Sustainable Technologies
EVALUATION PROGRAM

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 stormwater 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.

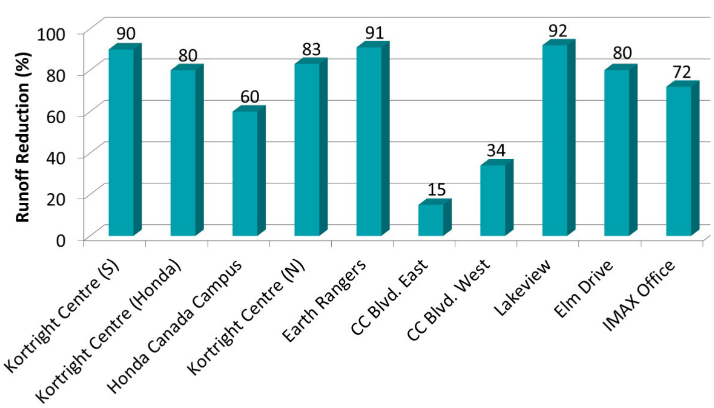

Figure 1. Runoff volume reductions for monitored events

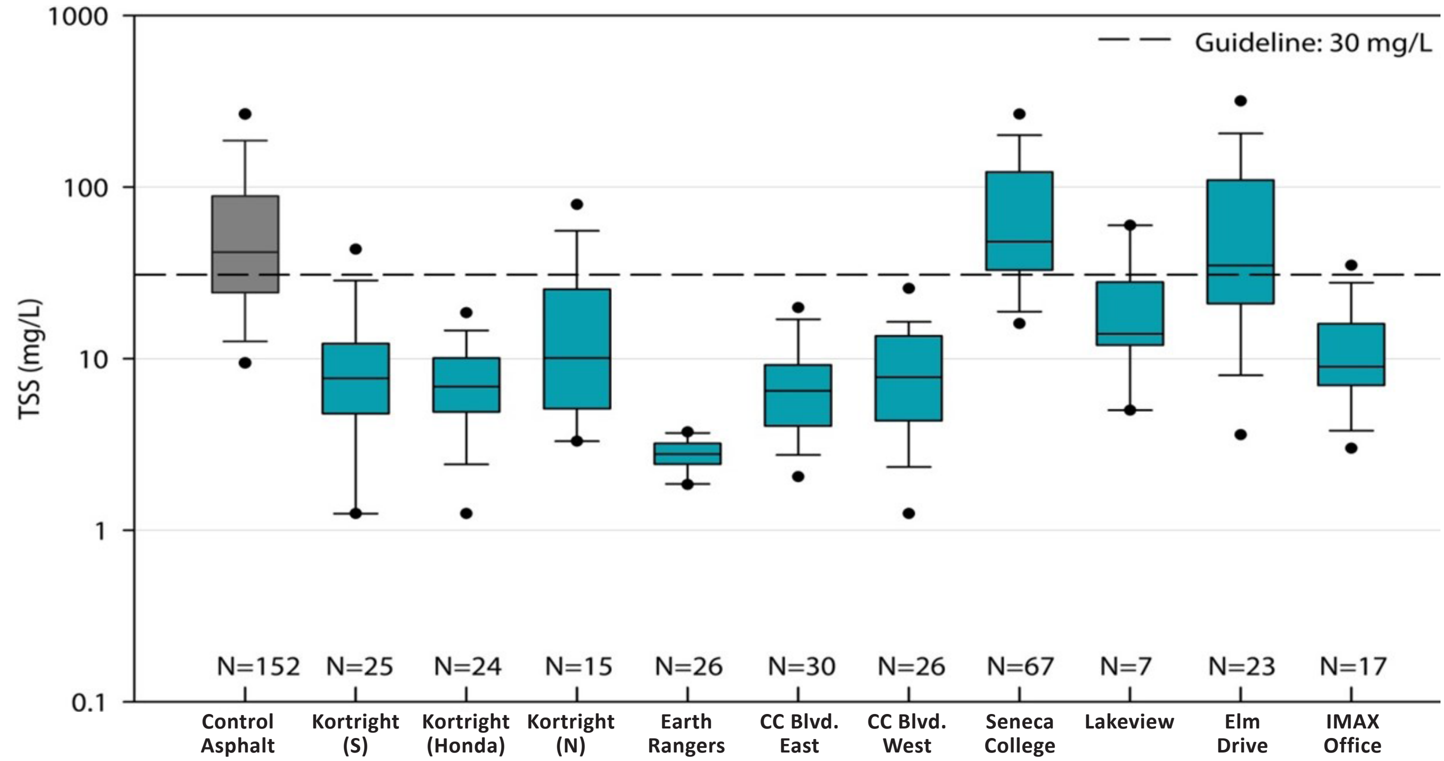

Figure 2. Effluent concentrations of Total Suspended Solids (TSS)

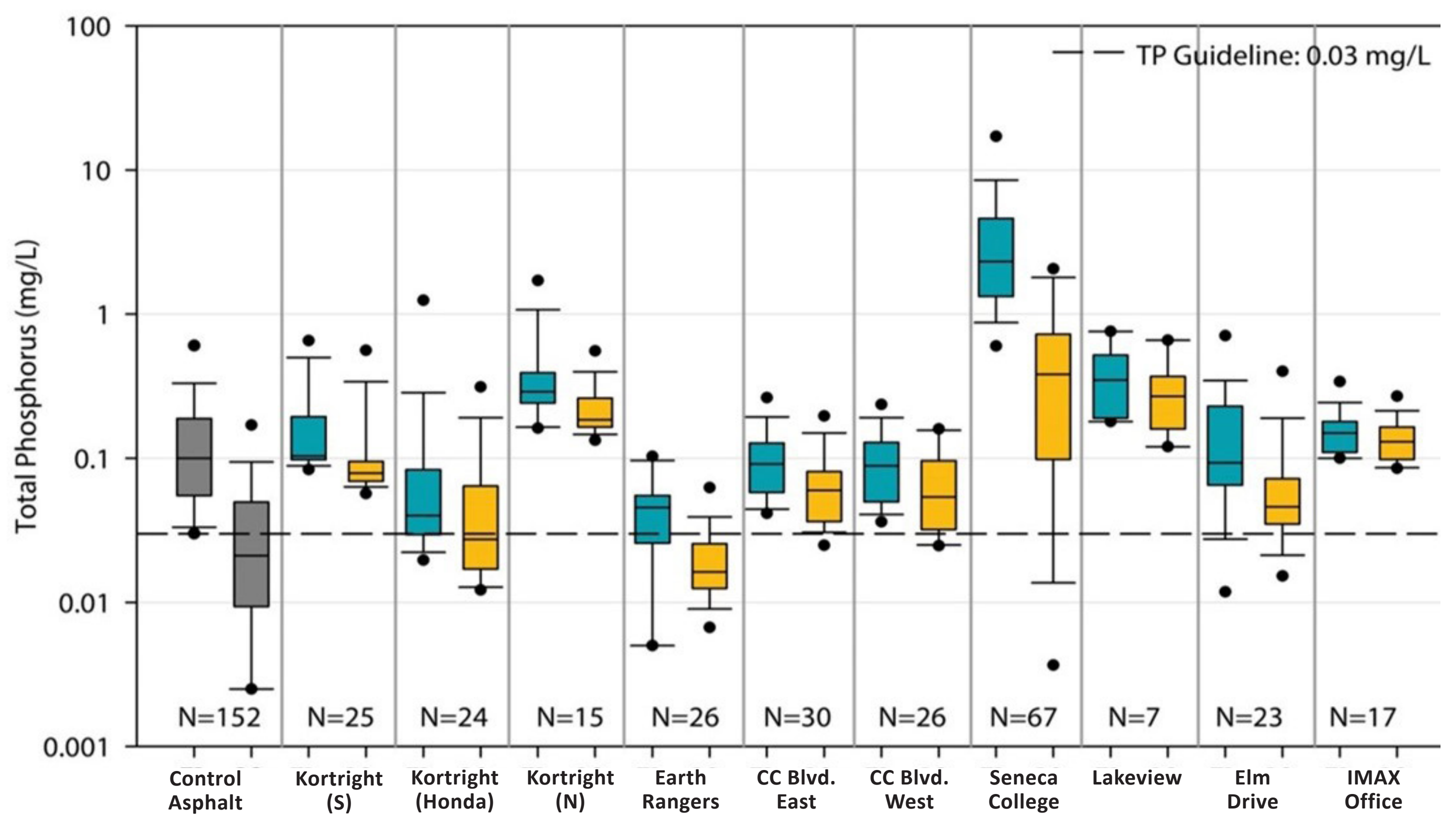

Figure 3. Effluent concentrations of Total Phosphorus (TP) and Ortho-phosphate (OP[4])

Detailed evapotranspiration estimates for two of the sites (Earth Rangers and Kortright Centre South) showed that evapotranspiration accounts for between 9 and 13% runoff volume reductions for monitored events. These were determined based on Bowen energy balance measurements of evapotranspiration in a nearby meadow at the Kortright Centre for Conservation. In general, evapotranspiration as a percentage of total annual runoff volume loss increases as the impervious-to-pervious area decreases. This occurs because evaporation from the impervious drainage area is very small. Hence, as the impervious portion of the drainage area increases, the facility contribution of volume losses through evapotranspiration becomes an ever smaller proportion of total rainfall runoff over the drainage area.

The two lined bioretention facilities located at County Court Boulevard (CC East and West) reduced runoff by 15 and 34%, even though these were not designed to significantly reduce runoff volumes (Figure 1). Evapotranspiration is the primary mechanism for runoff volume reductions. An evapotranspiration rate of approximately 30% over the study period is estimated based on the site I:P ratio and previous estimates based on bowen energy balance calculations (STEP, 2014). Runoff volume reductions were similar to this value on the west swale, but lower on the east swale, likely due to groundwater intrusion. Flow measurements showed continuous flow from the east swale even during dry weather. As expected, most of the volume loss occurred during the summer months when temperatures are high and antecedent moisture content is low, allowing for runoff to be temporarily stored and subsequently returned to the atmosphere through the process of latent heat transfer.

The bioretention facilities reduced total suspended solids (TSS) loads by 73 to 99% (Figure 4) and all but two had median effluent TSS concentations below 30 mg/L (Figure 2). The effective removal of suspended solids is important because many common stormwater pollutants, such as metals, bacteria, organic compounds and nutrients are readily adsorbed by sediment particles and are therefore effectively removed with the solids. The primary solids removal mechanism in bioretention facilities is filtration, typically within the upper 10 cm of soil. Media depth and texture appeared to have little influence on removal rates or effluent concentration. The primary difference in effluent concentrations among sites likely relates to the presence and subsequent mobilization of fine particles from the clear stone storage reservoir, although it is also possible that fine sediment from the filter media is migrating through the pea gravel choking layer or geotextile fabric separating the media from the gravel reservoir below. If this hypothesis is correct, the particles in the effluent would largely reflect the quality of the filter media, rather than that of the runoff from the paved drainage area.

As observed in previous studies, phosphorus removal rates and effluent concentrations exhibited significant variation both seasonally and between sites. The variation between sites likely reflects differences in the phosphorus content of filter media, and their capacity to adsorb and retain phosphorus. In the Seneca College bioretention, for instance, the media mix was comprised of a garden loam with high organic matter, resulting in elevated effluent concentrations of phosphorus and nitrogen. Seasonal variations in phosphorus relate to leaf fall and plant die back in the autumn months. Effluent concentrations of soluble phosphorus increased considerably during this period. Asphalt surfaces also showed high phosphorus release in the fall due to the build up of leaf litter in the catchbasin draining the site. Later studies showed concentrations of phosphorus in asphalt runoff exceeding 5 mg/L during some autumn rain events.

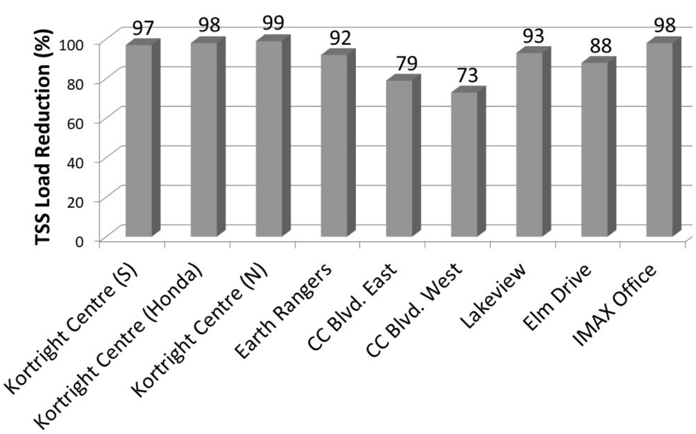

Figure 4. Total Suspended Solids (TSS) load reductions

The combined benefit of runoff volume reductions and water quality improvements resulted in TSS load reductions of between 88 and 99% for the unlined facilities, and 73 and 79% for the two lined facilities (Figure 4). These load based removal rates exceed the 80% target suggested by MOECC for enhanced treatment, and demonstrate the effectiveness of these practices as efficient sediment traps. Even the IMAX bioretention facility which exhibited lower than average runoff reduction through infiltration due to the presence of bedrock close to the surface, was shown to have TSS load reductions on par with other facilities, largely because of the effective filtration and capture of

Figure 5. Bioretention demonstration facilities

sediment at the surface. As mentioned previously, these load reduction rates are lower during large events when bypass is occurring, and higher for small events that generate little to no runoff.

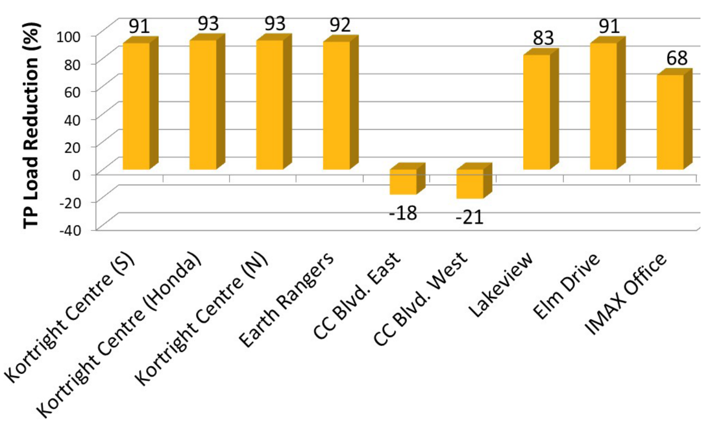

Figure 6.Total phosphorus load reductions

Phosphorus load reductions in unlined facilities were impressive, despite evidence of phosphorus leaching from the filter media (Figure 6). As with TSS, these load reductions were largely due to the reduction in runoff volumes. In the two lined facilities (CC East and West), negative load reductions were observed because effluent concentrations were higher than influent concentrations, and volume reduction through evapotranspiration was not sufficient to offset this increase in phosphorus concentrations.

Long term measurements of surface infiltration conducted at two locations (Earth Rangers and Seneca College) showed that the living plants and soil micro-organisms may be helping to maintain natural infiltration functions during the first several years after installations. The time it takes for water ponded on top of bioretention facilities to infiltrate after large rain events provides an indication of how quickly the filter media is able to absorb and infiltrate stormwater runoff. The ponding during several rain events was monitored with automated water level sensors at two sites soon after construction and again after the bioretention had matured. At the Seneca College site, the second set of measurements were taken 7 and 11 years after installation. At the Earth Rangers site, the measurements were repeated 7 years after construction. In both cases, the first 7 years showed no evidence of fine sediment buildup on the surface, or of a reduction in the rate of surface water level decline after large events. After 11 years, however, the Seneca bioretention infiltration rate was slower than measured 4 years earlier. This suggests that maintenance of the surface may be needed after 8-10 years to maintain rapid infiltration through the media. Plants at both sites were flourishing and received little to no irrigation during the summer.

Maintenance tasks were more intense during the plant establishment phase and declined thereafter. During the early phase of establishment and for the first two years, regular irrigation and some plant replacement was often needed. Once the plants were established and a dense cover of vegetation had formed, only periodic maintenance of plants and weeds was required. Curb inlets often need to be swept two to three times a season, and forebay inlets, such as at the Kortright bioretention, benefitted from annual sediment removal. Some sites showed minor surface slumping (3 - 5 cm), and required additions of filter media or mulch to re-establish the original surface elevation.

CONCLUSIONS

The bioretention facilities surveyed as part of this comparative assessment performed reasonably well, and in most cases, exceeded performance expectations. The most important influences on performance were the size of the drainage area relative to the footprint of the facility (or I:P ratio), the elevation of the underdrain above the native soils and the presence/absence of a liner. The depth of media, plant cover type, mulch characteristics and inlet configuration did not appear to strongly affect overall performance. Long term measurements of infiltration rates suggest that surface clogging may occur very slowly, thereby limiting maintenance activities within the first 8 to 10 years to routine tasks such as weeding, pruning, inlet cleaning, and occasional additions of mulch.

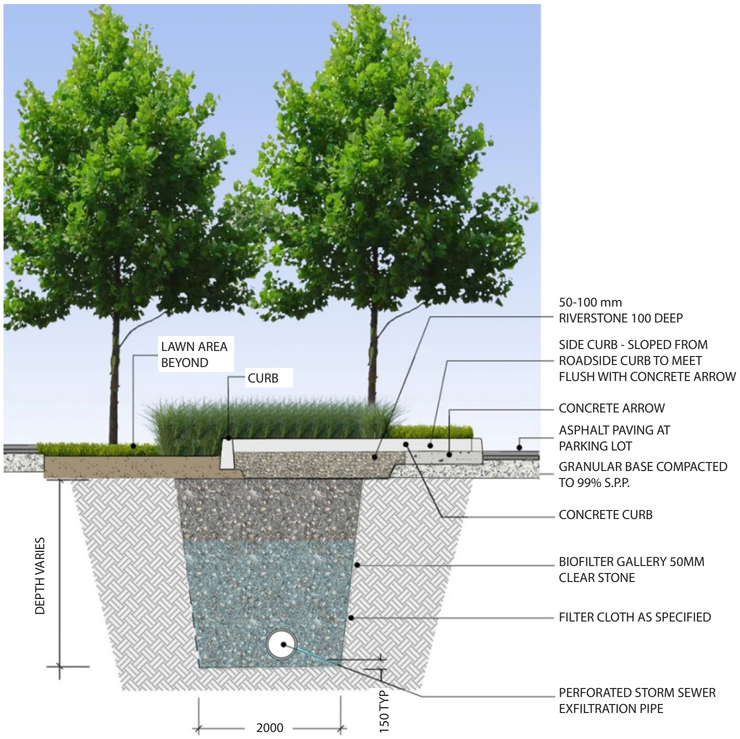

Figure 7. Cross section of the Honda Canada Campus biofilter swale. (Image courtesy of Schollen & Company Inc.)

Figure 8. Bioretention facility at Earth Rangers functioning during winter months

This communication has been prepared by the Sustainable Technologies Evaluation Program. Funding support for this study was provided by Region of Peel, York Region and City of Toronto. The contents of this report do no necessarily represent the policies of the supporting agencies and the funding does not indicate an endorsement of the contents.

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