

Lackawanna WWTP Elimination—A Study of Potential Impacts on Smokes Creek and the Buffalo Sewer System

Juraj M. Cunderlik, Christopher P. Martin, David Barnes, Kim N. Irvine
and David P. Comerford

This study presents the results of numerical modeling performed in support of the evaluation of the feasibility of conveying sanitary wastewater flows handled by the Erie County Sewer District (ECSD) No. 6 Lackawanna wastewater treatment plant (WWTP) to the Buffalo Sewer Authority's (BSA) Bird Island WWTP for treatment.

A coupled hydrologic–hydraulic–hydrodynamic–water quality numerical modeling approach was developed to capture and evaluate the range of potential environmental benefits and the impacts of eliminating discharge from the Lackawanna WWTP to Smokes Creek. The results showed that over 95% of the ammonia and TKN (total Kjeldahl nitrogen) loadings would be removed from lower Smokes Creek. Lead and zinc concentrations would be reduced by approximately two-thirds. Eliminating the Lackawanna WWTP discharges would result in only minor reductions in existing Smokes Creek flow velocities and water levels.

The potential impacts of redirecting the ECSD No. 6 flows to the BSA were evaluated using the BSA's XPSWMM model of its sewer system. The results showed that the Bird Island WWTP would be well suited to accept sanitary wastewater flows from ECSD No. 6. The Bird Island WWTP excess capacity would only be reduced by about 10% to treat flows from ECSD No. 6, thus maintaining flexibility. Potential additional combined sewer

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overflow (CSO) volumes from the BSA system due to the additional flow from Lackawanna are expected to be about 1% or less, on an annual basis. These CSO impacts would be distributed throughout all water bodies along the Buffalo waterfront.

In summary, the study showed that redirecting the ECSD No. 6 flows would allow the decommissioning of the Lackawanna WWTP and the removal of most treated wastewater discharges to Smokes Creek, leading to significantly improved water quality in the creek. The overall contaminant loading to the Niagara River watershed would also be reduced. These environmental benefits in turn would enhance regional efforts to develop Smokes Creek into a recreational area. Finally, improved sewer infrastructure would open up the 5 mi (8 km) Buffalo–Lackawanna waterfront to future development.

22.1 Background

The cities of Buffalo and Lackawanna in Western New York share approximately 5 mi (8 km) of waterfront along Lake Erie, as shown on Figure 22.1. This stretch of prime waterfront, mostly consisting of barren land and abandoned industrial properties, has long been underutilized. This has been changing over the past few years. Local, state and federal resources are focusing on reinventing the entire waterfront to promote residential, recreational, commercial and light industrial growth.



Figure 22.1 Planned redevelopment areas.

A significant roadblock exists that will eventually constrain redevelopment: lack of sewerage conveyance and treatment capacity, as illustrated on Figure 22.2. Within Buffalo, only about half the Outer Harbor waterfront area targeted for development contains sewers. In some portions of Buffalo's sewer waterfront areas, the available capacity would limit the type of development that can occur. Additionally, the BSA has been requested to consider relocating the S pumping station because it lies within the Erie Canal Harbor redevelopment area (see Figure 22.2).

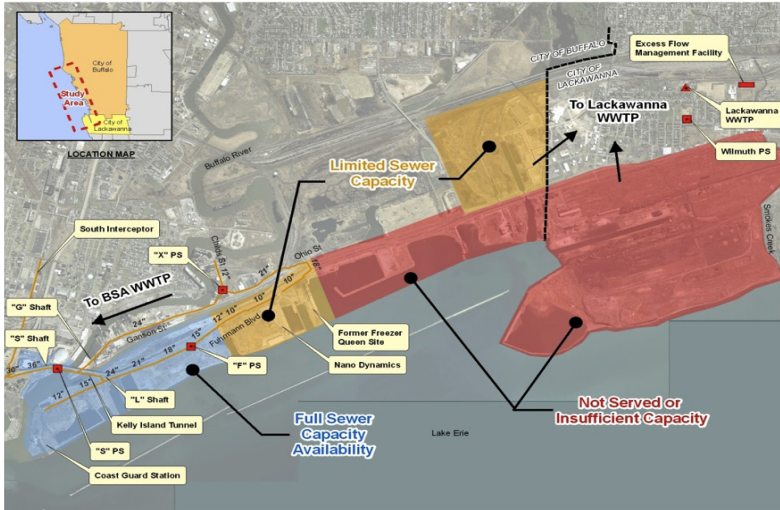


Figure 22.2 Existing sewer infrastructure capacity for the planned redevelopment areas.

Although the target areas in ECSD No. 6 have sufficient conveyance capacity, the Lackawanna WWTP, owned and operated by the Erie County Department of Environment and Planning, Division of Sewerage Management (ECDSM), has insufficient treatment capability to support the projected development and limited ability to treat industrial discharges. In addition, a draft State Pollution Discharge Elimination System (SPDES) permit renewal has been issued that, as presently written, would require significant reductions in ammonia and residual chlorine effluent concentrations, thus further limiting the potential of the Lackawanna WWTP to support development. The proposed changes to the ammonia and chlorine residual limits are the result of a change in the Smokes Creek stream classification from D (best usage of fishing, but these waters will not support fish propagation) to C (best usage for fishing, these waters support fish propagation).

The Lackawanna WWTP serves ECSD No. 6 and is permitted to treat a 30 d average flow of 4.5 mgd (17 ML/d) with a secondary treatment capacity of

approximately 8 mgd (30.3 ML/d). ECSD No. 6 has a separate sanitary sewer system and currently serves about 18 000 customers within Lackawanna, and portions of the City of Buffalo and the towns of West Seneca and Hamburg.

Two solutions to the infrastructure improvement in the waterfront area have been identified. The first is the segregated response approach. Under this approach, the cities of Buffalo and Lackawanna would proceed with the necessary infrastructure improvements separately. For Lackawanna this would mean:

- upgrading the Lackawanna WWTP to address potentially more stringent effluent limits;
- expanding the Lackawanna WWTP to accommodate increased flows from development; and
- capital improvements to the Lackawanna WWTP to maintain existing facility asset levels.

The City of Buffalo would have to:

- relocate the S pumping station; and
- install sewers to serve the remainder of the Outer Harbor area.

The second, alternative solution to the infrastructure improvement in the waterfront area, supported by the United States Environmental Protection Agency (USEPA, 1996), is the regional watershed approach. The regional watershed approach, which promotes opportunities for sharing treatment capacity and joint construction of sewer infrastructure, would include the following key modifications:

- relocating the S pumping station to the L shaft of the Kelly Island tunnel;
- rehabilitating the Kelly Island tunnel;
- upgrading the Wilmuth pumping station;
- eliminating the Lackawanna WWTP; and
- providing the necessary sewer system infrastructure.

Faced with a significant investment to address sewer capacity issues and because of their proximity, the ECDSM and the BSA jointly initiated a feasibility study to evaluate how the regional watershed approach might be employed to fully support waterfront development, offer the most efficient and effective wastewater service to existing and future ratepayers, and continue to protect the environment. Specifically, the feasibility study involved evaluating the engineering, environmental and regulatory, and economic benefits and the impacts of eliminating the Lackawanna WWTP and conveying ECSD No. 6 flows to the BSA for treatment, instead of proceeding with the necessary improvements separately (the segregated response approach).

This chapter presents the methodology and results of numerical modeling performed in support of the evaluation of the feasibility of conveying

ECSD No. 6 flows to the BSA for treatment. The objectives of the modeling were to:

- perform water quantity and quality study to evaluate the potential environmental benefits and impacts of eliminating ECSD No. 6 discharges on Smokes Creek;
- perform CSO peak/volume and pollutant loading analyses to evaluate the potential impacts of redirecting ECSD No. 6 flows on BSA's sewer system; and
- compare potential environmental benefits and impacts to verify if an overall environmental benefit would be gained under the regional watershed approach.

This chapter is organized as follows:

- we begin by outlining the methodology developed and applied in this study for evaluating the potential impacts of Lackawanna WWTP elimination;
- we then discuss the anticipated environmental benefits and impacts of redirecting the ECDS No. 6 flows on Smokes Creek and the Buffalo sewer system;
- we conclude with the main findings of the study.

22.2 Methodology

22.2.1 Data Collection

Limited data existed for Smokes Creek and data that do exist are relatively old. Historically, lower Smokes Creek flowed through steel mill property and most of the land currently sits unused. Black (1983) presented data for bed sediment that showed chrysene, fluoranthene and pyrene exceeded probable effect levels while phenanthrene and benzo[a]pyrene were lower than probable effect levels. The New York State Department of Environmental Conservation (NYSDEC, 1987) noted that arsenic, copper, selenium and zinc were detected in Bethlehem Steel wastewater discharges, while metals, cyanide and phenols were found in the ECSD No. 6 discharges. Daphnia and walleye fry had the lowest survival rates (40% to 57% for daphnia, 7% to 30% for walleye fry) at sites in the area of Bethlehem Steel and ECSD No. 6 discharges, when compared to sites upstream (97% to 100% for daphnia; 75% to 82% for walleye fry). The NYSDEC (1996) used PISCES (passive in-situ continuous extraction samplers) to assess dissolved-phase PCBs at two sites that bracketed the ECSD No. 6 WWTP, the Bethlehem Steel inactive hazardous waste site and the Lehigh Industrial Park inactive hazardous waste site. Essentially, the PISCES consist of a brass cylinder filled with hexane that is closed at the top

and sealed at the bottom with semi-permeable membrane. When submerged in water, the dissolved-phase PCBs diffuse through the PISCES membrane and accumulate in the hexane at a rate proportional to the concentration in the sampled water, the area of the membrane, and the temperature of the water. PISCES normally are deployed in the water for a period of two weeks (see also Litten et al., 2002).

The Bethlehem Steel site has coal tar sludge and the Lehigh site has PCB transformer oil. PCB levels in Smokes Creek were relatively low compared to other sites sampled in this study and it was concluded that the inactive hazardous waste sites and ECSD No. 6 WWTP were not significant PCB sources. NYSDEC (2002) has reported mercury in young-of-year fish collected in Smokes Creek, but at levels below USEPA guidelines, while pesticides, dioxins and furans generally have not been detected. PCBs were detected at low levels. Most recently, the NYSDEC (2005a; 2005b) reported that aquatic life (including macroinvertebrates), recreation, and aesthetics were stressed or impaired due to a combination of contaminants (metals, pathogens, sediment, nutrients, dissolved oxygen) and physical disturbance resulting from urban runoff and CSOs, possible industrial discharges and bank erosion.

Because of the limitations to available data, a field monitoring program was established to develop the database necessary to complete the benefit and impact evaluation. The field program was conducted between May 2010 and October 2010 and included the following receiving water evaluation components:

- bathymetric survey;
- discrete and continuous streamflow monitoring;
- discrete dry and wet weather water quality sampling; and
- continuous water quality monitoring.

A bathymetric survey of Smokes Creek was conducted so that the creek channel could be simulated in the numerical model. The survey was performed using a boat and from measurements taken along the creek bank.

A streamflow monitoring program was completed to measure existing creek flows upstream and downstream of the WWTP discharge (see Figure 22.3). Sigma 910 area-velocity meters were installed on bridgework for this purpose and measurements were recorded at 15 min time steps. Meters were checked and data were downloaded every two weeks. Flow was monitored at two additional flow sources to the Creek: at the cooling water discharge from Bethlehem Steel/Arcelor-Mittal, and in a small channel adjacent to the WWTP outfall (Figure 22.3). The cooling water discharge from the twin pipe system was measured using two Sigma 910 area-velocity meters and data were downloaded every two weeks. Flow from the small drainage canal was manually measured at a weir during the dry and wet weather sample dates.

The intent of the water quality sampling program was to obtain sufficient data to evaluate the benefits and impacts of eliminating discharges from the WWTP to Smokes Creek.

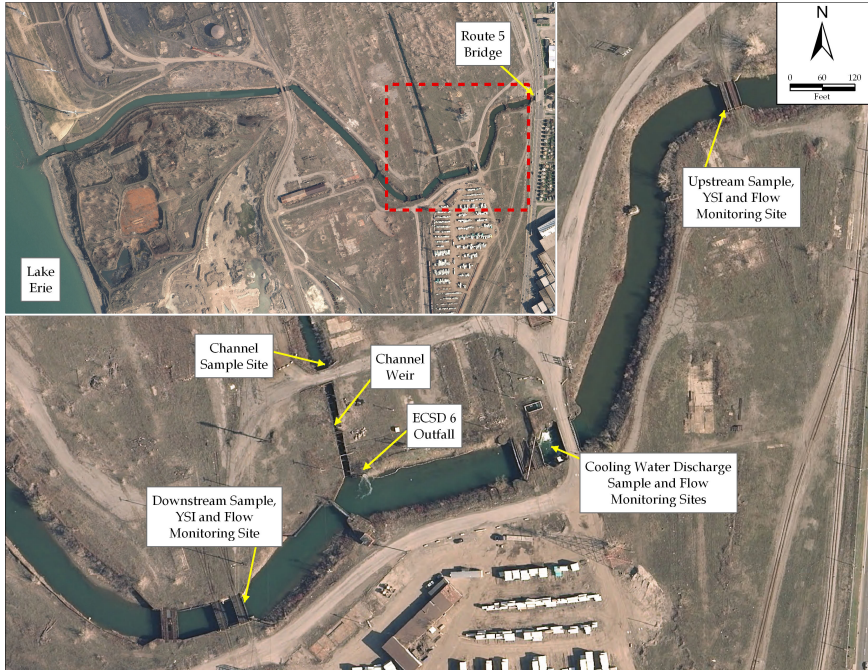


Figure 22.3 Field monitoring locations.

Sampling was done on five discrete dry weather dates and during two discrete wet weather sampling events between May 26, 2010 and August 19, 2010. Dry weather sample events were defined as days having a minimum of 48 antecedent hours with no rain (precipitation <0.10 in., 2.54 mm). For wet weather sampling events, samples were collected at approximately 1 h, 2 h, 4 h, 6 h, 12 h, and 24 h after the commencement of rainfall.

The grab samples were analyzed for the following analytes: BOD5 (five day biochemical oxygen demand), total suspended solids (TSS), total phosphorus, residual chlorine, fecal coliform, TKN, ammonia, mercury, phenolics, selenium, cyanide amenable to chlorination, nitrites plus nitrates, cadmium, chromium, copper, nickel, lead, zinc, and arsenic. These analytes were selected to be consistent with the BSA LTCP (long term control plan for CSO abatement) sampling (e.g. Irvine et al., 2005), pollutants identified by the New York State Department of Environmental Conservation (NYSDEC, 2005a; 2005b), contaminants of concern identified by the Niagara River Toxics Committee

(1984), and analytes listed in the existing WWTP SPDES permit. Sample analyses were performed by TestAmerica laboratories in Amherst, New York, a New York Laboratory Accreditation Program (NYLAP) certified laboratory. Quality assurance measures consistent with USEPA guidelines were implemented. All data were reviewed by qualified in-house chemists from the study team to verify they met accepted objectives.

YSI 6920 datasondes were used to continuously sample water quality at the upstream and downstream monitoring locations for the following parameters: temperature, specific conductance, dissolved oxygen, pH, and turbidity.

22.2.2 Numerical Modeling

A coupled hydrologic–hydraulic–hydrodynamic–water quality numerical modeling approach was developed to evaluate potential environmental benefits and impacts of eliminating discharge from the Lackawanna WWTP to Smokes Creek.

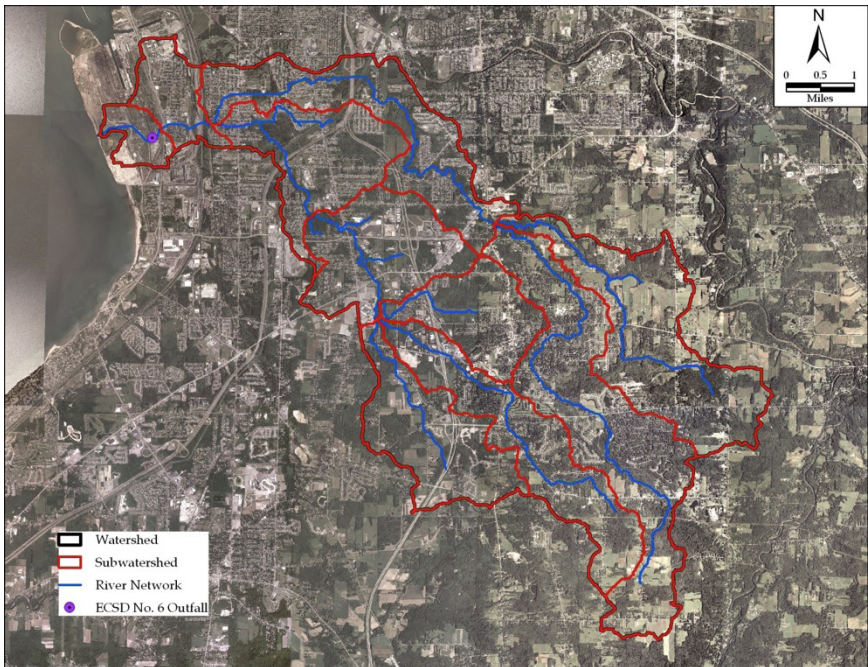


Figure 22.4 The Smokes Creek watershed.

The Smokes Creek watershed is a small urbanized watershed located south of Buffalo. The area of the watershed is approximately 33.2 mi² (86 km²). The watershed's annual precipitation averages approximately 40 in.

(1 016 mm). Smokes Creek begins in the town of Orchard Park, continues through the towns of West Seneca and Hamburg, and flows through the city of Lackawanna with an ultimate discharge into Lake Erie. The watershed is shown on Figure 22.4 above.

A process based, semi-distributed, continuous simulation hydrologic model was developed for the Smokes Creek watershed to generate continuous flow hydrographs for the creek. The XPSWMM hydrologic model was used in the modeling (xpsoftware, 2012). For the purpose of modeling, the Smokes Creek watershed was subdivided into ten smaller subwatersheds, as shown on Figure 22.4. The Creek channel was discretized into nine model reaches. Dynamic wave routing was used to simulate flows in the reaches.

The XPSWMM hydrologic model was also used for non point source modeling of water quality in the Smokes Creek watershed. The event mean concentration (EMC) method was used to simulate pollutant runoff processes. In the EMC method, the amount of pollutant runoff is proportional to the amount of precipitation runoff. The actual concentration varies from the mean with a logarithmic probability distribution. The event mean concentration is a flow-weighted average concentration and not a time-averaged concentration during a rain event (Rossman, 2004).

The United States Army Corps of Engineers RMA2 hydrodynamic model was used as the modeling platform for assessing the water quantity impacts of eliminating discharge from the Lackawanna WWTP to Smokes Creek. It was important to use a sophisticated hydrodynamic model because of the effects of Lake Erie on Smokes Creek flow (including seiches and flow reversals). RMA2 is a two dimensional, finite element, depth-averaged hydrodynamic model (Donell et al., 2009). The model is data intensive. Required inputs include river morphology, bathymetry, river flows and water levels, lake water levels, and wind and rainfall data. The model was developed, executed, and post-processed using the Surface Water Modeling System (SMS) interface, developed by Aquaveo and distributed by Environmental Modeling Systems Inc.

The RMA2 model was set up for a section of Smokes Creek downstream of the Route 5 bridge and the confluence of the creek with Lake Erie (see Figure 22.3 above). A high detail triangular–quadrilateral, non-orthogonal grid was developed for the creek. The grid was defined by 7 929 nodes connected into 3 584 triangular and quadrilateral elements. The element size in the grid varied from 30 ft² (2.8 m²) up to 200 ft² (18.6 m²). The element density was higher (smaller element sizes) between the upstream and downstream monitoring sites and lower (larger element sizes) elsewhere in the creek.

Several initial and boundary conditions were defined in the model to simulate key hydrodynamic features in Smokes Creek. Initial boundary

conditions were used to define the initial water surface elevation in the creek and in Lake Erie at the beginning of each simulation. Three boundary conditions characterized flows entering the model domain: the Smokes Creek upstream boundary, the cooling water lateral boundary, and the Lackawanna WWTP discharge lateral boundary. Calibrated flow hydrographs generated by the XPSWMM watershed model were used to define the Smokes Creek upstream boundary. The calibration procedure is discussed in the next section. Monitored cooling water and Lackawanna WWTP discharges were used to define the lateral boundaries. A downstream head boundary defined the water surface elevation in Lake Erie and the interaction between the lake and the creek. Hourly lake water level data were used from the National Atmospheric and Oceanographic Administration station Buffalo, NY (ID 9063020).

The United States Army Corps of Engineers RMA4 water quality model was used as the modeling platform for assessing the water quality impacts of eliminating the discharge from the Lackawanna WWTP to Smokes Creek. RMA4 is a two dimensional, finite element, advection–diffusion water quality transport model. It computes concentrations for up to six constituents, either conservative or non-conservative, within the two dimensional computational mesh domain (Letter and Donell, 2008). The RMA4 model was coupled with the RMA2 hydrodynamic model into one modeling system, in which the RMA4 model utilized the depth-averaged hydrodynamic solution produced by the RMA2 model. Other inputs to the RMA4 model included river and lake water quality, and the cooling water and Lackawanna WWTP effluent characterization. Similarly to RMA2, the RMA4 model was developed, executed, and post-processed using the SMS interface.

Calibrated water quality pollutographs generated by the XPSWMM water quality model were used to define the time-variable water quality in Smokes Creek at the upstream model boundary. Long term averages calculated from the available daily data were used to characterize concentrations of the pollutants in the cooling water and Lackawanna WWTP discharge. Data from the Fort Erie Station (Great Lakes Nearshore Monitoring and Assessment ID 1600011340) for the years with available data (2001, 2004, 2007 and 2010) were used to characterize water quality in Lake Erie.

Continuous dynamic simulations for the six-month long monitoring period May 2010 to October 2010 were run with the coupled XPSWMM, RMA2, and RMA4 models. The models used hourly input data and were run with hourly computational steps.

The potential impacts of re-directing the ECSD No. 6 flows to the BSA sewer system were evaluated by means of two models:

- ECSD No. 6 sewer hydraulic model; and
- BSA sewer hydraulic and water quality model.

The ECSD No. 6 model was developed using PCSWWM. The model was used to generate continuous hydrographs of combined sewer flows that were used as inputs to the BSA sewer model.

The BSA sewer hydraulic and water quality model was built in XP-SW-MM. The model consisted of 3 527 nodes connected by 3 829 links. The water quality model was used to trace the ECSD No. 6 flows in the BSA's collection system on a seasonal and annual basis assuming a unit tracer concentration of 100 mg/L (or 100%). The tracer was added to the ECSD No. 6 flows at the S pumping station and the associated dilution was tracked through the collection system.

It was determined that modeling using continuous period simulations (CPS) would be most appropriate for this analysis, which is consistent with USEPA's CSO Control Policy (USEPA, 1999). CPS modeling allows estimation of annual CSO volumes based on a typical precipitation year. It also allows for the comparison of alternative flow application points and evaluation of mitigation measures.

The ECSD No. 6 and BSA sewer models were run in continuous mode for a 9 month period of the typical precipitation year (March–November) to avoid analyzing the wintertime snowfall. The results from the 9 month period were extrapolated to a full 12 month period to estimate annual response. The extrapolation involved taking the arithmetic average of the three simulated seasons, and using the result to estimate the winter (non-modeled) season. All model simulations were performed under 2010 and 2032 flow projections to evaluate the potential impact under current and projected future buildout conditions.

The ECSD No. 6 model was run first to establish the hydrograph that simulated the expected annual discharge from ECSD No. 6 to the BSA. The hydrograph from ECSD No. 6 was used as the input file to the BSA's XPSW-MM model under 2010 and 2032 flow projections.

Each modeling scenario was run separately for the spring, summer and fall seasons. The computational wet time step used in the hydrologic component was 300 s, and the dry time step was 3 600 s. The time step used in the sanitary and hydraulic components was 20 s. A dynamic wave method was used for routing the flows in the hydraulic component of the model.

22.3 Results

22.3.1 Smokes Creek

The Smokes Creek watershed model was calibrated with the flow data obtained from the flow monitoring program. The calibration parameters includ-

ed subwatershed width and roughness parameters, depression storage, and Horton infiltration parameters.

Figure 22.5 compares the observed and modeled flows at the downstream monitoring site. The model reproduced the peaks of the observed hydrograph very well, including the highest flow event that occurred on June 6, 2010. Some peaks were under- and some overestimated by the model, but there is no tendency of the model to consistently under- or over-simulate. The mean relative error of the simulated flows is very low, -2.8% .

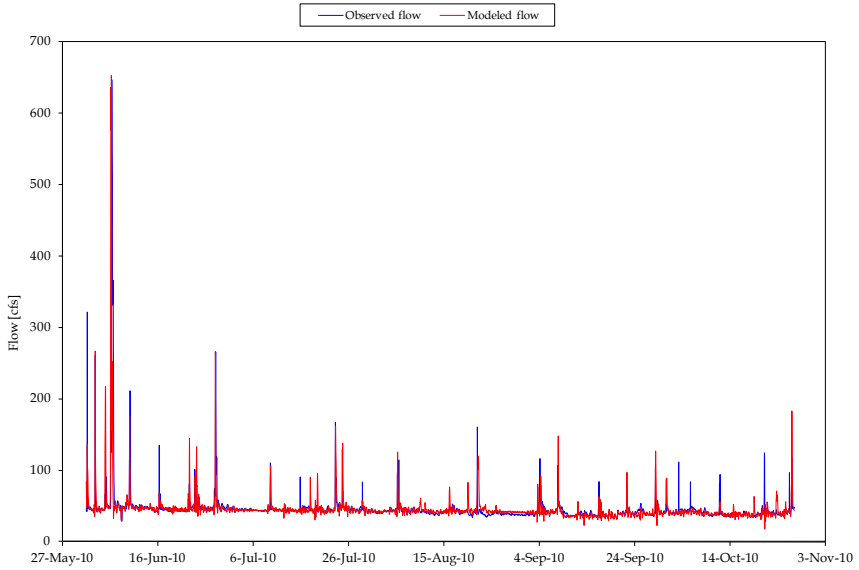


Figure 22.5 Observed and modeled flows in Smokes Creek at the downstream monitoring site.

The watershed water quality model was calibrated using the data collected at the upstream monitoring site during the wet and dry weather sampling events. The upstream site was chosen because the data collected at this site are not impacted by the cooling water and the WWTP discharge. The calibration parameters included the pollutant event mean concentration and standard deviation, and dry weather concentration. An example of the calibration is shown on Figure 22.6. The figure demonstrates that the calibrated water quality model was able to predict the lead concentrations during the wet-weather event, as well as the lead concentrations during the following dry weather event. The calibration results for other constituents were similar.

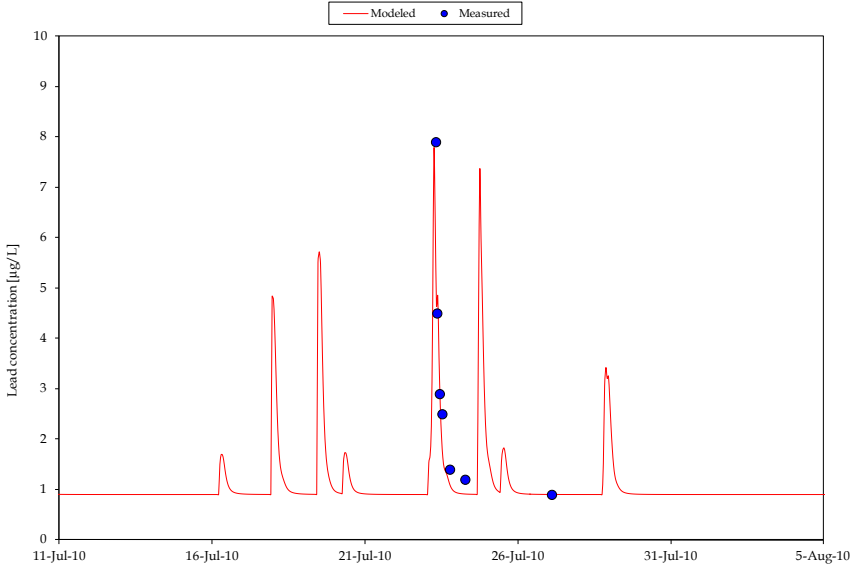


Figure 22.6 Lead concentrations in Smokes Creek at the upstream monitoring site.

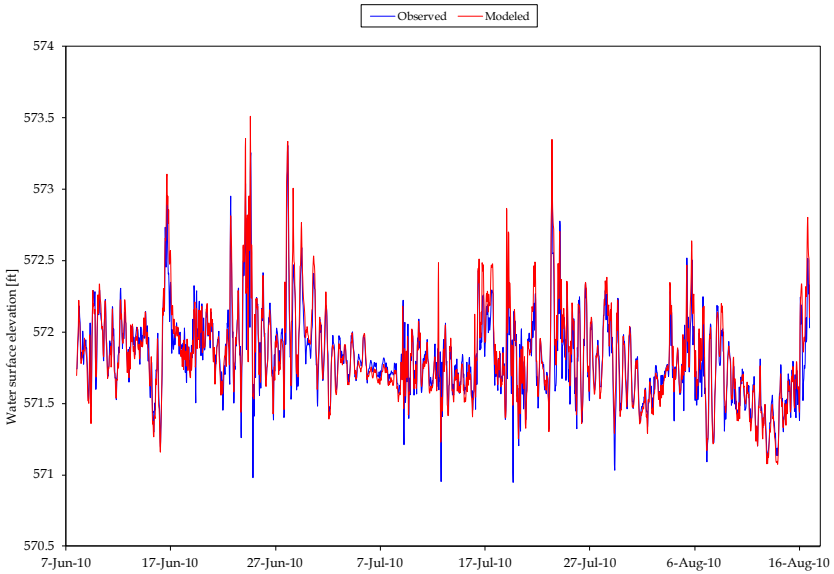


Figure 22.7 Water surface elevations in Smokes Creek at the downstream monitoring site.

Calibration of the hydrodynamic model involved changing the Manning roughness coefficient and the eddy viscosity parameters to achieve a good fit with water surface elevations in the creek observed at the downstream monitoring site (see Figure 22.7 above). Overall, the model reproduced very well the variability of the water surface elevations in the creek. It is noteworthy that this variability is impacted to a large extent by the fluctuation of Lake Erie water levels. Accounting for Lake Erie levels proved to be both challenging and essential in the modeling as the diurnal fluctuation of lake levels, due to tidal and seiche effects, greatly impacts the flow circulation in the lower section of the creek.

In order to evaluate potential benefits and impacts of eliminating the Lackawanna WWTP discharge to Smokes Creek, the calibrated model was modified by excluding the WWTP discharge boundary from the model setup. The model was re-run and the results generated by the two models compared.

The results showed that the impacts of eliminating the Lackawanna WWTP discharge to Smokes Creek on flow velocities are higher during low flow conditions (up to 10% decrease) and lower during high flow conditions (up to 5% decrease). In absolute terms, however, the decrease in flow velocities is very small, with an overall average decrease of 0.013 ft/s (0.004 m/s), minimum decrease of 0.001 ft/s (0.0003 m/s), and maximum decrease of 0.097 ft/s (0.03 m/s). Figure 22.8 illustrates the flow velocity profile obtained during a low flow event on July 8, 2010.

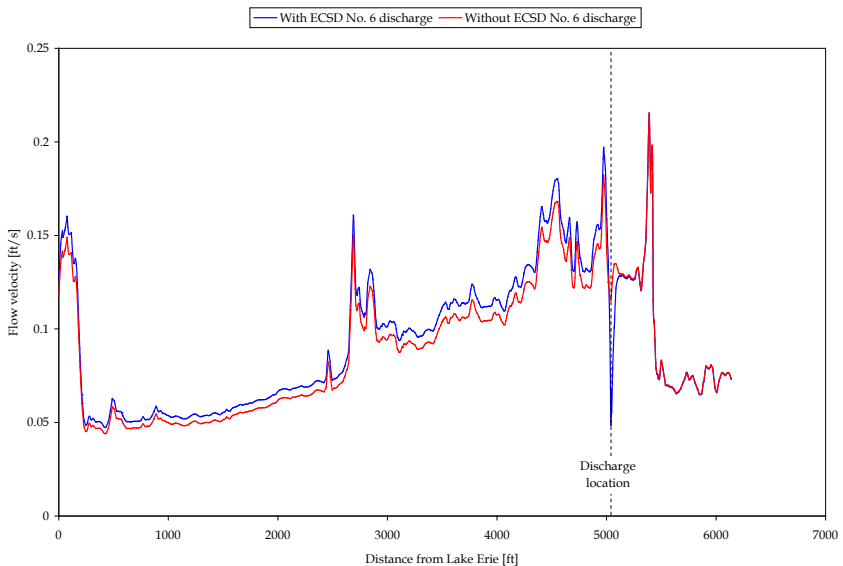


Figure 22.8 Flow velocity profile in Smokes Creek, July 8, 2010 low flow event.

The impacts of eliminating the Lackawanna WWTP discharge to Smokes Creek on water levels in Smokes Creek are higher during high flow conditions (0.006% decrease) and lower during low flow conditions (0.003% decrease). The region of highest impact is located upstream of the WWTP discharge location (see Figure 22.9), in contrast to mostly downstream impacts observed on flow velocities (see Figure 22.8 above). This suggests possible tail water effects of the WWTP discharge on flows in the creek. In absolute numbers the decrease in water levels is extremely small, with an overall average decrease of 0.004 ft (0.001 m), minimum decrease of 0.0 ft (0.0 m), and maximum decrease of 0.019 ft (0.006 m).

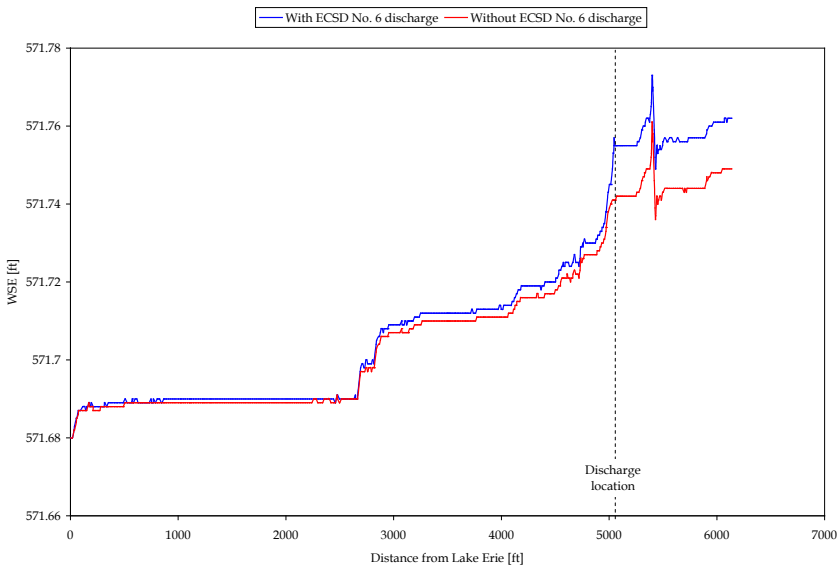


Figure 22.9 Water surface elevations in Smokes Creek, July 8, 2010 low flow event.

Figure 22.10 shows the concentrations of ammonia in Smokes Creek during a low flow event on July 8, 2010. The figure demonstrates that the concentrations of ammonia significantly increase in the creek as a result of the Lackawanna WWTP discharge. Table 22.1 summarizes the relative improvement in water quality calculated as a percentage from average concentrations of the pollutants at the downstream monitoring site for the period June 2010 to August 2010. The table confirms that the elimination of the Lackawanna WWTP discharge to Smokes Creek would significantly improve water quality in the downstream reach of Smokes Creek.



Figure 22.10 Ammonia concentrations in Smokes Creek, July 8, 2010 low flow event.

Table 22.1 Predicted water quality improvement in Smokes Creek at the downstream monitoring site.

Pollutant	Average concentration ¹ (June 8–August 16, 2010)		% Improvement
	With WWTP discharge	Without WWTP discharge	
Cadmium	2.202	0.021	99.0
Lead	1.333	0.415	68.9
Zinc	14.337	4.986	65.2
Ammonia	6.868	0.273	96.0
Total Phosphorus	0.274	0.019	92.9
Total Kjeldahl Nitrogen	6.746	0.361	94.6

¹[$\mu\text{g/L}$] for Cd, Pb and Zn; [mg/L] for NH_3 , TP and TKN

22.3.2 BSA Sewer System

The continuous period simulations were run with and without the ECSD No. 6 flows being applied to the BSA sewer system. This approach permitted isolation of potential CSO impacts from the additional ECSD No. 6 flows. ECSD No. 6 flows would discharge to the S pumping station location, which are then conveyed to a node on the South Interceptor, the discharge point of the pumping station force main. The model was configured assuming that the excess flow management facility (EFMF) operation would be in accordance with the current ECSD No. 6 Wet Weather Operating Plan.

The results showed that the discharge of ECSD No. 6 flows to the BSA would generate an average annual increase in CSOs peak flows of 1.4% under current conditions (2010) and 2.2% under future full buildout conditions

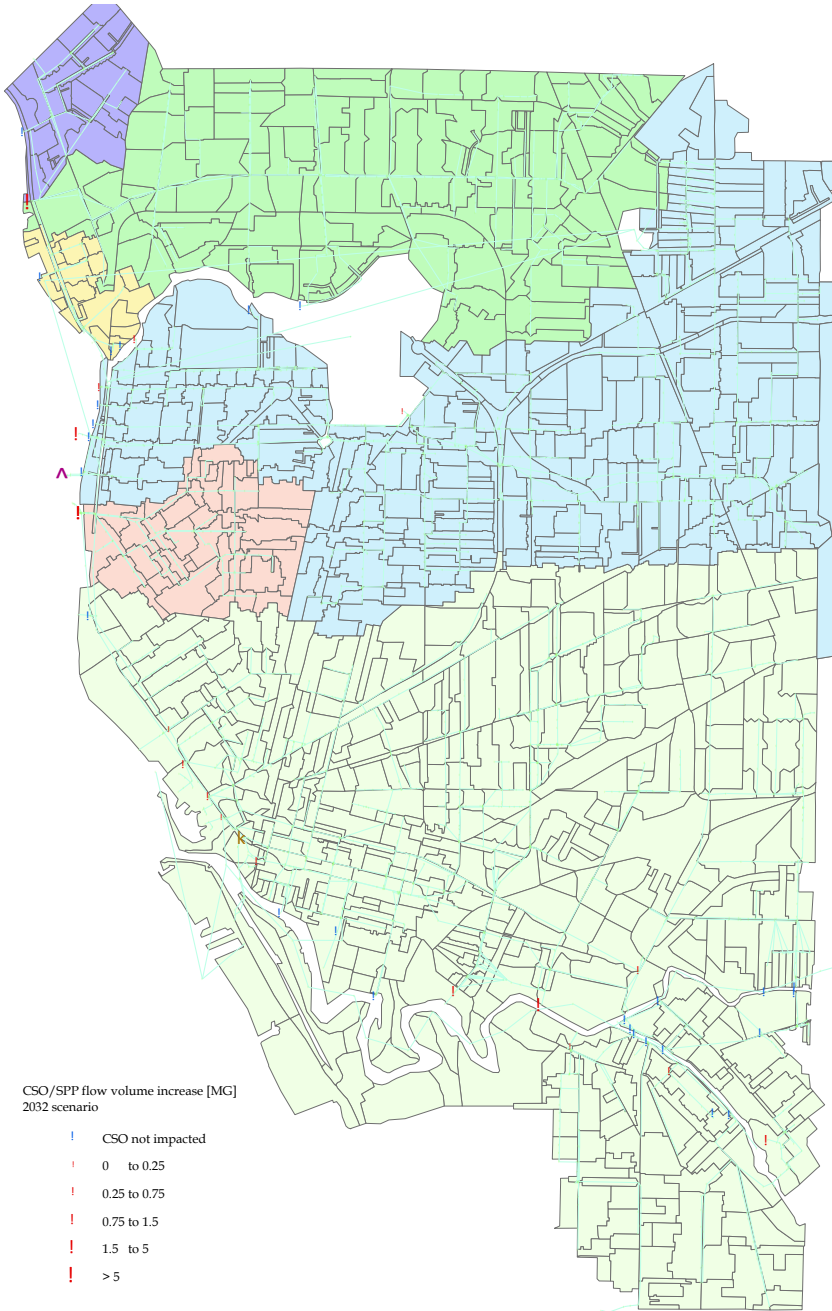


Figure 22.11 Predicted increase in total annual CSO volumes for the 2032 scenario.

(2032). Increase in total annual CSO volumes is estimated to be about 32.3 MG (0.12 ML) in 2010, which is about 0.78% of the current total CSO volume within the BSA system. In 2032, CSO volumes are predicted to increase by 45.4 MG (0.17 ML), which is about 1.1% of total current CSO volume. It is critical to note that these increases represent very conservative assumptions. For instance, the 2032 volume and percentage assume that no modifications would be made to the BSA's collection system. In reality, substantial improvements to address CSOs will be constructed as part of the BSA's LTCP.

The location and magnitude of predicted annual volumetric impact in 2032 is illustrated on Figure 22.11 overleaf. The total Buffalo River impact is predicted to be about 6.7 MG (0.02 ML) in 2010 and 13.8 MG (0.05 ML) in 2032. This represents a Buffalo River impact of about 0.51% and 1.05% for 2010 and 2032, respectively, over the predicted discharge if ECSD No. 6 flows were not conveyed to the BSA. The remaining impacted CSOs are in the Erie Basin Marina, Niagara River, and Black Rock Canal.

The ECSD No. 6 flows can be traced from the S Pumping Station to the WWTP. This shows that almost all (approximately 97% to 98%) of the sewage load from ECSD No. 6 flows to the Bird Island WWTP. Only a small fraction flows to CSO 17, and no other CSOs contain sewage from ECSD No. 6. The main reason that most of the tracer was conveyed to the Bird Island WWTP was that the S Pumping Station discharges directly to the South Interceptor. This is a deep interceptor with no overflow points. However, the flows from ECSD No. 6 displace flows within the BSA collection system.

22.3.3 Combined Environmental Benefits

Tables 22.2 and 22.3 summarize the respective predicted 2010 and 2032 total loadings removed from Smokes Creek and the potential additions to the BSA CSOs if the regional watershed approach were implemented.

Table 22.2 Net watershed loading benefit, 2010 (lb).

Receiving Water	Ammonia	TKN	Pb	Cu	Zn	Hg
Smokes Creek Reduction	42 200	42 100	50.26	27.02	161.58	0.573
Potential Additional CSO Impact	1 884	3 189	23.14	25.28	79.47	0.030
Net Watershed Benefit	40 316	38 911	27.12	1.74	82.11	0.542

Table 22.3 Net watershed loading benefit, 2032 (lb).

Receiving Water	Ammonia	TKN	Pb	Cu	Zn	Hg
Smokes Creek Reduction	65 800	65 600	78.34	42.12	251.86	0.892
Potential Additional CSO Impact	2 520	4 267	31.98	31.60	105.23	0.043
Net Watershed Benefit	63 280	61 333	46.36	10.52	146.63	0.849

These loads are grouped by receiving water body and represent the sum of inputs from all potentially impacted outfalls to the specific water body. The loads were calculated using event mean concentration data determined from sampling under the BSA's LTCP (e.g. Irvine et al., 2005) and the difference in annual overflow volume between the with and without ECSD No. 6 scenario.

The results of this assessment show the watershed would encounter a significant benefit with respect to ammonia and TKN loadings. In 2032, over 60 000 lb/y (27 215 kg/y) ammonia and TKN would be removed from the watershed and sent to the BSA's WWTP for efficient treatment. Excellent net removals of lead, zinc and mercury are also projected.

It is important to note that the projected net watershed benefit is conservative, in that the additional CSO impact assumes that no improvements would be made to the BSA's collection system to address CSOs. Given the ongoing efforts by the community with respect to water quality improvements, particularly for the Buffalo River Area of Concern (Hartig, 2010), it will be important not to simply divert water quality issues to a different location within the waterfront. In reality, the BSA will be required to reduce and treat CSOs as part of its LTCP. As the LTCP is implemented, CSOs impacted by ECSD No. 6 would be addressed, with facilities sized to offset the additional induced flow. Therefore, the proposed regional watershed approach would provide an overall environmental benefit to the watershed.

An updated financial comparison of the segregated response and regional watershed approaches was also performed to evaluate the economic viability of conveying ECSD No. 6's wastewater to the BSA. A breakpoint analysis was used to identify projected savings and the required amount of additional financing necessary to implement the regional watershed approach. A comparative present value analysis showed that implementing the regional watershed approach had a savings potential of almost \$59 million with respect to the segregated response approach. Implementing the regional watershed approach would result in over a \$39 million reduction in capital expenditures and almost a 45% saving.

22.4 Conclusions

This study showed that a significant environmental benefit can be achieved in Smokes Creek from the regional watershed approach, with only a minor decrease in creek flow velocities and water levels. This is because the hydrodynamic conditions in the lower portion of Smokes Creek are dictated by Lake Erie water levels; and that in reality, the downstream section can be characterized as an extension of the lake.

Redirecting the ESCD No. 6 flows would allow decommissioning of the Lackawanna WWTP and the removal of most treated wastewater discharges to Smokes Creek, leading to significantly improved water quality in the creek. Indeed, the modeling showed that over 95% of the ammonia and TKN loadings would be removed from lower Smokes Creek. Lead and zinc concentrations would be reduced by approximately two-thirds. Residual chlorine discharges from the Lackawanna WWTP to Smokes Creek would be eliminated.

These environmental benefits would enhance regional efforts to develop Smokes Creek into a recreational area and make the Bethlehem Steel site more attractive to development. Improving Smokes Creek water quality would yield significant human benefit to Lackawanna, resulting in improved quality of life for a community with a depressed economy. In addition, improving the water quality will support Erie County's plans to develop the lower Smokes Creek area for recreational use. Finally, by sending flow to the BSA along with supporting mitigation measures these benefits are achievable without degrading other areas in the watershed.

The BSA system would be well suited to accept sanitary wastewater flows from ECSD No. 6. The Bird Island WWTP excess capacity would only be reduced by about 10% to treat flows from ECSD No. 6, thus maintaining flexibility. Potential additional CSO volumes from the regional watershed approach are expected to be about 1% or less. These CSO impacts would be distributed throughout all water bodies along the Buffalo waterfront. Improved sewer infrastructure would open up the five mile (eight kilometre) Buffalo–Lackawanna waterfront to any current and future development vision.

Based on the modeling performed for this evaluation, the impact that a regional watershed approach would have on BSA's combined sewer system is expected to be small with respect to the benefit to Smokes Creek. Accounting for current treatment performance at the Bird Island WWTP and potential CSO impacts, the Niagara River would realize approximately 42 000 lb/y (19 091 kg/y) and 63 300 lb/y (28 773 kg/y) reduction in ammonia load in 2010 and 2032 respectively. Reductions in TKN, lead, copper, zinc and mercury loads would also be expected. This would result in an overall net benefit to the Niagara River watershed and shows a key benefit of implementing a USEPA supported regional watershed approach.

Implementing the regional watershed approach also has a savings potential of almost \$59 million with respect to the segregated response approach. Implementing the regional watershed approach would result in over a \$39 million reduction in capital expenditures and almost a 45% saving.

Ultimately, the regional watershed approach offers to enhance the quality of life for the entire region, and uplift an area that has over the past few decades seen stagnant growth, as well as a continued migration of population away from the core city to the suburbs or other regions.

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