3.0 LOW IMPACT DEVELOPMENT PRACTICES

3.1 Principles of Low Impact Development

As noted previously, in Ontario a treatment train approach to stormwater management, that utilizes a combination of lot level, conveyance and end-of-pipe practices, is advocated for new and infill development to maintain the hydrologic cycle, protect water quality and prevent erosion and flooding (OMOE, 2003). Low impact development (LID) practices can be an integral part of a treatment train approach to stormwater management. This section of the *LID SWM Guide* focuses on low impact development practices that have only recently been accepted and applied in Ontario as part of the treatment train approach. These practices include innovative site design strategies that minimize runoff (*i.e.*, nonstructural LID practices). They also include distributed, small scale lot level and conveyance practices (*i.e.*, structural LID practices) such as rainwater harvesting, green roofs, soakaways, bioretention, vegetated filter strips, permeable pavement, perforated pipe systems, and swales. Acknowledging that end-of-pipe facilities are also an integral part of the treatment train approach, the reader is urged to refer to the OMOE *Stormwater Management Planning and Design Manual* (OMOE, 2003) for direction on incorporating practices such as wet detention ponds and wetlands into the overall planning and design for stormwater management.

A variety of terms have been used to describe the overall design philosophy of managing runoff as close to the source as possible. Low impact development is the term used here but it can be alternately referred to as, better site design, sustainable urban drainage systems, water sensitive urban design, or stormwater source controls. All of these approaches attempt to reproduce the predevelopment hydrologic regime through innovative site design and distributed engineering techniques aimed at infiltrating, filtering, evaporating, harvesting and detaining runoff, as well as preventing pollution. Key principles for low impact development design can be summarized 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/subwatershed and neighbourhood scales;
   - Identify and protect environmentally sensitive resources;
   - see Chapter 2 for further guidance on the landscape-based approach to stormwater management planning and design.

2. **Focus on runoff prevention**
   - Minimize impervious cover through innovative site design strategies and application of permeable pavement;
   - 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 area as possible**
   - Utilize decentralized lot level and conveyance stormwater management practices as part of the treatment train approach;
   - Flatten slopes, lengthen overland flow paths, and maximize sheet flow;
   - Maintain natural flow paths by utilizing open drainage (*e.g.*, 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 practices on private property;
   - Establish legal agreements to ensure long-term operation and maintenance.

Typical LID designs incorporate more than one type of practice or technique to provide integrated treatment of runoff from a site. For example, in lieu of a treatment pond serving a new subdivision, planners might incorporate a bioretention area in each yard, disconnect downspouts from impervious surfaces, remove curbs and install grassed swales in common areas. Each LID practice incrementally reduces the volume of stormwater as it moves from the source area to the receiving waterbody. In doing so, LID practices are applied to meet stormwater management targets for water quality, channel erosion control and water balance. Although LID practices are not intended to meet stormwater management targets for flood control, they do provide some benefit in this regard.

LID practices, applied together with conventional end-of-pipe facilities, can provide better runoff and pollutant load reduction, be more cost effective, have lower maintenance burdens, and be more protective of aquatic habitat during extreme storms than end-of-pipe facilities alone. Several practices may be needed to achieve the required storage volume. The precise type and number of LID practices depends on several factors including land use, soils, geology, groundwater levels, groundwater uses, and the sensitivity of the receiving waterbody.

It should also be noted that LID practices may be beneficial in order to meet objectives other than those for stormwater management. For example, the City of Toronto, City of Mississauga and Town of Caledon have developed green development standards in which a variety of LID practices can help meet objectives relating to energy and water conservation, reduced use of materials and reduction of the urban heat island effect

(City of Toronto, 2007b; City of Mississauga, 2009; Town of Caledon, 2009). Furthermore, a recent housing development in Guelph (Reid Homes, 2007) and Halton Hills (Meadows in the Glen, 2009) have incorporated a variety of practices including rainwater harvesting, bioretention, enhanced grass swales and permeable pavement in order to meet green building certification requirements.

The following section provides guidance regarding innovative site design (*i.e.*, non-structural) strategies. The remainder of this chapter focuses on factors to be considered in the process of selecting and designing structural LID practices for stormwater management.

3.2 Low Impact Development Site Design Strategies

Increases in the quantity, rate, and frequency of runoff can be linked to two root causes: the conversion of undeveloped or agricultural land cover to urban uses, and the application of storm sewer systems. The goal of LID site design strategies is to minimize these two sources of hydrologic impacts. Avoiding downstream impacts through non-structural, innovative site design methods is more economical, operationally efficient, and aesthetically pleasing than concentrating all stormwater management efforts on treating and controlling runoff downstream. Therefore, site designers should exhaust all opportunities for non-structural methods to prevent runoff from being generated before determining how to mitigate the land cover change and storm sewer impacts through structural LID practices and detention ponds.

Sixteen (16) LID site design strategies can be grouped into four themes: Preserving important hydrologic features and functions; siting and layout of development; reducing impervious area; and using natural drainage systems. The strategies need to be considered together as they all overlap and relate to each other. For example, preserving a natural channel will impact the layout of the site, and the layout of the site determines the extent of impervious area and optimal locations of structural SWMPs.

3.2.1 Preserving Important Hydrologic Features and Functions

As discussed in Chapter 2, there are many features in the natural landscape that provide the important hydrologic functions of retention, detention, infiltration, and filtering of stormwater. These features include, but are not limited to; highly permeable soils, pocket wetlands, significant small (headwater) drainage features, riparian buffers, floodplains, undisturbed natural vegetation, and tree clusters. These features act as sponges and can sometimes be used to buffer the hydrologic impacts created by neighbouring development. They preserve the natural character of the site and in many cases improve the aesthetics and value of the developed property.

All areas of hydrologic importance should be delineated at the earliest stage in the development planning process. Once these areas have been mapped, they can guide the layout of the site.

Strategies

1. **Preserve stream buffers, including along intermittent and ephemeral channels.** Buffers provide filtration, infiltration, flood management, and bank stability benefits. Unlike stormwater ponds and other structural infrastructure, buffers are essentially a no capital cost and low maintenance form of infrastructure. In general, the literature recommends stream buffers for pollutant removal and support of aquatic and terrestrial riparian habitat (Wenger, 1999). The benefits of buffers diminish when slopes are greater than 25%; therefore steep slopes should not be counted as buffer (Schueler, 1995).

2. **Preserve areas of undisturbed soil and vegetation cover.** Typical construction practices, such as topsoil stripping and stockpiling, and site grading and compaction by construction equipment, can considerably reduce the infiltration capacity (and treatment capacity) of soils. In some instances, the bulk density of construction compacted soils is similar to values for impermeable surfaces. Native undisturbed soils have a structure that takes many, if not hundreds of years, to develop. The structure is created by the growth and decay of plant roots, earthworm, and insect activity. In addition to destroying the structure during topsoil stripping and stockpiling, biological activity in the soil is greatly diminished. The shallow rooted turf of lawns and landscaped areas will not provide the same stormwater benefits as the agricultural and native vegetation that it replaces. During construction, natural heritage features and locations where infiltration-based SWMPs will be constructed should be delineated and not subject to construction equipment or other vehicular traffic, nor stockpiling of topsoil.

3. **Avoid development on permeable soils.** Highly permeable soils (*i.e.*, hydrologic soil groups A and B) function as important groundwater recharge areas. Compacting or paving over these areas will have significant hydrologic impacts. To the greatest extent possible, these areas should be preserved in an undisturbed condition or set aside for stormwater infiltration practices. On sites with a variety of soil types, impervious land cover should be concentrated in areas with the least permeable soils and underlying geology. Where avoiding development on permeable soils is not possible, stormwater management should focus on mitigation of reduced groundwater recharge through application of stormwater infiltration practices.

4. **Preserve existing trees and, where possible, tree clusters.** Mature stands of deciduous trees will intercept 10 to 20% of annual precipitation falling on them, and a stand of evergreens will intercept 15 to 40% (Cappiella, 2005). Depending on understory vegetation, soils and topography, tree clusters may only produce surface runoff for major flood event storms. Preserving mature trees will provide immediate benefits in new developments, whereas newly planted trees will take 10 years or more to provide equivalent benefits. Tree clusters can be incorporated into development in many ways, including parking lot interiors or perimeters, private lawns, common open space areas, road buffers, and median

strips (Figure 3.2.1). Any areas of reforestation or new urban tree plantings need an uncompacted soil volume that allows the root systems to get air and water. An uncompacted soil volume of 15 to 28 cubic metres is recommended to achieve a healthy mature tree with a long lifespan (Casey Trees, 2008).

Figure 3.2.1. Development sites offer a number of locations for tree clusters

Source: Cappiella *et al.,* 2006

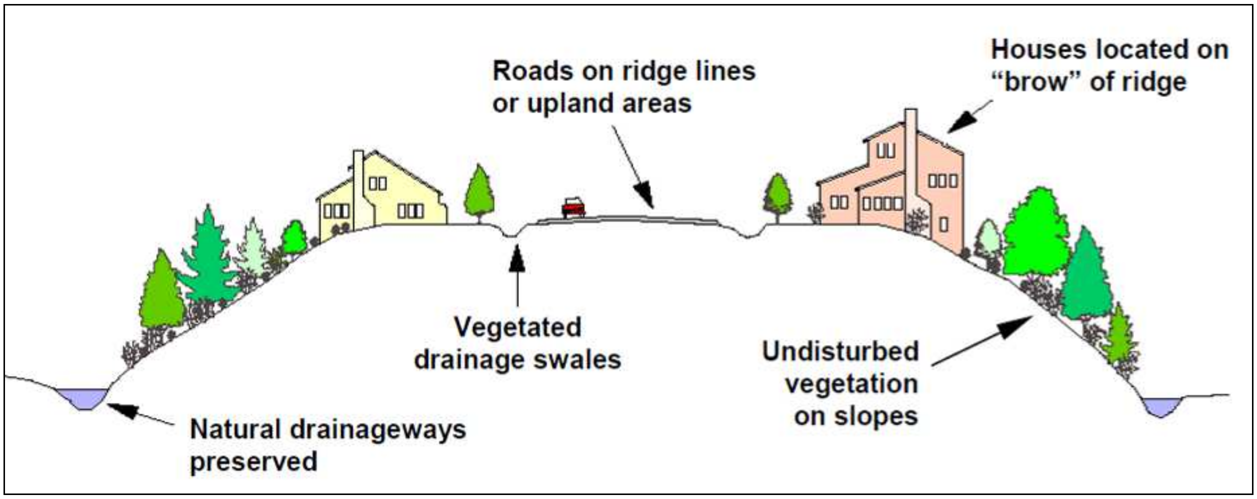
3.2.2 Siting and Layout of Development

The site layout is determined in part by the opportunities and constraints of the natural heritage system. The location and configuration of elements, such as streets, sidewalks, driveways, and buildings, within the framework of the natural heritage system provides many opportunities to reduce stormwater runoff. The goals of the site layout are to provide a functional and livable urban form while minimizing environmental impact. The techniques below highlight some of the ways in which site layouts can minimize their hydrologic impacts and preserve natural drainage patterns.

Strategies

5. **Fit the design to the terrain.** Using the terrain and natural drainage as a design element is an integral part to creating a hydrologically functional landscape (Prince George's County, 1999). Fitting development to the terrain will reduce the amount of clearing and grading required and the extent of necessary underground drainage infrastructure. This helps to preserve predevelopment drainage boundaries which helps to maintain distribution of flows. Generally, siting development in upland areas will take advantage of lowland areas for conveyance, storage, and treatment (Figure 3.2.2).

Figure 3.2.2. Site development in upland areas

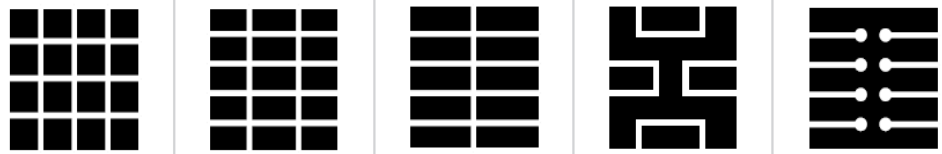


6. **Use open space or clustered development.** Clustering development increases the development density in less sensitive areas of the site while leaving the rest of the site as protected community open space. The open space can be undisturbed natural area or actively used recreational space. Features that often characterize open space or clustered development are smaller lots, higher density of structures in one area of a site, shared driveways, and shared parking. From a stormwater perspective, clustered development reduces the amount of impervious surface, reduces pressure on buffer areas, reduces the construction footprint, and provides more area and options for stormwater controls including LID practices (CWP, 1998).

7. **Use innovative street network designs.** Certain roadway network designs create less impervious area than others. Figure 3.2.3 from the Canadian Mortgage and Housing Corporation (2002) demonstrates that loop and cul-de-sac street patterns require less area for streets. These layouts by themselves may not achieve the many goals of urban design. However, used in a hybrid form together or with other street patterns, they can meet multiple urban design objectives and reduce the necessary street area (CMHC, 2002). A study comparing different road network designs for a hypothetical community showed a fused grid pattern can reduce impervious cover by 4.3% compared to a traditional neighbourhood design (CMHC, 2007).

8. **Reduce roadway setbacks and lot frontages.** The lengths of setbacks and frontages are a determinant for the area of pavement, street, driveways, and walkways, needed to service a development. Municipal zoning regulations for setbacks and frontages have been found to be a significant influence on the production of stormwater runoff. A study of residential parcels in Madison, Wisconsin found that reducing setbacks by 3 m and frontages by 5.5 m resulted in a 14% reduction of stormwater runoff (Stone and Bullen, 2006).

Figure 3.2.3 Comparison of buildable and street areas among 5 typical street patterns



	Square grid (Miletus, Houston, Portland, etc.)	**Oblong grid** (most cities with a grid)	**Oblong grid 2** (some cities or in certain areas)	**Loops** (Subdivisions – 1950 to now)	**Culs-de-sac** (Radburn – 1932 to now)
Percentage of area for streets	36.0%	35.0%	31.4%	27.4%	23.7%
Percentage of buildable area	64.0%	65.0%	68.6%	72.6%	76.3%

Source: CMHC, 2002

3.2.3 Reducing the Impervious Area:

Unnecessary hardscape can be found all around urban areas from paved but unused traffic and parking lot islands to rarely used overflow parking. Many of the strategies described previously are primarily for the purpose of reducing impervious area on a macro scale. The following strategies provide examples of how to reduce impervious area on a micro or lot level scale. Individually, these reductions in impervious area may seem small but they can add up to substantial decreases in runoff and infrastructure costs.

Strategies

9. **Reduce street width.** Streets constitute the largest percentage of impervious area and contribute proportionally to the urban runoff. Streets widths are sized for the free flow of traffic and movements of large emergency vehicles. In many cases, such as low density residential, these widths are oversized for the typical function of the street. Amending urban design standards to allow alternative, narrower street widths might be appropriate in some situations. There are a variety of ways to accommodate emergency vehicle movements and traffic flow on narrower streets, including alternative street parking configurations, vehicle pullout space, connected street networks, prohibiting parking near intersections, and reinforced turf or gravel edges (U.S. EPA, 2007).

10. **Reduce building footprints.** Reduce the building footprint by using taller multi-story buildings and taking advantage of opportunities to consolidate services into the same space. A single story design converted to a two- storey structure with the same floor space will eliminate 50% of the building footprint impervious area.

11. **Reduce parking footprints.** Parking footprints can be reduced in several ways. Excess parking not only results in greater stormwater impacts and greater

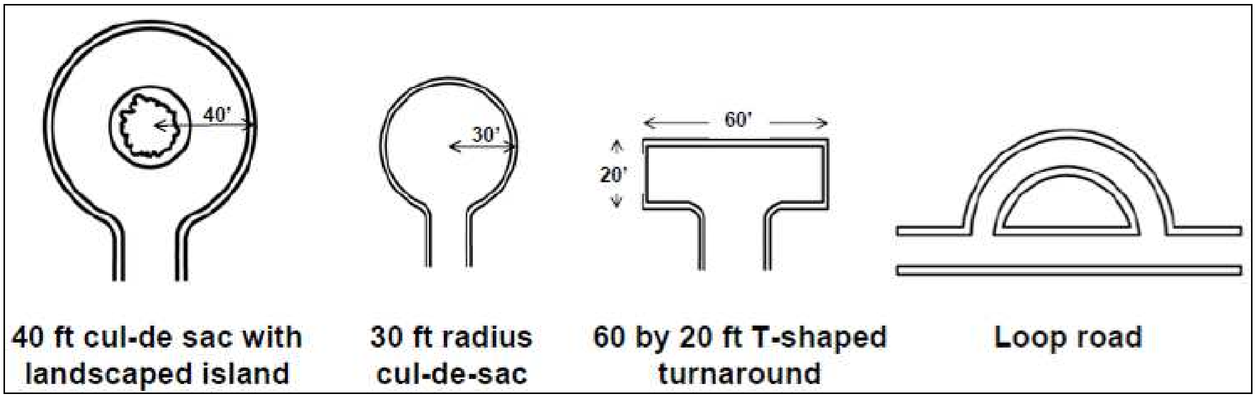
stormwater management costs but also adds unnecessary construction and maintenance costs and uses space that could be used for a revenue generating purpose.

- Keep the number of parking spaces to the minimum required. Parking ratio requirements are often set to meet the highest hourly parking demand during the peak season. The parking space requirement should instead consider an average parking demand and other factors influencing demand like access to mass transit.
- Take advantage of opportunities for shared parking. For example, businesses with daytime parking peaks can be paired with evening parking peaks, such as offices and a theatre, or land uses with weekday peak demand can be paired with weekend peak demand land uses, such as a school and church.
- Reductions in impervious surface can also be found in the geometry of the parking lot. One way aisles when paired with angled parking will require less space than a two way aisle. Other reductions can be found in using unpaved end-of-stall overhangs, setting aside smaller stalls for compact vehicles, and configuring or overlapping common areas like fire lanes, collectors, loading, and drop off areas.
- More costly approaches to reducing the parking footprint include parking structures or underground parking.

12. **Consider alternatives cul-de-sacs.** Using alternatives to the standard 15 metre radius cul-de-sac can further reduce the impervious area required to service each dwelling (Figure 3.2.4). Ways to reduce the impervious areas of cul-de-sacs include a landscaped or bioretention centre island, T-shaped turnaround, or by using a loop road instead.

13. **Eliminate unnecessary sidewalks and driveways.** Sidewalks are an essential part of the transportation, recreation, safety, and character of a community. A flexible design standard for sidewalks is recommended to allow for unnecessary sidewalks to be eliminated. Sidewalks that are not needed for pedestrian circulation or connectivity should be removed. Often sidewalks are only necessary on one side of the street. Driveway impervious area can be reduced through the use of shared driveways or alley accessed garages (CWP, 1998).

Figure 3.2.4 Reduced impervious area alternative cul-de-sac designs



Source: CWP, 1998

3.2.4 Using Natural Drainage Systems

The use of natural drainage picks up where stormwater leaves impervious areas. Rather than collect and move stormwater rapidly to a centralized location for detention and treatment, the goal of these strategies is to take advantage of undisturbed vegetated areas and natural drainage patterns (*e.g.*, small headwater drainage features). These strategies will extend runoff flow paths and slow down flow to allow soils and vegetation to treat and retain it. Using natural systems or green infrastructure to provide communities with environmental services is often more cost effective than traditional drainage systems, and they provide more ancillary benefits.

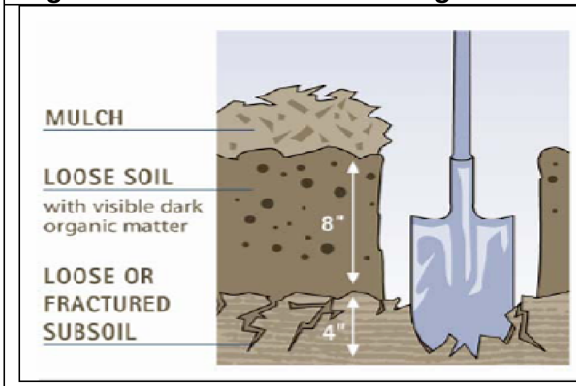
Strategies

14 "Disconnect" impervious areas. Impervious areas have varying degrees of hydrologic impact depending on their connection to the receiving waterbody. For example, impervious areas such as parking lots that drain directly to a concrete gutter and storm sewer will have a much greater impact than parking lots graded to drain to densely vegetated pervious areas. Roof leaders or downspouts, parking lots, driveways, sidewalks, and patios should be disconnected from the storm sewer and directed towards stabilized pervious areas where possible (see sections 4.3 – Downspout Disconnection and 4.6 – Vegetated Filter Strips for further design guidance). Opportunities for directing impervious surface runoff to pervious areas are first considered during the site layout stage. Sheet flow should be encouraged from all impervious surfaces draining to pervious areas. In cases of concentrated flow, the flow can be broken up with level spreaders or flow dissipating riprap. Use the following guidance for the pervious runoff receiving areas:

- *Undisturbed densely vegetated areas and buffers* – A hydrologist and/or ecologist should be consulted before designing a site to drain to sensitive natural heritage features like pocket wetlands.

- *Landscaped and disturbed areas* – With the proper treatment, the landscaped areas of the site can accept runoff from impervious areas. Deep tilling or soil aeration is recommended for topsoil that has been replaced or compacted by construction equipment. Former agricultural lands tend to develop a "hardpan" or compacted layer 0.5-1 meter below the soil surface from repeated plowings and farm equipment. Breaking up the hardpan may improve infiltration rates. Soil amendments can be applied to hydrologic soil group (HSG) C and D soils to encourage runoff absorption. See Figure 3.2.5 for guidance. Use deep rooting vegetation in landscaped areas when possible which will maintain and possibly improve the infiltration rates over time.

Figure 3.2.5. Soil amendment guidelines



Soil amendment sizing criteria:
impervious area / soil area = 1
– use 100 mm compost, till to 300 - 450 mm depth
impervious area / soil area = 2
– use 200 mm compost, till to 300 - 450 mm depth
impervious area / soil area = 3
– use 300 mm compost, till to 450 - 600 mm depth
Compost should consist of well-aged (at least one year) leaf compost. Amended soil should have an organic content of 8-15% by weight or 30-40% by volume.

Source: Soils for Salmon, 2005

15 **Preserve or create micro-topography.** Undisturbed lands have a micro-topography of dips, hummocks and mounds which slow and retain runoff. Site grading smoothes out these topographic features. Micro-topography can be restored in areas of ornamental landscaping or naturalization. Any depressed areas should drain within 48 hours, or they may provide breeding habitat for mosquitoes.

16 **Extend drainage flow paths.** Slowing down flows and lengthening flow paths allow more opportunities for stormwater to be filtered and infiltrated. Extending the travel time can also delay and lower peak flows. Where suitable, flows should be conveyed using vegetated open channels (see sections 4.8 – Enhanced Grass Swale and 4.9 – Dry Swale).

Figure 3.2.6. Open drainage applied in a medium density neighbourhood

Source: Seattle Public Utilities

3.2.5 LID Site Design Strategy Resources

Better Site Design: A Handbook for Changing Development Rules in Your Community, Center for Watershed Protection (1998)
http://www.cwp.org/Resource_Library/Better_Site_Design/#pwp

Low Impact Development Design Strategies: An Integrated Design Approach, U.S. EPA and Prince George's County, MD (1999)
http://www.epa.gov/owow/nps/lid/lidnatl.pdf

Pennsylvannia Department of Environmental Protection (PDEP). 2006. Pennsylvannia Stormwater Best Management Practices Manual. Harrisburg, PA. See Chapter 5: Non-structural BMPs.
http://www.portal.state.pa.us/portal/server.pt/community/best_management_practices_manual/10631.

3.3 Adapting Structural Low Impact Development Practices for Southern Ontario Conditions

Design guidance for the structural LID practices presented in chapter 4 was carefully adapted with consideration of the climate and predominant soil conditions in southern Ontario and of ultra urban development contexts that are particularly relevant to the Ontario Places To Grow legislation. Research and experience on LID practices from elsewhere in North America was evaluated to ensure that practices could be:

- adapted to withstand cold weather conditions in the region, withstand freeze-thaw conditions, and where possible treat the quality of snowmelt runoff;
- easily combined together to progressively reduce runoff volumes as a treatment train;
- feasible in the context of the more intense development and lot sizes that occur in the metropolitan areas that provide relatively little open space to locate practices;
- designed to collectively achieve target water balance and water quality storage volume requirements, contribute to stream channel erosion control, and reduce the size and cost of downstream conveyance and detention facilities;
- useful for reducing runoff volumes, even on sites with clayey soils with low infiltration rates;
- fit unobtrusively into open space and landscaping, and in some instances, provide amenity values;
- located within a stormwater easement, public right of way or conservation easement where they would be accessible for regular maintenance;

- applied in the context of new development, infill, redevelopment or retrofit projects; and
- evaluated to ensure the aggregate lifecycle cost for installation and maintenance of LID practices is equal to or less than the cost of constructing conventional stormwater conveyance and pond systems.

3.4 The Low Impact Development Design Process

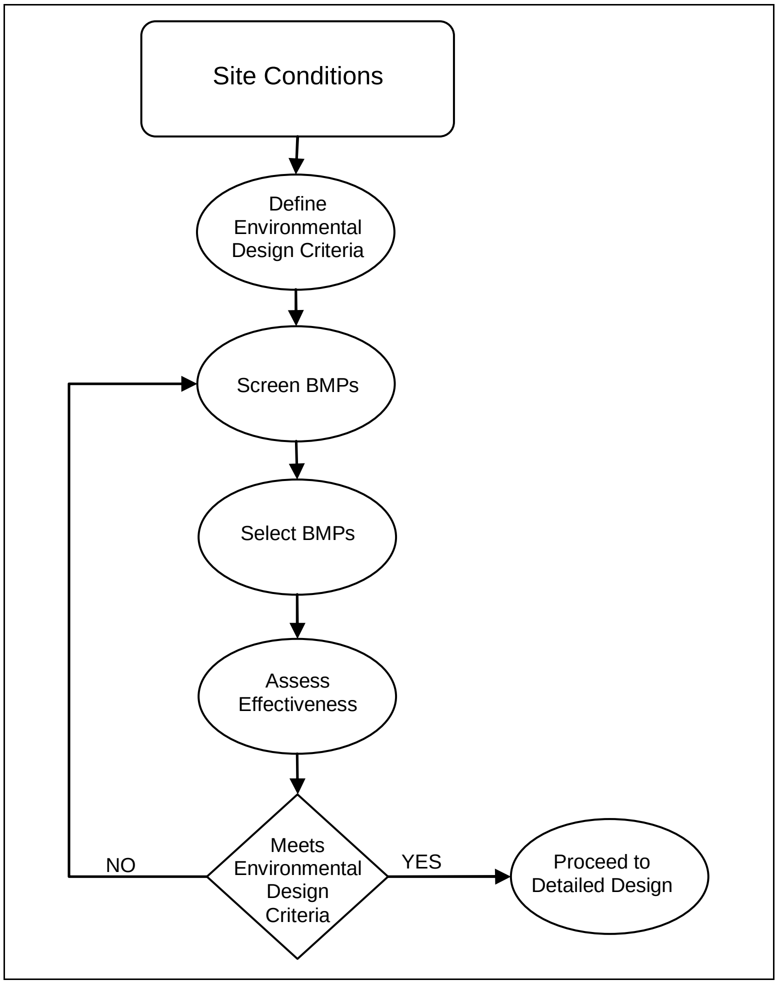
The ultimate goal of LID is to maintain natural or predevelopment hydrologic conditions, including minimizing the volume of runoff produced at the site (*i.e.*, neighbourhood, subdivision or individual lot). Runoff reduction is defined as the total runoff volume reduced through urban tree canopy interception, evaporation, rainwater harvesting, and engineered infiltration and evapotranspiration stormwater best management practices.

As described in chapter 2, the LID design process begins with a landscape-based approach to planning. The approach involves understanding regional and watershed-scale contexts, management objectives and targets relevant to the site. Where watershed or subwatershed scale studies or management plans are available, information and guidance they provide should be drawn upon. In the absence of a watershed plan, a subwatershed study may be required to establish the regional environmental context. Opportunities for LID practices are identified at the neighbourhood or subwatershed scales and refined at more detailed scales and planning stages. Inventories of the natural resources and drainage features present on the site are used as the integrating framework for stormwater management system planning.

Complete definition of pre-development site conditions is essential prior to screening of potential stormwater BMPs. The designer should prepare maps describing site conditions, to ensure that all environmental features and functions that need consideration in accordance with provincial, municipal and conservation authority development regulations are identified. This includes watercourses and small drainage features, floodplains, important recharge areas, steep slopes, wetlands, natural heritage conservation areas and significant wildlife habitats. In addition, information regarding native soil types, infiltration capacity and depth to water table must be determined. Using these conditions and the site design techniques described in Section 3.2, the natural heritage system, development footprint and constraints for stormwater BMPs can be established.

Once the site conditions are established, the designer evaluates the potential to apply a combination of best management practices (BMPs) to meet the environmental management criteria relevant to the site. Best management practices include the LID practices described in this guide and conventional end-of-pipe practices like wet and dry detention ponds and constructed wetlands. The general process for selecting the appropriate suite of best management practices (BMPs) is illustrated in Figure 3.4.1. Further description of each of the four steps is provided below.

Figure 3.4.1: Process for selecting a suite of best management practices



Step 1: Define Environmental Design Criteria

A detailed description of the design criteria that need to be defined is provided in the respective CVC and TRCA Stormwater Management Criteria documents. The criteria are required in order to:

- preserve groundwater and baseflow characteristics;
- prevent undesirable and costly geomorphic changes in the watercourse;
- prevent any increases in flood risk potential;
- protect water quality; and ultimately,
- maintain an appropriate diversity of aquatic life and opportunities for human uses

The design criteria required to protect, enhance or restore the environmental resources can be grouped under the following five categories.

- Flood Protection;
- Water Quality;
- Erosion Control;
- Recharge; and
- Natural Heritage Systems

Step 2: Screen Potential Best Management Practices

A number of factors need to be considered when screening the suitability of a given location within a development site for application of stormwater BMPs. Table 3.4.1 summarizes site constraints associated with some general types of structural LID practices for stormwater management that should be considered. Further details regarding each general type of LID practice can be found in section 4. Further information regarding constraints to the design of various end-of-pipe BMPs can be found in the Ontario Ministry of the Environment *Stormwater Management Planning and Design Manual* (2003). The use of LID BMPs should be considered first to meet the design criteria before the use of end-of-pipe BMPs.

Step 3: Selection of Suite of Best Management Practices

In order to assess if the selected suite of BMPs effectively meet the design criteria either computer models or simple spreadsheet models should be used. Model selection will be based on the size and type of development. A wide range of simple to complex computer models such as Visual OTTHYMO, SWMM, SWMMHYNO, HSP-F and QUALHYMO are available.

Step 4: Assessing the Effectiveness of the Selected Suite of Best Management Practices

Once the suite of best management practices have been selected and the models have been run, a comparison of the results and the environmental design criteria can be made. An iterative approach, which involves adjusting the size or adding/deleting BMPs should be used until the environmental design criteria are met. The project can then proceed to the detailed design stage.

Table 3.4.1 Comparison of site constraints for a range of structural LID SWM practices

LID Stormwater Management Practice	Depth to high water table or bedrock[1] (m)	Typical Ratio of Impervious Drainage Area to Treatment Facility Area	Native Soil Infiltration Rate (mm/hr)[3]	Head[4] (m)	Space[5] %	Slope[6] %	Pollution Hot Spots[7]	Set backs[8]
Rain barrel	Not applicable	[5 to 50 m^2][2]	Not applicable	1	0	NA	Yes	None
Cistern	1	[50 to 3000 m^2][2]	Not applicable	1 to 2	0 to 1	NA	Yes	U, T
Green roof	Not applicable	1:1	Not applicable	0	0	0	Yes	None
Roof downspout disconnection	Not applicable	[5 to 100 m^2][2]	Amend if < 15 mm/hr[9]	0.5	5 to 20	1 to 5	Yes	B
Soakaway, infiltration trench or chamber	1	5:1 to 20:1	Not a constraint	1 to 2	0 to 1	< 15%	No	B, U, T, W
Bioretention	1	5:1 to 15:1	Underdrain required if < 15 mm/hr	1 to 2	5 to 10	0 to 2	No	B, U, W
Biofilter (filtration only Bioretention design)	Not applicable	5:1	Not applicable	1 to 2	2 to 5	0 to 2	Yes	B, T
Vegetated filter strip	1	5:1	Amend if < 15 mm/hr[9]	0 to 1	15 to 20	1 to 5	No	None
Permeable pavement	1	1:1 to 1.2:1	Underdrain required if < 15 mm/hr	0.5 to 1	0	1 to 5	No	U, W
Enhanced grass swale	1	5:1 to 10:1	Not applicable	1 to 3	5 to 15	0.5 to 6	No	B, U
Dry swale	1	5:1 to 15:1	Underdrain required if < 15 mm/hr	1 to 3	5 to 10	0.5 to 6	No	B, U, W
Perforated pipe system	1	5:1 to 10:1	Not a constraint	1 to 3	0	< 15%	No	B, U, T, W

Notes:
1. Minimum depth between the base of the facility and the elevation of the seasonally high water table or top of bedrock.
2 Values for rain barrels, cisterns and roof downspout disconnection represent typical ranges for impervious drainage area treated.
3. Infiltration rate estimates based on measurements of hydraulic conductivity under field saturated conditions at the proposed location and depth of the practice.
4. Vertical distance between the inlet and outlet of the LID practice.
5. Percent of open pervious land on the site that is required for the LID practice.
6. Slope at the LID practice location.
7. Suitable in pollution hot spots or runoff source areas where land uses or activities have the potential to generate highly contaminated runoff (*e.g.*, vehicle fueling, servicing or demolition areas, outdoor storage or handling areas for hazardous materials and some heavy industry sites).
8. Setback codes: B = Building foundation; U = Underground utilities; T = Trees; W = drinking water wellhead protection areas.
9. Native soils should be tilled and amended with compost to improve infiltration rate, moisture retention capacity and fertility.

3.5 Costs and Benefits of Low Impact Development Approaches

The United States Environmental Protection Agency (U.S. EPA) examined the costs of LID approaches in *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices,* released in December 2007. The report summarized 17 case studies of developments in the United States and Canada that included low impact development approaches for managing stormwater. The case studies included a variety of different land uses and dealt with both greenfield and redevelopment scenarios. Table 3.6.1 summarizes findings from some of the projects that were reviewed along with a comparison of conventional development costs versus low impact development costs.

Some of the key findings from this study were:

- In 12 of the case studies, total capital cost savings ranged from 15 to 80 percent when LID methods were used. In one study, LID costs were higher than conventional stormwater management costs.

- The study focused on the cost savings and cost reductions that are achievable through the use of LID practices. It should also be noted that communities and/or developers can experience many amenities and associated economic benefits that go beyond cost savings. These include enhanced property values, faster home sales, improved habitat, aesthetic amenities and improved quality of life. The study did not monetize and consider these values in performing the cost calculations, it was noted that these economic benefits are real and significant.

- More research is needed to quantitatively estimate and compare full life cycle costs of municipal infrastructure for conventionally designed developments versus LID designs (including long term operation, maintenance and eventual replacement).

Table 3.5.1 Summary of cost comparisons between conventional and LID approaches

Projects[1]	Conventional Development Cost	LID Cost	Cost Difference[2]	Percent Difference[2]
2nd Avenue SEA Street, Seattle, Washington	$868,803	$651,548	$217,255	25%
Auburn Hills, southwestern Wisconsin	$2,360,385	$1,598,989	$761,396	32%
Bellingham City Hall, Bellingham, Washington,	$27,600	$5,600	$22,000	80%
Bloedel Donovan Park, Bellingham, Washington	$52,800	$12,800	$40,000	76%
Gap Creek, Sherwood, Arkansas	$4,620,600	$3,942,100	$678,500	15%
Garden Valley, Pierce County, Washington	$324,400	$260,700	$63,700	20%
Kensington Estates, Pierce County, Washington	$765,700	$1,502,900	-$737,200	-96%
Laurel Springs, Jackson, Wisconsin	$1,654,021	$1,149,552	$504,469	30%
Mill Creek, Kane County, Illinois[3]	$12,510	$9,099	$3,411	27%
Prairie Glen, Germantown, Wisconsin	$1,004,848	$599,536	$405,312	40%
Somerset, Prince George's County, Maryland	$2,456,843	$1,671,461	$785,382	32%
Tellabs Corporate Campus, Naperville, Illinois	$3,162,160	$2,700,650	$461,510	15%

Source: U.S. EPA (2007).

Notes:

1. While additional projects were part of the U.S. EPA review, available information does not allow comparison of costs between conventional and LID approaches.
2. Negative values denote increased cost for the LID design over conventional development costs.
3. Mill Creek costs are reported on a per-lot basis.