ELIMINATING THE BLIND SPOT OPTIMIZING COLLECTION SYSTEM OPERATIONS AND IMPROVEMENTS THROUGH A WEB-BASED FLOW MONITORING AND HYDRAULIC MODELING SYSTEM

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ABSTRACT

Like many municipal wastewater utilities, the Erie County Department of Environment and Planning/Division of Sewerage Management (DSM) in Western New York is continually seeking methods to maximize treatment of its sewerage flows, minimize overflows and prioritize collection system maintenance and capital improvements. The DSM completed development of the Real-Time Flow Monitoring System and Hydraulic Model to demonstrate the way these goals are achieved. This web-based system was developed for Erie County Sewer District No. 6, which contains over 75 miles of sewer and serves approximately 18,000 customers. This innovative tool allows County staff to obtain up-to-the-minute status of flow and operation anywhere within the District 6 collection system, develop focused operating and maintenance programs, and to model "what if" scenarios regarding new flows and capital improvements. The DSM is initiating expansion of the system to all seven sewer districts covering a population of 300,000 and about 800 miles of sewers.

Three technologies important to collection system decision-making were seamlessly integrated to develop this innovative web-based tool: remote wireless flow monitoring, geographic information systems (GIS) and computerized hydraulic modeling. Existing District flow monitoring stations and supplemental manhole-based flow meters and rain gauges are used to collect and transmit real-time data to the web site. The existing County GIS database was used as the basis for system mapping and hydraulic model development. The online model is driven by the latest hydraulics engine (USEPA's SWMM5) and a storm/sanitary system modeling-specific graphical decision support system (PCSWMM). A browser-based GIS interface enables visual access for users to review data, run models, and view results. Other functions allow the user to run models based on historical data or to simulate storm events. The GIS-based interface allows the user to quickly focus on areas of significance and evaluate using time scale graphing and animated hydraulic profiles.

KEYWORDS

Real-Time Flow Monitoring, Sewer System Modeling, Optimizing Collection System Operations, Web-Based Sewer Monitoring Systems

A NEW WAY TO OPTIMIZE COLLECTION SYSTEM OPERATIONS

Like many municipal wastewater utilities, the Erie County Department of Environment and Planning/Division of Sewerage Management (DSM) in Western New York is continually seeking methods to maximize treatment of its sewerage flows, minimize overflows and prioritize collection system maintenance and capital improvements. The DSM initiated development of a web-based tool in 2006 to significantly improve the way these goals are achieved. This web-based system was initially developed for Erie County Sewer District No. 6, which contains more than 80 miles of gravity sewer and serves approximately 18,000 customers in the City of Lackawanna. The web-based system was developed by a five-firm team using close coordination with the DSM: Conestoga-Rovers & Associates, TECsmith, Inc., Telog Systems, Inc., Computational Hydraulics International (CHI) and eSolutions Group.

This innovative web-based tool, known as the Real Time Flow Monitoring System and Hydraulic Model, allows County staff to obtain up-to-the-minute status of sanitary sewer flows and operation anywhere within the District 6 collection system, and to model "what if" scenarios regarding new flows, capital improvements and modifying operations rules. Ultimately, the DSM anticipated expanded the system over the next three years to incorporate all of the County's sewer districts, which serve more than 300,000 customers and contain 800 miles of gravity sewers, 87 pumping stations, seven treatment facilities, and five overflow retention facilities.

Presented herein are the key elements involved in developing the web-based model, how these elements were integrated and examples of how this system can be used to optimize collections system operations and improvements. Also discussed is the approach planned for expanding current online system to serve the entire DSM collection system.

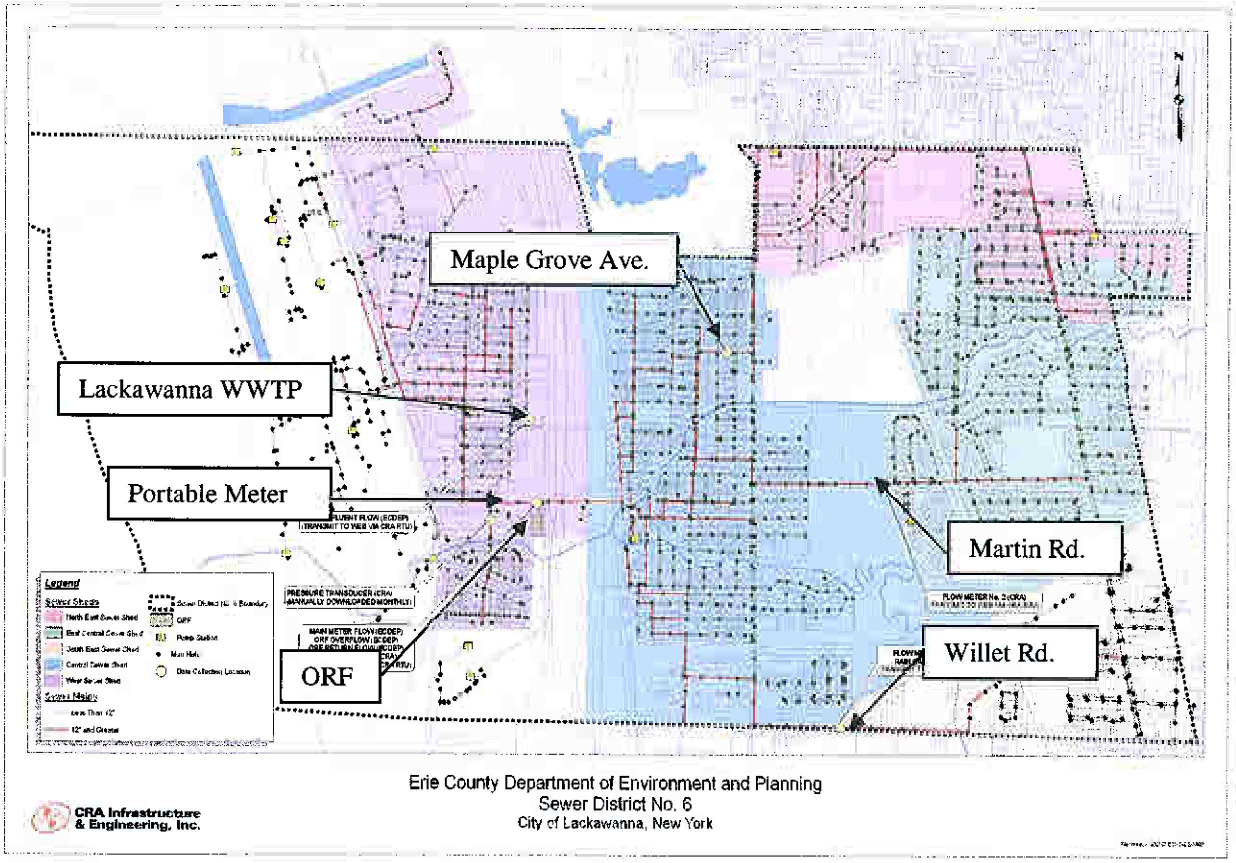
KEY SYSTEM COMPONENTS

Three technologies important to collection system decision-making were seamlessly integrated to develop this innovative web-based tool: remote wireless flow monitoring, geographical information systems (GIS) and computerized hydraulic modeling. Preparation of these three technologies for incorporation into the system was performed between May and August 2006. The web site platform serves to receive and store all data and to provide an end-user interface to allow data access and editing. Essentially, it serves to link GIS database and real-time flow monitoring information and hydraulic model results to the user for rapid analysis of existing collection system operation, as well as prediction of system response to future storms and improvements.

Real-Time Wireless Flow Monitoring

A key challenge to this project involved obtaining flow and rain data representative of District 6 operations while remaining within a limited budget. The District was divided into five sewer sheds as shown on Figure 1.

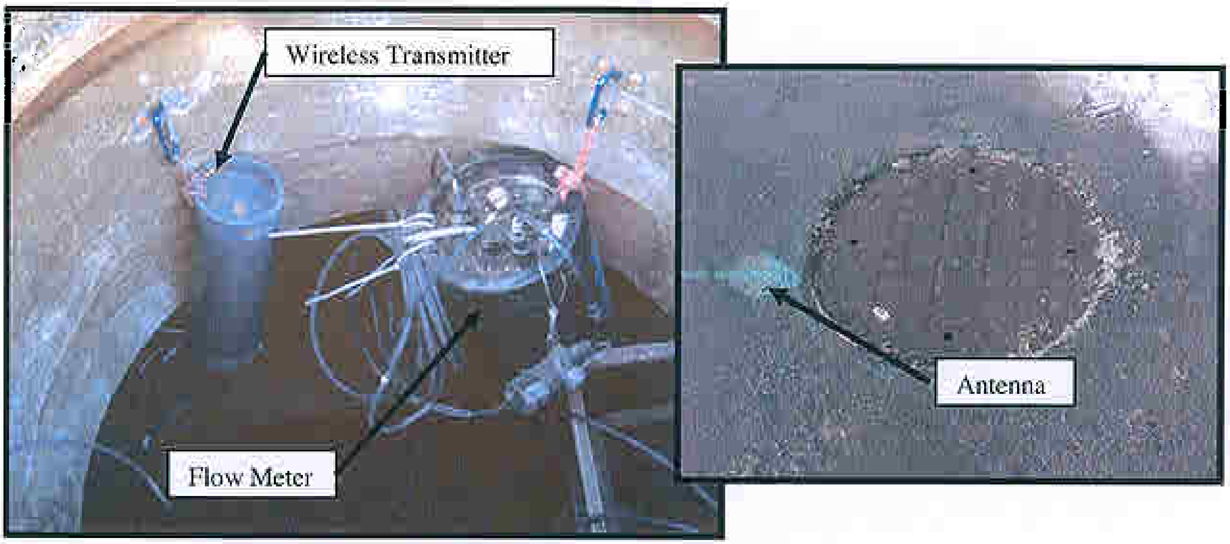
Figure 1 – Erie County Sewer District 6 Flow Monitoring Sewer Sheds



Three manhole-based flow monitoring sites were selected to collect flow data from the eastern portions of District 6; these were located on Maple Grove Avenue, Willet Road and Martin Road. Sigma 930 velocity-area (V-A) flow meters were used, and were equipped with primary and redundant level sensors. The flow meters were connected to Telog RU-33 remote telemetry units (RTUs), which transmitted data using switched-packet cellular communications technology. An antenna was installed in the pavement adjacent to the manhole to enable communications. The antennae were found to be highly durable and continued working when covered by snow. Figure 2 shows a typical wireless manhole installation. A rain gauge also was installed at Willet Road.

Final manhole selections were based on a visual site assessment. The most critical criterion of this assessment was hydraulic suitability in order to provide high quality data. Other factors considered included accessibility, traffic safety, structural condition of the manhole, and atmospheric conditions.

Figure 2 – Typical Wireless Flow Meter Installation



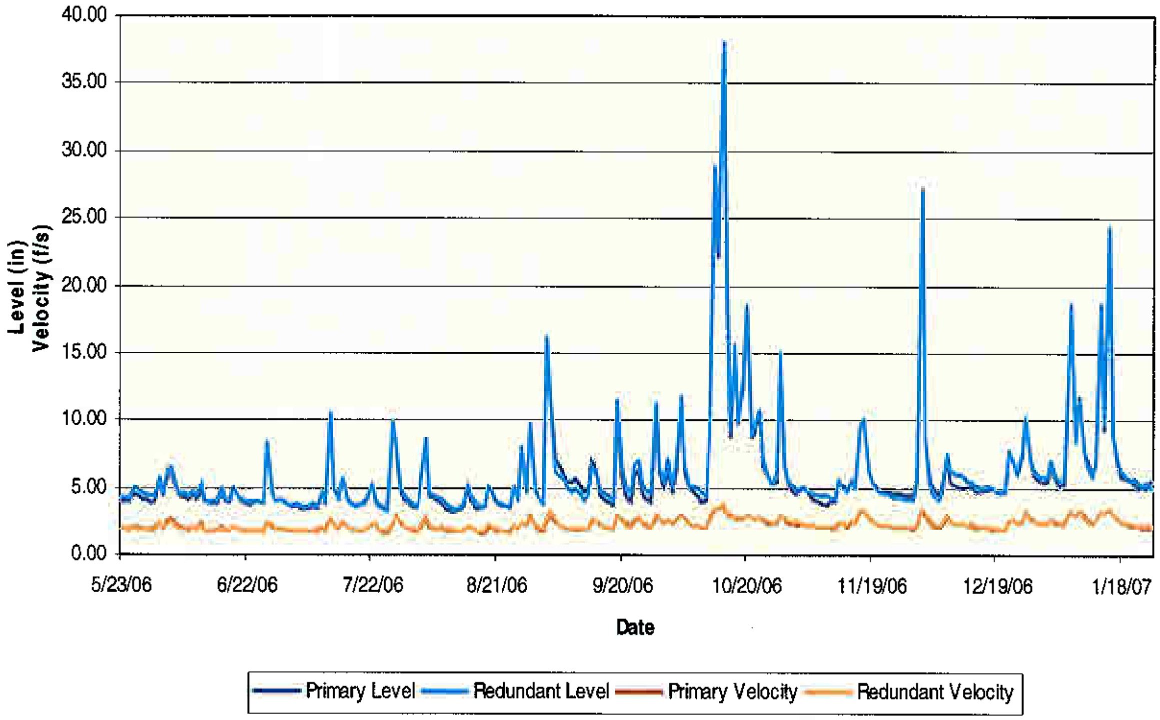
Two existing flow meter stations supplemented the remote wireless installations. The first was the influent flow meter to the Lackawanna Wastewater Treatment Plant (WWTP). A control loop tied the 4-20 milliamp (mA) signal from the instrument to a Telog R-3303 flow meter. The second station was located at the overflow retention facility (ORF). A Telog R-3308 RTU was connected to existing 1-5-volt instrument signals for the ORF Main Meter (measures flow to from the eastern part of the District to the WWTP), ORF overflow and return flow, and ORF basin levels. A second rain gauge was installed at the ORF. Data from the WWTP and ORF were transmitted via existing land-based phone lines.

During the flow monitoring program, it was determined that the existing ORF Main Meter was measuring flows greater than expected. This location uses a Parmer-Bowles Flume for measuring flow. Review of design drawings, a site visit and review of flow data indicated that the Main Meter was subject to elevated backwater conditions during wet weather. This causes an increase of water level in the flume that results in erroneously high flow measurements. To remedy this situation, a portable V-A meter was installed downstream of the Main Meter; flow from the portable meter was used for hydraulic model calibration.

Flow, basin level and rain gauge data were sampled in five-minute intervals. Instantaneous readings were transmitted to the Telog data host site every 15 minutes. Daily maintenance calls were made to upload all of the data collected to the host site. Data transmitted included flow, level, velocity, battery voltage, and precipitation. The three remote sites using switched-packet cellular technology were found to have between a 91% and 95% transmission success rate. While not quantitatively compared, the cellular technology showed significantly greater up time than the land-based phone lines. This was particularly the case during the "October surprise" snowstorm that knocked down thousands of electrical and phone lines in Western New York, and left residents without electricity for up to nine days. Communications to the District 6 ORF was unavailable for two weeks while the cellular-based flow meters were successfully transmitting.

Calibration and maintenance of the monitoring equipment was performed weekly during the first month of operation, and once per month thereafter. Daily checks of the flow meters were made remotely to verify that data was being transmitted and appeared reasonable. Two sets of level and velocity sensors were used to verify proper flow meter operation. When the difference between the sensors exceeded a set point (0.5 inches for level differential and 0.25 ft./s for velocity), a site visit would be initiated to clean and/or recalibrate the sensors. From a statistical standpoint, from June 1, 2006 through February 1, 2007, the average daily differential between primary and redundant velocity sensors was less than 0.25 ft./s 100%, 99.5% and 98.6% of the time for the Martin Road, Maple Grove and Willet Road sites, respectively. The average daily level differential was less than 0.5 inches 83.5%, 82.7% and 90.9% of the time for the Martin Road, Maple Grove and Willet Road sites, respectively. An example of how the primary and redundant sensors tracked in a time-series plot is shown on Figure 3.

Figure 3 – Primary vs. Redundant Level and Velocity Sensor Comparison for Martin Road Flow Meter (6/1/06 – 1/25/07)



The raw flow data was stored for viewing and analysis on a web-based database hosted by Telog. Data could be viewed within any time period in either time series or scatter plot type format. Active X controls were programmed to allow the user to see individual data points. Functions also were provided to allow graphs to be printed and data points to be downloaded in Excel-spreadsheet format. Time-series plots could be overlaid to permit comparisons of flow measurements at the various monitoring sites and response to rainfall. Scatter plots were used to validate flow data. An example flow vs. level scatter plot for the Martin Road site is shown on Figure 4. Between June 1, 2006 and January 25, 2007, the data between pipe invert and 80% of pipe diameter had an R^2 of 0.978. Similarly, the R^2 for the Willet Road and Maple Grove sites were 0.927 and 0.887, respectively. The scatter above 80% of pipe diameter was not evaluated as pipe capacity decreases and the sewer begins to surcharge. When surcharging begins, significant changes in head are required to increase pipe flow. As an additional quality control check, field measurements during routine flow meter maintenance were overlain onto level vs. velocity scatter plots. The field measurements fit well within the scatter for all three manhole-based flow meter sites; an example comparison plot is presented on Figure 5.

Figure 4 – Flow Vs. Level Scatter Plot – Martin Road Site (6/1/06 - 1/25/07)

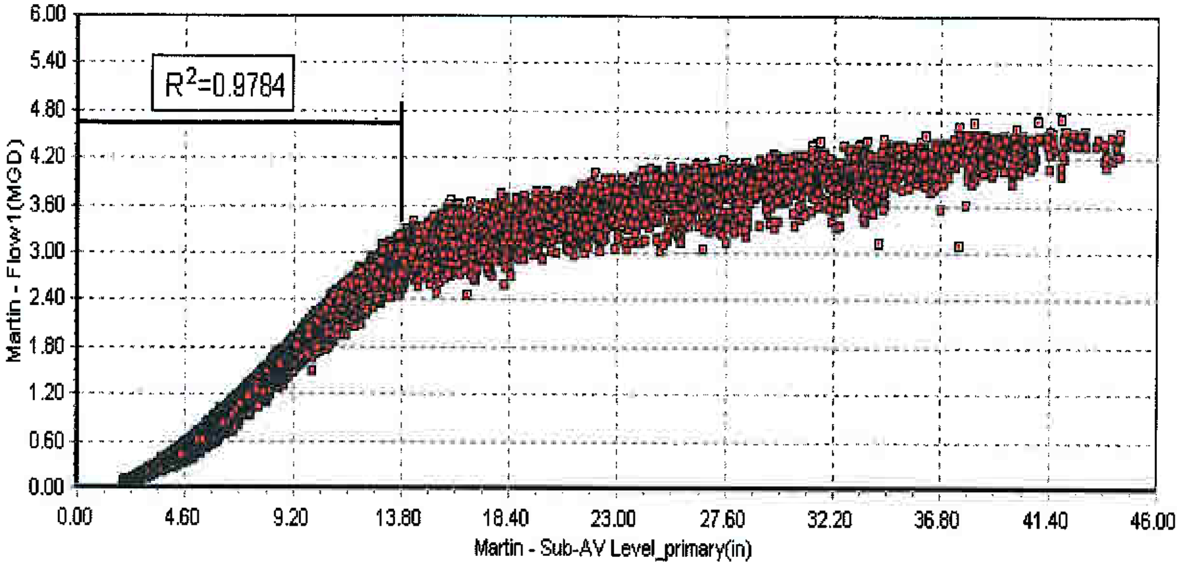
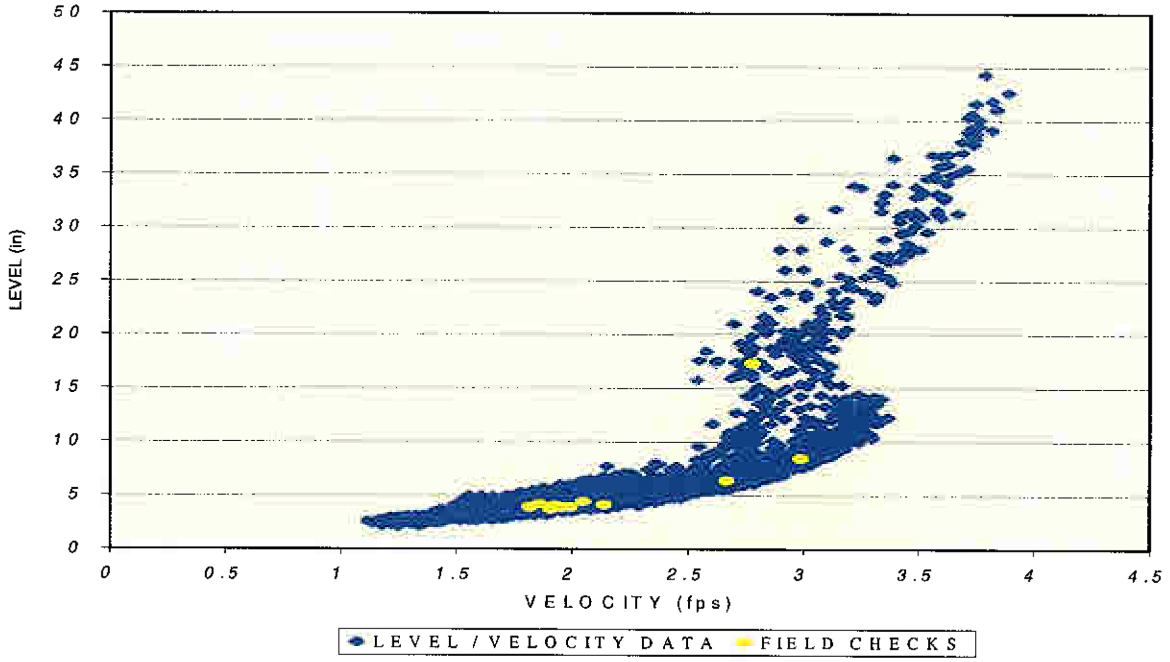


Figure 5 – Comparison of Field Measurements on a Level vs. Velocity Scatter Plot
Martin Road Site (6/1/06 – 1/25/07)



Maintenance and system operation alarms were developed in January 2007 to facilitate data collection. A maintenance alarm would be initiated should communications success fall below 90%, if a sensor failure or low battery voltage occurred, or if the differential between primary and redundant velocity and level sensors exceeded their set point. System operation alarms included surcharging, significant surcharge (depth = grade – 6.5 feet), high flow at the ORF Main Meter, or an ORF overflow. The impacted flow meter icon on the real-time web site would change to red should an alarm condition be present. Also, designated personnel were notified by email of the specific alarm condition. The Telog Instruments database included system health reports to allow the user to access conditions such as communications success rate, battery strength and alarm history.

GIS Database

The DSM's existing GIS database formed the basis of mapping for this project. The database information included existing sewers, force mains, pumping stations, roads, parcels, buildings, and manholes. Review of the database indicated the information was generally accurate. However, limited engineering-grade information was available on manhole rim and invert elevations, which are critical to proper development of a hydraulic model.

To obtain the necessary elevation data, a kinematic global positioning system satellite (GPS) survey was performed on 313 manholes. These manholes represented the District 6 trunk sewer system, defined as pipes 300 millimeters (mm) in diameter and larger. Using New York State and United States Geographical Survey (USGS) monuments, a Leica SR20 GPS unit was positioned and allowed to collect reference data. After reference data were collected, a Leica GS20 rover unit was used to communicate with the base unit and collect invert and rim data, with a target of sub-centimeter (cm) accuracy.

Several satellites lost function during the survey process, which impacted accuracy. In the x-y plane, average and median accuracy of the GPS survey was 2.74 cm and 0.91 cm, respectively. The average and median accuracy of elevation measurements was 6.1 cm and 2.1 cm, respectively, which did not meet the target accuracy level. Therefore, a level loop survey was subsequently performed to obtain elevation data meeting the accuracy requirements. The survey data was used to update the DSM's GIS database. Street information from New York State's Accident Location Information System (ALIS) also was used in updating the GIS database.

SWMM Model Development

The online model is driven by the latest hydraulics engine (USEPA's SWMM5) and a storm/sanitary system modeling-specific graphical decision support system (PCSWMM). PCSWMM provided useful tools for visually displaying results that could be integrated into the website.

The Lackawanna sewer system contains more than 80 miles of gravity sewer, 1,800 manholes, six pumping stations, a wastewater treatment plant, and an overflow retention facility (ORF). The model consisted of the trunk sewer system network and generally included sewers 12-inches in diameter and larger, with several smaller diameter pipes included to permit connectivity. The model was constructed around key system manholes (nodes), which were surveyed as part of GIS database modification. Sewer pipes (links) between these key manholes were amalgamated into single conduits with equivalent lengths and diameters. The model included a total of 190 nodes, seven storage nodes and 193 links. Catchment areas were assigned to key node locations in the system for dry weather flow and wet weather response contributions.

The SWMM model contains five pumping stations, as well as the three screw pumps operating at the ORF. One small-capacity pumping station was omitted from the model because the discharge was not significant. Record drawings were used to determine stage-storage characteristics for the pump wet wells. Pump curves and on/off operating levels were obtained from District 6 staff. The force mains were excluded from the model; pumps were connected to manholes downstream of the force mains. This eliminated problems with the model that were causing the force mains to backup and show flooding at all of the pumping stations.

The District 6 sewer system contains a four-cell, 5-million gallon ORF. In the model, the ORF was simplified as a single storage node with the combined volume of the four cells. Approximately two-thirds to three-quarters of the District 6 sewershed area is upstream of the ORF. A sluice gate controls flow past the ORF. During high flow conditions, the sluice gate limits flow past the ORF, such that inflow to the WWTP does not exceed its hydraulic capacity of about 8 million gallons per day (mgd). Excess flow enters the ORF, where it is stored until inflow to the WWTP decreases to an acceptable level, after which a return gate is opened to drain the ORF volume back into the sewer system. If the capacity of the ORF is exceeded, it overflows to an adjacent creek after receiving primary treatment and disinfection.

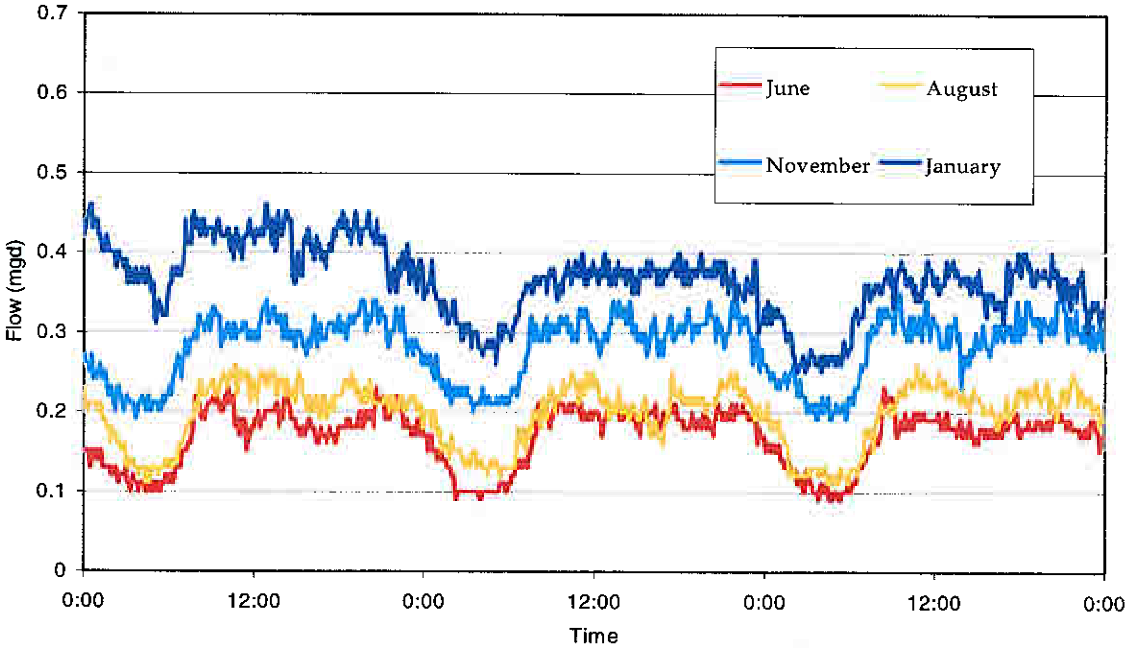
The overflow retention facility was the most challenging aspect of the system to accurately represent in the model. Flow entering and leaving the ORF is controlled manually by operators. This means that although there are some general guidelines for control of the gates, there are no absolute rules that could be programmed into the model. In conversation with District 6 operations staff, it was determined that approximately 80% of the time, the sluice gate at the ORF is adjusted to limit inflow to the treatment plant to 6.5 mgd. Opening of the return flow gate is also determined based on the inflow to the treatment plant.

The operation of the ORF and return gates was modeled using three weirs: two to direct flow into the ORF, and a third to control the return flow to the system. Detailed control rules were created in the model to adjust the two weir heights for directing flow into the ORF, thus limiting the flow past the ORF to 6.5 mgd. When modeled WWTP peak flows subside, the return flow weir height is decreased to allow volume stored in the ORF to return to the system. Although difficulties were encountered in matching observed flows at the ORF and WWTP using the programmed control rules, it was deemed important to attempt to match actual operating procedures as closely as possible. This allowed the model to be used as a tool to evaluate and optimize operating procedures.

SWMM Model Calibration

Dry weather flow patterns were manually calibrated at each flow meter location. Daily patterns were determined from flow monitoring records during periods with no precipitation. The average flow at each monitoring location was divided between the contributing sewer catchment areas. The size of each catchment was based on pipe length, as this relates to the number of customers. The dry weather flow patterns were originally calibrated during the summer months. However, throughout the fall and winter, considerable precipitation occurred, which raised the groundwater table. This led to higher observed dry weather flows during the fall and winter months. The variation of dry weather flows experienced at the Willet Road flow monitoring site is shown on Figure 6. This figure shows that dry weather flows can vary by up to three times between high and low groundwater levels. Monthly dry weather flow patterns were incorporated into the model to reflect these observations. Since flow observations were only available for the nine months of the project (May through January), this pattern was assumed to continue for the remaining spring months.

Figure 6 – Variation of Dry Weather Flows in Willet Rd. Sewer (June 2006 – January 2007)

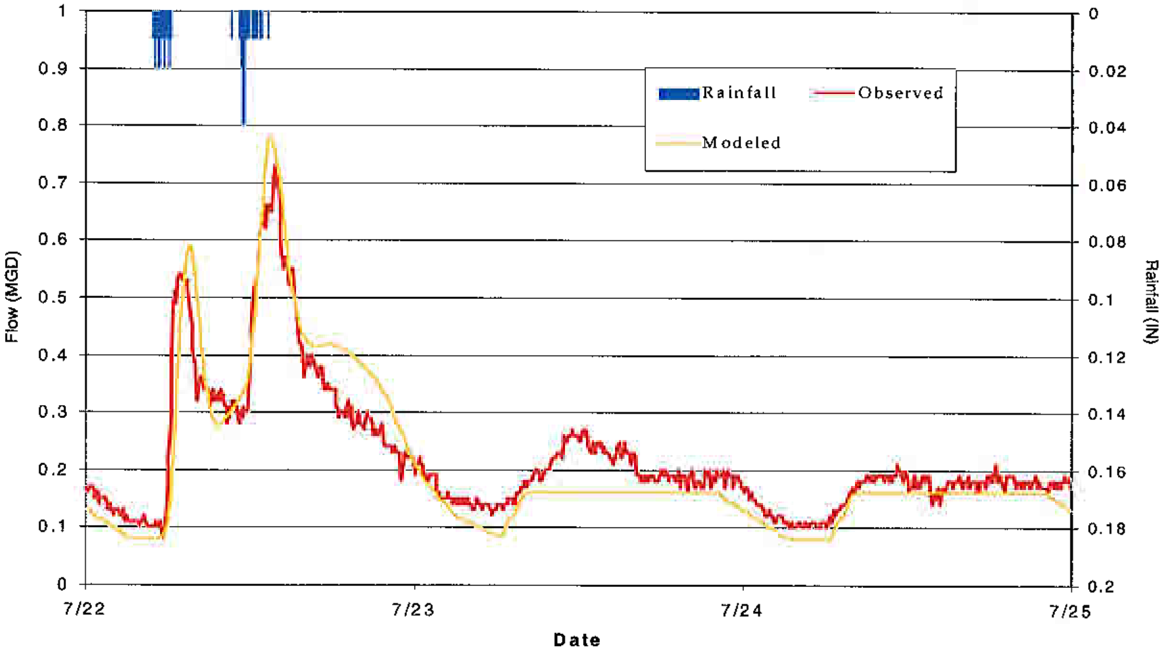


Modeled wet weather flows were calibrated using a combination of manual calibration and the genetic algorithm (GA) automatic calibration tool provided in PCSWMM (James, et al., 2003). The rainfall dependent infiltration and inflow (RDII) parameters in SWMM were the bases for wet weather calibration. These parameters consist of three overlapping triangular unit hydrographs, representing the slow-, moderate- and fast-responses of the sewer system. Each of the three hydrographs is characterized by three parameters (R-T-K):

R - the response ratio (the fraction of rainfall that enters the sewer system),
T - the time to peak in hours (the delay between the start of precipitation and the system response), and
K - the recession ratio (the ratio of the recession time to the time to peak).

These nine parameters were adjusted for each model catchment area to achieve a good fit between the observed and modeled response for selected calibration events. For the flow meter locations with large contributing areas, the GA automatic calibration tool was a useful method of adjusting the parameters simultaneously for several different catchment areas to matching observed peak flows in the system. In this process, manual estimations were made for all nine R-T-K parameters, followed by characterizing the uncertainty range for each parameter (the range over which each parameter could be adjusted by the GA calibration tool). The GA tool then follows a generational approach, successively changing the parameters within their defined uncertainly ranges according to the principles of genetic algorithms and evaluating the goodness of fit against the selected calibration events. There are a number of criteria that can be used in evaluating the goodness of fit, including event volume, event peak flow, time to peak, etc. Probably the most useful measurement criterion in unit hydrograph calibration was the evaluation of the entire response function – the shape of the resulting hydrograph. As this approach adjusts the entire event hydrograph shape to best fit the observed hydrograph, it addresses the slow, moderate and fast-responses simultaneously, while also matching peak flow and event volume (although not with the same priority). An example to the calibrated model hydrograph to observed hydrograph is shown on Figure 7. The RDII R-T-K parameters are an empirical method of calibrating the wet weather response in the model. In order to provide a physical relationship to the District 6 sewer system, the RDII sewerage areas were related to the length of pipe in each catchment area, and thus not subject to automatic calibration.

Figure 7 – Modeled (Calibrated) Vs. Observed Hydrographs for Willet Road Sewer (7/22/06 – 7/25/06)



Similar to the dry weather flow pattern, the wet weather flows also indicated a seasonal RDII response. Peak responses to precipitation observed during the fall and winter were higher due to saturated soil conditions. Seasonal RDII parameters were included in the model for several of the catchment areas to reflect these observations. Following development and calibration of the SWMM model, model results were reviewed with District 6 staff to verify that model results were consistent with observed conditions, such as reported surcharging and flooding incidents.

WEB SITE FUNCTION DEVELOPMENT AND INTEGRATION

Web site development proceeded parallel to flow monitoring, GIS database and SWMM model development. Integration of these key elements into a single web site occurred between August 2006 and February 2007.

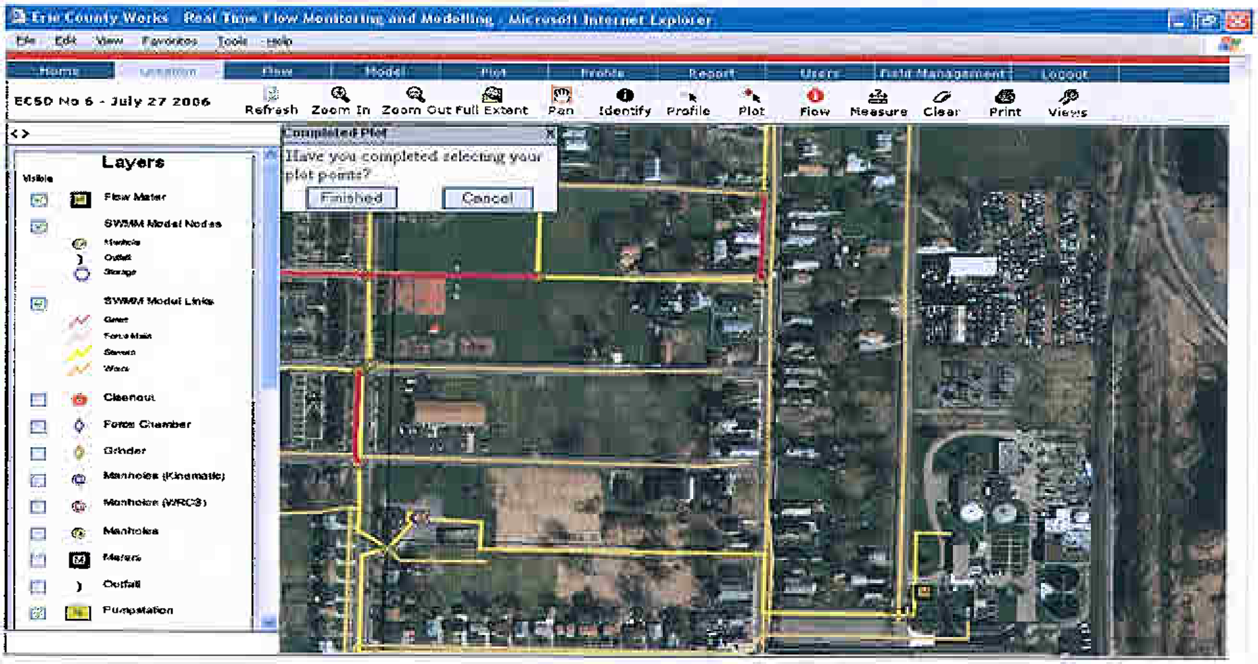
Web Site Function

The real-time web site enabled the varied components (GIS, flow monitoring and SWMM model) to act in a coordinated fashion, providing the user with the ability to see analytical results in a user-friendly environment. A Web-based GIS and mapping interface was built using ESRI ArcIMS 9.1 to provide users a visual access tool. Core functions provided with the GIS interface included map navigation, layer/legend management, printing/plotting, measurement, query functions, and export and reporting tools. The web site can be used to initiate, review and evaluate SWMM model results. The most powerful of these requests was initiating a real-time model. At the click of a button, the user could request a model run for the previous 48-hours of flow and precipitation data collected. This would allow up-to-the minute access to sewer system operation, including thematic mapping (color-coded) and model reports, as well as time-series plots and animated sewer profiles anywhere in the system. Using the desktop version of PCSWMM, the user could develop model runs for historical and simulated precipitation events. In addition, the desktop PCSWMM was used to evaluate "what-if" scenarios involving sewer improvements and system expansion. Once completed, the model runs would be uploaded into the real-time website, which could be used for evaluation by all users.

Advanced mapping and visualization functionality was provided with the plot and profile functions. The GIS mapping interface enabled users to select a node or link to develop a time-series plot or profile from the summary map. Time-series plots could be developed for depth, head, flow, velocity, Froude No., and capacity. The plot properties, such as line colors and types could be customized and stored between sessions. Actual flow meter data also could be inserted into the plot to enable comparison plotting as well as automatic error analysis of the model with most commonly used error functions. The profile function provided an easy to understand rendering of hydraulic grade line and user control based on all details and data presented in the profile. Animation of the profile was provided for the entire model run length to allow observing development of surcharging events. Additionally, plots and profiles could be copied to a clipboard to enable inclusion in reports.

Examples of the user interface are presented in Figures 8 –11. In Figure 8, the user has used the zoom function in the area of the Lackawanna WWTP to select four SWMM model links (sewer pipes) for a time-series plot. The selected links are highlighted in red. Note that an orthographic mapping background can be selected on the user interface. Figure 9 shows the time-series plots for the selected links; the selected model period (July 27, 2006) is shown in the upper left corner of the screen.

Figure 8 – Web Site User Interface – Selection of SWMM Model Links for Plotting

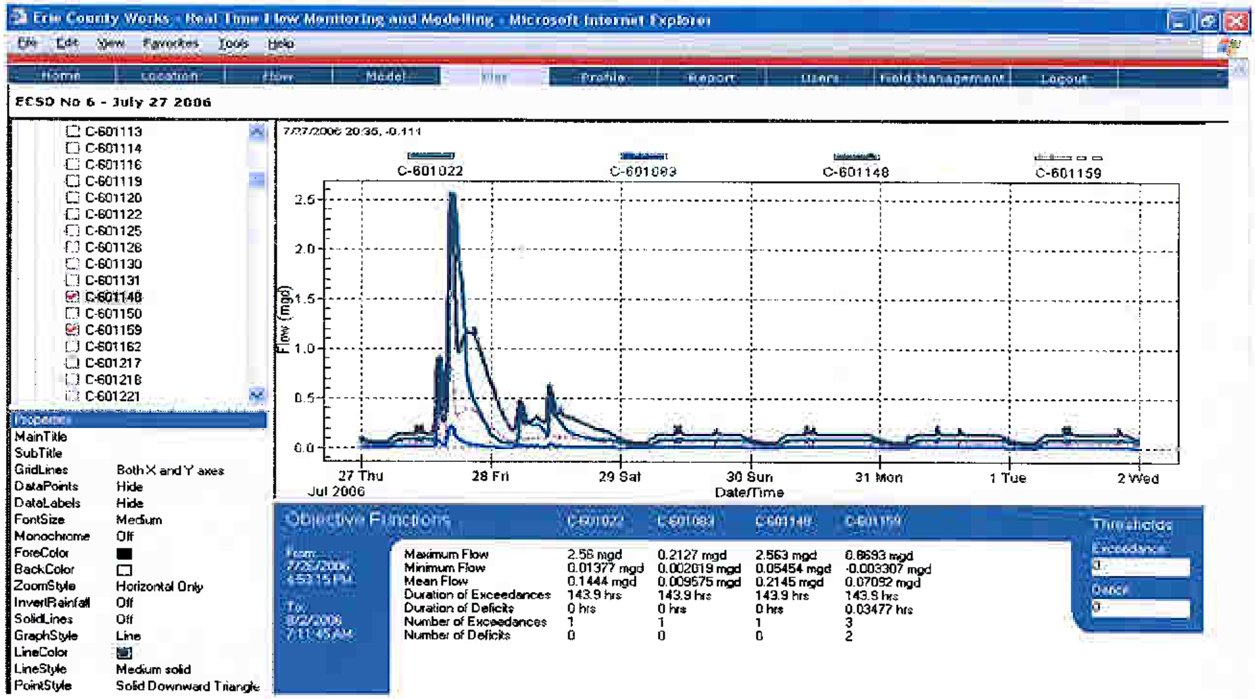


Completed Plot

Have you completed selecting your plot points?

Finished Cancel

Figure 9 – Time-Series Plots for Selected Links



☐ C-601113
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MainTitle	
SubTitle	
GridLines	Both X and Y axes
DataPoints	Hide
DataLabels	Hide
FontSize	Medium
Monochrome	Off
ForeColor	■
BackColor	□
ZoomStyle	Horizontal Only
InvertRainfall	Off
SolidLines	Off
GraphStyle	Line
LineColor	■
LineStyle	Medium solid
PointStyle	Solid Downward Triangle

Objective Functions

From: 7/26/2006 4:53:15 PM

To: 8/2/2006 7:11:45 AM

	C-601022	C-601083	C-601148	C-601159
Maximum Flow	2.56 mgd	0.2127 mgd	2.563 mgd	0.8693 mgd
Minimum Flow	0.01377 mgd	0.002019 mgd	0.05454 mgd	-0.003307 mgd
Mean Flow	0.1444 mgd	0.009575 mgd	0.2145 mgd	0.07092 mgd
Duration of Exceedances	143.9 hrs	143.9 hrs	143.9 hrs	143.9 hrs
Duration of Deficits	0 hrs	0 hrs	0 hrs	0.03477 hrs
Number of Exceedances	1	1	1	3
Number of Deficits	0	0	0	2

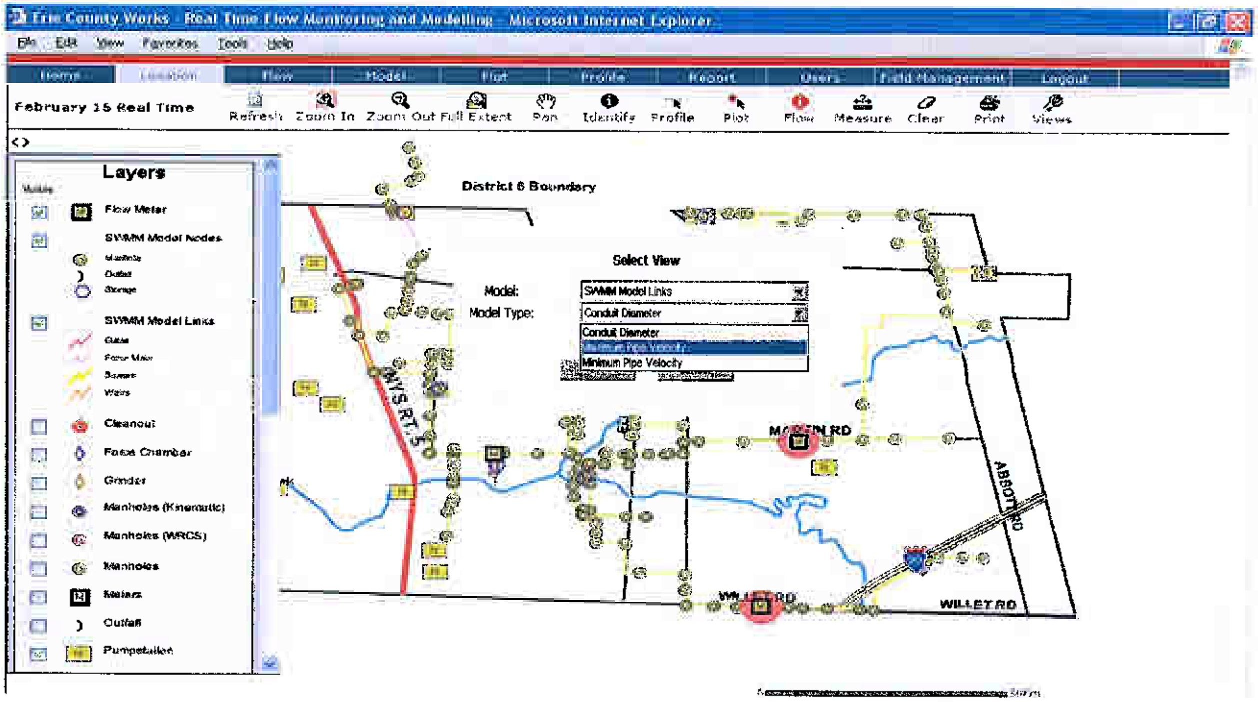
Thresholds

Exceedance: 0

Deficit: 0

Figure 10 shows a full extend of the District 6 boundary, and the user is selecting a thematic map for maximum pipe velocity. Figure 11 shows the maximum pipe velocity thematic map with the user looking up the GIS database for a point of interest.

Figure 10 – User-Interface – Selection of a Thematic Map



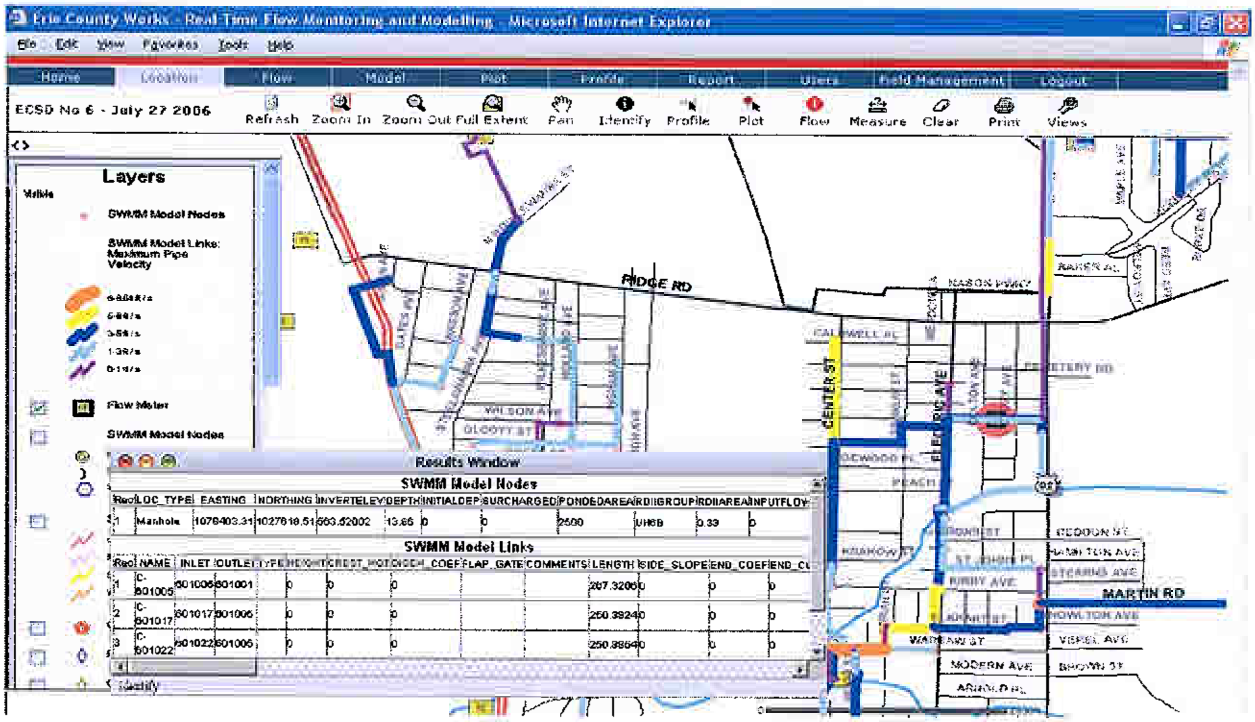
Select View

Model: SWMM Model Links

Model Type: Conduit Diameter

- Conduit Diameter
- Maximum Pipe Velocity
- Minimum Pipe Velocity

Figure 11 – Maximum Pipe Velocity Thematic Map – Reviewing GIS Database



SWMM Model Nodes

Rec	LOC_TYPE	EASTING	NORTHING	INVERTELEV	DEPTH	INITIALDEP	SURCHARGED	PONDEDAREA	RDIIGROUP	RDIIAREA	INPUTFLOW
1	Manhole	1076403.31	1027618.51	563.52002	13.66	0	0	2500	UH6B	0.33	0

SWMM Model Links

Rec	NAME	INLET	OUTLET	TYPE	HEIGHT	CREST_HGT	DISCH_COEF	FLAP_GATE	COMMENTS	LENGTH	SIDE_SLOPE	END_COEF	END_C
1	C-601005	601006	601001		0	0	0			207.3206	0	0	0
2	C-601017	601017	601006		0	0	0			250.3924	0	0	0
3	C-601022	601022	601005		0	0	0			250.3854	0	0	0

Web Site Development and Integration

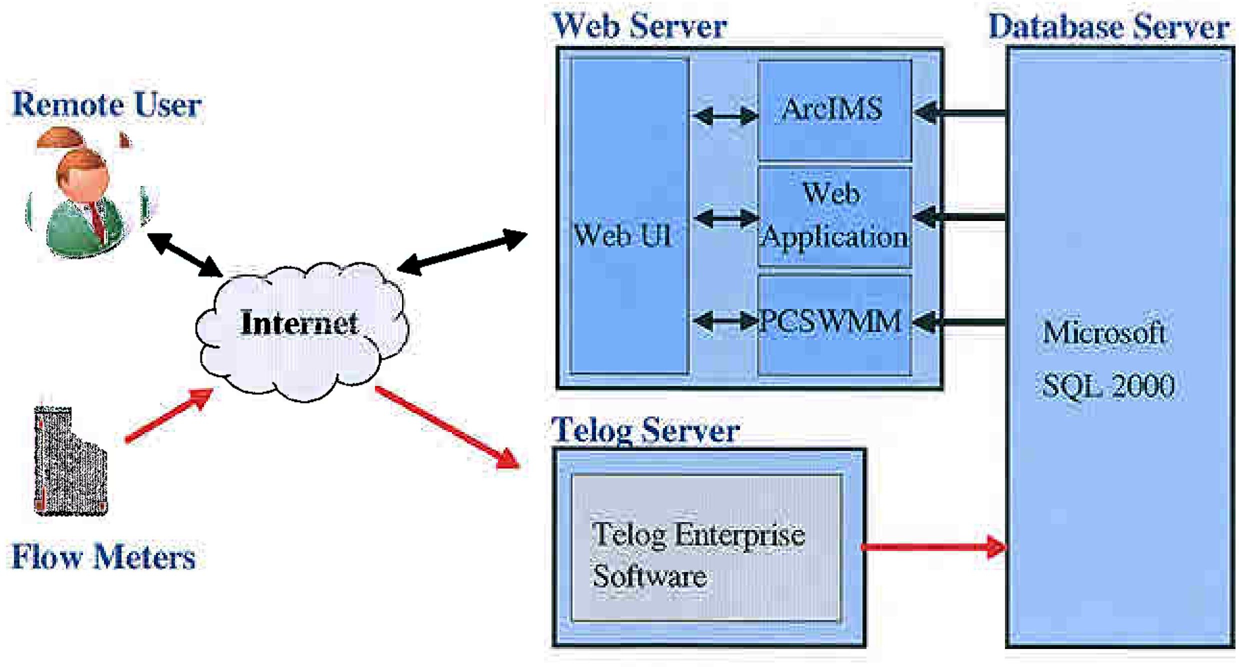
The Erie County Demonstration Project was designed and implemented for Microsoft Internet Information Services (IIS). The application was managed between two servers, a web server to process web requests and host the business logic to the end user, and a database server to manage tabular data and communication with the Telog web site that contained the raw flow monitoring data (Moore, 2006).

The web site was built around the Microsoft .NET 1.1 Framework and written in C#, which provides the application with the ability for future expandability to its overall structure and operation. This framework provided the key components for communication and synchronizing operations between the major products used in this application:

1. ESRI ArcIMS
2. PCSWMM Web Engine
3. Telog Instruments
4. Microsoft Sharepoint Site

Figure 12 schematically illustrates the interaction of the various servers and software packages. The ESRI ArcIMS application provided the end user with the graphical interface for viewing and plotting information on a flat imaged view within the District 6 system boundary (van Veldhuisen, 2001). ArcIMS was also used to dynamically render specific views generated based on the active model (examples presented later); these dynamic views are created instantly when generating a new model using PCSWMM. The data that is generated from PCSWMM can be funneled and populated onto the mapping interface for a graphical user experience.

Figure 12 – Schematic of Demonstration Web-Site Interaction



The PCSWMM Web Engine provided the ability to statistically analyze computed SWMM response functions (e.g. computed time series for depth, flow, storage volume, etc) and populate the model GIS layers with the results. The web-based GIS viewer uses the computed attributes to generate detailed thematic views for a specific model based on specified parameters, such as duration of surcharging, maximum flow depth, pipe diameter, and minimum and maximum pipe velocity (Schreiner, et al., 2000). To demonstrate the flexibility of this approach, the web-based system can present a graphical view of the locations and extent of potential surcharging sewers (full sewers under pressure flow) by creating a theme based on the duration for which computed head exceeds the connected sewer obverts at each node. The PCSWMM Web Engine removes a layer of work required on the model side and automates the process of generating output files online. The files are stored and saved for future recall. Included in the PCSWMM Web Engine is the ability to use the data from a model being graphically displayed on the ArcIMS interface to graph and scatter the information based on conduit or link selections.

A direct link was provided from the real-time web site to the Telog Instruments hosted database to allow the user to access and analyze raw flow data. The framework application of the real-time website processed 15-minute synchronization requests sent to the Telog Instruments database server. The data was accumulated and stored locally to facilitate requests to run the SWMM model (Kuhns and Askov, 2003). The 15-minute intervals would pull back the past 48 hours of data and compare missing data for consistency and accuracy.

The Microsoft Sharepoint Site provided the end user(s) with the ability to collaborate findings and upload documents to a central data repository. Examples of files that would be uploaded are (not limited too) calibration work files, health and safety plans, project correspondence, maps, schematics and drawings.

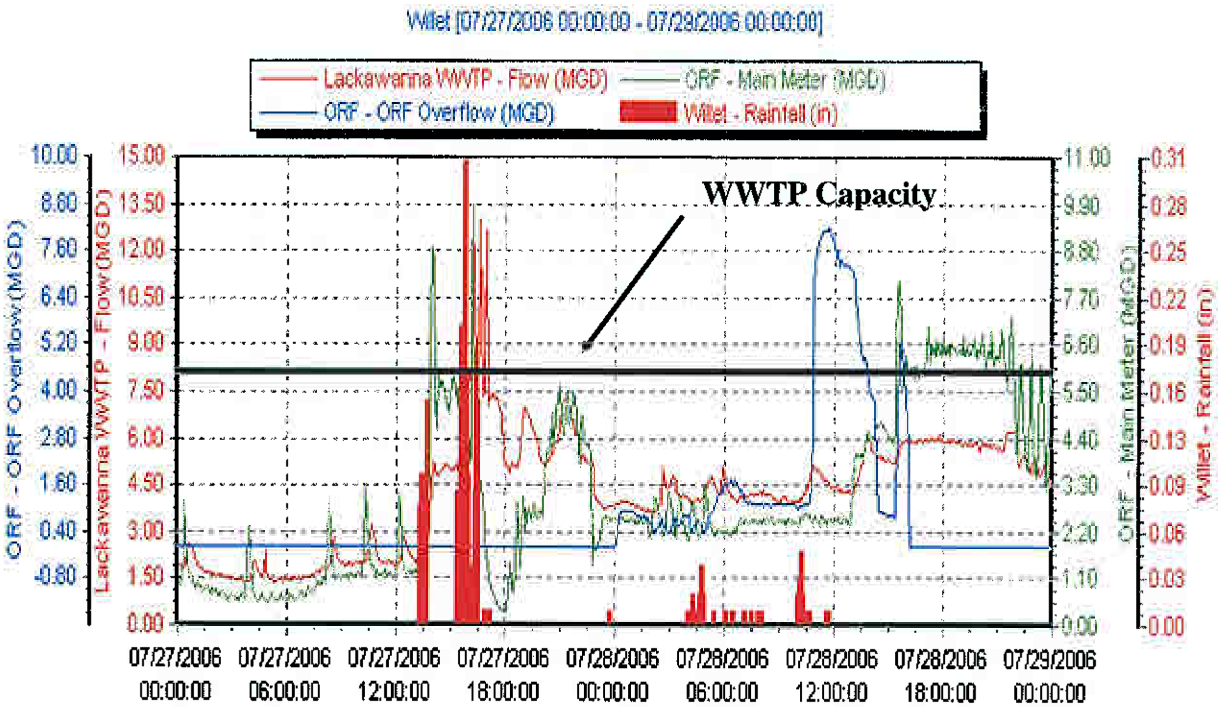
EXAMPLES OF REAL-TIME WEBSITE BENEFITS

This integrated system could be used as a predictive tool to rapidly evaluate operational and capital improvements. Examples of how this system can be used are described as follows.

Maximizing Conveyance to WWTP

During project development, a storm event on July 27/28, 2006 was identified as an opportunity for maximizing conveyance of flow to the WWTP. Figure 13 shows the relationship of the WWTP to the ORF and its flow control sluice gate. The Lackawanna WWTP has a capacity of 8 mgd. Influent flows beyond this capacity are bypassed and discharged directly into the plant's receiving stream. To prevent the plant from becoming overwhelmed, a sluice gate has been installed in the mainline sewer at the ORF. When flows from the eastern part of the District exceed 6.75 mgd, the sluice begins to close, diverting flow into the ORF for storage. Operators have the ability to modulate the sluice gate to vary the rate of flow diverted; however, at the time of the July event, the real-time system was not available for use.

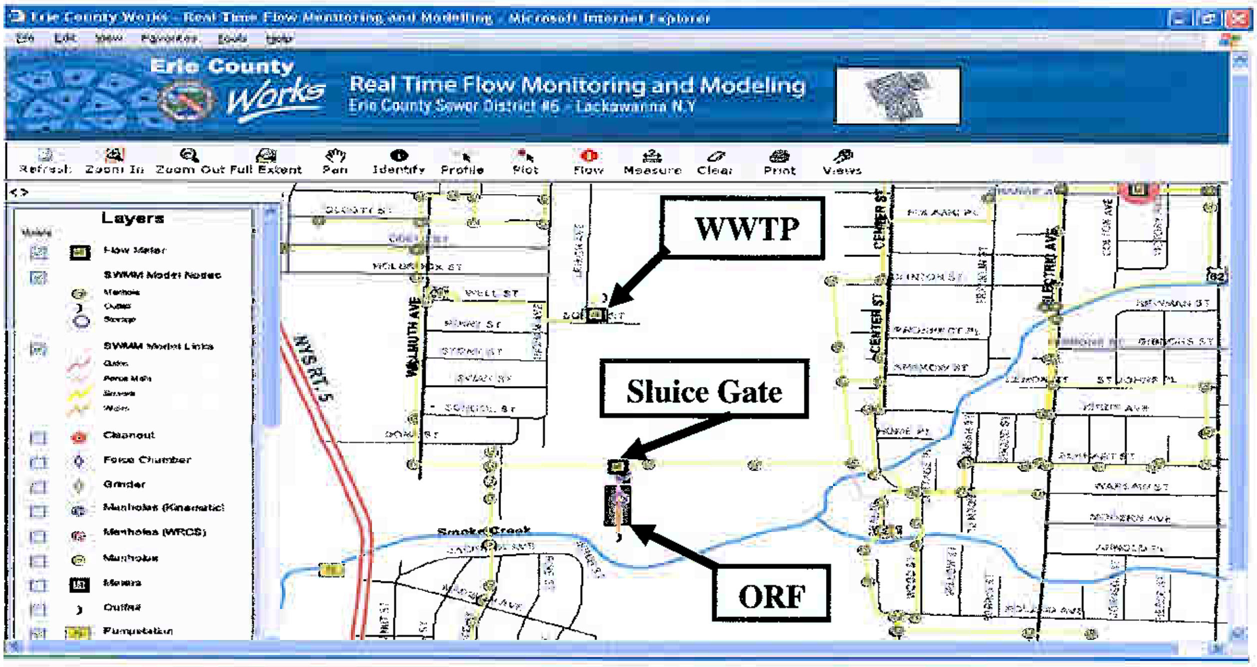
Figure 13 – Location of Lackawanna WWTP and District 6 ORF



Wet weather was experienced on consecutive days (see Figure 14). On July 27th, approximately 1.8 inches of precipitation was experienced, including about 0.31 inches in a five-minute period. The ORF Main Meter measured flows in excess of 6.75 mgd and the sluice gate closed partially to divert flow to the ORF. The intensity of this storm caused WWTP influent flows to approach 13.5 mgd, which is above the plant's hydraulic capacity. To counteract this flow spike, operators temporarily closed the sluice gate, which resulted in all flow from the eastern part of the District to be discharged into the ORF. The storm resulted in the five million gallon ORF to fill up in about six hours; the ORF had a peak flow of about 30 mgd during this time. The ORF had sufficient volume to contain the storm-derived flows, but was almost completely filled.

Figure 14 shows that flows to the WWTP subsided during the six hours following the storm. By about midnight on July 28th the WWTP had an excess capacity of approximately 4 mgd. However, flows continued to be diverted to the ORF, thus resulting in a small overflow to the receiving stream. These overflows received primary treatment and disinfection. The second storm had a rainfall of about 0.4 in. The second storm was less intense, but because the ORF was full, much of the RDII from this event overflowed into the receiving stream. The ORF had a peak overflow rate of 8.5 mgd. If this system were available to the operators at the time of the storm, the operators would have been able to quickly recognize that more flow could have been conveyed to the WWTP (including draining the ORF), thus reducing or eliminating the ORF overflow.

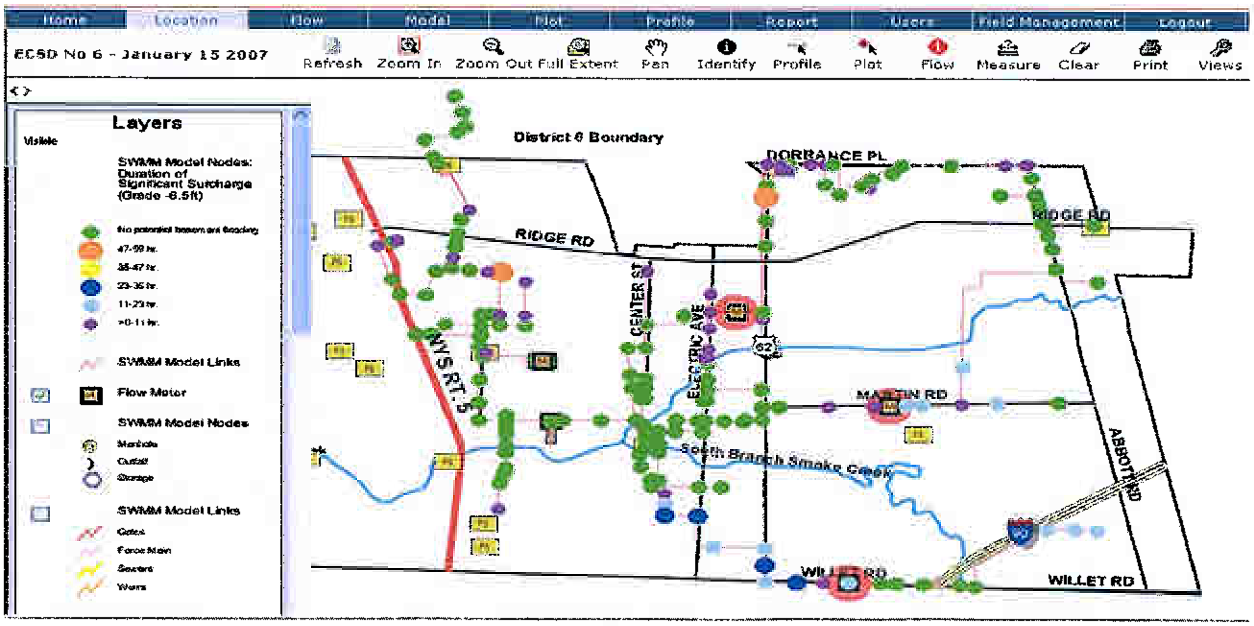
Figure 14 – Wet Weather Event on July 27/28, 2006



Identifying Manhole Surcharging

The web site has a summary view function that allows the user to quickly identify key issues in the District 6 collection system. Figure 15 shows a thematic view for duration of significant surcharging at manholes. The blue and orange dots represent areas where surcharging has resulted in water surface depths within 6 ½-feet of grade, thus showing areas where overflows could be potentially occurring.

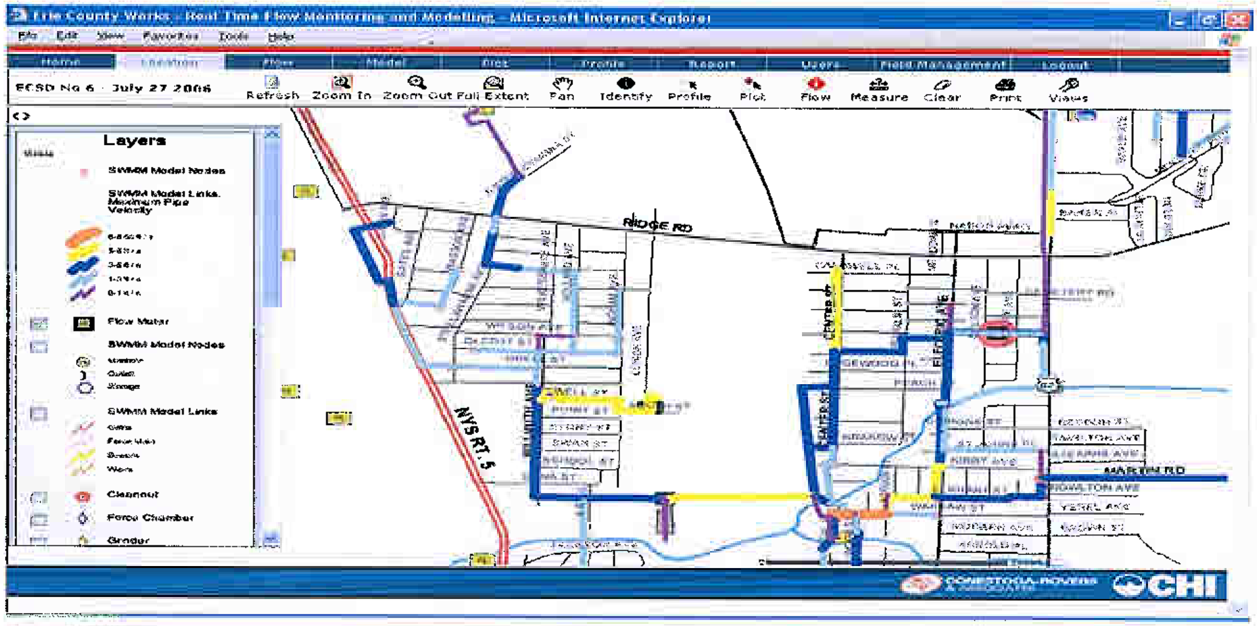
Figure 15 – Thematic View Showing Surcharging Locations (7/27/06)



System Maintenance Plans

Another power view available to users is of maximum flow velocity in pipes. This can be used to identify where low velocities are prevalent in the collection system during wet weather events. These lower-velocity areas are at greater risk for reduction in sewer capacity due to sedimentation. Figure 16 shows the maximum velocity during the July 27/28, 2006 wet weather event. In this thematic view, about one-third of the pipes are near or below minimum settling velocity. Therefore, this information can be used in developing and maintaining a sewer flushing program.

Figure 16 – Thematic View Showing Maximum Pipe Velocities (7/27/06)



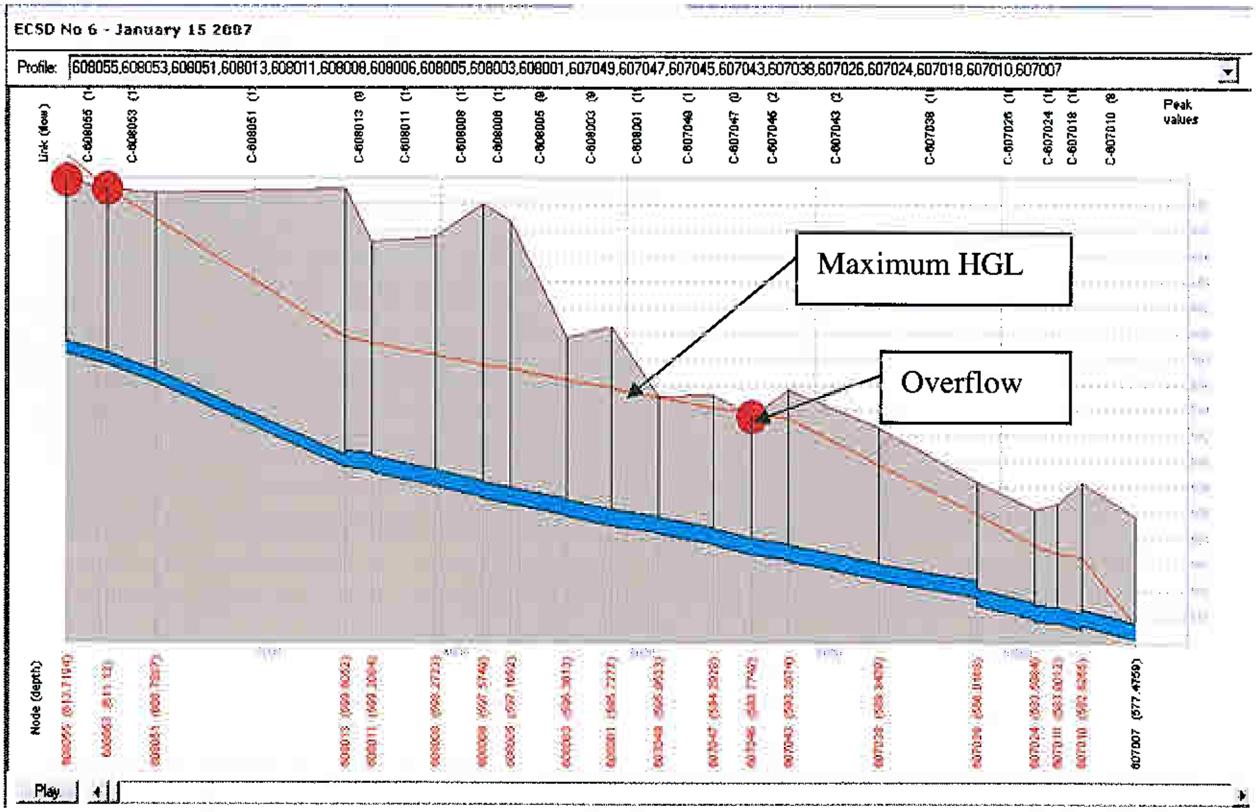
"What-If" Scenario Evaluations

The DSM uses an asset management approach to identifying and prioritizing improvements throughout its service area. Another powerful use of this web-based tool, consistent with asset management, is the ability of the user to model what-if scenarios. This can be performed to predict the impact of proposed developments, to optimize system operation, determine where new developments/industrial users should be connected, or to determine the benefits of potential capital improvement projects. The authorized user has the ability to download a selected model from the website and edit the model with the desktop version of PCSWMM to represent desired scenarios. Once the scenario is complete, the user can then choose to load the edited model back onto the website to share the results with other users.

The following is an example of one of these what-if scenarios that was modeled as a demonstration for this project: the Willet Road trunk sewer optimization. The Willet Road trunk sewer is located in the southeast quadrant of District 6 and carries flow from a predominantly residential area. The trunk sewer includes 12-inch and 15-inch diameter pipes. This trunk sewer is known to have capacity issues; complaints of surcharging and surface flooding as a result of precipitation events are common.

The existing sewer performance was examined using a recorded precipitation event from the project study period, the July 27, 2006 storm, which had a total of about 1.8 inches of rainfall, and was approximately a two-year event. The existing conditions model calculated surface flooding in four locations along the Willet Road trunk sewer for this event. Figure 17 displays the HGL in the sewer profile with the three surface flooding locations. The model scenario was used to determine what system improvements would be necessary to eliminate this surface flooding. Figure 18 shows the resulting HGL if the recommended improvements are made. This entire analysis and recommendations took an engineer approximately five hours to complete.

Figure 17 – Profile of Willet Road Trunk Sewer (7/27/06)



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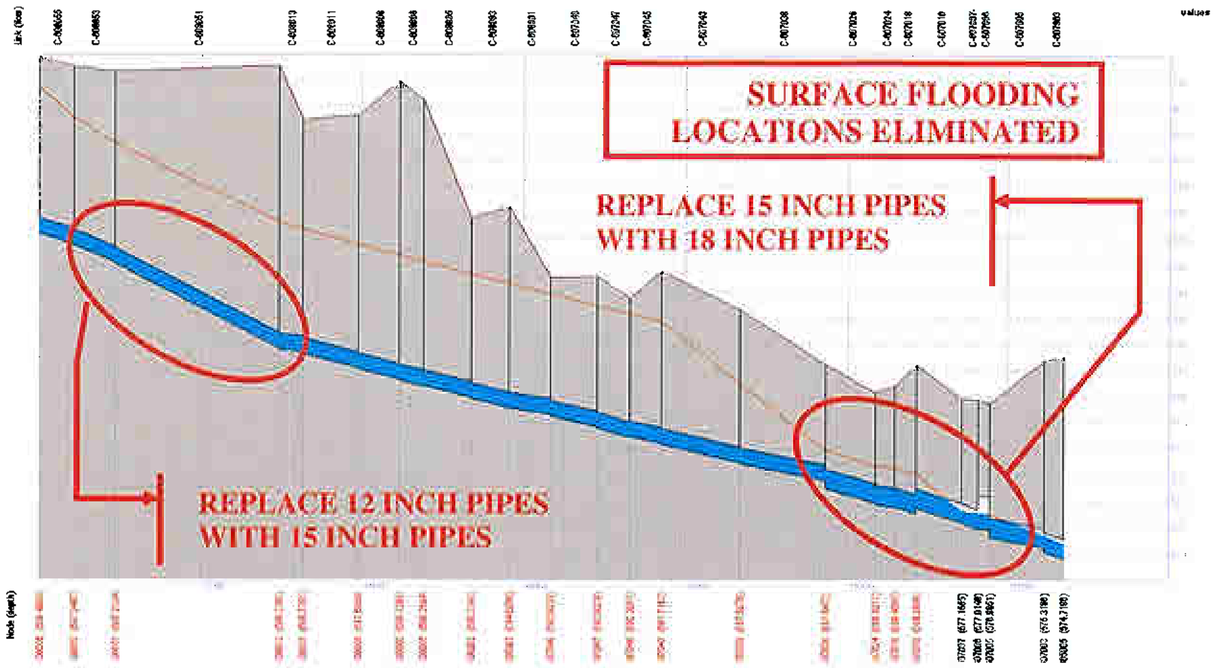
Profile: 608055,608053,608051,608013,608011,608008,608006,608005,608003,608001,607049,607047,607045,607043,607038,607026,607024,607018,607010,607007

A key finding from this evaluation was that the entire trunk sewer did not require replacement to mitigate overflows during a two-year storm event. About 6,000 lineal feet less of sewer would require upsizing. This reduction in sewer replacement would equate to approximately $1,000,000 in savings. This entire analysis and recommendations took an engineer approximately five hours to complete.

Figure 18 – Profile of Willet Road with Proposed Improvements



Sewer Investigations and Rehabilitation

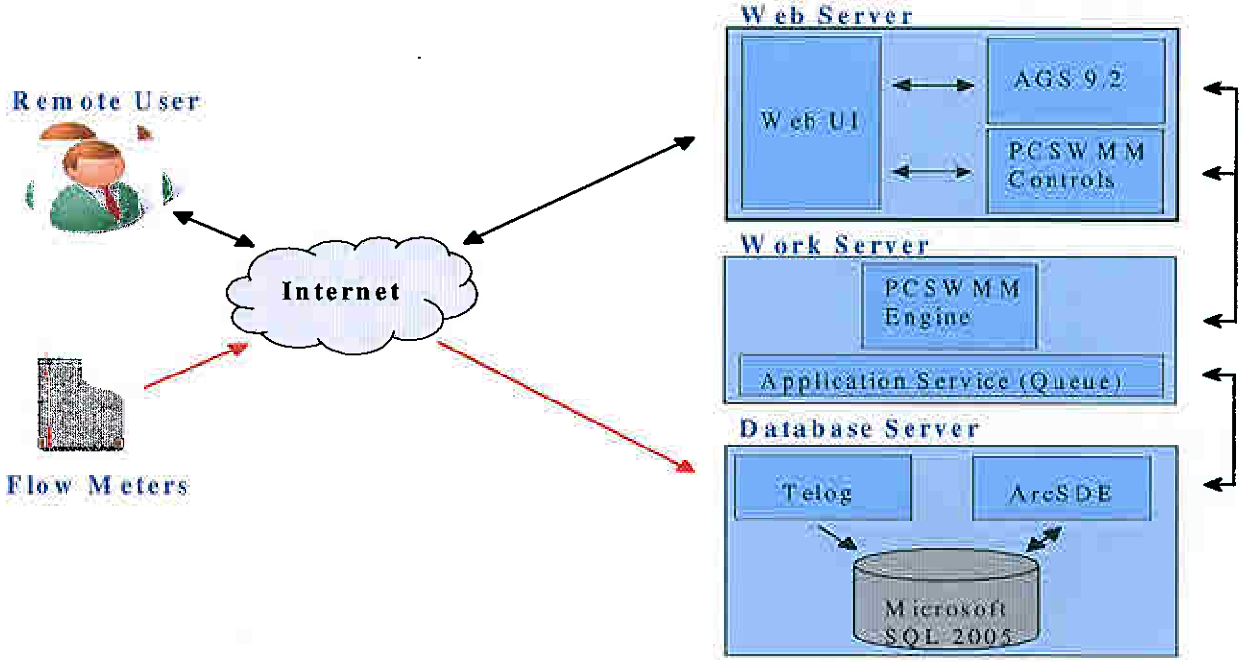
The web-based model also can be used to facilitate the ability to prioritize catchments by the amount of RDII occurring in each area. This would allow utility managers to focus on the areas of disproportionately higher RDII for investigation and rehabilitation, thus gaining the best value for their dollar. Programs where this prioritization of investigative activities would be beneficial include development of video inspection, and dye and smoke testing programs in preparation of sewer rehabilitation. For example, catchments that are found to respond quickly to precipitation events would be investigated using smoke testing to identify roof leader connections or other cross connections. Those catchments that respond slowly to precipitation events would be video inspected to evaluate pipe conditions.

SHIFTING FROM DEMONSTRATION TO FULL-SCALE SYSTEM

A large question was answered during the demonstration: can GIS, flow monitoring, and hydraulic modeling be integrated onto a web-based system and used to manage of operations? - Yes. The next question: how do we go about to implement a full-scale system? The DSM's total service area is over ten times the size of District 6, and has been growing as it merges the assets of adjacent towns and villages. Therefore, the full-scale system must be expandable. Another important component to be place into the full-scale system is the ability to bring the ability to develop, modify and run the SWMM model over the web. In addition, the system should have an open-architecture design to allow future upgrades to be performed by DSM personnel, as well as the ability for DSM staff to expand and modify the GIS interface to incorporate other functions.

A service oriented architecture (SOA) approach will be used in developing the application, which represents the current trend in software engineering. Generally, SOA refers to a system developed from a number of autonomous services typically bundled together using applications programming interfaces (APIs). The benefit of using SOA is to provide a transparent, highly modular architecture that can be rapidly extended and reconfigured to meet the changing needs of the DSM. Based on this design principle, a SOA, thin-client, Web 2.0 approach will be used to provide system functionality without using Active X, Java applets or other thick-client based technology. Figure 19 schematically illustrates the architecture of the full-scale system.

Figure 19 - Schematic of Full-Scale Web-Site Architecture



Three servers would be used: a database server, web server and a work server. The database server would be used to host the flow monitoring data, the web server would act as the user interface and the work server would be used to run the hydraulic model functions. Components that would comprise the web site are as follows:

- An ESRI ArcGIS Server 9.2 (AGS) based client-side user interface to facilitate work flows,
- AGS and ArcObjects based server-side procedures to provide access to GIS functionality,
- Telog's Enterprise software (flow monitoring management) integration with the AGS interface, providing access to the most current flow data from the database server,
- PCSWMM.NET client-side and server-side integration to facilitate online modeling through a custom-built MS Windows service using a common language specification,
- A user management system capable of delivering a customized user interface based on pre-defined user roles, and
- A custom designed Windows service capable of scheduling threads and managing requests between servers to optimize the system's performance without impacting the system's usability.

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