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Canada's Premier Stormwater and Erosion and Sediment Control Conference

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


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


***2023 Source to Stream Conference***
*March 23, 2023*

*The water component of STEP is a collaborative of:*

Toronto and Region Conservation Authority

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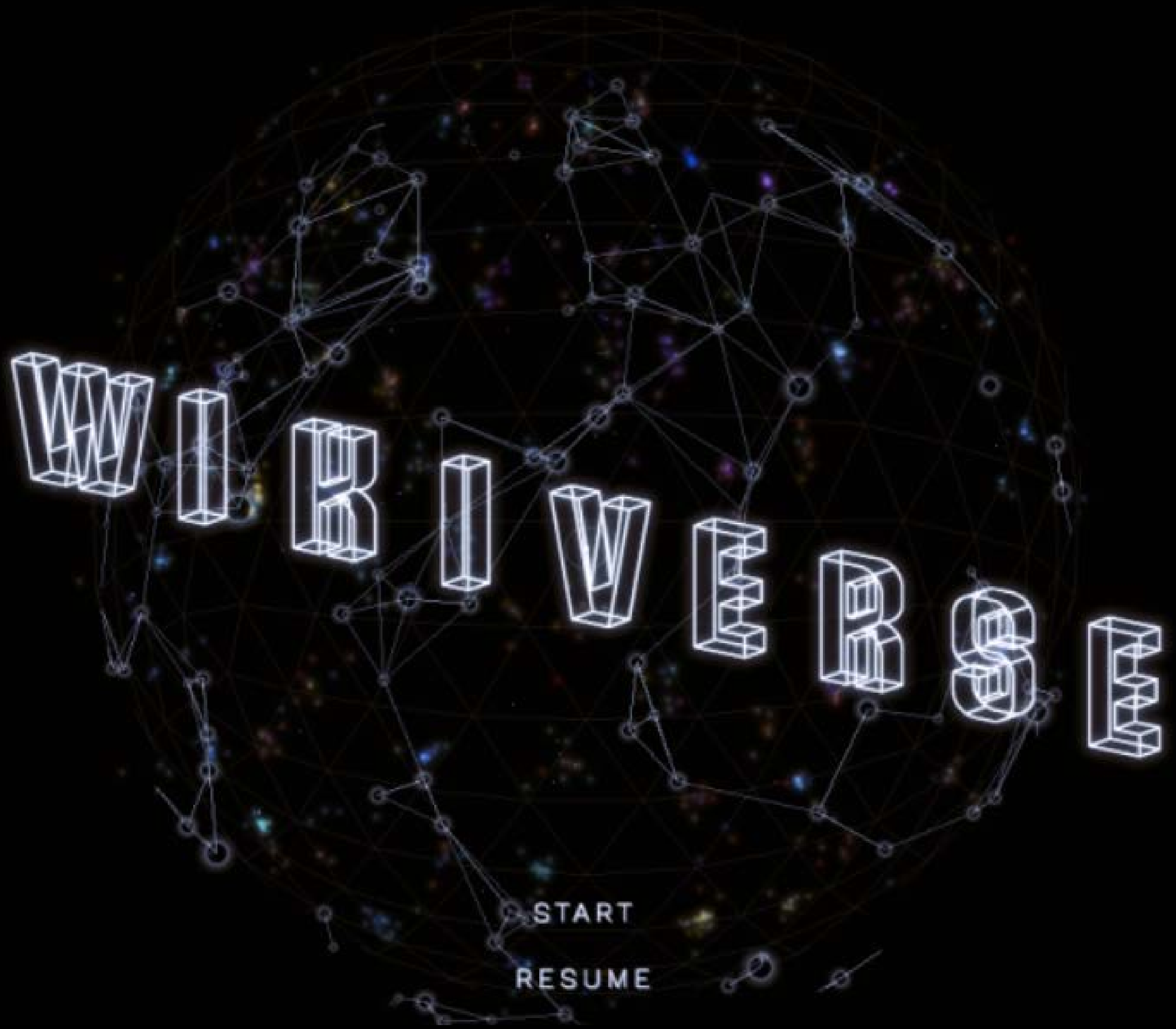
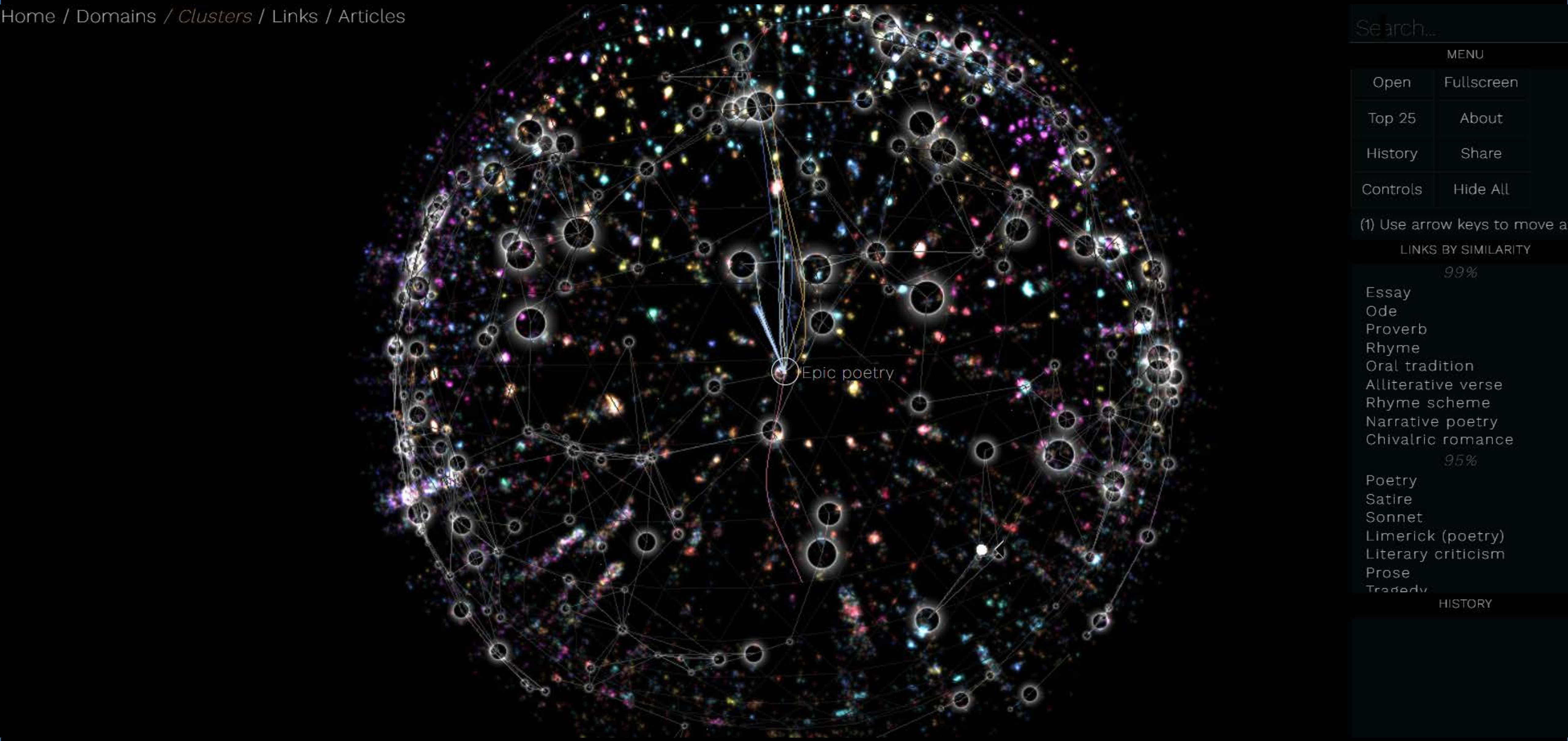



https://www.wikiverse.io/

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.

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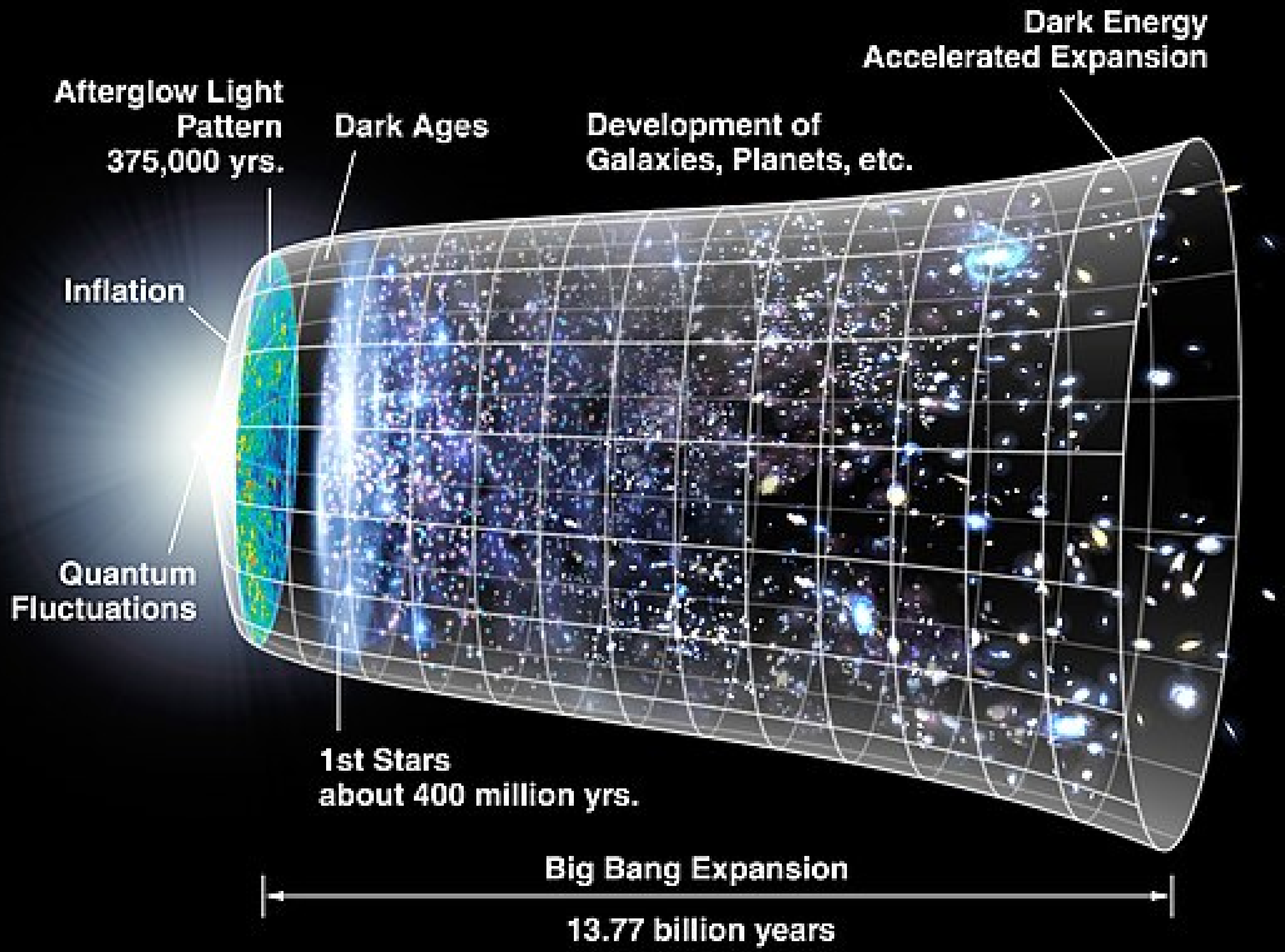


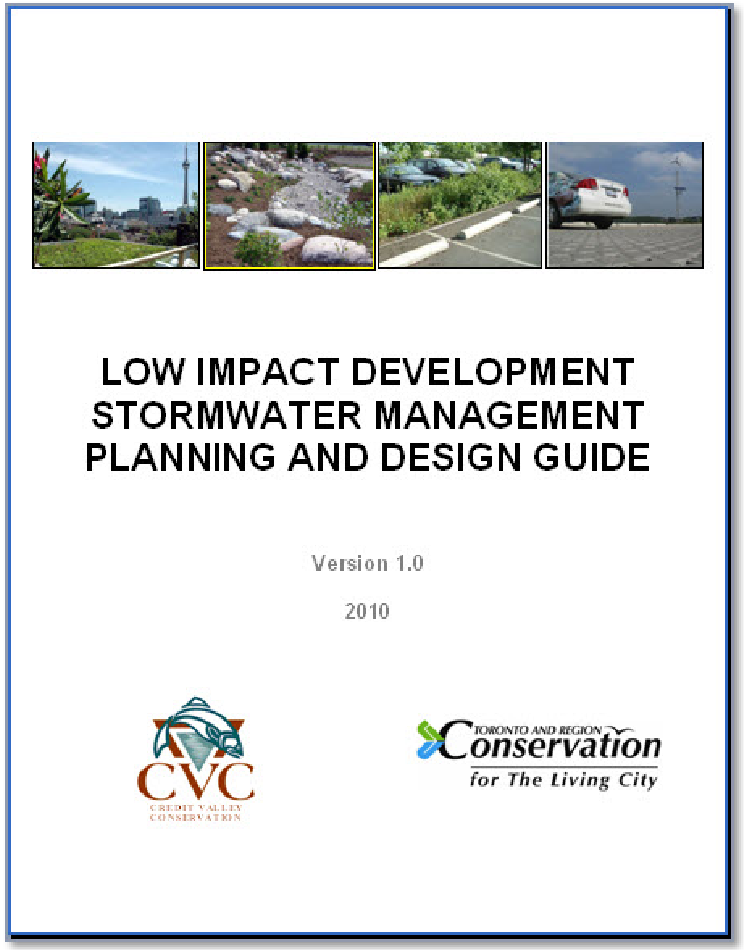

https://en.wikipedia.org/wiki/Expansion_of_the_universe

Source: Marvel Studios


Source: Marvel Studios

# 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.


LOW IMPACT DEVELOPMENT
STORMWATER MANAGEMENT
PLANNING AND DESIGN GUIDE

Version 1.0

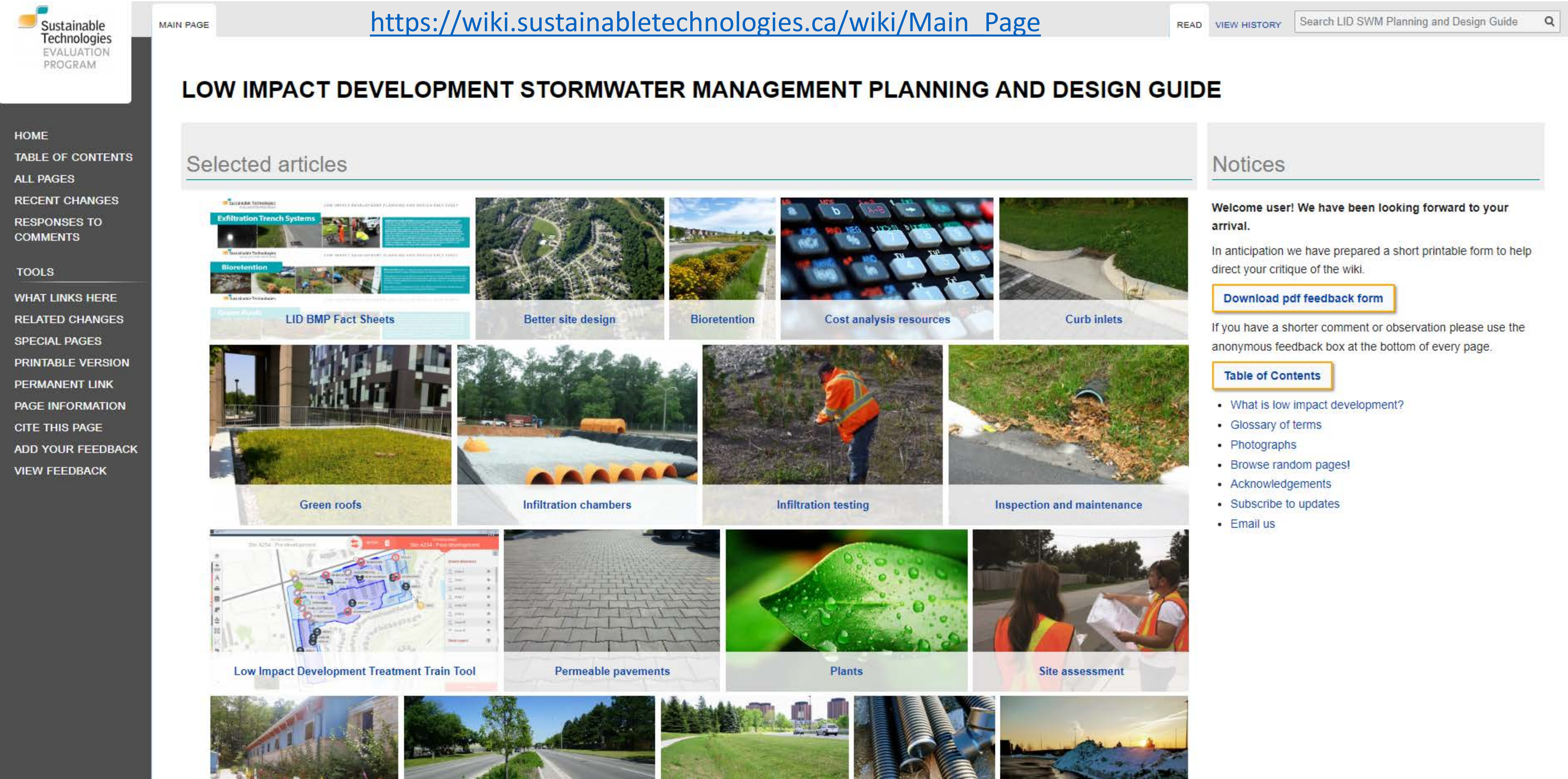
2010

CVC
CREDIT VALLEY CONSERVATION

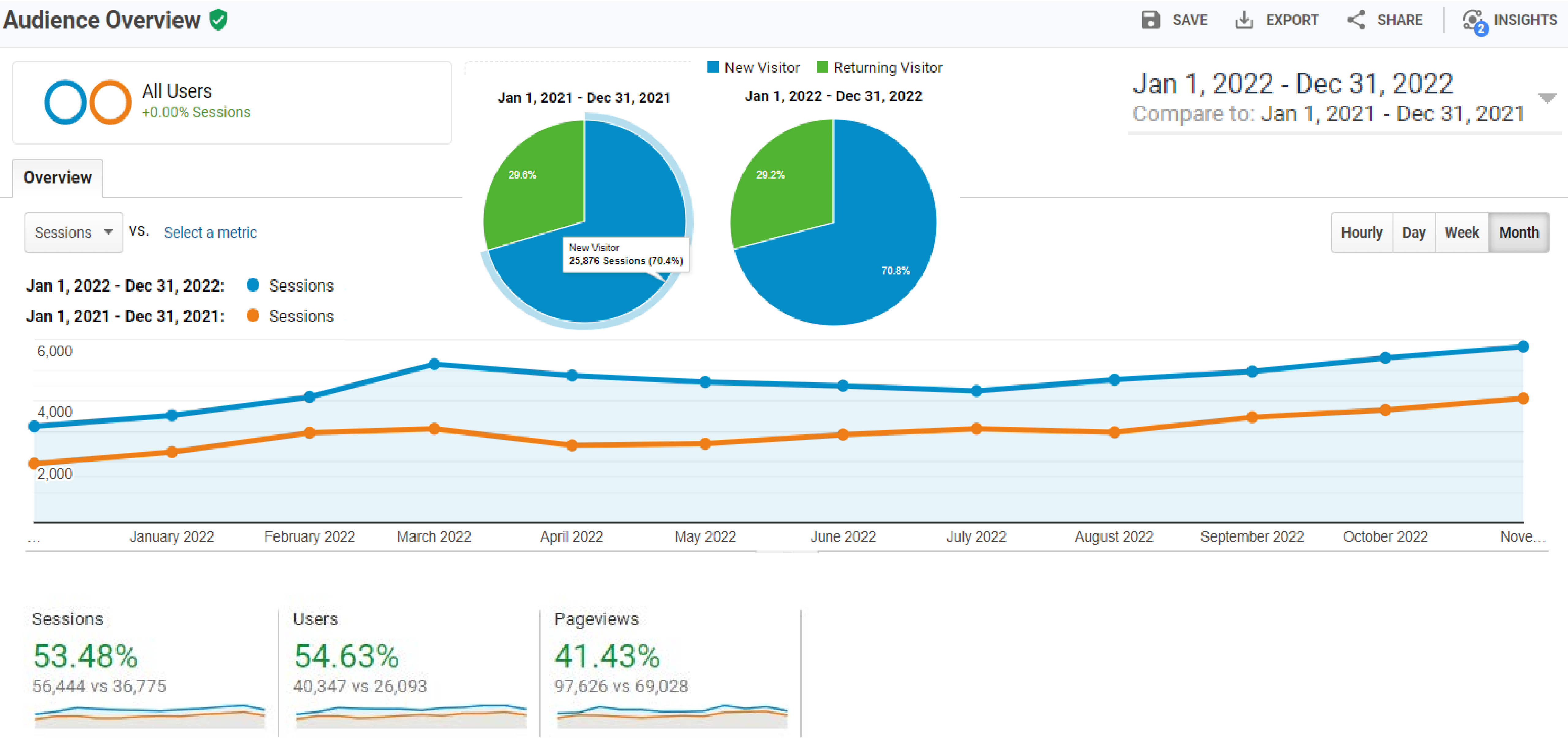
TORONTO AND REGION Conservation
for The Living City

# LID SWM Planning and Design Guide wiki website

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



# Google Analytics



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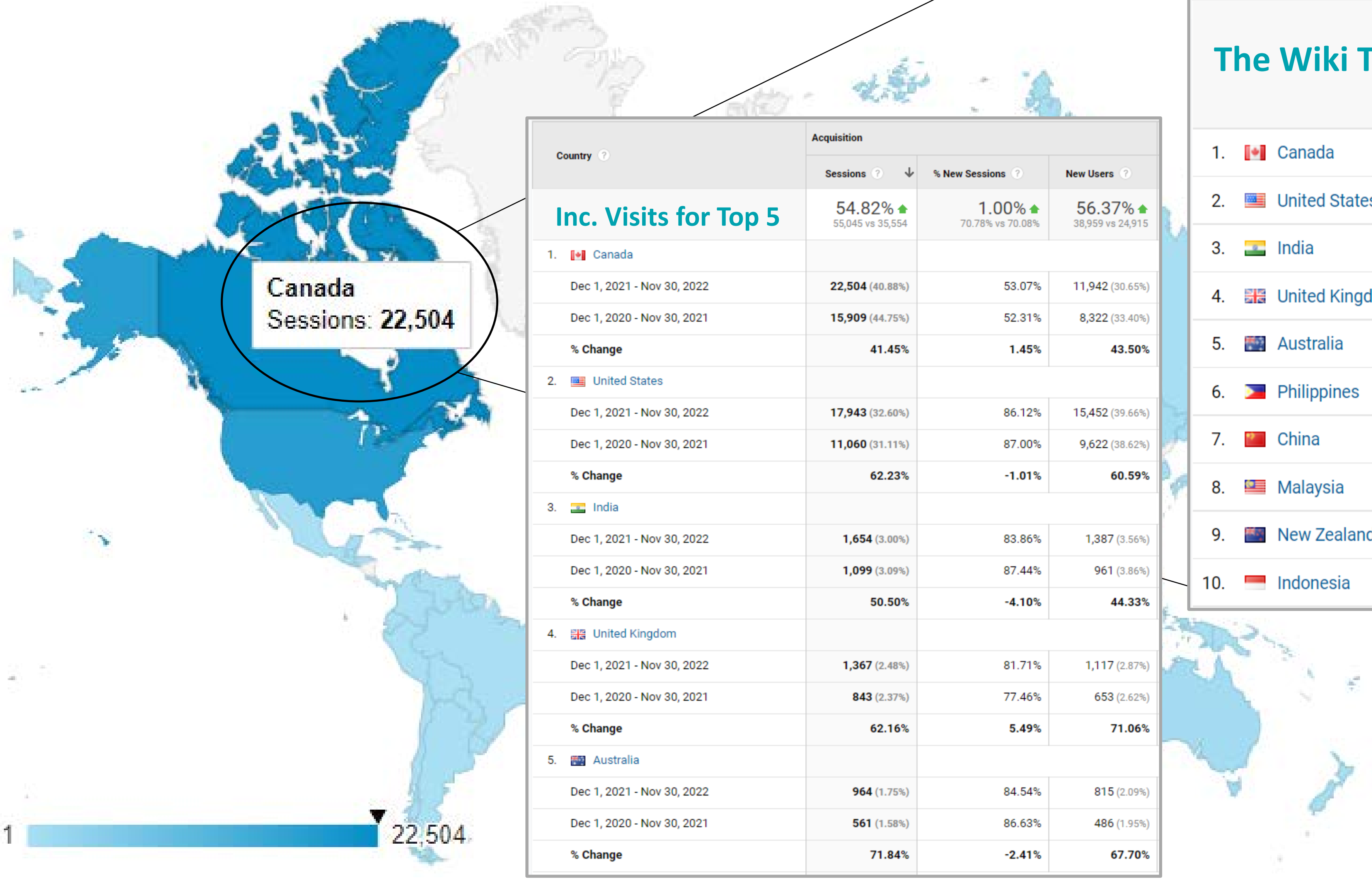


| Country | Acquisition | | |
|---|---|---|---|
| | Sessions | % New Sessions | New Users |
| **Inc. Visits for Top 5** | 54.82% ▲ 55,045 vs 35,554 | 1.00% ▲ 70.78% vs 70.08% | 56.37% ▲ 38,959 vs 24,915 |
| 1. Canada | | | |
| Dec 1, 2021 - Nov 30, 2022 | 22,504 (40.88%) | 53.07% | 11,942 (30.65%) |
| 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% |

| Country | Acquisition | | |
|---|---|---|---|
| | Sessions | % New Sessions | New Users |
| **The Wiki Top 10** | 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%) |

# 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.

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LOW IMPACT DEVELOPMENT PLANNING AND DESIGN FACT SHEET

# Stormwater Tree Trench

**Stormwater tree trenches** are linear tree planting structures featuring supported impermeable or permeable pavements that promote healthy tree growth while also helping to manage runoff. They consist of subsurface trenches filled with modular structures and growing medium, or structurally engineered soil medium, supporting an overlying sidewalk pavement. They improve tree health by providing access to soil, air and stormwater for irrigation, allowing them to survive longer in harsh urban conditions. They also provide road and walkway drainage, contribute to stormwater pollutant removal and decrease the volume of urban runoff entering local waterways. They feature trees, soil, inlet and outlet structures, distribution and drainage pipes, and may include soil support structures, structural soil medium or structural concrete panels. The tree planting pits and adjacent supported sidewalk pavements provide more soil volume for tree growth and water retention.

## DESIGN

### GEOMETRY AND SITE LAYOUT

Stormwater tree trenches are continuous, linear urban tree planting systems, often located behind the curb within the road right-of-way and feature sidewalk pavement and tree openings on top. Trench sections are connected hydrologically through sub-surface stormwater distribution and drainage pipes.

### INLETS

Water can enter the tree trench in a variety of ways: from the overlying sidewalk via sheet flow or curb cuts into tree openings, trench drains or infiltration through permeable pavement; and from the road via distribution pipes connected to road or side inlet catch basins, and curb cuts or depressed drains at tree openings. It is recommended that each tree trench have multiple inlets to keep the contributing drainage area relatively small, which provides redundancy to the system. Inlets and distribution pipes should be offset from tree root ball locations to avoid impacts of de-icing salt laden runoff on newly planted trees during establishment.

STORMWATER TREE TRENCH:
**SOIL CELL CONFIGURATION**

STORMWATER TREE TRENCH:
**STRUCTURAL SOIL CONFIGURATION**



### PRE-TREATMENT

If water enters the trench via a catch basin, a removable pre-treatment device, like a Goss trap or proprietary catch basin insert device or filter should be included to help retain coarse sediment, debris and floatables and prevent it from entering the pipe or trench. Inlet structures should have a sump and curb cut inlets should include stone mulch or diaphragms to dissipate energy and spread flows. Pre-treatment features should be easy to access and clean out.

### SOIL VOLUME

Each tree planted should have access to a minimum 30 $m^3$ of soil volume, including the growing medium within the tree pit and growing or structural soil medium below adjacent supported pavement. If more than one tree shares the same trench a minimum 20 $m^3$ of soil per tree may be acceptable.

### MODULAR SOIL SUPPORT SYSTEMS

Modular soil support systems (also referred to as “soil cells”) consist of plastic or concrete structures, available in a variety of shapes and sizes, that provide structural support for the overlying pavement while providing uncompacted planting soil within the tree root zone. They are installed adjacent to tree pits to provide room for roots to spread out under the supported pavement portion of the trench. Growing medium backfill typically has higher organic matter content than structural soil medium. The looser structure and higher nutrient content of the growing medium provides the most favorable environment for healthy tree growth in an urban setting.

### 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 medium filled trenches are installed adjacent to tree pits to provide room for tree roots to spread out under the supported pavement portion of the tree trench.

### STRUCTURAL CONCRETE PANEL

Trenches where the overlying sidewalk pavement consists of reinforced structural concrete panels is another configuration. Panels are supported on each side by concrete footings and rows of modular soil support structures or structural soil medium, installed on aggregate bases. The benefit of this approach is that the native subgrade soil under the portions of the trench below tree pits and between rows of supports does not need to be highly compacted, allowing greater opportunity for drainage via infiltration.

| 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 |

### CONVEYANCE AND OVERFLOW

Runoff is directed from overlying and adjacent pavements to the trench through such means as tree openings, perforated distribution pipes connected to catch basins or trench drains, or curb cuts and depressed drains at tree openings. Runoff water percolates through the growing or structural soil medium to the underlying native subgrade soil. When runoff volume exceeds the trench water storage capacity, the perforated underdrain pipe directs excess filtered water to a downstream outlet storm sewer or other practice. During intense storm events, runoff in excess of the infiltration capacity of the growing or structural soil medium will overflow to the storm sewer either through an outlet pipe connection in the catch basin or via surface overflow standpipes or structures within tree openings.

### CONFIGURATION

Modular soil support system and structural concrete panel trench configurations should provide a better growing environment for trees, and thereby improve tree longevity. Structural soil medium and structural concrete panel trench configurations provide the benefits of being more adaptable around utilities and existing trees and providing easier access to utilities when repairs are needed. Structural concrete panel trench configurations featuring rows of modular soil supports provide greater soil volume per unit area than those featuring structural soil medium.

### DISTRIBUTION AND UNDERDRAIN PIPES

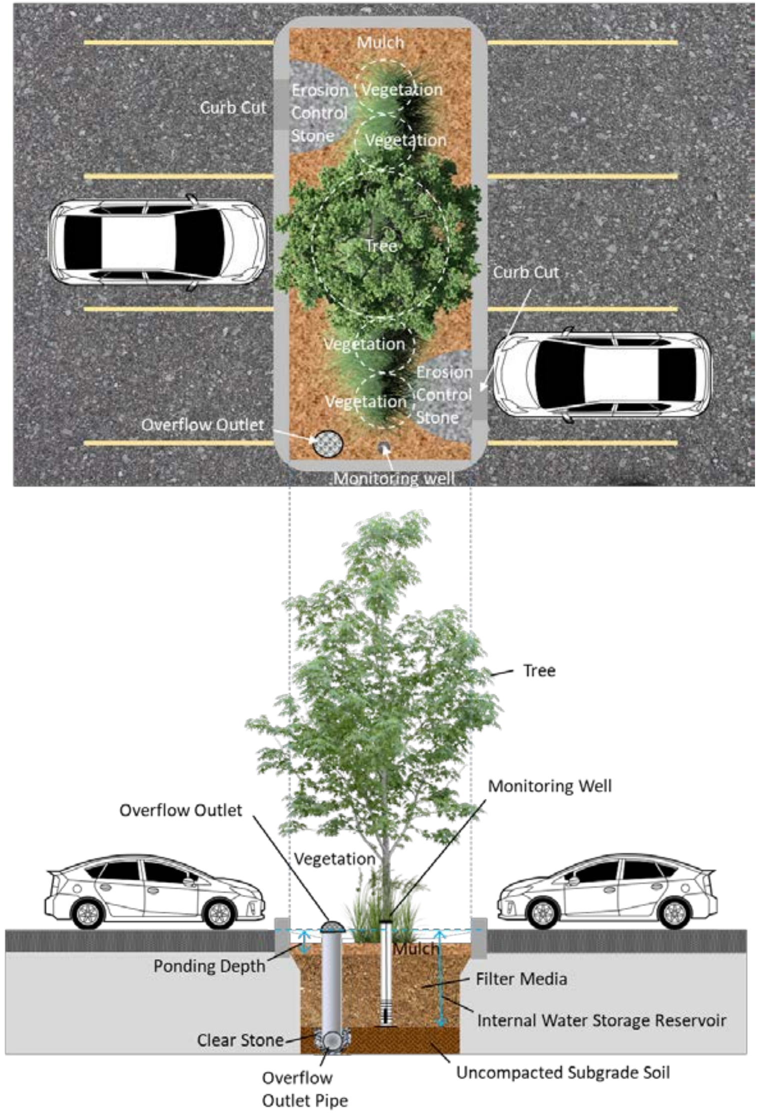
To maximize the quantity of growing or structural soil medium irrigated, distribution pipes should be installed flat, just below modular soil support tops or at the top of the structural soil medium layer and in both tree pit and supported pavement portions of the trench. Pipe perforations should be oriented to the sides and section ends should be sealed with a solid cap. To enhance runoff volume reduction underdrain pipes can be installed above the bottom of the trench and/or include flow control. Alternatively, the underdrain pipe may be installed on trench bottom and connected to a riser assembly in the outlet manhole. It is critical to include connections to outlet storm sewer pipes and multiple cleanout access points.

## New

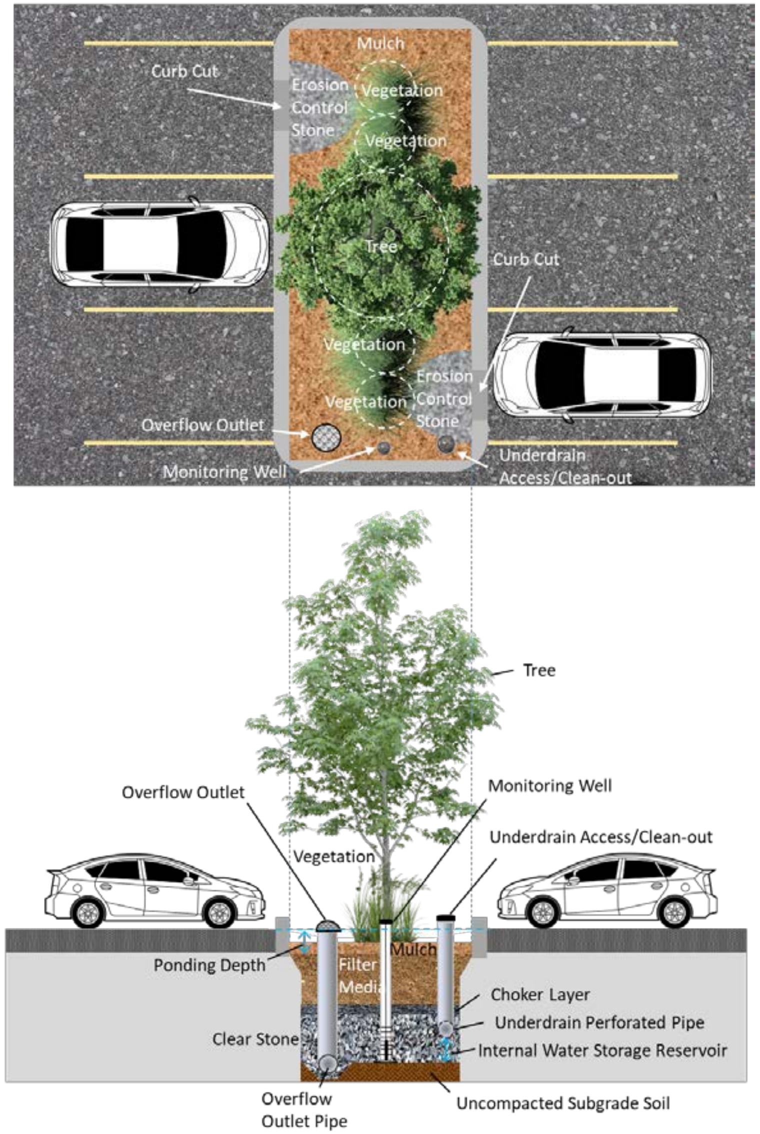
9. Stormwater tree trenches.

# New image map schematic diagrams

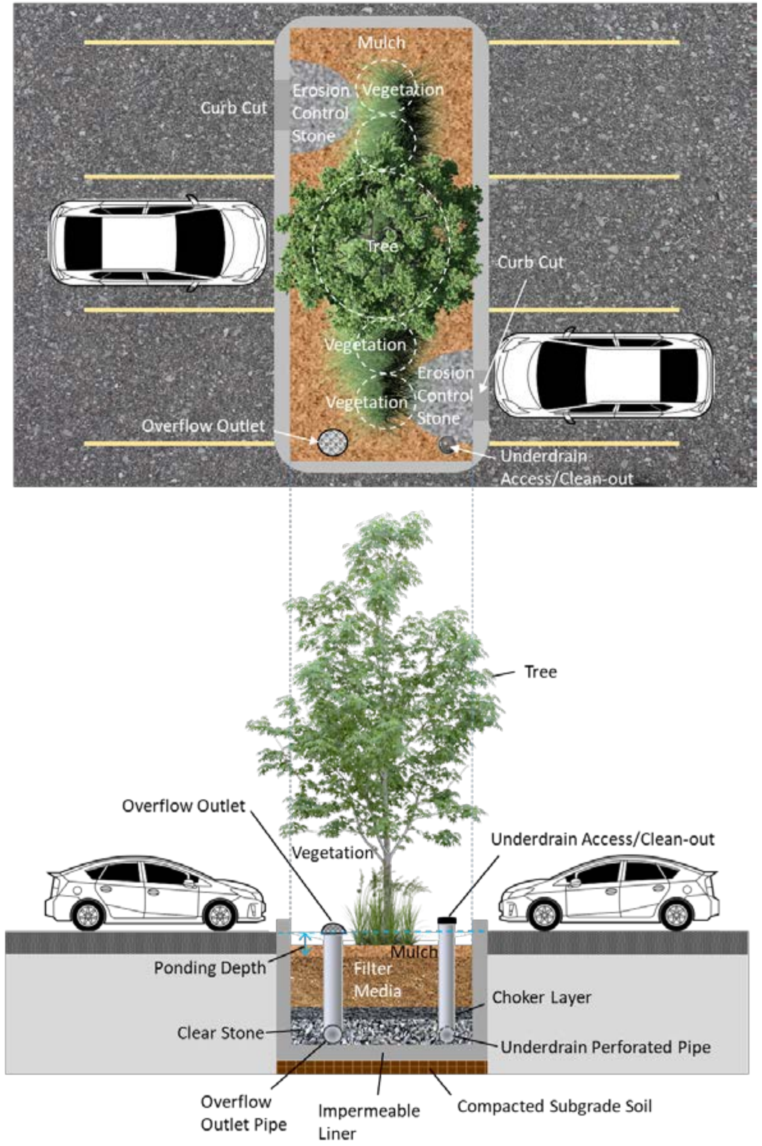
**Bioretention – Full infiltration**




**Bioretention – Partial infiltration**

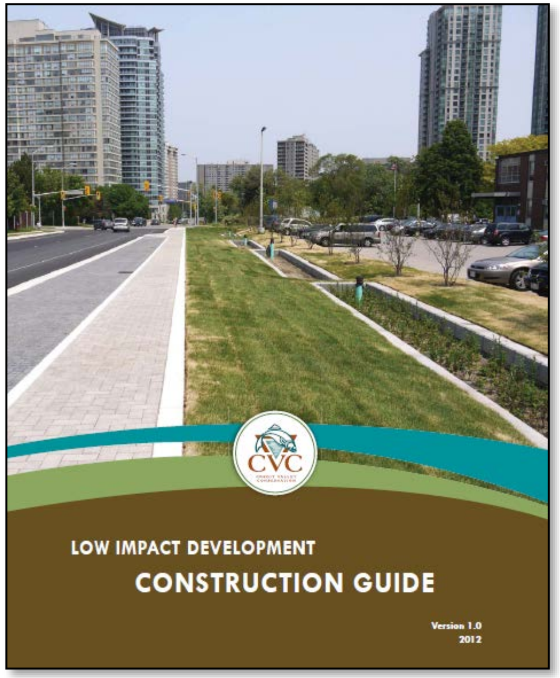


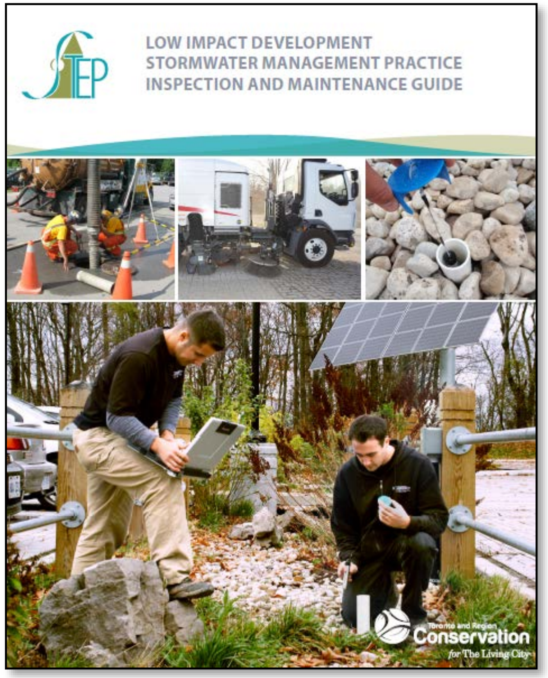

**Stormwater planter / Bioretention - No infiltration**

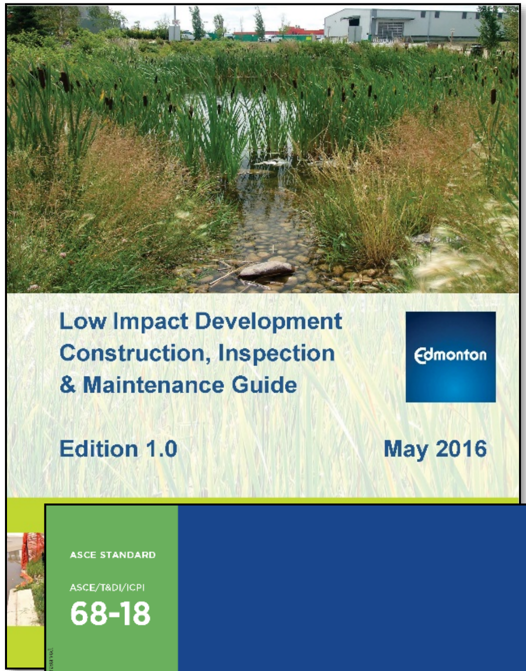


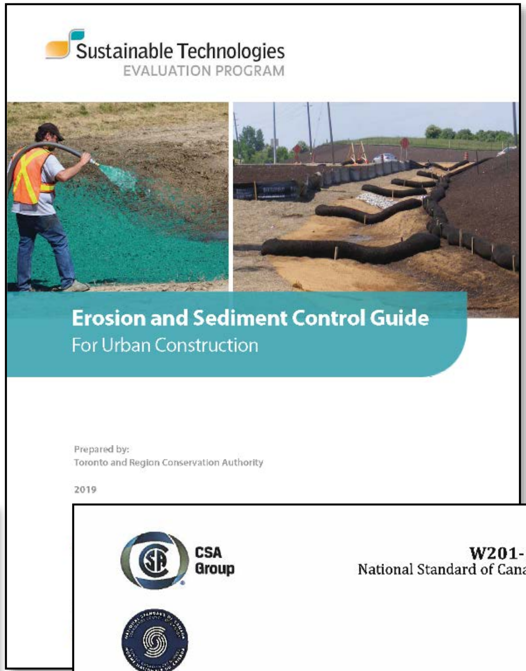

https://wiki.sustainabletechnologies.ca/wiki/Bioretention#Design_Variations

# Enhanced guidance on construction, inspection and maintenance

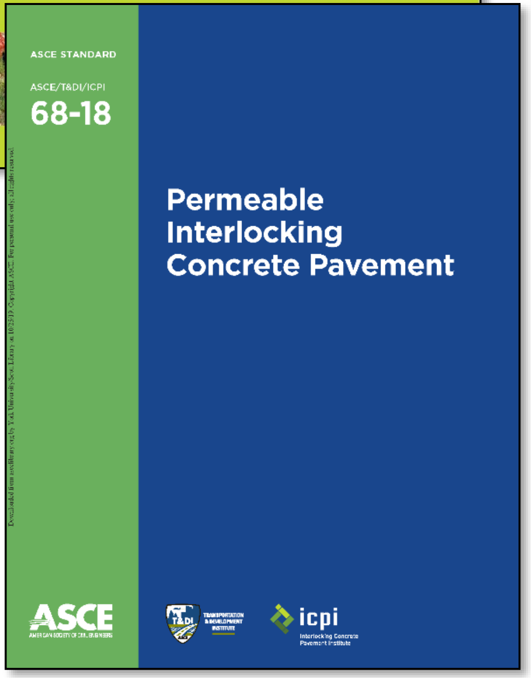


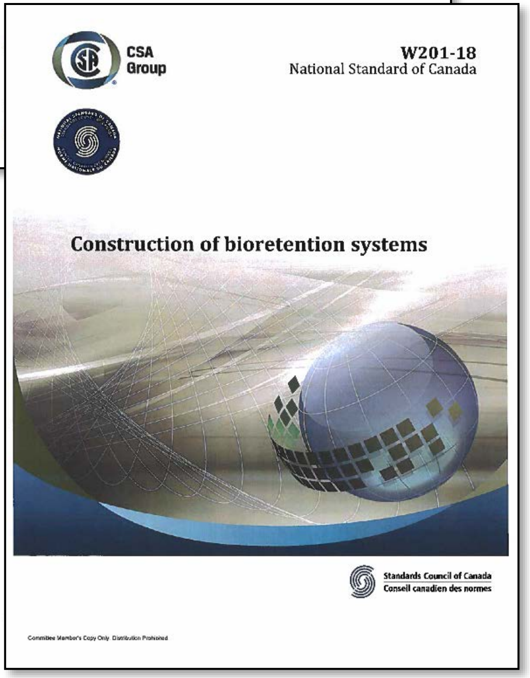





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# Construction hub

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## 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

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## Inspections and maintenance

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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.

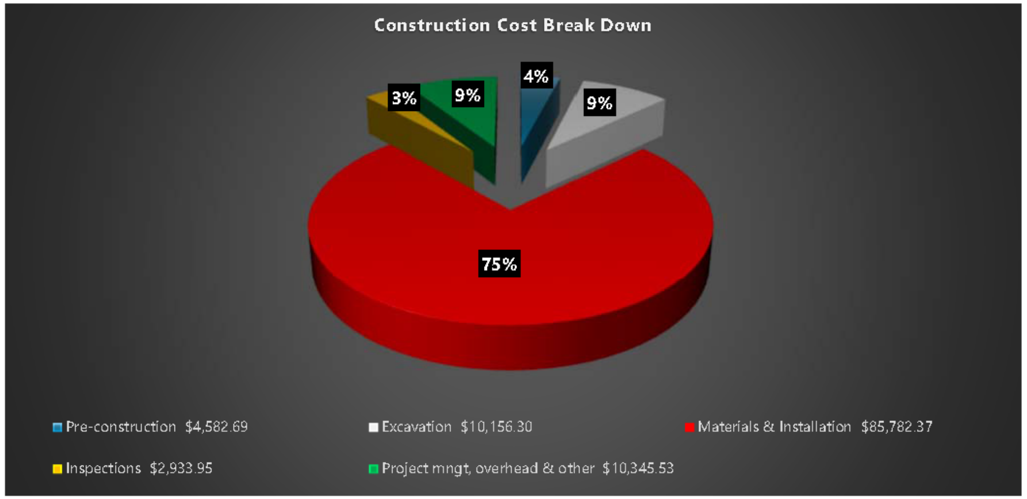
A 2009 survey of stormwater BMPs in the James River watershed (Virginia) by the Center for Watershed Protection found approximately half (47%) of the 72 BMPs deviated in one or more ways from the original design, or were receiving inadequate maintenance (CWP, 2009)[4]. Similar results have been revealed 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]),

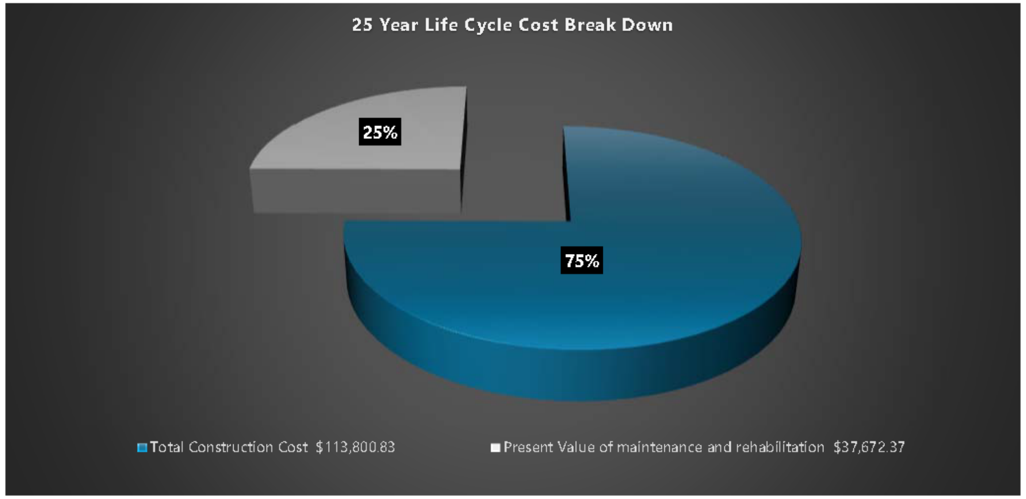
https://wiki.sustainabletechnologies.ca/wiki/Inspections_and_maintenance

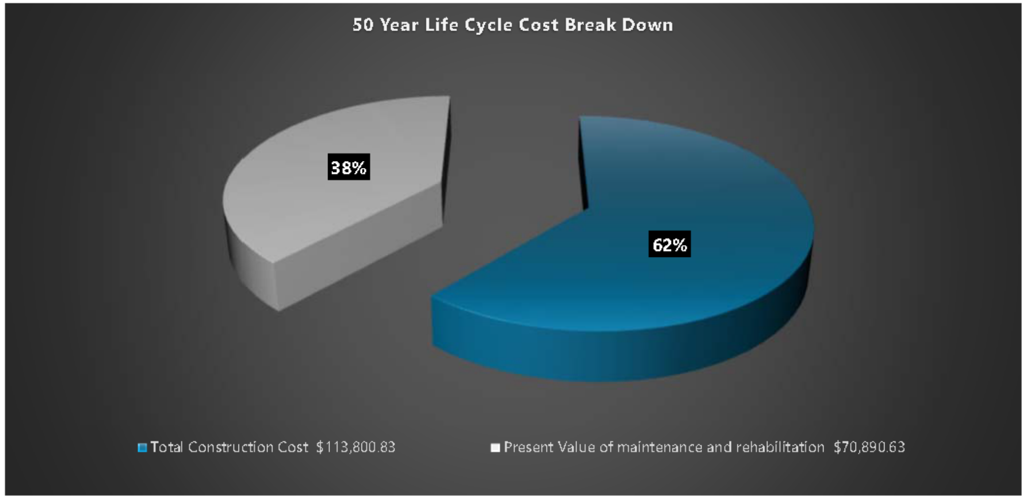
# Updated content on life cycle costs

## Bioretention, Partial Infiltration

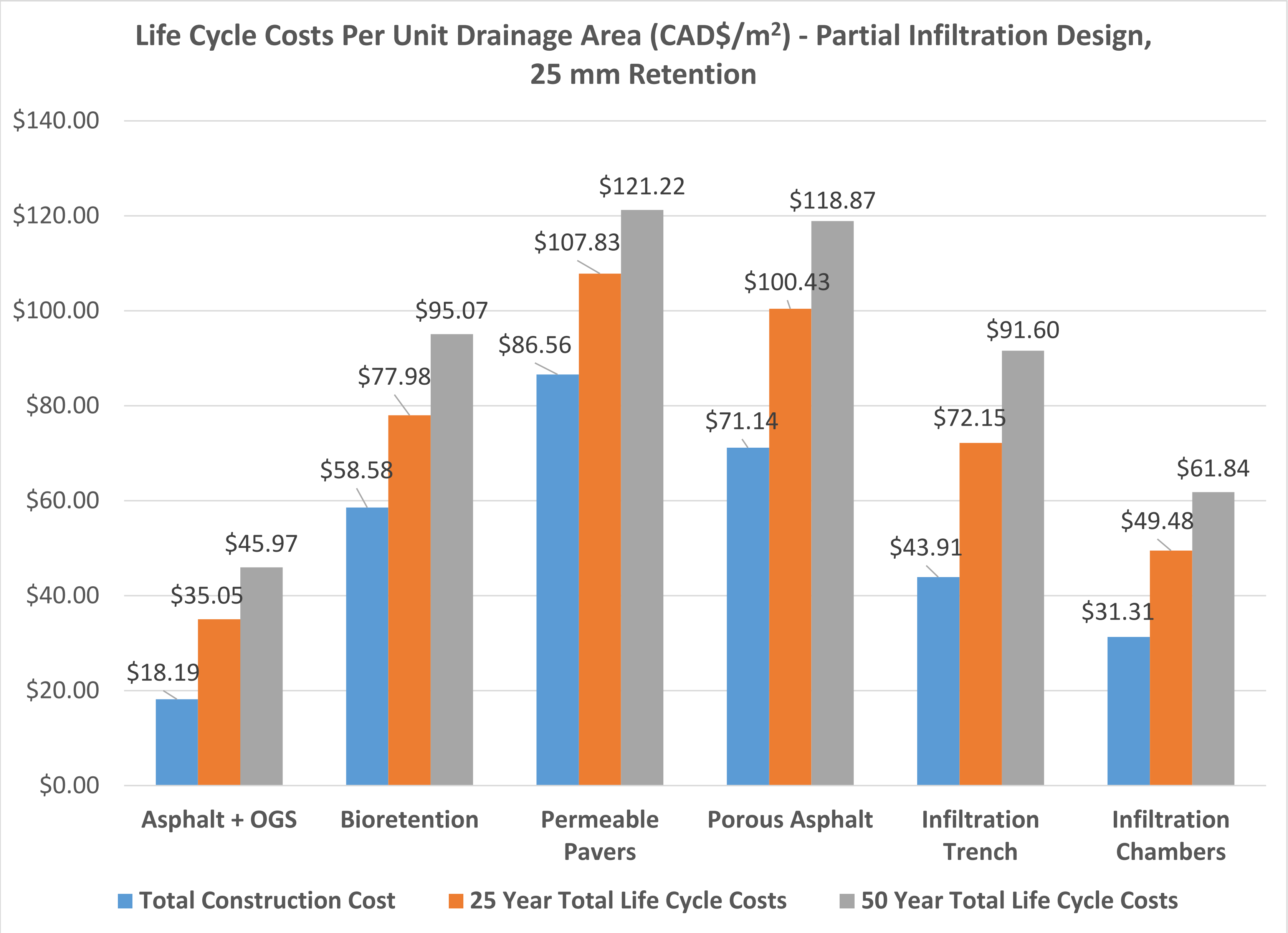
| COST SUMMARY | Value |
|---|---|
| **Construction Cost Break Down** | |
| Pre-construction | $ 4,582.69 |
| Excavation | $ 10,156.30 |
| Materials & Installation | $ 85,782.37 |
| Inspections | $ 2,933.95 |
| Project mngt, overhead & other | $ 10,345.53 |
| Total Construction Cost | $ 113,800.83 |
| **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 |



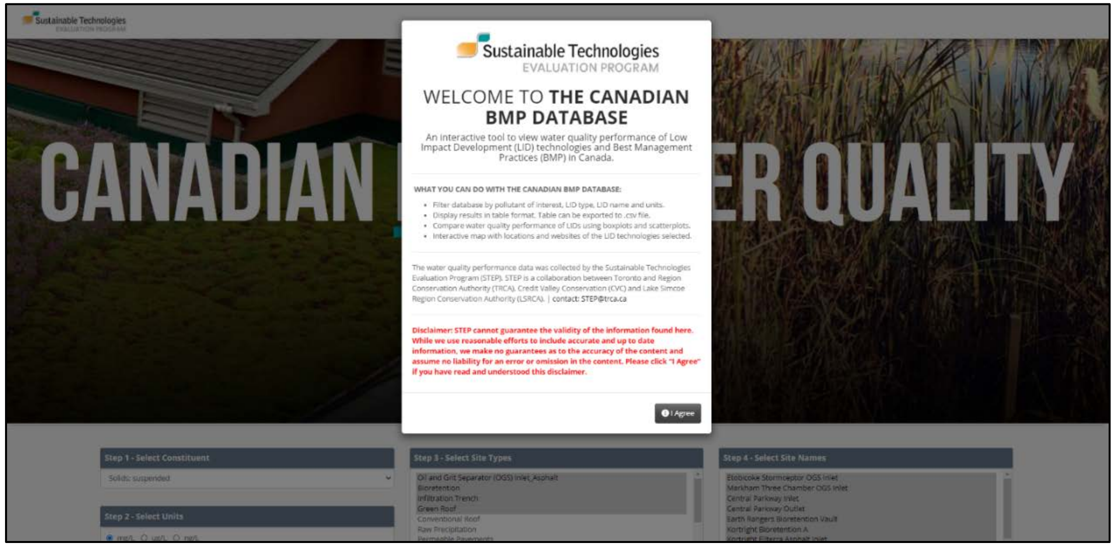
# Low Impact Development Life Cycle Costing Tool hub




https://wiki.sustainabletechnologies.ca/wiki/Low_Impact_Development_Life_Cycle_Costing_Tool

# Enhanced content on water quality 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 reviews;
- Updated **Water Quality** hub page and Performance sections on **BMP pages**.





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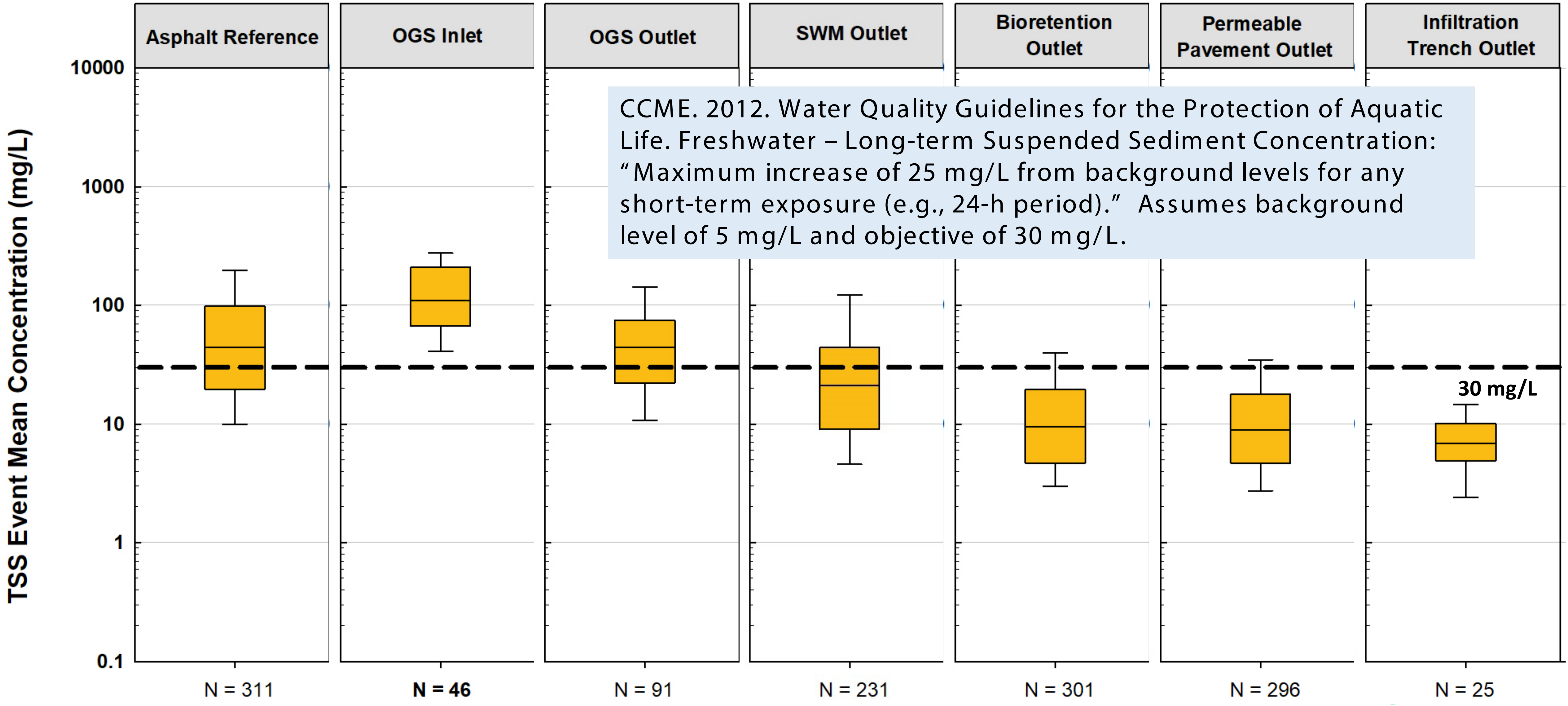
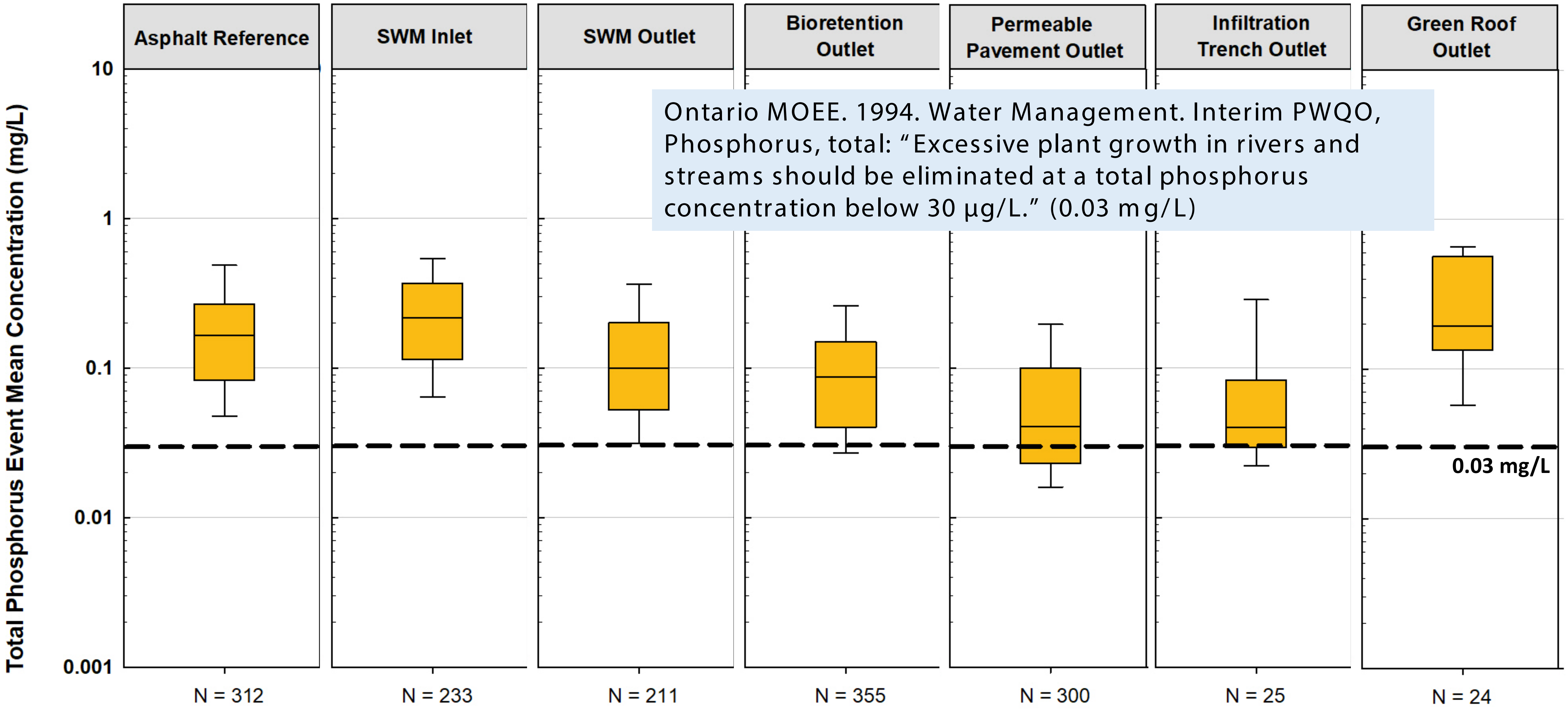
# Total Suspended Solids (TSS) effluent concentration




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.

https://wikidev.sustainabletechnologies.ca/wiki/Water_quality

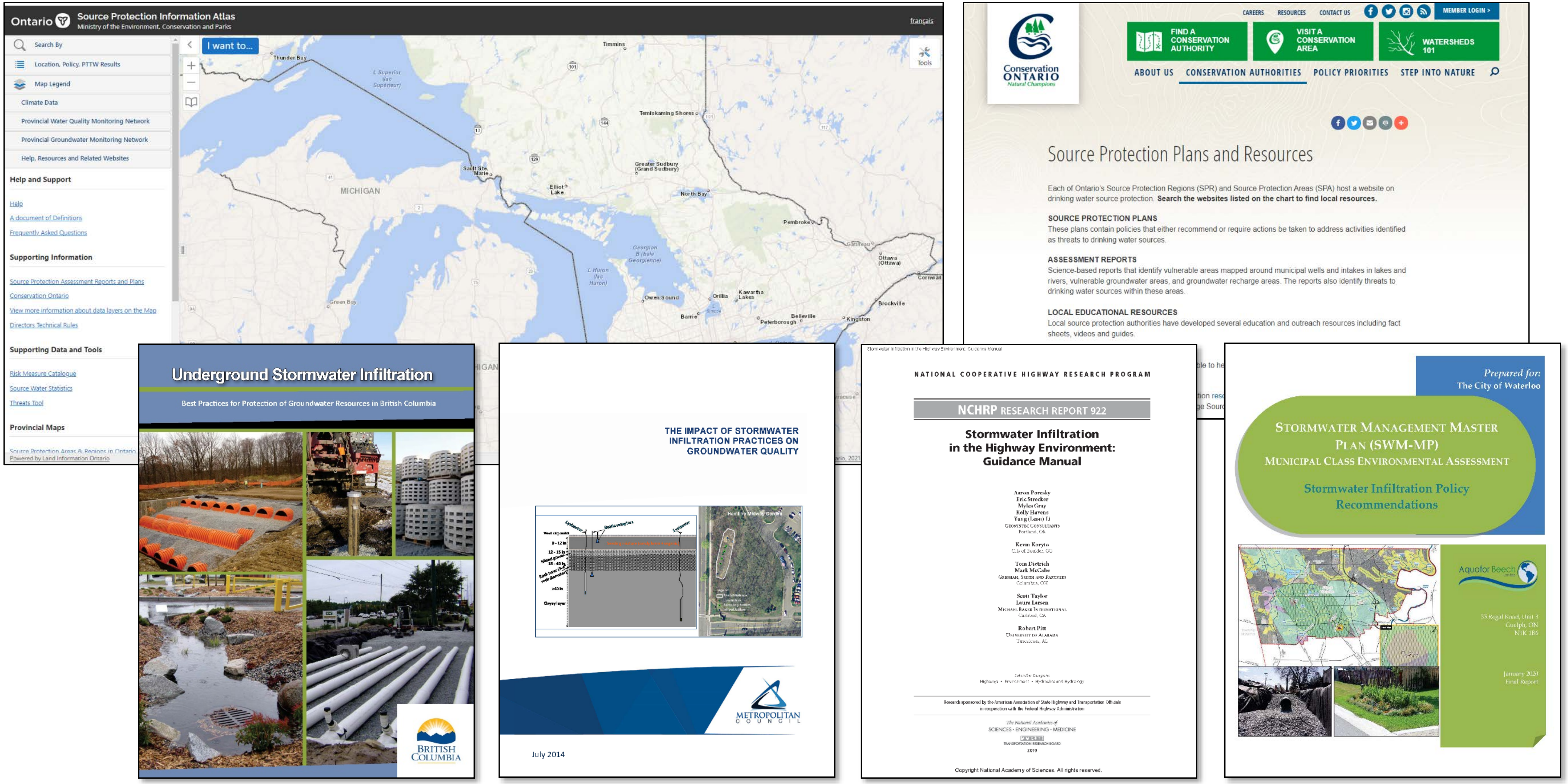
# Total Phosphorus (TP) effluent concentration




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)

https://wikidev.sustainabletechnologies.ca/wiki/Water_quality

# Enhanced content on drinking water source protection



# Source Water Protection page

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## Source Water Protection

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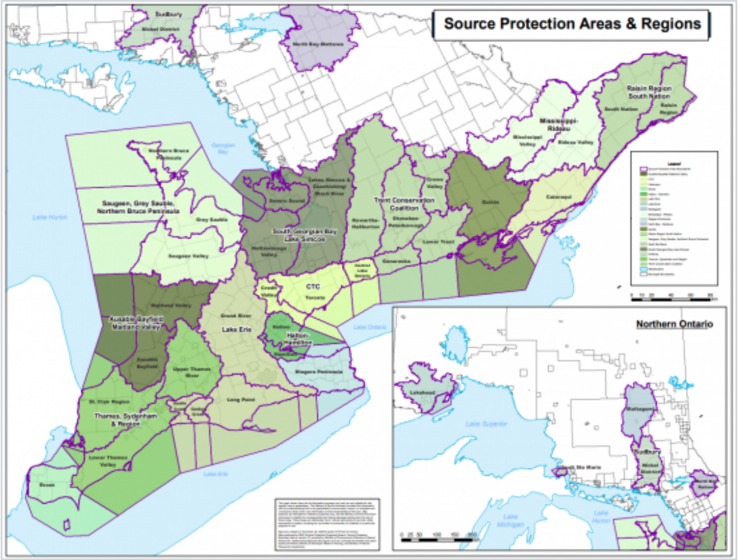


Image of the 19 Source Protection Regions (SPRs) and Source Protection Areas (SPAs) in Ontario (Conservation Ontario, 2022)[1]. Visit the map link here for a higher resolution image.

### 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

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## Salt

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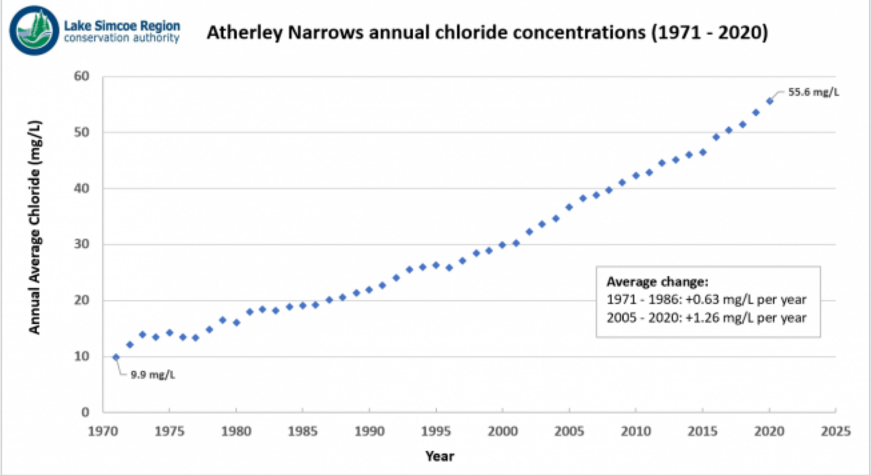


A graph showing increasing average levels of chloride found in Atherley Narrows, (a rural sampling location, between Lake Couchiching and Lake Simcoe), over the past few decades, due in part to increased use of rock salt in parking lots, roadways and commercial and residential properties. From 2005 - 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]

https://wiki.sustainabletechnologies.ca/wiki/Salt

# Stormwater Thermal Mitigation page

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## Stormwater Thermal Mitigation

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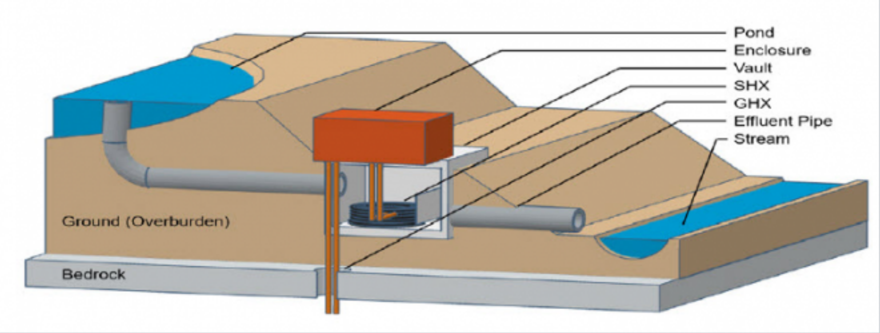


A simplified 3D cross section of a geothermal cooling system used in a SWM pond in Brampton, Ontario. The system contains a closed hydronic circuit where piping connected a surface water heat exchanger (SHX) to a ground heat exchanger (GHX). A pump continuously circulates a cool hydronic fluid around 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 ($m^3/s$)
$\rho$ = water density ($1000 kg/m^3$)
$T$ = 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 summer, the overall thermal load increases to streams can be very significant (Van Seters and Dougherty, 2010) [3]

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

# The expanding STEP LID wikiverse

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

- Updated eight (8) 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 **water quality 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 Stormwater Infrastructure;
- New **LID Case Studies** page, highlighting STEP research over the past 20 years (60+ reports by BMP type).

Source: Marvel Studios

# Thank you

## For more information:

**STEP LID SWM 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/

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