Prepared by:

**TOWN OF LINCOLN**

# Low Impact Development and Green Infrastructure Design Guidelines

**May 2020**

GUELPH | OWEN SOUND | LISTOWEL | KITCHENER | LONDON | HAMILTON | GTA

www.GMBluePlan.ca

# Table of Contents

# 1 INTRODUCTION

Over the past several years in Ontario, the practice of stormwater management has shifted from an approach narrowly focused on centralized water quality treatment and peak flow control towards a broader approach focused on maintaining and re-establishing the hydrological regime of a space in its pre-development state. This new approach uses a series of micro-controls at, or near, the source of drainage networks to supplement conventional infrastructure by minimizing alterations to the water cycle. This is achieved through site planning techniques aimed at infiltrating, filtering, evaporating and detaining runoff. This practice is widely known as Low Impact Development (LID).

Sustainable solutions are becoming increasingly utilized across Ontario as managing and mitigating stormwater continues to be a focus. In fact, the results of several studies in Ontario and the Greater Toronto Area have concluded that the shift towards Low Impact Development is essential to improving the resilience of watercourses to the hydrologic impacts associated with climate change. In July 2010, the Toronto and Region Conservation Authority (TRCA) and Credit Valley Conservation (CVC) published the *Low Impact Development Stormwater Management Planning and Design Guide* (hereafter referred to as the *LID Guide*), established to assist developers, consultants and landowners in implementing sustainable stormwater management practices in their watersheds. This guide provides a wealth of information on the planning, site selection and design of many LID practices, aiming to streamline the process to encourage widespread adoption of these principles.

As this field is continually progressing, even more up-to-date information may be found at www.wiki.sustainabletechnologies.ca. This website is a product of the Sustainable Technologies Evaluation Program which was developed by TRCA, CVC, and the Lake Simcoe Region Conservation Authority to support further implementation of these technologies and practices across Canada. This online version is expected to eventually supplant the TRCA/CVC LID Guide.

The Town of Lincoln has experienced extensive damage from Spring flooding over the last few years. The implementation of LID techniques can allow the Town, as well as other similar municipalities, to have an additional method for mitigating the impacts of stormwater.

Many jurisdictions have unique definitions for the term Low Impact Development. For this document, the following definition, as provided in the *LID Guidelines,* will be used:

> **Low Impact Development** (LID) is defined as "…a 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. LID comprises a set of site design strategies that minimize runoff and distributed, small scale structural practices that mimic natural or predevelopment hydrology through the processes of infiltration, evapotranspiration, harvesting, filtration and detention of stormwater. These practices can effectively remove nutrients, pathogens and metals from runoff, and they reduce the volume and intensity of stormwater flows."

This document was developed in accordance with existing best practice guides such as the CVC *LID Manual*, with requirements tailored to the Town of Lincoln's needs. It is intended to be utilized by the Town as a reference guide for implementing and managing sustainable stormwater practices.

## 1.1 The Town of Lincoln

The Town of Lincoln (**Figure 1-1**) is located in the Niagara Region of Ontario, Canada, at a latitude and longitude of 43.1879° N, 79.4649° W respectively. Comprised of several communities including Beamsville, Campden, Jordan, Jordan Station, Rockway, Tintern, Vineland and Vineland Station, the Town of Lincoln covers a total of 162.8 km$^2$ of land.

As of 2020, the Town has a population of approximately 25,000. The Town is at the forefront of a significant growth phase and it is anticipated that the current population will increase by 50% by 2031.

The Town of Lincoln lies in the heart of Ontario's wine country and is well known for its orchards, vineyards and wineries. As such, a large component of the Town is rural, encompassing large, open agricultural spaces.


**Figure 1-1: The Town of Lincoln**

### 1.1.1 Stormwater Challenges

In 2017, back-to-back spring storms combined with record-high lake levels caused extreme flooding from Lake Ontario, resulting in damage of $1 million and forcing the Town to declare a State of Emergency and issue a voluntary evacuation. A second voluntary evacuation was issued in the Spring of 2019 as a result of significant rainfall, winds, beach closures and further shoreline damage.

A need for the Town to address wet weather issues, specifically in Jordan Station and Campden, became apparent as specific portions of these communities experienced flooding as a result of surface water/groundwater, sewer backups due to significant inflow and infiltration (I/I) and, in some cases, both. The Town is exploring adaptive and mitigative stormwater management measures in an effort to reduce the vulnerabilities associated with stormwater, proximity to the Lake Ontario shoreline, sanitary sewer backups, I/I, downspout and sump pump connections, and climate change and extreme weather.

The several intense rainfall events in recent years have exceeded probability and likely suggest a new normal. While it is not possible to attribute a single storm event to climate change, the numerous strong storms that have impacted this area in recent years are consistent with the climate change projections that are supported by the overwhelming majority of the world's scientists.

## 1.2 Effects of Urbanization

Changes in land use from natural cover, such as converting rural lands to urban development forms or clearing forests for cultivation, alters the water balance as pervious surfaces become impervious surfaces. Infiltration characteristics of the soils and vegetation are altered or removed. When rural lands are urbanized, porous soils are replaced with impervious materials such as concrete and asphalt which yield high runoff during precipitation events. Common environmental consequences of increased impervious surfaces that can be mitigated via improved stormwater management include the following:

1. **Channel enlargement and increased erosion:** In urban areas, streams adjust to their altered hydrologic regime by enlarging their cross-sectional area to accommodate higher flows. This can cause significant damage to property and infrastructure adjacent to or within the channel. Channel alignment or pattern can also become altered due to changes in the hydrologic regime or the addition of hydraulic structures such as culverts or bridges.
2. **Increased frequency and severe flooding:** Urban catchments produce, and subsequently transport, more runoff than natural areas. The combined effect of larger runoff volumes and increased drainage efficiency leads to an increase in peak flow rate. Watercourses in urban catchments are more susceptible to flooding, especially from short duration, highly intense rainfall events.
3. **Impaired water quality:** As a catchment becomes urbanized, water quality deteriorates due to runoff from impervious surfaces. Urban runoff tends to contain elevated levels of suspended solids, nutrients, bacteria, heavy metals, oils and grease, and sodium and chloride from winter applications of road salt.
4. **Degradation of habitat and associated biota:** Changes to hydrology, geomorphology and water quality has a profound impact on local ecology, including:
   - A reduction in the diversity of aquatic communities
   - A reduction or loss of sensitive cold-water fish species due to thermal pollution
   - A loss of wetlands, riparian buffers and springs
   - A general decline in habitat quality.
5. **Decline in aesthetic and recreational potential:** Ontario's water bodies are used for a wide range of recreational activities including fishing, swimming and paddling. If water quality is impaired, individuals are less likely to participate in these activities. Preserving natural stream functions is vital for the continued use of these recreational purposes.

Urbanization decreases the volume of infiltration recharging shallow and deep groundwater which supplies baseflow to local watercourses and wetlands and is a source of drinking water for many Ontarians. The dramatic increase in water borne pollution such as litter, heavy metals and nutrients, in addition to increases in stream water temperature, all contribute to the alteration to the hydrology of the watershed and its associated water balance which can have a significant and often irreversible impact.

The goal of maintaining and restoring the natural or pre-development hydrologic integrity of a watershed and its associated water balance is to avoid alterations to instream erosion rates, water quality degradation, losses in groundwater recharge rates and impacts to the natural environment. As such, avoiding changes to the natural watershed hydrology and the associated water balance as a result of development must be the primary focus of stormwater practitioners. To effectively mitigate the impacts, stormwater strategies must include a means to reduce runoff volume with the objective of maintaining the predevelopment water balance.

### 1.2.1 Water Balance

Precipitation that falls onto the ground either flows over land as surface runoff and makes its way directly to a watercourse, soaks into the ground as infiltration, or is retained by vegetation and other surface materials as interception storage. Rainfall retained as interception storage is returned to the atmosphere through evaporation and never contributes to runoff. A portion of the waters infiltrating into the soil recharges deep groundwater reserves and the remainder is stored near the ground surface where it is depleted through transpiration by plants. Some groundwater migrates laterally and is intercepted by valleys, ravines or the banks of watercourses where it emerges to become surface flow. This shallow groundwater discharge, known as baseflow, maintains flow in the watercourse channel during periods between precipitation events and consequently is a very significant factor in the determination of habitat value and the maintenance of ecological flows. These processes and pathways are all part of the hydrologic cycle for undeveloped and developed lands.

The proportion of precipitation that becomes surface runoff versus infiltration and how rapidly the surface runoff is delivered to the receiver determines the impacts to the natural environment, habitats, and people. The proportions of precipitation (P) which enter the hydrologic pathways of runoff (R), infiltration (I) and evapotranspiration (ET) is known as a water balance and is represented by the following simplified equation:

$$\boldsymbol{Precipitation\ (P) = Runoff\ (R) + Infiltration\ (I) + Evapotranspiration\ (ET)}$$

Or

$$\boldsymbol{P = R + I + ET}$$

A water balance is a way of accounting for what portion of precipitation occurs as runoff versus infiltration or interception, how much water is returned to the atmosphere through evaporation and transpiration or supplied to the watercourse through shallow groundwater discharge. The portion of precipitation accounted for in each of these components of the water balance is determined by various factors which can be broadly classified as:

1. Climate
2. Vegetation
3. Geology.

Climate refers to long term trends in meteorological conditions typically measured in units of decades to thousands of years. Although there may be short-term changes to the water balance as a result of climate variations, over the long term the water balance is constant, provided that vegetation and geology are not altered.

### 1.2.2 Treatment Train Process

As previously discussed, a **LID practice** may perform one or more functions, such as pre-treatment or treatment, infiltration or storage for flood and erosion control that seeks to mitigate the impacts of increased runoff and stormwater pollution by managing runoff as close to its source as possible. However, a single practice can rarely perform all the necessary functions of a SWM system.

A stormwater management "**Treatment Train**" is a stormwater management strategy made up of a series of LID practices that work together to meet stormwater management objectives for a given area. For example, enhanced grass swales (a lot-level control), a vegetated swale (a conveyance control) and a bioretention area (an end-of-pipe control) may comprise a treatment train. Additionally, soil cells are increasingly being used in the Treatment Train process to support the growth and protection of urban trees, while preventing compaction of the tree roots. The soil cells play an additional role in capturing excess runoff water, similar to a bioretention facility.

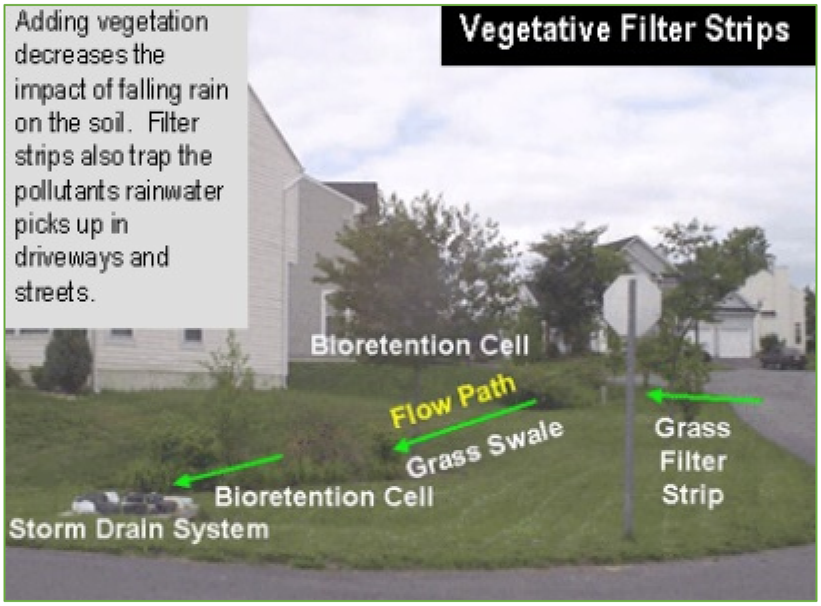



**Figure 1-2: An example of the Treatment Train Process (Source: U.S. EPA).**

**A Stormwater Management Strategy** is a combination of preventative measures and stormwater management systems, collectively working to minimize the effects of stormwater in a sub watershed.

## 1.3 Traditional Stormwater Management

Traditional stormwater management systems (typically referred to as "Grey Stormwater Infrastructure") consist of the onsite collection and direct conveyance of stormwater to either a basin, water body, or sewer system.

Separate sewer systems, used for most of the serviced areas in the Town of Lincoln, collect stormwater and convey the flow to a body of water with little treatment, resulting in higher concentrations of runoff pollutants. Combined sewer systems convey a mixture of stormwater runoff and wastewater from end users, thus are susceptible to overflows of raw sewage during wet weather. In either case, this type of stormwater management could potentially lead to a variety of negative environmental, economic, and social consequences.

Conventional improvements to these systems typically involve practices to increase the capacity of stormwater infrastructure and include practices such as enlarging sewer systems, increasing the capacity of wastewater treatment plants, or building containment facilities for collecting stormwater before treating and releasing run-off into natural waterways. The most common issues associated with these practices include:

1. Bank erosion and increased turbidity
2. Destruction of wildlife and habitats
3. Contaminated water bodies and beach closures
4. Downstream flooding
5. Infrastructure damage
6. Unnecessary conveyance and treatment costs
7. Disruption of groundwater table and natural cycle.

Such a singular approach to stormwater management is often no longer possible or desirable. In an age of climate change, urbanization, and increasingly frequent, intense storms and prolonged, devastating droughts, cities are now treating stormwater as a resource to be valued, not waste to be managed.

## 1.4 Introduction to Green Infrastructure

The term Green Infrastructure is used to convey the idea that green space is an essential component of urban development and must be strategically planned as carefully as other grey infrastructure to provide a range of ecosystem, social, and economic benefits. Any green space such as parklands, street trees, natural channels, wetlands, and other natural heritage features, along with engineered LID approaches can be considered green infrastructure and contributes to environmental resilience.

The term is also used to describe a wide array of specific stormwater management practices and techniques that use nature as a driver for onsite management of stormwater. Green infrastructure uses vegetation, soils, and natural processes to improve infiltration rates and/or capture and reuse stormwater to reduce the quantity and improve the quality of stormwater runoff. These techniques aim to minimize onsite production of stormwater flows thereby minimizing the required capacity of grey infrastructure. This reduction in stormwater conveyance has many advantages such as:

- Increased capacity within the existing sewers
- Decrease in CSO frequency, volume, and peak flow
- Less treatment required at facilities.

Many municipalities are finding that for their unique system, they can effectively manage stormwater runoff in a more cost-effective and overall beneficial way in comparison to the traditional collect and convey approach. Green infrastructure can be implemented at any scale from a single lot to an entire citywide plan. Green infrastructure can refer to a "system" similar to wastewater, water, and stormwater systems. With respect to combined sewer systems, municipalities do not have to rely solely on conventional storage or sewer separation techniques. The individual techniques that make up the green infrastructure systems are dependent on many aspects of the area or community in which it is to be implemented. The appropriate type of green infrastructure will depend on the type of development, topography, weather, and other area specific characteristics.

Green infrastructure techniques provide great flexibility with a variety of benefits that support LID principles and can be used **to meet LID targets.**

### 1.4.1 Low Impact Development (LID)

Low Impact Development (LID) refers to a land development or re-development approach that utilizes site specific methods and techniques to manage both the quantity and quality of stormwater runoff, at the source. It is a subset of green infrastructure, and it can serve as a cost-effective approach to minimize the potential capital costs associated with new grey infrastructure. It is a sustainable stormwater practice that can be applied to high density urban areas as well as low density neighborhoods.

As previously mentioned, traditional stormwater management systems collect and convey runoff from the site into sewers, and then either to storage facilities, large retention ponds, or direct discharge into water bodies. These controls do not allow for the recharge of groundwater or pollution control. The need for conveyance and retention of stormwater can be minimized through the LID approach resulting in less stress on existing separate or combined sewer system infrastructure. The LID approach focuses on reducing the quantity of stormwater runoff and therefore any associated pollutants. This stormwater management approach focuses on the problem, being development patterns and imperviousness, rather than the symptoms, which are large stormwater volumes.

Capacity issues, which have resulted in basement flooding and/or discharge of runoff pollutants in the Town of Lincoln, are not only a result of growth and increased imperviousness but also changes in precipitation patterns. Precipitation events are expected to increase in frequency and severity and for this reason, limiting the source may be more adaptable for the future than increasing the amount of grey infrastructure. Planning for and maintaining waste and stormwater infrastructure should be done with a changing climate in mind. The expected intensity, duration, and frequency of events over the lifetime of the infrastructure should be considered, along with other best practices instead of conveyance.

According to the TRCA/CVC *LID Guide,* the key principles for LID design are as follows:

1. Use existing natural systems as the integrating framework for planning
    - Consider regional and watershed scale contexts, objectives and targets
    - Look for stormwater management opportunities and constraints at watershed/sub-watershed and neighbourhood scales
    - Identify and protect environmentally sensitive resources.

2. Focus on runoff prevention
    - Minimize impervious cover through innovative strategies and application of permeable surfaces
    - Incorporate green roofs and rainwater harvesting systems in building designs
    - Drain roofs to pervious areas with amended topsoil or stormwater infiltration practices
    - Preserve existing trees and design landscaping to create urban tree canopies.

3. Treat stormwater as close to the source as possible
    - Flatten slopes, lengthen overland flow paths and maximize sheet flow
    - Maintain natural flow paths by utilizing open drainage (ie. swales).

4. Create multifunctional landscapes
    - Integrate stormwater management facilities into other elements of the development to conserve developable land
    - Utilize facilities that provide filtration, peak flow attenuation, infiltration and water conservation benefits
    - Design landscaping to reduce runoff, urban heat island effect and enhance site aesthetics.

5. Educate and maintain
    - Provide adequate training and funding for municipalities to monitor and maintain lot level and conveyance stormwater management practices on public property
    - Teach property owners, managers and their consultants how to monitor and maintain lot level stormwater management best management practices (SWM BMPs) on private property
    - Establish legal agreements to ensure long-term operation and maintenance.

### 1.4.2 LID Design Considerations

The application of LIDs uses existing natural systems, where feasible, and practical engineered systems that use natural materials. These applications are based on the individual requirements and design of the development or site. Application ranges from lot level to site level to regional level, and facilities are often combined to meet the requirements of the site. Unique characteristics (site location, climate, vegetation, regulations) may affect the performance of LID facilities and must be accounted for in the design, including:

- Tight soils
- Frost depth
- Local precipitation and hydrology
- Vegetation suitability to precipitation characteristics
- Winter maintenance materials including sand, gravel and salt
- Maintenance responsibilities and commitments
- Regulatory conflicts or resistance
- Regulation gaps (e.g. greywater re-use code)
- Objectives or drivers for implementation.

Some sites may have unique challenges or constraints for the application of LIDs that must be addressed by a qualified engineer/designer on a case-by-case basis. There is no universal prescriptive guide for LIDs that applies to all sites. One unique challenge facing designers of LID facilities in the Town of Lincoln relates to cold climate considerations. These considerations will be addressed in Section 5.

# 2 LOCAL CHARACTERISTICS

Since the application of LID is site-specific, a full understanding of the characteristics of the local environment, such as climate, hydrology, soil and vegetation conditions, is instrumental in LID planning design, construction and maintenance.

## 2.1 Climatic Considerations

Lincoln’s orientation between Lake Ontario’s southern shore and the Niagara Escarpment results in a moderate climate and mild winters. **Table 2-1** provides a summary of past temperature and precipitation patterns for the Town of Lincoln, as well as anticipated projections for 2050 and 2100.

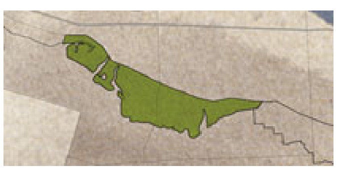
**Table 2-1: Climate Projections for the Town of Lincoln (Source: climatedata.ca)**

| Variable | Sub-Variable | Recent Past Average (1976-2005) | 2050 Projection | Difference (Past Avg vs. 2050) | 2100 Projection | Difference (Past Avg vs. 2100) | Trend |
|---|---|---|---|---|---|---|---|
| **Temperature** | Hottest day °C | 33 | 37 | 11% | 40 | 21% | ↑ |
| | Mean Temp °C | 9 | 12 | 33% | 15 | 71% | ↑ |
| | Min. Temp °C | 4 | 7 | 65% | 11 | 145% | ↑ |
| | Max. Temp °C | 13 | 16 | 23% | 19 | 47% | ↑ |
| | Days Over 30 °C | 11 | 47 | 311% | 91 | 704% | ↑ |
| | Coldest Day °C | -20 | -13 | -35% | -8 | -60% | ↑ |
| | Days Below -15°C | 8 | 0 | -100% | 0 | -100% | ↓ |
| | Days Below -25°C | 0 | 0 | - | 0 | - | ↓ |
| | Frost Days | 124 | 85 | -31% | 46 | -63% | ↓ |
| | Cooling Degree Days | 328 | 670 | 104% | 1200 | 265% | ↑ |
| | Growing Degree Days 10°C | 1390 | 1996 | 44% | 2725 | 96% | ↑ |
| | Growing Degree Days 5°C | 2390 | 3096 | 30% | 3977 | 66% | ↑ |
| | Cumulative Degree Days >0 °C | 3657 | 4440 | 21% | 5526 | 51% | ↑ |
| | Heating Degree Days | 3402 | 2669 | -22% | 2011 | -41% | ↓ |
| | Ice Days (below 0°C) | 48 | 24 | -50% | 6 | -88% | ↓ |
| | Tropical Nights >18°C | 26 | 61 | 133% | 106 | 303% | ↑ |
| | Tropical Nights >20°C | 10 | 39 | 288% | 84 | 747% | ↑ |
| | Tropical Nights >22°C | 2 | 18 | 1084% | 60 | 3814% | ↑ |
| **Precipitation** | Total Precipitation mm | 864 | 1016 | 18% | 955 | 11% | ↑ |
| | Max 1 Day Total mm | 39 | 39 | 0% | 38 | -1% | ↓ |
| | Wet Days >10mm | 26 | 33 | 24% | 32 | 22% | ↑ |
| | Wet Days >20mm | 6 | 9 | 36% | 9 | 44% | ↑ |

## 2.2 Physiographic Considerations

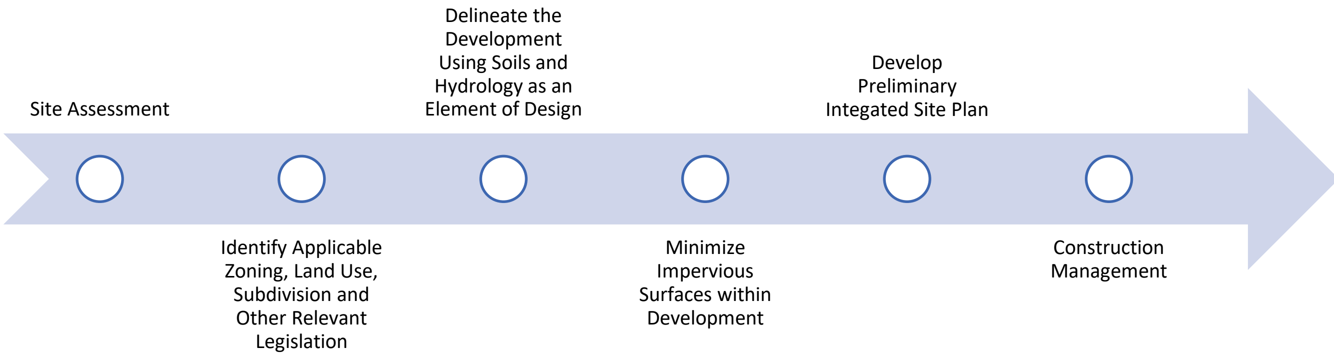
The Town of Lincoln covers 162km$^2$ and spans one regional physiographic appellation, the Niagara Escarpment, and two sub-appellations, the Bench and Lakeshore. The Niagara Escarpment, a prominent feature cutting across the Niagara Peninsula, is characterized by north-facing slopes below a forested ridge. It is recognized by UNESCO as a World Biosphere Reserve and is the most prominent topographical feature in Southern Ontario. This regional appellation supports a vital ecosystem, with hundreds of unique species of birds, mammals, reptiles, fish and flora. The Bench runs from Four Mile Creek gully to west of Beamsville and is comprised of a narrow plateau sloping gradually from the cliff of the Niagara Escarpment northwards to Regional Road 81, marking the bottom of Lake Iroquois Shore Bluff. The Lincoln Lakeshore runs along the Lake Ontario shore, backed by the foot of the escarpment. A summary of each appellation is provided in **Table 2-2.**

**Table 2-2: Summary of the Topography, Soil and Climate of the Town of Lincoln's Physiographic Regions (*Source: VQA Ontario*)**

| Physiographic Region | Topography | Soil | Climate |
|---|---|---|---|
| Niagara Escarpment<br> | • Ranges from distinct bench backed by steep cliff faces, to streams and tributaries with headwaters rising from the Escarpment.<br>• Streams in this area act as a groundwater source and provide crucial water drainage during the spring melt. | • Highly variable.<br>• Ranges from water-stratified clay and silt to clay-rich loam.<br>• Primarily deep and moderately drained with good water-holding capacities.<br>• Provides consistent moisture and sufficient drainage. | • Higher elevations allow gradual warming in the spring.<br>• In fall, topography traps warm lake air and allows for more gradual cooling. |
| Bench<br> | • Small streams and ravines.<br>• Landscape of north- and east-facing slopes.<br>• In summer, the headwaters of streams serve as a reliable water source for agricultural activities (primarily vineyards). | • Heterogenous; ranging from clay to boulders<br>• Hints of shale, sandstone and limestone from the erosion of the Escarpment.<br>• Complex mix allows for relatively high water-holding capacities and good drainage. | • Escarpment shelters Bench from stronger prevailing southwesterly winds<br>• Well moderated through the year. |
| Lincoln Lakeshore<br> | • Long, shallow grade – provides groundwater drainage and keeps moisture in balance.<br>• Large streams (Thirty Mile, Forty Mile and Fifty Mile Creek) provide a source of water and good seasonal drainage. | • Variability in soil type and depth.<br>• Soil overlay red shale of the Queenston Formation<br>• Light, sandy soil (well – moderately drained) cover 55%.<br>• Red clay loam scattered throughout, providing thick and fertile pockets with high water retention. | • Subdued topography allows for temperature difference between cool air over Lake Ontario and warm air over land.<br>• Localized circulation systems that moderate the rate of warming and cooling. |

# 3 LID SITE PLANNING AND DESIGN PROCESS

The LID site design process builds on conventional site design with modifications to capitalize on natural characteristics of the site. This design process seeks to minimize detrimental hydrological impacts of development by reducing the compaction of soils, reducing the development of impervious surfaces and using the natural landscapes soil, vegetation and topography to maintain the hydrological cycle. As a result, the LID aims to reduce or prevent stormwater runoff during small storm events, providing treatment close to the source as possible. This process treats water as a resource, rather than a nuisance.




## 3.1 Site Assessment

The characterization of key aspects of the site, including soils, geotechnical vegetation and hydrological conditions, must be completed prior to development of the site. Achieving a thorough understanding of these elements enables development of designs that work to preserve the natural hydrologic response of the developed watershed.

Site assessments provide the information needed to fully understand the unique aspects of a potential development area. **Table 3-1** provides an overview of the recommended parameters to be captured in each assessment and at what stage of planning these assessments should be conducted.

### 3.1.1 Soils and Geotechnical Assessment

As outlined in **Table 3-1**, soils and geotechnical assessments are required to determine pre-development soil and sub-surface conditions. The following planning decisions are based on the results of these assessments:

- Suitable LID facility locations
- Recommended soil amendments
- Required soil protection measures during construction.

Failures of the facility, such as flooding, clogging and ponding can occur if infiltration-based LID facilities are constructed in soil zones with poor infiltration due to the presence of tight soils, compacted soil, or bedrock. Alternatively, high soil permeability increases the potential for groundwater contamination if pollutant concentrations are elevated.

### 3.1.2 Vegetation Assessment

A vegetation assessment will identify any areas requiring protection during the construction process. Areas requiring protection may be selected to:

- Maintain a connecting riparian or wildlife corridor
- Preserve rare plants
- Maintain mature trees
- Maintain slope stability during construction.

### 3.1.3 Hydrologic Assessment

Hydrology is a function of the topography, soils and vegetation of a site. Further, climate influences the hydrology of a site via precipitation patterns. An assessment of precipitation and meteorological conditions of the site must be combined to determine the hydrologic patterns and response of the site. An understanding of hydrologic response is used to determine the impact of the site on the receiving stream or downstream stormwater management facilities.

**Table 3-1: Site Assessment Requirements**

| Assessment | Parameter(s) | Location | Timing |
|---|---|---|---|
| **Soils** | | | |
| Field Investigation | Structure<br>Colour<br>Texture<br>Predevelopment saturation condition<br>Particle distribution<br>Bulk density<br>Nutrient content<br>Cation exchange capacity (CEC)<br>pH | Across Site | Prior to Development Delineation |
| **Geotechnical** | | | |
| Assessment of existing information | | | Ongoing |
| Field Testing | Soil types<br>Soil layer depths<br>Depth to bedrock<br>Groundwater elevation<br>Groundwater quality<br>Hydraulic conductivity | Across Site | Prior to Development Delineation |
| **Vegetation** | | | |
| Field Investigation | Protected area delineation<br>Rate plants survey | Across Site | Prior to Development Delineation |
| **Hydrologic** | | | |
| Site Survey | Surface flow paths | Across Site | Prior to Development Delineation |
| Meteorological Investigation | Precipitation<br>Temperature<br>Humidity<br>Wind | Across Site | Prior to Development Delineation |

## 3.2 Delineation of the Development Area

Development delineation and design is the result of a series of considerations made based on topography, soils and soil variability, hydrology, surrounding land use, environmental contamination and impacts, and servicing constraints. Involvement from a multi-disciplinary design team is crucial at this stage to account for unique site constraints and challenges impacting the implementation of LID designs.

The first step in LID site development is identifying ‘primary’ and ‘secondary’ conservation areas. Primary conservation areas typically consist of non-developable lands adjacent to waterbodies, wetlands and steep slopes, identified as a result of the site assessment. Secondary conservation areas may consist of less significant natural areas such as existing tree stands, sites with exceptional views of surrounding land, high quality agricultural land, or historically and culturally significant sites. The remaining land is considered potential development area.

## 3.3 Site Planning

It is important to assess how the development design can be integrated with the landscape to preserve natural features and reduce the need for grading. Grading generally increases costs and reduces opportunities for LID implementation. Preservation of natural topography and existing drainage is more likely to result in multiple outlets to a nearby water body and a more sensitive water balance design. A site graded to one location as traditionally done often requires a large end-of-pipe facility for flood control which can be avoided or minimized with multiple outlets.

## 3.4 Reduction of Impervious Surfaces within the Development

Increase in the total impervious area causes an increase in total runoff volumes and peak runoff rates. LID sites may use a variety of methods to minimize impervious areas, including the use of:

- Narrower road widths
- Flat curbs and roadside bioswales in place of traditional curb and gutter
- 'Green' laneways using pervious materials and surfaces
- One sided on-street parking.

After minimizing impervious areas, portions of the remaining impervious area may be routed to vegetated areas throughout the neighbourhood, deriving further hydrologic benefits. In a LID context, this can be accomplished by:

- Disconnecting roof drains / downspouts from the weeping tile systems and re-routing flow to vegetated areas
- Directing sheet flow through vegetated areas
- Locating impervious areas to drain to LID facilities.

## 3.5 Development of Preliminary Integrated Site Plan

To provide an opportunity to fine-tune the selected LID strategy, a preliminary integrated site plan should be developed. This plan provides a basis for comparison of pre- and post-development hydrology to ensure that the objective of creating a hydrologically sustainable site has been satisfied. Further, this plan provides construction management strategies for soils and vegetation to maintain the biologic, ecologic and hydrological functions of the LID site.

### 3.5.1 Hydrologic Modelling

Hydrologic modelling allows stormwater engineers to identify where LID facilities will be most beneficial. It also helps understand the level of stormwater management provided through the selected facilities. Stormwater modelling calculates any additional level of control required beyond the planned LID facility, ensuring the site's release rate and volume meet discharge requirements to the receiving stream or downstream stormwater management facility.

The site's modelled hydrology can be compared to pre-development hydrology, providing the ability to quantify stormwater impacts of the LID. Monitoring of the site following development will provide information on real-world performance of the LID site.

## 3.6 Construction Management

Critical to the success of a LID development is soil and vegetation management during construction. A management plan should be developed early in the planning process.

### 3.6.1 Soil Management

Soil construction management is critical to the success of LID facilities. Although soil permeability is largely influenced by soil type and texture, compaction can drastically modify infiltration rates. Soil management is recommended from initial site planning through to the completion of the facility. Best soil construction management practices include:

- Delineating and flagging on-site soil preservation areas, identified during the soil assessment process (Table 3-1) to ensure the protection of the soil to ensure no compaction or grading occurs.
- Restricting construction access and traffic to clearly defined on-site routes.

- Measuring soil characteristics immediately prior to construction to confirm characteristics and document any changes.

Infiltration rates vary over a wide range based on soil type, moisture content, texture and level of compaction. Finer soils (clay and silt) will experience a more substantial decrease in infiltration rate, compared to soils with a coarser texture (sands). It is important to note that tight soils with low infiltration rates do not necessarily preclude the implementation of LID facilities, rather, for successful implementation, further adaptations such as underdrains connected to downstream LID facilities may be required.

### 3.6.2 Vegetation Management

The preservation and/or restoration of site vegetation on a construction site may be achieved through the following steps:

- Delineating and flagging any on-site vegetation preservation identified during the site assessment process (Table 3-1).
- Select vegetation species to incorporate into the facility with considerations given to site conditions, coverage and viability, as discussed in Section 5.

# 4 LID BEST MANAGEMENT PRACTICES OVERVIEW

LID facilities are intended to manage stormwater near or at its source in addition to efficiently conveying and discharging excess stormwater into a receiving water body. Although there are various types of LIDs, they all follow the same principle of “slowing it down, spreading it out, and soaking it in” (EPA, 2011), aimed to replicate the natural hydrological processes of absorption, infiltration, evaporation and evapotranspiration.

Through a literature review, and in accordance with the Low Impact Development Stormwater Management Guide developed by the CVC, LIDs were assessed considering the Town of Lincoln’s climate and physical characteristics. While a wide array of LID practices exists, the following practices may be best suited to the Town of Lincoln’s environment, climate and land-use types: (1) bioretention; (2) vegetated filter strips; (3) enhanced grass swales; (4) permeable pavement, (5) dry swales/bioswales; and (6) perforated pipe systems. Each LID facility, as described below, works to reduce the volume of stormwater on its way to the receiving body of water.

Design considerations are site specific, and as such, there is no universal prescriptive guide for LID practices that applies to all sites. For more in-depth guidance on facility design, vegetation selection, soil management and operations and maintenance activities, please refer to the appropriate Design Template sections of the TRCA/CVC *LID Guide* (Section 4).

## 4.1 Bioretention Areas

Bioretention areas are stormwater management and treatment facilities that are constructed into a shallow depression of land, using vegetation and amended topsoil. They provide water quality treatment and runoff reduction by allowing for infiltration near the source of runoff – such as driveways, sidewalks and/or roofs. As a stormwater filter and infiltration practice, bioretention temporarily stores, treats and infiltrates runoff.

The fundamental difference between a bioretention area and a conventional planting bed are that bioretention area utilize engineered soils and vegetation to capture and treat rainwater and are typically located at the low points of a landscape. Rainwater then flows to it, either naturally or via an inlet, into the bioretention area’s concave surface. As illustrated in **Figure 4-1**, a bioretention area typically has four components:

1. Vegetation and aged mulch
2. Topsoil (natural, or amended)
3. Gravel storage/drainage layer
4. Under drain with cleanouts.

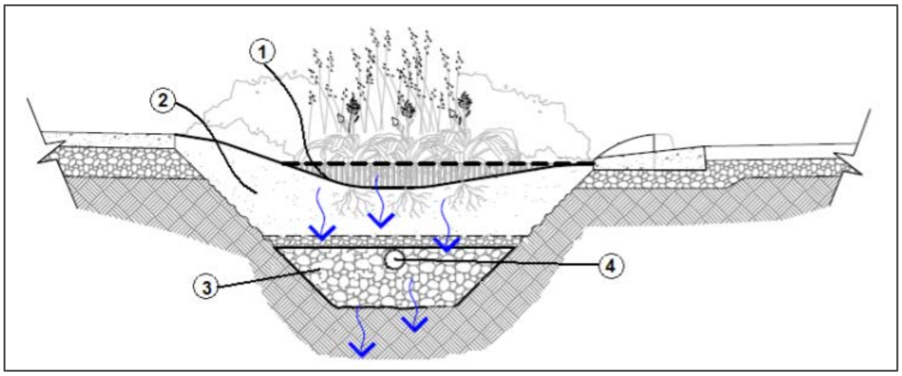



**Figure 4-1: Typical Composition of a Bioretention Area (Source: City of Edmonton).**

Bioretention can take a variety of forms and can be adapted to fit many different development contexts, as shown in **Figure 4-2**.

**Bioretention Cell** (Source: TRCA) at the Earth Rangers Centre, Vaughn, ON.

**Rain Garden** (Source: TRCA) at a home in Toronto, ON.

**Stormwater Planters** (Source: NACTO) in Portland, Oregon.

**Curb Extensions** (Source: NACTO) in British Columbia.

**Extended tree pits** (Source: TRCA) in Portland, Oregon.

**Figure 4-2: Typical Developmental Orientations of Bioretention**

- Bioretention cells can be used in development types with large landscaping areas with no tight space constraints – such as parks or parking lots, typically accepting inflow as sheet flow.
- Rain gardens are intended for smaller spaces such as private properties, capturing root, lawn and driveway runoff in a shallow depression.

- Stormwater planters are typically used in highly urbanized areas with large amounts of impervious surface.
- Curb extensions are facilities where the curb is extended into the street, and a bioretention facility is placed in the space between the extended curb and the original curb line.
- Extended tree pits, or parallel bioretention, are installed within the right of way and utilize the landscaped space between the sidewalks and the street.

## 4.2 Vegetated Filter Strips

Vegetated filter strips, also known as buffer strips or grassed filter strips, are gently sloped, often densely vegetated areas that are typically constructed adjacent to impervious areas. Their design is intended to slow stormwater runoff velocity by increasing surface roughness, resulting in increased surface contact time. More contact time allows more time for infiltration and evaporation thus enhancing the quality of runoff prior to entering another stormwater management facility (such as a bioretention facility). This method was originally utilized as an effective agricultural treatment practice although they are commonly used in urban practices as well. **Figure 4-3** displays a typical cross-section of the patterns of flow through these facilities.

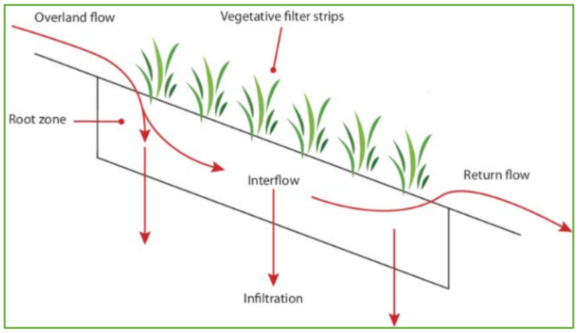



**Figure 4-3: Typical Cross-Section of Vegetated Filter Strips (Source: Grismer, 2006).**

Filter strips are best used as pre-treatment devices for runoff from roads or parking lots, and with proper design and maintenance, they can provide relatively high pollutant removal. Vegetated filter strips can also provide area for snow storage, and due to the simplicity of their design, physical changes are not required for winter operation. **Figure 4-4** displays common configurations and uses of vegetated filter strips.

**Figure 4-4: Filter Strips for Pre-Treatment for Parking Lot Runoff (Left, Source: CWP) or Prior to Entering Another Stormwater Management Facility (Middle, Source: Minnesota Stormwater Manual. Right, Source: Seattle Public Utilities).**

## 4.3 Enhanced Grass Swales

Enhanced grass swales are swales with grass and other vegetation, enhanced topsoil and an underlying infiltration layer. Check dams and vegetation in the swale work to slow the runoff, allowing for filtration, evapotranspiration and infiltration into the native soil. Grass swales typically require a large area of pervious surface and are well suited for highly rural areas such as the Town of Lincoln. **Figure 4-5** displays a typical configuration of an enhanced grass swale.

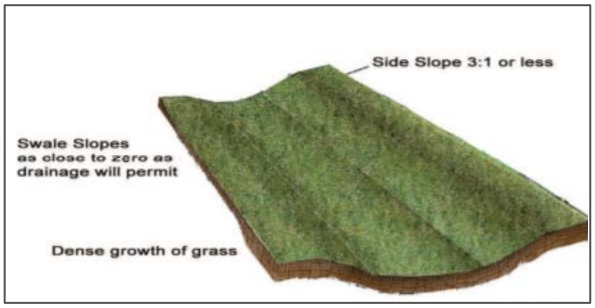



**Figure 4-5: Typical Configuration of an Enhanced Grass Swale (Source: CVC).**

Because grass swales are linear practices, they are well-suited for treating runoff from residential roads or other higher traffic areas. In the winter, they can also be used as snow storage areas. Examples of typical applications are displayed in **Figure 4-6**. Where development density, topography and depth to water table permit, enhanced grass swales can provide an effective alternative to curb and gutter storm drains. They can also be used to reduce impervious cover, accent the natural landscape, and provide aesthetic developments when incorporated into site design.

**Figure 4-6: Enhanced Grass Swales Adjacent to Major Roads or Parking Lots to Increase Pollutant Retention and Decrease Flow Velocity (Left, Source: Delaware Department of Transportation, Right, Source: CVC).**

## 4.4 Permeable Pavement

Permeable pavement is a variation on traditional pavement that utilizes pervious material to prevent runoff by allowing precipitation to percolate into the porous structure. Porous asphalt, porous concrete and open grid pavers (**Figure 4-8**) are all considered to be permeable pavement options. Incorporating permeable pavement into developments can reduce the effective impervious area of the development without losing any functionality. This option is best suited for lower traffic areas such as parking lots. Generally, permeable pavement consists of four components, as illustrated in **Figure 4-7**:

1. Permeable pavement
2. 'Choker course' or bedding layer of washed stone
3. Reservoir layer consisting of clean washed, uniformly graded aggregate, or a tank consisting of a matrix of open-weave boxes
4. Perforated underdrain incorporated into the reservoir layer as required.

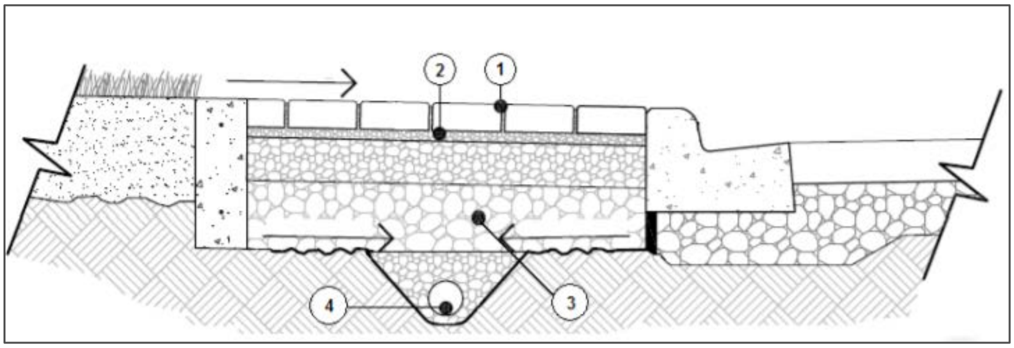



**Figure 4-7: Typical Layout of Permeable Pavement (Source: City of Edmonton).**

**Pervious Pavement** (Source: NACTO) can have multiple applications, including sidewalks, street furniture zones or driveways.

**Porous asphalt** (Source: NPCA) can be implemented on pathways, driveways or roadways.

**Open grid pavers** (Source: ICPI) are less than 50% impervious and contain vegetation in the open “cells”.

**Figure 4-8: Permeable Pavement Options**

## 4.5 Dry Swales / Bioswales

Dry swales, or bioswales, have many of the same characteristics as an enhanced grass swale, but they also incorporate an engineered soil (filter media) bed and often, a perforated pipe underdrain. Their configuration is comparable to that of a bioretention cell – filter media bed, gravel storage layer and the optional underdrain components (**Figure 4-1**). Dry swales can simply be planted with grasses or they can have more elaborate landscaping (**Figure 4-9**), but overall, the objective is to slow runoff to allow for filtration through the root zone.

**Figure 4-9: Dry swales can be vegetated in a variety of ways, or simply turfed (Source: NPCA). Elaborate vegetation can provide aesthetic value (Source: NPCA).**

Due to their linear nature, dry swales are well-suited to treat runoff adjacent to impervious surfaces (such as roadways and parking lots) as well as pervious surfaces (such as yards and parks). Similar to grass swales, dry swales may be well suited to the Town of Lincoln as they require a considerable amount of space and are often impractical for densely developed urban areas.

## 4.6 Perforated Pipe Systems

Perforated pipe systems are designed to artificially convey and infiltrate stormwater runoff; typically consisting of a perforated pipe embedded in stone-filled trenches installed within the right-of-way. Stormwater is directed to the pipe through catchbasins, and runoff is captured from the surrounding impervious area and stored in the trench where it infiltrates into the surrounding soils (**Figure 4-10**).

Perforated pipe systems are often combined with other pre-treatment practices such as vegetated swales but can also be located in the roadway. Where suitable, perforated pipe systems can be used in place of conventional storm sewer pipes to treat drainage from low to medium traffic areas with relatively flat or gentle slopes, as well as areas such as parking lots, roofs and walkways.

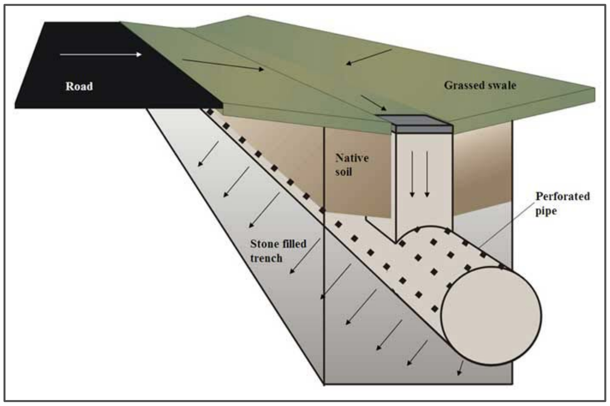



**Figure 4-10: Typical Perforated Pipe System (Source: Sustainable Technologies).**

## 4.7 LID Benefits

The benefits of LID originate from its approach of treatment stormwater close to its sources by mimicking natural systems. **Table 4-1** displays a summary of the benefits that the LID practices in this guide can offer. These benefits can be experienced at various scales according to site-specific and local factors. Some benefits are more challenging to quantify such as increased biodiversity or human psychological and health benefits from green space, while others can be quantified with a monetary value. Benefits that can be quantified with economic values include total suspended solids (TSS) reduction, air pollutant removal and avoided runoff treatment. The possible benefits of LID practices are further described below.

**Reduced stormwater runoff:** LID facilities intercept, infiltrate, filter, store and detain stormwater runoff. For example, bioretention facilities infiltrate and attenuate stormwater runoff.

**Reduced flooding:** When applied throughout a watershed, LID practices can reduce urban runoff volumes and has the potential to reduce subsequent overland flooding risk.

**Reduced combined sewer overflow:** Overflow volume, frequency and impacts can be reduced for both combined and separated sewer systems by reducing peak volumes and improving water quality. Some municipalities have found that the reduction of combined sewer overflows through implementing LID practices was more cost-effective than conventional practices such as sewer separation (Riverkeeper, 2007).

**Improved water quality:** LID can improve water quality by effectively capturing and treating sediments and pollutants typically found in overland flow that would wash into sewers and/or receiving water bodies. With LID practices, pollutants are instead filtered, absorbed or biodegraded while moving through infiltration media.

**Increased groundwater recharge:** By infiltrating stormwater on-site, groundwater recharge can increase, thereby decreasing flow into pipes.

**Improved air quality:** Vegetated LID facilities, such as bioswales and bioretention facilities can improve air quality through uptake of air pollutants.

**Improved aesthetic and property values:** The vegetation cover of LID facilities can enhance the appeal of an area and increase adjacent property values. These facilities also contribute green space which is often sought after in urban areas.

**Reduced cost of stormwater infrastructure:** LID practices may help reduce the demand for conventional stormwater controls and reduce requirements to upgrade downstream capacities. Through improved environmental performance, LID can reduce the long-term cost of operation, maintenance and rehabilitation of stormwater management infrastructure.

**Table 4-1: Possible Benefits Achieved Through LID Practices (Sources: CVC, City of Edmonton)**

| Benefits | LID Practices | | | | | |
|---|---|---|---|---|---|---|
| | Bioretention Areas | Vegetated Filter Strips | Enhanced Grass Swales | Permeable Pavement | Dry Swales / Bioswales | Perforated Pipe Systems |
| Reduced Stormwater Runoff | + | + | + | + | + | + |
| Reduced Overland Flooding | + | + | + | + | + | + |
| Reduced CSO | + | + | + | + | + | + |
| Improved Water Quality | + | + | + | + | + | + |
| Increased Groundwater Recharge | + | + | + | + | + | + |
| Improved Air Quality | + | | + | | + | |
| Improved Aesthetic and Property Value | + | | + | + | + | |
| Reduced Cost of Stormwater Infrastructure | + | + | + | + | + | + |

## 4.8 LID Life Cycle Costs

There is significant interest in comparing the costs of sites designed using LID practices to manage stormwater runoff, and those designed using conventional stormwater management practices. In most cases, the development of LID stormwater management systems costs less than comparable conventional systems. Further, an understanding of the life cycle costs of LID facilities is necessary for planning and decision-making processes. **Table 4-2** provides a breakdown of typical capital costs, annual maintenance costs and expected life cycle of well designed, constructed and maintained facilities.

These costs are provided for comparison with conventional systems. Additionally, the value of environmental and social benefits should be incorporated into cost-benefit analyses. Of note, design and engineering costs for LID facilities often range from 5% to 40% of construction costs (TRCA, 2009) and are not included in the costing summary below. However, every development is unique and should be considered and assessed individually.

**Table 4-2: Life Cycle Costs of LID Facilities [Sources: CVC, TRCA (2009, 2013), City of Edmonton].**

| LID Facility | Generalized Costs | | | |
|---|---|---|---|---|
| | Construction | Annual Maintenance | Replacement | |
| | | | Life Cycle[1] | Cost |
| Bioretention Area | \$30-\$350/$m^2$ | \$13-\$30/$m^2$ | >20 years | Major rehabilitation: \$4-\$170/$m^2$ every 15-20 years |
| Vegetated Filter Strips | \$3.50-\$9.00/$m^2$ | \$3.50-\$9.00/$m^2$ | >20 years | Construction costs, replacement of sod and seed (\$15-\$20/$m^2$) |
| Enhanced Grass Swales | ~\$60/$m^2$ | <\$1-\$18/$m^2$ | >20-50 years | Construction costs. |
| Permeable Pavement | \$340-\$500/$m^2$ | \$0.15-\$0.30/$m^2$ for vacuum or deep clean | >20 years | Construction costs. |
| Dry Swales / Bioswales | \$11-\$35/$m^2$ | \$0.20-\$1.00/$m^2$ | >20 years | Construction costs; drainage area may require sod and soil replacement (\$15-\$20/$m^2$) up to 2x more often than drainage structure |
| Perforated Pipe Systems[2] | \$11-\$35/$m^2$ | \$0.20-\$1.00/$m^2$ | >20 years | Construction costs; drainage area may require sod and soil replacement (\$15-\$20/$m^2$) up to 2x more often than drainage structure |

[1] Expected life cycle for well-designed and maintained facilities.
[2] Very limited information is available regarding construction costs, but due to similarities in design components, base construction costs would likely be similar to dry swales.

**Table 4-2** displays a wide range of costs, and economies of scale must be considered in the development of LID practices. For instance, sites designed with several similar features using the same materials will reduce cost per unit area, compared to sites with a single LID feature. Additional factors influencing cost include:

- Pre-existing site condition: retrofitting a highly urbanized area vs. a greenfield development. Typically, retrofitting applications are more costly due to site preparation costs.
- Site soil condition: Poor quality soil may require extensive amendments or transport of soil.
- Requirement of geotextiles to prevent infiltration where groundwater contamination may occur.
- Plant selection variations: Vegetation is selected on a site by site basis and range in price depending on location and micro-climate.

Further, **Table 4-2** compiles information from a literature review of similar municipalities and applies an approach for cost estimating where capital, operation and maintenance (O&M) costs are estimated based on facility size. While this method is convenient to use, many assumptions are reflected in the cost and it does not represent specific site conditions and installation options. Cost varies greatly on a site by site basis; these values should be considered only as rough estimates.

## 4.9 LID Limitations

Despite the numerous tangible and intangible benefits from implementing LID practices, limitations exist which should be regarded. **Table 5-1** summarizes possible limitations of each of the LIDs outlined in this Guide. For further information and specifications, please refer to the CVC *LID Guide* (Section 4).

Unless otherwise specified in the sections below, common constraints exist between each facility:

- Wellhead protection: Facilities receiving road or parking lot runoff should not be located within two (2) year time-of-travel wellhead protection areas.
- Depth to water table: To avoid groundwater interaction and potential contamination, design should ensure that the bottom of the facility is separated from the seasonally high-water table, or top of bedrock elevation, by at least 1m.
- Proximity to underground utilities: Local utility design should be consulted to define appropriate horizontal and vertical offsets. The designer should consider the requirements of long-term maintenance of the facility when implementing facilities near other underground utilities.
- Pollution uptake level: Highly contaminated runoff (i.e. vehicle fueling, servicing and demolition areas, outdoor storage and handling areas for hazardous materials, heavy industry sites) should not be treated by the facilities, in order to protect the groundwater from contamination.
- Setback from buildings: Facilities should be located a minimum of four (4) metres from building foundations to prevent water damage.

# 5 FACILITY DESIGN CONSIDERATIONS

This section provides general considerations for the design and implementation of the LID practices included in this manual. The information provided is tailored to the Town of Lincoln's unique climate and soil type and intended to accompany the information provided in the TRCA/CVC *LID* Guide.

Each LID site is unique and has specific characteristics that require consideration during the planning and design stages to ensure successful implementation. A thorough investigation of each parameter is required to ensure the design accounts for all local conditions surrounding the proposed application.

## 5.1 Vegetation Selection and Planting

Vegetation selection and survival is an important facility feature as vegetation type, morphology and structure influence pollutant settling and transport, water retention capability and overall hydraulics of the site.

Where appropriate, the use of native vegetation throughout the facility is recommended. However, a large selection of ornamental trees, shrubs and perennials can be successful in specific LID facilities. For a comprehensive guide on site-specific vegetation selection, please refer to the Landscaping Guidelines in the TRCA/CVC *LID Guide* (Appendix B of the manual). More recent plant selection guidance and plant lists may be found at: https://wiki.sustainabletechnologies.ca/wiki/Plant_lists

The following practices are also suggested:

1. Plan to incorporate ground cover, understory shrubs and trees. Planting in the spring or fall will allow for quicker establishment. Make note of typical rooting depths, as deep-rooted vegetation (such as trees) may damage buried infrastructure, such as perforated weeping tile systems.
2. Plant vegetation at adequate depths, locations and groups.
3. Provide Town of Lincoln maintenance staff with a written Landscape Maintenance Plan and train as required.

**Table 5-1: Possible Limitations and Considerations when Implementing each LID Facility (Source: TRCA/CVC LID Guide)**

| LID Facility | Parameter Consideration | | | |
|---|---|---|---|---|
| | **Available Space** | **Site Topography** | **Drainage Area & Runoff Volume** | **Soil** |
| **Bioretention Area** | • May consume considerable space.<br>• 10-20% of the size of the contributing area.<br>• For shallow-sloping sites, more space may be required. | • Ideally constructed in a natural depression with a contributing slope between 1-5%.<br>• Flat middle area to minimize need for excavation (and minimize construction cost). | • Conveyance capacity should match drainage area.<br>• Drainage areas between 100m$^2$ to 0.5 ha.<br>• Max recommended drainage area is 0.8 ha.<br>• If an underdrain is used, 1 – 1.5m elevation difference between inflow point and downstream storm invert. | • Suitable for any soil type.<br>• Refer to TRCA/*CVC LID Guide* for information on recommended soil amendments. |
| **Vegetated Filter Strips** | • Flow path length minimum of 5m (less than 25m)<br>• May be shorter if LID is being incorporated as pre-treatment to another LID practice. | • Recommended slope is 1-5%. | • Conveyance capacity should match drainage area. | • Suitable for any soil type.<br>• Refer to TRCA/*CVC LID Guide* for information on recommended soil amendments. |
| **Enhanced Grass Swales** | • Typically consume 5 – 15% of the contributing drainage area.<br>• At least 2m width is required. | • Can constrain application.<br>• Longitudinal slopes between 0.5 – 6% are allowable.<br>• Check dams should be used on slopes larger than 3%. | • Conveyance capacity should match drainage area.<br>• Sheet flow to facility is preferable.<br>• Typical ratio of impervious drainage area to treatment facility is between 5:1 to 10:1. | • Suitable for any soil type.<br>• Refer to TRCA/*CVC LID Guide* for information on recommended soil amendments. |
| **Permeable Pavement** | NA* | • Surface should be at least 1% and no greater than 5%. | • Impervious area treated should not exceed 1.2 times the area of permeable pavement which receives runoff. | • Facilities located on top of low permeability soils (infiltration rate less than 15mm/hr) require an underdrain. |
| **Dry Swales / Bioswales** | • Footprints are 5 – 15% of their contributing drainage areas.<br>• Between culverts, swale lengths should be 5m or greater. | • Longitudinal slopes ranging from 0.5 to 4%.<br>• On slopes steeper than 3%, check dams should be used. | • Typically treat drainage areas of two hectares or less.<br>• Typical ratio of 5:1 to 15:1. | • Suitable for any soil type.<br>• Soil group A and B soils are best for achieving water balance benefits. |
| **Perforated Pipe Systems** | NA* | • Cannot be located on natural slopes greater than 15%.<br>• Gravel bed between 0.5 to 1%. | • Typical ratio of 5:1 to 10:1. | • Suitable for any soil type.<br>• Soil group A and B soils are best for achieving water balance benefits. |

*NA indicates this is not a typical consideration in implementing the specified LID facility.

## 5.2 Soil Management

Infiltration refers to the seepage of water through soil. The rate at which water infiltrates is based on the soil's permeability (i.e. hydraulic conductivity). While it is difficult to determine standard infiltration rates, typical infiltration rates for native Town of Lincoln soils are moderate to high.

Compaction of soil particles is a factor in permeability. For instance, materials consisting of strongly compacted clays have a hydraulic conductivity of around 0.5mm/hour (McKeague et al, 1986). To increase plant survival and health, the following steps should be taken following construction:

- Loosen subsoil to a minimum depth of 150mm in areas without compaction and 300mm in areas with heavier compaction.
- Remove all subsoil material exceeding 50mm in diameter (TRCA, 2009).
- Cover loose subsoil with 200 – 300mm of top soil for grassed area and 450 – 600mm.

For more information on soil management and specifications for media compositions, please refer to the Design Specification sections in the TRCA/*CVC LID Guide* (Section 4).

## 5.3 Cold Climate Considerations

Similar as to the design of conventional stormwater management facilities, there exists several cold climate design challenges for LID facilities. These challenges summarized in **Table 5-2** do not necessarily inhibit implementation, but they must be considered in the designs of any LID facility operation in a cold climate. These factors are further discussed in the Common Concerns sections of the TRCA/CVC *LID Guide* (Section 4).

**Table 5-2: Cold Climate Considerations for LID Facility Installation (Source: City of Edmonton LID Guide)**

| Cold Climate Factor | LID Facility Design Challenge |
|---|---|
| **Deep Frost Line** | • Frost heaving<br>• Reduced soil infiltration<br>• Pipe freezing |
| **Significant Snowfall** | • High runoff volumes during snowmelt and rain-on-snow<br>• High pollutant loads during spring melt<br>• Snow management affecting storage of facility<br>• Weight of snow causing soil compaction<br>• Other impacts of road salt / de-icing materials |
| **Cold Temperature** | • Pipe freezing<br>• Reduced biological activity<br>• Reduced selling velocities |

## 5.4 Maintenance and Operation

An important consideration when choosing which LID facilities to implement is the required maintenance and operation and the frequency of inspection. LID facilities will not operate effectively without proper ongoing maintenance. **Table 5-3** summarizes the suggested routine inspection and maintenance parameters of the LID practices included in this manual, and a recommended schedule. These parameters are discussed in larger detail in the CVC *LID Guide* (Section 4), which also provides a list of corrective actions for each facility. Further information may be found at:

https://sustainabletechnologies.ca/home/urban-runoff-green-infrastructure/low-impact-development/low-impact-development-stormwater-practice-inspection-and-maintenance-guide/

**Table 5-3: Suggested Maintenance and Operation for LID Facilities (Source: CVC and Minnesota Stormwater Manual)**

| Activity | Schedule |
|---|---|
| **Bioretention Area** | |
| Inspect for vegetation density (at least 80%) coverage, damage by foot or vehicular traffic, channelization, structural damage to any treatment devices, and accumulation of trash, debris or sediment. | Following every major storm event (>25 mm), quarterly for the first two years, and twice annually thereafter. |
| Regular watering required during the first two years, until vegetation is established. | As needed for first two years of operation.<br>More frequently if desired for aesthetics. |
| • Remove accumulated sediment from pre-treatment devices, facilities surface, inlets and outlets<br>• Prune trees and shrubs<br>• Remove invasive growth, replace dead vegetation<br>• Repair eroded or sparsely vegetated areas<br>• Remove sediment that exceeds 25 mm in depth<br>• If gullies are observed along the facility surface, re-grading and re-vegetating may be required. | Annually, or as needed. |
| **Vegetated Filter Strip** | |
| Inspect for vegetation density (at least 80%) coverage, damage by foot or vehicular traffic, channelization, structural damage to any treatment devices, and accumulation of trash, debris or sediment. | Following every major storm event (>25 mm), quarterly for the first two years, and twice annually thereafter. |
| • Regular watering required during the first two years, until vegetation is established<br>• Mow grass to maintain a height between 50 – 150 mm. | As needed for first two years of operation. More frequently if desired for aesthetics. |
| • Remove accumulated sediment from pre-treatment and level spreader devices<br>• Replace mulch in spring<br>• Prune trees and shrubs<br>• Remove invasive growth, replace dead vegetation, dethatch, remove thatching and aerate<br>• Repair eroded or sparsely vegetated areas<br>• Remove sediment that exceeds 25 mm in depth<br>• If gullies are observed along the facility surface, re-grading and re-vegetating may be required. | Annually, or as needed. |
| **Enhanced Grass Swales** | |
| Inspect for vegetation density (at least 80%) coverage, damage by foot or vehicular traffic, channelization, structural damage to any treatment devices, and accumulation of trash, debris or sediment. | Following every major storm event (>25 mm), quarterly for the first two years, and twice annually thereafter. |
| • Regular watering required during the first two years, until vegetation is established;<br>• Mow grass to maintain a height between 75 – 150 mm. | As needed for first two years of operation. More frequently if desired for aesthetics. |

| Activity | Schedule |
|---|---|
| • Remove accumulated sediment from pre-treatment devices, facilities surface, inlets and outlets<br>• Remove invasive growth, replace dead vegetation<br>• Repair eroded or sparsely vegetated areas<br>• Remove sediment that exceeds 25 mm in depth<br>• If gullies are observed along the facility surface, re-grading and re-vegetating may be required. | Annually, or as needed. |
| **Permeable Pavement** | |
| Clean out drainage pipes and structures within or draining to the subsurface bedding beneath permeable pavement. | As needed on regular intervals. |
| Monitoring salt or sand use for de-icing purposes in the winter[1]. | Throughout winter. |
| Vacuuming and surface sweeping to remove sediment deposition[1]. | At least twice a year, typically at the end of winter and after autumn leaf fall. Frequency should be adjusted according to the intensity of use and deposition rate. |
| • Inspect to ensure continued infiltration performance<br>• Check for deterioration and ensure water is draining between storms (pavement reservoir should be completely drained within 72 hours of the end of the storm event). | Annually, or as needed. |
| **Dry Swales / Bioswales** | |
| Inspect for vegetation density (at least 80%) coverage, damage by foot or vehicular traffic, channelization, structural damage to any treatment devices, and accumulation of trash, debris or sediment. | Following every major storm event (>25 mm), quarterly for the first two years, and twice annually thereafter. |
| • Regular watering required during the first two years, until vegetation is established;<br>• Mow grass to maintain a height between 75 – 150 mm. | As needed for first two years of operation. More frequently if desired for aesthetics. |
| • Remove accumulated sediment from pre-treatment devices, facilities surface, inlets and outlets<br>• Prune trees and shrubs<br>• Remove invasive growth, replace dead vegetation, dethatch, remove thatching and aerate<br>• Repair eroded or sparsely vegetated areas<br>• Remove sediment that exceeds 25 mm in depth<br>• If gullies are observed along the facility surface, re-grading and re-vegetating may be required. | Annually, or as needed. |
| **Perforated Pipe Systems** | |
| Inspection via manholes, to ensure the facility drains within the maximum acceptable length of time (typically 72 hours after the end of the storm event). | At least annually and following every major storm event (>25mm). |
| Clean out leaves, debris and accumulated sediment caught in pre-treatment devices. | Annually, or as needed. |

[1]As per Minnesota Stormwater Manual.

## 5.5 Design

The design of LID facilities is site-specific. For detailed design guidance, including specifications on soil characteristics, geometry and site layout, pre-treatment devices, filter media, conveyance and overflow, monitoring wells and more, please refer to the appropriate section at: https://wiki.sustainabletechnologies.ca/wiki/Table_of_contents

This information is also available in the Design Template sections of the TRCA/CVC *LID Guide* (Section 4), however, the website contains the latest modified and improved guidance.

## 5.6 Monitoring

An important component of implementing stormwater management plans and facilities is a monitoring program to evaluate if the facility is functioning as designed, and how effective the plan is in meeting the designated goals. Monitoring can generally be separated into three types – compliance, performance and environmental effects.

### 5.6.1 Compliance Monitoring

Compliance monitoring is designed to evaluate whether a facility is functioning as designed and whether it meets minimum acceptable requirements. A typical timeframe for compliance monitoring for new facilities is within 2 to 5 years following construction. Characteristic monitoring components may include:

- Flow
- Water quality
- Erosion and slope stability
- Vegetation survival
- Condition of inlet/outlet structures
- Sediment accumulation or other maintenance issues.

Compliance monitoring is often undertaken as part of the construction and commissioning of a facility or as part of a municipal stormwater infrastructure operation and maintenance program. For new facilities, compliance monitoring is the responsibility of the facility developer and is undertaken to demonstrate that the facilities design requirements have been met. Once facilities on public property are assumed by the municipality, compliance monitoring becomes the responsibility of the municipality and is undertaken as part of a municipal stormwater infrastructure operations and maintenance program. For facilities on private property, legal agreements must be made between the property owner and the municipality in order to ensure compliance monitoring and operations and maintenance tasks are completed. This responsibly varies on a case by case basis and can be on the municipality or the property owner.

### 5.6.2 Performance Monitoring

Performance monitoring determines the effectiveness of the LID practice, according to design objectives and targets. This type of monitoring is usually undertaken when little information is available regarding the effectiveness of a certain facility type in a certain environmental context or if the technology is new and being implemented for the first time. Performance monitoring is also used to develop a better understanding of how the design of conventional stormwater management facilities can be adapted when LID practices are implemented upstream (as part of the treatment train approach). The TRCA, CVC and other similar agencies have two jointly funded programs to monitor and evaluate new and emerging technologies. For more information, please refer to the CVC *LID Guide* (Section 5.2).

### 5.6.3 Environmental Monitoring

Initiated in 2001, the Niagara Peninsula Conservation Authority (NPCA) has established a network of regional environmental monitoring stations and is operated in partnership with the Ontario Ministry of Environment, Conservation and Parks, Regional Municipality of Niagara, Haldimand Count and the City of Hamilton. Water quality samples are obtained at 80 surface water stations and 13 groundwater stations throughout the NPCA watershed, which monitor a range of parameters such as nutrients, *E. coli*, suspended solids and metals that act as indicators of ecosystem health.

# 6 FACILITY SELECTION

Selecting an appropriate LID facility to address site requirements is critical. A matrix has been developed to define the capabilities of each facility to help meet SWM objectives. In accordance with the CVC *LID Guide* and the TRCA *Stormwater Management Criteria Guide,* the primary objectives of stormwater management are as follows:

1. Water balance benefit
2. Water quality improvement
3. Stream channel erosion control benefit.

The combination of information provided in **Table 6-1** and the design considerations provided in Section 5 (**Table 5-1**) will facilitate appropriate LID selection based on site characteristics.

**Table 6-1: Ability of Selected LID Practices to meet Primary SWM Objectives (Source: CVC LID Guide)**

| LID Practice | Water Balance Benefit | Water Quality Improvement | Stream Channel Erosion Control Benefit |
|---|---|---|---|
| **Bioretention Area** | | | |
| Bioretention with no underdrain | Yes | Yes – size for water quality storage requirement | Partial – depends on available storage volume and infiltration rate |
| Bioretention with underdrain | Partial – depends on available storage volume beneath the underdrain & soil infiltration rate | Yes – size for water quality storage requirement | Partial – based on available storage volume beneath the underdrain and soil infiltration rate |
| Bioretention with underdrain and impermeable liner | Partial – achieves some volume reduction via evapotranspiration | Yes – size for water quality storage requirement | Partial - achieves some volume reduction via evapotranspiration |
| **Permeable Pavement** | | | |
| Permeable pavement with no underdrain | Yes | Yes – size for water quality storage requirement | Partial – depends on available storage volume and infiltration rate |
| Permeable pavement with underdrain | Moderate – based on native soil infiltration rates and storage beneath underdrain | Yes – size for water quality storage requirement | |
| Permeable pavement with underdrain and liner | No – some volume reduction occurs via evapotranspiration | Moderate – limited filtering and settling of sediments | |
| **Dry Swale / Bioswale** | | | |
| Dry swale with no underdrain or full infiltration | Yes | Yes – size for water quality storage requirement | Partial – depends on available storage volume and soil infiltration rate |
| Dry swale with underdrain or partial infiltration | Partial – depends on available storage volume beneath the underdrain and soil infiltration rate | Yes – size for water quality storage requirement | Partial – based on available storage volume beneath the underdrain and soil infiltration rate |
| Dry swale with underdrain and impermeable liner or no infiltration | Partial – some volume reduction via evapotranspiration | Yes – size for water quality storage requirement | Partial - achieves some volume reduction via evapotranspiration |
| **Vegetated Filter Strips** | Partial – depends on the soil infiltration rate | Partial – depends on flow path length and soil infiltration rate | Partial – depends on soil infiltration rate |
| **Enhanced Grass Swales** | Partial – depends on soil infiltration rate | Yes - design velocity must be 0.5 m/s or less for a 4 hour, 25mm Chicago storm event | Partial – depends on soil infiltration rate |
| **Perforated Pipe Systems** | Yes | Yes | Partial - depends on soil infiltration rate |

# 7 CLOSING

This document was developed in accordance with existing best practice guides such as the TRCA/CVC LID Guide, with requirements tailored to the Town of Lincoln's needs. Moving forward, it is intended to be utilized by the Town as a reference guide for implementing and managing sustainable stormwater practices.