Sustainable Technologies
EVALUATION PROGRAM

www.sustainabletechnologies.ca

The expanding wikiverse: Next level guidance to cover the full life cycle of LID facilities

Presented by: Dean Young and Daniel Filippi, Toronto and Region Conservation Authority

STEP Webinar Series
December 8, 2022

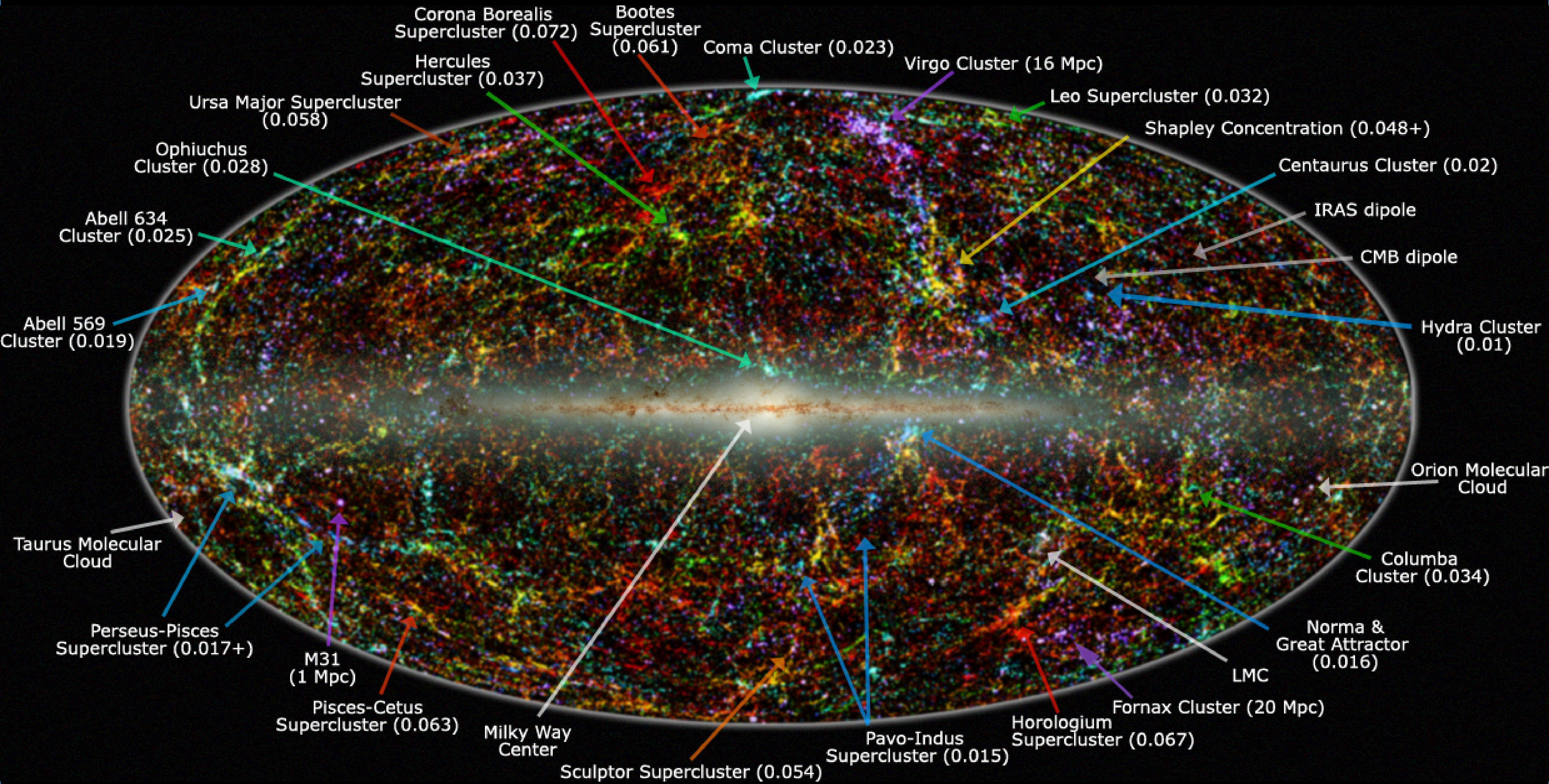
The water component of STEP is a collaborative of:

Toronto and Region Conservation Authority

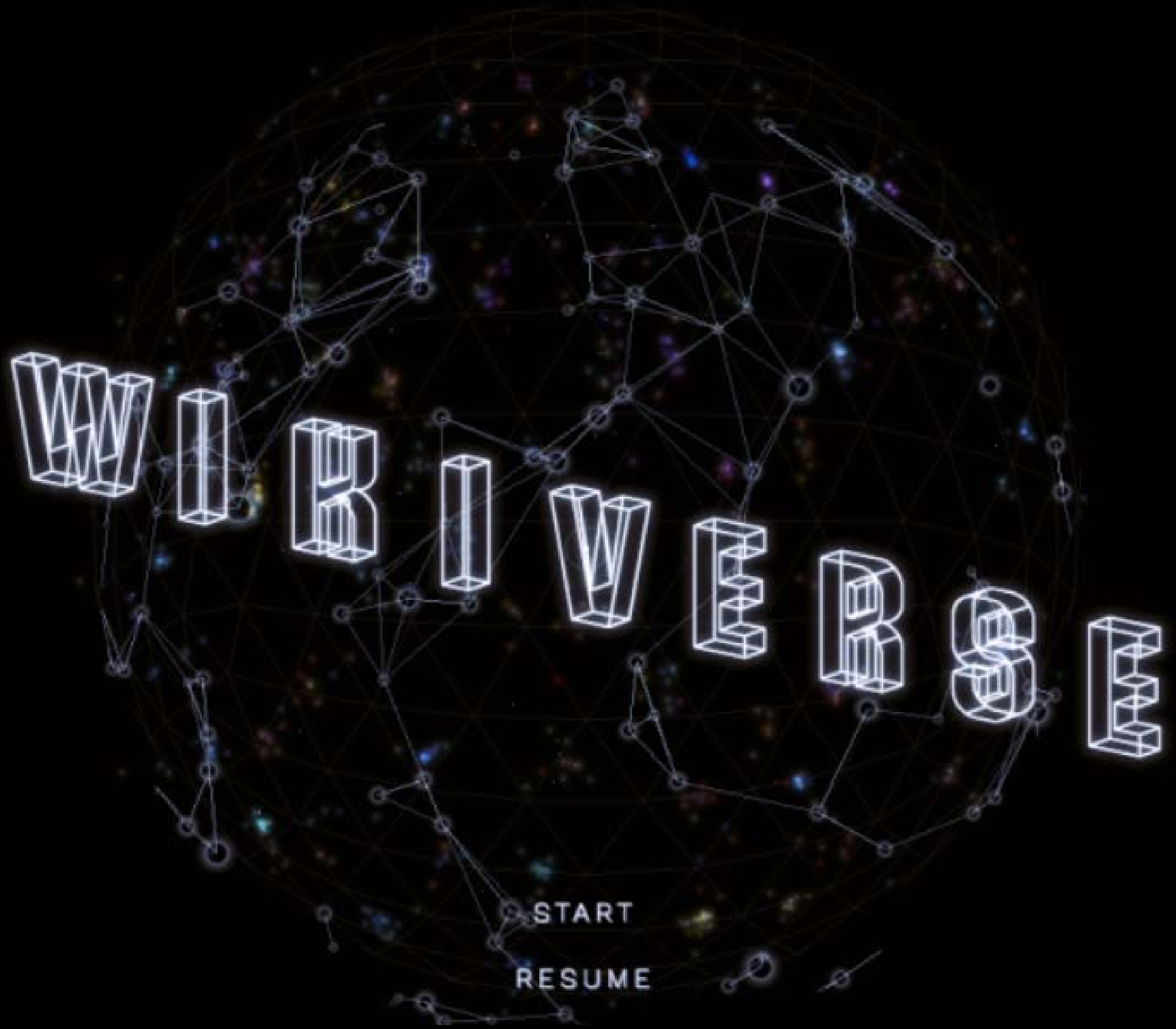
Credit Valley Conservation
inspired by nature

Lake Simcoe Region conservation authority

Composite infrared image of the Milky Way and galaxies in the Local Universe (Jarrett, 2004)



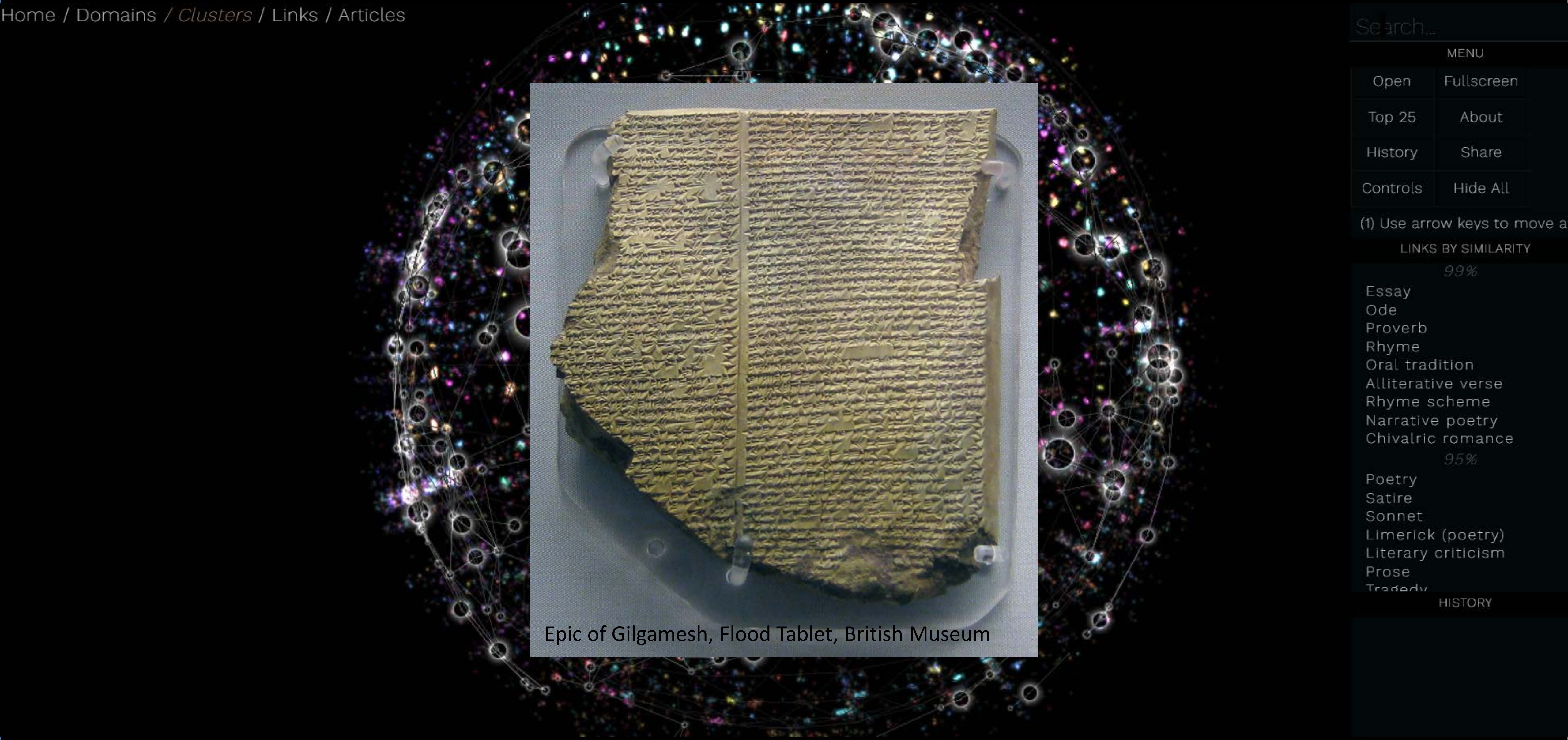
https://wise2.ipac.caltech.edu/staff/jarrett/galaxies/



https://www.wikiverse.io/

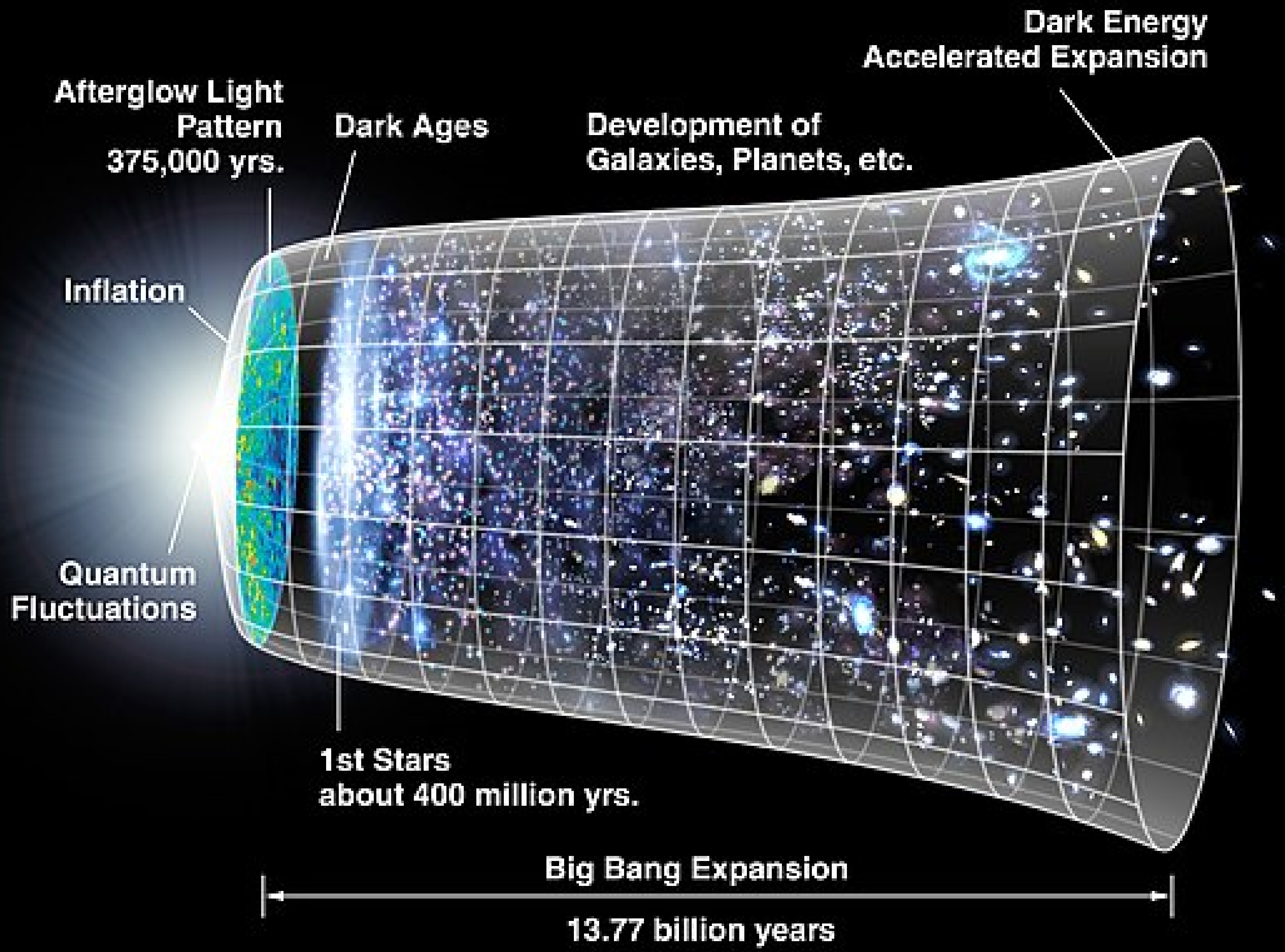
The Wikiverse project, brainchild of French computer scientist, Owen Cornec, is an interactive 3D visualization of Wikipedia, reimagined as a cosmic web of knowledge.

Clicking on a "star" will load the article. Clusters of "stars" are articles on similar topics, and related entries are connected by colored lines.



Epic of Gilgamesh, Flood Tablet, British Museum

https://www.wikiverse.io/



https://en.wikipedia.org/wiki/Expansion_of_the_universe

Source: Marvel Studios

Source: Marvel Studios

Source: Marvel Comics

Overview

STEP is a multi-agency initiative developed to support broader implementation of sustainable technologies and practices within a Canadian context.

The water component of STEP is a conservation authority collaborative. Current partners are:

Toronto and Region Conservation Authority

Credit Valley Conservation inspired by nature

Lake Simcoe Region conservation authority

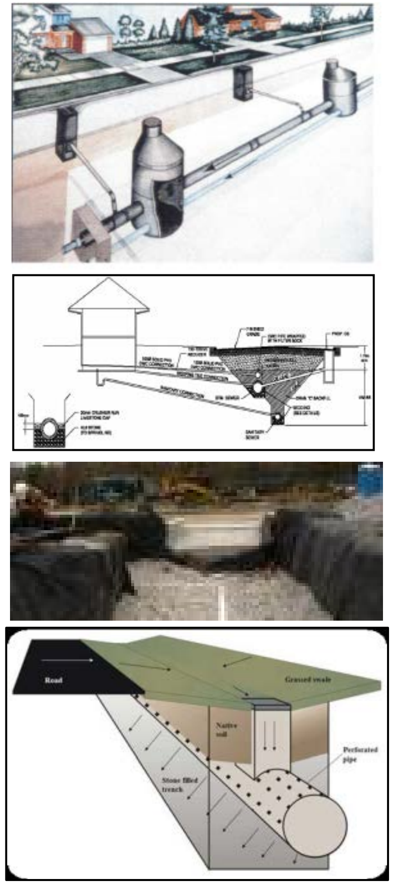
Our key areas of focus are:

- Low Impact Development
- Erosion and Sediment Control
- Road Salt Management
- Natural Features Restoration

Over 20 years of demonstration, monitoring and evaluation

End of pipe facilities

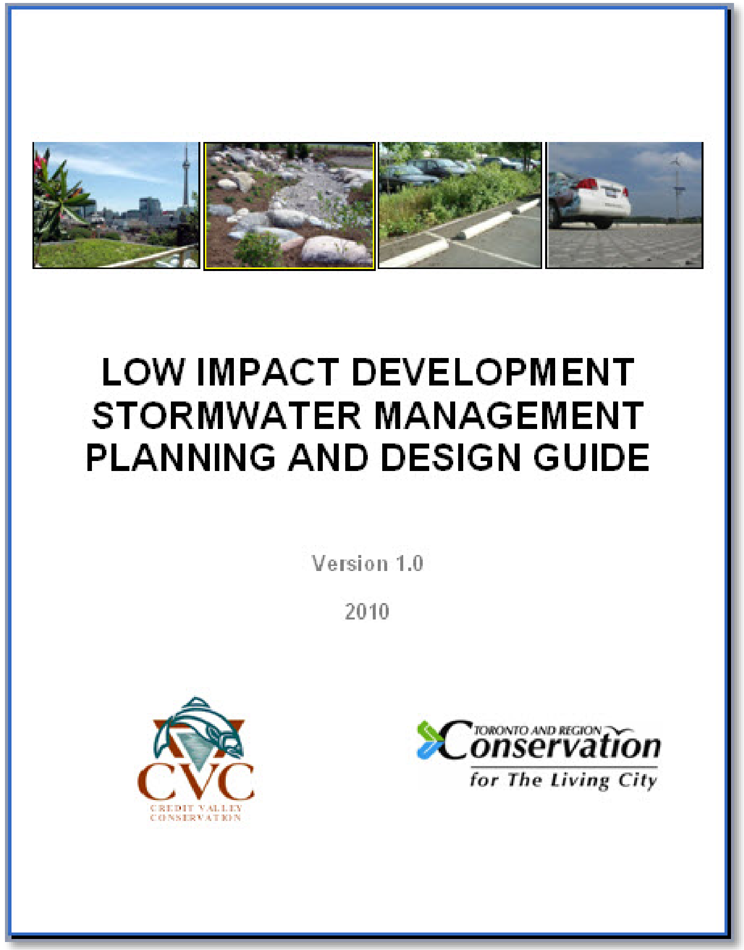
Conveyance practices



Source controls

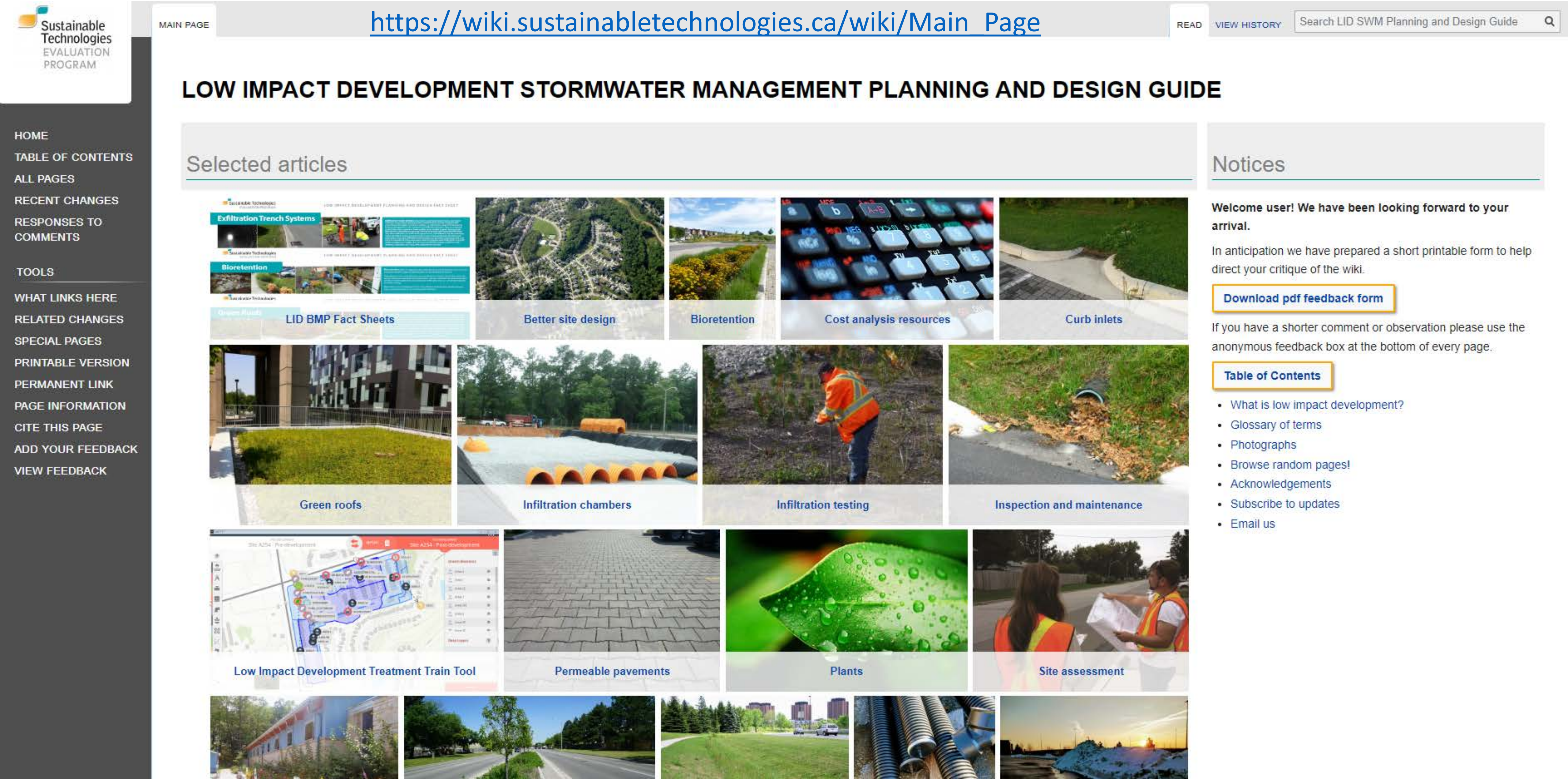
Low Impact Development Stormwater Management Planning and Design Guide

- Version 1.0 published in 2010;
- Developed as tool to help facilitate implementation of sustainable stormwater management approaches;
- Augments MOECC 2003 SWM Planning and Design Manual;
- Widely used resource by practitioners;
- Audience: consultants, municipalities, agency review and approvals staff, NGOs.

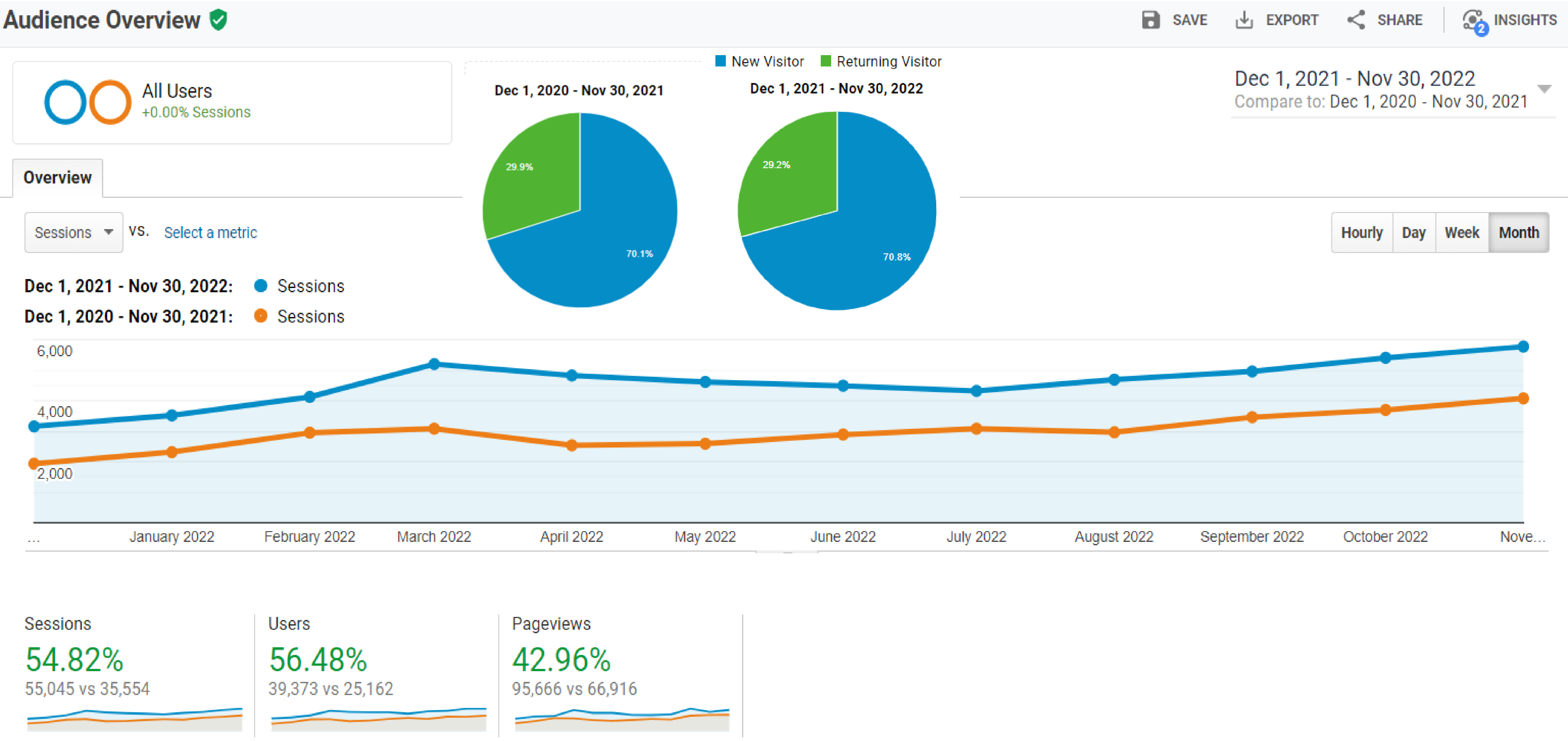


LID Wiki Homepage

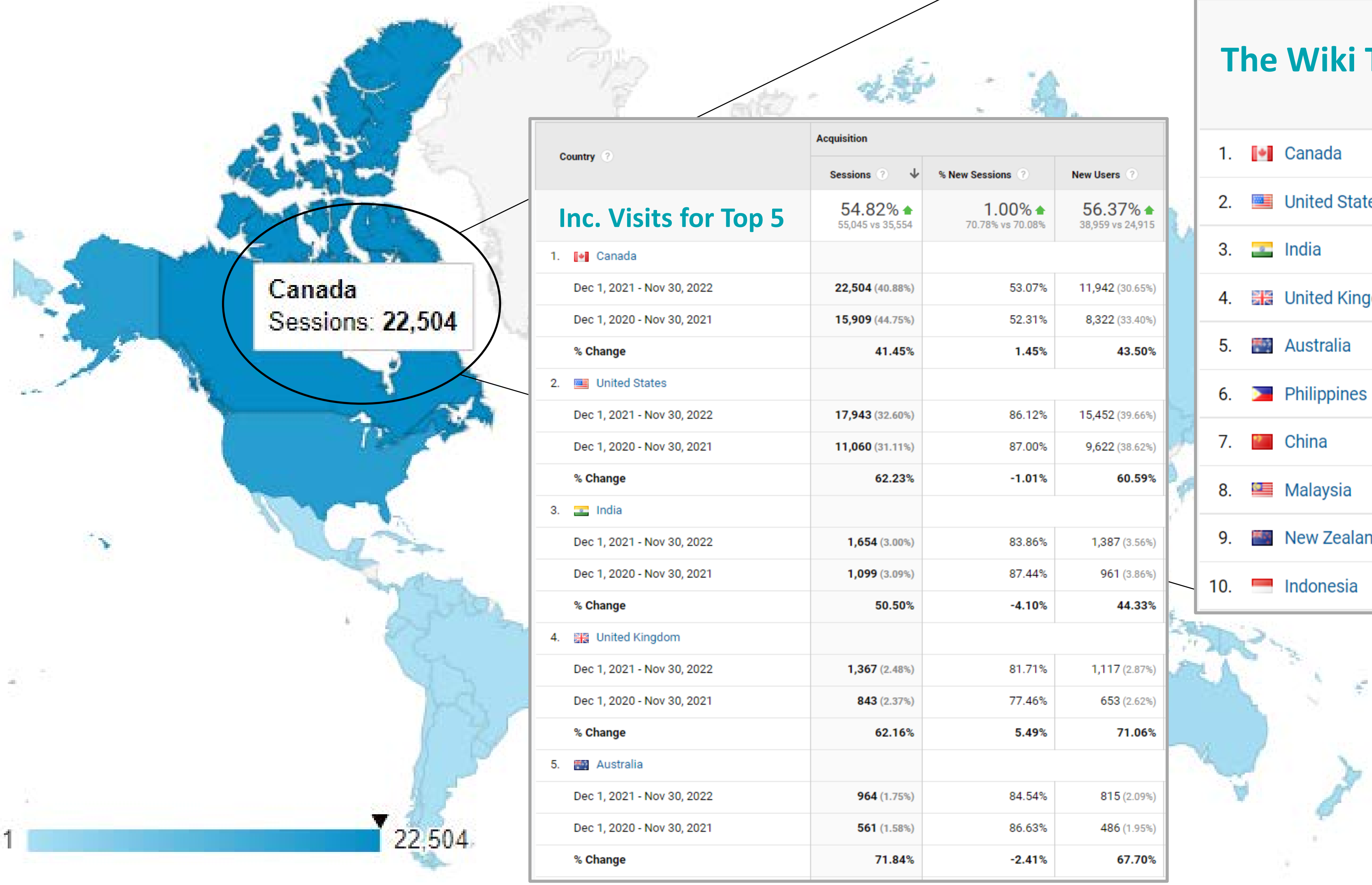
https://wiki.sustainabletechnologies.ca/wiki/Main_Page



Google Analytics



Google Analytics



Inc. Visits for Top 5

Country	Acquisition: Sessions	% New Sessions	New Users
	54.82% (55,045 vs 35,554)	1.00% (70.78% vs 70.08%)	56.37% (38,959 vs 24,915)
1. Canada			
Dec 1, 2021 - Nov 30, 2022	22,504 (40.88%)	53.07%	11,942 (30.65%)
Dec 1, 2020 - Nov 30, 2021	15,909 (44.75%)	52.31%	8,322 (33.40%)
% Change	41.45%	1.45%	43.50%
2. United States			
Dec 1, 2021 - Nov 30, 2022	17,943 (32.60%)	86.12%	15,452 (39.66%)
Dec 1, 2020 - Nov 30, 2021	11,060 (31.11%)	87.00%	9,622 (38.62%)
% Change	62.23%	-1.01%	60.59%
3. India			
Dec 1, 2021 - Nov 30, 2022	1,654 (3.00%)	83.86%	1,387 (3.56%)
Dec 1, 2020 - Nov 30, 2021	1,099 (3.09%)	87.44%	961 (3.86%)
% Change	50.50%	-4.10%	44.33%
4. United Kingdom			
Dec 1, 2021 - Nov 30, 2022	1,367 (2.48%)	81.71%	1,117 (2.87%)
Dec 1, 2020 - Nov 30, 2021	843 (2.37%)	77.46%	653 (2.62%)
% Change	62.16%	5.49%	71.06%
5. Australia			
Dec 1, 2021 - Nov 30, 2022	964 (1.75%)	84.54%	815 (2.09%)
Dec 1, 2020 - Nov 30, 2021	561 (1.58%)	86.63%	486 (1.95%)
% Change	71.84%	-2.41%	67.70%

The Wiki Top 10

Country	Acquisition: Sessions	% New Sessions	New Users
	55,045 % of Total: 100.00% (55,045)	70.78% Avg for View: 70.75% (0.04%)	38,959 % of Total: 100.04% (38,945)
1. Canada	22,504 (40.88%)	53.07%	11,942 (30.65%)
2. United States	17,943 (32.60%)	86.12%	15,452 (39.66%)
3. India	1,654 (3.00%)	83.86%	1,387 (3.56%)
4. United Kingdom	1,367 (2.48%)	81.71%	1,117 (2.87%)
5. Australia	964 (1.75%)	84.54%	815 (2.09%)
6. Philippines	923 (1.68%)	75.19%	694 (1.78%)
7. China	865 (1.57%)	94.22%	815 (2.09%)
8. Malaysia	429 (0.78%)	82.52%	354 (0.91%)
9. New Zealand	368 (0.67%)	80.71%	297 (0.76%)
10. Indonesia	355 (0.64%)	72.68%	258 (0.66%)

Expanding the STEP LID wikiverse

<u>Enhancements in 2021/22</u>:

- Updated nine (9) existing **LID BMP Planning and Design Fact Sheets** and created new one on **Stormwater Tree Trenches**;
- New and improved image map **schematic diagrams**;
- New and updated information hubs on **Construction** and **Inspection and Maintenance** based on STEP guides and professional training;
- Integrated information on **life cycle costs** based on Life Cycle Costing Tool version 3.0 (STEP 2021);
- Enhanced content on **treatment performance** based on Canadian BMP Water Quality database records (STEP 2022) and international literature reviews;
- New and enhanced pages on **Source Water Protection**; **Salt**; **Nutrients**; **Phosphorus**; and **Stormwater Thermal Mitigation**;
- New **Drawings** page compiling examples of municipal standard engineering drawings and details for LID BMPs/Green Infrastructure;
- New **LID Case Studies** page, highlighting STEP research over the past 20 years (60+ reports by BMP type).

New and improved LID Planning and Design Fact Sheets

Improved

1. Bioretention;
2. Enhanced grass swales;
   - Includes bioretention swales (bio-swales)
   - Replaces “Dry Swales”
3. Exfiltration trench systems;
   - Replaces “Perforated Pipe Systems”
4. Green roofs;
5. Permeable pavement;
6. Rainwater harvesting;
7. Site design strategies;
8. Soakaways, infiltration trenches & chambers.

Sustainable Technologies EVALUATION PROGRAM

LOW IMPACT DEVELOPMENT PLANNING AND DESIGN FACT SHEET

Site Design Strategies

The goal of **LID site design** is to minimize the hydrologic impacts of land cover changes and storm sewer systems through non-structural, innovative strategies that preserve or mimic natural drainage features and functions, minimize runoff, and manage it as close to the source as possible. Site designers should exhaust all opportunities for non-structural methods to minimize impervious cover and runoff before determining how to mitigate impacts through structural stormwater management practices. Four key categories of site design strategies include: ***preserving important hydrologic features and functions, siting and layout of development, reducing impervious area,*** and ***using natural drainage systems.***

PRESERVING IMPORTANT HYDROLOGIC FEATURES AND FUNCTIONS

STRATEGIES

SITING AND LAYOUT OF DEVELOPMENT

STRATEGIES

New

9. Stormwater tree trench;
10. Site Design Strategies

Stormwater Tree Trench - Factsheet

Stormwater Tree Trench

Stormwater Tree Trenches are linear bioretention practices that manage stormwater while also promoting healthy tree growth. They are most often located behind the curb in the road right-of-way and consist of a series of tree planting pits connected to subsurface trenches filled with special engineered soils and/or structural soil support systems that support the surrounding pavement and foster root growth. Tree trenches offer solutions to multiple urban environmental challenges: they improve urban tree health by providing irrigation and allowing them to survive longer in harsh conditions, while also reducing roadway flooding, contributing to stormwater pollutant removal, and decreasing the volume of runoff entering local waterways. Tree trenches consist of planting soil, stormwater piping, structural soil media or filter media contained within a modular soil support system, and trees. The engineered soil (or soil support system) may extend under paved surfaces next to the tree planting pit to provide more soil volume for water storage and tree growth.

DESIGN

GEOMETRY AND SITE LAYOUT

Tree trenches are most often modular systems that are connected hydrologically through a sub-surface drainage pipe network, however road runoff may also be directed to the surface via curb cuts or surface drains. In both cases, inlets are offset from the root ball to avoid accumulation of road salt during early tree establishment.

INLETS

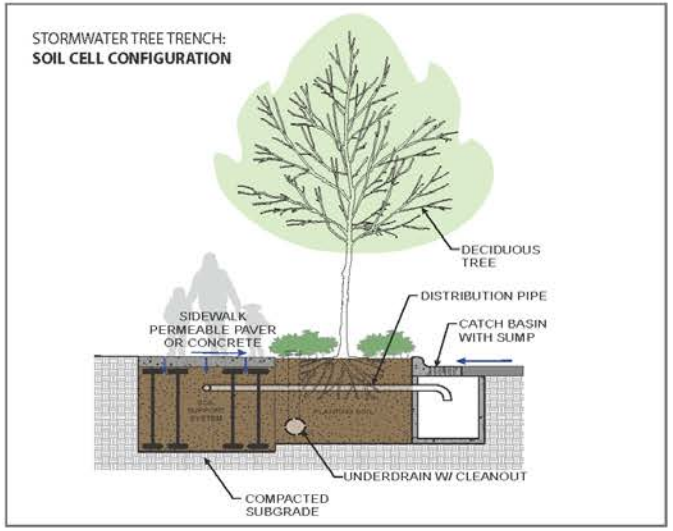
Water can enter the tree trench in a variety of ways from surface drainage into the tree well from adjacent sidewalks and from the road through curb cuts or depressed drains, to direct vertical drainage through permeable pavers, and from catch basin inlets in the roadway that direct runoff into the trench through distribution pipes. It is recommended that each tree trench have multiple inlets to keep any one drainage area relatively small, which provides redundancy to the system.

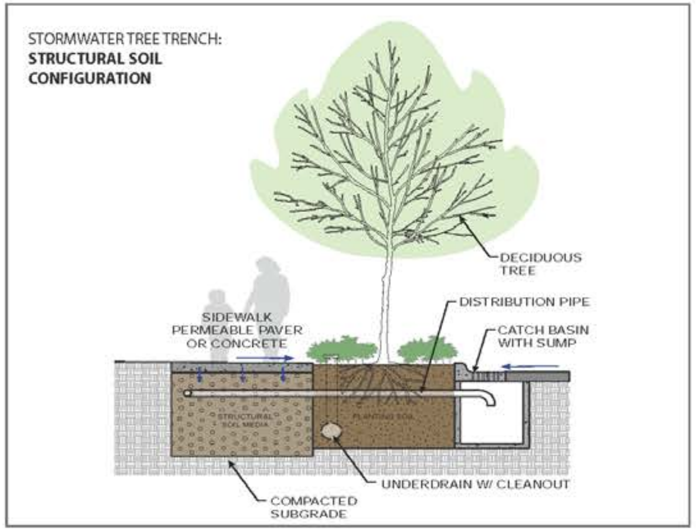
PRE-TREATMENT

If water enters the trench via a catchbasin, a structural pre-treatment device, like a catch basin shield or filter, should be included to collect silt and sediment from the runoff before it enters the trench. Surface inlet systems should have a sump or stone diaphragm to dissipate energy and spread flows. Pre-treatment devices should be easy to access and clean out, as maintenance of these devices is key to the long-term success of tree trenches.

SOIL VOLUME

Each tree planted should have minimum 30 m^3 soil volume. This can be 30 m^3 of soil within the planting pit or 16 m^3 within the planting pit, with root access to an additional 14 m^3 of engineered structural soil media or planting soil under adjacent supported pavements. If more than one tree shares the same trench a minimum 20 m^3 per tree is acceptable as the roots will still have ample room to spread.





BMP	Ability to meet stormwater criteria		
	Water balance	Water quality	Stream erosion control
Tree Trench	Partial, based on native soil infiltration rate and if flow restrictor is used	Yes - size for water quality storage requirement	Partial - based on native soil infiltration rate, available storage and if flow restrictor is used

STRUCTURAL SOIL MEDIA

Structural soil is an engineered soil medium that can be compacted to support sidewalk or roadway pavement installation requirements while also permitting tree root growth. Structural soil media is used adjacent to tree pits to provide more room for tree roots to spread out under paved surfaces that surround the tree trench.

MODULAR SOIL SUPPORT SYSTEMS

Modular soil support systems consist of modular frames (or cells), in a variety of sizes, that provide structural support for paved surfaces without the need for a compacted soil base within the root zone. Modular soil support systems are an alternative to structural soil media and are used adjacent to tree pits to provide room for tree roots to spread out under paved surfaces surrounding the tree trench. Growing media in soil support systems typically has higher organic content than structural soils. The looser structure and higher nutrient content of the soil in modular support systems provides the most favourable environment for healthy tree growth in the urban setting.

STRUCTURAL CONCRETE PANEL

A structural concrete panel configuration is an alternative to modular soil support systems that uses a "bridge deck" over bioretention or growing media that extends into the pedestrian clearway, and is supported on each side by concrete supports and compacted granular material. The benefit of this approach is that the soil under the drainage media does not need to be compacted, allowing for greater infiltration.

CONVEYANCE AND OVERFLOW

Runoff is directed from surrounding impervious surfaces through curb cuts and surface drains to the tree trench where it percolates through the soil media to the underlying ground or underdrain. If the runoff exceeds the design capacity, the underdrain directs the excess filtered stormwater to a storm sewer or downstream LID practices. During intense storm events, excess runoff will overflow directly to the storm sewer either through an outlet in the catchbasin or via a surface overflow within the tree trench.

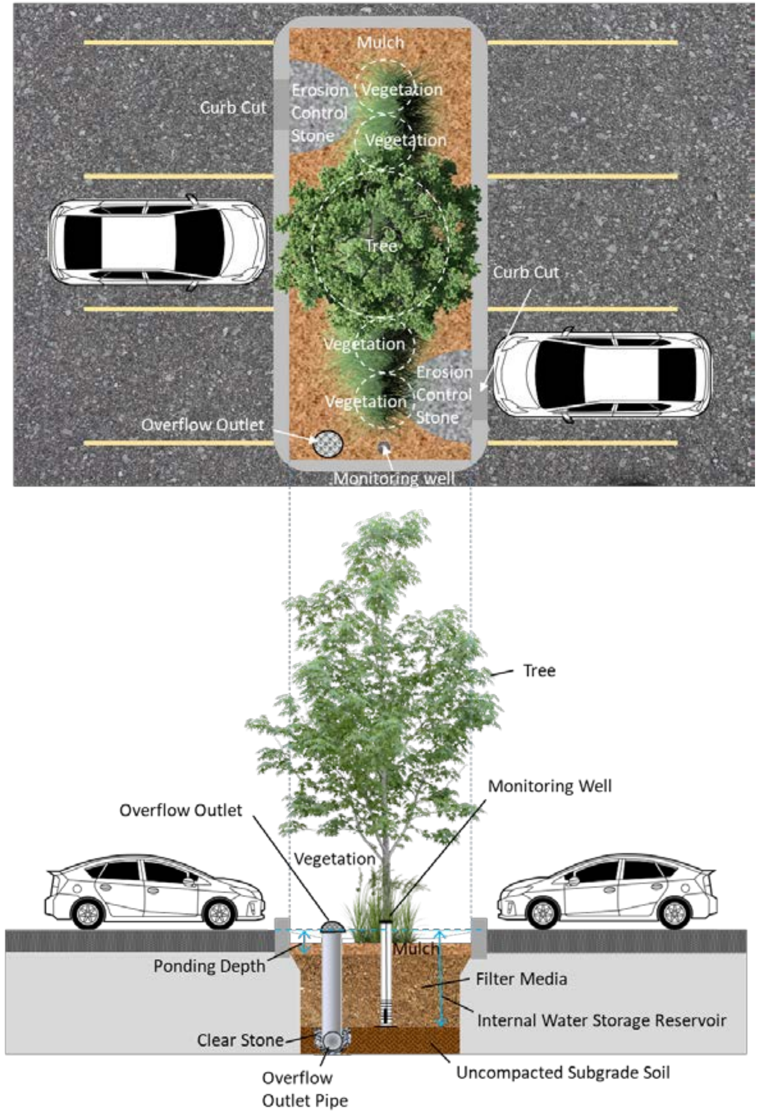
CONFIGURATION

Liners and gravel storage areas below the trench should be avoided to maximize infiltration and to encourage tree roots to penetrate the sub-soil.

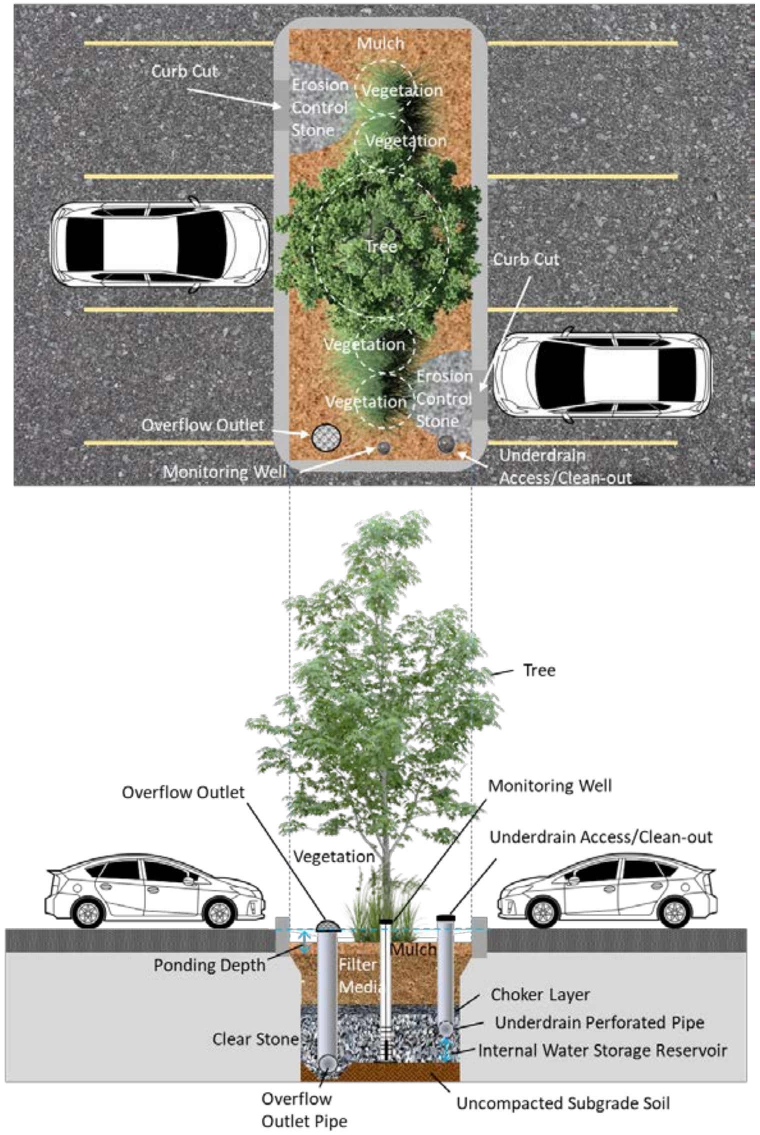
https://wiki.sustainabletechnologies.ca/wiki/Stormwater_Tree_Trenches

New image map schematic diagrams

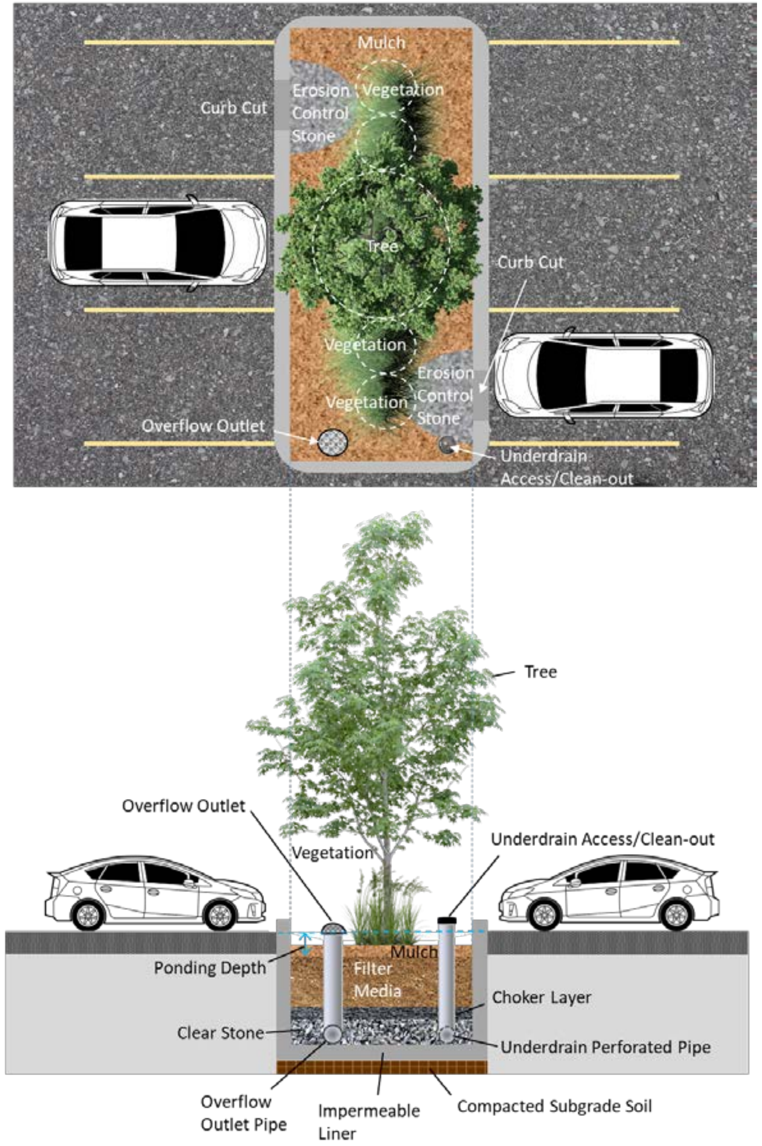
Bioretention – Full infiltration



Bioretention – Partial infiltration

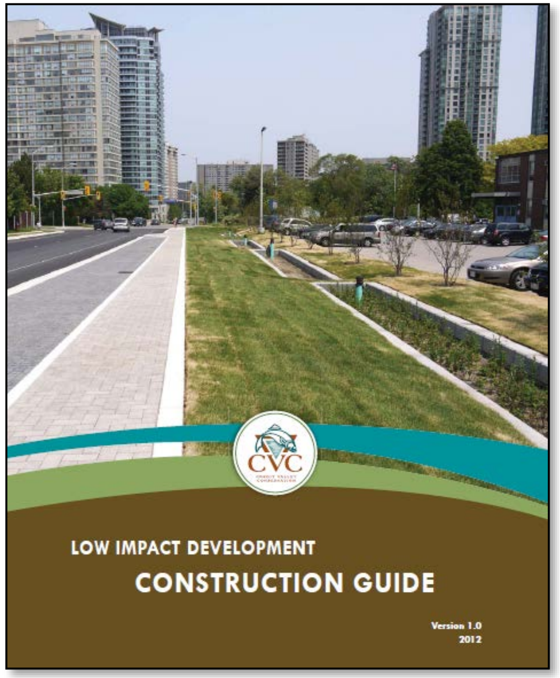


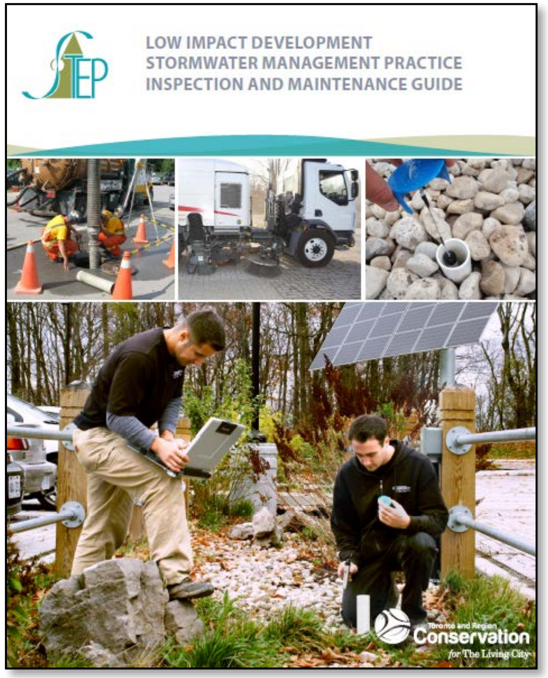
Stormwater planter / Bioretention - No infiltration

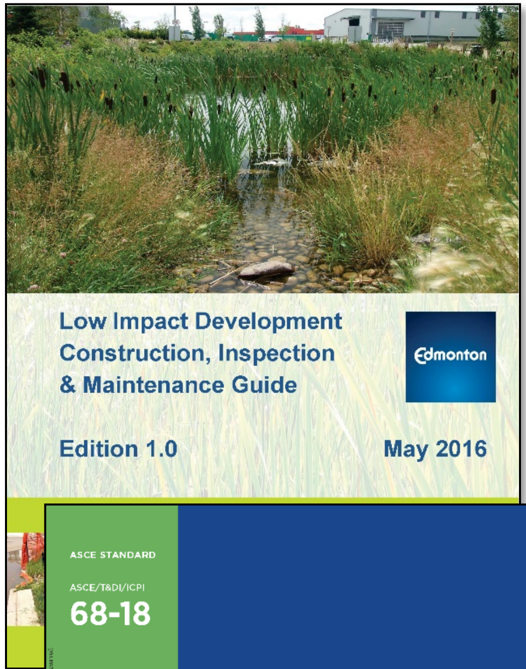


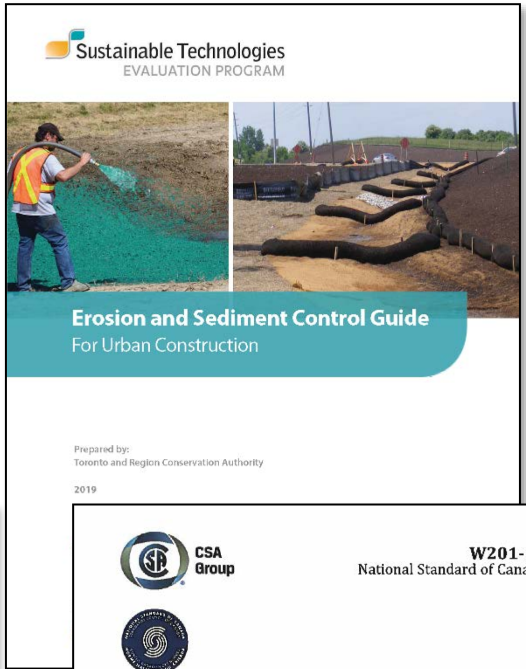
https://wiki.sustainabletechnologies.ca/wiki/Bioretention#Design_Variations

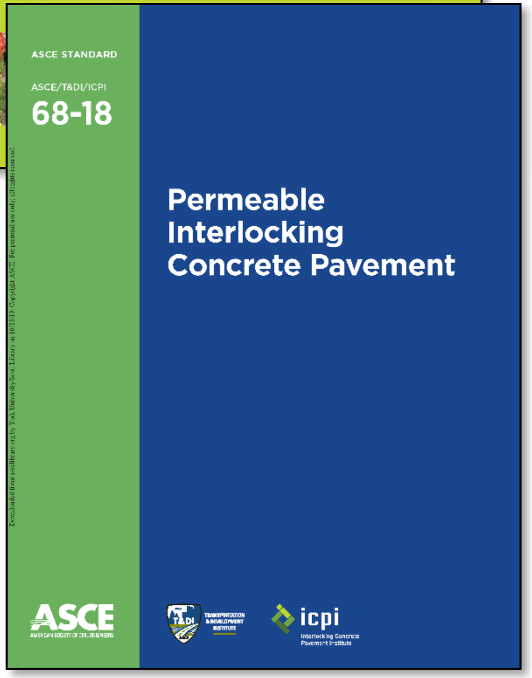
Enhanced guidance on construction, inspection and maintenance

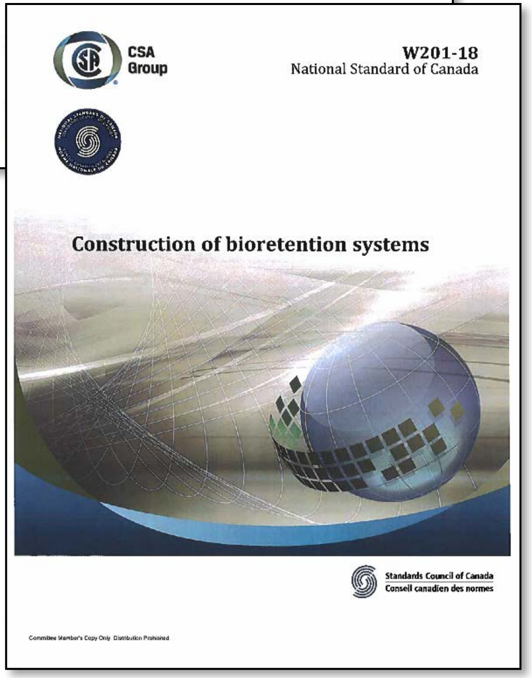












Sustainable Technologies
EVALUATION PROGRAM

Construction hub

Construction

Contents [hide]

CVC staff conducting a construction inspection at Kenollie Public School, Mississauga, Ontario. (Photo source: CVC, 2015)

Overview [edit]

LID techniques and technologies are new to many municipalities, consulting engineers, and contractors. STEP's construction guidance aims to give practical advice, specific to LID construction, to enable practitioners to successfully construct LID practices.

Common reasons LID projects fail at the construction stage are:

- lack of detail in designs and construction documents
  - Contractors can struggle to build LID facilities properly without enough detail in the contract drawings and without guidance and inspection throughout the construction process.
- lack of knowledge
  - Designers often do not understand the complexities of the construction process, and contractors often don't understand the purpose of LID practices or the technologies they employ.
- lack of effective erosion and sediment control during construction
  - LID practices are most vulnerable to sedimentation and clogging during their own construction or construction of adjacent lands.
- lack of planning and communication
  - Poor communication protocols and the pace and extent of construction may preclude proper inspections and certifications.

Published research corroborates STEP's experiences in the field (e.g., DelGrosso et al., 2019 [1]; LSRCA, 2011[2]; CWP, 2009[3]). Del Grosso et al. (2019) note that LID requires more considerations during construction compared to traditional stormwater management facilities, and that proper construction of is centered around thoughtful construction sequencing, ensuring all parties involved know their responsibilities, protecting soils and media from compaction and clogging, properly installing filter media and aggregate, and ensuring facilities are kept off-line until the entire drainage area is stabilized.

In short, successful construction of LID practices and treatment trains is dependent on proper training of contractors, project managers and inspectors to ensure they understand the functionality of the practices, the proper timing and sequencing of BMP construction as part of overall site activities, the use of flow diversion, erosion and sediment controls during construction, and the oversight needed to avoid common pitfalls.

https://wiki.sustainabletechnologies.ca/wiki/Construction

Inspections and maintenance hub

Inspections and maintenance

Contents [hide]

the content on this page and subsequent pages separated by LID practice are based on the Low Impact Development Stormwater Management Practice Inspection and Maintenance Guide, 2016[1] shown above. To read the guide in its entirety you can click the image above.

Overview [edit]

Integration of Low Impact Development (LID) best management practices (BMPs) into stormwater management (SWM) systems is widely advocated to better address the potential stormwater-related impacts of urbanization on the health of receiving waters. A substantial amount of guidance is available on the planning and design of LID BMPs (CVC & TRCA, 2010)[2] and their construction (CVC, 2012)[3] and some municipalities and conservation authorities commonly require them to be a part of new SWM systems.

However, even with sound design, LID BMPs may not provide the intended level of treatment if they are not installed properly or protected from damage during construction. Experiences with early applications have shown that failures are often due to:

- Practices not being constructed as designed or with specified materials
- Lack of erosion and sediment controls (ESCs) during construction; and/or
- Lack of rigorous inspection prior to assumption.

A 2009 survey of stormwater BMPs in the James River watershed (Virginia) by the Center for Watershed Protection found approximately half (47%) of the 72 BMPs deviated in one or more ways from the original design, or were receiving inadequate maintenance (CWP, 2009)[4]. Similar results have been revealed from surveys of stormwater detention ponds in Ontario (Drake et al., 2008[5]; LSRCA, 2011[6]), LID stormwater infrastructure in Virginia (DelGrosso et al., 2019 [7]), and international research reviews (e.g., Blecken et al., 2015 [8]),

https://wiki.sustainabletechnologies.ca/wiki/Inspections_and_maintenance

Updated content on life cycle costs

Bioretention
Construction and Life Cycle Costs

Step 1: LID Overview | Step 2: Design & Construction Estimates | Step 3: Operation & Maintenance Estimates | Step 4: Design & Cost Summary

Back End | Table of Contents | LID TTT Costing Equations

BIORETENTION OVERVIEW

Design Guidance

- Bioretention is an ideal technology for fitting functional vegetation into urban landscapes and treating runoff collected from nearby impervious surfaces.
- Components include: a 'filter bed' with filter media, storage layer of resovoir aggregate, planting and a finishing surface layer of mulch and/or stone.
- Additional components include an underdrain to remove excess water and soil additives to enhance pollutant removal.
- Tool defaults based on STEP recommendations:
  - Maximum drainage area to surface area ratio of 20:1
  - Default depth of 0.75 meters.
  - Default mulch depth of 75 millimeters.
  - An underdrain (minimum 200 mm perforated pipe) is only needed when native soil infiltration is less than 15 mm/hr or infiltration is percluded.

Bioretention cell capturing / treating runoff from adjacent parking lot. Kortright Centre, Vaughan.
Source: https://wiki.sustainabletechnologies.ca/images/b/be/IMG_2457_750X500.jpg

Tool Instructions and Assumptions

- **Green cells** are for mandatory user-input values. Do not leave green cells blank.
- **Purple cells** are where users can edit defaults. The defaults are based on STEP's LID Planning & Design Guide.
- **Red cells** indicate Tool conditions are not being met. Adjust user-input values in accordance with the error message.
- **Orange Cells** highlight the top 5 construction costs.
- Designs include pretreatment through stone diaphragms at curb inlets. Pretreatment through settling forebay and vegetated filter strip not included.
- The tool calculates costs for new designs and includes costs for contractor overhead and profit, material, delivery, labour, equipment (rental, operating and operator costs), hauling and disposal. Mobilization and demobilization costs not included. The tool adds 10% contingency and additional overhead.
- **Design and Engineering cost estimates are not calculated by the tool and must be supplied by the user.**
- Unit costs are based on 2018 pricing; the tool automatically adds inflation. See the Assumptions sheet for details.
- The cost of retrofitting is ~16% higher than the cost of new construction.
- Retrofit costs are included in the 'Costs Summary' section and can be added to the Total Construction Cost for increased accuracy.

For more information on design guidance, please review STEP's LID Planning and Design Guide at: www.wiki.sustainabletechnologies.ca
For further instructions on how to use the tool, please review the STEP Lifecycle Costing Tool User Guide.

User-Input | Editable Defaults | Design Error | Top 5 costs

STEP 2: DESIGN AND CONSTRUCTION ESTIMATES

SITE AND DESIGN INFORMATION	Default	Value	Units
User Inputs			
Drainage Area (DA)		2000	m²
Native Soil Infiltration Rate [1]		10	mm/hr
Design type [2]		Partial Infiltration	Unitless
Drainage period [3]		72	hours
BR surface area length to width ratio		10	Unitless
Project land value classification		None	Unitless
Design Defaults			
Max. drainage area to surface area (DA/SA) ratio [4]	20	20	Unitless
Instantaneous Rainfall Capture (Water Quality Design Event) [5]	25	25	mm
Filter Media Depth [6]	1	1	m
Ponding depth	0.2	0.2	m
Safety factor	2.5	2.5	Unitless
Porosity [7]	40	40	%
Mulch depth	0.075	0.075	m
Pea gravel depth	0.1	0.1	m
Gravel storage layer depth	0.92	0.7	m
Underdrain diameter	0.2	0.2	m
Filter media infiltration rate [8]	25	25	mm/hr

CONSTRUCTION COSTS	Value	Unit	Cost	Cost adjustment	Sales tax / HST (%)
Pre-Construction					13%
Test pits (2)	9.00	m³	$ 2,092.74	0%	
Infiltration tests (2 per test pit)	4.00	tests	$ 619.48	0%	
Stakeout of utilities	1.00	visit(s)	$ 635.91	0%	
Erosion and sediment controls:					
2" Submersible gas pump	3.00	days	$ 113.89	0%	
Silt sack in catchbasin	1.00	each	$ 85.63	0%	
Silt fence 2 m around excavation	125.54	m	$ 1,035.04	0%	
Value of project land	250.00	m²	$ -	0%	
Add additional costs if necessary			$ -		
Excavation					
Excavation	585.08	m³	$ 1,800.30	0%	
Loading	15%	% of excavation cost	$ 270.05	0%	
Hauling	18.00	hours	$ 4,018.08	0%	
Safety fencing 6 m around excavation	158.00	m (1 week rental)	$ 3,776.32	0%	
Trenching for pipe to sewer	6.00	m	$ 291.55	0%	
Add additional costs if necessary			$ -		
Materials and Installation					
Impermeable membrane	0.00	m²	$ -	0%	

Cost Adjustment:
Set to 0% if no adjustment is needed,
-100% to exclude cost completely,
>0% to increase cost,
<0% to reduce cost

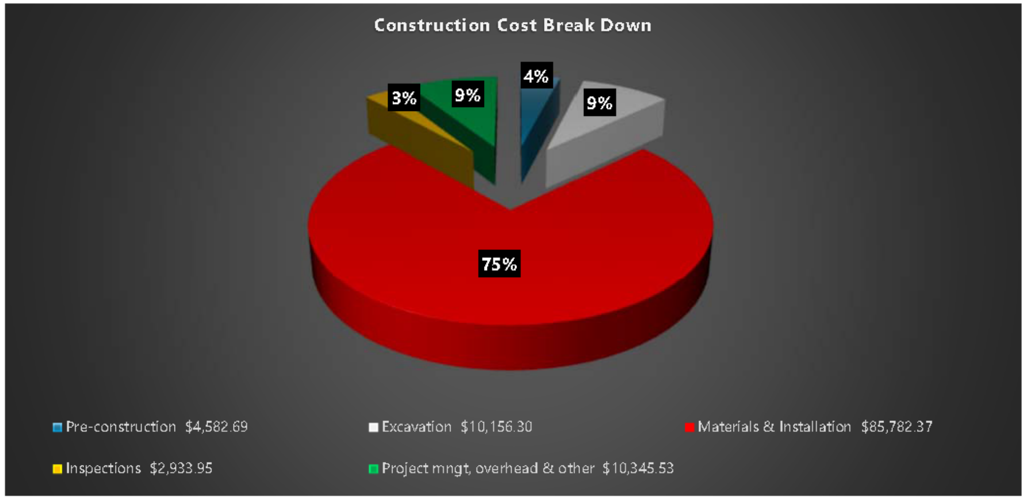
Introduction | TableOfContents | Bioretention | EnhancedSwale | VegFilterStrip | GreenRoof | InfiltrationChamber | InfiltrationTrench | PermeablePavers | PorousAsphalt | RainWHarvest | WetPond | DryPond | ...

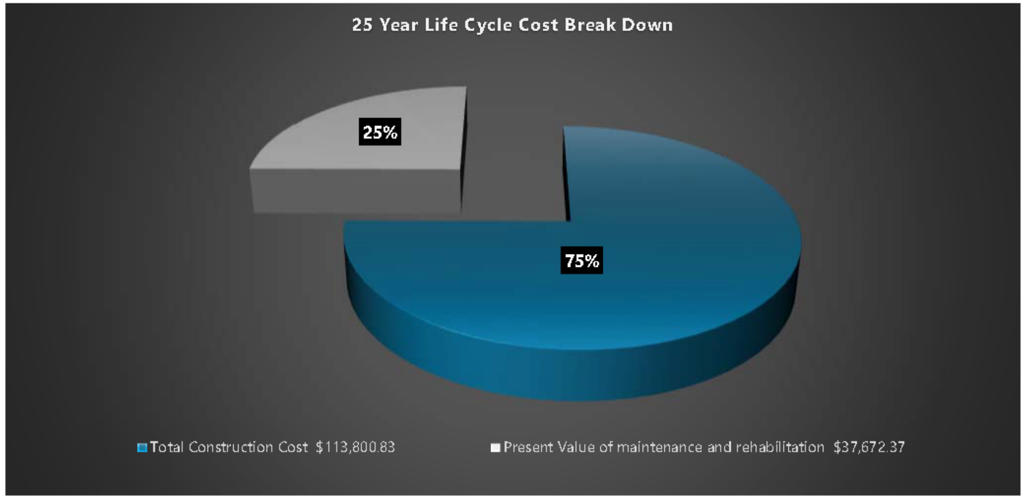
Updated content on life cycle costs

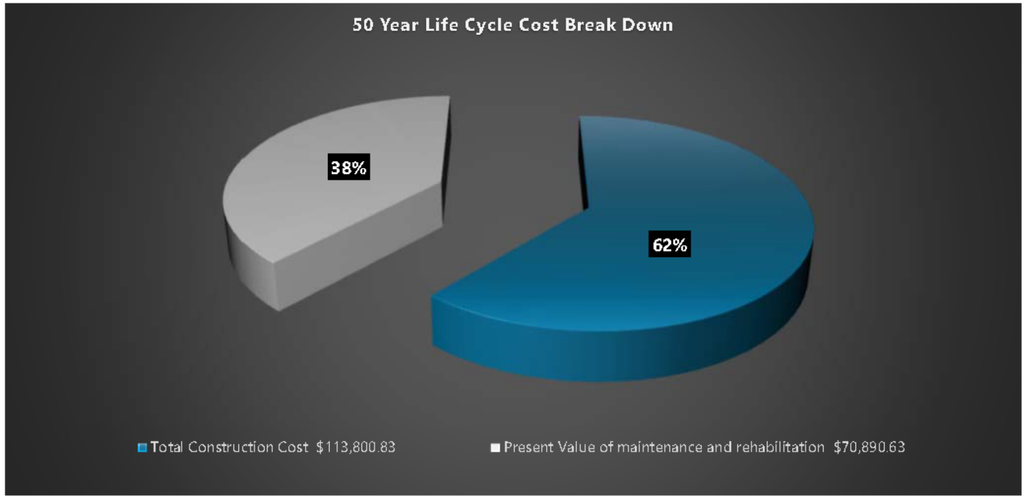
Bioretention, Partial Infiltration

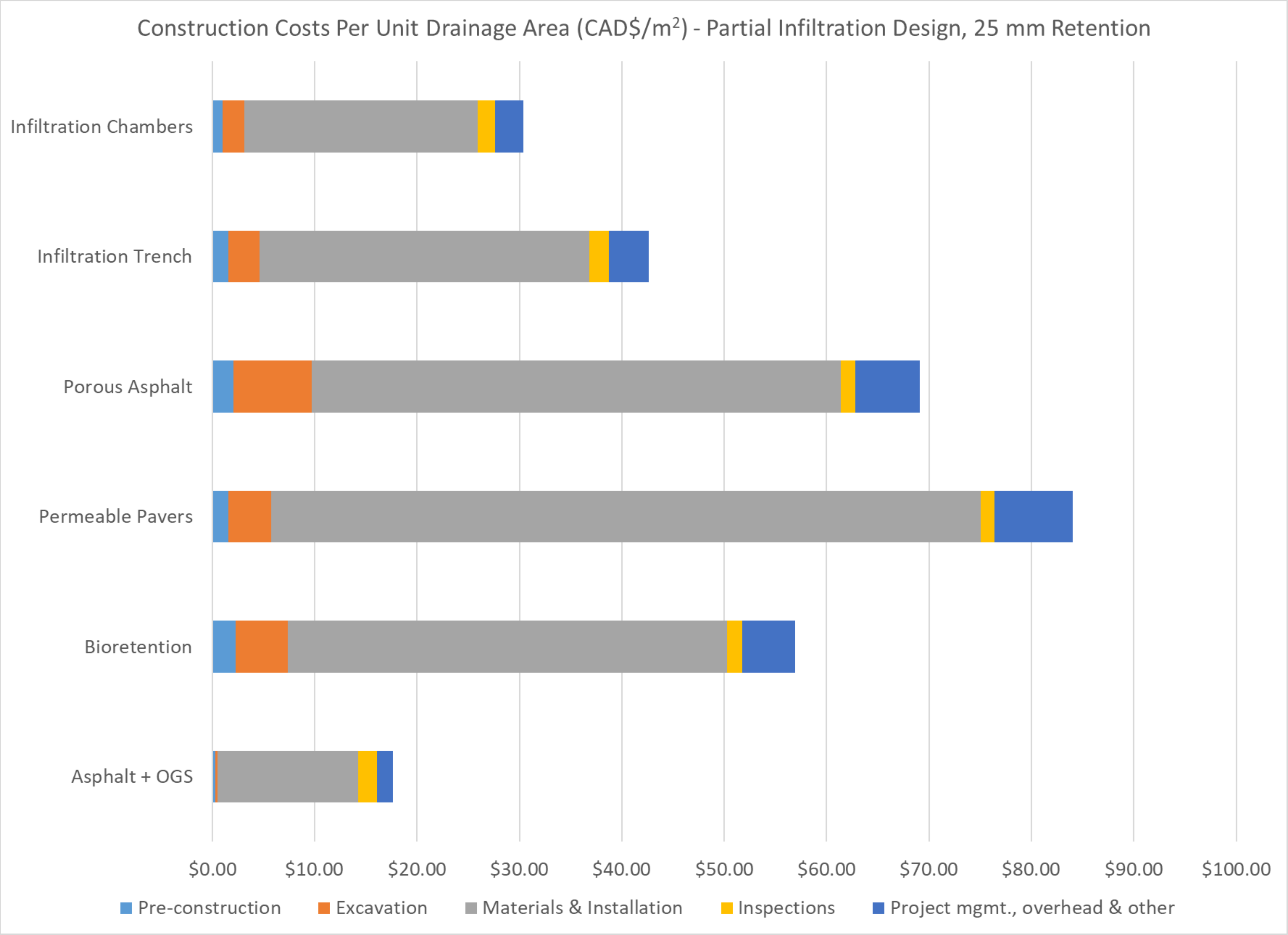
STEP 4: DESIGN SUMMARY	Value	Units
Drainage Area (DA)	2000	m^2
Native Soil Infiltration Rate	10	mm/hr
Surface Area	250.00	m^2
Design type	Partial Infiltration	unitless
Storage Volume	187.50	m^3

COST SUMMARY		Value
Construction Cost Break Down		
Pre-construction	$	4,582.69
Excavation	$	10,156.30
Materials & Installation	$	85,782.37
Inspections	$	2,933.95
Project mngt, overhead & other	$	10,345.53
Total Construction Cost	$	113,800.83
Life Cycle Totals		
50 Year Evaluation Period		
Present Value of maintenance and rehabilitation	$	70,890.63
Present Value of all costs	$	184,691.47
25 Year evaluation period		
Present Value of maintenance and rehabilitation	$	37,672.37
Present Value of all costs	$	151,473.20
Estimated Retrofit Cost		
Percentage of total cost		16%
Total construction cost with retrofit	$	132,008.97

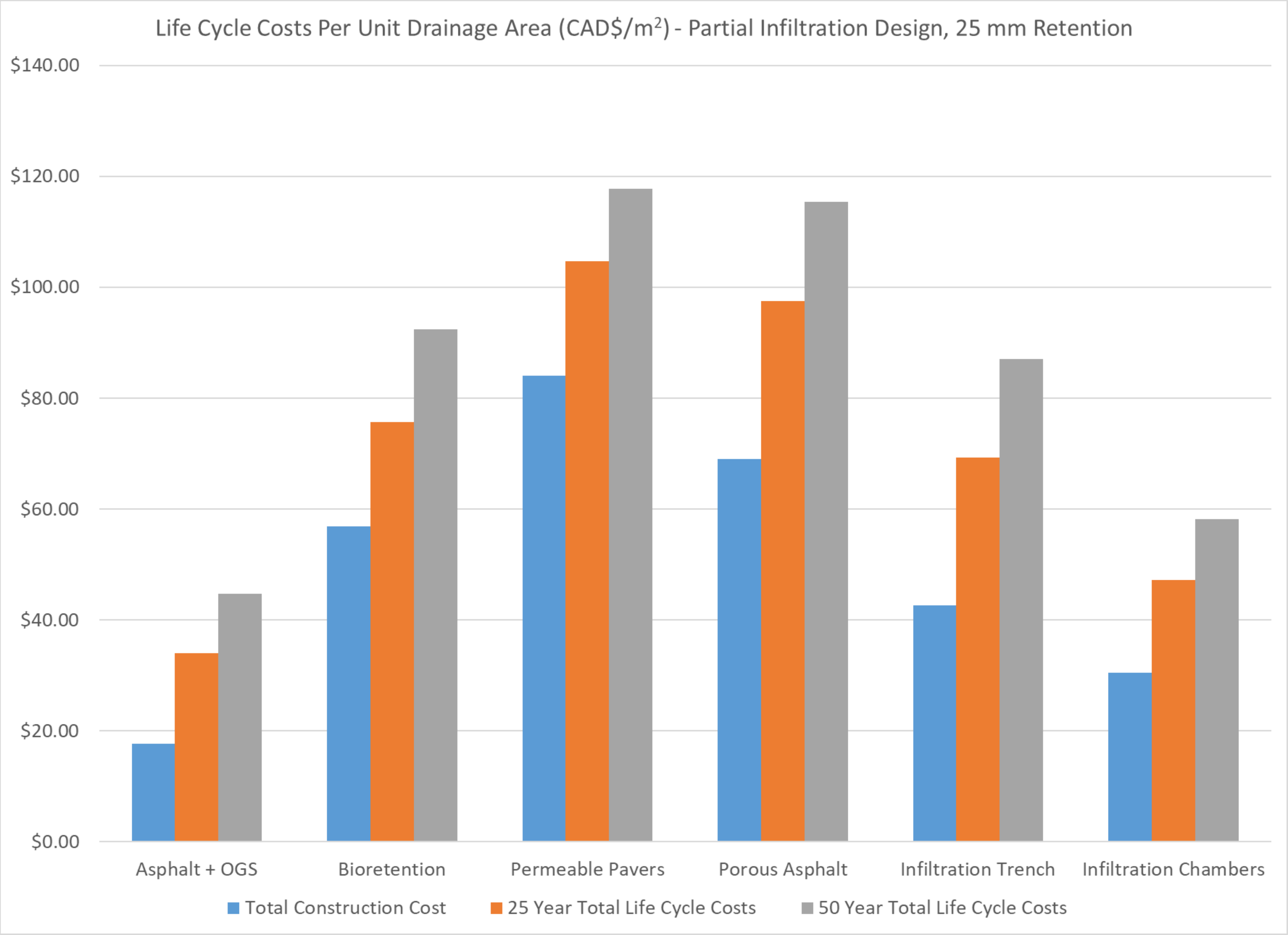




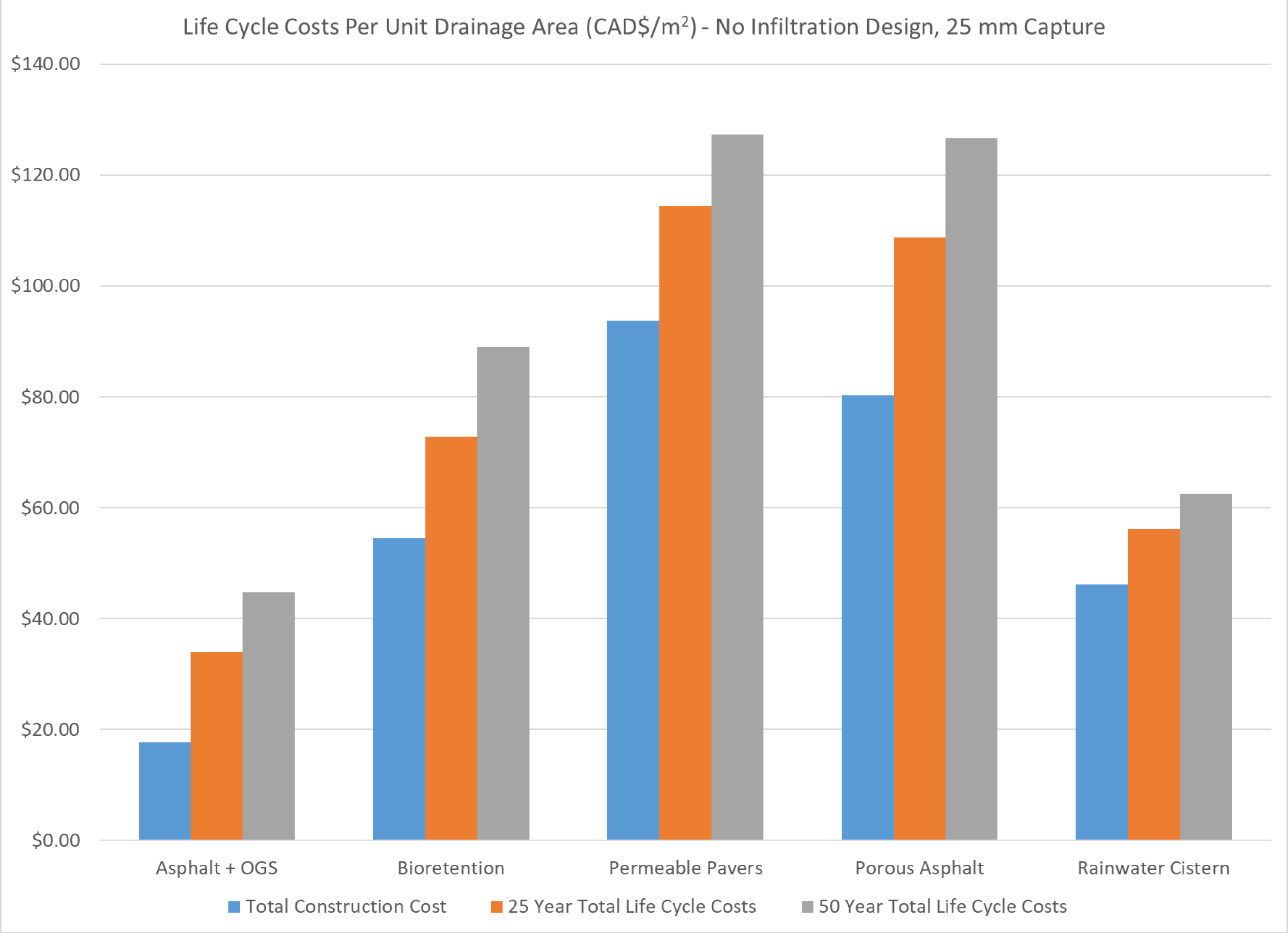




Construction Costs Per Unit Drainage Area (CAD$/m²) - Partial Infiltration Design, 25 mm Retention
Infiltration Chambers
Infiltration Trench
Porous Asphalt
Permeable Pavers
Bioretention
Asphalt + OGS
$0.00
$10.00
$20.00
$30.00
$40.00
$50.00
$60.00
$70.00
$80.00
$90.00
$100.00
Pre-construction
Excavation
Materials & Installation
Inspections
Project mgmt., overhead & other

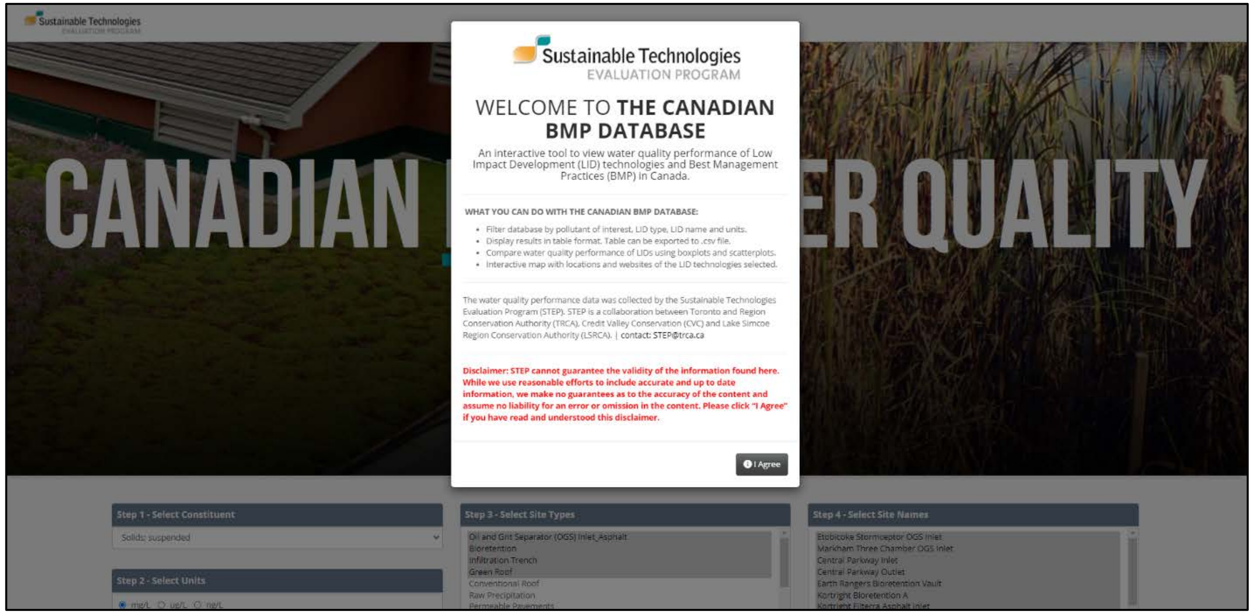


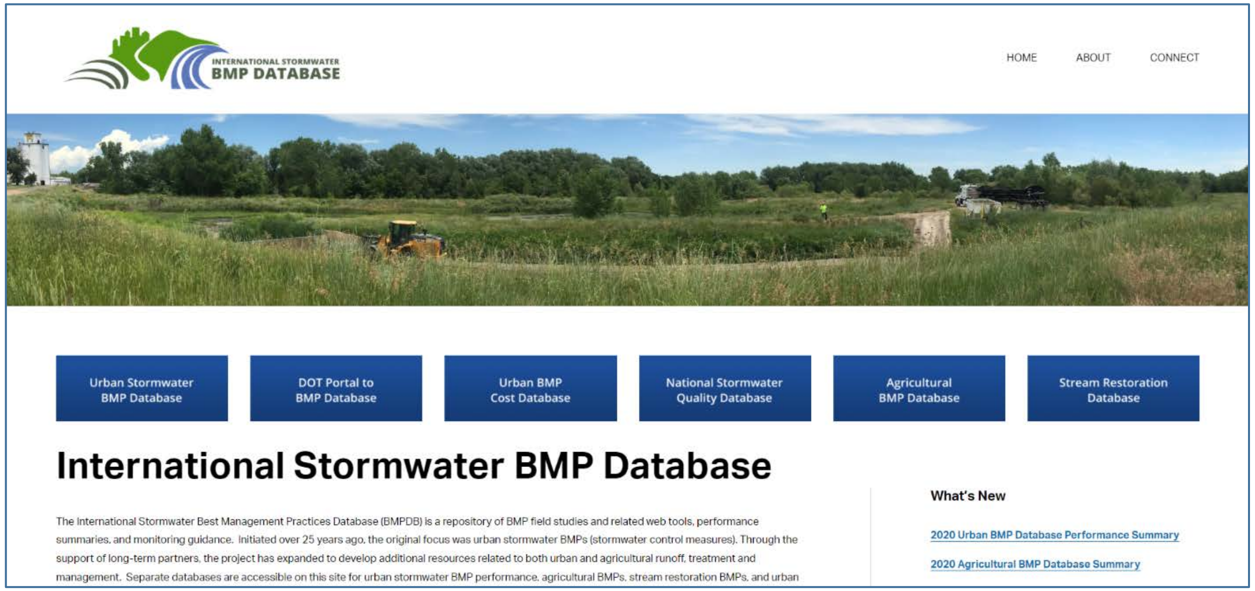
Life Cycle Costs Per Unit Drainage Area (CAD$/m2) - Partial Infiltration Design, 25 mm Retention
$140.00
$120.00
$100.00
$80.00
$60.00
$40.00
$20.00
$0.00
Asphalt + OGS
Bioretention
Permeable Pavers
Porous Asphalt
Infiltration Trench
Infiltration Chambers
Total Construction Cost
25 Year Total Life Cycle Costs
50 Year Total Life Cycle Costs


Life Cycle Costs Per Unit Drainage Area (CAD$/m2) - No Infiltration Design, 25 mm Capture
$140.00
$120.00
$100.00
$80.00
$60.00
$40.00
$20.00
$0.00
Asphalt + OGS
Bioretention
Permeable Pavers
Porous Asphalt
Rainwater Cistern
Total Construction Cost
25 Year Total Life Cycle Costs
50 Year Total Life Cycle Costs

Enhanced content on treatment performance

- Statistical analyses of **Canadian BMP Water Quality Database** records for Total Suspended Solids (TSS) and Total Phosphorus (TP) event mean effluent concentration (STEP 2022);
- Compared to Canadian and Ontario receiving water protection guidelines or objectives;
- Recent local and international research literature (e.g., STEP Technical Briefs, International Stormwater BMP Database 2020, recent research review articles);
  - Bioretention
  - Green Roofs;
  - Permeable Pavements;
  - Grass Swales.





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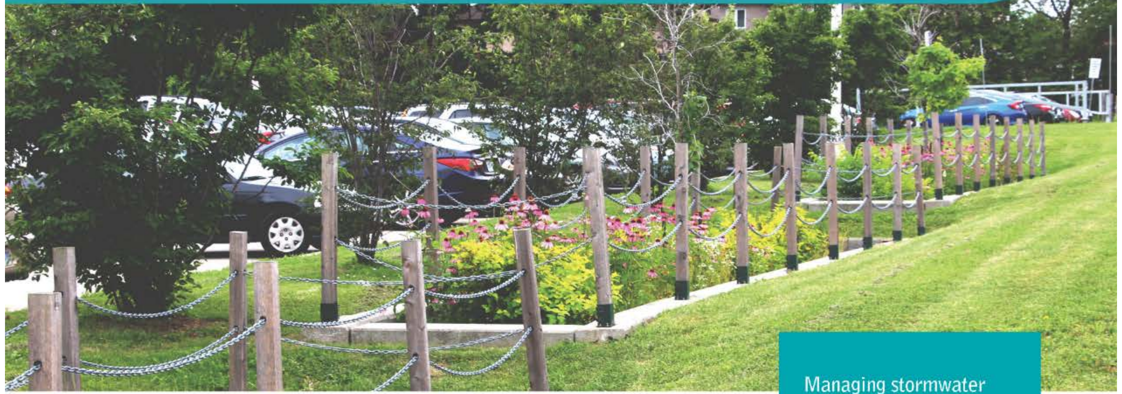
TECHNICAL BRIEF

Comparative Performance Assessment of Bioretention in Ontario



This study compares the performance of nine different bioretention facilities monitored by Toronto and Region Conservation Authority (TRCA) and Credit Valley Conservation (CVC) in the Greater Toronto Area. The monitored facilities of varying shape, size and design were constructed to manage runoff from parking lots, public roads and residential areas. Key performance variables assessed included peak flows, runoff volume, water quality, water temperature and functional characteristics. Results showed runoff volume reductions for the seven systems not wrapped in an impermeable liner of between 60 and 92%, despite the presence of fine textured native soils. The two lined bioretention cells reduced runoff volumes by 15 and 34%. Load reductions of total suspended solids across all nine facilities ranged from 73 to 99%. The primary design and catchment characteristics explaining site to site variations in water quantity and quality control were the size of the facility relative to its drainage area and the capacity of native soils to infiltrate runoff. The influence of plant surface cover and filter media type and depth on overall performance was not discernable.

The terms bioretention and rain gardens are often used interchangeably. While the two have similar functional characteristics, bioretention often treats larger areas than rain gardens, and is engineered to meet site specific goals for pollutant removal, runoff control and plant health.

Managing stormwater runoff with bioretention has become more common in Ontario over the past decade, with new facilities appearing on city street corners, along residential roads, in commercial parking lots and on front lawns. While design guidelines for bioretention have been developed based on monitoring and research across North America, varying perspectives on how bioretention should be configured to meet different site specific objectives has led to a wide diversity of field designs and applications.

Table 1. Study area catchment characteristics.

Site Name	Location	Land Use	Time of Year monitored	Effective Impervious to Pervious Ratio	Cover type	Underlying native soils	Filter media texture
Kortright Centre (S)	Vaughan, ON	Parking lot	Apr - Nov	9:1	Shrubs and herbaceous plants	Silty clay	Sandy
Kortright Centre (N)	Vaughan, ON	Parking lot	Apr - Nov	10:1	Shrubs and herbaceous plants	Silty clay	Sandy
Honda Canada Campus*	Markham, ON	Parking lot	Apr - Nov	9:1	Trees, shrubs with gravel inlet	Silty clay	Gravel
Earth Rangers at Kortright Centre	Vaughan, ON	Parking lot	Year round	11:1	Shrubs, herbaceous plants and cobbles	Silty clay	Clay, silt, sand mix
Seneca College	King City, ON	Parking lot	Year round	10:1	Shrubs and plants	Silty clay	Garden loam
County Court (CC) Blvd.**	Brampton, ON	Residential road	Year round	5:1	Shrubs, plants and stone	Clayey silt	Sandy
Community of Lakeview	Mississauga, ON	Residential road	Year round	Approx. 10:1	Shrubs, plants and grass	Fine textured	Sandy
IMAX Corporate Office	Mississauga, ON	Parking lot	Apr - Nov	30:1	Shrubs and plants	Fine textured	Sandy
Elm Drive	Mississauga, ON	Residential road	Apr - Nov	6:1	Shrubs and plants	Fine textured	Sandy

*A smaller version of the Honda Canada Campus biofilter was reconstructed at the Kortright Centre for Conservation in Vaughn, ON in order to evaluate the stomwater benefits of the practice. The hydrologic performance of several biofilters connected in series were evaluated at the Honda Canada Campus site in Markham, ON. **The County Court Blvd bioretention was lined to prevent infiltration of water onto a water main below the system.

INTRODUCTION

An increasing number of bioretention facilities in Ontario have been, or are currently being monitored for stormwater management performance and other co-benefits. Each bioretention facility is designed and configured to meet specific site objectives and performance criteria. This study compares stormwater monitoring data from nine facilities to assess overall effectiveness of the practice and evaluate relationships between practice design features and performance.

STUDY SITES

The nine study sites selected for investigation are presented in Table 1. The sites consisted of plant or plant/cobble surface covers with relatively sandy filter media and low permeability native soils. The effective impervious to pervious ratio (I:P ratio) represents the size of the drainage area relative to the area occupied by the facility. Since impervious areas (e.g. roads, roof) generate more runoff than pervious areas (e.g. gardens, lawns), they are assigned a larger area weight in the drainage area calculation. Table 1 shows that monitored installations had a wide range of I:P ratios. Design guidelines in Ontario suggest a maximum I:P ratio of 20:1.

The Honda Canada Campus biofilter study consisted of two parts. The hydrologic performance was monitored at the site, and the water quality component was monitored at the Kortright Centre for Conservation through a scaled down version of the biofilter system, which was the primary LID feature on the site. The biofilter differs from other bioretention facilities in that runoff does not drain onto the planted surface, but instead drains through a gravel inlet into the gravel storage reservoir below the facility. Plants and trees on top of the trench access the moisture from above.

STUDY FINDINGS

Bioretention facilities that were not lined to prevent infiltration into the native soils were found to reduce runoff volumes by 60 to 92% over the monitoring period (Figure 1). In all cases, these large volume losses occurred despite the presence of fine textured native soils (hydrologic C type soils). On an individual event basis, the event size was found to exert a significant impact on volume reductions. That is, rainfall events less than 10 mm generated very little runoff while larger rainfall events, greater than 30 mm, generated considerably more runoff. In the latter case, a portion of the inflows were often bypassed through the surface overflow drains, either because the infiltration capacity of the filter media was exceeded or available storage in the facility was insufficient to contain all of the runoff. During the events monitored, overflows typically accounted for less than 5% of total flow volumes routed through the facilities.

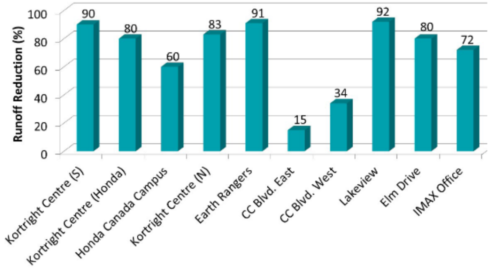
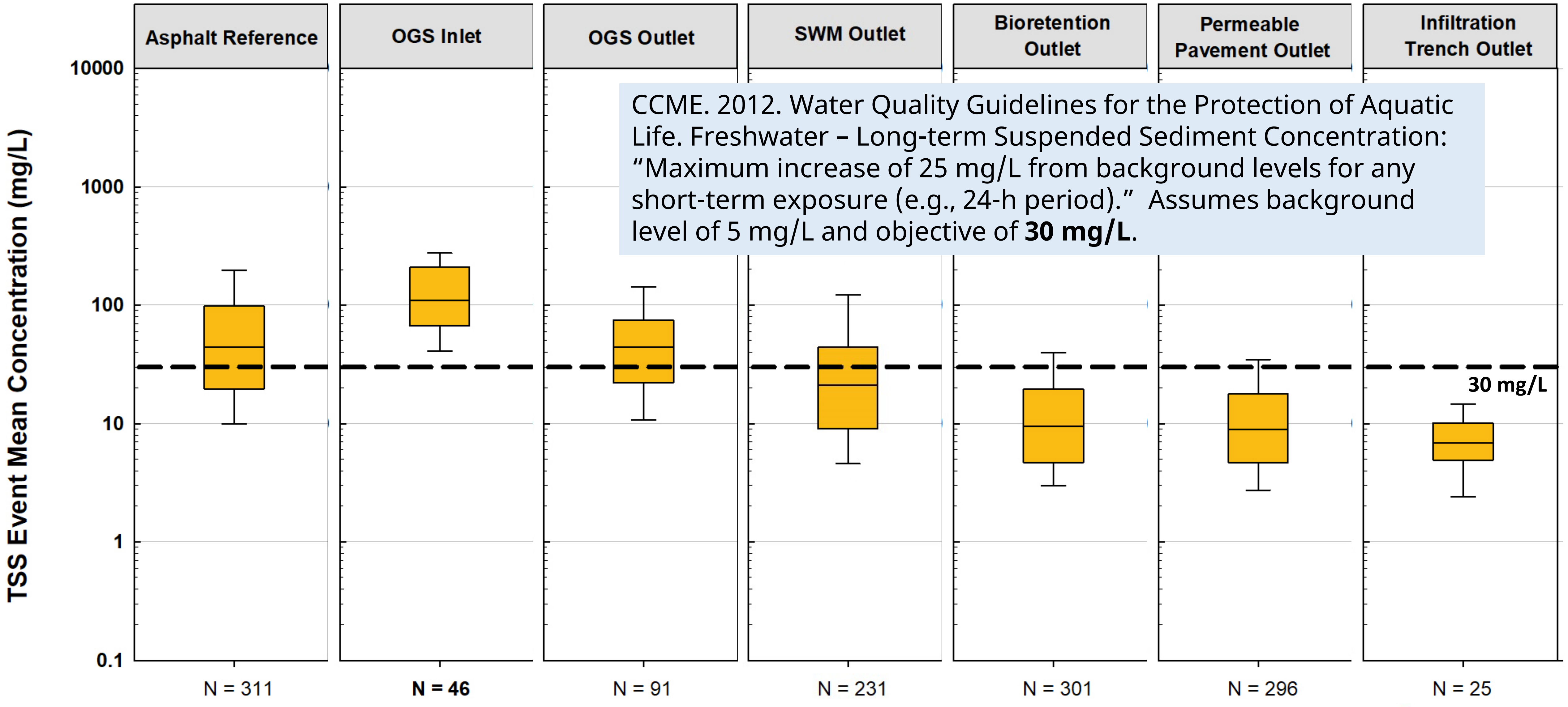


Figure 1. Runoff volume reductions for monitored events

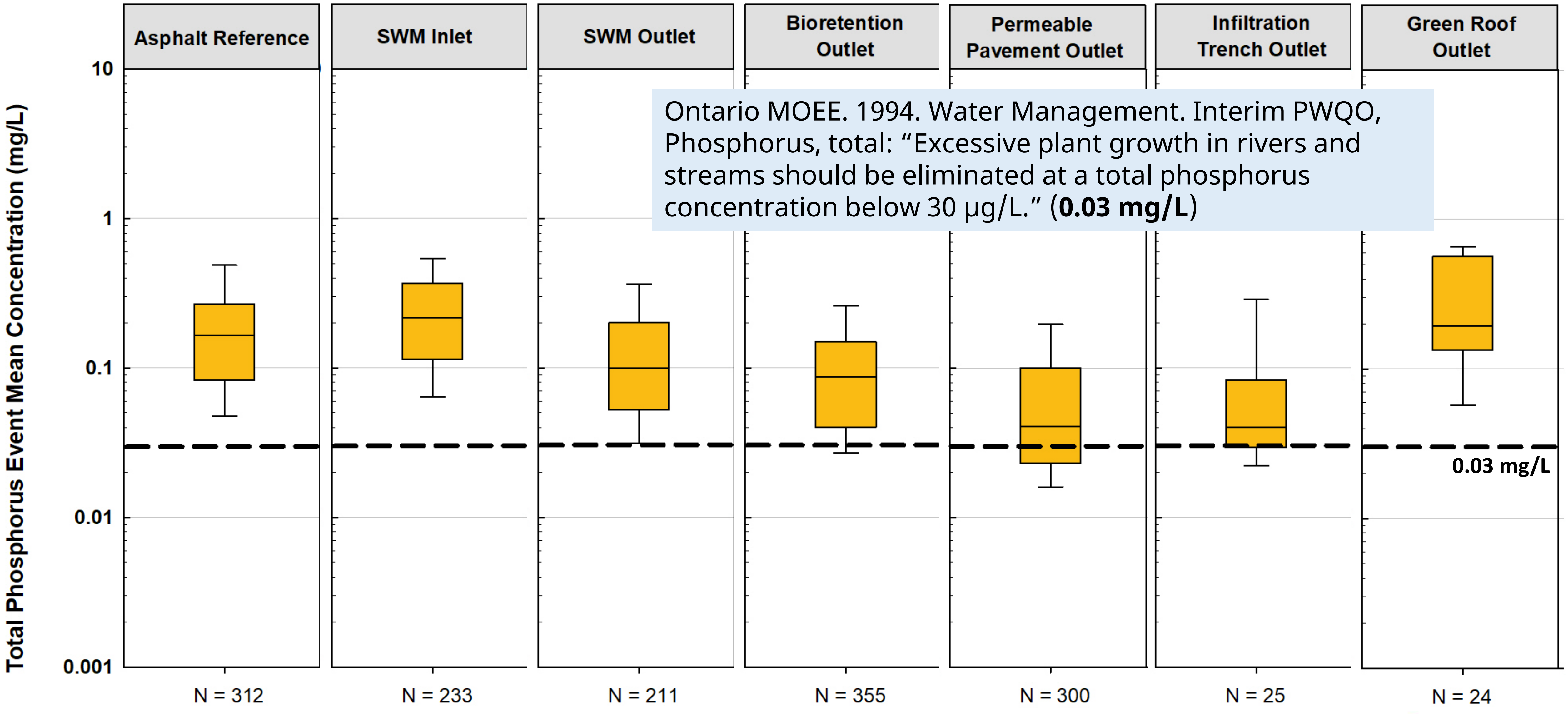
https://sustainabletechnologies.ca/app/uploads/2019/10/STEP_Bioretention-Synthesis_Tech-Brief-New-Template-2019-Oct-10.-2019.pdf

Total Suspended Solids (TSS) Effluent Concentration



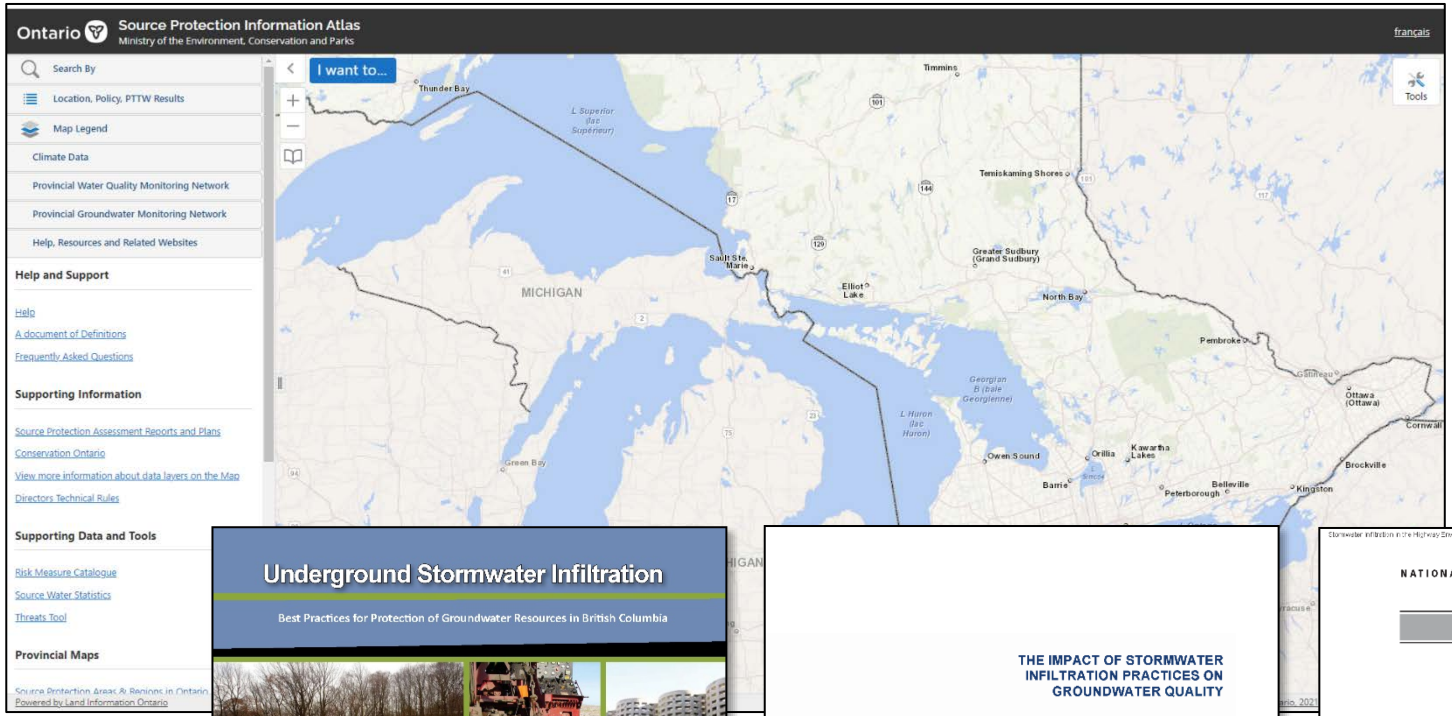
CCME. 2012. Water Quality Guidelines for the Protection of Aquatic Life. Freshwater – Long-term Suspended Sediment Concentration: “Maximum increase of 25 mg/L from background levels for any short-term exposure (e.g., 24-h period).” Assumes background level of 5 mg/L and objective of **30 mg/L**.

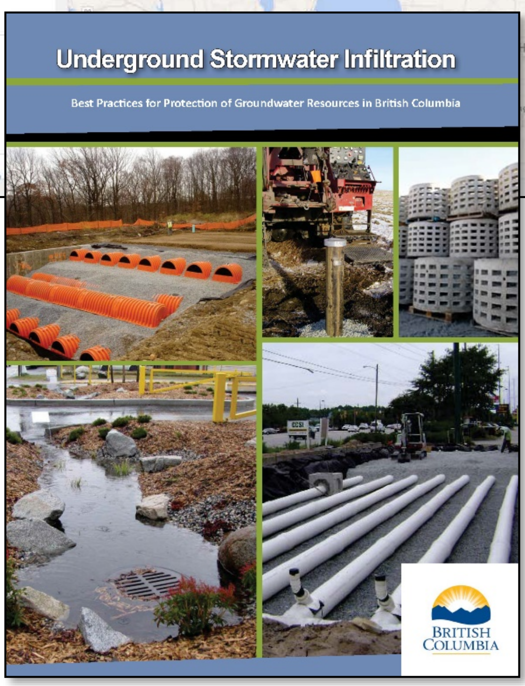
Total Phosphorus (TP) Effluent Concentration

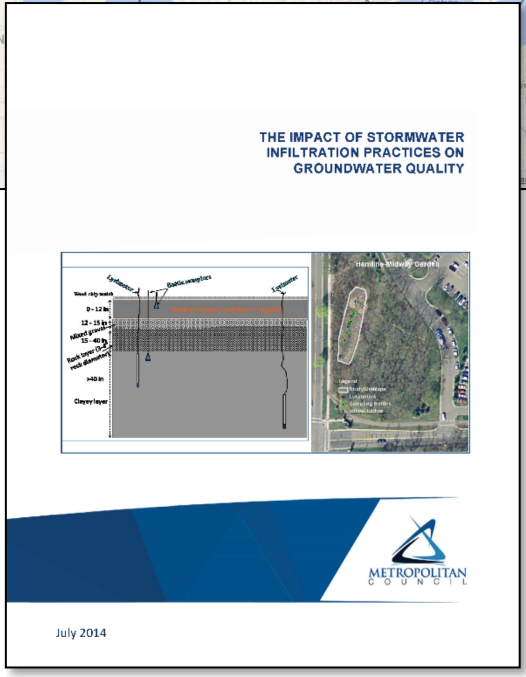


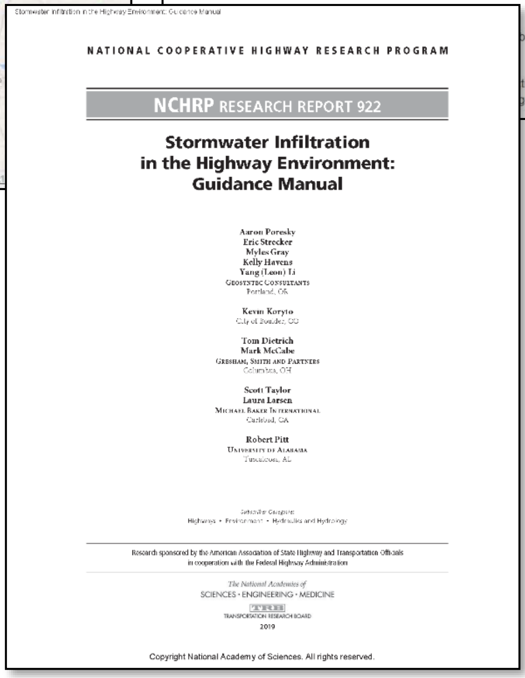
Ontario MOEE. 1994. Water Management. Interim PWQO, Phosphorus, total: “Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 30 µg/L.” (**0.03 mg/L**)

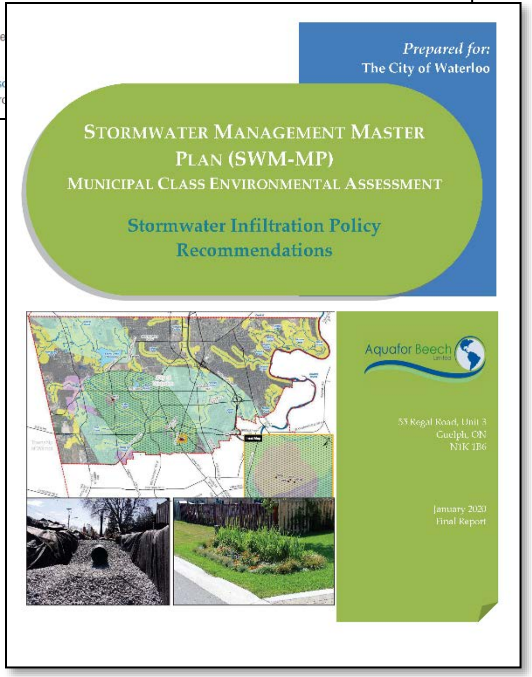
Enhanced content on drinking water source protection











Source Water Protection page

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Source Water Protection

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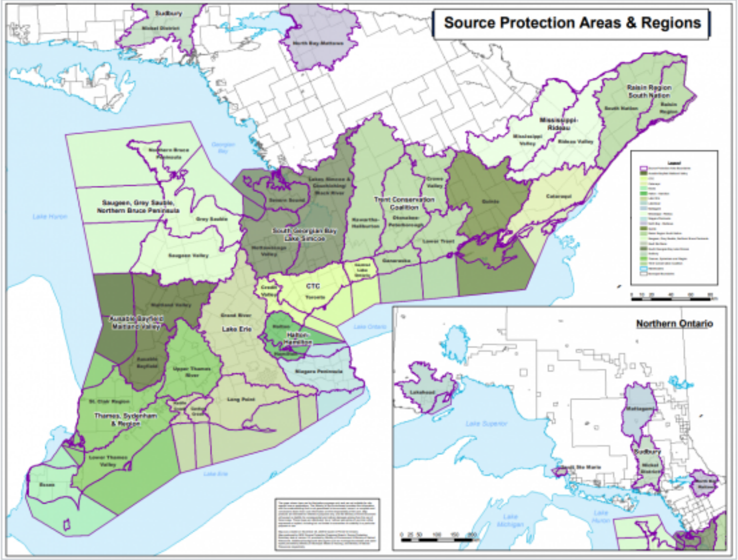

Image of the 19 Source Protection Regions (SPRs) and Source Protection Areas (SPAs) in Ontario (Conservation Ontario, 2022)[1]. Visit the map link here for a higher resolution image.

Overview [edit]

In response to the Walkerton tragedy in May of 2000, where 2,500 residents of the town fell ill due to ingesting high levels of E.coli bacteria and 7 individuals died due to poor monitoring and maintenance of the drinking water system, the Province of Ontario enacted new rules and safeguards to ensure drinking water sources are adequately protected. Following an inquiry into the Walkerton tragedy, Justice O'Connor made over 120 recommendations to better protect the province's drinking water, which have formed the foundation of the province's source water protection framework. The first of the Walkerton Inquiry recommendations was that drinking water should be protected by developing watershed-based source water protection plans.

Source Water Protection In Ontario [edit]

The Clean Water Act requires municipalities to protect their drinking water sources and supplies through prevention, by developing collaborative, watershed-based source water protection plans.[2]

> *The Clean Water Act defines source water protection areas and source water protection regions as follows:*
>
> - ***Source Protection Region (SPR)**: Encompass one or more source protection areas (e.g., Credit Valley-Toronto and Region-Central Lake Ontario, or "CTC"*

https://wiki.sustainabletechnologies.ca/wiki/Source_Water_Protection

Salt page

Salt

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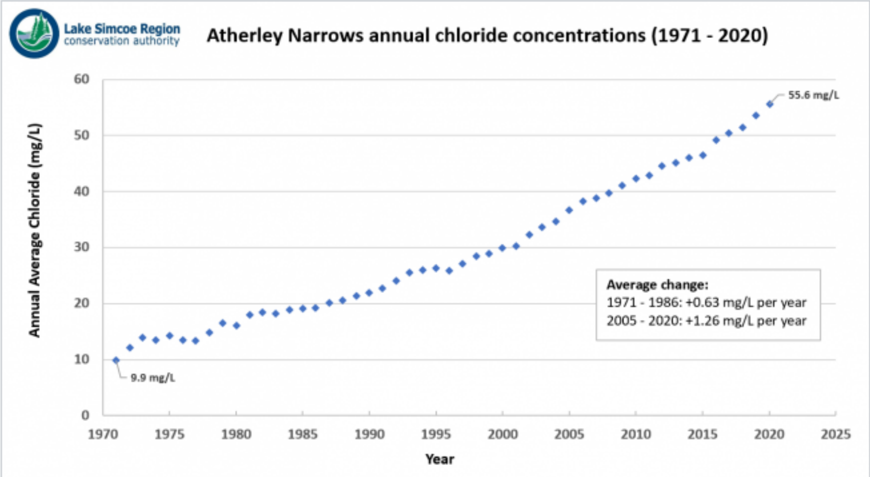

A graph showing increasing average levels of chloride found in Atherley Narrows, (a rural sampling location, between Lake Couchiching and Lake Simcoe), over the past few decades, due in part to increased use of rock salt in parking lots, roadways and commercial and residential properties. From 2005 - 2020 the amount of chloride increase per year has doubled when compared to 1971 - 1986 (1.26 mg/L per yr. vs. 0.63 mg/L per yr.) (LSRCA, 2021). It is estimated that by 2120 the average level of chloride within the the Lake Simcoe watershed will exceed the 120mg/L guideline set by CWQG. (LSRCA, 2018)[1]

Overview [edit]

Between 5 and 7 million tonnes of salt is applied every year in Canada for winter maintenance of roads and other paved surfaces, making it one of the most ubiquitous contaminants in urban environments. Canadians spend over $1 billion in winter maintenance costs to clear snow/ice on public and private roads, parking lots and sidewalks, this includes the use and application of greater than 5 million tonnes of rock salt for both deicing and anti-icing operations (Hossain et al., 2015)[2]. While the use of salt is essential to ensure public safety, there is a growing concern regarding the large quantities of salt (mainly chloride ions), being released to the environment.

$NaCl^-$ is the most common de-icer applied for winter maintenance, comprised of 40% sodium and 60% chloride. Sodium chloride rock salt is often treated with liquid $MgCl_2$ and $CaCl_2$ to reduce the effective temperature range of salts. Liquid brines comprised of $NaCl^-$, $MgCl_2$ and $CaCl_2$ or a combination of these products are increasingly being used on roads for anti-icing to help reduce the amount of rock salt used and lower overall operations costs.

Impacts on the Environment, Human Health and Built Infrastructure [edit]

While salt is needed to keep roads safe in the winter, it is highly corrosive and toxic to freshwater wildlife at relatively low concentrations. Some of the impacts of salt on infrastructure, human health and the environment include the following:

Freshwater wildlife [edit]

Just as we depend on air with the right makeup of oxygen, freshwater species – like fish, frogs, mussels, salamanders and zooplankton – need water with the right balance of chloride to survive. Having adapted to low levels of chloride in their habitats, increased levels begin to disrupt their basic functions – such as regulating their water content (osmoregulation) and breathing. Studies have shown widespread effects of salt on ecosystems at all trophic levels from biofilms to fish species. Specific effects vary based on exposure concentrations, and may include reductions in fecundity, size, shape, growth and abundance (Hintz and Relyea, 2019)[3]

Vegetation [edit]

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Nutrients page

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Nutrients

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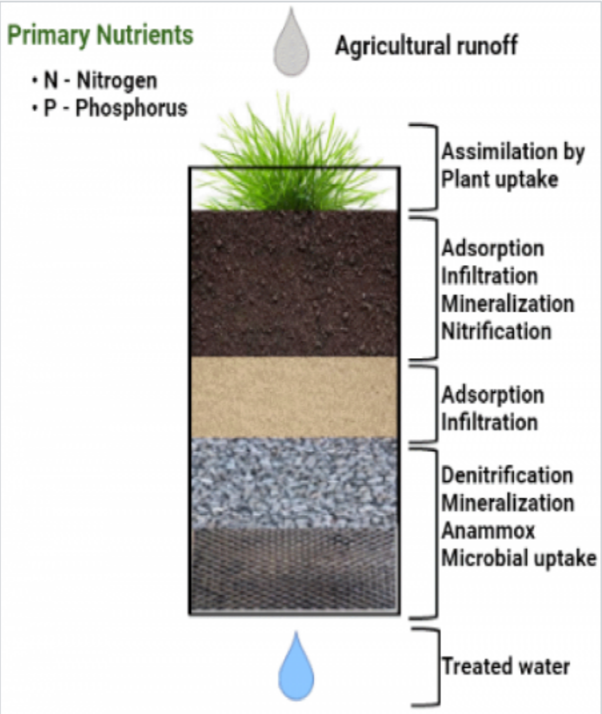

The profile view of a bioretention feature with associated zones and the processes used to remove excess nitrogen and phosphorous inputs out of incoming overland water from agricultural lands (Photo Source: Osman, et al. 2022)[1]

Overview [edit]

Nutrients are an essential part of life, however excess amounts of them can harm the environment. Anthropogenic activities can lead to such excessive amount of nutrients in runoff and cause degradation of receiving waters. Phosphorus and Nitrogen are the main nutrients of concern in stormwater runoff. This page provides information on the sources of nutrients, the issues caused by their excess amounts, and strategies to manage them.

Nutrient pollution [edit]

The primary concern with excess amounts of nutrients is eutrophication (U.S. EPA 1999[2]). Eutrophication is the process of excessive algae growth due to abundance of nutrients that can cause hypoxic condition in water. Excessive algal growth can cover the surface of water and prevent light penetration. Without light, the desirable aquatic plants die off. The eventual decay of aquatic plants and algae, consumes the dissolved oxygen in the water and creates hypoxic condition that can kill fish and other aquatic animals.

Nutrient pollution has been noted as a critical environmental, public health, and economic concern in Canada, Great Lakes, Lake Winnipeg, Lac St. Charles, Lake Simcoe and other water bodies (CWN, 2017[3]). Nutrient pollution can cause environmental imbalance, pose a public health risk for drinking water (USEPA, 2009[4]) and swimming, as inhalation of algae by swimmers or pet can cause hypoxic condition. It can also affect the economy by harming fisheries, tourism, recreation, and increase the treatment cost of drinking water. Historical algal bloom in the Lake Erie during 1960s caused a substantial decline of native aquatic species (CWN, 2017[3]). In 2015 more than 5,000 km^2 of Lake Erie was covered by algal blooms rendering the water unsuitable for drinking for residents of Pelee Island, Ontario and Toledo, Ohio (CWN, 2017[3]). In 2011 and 2014, severe nutrient pollution in this lake caused service interruption, equal to $71 million and $65 million USD (Bingham, Sinha, & Lupi, 2015[5]). Reports of nutrient pollution are increasing across Canada causing more beach closures and decline in water quality and fisheries (CWN, 2017[3]).

Excessive algal growth requires both phosphorus and nitrogen. While in some environments nitrogen is considered to be the limiting nutrient that controls such growth, phosphorus has been considered as the main limiting factor in most freshwaters (Howarth & Marino, 2006[6]; Schindler et al., 2016[7]). Therefore, controlling the load of phosphorous leaving a sub-watershed can reduce the chances of nutrient pollution in receiving surface waters. Formation of policies such as Lake Simcoe Phosphorous Offsetting Policy (LSPOP) are examples of such an approach. LSPOP requires a Zero Export Target where all new developments should control 100% of phosphorus from leaving the property (LSRCA, 2021[8]).

In addition to contaminating surface waters, abundance of nutrients can also contaminate the ground waters. Contrary to surface waters, nitrogen is the primary nutrient of concern regarding groundwater quality. Hobbie, et al. (2017[9]) reported that only 22 % of phosphorous is retained within its watershed, while the same estimated for nitrogen is 80%. Therefore, most of the nitrogen is leached in the groundwater or transformed through denitrification. Phosphorus retained in the watershed is often in particle form. Therefore, it

https://wiki.sustainabletechnologies.ca/wiki/Nutrients

Phosphorus page

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Phosphorus

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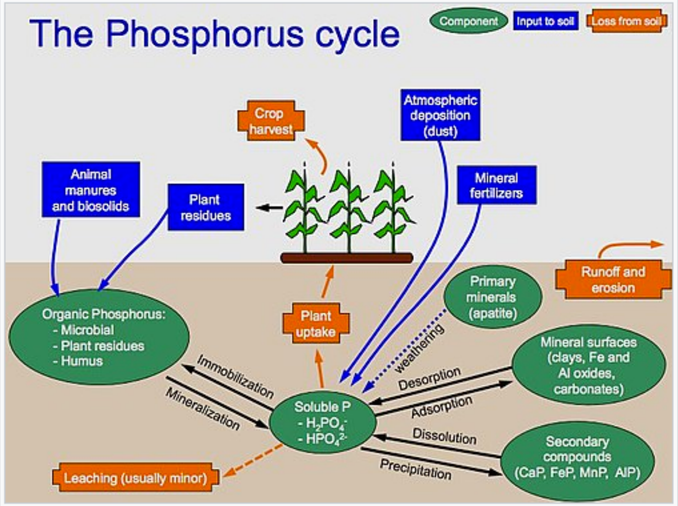

Phosphorus Cycle from Wikimedia Commons

Phosphorus in stormwater [edit]

Phosphorus in stormwater exists in both particulate and dissolved forms and is often explained in terms of total phosphorus (TP) and orthophosphate (–PO_4^{3-}). Total phosphorus is the sum of particulate and dissolved phosphorus and contains both organic and inorganic forms. Particulate phosphorus is often associated with solids and sediments. Dissolved phosphorus consists of mainly inorganic orthophosphate and organic phosphorus. Orthophosphate meanwhile indicates the bioavailable phosphorus.

Phosphorus in stormwater is commonly considered to be primarily available in particulate form. While most studies reported majority of phosphorus (~55%) in particulate form (Maestre and Pitt 2005[1]; Erickson et al, 2012[2]) in some cases the dissolved form may explain up to 90% of the total phosphorus (Erickson et al. 2007[3]; Kayhanian et al. 2012[4]).

Phosphorus levels in stormwater [edit]

The total phosphorus concentrations in stormwater runoff depend on the type of land use and range in 0.16-0.46 mg/L (Maestre and Pitt 2005[1]). Stormwater features should reduce these nutrient concentrations before reaching receiving streams and lakes. Environment Canada (2004[5]) indicates a range of 0.001-2 mg/L (1-200 µg/L) for concentration of total phosphorus in natural waters, while the same range for uncontaminated freshwaters is within 0.01-0.05 mg/L (10-50 µg/L). Within lakes and rivers, trigger concentration ranges are identified and used internationally to explain trophic status of these waters. Based on these triggers, Environment Canada has identified the acceptable range of nutrients as 0.01-0.035 mg/L (10-35 µg/L). Given the flow of water within streams and capacity to flush out pollutants, rivers can maintain higher phosphorus loads than lakes without alterations of community composition and biomass (Environment Canada, 2004[5]). Stormwater features often drain into streams and therefore a similar outflow concentration ranges for total phosphorus is expected from those.

Test methods to estimate phosphorus levels in water & soil [edit]

Phosphorus concentrations mentioned above relate to the phosphorus content in water. Depending on the LID type, phosphorus exists in the soil/media as well. Such LIDs include, bioretention, enhanced grass swales, vegetated filter strips, absorbent landscapes, and green roofs. The methods used for phosphorus concentration estimation in both water and soil are summarized below.

Measuring the phosphorus concentrations in stormwater is important for performance evaluation/inspection and ensuring that outflow to the streams meets the mentioned concentration requirements. For performance evaluation, both inflow and outflow of a stormwater feature should be sampled. Sampling of just outflow reveals the concentrations entering streams and checks if they meet the requirements. There are several sampling methods, decision on the most appropriate method to use, depends on the sampling objectives and budget limitations.

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Stormwater Thermal Mitigation page

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Stormwater Thermal Mitigation

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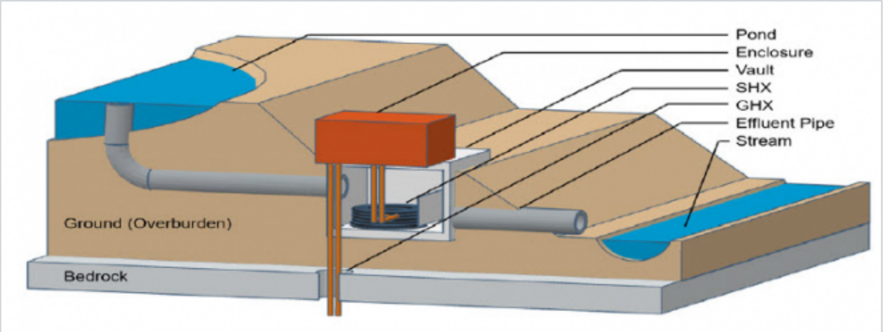

A simplified 3D cross section of a geothermal cooling system used in a SWM pond in Brampton, Ontario. The system contains a closed hydronic circuit where piping connected a surface water heat exchanger (SHX) to a ground heat exchanger (GHX). A pump continuously circulates a cool hydronic fluid around the circuit. The SHX (placed in the path of the pond outflow) has the water pass through it. The hydronic fluid circulating through the SHX is cooler than warm stormwater outflows. This temperature difference forces heat energy from the stormwater into the hydronic fluid, thus cooling the stormwater leaving the pond. Read more about the system Here. Photo Source: (Janssen and Van Seters,2022.)[1]

Overview [edit]

Streams draining urban areas are often much warmer than those draining natural ones due to changes in surface cover and hydrology. Urbanization increases stream temperatures by decreasing riparian shading and replacing natural landscapes with hard, dark-coloured pavements and roofs that absorb and store heat from the sun. The added impervious cover increases the volume of heated runoff while at the same time reducing discharge of cool groundwater to streams. This heating effect is further exacerbated as runoff flows through stormwater management ponds or other impoundments, where detained water is exposed to solar warming for extended time periods between rain events. This page explores different techniques for mitigating the effects of urbanization on the stream thermal regime.[2]

Thermal Load [edit]

Since stream warming is influenced by the runoff temperature and volume of runoff draining to streams, impacts are best assessed through an evaluation of thermal loads both in the stream and in runoff discharged to streams. The thermal load is a function of the flow rate, water temperature, water density and heat capacity of water (or the energy required to increase a kg of water by 1 degree C).

Thermal Load = Q x ρ x T x C

Where:

Q = flow rate (m^3/s)
ρ = water density (1000kg/m^3)
T = water temperature (°C)
C = heat capacity of water (4187J/kg°C)

Since urban runoff volumes often increase by 2 to 5 times after development, and stormwater pond effluent temperatures are between 4 and 11°C warmer than pond influent temperatures in the

https://wiki.sustainabletechnologies.ca/wiki/Stormwater_Thermal_Mitigation

Drawings page

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Drawings

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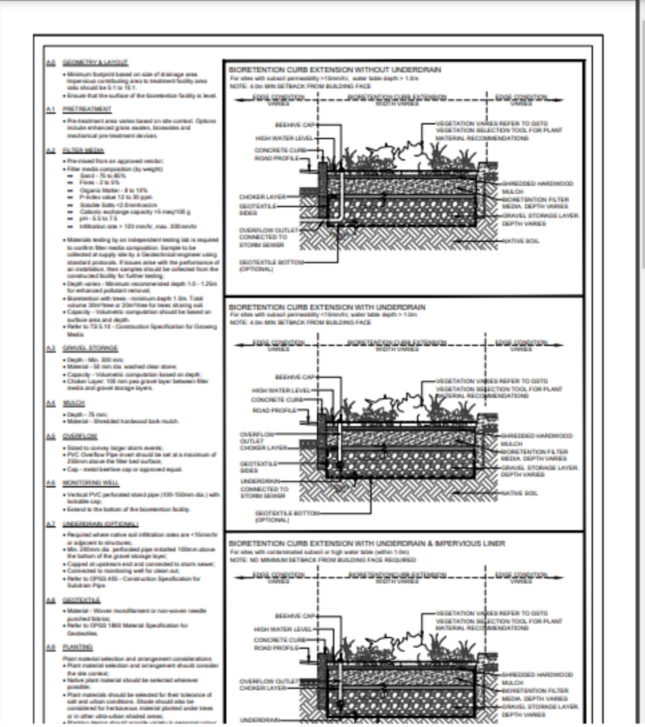

Overview [edit]

This page provides a collection of links to design standard and drawing examples from Ontario and/or North American-based sources.

If you want help in finding example details for an LID design, please email the Wiki Guide email account or use the comment box below.

> *You know that typical drawings are no substitute for properly configured design!*

Ontario Municipal Standards [edit]

- City of Toronto Green Streets program has produced "typical" road cross-section drawings for a wide variety of road types and contexts. See example of curb extensions to the right.[1]
- City of Toronto, Construction Specifications and Drawings for Green Infrastructure include many LID standard drawings, cross sections and details. See some examples below. [2]
- City of Kitchener has standard details for pervious concrete pavement, precast permeable interlocking pavement and permeable pipe exfiltration systems, a note - you will have to send them an email requesting access to their development manual[3].
- City of Cambridge's, Stormwater Management Policies and Guidelines show typical cross section drawings for dry ponds, constructed wetlands, bioretention, etc. [4]

https://wiki.sustainabletechnologies.ca/wiki/Drawings

LID Case Studies page

Sustainable Technologies EVALUATION PROGRAM

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LID Case Studies

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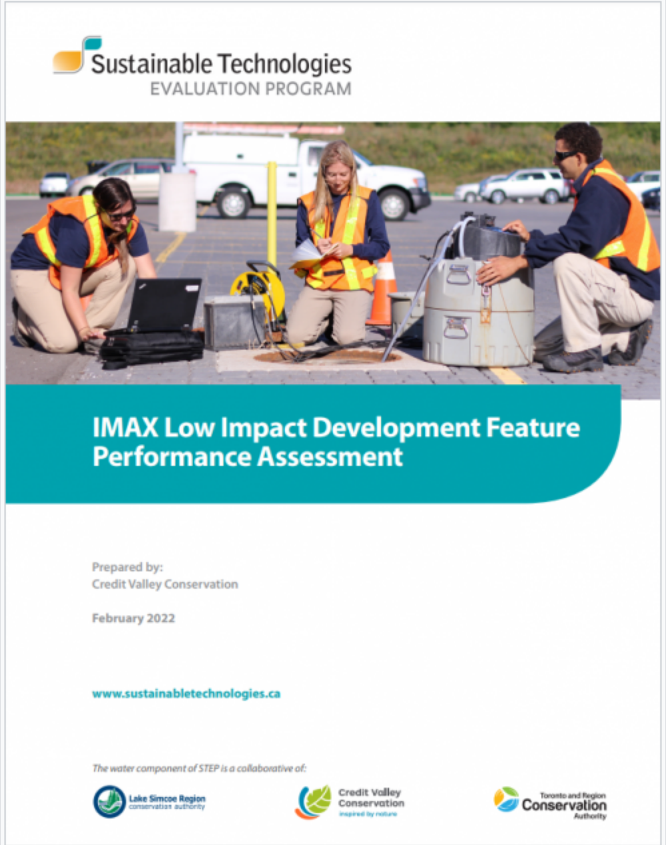

Click the image above to access STEP's most recent report on the performance assessment of multiple LID features located at IMAX's corporate offices in Mississauga, ON.

Overview [edit]

This page is a repository of recent case studies that the Sustainable Technologies Evaluation Program (STEP) have conducted over the past two decades or so. Keep your eye on this page as current projects wrap up and new technical briefs or reports are developed, they will be added to this page.

Each of the documents are separated by the LID BMP feature that was studied / monitored or built, a number of these documents will appear several times throughout this page as many have information on multiple LIDs' and their design, performance and associated inspection requirements.

Feel free to review the documents and redirect back to the main LID practice's BMP page at the end of each section to learn more.

Bioretention [edit]

https://wiki.sustainabletechnologies.ca/wiki/LID_Case_Studies

Questions? Concerns? Complaints?

Thank you

For more information:

STEP LID Planning and Design Guide wiki:
https://wiki.sustainabletechnologies.ca

Sustainable Technologies Evaluation Program (STEP) website:
https://sustainabletechnologies.ca

STEP Canadian BMP Water Quality Database:
https://stepapps.shinyapps.io/WQ_Interactive4/

Contact:

STEP LID Planning and Design Guide wiki
lid.pd.guide@gmail.com

Daniel Filippi, Research Scientist
Toronto and Region Conservation Authority
Daniel.filippi@trca.ca

Dean Young, Project Manager
Toronto and Region Conservation Authority
Dean.young@trca.ca