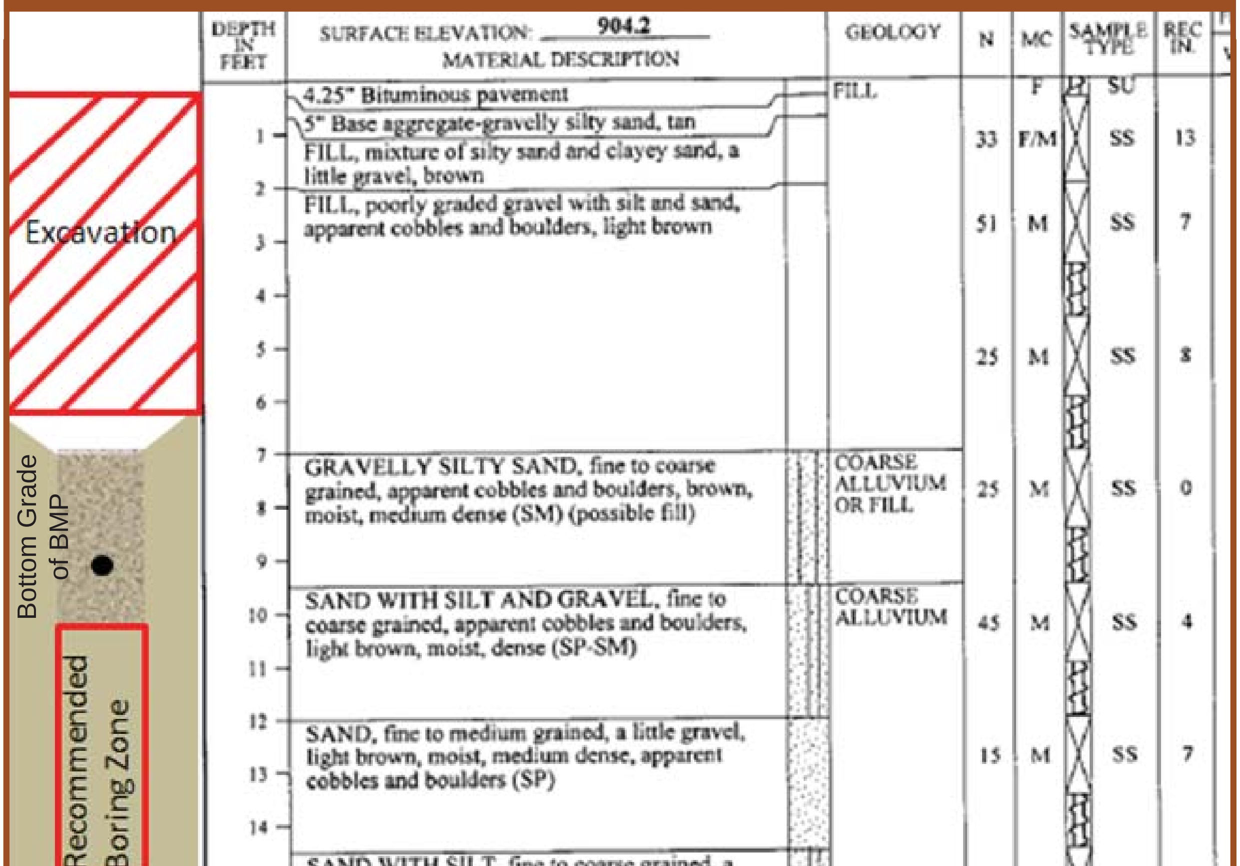
bottom elevation. A minimum of two tests per test pit are recommended. More tests are warranted if results from the first two tests are substantially different. Further information on infiltration test result interpretation and safety correction factors can be found in Appendix C of the *LID SWM Guide*.

3.4 Final Design

Once the preliminary design consideration are confirmed, It is recommended that the consultant contact review agencies before moving into the final design phase. There are still a number of siting issues to be considered.

1. **Setbacks**
   Certain infrastructure and environmental resources will influence where a practice can be sited. The type and scale of the practice relative to the location specific factor will determine the setback. Consult local conservation authority for requirements pertaining to setbacks.

IMPORTANT:



Soil borings and test pits should extend a minimum of 1.5 metres below the bottom grade of the infiltration BMP, not the current grade.

Infiltration practices are often integrated into site plans and in close proximity to buildings, roads, or other hard surfaces. Care should be taken not to create vectors for water migration to adjacent infrastructure. Setback considerations should be given to all, but not limited to the following, factors:

- Buildings
- Utilities
- Structures
- Sinkholes
- Wetlands
- Steep slopes and valleylands
- Septic systems
- Roads
- Floodplain
- Watercourses
- Stream erosion
- Meander belt
- Lake shorelines
- Drinking water wellhead protection areas
- Environmentally sensitive lands

2. Sequencing and access

Construction sequencing is one of the most important aspects of successful LID and should be addressed in design drawings and specifications. BMPs are often not finalized until the contributing drainage area is stabilized – a construction access route or strategy needs to be provided to finalize BMP construction in a "finished" landscape.

The use of LID locations for temporary sediment basins during construction should be avoided whenever possible. LID facilities should be protected and kept offline until the contributing drainage area is stabilized. If the facility has to be used as a temporary sediment basin during construction, then steps should be taken to protect the facility while allowing it to provide temporary sediment control services. Potential techniques can be found in Chapter 6 Mass Grading.

THINGS TO REMEMBER:

Protecting Adjacent Infrastructure

- Minimum setback from buildings, as outlined in the *LID SWM Guide*, is 4 metres for infiltration practices.
- Impermeable liners can be used to protect adjacent infrastructure when setbacks are encroached upon.
- In retrofit applications older foundations and infrastructure may require greater attention due to greater susceptibility to water penetration from increased subsurface hydrology.

3. **Inline vs. Offline**

   Runoff can be delivered to LID BMPs inline or offline from the catchment's drainage system - see *LID SWM Guide* for further discussion on inline vs. offline. There are several advantages to placing the facility offline, which allows runoff to bypass the facility when it is full.

   Because of the ability to keep runoff out of the facility, offline BMPs are easier to: protect during construction, establish plugs and/ or seeded areas, and provide necessary repairs or maintenance. Additionally, very large events with high velocity flows are kept out of the facility, protecting the BMP from erosion and excessive flooding if outlet is clogged or overwhelmed.

4. **Pretreatment**

   Pretreatment of runoff to reduce sediment delivery to the LID practice is an important element in the long term success of LID practices. How post construction runoff will be treated before delivery to the practice should be a primary consideration in the final siting of these practices.

IMPORTANT:

Offline Benefits

Offline practice only allows the designed volume to enter and be treated - larger storms are bypassed.

Offline facilities can be kept offline during construction and vegetation establishment. A wooden board placed behind the curb cut keeps runoff away during construction.

IMPORTANT:

Pretreatment Strategies

1. Use Vegetation

Vegetation can be an effective pretreatment strategy if sized correctly. Vegetation as pretreatment functions more effectively in areas with more dispersed flow and does not work as well in concentrated flow and sediment areas. Maintenance (sediment removal) can be more difficult in areas of dense vegetation. Vegetative pretreatment can be readily integrated into the landscape design.


turf strip pretreatment


naturalized pretreatment filter strip for bioretention swale

IMPORTANT:

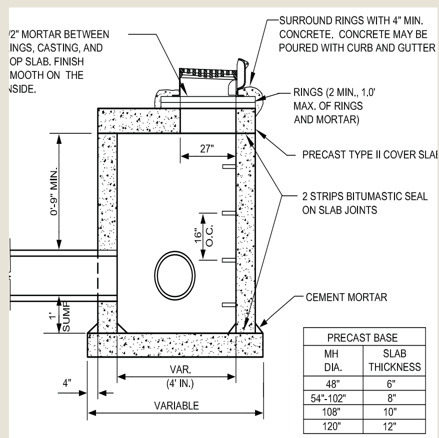
Pretreatment Strategies

2. Integrated Infrastructure

Infrastructure is a good pretreatment option in areas of concentrated flow and sediment accumulation. Infrastructure can be "invisible" such as catch basin sumps, or can be integrated into the design of the BMP. Maintenance is generally more accessible and these types of pretreatment should be strongly considered in BMPs where frequent maintenance is expected.

Hardscape forebays and catch basin sumps:

- highly recommended for ease of long-term maintenance
- may have higher initial costs but lower long-term maintenance costs



Gravel diaphragms and stone splash pads:

- gravel filters sediment, but will need to be replaced periodically
- splash pads prevent erosion but don't pretreat sediment

IMPORTANT:

Pretreatment Strategies

3. Proprietary Devices

Several proprietary devices on the market provide pretreatment. Pretreatment techniques can be the treatment itself - releasing directly to receiving water body, or can pretreat runoff before releasing to another infiltration or filtration BMP. There are numerous pretreatment devices - a sample found below.

Oil and Grit Separator -

Infrastructure based pollutant removal units *(image courtesy of Stormceptor).*

Pretreatment Chamber -

Small scale curb cut, pre-cast structure for easy residential maintenance. *(image courtesy of Anoka Conservation District).*

Underground Storage Pretreatment -

A header row used for pretreatment in larger scale below ground systems *(image courtesy of Triton Stormwater System).*

4. TENDERING AND OWNERSHIP

Many of the critical construction techniques and elements of a LID project are new to experienced and inexperienced contractors alike, and easily misinterpreted and/or inappropriately executed by contractors. A clear set of plans and construction documents, knowledge of intent, and experience with execution are necessary to create long lasting, highly effective BMPs.

1. **Contractor Experience**
   This issue can be addressed through pre-qualification of contractors, subcontractors and vendors. The prime contractor is asked to furnish a list of projects completed with references.

2. **Bid Process**
   Communication is important. Mandatory pre-bid meetings have been successful in attenuating the non-serious bidders and attracting a number of qualified contractors to the project. This meeting is an excellent opportunity for the owner and design team to discuss the intricacies of the project and to get feedback from the contractors on potential changes to plans before the project is opened for bids.

3. **Bid Bond**
   This is another tool that will help assure the contractor pool is reputable by providing a guarantee to the project owner that the bidder will accept the job if selected. The existence of a bid bond provides the owner with assurance that the bidder has the financial means to accept the job for the price quoted in the bid.

4. **Awarding the Tender**
   Once the project is tendered, communication between all parties is essential. The process should begin with a pre-construction meeting that includes representatives of the owner, designer, contractor and all subcontractors, utilities and government agencies and their inspectors. The respective parties should assemble weekly throughout active construction to report, review and keep record of progress.

IMPORTANT:

Pre-Qualifications

Attracting quality contractors to a project is the first step in successful construction. These initial steps can help eliminate non-serious bidders and those without proper experience or skill:

- Bid bonds
- Pre-qualifications of contractors
- Pre-bid meetings
- Lists of projects with references

4.1 Erosion and Sediment Control Report

The development of an Erosion and Sediment Control Report (ESC Report) is a critical element of a successful project. This should be a "living" document that is reviewed at the pre-bid, pre-construction, and weekly construction meetings as well as after storm events. The plan should be amended when inspections indicate ineffective practices or changes to the plan affect the discharge of pollutants. The *ESC Guide* should be looked to for further guidance in developing an ESC report.

The ESC Report should:

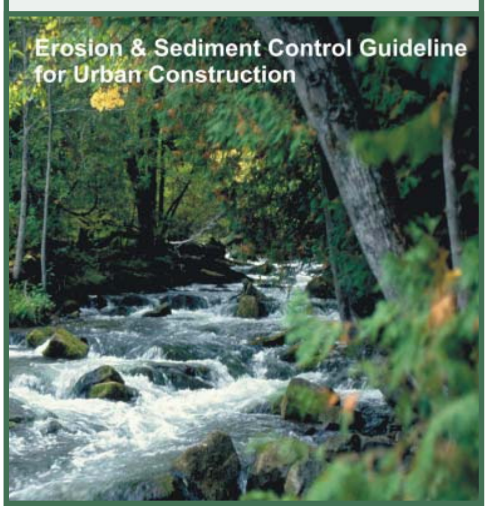
1. Discuss potential sources of sediment and other pollutants on site during the construction process.
2. Identify areas of the site where flows concentrate.
3. Identify who will be responsible to oversee the implementation and maintenance of the practice.
4. Ultimately the responsibility lies with the owner and the general contractor as the owner usually posts a Letter of Credit with the municipality to address such issues and the owner holds back funds from the general contractor. Identify a chain of responsibility between the owner, general contractor, subcontractor and vendors involved in the project. Note: do not discount the vendors, many times problems are the result of a lack of communication between the contractor, vendors, and delivery drivers (i.e. creating mud on the streets and sediment issues).
5. Identify temporary sediment basins and how they will be managed.
6. Identify the permanent stormwater management system and how it will be managed.
7. Identify erosion protection practices such as construction phasing and minimization of land disturbances, vegetative buffers, temporary seeding, sod stabilization, horizontal slope grading, preservation of trees and other natural vegetation, and temporary and permanent vegetation establishment.

HAND OFF MOMENT:

A Living Document

The Erosion and Sediment Control Report is an important tool that should be reviewed and updated by all appropriate parties at hand-off moments.

Inspectors, designers, prime contractors, and sub-contractors should review the *ESC Report* at pre-bid, pre-construction, weekly meetings, and additionally as needed. Updates and changes should be made and communicated throughout the construction team.



8. Identify sediment control practices such as installation and maintenance of perimeter controls, practices to control vehicle tracking, control of temporary soil stockpiles, and protection of storm drain inlets.

9. Identify dewatering and basin draining practices to prevent erosion & scour of discharged water.

10. Identify inspection and maintenance practices to ensure that inspections occur weekly or after individual rainfall events, are routinely recorded, that repairs and maintenance and replacement of ineffective practices are completed in a timely manner - see *ESC Guide* for further guidance.

11. Identify pollution prevention management measures to address proper storage, collection and disposal of solid waste, oil, paint, gasoline and other hazardous materials, and fueling and maintenance areas.

12. Include a strategy for retaining records and who is responsible for them.

4.2 Emergency Erosion and Sediment Control

Additional line items should be included in the bid and construction documents to better protect the ongoing project from unforeseen issues such as large storm events or emergencies during construction. These line item(s) should establish a unit price and/or maximum amount of additional payment if additional erosion control is needed. Including the additional line items should result in tighter bids and more importantly, permit the contractor and owner to better protect the site and investments in real estate. This strategy helps protect the owner, because the contractor will have little reason to avoid addressing erosion and sediment control issues as they arise if they know they will get paid for proper work performed.

THINGS TO REMEMBER:

Emergency Erosion and Sediment Control

- It is often difficult to predict the timing and nature of major storms, and estimate quantities and costs of additional erosion control measures needed for emergency events.
- A separate line item for emergency erosion control provides owner and contractor protection by agreeing on reasonable costs ahead of time and letting the contractor know they will get paid for their extra effort.

4.3 Separate Maintenance Specification

Long-term plant establishment is often included in the construction contract with plant installation. Establishment can extend years beyond construction and has proven to be a logistical headache for both owner and contractor, given that sureties and payments are strung over this period of time. Often, writing a separate specification and contract for the initial installation establishment and maintenance of LID practices is beneficial. This contract typically runs two to five years after completion and can cover the installation, establishment (including watering as necessary) and warranty of plant materials, and initial and extended maintenance of the practices.

4.4 LID Practice Ownership

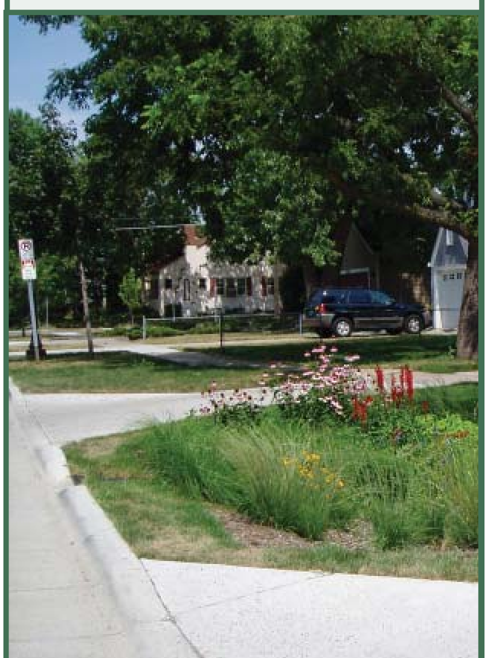
Clearly defined and accepted ownership roles are necessary to improve the aesthetics, function and life-span of all LID practices. Roles prior to, during and post construction should be clearly articulated and understood by all parties and stakeholders. Ambiguity associated with the transfer of responsibility within an organization can be particularly troublesome.

Public projects completed within the right-of-way have posed maintenance challenges for many communities. Some communities are insistent on assuming all maintenance responsibilities and other communities prefer adjacent landowners be responsible for some or all maintenance activities. In both scenarios the party must accept ownership, understand the responsibilities and be able to perform the tasks. Under the landowner responsibility scenario, the community must also have a system for promptly determining when maintenance is not occurring and taking necessary corrective action.

HAND OFF MOMENT:

Ownership

- One of the most important handoff moments is from contractor to owner. Owners are responsible for long-term maintenance and this role should be clearly defined and established prior to construction.
- Often it is unclear who is taking ownership over BMPs that overlap property lines/ appear to be in the public R.O.W. or on private property. The example below is within the R.O.W. but also appears to be a private raingarden.



5. SITE PREPARATION

5.1 Clearing and Grubbing

The major pitfalls associated with clearing and grubbing activities are:

1. Clearing more area than is essential at the time.
2. Insufficiently marking areas to be protected.

These pitfalls lead to undesirable erosion and sedimentation and/ or unnecessary damage to the landscape. Trees, shrubs, grasses, or ground cover reduce runoff volume and peak discharge rates thereby preventing the transport of sediment. Any areas subjected to clearing and grubbing are destabilized. Maintaining site stability is one, if not the primary, target to strive for throughout the construction process for successful implementation of LID practices.

Sediment collection in LID practices leads to malfunction at best and failure at worst. Clearing and grubbing activities must be coordinated with the construction schedule so as to limit the duration and size of disturbed areas. Down gradient perimeter control must be in place prior to conducting any up gradient activities.

The *Erosion and Sediment Control Guideline for Urban Construction* reminds us that an effective Erosion and Sediment Control Plan will “Retain existing vegetation where possible; limit the size [and duration] of disturbed areas by minimizing nonessential clearing and grading; minimize slope length and gradient of disturbed areas.” Elements of winter construction season clearing include limiting clearing and excavation to areas in which work is to occur during the next 14 days and that can be mulched in 1 day prior to any weather event.

Biorentention clogged with construction sediment which could have been prevented with an effective ESC report and implementation. Source: LID Center

5.2 Natural Heritage Protection

The *GGHA Erosion and Sediment Control Guideline for Urban Construction* explains that among the serious deficiencies in current planning and implementation is unnecessary clearing of environmentally sensitive areas, such as stream riparian buffers, steep slopes, wetlands and seeps. LID takes planning and implementation a step further. It requires protecting natural heritage features and functions as a landscape-based approach to stormwater management. Prior to clearing and grubbing or perimeter control, communicate to construction contractors the natural heritage features to be protected with proper controls prior to any construction activity on site. These areas should also be indicated on the site plan and/or grading plan, whichever ensures the contractor will see and follow protection measures for these areas. Designers are encouraged to include "Limits of Construction" on the design drawings that coincide with the areas to be protected. This protection can vary depending on the scale of the project but may include sediment fencing, construction fencing, flagging, stakes etc.

EXAMPLES:

Natural Heritage Features Protection - example for properly marking protected areas

- The limits of the areas to be cleared and grubbed will be marked by fencing, flags, stakes, tree markings or other suitable method.
- Trees and other vegetation to be removed will be designated by a different color flag, ribbon or stake and clearly marked on plans.

Natural heritage features are protected with a double row of silt fence. The first row is on the verge of being overwhelmed and requires immediate maintenance (Source: CVC).

Poor example of improperly marked critical root zone of a designated historically important tree - soil and material storage as well as equipment will compact the root zone potentially damaging or killing tree.

IMPORTANT:

Perimeter Controls

- Perimeter controls are only effective with routine inspection and maintenance.
- A failure of a single portion of any perimeter control can result in complete sedimentation of the LID practice.
- Failure results in contractor lost time for repairs and mitigation efforts.
- In the case of infiltration practices, any accumulated sediment must be removed without exposure to construction equipment or other vehicular traffic so that compaction is avoided and the proper function of the infiltration practice is ensured.
- See Emergency Erosion and Sediment Control section of Chapter 4.2 for discussion on providing an additional line item for addressing perimeter control issues associated with major storms or atypical events.

5.3 Perimeter Controls for Important Features

Perimeter controls are one component to a multi-barrier approach that includes settling and filtration controls. These controls protect off-site areas, natural resource features and BMP sites from disturbances that generate sediment laden runoff and compaction from vehicle traffic. Drip lines of trees, soil stockpile sites and infiltration practices are a few of the key features that must be protected by perimeter controls to prevent sedimentation and soil compaction throughout the construction time frame.

The locations of infiltration practices must be clearly identified on the construction plans and marked during the initial stage of construction when perimeter controls are being installed. By marking and protecting the locations of infiltration practices at this stage:

1. Sedimentation and compaction are minimized from the start.
2. Contractors are made aware of the significance and intended function of the infiltration practices - building understanding and awareness.
3. The infiltration capacity of the LID practice is protected long-term.

Caution fencing prevents traffic and building materials storage within the BMP.

Perimeter controls continue to be necessary through the entire construction process, even after pavement is in place. Until LID practice drainage areas are stabilized and construction vehicles are no longer tracking sediment onto finished surfaces, no LID practice should be put online. Therefore, the following perimeter controls may be necessary for extended periods around LID practices:

1. Compost biofilter socks
2. Sand or pea gravel bags
3. Straw logs and bales
4. Silt fences and other perimeter controls

The *GGHA Erosion & Sediment Control Guideline for Urban Construction* provides definitions, applications, design considerations and installation and maintenance consideration for the following commonly used perimeter controls:

- Sediment/silt fence
- Interceptor swale/dike
- SiltSoxx
- Vehicle tracking control/mud mat
- Vehicle wheel washers
- Channel soxx
- Ertec perimeter control

Failure at a single point of a perimeter control - see ESC Guide for maintenance scheduling

Pervious pavement LID practice
Top: showing good perimeter control protecting porous asphalt
Lower: Perimeter control requiring maintenance, sediment potentially clogging porous asphalt

6. MASS GRADING

Many times the concept of LID may be considered to be exclusive of mass grading. Cluster development is preferable as it often utilizes mass grading across a smaller area, preserving valuable natural resource areas. However, sites with high development densities such as commercial centres and typical suburban cores as well as areas where steep topography requires large cut/fill volumes are examples where mass grading is unavoidable. Additionally, mass grading can be more cost effective. LID can still be effectively utilized in a mass graded development. If certain areas are to be used for infiltration, it is critical that they be staged and protected throughout the construction process.

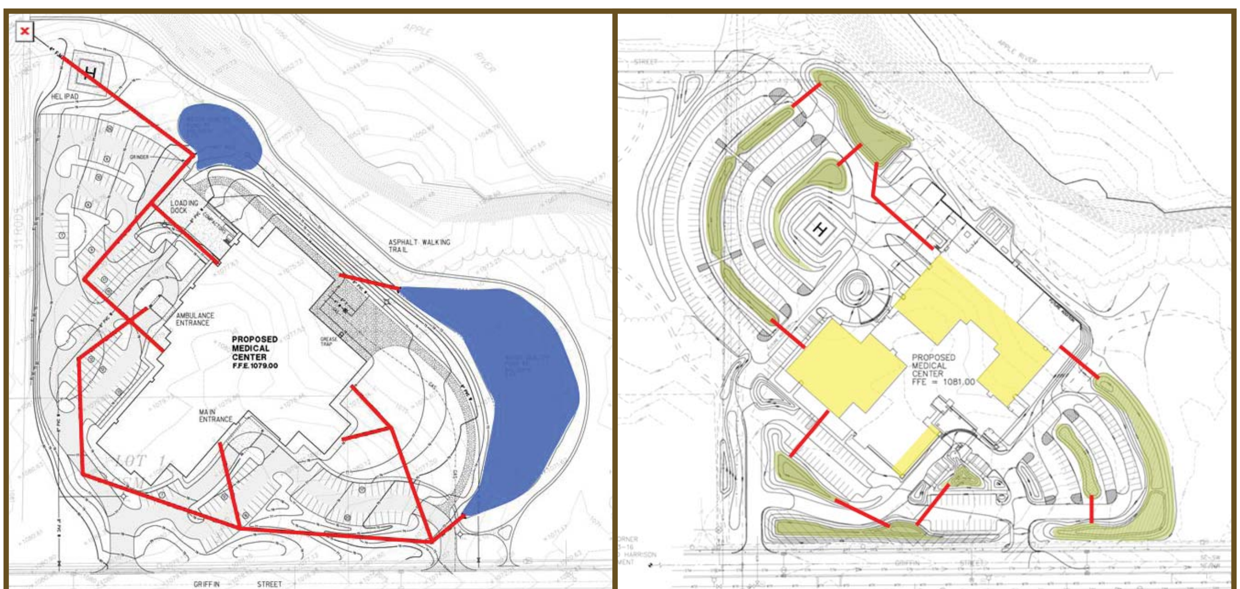
6.1 Offsite Drainage

Treatment of off-site drainage should be considered prior to beginning design and construction of on-site facilities.

1. Keep clean water clean. This can be done by diverting runoff away from bare soils.
2. Make sure that incoming channels, emergency overflows (EOF's) and outfalls are stabilized.

6.2 Decentralization

Traditional construction methods typically utilize a limited number of large-scale sedimentation ponds and design features to limit erosion and sediment impacts. Because LID moves away from connecting all drainage, instead mimicking natural hydrology, erosion control methods will also adapt to site conditions. This can be accomplished by implementing a decentralized, multi-barrier approach.



Left: Traditional stormwater approach with pipes and regional ponding
Right: Decentralization distributing stormwater BMP's across the site - mimicking natural hydrology

A higher number of smaller scale facilities spread throughout the site will have smaller runoff volumes than a singular large scale facility that collects all the site's runoff from across the entire site. Breaking the total volume of runoff up into manageable amounts is usually more successful at controlling erosion and sediment than concentrating it in one large facility.

6.3 Offline Protection

It is recommended that BMPs be kept offline until contributing drainage area is stabilized, unless they will be used as temporary sediment basins. Certain BMPs, such as below ground facilities, can be constructed during mass grading. However, a barrier or bulkhead must be provided for infiltration or filtration BMPs to prevent any introduction of sediment during construction.

6.4 Temporary Sediment Basins

In general, using permanent LID stormwater BMPs as temporary sediment basins is discouraged. By directing large amounts of construction sediment-laden runoff to future facilities, the designer and contractor are introducing fine sediments that can clog the in-situ soil structure and potentially compact the sub-soils from machinery used to remove the accumulated sediment.

However, a facility's position in the landscape may often require it to act as a temporary sediment basin during construction. If this is the case, success can be achieved with consistent inspections and limiting the depth of temporary excavation. A buffer to protect the sub-soils from fine sediment introduced during construction can be created by leaving the bottom of the temporary sediment basin at finish grade or higher and cutting to required

Temporary Sediment Basin

sub-grade elevation once the surrounding drainage area is stabilized (see illustration below). Different types of facilities require different depths of protection. Temporary sediment basins will need to be provided with a temporary outlet during the construction process that provides emergency overflow and prevents sediment migration downstream.

IMPORTANT:

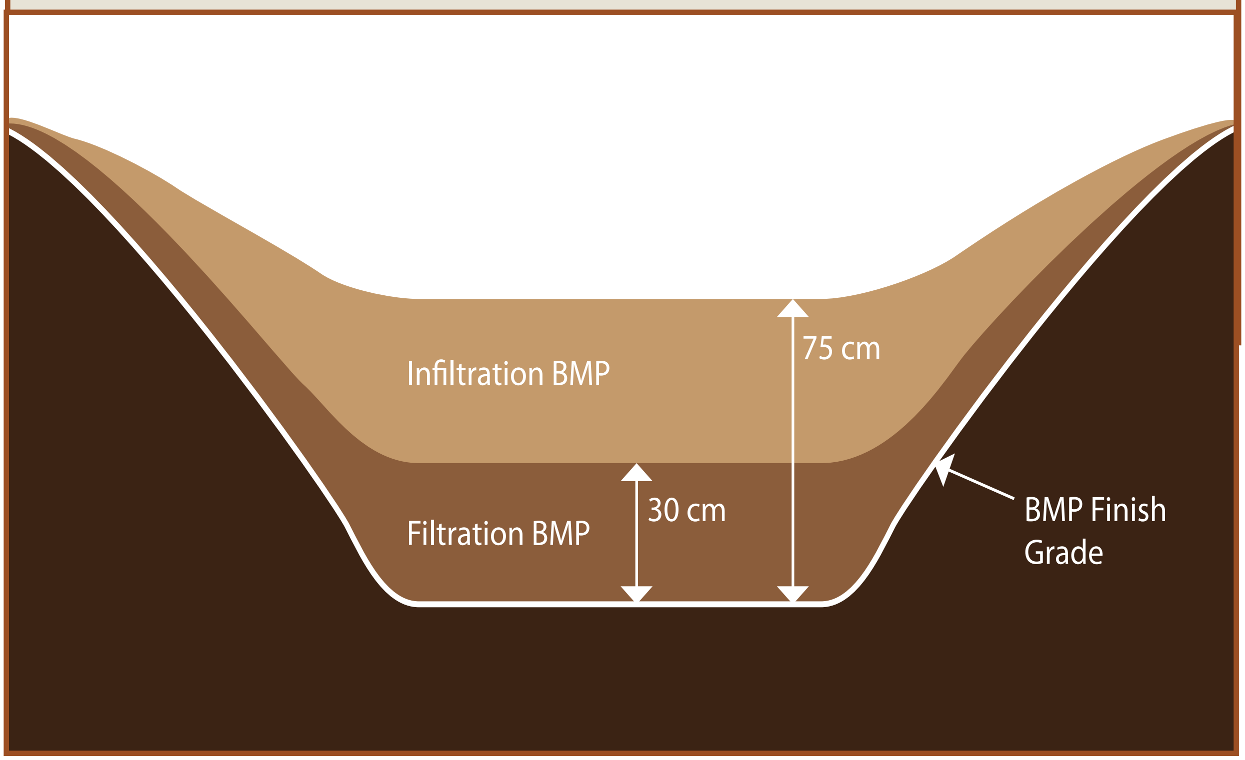
Temporary Sediment Basin and Cut Area Construction

Filtration BMPs

– If the facility will be used as a filtration BMP, cut to a minimum of 30 cm above finish grade. Once contributing drainage area is stabilized, basin can be cut to finish sub-grade and scarified in preparation for installation of soil biomedium.

Infiltration BMP

– If the facility will be used as an infiltration BMP, cut to a minimum of 75 cm above finish subgrade to protect during construction. Once contributing drainage area is stabilized, basin can be cut to finish sub-grade and scarified in preparation for installation of soil biomedium.



6.5 Stabilization

Timely stabilization is critical to the success of every project. The steeper the slope, the more important this becomes. Stabilization is important in all phases of construction and should be stressed continually throughout the life of the project.

1. Cut and stabilize access and staging areas.
2. Cut and stabilize channels and slopes – stabilization is critical - prior to connection to a surface water and as soon as possible within 14 days.
3. Once graded, perimeter controls should be inspected and reestablished as necessary.
4. Temporary vegetative cover mix and stabilization techniques should be reviewed in the context of slope suitability, overall construction phasing and time line. See Appendix C and D of the *ESC Guide* for recommended practices and seed mixtures.
5. Excavated topsoil, if suitable for reuse in final landscaping, should be separated from sub-soils. Protect stockpile sites with perimeter control and keep stockpiles away from practices.
6. Protect stormwater practices, particularly infiltration areas with suitable perimeter control or other erosion and sediment control techniques, until contributing drainage areas are stabilized.

THINGS TO REMEMBER:

Stabilization and Remediation

- Stabilization is critical in ALL phases of construction.
- See Chapter 13 Overwintering for further information on stabilization techniques for off-season work
- If sensitive soils are impacted during construction, modifications must be made to remove sediment (scrape and amend) or de-compact (deep tilling, etc.) - see Chapter 9 Finish Grading for discussion on techniques.

6.6 Infiltration Practice Grading

Constructing infiltration features in sites that are mass graded can be challenging. The typical steps are as follows.

Fill Areas:

1. Remove topsoil and lower permeability soils located above the target infiltration soils where the practice was designed to function. Fill the area above the target soils with soils of a higher permeability than the in situ soil (typically sand). Fill this area to a height greater than the surrounding grades.

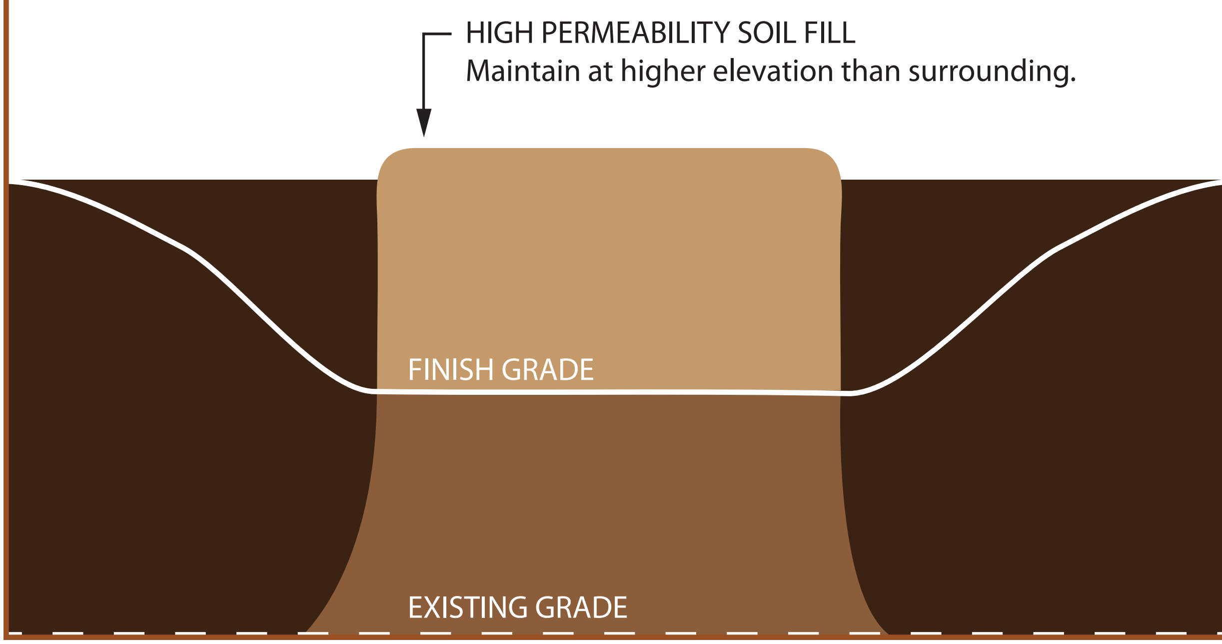
2. Raise the surrounding grades to the elevation of the infiltration feature, but do not exceed height of the infiltration fill material. Fill additional high permeability soils over the infiltration feature such that the site of the infiltration feature is at a greater elevation than the surrounding grades. By maintaining the stormwater feature elevation greater than the surrounding, mixing of soils from construction traffic or runoff is prevented.
3. Repeat until finish grade of the BMP is achieved, then the surrounding area can be raised to finish grade. The stormwater feature can then serve as a temporary sedimentation basin until the surrounding area is stabilized (see illustration below).
4. Following stabilization, the practice should be cut to designed subgrade elevation and replaced with filter media per Chapter 9 Finish Grading.

Cut Areas (See Figure page 29):

1. Excavate the basin and the surrounding area to finish grade.
2. Following stabilization of the tributary area, the practice should be cut to designed subgrade elevation and replaced with filter media per Chapter 9 Finish Grading.

IMPORTANT:

Infiltration Practice Grading in Fill Areas



7. UTILITY INSTALLATION

The installation of utilities typically occurs after the project has been rough graded and the project is at the correct hold down elevation for roads, building pads, and topsoil application. At this stage, the stormwater features are graded and remain offline or are functioning as temporary sediment basins. Locating utilities outside of LID features is preferred for practical, maintenance, and jurisdictional reasons. However, as R.O.W.'s become increasingly crowded, there are many instances where LID and utilities will need to share the same or adjacent corridors. Designers and contractors should be aware of numerous pitfalls that may arise when LID and utilities overlap. Contacting utility companies and municipalities to work with at the beginning of the design process is the best approach to solving any potential LID-utility conflicts.

7.1 Design

A good portion of the challenges of installing utilities in an LID setting can be tempered through insightful design. Consideration of the three-dimensional relationship between the utilities and the soils is a key factor in making the LID project as manageable as possible for the contractor.

1. Site footprint and impact to natural resources can be reduced by clustering development. Additionally, using surface conveyance is recommended when feasible.
2. Creating shared utility corridors for residential development makes it easier for utilities to avoid conflict with LID practices and natural resources. This can also allow for more areas of treatment within boulevards.
3. Stormwater features should not be designed above or immediately adjacent to existing or proposed utilities. This causes problems from both a functionality standpoint as well as for maintenance in the future. Stormwater features frequently involve sloped surfaces that inherently require more attention to restoration than flat areas. In addition, the degree of compaction required for utility installation may not be conducive to filtration/infiltration nearby. If future maintenance is necessary, restoration of the stormwater feature will be needed. Restoration includes protecting the soils from compaction or mixing, installing the soil planting media, and re-vegetating with proper vegetation. It is best to avoid this situation if feasible.
4. Underground trenches containing utilities should utilize anti-seepage collars periodically along their length to prevent preferential flow of shallow groundwater along the trenches.

HAND OFF MOMENT:

New Subcontractors

- This is a point in the project where the site is handed over several times to a new contractor or contractors. LID protection measures must be clearly communicated again.
- A preconstruction meeting can set the stage for contractor coordination, but LID methods and protection measures should be revisited at all construction meetings.

7.2 Contractor Coordination

Because there are a variety of utilities and specialized utility subcontractors, assuring that all installers are cognizant of the LID features and that their protection is critical. The function of the stormwater feature, particularly an infiltration feature, can be hindered by compaction and mixing of the subsurface soils while installing utilities. Contractor awareness and a plan to prevent and/or mitigate these issues is crucial. The utility installation and LID conflicts should be reviewed, updated and discussed frequently at construction meetings.

7.3 Construction Considerations

Typical construction issues and considerations at all LID sites include:

1. Stabilization of mass grading and infrastructure already completed should be accomplished by the excavation contractor and communicated to the utility contractor – especially if utility contractor is going to be working in areas of flow.
2. Materials excavated need to be controlled through the use of temporary perimeter controls and stockpile management.
3. Make sure staging areas are sized appropriately for delivery quantity and traffic.
4. Designated concrete washout areas need to be provided.
5. A dewatering plan should be provided for trenches or if work will be conducted in an area of flow.

THINGS TO REMEMBER:

Concrete Washouts:

- Bioretention facilities or other LID features near the building are often a favorite spot for concrete truck washouts.
- Once plugged with sediment or concrete it may be impossible to achieve the expected levels of function.
- Communication about the end use and protection of these devices is crucial.
- A safe designated location for concrete washout should be identified onsite.

Because LID features are typically landscaped rather than left as bare dirt ponds, it is not as apparent where they are located to a contractor unfamiliar with the design. Because of this, and the typical timing of their installations, electrical, telephone and cable contractors will need the most coordination and communication. Examples of common potential conflicts between typical utility construction techniques and LID include:


Lighting base installation.

1. Lighting installations within/above BMPs (bioretention, permeable pavement, etc.) requires attention by both designer and electrical contractor. Loose soil mediums of bioretention facilities and to a lesser extent the angular stone used as the infiltration bed of permeable pavement may not provide structural support for overhead parking lot lighting. The design team should address the structural concerns of placing utilities in these substrates. Increasing the base is often a solution, but this is often an unforeseen issue for electrical and utility contractors, requires communication and heightened construction observation, and can add costs late in the construction process.

2. Electrical contractors will need to know water conveyance routes and standing water locations. Knowing which landscaping lights will be exposed to ponded water is also important for electrical installations.

7.4 Proprietary Devices

There has been an increase in the use of proprietary devices such as grit chambers, underground storage systems, precast bioretention systems, and structural soil systems (e.g., Silva Cells) that promote tree root growth, particularly in small site and retrofit applications. Many times, surface bioretention and biofiltration cells or grit chambers will be used as the first device in a treatment train to provide pretreatment for underground storage and infiltration chambers.

These devices are usually installed during the mass grading or utility phases of the project. As with all LID practices, the decision needs to be made whether they will be used online as a temporary sediment control or whether they will be protected and kept offline until the site is stabilized. It is important that infiltration facilities are kept offline and protected until the site is stabilized. If infiltration is not proposed, grit chambers can typically be used online and cleaned at the end of the project.

8. BUILDINGS AND PAVEMENT

Often the building contractor is not concerned with the area outside the building envelope. The general contractor, project manager, or grading/ utility contractor must communicate all sensitive areas of the site to the building contractor who in turn is responsible for communicating to his subcontractors and vendors. Ideally, by the time the building is being constructed, the various BMP's should be demarcated and well protected by the erosion and sediment control measures, however, this phase of construction often offers unexpected challenges. Sites can quickly become a quagmire as tools and materials are moved around the site.

8.1 Commercial Development

Infiltrating LID features will typically be four metres or greater distance away from building pads to decrease the likelihood of water infiltrating near building foundations. Despite that separation, building construction could have a considerable impact on stormwater function. Typically parking lots, roads and most of the areas surrounding the building will be complete prior to building construction.

The building staging area for commercial buildings may have stormwater features that are not yet constructed. Grading of these features should not be completed until after the heavy construction equipment has left the site. Over excavation to amend the compacted soil should be anticipated. Construction of buildings, particularly when soils are saturated, can impact soils to depths in excess of one meter. Depending on the depth of compaction, infiltration practices will at a minimum require aeration and potentially excavation to at least 1.5 meters below the existing grade.

Even though many of the stormwater features may not be located near building pads, consideration of certain features will need to occur frequently. The following are some of the more often impacted features:

HAND OFF MOMENT:

Building Contractors

- Building related construction contractors usually have the least amount of site related BMP knowledge.
- Electricians, plumbers, framers, etc. will have little interest in BMPs and protection strategies. However, they often have materials, will be using the site often, and will need to be accounted for.
- Having BMPs clearly demarcated and protected is the first step in protecting facilities.
- Communication is again essential to provide greater protection.

Tracked sediment on permeable pavement.

Permeable Pavement:

Permeable pavement can be affected in a number of ways from building construction.

- If not properly protected, construction traffic may not notice the different type of pavement or know that permeable pavement should not be driven on immediately after being placed or be loaded with heavy equipment (except pavers). Compaction of the surface material will prevent water from reaching the rock beds beneath the pavement and can cause water to pond on the surface. This in turn can cause dangerous ice conditions in winter and reduce the life of the pavement.
- At this phase, tracking caused by mud-filled tires from construction traffic are often a major source of sediment. Protecting pavement areas using effective sediment controls is critical. Jersey barriers or fences to protect areas from traffic with perimeter controls or filter socks (compost/rock/wood chip) should be used to protect from sedimentation.

Roof Drains and Leaders:

Roof drains are stubbed out of the building during roof construction and many times become a major contributor to sediment washoff, negatively impacting any LID practices to which it is conveyed. With effective management these can become a conduit to safely drain water away from the foundation and adjacent work areas. The use of plastic pipe is often an adequate temporary means to safely direct water to a stabilized area. If this is not feasible, scupper or gutter outfalls should be stabilized and water directed to a turf or geotextile lined channel.

8.2 Contractor Coordination

Erosion control and protection of LID features during building pad construction is often difficult as contractors will vary in their method of construction and how they will handle the most common issues. Site conditions can change in an instant with an afternoon thunderstorm, this requires that the erosion control plan be dynamic for this phase of construction. Timing of construction relating to adjacent areas will vary and will affect how erosion control will be handled. As such, an erosion control plan should be developed and reviewed frequently with the building contractor.

There are also a number of items that should be considered and discussed with the contractor to limit the likelihood of a negative impact to the LID features during building construction:

1. A secure, stabilized storage/staging area should be provided to minimize distances that materials must be moved that also avoids compaction or contamination of LID areas.
2. During building construction the ESC inspections usually wane. The site should be inspected at least once a week and after every rainfall to assure all practices are working.

8.3 Residential Development

In a residential setting, LID practices and conveyances will often be constructed on individual lots or over a series of lots. Many times lot lines are shared and houses are constructed by different and sometimes competing builders. Due to the finer scale associated with residential construction and wider variety of variables, even more caution and communication will be required for a successful LID project.

Residential raingarden as turnabout in a highly urbanized neighborhood.

Each builder and subcontractor on site must be made aware of their responsibilities. Developing a written Builders Agreement, signed by each builder and his subcontractors, has been found to be beneficial.

Example conditions in a builder's agreement:

1. Erosion and Sediment Control Report (ESC Report), including erosion and sediment control drawings, should be developed for each individual lot constructed within the development.
2. ESC measures - refer to a wider range of ESC practices than just perimeter-type practices and backs up the use of the multi-barrier approach along all down gradient slopes prior to any construction activity.
3. PESC measures should be established as needed to protect future areas of infiltration from compaction and mixing with undesirable soils.
4. Catch basin inlets in the immediate vicinity of home construction should be lined with monofilament filter fabric, or other approved inlet protection, before any excavation begins.
5. All erosion control measures such as silt fences and lined catch basins should be monitored and maintained at least once a week and especially following all rain events. Sediment shall be removed if deposits reach 1/3 of the silt fence height. If structures are found to be inadequate or damaged, they must be replaced or repaired within 24 hours.
6. All stockpiles will be placed no closer than 3 metres from the curb and maintained onsite.

7. ESC measures should be established around all non-aggregate stockpiles (even if it will be used for backfill) on the day the pile is created.

8. A project stockpile site should be provided for the development. All excess materials not needed for backfill should be immediately taken away during excavation.

9. Stockpiles should be seeded and mulched if the pile will not be moved within 7 days for slopes that are 3:1 or greater and 14 days for slopes that are 3:1 and flatter.

10. Follow municipal standards for construction entrances. If no standard applies, footprint of driveway should be temporarily covered by 15 cm deep rock (or approved recyclable material). Construction entrance should be provided on the lot at all times during the construction period until the permanent driveway is installed. 3.5-7.5 cm clear aggregate is recommended.

11. Dirt that is tracked on to pavement shall be removed immediately upon discovery to prevent sediment from entering storm drains. An inspection of the pavement adjacent to the site should be performed daily.

12. Contractors should refrain from driving or parking on any part of the lot other than the construction entrance during muddy conditions.

13. Contractors and material suppliers should refrain from entering any adjoining lot at any time without permission from the owner (damage to the lot will be the builder's responsibility).

14. Approved materials should be installed behind all curb areas on the lot except for the construction entrance immediately after the basement is backfilled. Materials may include wood mulch berms, 60 cm of sod, erosion control blankets, and/ or silt fence.

15. Gutters and downspouts should be provided on all buildings and roof runoff should be directed from downspouts to permanently vegetated areas. Downspout extenders may be used to direct runoff to the street until vegetation has been established.

16. Surface footprint for soakaways and other infiltration practices should be clearly marked and protected from soil compaction.

17. All exposed soil areas that are not being actively worked must have temporary erosion protection or permanent cover within 7 days for slopes 3:1 or greater and 14 days for slopes 3:1 or flatter. This should apply to all exposed soil areas year round and until the site is stabilized.

18. All trash should be contained on site and in the appropriate waste container. Solid waste including floating debris, paper, plastic, fabric, and other trash will be collected in designated containers at the project site. Containers should be emptied regularly and disposed of properly at an off-site waste collection facility.

19. The contractor should provide portable toilets at the work site to collect sanitary and septic waste during construction. Portable toilets should be emptied, cleaned, and maintained on a regular basis by the supply company and removed from the site following completion of construction activities.

20. Construction debris including collected sediment, concrete millings, asphalt and scrap wood, metal and other wastes should be collected and disposed of properly.

21. All dumpsters should be covered nightly or when weather conditions warrant (e.g. windy).

22. Discharge concrete truck wash water only in designated concrete washout areas.

23. Construction materials and supplies including but not limited to all lumber, equipment, and dumpsters should be stored on site and not in adjoining lots, street or sidewalks.

24. Builders and homeowners are urged to use and install alternative permanent stormwater control measures such as rain gardens and rain barrels.
25. All sites shall be inspected by the lead contractor, builder, and/or their subcontractors after each 1.25 cm rain event and once every 7 days during dry periods.
26. Prior to installation of permanent vegetation, a minimum 5 cm of compost shall be spread over the topsoil and tilled to a depth of 30 cm. The final amended topsoil should have an organic matter content of 5 to 15% by dry weight.
27. Permanent vegetation should be provided on all sites prior to occupancy. If this is not possible due to weather considerations, down gradient perimeter controls and temporary cover should be provided until permanent vegetation can be established.
28. Each builder should have a designated contact person to be responsible for implementing and maintaining these protective measures.
29. All builders are responsible for the actions of the people they have on site.
30. The frequency and type of communication (e.g. meetings, reports) between contractors and regulators should be documented.
31. No dewatering should be sent directly to streams or wetlands.
32. Maintain a rain gauge onsite. ESC inspections may not be necessary for small rain events but moderate to large rain events will require inspections.
33. It is the responsibility of property owners, consulting engineers and contractors to ensure all planning approvals and permits are received prior to starting any works.
34. Once site is stabilized all ESC measures must be removed and any captured sediment needs to be stabilized or removed.

8.4 Developer Agreement/ Letter of Credit

A letter of credit or escrow deposit for public improvement maintenance, soil erosion and sediment control, noise abatement and other enforcement measures should be required. Any damage to the pavement, curb, sidewalks, boulevards, or other infrastructure within the public right of way caused by a builder or owner, or their contractors or subcontractors, shall be repaired before this deposit is refunded. To the extent such damage is not paid for by the builder or owner, funds from the deposit may be used to make these repairs.

HAND OFF MOMENT:

Utility Connections

- As interior utility hookups are installed, excavation management and stabilization again become critical – another important handoff moment

9. FINISH GRADING

The finish grading process is another critical handoff moment as a number of elements such as curbs, sidewalks, roadways, soils, and vegetation start to come together to create the functional and aesthetic value of a site. The same care and communication that was put into controlling sediment and erosion in earlier stages is also required during finish grading. In many cases, greater attention to detail is required for elements in this phase that will make or break the success of the final product.

9.1 Design Verification and Construction Adjustments

HAND OFF MOMENT:

Contractor Coordination

- As roadways come to finish elevation this is sometimes another handoff moment between excavator sub-contractors such as paving and curbing.
- Communication is critical. A weekly construction meeting including all subcontractors is an effective tool to communicate intent and key points of the overall design.
- Discuss BMP construction approach with all contractors.

The finish grading phase of construction is very important to the overall function of the practice, but is often the portion of work that diverges furthest from the original design intent. Several elements of finish grading are new to contractors and this phase is directly influenced by construction mistakes and adjustments made in previous phases.

9.2 Design Drawings

Accurate, legible, and detailed drawings are the first step in reducing problems. Provide several options, pictures, detail cross sections and/or profiles showing critical slopes, low points, ribbon curb, flume-style catch basins with low outlet to describe the design to contractors.

9.3 Construction Adjustments

Attentive observation on site can also identify and rectify issues that can arise from contractor misinterpretation or adjustments that may need to be made in order to adapt the BMP facility to the landscape that may have been modified in earlier construction phases. It is quite common for field conditions to dictate adjustments to the original plans, in maintaining the integrity of the design. As mentioned previously, many of these modifications occur during the final grading and finish work.

9.4 Construction Techniques and Timing

Contributing Drainage Area

1. All erosion and sediment controls must be installed and properly maintained prior to commencing finish grading.

2. Compacted soils throughout the contributing drainage area can be an issue at this stage, increasing runoff, concentrating flows, and stifling long-term vegetation establishment. Compaction in areas to remain pervious must be mitigated by the following scarification and sub-soiling techniques:

Soil Amendments:

- Compost - Apply compost to soil in a ratio of 1:3 (33% compost) or 1:2 (50% compost) for tighter HSG C and D type soils. The final amended topsoil should be a minimum of 30 cm deep. The depth could be up to 90 cm deep for tree planting areas or areas that take runoff from impervious surfaces. Refer to *LID SWM Guide* for further guidance if the area will receive runoff from impervious surfaces.

Tilling:

- Tillage is a soil preparation technique using various types of mechanical agitation, such as digging, stirring, and overturning. A small rototiller may be used to till soils up to a maximum of 30 cm deep. Depths greater than 30 cm will require a larger machine such as a tractor-mounted rototiller, chisel plow, subsoiler or use of a backhoe to excavate, decompact and replace the soil.

Deep Tilling:

- Urban soil compaction has been shown to extend to depths more than 60 cm below the surface, with most compaction reaching deeper than 30 cm (Lichter and Lindsay, 1994). Reducing compaction at these depths can be completed by subsoiling, a process of deep tilling (or ripping) the construction area soil to a depth ranging from 30 – 46 cm to 60 - 90 cm. One way to create the rips is using heavy machinery (tractor) with two shanks (curved metal bars). Deep tilling may also be useful for breaking up the plow pan for greenfield developments in former agricultural lands.

IMPORTANT:

Contributing Drainage Area Must be Stabilized

- Runoff sediment can destroy or damage previously completed work.
- Lawn areas and planting beds are often overlooked.
- Communication is critical to ensure appropriate scheduling of contractors and outline responsibilities.

IMPORTANT:

Alleviating Soil Compaction

- **Why:**
  Typical residential lawn areas have been found to produce 40-60% of the total runoff in a residential development, due to compaction during construction (*Schueler, 2000*). A typical construction-compacted soil's bulk density is raised to levels limiting root penetration, and just below those of concrete pavement.

- **How:**
  Protecting existing soils is the best defense. However, if soils are compacted during construction, a combination of deep tilling and addition of compost has been shown to reduce runoff by 74-91% of typical construction compacted soils (*Balousek, 2003*).

Tilling:
up to 30cm deep
- small rototiller
- chisel plow
- harrow

Deep Tilling:
greater than 30cm deep
- depth chisel plow,
- larger mechanical rototiller

3. The contributing drainage area must be stabilized and finalized with landscaping or hardscaping prior to finishing work on the LID practice.

4. Diversions of construction runoff from BMPs and inlet protection are again critical at this stage and should be installed and maintained prior to and during the construction of the practice.

5. Water and/or sediment introduced into the practice during previous phases must be removed prior to commencing final grading. Water should be discharged to a stabilized area to eliminate additional sediment issues.

9.5 BMP Construction

General

1. Identify specific construction access areas for final grading and BMP construction. Limited construction access allows work to be undertaken on the facility while landscaping is established to stabilize the contributing drainage area. This is desirable in facilities that receive sheet flow across a large expanse that would be difficult to take offline until the facility is complete. Place a high priority on protecting steep side slopes and areas expected to receive runoff and concentrated flow (e.g. compost blankets, erosion control matting, etc). Restore access areas immediately following construction completion.

2. All finish grading activities in the infiltration BMP should be performed during dry conditions to prevent soil smearing and compaction. Dewatering may be necessary prior to commencing work.

3. The right equipment is critical to the success of the project:

    - Excavation of the infiltration BMP should be done from the outside reaching in when possible, using a back hoe or bucket with extension arm. A toothed bucket is recommended so compaction caused by excavation can be broken up by scarifying the finished surface.

    - If equipment is needed inside the facility, low ground pressure rated or marsh track equipment should be used to minimize compaction.

4. Once excavated to subgrade, the infiltration BMP bottom and side slopes should be scarified or tilled to loosen compacted soils.

5. Once excavated to subgrade, soil types and design parameters and assumptions should be confirmed through in-situ permeability testing (e.g., permeameter measurements to determine hydraulic conductivity). Results of permeability testing should be reviewed by the designer and, if necessary, changes to the BMP design may be required.

6. Any underdrains, iron enhanced sand filtration, and/or observation wells should, be installed at this point, if they are specified in the design. If BMP design includes an underlying aggregate storage layer, careful consideration of specifications is necessary. Minimize initial fines content and material susceptibility to in place weathering and breakdown. See section 10.6 Rock Material for discussion on aggregate considerations.

Bioretention

1. For small bioretention applications, apply soil media in 300 mm lifts until desired top elevation of bioretention area is achieved. Thoroughly wet each lift before adding the next and wait until water has drained through the soil before adding the next lift. Avoid manual or machine compaction. If possible, equipment should not be operated within the infiltration practice. If necessary, allow soil to dry before equipment is allowed back into the practice.

2. For large bioretention applications, slinger trucks are recommended for spreading soil in even layers and reducing the need to move soil media manually or by backhoe. If possible, equipment should not be operated within the infiltration practice. If necessary, appropriate low ground pressure rated equipment can enter after at least 45 cm of bioretention soil is installed and has properly dried.

9.6 Common Construction Issues

Turf blocking inlet (CVC).

Curb cuts

Be sure that the contractor responsible for curb construction understands curb cut designs and elevations. This is often a new technique for contractors and they may not understand the overall concept of water in the gutter line being directed behind the gutter. Elevated curb cuts and reverse slopes (sloping from back of curb toward street instead of depressing from gutter line toward the back) are the most common mistakes during construction. Curb cut size (width) is another common issue as well as placement on steep slopes or the down slope side of a catch basin.

Proper Disconnection

The interface between impervious surfaces and the pervious landscapes that are designed to accept runoff is a critical component and one of the most common mistakes. Typical disconnection issues observed include:

1. Pretreatment areas and planting beds are often installed at higher elevations than adjacent impervious surfaces in traditional site design and construction. However, this is directly opposite in many LID designs. Soil, landscaping materials, and/or final erosion control practices installed at higher elevations than adjacent pavements and curb cuts will block water from flowing into a practice, causing runoff to bypass the practice all together.

IMPORTANT:

Scour Protection Strategies

Hard Armorment:

Traditional rock and cable concrete mats can slow flows and prevent erosion.

These types of scour protection are heavy duty and may not be attractive for some small scale applications.

Reinforced Vegetation:

Vegetation with reinforcement, such as turf reinforcement mats, certain types of cellular confinement, and numerous proprietary products can provide effective protection.

Integrated Pre-treatment:

Pre-treatment structures are most cost effective when they slow incoming flows, collect sediment for easy clean out, and release water to the BMP in a non-erosive manner.

IMPORTANT: Common Construction Field Adjustments

- One of the most common issues with BMP construction is improper inlet and runoff delivery.
- Contractors often improperly construct inlets making BMPs worthless and causing runoff to bypass.

Source: CVC - improper construction causes facility bypass

2. Turf grass – when runoff is directed to turf grass, the top of the sod should be installed a minimum 4-5 cm below the top of adjacent hard surface. Turf grass, especially Kentucky bluegrass, builds a thatch layer over time and its elevation can raise above adjacent surfaces providing blockage.
3. Rip-rap, gravel diaphragms, splash pads, and other erosion control measures at practice inlets should be a minimum 5 cm below the adjacent hard surface elevation to allow for proper drainage and continued function if sediment deposition should occur.
4. Inadequate slope of grades sometimes results in blockage by debris.
5. Scour protection, both temporary and permanent, will protect the facility from high velocity runoff flows.

Typical steps and adjustments for BMPs:

1. Once excavated to sub or finish grade, inspect underlying soils to confirm design assumptions and consistency with soil borings. Soil permeability tests are recommended if unexpected site conditions are discovered.
2. Changes to BMP dimensions or adding an underdrain may be needed if underlying soil are found to have lower infiltration rates than anticipated, pollution concerns arise during excavation, or the amount of runoff delivered to the facility is increased.
3. Further excavation to contact appropriate soils may be needed. One successful strategy has been to over excavate to suitable soils below drainage structures and backfill with appropriate free draining material.
4. Plant substitutions may be necessary if the encountered soils are expected to change hydrology from design assumptions.

5. Inlet and outlet elevations may need adjustment. Infrastructure adjustments are more easily modified prior to final soil medium and mulch placement – catching mistakes early can save time and money.
6. Soils different than anticipated during design may require outlet elevation modifications, underdrains.
7. Surrounding grades are different than designed including roadways, sidewalks, curbing, etc.
8. Contributing drainage areas can change due to grading issues or plan misinterpretation – a designed feature may receive more or less runoff than originally planned.
9. Erosion and sediment control practices should be reevaluated at this stage and improved upon if necessary.

9.7 Final Grades

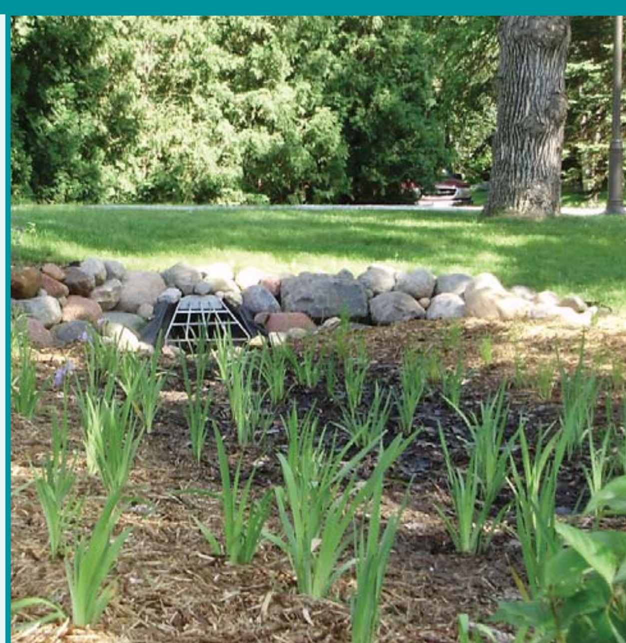
The final elevations at the bottom, sides, inlets, outlets, and overflows of some facilities are often only centimeters apart, requiring accurate grading and elevation verification. Some important final grade aspects to note include:

1. Overfill above proposed surface invert to accommodate natural settlement to the proper grade. Some soil mixtures can settle as much as 15-20%. It is best to allow natural settlement from rainfall, if the construction schedule allows. However, the process can be accelerated by saturating the soil medium with water and allowing for settling.

THINGS TO REMEMBER:

Bioretention Soil Mixes

- Engineered bioretention soils can settle as much as 15-20%. This should be accounted for during installation and when estimating quantities for costs.
- During design - use the top of mulch as final grade or bottom of the BMP - communicate to contractor in the plans and/ or specs with notes, details, spot elevations, etc..



IMPORTANT:

Bioretention Soil Mix Placement

- **Why:**
  If settling isn't accounted for the increased storage volume can negatively influence the designed inundation regime and soil can settle around plants, leaving roots exposed to drying. Filtration soil depths can be reduced below designed levels.

- **How Much:**
  Soil settlement of 50-75% (by volume) of a soils organic amendment should be anticipated. If compost is 5%, by volume, of the soil medium, a minimum of 2-4% shrinkage of the installed soil depth should be expected (*Urban, 2008*).

Unanticipated soil settlement resulted in increased ponding depth
(Source: LID Center)

Pneumatically applied bioretention soil medium
(*Source: Windscapes*)

Slinger truck evenly placing bioretention soil in a large cell

2. Top of the mulch layer, if utilized, should be used as final grade. Mulch depth is typically 75 mm.

3. Double check final inlet, outlet, and emergency overflow elevations. Stabilization of inlets and outlets is critical before LID practices are placed online.

9.8 Final Stabilization

1. Final stabilization and protection including mulch, additional erosion control and vegetation should be installed immediately.

2. Offline protection is highly recommended until vegetation is established. However, if facilities are completely offline during the growing season, watering or irrigation will be necessary.

9.9 Housekeeping

Street sweeping and other good housekeeping practices are essential in the finish grading phase due to the new and additional sources of sediment and other pollutants. A majority of contractors are familiar with erosion control measures typically associated with mass grading. However, the finish grading phase introduces a number of new sources of sediment and pollution that contractors are not often familiar with.

THINGS TO REMEMBER:

Offline Facilities

- Keeping facilities off-line during active construction is important to long-term function and can speed up construction process
- Water should be removed and soils allowed to dry before any grading, mulch placement, planting, or other activities that could potentially compact the bioretention soil medium is undertaken.
- Acceptable methods for placing facilities offline include sandbags (as shown), capping or plugging inlets to subsurface storage/ infiltration, and diversion swales. Hay bales are not an effective method for placing a facility offline.

Top: concrete washout next to future BMP - poor location

Middle: dewatering technique

Bottom: Bioretention soil mixes should be pre-mixed off site and delivered on the day of installation.

Excavated materials are often stockpiled on site, requiring additional erosion control measures. Pavements and compacted soils can increase runoff volumes and flow rates that may negatively affect practices under construction. Erosion control measures installed at the beginning of the project may need maintenance to further protect facilities. New sources of potential sediment and pollutants include concrete wash outs, amended soil stockpiles on site and landscaping materials temporarily stockpiled.

1. **Concrete Washout:**

   Pouring concrete on site for curbing, sidewalks, driveways, etc. becomes a potential pollutant when the hoppers and concrete pumps are washed off after delivery. The resulting wash water will flow to predominant drainage patterns that often lead directly to a practice under construction. This is an issue due to the chemical makeup of the wash water that is a contaminant itself, and the remaining concrete paste that can set after drying out, effectively sealing off a small surface that may be in the infiltration BMP. Proper concrete wash out facilities will prevent potential concrete pollution issues.

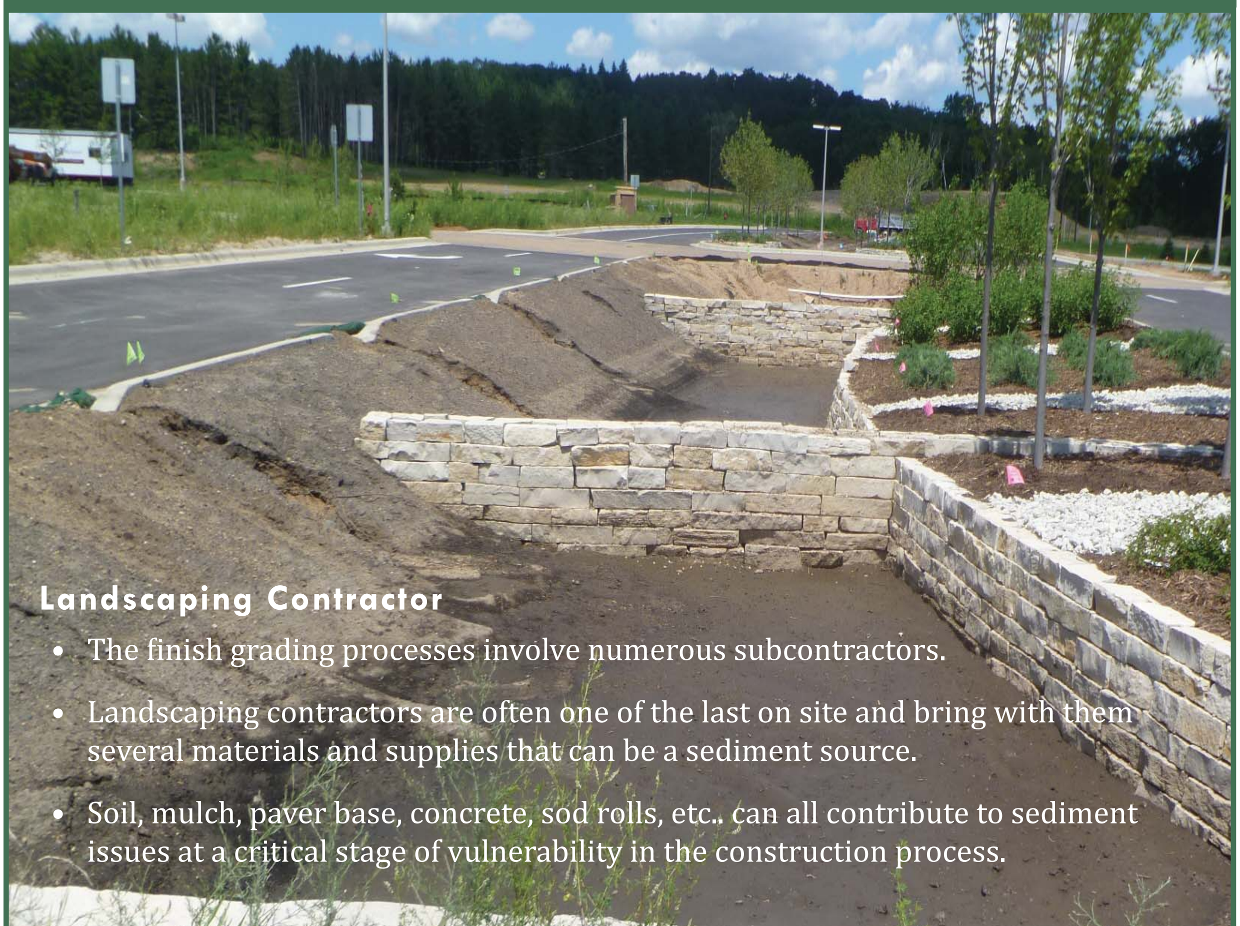
2. **Dewatering:**

   May be required prior to finish grading. Dewatering can become a significant issue due to the potentially high sediment and pollution composition of the water. Keeping facilities offline until the site is stabilized will help minimize frequency and clean up effort should dewatering be needed. The dewatering plan should be updated with each phase of construction and be prepared to be ramped up should significant storms require maintenance.

3. **Material Storage:**
There is a tendency for contractors to temporarily store topsoil and landscaping materials on finished surfaces which create new sediment sources. Protection, sweeping and good housekeeping are mandatory. Plant materials should not be delivered to site until areas have been prepared for planting. Vegetation should be tagged for identification and matched to the design planting plan and schedule.

4. **Engineered Soil Mixes:**
Bioretention mixes should be pre-mixed before arriving on site. Premixed soils should not be delivered until the bioretention site has been excavated to proper subgrade and the underdrain systems are in place. Soil sample submittals and lab analysis results for engineered soil mixes should be required prior to placement. Observation for soil uniformity during placement is highly recommended.

HAND OFF MOMENT:



Landscaping Contractor

- The finish grading processes involve numerous subcontractors.
- Landscaping contractors are often one of the last on site and bring with them several materials and supplies that can be a sediment source.
- Soil, mulch, paver base, concrete, sod rolls, etc.. can all contribute to sediment issues at a critical stage of vulnerability in the construction process.

10. LID PRACTICE MATERIALS

LID techniques are built with materials that can be unfamiliar terms for contractors and designers. However, they are the building blocks of a successful BMP and are often the cause of failure.

10.1 Bioretention Soil Media

These materials, commonly referred to as filter and/or soil media, are an engineered soil medium with high soil pore space that provide storage for runoff, allows runoff to be infiltrated or slowly released to an underdrain system, and is a growth medium for vegetation. A number of chemical and biological processes occur in the soil medium to help remove/bind pollutants and nutrients.

Material samples

The following soil medium (see Table 1) is often cited in manuals and research. Correctly mixed and applied, this mix provides ideal infiltration capacity, vegetation growth, and pollutant removal ability. The main cause of failure of this mix is improper mixing, resulting in elevated fines and/or clay materials which leads to limited infiltration. The use of topsoil in bioretention soil mix is discouraged. Ontario soils in general contain a high fraction of fines and sources of topsoil vary considerably from location to location making standardized mixes difficult to reliably produce. Often the mix specification can be achieved with sand and compost. As previously noted – this mixture should only be used when the designer has full confidence it will be mixed and installed properly. This requires frequent soil samples, tests, and inspection during construction.

Table 1. Bioretention Soil Specification

Grain Size Distribution	
Particle Size	**Percent by Weight**
Coarse to Medium Sand (2.0-0.25 mm dia. or between sieve #10 and #60):	71 - 92%
Fine Sand (2.0-0.050 mm dia. or between sieve #60 and #270)	0 - 17%
Silt and Clay (<0.050 mm dia. or passing through #270)	8 – 12% (5% clay max.)
Other Criteria	
Organic Content	3 - 5%
Cation Exchange Capacity (CEC)	10 meq / 100g
pH	5.5 - 7.5
Infiltration Rate	greater than 25 mm/hr

10.1.1 Mixing

Mixing should be done off site by a reputable supplier that can certify that the engineered soil contains proper component ratios. The soil medium should be delivered to the site once the facility is prepped and ready for final soil placement. Do not store engineered soil mediums on site for extended periods. Mixing engineered soil medium on site is not recommended. Using backhoes, bobcats, and front end loaders to mix soils on site has had limited success in creating uniform mixing. On-site mixers, similar to mortar or concrete mixers, have been successfully used but require preparation in smaller batches. Not all contractors possess the specialized machinery required for this process.

10.1.2 Recommended Sample Testing Protocol

Three samples of soil should be tested from every batch prepared by the supplier: a sample from the top of the pile, middle of the pile, and bottom of the pile. No bioretention soil should be brought to the site until the lab tests have been approved by the site engineer. It is recommended that soil testing be requested a minimum of two weeks before the soil is needed on site. Suppliers new to mixing bioretention soil will require additional time for testing and refining their mix to meet the specification. Tests should address:

1. Proper component composition and blend rate as identified in Table 1.
2. Soils with cationic exchange capacity (CEC) exceeding 10 milliequivalents per 100 grams (10 meq/100 g) are preferred for pollutant removal *(Hunt and Lord, 2006)*.
3. For optimal plant growth, the recommended pH is between 5.5 to 7.5. Lime can be used to raise the pH, or iron sulphate plus sulphur can be used to lower the pH. The lime and iron sulfate need to be uniformly mixed into the soil *(Low Impact Development Center, 2003a)*.

THINGS TO REMEMBER:

Value of Compost

- As mentioned in Chapter 9 Finish Grading, compost can be used as a tool throughout the contributing subwatershed increasing bulk density and helping establish vegetation.
- Compost does have an initial cost but has been shown to have a quick payback period due to the reduced need for fertilizer, pesticide, and irrigation.
- Seed turf establishment - payback occurs between years 5 & 6.
- Sod turf establishment - payback can be after 1 year *(Chollak and Rosenfeld, 1998)*

4. The mixture should be free of stones, stumps, roots, or other similar objects larger than 50 mm. The mixture's sand component should be coarse to medium sand; only up to 17% of the mix can be medium to fine sand.
5. The organic content should be 3-5% by dry weight (supplied by leaf and yard compost or composted pine mulch).
6. The media should have an infiltration rate of greater than 25 mm/hr.

IMPORTANT:

Geotextiles - using the right material

- See *LID SWM Guide* bioretention section for specification guidance on geotextiles.
- Woven slit film (typically used for silt fence), subgrade stabilization fabrics, and heat bonded fabrics should not be used for separating infiltration layers or lining an infiltration practice. In most cases, bioretention practices do not need a geotextile liner.

(Image-silt fence incorrectly lining BMP - *Source: LID Center*).

10.1.3 Depths

Soil mix will settle as much as 20% over time and should be accounted for in final construction. Natural settlement over time is preferred if the construction schedule allows, but soil can be saturated with water to speed up compaction.

10.2 Compost

Fully mature compost must be used, preferably organic leaf compost or other organic matter from local compost sources. Do not use peat or animal derived compost. Mature compost will smell like a forest, while immature compost will have a strong ammonia smell.

10.3 Geotextiles

Geotextile materials are often used between the subgrade and aggregate layer as well as between the filter media and gravel storage areas to prevent migration of materials. See the *LID SWM Guide* for guidance on specifying geotextiles. Generally, material specifications should conform to Ontario Provincial Standard Specification (OPSS) 1860 for Class II geotextile fabrics.

The use of geotextile has been reconsidered in non-structural applications (i.e. not load bearing) where the migration of soils is deemed insignificant. In healthy bioretention applications extensive root development is encouraged to cross soil gradients and this may be limited or initially reduced with the use of a geotextile layer. Structural considerations of geotextiles are critical in urban sites or BMP's adjacent to infrastructure.

10.4 Mulch

Wood mulch provides numerous functions to a bioretention practice including reducing soil erosion, filtration, protecting underlying soils from compaction, retaining moisture, and minimizing volunteer weed establishment.

In addition, the organics in the mulch layer and compost provide excellent treatment for heavy metal pollutants such as cadmium, zinc, and petroleum hydrocarbons *(Morgan, Gulliver, and Hozalski, 2010)*.

Shredded hardwood mulch provides a good humus layer and is less susceptible to floating than wood chips or mulches with larger pieces.

Mulch depth should be no greater than 75 mm to maintain oxygen to underlying soils. The top of the mulch should be used as the finish elevation on plans.

Photodegradable erosion control nets can be used initially to minimize floating mulch material. Shredded hardwood mulch will bind together over time as it settles but can be prone to floating initially. Hardwood mulch shall be free of bark, soil, green material, and debris.

10.5 Underdrain

Generally 100 mm, 150 mm , and 200 mm single-wall corrugated plastic or smooth-wall plastic pipes are used for the underdrain. 200 mm diameter pipe is recommended when freezing conditions are a concern.

Single-wall HDPE is preferred from an environmental perspective. Pipes should be wrapped or surrounded by a washed gravel blanket and should NOT be wrapped with a geotextile sock.

A general guide for pipe sizing – pipes should be sized to carry 10 times the maximum inflow from the engineered soil medium layer above *(Hunt, White, 2001)*.

Top: Mulch blown-in
Middle: Wood chips float
Bottom: Shredded hardwood mulch

10.6 Rock Material

The *LID SWM Guide* provides guidance on using non - structural BMP practices containing rock material. Clean, washed granitic rock material is recommended. However granitic material can be cost prohibitive in some regions with a limestone-based geologic history.

If limestone is specified, no fines should be associated with the material and certain hardness aspects laid out in Chapter 11 Permeable Pavement are highly recommended. All structural applications of rock material in the base and sub-base should also follow these recommendations.

10.7 BMP Monitoring Wells

A capped vertical standpipe consisting of an anchored 100 to 150 mm diameter perforated pipe with a lockable cap installed to the bottom of the facility is recommended for monitoring the length of time required to fully drain the facility between storms.

Separate monitoring wells extending to the bottom of the facility can be used to collect information on infiltration rates but may not be appropriate for water quality sampling.

10.8 Outlets and Outlet Structure Grates

Where possible, outlets should be elevated a minimum of 100 mm from the bottom of the facility to reduce the amount of debris exiting or clogging the outlet. Use dome-shaped grates where possible to protect against clogging from floating debris. Flat drainage grates have been shown to clog easier.

Grates that lock or screw into place are advisable in high traffic areas. Adjustable internal weirs allow managers to back up water at different elevations or remove completely to function as a traditional draintile.

THINGS TO REMEMBER:

Monitoring Wells

- A valuable tool for long term maintenance and monitoring. Monitoring wells are inexpensive pieces of infrastructure that can be used for observation, maintenance, and sampling.

11. PERMEABLE PAVEMENT

Permeable pavements are mentioned in other sections, however there is a benefit in grouping a variety of comments into one section with other idiosyncrasies unique to permeable pavements. For this section, permeable pavements consider: porous asphalt, pervious concrete, permeable pavers, and porous/reinforced turf parking materials.

11.1 Special Construction Considerations

11.1.1 Porous Asphalt

1. Porous pavement typically should not be located along heavy truck routes. This is particularly true for porous asphalt.

2. Porous asphalt should be located at lower volume traffic areas because turning and heavy traffic volume can deteriorate surface and reduce porosity.

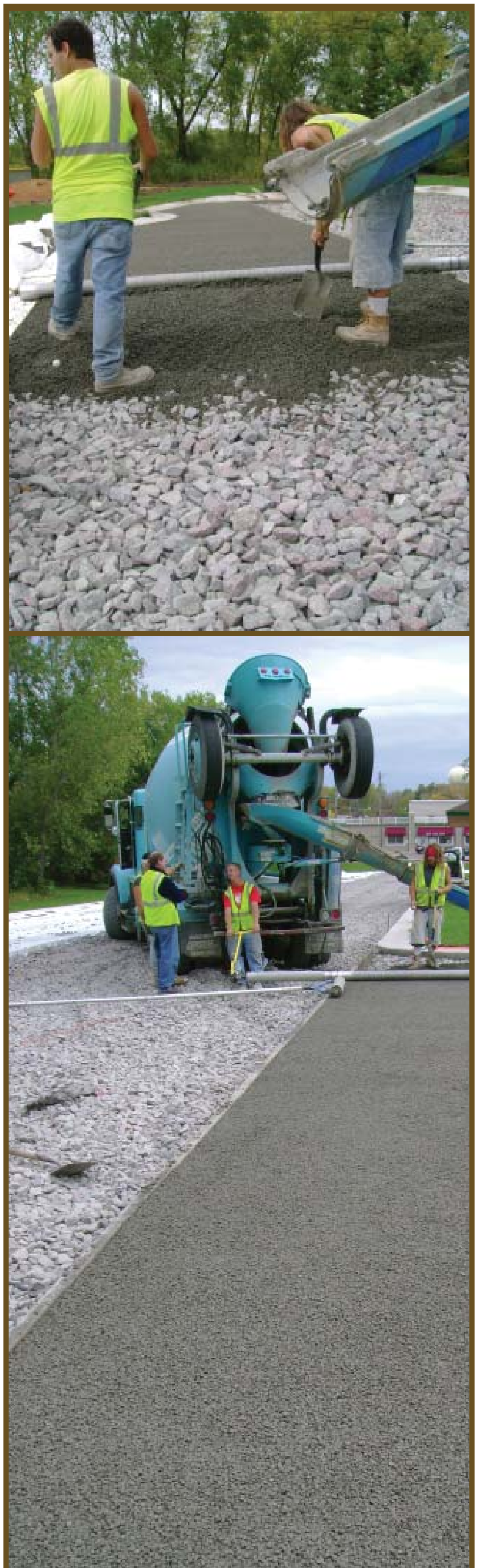
3. Specifications typically have tighter allowable temperatures for construction of porous asphalt than typical asphalt mixes.

4. Special attention should be paid to allowable binders and oils for porous pavements because porous asphalt has specific requirements, particularly between base and wear lifts.

IMPORTANT:

Installation Conditions

Porous asphalt and porous concrete have tighter climate considerations for installation than typical pavements, such as temperature and level of humidity.



Installation of pervious concrete; community recreation application.

11.1.2 Pervious Concrete

1. CVC/TRCA do not recommend pervious concrete for high loading applications.

2. Pervious concrete has the most particular installation requirements of all permeable pavements.

3. Because pervious concrete is already a dry mix with a critical moisture content requirement, mist or dampen the subbase prior to placement to ensure that the subbase does not suck moisture out of the pervious concrete.

4. It helps to receive the ready mix concrete a little on the dry side because adding water is easier than drying it out if it's too wet. If water is added, ensure uniformity. This may be best accomplished by spraying water from the top of the truck into the mix while mixing. Moisture content may be appropriate if a person can form a ball in their hand that holds together but does not bring paste to the surface. An expert should certify the moisture content prior to placement.

5. The placement process must often be stopped so the moisture content of the ready mix can be brought back up to specification before proceeding.

6. Forms should have a 10 mm vertical spacer that is removed prior to final rolling.

7. Use of a vibratory screed, known as a Texas Screed, is recommended on top of the half-inch spacer. The screed forms the concrete level, and the vibration provides consolidation while maintaining the void space required for hydrologic performance.

8. If the concrete sits too long prior to being screeded, it can be difficult to get proper consolidation.

9. Have a pressure mister on hand (especially in drier, hotter weather) to put a fog of moisture over the surface of the concrete while awaiting the plastic cover. DO NOT use the hose of the ready mix truck to spray the surface. This can result in washing the cement base off the rock in the pervious concrete, which results in excessive surface raveling.

10. Within 15 minutes of placement, cover the pervious concrete with a plastic cover (typically 6 mil) to prevent moisture loss and ensure the final strength of the surface. The timing is particularly critical if outside air temperatures are hot and/or conditions are windy and dry. Installation in air temperatures of 15 degrees Celsius, overcast with little to no wind and some humidity are ideal. The plastic cover should be white in hot weather in order to reduce solar load on the pavement.

11. A 30 cm piece of schedule 40 PVC pipe filled with water is ideal for roller compacting the surface the final half-inch (after removing the half-inch spacer on the forms). The plastic will help prevent concrete from sticking to the roller.

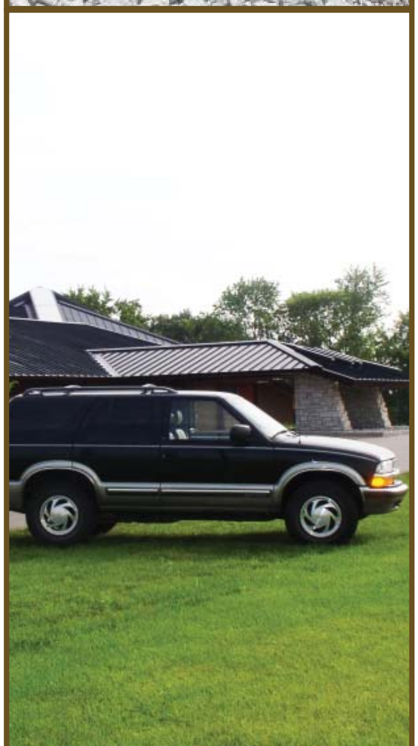
12. Some surface raveling will always occur, but most is preventable. It is critical to leave the surface covered in plastic, nailed down or weighed down with two-by-fours, for seven days during which time no traffic should travel on the surface.

13. Do not shovel dirt onto the plastic cover in order to keep it down; dirt can be misplaced or disturbed and end up filling voids and clogging the surface of the pervious concrete.

11.1.3 Permeable Pavers

1. Permeable interlocking concrete pavers are able to tolerate the highest loading of permeable pavement surfaces.

Top: roller compaction
Lower: plastic placement



Top: Installation of permeable pavers

Lower: Example of porous turf used for excess parking area

2. Providing a proper leveling course is critical to provide a level paver surface.

3. Set edges into concrete or other abutment.

4. To eliminate handwork, it is helpful to design the project around the equipment that will be used to install it. Typically, the blocks come palletized and are installed with an attachment that lifts them off the pallet and drops them in place. Matching the dimensions to the size of the pallet square will dramatically reduce installation time.

5. Rock chips need to be installed between surface voids. Sand or finer gradations will clog too quickly.

6. Routine maintenance by vacuuming will remove the rock chips and sediment between voids. Re-application of rock chips is needed after maintenance.

7. Large porous articulated mats are being developed for large surfaces and may allow for more rapid installation and lower costs, as pavers are often the most expensive (and aesthetic) permeable surface.

11.1.4 Porous Turf/Cellular Confinement

1. Turf parking should be located at a sufficient distance from asphalt parking lots due to the heat generated by asphalt parking lots and the associated harm to vegetation.

2. Consideration should be given to the use of de-icing salt during winter maintenance and the associated harm to vegetation.

3. Porous turf should be located in lower traffic areas because turning and frequent traffic makes the surfaces prone to failure.

4. Cells should be overfilled by 25-50 mm to allow for settling and compaction.

5. If seeding in dry conditions, the use of hydroseeding mulch and irrigation will benefit vegetation establishment.

11.1.5 Construction Techniques and Timing

If possible permeable pavement should be constructed last. If this is not feasible, a plan needs to be in place to keep construction equipment and traffic off the pavement. The typical permeable pavement construction process is as follows:

1. Stabilize all tributary areas. If the permeable pavement is immediately adjacent to traditional pavement, the traditional pavement should be installed to at least the base course prior to porous pavement construction.
2. Excavate porous pavement area to subgrade elevation. Using a toothed backhoe for excavation will help to scarify the subgrade soil and promote infiltration.
3. Install geotextile fabric if necessary. Typically a geotextile fabric can be used on the sidewalls of the feature to limit soil mixing and protect the adjacent area from sloughing into the infiltration bed. If soils are poor and underdrain system will be used, then a geotextile fabric should also be used on the bottom of the feature.
4. Leave the geotextile fabric roughly 50 cm long on all sides.
5. Install infiltration bed and choker course, compacting in lifts per specifications and creating a smooth surface to place pavement.
6. Fold the extra geotextile fabric over the top of the infiltration bed/choker course to serve as a backup sediment protection until permeable pavement is placed.
7. Place porous pavement per specifications.
   - *For porous asphalt, both base and wear courses should be placed before the wear course of the surrounding pavement for ease of construction.*
8. Establish perimeter controls to protect the pavement from compaction and sedimentation while construction continues on adjacent parts of the site.
9. Vacuum sweep the pavement regularly to remove accumulated sediment.

THINGS TO REMEMBER:

Keep Overflow Capacity in Mind:

Consider overflow capacity where there is potential for higher inflow volumes than there is storage.

Especially in cold climates, if water has the ability to rise in the underground storage below the pavers, it must have a free discharge below the elevation of the pavers in order to ensure that freeze/thaw issues are prevented.

Similarly, a valved underdrain that is opened in late fall could be installed to ensure there is no standing water left in the system when winter sets in.

SPECIAL CONSIDERATIONS:

Rock

Harder, non-limestone rock such as granite is generally specified for base and sub-base use in permeable pavement applications. Granitic material can be cost prohibitive and may lead designers and contractors to consider local limestone aggregate as an alternative. Concerns about using limestone have been raised due to it's inherent properties to break into small particles (fines) when fractured, its ease of fracturing, the dissolution of the material, and unknowns if solubalized limestone would precipitate at the sand interface.

If limestone based aggregate is proposed the following specification for fines and hardness should be considered:

- The Los Angeles Rattler (LAR) loss on the coarse aggregate fraction (material retained on the 4.75 mm [no.4] sieve) shall not exceed 40% for any individual source used within the mix. The composite maximum LAR loss shall not exceed 35.

All aggregate rock proposed to be used should consider the following specifications:

- All aggregates shall have a maximum wash loss of 1.5%.
- Material shall be 80% crushed (one fractured face).
- The use of recycled materials is not permitted. Recycled materials shall include, but are not limited to: glass, recycled asphaltic pavement, crushed concrete, and roofing shingles.

11.2 Permeable Pavement Maintenance

The primary goal of permeable pavement maintenance is to prevent the pavement surface and/or underlying infiltration bed from being clogged with fine sediments. In addition to owners not being aware of permeable pavement on a site, not performing these maintenance activities during construction or immediately following is a primary reason why this practice fails.

11.2.1 Maintenance Schedule

Ongoing Maintenance

- Prevent soil from being washed onto pavement.
- Never stockpile soil, mulch or other materials on pavement.
- Ensure that contributing drainage areas are stable and well vegetated.
- Ensure that pavement structure draws down between storms.
- Clean pavement surface annually or at least biannually with a commercial vacuum sweeping unit.
- Inspect and clean inlets.
- Remove weeds as needed.

IMPORTANT:

Make a Plan:

- A maintenance plan clarifying maintenance responsibility must be developed for every project.
- Effective long-term operation of practices necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules.
- Proper maintenance will not only increase the expected lifespan of the facility, but will also improve aesthetics and property value.

THINGS TO REMEMBER:

Important Notes:

Critical LID Practices -
should not be pursued without a clear understanding of maintenance requirements, associated cost and a commitment to implementing these tasks throughout the life-cycle of the practice

Critical Design -
should ensure easy access is possible for maintenance personnel and any associated machinery

11.2.2 Maintenance Issues

Cleaning & Restoring

1. Vacuum sweep frequently to keep the surface free of sediment. Pure vacuum sweepers are preferred over regenerative air sweepers as fines can be forced by the air column deeper into voids. Simple broom sweepers are not effective. For permeable pavers, adjustments to the vacuum force likely will be required to minimize removal of stones from the openings between pavers. Higher vacuum settings with aggregate replacement can be applied when sediment is more difficult to remove.
2. If vacuuming does not restore permeability, a treatment of pressure washing (clean, low-pressure) followed by vacuuming has shown to be effective. Avoid high pressure applications which may drive contaminants further into the porous surface.
3. As a last resort, clogged sections of unit pavers should be disassembled and repaired. Disassembling may require breaking a paver as the pavers are tightly packed.

Repairs

1. Do not seal or repave with non-porous materials.
2. Reconstruct portions of the surface that are below acceptable infiltration rates.
3. Potholes and cracks can be repaired using conventional, non-porous patching mixes as long as the cumulative area repaired does not exceed 10% of the parking lot area.

Winter Operation

1. Eliminate the use of sand or other grit as anti-skid agents during winter maintenance.
2. Plowing: Setting blade about 2.5 cm off pavement can protect uneven porous pavers.
3. Salt application is acceptable, although more environmentally-benign non-chloride deicers are preferable.

12. PERMANENT VEGETATION ESTABLISHMENT

Establishment of permanent vegetation refers to the time necessary to acclimate the plants to their new environment after installation. Plants are generally considered established once they have rooted into the growing medium, are producing new growth, and when watering is no longer required .

12.1 Site Conditions

The unique stressors of a BMP should be fully understood and minimized. In addition to the customary environmental factors, the following stormwater factors should be considered during planning and plant selection:

1. The duration, depth and frequency of stormwater inundation should be accurately predicted for each facility. Plant selection should be based on corresponding species tolerances to the specific hydrology of the location within the facility.
2. While sediment, salt and other nutrients must be minimized higher concentrations are expected in these receiving facilities, therefore species with higher tolerance should be utilized.
3. Refer to *LID Landscape Design Guide* for guidance on plant selection and plant lists for each vegetated LID practice.

A defined edge contains floating mulch and debris, providing a clean and well maintained public appearance.

IMPORTANT:

- Vegetated BMP's should not be considered without an appropriate maintenance plan and dedicated resources.
- Establishing high quality vegetation via seed is challenging within a BMP and takes years to mature – therefore live plantings should be considered for all small and high traffic BMP's.

12.2 Environmental Factors

Establishing high quality vegetation within a stormwater facility can be challenging at times. Every effort should be made to reduce the stressors on the facility, select species with appropriate tolerances, and utilize plant types and planting methods necessary for establishment within these facilities:

THINGS TO REMEMBER:

In LID soil health and porosity of the entire drainage area is equally important to stormwater management as the receiving BMP's.

A healthy, vibrant soil and vegetation structure provides valuable plant nutrients, holds and retains water and oxygen, binds and degrades pollutants.

Construction activities have caused adverse impacts to the environment in the past.

Two main aspects are:

- cumulative, long-term increased stormwater runoff due to soil compaction
- impervious surfacing

1. While there is a place for select non-native plant species in LID, native species are recommended over non-natives because they generally require fewer inputs and because they are adapted to our climate and soils.

2. Emergent and aquatic wetland vegetation is not suitable for infiltration and filtration facilities. These facilities are intended to drain with 24-48 hours and therefore wetland vegetation is inappropriate.

3. Establishing high quality vegetation in areas of frequent ponding and concentrated flow via seeding methods is challenging. Robust live plants should be considered and prioritized for these areas.

4. Trees / shrubs, grasses / sedges / rushes and forbs / ferns each have unique benefits and limitation in LID facilities. While debris from tree / shrubs may block outlets, the size and form of the planting can provide superior establishment in challenging locations.

5. Facilities planted in clusters of like species with moderate diversity are easier to maintain and more visually acceptable to the general public.

6. A planting plan design should include species that tolerate extremes. There will be periods of water inundation and very dry periods. Most riparian plant species will do well in rain gardens.

12.3 Other Considerations

Consider additional lessons learned for proper function and aesthetic improvements:

1. When feasible incorporate a turf buffer between impervious surfaces and receiving facilities. A minimum of 60 cm buffer of turf will reduce the erosive velocities of runoff, filter particulates, as well as provide functional space and an aesthetic frame.

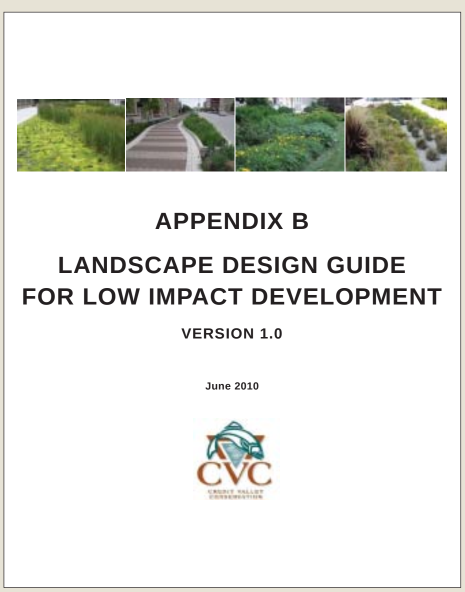
2. Permanent irrigation is not recommended for stormwater facilities, but a temporary establishment irrigation plan should be prepared for very sandy sites and if dry conditions persist during establishment.

3. Mulch is necessary in most planting scenarios to limit growth of volunteer species, but its mobility can be troublesome in stormwater facilities. Avoid mulch in areas of concentrated flow and utilize options such as river-run stone, compost biofilter socks or erosion control blankets. Utilize a double-shredded hardwood mulch for its binding characteristic to reduce floating and transport.

4. The facility should not be an isolated feature - consider the shape of the facility and plant composition to fit the facility into the landscape.

5. Many of the common species utilized in stormwater facilities are warm-season species, which lack interest in the spring. To incorporate year-round interest utilize multiple plant forms and provide some bloom interest across the growing season.

IMPORTANT:



APPENDIX B

LANDSCAPE DESIGN GUIDE
FOR LOW IMPACT DEVELOPMENT

VERSION 1.0

June 2010

CVC

Things To Remember:

- Understanding plant species' susceptibility to water-level fluctuations and landscape pollutants will enable better stormwater detention treatment and aesthetically pleasing systems.

- Plant selection must take unique site conditions and stressors into account, but there is no suite of desirable plants available for a poorly designed or constructed site.

Stock Plants and Seedlings:

- Plants and/ or seedlings establish much faster than seed.
- Plants allow more flexible design to match the BMPs surrounding context They can be planted formally, in drifts, randomly, etc.
- Live plants are much more tolerant of inundation while they are establishing than seed.
- Larger plant sizes are recommended for BMPs that will be online immediately after planting (minimum size 1 gallon pot (or equivalent) recommended).
- Plugs are much more economical but are more susceptible to inundation, covering by mulch, and predation by wildlife.
- Plant growth rates should be considered when specifying planted sizes as some species take much longer to mature.
- Volunteer planting efforts have been successful at building public ownership and continued care from those who planted material and watch it mature.

Seed and Seedling:

- Seeding is NOT recommended for BMPs.
- Seeding areas often take several years to establish.
- If seed is used for large scale BMPs, they should be kept off-line until they are established. Seed can become mobile with water and transported to unintended areas, or out the overflow or outlet structure.
- Seed quality and planting per specification is more difficult to visually inspect than plants and planting.


The vegetation establishment period is a significant factor in the overall success and performance of BMPs.

12.4 Vegetation Maintenance

The maintenance of LID facilities is essential to ensure that stormwater management and other benefits continue over the full life cycle of the installation.

Public projects completed within the right-of-way have posed maintenance challenges for many communities. Most communities will assume maintenance responsibilities for facilities within the R.O.W. For facilities outside the R.O.W., some communities prefer to transfer responsibility to adjacent landowners.

In the latter scenario, landowners must accept ownership and be informed of their responsibilities. The community must also have a system for promptly determining when maintenance is not occurring and taking necessary corrective action.

Although maintenance activities can be very similar to traditional landscape requirements, there are many elements that are often intimidating and/or unknown. Training of staff or homeowners may be necessary.

12.4.1 Vegetated Practices

Vegetated practices, such as bioretention facilities, require maintenance that is dependent on two major things:

1) **The planting soil's ability to drain;**

and

2) **The survival of desirable plants.**

12.4.2 Maintenance Sequencing & Categories

Maintenance is more intense during initial establishment (0-2 years), but less maintenance is needed over time. In general – a reduction factor of 0.5-0.7 can be applied to yearly maintenance requirements as you move from one maintenance category to another. In many cases, maintenance tasks can be completed by a landscaping contractor, who may already be hired at the site.

Establishment (0 to 18 months from installation)

- Water plants – water regularly the first growing season and as necessary the second and subsequent growing seasons
- Protect and replace plants as needed
- Weed control – monthly

Development (18 months to 3 years from installation)

- Replace dead/ dying plant material - adjust species if needed
- Additional mulch - as needed
- Weed control – as needed

Maturity (3 years + and in response to large storms)

- Remove sediment from pretreatment device AND/or filter strip as well as any curb cuts
- Remove mulch from outlet (if applicable)
- Redistribute consolidated mulch
- Remove litter and debris
- Remove any deposited sediment
- Repair erosion at inflow points and take correct action if washout continues
- Remove weeds
- Remove and replace dead and diseased vegetation

Left: Establishment phase. Right: Vegetation in maturity phase (same location).

Additionally, maintenance sequencing and activities can be divided into High Profile sites and Low Profile/ Natural sites. High Profile sites may require greater maintenance inputs, whereas Low Profile/Natural sites can be considerably less and require a shift in focus to weed control of mainly aggressive and non-native species.

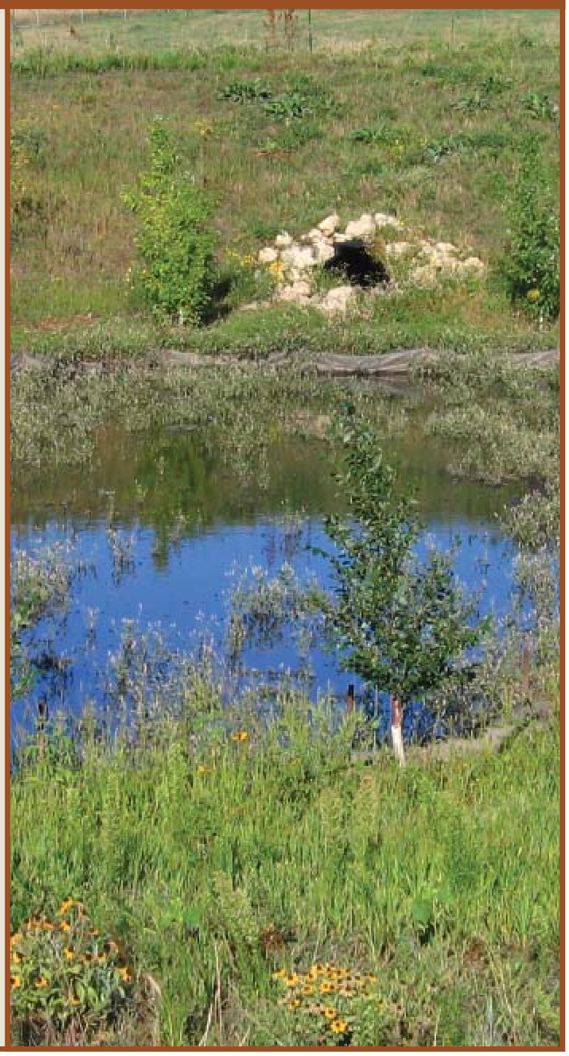
It is recommended that grooming of perennials be limited to spring only. Dead stands should remain through the winter to provide protection/ insulation for root stock, overwintering habitat for beneficial insects and predators as well as providing winter interest. Grooming can be limited to spring clean-up activities (dead stand removal, mulch replacement (as necessary) and general clean-up) as well as pruning of woody plants based on removal of diseased, damaged and interfering stock.

IMPORTANT:

Problem Area: Standing Water

Bioretention facilities are designed to have surface water drain away within 24 to 48 hours. If standing water for more than 48 hours is routinely exceeded, then corrective actions should be taken. The following actions are listed in order of increasing effort and cost:

- Remove the mulch layer and rake the surface.
- Check the underdrain for clogging and flush it out.
- Replace the top 75 mm of soil with new soil.
- Apply core aeration or deep tilling and mix sand or compost amendments into the soil.
- Full replacement of soil or addition of an underdrain if the facility does not already have one.



13. OVERWINTERING

Overwintering is an important concept of LID construction that is often overlooked due to scheduling pressures, unpredictable weather, and lack of foresight. Numerous issues can be created by multiple freeze-thaw cycles and potential erosion that may occur from late fall through the spring meltwater. One of the major concerns of conducting late season work is running into work-stopping weather before the drainage area is stabilized. In this case spring snowmelt will almost always result in sedimentation of LID practices.

Spring melt can contribute to the sedimentation and reduced performance of BMPs.

A construction site that is not fully stabilized by October 15th should be protected with overwinter stabilization. Areas are not considered fully stabilized unless they are covered with pavement; have a properly compacted gravel base or rip rap; or have a minimum of 85% healthy vegetation coverage, or compost blanket. Appropriate erosion control measures must also be in place as outlined in Appendix C of the *ESC Guide*.

13.1 Winter Construction Period and Overwinter Stabilization

The winter construction period runs from October 15th through April 1st. It requires construction activity limits and erosion control measures in order to minimize potential erosion and sediment impacts. Erosion control measures are found in Appendix C of the *ESC Guide*.

13.1.1 Construction Activity Limits and Procedures

1. The maximum area of exposed site is 0.4 hectare. The area should be limited to work which will occur within the following 15 days and that can be mulched in 1 day prior to any precipitation event.

2. New work areas should not be exposed prior to stabilization of previous work areas.

3. All areas are considered exposed if they have not been stabilized by pavement, a properly compacted gravel base, rip rap, a minimum of 85% healthy vegetation coverage, mulch, compost blanket, or appropriate erosion control measures.

4. Sites should be inspected after snowmelt events. These are typically days when temperatures rise to above 4° Celsius.

5. Erosion and sediment control measures should be inspected and maintained as outlined in the *ESC Guide*. Temporary stockpiles should be fully vegetated or otherwise stabilized by winter mulching or other accepted practice.

13.2 Maintenance Sequencing

13.2.1 Overwintering Stabilization Techniques

1. Mulching – Straw mulch used during winter construction should be applied at a higher rate than normal (up to double the rate) and shall be anchored, per the *ESC Guide*, by netting, tracking, or wood cellulose fiber. Between November 1 and April 15, all mulch should be anchored by either erosion control net, Lockdown Netting, tracking or approved soil binders.

2. Seeding – During winter construction seeding will not be required unless dormant seeding will be performed. When finish grading is completed during times of above freezing temperatures, the area shall be protected with mulch or temporarily seeded and mulched until final treatment can be applied. If dormant seeding is not performed, all disturbed areas should be properly mulched and revegetated in the spring.

   - Proposed permanent vegetation areas - If proposed vegetated areas do not have a minimum 85% vegetative growth by Oct. 15th, then those areas should be seeded and covered with either straw mulch and anchored netting, in areas with slopes less than 15%, or an anchored erosion control blanket on slopes greater than 15%.

   - Dormant seeding – Seeding and mulch installation should not occur in snow over 2.5 cm deep.

   - Erosion control blanket – If installed in frozen conditions, 15 cm long metal nails with washers should be used in lieu of staples.

   - Sod and grass seeding - Properly installed and anchored sod should be placed by November 1. Grass lined ditches should be constructed and stabilized by September 1st. Any grass-lined ditch which does not have 85% vegetative growth by October 15th should be stabilized temporarily with stone or erosion control blanket per appropriate flow conditions as outlined in the *ESC Guide*.

   - Frozen soils – Frozen excavated material should be stockpiled separately from other soil stockpiles. Frozen soil stockpile should be protected by appropriate erosion control measures as outlined in the *ESC Guide*. Frozen soil material should be completely thawed and dry in the spring before transport or use in other areas.

IMPORTANT:

Winter Effectiveness -

LID practices are effective in winter and early spring if constructed properly and the contributing drainage area is stabilized.

13.2.2 Online Facilities in Winter

If the drainage area is stabilized, infiltration practices can be online over the winter. Infiltration practices are capable of infiltrating snowmelt if the soil media functions properly under warm season conditions. Infiltration practices that are wet during the late season (because they are sediment-laden or have not yet been fully constructed), will exhibit significant ice formation preventing infiltration of snowmelt.

If the contributing drainage area is not stabilized prior to overwintering, the practice should be kept offline with the use of inlet barriers, temporary grading and sedimentation basins, and geotextile covers, among other techniques.

THINGS TO REMEMBER:

The ***Erosion & Sediment Control Guideline for Urban Construction*** recommends monthly inspections for sites left alone for **30 days or longer**.

14. CERTIFICATION

Certification occurs at all stages of project construction. Field verification of LID design assumptions should occur at the beginning of construction and materials should be verified/certified (e.g. engineered soil media, plants). LID features should be inspected throughout project construction and ultimately, the form and function of LID practices should meet standards of construction prior to return of the contractor's performance bond.

14.1 Certification throughout Construction

The success of LID features is dependent upon the attention paid to control of up gradient construction activities, establishment and maintenance of perimeter controls and use of proper LID construction materials (e.g. engineering soil media, washed rock). Inspection and certification throughout the construction process will dramatically reduce problems in the end product and is critical to success of the project.

The following list of items should be inspected and certified during construction. LID inspection guidance and checklists are provided in the *Contractor's and Inspector's Guide to Low Impact Development Construction.*

14.2 Prior to Construction

1. Divert runoff from adjacent areas.
2. Clear the area where the LID practice will be constructed.
3. Establish and protect a nearby project benchmark.
4. Stake out and confirm grades of the practice location.
5. In infiltration areas, test the soil for permeability to confirm design assumptions.
6. Verify groundwater and bedrock design assumptions.
7. Ensure temporary erosion and sediment controls have been properly installed.

IMPORTANT:

The *Contractor's and Inspector's Guide to LID Construction* is a companion to this guide and provides a more detailed list of items to inspect throughout the construction process.

THINGS TO REMEMBER:

Certification occurs at ***all*** stages of project construction

14.3 Excavation

1. Ensure the contractor has the right equipment.
2. Discuss the goals of the project and purpose of the LID practices with the operators and crew.
3. Ensure side slopes are stable and within design range.
4. Stabilize stockpile locations with vegetation and/or silt fence. Stopckpiles must not be adjacent to excavation area.
5. Scarify soils compacted during excavation.
6. If necessary, adjust the facility’s depth to meet soil type and permeability design assumptions.
7. Put sufficient perimeter controls in place to protect the practice.

14.4 Structural Components

1. Ensure materials (aggregate, perforated pipe, etc.) are per specifications.
2. Ensure forms are adequately sized.
3. Place and install geotextile drainage fabrics or impervious liners per plan.
4. Install underdrain system to grade.
5. Install anti-seep collars per plan.
6. Install inlets/outlets and emergency overflows at correct elevations per plans.
7. Install pretreatment measures per plans.
8. Install materials, spacing and grade of check dams per plans.

14.5 Soils

1. Ensure common borrow complies with specification for fill areas.
2. Ensure topsoil complies with spec in composition and placement.
3. Ensure the engineered soil composition and texture conform to specification.

14.6 Vegetation Establishment

1. Stabilize the surrounding drainage area for permanent erosion control.
2. Ensure seed or plants to be used conform to planting specifications.

14.7 Final Inspection

1. Ensure the practice has been installed per plans.
2. Ensure the pretreatment is operational.
3. Ensure the inlet/outlet is operational and at the correct elevation.
4. Verify the soil/filter medium permeability.
5. Ensure vegetation been established to 85% cover.
6. Remove construction generated sediments.
7. Ensure the contributing watershed is stabilized before flow is diverted to the practice.

IMPORTANT:

Stormwater Treatment - Assessment and Maintenance

The University of Minnesota in partnership with the Minnesota Pollution Control Agency produced an online manual in March 2010 for assessment and maintenance of stormwater treatment practices. The manual provides guidance on applying the *Four Levels of Assessment* and analyzing data collected from these assessments:

1. Visual Inspection
2. Capacity Testing
3. Synthetic Runoff Testing
4. Monitoring

Link to online manual: *http://stormwaterbook.safl.umn.edu/*

14.8 Final Certification

Once the contractor completes the job, LID practices may or may not be installed per the site plans. The pace and extent of construction may preclude inspections and certifications from ensuring the critical design elements of each LID practice. A wide range of opportunities for LID failure have been discussed throughout this guide. Routine inspections may catch mistakes such as bad material substitution or incorrect outlet elevation, but having a final certification requirement in place allows for site-wide inspection and mitigation before the contractor is released of responsibility. Certification ensures that knowledgeable personnel (e.g. inspector, design engineer, or permitting agency) evaluate whether the LID practices have been installed properly and function as intended. Certification of the LID practices should take place when clearing and grading for roads, lots and other land uses, which drain to LID practices, have been completed and up gradient areas are stabilized as defined by the construction or site plan.

Certification of project completion involves a performance bond submitted by the contractor to the owner as a condition of the contract. Contract language for certification of project completion should specifically require certification of LID practices. In this case, the designer would be best equipped to handle the final certification process on behalf of the owner. This system may fail when implementation of the LID features is not in the owner's self-interest.

The regulatory authority (e.g. the municipality or conservation authority) should require a performance surety as part of the permitting process, which specifically requires certification of LID features. In this case, qualified regulatory personnel would handle the final certification process, including certification of the LID features, if the local regulatory authority requires a performance surety as part of their permitting process. Final certification should be performed by qualified regulatory agency personnel.

The protocol recommended for final certification of LID infiltration or filtration practices (including permeable pavements) is based on research by the University of Minnesota and the Minnesota Pollution Control Agency. Their online manual guides users through the *Four Levels of Assessment*. These levels are summarized below. The actual procedure for each level of assessment varies for each stormwater treatment practice and assessment goal.

HAND OFF MOMENT:

Final certification is an important hand off moment from the contractor to the owner for long term maintenance.

This is the last opportunity to identify issues due to improper construction and/or unforeseen site condition issues. Issues should be resolved before the owner takes over maintenance responsibilities.

Level 1 - Visual Inspection:

Considering the minimal effort and cost required for visual inspection, it is recommended that visual inspection be used as the initial assessment tool for all stormwater treatment practices. Visual inspection involves inspecting a stormwater treatment practice for evidence of malfunction and can be accomplished with a brief site visit. Visual inspection can be used to quickly and cost-effectively determine if, and potentially why, a stormwater treatment practice is not operating properly.

If a stormwater treatment practice is determined to be non-functional based on visual inspection (e.g. it contains ponded water longer than 24 hours after the end of the last precipitation event), no further performance assessment is warranted until the stormwater treatment practice is repaired or replaced.

BMP holding water longer than design drawdown time

Visual inspection alone cannot provide quantitative information about stormwater treatment practice performance. Quantitative information on performance will require additional assessment via capacity testing (level 2), synthetic runoff testing (level 3), or monitoring (level 4).

Level 2 - Surface Infiltration Capacity Testing:

Surface infiltration capacity tests can be performed on the following stormwater treatment practices: bioretention practices (rain gardens), sand or soil filters, infiltration trenches, infiltration basins, filter strips, and swales. Infiltration testing can be performed on permeable pavements, however plumbers putty and/or clay are necessary to seal the infiltrometer to the pavement. Synthetic runoff testing is the better method to evaluate the infiltration rate of permeable pavements.

Double-ring infiltrometer

The key to accurate capacity testing is conducting hydraulic conductivity measurements in several locations at several times of year using infiltrometers or permeameters.

Contractors’ schedules may preclude high-accuracy measurement regimes. The online Assessment and Maintenance manual identifies measurement uncertainty as a function of the number of infiltration tests conducted within a single infiltration practice.

Synthetic flooding for a winter infiltration study.

Level 3 - Synthetic runoff testing:

After visual inspection (level 1) and capacity testing (level 2) have been considered and either dismissed or performed, synthetic runoff testing should be considered if warranted by the goals of the assessment. Synthetic runoff testing to assess drain time can be performed on the following stormwater treatment practices: bioretention practices (rain gardens), dry ponds, infiltration basins, sand and soil filters, underground sand filters, underground wet vaults, and most permeable pavements.

Synthetic runoff testing can be used to evaluate the infiltration rate by a stormwater treatment practice. Synthetic runoff testing uses a clean water source (e.g. a fire hydrant or water truck), applied to the stormwater treatment practice under well-controlled conditions and while performance is measured.

For filtration or infiltration rate assessment, the following four conditions must be met for synthetic runoff testing to be feasible:

1. There must be a water supply that can provide the required discharge and total volume of runoff needed.
2. The BMP must be offline and/or no precipitation is expected for at least 48 hours.
3. Outflow paths other than infiltration are either measurable or can be temporarily plugged.
4. The water surface elevation in the stormwater treatment practice can be measured continuously during the test.

Once the stormwater treatment practice is filled with synthetic runoff, measure the change in water level with time to evaluate the infiltration rate.

For permeable pavements and other subsurface BMPs, the change in water level will be measured within the observation well.

Level 4 - Monitoring:

If capacity testing (level 2) and synthetic runoff testing (level 3) are not feasible assessment approaches for a specific location, or do not achieve assessment goals, monitoring should be considered. Monitoring is the most comprehensive assessment technique and can be used to assess water volume reduction and peak flow reduction (and pollutant removal efficiency) for most stormwater treatment practices by measuring discharge (and pollutant concentration) during natural runoff events. This level of monitoring is recommended when such a stormwater practice is being implemented for the first time in that jurisdiction or development context (e.g. pilot testing of a new technology, challenging soil or geologic contexts, unique or hybrid facility design) or if the facility has been designed to meet higher standards due to the sensitivity of the receiving water or presence of species of concern.

To assess runoff volume reduction, peak flow reduction, or both, the inflow(s) and outflow(s) must be measured or estimated as in conducting a water budget. *The summation of the inflows can then be compared to the summation of the outflows to determine the runoff volume reduction, peak flow reduction, or both. Natural runoff events have variable discharge and duration that require continuous flow measurement (or estimation).*

Besides having additional costs, monitoring has more potential for uncollected or erroneous data as compared to synthetic runoff tests for the following reasons: Weather is unpredictable and can produce various runoff volumes of various durations with varying pollutant concentrations at various times. In order for a storm event to be monitored correctly and accurately, all monitoring equipment must be operating properly and the parameters (water depth, etc.) must be within the limit ranges of the equipment. Equipment malfunction due to routine wear or vandalism is more likely. Without proper equipment installation and consistent inspection , maintenance and data quality control, storm events may be measured or sampled incorrectly or not at all.

Bioretention monitoring station.

IMPORTANT:

Comparison of Four Levels of Assessment			
Levels	**Costs - Relative**	**Advantages**	**Disadvantages**
Level 1 Visual Assessment	$	• Most cost and time effective	• No quantifiable data on performance
Level 2 Infiltration Capacity	$$-$$$	• Can be performed for all sizes of stormwater treatment practices	• Only estimates permeability of the BMP surface • Requires numerous tests for greater accuracy
Level 3 Synthetic Runoff Test	$$-$$$	• Accounts for increased infiltration due to vegetation stems • Shows when filtration is limited by subsurface collection system and not by the surface or near-surface layers • Less time and expense required for the assessment	• Dependent on adequate water supply - limits size of BMP that can be tested • Uses a lot of water • Typically lasts 14 continuous months • Requires equipment to be left at a site - opportunities for malfunction
Level 4 Monitoring	$$$$	• Most comprehensive method	• Time consuming, susceptible to vandalism, malfunction, weather, etc.

15. AVOIDING COMMON MISTAKES: A Sub-Chapter Summary

3. Verification of Siting and LID Practice Design:

Physical site inspection is often the most overlooked aspect of LID. Surveys, aerial photography, and incomplete or old mapping is often unsatisfactory for a fully functional LID design and construction.

- Soil borings and test pits
- Understanding the site's context
- Knowing contributing watersheds

4. Tendering and Ownership:

Emergency Erosion Control Measures to address major storm events and flooding are difficult to predict and budget for. A separate line item for emergency erosion control is one strategy to ensure EC is performed properly and contractors are paid for their additional work.

5. Site Preparation:

Insufficient marking of protected areas can lead to natural resource destruction and mass sediment loss due to large, unprotected areas of bare soil exposed to storm events. Clearing activities must be coordinated with the construction schedule to limit the duration and size of disturbed areas. Down gradient perimeter control must be in place prior to conducting any up gradient activities.

Placement and maintenance of perimeter controls is critical throughout the construction process:

- Infiltration practices are resources that should be protected with perimeter controls.
- A failure of a single portion of any perimeter control can cause sedimentation of the LID practice.
- Perimeter controls are only effective with routine inspection and maintenance.

6. Mass Grading:

Mass grading can occur in LID with precautions to protect future BMPs.

- Below ground BMP facilities _can be_ constructed during mass grading _if_ bulkheaded for remainder of construction.
- Using BMPs as temporary sediment basins during mass grading requires planning and contractor communication.

7. Utility Installations:

If possible, avoid locating utilities within LID features. Communication and coordination with utility companies is critical to integrating LID and utility corridors

- Lighting installations within or above BMPs which may require special structural support considerations.
- Water and sewer utilities in or below BMPs may require insulation and/or anti-seepage measures.
- Electrical utility routes may conflict with water conveyance and standing water/ ponding areas.

8. Buildings and Pavement:

Building contractors generally have the least amount of knowledge and concern for stormwater BMPs.

- Clearly mark all BMPs in plans and on site; avoid compaction or contamination of LID areas from machinery or materials storage over BMP footprints.
- Inspect the site at least once a week and after every rainfall to ensure LID protection measures are in place.

9. Finish Grading:

Conveyance of runoff into BMPs is one of the most common errors in LID.

- Inlets (sod, rip rap, or pretreatment measure) are installed higher than the contributing impervious surface, runoff then bypasses the practice.
- Inadequate scour protection is provided at the practice's inlet leading to erosion and scouring.
- Pretreatment can prolong the life of a practice and make maintenance easier.
- Inlet, outlet, and emergency overflow elevations are often only centimetres apart - requiring precise grading.

10. LID Practice Materials:

Bioretention soil medium and installation is new to many contractors.

- Soil medium should be premixed, and samples should be pre-approved to ensure proper material.
- Settling should be accounted for, both in quantities and process.

11. Permeable Pavement:

Permeable paving should be protected in all phases of construction.

- Protect paving area from surrounding drainage area with perimeter controls.
- Keep all construction equipment off permeable areas because sediment tracking can clog permeable pavement.

12. Permanent Vegetation Establishment:

Plant establishment is often overlooked but is critical to long term LID success.

- Seed is difficult to establish in online stormwater practices.
- Establishing vegetation is often more successful if facilities are kept offline the first growing season.
- The first few years of establishment will require greater maintenance.
- Plant the right plant. Beware of uncommunicated plant substitutions.

13. Overwintering:

The winter construction period - October 15th to April 1st - will require special construction measures.

- Unstabilized natural heritage features should be protected within 30 metres of their boundary by Oct. 15th.
- Areas cleared and exposed should be limited to 0.4 hectares
- Seeding is not recommended during winter construction, unless dormant seeding.
- Mulch should be applied at higher rates and anchored when overwintering.

14. Certification:

Final certification is the last chance to identify and solve potential issues before the owner takes over.

- Issues should be resolved before the owner takes over maintenance responsibilities.
- Assessment and maintenance of stormwater treatment practices can be divided into four main categories: visual inspection, capacity testing, synthetic runoff testing, and monitoring.