Modeling Approach using PCSWMM to Support Infiltration/Inflow Remediation Area Studies

Julie A. McGill, Gregory R. Barden, C. Gibson Chen and
W. Robert C. James

Launching a series of sewer system inflow and infiltration (I/I) remediation projects, the City of Columbus, Ohio structured the project schedules so that the first I/I project would set the technical approach “cornerstone” of the projects to follow. In particular, it was important that the initial project develop a set of modeling tools and application approaches designed to streamline all the hydrologic and hydraulic (H/H) models and provide a consistent approach for the entire series of projects.

The first I/I project is known as the Livingston/James Sewer System I/I Remediation Project. To ensure consistency and compatibility, the City established PCSWMM as the platform for all the City’s I/I remediation projects. In developing the modeling approach for the first project, the City of Columbus, CDM Inc., and CHI worked together as a team to enhance and apply PCSWMM and the SWMM 4.4h computational engine to model the subject sewer system.

This chapter discusses the lessons learned and the solutions that the project team developed, including several SWMM code revisions and the development of new PCSWMM routines. Each of these solutions represents valuable developments potentially applicable to other PCSWMM modeling projects.

McGill, J.A., G. Barden, G. Chen and R. James. 2007. "Modeling Approach using PCSWMM to Support Infiltration/Inflow Remediation Area Studies." *Journal of Water Management Modeling* R227-17. doi: 10.14796/JWMM.R227-17.

© CHI 2007 www.chijournal.org ISSN: 2292-6062 (Formerly in Contemporary Modeling of Urban Water Systems. ISBN: 0-9736716-3-7)

17.1 Project Background

17.1.1 Columbus Modeling History

In 1988, the City of Columbus launched its first modeling project to evaluate the City's combined sewer system. The project used the SWMM 3.1 Transport block to analyze the performance of the Olentangy Scioto interceptor sewer (OSIS) and to determine the frequency and duration of combined sewer overflow (CSO) activations during large storm events. In addition, the City formed a committee to identify specific goals to improve its sewer services. Based on the goals and needs identified by the committee, an updated model became essential as a cost-effective tool to analyze the sewerage system. Therefore, the City initiated the Columbus Sewer Capacity Study (CSCS) in three phases.

1. Phase I: A full description of the existing sewer system tributary to the Jackson Pike Wastewater Treatment Plant (WWTP) including initial estimates of tributary flow.
2. Phase II: A comprehensive approach to the entire collection system tributary to both Columbus wastewater treatment plants, including: a detailed dynamic SWMM 4.0 model for separate sanitary and combined sewers 18 in. (457 mm) and larger, and storm sewers 15 in. (381 mm) and larger, that discharge to a combined sewer, an advanced database, and a digital map of modeled sewers. The CSCS Phase II also included installation of flow monitors and rain gauges across the collection system.
3. Phase III: A calibrated SWMM 4.3 sewer model using observed flow data for three events. The model was used to identify segments of the collection system with inadequate capacity, estimate future flows using derived parameters, estimate per capita sanitary flow contribution at different locations across the City, and apply the developed model for planning, design, and operation purposes.

Due to the continuous improvements and changes in the sewerage system and WWTPs, it became apparent that the developed model required regular updating for continued application. Therefore, the City initiated the Sewer System Capacity Model (SSCM) in 2002. The SSCM is an update of the CSCS Phase III model to reflect year 2000 conditions. As part of the updating process, model parameters were refined using the PCSWMM 2002

and SWMM 4.4h engine. Updates were made to reflect changes in the sewerage system including changes to tributary areas and population, any completed sewer rehabilitation projects, as well as upgrades to the WWTPs treatment capacity (City of Columbus, 2005).

In addition to the sewer system capacity study, the City of Columbus also initiated five I/I studies between 1997 and 2000. Four consulting firms assisted the City in the investigation of I/I problems, constructing four H/H models (two study areas were combined into one study area and, therefore, only one model was built for these two areas). During the studies, each of the four firms used different approaches and software to construct the models, including MOUSE, MIKE SWMM/MIKEView, XPSWMM, and U.S. EPA SWMM. Although these studies provided recommended solutions to mitigate the I/I problems, the various modeling platforms did not allow the City to bring all the models into one software environment.

When it came to the remaining five I/I studies, the City decided to use PCSWMM as the only modeling software. The decision was made based on several reasons:

1. PCSWMM is widely accepted;
2. The SWMM engine has been tested, accepted, and exists in the public domain;
3. PCSWMM is suitable and familiar to City staff;
4. PCSWMM's GIS components will help to support data management, editing, analysis, and reporting for model input and output;
5. PCSWMM is compatible with the City's SSCM and modeling performed for the City's System Evaluation Capacity Assurance Plan (SECAP), Long Term Control Plan (LTCP) and Priority Areas under the City's Wet Weather Management Plan; and
6. PCSWMM offers the ability to incorporate the City's requests for new or enhanced software features.

17.1.2 Livingston/James Sewer System I/I Remediation Project

The first of the City's second five I/I study areas, the Livingston/James study area consists of 7,560 acres (3,070 ha) of mostly 1950s residential and commercial development, of which 4,800 acres (1,950 ha) are located in Columbus. The remaining area is divided between two smaller cities that discharge to the City of Columbus sanitary sewer system.

Figure 17.1 Study area and water-in-basement (WIB) complaint locations for January 2000 through March 2005.

The City is aware of street, yard, and basement flooding; sanitary sewer surcharges; and sewerage overflows from manholes within the Livingston/James study area. During an exceptionally wet January 2005, the City received 439 basement flooding complaints in this study area alone. Figure 17.1 shows the 7,560-acre (3,070 ha) study area and the 1,825 basement flooding complaints received between January 2000 and March 2005.

The purpose of the Livingston/James Sewer System I/I Remediation Project is to conduct a detailed study of the sanitary collection system to identify locations of sewerage overflows out of manholes, sanitary reliefs, sewerage system surcharging, and sewerage backup into basements, and identify the causes of these occurrences. After identifying locations and causes, the project will recommend cost effective improvements to the sanitary collection system to mitigate and/or eliminate these occurrences for selected design criteria.

The study comprises several different tasks including cleaning and televising all sewers and inspecting all manholes in the area; investigating

private and public I/I sources; investigating the area's Maintenance and Service Requests over a 5-y period; and developing and applying a newer computer model for the area. These tasks, when completed and coordinated, will provide for an accurate assessment of the actions required to significantly reduce I/I and augment capacity in the area's sewers.

For the modeling task, the CDM team developed an updated computer model of the current sanitary sewer system in the Livingston/James study area. This model will be the primary tool used to study and evaluate the hydraulic performance of the sewer system and to explore rehabilitation alternatives. As the first in a series of I/I studies, the Livingston/James modeling task will also help to develop a set of modeling tools and application approaches designed to streamline all the H/H models and provide a consistent approach for the entire series of projects. This chapter focuses on developing the application approach and modeling tools.

17.2 Challenge: Balancing Detail and Practicality

The primary challenge of the task was achieving a balance between adequate model detail and practicality, with the future series of projects in mind. This has become a common challenge to most large-scale modeling projects as improved technology allows increasingly detailed models, and owners are challenged to coordinate their growing modeling projects.

With a series of projects to perform, the approach must be practical and flexible to avoid becoming obsolete during the series of five projects. The City scheduled the five projects to commence over a three-year period. During the next five years, computer hardware and software will continue to evolve. In addition, each project will have unique characteristics.

From past experience and project objectives, the City requested that the model include all pipes 8 in. (203 mm) or larger in diameter. From previous I/I studies, the City had learned that for sanitary sewer systems experiencing surcharge, overflows, or water-in-basement complaints on small diameter pipes, it is necessary to model and show the existing hydraulic grade line and the improvement resulting from recommended alternatives.

This guidance resulted in relatively large array sizes: initially over 3,400 nodes and pipes, but the number was reduced to over 2,800 by removing unnecessary pipes from the model (e.g. cleanouts, abandoned and bulkheaded pipes) and consolidating pipes in some newly constructed portions of the system.

Theoretically the entire pipe network in the study area can be modeled as long as information is available. In this case, the City's sewer database and closed-circuit televising of the entire study area's sewer network would provide the necessary data. However, even with readily available sewer network data, this approach has advantages and disadvantages from both the technical and practical perspective.

17.2.1 Technical Issues

From the technical perspective, the simple advantage of the approach is that the complete sewer network is modeled.

The latest version available of the SWMM 4.4h engine allowed 3000 Runoff subcatchments and 5000 Extran nodes and conduits, approximately what would be needed. However, with a detailed sewer network in the model also comes the challenge to include adequate detail in both the sewershed subcatchments and the associated dry-weather flow, rainfall, and other model input parameters. To provide an equivalent level of detail for these other model parameters could mean an equally large number of subcatchments and dry-weather flow loading locations, and the possibility of an equally large number of radar rainfall hyetographs specific to each subcatchment during wet-weather calibration. The required data array sizes would exceed several of this latest SWMM version's limitations. The following array sizes were limiting:

1. Number of Interface Locations for all Blocks (NIE): 2000
2. Number of Input Hydrographs in Extran (NEH): 500
3. Number Rain Gauges in Rain and Runoff (MAXRG): 200
4. Number of Subcatchments in Runoff (NW): 3000

17.2.2 Practical Issues

From the practical perspective, the effort to model the complete sewer network could be justified to ensure each problem is addressed. Seventy-one percent of pipe length in the Livingston/James study area consists of 8 in. diameter pipes. The investigation of the City's Maintenance and Service Requests over the previous 5-y showed that many of the study area's problems (e.g. basement flooding) occur on the 8 in. diameter pipes; therefore, the model required at least this level of detail to identify and prioritize excessive I/I areas and localized capacity restrictions.

However, the network size does not necessarily improve the quality of model outcomes. Most traditional hydraulic and hydrological models, are built upon layers of estimates from flow meter data, rainfall data, roughness coefficients, sediment levels, runoff parameters, etc. Each layer of estimates increases the composite error margin of the models. Even very detailed models still require calibration prior to application. Therefore, the models, through the calibration process, represent the best engineering estimates with acceptable error margin embedded.

For example, development of the Livingston/James SWMM model was based upon 27 flow meters and one to fourteen useful rain events per flow meter for a total of 243 events. The number of flow meters was selected to match the level of detail of the model; the number of rain events analyzed was necessary to provide adequate understanding of the characteristics of the wet weather responses from the study area.

Furthermore, it is time and effort consuming to build and calibrate a highly detailed model. More flow meters, more rain events, and more subcatchments result in more time consumed in the calibration process.

17.3 Solutions

With the goal of modeling every pipe 8 in. and larger in diameter, and supporting the evaluations to reduce I/I and augment capacity in the area's sewers, the City of Columbus, CDM, and CHI worked together to develop the necessary modeling tools and approaches that would overcome the challenges of balancing adequate model detail and practicality. The following discusses the most significant decisions and solutions, including several SWMM code revisions and the development of new PCSWMM routines.

17.3.1 Developing a Unified Model versus Multiple Basin Models

In one of the first decisions, the City and CDM debated the development of a unified model versus multiple basin models. A unified model approach would involve one Runoff object and one Extran object for the entire study area; whereas, multiple basin models would involve individual Runoff and Extran objects for each flow meter basin or groups of basins. This decision was important because it would determine other requirements for the model.

The City and CDM elected to develop a unified model encompassing the entire study area, primarily to simplify boundary conditions. The existing Columbus Sewer Capacity Model and historical flow monitoring showed that the study area's main trunk sewers surcharge during wet-weather events. Breaking the Extran model into multiple basins along the surcharged trunk sewers would require the use of multiple boundary conditions that change from event to event.

A unified model also offers a more streamlined structure for the user. Instead of organizing multiple basin models for multiple scenarios (e.g., calibration, alternatives), the user must only organize the different scenarios.

However, with a unified model approach, the question then becomes one of determining the adequate model network size (Section 17.3.2).

17.3.2 Determining the Adequate Model Network Size

As discussed in Section 17.2, the City requested that CDM model all pipes eight inches and larger in diameter – over 2,800 nodes and pipes. If all these nodes, pipes, and associated data were contained in one, unified model, the required data array sizes would exceed several limitations of the latest public domain SWMM engine. If the array size limitations were to be increased, the project team first needed to determine an adequate model network size.

The City recognized that practical limits must be set. Therefore, the City, CDM, and CHI worked together to determine a practical array size that would set the level of detail for the series of projects. If these limits are exceeded in the future I/I projects, the building of the model could still be done in a manner to accommodate these limits.

There is no data array size limit imposed by PCSWMM; however, there are array limits in the SWMM engine that depend on the version of SWMM the user chooses. For example, PCSWMM 2005 uses the SWMM4.4h engine which has a maximum of 2000 Extran conduits and 2000 Runoff subcatchments per data file. For larger models, PCSWMM can divide model elements into multiple data files. Due to the nature of I/I studies, it is not always practical to determine exact locations where there are no backwater effects. Therefore, array size should be large enough to construct unified models in those I/I studies.

As discussed in Section 17.2.1, the SWMM engine also limits the number of interface locations between SWMM model blocks, the number of input hydrographs in Extran, the number of rain gauges in Rain and Runoff, and the number of subcatchments in Runoff.

Based on the five pre-defined I/I study areas, Table 17.1 compares the approximate number of sanitary sewer manholes and pipes. The numbers of manholes in these areas include cleanouts, and the numbers of pipes include abandoned and bulkheaded pipes. Each of the I/I study areas consists mostly of residential areas with 8 in. sewer pipes.

Table 17.1 Comparison of I/I study areas.

Study Area	Livingston/ James	Early Ditch	West 5 th Avenue	Barthman/ Parsons Ave.	Northwest Alum Ck
No. of Pipes	3200	3200	300	2200	2200
No. of Nodes	3100	2900	340	1900	2500

From examining Table 17.1, it was apparent that an array size of 3,000 is an appropriate limit for the SWMM nodes and pipes for these projects. With the removal of unnecessary nodes and pipes (e.g. cleanouts, abandoned) and possible consolidation of some pipes, the total numbers of each of the SWMM components would be below 3,000, allowing the addition of new pipes and node during the alternatives analysis.

If 3,000 was an adequate limit for nodes, then the project team determined that 3,000 subcatchments – one for each node – would be an adequate limit as well. With this decision, it was necessary to increase the number of interface locations to match the number of Runoff subcatchments for the rainfall-dependent infiltration and inflow (RDII) calculations. Increasing the allowable number of input hydrographs in Extran would also be useful as a way of inserting dry-weather flow for each subcatchment to the conveyance system.

In selecting a SWMM engine with adequate array limits, the City had concerns with using a “custom-made” SWMM engine developed for this or other CDM projects. CDM had previously addressed many of the issues encountered on this project by developing custom SWMM engines for other projects; however, those engines are not in the public domain. Because one of the goals of this project is to develop modeling tools that can be used consistently by this and other future I/I project teams, the City preferred to use a SWMM engine that already existed in the public domain.

Fortunately, although not yet widely used, there was another SWMM 4.4h engine available to meet some of the necessary array limits: 3000 Runoff subcatchments and 5000 Extran nodes and conduits. This engine was provided by Dr. Wayne Huber, professor of Oregon State University (OSU).

CDM coordinated with CHI for the SWMM code revisions to increase other allowable array sizes in the SWMM 4.4h engine. This newly adopted version supports 3000 subcatchments and 3000 input hyetographs in Runoff, 3000 input hydrographs in Extran, and 3000 interface file locations in all modules. CHI incorporated this revised SWMM 4.4h (2005.10) engine into PCSWMM; it will also be available in the public domain through OSU.

17.3.3 Using Unique Structure IDs

Another decision made early in the modeling task was the node and pipe naming scheme. The method used in Livingston/James to name conduit and nodes will also serve as the standard for the City's remaining I/I studies.

The City of Columbus currently maintains a sewer infrastructure database with its own unique, nine-character manhole IDs. The first four characters represent the City Atlas Map number, the fifth character is a one letter abbreviation for the system (e.g. "S" for sanitary), and the last four characters represent the manhole number on the Atlas Map.

The City and CDM agreed that using the City's own manhole IDs would provide a user-friendly, meaningful ID for City staff that would aid in visualization. For example, knowing the Atlas Map number from the ID would give City and project staff an approximate location. Using unique IDs would also simplify the unifying or linking of models in the future.

However, the project team initially encountered problems with this naming scheme. The SWMM engine, depending on the version, limits IDs to eight or nine characters. Although the ID is alphanumeric, the SWMM engine dropped the leading zeroes or chopped off portions of the ID in the model output. PCSWMM uses the model output, so the affected IDs appeared incorrect in the PCSWMM interface. Some investigation determined that it would be time consuming to change the SWMM and PCSWMM code; therefore, the City and CDM opted to drop the leading 0 of each ID. Dropping the leading zero creates a nine-character ID, including a one character suffix (e.g. N, S, E, and W for flow splits).

17.3.4 Estimating Dry Weather Flow from Water Billing Records

Water billing records are often available on the parcel level and offer a more accurate estimate of the base wastewater component of the DWF than the traditional method of allocating DWF measured at the downstream flow monitoring site throughout the upstream system (Vallabhaneni et al, 2002).

For the Livingston/James project, CDM used the City's water billing record data to define average dry-weather flow at each modeled subcatchment area, and flow monitor data to confirm average flow rates, estimate GWI contributions, and define diurnal variability (both weekday and weekend) within each monitored basin area. This was only the second such application of water billing records in the City of Columbus.

To generate dry-weather flow inputs, CDM extracted the winter season water usages for the last two years. Winter season was defined as from November 1st to the next April 30th to avoid months with outdoor water usage. CDM then geocoded 10,864 average daily winter season water usage records using ArcGIS 9.0. Many of these water usage records actually cover multiple commercial or multi-family addresses. CDM then calculated water usage at the subcatchment level by spatially joining the water usage records with the delineated subcatchments. The subcatchment water usage is the summation of all the water usage within the subcatchment. Lastly, dry weather flow hydrographs were generated for each subcatchment using average dry-weather flow patterns from the flow meters.

Because the dry weather flow hydrographs could be cumbersome to represent using Extran's K card hydrograph inputs, as there are 2,185 detailed subcatchments in this model, the modeling team considered the use of the Transport object in PCSWMM for dry weather flow. The Transport dry weather flow inputs would account for the base flow, GWI, and diurnal pattern. However, the City and CDM recognized the possible move to SWMM 5 in the future; therefore, to be flexible for future model upgrades to SWMM 5, the approach should be consistent with SWMM 5 data and routines. SWMM 5 allows timeseries input data for flow, similar in format to Extran's K1, K2, and K3 cards. Avoiding the use of Transport would also help streamline the model for simplicity. Given these considerations, the City and CDM chose to hard code the dry weather flows using Extran's K card hydrograph inputs (K1, K2, and K3 cards).

17.3.5 Incorporating Radar-Rainfall Data in PCSWMM

Analysis of radar rainfall data in collection system modeling may provide a more reliable means of estimating the spatial variability of rainfall than analysis of data from the ground rain gauges, which are usually sparse, or than other traditional mathematical means of describing interpolated rainfall between ground gauges. More reliable rain data leads to more reliable RDII parameters and greater confidence in wet-weather flow calibration. A reliable set of RDII parameters is crucial to design storm modeling. More

reliable rain data will generate more reliable computed sanitary flows using design storms, which are required for this project (Vallabhaneni et al, 2004).

In conjunction with the Livingston/James project, CHI developed routines to incorporate radar-rainfall data in PCSWMM. Incorporation of radar-rainfall data in PCSWMM bypasses the data pre-processing formerly necessary to area-average grid-based precipitation data across the modeled subcatchments, saving time and effort. CHI also updated the GIS tool of PCSWMM so that it handles RDII data in the Runoff layer.

Background

Significant hydrologic/hydraulic modeling uncertainty is associated with the hydrologic processes. In addition, the hydrologic input function (rainfall) can be difficult to characterize and is always sensitive. Better rainfall characterization reduces error between computed and observed runoff. Increased rainfall spatial resolution has been shown to improve computed peak flows and, to a lesser extent, total volumes of computed flows.

Rain events can be classified by spatial character and atmospheric generating mechanism. The class of rain event can have implications on measuring technology. For example, stratiform rain events typically comprise large spatial extents and gradual temporal intensity gradients, while convective rain events typically comprise one or more cells with sharp spatial and temporal intensity gradients. Climatic factors can also influence optimal precipitation measurement strategies: large water bodies and significant elevation changes can both create climatological gradients that increase precipitation locally.

Raingauge data are frequently the sole source of precipitation data for many modeling projects, often transposed over long distances, and usually applied uniformly over the study area. Local gauge data (located in the study area) have been shown to significantly improve rainfall characterization. Rain gauge networks (three or more) located within the study area can also improve rainfall characterization by allowing the dynamic rain cells to be incorporated. Optimal gauge density and distribution depend on orographic and climatological influences as well as target rain type and its prevailing direction.

Watershed-scale projects may benefit from further spatial resolution of rainfall, especially for convective storms, where intensive rainfall from cells of small spatial extent (say 1km^2) may slip between gauges in a typical urban rain gauge network. Cost is usually a factor in implementing sufficiently dense rain gauge networks. Rainfall observations based on

NEXRAD radar data can provide a spatial resolution of 1 km². It has been shown that computed peak flows (if not total flows) can be improved using raingauge-calibrated radar rainfall data.

Problems in implementing radar rainfall data

While radar data can give a good indication of relative spatial distribution of rain intensity, it does not give accurate rainfall intensities. Calibrating radar rainfall against rain gauge rainfall can improve characterization of rainfall over the study area and also reduce the required density of the rain gauge network. Radar data measure reflectivity of high intensity radio waves and translating reflectivity (Z) to rainfall (R) is problematic: there are a number of Z-R equations, depending on storm type or drop size distribution, and, after translation, systematic error must be addressed (bias removed). Random errors must also be accounted for.

Bias can be removed by calibrating radar rainfall data against rain gauge data. The benefits and pitfalls of raingauge-calibrated radar-rainfall (RGCR) benefits and pitfalls are not well known by stormwater modelers. Implementation is not easy and cost may be significant. In order to address this, CHI, in conjunction with the City of Columbus, CDM and Vieux and Associates developed a simplified delivery and integration protocol for utilizing RGCR in PCSWMM, reducing the cost, complexity and time required. Vieux and Associates provide historic, real-time calibrated and predicted rain gauge-calibrated radar rainfall services, and can provide rainfall data in the native PCSWMM time series file format for square grid or polar coordinates. PCSWMM uses an area-weighting algorithm to compute individual synthetic hyetographs at the subcatchment or sewershed level for user-delineated polygons.

Area Weighted Time Series Calculator

The area weighting algorithm was integrated into a PCSWMM utility called the Areal Weighted Time Series Calculator (AWTSC), available in the PCSWMM 2006 release. This utility aggregates time series data obtained from one spatial system (layer of polygon shapes) into another. A common application is to generate individual hyetographs for subcatchments from rain-gauge calibrated radar-rainfall data as discussed here. The program utilizes two layers:

1. a data source shape file containing polygons representing the rainfall spatial distribution, and

2. a subcatchment shape file containing polygons representing the subcatchment spatial extents.

The polygons in the data source shape file represent areas of spatially-averaged rainfall intensity. The shape file also must contain rainfall time series stored as a series of attributes for each polygon. Overlaying the layers, the AWTSC attributes to each intersection an amount proportional to the area and reaggregates per subcatchment polygon for each data point in the rainfall record.

Data Source shape file format

Typically the data source layer polygons represent a rectangular grid or polar coordinate system of cells (components) of spatially-uniform rainfall intensities. The current format is a shape file in which there is a unique identifier (ID) attribute and a sequence of attributes storing the time series for each polygon (component). The ID field can be stored in any of the following attribute fields: ID, INDEX, RNP_ID, or PIXEL. The program searches for the identifier attribute in the sequence shown. The time series attributes must have the following naming convention: ZMMDDHHNN, where:

Z = initial field identifier
MM = two digit month
DD = two digit day
HH = two digit hour
NN = two digit minute

For example, attribute Z11121510 contains the time series value for November 12 at 3:10 pm. The current year is assigned in lieu of any additional information (the user can adjust the year value once processed by means of the Timeseries Manager tool of PCSWMM).

Furthermore, the time series attributes must appear chronologically in the shape file's associated database. In other words a listing of the attributes will display the attributes in chronological order.

Subcatchment shape file format

The subcatchment layer polygons represent the subcatchments or sewersheds for the model. The only required attribute is an identifier, which should be the same as the hyetograph ID for the subcatchment in the SWMM model. Again, the identifier can be stored in any of the following attribute fields: ID, INDEX, RNP_ID, or PIXEL. The program searches for the identifier attribute in the sequence shown.

Area weighting computations

The program performs the computations as soon as the two shape files (data source layer and subcatchment layer) are loaded. Moving the cursor over the map will display the IDs for the polygons in both layers. Clicking on a location will open a graph of the time series from the data source layer cell (i.e. the radar rainfall time series) and the computed time series from the subcatchment layer polygon (i.e. the synthetic hyetograph generated by basin-weighted averaging).

Output formats

The area-weighted time series can be exported to a PCSWMM Timeseries file. This Timeseries file will contain the computed time series for each subcatchment/sewershed on the subcatchment layer. Once exported, the model input rainfall time series can be updated from the Timeseries file. The unedited data source time series can also be exported from the data source layer to a PCSWMM Timeseries file for further analysis in PCSWMM. Finally, provision is made for exporting the subcatchment layer's polygon vertices for each subcatchment or sewershed to a Map file (.xys file) for importing the subcatchment polygon shapes into a PCSWMM GIS layer.

17.4 Conclusions

Each of these decisions or developments, commonly faced by many similar projects, provided practical solutions for the Livingston/James modeling task team:

1. the unified model approach simplified and streamlined the models;
2. setting an adequate model network size allowed more detailed models, yet maintained practicality, and made the larger array sizes available to future project teams in a public domain model;
3. using the City's own unique structure IDs provided meaning and flexibility;
4. using the City's water usage data to develop dry-weather flows provided more accuracy and detail; and
5. incorporating radar-rainfall data in PCSWMM saved time and effort.

By pausing to carefully examine the project goals and approach, the project team was able to develop a set of modeling tools and application approaches designed to streamline the City's I/I models and provide a consistent approach for this and future City of Columbus I/I project teams to build upon.

Acknowledgments

The authors would like to acknowledge Dr. Wayne Huber, Vieux and Associates, CHI, CDM, and the City of Columbus, Ohio for their contributions to this project.

References

- City of Columbus, Ohio. (2005). Wet Weather Management Plan.
- Vallabhaneni, S., B. Vieux and T. Meenaghan. 2004. "Radar-Rainfall Technology Integration into Hydrologic and Hydraulic Modeling Projects." *Journal of Water Management Modeling* R220-02. doi: 10.14796/JWMM.R220-02.
- Vallabhaneni, S., Wride, D., Koran, J., Moisio, S., and Burgess, T. (2002). Integration of Water Billing Records in Estimating Base Wastewater Flow Rates to Support Large-scale Sewer System Computer Modeling. Proceedings of the WEFTEC 75th Annual Conference & Exhibition, September 28 – October 2. Alexandria: WEF.