# PERFORMANCE ASSESSMENT OF A STORMWATER RETROFIT POND - HARDING PARK, RICHMOND HILL, ONTARIO

a report prepared by the

STORMWATER ASSESSMENT MONITORING
AND PERFORMANCE (SWAMP) PROGRAM

for

Great Lakes Sustainability Fund of the Government of Canada
Ontario Ministry of Environment and Energy
Toronto and Region Conservation Authority
Municipal Engineers Association of Ontario
Town of Richmond Hill

June, 2002

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# PUBLICATION INFORMATION

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# THE SWAMP PROGRAM

The Stormwater Assessment Monitoring and Performance (SWAMP) Program is an initiative of the Government of Canada's Great Lakes Sustainability Fund, the Ontario Ministry of Environment and Energy, the Toronto and Region Conservation Authority, and the Municipal Engineer's Association. A number of individual municipalities and other owner/operator agencies have also participated in SWAMP studies.

During the mid to late 1980s, the Great Lakes Basin experienced rapid urban growth. Stormwater runoff associated with this growth has been identified as a major contributor to the degradation of water quality and the destruction of fish habitats. In response to these concerns, a variety of stormwater management technologies have been developed to mitigate the impacts of urbanization on the natural environment. These technologies have been studied, designed and constructed on the basis of computer models and pilot-scale testing, but have not undergone extensive field-level evaluation in southern Ontario. The SWAMP Program was intended to address this need.

The SWAMP Program's objectives are:

* to monitor and evaluate new and conventional stormwater management technologies; and
* to disseminate study results and recommendations within the stormwater management industry.

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Additional information concerning SWAMP and the supporting agencies is included in Appendix A.

# ACKNOWLEDGEMENTS

This report was prepared for the Steering Committee of the Stormwater Assessment Monitoring and Performance (SWAMP) Program. The SWAMP Program Steering Committee is comprised of representatives from:

- the Government of Canada's Great Lakes Sustainability Fund,
- the Ontario Ministry of Environment and Energy,
- the Toronto and Region Conservation Authority,
- the Municipal Engineers Association of Ontario.

This study was jointly funded by the Ontario Ministry of Environment and Energy (OMOEE), the Great Lakes Sustainability Fund (formerly the Great Lakes 2000 Clean-up Fund) and the Town of Richmond Hill. The OMOEE also provided office facilities and logistic support for the SWAMP program. The Laboratory Services Branch of the OMOEE provided laboratory analyses. Staff at the Town of Richmond Hill provided permission to conduct the monitoring study and assisted with the installation and operation of monitoring equipment. The Toronto and Region Conservation Authority provided administrative support for the SWAMP program.

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- Michael D'Andrea — City of Toronto, Municipal Engineers Association of Ontario
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# EXECUTIVE SUMMARY

## Background

In 1995, the Town of Richmond Hill converted its Harding Park Stormwater Management Facility from a water quantity dry pond to a multi-celled wetpond/wetland designed to improve stormwater quality and meet current erosion control objectives, while maintaining its original quantity control function. Located within the degraded Don River watershed, the Harding Park project is one of several community action sites identified by the Don Watershed Task Force as demonstrating techniques of regeneration at the local level. The combined effect of many such local projects within the watershed are expected to help restore health to the Don River and, in support of the Toronto and Region Remedial Action Plan (RAP), improve water quality and aquatic habitat along the Toronto waterfront.

Although several quantity-to-quality pond retrofits have been implemented in Ontario over the past 10 years, there is a paucity of data demonstrating the effectiveness of these retrofits, especially for pond-wetland systems. Also, little is known about operation and maintenance issues related to aspects such as the frequency of sediment clean out from stormwater ponds. To generate the necessary data, the Ontario Ministry of Environment and Energy (OMOEE), the Toronto and Region Conservation Authority and the Government of Canada, through the Great Lakes 2000 Clean-up fund (superseded by the Great Lakes Sustainability Fund), jointly agreed to monitor the facility under the Stormwater Assessment Monitoring and Performance (SWAMP) program. This report presents the results of the monitoring program, discusses implications with regard to receiving water impacts, and provides recommendations for improvements to the facility.

## Study Objectives

The overall objective of this study was to provide guidance to urban planners, designers and owners of stormwater facilities concerning the design, performance, and maintenance of stormwater retrofit ponds. Within this general context, the specific objectives were to:

- determine hydrologic characteristics of the study catchment and stormwater retrofit pond/wetland (*e.g.* runoff coefficient, peak flows, hydraulic detention times) and evaluate these against the original design objectives;
- assess the stormwater treatment performance of the facility on an average event and seasonal load basis;
- identify aquatic plant species below the high water line of the facility and assess the effectiveness of planting plans;
- evaluate the use of algae as a indicator of spatial variations in stormwater quality within the facility;
- investigate the long-term operation, maintenance and dredging requirements of the facility;

- identify environmental benefits/limitations of the facility and provide recommendations for facility improvement.

## Site Description

The retrofit facility incorporates three cells in series: a small sediment forebay, larger wet pond and small wetland (Figure 1). The pond and forebay cover a 0.7 hectare area and have a total storage capacity of 2965 $m^3$ consisting of a 1015 $m^3$ permanent pool and 1950 $m^3$ of active (or extended detention) storage. By contrast, the former dry pond was 0.4 hectares in area and had a total storage capacity of 1650 $m^3$. Surface drawoff Hickenbottom risers at the forebay and wetland outlets provide for hydraulic control and extended detention. Emplaced sand lenses (or 'French drains') in the berm between the wet pond and wetland help to maintain moist soils in the wetland during dry weather periods. The design of the facility meets the OMOEE's stormwater quality and erosion control guidelines with respect to maximum depth (less than 3 m), drawdown time and storage volume, but the 1:1 length-to-width ratio was less than the 3:1 ratio recommended by the OMOEE.

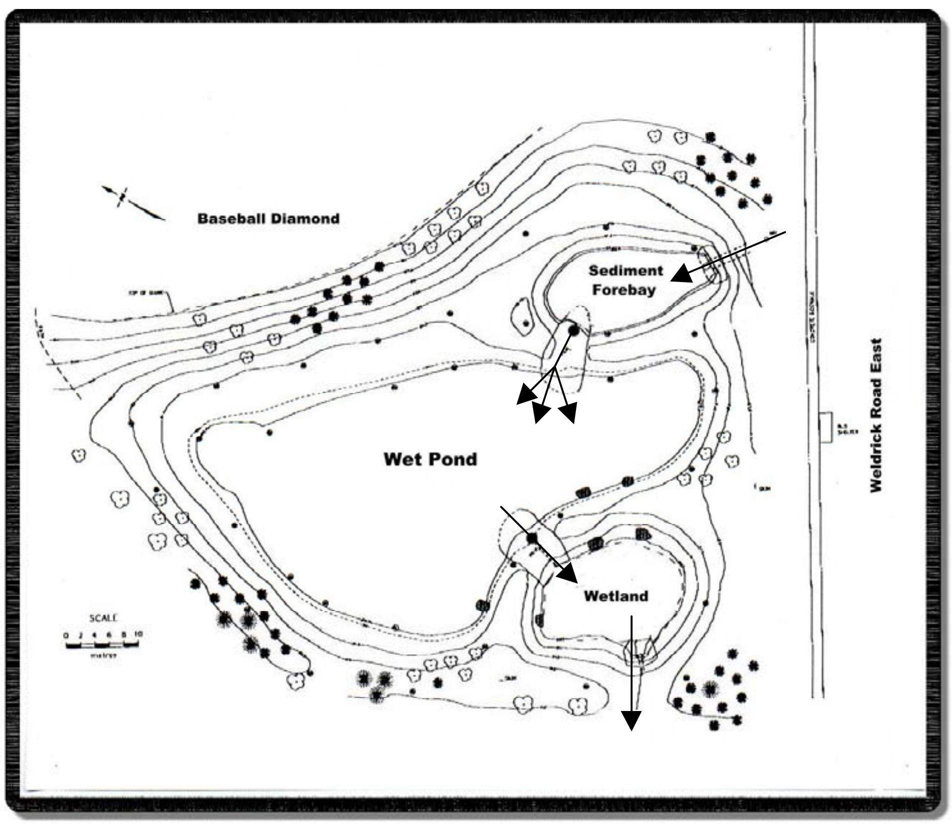


***Figure 1:*** Study site

The facility receives runoff from a 16.8 hectare residential catchment that lies on the southern edge of the Oak Ridges Moraine. The primary local surface water body is German Mills Creek, which drains to the Don River. Land use in the drainage catchment is medium to high density residential, serviced to about 70% by curb, gutter and storm sewers and 30% by roadside ditches and culverts. Prior to construction of the retrofit facility, aquatic habitat in the creek was degraded as a result of urban development and instream erosion control works. Soils in the area were considered to have low infiltration and high runoff potential. Climate is temperate with thermal highs and lows in all seasons moderated by the dominant lake effect from Lake Ontario, 30 km south of the study site.

## Study Methods

The monitoring study was conducted from January 1996 to November 1997. Data were analyzed separately for the 'summer/fall' period, from May 1 to November 30, and the 'winter/spring' period, from December 1 to April 30. During the first year of the monitoring period, from January to late August 1996, the berm separating the wet pond and wetland was in a state of disrepair, resulting in unreliable and unrepresentative effluent flow data. Therefore, the focus of the data analysis was on results collected after berm repair (September 1996 to November 1997).

The key components of the monitoring program included rainfall, runoff, water quality, temperature, aquatic vegetation, and in-pond algal communities. Rainfall data in 1996 were obtained from the Buttonville Airport weather station, seven kilometers southeast of the study site, and in 1997, from a tipping bucket rain gauge located immediately adjacent to the Harding Park facility. Temperature impacts of the facility on the downstream watercourse were assessed via continuous temperature monitoring at the inlet, outlet and immediately upstream of the outlet in German Mills Creek. Continuous runoff data were collected at the inlet and outlet using area-velocity flow meters from May to November in 1996 and 1997. During rain events over the same period, flow-proportionate water quality samples were collected using automated instruments. Grab samples were collected during the winter/spring season (December to April). Samples were submitted to the Ministry of Environment and Energy laboratory in Toronto for analysis of total suspended solids (TSS) and all major pollutant groups, including nutrients (phosphorus and nitrogen compounds), metals, organics, bacteria and parameters such as pH, conductivity and particle size distribution.

Subsequent data analysis included calculation of event flow volumes, runoff coefficients, peak flow attenuation, flow durations, lag and hydraulic detention times, hydrological mass balances, average event mean concentrations (AEMCs), 95% confidence intervals, inlet and outlet loading and load-based removal efficiencies. The catchment area and facility were modelled using PCSWMM™ to predict long-term flow rates and suspended solids loading. The model was calibrated using field data collected at the Harding Park site, and a long-term continuous simulation of the model was based on 12 years (1986 to 1997) of rainfall data from the Toronto Buttonville Airport, 7 km southeast of the facility.

The vegetation study inventoried plant species composition and coverage below the high water mark in the facility and assessed the validity of natural colonization as a planting strategy. The aquatic community study focused on the algal communities in the sediment forebay and wet pond with a view to better understand the water quality improvement function of the facility.

## Study Findings

***Water quantity***

The post-berm repair data set includes 6 large storms (greater than 20 mm), 8 medium sized storms (10 to 20 mm) and 1 small storm (less than 10 mm). On average, 34% of catchment rainfall appeared as surface runoff during storm events over the monitoring period. Storms with less than 4.0 mm of rainfall produced negligible runoff, probably due to depression storage and infiltration in roadside ditches. This observation approaches the 5 mm level suggested in the Ontario Stormwater Management Practices and Planning (SWMP) manual for stream baseflow maintenance.

Rain events during the study period generated an average influent storm flow volume of 1451 $m^3$. The balance between storm flow at the inlet and outlet averaged 11% during monitored rain events, possibly due to exfiltration within the pond (which was not measured), but more likely due to under or over estimation of flow by automated flow instruments. Dry weather baseflow rates were estimated to be 1.5 L/s at the inlet and 1.3 L/s at the outlet, indicating that water losses to pond exfiltration below the permanent pool water line were relatively minor.

During the period after berm repair, mean peak discharge rates were 137 and 27 L/s at the inlet and outlet, respectively. Only two storms had peak outlet flow rates beyond the post-berm repair design threshold of 52 L/s. Peak flow reduction was accompanied by a significant increase in the duration of flow from a 22-hour mean at the inlet to a mean of 46 hours at the outlet.

The hydraulic detention time, defined as the time delay between inlet and outlet hydrograph centroids, provides a measure of the extended detention feature of the facility, by which stormwater influent is temporarily detained, or held back within the facility. The detention time averaged 5.3 hours, with a range between 3.5 and 10.7 hours during individual events. Assuming plug flow displacement conditions (*i.e.* no mixing, no short circuiting), the residence time of an element of fluid within the facility was estimated at roughly 18 hours. This estimate suggests that under actual conditions of short-circuiting and mixing of the influent and permanent pool water, the residence time of a fluid element passing through the facility would be somewhat less than 18 hours. A falling head drawdown equation was used by the designer to meet the OMOEE ‘detention time’ guideline of 24 hour detention of a 25 mm storm (4 hour Chicago distribution). In general, the observed drawdown time for storms with greater than 20 mm exceeded the 24 hour target.

### *Water quality*

Total suspended solids (TSS) is a critical variable in stormwater quality analysis because several pollutants (*e.g.* phosphorus, metals and some organics) are bound to suspended particles and, hence, the removal of TSS also serves as a measure of the removal of these bound pollutants. For the summer/fall monitoring period after berm repair, removal of TSS averaged 80%, ranging between 26 and 92% during individual events. Influent and effluent AEMCs were 345 and 46 mg/L, respectively. Winter/spring average performance based on grab samples was similar, averaging 78% and ranging between 58 and 97%. Winter/spring influent and effluent average concentrations were 270 and 39 mg/L, respectively. Removal efficiencies during both seasons exceeded the 70% recommended in the SWMP manual for the level of fisheries protection (*i.e.* level 2) deemed appropriate for the reach of German Mills Creek downstream of the Harding Park facility. The geotextile wrapped Hickenbottom risers at the forebay and wet pond outlets, as well as the location of the discharge point at the surface of the permanent pool may have contributed to the reasonably good TSS removal efficiency results.

On average, the median particle size of TSS was 4.5 :m (fine silt) at the inlet and 2.3 :m (clay) at the outlet. Removal efficiencies for sand, silt and clay were estimated at 81, 65 and 48%, respectively. Particles greater than 4 μm (*i.e.* silt and sand size classes) accounted for 55% of the inlet particles compared to only 34% at the outlet, indicating size selective removal of suspended solids.

Removal efficiencies for most parameters were less than observed for TSS (Table 1). During the summer/fall season, load-based removal efficiency was 42% for total phosphorus, 54% for total ammonia, and a range of 11 to 83% for most metals. In contrast, winter removal efficiencies were 56% for total phosphorus, 18% for total ammonia and a range of –13 to 83% for most metals. The surface drawoff configuration of the Hickenbottom risers in the sediment forebay and wet pond did not provide adequate protection from the rapid release of floating oil and grease, which may partly explain the relatively low summer/fall removal efficiency (48%) for this constituent.

During the summer/fall monitoring period, effluent AEMCs of unionized ammonia, zinc, cadmium and copper were less than the Ontario Provincial Water Quality Objectives (PWQOs). PWQO exceedances during warm and cold seasons were noted for average concentrations of *E. coli*, total phosphorus, lead, iron, and during the winter/spring period only, for zinc and copper. Among the 17 herbicides and pesticides and 24 PAHs analyzed in this study, only pentachlorophenol and 2,3,4,6 tetrachlorophenol were found at influent concentrations above laboratory analytical detection limits in greater than 5% of samples analyzed. Effluent concentrations of both pollutants were consistently less than laboratory detection limits, suggesting that the pond was effective in reducing the likelihood that these contaminants will enter the creek.

***Table 1:*** Average seasonal effluent concentrations and overall load based removal efficiencies for selected parameters

| **Parameter/season** | **Summer/fall** | | **Winter/spring** | |
|---|---|---|---|---|
| | **Avg. Conc.** | **Rem. Eff. (%)** | **Avg. Conc.** | **Rem. Eff. (%)** |
| **TSS (mg/L)** | 48 | 80 | 39 | 78 |
| **Total Phosphorus (mg/L)** | 0.11 | 42 | 0.10 | 56 |
| **Phosphate (mg/L)** | 0.01 | 86 | 0.06 | 66 |
| **Ammonia (mg/L)** | 0.10 | 54 | 0.35 | 18 |
| **TKN (mg/L)** | 1.0 | -24 | 1.1 | 31 |
| **Copper (μg/L)** | 4.5 | 48 | 10.2 | 22 |
| **Zinc (μg/L)** | 16.4 | 70 | 40.0 | 38 |
| **Lead (μg/L)** | 7.7 | 83 | 6 | 11 |
| **Chromium (μg/L)** | 2.4 | 53 | 2.2 | -13 |
| **Cadmium (μg/L)** | 0.5 | 11 | 0.1 | 83 |
| **Oil and Grease (mg/L)** | 0.8 | 48 | 1.1 | 6 |

## *Water Temperature*

Continuous water temperature measurements indicated that the facility effluent was 6 to 9°C warmer than inlet and upstream creek temperatures during the warm summer months of July and August. The average daily temperatures of the influent, effluent and creek were 14, 23 and 15°C, respectively. Outlet temperatures were frequently above the 21°C limit generally accepted as the threshold for cold water fisheries habitat. However, dilution of facility effluent by the much larger discharge volumes from German Mills Creek would likely result in relatively minor impacts on creek temperatures downstream of the facility.

### *Aquatic Vegetation and Algae Monitoring*

Plants in wet pond treatment systems perform several functions, including bank stabilization, chemical uptake, root zone aeration, surface area attachment for bacteria and aesthetic appeal. Therefore, the type of plants established within the facility, and the success of planting programs was considered to be an important component of the overall performance assessment.

For two years, the aquatic vegetation below the high water level was monitored to determine the success of planted species in colonizing the area and extent of natural colonization by native and non-native species. Results indicated rapid natural colonization with full vegetation cover achieved after only two growing seasons (1996 and 1997). The community structure in all three cells of the facility tended towards a common group of dominant species characterized as aquatic/meadow marsh habitat. Natural colonization of both native and non-native species increased significantly in number, but the ratio of native to non-native species remained generally the same. If rapid natural colonization is found to be a common pattern at stormwater ponds and wetlands, there may be justification for reducing the number and diversity of plant species planted after construction. Although further study is required, the monitoring results suggest that cattail (*Typha*), spikerush (*Eleocharis*), rush (*Juncus*), bulrush (*Scirpus*), water plantain (*Allisma*) and waterweed (*Elodea*) may be worthy candidates for planting plans.

The use of algae as an indicator of biological response to differences in physical and chemical conditions between the forebay and wet pond was investigated. Results showed that the algal community in the forebay was generally poor and dominated by only one genus, whereas the wet pond algal community was significantly more diverse. Low diversity in the forebay was attributed to poor water quality, high and turbulent flow and cool water temperatures relative to the wet pond. Based on the algal community, the conditions in the forebay and wet pond were assessed as hypereutrophic and hypereutrophic-to-eutrophic, respectively. This assessment generally supports the concept of the forebay as a pollutant containment zone and buffer to downstream treatment cells.

***Facility Maintenance***

The stormwater catchment and facility was modelled to predict total flows, TSS loads, and provide information on the long-term maintenance needs of the facility. The long-term simulation indicated TSS removal efficiency of 75%, which is lower than the short-term removal rate of 80% observed during the study period. Results indicated that, in order to abide by the OMOEE's guidelines, the pond must be dredged every 16 years, with an error range between 13 and 22 years. Actual TSS accumulation within the facility should be field assessed in detail every 5 years. The forebay should also be assessed to ensure sediment deposition in this cell is not clogging the riser. More frequent dredging of the forebay would likely extend the maintenance interval for the wet pond.

## Conclusions and Recommendations

Despite constraints inherent in the design of the facility and the relatively short detention time, the facility met design levels of protection with respect to contaminant removal and flow attenuation. This study demonstrates that significant water quality improvement can be achieved through retrofitting existing stormwater quantity control facilities to wet pond and wetland configurations, even in locations where significant site constraints exist.

The following recommendations are provided based on study results and site observations:

(i) Wetland performance could be improved if channelized flow through the wetland were distributed over a larger portion of the wetland via a perforated pipe or similar distribution system installed at the upstream end of the wetland.

(ii) A mid to low level drawoff configuration for the outflow structures would help to improve removal of floating contaminants (e.g. oil and grease, some organics), reduce effluent temperature and minimize adverse effects related to short circuiting across the surface of the pond. Such a structure may, however, result in decreased effluent quality because of reduced sedimentation efficiency over the mean flow path. Data from facilities with different outlet structures should be compared to assess the benefits and weaknesses associated with each design.

(iii) The feasibility of increasing the time period over which stormwater is detained within the facility should be investigated. This objective could be achieved by modifying the outlet structure such that drawdown times more closely match the average inter-event period. Before implementing this measure, however, the impact on pond levels and the frequency of overflow should be carefully assessed.

(iv) Further monitoring of vegetation at the site is recommended in order to better characterize the climax community and verify tentative conclusions provided in this study.

(v) Sediment accumulation depths in the forebay and pond should be monitored regularly to determine maintenance requirements.

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