Chapter 10

Calibration of PCSWMM to Estimate Metals, PCBs and HCB in CSOs from an Industrial Sewershed

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10.1 Introduction

The Buffalo River, New York, is one of forty-three "Areas of Concern" identified by the International Joint Commission as exhibiting environmental impairment. The impairments identified for the Buffalo River in a level I Remedial Action Plan (New York State Department of Environmental Conservation (NYSDEC), 1989) included: restrictions on fish and wildlife consumption; fish tumors and other deformities; degradation of benthos; restrictions on disposal of dredged sediment; and loss of fish and wildlife habitat. In addition, it was noted that degradation of fish and wildlife populations and bird or animal deformities and/or reproduction problems were likely. The NYSDEC (1989) identified multiple possible pollutant sources to the Buffalo River, including: combined sewer overflows; direct industrial discharges; leaching from inactive hazardous waste sites; water column interaction with historically contaminated bed

Irvine, K., B.G. Loganathan, E. Pratt and H.C. Sikka. 1993. "Calibration of PCSWMM to Estimate Metals, PCBs and HCB in CSOs from an Industrial Sewershed." *Journal of Water Management Modeling* R175-10. doi: 10.14796/JWMM.R175-10.

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sediment; and upstream point and nonpoint sources such as municipal wastewater treatment plants and agricultural runoff.

A mass balance evaluation of pollutant level dynamics and loadings within the Buffalo River Area of Concern (AOC) has been initiated under the U.S. Environmental Protection Agency's ARCS (Assessment and Remediation of Contaminated Sediment) Program. An objective of the mass balance evaluation is to apply a combination of hydrodynamic, sediment transport and chemical fate models to estimate pollutant movement through the lower Buffalo River (Wang and Martin, 1991). The modelling results will be used to guide the selection of remediation strategies for the river. The ability of the chemical fate model to accurately reflect pollutant dynamics within the river is predicated, in part, on reliable estimates of pollutant loads to the river from the various sources.

Combined sewer overflows (CSOs) are a possible source of organic compounds, metals and bacteria to the Buffalo River and this chapter communicates initial results of an ongoing CSO evaluation. A personal computer (PC) version of the Stormwater Management Model (PCSWMM) is being used for planning level estimates of overflow quantity to the river. Model calibration for overflow quantity estimates and characterization of overflow quality from a major outfall servicing a large, industrialized sewershed are discussed in this chapter. Model sensitivity, the range of calibrated parametric values, model inaccuracies and pollutant level characterization also are discussed in terms of using modelled results for planning level evaluations of CSO impacts. Ultimately, the CSO pollutant loading estimates will be incorporated into the mass balance evaluation of pollutant level dynamics for the Buffalo River.

Levels of total PCBs, HCB, Mn, V and Cu are examined in this chapter. Organochlorine compounds such as PCBs and HCB are of concern as widespread, persistent and harmful contaminants in view of environmental quality and health (Safe, 1987; Tanabe, 1988; Loganathan et al., 1990; Loganathan and Kannan, 1991). The metals, Mn, V and Cu were chosen for evaluation because elevated levels may have a negative impact on animal, fish and

human health (e.g. Irvine et al., in press; Forstner and Wittmann, 1983), data are available from past and ongoing Buffalo River studies (e.g. NYSDEC, 1989) and because of limitations on the types of elements that can be determined by short-lived instrumental neutron activation analysis, the analytical methodology available for this study.

10.2 Study Area

10.2.1 The Buffalo River

The Buffalo River is located in western New York State and drains an area of 1244 km², primarily to the south and east of the city of Buffalo. Landuse within the watershed varies. The upper portion of the watershed is characterized primarily by woods and farmland. However, tributaries to the river also pass through several small communities, receiving both industrial and municipal discharges.

The Buffalo River AOC spatially extends from the mouth of the Buffalo River to the point upstream at which backwater effects during Lake Erie's highest monthly average level does not impact river flow (Figure 10.1). Historically, the AOC was heavily industrialized, with activities such as: steel production; coking operations; oil refining; chemical and dye production; and flour milling. Industrial activity has declined along the river in the last decade and steel production, coking operations and oil refining have ceased. The AOC below highway 62 (Figure 10.1) is a navigable channel and is maintained at a depth of approximately 7 meters by the Buffalo District Army Corps of Engineers.

Historical (1940-1985) monthly mean inflows into the upper end of the AOC range between 45 m³s⁻¹ in March and 3.3 m³s⁻¹ in July (Meredith and Rumer, 1987). The AOC can exhibit estuarine-like characteristics during lowflow periods when levels at the eastern end of Lake Erie increase due to higher velocity, south-westerly winds. Flow reversals and thermal stratification

Figure 10.1: The Buffalo River Area of Concern and location of combined sewer outfalls (after NYSDEC, 1989). "Sample Outfall" indicates the location of the Babcock St. sewershed outfall.

between lake and river water have been observed for several kilometers upstream during these times of wind setup.

The Buffalo River Improvement Corporation (BRIC) augments flows within the AOC through pumping operations that transfer water from Lake Erie to industries along the river. The industries discharge the lake water to the river after using it for cooling and other processing purposes. The BRIC flow augmentation has diluted pollutant concentrations within the river and decreased residence times (Sauer, 1979). Prior to the industrial decline, the BRIC often contributed 90% of the total river flow during the drier summer months (Sauer, 1979). Pumping rates from the lake have declined along with industrial activity, averaging around $0.7 \text{ m}^3\text{s}^{-1}$ in recent times (J. Dietz, BRIC, pers. comm.). A more detailed discussion of the physical, industrial and cultural characteristics within the Buffalo River AOC is provided by Irvine et al. (1991).

10.2.2 Sewer System and Sample Sewershed Characteristics

The city of Buffalo is serviced primarily by a combined sewer system and there are a total of 39 combined sewer outfalls to the Buffalo River AOC (Figure 10.1). The outfalls drain various landuses, including: industrial; commercial; residential; and railway yards. Industries are granted permits to discharge waste and processing effluents to the sewer system. In the absence of overflows, these effluents are treated at the Bird Island Sewage Treatment Plant.

This chapter focuses on the detailed assessment of overflow quantity and quality associated with one of the outfalls in Figure 10.1. Sampling and detailed modelling are planned for additional outfall points to the river, but the Babcock St. sewershed was chosen for initial study because of several factors. First, the sewershed is large (contributing area of approximately 256 ha) and the outfall represents one of the major overflow points from the entire city (Calocerinos and Spina, 1989). The sewershed is industrialized and represents a high potential source of various

types of pollutants. The sewer system for the sewershed was easily defined and the overflow was easily instrumented in a secure location. Finally, rainfall data for this area were available from the Buffalo Sewer Authority (BSA).

Landuse within the Babcock St. sewershed primarily is industrial (20% heavy and 67% light industry) with smaller percentages of residential (11%) and commercial (2%) zones. There are a variety of industries located in the sewershed, including those related to food processing, automobiles and automobile recycling, metal workings, china and chemical production. The industrial properties often include large, open pervious areas. The Erie-Lackawana rail lines occupy the central portion of the sewershed. The BSA estimates that the average industrial waste flow in the Babcock St. sewershed is 2,419,152 liters per day. Residential structures are a mix of primarily double and multi-family dwellings of a relatively high density. High-rise apartment structures are not present. The BSA estimates that the average residential waste flow in the Babcock St. sewershed is 1,355,682 liters per day.

As shown in the sewershed schematic (Figure 10.2) a 1.8 meter diameter brick conduit carries flow from the sewershed into the primary overflow chamber. The overflow weir is 4.9 meters long and 1.7 meters in height. Interevent sanitary flow enters the chamber and is deflected to the right by the weir (Figure 10.2). The flow leaves the chamber by a 0.61 meter diameter pipe. Excess combined flow during storms is routed over the weir and through a 1.8 meter diameter pipe to the Buffalo River.

10.3 Methodology

10.3.1 Field Sampling

Overflow rates were recorded at 5-minute time steps using a Montedoro-Whitney System Q flow device. The System Q consists of a datalogger connected to a probe that measures average (directional) flow velocity and flow depth. The flow

Figure 10.2: Schematic of the Babcock St. sewershed. Subcatchment areas and the sewer system used in the model are shown.

probe was fixed to the top of the overflow weir in the primary overflow chamber. All data was uploaded from the datalogger to a laptop computer and was used to calculate overflow rates. The System Q was connected to a Sigma Streamline Model 701 Discrete Pump Sampler that was used to obtain samples for overflow quality analyses. The System Q communicates with the pump sampler to provide a flow-proportioned, composite sample

for each overflow event. The sampling system was programmed to take 250 ml samples at 250 m³ overflow intervals. The intake for the pump sampler was fixed at a level several centimeters in front of, and below the crest of the weir. The system was installed in the primary overflow chamber for two field seasons. The first field season began June 25, 1990 and ended December 4, 1990. The second field season began April 12, 1991 and ended November 4, 1991.

Rainfall intensity data at 5-minute intervals was obtained from the BSA raingauge located on the roof of the South Buffalo Pump Station, approximately 900 meters east of the outfall. The raingauge is a tipping-bucket type with a sensitivity of 0.25 mm of rain.

10.3.2 Analytical

Levels of Mn, Cu and V were determined using short-lived instrumental neutron activation analysis (INAA) at the McMaster Nuclear Reactor, Hamilton, Ontario. The overflow samples were wet-filtered using Millipore filters (minimum pore size of 0.45 microns) to separately determine metals levels associated with the particulate and dissolved phases. The mass of filtered sediment used in the analyses ranged between 0.001 and 0.155 gm, while 5 ml of filtrate was analyzed. No pre or post irradiation chemistry is required. Irradiation, delay and count times, details of the reactor flux and characteristics of the detector used for the analyses are provided in Vermette et al. (1987) and Irvine (1989). The efficacy of INAA for the analysis of these types of samples is discussed by Irvine et al. (in press). In general, INAA results for water and sediment samples are comparable to more frequently used analytical methods such as atomic absorption and inductively coupled plasma.

Total PCBs and HCB also were analysed in the dissolved and particulate phase of the CSO samples following the procedures described in the Federal Register (1984) and Loganathan et al. (1990), with some modifications. Approximately 1 litre of

sample was filtered through 0.45 micron Whatmann Glass Fibre Filters using Millipore filter systems to separate the dissolved and particulate phases. The dissolved phase was extracted thrice (60 ml each time) using methylene chloride in a separatory funnel. The extract was passed through anhydrous sodium sulfate and collected in an Erhlenmeyer flask. The volume of the extract was brought down to 10 ml using K-D concentrator and transferred to hexane. The sample extract was treated with 5% fuming H_2SO_4 in concentrated sulfuric acid and washed with hexane-washed water. The extract was concentrated to 1 ml and an aliquot of this extract was injected into a gas chromatograph.

The particulate phase was soxhlet extracted for 16 hours using methylene chloride. The methylene chloride extract was K-D concentrated and transferred to hexane. The extract was subjected to silica gel column chromatography for separation of PCBs from pesticides. The fraction containing PCBs and HCB were K-D concentrated and the extract was treated with 5% fuming H_2SO_4 in concentrated sulfuric acid and washed with hexane-washed water. The extract was concentrated to 1 ml using nitrogen gas and injected into a gas chromatograph.

A gas chromatograph (Varian model GC-3400) equipped with a ^{63}Ni electron capture detector and automatic sampler (Varian model 8100) was used for quantification of PCBs and HCB. A capillary column, DB-5 (J&W Scientific) having dimensions of 30m x 0.25 mm i.d. and 0.25 micron film thickness was used. The temperature was programmed from 160° to 230°C at a rate of 2°C min⁻¹ with initial and final hold times of 10 minutes, respectively. The injector and detector temperatures were kept at 250°C and 300°C, respectively. Nitrogen was used both as carrier and makeup gas. HCB and PCBs were quantified using individually resolved peaks with corresponding standard peaks. PCBs standard containing 1:1:1:1 mixture of 1242,1248,1254 and 1260 was used for PCBs quantification.

The dissolved, particulate phases and blanks were spiked with surrogate standards (2,4,5,6-tetrachloro-*m*-xylene and 2,2',3,4,4',5-,6,6'-octachlorobiphenyl) in order to check the efficiency of the analytical procedure. Hexane-washed distilled water was used as

blank. Recoveries of the surrogate standard were 100 +/- 20%. Analytical results were not corrected for the surrogate standard recoveries.

10.3.3 Modelling

The RUNOFF and TRANSPORT blocks of PCSWMM, (version 3.2c, Computational Hydraulics Inc.) were used in all model runs. It was decided to use TRANSPORT in this study because surcharging does not frequently occur in the Babcock St. sewershed and the block also provides the ability to route water quality parameters, which cannot be done with EXTRAN. Future research will consider pollutant scour and deposition within the sewer network.

It was determined through preliminary modelling of the inflows to and outflows from the overflow chamber that flows exceeding $0.32 \text{ m}^3\text{s}^{-1}$ would discharge to the Buffalo River. Therefore, rather than providing a detailed representation of the overflow weir hydraulics, any modelled flows greater than $0.32 \text{ m}^3\text{s}^{-1}$ were considered input to the Buffalo River. The sewershed discretization and general system configuration used in the model are shown in Figure 10.2.

10.4 Results

10.4.1 Model Calibration

A total of 8 overflow events were observed during the 1990 field season and 9 overflow events were observed during the 1991 field season. An overflow "event" arbitrarily was defined as a period of overflow separated from other overflows by a minimum of 2 hours. Overflow event characteristics are summarized in Table 10.1 and corresponding rainfall characteristics are summarized in Table 10.2. The BSA had removed all raingauges prior to the December 3, 1990 event and rainfall data therefore

are not included for this event in Table 10.2. It was observed that this event was generated by a rain-on-snow process. The rainfall records for the May 29, July 8 and September 26, 1991 events have not been processed to date.

The model has been calibrated for 8 events, as denoted in Table 10.1. These events were selected for calibration because a full rainfall record was available; a range of event characteristics (overflow volume, peak overflow rate, overflow duration) was represented; and in several cases samples of overflow quality had been obtained.

The calibration events exhibiting the best and worst fit to the observed data are shown in Figure 10.3. The accuracy of fit for the peak overflow rate and event volume for all calibrated events is summarized in Figure 10.4. It was decided that for planning level estimates of pollutant loadings, an accurate representation of event volume was most important. Calibration therefore focused on minimizing the error of estimate for event volume and this is reflected in the nearly linear 1:1 plot in Figure 10.4a. The average (absolute) prediction error of overflow volume for the 8 events was 4% and the average (absolute) prediction error of peak overflow rate was 24%. The calibration results for the Babcock St. sewershed compare favorably with results reported in the literature (e.g. Warwick and Tadeipalli, 1991; Nix et al., 1991; Zaghloul and Al-Shurbaji, 1990).

Three parameters provided the greatest flexibility in model calibration for the sewershed: subcatchment surface slope; subcatchment width; and per cent imperviousness. The range of values for these three parameters from the calibration runs is presented in Table 10.3. Subcatchment width, W , is defined as:

$$W = A/l \quad (10.1)$$

where A is the total subcatchment area and l is the subcatchment length. Subcatchment width is a conceptual parameter that is difficult to measure precisely and therefore can be used to calibrate hydrograph shape (James and Robinson, 1986; Nix et al., 1991). Warwick and Tadeipalli (1991) noted that although

Table 10.1: Overflow Characteristics

Event Date	Event Volume m^3	Peak Overflow Rate m^3s^{-1}	Event Duration hr
Jul 9, 1990*	3021	0.458	2.6
Aug 13, 1990*	5245	0.471	4.8
Aug 28, 1990	933	0.298	1.6
Sep 5, 1990* event "a"	1020	0.393	1.3
Sep 5, 1990* event "b"	1716	0.429	1.75
Sep 7, 1990*	1306	0.349	1.6
Oct 11, 1990*	815	0.327	1.2
Dec 3, 1990	11817	0.671	10.5
Apr 19, 1991	1667	0.490	1.4
Apr 20, 1991	3218	0.507	2.4
Apr 21, 1991	3417	0.456	3.2
Apr 22, 1991	10554	0.472	9.2
May 29, 1991	0.018	0.00005	0.25
Jul 4, 1991*	4060	1.11	2.8
Jul 7, 1991*	597	0.224	1
Jul 8, 1991	32	0.066	0.3
Sep 26, 1991	578	0.174	1.5

* model calibration event

Table 10.2: Rainfall Characteristics

Event Date	Event Depth mm	Peak 5 min Intensity mm hr ⁻¹	Peak 15 min Intensity mm hr ⁻¹	Event Duration hr
Jul 9, 1990	24.6	48.8	38.6	3
Aug 13, 1990	35.3	51.8	21.3	11.6
Aug 28, 1990	23.1	61.0	46.8	2.6
Sep 5, 1990 Event "a"	23.9	94.5	44.7	1
Sep 5, 1990 Event "b"	8.9	61.0	28.5	0.75
Sep 7, 1990	16.0	24.4	19.3	3.2
Oct 11, 1990	17.5	6.1	5.1	9.4
Dec 3, 1990	NA*	NA	NA	NA
Apr 19, 1991	15.2	9.1	9.1	3.25
Apr 20, 1991	10.0	6.1	5.1	4.1
Apr 21, 1991	10.1	3.0	3.0	4.1
Apr 22, 1991	16.7	3.0	3.0	10.0
May 29, 1991	NA	NA	NA	NA
Jul 4, 1991	46.8	61.0	45.7	2.2
Jul 7, 1991	14.1	42.7	26.4	2.2
Jul 8, 1991	NA	NA	NA	NA
Sep 26, 1991	NA	NA	NA	NA

* data not available

Figure 10.3: Calibration results for the best fit event (a) occurring on Sept. 5, 1990 (event "b"); and the worst fit event (b) occurring Oct. 11, 1990.

Figure 10.4: Calibration results for 8 events: event volume (a); and event peak overflow rate (b).

from aerial photographs, not all impervious areas are directly connected in a hydraulic sense. Therefore, the effective per cent imperviousness could be used as a calibration parameter. It might be expected that the effective per cent imperviousness would vary, depending on storm characteristics and relative contributions from different parts of the sewershed. A similar conclusion might be drawn for the "lumped" approach to representing subcatchment surface slope.

The range of calibrated values for subcatchment width, slope and per cent imperviousness suggests that there will be some uncertainty when using the model to estimate long term (e.g. annual) pollutant loadings. A quantitative analysis of the relationships between parametric values, antecedent conditions and storm characteristics has not yet been accomplished. Qualitatively, it appears that parameter values should be selected to maximize runoff for long duration, low intensity rainfall events (e.g. August 11, 1990; Figure 10.3) and for short duration events that experience wet antecedent conditions (e.g. September 5, 1990, event "b"; Figure 10.3). Parameter values should be selected to minimize runoff for rainfall events having extended periods (e.g. 15 minutes or more) of high intensity (greater than

Table 10.3: Parametric values, subcatchment width, slope and percent imperviousness.

Subcatchment	Area (ha)	Width (m)	Slope (m/m)	Per Cent Impervious
1	14.1	115-450	.0005-.0017	10-40
2	9.1	75-320	.0005-.0017	10-40
3	13.5	75-340	.0005-.0017	10-30
4	8.8	75-315	.0004-.0016	10-30
5	5.4	75-350	.0005-.0017	10-30
6	24.5	130-550	.0005-.0017	10-30
7	8.6	75-345	.0005-.0019	10-30
8	4.4	75-300	.0005-.0019	10-30
9	24.8	100-450	.0004-.0016	10-23
10	23.9	100-475	.0004-.0016	10-30
11	35.0	105-575	.0004-.0018	5-12
12	23.9	120-590	.0004-.0018	10-50
13	16.2	105-515	.0005-.0019	10-40
14	19.2	105-525	.0005-.0021	5-12
15	6.0	75-300	.0005-.0021	5-12
16	3.4	75-275	.0005-.0021	10-45
17	15.0	120-560	.0004-.0021	10-50

approximately 40 mm hr^{-1}). A continuous modelling approach also could be used to eliminate the need to specify antecedent conditions. This type of approach is discussed, for example, by

Robinson and James (1981). Calibration procedures for continuous modelling may be different than event-based calibration.

Typical values for other parameters used in the model calibration are presented in Table 10.4. Values for these parameters initially were selected using the PCSWMM RUNOFF Manual (James and Robinson, 1986) and Calocerinos and Spina (1989) as reference. The Manning's n values appear towards the high end of those typically used, but this is reasonable for the Babcock St. sewershed. The pervious surfaces in the sewershed can be rugged, abandoned industrial land and railway yards. Many of the impervious surfaces are in poor repair, thereby increasing surface roughness. These same surface characteristics also would produce greater depression storage.

Although model results, in general, were reasonable, it appears that some model inaccuracy may result from the simplifying assumptions used to estimate runoff from pervious surfaces. The practice of identifying single minimum and maximum infiltration rates for each subcatchment should be re-examined in future modelling efforts. Ando et al., (1986) found large variations in the infiltration characteristics of urban areas, depending on landuse. The large proportion of pervious land in the south Buffalo area suggests that a closer examination of infiltration characteristics would be appropriate.

10.4.2 Model Sensitivity

The sensitivity of model results to the three parameters that provided the greatest flexibility in calibration was examined using the rainfall input of the September 7, 1990 storm event. The actual calibrated model results are shown in Figure 10.5. This event was chosen for a sensitivity analysis because it had a well defined rainfall and runoff period and antecedent dry period; the calibration results were reasonable; and the event was of moderate size. Subcatchment width, surface slope and per cent imperviousness were varied within the observed range of calibration

values that had been determined from the eight calibration runs. The parametric values (Table 10.3) that would produce the minimum and maximum flow from each subcatchment were taken as the extremes for the sensitivity analysis. The value for each parameter subsequently was increased at intervals of 25% of the range between the minimum and maximum values. The other parametric values were held constant at the previously calibrated level.

A total of fifteen sensitivity runs were done (five runs for each of the three parameters) and the results are presented in Figure 10.6. For this example, the model appears least sensitive to changes in slope. Sensitivity to changes in subcatchment width and per cent imperviousness varies over the range of the sample runs. The difference between the maximum and minimum parametric values is greater for the subcatchment width than for per cent imperviousness and in general it appears that the model is more sensitive to changes in per cent imperviousness.

10.4.3 Analytical Results

Analytical results currently are available for three overflow "periods". The first overflow period represents the overflow events that occurred on August 28; September 5 and September 7, 1990. The four events were composited in one sample since the birth of Gordon William Irvine (September 3, 1990; 7 lbs. 4 oz.) precluded a field visit to collect samples and reset the system between events. The second overflow period represents four overflow events that occurred between April 20 and April 22, 1991. The third overflow period represents the event of July 4, 1991. The analytical results for various metals, HCB and total PCBs are presented in Tables 10.5 and 10.6. Results from other studies are presented in Table 10.7 for comparison purposes. The results available in the literature often do not report levels for the solid and dissolved phases separately.

Table 10.4: Typical parametric values, Babcock St. Sewershed calibration.

Parameter	Value
Surface Manning's n impervious pervious	0.022-0.025 0.32-0.33
Conduit Manning's n concrete brick	.017 .025
Depression Storage (mm) impervious pervious	2.5-4.5; 4.0 was typical 8.0-9.9; 9.9 was typical
Per Cent Zero Detention	5-25; 5 was typical
Horton Infiltration maximum rate (mm hr ⁻¹) minimum rate (mm hr ⁻¹) decay coefficient (sec ⁻¹)	76.2 13.2 .01330-.03330

The NYSDEC target limit on total PCBs levels in water is 1 ng l⁻¹, which is based on the standard to protect wildlife from the toxic effects of eating contaminated fish (NYSDEC, 1989). The total PCBs levels in the Babcock St. overflows therefore are of some concern. The BSA does not permit discharge of PCBs to the sewer system and to date the source(s) of the total PCBs have not been determined, although research in this area is planned.

Levels of metals, total PCBs and HCB typically are lower and less variable in the dissolved phase than the particulate phase. Although the analytical results represent a minimum of four events and a maximum of nine events, more overflow samples should be obtained to thoroughly evaluate pollutant level dynamics and more accurately quantify level variability. This information is essential in evaluating the uncertainty related to long-term pollutant loading estimates. For example, long-term

Figure 10.5: Calibration results for overflow event of September 7, 1990.

Table 10.5: Metal levels from sampled overflows.

Period	Particulate Phase, ppm			Dissolved Phase, ppm		
	Mn	V	Cu	Mn	V	Cu
Sep, 1990	448	86	414	.750	.0025	.131
Jul 4, 1991	1229	100	478	ND*	ND	ND

* not determined for the event

Figure 10.6: Sensitivity analysis for the Babcock St. sewershed model using the September 1990 rainfall data.

Table 10.6: Total PCBs and HCB levels from sampled overflows.

Period	Particulate Phase, ng l ⁻¹		Dissolved Phase, ng l ⁻¹	
	Total PCBs	HCB	Total PCBs	HCB
Sep, 1990	400	6	30	BDL*
Apr, 1991	ND**	ND	20	.045
Jul 4, 1991	970	16	38	.98

* below instrument detection limit of 3 ng ml⁻¹

** not determined for this event

Table 10.7: Comparison total PCBs, HCB and metals levels.

Parameter	Level	Comments	Reference
total PCBs*	463 ng l ⁻¹	mean level, 3 events, separate storm system	Granier et al., 1990
total PCBs*	27-179 ng l ⁻¹	samples from combined systems, 3 Canadian cities	Marsalek and Ng, 1989
HCB*	0.46-98 ng l ⁻¹	samples from combined systems, 3 Canadian cities	Marsalek and Ng, 1989
V**	0.00393 ppm 70 ppm	dissolved phase particulate phase	Droppo, 1987
Mn**	0.209 ppm 424 ppm	dissolved phase particulate phase	Droppo, 1987

* particulate and dissolved phase not separately analysed

** results from one CSO event, Hamilton, Ontario.

loadings to the Buffalo River from the CSOs currently are being estimated as:

$$L_{p_j} = (\sum V_i)C_{p_j} \tag{10.2}$$

where L_{p_j} is the loading of pollutant, j ; V_i is the overflow volume for each event in the time period under consideration; and C_{p_j} is a "representative" level for pollutant, j . Equation (10.2) is calculated separately for both the dissolved and particulate phases. A "representative" level could be an average value from several events for each site. One standard deviation around the average could be used as a simple measure of uncertainty for C_{p_j} . Alternatively, a range for the loading estimate could be calculated using the minimum and maximum observed levels for pollutant, j . To illustrate this latter approach, the 1991 overflow volume results (observed) were used with the available total PCBs data (Table 10.6) and the results are presented in Table 10.8.

Table 10.8: Total PCBs loadings, 1991 field season.

Phase	Loading, gm	
	Minimum C_{p_j}	Maximum C_{p_j}
Dissolved	0.5	0.9
Particulate	9.6	23.4

The results in Table 10.8 do not consider uncertainty that would be introduced by modelling overflow volume, since the observed volumes were used in the calculations. However, if loading estimates are to be made for years in which overflow volume was not monitored, model estimate uncertainty will need to be considered.

10.5 Conclusions

The calibration procedure and results were discussed for the application of PCSWMM to an industrialized sewershed that overflows to the Buffalo River, New York. The average (absolute) prediction error of overflow volume for eight calibration events was 4% and the average (absolute) prediction error of peak overflow rate was 24%. These calibration results compare favorably with results reported in the literature. Three parameters had the greatest flexibility in model calibration for the sample sewershed: subcatchment surface slope; subcatchment width and per cent imperviousness. Sensitivity analysis indicated that, in general, the model for the sewershed was least sensitive to changes in surface slope and most sensitive to changes in percent imperviousness.

The levels of total PCBs, HCB, Mn, V and Cu associated with the particulate and dissolved phases of several sampled overflows were reported. The total PCBs levels are of some concern, as they exceed state-targeted guidelines for water quality. Future research in the U.S. should concentrate on determining pollutant levels separately for the particulate and dissolved phases because proposed amendments to the Clean Water Act explicitly consider sediment quality in regulations.

An approach to estimate long term pollutant loadings to the Buffalo River from the sampled sewershed was discussed. Overflow volumes from the 1991 field season and data on total PCBs levels were used to illustrate the estimation approach. A total of eight years of rainfall data are available for the south Buffalo area. The calibrated model will be used with these data to estimate overflow volumes from the sewershed on a longer term than presented in this chapter. Additional overflow samples will be taken in 1992 for quality analysis. These additional samples will be used to evaluate the uncertainty of the "representative" pollutant levels in the calculation of long term pollutant loadings. The loading estimate approach also will be applied to other sewersheds contributing to the Buffalo River as a first step in identifying appropriate CSO remedial measures.

10.6 Acknowledgements

Funding for this research partially was provided by the U.S. EPA, Great Lakes National Program Office (grant X99502401) and from the Research Foundation of SUNY. Several individuals assisted in the collection of field data and provision of background data for this study, including Mr. Dennis Torok, SUNY College at Buffalo; Mr. Greg McCorkhill, P.E., Calocerinos and Spina; Mr. Jim Caruso, Mr. Frank DiMascio, P.E. and other personnel at the Buffalo Sewer Authority.

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