Lakeview Neighbourhood

Location: Mississauga
Constructed: August 2012

Case Study

Road Right-of-Way

Project Objectives, Design and Performance

- Construct one of Ontario's first green streets in a residential neighbourhood using low impact development (LID)
- Retrofit an older neighbourhood to improve drainage, add modern stormwater controls and enhance street aesthetics.
- LID features include boulevard bioretention cells and permeable paver driveway aprons along the road right-of-way.
- Monitor water levels, landscape health and maintenance needs in order to understand the life cycle performance of LID practices.
- Evaluate the performance of LID retrofits in treating stormwater and reducing runoff in a residential setting.

Overcoming Barriers and Lessons Learned

- As the Lakeview project was the first of its kind, the project team had to be flexible and adaptable. Many stakeholders across departments and disciplines provided input during all project phases.
- The project team used an open house style public consultation method to earn project support from neighbourhood residents.
- Site reconnaissance discovered several issues, including fence and driveway encroachments, utilities located in the right of way, traffic safety concerns, and poor grading. All issues were addressed during the planning, design and construction phases.
- Sacrificial pieces of filter fabric laid over top of clearstone reservoirs protected the bioretention infrastructure from contamination. LID projects require simple and creative erosion and sediment control solutions.

Practices Implemented

Bioretention

Permeable Pavement

Barriers & Issues Encountered

Planning & Regulations

Design

Construction & Comissioning

Operation & Maintenance

Case Study Outline

The Lakeview Project case study consists of the following sections:

Overview

The Lakeview district is a residential neighbourhood within the City of Mississauga. It is located just outside of the Cooksville Creek watershed and drains directly into Lake Ontario, a source of drinking water for over 8.5 million people.

Several residents expressed concerns about the condition and maintenance of the ditches in this older neighbourhood. Ditches had poor water conveyance capacity, locations with standing water, and sections with very steep side slopes. Residents also identified parking encroachment outside the paved area of the road as a concern.

City of Mississauga's Transportation and Works Department decided to retrofit existing ditched streets in the Lakeview neighbourhood in order to address some of these concerns. At the same time, the City choose to address some of the stormwater conveyance and water quality issues by developing a phasing strategy to introduce low impact development (LID) practices.

The City collaborated with Credit Valley Conservation, (CVC), engineering consultant Aquafor Beech Ltd and landscape architect Schollen and Company to implement the Lakeview Project. Existing ditch and culvert systems were replaced with boulevard bioretention and permeable pavement practices within the municipal road right of way (ROW). Permeable pavement was incorporated at the end of resident's driveways and bioretention units were situated along frontages in the boulevard. Portions of both First Street and Third Street between Alexandra Avenue and Meredith Avenue were retrofitted with these features (outlined in **Figure 1**).

The Lakeview project offered a great opportunity to build an LID demonstration showcase that would be a model for future ROW retrofit projects. LID practices constructed in the Lakeview neighbourhood are intended to reduce stormwater runoff and improve water quality flowing into storm sewers and eventually into Lake Ontario. These features have also improved the overall aesthetics of the neighbourhood.

Construction of the Lakeview Project was completed in August, 2012. Since completion, the site has been showcased through multiple presentations, media, events, and site tours. The site has garnered lots of attention from municipal and agency staff across Ontario who are interested in constructing similar retrofits in their area. The local community has also shown a great amount of interest in the project, with many neighbouring residents asking when their streets will be retrofitted.

As part of the partnership with CVC, an infrastructure performance and risk assessment program has been implemented to monitor the performance of the LID practices. Monitoring equipment has been installed to provide localized performance monitoring including both flow and water quality parameters. CVC also conducts regular site visits to document landscape health and maintenance needs.

Figure 1 – Location of the Lakeview Project

Goals and Drivers

There were several primary and supplementary goals and drivers that motivated the Lakeview project. The primary goals describe those directly impacting the City of Mississauga, its residents and the surrounding natural environment. Supplementary goals have many indirect benefits and represent the long-term and wide-scale objectives of LID implementation.

Primary Goals

- Construct LID practices on First Street and Third Street that improve stormwater management within a residential ROW setting.
- Ensure proper drainage and provide treatment within the road ROW in order to increase groundwater recharge, sustain natural flows of rivers and creeks and meet municipal levels of service.
- Demonstrate an alternative to traditional curb and gutter stormwater conveyance that will improve water conveyance and eliminate standing water in the ditches.
- Improve overall aesthetic appearance of the street with attractive plantings.
- Try a new 'open house' style to engage the community in the project. Involve residents in determining the type of street restoration they wanted.
- Address resident concerns regarding drainage difficulties and mowing with ditches by minimizing ditch profile for improved maintenance.
- Demonstrate road ROW stormwater management retrofit within an older residential neighbourhood that meets stormwater objectives for fully developed areas with no stormwater controls.
- Build and monitor LID infrastructure in Ontario.

Supplementary Goals

- Support growth and development of green jobs and build LID expertise within the construction industry.
- Compile long-term data on operation and maintenance needs for LID in the road ROW.
- Evaluate how well native plants can grow in boulevard bioretention units.
- Assist Mississauga in meeting sustainability planning provisions.
- Increases property value and contribute to improved public and community health.
- Support healthy Great Lakes and assist municipalities in meeting sustainability planning provisions.

Project Successes

The following summarizes the successes achieved with this project. Further details are provided throughout the case study.

Innovative Project – The Lakeview Project is one of the first green streets in Ontario. This innovative project marks one of the earliest instances of LID practices implemented in a residential ROW.

Aesthetically Pleasing Street – Several of the LID features enhanced the overall aesthetics of the neighbourhood including the integration of permeable pavement and elaborate planting schemes. The improved aesthetics have sparked interest from surrounding streets, with residents asking when their street will be retrofitted.

Community Amenities – Community amenities such as the Third St parkette provide a public common area and reduce traffic safety concerns.

Demonstration Showcase – LID practices at the Lakeview Project have been showcased through numerous presentations, events, media and site tours. These efforts have helped educate many stakeholders on the benefits of implementing LID.

Performance Assessment – Monitoring infrastructure was successfully installed as part of construction in April 2012. A multi-year performance assessment program is underway in order to evaluate the performance of the LID features.

Construction Adaptation – Design team and contractors worked together to overcome challenging conditions including utilities, space constraints, on-site storage, erosion and sediment control.

Model for Future LID Retrofits – This project serves as a model for addressing stormwater management in older residential neighbourhoods within the Greater Golden Horseshoe area.

Support from Political Champions – Local councillor was a key factor in the success of the Lakeview project. He championed the project by speaking directly with residents about concerns, and regularly showcasing the site to interested parties.

Overcoming Barriers & Lessons Learned

Table 1 lists several barriers and issues encountered during the course of the Lakeview Project as well as how those issues were addressed and the lessons learned by the project team.

Table 1 – Summary of the Lakeview Project Barriers, Solutions & Lessons Learned

Project Phase	Issue/Barrier	Solution	Lesson Learned
Planning & Regulations	As the Lakeview project was one of first green street LID projects implemented in Ontario, project partners had to be flexible and adapt, as many aspects of the design and construction were new.	A multi-departmental and public consultation process was used to provide input during each phase of the planning and design process.	Consulting with all of the partners at an early stage ensures everyone is on the same page and there aren't big surprises later in the development process.
	Several design issues were identified early in the construction process.	Site reconnaissance was completed in order to evaluate site conditions and identify potential issues that may affect the design. Foreseeable design barriers should be confronted as early in the design process as possible.	Site reconnaissance is a necessary step in the design process that helps ensure issues are identified early in the design process.
	The partners wanted to increase participation and engagement of residents in the public information centres.	Additional opportunities for resident input were provided. Multiple public meetings and events such as community barbeques were held in order to engage public interest and encourage public attendance to information sessions	Going above and beyond the traditional expectations for engaging the public may be necessary to gain public support, especially during demonstration projects.
Design	There were concerns regarding how the LID practices would affect the usability of the streets and what alterations were required to the municipal design standards.	Design concepts were presented to all municipal departments to gain a perspective of the sites usability, maintenance and overall function Technical considerations were obtained for all municipal departments and examples of the infrastructure that was to be installed as part of the LID project was provided to municipal staff.	It is recommended that the all parties who will be affected by the project get involved during the design process. This is key to flushing out any potential issues that might be encountered later in the project.
	As Lakeview was an older neighbourhood, there were several fence and driveway encroachments.	Due to the number of encroachments, the scope of project was ultimately reduced	Encroachment issues should be identified during the planning phase prior to project initiation to ensure that such issues are addressed before the design phases is undertaken
	Utilities were located within the municipal right of way, which is common with older residential neighbourhoods.	Utilities were avoided as much as possible during the design phase.	Utilities will always be a concern when retrofitting LID within older neighbourhoods. Utility locates should be performed early in the design process.
	Site reconnaissance showed that there were traffic safety concerns at an intersection in the project area had to be addressed.	A parkette was added to the design to improve the intersection at Alexandra Ave and Third Street.	Site reconnaissance is a necessary step in the design process, as it will help the project team to understand how a site is used on a day-to-day basis. This will inform design decisions.
	The grade of some private properties did not drain towards the road	Provisional lot drains were added to the design drawings.	LID retrofits aim to achieve the best water quality benefits that the site will permit.
	Subsoils had low permeability and there was limited area to achieve water quality volume.	Size of LID practices were maximized to achieve the greatest amount of water quality control possible	

Project Phase	Issue/Barrier	Solution	Lesson Learned
Construction	During construction, design changes were made and some items were deleted.	The project team worked with the City and contractor to agree on diplomatic solutions that benefitted all parties.	Project team and contractor working together often results in an efficient and successful LID construction. Individuals competent in LID construction and design not only provide a resource for other contractors but also act as a liaison between the contractor, client and other stakeholders to ensure that the expectations of all parties are properly coordinated and fulfilled.
	Bioretention soil media was not mixed to standard.	Project team worked with the bioretention soil media supplier to develop an approved mix	Few LID projects the scale of Lakeview has been implemented in Ontario and the supply of specific LID materials is limited. Working with local suppliers to develop LID specific material is part of the evolution of LID implementation
	Utilities and obstructions were found during the construction process.	Minor adjustments to individual design elements were made to avoid or accommodate existing utilities and obstructions. These methods provided a cost effective and efficient means of addressing such construction issues.	Utilities will always be a concern when retrofitting LID within older neighbourhoods. Designers and contractors need to be flexible when implementing LID projects in older neighbourhoods.
	Incorrect materials were delivered to site.	Materials that did not meet the specifications were not used during construction.	Construction supervision and administration is critical to the success of LID projects. Where possible, a contractor or engineer experienced in LID should be on site.
Infrastructure Performance and Risk Assessment	Monitoring equipment could not be placed in the manhole at LV-4 due to space constraints.	Equipment was placed in a metal box on resident's property.	When including an infrastructure performance and risk assessment program at your LID site, ensure infrastructure sizing is adequate for equipment.
	Some plants in the bioretention units grew extremely tall, resulting in resident complaints.	Nuisance species were removed and replaced with shorter, easy maintenance plants.	Qualified landscapers should be involved during the design process. Species selection may need to be revisited after planting, as some species may flourish more than others.
Erosion and Sediment Control	Heavy duty sediment fencing was not practical to provide erosion and sediment control for bioretention units surrounded by curbs, sidewalks or other obstructions.	Creativity is essential when determining the most suitable methods of providing erosion and sediment control. Sacrificial pieces of filter fabric laid over top of the clearstone reservoirs protects the bioretention infrastructure from contamination and wood boards wrapped in filter cloth provided adequate protection of the bioretention systems.	LID specific erosion and sediment controls should be specified in contract documents. Simple and creative ways of protecting LID practices are required since many typical erosion and sediment control are not practical.

Background

The Credit River Water Management Strategy Update (CRWMSU) undertaken by CVC in 2007 developed a detailed inventory of existing resources and key features, reviewed existing and future land use plans, and assessed the potential impacts from proposed land use change within the Credit River watershed. A series of best management practices were evaluated for the watershed with the overarching goal of developing a watershed wide implementation plan for sustainability including definition of the roles of various agencies, policy review, funding arrangements and completion of the ongoing public participation program.

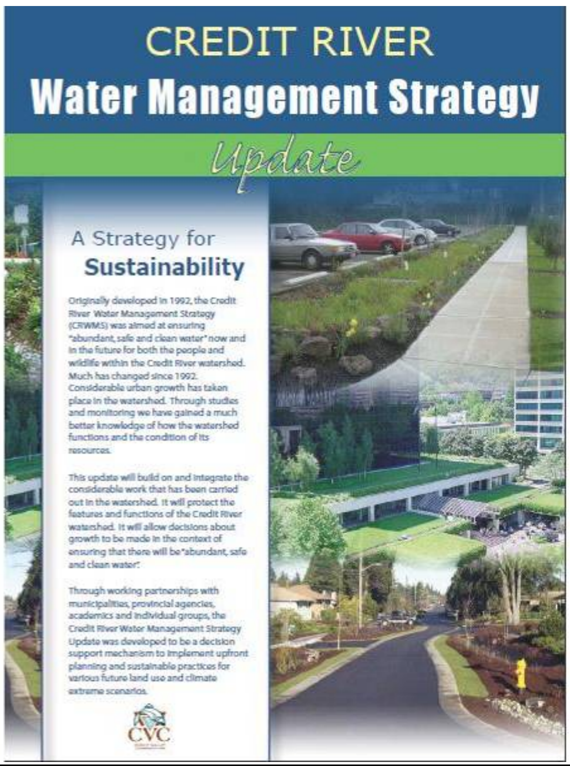


Figure 2 – Cover of the CRWMSU. Full document is available at www.creditvalleyca.ca

The City of Mississauga considered the findings and recommendations from the CRWMSU in the Mississauga Storm Water Quality Control Strategy Update (MSWQCSU). The objective of the update was to develop a comprehensive citywide approach to control the impact of stormwater runoff.

The City completed a comprehensive field reconnaissance program to define LID source, conveyance and downstream opportunities for residential, commercial and industrial environmental conditions. A social marketing study was also undertaken to define the willingness and potential barriers to implementing a wide range of source and conveyance control measures.

A number of streets in the Lakeview community, bounded by Cawthra Road, Lakeshore Road East, Meredith Avenue and the CNR tracks, were previously identified in the City's capital budget for some form of rehabilitation. Following the results of the MSWQCSU, these streets were also identified as opportunities to implement LID practices.

Implementing an LID project was also in accordance with the City's goals to be more environmentally responsible, as outlined in their strategic plan. The City opted to undertake a demonstration project that would include the application of LID practices within the municipal ROW for two streets within the Lakeview community. These included 560 m of First Street between Greaves Avenue and Meredith Avenue, and 120 m of Third Street between Alexandra Avenue and Meredith Avenue, a distance of approximately 120 m. The demonstration site became known as the Lakeview Project.

Lakeview Pre-retrofit Site Conditions

The Lakeview community drainage network consists of a combination of traditional catch basins and sewer networks and roadside ditch and culvert systems that discharge directly to Lake Ontario. **Figure 4** demonstrates the Cawthra drainage network which includes the Lakeview community.

Many residents in the Lakeview community were concerned about the severe degradation of the road surface and issues related to poor drainage. Following wet weather events, standing water was sustained within roadside ditches for prolonged periods. Saturated subsoils and asphalt base layers influenced by poorly draining subsoils are assumed to have assisted the degradation of the asphalt surface.

Figure 3 - Third Street pre-retrofit conditions

Figure 4 – Existing storm sewer conveyance network to Lake Ontario. Cawthra Drainage area is marked by blue and the sewer system is identified by red.

Initial Resident Buy-in

The City approached CVC's Water Resources Management & Restoration department in 2009 with the goal of retrofitting both First Street and Third Street with LID practices. CVC was very interested in promoting these techniques and supporting the neighbourhood residents and provided enthusiastic support for moving ahead with the project.

First Street and Third Street were residential areas identified by the City as overdue for rehabilitation and recognized by local residents as needing upgrades for several years. The intent for the project was to provide residents with a viable solution to address the functional concerns of the worn-out roadside ditches as well as beautify the street.

Early on, it was recognized that a different approach to the public consultation process was necessary. The current outreach on public works projects and environmental endeavours was focused on education, functionality and arcane engineering details. In order to motivate change with the public, the Lakeview project team needed to tap into people's emotional connections because lifestyle changes are driven by intrinsic values. For this reason, the team took a marketing approach. People have an emotional connection with their home's landscape and if individuals can be reached on an emotional level then they will often seek further information.

As this LID demonstration site would take place on residential streets, CVC and the City consulted with a marketing company to gain insight on how to achieve resident buy-in. It was determined that an open house style meeting would be used for the initial approach, rather than a regular presentation followed by question-and-answer style meeting. The open house included various marketing components. These marketing approaches were infused throughout the entire residential outreach component of the project.

The first component in capturing the residents' interest was to use common language to connect with the residents. The first public open house was held on June 25, 2009. Using the name "Lakeview Community Improvement Project" as opposed to stormwater management improvement or road reconstruction open house created buzz and excitement.

The second component to entice residents was a focus on aesthetics. Displays with beautiful landscapes were placed around the room on easels like an art gallery as opposed to having a PowerPoint presentation. This was done to provide homeowners an aesthetic vision they could embrace. The posters helped them visualize the beauty and vibrancy of a sustainable landscape

The third component to gaining residents' buy-in was to engage with them. CVC and City staff dressed casually to create a comfortable atmosphere with the residents. Initially the residents seemed unsure of the project, as it was a new concept. The casual atmosphere allowed residents to interact with staff as they visited the different displays filled with colourful street views and alternative landscape options. Residents started to ask more questions about the project, suggesting they were becoming more interested. They realized if the project went ahead, it would benefit their property in addition to the environment. After everyone was given a chance to visit the various displays, a round circle was held where residents were invited to voice their concerns. These concerns were noted and where possible addressed. Prior to leaving, residents were encouraged to fill out short questionnaires that were used to gauge the level of resident support and gather feedback. The questionnaires also allowed residents to choose which of the proposed LID practice alternatives they preferred in front of their properties.

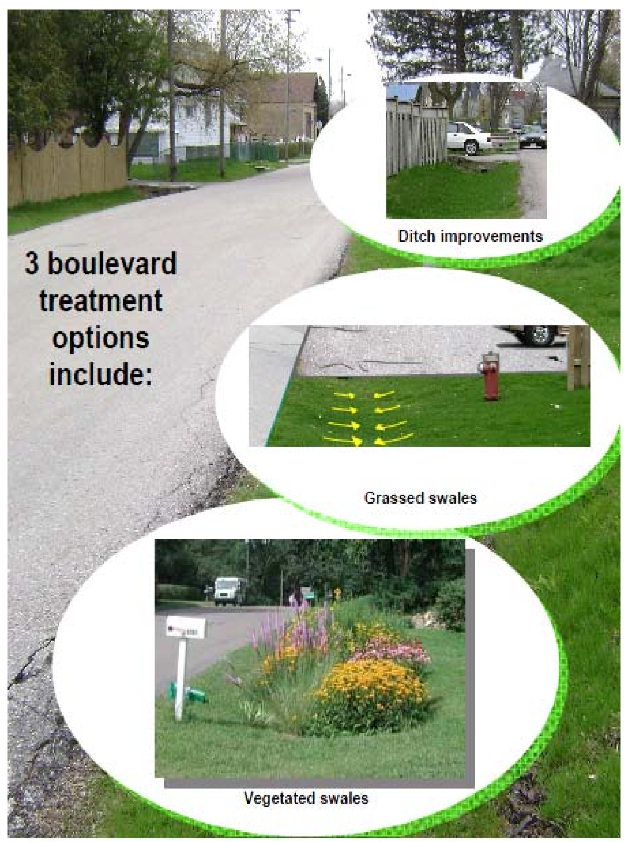


Figure 5 – Conceptual presentation of the alternative landscapes – vegetated swales, grassed swales

The goal of the open house was to gain residents buy-in and gauge their preferred roadside aesthetic, which would eventually guide the overall design concept. With the extra consideration given to creating an open, beautiful and approachable atmosphere, the first open house achieved 95% residential approval to go ahead with the project. This favourable feedback and high percentage of resident buy-in was responsible for advancing the project to design. **Figures 5** and **6** demonstrate the alternatives presented and the responses received from the residents.

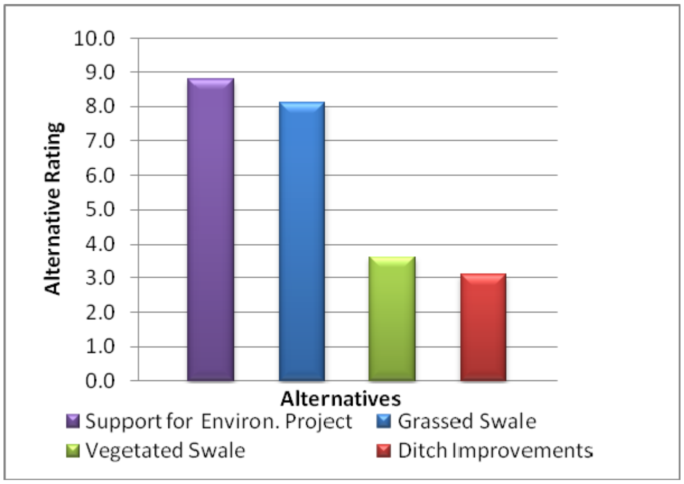


Figure 6 – Residents ratings of the presented landscape alternatives

Building the Project Team

Making the demonstration project happen required a collaborative approach between managers and staff in the City's roadway program and environmental engineering sections as well as input from CVC stormwater specialists. The project also required participation and buy-in from Transportation and Works, as they would have the long-term responsibility of maintaining the new street design. To be a successful the project also needed the full support of City leadership and especially the local Ward 1 Councillor.

Given the innovative nature of the project, a more detailed request for proposals (RFP) was necessary to get the right consultant design team. The City and CVC consulted Seattle Public Utilities, which had 10 years of experience with implementing their Street Edge Alternative (SEA Streets) program. They offered advice and lessons learned on putting together a multi-disciplinary team and how to get the public participation process right.

Based on these discussions, the following provisions were added to the standard RFP for a City road reconstruction project:

- **Expanded purpose and goals** - The project goals clearly stated the innovative nature of the project, the enhanced stormwater management goals, and the high expectation for aesthetics (see callout box for details).
- **Multi-disciplinary design team** - The RFP emphasized the importance of having sustainable urban and landscape designers as an integrated member of the design team, not just for final input. The landscape designer had to work with the engineer to ensure the chosen landscape would survive and thrive. They also needed to work with the residents to set expectations and gain their buy-in to the project.
- **Hydrologic and hydraulic assessment** - This project required more than the typical evaluation of peak flows. To assess water quality and water balance performance, a continuous modelling approach was also required.
- **Public involvement process** - The 2009 open house brought residents on board with the overall concept. The RFP defined several more meetings with the residents to bring the project to completion. There would still be more public information sharing interactions needed. (see callout box for details)
- **Infrastructure performance assessment provision** - The RFP emphasized that the project would use monitoring equipment to assess water quality and flow. The project designers had to be aware early on that monitoring was a goal and that they need to design for it. This included designing in certain types of structures that would fit the monitoring equipment or ensuring that flows were routed to a particular monitoring port.

Project Goals Stated in the Request for Proposals

1. Implement environmentally responsible LID practises on both First Street and Third Street to provide storm water quality treatment and natural filtration before discharging into the storm sewer system and ultimately Lake Ontario
2. Improve water conveyance and eliminate standing water in the ditches
3. Improve the overall aesthetic appearance of the right of way with attractive plantings where feasible
4. Minimize the ditch profile for improved maintenance
5. Demonstrate new LID designs
6. Assess the performance of the implemented LID practices.

Proposals were evaluated based on experience and understanding of the project in addition to cost. The chosen proposal by engineering consultant Aquafor Beech Limited and landscape architect Schollen & Company best fit the RFP requirements. Their joint proposal brought together a project team with expertise in LID principles, water resources engineering, landscape architecture, and urban planning.

Public Participation Process Specified in RFP

1. **Meeting #1: Kickoff Meeting**
   The consultant team will give a short presentation introducing the project and walk the project area with residents to gather background and feedback.
2. **Meeting #2: Presentation of 60% Plans and Plant Selection**
   Project Team will meet with homeowners and present the engineered concept, and the consultant landscape architect will provide planting plan options for the homeowners to choose from.
3. **Meeting #3: Presentation of 100% drawings and Construction Kickoff:**
   The intent of this meeting is to show the completed plans, set construction expectations, address any final concerns, and discuss the maintenance responsibilities.

Site Reconnaissance

Site reconnassiance and a background review of existing ducumentation was perfromed by the engineering consultant in 2009, which included the review of City mapping, geotechnical reports, and serviceing plans.

During the site reconnaissance a number of key design issues were revealed. Issues identified during the course of the site reconnaissance included:

- Encroachments
- Utilities and obstructions
- Traffic safety
- Flooding and drainage

Encroachments

Since the project was implementing LID pracitces within the municipal road ROW, areas adjacent to the road had to be available for design purposes. In many cases encroachments from private fences, parking areas, and other structures impacted the availablity of space for LID implementation. **Figure 7** demonstrates the type of encroachment observed throughout the site area. A photograph of an encroachment is provided in **Figure 8**.

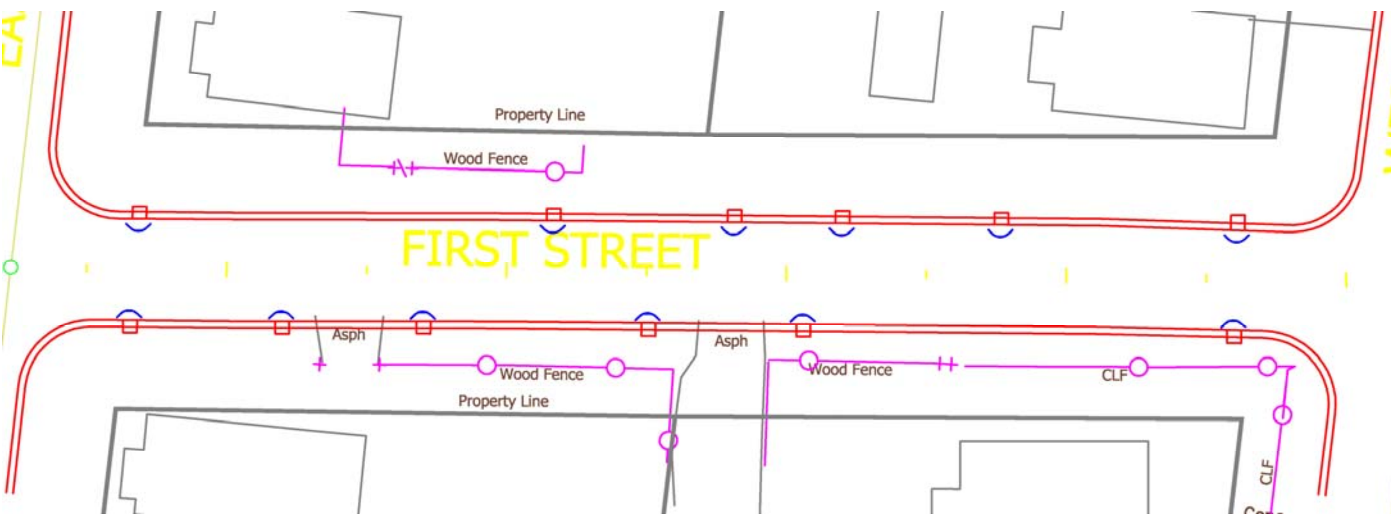


Figure 7 – Encroachment of First Street property line (Grey) versus private wood fence (Magenta)

Figure 8: Fence line encroachment on First Street

Utilities and Obstructions

Utilities both overhead and underground were located throughout the proposed locations for the LID practices. Locate information was surveyed during the completion of pre-design tasks and added to existing mapping to ensure as much utility information was available during the design phase.

Figure 9: Many buried utilities were located along First Street and Third Street, posing a challenge for construction

Other obstructions within the ROW were generally limited to roadside trees; however, signage, established parking areas and other structures were noted during the site reconnaissance.

Traffic Safety

The local road configurations and long, unobstructed, lengths of road posed many safety risks in terms of excessive vehicular speeds and poor line of sights. It was evident during the site reconnaissance and from resident complaints that traffic calming measures and potential road re-alignments should be considered during the design phase.

Flooding and Drainage

Several residents voiced concerns about degraded stormwater and road infrastructure in the Lakeview neighbourhood. Following wet weather events, standing water was sustained within the roadside ditches for prolonged periods. In addition, the age of the area led to many encroachment issues and alterations made to existing lots and drainage system.

Figure 10 and 11: Obstructed and damaged culverts in need of repair.

Figure 12: Ditches filled in for parking purposes

Pre-Design Tasks

Several tasks were undertaken by the engineering consultant to fully characterize the site conditions and guide the development of the detailed design. These include:

- Topographic survey
- Review of geotechnical investigation
- Infiltration testing
- Vegetation assessment

Topographic Survey

A topographic survey of the municipal ROW along First and Third St. was completed in order to produce base mapping for the design phase. The survey included the following site features:

- Topography of the proposed site
- Identification of above ground and below ground services
- Utility locate markings
- Inverts and sizes for existing sewers, catch basins and manholes
- Location and description of on-site structures
- Significant vegetation (coordinated with tree inventory assessment)
- Existing lot features
- Fence lines and existing landscaping.

Review of Geotechnical Investigation

A geotechnical investigation was undertaken by the City of Mississauga prior to initiation of the project as part of the intended road rehabilitation works. Information related to the subsurface conditions, including particle-size distribution, observed groundwater levels, soil stratigraphies and moisture content were included within the report.

Infiltration Testing

Guelph Permeameter testing was performed in November 2010 to determine the saturated hydraulic conductivity (Kfs) of the in-situ soils. The experimentally determined Kfs was then converted to infiltration rate (mm/hr) and a factor of safety corresponding to the non-stratified soil conditions was applied as per Appendix C of the Low Impact Development Planning and Design Guide. The calculated design infiltration rates for were determined to range from 0.04 – 7.67 mm/hr across the site. The average design infiltration rate was determined to be 5.45 mm/hr for First and Third St and was used as the basis for design calculations for the LID practices.

Figure 13: Infiltration testing conducted at Lakeview

Proposed Design Concept

Design concepts for the Lakeview Project were developed by the landscape architect based on the objectives set by the City including:

- Implementing environmentally responsible LID practices on both First Street and Third Street
- Improving water conveyance and eliminating standing water in the ditches
- Improving the overall aesthetic appearance of the street through attractive plantings
- Minimizing the ditch profile for improved maintenance
- Demonstrating new LID designs that will serve as a template for other street redevelopment projects.

Figure 14 – Artist rendering presented by the landscape architect

The concept incorporated a combination of vegetated and grass bioretention units within the boulevard and permeable pavement at the end of driveways. The concept drawing was presented to the City in April 2010 at which time the project team discussed the overall usability of the street and other design considerations.

The topics of discussion focused on technical considerations, including:

- Driveway widths and replacement
- Road surface improvements
- Sidewalks
- Encroachment issues
- Boulevard drainage
- Aesthetics/landscaping and property impacts
- Traffic safety and parking

All municipal departments that would be involved with the Lakeview Project were presented the design concept. This multi-departmental approach was used to ensure that a basic agreement amongst the departments was obtained prior to presenting concepts to the public or moving forward to subsequent design phases. Issues and potential design constraints were resolved technically by consulting municipal specifications, by-laws, policies and operation procedures which were both general and specific to each individual department. This approach allowed all potential concerns to be addressed during the design phase and lent confidence when presenting these concepts to the public. This approach limited potential causes for delays, re-designs and public confusion during later stages of the planning and design process.

Any of the discussion topics listed which were not resolved technically between the project team and municipal staff guided the focus of subsequent PICs. Public insight and preference would be used to resolve many of the outstanding issues. As such, the decision making process for many of the higher level design elements was considered an organic process in which municipal discussions were built on a foundation of municipal technical requirements and amended using public feedback of the unresolved details. **Table 2** demonstrates the municipal discussions of the aforementioned design issues and the resulting course of action taken following those discussions.

Table 2: Conceptual design issue discussions

Design Issues	Discussion	Action
Driveway width and replacement	The installation of a subsurface conveyance system in the form of bioretention units required resident driveways to be removed and replaced for pipe laying purposes. It was discussed during the conceptual design phase if driveway widths would be limited since many of the existing driveways exceed municipal standards in terms of width and location.	This issue was placed on hold to determine appropriate solution
	The design team suggested replacing driveway sections that crossed the ROW with permeable pavement; however, the City indicated that tie ins with resident owned driveway sections may be difficult and asphalt should be utilized.	Present to public for feedback
Road surface improvements	It was indicated by the design team that existing road widths (asphalt edge to asphalt edge) ranged from 6.0 – 6.4 m. Design concept was laid out as 6.0m from back of curb to back of curb.	Resolved technically per municipal specifications
	The municipality noted that minimum road width for emergency vehicle passage and snow removal had to be 7.4 m from edge of pavement to edge of pavement.	
Sidewalks	Concept assumed that sidewalks would be replaced only where there currently exists a sidewalk	Present to public for feedback
Encroachment issues	Implementation of the concept would require encroachments to be address	City to undertake action through enforcement of by-laws
Boulevard drainage	Connections to the proposed LID infrastructure would need to accommodate sump outlets via bioretention unit underdrains.	Design team addressed by ensuring the design accommodated existing sump outlets
Aesthetics, landscaping and property impacts	Design team required City to confirm the process for contravening existing bylaws relating to noxious weeds, planting heights and type of plant material to be planted in ROW. By-law review and revision would be necessary to address the matter in the long-term	Pending by-law review, there could be short-term by-law contravention.
	Design team suggested allowing residents to choose plant scheme and types to be installed out front of individual homes.	Presented planting options to public again to gauge interest of LID options presented
	Planting options (i.e. sod or perennials) were presented during the initial PIC conducted in June 2009; however, clear direction was not received.	
Traffic safety and parking	Design team suggested the use of permeable parking as parking stalls were existing constraints exist i.e. Telephone poles etc. City indicated that this option should be investigated but raised potential issue with placement of parking stalls in front of residences.	Presented to public for feedback in order to develop a solution.

Despite some of the outstanding issues, the overall Lakeview concept was agreed upon by the various municipal departments and was presented to the public for feedback during a PIC held on July 8, 2010. An 'open house' approach was used at the PIC instead of traditional public consutlation methods. The aim of this approach was to create a more casual and comfortable atmosphere where people could talk directly and on-on-one with members of the project team . Staff on hand were dressed in business casual instead of uniforms to ensure that there was no authoritarian presence at the meeting. The goal was to include residents in the decision making process, and not simply dictate what changes would be made to their street.

During the PIC, residents were encouraged to complete questionnaires which highlighted many of the unresolved issues which were discussed between the design team, CVC, and City of Mississauga.

Figure 15: PIC #2 undertaken to obtain resident input

Residents provided the following feedback during the PIC:

- Issues were was ranked from most important to least important:
    - Parking
    - Water quality
    - Environmental benefits

- Preventing flooding
  - Integration with the evnironment
  - Improved conveyance
  - Integration with existing infrastruction
  - Aesthetics
- Sidewalks are not wanted
- Cost is not important
- Would like to maintain existing driveway widths
- 50% now wanted perennial plants (grassed swales preferred per Initial PIC – June 2009)
- 83% had high acceptance of permeable pavement being located across ROW
- 67% of residents were willing to do 2-4hrs of maintenance per month
- Ditch to be eliminated

Community input guided the detailed design and tackled many of the design issues aforementioned. **Table 3** demontrates the resulting actions undertaken for the perviously identified design issues following public consultation.

Key Facts

Issues:
- Design problems related to LID implementation could not be strictly resolved by technical input from municipalities, design teams and agencies.
- Support from the residents would be needed in order to create a successful project.

Solutions and lessons Learned
- Public input is key to determining the solutions that are most appropriate.
- Retrofit projects present unique problems which can be site specific.
- CVC and partners worked together to deliver an open-house style event to encourage greater one-on-one discussion and secure support from residents.

Table 3 - Conceptual Design Revisions Following Public Consultation

Design issues	Actions following municipal discussions	Actions following public feedback
Driveway width and replacement	• This issue was to be further discussed in terms of the potential impacts and determine the appropriate solution. • Present to public for feedback.	Residents preferred driveway widths to remain unaltered. Since driveways would be more formalized within the ROW following rehabilitation, municipal staff identified that this would effectively improve parking availability within residents' driveways. The City also researched local bylaws and realized that parking infractions were minimal throughout the area. Minimal infractions, low traffic and more formalized driveways result in little reason to implement street side parking.
Road surface improvements	• Resolved technically based on municipal specification for allowable road widths • Still present to public for feedback regarding road width alterations	Public feedback corresponded with municipal specifications.
Sidewalks	Present to public to determine obtain feedback regarding the need/want for sidewalks	No new sidewalks were implemented.
Encroachment issues	City to undertake action through enforcement of Bylaws	N/A
Boulevard drainage	Detailed design will accommodate sump outlets	N/A
Aesthetics, landscaping and property impacts	• Design team established planting options to be presented to the public that were accepted by the City's Parks and Operation and Maintenance Departments. • Present to public for feedback • Present planting options to public again	• Residents indicated that they were willing to participate with the maintenance of the plantings • 50% interest in perennials. Further encouraged City to move forward with the project
Traffic safety and parking	Present to public for feedback	Residents identified traffic issues at the intersection of Third St. and Alexandra Ave. due to limits access and poor lines of sight. Area to be investigated during the detailed design phase.

City staff allowed residents to decide on the planting scheme implemented within the boulveard. Using a “dot-mocracy” approch, residents were allowed to choose between two planting schemes: an assortment of perrenial plantings or a tradtional turf options. These options were presented during the second PIC. Residents were assured that the planting scheme that they selected would be what was installed during construction and residents were assured that they could change their minds at any time.

For residents who did not attend PIC #2, follow up letters were delievered to the residents homes to provide them an opportunity for input on the project. In attempts to receive further input from residents who did not attend or missed PIC #2, the project team and municipality teamed up with the local counciller to engage the public. The councillor engaged residents by attending community meetings and addressing questions and concerns about the Lakeview project.. Although many local residents from the ward attended the information session, no additional input specific to the Lakeview Porject was received.

Figure 16 – Planting schemes presented at PIC #2

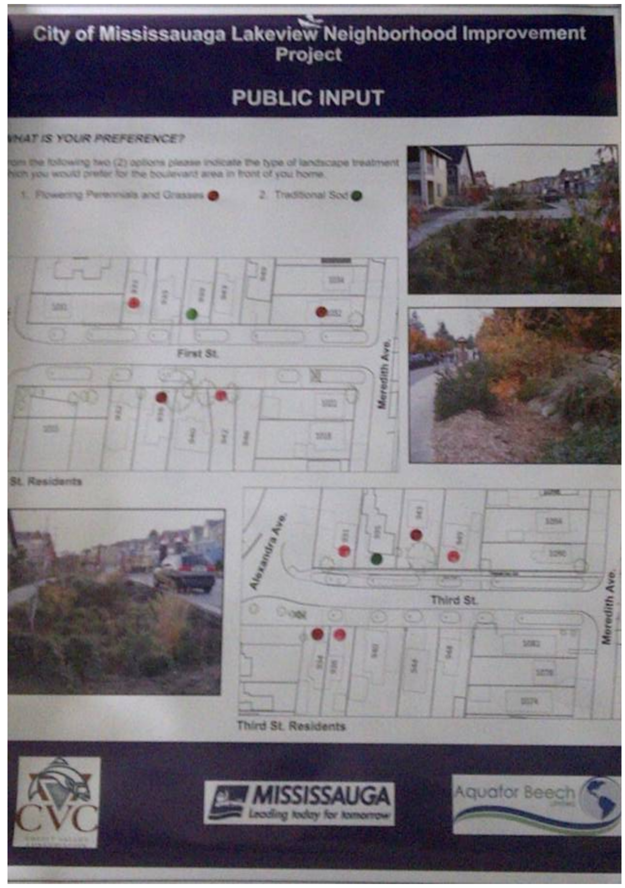


Figure 17 – “Dot-mocracy” board from BBQ hosted by CVC and the Ward Councillor where residents stuck markers on their to indicate their preferred planting scheme

Detailed Design

The detailed design of the Lakeview Project utilized information obtained during the pre-design and conceptual design phase to further develop a design that fulfilled both the municipal and resident objectives.

The following sections provide further insight into the detailed design process and the decisions made that refined the design concept.

General Design Elements

Inlets and Curbs

Municipal staff and members of the project team travelled to other LID related projects within Mississauga to evaluate different types of curb and inlet types that would best suit the Lakeview Project. Barrier, semi mountable, and various types of roll curbs were discussed with several municipal departments. A semi mountable curb was selected for the following reasons:

- It provides a low profile barrier for cars to park against and distinguish limits for snow removal operations
- It provides separation between road and areas adjacent to the curb for safety reasons
- It eases the tie-in of bioretention soil media with the back of curb. A low profile curb barrier decreased the swale depth which complemented resident requests for no deep ditches.

Inlet types were also discussed. Many options for covered inlets or steel grated inlets were proposed. However, concerns regarding snow removal operations damaging the covers discouraged the alternatives**.**

Figure 18 &19 – Covered inlet option (top) and side inlet catch basin (bottom)

A simple curb cut design was selected for the Lakeview project. However, for one of the bioretention units implemented on Third St., side inlet catch basins were used. This would allow the City to assess the difference in maintenance efforts and modifications required in integrating traditional side inlet catch basins with LID design. See Figure 20.

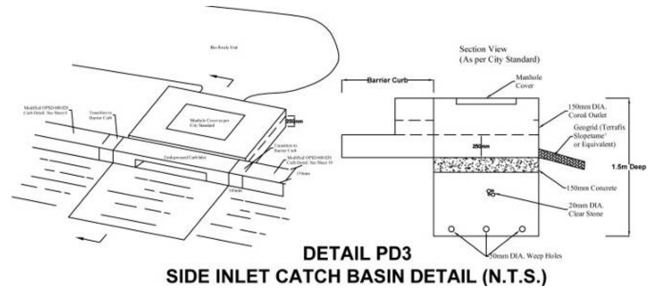


Figure 20 - Design and integration of side inlet catch basins with the boulevard bioretention units.

Usability

Similar to the curb and inlet selections, many other design features were added to the design following discussions related to the overall usability of the site. For example, non-woody vegetation was proposed for the bioretention units since the areas were to be used for snow storage during the winter months. Woody vegetation in the bioretention units would have been damaged by snow load. As such, low maintenance sod and perennial plantings were selected for the landscaping plans

Figure 21 – Perennials planted within bioretention units

Initially, it was proposed that perennials be planted throughout the entire bioretention unit from back of curb to the resident property line. However, the design team felt that encroaching vegetation and lack of available foot space would make it difficult for individuals parking on the street to exit their vehicles. To resolve this issue a 0.6 m buffer was added around the bioretention units which were to be strictly sod. This area would provide access for residents exiting street parked vehicles and also provide a formalized snow storage area. See **Figure 22**.

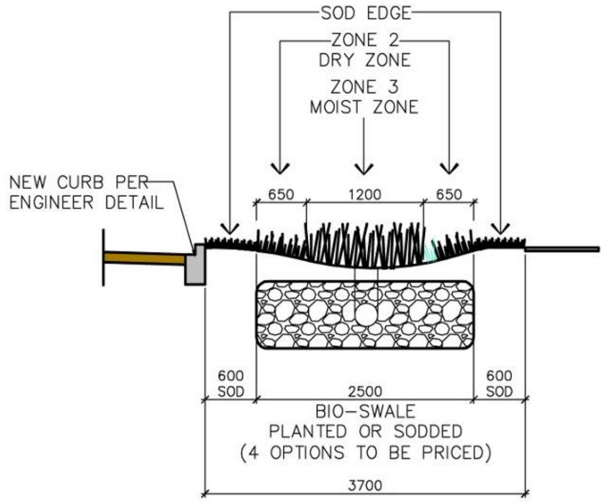


Figure 22 – Bioretention unit planting configuration

Permeable Pavement Driveways

When discussing the overall staging and constructability of the bioretention units and driveway areas, issues related to the type of driveway surface treatment was revisited. Discussions held during the conceptual design phase determined that an asphalt surface treatment would be reinstated in order to tie-in with the asphalt sections on resident properties.

A different sub-base is used in the construction of asphalt driveways compared to permeable pavement. However permeable pavement and bioretention use the same base material, 20mm clearstone. Ensuring that the two types of base materials could be adequately separated to avoid fines contaminating the bioretention reservoirs was a concern. Phasing construction in order to properly incorporate the asphalt driveways would create additional costs and inconvenience to residents. This did not seem to outweigh the additional costs of the permeable pavers or the convenience of using only one type of base material. For these reasons and the fact that the residents highly accepted the aesthetics of the permeable pavement concept, the use of permeable pavement for the driveways was approved.

As an added benefit, the use of permeable pavement within the driveway areas also increased the water quality storage volume provided on-site. Since no formal major systems existed for the Lakeview area the additional storage and decreased runoff volumes was considered an added benefit by the municipal staff.

Figure 23 – Permeable pavement driveways

Parkette

During the detailed design process, a vacant property located at the east corner of the Third St and Alexandra Ave was identified. Municipal staff was able to confirm that this was City owned land.

Previous discussions with residents identified the intersection as a potential traffic hazard due to the existing alignment of the intersection (Third St. being misaligned from one side of Alexandra to the other). The misalignment made lines-of-sight for drivers and pedestrians difficult and there were no defined crossing routes to ensure a safe crossing for pedestrians. **Figure 24** demonstrates the pre-retrofit intersection alignment of Third St and Alexandra Ave.

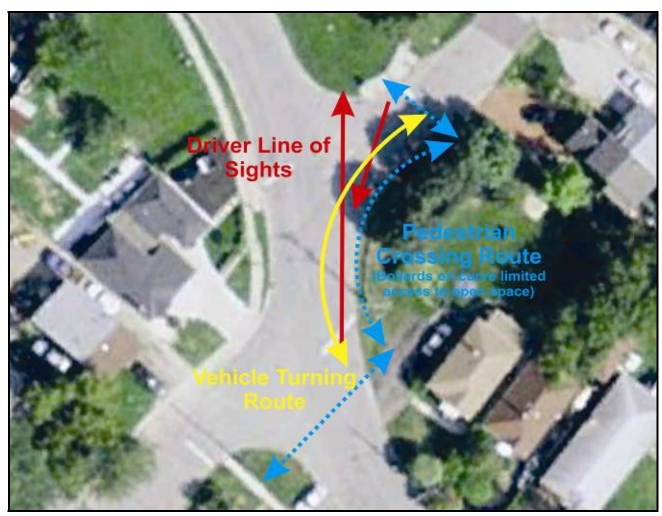
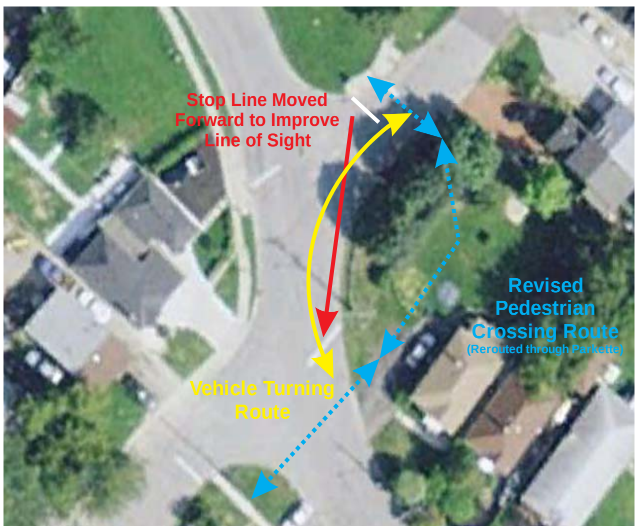


Figure 24 - Third St. and Alexandra Ave Intersection (North being top of page)

In most cases, pedestrians walking westbound on Third St. who wanted to travel southbound on Alexandra Ave were forced to walk along the east curb. Guard rails on the curved profile of the road prohibited pedestrians from walking through the adjacent green areas. The curve in the road and location of the stop lines made lines-of-sight for both pedestrians and drivers difficult.

With no option to realign the intersection, a parkette was proposed for the vacant property. The parkette would not only create a community space for local residents but also provide a safer crossing route for pedestrians. The stop line of Third St. was also moved forward in order to improve driver's line-of-sight to northbound drivers on Alexandra Ave.

Figures 25 & 26 provides an overview of the revised layout and travel route provided by the parkette.



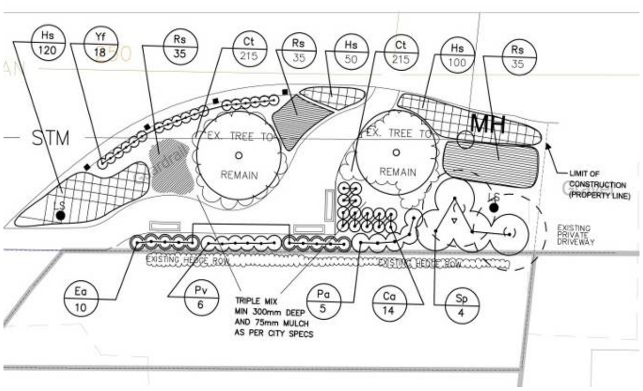


Figure 25 & 26 - Revised pedestrian route and parkette detailed design

Subsurface Infrastructure

The design team and municipal staff discussed the proposed subsurface underdrains and the potential for heaving. They also assessed whether clay plugs were required to isolate the various bioretention cells.

It was established that pipe heaving was not an issue due to the overall depth of underdrain and thickness of the free draining bedding material situated below the invert of the underdrains. Clay plugs were determined to be unnecessary due to the proposed grading of the bioswale and permeable pavement subgrade. The variations between the subgrade of the permeable pavement and boulevard bioretention sections created a series of check dams which would control subsurface flow rates.

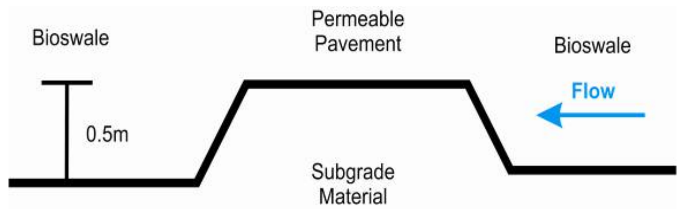


Figure 27 - Grading of the bioretention unit and permeable pavement driveway subgrade.

Technical Design Elements

Drainage Areas

To evaluate the hydrology of the existing and proposed site conditions, drainage areas and runoff coefficients were selected based on previously existing and proposed drainage patterns and land uses per City of Mississauga standards and as determined by the design team.

The existing condition drainage areas were divided by the configuration of the lots and drainage patterns observed during the site reconnaissance. However in several cases surface drainage patterns of individual lots drained to adjacent lots not part of the study area. These questionable areas were nevertheless included to ensure a conservative design and redundancy in case grading of the individual lots was revised in the future.

Hydrologic and Hydraulic Assessments

The hydrologic and hydraulic assessments conducted for the Lakeview project were completed according to City of Mississauga standards for minor system flows to storm sewers which shall be designed using the 10-year storm events. Existing grading created challenges for major storm flows. Nevertheless, the 100 year flow event was evaluated. As such, intensities for the 10-year and 100-year storm events were applied to the rational equation for the existing and redevelopment land use conditions to compute the corresponding peak flow rates and runoff volumes. The rational formula is as follows:

$Q=C\ IA/360$;

where

Q=Runoff rate (m^3/s)
C=Runoff coefficient
I=Rainfall intensity (mm/hr)
A=Site area in hectares (Ha)

Underdrain and surface swale capacities and sizing were determined using Manning's equation and runoff flow rates from the individual drainage areas.

LID Design Elements

The primary LID design practices incorporated into the Lakeview Project included permeable pavers and boulevard bioretention units

These LID practices improve water quality and reduce the quantity of runoff reaching local drainage features. The following sections provide additional detail with respect to the characteristics and function of the individual LID practices implemented in the Lakeview Project. **Figure 28** below demonstrates the layout and configuration of the LID practices implemented at the Lakeview site. Sizes of LID practices installed throughout the Lakeview neighbourhood were dictated by the maximum area available for implementation.
Although structural analyses were conducted for the permeable pavers and general sizing calculations were completed for the bioretention units, actual storage volumes were dictated by the following two design constraints:

- Depth of storage available above the underdrain was restricted by the existing ground surface elevations and the tie-in location of the underdrain to the existing storm sewer system
- Width of the systems was restricted by the available distance between the proposed back of curb and property lines

The underdrain of the permeable pavement and bioretention units was installed so that it could be positively connected to existing catch basins or manholes at the termination point of the street (i.e. downstream extent) and sloped so that flow velocities were within the applicable City of Mississauga standards.

Permeable Pavement

Permeable pavement allows for the filtration, storage, and infiltration of stormwater, which can reduce stormwater flows compared to traditional impervious paving surfaces like concrete and asphalt. The permeable pavement design at Lakeview acts as both a subsurface detention basin and a filter to improve water quality.

The design of the permeable pavement cross-section and associated aggregate depths was determined through a structural analysis. The structural design method utilized for the Lakeview site was the AASHTO flexible pavement design methodology, specifically the empirically based AASHTO 1993 Guide for Design of Pavement Structure in combination with the Interlocking Concrete Pavement Institute (ICPI) Design Guide, 4th edition, D.R. Smith (2011). The concepts in

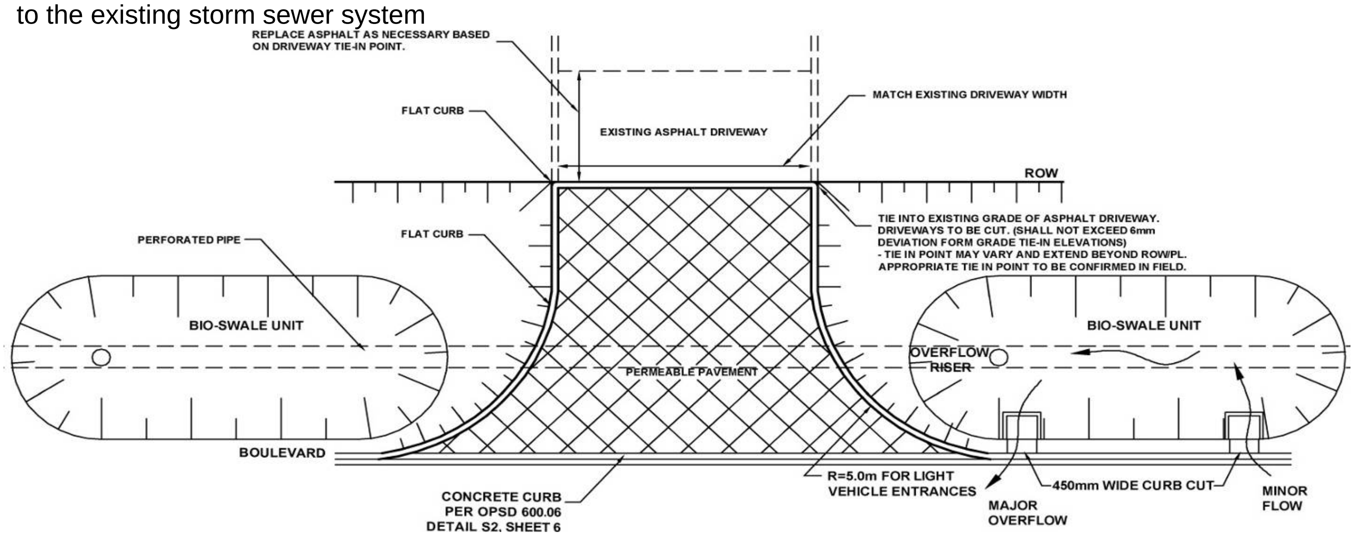


Figure 28 – Configuration and layout of LID features implemented within the residential road ROW

the 1993 guide emerged from tests in the 1950's that established relationships among material types, loads and serviceability using a structural number (or SN) given the traffic load (ESAL's), soil type climatic and moisture conditions. Through this process, the designer finds the appropriate combination of pavement surface and base material to meet or exceed the required SN. Layer coefficients for the various open graded aggregates commonly used in permeable pavement construction are generally recognized as being approximately 30% lower than standard dense-graded materials as such base courses of PICP will typically need to be thicker to compensate for lower strength and stiffness associated with the less dense grading

Based on the subgrade soil strength and computed equivalent axel loads the recommended permeable pavement cross-section was determined. **Table 4** summarizes the components and aggregate depths within the PICP paver cross-section.

Table 4 – Permeable Pavement Design Cross-sections

System component	Value
Paver thickness and type	80 mm – Aqua Paver (by Hanson)
Bedding	50 mm of No.8 angular chip stone (5-7mm ø)
Aggregate depth (min.)	370 mm of No.57 angular clearstone (20 mm ø)
Underdrain bedding depth	100 mm of No.57 angular chip stone (20 mm ø)
Total excavation depth (min.)	500mm
Underdrain system	300 – 375 mm ø perforated HDPE main collection pipe

An aggregate depth of 370mm was used as a minimum based on the result of the structural analysis and the site conditions (**Figure 29** and **30**). In many cases, aggregate depths for the driveways were much greater than 370 mm given the required location of the underdrain.

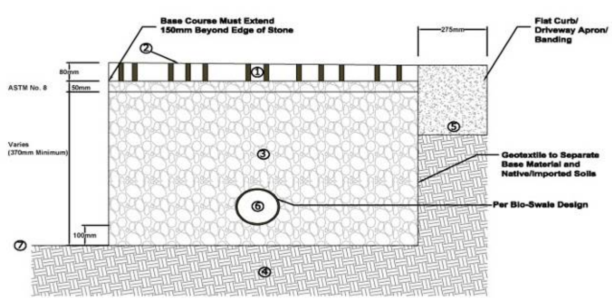


Figure 29 – Permeable pavement driveway cross section

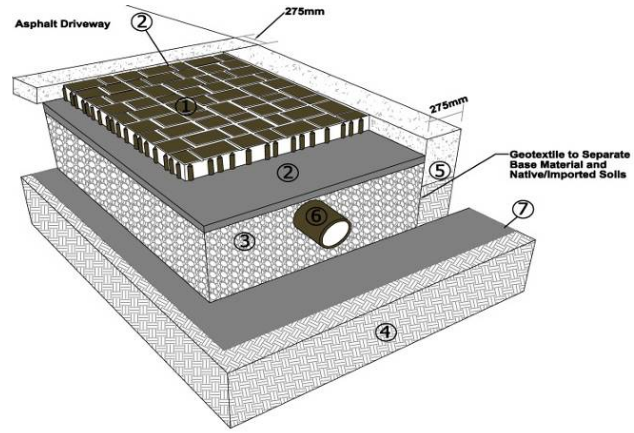


Figure 30 – Permeable pavement driveway exploded cross section

In preparation of the base material installation, a non-woven geotextile was placed directly on the prepared subgrade and up the sides of the excavated trench to prevent fines from the native subsoils from migrating into the clearstone base material. The geotextile was rolled out flat and tight with no folds. Adjacent rolls were overlapped and held in place by workers as base material was placed on top. Unlike the preparation of boulevard bioretention unit reservoirs, the top of the permeable pavement base layer was not wrapped with filter fabric.

Figure 31 – Preparation of permeable pavement driveways base material

The following tables detail the specified base course gradations utilized in the permeable pavement cross sections. **Table 5** summarizes the particle size distrbution for 20 mm ø clearstone.

Table 5 – 20mm ø Clearstone Particle Size Distributiuon

20 mm Ø / ASTM C33 No 57	
Sieve Size	**Percent Passing**
37.5 mm	100
25 mm	95 to 100
12.5 mm	25 to 60
No. 4 (4.75 mm)	0 to 10
No. 8 (2.36 mm)	0 to 5

Clearstone brought to grade was compacted and topped with the No.8 chip stone bedding layer. This layer was compacted prior to the placement of band curbing and permeable pavement.

Figure 32 – Installation of bedding material and permeable pavement

Boulevard Bioretention Units

Bioretention units are soil filter systems that temporarily store and filter runoff. These units rely on the engineered bioretention soil media placed below the channel invert to provide runoff reductions and improve water quality. Runoff treated by the media bed flows into an underdrain, which moves treated runoff back to the conveyance system further downstream. The underdrain system consists of a perforated pipe within a gravel layer placed below the engineered media bed. On the surface, bioretention units may appear as simple grass channels with the same shape and turf cover, while others may have more elaborate landscaping. Bioretention areas can be planted with turf grass, tall meadow grasses, decorative herbaceous cover, or trees.

The proposed Lakeview design consisted of individual bioretention units connected in series and located between permeable pavement driveways and property frontages.

A series of design computations were undertaken as part of the design of the proposed bioretention units, including:

1. **Storage Assessment –** Volumetric storage calculations which evaluated the proposed design and its ability to provide adequate storage for the water quality volume for the 25mm event. This analysis was used to determine the quantity of storage to be provided throughout the bioretention unit's profile. As specified in the Low Impact Development Stormwater Management Planning & Design Guide, the maximum depth of the stone permitted below the underdrain was calculated based on the permeability of the native soil material (underdrain required as subsoil infiltration rates were <15 mm/hr).

2. **Surface Area Requirement Assessment** –The recommended surface area of the bioretention units was calculated based on the quantity of water quality storage volume (25mm event) to be provided from the respective drainages and the recommended bioretention unit depth (determined by Assessment #1 and design constraints) and void ratio of the bioretention soil media and clearstone material. In many cases, the required area was much larger than the area actually available within the municipal ROW. As such, the bioretention unit areas were maximized as much as possible given the area available for implementation.

Key Facts

Issues:

- Design constraints made it difficult to accommodate water quality volumes.

Solutions and lessons Learned

- Retrofits should be recognized as opportunities to provide the most amount of water quality benefit possible given the site constraints.

All bioretention units were sized to treat as much of the 25 mm event (water quality event) as permissible by the site conditions. **Table 6** summaries the general physical attributes of the proposed bioretention unit design.

Table 6 – General Dimensions of the Boulevard Bioretention units

System component	Value
Top width	2.5 – 3.0 m
Bottom width	2.5 m
Aggregate depth (Min)	1025 – 950 mm of No.57 angular clearstone (20 mm ø)
Bioretention soil media depth	450 – 600 mm
Underdrain bedding depth	500 mm of No.57 angular chip stone (20 mm ø)
Total excavation depth (Min)	1.5 – 2.0 m
Underdrain system	300 – 375 mm ø perforated HDPE main collection pipe

The bioretention unit underdrain systems consisted of an excavated trench lined with non woven geotextile and filled with an open void 20 mm diameter clearstone. 300 – 375 mm diameter HDPE peforated pipes situated within the clearstone bedding underdrain the entire length of the bioretention units and permeable pavement sections (see **Figure 33**). The 20 mm diameter clearstone bedding material is fully wrapped with non-woven geotextile so that it overlaps to cover the top of the cleanstone bedding material.

Figure 33 - Bioretention unit with non-woven geotextile, 20mm diameter clearstone with an HDPE perforated pipe

Figure 34 demonstrates the varying excavation depths of the permeable pavement and bioretention unit sections. The bioretention areas were excavated deeper to provide additional water quality storage whereas storage below the permeable pavement section was constructed such that pipe bedding material would be provided but prolonged periods of standing water would be minimized in order to protect the structural integrity of the subsoils.

Figure 34 - Varying excavation depths for the bioswale and permeable pavement sections

A 450 mm – 600 mm thick layer of engineered filter media mix (see **Table 7**) was placed on top of the clearstone bedding material with geotextile separating the two materials. This was to avoid bioretention soil media from migrating into the clearstone and filling available void space wihtin the clearstone. **Table 7** demonstrates the composition of the engineered bioretenion soil media.

Table 7 - Bioretention Soil Media Composition

Component	Percentage by weight
Sand (2.0 to 0.05mmØ)	85 – 88%
Fines (<0.05mmØ)	8 – 12%
Organic Matter	3 – 5%
Additional requirements • CEC greater than 10mg/100g • pH = 5.5 – 7.5 • Hydraulic conductivity greater than 25mm/hr • No objects greater than 50mm	

Figure 35 - Bioretention soil media placed within bioretention units along Third St.

Tendering and Preconstruction

Following the completion of the detailed design, contract documents including engineering estimates and tenders were compiled and released for contractor bidding. Significant design changes were made during this phase of the implementation process.

Encroachment Issues

During the detailed design phase the design team undertook an analysis which identified all the existing encroachment infractions located along First St.and Third St. Initial discussions with the City indicated that the general approach to ensure the ROW was available for construction was to enforce the municipal by-laws and have any encroaching structures or property be removed from the municipal ROW. However, further discussions between the municipality and design team determined that due to the significant amount of encroachments, by-law enforcement would be impractical given the scpoe of the infractions. Municipal staff determined that further thought and discussions must be had to determine the appropriate actions to be followed in order to address the encroachment issues. As such, the scope of the Lakeview Project was reduced. The revised scope of the project was limited to First and Thrid St. between Meredith Ave and Alexandra Ave.

Tendering Results

One of the first issues encountered with the Lakeview tender was high bids from contractors. Prices received from contractors were considerably higher compared to engineering estimates. This was presumed to be a result of contractors exploiting the available Infrastructure Stimulus Funds (ISF) provided by Infrastructure Canada to municipalities in order to fund capital works and other municipal projects at the time.

The received tender bids and high prices further supported the motion to reduce the scope of the Lakeview Project and re-tender.

Construction & Commissioning – General Issues

The construction of the Lakeview project commenced in April 2012 and concluded June 2012. During the course of the construction process a variety of challenges and obstacles were encountered, some of which were general and other which were LID specific.

Utilities

Utilities were major construction obstacles given the age of the neighbourhood and combination of overhead and subsurface utilities. On several occasions utilities that were encountered were not identified on the contractor's locate report. These utilities were generally not in service however in a few incidences, old utilities lines were used as conduits for new service lines. Such situations made identifying active utilities difficult and required caution during the construction process. To limit the potential damage to utilities, hand digging for daylighting purposes was used as a standard procedure during the construction.

Figure 36 - Daylighting of Utilities

Although all reasonable actions were taken to avoid damaging utilities, on several occasions utilities were damaged and had to be repaired. Repair costs were incurred by the contractor.

Figure 37 - Damaged water service line

Figure 38 - Examples of utilities being avoided or accommodated


Figure 39 - Repair of a damaged telephone communication line

In situations where utilities interfered with the proposed design, design elements were revised to either avoid or accommodate the utility of concern.


Figure 40 - Existing gas line being avoided by notching the perforated underdrain

Excavation & Grading Issues

Excavation and grading errors and necessary design alterations were common throughout the construction of the Lakeview Project mainly due to the relatively confined working environment and obstacles located within the ROW.

Over Excavation

In order to avoid utilities and other obstacles, the contractor had to alter the extent of excavation either through narrowing, shallowing, deepening or widening the limits of excavation depending on the location of the obstruction. This was generally accepted as long as the final excavation would accommodate the necessary water quality storage volume specified for the design. This was accomplished by compensating for the change in excavation in subsequent sections. For example, if a section of the excavation was narrowed by 0.5 m for over a 10 m length in order to avoid a utility, the subsequent 10 m was widened by 0.5 m to compensate.


Figure 41 – Over-excavation of the bioretention unit trench by the contractor to avoid utilities

Provisional Lot Drainage

Topographic surveys used during the design phase were limited to the extent of the road ROW. Field reconnaissance confirmed much of the lot drainage however survey information of individual lots and private property was not obtained.

As part of the tender documents, provisional lot drainage was added for cases where surface drainage from resident's lots could not drain overland to the bioretention units. During the beginning of the construction, the project team and contractor identified lots which may have surface drainage issues. Following discussions and permission from the residents, surface inlets were installed on private property to collect local lot drainage and discharged to the bioretention unit underdrains.


Figure 42 - Installation of provisional catch basin within resident front lawn

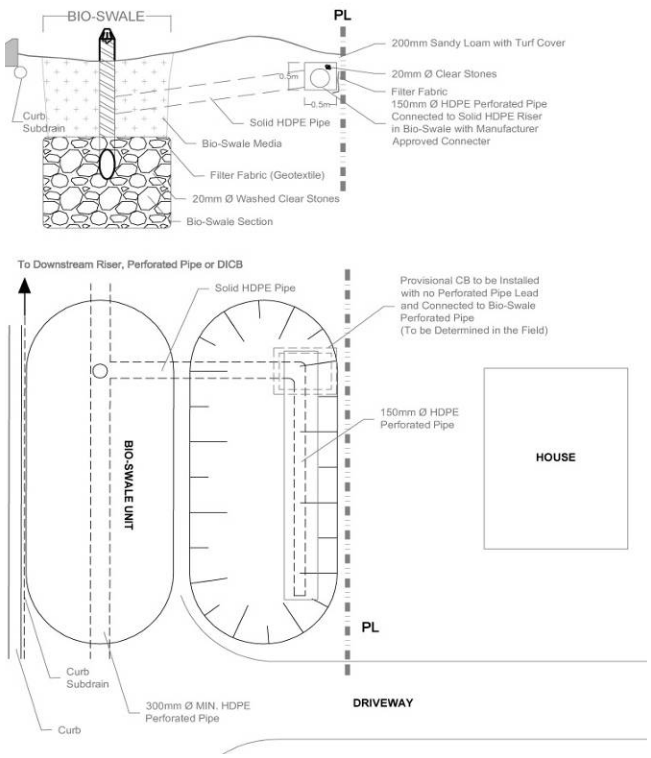


Figure 43 - Detail of provisional lot drainage

Grading Revisions

Grading revisions were required on several occasions due to the lack of survey information of adjacent private properties. During the installation of the sidewalk on Third St., the high point of the sidewalk was constructed higher than the adjacent private property and acted as a barrier between the lot drainage and bioretention units. A design solution had to be provided in order to:

- Prevent lot drainage from building up behind the sidewalk
- Prevent flows over the sidewalk, creating potential safety risk during the winter months.

As such a subdrain was installed along the lot side of the sidewalk to capture local drainage and discharge it to the bioretention unit.

Figures 44 & 45 - Installation of subdrain adjacent to sidewalk (top) and subdrain outlet to bioretention unit (bottom)

Soil and Sod Grading Compensation

During the installation of the sod material, the contractor and designer expected much more settling and compaction of the bioretention soil media to occur. In effect, the sod acted as a barrier to runoff flowing through the curb cut inlets. During larger rainfall events a certain portion of runoff would bypass the inlets as a result. To rectify the deficiency, sod sections near the inlets were removed, soil heights adjusted and the sod reinstalled.

Figure 46 –the sod at the curb cut inlets was too high following construction, creating a barrier for stormwater to enter the bioretention units.

Design Modifications

Design modifications were necessary during the course of construction. General site conditions, in-fill developments and additional infrastructure implemented between the detailed design and construction phases impacted the design.

Culvert Connection

A set of double culverts at the intersection of Meredith Ave. and Third St. were designed to convey drainage from the lots north of Third St. down Meredith Ave towards Lakeshore Blvd. During construction it was determined that an insufficient amount of cover would exist over the culverts should they be installed. Design calculations were revisited to determine if the underdrain system of the bioretention units had sufficient capacity to accept the addition drainage area from the north. With capacity available, a catch basin was installed at the end of the Meredith Ave drainage system to collect the addition drainage. The catch basin outlet pipe was connected directly to the bioretention underdrain.

Figure 47 – Installation of required catch basin

In-fill Development and Sump Connections

Several homes along First St. were redeveloped or renovated between the detailed design phase and construction and were not accounted for during the design process. Sump pumps and lot drainage alterations required several design changes in order to provide drainage for local residents.

Residences with sump pump outlets that were identified during the detailed design phase were provided a new outlet connection to the bioretention unit underdrains. In other cases where residents had undertaken renovations or landscaping projects during the course of construction, design alterations were made to provide residents with outlet connections to the bioretention unit underdrain. These connections were left exposed for resident to later connect to once their renovations were completed.

Curbs

Curb subdrains were specified within the design drawings. During construction the limit of excavation for the bioretention units and permeable pavement was not perfect and much of the native material where the proposed curbs were to be constructed had to be reinstated with clearstone in order to provide a base for the curb installation. With free draining material situated directly underneath the curb and the bioretention unit underdrain in close proximately, subdrains were determined to be unnecessary items and were not installed.

Whether it was a communication or availability error, incorrect curb molds were used on Third St and did not conform to the OPSD standard listed in the design drawings. The design drawings called for a 2" roll curb and instead the subcontractor installed a 4" roll curb. Unfortunately, this caused some grading issues at the inlets and behind the curb since there was now an additional 2" of concrete. In addition, during the tamping of the curb Granular A sub-base, excess Granular A spilled into the bioretention units and had to be removed prior to installation of the soil.

Due to the unique sequencing aspects of LID construction, the concrete subcontractor did not expect to have a significant drop behind the curbs without any soil media. As a result, the contractor's stakes for the string line were too short and had to be doubled up in order for the string line to be at the correct height.

Figure 48 – Concrete subcontractor doubling up the stakes for the string line

Key Facts

Issues:

- Curb underdrains were considered a Major Item per OPSS Standards

Solutions and lessons Learned

- An exception of OPSS General Condition 8.01.02 – Variation in Tender Quantities subsection B states that In the case of a Major Item ($100,000 or 5% of the total tender value) where the quantity of work performed and/or material supplied by the contractor is less than eighty-five percent (85%) of the tender quantity, the contractor may make a written request to negotiate payment for the portion of actual overheads and fixed costs applicable to the amount of the underrun in excess of fifteen percent (15%) of the tender quantity.
- It is worth noting that design changes may result in payment being made to the contractor as a result. OPSS standards should be consulted prior to making such design changes. In the case of the subdrains, negotiations between the City and contractor were such that either party was satisfied with the agreement.

Delineated Driveway

A 'soldier course' was added during the construction phase (the perpendicular stone shown in **Figure 49**). The soldier course was not specified within the contract document; however, it was added to improve aesthetics and ease construction. This solider course was also used to delineate property lines for residents who shared driveway entrances. This was high valued by residents since driveway ownership was now formalized.

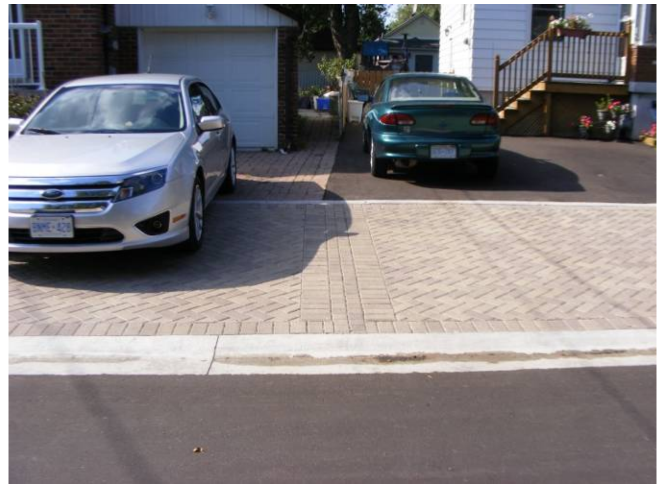


Figure 49 – Soldier course and delineation of driveways

Contractor substitution

Contract documents specified that landscaping tasks must be performed by qualified professionals. The primary contractor insisted that no subcontractor was necessary and attempted to undertake the installation of landscaping items. The contractor was directed to obtain the approved landscaping subcontractor provided in the submitted tender bid. This was enforced due to quality control and assurance purposed.

Access to driveways

Clearstone does not provide a drivable surface stable enough to permit access for vehicles. Temporary plywood access roads were installed across driveways with exposed clearstone aggregate.

Figure 50 – Temporary driveway accesses

Public Expectations and Consultation

Residents of First and Third St were anxious to get work started considering the long wait for the local roads to be rehabilitated. Adhering to proposed construction start times and continual communication with residents regarding project progress and finish dates was highly important. This ongoing communication was sustained between the residents and the project team for the duration of the construction process.

Key Facts

Issues:

- Public expectation for presented design concepts involves ensuring that the end product reflects what was presented.

Solutions and lessons Learned

- Interpretive signage was prepared and posted at the streets undergoing reconstruction. Signage included detailed artist renditions of the finished streetscaping and included information related to the design including its environmental and aesthetic benefits, construction start and end dates, and contact information of project team members.

Third St in artist rendering (top) after construction (bottom)

A community barbecue was also hosted by CVC and the design team during construction to provide an educational experience and opportunity for residents to select the type of restoration measures (i.e. sod or perennial planting) to be implemented on their property. Topics such as maintenance programs, construction issues, and overall concerns were discussed during this process. The local Ward Councillor was also on hand to speak with residents and help promote the project.

Figure 51 - Community barbecue held during Lakeview Project

Education

Providing an onsite supervisor as a resource to interpret and explain features of the design drawings to the contractors was highly important during the construction of the Lakeview project. Many of the innovative stormwater technologies and LID practices detailed within the design drawings were not familiar to the contractor onsite.

The design drawings were prepared with enough clarification that the contractor had little issues interpreting the installation and construction of the design. Challenges faced by the contractor were addressed through a cooperative process between the design team and contractor. Utilities encountered during construction were either relocated or avoided and design conflicts or alterations were resolved with input from the various stakeholders. General questions and inquiries regarding the various design elements and installation procedures were generated primarily out of interest as opposed to confusion.

Construction & Commissioning – LID Specific

The following section details the challenges faced as part of the implementation of the LID practices at the Lakeview Project and items to consider when implementing future LID projects.

Media Development

Included within the tender documents was the contact information for a local bioretention soil media supplier. The supplier was included since the company was experienced with supplying bioretention soil media and had proven through past projects that their internal operations could produce bioretention media that met the specifications per the Low Impact Development Stormwater Management Planning and Design Guide. The supplier's contact information was provided as a resource for the contractor however he was not obliged to use this supplier.

The awarded contractor did not opt to use the supplier provided within the tender and was cautioned that the development of bioretention soil media and the ability for a supplier to successfully meet specification takes time and numerous testing trials to be successful.

Figure 52 – Bioretention soil media consisting primarily of sand and organic material

The first samples submitted by the contractor's supplier did not meet specifications. The Lakeview design team worked closely with the contractor's chosen supplier to develop the bioretention soil media. First, hand mixed samples were submitted to the lab to get the mix close to the required portions of sand and organic prior to initiating the mechnically mixing process.

Once a passing hand mix sample was received, mechanically mixed bioretention soil media samples were collected and submitted to a certified laboratory for analysis. When a passing mechanically mixed sample was received and it was determined that the supplier could manufacturer the media with confidence, it was accepted for installation.

Key Facts

Issues:

o Contractors may obtain any bioretention soil media supplier they wish provided supplied material meets the CVC specification for mechanically mixed samples.

Solutions and lessons Learned

- Media testing results can be expected approximately 2 - 3 weeks after submission to the lab
- As such, it is necessary to specify within contract documents that the contractor is responsible for any delays suffered as a result of testing and that no compensation will be provided for delays due to media analysis

Media Placement

Prior to placing bioretention soil media within the bioretention units, filter fabric was installed between the media and curb base aggregate to ensure that fines from the Granular "A" material did not contaminate the soil.

Figure 53 – Installation of filter fabric to separate Granular "A" from the bioretention soil media

Permeable Pavement Installation

Per the contract documents and supplier installation guide, permeable pavement stones were to be tamped in place and bedding material (No. 8 stone) swept into the pavement gaps. During construction, bedding material was swept into the pavement gaps before tamping. Excess bedding material left on the permeable pavement was pulverized by the plate tamper, filling the gaps of the pavers with ultra-fine material.

To address this issue, the fine material was removed via a vacuum truck and disposed of. The gaps were subsequently filled with chip stone to ensure free drainage was provided.

Figure 54 – Gaps of permeable pavement filled with fines from tamping activities

During placement of the permeable pavers, a significant amount of fine dust was created by the cutting process when the contractor was creating the soldier course. It was then requested that the contractor cut pavers away from the infiltration area or use a sacrificial piece of geotextile laid on the permeable pavers during cutting.

Figure 55 – Fine dust during cutting of permeable pavers

Quality Control and Assurance

During construction, clearstone supplied to the site did not meet the specification detailed on the drawings which stated that double washed stone was to be provided. The first load supplied to the site consisted of single washed stone. Although seemingly a very minor detail to enforce during construction, the difference between the two types of material are quite distinguishable.

Figure 56 – Double washed (left) vs. single washed (right) clear stone. Specs called for double washed

Sequencing and stockpiling material on site was also critical to successful construction. When storage areas are moved because materials are delivered with too much lead time, chances of contamination increase significantly. Materials were not moved as it was stressed how crucial it was to have infiltration areas free of contaminated materials.

Figure 57 – Bioretention soil media delivered to one of the storage areas

Boulevard Bioretention Unit Vegetation

During the planting phase, staff from the landscape architect was on-site directing and supervising the planting installation and quality of the material delivered to the site. The month of June 2012 was an exceptionally hot month, which sustained a prolonged drought period following the installation of the plant material. It was prudent during the remainder of the summer that the contractor consistently watered the plant material to ensure survival.

Figure 58 – Installation of planting material

With the exception of a few plantings, the majority of the plant material survived until the following growing season.

Complaints were received by local residents regarding a specific plant species that grew vigorously (as high as 7-9 feet tall after the first growing season). The plant species was initially added to the Lakeview planting plan because of its quick establishment, vigorous growth and resistance to harsh growing conditions. From past experience, some plant species do not establish as well within bioretention units because of the harsh growing condition caused by their location adjacent to roadways, the free draining properties of bioretention soil media and contaminates found within the stormwater runoff. As such, more resilient species are added to planting plans to compensate ensure plant establishment.

For the Lakeview project, the growing conditions during the first year must have been favourable enough to stimulate the excessive growth. The plant material was removed from the bioretention units and replaced with a different species with shorter growing heights. See the *Post-Construction* section for details.

Sediment and Erosion Control

An erosion and sedimentation control (ESC) plan was included with the design drawings. It consisted of catch basin inlet controls, filter socks and other LID specific ESCs.

General housekeeping of the site and road cleaning operations were undertaken every couple of days in order to control dust and prevent debris and sediment from washing off the road surfaces.

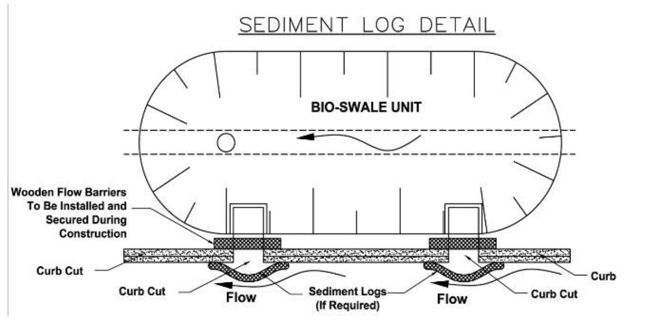


Figure 59 – Sediment Logs Detail for Lakeview

Prior to the installation of the bioretention soil media and paving of the road surface, filter cloth wrapped wooden boards were staked behind curb cuts and sacrificial pieces of filter cloth were installed to protect the bioretention unit infrastructure from contamination. The sacrificial pieces of filter cloth were installed over the cloth wrapped clearstone reservoir of the bioretention unit. This filter cloth was removed prior to in the installation of the bioretention soil media including any contaminating fines which was captured (See **Figure 60**).

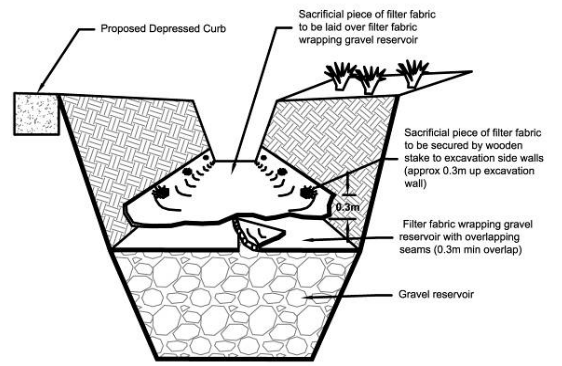


Figure 60 – Conceptual of the sacrificial piece of filter cloth used to protect bioretention units.

Figure 61 – Filter cloth wrapped wooden boards installed at bioretention unit curb cuts

Post-construction

The period of time that immediately follows the completion of construction activities is critical, as it is this time that any issues with the design and construction can be identified and addressed. Techniques for identifying issues include conducting on-site inspections of the practices (during dry periods and, importantly, during precipitation events) and undertaking a performance assessment of the practices to ensure that they are working as intended.

With the Lakeview Project, major construction activities were completed by August 2012. Initial impressions on the functioning of the LID features were positive from both municipal staff and residents. Like most construction projects, a formal inspection took place in September 2012, to identify project deficiencies. The deficiency inspection included the engineering consultant, contractor, landscape contractor, municipal inspector and project manager. A list of deficiencies were identified and provided to the contractor to be addressed.

As-built survey & stormwater bypass

As part of any deficiency inspection, it is recommended that an as-built survey be conducted as it verifies that the final site grading matches that specified in the design. These surveys are valuable for LID practices in particular, as they are often sensitive to very minor changes in grade.

For the Lakeview Project, initially an as-built survey was not completed due to budget constraints and because initial observations had noted positive drainage through the system.

While visual inspection can fall short, performance assessment of any LID site can provide a more comprehensive understanding of site function and performance. An Infrastructure Performance & Risk Assessment (IPRA) was conducted by CVC staff in 2011 to characterize baseline conditions and was initiated again immediately following construction in August 2012.

By examining the performance of the LID practices throughout multiple precipitation events, the IPRA identified an issue with the flow of stormwater through the bioretention units on the north side of First Street. While flow was being observed through the LID features on the south side of the street, little to no flow was observed from those on the north side. For more information on the IPRA conducted at the site, refer to the *Infrastructure Performance & Risk Assessment* section of the case study.

To better understand why there was a discrepancy, a visual inspection of the bioretention units was conducted during a precipitation event. The inspection revealed that several of the inlets were being bypassed. Because of this, insufficient stormwater runoff was able to enter the bioretention units at the curb cuts (shown in the following figure).

Figure 62 – Bypassing of bioretention units during a rainfall event

To better understand this issue, CVC had an as-built survey completed in the summer of 2013. The as-built survey confirmed that at some of the curb cut inlets and grade changes were insufficient to encourage the runoff to enter the bioretention unit. The as-built survey also revealed that grade changes didn't allow for positive drainage within some of the bioretention units, and that the ponding depths were not to that specified in the design.

CVC was able to take the information garnered from the as-built survey and present it to the municipality for the contractor to correct the deficiencies with both inlet grades and ponding depths.

Further investigation revealed that the primary issue with the inlets was that the sod located at the inlets was at too high an elevation, blocking flow into the bioretention cell. This was caused by bioretention soil media not settling as much as expected by the designer and contractor.

To address the issue, the sod was lowered by a minimum of 25 mm below the curb-cut invert to ensure positive drainage into the bioretention unit. Specific activities involved in adjusting the grade within the bioretention units included:

1. Temporary removal of plants
2. Media re-grading - grading, surveys, and string lining by the landscaper
3. Fine grading
4. Re-planting plants
5. Final survey of the start and stop of the planting beds

Figure 63 - Adjusting inlets by removing excess media

Performance assessment to ensure positive drainage through the entire LID feature and appropriate ponding depth is ongoing. Hydrological monitoring does not help only in measuring performance, but can be a key factor in identifying site deficiencies not caught by visual inspection.

Landscaping

After two full growing seasons, a better understanding of plants was also established. Both successful and unsuccessful plants were identified. Resident comments were also taken into consideration as to what plants they liked and didn't like.

During the summer of 2013, residents began voicing complaints to CVC monitoring staff and the City of Mississauga staff about some of the plants in the bioretention units. The Lakeview area had received plenty of rain that year and the plants had healthy growth, especially the green headed coneflower, *Rudbeckia laciniata*, and New England Aster, *Aster novae-angliae*. The green headed coneflower grew to over 6 feet tall. The residents said that they couldn't see when they were backing out of their driveways and that the plants were very unattractive and weedy looking.

In September 2013, contractors removed all the green headed coneflower and New England aster from many of the bioretention units and disposed of the material off-site. Unattractive grasses were also removed. The contractor replaced them with butterfly weed, black-eyed Susan, bee balm, obedient plant, and blue flag iris. These plants were chosen because they were already planted in the gardens, residents liked them, and they had established well. The bioretention units were then mulched and watered. For more information about regular landscaping maintenance that took place during the first two growing seasons see the *Operations and Maintenance* section.

Figure 64 - Overgrown New England Asters that were removed from the bioretention unit.

Figure 65 - Plants chosen to replace green headed coneflower based on this bioretention unit. Irises in the center, black-eyed Susans, and bee balm

Economic (Capital & O&M Costs)

Staff time, external labour, equipment, and materials are obvious factors to consider when evaluating the overall cost of a construction project. A comprehensive analysis of ROW retrofit project costs also includes planning, design, construction overhead, removals and disposal fees. The total cost of the Lakeview Project covering the planning, design and construction phases totalled approximately $892,500. This value includes a contingency of $90,000 as well as consulting fees of approximately $40,000 and $80,000 during the planning and design phases respectively.

Table 7 breaks construction phase costs into ten items. Some important design details to remember when reviewing this cost are:

- The total length of road improvement is 285 m
- The total catchment area of the LID features is 1.6 ha
- Total permeable pavement area is 800 m^2
- Total boulevard bioretention area is 890 m^2

Several of the costs shown in Table 7 are comparable to those of a conventional road reconstruction project. The three items which require additional cost are erosion and sediment control (to ensure LID infiltration is not compromised), drainage and stormwater management (perforated pipe and additional inlets), and landscaping (boulevard bioretention areas).These additional costs can be offset by reduced paving and curbing costs and the lack of costs associated with end-of-pipe stormwater management controls.

The Lakeview Project was one of the first green street residential retrofits in Ontario. As with any demonstration project, costs can be higher than projects using standard design features. The project showcased new design concepts within the residential ROW that incorporated sophisticated monitoring components in order to assess the performance of the LID features implemented. CVC and the City of Mississauga are currently working together to track the operations and maintenance activities taking place on the retrofitted streets to determine their lifecycle costs. For further information, refer to the *Infrastructure Performance & Risk Assessment* section.

Table 8 - Lakeview Project Construction Phase Costs

Item	Cost	Notes
Site Preparation	$14,200	Includes removals, disposal, salvaging of existing asphalt and concrete structures.
Erosion and Sediment Control	$6,500	Includes catch basin controls, silt fencing and dust suppression.
Earth Work	$54,600	Includes all earth excavation and grading.
Paving and Curbing Work	$126,300	Includes granular bedding for roadway and sidewalk, asphalt and concrete curbing.
Drainage and Stormwater Management	$240,200	Includes piping and hydraulic structures.
Driveway Pavers	$137,400	Includes pavers and bedding.
Utility Conflicts	$5,000	Includes design modifications and external consultation.
Parkette	$27,000	Includes all works associated with construction of parkette.
Landscaping	$57,400	Includes trees, grasses and perennials.
Provisional	$13,900	Includes provisional all provisional items.
Total Construction Phase Cost	**$682,500**	Does not include planning, design and contingency.

Operations & Maintenance

Maintenance of Boulevard Bioretention Units

Maintenance is important, particularly during the initial establishment phase, because it enhances the performance, aesthetics, and longevity of the LID practice. In the long run, maintenance will prevent small problems from becoming large ones and improve the overall public acceptance of the practice. Maintenance requirements for most LID technologies are not very different from most turf, landscaped, or natural area and do not typically require new or specialized equipment.

During the establishment period at Lakeview, maintenance has been carried out by the contractor, the City of Mississauga, CVC and the local residents. It is important to follow-up with the contractor throughout the warranty period to ensure that activities specified within the maintenance agreement are taking place.

To date only establishment maintenance is taking place and is not typical of long term maintenance. In the case of the bioretention units and permeable pavement driveway aprons, maintenance includes removing accumulated trash and sediments, weeding, mulching and watering. Long term, maintenance requirements should lessen.

Feedback from PICs indicated that local residents were willing to undertaken 2-4 hours of maintenance per month. However in reality, the level of maintenance done by each homeowner varied. Residents were encouraged to undertake maintenance activities such as weeding, pruning and general clean up. Some residents were renters or away for most of the summer so they maintained their bioretention units and permeable pavement less frequently. The amount of maintenance needed also increased if the landscaped option was chosen instead of turf for the bioretention unit.

Figure 66 - Example of a boulevard bioretention feature that is being well-maintained by the homeowner

Table 9 - Lakeview bioretention unit and permeable pavement establishment maintenance activities (2012-2013)

Task	Frequency
Boulevard Bioretention Units	
Remove weeds	Monthly to every two months during growing season
Remove litter and debris from curb cut inlets and inside the bioretention practice	Monthly
Replace or re-spread mulch	Annually
Replace dead or unattractive plants	June and September
Remove sediment	Annually
Watering	Monthly during growing season
Replace all missing or damaged overflow grates	Annually
Remove all in-grown sod around bioretention units a distance of 150mm (6") from perennial plants planted along the current garden edge.	Annually
Replace all dead sod	Annually
Shovel snow from inlet	As needed
Permeable Pavement	
Remove weeds	Monthly to Annually
Remove sediment	Annually
Add jointing aggregate	Annually

Since June 2012, CVC monitoring staff have been collecting data on maintenance activities performed and inspecting conditions of the bioretention units and permeable driveways at Lakeview on a biweekly basis. A standard site inspection checklist has been created and is used by staff during each site visit. Review of the preliminary data shows that plants are establishing well but that recurring maintenance issues involving weeds, sediment and debris accumulation are occurring. Sediment accumulation in the curb cut inlets can change the grade of the inlets, reducing the flow of water into the bioretention units. Sediment also builds up in between the permeable pavers, encouraging weeds to grow. Leaf debris and trash accumulation within the bioretention unit can also reduce infiltration into the practice. The bioretention units and permeable pavers should be inspected for sediment, trash and debris accumulation and weeds on a regular basis. Going forward, these issues should be addressed and maintained more frequently to improve aesthetics and performance of these LID features.

Figure 67 - Accumulation of debris in the inlets from nearby tree

Figure 68 - Sediment build-up and subsequent weed growth in between permeable pavers

Infrastructure Performance & Risk Assessment

The Lakeview Project provides a unique opportunity to evaluate the performance of LID practices implemented within the municipal ROW in a residential setting. The Lakeview Infrastructure Performance and Risk Assessment Program (IPRA) will directly address several knowledge gaps to elevate confidence in LID technologies within Ontario and provide as-built performance data.

Performance Assessment Locations

Four monitoring stations have been installed for infrastructure performance assessment purposes. Currently, performance assessment efforts have been focused upon First Street only. Two LID performance assessment stations have been implemented at the downstream extents of the LID infrastructure for both the north and south side of First Street. A control site located on a nearby street with a traditional curb and gutter drainage system is being assessed as well as another station monitoring a swale (traditional roadside ditch) system. The individual performance assessment locations are as follows:

- **Location 1 (LV-1):** located on Northmount Avenue north of Fourth Street. The street has curb and gutter drainage and will be used as a control site. Four catch basins collect water from this street and convey it to the sampling manhole.
- **Location 2 (LV-2):** located at First Street and Alexandra Avenue. This manhole receives runoff from both the north and south sides of First Street between Alexandra Avenue and Westmount Avenue. This site was used for pre-construction monitoring and continues to be monitored to provide baseline data for traditional roadside ditches.
- **Location 3 (LV-3):** located on the north side of First Street near Alexandra Avenue. This area drains the north side of First Street between Alexandra Avenue and Meredith Avenue. The monitoring station collects an outflow sample from the downstream extent of boulevard bioretention units and permeable pavement for the north side of the street.
- **Location 4 (LV-4):** located on the south side of First Street near Alexandra Avenue. This area drains the south side of First Street between Alexandra Avenue and Meredith Avenue. Similar to LV-3, the monitoring collects an outflow sample from the downstream extent of boulevard bioretention units and permeable pavement for the south side of the street.

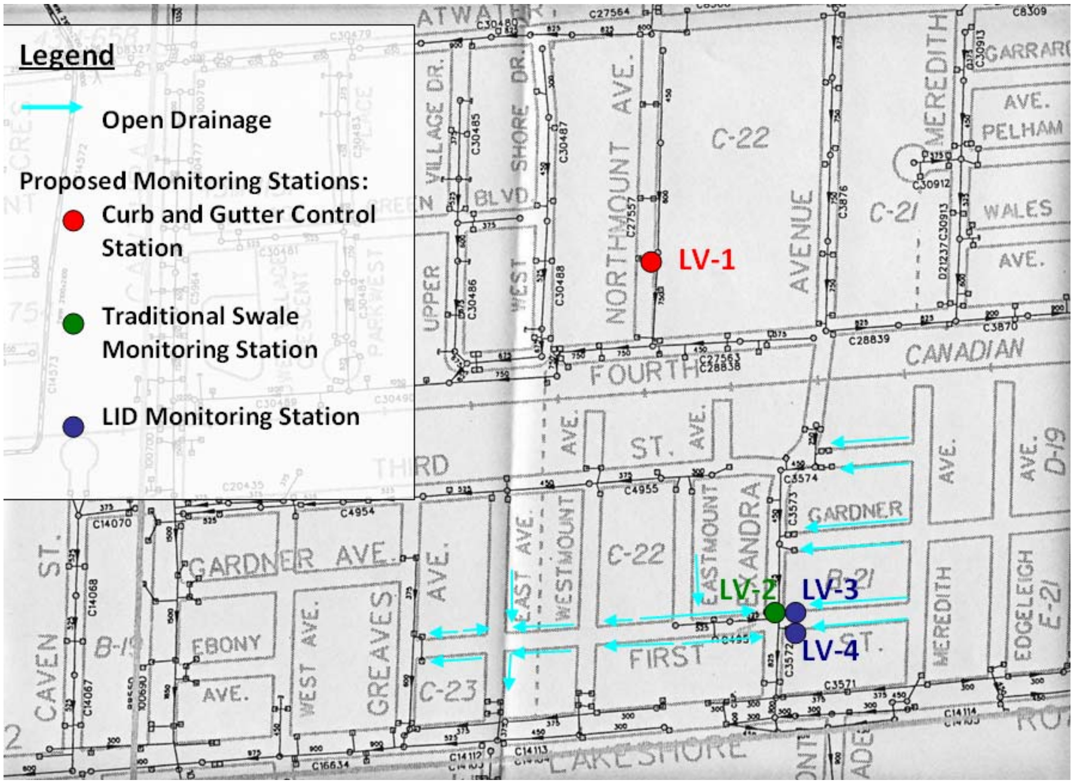


Figure 69 - Performance assessment locations within the Lakeview neighbourhood

Table 10 – Details on ongoing performance assessment activities

Monitoring station	Stormwater management system	Performance assessment activities	Priority pollutants	Continuous monitoring	Sampling interval
LV-1	Control site (curb and gutter drainage)	Water quality sampler and flow measurement in manhole receiving runoff from Northmount Avenue.	• General chemistry • Total suspended solids • Total dissolved solids • Total metals • Nutrients • Polycyclic aromatic hydrocarbons	Temperature	10 min
LV-2	Traditional ditches	Water quality sampler and flow measurement in manhole receiving runoff from the north and south sides of First Street between Alexandra Avenue and Westmount Avenue.	• General chemistry • Total suspended solids • Total dissolved solids • Total metals • Nutrients • Polycyclic aromatic hydrocarbons	Temperature	10 min
LV-3	Boulevard bioretention units and permeable pavement	Flow measurement in manhole receiving flow from bioswales and permeable pavement driveways on the north side of First Street between Alexandra Avenue and Meredith Avenue.	N/A	Temperature	10 min
LV-4	Boulevard bioretention and permeable pavement	Water quality sampler and flow measurement in manhole at outlet of bioswales and permeable pavement driveways on the south side of First Street between Alexandra Avenue and Meredith Avenue.	• General chemistry • Total suspended solids • Total dissolved solids • Total metals • Nutrients • Polycyclic aromatic hydrocarbons	Temperature	10 min

Objectives

Fifteen overarching objectives were selected for this program to meet the priorities of stakeholders. These objectives were structured to address top stakeholder priorities. These priorities include long-term maintenance and subsequent performance, lifecycle costs, water quantity and quality in poor infiltration soils and how multiple LID systems work to provide flood control, erosion control, improve water quality and protect natural heritage systems.

Other agencies that were consulted in the development of these objectives include municipalities, Ministry of the Environment (MOE); Building Industry and Land Development Association (BILD); Credit Valley, Toronto and Region and Central Lake Ontario Source Protection Region; as well as developers.

The overarching objectives of this project are presented in **Table 11** along with details on how the goals are being met.

Table 11 – Objectives of Infrastructure Performance & Risk Assessment

Objective	Details
Evaluate whether LID stormwater management systems are providing flood control, erosion control, water quality, recharge, and natural heritage protection as per the design standard.	The Lakeview performance assessment will provide data for the evaluation of water quality (hydrologic measurements and water quality samples), and recharge (monitoring wells/infiltration measurements). Outflow volumes from the bioretention units will be compared with the control and ditch outflow volumes. This shall provide a frame of reference to compare the runoff reduction benefits of LID practices to conventional approaches.
Evaluate and refine construction methods and practices for LID projects.	Performance will be assessed over time to determine if there are any construction characteristics that cause the facility to operate differently than intended. Documentation of maintenance will also be informative in the long-term assessment of the project.
Evaluate long-term maintenance needs and maintenance programs, and the impact of maintenance on performance.	Details including costs and history of maintenance and repair activities will be established for each of the sites over the short and long term through detailed maintenance inspections. Inspections include documenting vegetation health, debris or sediment accumulation, and a photographic log.
Assess the performance of LID designs in reducing pollutants that are dissolved or not associated with suspended solids (i.e. nutrients, oils/grease, and bacteria)	Dissolved parameters such as chloride, nitrates and total dissolved solids will be assessed for loading reduction.
Assess the water quality and quantity performance of LID designs in clay or low infiltration soils and those that do not use infiltration.	Given the predominance of clay soils in the lower part of the CVC watershed, many LID practices will be located over these soils. To accurately determine the pollutant load capture and volume reduction, runoff will need to be monitored at the inlet and the underdrain and overflow outlet(s). The Lakeview LID sites are constructed with underdrains and provide examples of water quality control systems that are suitable for application in areas with soils with low to marginal infiltration capacity. The LID performance assessment program will evaluate volume reduction and flow attenuation from permeable pavement and bioretention units overlaying clay soils.
Determine the life cycle costs for LID practices.	The Lakeview performance assessment allows for long term monitoring and documentation of maintenance, repair and eventual rehabilitation costs. CVC staff, in collaboration with the City of Mississauga, will establish lines of communication to keep track of maintenance activities, and when monitoring or site observations indicate maintenance may be needed. To assess life cycle costs, documentation of maintenance activities shall be conducted.
Evaluate how a site with multiple LID practices treats stormwater runoff and manages stormwater quantity as a whole.	The monitoring stations downstream of the LID sites monitor the outflow from a treatment train of practices - permeable pavement and boulevard bioretention units. Effluent data will characterize the overall performance of the system as a whole. The traditional swale site may demonstrate some benefits of disconnected impervious area relative to the control site.
Develop and calibrate event mean concentrations (EMCs) for total suspended solids, phosphorous, chloride, copper, zinc, nitrate/nitrite, total nitrogen, and E-coli.	The control site characterizes event mean concentrations (EMCs) from a typical medium-density residential neighbourhood. The inflow EMCs from the control site are expected to be representative of inflow conditions for the other stormwater practices that are being assessed. These values will allow any reductions in pollutants to be documented for future use.
Demonstrate the degree to which LID mitigates urban thermal pollution	Temperature loggers were installed at each of the Lakeview monitoring stations in 2013. The data collected at the Lakeview sites will provide side-by-side comparisons of thermal benefits, improvements in thermal loading and event mean temperatures for streets retrofitted with LID versus conventional curb and gutter.
Assess the potential for soil contamination for practices that infiltrate	Sampling of sediments captured in the roadside ditches, bioretention surface sediment deposits and shallow soil samples will aid in assessing possible contamination. In addition, a sample of sediment collected in the control catch basin will be collected and analyzed for contaminants of concern.
Evaluate effectiveness of soil amendments and increased topsoil depth for water balance and long-term reliability	The bioretention soil media installed in the bioretention units is amended media designed for efficient infiltration. Infiltration testing over time will assess this reliability.
Assess performance assessment data to determine potential rebates on development charges, credits on municipal stormwater rates and/or reductions in flood insurance premiums	The performance assessment provides comparisons of three street drainage strategies for residential areas, demonstrating the strengths and weaknesses of each system. Data on runoff reduction, lag in peak flow and other performance criteria can be used to determine the appropriate credit to award LID practices.
Assess the potential for groundwater mounding in localized areas	The piezometers installed in the boulevard bioretention units will provide data that will characterize how long water levels remain elevated following precipitation events.
Assess the ancillary benefits, or non-SWM benefits	CVC has interacted with residents throughout the construction of the LID practices at the Lakeview site and continues to do so while collecting performance assessment data. Continued interaction with residents and assessment of changes on private property are important and will provide a sense of how the residents perceive the LID practices.

Data Collection Methods & Equipment

In order to evaluate the performance of LID systems, staff collects climatic data (precipitation and temperature), hydrologic data (inflow, water level, soil moisture) and water samples for water quality analysis. The following sections provide an overview of the methodology used to monitor these parameters.

Climate
Precipitation is measured using a City of Mississauga-managed rain gauge located less than one kilometre from Third Street. Further precipitation data is collected via a CVC climate station installed on the roof of the Cawthra Community Center.

Water Quantity Monitoring
Outflow from the underdrains of the bioretention units and permeable pavement driveways are measured using a stage-based method with weirs and water level loggers.

A compound weir plate has been installed and calibrated by a consultant at all four performance assessment stations. An ISCO 4150 or Hach FL900 flow meter was installed in each manhole with the probe secured to the weir to make certain that accurate water level measurements are recorded. The flow meters are set to record water levels at 10-minute intervals.

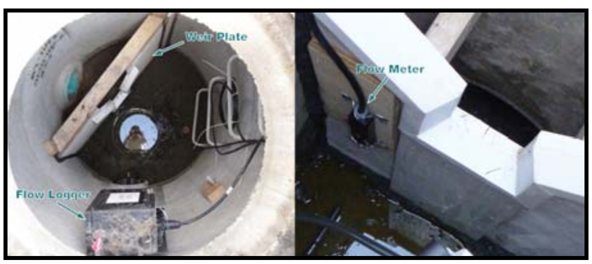


Figure 70 - Flow monitoring equipment and compound weir

Temperature Assessment
Three of the performance assessment locations record the water temperature in the manhole on a continuous basis. A HOBO UA-002-64K temperature logger was installed at stations LV-1 and LV-4 in 2013. The flow meter at station LV-3 also records temperature.

Water Quality Assessment
Stormwater quality is monitored with flow proportioned composite samples collected by automatic samplers and analyzed for a variety of common stormwater runoff constituents. These measurements are made in accordance with the provincial water quality objectives (PWQO), with priority given to pollutants of concern for the Cooksville Creek watershed.

Constituents
The collected samples are analyzed for the following constituents:

- Chloride
- Turbidity
- Conductivity
- pH
- Total suspended solids (TSS)
- Total dissolved solids (TDS)
- Nutrients:
  - Total phosphorus
  - Orthophosphate
  - Total kjehldahl nitrogen (TKN)
  - Total ammonia
  - Nitrate and nitrite
- Total metals
- Polycyclic aromatic hydrocarbons (PAHs)

Water quality parameters were chosen to include parameters that have been commonly analyzed in published literature. This will allow the performance assessment data from the Lakeview project to be interpreted and discussed in context with other LID projects in Canada and the United States. Water quality parameters were also selected to ensure pollutants of concern as identified in the CVC *Impact Monitoring Program 2007-2011 Report* were included in the monitoring program.

Sampling Frequency
A minimum of ten precipitation events will be sampled per year from three of the performance assessment locations (LV-1, LV-2, & LV-4) with an ISCO 6712 Automatic sampler. The samplers are connected to the water flow loggers and triggered when a predetermined water level is recorded by the flow logger. The monitoring program will continue until a minimum of thirty precipitation events have been collected.

Figure 71 - Water quality sampling

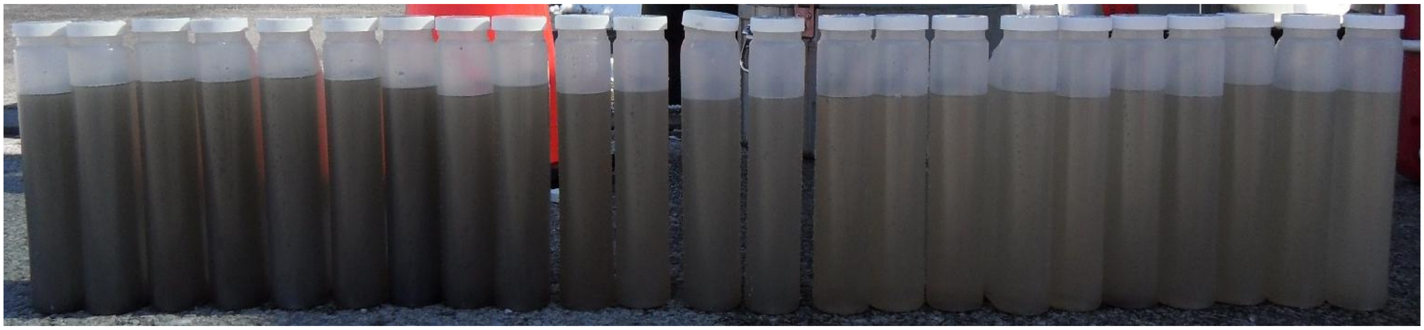


Figure 72 - Sampling bottles depicting the first flush, first six bottles from left and composite samples

Sampling Methodology
During water quality monitoring event sampling is conducted using the following procedures:

- Two samples are submitted per surface water quality monitoring station per event.
- One composite grab sample is collected from the first six bottles sampled by the ISCO sampler and submitted for analysis to analyze the initial first flush of the storm event.
- The remaining eighteen bottles are used to collect a flow-weighted composite sample. The length of time between bottle fills may be lengthened or reduced depending on the event forecasted. This will either shorten or lengthen the sampling program in order to get a sample that best represents the event.
- Water quality samples are brought to Maxxam Analytics for laboratory analysis.

Surface Water Infiltration
To assess surface water infiltration, two piezometers were installed within the First Street bioretention units during construction. The piezometers are located near monitoring stations LV-3 and LV-4. HOBO U20 continuous water level loggers were placed in the piezometers to measure variations in water level throughout the profile of the bioretention units. Level readings are then compared to rainfall amounts to calculate surface water infiltration in the cells and determine the drawdown time required for stormwater to fully infiltrate through the bioretention units.

An additional logger is located at Green Glade Sr. Public School (approximately nine kilometres from the site) to record barometric pressure. These measurements are used to normalize the water level measurements for barometric pressure. All loggers recorded water level readings in 10 minute intervals.

Figure 73 - Manual level measurements are taken to verify the accuracy of readings and level logger is calibrated as needed

Sediment/Soil Sampling
Sediment is a very important stormwater pollutant, because it carries many hydrophobic pollutants and creates potentially toxic conditions in receiving environments. LID practices capture sediments by design. These deposited sediments have the potential to become an in-situ source of pollution, which may be released by changes in the ambient water quality. Routine maintenance of LID practices, including removal and disposal of sediments can help to control the in situ pollution potential of captured sediments.

Monitoring data will be collected to characterize captured sediments and associated stormwater pollutants. This component of the performance assessment program will be important for evaluating frequency of maintenance and for quantifying pollutant load reductions when maintenance is performed.

At the Lakeview performance assessment sites, sediment samples will be collected annually at each of the monitoring stations to characterize stormwater sediments and pollutant accumulation. For LV-2, LV-3 and LV-4, two sediment/soil samples will be collected each year:

- One sample will consist of surficial deposits of sediments remaining in the facility after runoff events. If deposits are visible, they can be sampled using a clean spade. Multiple deposits may be sampled to create a composite sample. If there are no visible sediment deposits, a soil sample consisting of the top 1 to 2 cm of soil in the cells near an inlet (soil separated from vegetation) shall be used.
- The second soil sample will be collected in each swale near the outlet and will consist of soil from the top 10 cm of the cell (surface sediments and top 1 - 2 cm excluded). Comparison of this sample result with the sediment deposit/surface sample will provide an idea of whether or not pollutants are migrating into the soil column over time. For LV-1, sediments collected in the catchbasin will be collected and analyzed. These samples will be collected in the fall after summer precipitation events but before the ground freezes. Samples will be analyzed for total metals (same that are being monitored in water samples), nutrients and pH. Depending on results, CVC may increase the frequency or extent of this type of sampling in the future.

Quality Assurance and Quality Control

The sites are visited at minimum every two weeks by CVC staff to inspect equipment, check battery power and verify that all systems were operational. Data is downloaded in person using ISCO Flowlink 5 or Hoboware software. The software automatically summarizes and plots the data graphically, which is then easily exported to a program like Microsoft Excel.

Field and lab data management follows CVC's *Data Storage, Organization, and QA/QC Protocol*. Unaltered data that has been downloaded in the field or acquired from the lab is stored on an external drive and backed up regularly. Files that are undergoing review are organized by site, date and employee initials to ensure raw data is not manipulated or adjusted. Each file is subject to a quality assurance and quality control review to ensure any inconsistencies are noted and to determine possible reasons for the inconsistency.

Maintenance Monitoring

Maintenance needs for the boulevard bioretention units and the permeable pavement is currently being evaluated by CVC and the City of Mississauga. CVC staff conducts bi-weekly maintenance inspections and completes an inspection checklist documenting obvious visual maintenance needs. Checklists include documenting common issues such as sediment deposition, trash accumulation, vegetation health, and a photographic inventory. This log of maintenance needs will not only assist the City and residents with maintenance of these LID practices, but also provide an indication for maintenance requirements for future LID projects across Ontario.

Landscaping

Maintenance logs also include communication with residents in the Lakeview neighbourhood. Through the visual logs and communication with residents, concern regarding one of the plant species selected for the boulevard bioretention units was brought to the attention of the City of Mississauga. The boulevard bioretention planting plan included shorter species in front of the swale with larger species in the back. One species, *Rudbeckia laciniata*, grew much larger and taller than expected. To resolve this issue, the plants were removed and replaced with more appropriate species. For more details, refer to the *Post-construction* section of the case study.

Damage to Overflow Grates

Each boulevard bioretention unit incorporates an overflow that allows excess water to directly enter the underdrain. The grates for the overflow pipes at Lakeview are made of plastic, and the maintenance monitoring program has identified issues with the long term suitability of this material type for this application. Several of the grates have broken since the completion of construction, likely due to the weight of snow piled on the overflows, and during summer months, damage from lawn mowing equipment. A photograph of a broken overflow grate is shown in the following figure.

Based upon these findings it is recommended that overflows for landscaped bioretention practices utilize a heavy-duty metal grate to ensure they do not break shortly after construction.

Stormwater Bypass
An important finding of the Infrastructure Performance & Risk Assessment program at Lakeview was that several of the boulevard bioretention cells were being bypassed – stormwater not was entering the cells, and instead traveling along the curb to a downstream catchbasin. As this significantly affects the performance of these LID stormwater management practices, steps were taken by the project team to address this issue as soon as it was identified. For further details on what actions were taken to address the stormwater bypass issue, please refer to the *Post-construction* section of the case study.

Long Term Assessment
Performance assessment results will be summarized in a technical report in the spring of 2014.

The Infrastructure Performance and Risk Assessment program at Lakeview is currently ongoing and will provide a long-term assessment on the performance of LID practices within the road ROW in a residential setting. Long-term assessment activities at the site will continue to include, water quantity and quality performance as well as detailed site inspections to identify maintenance requirements and lifecycle costs. Further information on the performance of the Lakeview Project will be posted on CVC's website in 2014. Refer to bealeader.ca for updates.

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