TECHNICAL BRIEF

Sustainable Technologies
EVALUATION PROGRAM

Low Impact Development

Evaluation of Retrofitted Lot Level Stormwater Source Control Practices – Calstone Inc., Toronto

This study evaluates the performance of stormwater source control practices retrofitted into an industrial-commercial lot located in a densely-developed portion of Toronto that drains to the Malvern Branch of Highland Creek. The rainwater cistern and landscape irrigation system, infiltration trench and three soakaway ponds implemented receive runoff from approximately 2,600 square metres (m^2) of the 3,900 m^2 flat roof (4 of 6 roof drains). A 9,300 litre (L) capacity, above ground polymeric cistern was installed adjacent to the newly constructed planting beds and connected to one of the building roof drains (650 m^2 area). The cistern overflows to its 0.45 metre (m) deep open graded gravel base and a sub-drain pipe connected to the front lot catchbasin and municipal storm sewer. A 65 m long infiltration trench along the rear lot line receives flows from one roof drain and overflows to the soakaway ponds. The three soakaway ponds also receive flow from two roof drains (1,300 m^2 area).

Performance parameters examined were runoff volume reduction, rainwater use/ municipal water conservation, pond drainage rate and frequency and cause of overflows. Results show that the rainwater cistern/irrigation system and soakaway ponds/infiltration trench systems reduced runoff volume from their roof drainage areas by 64% and 89% respectively over the summer to fall 2015 evaluation period. Based on these findings, several recommendations for future designs and further research are provided.

"The idea started as a rainwater harvesting tank and some raspberry bushes – we're now committed to capturing 100% of the rainfall off our roof." – Jim Ecclestone, CEO/President, Calstone Inc.

This project has been featured in several stormwater trade magazine articles about low impact development practices:

- Worldwater Stormwater Management magazine (June/July 2015)
- Water Online / Water Innovations magazine (July 2015)
- Environmental Science & Engineering magazine (September 2015)

INTRODUCTION

Highland Creek is a largely urbanized watershed (89% urban) that drains to the north shore of Lake Ontario in the City of Toronto and includes a minor portion of the City of Markham. Much of the development (91%) occurred prior to requirements for stormwater quality and quantity controls that we have today (TRCA, 2018). As such, most impervious areas like roofs and pavements drain directly to municipal storm sewers that outlet to the creek untreated. Urban runoff transports contaminants like sediment, nutrients, metals and bacteria to the creek and the Lake Ontario waterfront where they degrade natural ecosystems and impact beneficial uses of the water resources. Changes to the local water cycle from the creation of impervious areas and urban drainage systems have radically changed stream flow patterns.

Low Impact Development (LID) is a more sustainable approach to stormwater management that supplements conventional detention ponds with smaller scale practices distributed upstream and throughout the catchment to retain and treat runoff as close to its source as possible. Retrofitting stormwater source control practices that reduce the volume of runoff from a lot helps to alleviate stresses on urban watercourses and municipal storm sewer systems, replenish groundwater resources, maintain stream baseflow during dry weather and restore a more natural water cycle.

On densely developed lots, where available space is often small, isolated and irregularly shaped, stormwater practices must be compact and adaptable. Rainwater cisterns are one type of LID practice that can fit into tight spaces. They capture and store roof runoff, providing a source of water for non-potable purposes (e.g., landscape irrigation, toilet flushing, outdoor washing), which conserves municipal water. They can be installed underground or as building integrated features for use year-round, or above ground for seasonal use. Other LID practices with minimal surface footprints are soakaways and infiltration trenches. They are excavations lined with geotextile filter fabric and filled with void forming material or modular structures, and the pipes or structures that convey runoff to and from the practice. They temporarily store runoff underground and allow it to drain by infiltration into the underlying soil.

STUDY SITE

Calstone Inc. is a local industrial furniture manufacturing business that has been located in the former city of Scarborough (now Toronto) since 1985. The company is strongly committed to environmental stewardship, conservation and the community it is a part of. Calstone Inc. has shown corporate leadership by demonstrating building integrated and process innovations that conserve energy and water. In 2014 a project was conceived to create a new green space for employees by renovating an underutilized landscaped area, while also helping to reduce the volume of runoff being sent to storm sewers and Highland Creek from their property.

With supportive grants from Earth Day Canada and Ontario Ministry of the Environment and Climate Change, the scale of the project was expanded to include a 9,300 L rainwater cistern and irrigation system to provide a source of water for landscaping, a rear lot infiltration trench, three soakaway ponds and a lined, decorative pond and fountain, to reach a total value of $97,920. Combined these features disconnect 4 of 6 roof drains (2,600 m^2 roof area) from municipal storm sewers, which produces approximately 1.8 million L (1,800 m^3) of runoff in an average year. Selection of LID practices implemented was influenced by the relatively small pervious area available, which favored practices with small surface footprints, and the desire to create attractive landscape and water features for aesthetic value, in addition to stormwater management benefits. Locations and configurations of stormwater practices on the Calstone Inc. lot are illustrated in Figures 1 and 2. Characteristics of the lot and source control practices are described in Table 1 and Table 2.

With the inclusion of a rainwater cistern, infiltration trench and soakaway ponds to their landscape renovation plan, Calstone Inc. has demonstrated ways that industrial/commercial property owners can contribute to improving the health of Highland Creek. These stormwater practices set Calstone apart from other businesses in the area by providing a distinctive green space for employees and showing exemplary water stewardship in the community. With the help of the Toronto and Region Conservation Authority (TRCA), through Partners In Project Green (PPG) and the Sustainable Technologies Evaluation Program (STEP), the project outcomes and experiences were shared with the community through showcasing events, tours and publications to inspire further action.

Figure 1. Calstone Inc. property and stormwater source control practice locations

Table 1. Calstone Inc. Site Characteristics

Site Details		
Watershed (Subwatershed)		Highland Creek (Malvern Branch)
Address		415 Finchdene Square, Toronto, Ontario
Lot area (m^2)		7,835
Annual precipitation (mm)[1]		779.3
Lot imperviousness (%)		91.2
Drainage features		Roof drains and pavement catchbasins
Roof area (m^2)		3,900
Annual roof runoff volume (m^3)[2]		2,753.3
Lot Land cover (m^2)	Building/Roof	3,900 (49.7 %)
	Pavement	3,245 (41.4 %)
	Pervious	690 (8.8 %)
Soil texture		Loamy
Soil particle size distribution[3]	Sand	49%
	Silt	41%
	Clay	10%
Soil infiltration rate (mm/h)[4]	Mean	1.9
	Median	1.7
	Minimum	0.8
	Maximum	4.1

Notes:
1. Average annual precipitation is based on Environment Canada Climate Normals, Toronto Malvern station, 1971 – 2000 (Environment Canada, 2000).
2. Runoff volume is based on roof area, annual precipitation depth and runoff coefficient of 0.9.
3. Based on laboratory analyseis of soil samples taken at 1.5 m depth below grade in the soakaway ponds location prior to construction.
4. Based on pit percolation test at 1.5 m depth below grade in the soakaway ponds location prior to construction, and observed pond drainage rates over the 2015 field monitoring period (23 rain events).

Table 2. Calstone Inc. Site Characteristics

Stormwater source controls:	Volume (m^3)	Roof Area (m2)
Rainwater cistern	9.3	650
Infiltration trench	6.5[1]	650
Soakaway pond #1	15.6[2]	1300
Soakaway pond #2	1.0[3]	
Soakaway pond #3	20.6[4]	
Combined	53.0	2600

Notes:
1. Based on trench dimensions and assumed 40% void space ratio of open graded gravel fill.
2. Based on cylindrical geometry with 4.88 m diameter and maximum depth of 0.84 m.
3. Based on cylindrical geometry with 1.28 m diameter and maximum depth of 0.82 m.
4. Based on cylindrical geometry with 5.66 m diameter and maximum depth of 0.82m.

EVALUATION APPROACH

Performance of the stormwater source controls implemented was evaluated through continuous field monitoring of rainfall depth and practice water levels over a 5 month, July to November 2015 period. A tipping bucket rain gauge was installed on the roof and pressure transducer water level loggers were installed in the cistern and three soakaway ponds and all were set to record readings on 5 minute intervals. Monitoring data was used to assess runoff volume reduced, rainwater used/municipal water conserved, soakaway pond drainage rates and frequency and causes of overflows.

STUDY FINDINGS

The rainwater cistern and irrigation system reduced runoff volume from the 650 m² roof drainage area by approximately 64% over the 2015 growing season. A total of 56,331 L (56.3 m3) of rainwater was harvested and used to irrigate the planting beds over the July 1 to October 26, 2015 cistern operating period, resulting in a municipal water cost savings of $180. Drainage of cistern overflow water via infiltration below its gravel base accounted for around 25% of roof runoff, which contributed substantially to overall system performance. Weather during July and September was much drier than normal, while October was much wetter. Despite these deviations from climate normals, monthly quantities of rainwater used for landscape irrigation remained relatively consistent (Table 3), indicating that the irrigation system was being routinely operated by Calstone staff. The cistern overflowed on 9 occasions when roof runoff exceeded available storage capacity. When fully drained, the cistern has the capacity to fully capture runoff from a 15.7 mm rain event without overflowing, which was evident on September 11, 2015 when a 15.4 mm storm filled the cistern from empty to just below the overflow outlet elevation (Figure 4).

Water levels in soakaway ponds 1 and 2 never exceeded their respective spillways, while pond 3 overflowed twice into the neighbouring property catchbasin during two major storm events. On August 10, 2015 54.4 mm of rain fell over 5.5 hours, which exceeded the 10 year return period 6 hour storm for the area (Environment Canada, 2014). On October 28, 2015 70 mm of rain fell over 16.5 hours, which is close to the 50 year return period 24 hour storm. To prevent future overflows into the neighbouring property catchbasin, it is recommended that an overflow pipe be installed in pond 3 that outlets to the pavement catchbasin at the front of the property.

Together the infiltration trench and three soakaway ponds reduced runoff volume from their combined drainage areas by approximately 89% over the July to November evaluation period. The three soakaway ponds infiltrated approximately 203.6 m³ of stormwater during the 5 months, which is equivalent to 10 tanker truck loads of water and represents about 44% of runoff from the roof drainage area. Water loss via evaporation from the soakaway ponds also substantially contributed to their drainage performance. Based on continuous monitoring of soakaway pond water levels, soils below the ponds were observed to drain at rates ranging between 0.8 and 4.1 mm/h (1.9 mm/h mean rate for all pond data combined) over the monitoring period. Drainage rates were highest when the ponds were closest to being full, owing

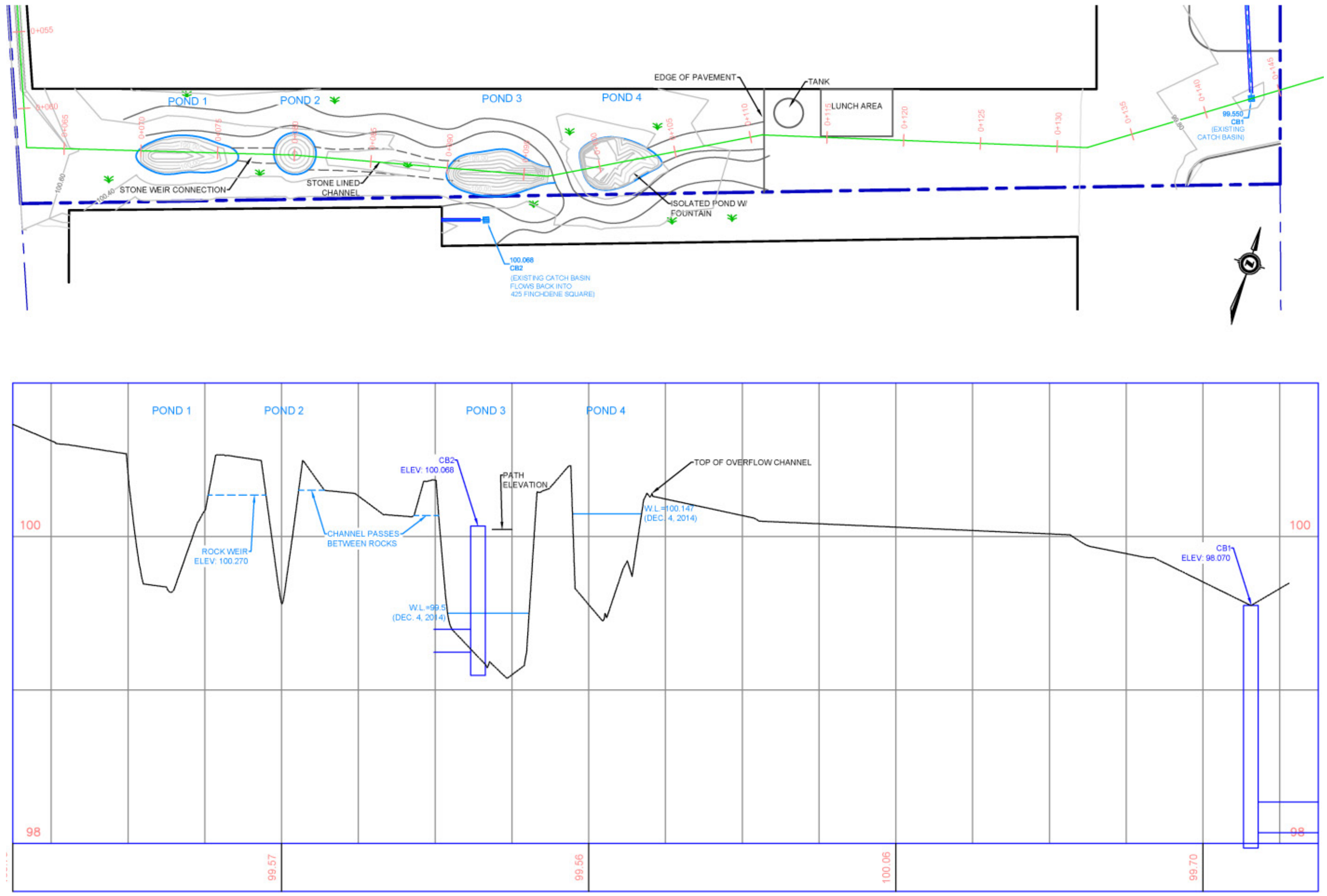

Figure 2. As-built drawing of Calstone rainwater harvesting and landscape renovation project

Figure 3. Water level monitoring well being checked

to greater pressure head at the pond bottom helping to force the water into the underlying soil. Pond 3 was observed to drain from full to half full in approximately 9 days, while it took 13 days to drain from half-full to empty (Figure 5). The ratio of impervious area to infiltration practice footprint area for the three soakaway ponds combined is 29:1, which is similar to ratios applied to the design of roof runoff infiltration practices examined previously by STEP (TRCA, 2013).

CONCLUSIONS & RECOMMENDATIONS

This study demonstrated the viability of above ground cisterns, infiltration trenches and soakaway ponds, as stormwater source control practices within the climatic context of the Greater Toronto Area. The following recommendations on practice design and further research needs are offered based on the findings from this study.

Facility Design

- In cold climates like Ontario, to provide year-round runoff reduction benefits, install stormwater infiltration practices underground with the base located below the maximum frost penetration depth for the region, and at least one metre above the seasonally high groundwater level;

- Where opportunities for year-round rainwater use exist, install cisterns underground or as part of building integrated rainwater harvesting systems.

Table 3. Monthly and total rainwater use, July 1 to October 26, 2015

Time period	Rainfall Depth (mm)	Rainwater Use (m^3)
July	23.8	11,874
August	98.8	17,763
September	63.2	16,274
October	129.2	13,017

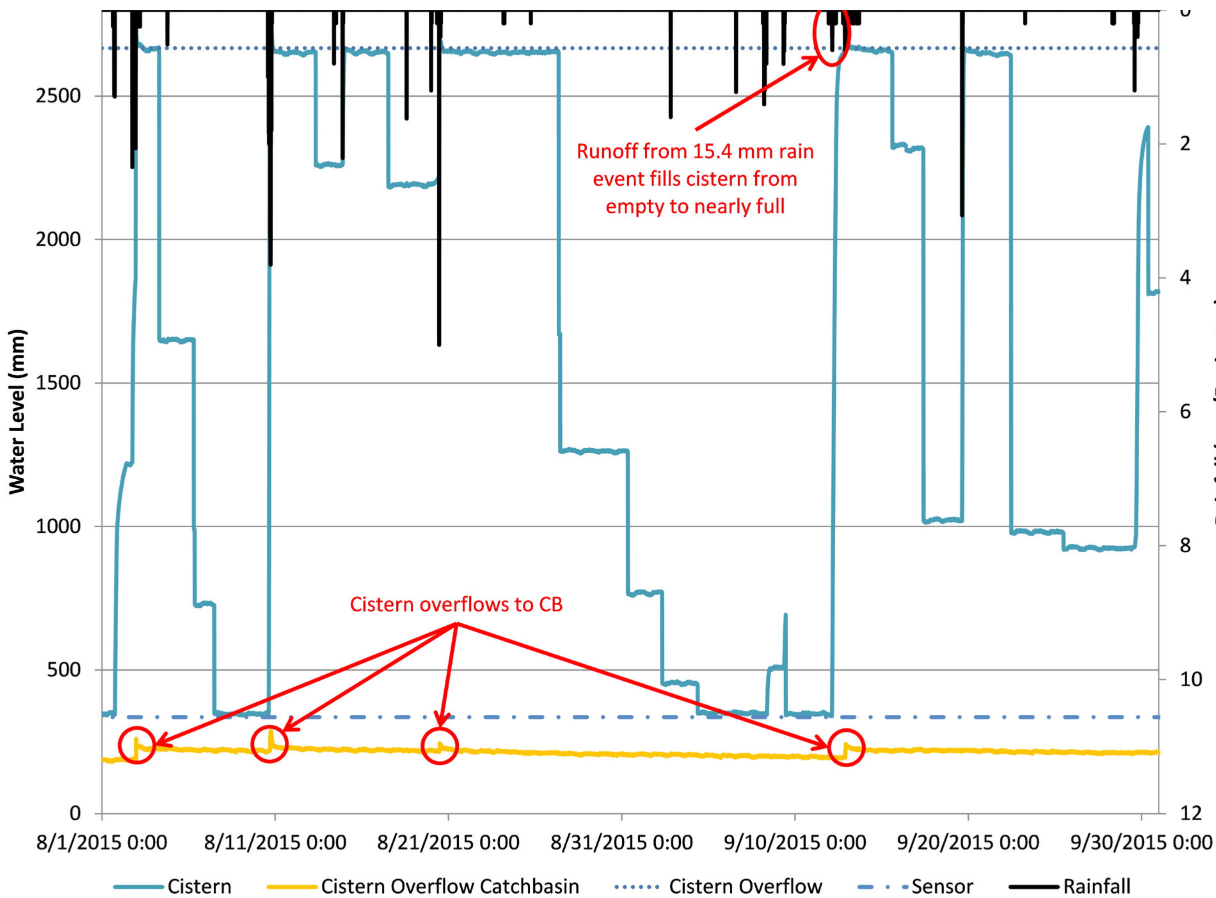

Figure 4. Hydrograph showing rainfall depth and cistern water level during August and September 2015

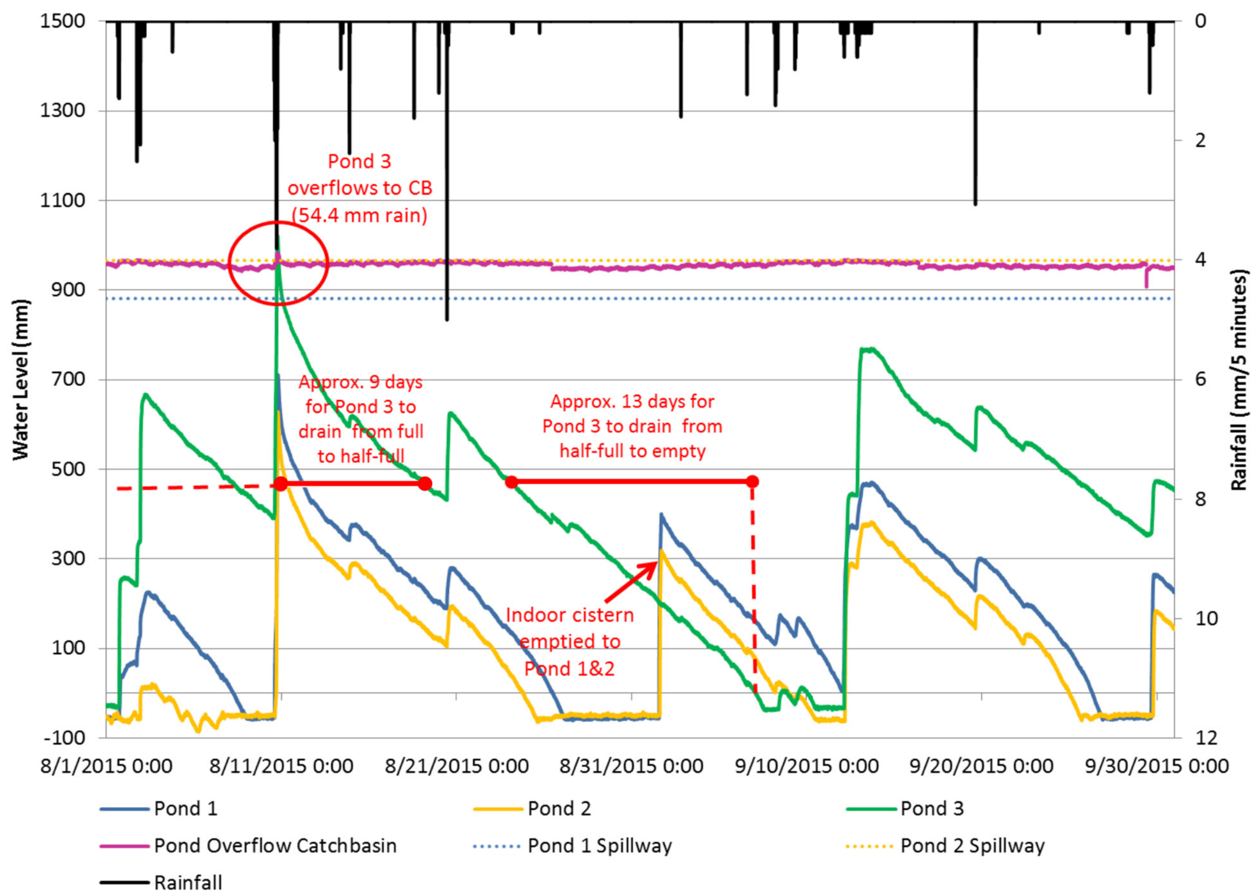

Figure 5. Hydrograph showing rainfall depth and soakaway pond water levels during August and September 2015

- To improve drainage performance, design stormwater infiltration practices as continuous or connected "treatment trains" of features with rectilinear trench configurations that aim to maximize side surface area.

- An additional outlet should be added to Pond 3 that connects to the front lot catchbasin to prevent the pond from overflowing into the neighbour's catchbasin, like the one that conveys cistern overflows.

- The rear lot infiltration trench should have included standpipes on the up- and down-gradient ends of the perforated pipe to permit push camera inspection and flushing with a sewer cleaning jet nozzle, and at least one monitoring well in the furthest downgradient end, screened to the base of the trench, to allow water level and drainage performance to be tracked over time.

- To disconnect the remaining two roof drains from direct connection to the municipal storm sewer, it is recommended that they be directed to an underground infiltration trench, installed below the asphalt area on the north side of the property, that is sized to capture runoff from a 27 mm rain event over the 1,300 m2 roof area, that overflows to a front lot catchbasin.

Further Research Needs

- Drainage performance of soakaway ponds during winter thaw periods and spring freshets is needed to better understand their year-round benefits and seasonal limitations.

- Further research on the long-term performance of soakaway ponds is needed to provide better data on changes in functional performance over time, required frequency of maintenance and the interval at which full scale rehabilitation may be needed.

- The role of soil, cover (i.e., stone versus mulch), vegetation and associated microbial processes in maintaining infiltration in stormwater infiltration practices is not well understood. Further research is needed to identify the types of soil, cover, maintenance practices and vegetation best suited to meeting their runoff control functions, and how selections influence long term maintenance.

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Figure 6. Cistern and disconnected downspout at Calstone

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About STEP

The water component of the Sustainable Technologies Evaluation Program (STEP) is a partnership between Toronto and Region Conservation Authority (TRCA), Credit Valley Conservation (CVC), and Lake Simcoe Region Conservation Authority (LSRCA).

Toronto and Region Conservation Authority