Chapter 7

Urban Runoff Control Costs at Ontario RAP Sites

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The Great Lakes Water Quality Agreement between Canada and the United States was established in 1978 with the objective of restoring water quality in areas where impairment of water uses was found. Forty-three Areas of Concern have been identified, of which seventeen are

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located in the province of Ontario. Remedial Action Plans (RAP) are currently being developed to investigate and address water quality impairment at each of these sites.

In support of the RAP Program, and through the Great Lakes Cleanup Fund, Environment Canada and the Ontario Ministry of Environment and Energy have initiated several studies to determine planning level costs for the control of wet weather (or non-point source) discharges. A recent study presented cost estimates for the control of combined sewer overflows in Ontario RAP municipalities (CH2M HILL estimates, 1992). Some preliminary cost estimates were also carried out for the control of stormwater runoff by the Ontario Ministry of the Environment in 1992 (Ontario MOE, 1992). However, these preliminary cost estimates were not carried out for all sites. As well, factors which could influence the control cost, such as removal efficiencies, land costs, and cost optimization, were not considered. A follow-up study for stormwater runoff control was therefore recommended by Environment Canada and the Ontario Ministry of Environment and Energy to cover all of Ontario's seventeen RAP sites in detail. This chapter presents the findings of this study.

7.1 Methodology

The study involved the development of a methodology that can be uniformly applied to determine planning level costs for the control of stormwater runoff at the seventeen Ontario RAP sites. Table 7.1 summarizes the locations of some of these sites. An overview of the methodology is shown in Figure 7.1 and various tasks can be grouped into the following five steps: (1) determination of site characteristics; (2) development of control objectives; (3) formulation of control technology; (4) evaluation of different combination of control alternatives; (4) cost optimization of different control alternatives; (5) selection of the most cost-effective control alternatives.

The study considered some of the typical constraints in implementing stormwater control measures in urbanized areas. Land available in developed urban centres is limited. As a result, controls are more costly to apply, or less effective techniques have to be applied. Land cost at the RAP site, different stormwater control technologies, and treatment efficiencies were considered. The application of source control in the form of exfiltration pipes, which is currently being tested by the City of

Table 7.1: Selected RAP site catchment data.

RAP Site	Residential Area (ha)	Commercial Area (ha)	Industrial Area (ha)	Open Space (ha)	Total Area (ha)	Separated Area* (ha)
Thunder Bay THUNDER BAY	2,030	177	711	772	3,690	2,090
Jackfish Bay JACKFISH BAY	-	-	-	-	-	-
Nipigon Bay NIPIGON, RED ROCK	117	13	41	34	205	171
Peninsula Harbour MARATHON	149	16	52	47	264	217
St. Mary's River SAULT STE. MARIE	2,610	360	580	950	4,500	3,550
Spanish River ESPANOLA	149	16	52	46	263	217
Severn Sound MIDLAND	316	31	111	104	562	227
PENETANGUISHENE	164	17	57	52	290	238
COLDWATER, PORT MCNICOLL, VICTORIA HARBOUR	154	18	54	44	268	224

* Open Space is not included in separated areas.

Figure 7.1
Overview of analysis methodology.

Etobicoke (Tran, 1993), and roof leader disconnection, were also evaluated.

7.2 Selection of Model

Specific capabilities, for example simulation of removal efficiency of treatment technology and cost optimization, were considered in the selection of a computer model for the development of control costs. Because of its diverse capabilities, a planning level model, called Extended Statistical Urban Drainage Simulator (EXSUDS) (Li, 1991), was selected for this study.

Figure 7.2 shows a schematic of an urban runoff system simulated with EXSUDS. EXSUDS is an analytical-probabilistic model which transforms the statistics of rainfall characteristics (e.g. rainfall event volume, duration, interevent time) into long-term pollution control performance of storage/treatment systems. A constant concentration of pollutants is assumed for all runoff events. If the runoff event volume is less than the combined capacity of available storage volume and controlled outflow capacity, no overflow occurs at the storage reservoir, and the only source of pollution comes from the treated effluent. For larger runoff event volumes, part of the runoff, in addition to the treated effluent, is spilled from the reservoir into the receiving water. Pollutant loads from both the overflows and treated effluent are considered in the derivation of long-term pollution control performance. This model provides closed-form solutions of the performance equations which are highly efficient in both a conceptual and computational sense. Additionally, the model also includes a cost-optimization procedure which can determine the least-cost combination of storage/treatment systems. As a result, it is particularly useful for preliminary screening of urban runoff control alternatives. The EXSUDS model provided satisfactory results compared with the STORM model (U.S. Army Corps of Engineers, 1977) in the CSO control cost study (CH2MHILL, 1992). A comparison of the stormwater control costs determined with EXSUDS and detailed costing analysis for the City of Toronto for stormwater control (Gore & Storrie and Macviro, 1992) showed that the control costs determined by EXSUDS were in good agreement.

where:

V	total rainfall volume, mm	S	maximum storage capacity, mm
t	rainfall event duration, hr	Ω	controlled outflow rate from storage, mm/hr
b	inter-event time, hr	ϕ	volumetric runoff coefficient
P	uncontrolled overflow, mm	S_d	depression storage, mm

Figure 7.2
Schematic representation of EXSUDS model - storage-treatment system.

7.3 Evaluation of Control Technologies

The most often used technology for stormwater control is surface detention ponds. Detention ponds reduce the rate of discharge by storing the stormwater runoff temporarily and releasing the stormwater at a controlled rate. Depending on the length of detention time, the stormwater is treated by the settlement of solids and die-off of bacteria over time, and released to the receiving water at a lower discharge rate. The rate of release is typically controlled by a small perforated riser pipe.

Detention ponds, however, require extensive land, which often is not available in developed urban centres. A combination of storage with a satellite treatment facility, for example, can minimize the size of the detention pond. Source control measures, by means of exfiltration pipes and roof leader disconnections, may be considered to further reduce the size of storage or treatment required. The advantage of source controls is that they can be phased over time with a municipality's road re-construction and sewer replacement capital works program. Source controls do not require a large initial cost and can be easily incorporated into a municipality's annual capital works program.

The control technologies selected for evaluation in this study included extended dry detention ponds, extended wet detention ponds, underground storage facilities, satellite high-rate treatment (with coarse screens, vortex separator, and ultra-violet disinfection), and source controls with exfiltration pipes and roof leader disconnection.

The cost of a control facility includes capital cost, operation and maintenance (O&M) cost, and land cost. A least-cost optimization of stormwater control technologies at each RAP site was then carried out with EXSUDS under four scenarios: with and without the land cost, combined with and without source control. In each optimization, extended dry detention ponds versus satellite treatment, extended wet detention ponds versus satellite treatment, and underground storage versus satellite treatment, were evaluated and compared with each other. A fixed percentage of the catchment was assumed to be fitted with source controls.

As shown in Figure 7.3, the performance isoquants represent possible combinations of storage and treatment required to achieve a particular level of stormwater control. The isocost curves on the other hand represent combinations of storage and treatment for the same total cost. Along each isoquant, the least-cost and optimal combination is

Figure 7.3: Performance isoquants and isocost curves.

located at the tangent point of the performance isoquant and isocost curve. The expansion path is a plot of the tangent points for increasing levels of control. It illustrates the incremental units and costs of storage and treatment for increasing level of control. The cost for each type of storage and treatment was compared after each evaluation to determine the least-cost combination.

Generally, quantity control is based on reducing the volume and frequency of untreated stormwater discharge, while water quality control is based on removing or treating the pollutants contained in stormwater. The level of control that can be provided by a control technology may be established by its ability to meet receiving water or end-of-pipe control criteria. Receiving water criteria would require the knowledge of site-specific water quality background, which was not available at planning stage unless a detailed assessment was carried out. The end-of-pipe control criteria were therefore applied. The end-of-pipe control levels may be specified by means of the frequency of untreated discharges to the receiving water in events per year (N_s), percent volumetric control (C_r), or percent pollutant control (C_p). It was concluded that percent pollutant control was the most appropriate criterion as it measures the performance of the control technology in controlling pollutants.

The cost-effectiveness of Ontario Government's Interim Stormwater Quality Control Guidelines for New Development (Ontario MOE, 1991) which recommends the retention of 25 mm of total daily rainfall for areas sensitive to coldwater fisheries, was also evaluated as part of the study.

7.4 Conclusions

Figure 7.4 summarizes the total aggregate costs determined for the control of total suspended solids for the range of scenarios simulated. These control costs were developed separately for fecal coliform, total phosphorus, lead, copper, and zinc, using the corresponding removal efficiencies provided by each control technology. The following conclusions were drawn from this study:

1. Land cost has a direct impact on the type, or combination, of stormwater control technology(ies). If there is no land cost, surface detention ponds would be the most cost-effective technology. However, if land cost is included in the cost of the

Figure 7.4: Ontario RAP site aggregate costs - cost-effectiveness curve for CP-SS.

control facility, satellite treatment or underground storage, which requires less land, would be the more cost-effective alternative. The latter is more likely to be the case in urban areas since land cost is a factor most of the time.

2. Source control by means of exfiltration pipes and roof leader disconnection provides additional pollutant removal. If a high control level is desired, or if land cost is included, source control is a cost-effective technology, compared to using storage/treatment alone.

3. Control costs are influenced by local constraints. The proportion of facilities requiring land cost and the amount of source control that can be implemented, may vary from site to site. A more realistic approach should be applied in the interpretation of the results.

For example, cost optimization concludes that satellite treatment alone is the least-cost control combination when there is land cost. In practice, a combination of underground storage in the form of deep tunnel and satellite high-rate treatment, both of which require less land cost, will be a more realistic combination, even though it is more expensive. This is demonstrated as shown in Figure 7.5 for the City of Etobicoke, where combinations of underground tunnel storage without land cost, satellite treatment facility with land cost, and with or without source control (with 20% exfiltration pipes and 30% roof leader disconnection), are applied. The cost curves for these two combinations (as indicated by the dashed lines) will lie between the cost curves for no land cost and no source control and with land cost and source control.

Integrating the four scenarios analyzed in this study on the basis of local constraints would present more realistic cost estimates.

4. Control technologies are limited by their treatment efficiencies. Based on the treatment efficiencies assumed in this study (see Table 7.2), if storage and treatment are applied, the most cost-effective pollutant control level for controlling total suspended solids is approximately 70%. This is the level

Figure 7.5: Control costs for City of Etobicoke (percent removal of suspended solids).

Table 7.2
Efficiencies used in "EXSUDS" analysis.

Control Technology	Removal Efficiency (%)					
	Total Suspended Solids	Fecal Coliform	Total Phosphorus	Lead	Zinc	Copper
Extended dry detention ponds	70	70	40	60	40	40
Extended wet detention ponds	75	75	50	70	40	40
Underground storage	60	60	40	40	40	40
Satellite high-rate treatment	40	80	15	15	15	15

beyond which diminishing returns begins to dominate. For fecal coliform, it is approximately 80%. For total phosphorus and metals, it is approximately 45% to 60%. If satellite treatment alone is applied because of high land cost, the maximum attainable pollutant control level will be limited by the efficiencies offered by satellite treatment. They are approximately 40% for suspended solids, 80% for fecal coliform, and 15% for total phosphorus, lead, copper, and zinc.

The study demonstrates advantages of control technologies with higher efficiencies. Without land cost, extended dry detention ponds are the least cost alternatives up to a control level of about 60%, but beyond this control level, extended wet detention ponds are more cost-effective than dry ponds, because extended wet ponds can provide a higher treatment efficiency, compared to extended dry ponds.

5. The 25 mm design rainfall retention guideline implies that storage is the best alternative for the control of stormwater pollution. Based on the results of this study, satellite high-rate treatment is found to be a more cost-effective control technology. However, if there is no land cost, and assuming that

about half of the rainfall (i.e. 12.5 mm of runoff) will be stored and treated, the 25 mm design rainfall guideline will provide approximately 70% to 80% pollutant control. Under these conditions, the guideline is found to provide high control levels. However, if source controls are applied in conjunction with the 25 mm design rainfall guideline, the level of control would increase, since source controls can provide an initial control of 20% to 40% of stormwater runoff. In this case, the guideline will be more conservative, as less than 25 mm is required for meeting the same control level.

Several improvements may be possible:

1. This study uses a uniform methodology to estimate the costs for stormwater runoff control. Due to specific site constraints, the optimal cost for a particular RAP site may be near the low or high end of the cost range. As shown by the example carried out for the City of Etobicoke (Figure 7.5), the cost expansion path for the particular storage-treatment combination considered lies between the minimum and maximum cost curves, but it is more representative and realistic compared to a range of minimum and maximum costs as provided.
2. The study analyzed only fixed levels of source controls. A cost optimization of source controls, together with storage and treatment facilities, would give additional information on cost comparisons.
3. The mean and most probable efficiencies of the control technologies have been used in this study. However, the treatment efficiency of a particular control technology may vary significantly depending on the characteristics of each rainfall event as well as the size of the facility and duration of detention or treatment. A more generalized approach would be to develop cost expansion paths for the full range of possible treatment efficiencies for each technology. Once these general cost curves are developed, it is possible to use the curves to interpolate the cost for any given efficiency. This approach has been demonstrated in this study for ex-

tended wet detention ponds. Cost optimization was conducted for satellite treatment efficiencies of 15%, 40%, and 80% combined with storage treatment efficiencies of 10%, 30%, 50%, 70%, and 90%. Using these generalized cost curves, as illustrated in Figure 7.6, it is possible to determine the costs of extended wet detention ponds for a wide combination of efficiencies and for any given pollutant. If similar cost curves are developed for extended dry detention ponds and underground storage facilities, the methodology for this study will be more versatile.

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Figure 7.6: Thunder Bay cost-effectiveness costs - land cost and 80% treatment efficiency.

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