Chapter 25

Techniques Used in an Urban Watershed Planning Study

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For planning level studies of urban flooding, it is important to obtain reasonable estimates of hydraulic performance and water quality improvements at a cost commensurate with the level of detail. The Buffalo District Corps of Engineers needed a planning-level study for a 1,400 acre (570 ha) flood-prone area in the City of Buffalo, New York. This planning study included: reviewing previous studies and models; and adjusting, refining and expanding an existing SWMM 3.0 model to SWMM 4.3. Improvements to the SWMM 4.3 model better reflected existing and proposed conditions. The proposed conditions included a diversion/storage plan. Hydraulic performance and water quality improvements resulting from the plan, were used to determine it's economic viability.

25.1 Introduction

This planning study for the Buffalo District Corps of Engineers evaluated the potential for Federal interest in constructing improvements to reduce flooding in a 1,400 acre (569 ha) area in the City of Buffalo, New York. The flood-prone area, located in North Buffalo, straddled twin trunk sewers on Hertel Avenue. Previous studies performed by the Buffalo Sewer Authority (BSA) identified inadequate capacity of the twin Hertel Avenue trunk sewers as the cause of

Avery, K. and Y. LaBombard. 1997. "Techniques Used in an Urban Watershed Planning Study." *Journal of Water Management Modeling* R195-25. doi: 10.14796/JWMM.R195-25.
 www.chijournal.org ISSN: 2292-6062 (Formerly in Advances in Modeling the Management of Stormwater Impacts. ISBN: 0-9697422-7-4)

basement flooding. Of the alternatives evaluated, a diversion/storage plan called the Tunnel-Quarry Plan offered the greatest benefit at the lowest cost (Buffalo Sewer Authority (BSA), 1987). The plan would divert peak flows exceeding ten times the dry weather flow from a 1,000 acre (407 ha) area to the existing Amherst Quarry by means of a drop structure and tunnel (ECCO, Inc. and Hatch Associates Consultants, Inc., 1990).

The purpose of this planning study was to evaluate the technical adequacy of the plan. The planning study objectives were to:

- review an existing SWMM 3.0 model of the area,
- upgrade the existing model to SWMM 4.3,
- assess the adequacy of the plan for reducing basement flooding for storms having recurrence intervals up and including the BSA 5-year design storm,
- determine the impacts of the plan on flood protection of the neighborhood that currently drains to the quarry, and
- assess the water quality improvements resulting from the plan.

25.2 Tunnel-Quarry Plan Model Development

This section describes adjustment, refinement and expansion of the SWMM 4.3 model for the plan. This section also describes the potential water quality improvements provided by the plan.

25.2.1 Adjustments to SWMM 3.0 Model

In 1989, BSA developed a SWMM 3.0 model of the North Buffalo area (Calocerinos & Spina Engineers, 1987). The planning area for the SWMM 3.0 model covered approximately 5,000 acres (2,030 ha). The purpose of the SWMM 3.0 model was to determine combined sewer overflow volumes. In the model input junction ground elevations were set 100 feet (30.5 m) above ground elevations to prevent surcharge above the ground level. This planning study updated the SWMM 3.0 model to SWMM 4.3 and lowered junction ground elevations to real elevations.

25.2.2. Refinements to SWMM 4.3 Model

The first refinement made in this planning study changed the method of modeling the diversion points in the plan from the SWMM 3.0 method. When the BSA developed the plan, they established three diversion points to the tunnel from the surface sewer system. The BSA established a maximum allowable flow rate conveyed by the sewers downstream of the diversion points. This flow rate was equal to ten times the dry weather flow upstream of the diversion points. The BSA's intention was to construct diversion chambers with side overflow weirs and downstream automatic gates in the sewer. This would truncate the hydrograph peaks in the sewers downstream of the diversion points. The SWMM 3.0 model approximated the diversions as free outfalls. Improvement of the diversion concept included these changes:

- added the hydrographs, from an initial run of the SWMM 4.3 model for existing conditions, to the external dry weather flows at the junctions nearest the diversion points;
- developed an external truncated hydrograph for the sewer system, based on the maximum ten times dry weather flow criteria; and
- ran a model of only the sewer system downstream of the diversion points with the truncated hydrographs.

The second refinement added the effects of storage due to basement flooding. Basement flooding can occur whenever the HGL in a sewer main and building connection exceeds the elevation of the lowest pipe or plumbing fixture in the basement of a building. The SWMM 3.0 model did not include storage due to basement flooding. The BSA compiled a history of basement flooding complaints for use in this planning study. Development of storage due to basement flooding included:

- areal distribution of basement flooding using an ARCINFO GIS database of basement flooding complaints;
- conversion of junctions to storage junctions in the SWMM 4.3 model along the portion of the modeled sewer network corresponding to the basement flooding complaints as shown on Figure 25.1; and
- setting area of basements equal to the area of houses in the subcatchments.

Development of a storage-junction-area versus elevation relationship as shown on Figure 25.2 involved:

- set the top of the EXTRAN storage junctions to the real ground elevations of the storage junctions and set the inverts of the storage junctions to the corresponding lowest pipe inverts;
- begin basement flooding 5 feet (1.5 m) below the ground elevation of the storage junctions, (determined by assuming that basement elevations were: 8 feet (2.4 m) from floor to ceiling, 2 feet (.61 m) above ground at the building, and the ground at the building nearest the storage junctions was 1 foot (0.30 m) above ground at the downstream storage junctions);
- determine an average rise in subcatchment ground and basement elevations upstream in the subcatchment from the input length and slope data for the RUNOFF block.

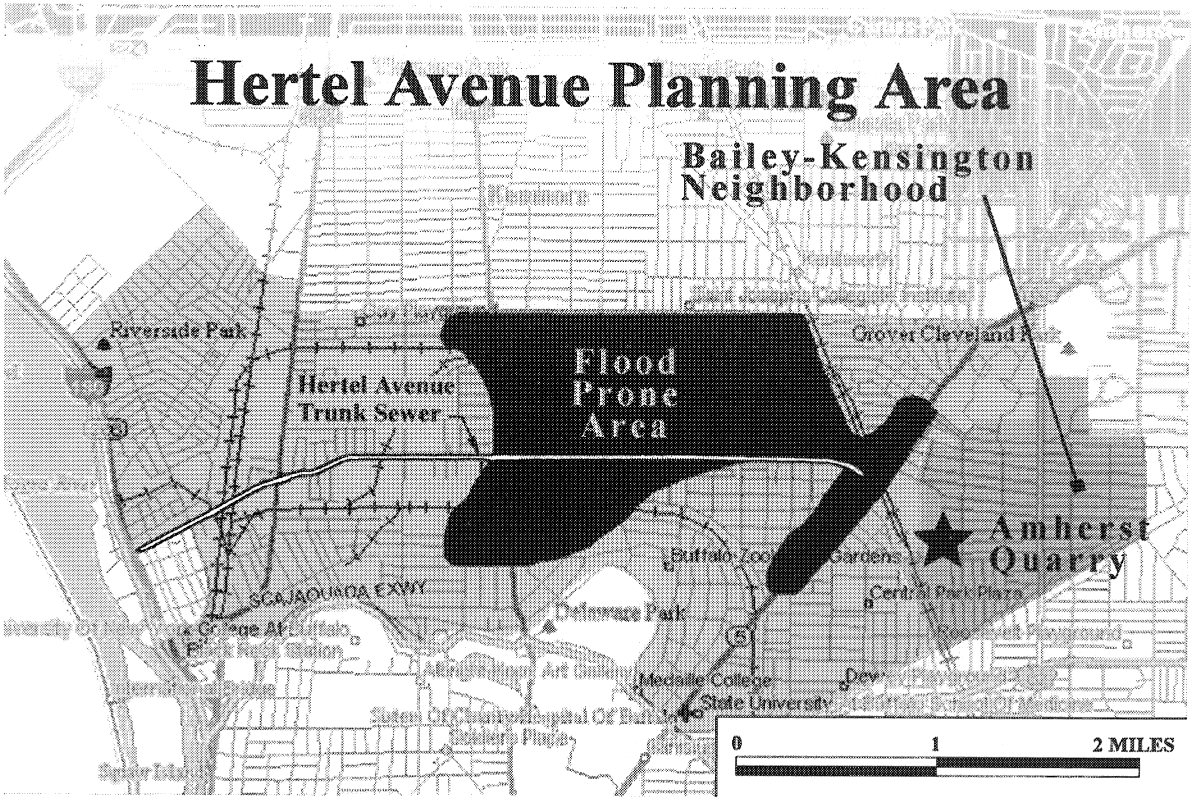

Figure 25.1 Map of basement flooding complaints.

The third refinement was the addition of connector pipes between the twin Hertel Avenue trunk sewers. Initial runs of the SWMM 4.3 model indicated differences in hydraulic grade lines (HGLs) in the twin trunk sewers up to 10 feet (3 m). Review of as-built drawings showed 24 and 36 inch (610 and 915 mm) connector pipes that joined the twin trunk sewers at six locations. The model refinement for the six connector pipes combined the junctions opposite each other into one junction. This refinement produced equal HGLs on the twin trunk sewers and results that were more consistent with the GIS database of basement flooding complaints.

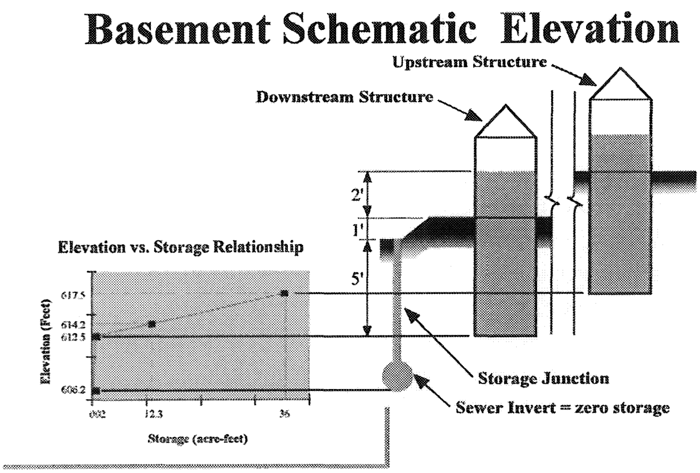

Figure 25.2 Basement storage schematic.

25.2.3 Expansion of SWMM 4.3 Model

The original SWMM 3.0 model did not include the 590 acre (240 ha) Bailey-Kensington neighborhood. This planning study expanded the model to include the Bailey-Kensington neighborhood. The neighborhood was divided into 25 subareas and run through the RUNOFF block using a five minute time step and 30 minute incremental rainfall. The SWMM 4.3 model assessed two rainfall events: the BSA 5 year, 6 hour storm and observed storm of September 17, 1976.

The SWMM 4.3 input comprised pipe diameters, inverts, and lengths obtained from sewer record maps and as-built drawings. The junctions included ground elevations obtained from 1" = 200' (1:2400) scale mapping and inverts from sewer record maps and as-built drawings. Storage junctions with cross sectional areas greater than 18 sq. ft (1.67 m^2), were input as constant cross sectional areas. The quarry was modeled from topographic mapping as a storage junction.

The model routed the hydrographs using EXTRAN, which can handle the effects of reverse flow and system storage. Reverse flow occurred when the water surface elevation in the large junction chamber on the Bailey Avenue trunk sewer exceeded elevation 645.02.

25.2.4 Water Quality Assessment

Previous studies and published documentation were used to assess the potential water quality improvements of the plan used. The six indicator constituents evaluated were: BOD5, COD, total nitrogen, total phosphorus, lead, and coliforms.

The contribution of pollutants from the watershed included components of stormwater runoff and sanitary sewage. Event mean concentrations for the six constituents in stormwater runoff were obtained from the Executive Summary of the National Urban Runoff Program (Environmental Protection Agency, Water Planning Division, 1983). Concentrations of the six constituents for domestic sewage were obtained from Metcalf & Eddy (1972). Development of the total mass loadings and diverted mass loadings for the six constituents consisted of:

- multiplying mean domestic sewage concentrations by constant dry weather flow, at the hydrograph time intervals, to calculate dry weather mass loading;
- multiplying the urban runoff event mean concentrations by the average flow in the conduit, over the time step and by the time interval, to calculate stormwater runoff mass loading;
- summing the dry weather and stormwater mass loadings to determine the total mass loading;
- subtracting ten times the dry weather flow from the total flow and dividing by the total flow to calculate a diversion ratio; and
- multiplying the total mass loading, at each time interval, by the diversion ratio to calculate the diverted mass loading.

25.3 Assessing Effects of Disconnecting Directly-Connected Impervious Areas

Previous studies and field observations confirmed that existing roof drains, with few exceptions, connected directly to the sewers. A previously-identified option to reduce basement flooding was to remove the direct roof-drain connections and install splash blocks outletting to lawn surfaces; a method to obtain a planning-level estimate of the hydraulic performance of this was developed.

25.3 Assessing Effects of Disconnecting DCIAs

Directly-connected impervious areas (DCIA) are: driveways, streets and piped connections from impervious surfaces to the sewer. Non-directly-connected impervious areas (non-DCIA) are impervious surfaces that have pervious surfaces between their boundaries and the sewers.

Evaluation of 35 representative street blocks, a total of 261 acres (106 ha), verified the percent imperviousness used in the SWMM 3.0 model. The evaluation also developed a relationship between percent impervious area and percent DCIA. Figure 25.3 is a plot of the relationship between percent impervious areas and percent DCIA used for existing and proposed conditions in the Hertel Avenue neighborhood.

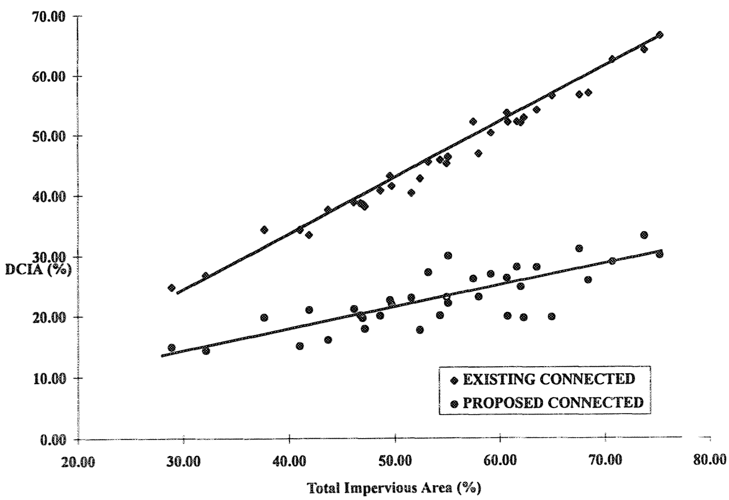

Figure 25.3 Relationship between percent impervious and percent DCIA.

Urban Hydrology for Small Watersheds describes the SCS method of modeling DCIA and non-DCIA (United States Department of Agriculture, Soil Conservation Service, Engineering Division, 1986). The SCS method provided a planning tool that could assess the potential for reducing peak runoff rates and volumes by disconnecting the roof drains. The SCS method used subcatchment RUNOFF block input data to compute: SCS curve number (CN), initial abstraction (a function of CN), and SCS lag time. Conversion of RUNOFF block input to SCS input included changing:

- RUNOFF area in acres to area in square miles,
- RUNOFF pervious and impervious area depression storage to initial abstraction,

- RUNOFF percent impervious to CN value, and
- RUNOFF area, width, slope, and roughness coefficients as input to determine the SCS lag time.

From Figure 25.3 DCIA with roof drains disconnected from the sewers can be estimated. Adjustment to CN for proposed conditions typically resulted in CN reductions of no more than 5.

SCS hydrographs for the BSA 5 year, 6 hour design storm were developed using HEC-1 Version 4.0 (United States Army Corps of Engineers, 1990). The HEC-1 hydrograph output for existing and proposed conditions was input to the EXTRAN block to assess hydraulic performance of this option.

25.4 Model Results

25.4.1 Hertel Avenue Flooding

Table 25.1 presents results for the existing conditions. The results show that basement flooding is computed to occur for events equal to and greater than the BSA 5 year design storm. The depth of basement flooding is computed to be approximately a quarter foot to a half foot (76 to 152 mm). The SWMM 4.3 model computed that basement flooding would occur only north of Hertel

Table 25.1 Hertel Avenue hydraulic gradeline results.

				HGL's with Basements Modeled			
Street Name	Location	Ground Elevation	Minimum Basement Elevation	BSA 5yr With Plan	BSA 5 yr. Existing	50% Freq. Existing	70% Freq. Existing
Parker	Trunk	615.9	610.9	597.7	615.9	602.4	601.3
	South	616.5	610.9	604.9	616.5	604.5	604.3
Stairn	Trunk	615.4	N607.8/ S610.4	596.4	603.6	600.0	598.9
	North	612.8	607.8	604.5	604.1	603.9	603.6
	North	615.5	607.8	605.3	605.1	604.8	604.6
Colvin	Trunk	604.7	N597.5 S599.7	591.4	597.8	592.5	591.6
	North	612.0	607.0	599.4	599.5	599.1	598.8
Delaware	Trunk	603.3	N594.0/ S598.3	589.1	594.5	588.9	588.0
	North	603.2	598.2	594.6	595.0	594.0	593.8
	North	605.4	600.4	594.5	598.1	594.0	593.7

Avenue; the GIS database recorded complaints south of Hertel Avenue. The GIS database of basement flooding complaints located approximately 85% in the area north of Hertel Avenue. Therefore, the results generated by the SWMM 4.3 model were generally representative of basement flooding.

Table 25.1 also presents the results computed for the plan. The results indicate that the plan removes basement flooding. This conclusion was in general agreement with previous studies that claimed that such reductions were possible. The reduction in HGL ranged between the existing conditions 50% exceedence frequency and the existing conditions 70% exceedence frequency. The 50% and 70% exceedence frequency events were taken from the depth-duration-frequency curve that includes all precipitation records, not just annual peaks.

25.4.2 Bailey-Kensington Flood Protection

The results indicate no flooding in the Bailey-Kensington neighborhood due to the plan. Increases in the water elevation in the Quarry due to the plan were approximately 8.0 and 10.5 feet (2.44 and 3.20 m) for the BSA 5 year design storm and the observed 1976 flood respectively. However, the water elevations in the Quarry with the plan were approximately 12.5 and 7.0 feet (3.81 and 2.13 m) below the zero damage point for the BSA 5 year design storm and the observed 1976 storm respectively. A check of the zero damage point, determined in previous investigations, confirmed the zero damage point to be elevation 655. Therefore, the plan would not compromise flood protection for the Bailey-Kensington neighborhood for storms equal to and less than the BSA 5 year design storm. It also was probable the plan would not compromise flood protection in Bailey-Kensington neighborhood for storms of greater recurrence interval and longer duration. The overflow to the Bailey Avenue trunk sewer, at a junction chamber, provides flood relief for these storms.

25.4.3 Water Quality

The water quality assessment was an estimate of the reduction in total mass loading at the drop structure, between existing conditions and conditions with the plan. Water diverted and stored in the Quarry would be treated later. The water bypassing the diversion structure would be conveyed in the Hertel Avenue trunk sewers to an overflow structure. The overflow structure discharges to the Niagara River. The six constituents modeled were: BOD5, COD, Total Nitrogen, Total Phosphorus, Coliforms and Lead.

Table 25.2 presents the reduction in pollutant loads along with the total loading and diverted loading for each constituent. Three of the six constituents: BOD5, Pb, and COD display greater than 50% reduction in pollutant loading. Total Nitrogen and Total Phosphorus had a greater than 40% reduction. The

Table 25.2 Reduction in pollutant loadings (BSA 5yr. design storm).

Pollutant	Total Loading (lb)	Diverted Loading (lb)	Percent Reduction
BOD5	1100	659	60
Total Phosphorus	55.7	27.1	49
Total Nitrogen	185	85.8	46
Lead	20.3	12.2	60
COD	6770	6750	55
Coliforms	2.63E+13	1.06E+13	40

reduction in pollutant loading for coliform was approximately 40%. Warm weather concentrations of coliform in urban runoff provided a worst-case scenario to determine the reduction.

25.5 Recommendations for Additional Modeling

The Hertel Avenue SWMM 4.3 model can still be improved. Recommendations for additional modeling are:

- detailed determination of the basement floor area and elevation of point of entry from the sewer lateral for the approximate 1,500 structures that experience basement flooding;
- a comparative simulation of the existing conditions and plan models for significant observed rainfall events that have occurred over a 20 year period of time; and
- further development of methodology using the SWMM 4.3 RUNOFF block to assess the impact of: disconnecting the roof drains, disconnecting downspouts and providing splash blocks to distribute the roof drainage onto lawns.

Acknowledgments

This planning study was performed under contract to the Buffalo District Corps of Engineers.

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