PERFORMANCE ASSESSMENT OF TWO TYPES OF OIL & GRIT SEPARATOR FOR STORMWATER MANAGEMENT IN PARKING LOT APPLICATIONS

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MARKHAM & TORONTO, ONTARIO

a report prepared by the

STORMWATER ASSESSMENT MONITORING
AND PERFORMANCE (SWAMP) PROGRAM

for

Ontario Ministry of the Environment
Toronto and Region Conservation Authority
Municipal Engineers Association of Ontario
The City of Toronto

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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 Engineers Association. A number of individual municipalities and other owner/operator agencies have also participated in the SWAMP studies.

Over the past 15 years, the Great Lakes Basin has experienced rapid urban growth. Stormwater runoff associated with this growth is a major contributor to the degradation of water quality and the destruction of fish habitats. In response to these environmental 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 Ontario. The SWAMP Program was developed to address this need.

The SWAMP Program's objectives are:

- to monitor and evaluate the effectiveness of conventional and innovative stormwater management technologies; and
- to disseminate study results and recommendations within the stormwater management industry.

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

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

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EXECUTIVE SUMMARY

Oil grit separators (OGS) are designed to remove sediment, screen debris and trash, and separate oil from stormwater. Removal processes vary for different types of OGS, but most depend at least partly on gravity based settling for sediment and associated contaminants (e.g. heavy metals), and phase separation for oil. OGS do not effectively remove dissolved or emulsified oils and pollutants.

OGS are typically applied to small, highly impervious areas such as parking lots, loading areas at commercial sites, gas stations or as part of a multi-component approach for water quality control. Runoff quantity control is not provided because OGS are not designed with extended detention storage. However, peak flows can be attenuated if temporary storage is provided upstream of the OGS on roof tops, paved surfaces and/or within the storm sewers as part of the site drainage plan.

Although oil grit separators (OGS) are widely employed in Ontario, there are few third party studies demonstrating their effectiveness in improving water quality. To help fill this knowledge gap, the Ontario Ministry of the Environment (OMOE), the Toronto and Region Conservation Authority and the Government of Canada (through the Great Lakes Sustainability Fund), jointly agreed to monitor two types of OGS (Three-Chamber and Stormceptor®) under the Stormwater Assessment Monitoring and Performance (SWAMP) program. The objectives of this study were to:

- (i) conduct a literature review of OGS performance and maintenance requirements;
- (ii) evaluate the field performance of two types of OGS in terms of runoff quality;[1]
- (iii) identify benefits and limitations of the technology, and
- (iv) provide recommendations for technology improvements and further research needs.

Literature Review

The literature review provides a general overview of the theory and application of Oil Grit Separators (OGS). Various commercially available OGS designs are grouped and discussed for the purposes of the review with regards to their respective functional attributes: high flow bypass, swirl action, screening action, coalescence action and combined system types. Detailed review of design and sizing criteria, performance literature and maintenance requirements is limited to OGS devices for which sufficient literature and monitoring data were available at the time of writing. These devices include the traditional 3 chamber OGS, Stormceptor®, Bay Saver, Vortechs, Downstream Defender and Continuous Deflective Separation Unit. Coalescing Plate

[1] This evaluation should be interpreted within the context of the particular OGS designs and site conditions monitored, not as a general evaluation of all Three-Chamber and Stormceptor® OGS technologies.

separators and combined system type OGS (Multi-chambered Treatment Train and Storm Treat™) are discussed in more general terms.

Most laboratory and field monitoring performance assessments cited in this literature review were conducted by the manufacturer or by manufacturer sponsored organizations. There were considerably fewer independent third party studies available. A review of available studies revealed a wide variation in site conditions (e.g. climate, soil texture, land use) and field monitoring and data analysis protocols, making it difficult to compare performance results among studies, even for the same device. In some studies, essential information (e.g. effluent concentrations, design specifications) required to interpret results was not provided.

Like other stormwater technologies, the water quality performance of OGS declines significantly if they are not regularly maintained. The literature review provides an overview of government agency and manufacturer recommendations for maintenance procedures and schedules. Most guidelines from both sources suggest that the maintenance frequency for OGS be at least once or twice per year, or when the accumulated sediment reaches 15% of the sediment capacity.

Monitoring Study

Study Area and OGS Design

Two types of OGS were monitored in this study: a standard 3-chamber OGS and a Stormceptor® model STC 4000. Both technologies were installed as two parallel units in the parking lots of large Home Depot stores. The 3-chamber OGS study, located in Markham, and the Stormceptor® site, located in Etobicoke, had design drainage areas of 2.2 and 2.6 hectares, respectively. Influent flows were distributed to each unit via a Y-splitter. The asymmetric configuration of these splitters favours greater flow into one of the two parallel units. Recognizing the tendency for uneven flows, the 3-chamber OGS design consists of one larger (35 m^3 capacity) and one smaller unit (17 m^3 capacity). The Stormceptor® OGS parallel units were the same size (17.8 m^3 each), but unlike the 3-chamber site, temporary storage was provided within the sewer network and on the paved surface upstream of the two OGS units. This temporary storage was intended to help control flow rates entering the system and decrease the number of potential by-passes. The upstream storage and differential sizing of units are important features of the overall site design that can influence influent particle size distributions, pollutant removal rates and the variability of system performance among events.

The design of the 3-chamber OGS is presented in Figure 1. Each separator is a concrete precast tank with three chambers. The first chamber is the sediment chamber, which is designed to trap the heavy grit and large floating trash washed off from the streets. The second chamber is the oil chamber. As the water level of the second chamber rises, water is forced through two elbow pipes (375 mm and 300 mm diameter for the large and small units, respectively) into the third chamber. The intake of the elbow pipe is submerged and located one meter from the bottom of the second chamber. This configuration is effective in capturing free oil because oil has a specific gravity less than water and therefore floats to the top. The third chamber is primarily used to discharge treated runoff from OGS, although the chamber also provides an opportunity for further settling of suspended particles. The opening that discharges the treated runoff to the sewer also determines the permanent pool level. Once the hydraulic capacity of the trash rack or elbow pipes in the first chamber is exceeded, overflow into the second chamber will occur through the openings located at the top of the interior walls. The permanent pool water levels in the large and small units were approximately 1.8 and 1.5 m deep, respectively. The permanent pool is an important feature for pollutant removal as it helps to slow down incoming flows, thus improving the settling of suspended particles. The capacities for the large and small units are 31.5 m^3 and 15.5 m^3.

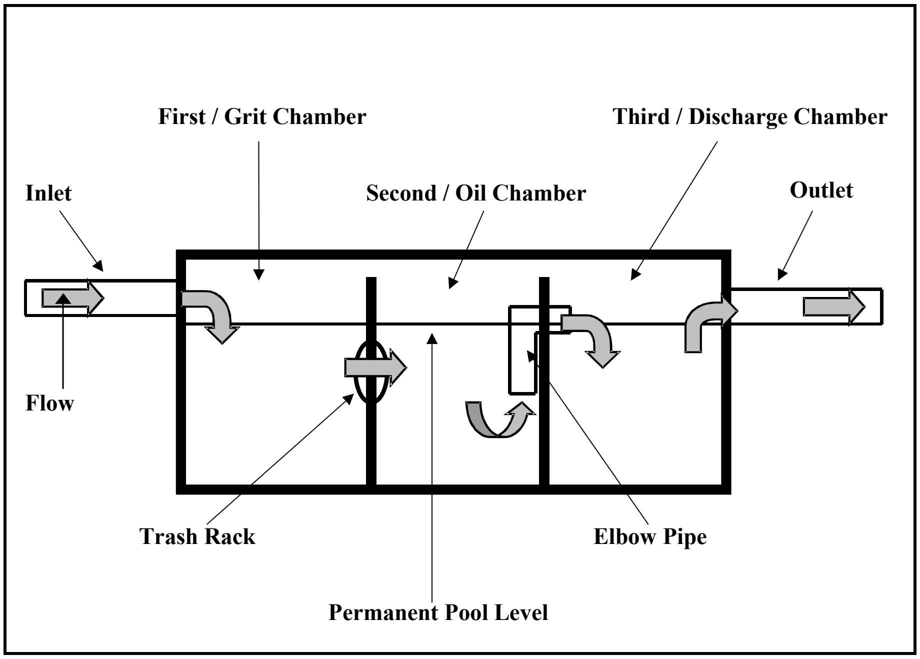

Figure 1 : Design of a three-chamber OGS

Figure 2 shows the design of the Stormceptor® OGS and operation during high flow conditions. Each of the two concrete precast units installed in parallel consists of a treatment chamber and a by-pass chamber. Stormwater runoff flows into the by-pass chamber from the inlet sewer pipe. Low flows are diverted into the treatment chamber by a weir and drop pipe arrangement. The drop pipe is configured to discharge water tangentially along the treatment chamber wall. Water flows through the treatment chamber to the outlet riser pipe, which is also submerged. The flow rate through the outlet pipe is based on the head at the inlet weir. Stormwater is discharged back into the downstream section of the by-pass chamber, which is connected to the outlet sewer pipe. Oil and other liquids with specific gravity less than water will rise in the treatment chamber and become trapped above the submerged outlet riser pipe. Sediment will settle to the bottom of the chamber by gravity forces. According to the manufacturer, the circular design of the treatment chamber is critical in preventing turbulent eddy currents and promoting settling (Stormceptor®, 1998). During high flow conditions, stormwater in the by-pass chamber will overtop the weir and be conveyed to the outlet sewer directly. The overflow creates a backwater effect on the outlet riser pipe due to head stabilization between the inlet drop pipe and outlet riser pipe. According to the manufacturer (Stormceptor®, 1998), this design ensures that excessive flows will not be forced into the treatment chamber and re-suspend settled material. The oil and sediment holding capacity of the model monitored in this study is 3,490 and 14,060 L, respectively.

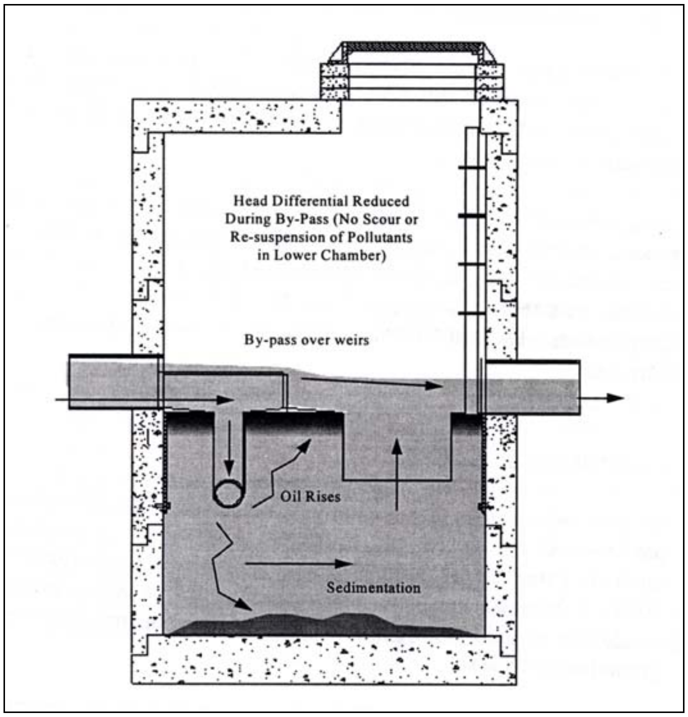

Figure 2: Stormceptor® operation during high flow conditions (Stormceptor®, 1996)

The 1994 version of the Province of Ontario's *Stormwater Management Practices Planning and Design Manual*, which was current at the time the units were installed, recommends a minimum permanent pool storage of 30 m^3 per impervious hectare for 3-chamber OGS, and 15 m^3 per impervious hectare for manhole type OGS (such as Stormceptor®). The total design permanent pool storage provided was 21.3 and 14.0 m^3/impervious ha for the 3-chamber and Stormceptor® sites, which is below the minimum recommended in the manual. Note, however, that the Stormceptor® site has temporary storage upstream of the separator both within the drainage network and on the paved surface, and flow is distributed unequally to two parallel units of the same size. The first of these factors – additional upstream storage - helps to control flow rates and limit bypasses, thereby contributing to better treatment (*i.e.* lower effluent concentrations/loads). The second factor – unequal flow distribution to parallel units of the same size – reduces the effective storage of the combined units and may contribute to poorer overall water quality performance than would have been the case if the flow were equally distributed.

Study Approach

The performance assessment of the two types of OGS was based on continuous monitoring of precipitation and flows, and water quality sampling during wet weather periods. Precipitation data were obtained at nearby rainfall gauging stations. Flow was monitored at the outlet, downstream of where effluents from the two parallel units merged into a single storm sewer pipe. Inflow measurements were not undertaken because OGS technologies are generally not designed to provide significant peak flow attenuation and detention times are relatively short. Water quality samples were collected during rain events at the inlet of the unit receiving greater flows and at the combined outlet location. Ideally, influent samples would have been collected upstream of the flow splitter, but at both sites, this location was deemed unsuitable for water quality monitoring (see below for results of an error analysis associated with monitoring influent in only one of the two parallel units). Samples were submitted for analysis of solids, oil and grease, and metals to a certified laboratory operated and run by the Ontario Ministry of the Environment. Depth profiles of conductivity at 0.5 m intervals were taken in the treatment chambers of both technologies using a portable meter to determine the degree of mixing occurring within the units and assess potential problems associated with chloride stratification.

The OGS units at both sites were cleaned out prior to the beginning of monitoring. At the end of the study period, the sludge and liquid contents of the OGS were transferred to two off-line sediment holding tanks for further settling. Samples from the tanks were analysed for chemical properties by the OMOE laboratory to determine disposal options and for physical (volume, mass, density) characteristics to determine the total dry mass of the trapped sediment.

The monitored data were used to calibrate and apply a water quantity/quality model (PC-SWMM 98), run in continuous mode for the entire study period. The purpose of the modelling exercise was to (i) verify measured performance and sediment accumulation results, and (ii) estimate water quality loads and removal efficiencies for rainfall events during the study period for which measured flow and/or quality data were not available.

Study Findings

Water quantity

<u>Three-chamber OGS</u>

A total of 60 runoff events were monitored at the site from May 1997 to December 1998. Rainfall measurements were available for 30 events occurring during the spring, summer and fall. Average rainfall was 11.4 mm, with a range between 1.8 and 28.6 mm. Mean rainfall intensities averaged 2.1 mm and ranged from 0.5 to 6.8 mm/hour. Twenty out of thirty rainfall events resulted in significant runoff volumes.

The average volumetric runoff coefficient was 0.85, indicating that, on average, 85% of the precipitation that fell within the drainage area during monitored rain events passed through the OGS as stormwater runoff. As expected, rainfall depths were well correlated with runoff volumes (R^2=0.81).

The capacity of the system to control water quantity (i.e. attenuate peak flows and extend release times) was not evaluated because the storage-to-drainage area ratio is relatively small and the technology is not designed with extended detention storage. This assumption is further corroborated by hydrologic data showing that the duration of effluent runoff and rainfall were similar during individual storm events.

<u>Stormceptor®</u>

A total of 44 events were monitored at the Etobicoke site during the period from August 1997 to December 1998. The absence of winter rainfall measurements meant that only 24 of the 44 runoff events were monitored for rainfall. Rainfall depths averaged 11.8 mm, ranging in depth between 2.3 and 36.8 mm. Mean rainfall intensities averaged 2.3 mm/hour, with a range between 0.4 and 8.6 mm/hour.

The volumetric runoff coefficient averaged 0.98. There were substantial variations in the runoff coefficient among individual events, suggesting possible discrepancies between the rainfall gauging stations, located 3 to 5 km away, and actual rainfall at the site. The relatively weak correlation between runoff volumes and rainfall depths (R^2 = 0.54) lends additional support to this hypothesis.

As at the Markham site, the duration of rainfall and outflow were similar during rain events, indicating that stormwater runoff was not detained for significant time periods within the OGS units. Although not monitored in this study, additional storage provided upstream of the OGS units (via a flow restrictor) may have helped to reduce peak flow during large events.

There were few overflows and those that did occur were of relatively short duration. Hence, effluent concentration and removal efficiency estimates provided in this study are based largely on flows that passed through the treatment chamber of both units.

Water Quality

<u>Three-chamber OGS</u>

A total of 26 influent and 54 effluent water samples were collected from May 1997 to December 1998. Fewer influent samples were available because of challenges associated with sample collection at this location in the early part of the study. Samples were analyzed for particle size, total dissolved and suspended solids, heavy metals and oil and grease.

The median influent and effluent TSS concentrations were 109 and 40 mg/L, respectively (Table 1). Concentrations during individual events ranged widely from 34 to 378 mg/L at the inlet and 4 to 268 mg/L at the outlet. Median concentrations of oil and grease (solvent extractable) were 22 and 8 mg/L at the inlet and outlet, respectively. The highest concentrations of TSS and O&G were measured in winter and early spring, approximately from January to April 1998.

Total suspended solids were well correlated with most heavy metals, indicating that these contaminants are removed with suspended solids through sedimentation processes.

Load based removal efficiencies for metals ranged from 42 to 60%. Median effluent concentrations of copper (17 μg/L), lead (11 μg/L), zinc (77 μg/L), and iron (383 μg/L) exceeded provincial receiving water standards (Table 1). Although effluent concentrations are not expected to meet receiving water criteria, comparisons made against the provincial standards are helpful in identifying water quality variables of potential concern.

The size of particles entering the OGS units was significantly lower than those exiting the units. Average influent and effluent particle size distributions (n=18) had median particle sizes of 8.7 and 3.8 microns, respectively. These were significantly different at the 95% level of confidence. Particle size distributions in the warm and cold seasons were similar.

On-site depth profiles of electrical conductivity in all three chambers did not show any signs of stratification, suggesting well mixed conditions and periodic re-suspension of previously settled solids. The tendency for re-suspension may partly explain the wide range of removal efficiencies observed among storm events.

The total load based TSS removal efficiency for 19 events was 57%, with individual event removal efficiencies ranging widely from –81 to 96%. In comparison, the total load-based removal of oil and grease was 51%, with a range between -200 and 84%. Total runoff volumes were not well correlated with removal efficiencies either for TSS or oil and grease. There was also no discernible seasonal variation in removal.

Continuous model simulation results for all storms occurring over the study period indicated a total load TSS removal efficiency of 62%, which matches results from the monitoring study within 5%.

<u>Stormceptor®</u>

A total of 20 influent samples and 37 effluent samples were collected from the Stormceptor® OGS between August 1997 and December 1998. As at the Markham site, collection of reliable samples was more challenging at the inlet than at the outlet, hence fewer influent samples were collected.

Median influent and effluent TSS concentrations were 112 and 48 mg/L, respectively (Table 1). Influent TSS concentrations ranged from 28 to 634 mg/L, compared to an effluent concentration range of 10 to 451 mg/L.

These ranges are considerably wider than at the 3-chamber site in Markham. Median concentrations of oil and grease (solvent extractable) were 17 and 7 mg/L at the inlet and outlet, respectively.

Load based removal efficiencies for heavy metals commonly found in urban runoff ranged from 42 to 52%. Median effluent concentrations of the following metals exceeded provincial receiving water standards: copper (22 μg/L), lead (19 μg/L), zinc (120 μg/L), and iron (515 μg/L) (Table 1). As at the3 chamber site in Markham, total suspended solids were strongly correlated with most heavy metals.

Influent and effluent concentrations were well correlated for the two main parameters of interest, TSS and O&G. The relationship (R^2 = 0.7 for TSS), which is also observed at the 3 chamber site, suggests that unit sizing should be based not only on the size of the drainage area and level of imperviousness, but also on pollutant loading potentials associated with specific land use types.

Average influent and effluent particle size distributions were similar. The median particle size at the inlet was 6.5 um, compared to a median size of 5.8 um at the outlet. The low influent particle size relative to the 3-chamber OGS site may be partly explained by the presence of upstream storage and catchbasin sumps, where coarser particles may have settled out of suspension before reaching the OGS units. The cause of the unexpectedly coarse effluent particle size distributions requires further investigation.

Table 1: Median influent/effluent concentrations and overall load based removal efficiencies for selected parameters

		Three-Chamber OGS			***Stormceptor® OGS***		
Parameter	*PWQO*	*Median influent conc.*$^{+}$ *(n=26)***	*Median. effluent conc (n=54)**.*	*Rem. Eff. (%)*$^{+}$ *(n=19)***	*Median influent conc.*$^{+}$ *(n=18)***	*Median. effluent conc (n=36)***	*Rem. Eff. (%)*$^{+}$ *(n=16)***
TSS (mg/L)	--	109.0	40.0	57.2	112.5	47.5	60.1
O &G (mg/L)	--	22.0	7.8	51.2	17.0	6.8	44.1
Cu (μg/L)	5	46.2	17.0	55.6	46.7	22.0	43.7
Zn (μg/L)	20	217.0	77.2	61.7	247.5	120.5	43.1
Pb (μg/L)	5	28.7	11.1	50.0	35.4	18.8	42.4
Cd (μg/L)	0.5	0.7	0.4	49.0	0.6	0.5	42.7
Fe (μg/L)	300	762	383	40.4	922	516	45.3
Co (μg/L)	0.9	1.4	0.6	28.7	1.3	0.8	51.9
Cr (μg/L)	8.9*	9.5	4.7	44.1	10.8	6.1	49.4
Ni (μg/L)	25	6.2	2.9	56.5	6.8	2.9	45.0

+ Based on samples collected at the inlet of only one of the two parallel units (see text for discussion)
* CrIII = 8.9 μg/L; CrVI = 1 μg/L
**The heavy metal concentration and removal efficiency data sets contained two to three fewer observations than indicated.

Depth profiles of electrical conductivity showed a distinct stratified layer in the winter and summer, starting at 0.5 to 1 m depth below the permanent pool surface in the treatment chamber. The stratified layer had completely dissipated by the fall, when a third measurement was taken. Winter conductivity levels reached a maximum of 72,700 µS/cm at 1.5 m below the water surface, which is roughly equivalent to a chloride concentration of 36,500 mg/L. The existence of a stratified layer of chloride suggests that turbulent flows causing re-suspension of accumulated solids were minimized. However, the stratification also raised concerns as reduced vertical mixing may decrease the effective storage available for treatment, resulting in poorer pollutant removal during the winter and spring.

The total load based TSS removal efficiency for events with co-ordinated inlet and outlet sampling (n=16) was 60%, with individual event removal efficiencies ranging from 4.5 to 83%. Total load-based removal for oil and grease was 44%, with a range between -6 and 84%. Both of these ranges are less than observed at the 3-chamber site, although the total load results are similar (Table 1). Runoff volumes were not well correlated with removal efficiencies either for TSS or oil and grease, but unlike the 3-chamber site, TSS removal was generally better during the summer.

Continuous simulation results for all storms occurring over the 16-month study period indicated a total load TSS removal efficiency of 60%, which closely matches results from the monitoring study.

Analysis of Potential Errors

There was some concern that the performance results may be biased because influent concentrations were measured at only one of the two inlets, whereas effluent concentrations were measured from the combined discharge of both units. To estimate the potential error associated with unequal influent TSS concentrations, total TSS load calculations were repeated assuming that: (i) inflow was equally distributed between the two units; and (ii) influent TSS concentrations in the unmonitored unit differed consistently (*i.e.* during all events) by ±20% from that measured in the monitored unit. Results of this scenario indicated a total load TSS removal efficiency range of between 52 and 61% for the 3-chamber OGS and between 56 and 64% for the Stormceptor® OGS. These ranges narrow slightly if the error calculations account for larger flow volumes entering the monitored unit, which is known to occur at both sites.

The potential error associated with flow measurement inaccuracies were estimated by randomly varying the measured flow rate among events by ±20%. This exercise was repeated for several randomly generated combinations resulting in an error range in TSS removal efficiencies at both sites of approximately ±3%. A consistent increase or decrease in flow volumes by exactly the same magnitude for all events would, of course, have no impact on removal efficiencies because a perfect flow balance through the OGS is assumed (i.e. the volume of stormwater entering the OGS units is the same as the volume of stormwater leaving them).

Another source of error relates to the use of removal efficiencies as an indicator of performance. The removal efficiency equation is a biased indicator of performance because the fraction of pollutants removed by hydrodynamic separators (and stormwater BMPs generally) is partly a function of the influent concentration. Thus a performance evaluation based solely on removal efficiencies can lead to misleading conclusions, especially when additional water quality storage or treatment provided upstream of the OGS facility contributes to cleaner influents. Effluent concentrations or loads are a more reliable indicator (*i.e.* not subject to the errors noted above) and in any assessment of OGS performance, should be evaluated in combination with removal efficiencies, and in relation to effluent concentration ranges of other similar technologies.

Sediment Analysis

The total dry mass of sediment measured in the two parallel three chamber OGS units from July 1997 to August 1998 was 957 kg. This compares reasonably well to the 922 kg of sediment accumulation generated over the same period by the calibrated water quantity/quality model.

The measured and simulated dry mass of accumulated sediment in the Stormceptor® units from July 1997 to August 1998 was also in reasonably good agreement. Measured sediment accumulation from the offline holding tanks was 1067 kg, compared to a dry mass of 1142 kg of sediment generated by the model.

The good correspondence between accumulated sediment measured from the holding tanks and model simulations based on influent and effluent measurements lends confidence to the monitored results.

The concentrations of several metals in the trapped sediment of both OGS types were above the lowest effect level guidelines defined by the Province for the protection of aquatic life. High concentrations of oil and grease in the sediment suggest that special considerations may be required in the disposal of trapped sediment.

Conclusions and Recommendations

This report reviews the literature on various OGS technologies and provides a detailed field study evaluation of two types of OGS commonly used in Ontario. In general, results indicate that effluent concentrations of TSS, oil and grease and some heavy metals are greater in OGS than have been reported for other end of pipe facilities in Ontario (see other SWAMP reports in this series). However, these concentrations still represent a significant improvement over the quality of untreated stormwater runoff. Removal efficiency calculations indicate that both types of OGS provide moderate removal of oil and grease, suspended solids and heavy metals.

As reports of OGS water quality performance vary widely among studies, the monitoring results should be reviewed carefully in relation to other studies of similar technologies and with full consideration of the technology/site design (*e.g.* unit sizing, provision of upstream storage, distribution of influent to the two parallel units), the drainage area characteristics of the sites selected for the study (*e.g*. runoff quality, influent particle sizes), and the potential errors associated with the monitoring and data analysis protocols used to generate results.

The following recommendations are provided based on study findings and field observations:

Maintenance issues

- To avoid re-suspension of trapped oil and sediment, an aggressive maintenance schedule/plan for inspections and clean-out should be established upon the installation of any and all OGS. High oil and grease concentrations may limit disposal options.

- To help prevent adverse effects on performance due to chloride stratification, annual or bi-annual maintenance of OGS units should be timed to correspond with the end of the snow melt season, when elevated concentrations of chloride are commonly observed in the treatment chamber.

Site/technology design improvements

- The Three chamber OGS should include a high flow bypass design feature to avoid re-suspension of accumulated pollutants.

- The asymmetrical “Y” splitter at both sites consisted of one straight and one angled pipe section that distributed flows unequally to the two parallel units. The two 3-chamber units were sized differently to accommodate variable flows, but the Stormceptor® units were the same size. The storage treatment capacity of the two Stormceptor® units could be better utilized if either the splitter was redesigned to distribute equal or similar flow volumes to both units (i.e. it was shaped like a true “Y”), or the units were sized to compensate for unequal flow distribution.

- The correlation between influent and effluent concentrations for TSS and O&G suggests that unit sizing should be based not only on the size of the drainage area and level of imperviousness, but also on estimates of how much O&G and sediment are likely to be generated by land use activities within the drainage area.

Further Research

- Removal efficiencies and effluent concentrations varied widely among events for both types of OGS monitored in this study. Factors contributing to this variability may include resuspension of settled solids (especially in the 3- chamber OGS), varying inter-event periods, storm sizes and intensities, chloride stratification (Stormceptor), presence of upstream storage (Stormceptor), and bypass events (Stormceptor). Detailed research into the inter-relationships between these and other potential contributing factors is required in order to quantify their effects on performance and better understand how application of the technology or maintenance procedures may be modified to minimize adverse effects.

- Oil Grit Separators require regular maintenance if they are to function according to design. However, discharge regulations are not currently enforced to the degree necessary to ensure that the required maintenance is indeed being undertaken. A detailed field assessment of accumulated sediment in previously installed units would help to show whether or not owners and operators are actually maintaining their separators according to manufacturers' recommendations. If OGS are not being appropriately maintained, the cause of these failures and the need for enforcement mechanisms required to correct them should be further investigated.

- OGS are often recommended in provincial and state stormwater guidance documents as best applied in conjunction with other treatment technologies (i.e. as part of a treatment train) or as part of a 'multi-component' approach to stormwater management. The effectiveness of separators when installed together with other control measures, both from a quantity and quality perspective, needs further study.

- This study showed strong stratification of chloride in the Stormceptor units. It has been suggested that this stratified layer may inhibit mixing and reduce the effective permanent pool storage available for treatment. Further research is required to quantify the effect (if any) of chloride buildup and stratification in the treatment chamber on water quality performance.

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