Appendix A

ETS Model Modification Memo

To	Kristen Lundeen, PE	Page	1
CC	Bryan Rogne		
Subject	**2015 East Trunk Sanitary Sewer Model Modification**		
From	Ashley Leisgang, Chuck Boehm		
Date	April 24, 2015		

Background / Scope of Work

In 2013 the City raised concerns about how the sanitary sewer system performs based on field observations compared to the existing sanitary sewer model representation of the system. The two concerns raised by the City were: 1) the model was overestimating flows and hydraulic grade line upstream of the bypass location (Brookdale Drive and Clover Lane) and; 2) the model was underestimating the impact of the forcemain that enters the system at Zedler Lane and Port Washington Road which they observed to be causing backwater effects and an elevated hydraulic grade line that was not matching the model results.

There was only one flow meter in the field during the original study that was used to calibrate this area. This led to the decision to install 8 flow meters in an area of the East Trunk Sanitary Sewer system from Hidden Reserve Court south of Hidden Reserve Circle south to West Zedler Lane extended East of North Port Washington Road to better determine the existing system response to rainfall events (see Table 1).

A review of the meter results from 2014 and the subsequent recommendation to make sanitary sewer model adjustments based on that data was documented in the “2014 East Trunk Sanitary Sewer Flow Monitoring Analysis” memo, AECOM, March 13, 2015.

Following that memorandum development, AECOM requested additional rainfall and flow meter data from the Milwaukee Metropolitan Sewerage District (MMSD) and data from the City of Mequon. Flow monitoring data from the June 17-18, 2014 rain event was utilized as a comparison to make model adjustments to better match the modeled system response to the metered rain event.

The existing sanitary sewer system model developed and calibrated for the April 2009 rain event, was adjusted using rainfall and observed flows during the June 17-18, 2014 rainfall event. The results of the adjusted model will allow the City to have better confidence in the model representation of the existing system performance and to move forward with further evaluation and recommendation of future system improvements. The purpose of this memorandum is to summarize the results of the model adjustment process in the East Trunk Sewer System from south of Sunnydale Lane to Zedler Lane East of North Port Washington Road.

The specific tasks of this study include:

- Run existing conditions model incorporating the June 17-18, 2014 rainfall event;
- Modify runoff/flow data for existing sewersheds (sanitary basins);
- Refine the model flow generation parameters to better align with the June 17-18, 2014 meter data results; and
- Run the 2009 model event, making adjustments if needed based on the efforts in the 2014 modeling as a re-check/model verification.

Project Area

The area of focus during the model adjustment process was in the East Trunk Sewer System from south of Sunnydale Lane to Zedler Lane East of North Port Washington Road.

A total of 8 sites as shown in Table 1 and Figure 1 were utilized to adjust a portion of the East Trunk Sewer System during wet weather flows. They are listed in order from upstream to downstream in the sanitary sewer system.

Table 1
Flow Meter Locations

U/S to D/S Order	Flow Meter Site	Mequon Manhole Number	Location	Pipe Size (in)
1	ME3008	0430-108	Hidden Reserve Court, South of Hidden Reserve Circle	24
2	ME3013	0430-113	East of N. Stone Creek Drive, North of W. Donges Bay Road	24
3	ME3015	0430-115	N. Greenview Drive Extended, North of W. Donges Bay Road	24
4	ME3086	0430-086	W. Donges Bay Road, West of Westport Circle	27
5	ME3149	0431-149	Westport Circle, South of W. Donges Bay Road	27
6	ME3175	0431-175	N. Brookdale Drive, South of W. Clover Lane	27
7	ME3169	0431-169	W. Zedler Lane, West of N. Port Washington Drive	24
8	ME3205	0432-005	W. Zedler Lane extended, East of N. Port Washington Road	27

Summary of Analysis

The City of Mequon completed a study of its sanitary sewer system in 2010, with the final “Sanitary Sewer System Evaluation” report (AECOM January, 2011) providing information on dry and wet weather flows under existing and future development conditions. The model created for that study was used as a starting point for this analysis.

Updated rainfall information was entered into the model with the focus on system performance during June 17-18, 2014. The flow meter data was then used as a guide to adjust the various flow generation components in the model for the area of interest to refine the system to better align with 2014 observed data.

Rainfall Data

Multiple rain events were recorded during the 2014 analysis period, with two being sufficient enough to cause the city to manually pump bypass water from the sanitary sewer system to avoid potential basement backups. Pumped bypassing in 2014 was required during the April 12-14 and June 17-18 rain events.

Table 2 shows the total rainfall for the April 12-14 and June 17-18, 2014 rain events.

Table 2
Rainfall Totals

Event	Total Rainfall Amount (in)
April 12-14, 2014	2.48
June 17-18, 2014	3.11

June event was selected for model adjustments for the following reasons:

- it was a more significant event;
- it caused bypassing in several locations throughout the City similar to the 2009 event;
- bypassing volume was greater; and
- the MMSD's master area-velocity flow meter for this system was not installed until June, 2014 and therefore did not meter the April 2014 event.

The original existing conditions model included rainfall from 2007 to 2009. A sensitivity analysis was run to determine the how much rain fall data was needed to fill up the soil storage reservoirs in the RDII model. It was determined that 2-years' worth of rainfall data is needed. The data collected from MMSD's rain gage WS1214 from 2012 through 2014 was entered into the model. For the April and June 2014 storm events, the data from the City rain gage, located at City Hall (over the City Clerks' office), was used. This was done to match the total depth of rain collected for the City of Mequon.

Model Adjustments

The model used for this study is Mike Urban version 2014, a proprietary model by the Danish Hydraulic Institute (DHI). The model uses the Rainfall Dependent Inflow and Infiltration (RDII) modules to simulate a fast (inflow), medium (rapid infiltration), and slow (interflow) I/I components. These components, when added together, make up the overall wet weather flow response for each sub-sewershed. Sub-sewershed time series flows are then routed through the sewer network to simulate water levels throughout the system, also known as hydraulic grade lines (HGLs).

The model treats inflow as originating from surface water runoff from either impervious or pervious areas of the basin. The amount of runoff reaching the sewer system as inflow is related to model parameters that represent the physical conditions of pertinent elements of the system. Inflow from impervious areas is typically very sensitive to the timing and intensity of rainfall. In pervious areas, runoff often is not generated until the ground becomes saturated, so inflow from these areas

exhibits a slower response to the timing and intensity of rainfall, depending upon the antecedent condition of the ground. The model simulates inflow using the time-area method. This is appropriate for representing inflow because it is directly linked to each rainfall event. The adjustable parameters in the model allow the user to calibrate peak flow, hydrograph volume and shape against measured flows.

The overall goal of the model adjustment process is to modify the model parameters to better match the observed flow response (peak flow, hydrograph volume and hydrograph shape) of the June 17-18, 2014 rainfall event.

The first objective was to adjust parameters to match the simulated peak flow to the measured peak flow at the flow metered locations. This was done by modifying parameters in the model as seen in Table 3. The bypass volume in the simulation is replicating the bypass pumping volume conducted by the City. Table 3 compares the measured peak flow against the simulated peak flow for the June 17-18, 2014 rain event.

Table 3
June 17-18, 2014 Peak Flow Comparison

Manhole ID	Flow Meter Peak Flow (cfs)	Simulated Peak Flow (cfs)	Percent Difference
430.108	8.5	8.9	4%
430.113	8.6	8.8	2%
430.115	8.1	8.9	9%
430.086	10.7	10.6	-1%
431.149	10.2	10.1	-1%
0431-176 Bypass Location - Volume (gal)	572,250	572,250	
431.175	10.9	10.6	-3%
431.169	11.4	10.5	-9%
432.005	16.5	18.3	10%

The simulated peak flows match well with to the metered peak flows and within desired tolerances. Differences between the model data and the actual system include the smaller number of sanitary sub-sewersheds modeled compared to the actual inflow location of sewers within the system, actual pumping scheme compared to the automated model characteristics, and other factors such as potential rainfall variations over the study area compared to the single rainfall event used in the model.

The secondary objective was to match the maximum hydraulic grade line (HGL) to the measured values from the flow meters and the sliding level indicators (SLIs). Variables that control the maximum HGL include the tailwater at the outfall of the system and system flows. The flow meter data collected at manhole MS0409 was used as a starting point for the tailwater condition at the outfall. Through an iterative process, this data was modified with flows until a satisfactory HGL was established. Table 4 compares the measured maximum simulated HGL to the simulated maximum HGL for the June 17-18, 2014 rain event.

Table 4
June 17-18, 2014 Maximum HGL Comparison

Manhole ID	Measured Maximum HGL (ft)	Simulated Maximum HGL (ft)	Difference (ft)
430.011	107.7	102.1	-5.7
430.108	99.5	98.3	-1.2
430.112	99.5	97.1	-2.4
430.113	97.6	96.6	-1.0
430.115	96.5	95.9	-0.6
430.086	95.6	95.1	-0.5
431.149	94.1	94.4	0.3
431.152	95.1	93.9	-1.2
431.175	92.9	93.4	0.5
431.169	91.4	91.5	0.2
431.021	90.6	91.2	0.6
432.005	89.8	90.0	0.3

	Surcharge Level Indicator (SLI) Data
	Flow Meter Data

At manhole 430.011, there is a significant difference in measured maximum HGL and simulated maximum HGL. This difference is caused by how the flow is being injected into the model. The flow to this manhole is only that from the forcemain, additional flow from the sewershed areas are being entered downstream of this location. Sub-sewersheds would have to be broken up and refined in order to raise the HGL at this location. However, this may not be necessary, since the overall behavior of the sewer systems follows the measured peak flow and maximum HGL behavior.

Figure 2 shows the simulated and measure maximum HGL profile of the sanitary sewer from the intersection of Sunnydale Lane and Hidden Reserve Circle south to the system outfall. The longer forcemain from the north enters the system just upstream of Zedler Lane and Port Washington Road at manhole 0431.020. The flat hydraulic grade line at the downstream portion of the profile indicates that the flow from the forcemain is causing an increase in the hydraulic grade line upstream. In other words, the system upstream of Zedler Lane and Port Washington Road is being backed up because of the flow from the forcemain downstream.

There are a few items to note about the collected meter data. There is a MMSD flow meter that is used to measure all flows from the City of Mequon and aids in setting the boundary conditions of the model (MMSD meter MS0409). However, the meter data does not appear to be valid for much of the storm event being analyzed. The meter appeared to stop recording data on June 18, 2014, during the intense part of the storm event, and a peak HGL was not recorded. In addition, the remaining meter data appeared to be offset/delayed approximately seven hours when compared to the model and rainfall timing. In order to closely align the recorded timing of the metered peaks and

simulated peaks, the flow meter data had to be shifted seven hours. MMSD should check the flow meter set up.

Overall, the model adjustment process went well and provides a very reasonable representation of how the system operated during the June 17-18, 2014 event. For the most part, the percent difference between peak flow values is from 0-10%.

Re-run 2009 model with 2014 Adjustments

After the model was calibrated for the June 2014 storm event, the 2009 rainfall was run with the model adjustments in place.

Table 6 displays the 2009 simulated peak flow compared to the peak flow of the 2009 rainfall with the updated existing conditions model. The results show that the 2014 model adjustment process lowered the peak flow upstream and downstream of the bypass. In addition, the peak flow is higher downstream of the bypass than upstream of it. This pattern is more consistent with what the City expected to see.

The only flow meter available for comparison in the 2009 event is at manhole 0430-086 which had a measured peak flow of about 9.8 cfs during the April 25-26 2009 event. The prior model had a peak flow that was higher at this point running about 10.4 cfs and the current model has a peak flow that is lower at about 8.6 cfs. However, since the 2014 event caused greater bypassing and has more data points for comparison with the additional flow meters, it is best to utilize the more current analysis associated with the June 2015 storm event.

Table 6
2009 Simulated Peak Flow Comparison

Manhole ID	April 2009 Simulated Peak Flow (cfs)	April 2009 with 2014 Revisions Simulated Peak Flow (cfs)
430.108	10.7	8.3
430.113	10.4	7.7
430.115	10.4	7.7
430.086	13.2	8.6
431.149	13.2	8.6
0431-176 Bypass Location - Volume (gal)	280,800 (measured)	280,800
431.175	11.1	9.3
431.169	12.2	9.0
432.005	17.8	16.5

Conclusions

While the areas of concern appear addressed, outfall conditions could not be validated for the June 2014 event because the data from meter MS0409 does not appear to be reliable for the peak of the event. This means that peak flows for system performance during the event in question cannot be evaluated at the connection point based on metered data for this event. Recently, the MMSD also installed a flow meter at another manhole in the City of Mequon system at 0532.082. This meter was installed and would have captured the more severe April 9, 2015 rain event that caused the most recent system surcharging and backup and hopefully the connection point meter was functioning properly. Because it will be necessary to evaluate peak flows at the connection point with some certainty and also to understand impacts associated with the recommended alternative or future variation of the alternative to improve system performance, it is recommended that the City consider evaluating the most recent event on April 9, 2015.

In summary, the overall results of the model adjustment efforts based on the June 17-18, 2014 storm event are very reasonable when compared to meter data and reports of system performance from City of Mequon staff. The two areas of concern appear to be addressed. The older model was over estimating flows upstream of the bypass which is now corrected. The refined model lowers these peak flows and is more aligned with the flow meter data. The model also exhibits the behavior observed in the field regarding the impact of the Zedler Lane forcemain on the existing system. Figure 2 shows that this forcemain has a tendency to cause an increased hydraulic grade line in the upstream portions of the system. It appears that this model is now better aligned with observed conditions and reasonable to use in the analysis of future improvement alternatives. It is also recommended that the June 17-18, 2015 event be used for the alternatives analysis because of the higher degree of confidence associated with the model adjustment process allowed by the expanded meter data and not the April 25-26 2009 event. However, it is also strongly encouraged that the City evaluates the meter data associated with the April 9, 2015 as a further verification event analysis that may also serve to provide more confidence of the results at the connection point.

Figure 1

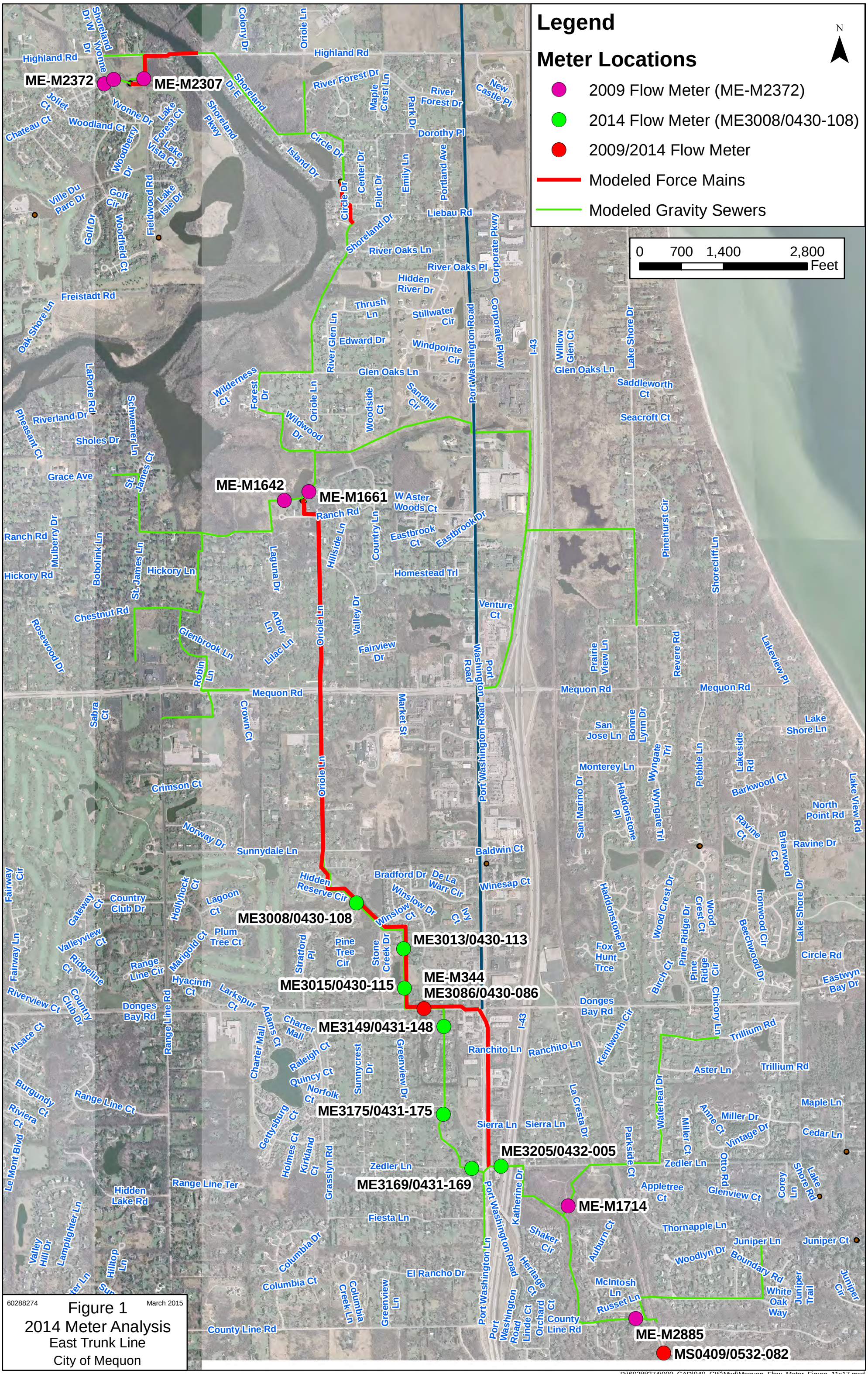

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Figure 1
2014 Meter Analysis
East Trunk Line
City of Mequon

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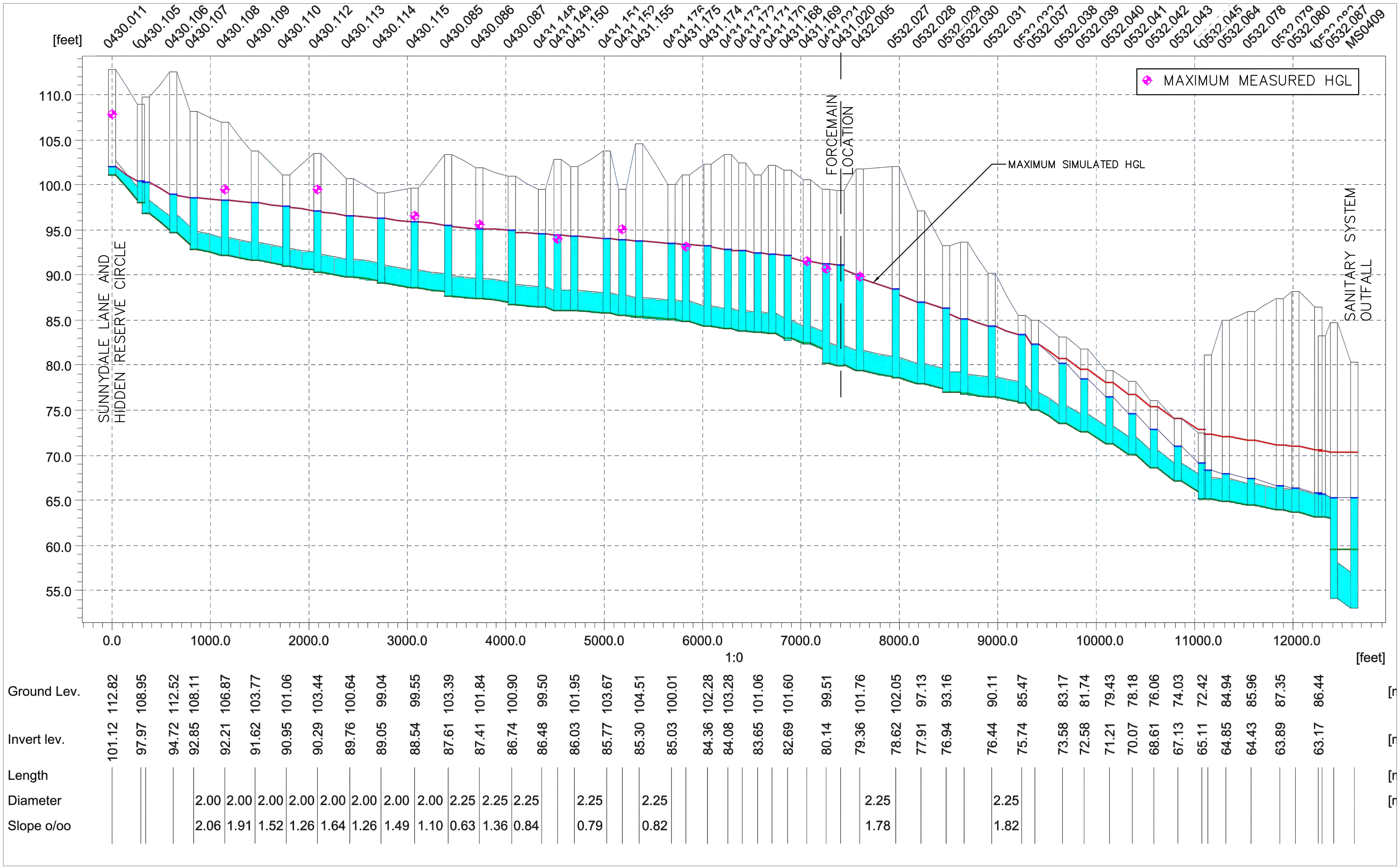
Figure 2

PROFILE OF SANITARY SEWER SYSTEM
MAXIMUM HYDRAULIC GRADE LINE (HGL)
JUNE 17–18, 2014 STORM EVENT