GREAT LAKES WATER AUTHORITY

DETROIT EAST SIDE FLOODING EVENT ANALYSIS
JULY 8 AND AUGUST 16, 2016

NOVEMBER 21, 2016

GLWA

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Executive Summary

On July 8, 2016, severe thunderstorms moved across the City of Detroit with the most intense rainfall occurring over the city's east side. The rainfall intensity and the resulting flows exceeded the design criteria for the combined sewage collection and conveyance system, causing basement flooding throughout the City of Detroit. The areas with the most concentrated number of flooded basements were on the east side of the city, in the Jefferson-Chalmers and Cornerstone neighborhoods.

Following the July 8, 2016 flooding event, representatives of the Great Lakes Water Authority (GLWA) and Detroit Water and Sewer Department (DWSD) attended a public meeting on July 20, 2016 organized by City of Detroit Councilman Spivey to provide the residents with information about the event. During the course of the public meeting, GLWA and DWSD stated their intention to further analyze the circumstances associated with the July 8th storm. This document presents the GLWA findings and the actions that GLWA is taking to address flooding in the east side of Detroit and continue to improve the overall level of service to the City of Detroit and other GLWA customers who are tributary to this area.

The July 8, 2016 storm was followed by another large storm on August 16, 2106. The rainfall associated with the August storm was less intense when compared to that of the July storm but still exceeded the design rainfall criteria. Following the storm, basement flooding was reported by some area residents. These reports were significantly fewer in number and geographically more widely scattered when compared to those of the July storm. After the occurrence of the August rain event and basement flooding reports, the GLWA decided to add the August event to the analysis which was already underway for the July event and prepare a single report.

To fully understand the circumstances surrounding these events, the investigation and analyses considered several distinct but related elements: prediction/warning of the July rainfall event; the intensity of the rainfall; the local and regional system's collection and conveyance systems' ability to convey the rainfall; the characteristics of the area and sewers where the flooding occurred, and the operators' responses to the rising sewer systems levels.

Rainfall intensity analyses concluded that both the rain events were more intense than the prescribed rainfall criteria used to design the east side collection and conveyance systems. The Michigan Department of Environmental Quality prescribes a rainfall criteria for combined sewer systems that is commonly referred to as the 10-year, one-hour event. This design criteria means that each and every year there is a 10 percent chance that a storm of this intensity will occur. Although varying rainfall distributions can be applied for the one-hour duration, the rainfall is commonly modeled as 1.89 inches of accumulated rainfall spread equally over four 15-minute intervals. A summary of the results of the analyses is included in the table below.

	System Design	**July 8, 2016 Event**	**August 16, 2016 Event**
Rainfall Forecast	-	70% Chance	100% Chance
Forecasted Warnings Issued?	-	No	Yes
Max Rainfall Intensity*	1.89 inches in a 1-hour period	2.98" in a 1-hour period	2.98" in a 3-hour period
Statistical Occurrence	Once in 10 Years	Once in 238 Years	Once in 23 Years
Probability of Occurrence	10%	<1%	<5%
Rainfall Exceeded Design Criteria?	-	Yes	Yes

*Rainfall data source: GLWA Rain Gauges and National Oceanic and Atmospheric Administration

The area with the most significant occurrence of basement flooding for both events is topographically very low and therefore vulnerable to both surface and basement flooding. Flows in a collection system are typically routed by gravity through a network of pipes starting in areas of higher elevation and leading to areas that are lower-lying. Flows are typically aggregated at lower points where they are treated and discharged or pumped up to shallower sewers to continue on to a location of treatment and discharge. These low points of aggregation are vulnerable to both surface and basement flooding. Large tracts of land in the area where the most basement flooding occurred are within the 100-year floodplain boundary as established by Federal Emergency Management Agency with some areas lying at or below the current water level of the Detroit River. The Detroit River is the water body to which wet weather flows are discharged. Homes having a ground elevation, and therefore basement elevations, below the receiving water level is very uncommon because they are more susceptible to flooding.

It should be noted that the local sewers in the areas of the basement flooding, which are owned and operated by the DWSD, have not been inspected and therefore their condition at the time of the July and August events is unknown. Further, it is known and has been reported that some areas in the city have local sewers that are not sized or properly installed to convey the 10-year, one-hour design storm. Together these two facts call into question the adequacy of the local sewers to convey flows as designed during the both the July and August storm events.

The low lying area is served by two pumping stations in the regional system that is leased and operated by GLWA. These are the Freud and Conner Creek pump stations. The area is also served by a single combined sewer overflow (CSO) retention and treatment basin (RTB). The wet weather flow patterns of these three facilities and their interconnections are very complex. GLWA staff members are trained to operate the facilities, operational protocols are documented and skilled staff members manage system flows during periods of heavy rain.

On July 8, 2016, weather monitoring services provided no advanced warnings predicting severe weather. After the rain started to fall, the levels in the sewer system rose rapidly and wet weather staff were dispatched across the city to wet weather facilities as the storm moved through the area. At GLWA's Freud pumping station, when wet well levels reached 71 feet, staff started storm water pumps as prescribed in their operational protocol. In rapid succession and within 15 minutes, staff started all six available storm water pumps. At GLWA's Conner Creek pump station, although six of eight storm water pumps were available to operate, problems with the station's vacuum priming system rendered the pumps effectively inoperable. Staff members that were deployed to the Conner Creek CSO basin were initially unable to access the facility due to street flooding in the area. Once able to access the facility, staff opened control gates which allowed discharge of water to the Detroit River. Although a detailed post-event review of the staff response indicated that it was both rapid and appropriate, the inoperability of some of the equipment and the street flooding hindered GLWA's ability to move water through the facilities as designed.

After considering the rapid rise of sewer levels that occurred during the July 8, 2016 storm, the GLWA modified their operational protocol for systems within the east side area to be able to respond more quickly. These changes included assigning staff round-the-clock (24/7) and modifications to the normal gate settings within the CSO basin. These modified gate settings allow the CSO basin to remain in a more "open state" at all times allowing flow through the facility without manual intervention. Also, engineers and operators focused intently on the operability of the Conner Creek pump station's vacuum priming system and were able to make some modifications which have promise to improve their ability to prime the pumps.

Then came the rain event that occurred on August 16, 2016. Although it was not as large and intense as the July 8, 2016 storm, the flow rates it generated approached the capacity of the regional collection system. During this storm, five out of eight storm water pumps were in operation at the Freud pump station and two of the eight storm water pumps were put into operation at the Conner Creek pump station. The combination of a less intense storm and the more "open state" of the CSO basin provided a condition that significantly reduced the wet weather impacts on the system, however basement flooding did occur.

Beyond what was initially done by way of changes to the operating protocol and equipment, GLWA has identified additional opportunities to further improve the wet weather operations in this area. A number of immediate and near-term improvements have been identified, a funding source has been secured and work on the projects is underway. In total, the immediate and near term projects are estimated to have a total cost of $12,000,000. The projects in summary are noted below.

Immediate Projects (Complete)

- Round-the-clock staffing of the Conner Creek CSO Basin (24/7) until such a time as automation and remote operating capability has been increased
- Staffing at the Conner Creek and Freud pumping stations when rain occurs anywhere in the collection system
- Changes in the operational protocol to maintain gate positions in a more “open state” at the CSO basin to improve early flow through characteristics
- Modifications to operational protocol at a downstream pumping station known as Fairview whereby pumps are run continuously through rain events. It should be noted that this likely results in increased volume and frequency of raw sewage discharges for some events, however, it is more protective of basements
- Repair of the two storm water pumps at the Freud pumping station
- Evaluation and recommendation for modification to the vacuum priming system at the Conner Creek pump station to improve reliable operability of the pumps

Near Term Projects (In Process)

- Permanent modifications to the vacuum priming system at the Conner Creek pump station to improve reliable operability of the pumps
- Repair and improvements of the instrumentation and controls at the CSO basin to increase automation and remote operability
- Repair of select effluent gates, flushing system and disinfection system at the CSO basin
- Upgrade or automation of various control gates in the collection system
- Cleaning, inspection and rehabilitation of major trunk sewers in the east side system.

In conclusion, the primary cause of the basement flooding that occurred during the July 8, 2016 and August 16, 2016 storms was intense rainfall resulting in sewer system flows that exceeded the design criteria for the local and regional systems. GLWA staff members responded timely and with appropriate actions, however, the inoperability of key equipment in the regional system, namely pumps and pumping systems, hindered the ability of the regional system to perform as designed. Finally, it is known that some of the local sewers are not adequate to convey the prescribed design event and the condition of the local sewer system is unknown due to lack of inspection. As such, the ability of the local pipes to adequately convey the wet weather flows on July 8, 2016 and August 16, 2016, is questionable.

1.0 Introduction

On July 8, 2016, a severe thunderstorm moved across the City of Detroit with the most intense rainfall occurring over the city's east side. The rainfall intensity and the resulting flows exceeded the design criteria for the combined sewage collection and conveyance system, causing basement flooding throughout the City of Detroit. The areas with the most concentrated number of flooded basements were on the east side of the city in the Jefferson-Chalmers and Cornerstone neighborhoods. The peak flow rate into the Conner Creek Combined Sewer Overflow Basin (CSO basin) during this storm is estimated to have been 14,059 cfs. This peak flow rate is approximately 6% greater than the 10-year design flow rate of 13,262 cfs.

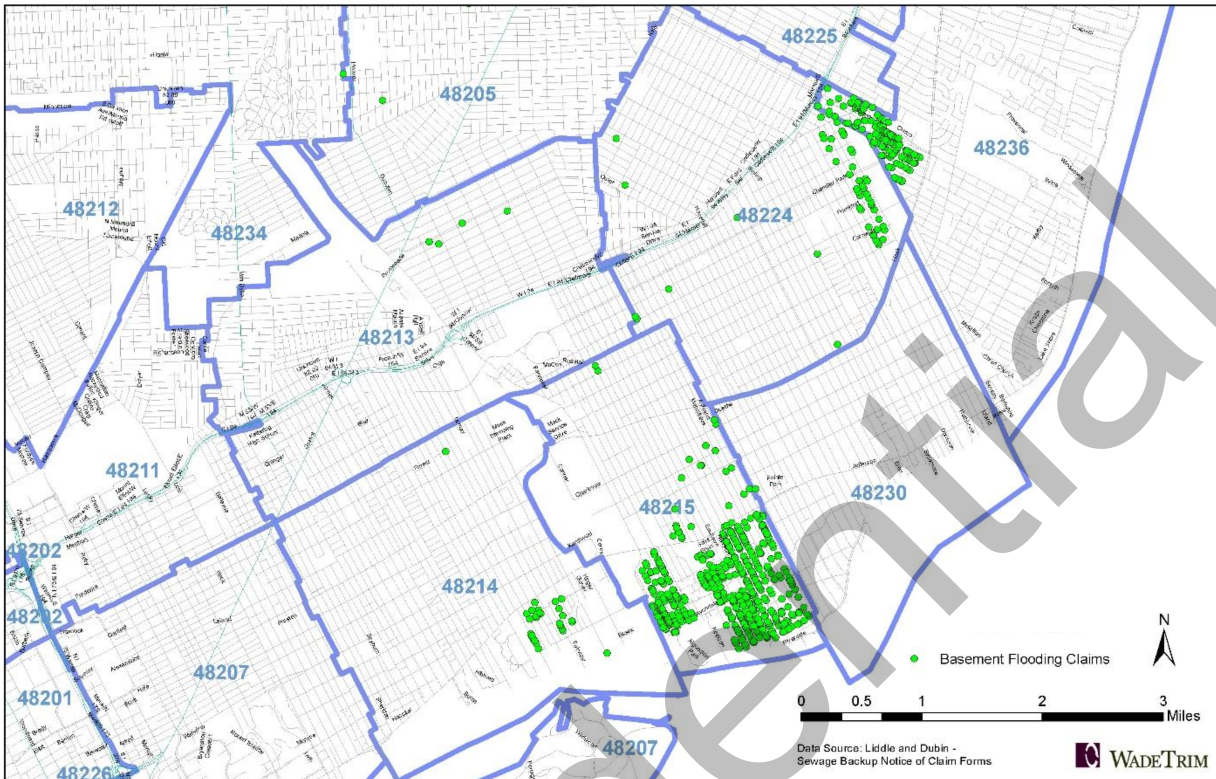
A map showing the addresses with basement flooding claims from the July 8, 2016 storm compiled by Liddle and Dubin is presented in **Figure 1.1**. These claims show clusters of basement flooding in the 48214, 48215, 48224, and 48236 zip codes. The area with the most significant amount of basement flooding claims is in the 48215 zip code. This area is referred to as the Jefferson-Chalmers neighborhood. This neighborhood is in a topographically low-lying area that is reflected in the Federal Emergency Management Agency (FEMA) floodplain map presented in **Figure 1.2**. This map shows that a significant amount of this neighborhood is within the 100-year floodplain. The areas outside of the Jefferson-Chalmers neighborhood are on higher ground and outside of the 100-year floodplain.

Following the July 8, 2016 flooding event, representatives of the Great Lakes Water Authority (GLWA) and Detroit Water and Sewer Department (DWSD) attended a joint public meeting on July 20, 2016 organized by City of Detroit Councilman Spivey to provide the residents with information about the storm and to get feedback from the residents about storm impacts. At this meeting, residents were encouraged to fill out forms and identify the addresses impacted by flooding. Residents filled out 90 forms as part of this meeting. A review of the comments on these forms shows there were approximately 67 comments or questions related to basement flooding. During the course of public meeting, GLWA and DWSD stated their intention to further analyze the circumstances associated with the July 8th storm and prepare a report of their findings. This document presents the GLWA findings and the actions that GLWA is taking to address flooding in the east side of Detroit and continue to improve the overall level of service to the City of Detroit and other GLWA customers who are tributary to this area

The July 8, 2016 storm was followed by another large storm on August 16, 2106. Although this storm was not as severe as the July 8th event, the rainfall totals again exceeded the design storm rainfall for the system. Due to the intensity of the storm, flow rates in the system approached the 10-year design flow rates. This storm also resulted in basement flooding. A map showing the addresses with basement flooding claims from the August 16, 2016 event compiled by Liddle and Dubin is presented in **Figure 1.3**. These reports were significantly fewer in number within the Jefferson-Chalmers and Cornerstone neighborhoods and geographically more widely scattered when compared to those of the July storm. This map also shows the basement flooding claims extending into the communities north of 8 Mile Road. After the occurrence of the August rain event and basement flooding reports, the GLWA decided to add the August storm event to the analysis which was already underway for the July storm event and prepare a single report.

The purpose of this report is to provide an understanding of the circumstances surrounding these storm events. The investigation and analyses considered several distinct but related elements: prediction/warning of the July rainfall event; the intensity of the rainfall; the local and regional system's collection and conveyance systems' ability to convey the rainfall; the characteristics of the area and sewers where the flooding occurred, and the operators' responses to the rising sewer systems levels. This report summarizes the major physical components of the system and data recorded from system instrumentation. The report also identifies immediate operational changes that have been implemented, as well as near-term system improvements and future flood mitigation actions; all directed toward mitigating basement flooding in the future.

Figure 1.1: East Side Flooding Areas - July 8, 2016 Storm



Source: Basement flooding claims compiled by Liddle and Dubin

Figure 1.2: East Side FEMA 100-Year Floodplain

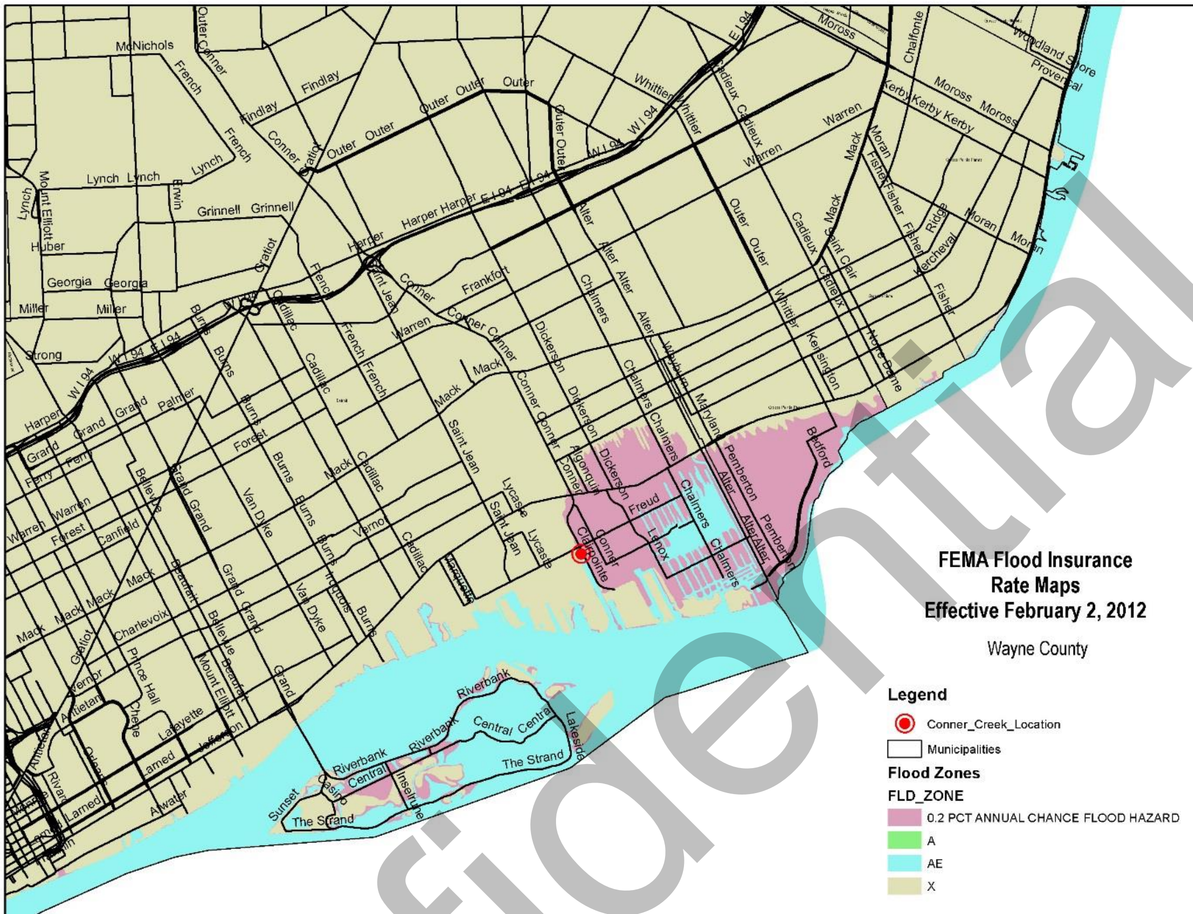
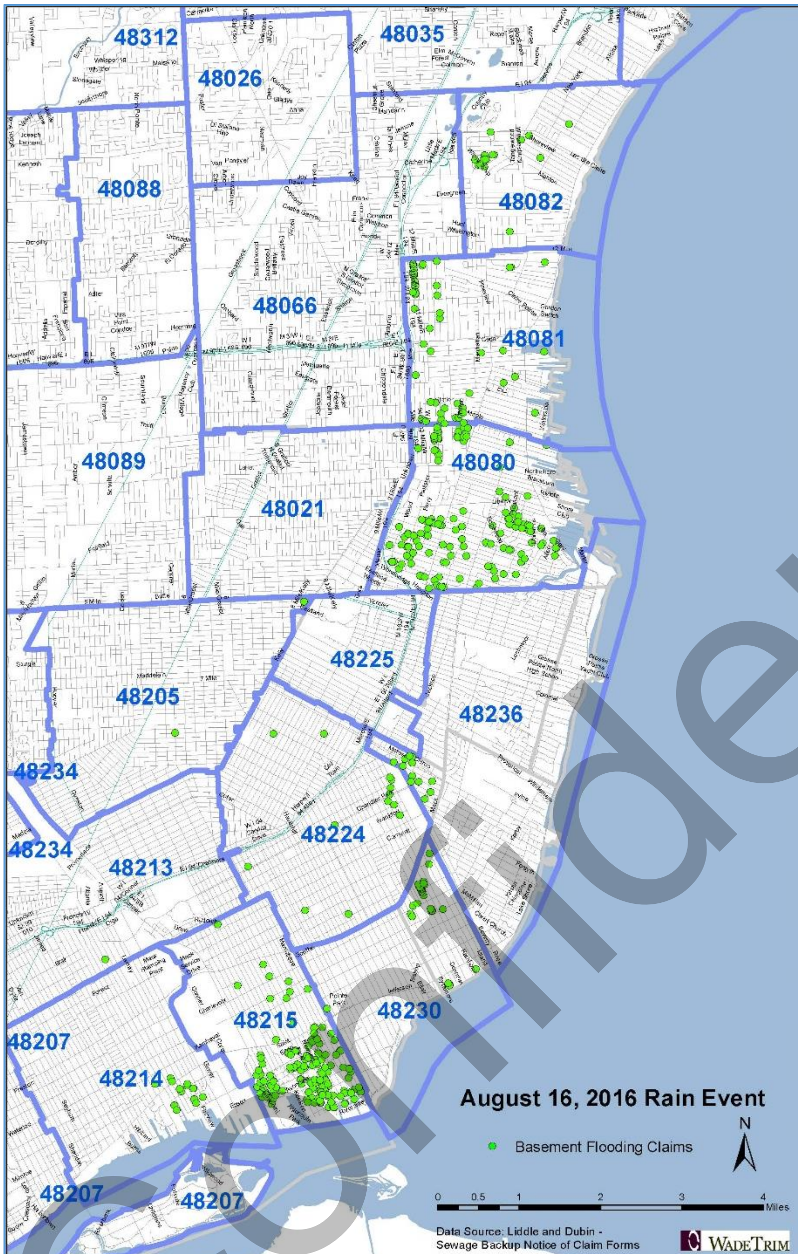


Figure 1.3: East Side Flooding Areas – August 16, 2016 Storm

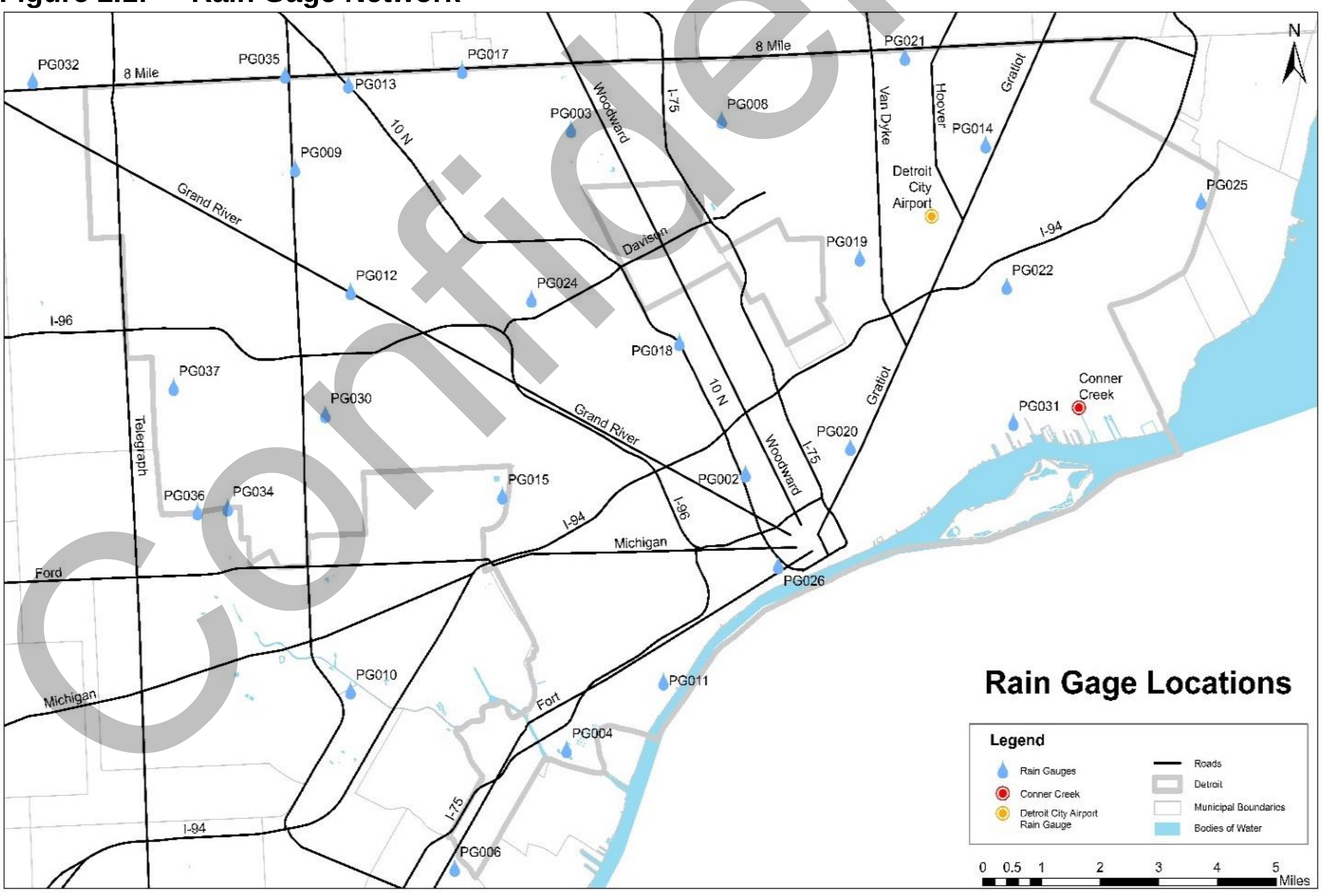


Source: Basement flooding claims compiled by Liddle and Dubin

2.0 Rainfall Analysis

There is substantial rainfall data available for the July 8 and August 16, 2016 storms. Rainfall data available for these storms includes an extensive rain gage network that is maintained by the Great Lakes Water Authority (GLWA) and the National Oceanic and Atmospheric Administration (NOAA). Also available are radar rainfall data collected and compiled by NOAA. Due to the number of GLWA rain gages within the Detroit area, the rainfall analysis focused almost primarily on the use of the ground-based rain gages while using radar rainfall data to confirm rainfall distribution and storm direction. A map showing the location of the ground-based rain gages available for this analysis is presented in **Figure 2.1**. The GLWA rainfall data is routinely collected in 5-minute increments and the NOAA data is routinely collected in 15-minute increments. The GLWA and NOAA rainfall data was retrieved for the duration of these two storms.

Figure 2.1: Rain Gage Network



The rainfall data for both storms were analyzed to determine the total rainfall for the event, peak rainfall period during the event, annual probability of occurrence, and the rainfall distribution. For each event, the rainfall data from the 35 available gages were reviewed for accuracy through a quality control review of the data and a comparison to the radar rainfall measurements. Data with obvious errors or variations in rainfall patterns when compared to adjacent gages or radar rainfall data were rejected from the analysis.

Rainfall annual probabilities of occurrence for a range of rainfall durations were based on the NOAA Rainfall Atlas 14, Volume 8, Version 2 for intervals 1 year and greater. Intervals less than one year were based on the Midwest Climate Center Bulletin 71.

The annual probability of occurrence is a method used to characterize the magnitude of a storm event. In general terms, the lower the probability of occurrence is (more rare), the more severe the storm is. Annual probability of occurrence can be related to an estimated frequency of occurrence, which is referred to as return frequency. For example, an event with a 4% annual probability of occurrence can be expected to have a return frequency of once every 25 years, also known as a 25-year storm. This does not mean that if a 25-year storm occurs on a given year that it will not occur for another 25 years. To the contrary, in any given year there is always a 4% chance of that size storm occurring regardless of what storms have occurred in the past. To better explain the relationship of annual probability of occurrence to return frequency, **Table 2.1** was developed for the 100% through 0.5% annual probability of occurrence.

Table 2.1:
Relationship of Annual Probably of Occurrence to Return Frequency

Annual Probability of Occurrence (%)	Return Frequency (years)
100	1
50	2
20	5
10	10
4	25
2	50
1	100
0.5	200

Every rain event is unique and has variations in total rainfall volume, storm intensity, and rainfall distribution. For example, summer thunderstorms tend to have relatively shorter durations with high rainfall intensities, while early spring or late fall storms will typically be less intense over a longer duration. Each of these storms can be assigned a probability of occurrence. To thoroughly characterize a storm, a critical duration must also be assigned. A short duration storm with an intense period of rainfall may be classified as having a 1-hour critical duration and be called a 1-hour storm, while a long duration event may be classified as having a 24-hour critical duration and be called a 24-hour storm. It is important to properly classify each storm event based on its critical duration when assigning an annual probability of occurrence. For example, a storm with 2 inches of rain falling over a 1-hour period would be properly classified as a 1-hour storm with a 4% annual probability. If the critical duration is ignored, and this same 2-inch, 1-hour storm is averaged over a 24-hour duration, it would be mis-classified as having a 100% annual probability (i.e. expected to occur every year on average).

The storm that occurred on July 8th was a stand-alone storm that did not have a significant amount of rainfall preceding the storm. Storms that occur after preceding rainfall (back-to-back storm events) will have wet antecedent soil moisture conditions that will increase the effective amount of surface runoff, thus increasing the flow rates in the collection system. This increased runoff from back-to-back storms can push a sewer system beyond its design condition even though the total rainfall is less than the design storm. Back-to-back storms are defined as multiple storms occurring close enough together in time to influence the stress on the collection system.

A review of the rain data that preceded the August 16, 2016 storm shows rainfall occurred prior to this storm, causing a treated overflow from the Conner Creek CSO basin on August 14, 2016. Based on this information, the August 16, 2016 storm can be classified as a back-to-back storm. The back-to-back storm impacts include the following:

1. Antecedent Soil Moisture Conditions
   Additional rainfall occurring before the soil infiltration capacity has had time to recover will result in a larger fraction of rainfall falling on soil areas turning into inflow to the sewer system. This condition will tend to increase the peak flow for that storm.
2. System Storage
   All sewer systems have a certain amount of system storage that can help to reduce (attenuate) the peak flow rates during storms. The east side system storage includes in-system storage in the form of large sewers and the Conner Creek CSO basin. If a subsequent storm occurs prior to dewatering the system storage, there will be less opportunity to attenuate the peak flow rate.

The following provides a summary of the analysis that was performed separately for the July 8, and August 16, 2016 storms.

2.1 July 8, 2016 Rainfall Analysis

The July 8, 2016 storm was a fast-moving thunderstorm traveling from west to east with a typical north-south alignment. The storm severity increased as it approached the Detroit River and continued through the northeast area of the City of Detroit. A review of the radar rainfall data for this storm shows the storm building in intensity as it passes over the central and east portion of the City of Detroit.

A review of the GLWA ground-based rain gage data shows accurate data was collected at all gages with exception of PG010, PG013, PG020, PG026, PG027, PG032, and PG034. The data collected at these rain gages was rejected due to missing data or data that was inconsistent with surrounding gages or the available radar rainfall data. A review of the temporal distribution of the rainfall shows the peak rainfall intensity occurred during the peak hour of the storm. As a result, the annual probability of occurrence calculated for this storm was based on the peak 1-hour rainfall period. The total storm rainfall, peak hour rainfall, and peak hour annual probability of occurrence is presented in **Table 2.2**. Rain gages within the east side system are highlighted yellow.

For this table, the annual probability of occurrence is defined as the likelihood that a one-hour rainfall intensity of a given magnitude would occur in any one year. The probability of occurrence is annual; so each year the likelihood of that rainfall intensity happening again is repeated. For example, from **Table 2.2**, the peak hour rainfall from precipitation gage PG014 was 2.60 inches which has a peak hour annual probability of occurrence of 1.04%. Each year, there is a 1% probability that a storm could deliver a 1-hour rainfall intensity of a 2.60 inch magnitude.

Table 2.2: Summary of July 8, 2016 Rainfall Data

Rain Gage ID	Rainfall Total (in)	Peak Hour Rainfall (in)	Peak Hour Annual Probability of Occurrence (%)
PG002	1.04	0.96	100.00
PG003	2.07	1.26	29.92
PG004	0.46	0.28	100.00
PG005	3.47	2.65	0.91
PG006	0.76	0.55	100.00
PG007	1.85	1.29	28.02
PG008	1.91	1.39	21.94
PG009	1.41	1.27	29.69
PG010	0.00	0.00	-
PG011	0.51	0.41	100.00
PG012	1.14	1.07	61.25
PG013	0.00	0.00	-
PG014	3.28	2.60	1.04
PG015	0.09	0.06	100.00
PG017	2.41	1.49	16.24
PG018	1.29	1.12	51.08
PG019	2.50	2.39	1.64
PG020	0.00	0.00	-
PG021	2.89	2.50	1.27
PG022	3.20	2.98	0.42
PG024	1.57	1.17	42.44
PG025	2.27	2.06	3.69
PG026	2.74	0.91	100.00
PG027	0.03	0.03	100.00
PG028	0.81	0.61	100.00
PG029	0.60	0.30	100.00
PG030	0.46	0.39	100.00
PG031	1.67	1.57	12.70
PG032	0.00	0.00	-
PG033	0.85	0.79	100.00
PG034	0.00	0.00	-
PG035	0.69	0.51	100.00
PG036	0.10	0.10	100.00
PG037	0.90	0.89	100.00
City Airport	2.99	2.55	1.14

Rain gages within the east side area

The data presented in the above table was used to develop two separate isohyet maps that show the distribution of the total rainfall and the peak hour rainfall for this storm. These maps are presented the **Appendix 1** of this report. A review of these maps shows the highest rainfall intensities in Detroit were concentrated in the east side system. A separate map was developed to show the distribution of the peak hour annual probability of occurrence. This return period map is also presented in **Appendix 1** of this report. The areas with the highest rainfall intensities and lowest annual probability of occurrence are also centered on the east side of Detroit. Much of this area received peak hour rainfalls with an annual probability lower than 4 % with significant areas receiving rainfall with an annual probability lower than 2 %.

2.2 August 16, 2016 Rainfall Analysis

The August 16, 2016 storm was also a fast-moving thunderstorm traveling from west to east with a typical north-south alignment. The severity of this storm was less intense but had a larger area of coverage when compared to the July 8, 2016 storm. For the August 16th storm, the areas with the largest rainfall totals extended along the area adjacent to Detroit River from Schaefer Highway near Zug Island, through Downtown Detroit, and up to Moross Road near Harper Woods. Due to prior rainfall occurring on August 13 and 14, 2016, the August 16th storm is classified as a back-to-back storm with wet antecedent soil moisture conditions.

A review of the GLWA ground-based rain gage data shows accurate data was collected at all gages with exception of PG010, PG013, PG021 PG025, PG026 and PG032. The data collected at the aforementioned rain gages was rejected due to missing data or data that was inconsistent with surrounding gages or the available radar rainfall data. A review of the temporal distribution of the rainfall shows the peak rainfall intensity occurred during the peak 3-hour period of the storm. As a result, the annual probability of occurrence calculated for this storm was based on the peak 3-hour rainfall period. The total rainfall, peak hour rainfall, peak 3-hour rainfall, and peak 3-hour rainfall annual probability of occurrence is presented in **Table 2.3**. Rain gages tributary to the east side system are highlighted yellow. Many of these highlighted rain gages show peak 3-hour rainfall intensities with an annual probability of occurrence less than 10%.

For this table, the annual probability of occurrence is defined as the likelihood that a 3-hour rainfall intensity of a given magnitude would occur in any one year. As stated previously, the probability of occurrence is annual; so each year the likelihood of that rainfall intensity happening again is repeated. For example, from **Table 2.3**, the peak 3-hour rainfall from precipitation gage PG031 was 2.26 inches which has a peak 3-hour annual probability of occurrence of 10%. Each year, there is a 10% probability that a storm could deliver a 3-hour rainfall intensity of a 2.26 inch magnitude. The probability of occurrence does not take into account the antecedent moisture effects of a back-to-back storm, such as the August 16th storm; this condition will result in flow rates in the sewer system that are even more rare than the storm annual probability of occurrence suggests.

Table 2.3: Summary of August 16, 2016 Rainfall Data

Rain Gage ID	Rainfall Total (in)	Peak Hour Rainfall (in)	Peak Hour Annual Probability of Occurrence (%)	Peak 3 Hour Rainfall (in)	Peak 3 Hour Annual Probability of Occurrence (%)
PG002	2.61	1.54	13.88	2.33	8.25
PG003	1.81	0.77	100.00	1.52	49.94
PG004	2.88	1.78	7.06	2.67	4.48
PG005	2.32	1.20	37.06	2.05	14.48
PG006	1.97	1.70	9.23	1.96	17.89
PG007	1.62	0.67	100.00	1.43	62.16
PG008	0.09	0.09	100.00	0.09	100.00
PG009	1.86	0.88	100.00	1.67	32.02
PG010	-	-	-	-	-
PG011	2.98	1.90	5.22	2.79	3.71
PG012	1.92	0.96	99.99	1.73	27.97
PG013	-	-	-	-	-
PG014	2.86	1.58	12.49	2.55	5.34
PG015	1.70	0.86	100.00	1.46	57.62
PG017	1.96	0.93	100.00	1.75	26.84
PG018	2.80	1.65	10.64	2.51	5.72
PG019	2.52	1.49	16.13	2.27	9.71
PG020	2.80	1.81	6.49	2.61	4.88
PG021	-	-	-	-	-
PG022	2.94	1.72	8.56	2.68	4.42
PG024	1.75	0.83	100.00	1.53	48.14
PG026	-	-	-	-	-
PG027	2.69	1.46	17.87	2.39	7.20
PG028	1.78	0.90	100.00	1.57	42.11
PG029	1.56	0.63	100.00	1.26	100.00
PG030	1.71	0.86	100.00	1.52	50.03
PG031	2.45	1.39	21.74	2.26	10.00
PG033	1.54	0.87	100.00	1.42	63.89
PG034	1.95	0.99	84.99	1.74	27.40
PG035	1.81	0.83	100.00	1.56	43.50
PG036	0.43	0.23	100.00	0.40	100.00
PG037	1.45	0.67	100.00	1.32	88.45

(yellow) Rain gages within the east side area

The data presented in the above table was used to develop two separate isohyet maps that show the distribution of the total rainfall and the peak 3-hour rainfall for this storm. These maps are presented in **Appendix 1** of this report. A review of these maps shows the highest rainfall intensities occurred along the Detroit River and on the east side of Detroit. A separate map was developed to show the distribution of the annual probability of occurrence. This annual probability of occurrence map is presented in **Appendix 1** of this report. The areas with the highest rainfall intensities and lowest probability of occurrence include downtown Detroit and the areas on the east side. Although this storm was less severe than the July 8th storm, the peak 3-hour annual probability of occurrence was less than the 10% annual probability of occurrence design condition with peak 3-hour rainfall annual probability of occurrence less than 5%. The peak 1-hour annual probably of occurrence was also less than 10% at multiple locations throughout the city. Further, due to wet antecedent soil moisture conditions, it is probable that flow rates in the collection system were intensified during the peak 3-hour period.

2.3 August 11, 2014 and May 25, 2011 Rainfall Analysis

Although the storms occurring on July 8, and August 16, 2016 are the focus of this report, the storms (with reported basement flooding) that occurred on August 11, 2014 and May 25, 2011 have also been evaluated. For each of these storms, a similar rainfall analysis of the GLWA rain gage network was performed to determine rainfall totals and the annual probability of occurrence. The results from this analysis are presented in **Tables 2.4** and **2.5**. Based on this data, rainfall maps were developed and included in **Appendix 1**. A review of these rainfall maps shows the August 11, 2014 storm had an annual probability of occurrence of less than 1% and the May 25, 2011 storm had an annual probability of occurrence of less than 2% in the areas tributary to the east side. As stated before, these probabilities of occurrence apply each and every year.

The August 11, 2014 storm was historic in many respects, with over 4 inches of rain within a 6-hour period at several rain gage locations indicating heavy rainfall over a widespread area. The 1-hour rainfall intensity for the August 11, 2014 storm was also significant; but it was far surpassed by the 1-hour peak rainfall on July 8, 2016.

Table 2.4: Summary of August 11, 2014 Rainfall Data

Rain Gage ID	Rainfall Total (in)	Peak 1-Hour Rainfall (in)	Peak 1-Hour Annual Probability of Occurrence (%)	Peak 6-Hour Rainfall (in)	Peak 6-Hour Annual Probability of Occurrence (%)
PG002	4.30	1.22	34.48	3.84	1.40
PG003	3.93	1.20	37.04	3.62	2.02
PG004	4.06	1.85	5.85	3.38	2.75
PG005	1.72	0.52	100.00	1.57	83.33
PG006	2.41	1.06	62.96	1.92	33.08
PG007	2.74	1.21	35.71	2.29	16.60
PG008	5.00	1.79	6.86	4.69	0.45
PG009	4.46	2.16	2.83	4.07	1.05
PG010	2.74	1.08	58.62	2.20	20.28
PG011	3.43	1.22	34.48	2.80	6.55
PG012	4.53	1.97	4.53	4.09	1.03
PG013	3.43	1.16	43.48	3.22	3.61
PG014	4.12	1.58	12.50	3.90	1.29
PG015	2.97	0.80	100.00	2.63	9.27
PG017	2.94	0.90	100.00	2.74	7.31
PG018	4.46	1.83	6.15	4.19	0.88
PG019	4.61	1.52	14.71	4.32	0.72
PG020	3.74	1.10	54.84	3.52	2.27
PG021	4.51	1.52	14.71	4.34	0.70
PG022	3.34	0.92	100.00	2.95	5.21
PG024	5.27	2.04	4.00	4.90	0.32
PG025	2.95	0.79	100.00	2.71	7.76
PG026	3.52	1.07	60.71	3.12	4.22
PG027	-	-	-	-	-
PG028	4.09	1.75	7.74	3.64	1.96
PG029	1.37	0.27	100.00	0.89	100.00
PG030	3.91	1.64	10.87	3.67	1.85
PG031	3.74	1.44	19.23	3.36	2.83
PG032	3.25	0.93	100.00	2.91	5.51
PG033	3.38	0.99	85.00	2.95	5.21
PG034	4.90	1.90	5.22	4.34	0.70
PG035	7.45	2.96	0.45	6.86	0.09
PG036	8.38	3.17	0.27	7.39	0.08
PG037	8.88	3.64	0.10	8.01	0.07

(Yellow) Rain gages within the east side area

Table 2.5: Summary of May 25, 2011 Rainfall Data

Rain Gage ID	Rainfall Total (in)	Peak Hour Rainfall (in)	Peak 1-Hour Annual Probability of Occurrence (%)	Peak 12-Hour Rainfall (in)	Peak 12-Hour Annual Probability of Occurrence (%)
PG002	2.13	0.67	100.00	2.13	38.66
PG003	3.45	1.59	12.20	3.45	4.42
PG004	1.82	0.70	100.00	1.82	84.37
PG005	--	--	--	--	--
PG006	1.57	0.67	100.00	1.57	100.00
PG007	2.03	0.53	100.00	2.03	50.94
PG008	3.62	1.33	25.00	3.62	3.52
PG009	3.48	1.42	20.41	3.48	4.29
PG010	1.52	0.71	100.00	1.52	100.00
PG011	1.77	0.70	100.00	1.77	100.00
PG012	3.45	1.68	10.00	3.45	4.42
PG013	3.06	1.02	73.91	3.06	7.50
PG014	3.93	1.63	11.11	3.93	2.29
PG015	1.03	0.58	100.00	1.03	100.00
PG017	2.67	0.87	100.00	2.67	14.24
PG018	2.46	0.87	100.00	2.46	21.10
PG019	3.10	1.58	12.50	3.10	7.00
PG020	2.02	0.63	100.00	2.02	51.92
PG021	3.48	1.36	23.26	3.48	4.29
PG022	2.91	1.45	18.52	2.91	10.12
PG024	3.99	1.43	20.00	3.99	2.15
PG025	4.13	2.35	1.87	4.13	1.77
PG026	1.65	0.48	100.00	1.65	100.00
PG027	--	--	--	--	--
PG028	2.17	0.87	100.00	2.17	35.11
PG029	1.58	0.38	100.00	1.58	100.00
PG030	2.71	0.70	100.00	2.71	13.33
PG031	1.96	0.72	100.00	1.96	58.70
PG032	3.03	0.97	94.44	3.03	7.92
PG033	4.05	1.87	5.58	4.05	2.02
PG034	2.67	0.64	100.00	2.67	14.24
PG035	--	--	--	--	--
PG036	--	--	--	--	--
PG037	--	--	--	--	--

Rain gages within the east side area

3.0 East Side Collection and Conveyance System

An overview of the east side collection and conveyance systems (east side system) that are tributary to the GLWA Fairview PS is given in this section. A map of the service areas, figures showing the layout and connectivity of the conduits, the pump station capacities and the general operating procedures of the pump stations and wet weather facilities are presented in this section.

Information was collected and summarized from the DWSD Segmented Facilities Plan (1978), the O&M manuals for the GLWA-operated pump stations (various years), the revised basis of design (BOD) for the Conner Creek CSO Basin (2000), a report prepared for Bluehill PS improvements titled "Fourth Pump Evaluation and Surge Study" (2003), and the Wayne County Fox Creek District Facility Plan (1983). Also, a detailed schematic that was previously prepared using as-built sewer drawings was updated and included in this section.

There is an extensive network of sewers, pump stations, regulators, gates and a CSO Basin tributary to the Fairview PS. An overview schematic of the east side system is shown on **Figure 3.1**. The east side system includes facilities owned and/or operated by the Southeast Macomb Sanitary District (SEMSD), the Wayne County Northeast Sewage Disposal System (NESDS), the Wayne County Milk River and Fox Creek Districts, the Grosse Pointe communities, DWSD and GLWA. The east side system areas are shown on **Figure 3.2** along with rain gauge locations.

A detailed schematic of the east side system is shown on **Figure 3.3**. The detailed schematic shows the major sewers with conduit dimensions and invert elevations, the pump stations and the CSO Basin. The GLWA-operated pump station capacities and normal range of wet well levels are summarized in **Table 3.1**.

Table 3.1:
Summary of GLWA Operated Pump Stations

Pump Station	Firm Rated Capacity (cfs)	Total Rated Capacity (cfs)	Normal Range of Wet Well Levels (feet Detroit datum)
Fairview	375	525	67 to 77
Conner Creek Sanitary	224	333	59 to 65
Conner Creek Storm	3,500	4,000	65 to 79
Freud Sanitary	20	55	25 to 65
Freud Storm	3,150	3,600	45 to 75
Bluehill Sanitary	10	20	68 to 72.5
Bluehill Storm	951	1,338	67 to 82

3.1 Fairview Pump Station

The Fairview PS was constructed in 1910 and serves to lift wastewater in the upstream Detroit River Interceptor (DRI) segment into a downstream DRI segment. An overflow to a canal exists on the DRI just upstream of Fairview PS. Backwater gates exist to prevent river flow into the DRI. Overflow to the canal occurs if the wet well level exceeds the river level. The GLWA does not have a Michigan Department of Environmental Quality (MDEQ) permit to discharge from this overflow. A surge chamber exists on the discharge side of Fairview PS to re-circulate surge flows back to the wet well if the downstream hydraulic grade line elevation exceeds 102 feet.

The Fairview PS has four sanitary pumps; three with a rated capacity of 150 cfs and one with a rated capacity of 75 cfs. The pumps are designed and operated to maintain the wet well level in the range of 67 to 77 feet. In dry weather conditions, one pump normally operates to keep the wet well in this range. In wet weather, the PS can achieve a peak pumping rate of 375 cfs into the downstream DRI.

Since about 2013, the Fairview PS has been generally turned off during peak wet weather conditions as part of the DWSD/GLWA adaptive management approach to reducing untreated CSO. When Fairview PS is turned OFF, the upstream flows in the DRI are directed to the Conner Creek PS through overflow connections between the DRI and the East Jefferson Relief sewer. The DRI flows are thereby directed to the Conner Creek CSO Basin through storm pumping at Conner Creek PS or Freud PS. This adaptive management approach provides additional capacity in the downstream DRI to receive flow from the numerous downstream trunk sewer connections that otherwise would create untreated CSO discharges. While adaptive management is supported by MDEQ as an operational means to further reduce the occurrence and duration of untreated CSO discharges, in a letter dated August 16, 2016, MDEQ stated that Fairview PS is to continue to operate during wet weather periods.

3.2 Detroit River Interceptor

The upstream segment of the DRI is a brick sewer that was constructed in 1908 and 1909. This segment of the DRI receives combined wastewater from DWSD owned/operated gravity laterals between Fairview PS and Conner Creek PS and at Alter Road, the Conner Creek PS sanitary pumps, the regulated flow rates from the Conner Creek Enclosure (CCE), and the discharge from the Grosse Pointe Park PS. Also, the DRI receives dewatering flow from the Conner Creek CSO Basin and filter backwash from the Waterworks Park (WWP-II) water treatment plant.

As shown on **Figure 3.3**, the upstream segment of the DRI varies from 8 to 9 feet in diameter. The invert of the DRI is generally about 20 to 30 feet below grade. The East Jefferson Relief sewer was constructed to relieve the DRI in the east side area. There are overflow structures between the DRI and the East Jefferson Relief sewers at Montclair and Tennessee that normally limit the surcharging on the DRI (assuming normal wet well levels in the Conner Creek and Freud PS). Overflow normally occurs from the DRI into the deeper East Jefferson Relief sewers whenever the hydraulic grade line elevation in the DRI is about the DRI crown elevation.

Also shown on **Figure 3.3**, there are stop log structures on sewer connections at Harding, Meadowbrook, Fairview, Beniteau and Hart that divert wastewater into the East Jefferson Relief Sewer from the DWSD laterals and allow overflow from the DRI into the deeper East Jefferson Relief Sewer whenever the hydraulic grade line elevation in the DRI is about the DRI crown elevation at these stop log structures (assuming normal wet well levels in the Conner Creek and Freud PS).

3.3 Conner Creek Pump Station

The Conner Creek PS receives wastewater from the East Jefferson Relief sewers. These sewers are two 14-feet diameter concrete sewer tunnels that run under Jefferson Avenue to the east and west of the Conner Creek PS. The East Jefferson Relief sewers are about 35 feet below grade and were constructed in about 1927. The East Jefferson Relief sewer transports wastewater from DWSD-operated gravity laterals between Fairview PS and Alter Road, wastewater from the Fox Creek regulator gates, the Freud PS sanitary pumps, and the Fox

Creek and Mack Avenue Relief sewers. There is about 10.9 MG of in-system storage at a wet well level of 70 feet in the large combined sewers that discharge to the Conner Creek PS.

The Conner Creek PS has two parts: a stormwater pump station that was constructed in about 1929 and a sanitary pump station that was constructed in about 1960. The sanitary pumps discharge low flow rates to the DRI. The storm pumps discharge wet weather flow rates into the Conner Creek outfall conduit that discharges in turn to the Conner Creek CSO Basin.

The Conner Creek PS has four constant speed sanitary pumps with rated capacities of 40, 75, 109 and 109 cfs that discharge into the DRI. Also, it has eight constant speed storm pumps each with a rated capacity of 500 cfs. The storm pumps must be primed with a vacuum pump before the stormwater pumps can be operated. The sanitary pumps are designed to turn ON between levels of 62 to 65 feet in the sanitary wet well and OFF between levels of 59 to 62 feet. The storm pumps are designed to turn ON between levels of 72 to 79 feet in the storm wet well and OFF between levels of 65 to 72 feet. The stormwater pumps discharge through a siphon block with a top invert elevation of 102 feet. Also, there are surge overflow weirs at the stormwater pump station with a crest elevation of 102.5 feet. Recirculation from the discharge channels is possible through idle pumps and over the surge weirs if the downstream hydraulic grade line elevation exceeds these levels.

The predicted peak flow rates for the 10-year, 1-hour design storm and the 10-year, 24-hour design storm for the storm pumps at the Conner Creek PS are 3,419 and 3,808 cfs, respectively. These design flow rates would require seven (7) of the eight (8) storm pumps to be operating with capacities about equal to or slightly above the rated capacity for each storm pump.

3.4 Freud Pump Station

The Freud PS was constructed in about 1955 to work together with the Conner Creek PS and supply additional wet weather pumping capacity for the east side system. The Freud PS receives wastewater from the Ashland Relief sewer and from two overflow structures on the East Jefferson Relief sewer. There is one overflow structure on the East Jefferson Relief Sewer at Algonquin and Jefferson that discharges into the Ashland Relief Sewer whenever the Conner Creek PS storm wet well level exceeds about elevation 68 feet. Also, there is an overflow weir in a structure at Manistique and Jefferson that discharges into the Manistique sewer toward the

Freud PS whenever the hydraulic grade line elevation exceeds 68.5 feet in the East Jefferson Relief sewer. Therefore, the Conner Creek PS and Freud PS are interconnected and pump from a common network of large combined sewers at wet well levels greater than 68 feet.

The Freud PS wet well is deeper than the Conner Creek PS wet wells. There is about 24.8 MG of in-system storage at a wet well level of 71 feet in the large combined sewers that are tributary to the Freud PS. Most of this storage is in the Ashland Relief sewer.

There is a small amount of dry weather wastewater that is pumped at the Freud PS by the sanitary/dewatering pumps to the East Jefferson Relief sewer. The Freud PS also includes stormwater pumps that discharge into the Conner Creek CSO Basin.

The Freud PS has two constant speed sanitary/dewatering pumps with rated capacities of 20 and 35 cfs. Also, it has eight constant speed storm pumps each with a rated capacity of 450 cfs. The sanitary/dewatering pumps are designed to turn ON between levels of 45 to 65 feet in the wet well and OFF between levels of 25 to 45 feet. The storm pumps are designed to turn ON between levels of 68 to 75 feet in the storm wet well and OFF between levels of 45 to 53 feet.

The stormwater pumps discharge through a conduit with a top invert elevation of 100.75 feet (See **Figure 3.3**). Also, there are surge overflow weirs at the stormwater pump station with a crest elevation of 100.75 feet. Recirculation from the discharge channels is possible through idle pumps and over the surge weirs if the downstream hydraulic grade line elevation exceeds these levels.

The predicted peak flow rate for the 10-year, 1-hour design storm and the 10-year, 24-hour design storm for the storm pumps at the Freud PS is 3,500 cfs. A design flow rate of 3,500 cfs would require seven (7) of the eight (8) storm pumps to be operating with capacities above the rated capacity for each storm pump.

3.5 Bluehill Pump Station

The Bluehill PS has two parts that were both constructed in about 1952: a stormwater pump station and a sanitary pump station. The Bluehill PS serves a portion of the east side combined sewer area of Detroit and a small part of Harper Woods along Kingsville Road. The 11.75-feet diameter Rivard sewer delivers combined wastewater to the Bluehill PS and has about 2.3 MG of in-system storage at a wet well level of 76 feet. The Bluehill PS has two sanitary pumps each with a rated capacity of 10 cfs that discharge into the Fox Creek Relief sewer. Also, it has three large constant speed stormwater pumps each with a rated capacity of 387 cfs and one smaller variable speed stormwater pump with a maximum rated capacity of 177 cfs. The firm capacity of the Bluehill PS is 951 cfs.

The stormwater pumps discharge into the Fox Creek Relief and Mack Avenue Relief sewers. There are surge channels at the pump station with invert elevations of 103 feet that allow recirculation if the downstream hydraulic grade line elevation exceeds 103 feet. The sanitary pumps are designed to turn ON between levels of 72 to 72.5 feet in the sanitary wet well and OFF between levels of 68 to 68.5 feet. The storm pumps are designed to turn ON between levels of 77 to 82 feet in the storm wet well and OFF between levels of 67 to 72 feet. The stormwater pumps are designed to be operated to maintain the wet well level between elevations 63 to 76 feet.

3.6 Conner Creek Enclosure

The Conner Creek Enclosure (CCE) is a large reinforced concrete drain enclosure that is 25 to 30 feet below grade, built between 1921 and 1931, operates under gravity and transports combined wastewater from the north and east side of Detroit. It also receives wastewater from the City of Centerline. The service area extends to 8 Mile Road in Detroit and the sewers tributary to the CCE are interconnected with the Conant Mt. Elliott and the Ashland Relief sewers.

The CCE is a large triple box sewer at the downstream end from Warren to Jefferson Avenues. The CCE ends at the forebay structure that is a large junction chamber south of Jefferson Avenue. The triple box section of the CCE has an open channel capacity of about 5,000 cfs. The predicted peak flow rates for the 10-year, 1-hour and the 10-year, 24-hour design storms are 6,343 and 6,655 cfs, respectively. There is about 61 MG of in-system storage in the CCE upstream of the forebay at elevation 98 feet. The current design flows require the CCE to surcharge slightly during peak design flows. There is about 14 MG of in-system storage in the CCE downstream of the forebay at elevation 98 feet.

The forebay includes regulator gates that are operated to discharge dry weather flow rates into the DRI. The regulator gates may be closed under wet weather conditions. The forebay also includes nine parallel in-system storage gates that discharge into a triple box outfall conduit that runs to the Conner Creek CSO Basin. The in-system storage gates are double leaf roller gates. For each in-system storage gate, both the lower and upper leaves were designed to be raised in wet weather to create a 10-feet wide by 17-feet high opening. In a closed position, the top elevation is about 97 feet. There is a two-foot gap above these gates in the closed position. The gates are raised 3 at a time whenever the upstream wastewater level in the forebay reaches about elevation 95 feet or the wastewater level in the Conner Creek CSO basin reaches 96 feet.

3.7 Conner Creek CSO Basin

The Conner Creek CSO Basin was constructed and placed into service in the fall of 2005. The basin was designed to capture and treat CSO and receives combined wastewater from the storm pumps at the Conner Creek PS, the storm pumps at the Freud PS and by gravity from the CCE. The basin has about 30 MG of storage at elevation 98 feet.

The basin includes 10 parallel screens with a bar spacing of 1.5-inches that discharge into 4 parallel basin compartments. There are double leaf slide gates on 7 of the 10 screen channels that were designed to be raised during peak flow conditions. The three remaining channels are ungated. There are chlorine injectors and mixers downstream of each screen.

The basin has a launder weir with a crest level of 98 feet and a peak design flow rate of 4,100 cfs. There are sixteen parallel 5-feet high by 12-feet wide effluent launder sluice gates downstream of the launder weir that can be opened up to 4 at a time to allow flow through the basin to the canal. Also, there are sixteen parallel 9-feet high by 12-feet wide emergency relief gates that are on the end wall of the basin below the canal water level. These gates were designed to be opened to pass flow rates greater than 4,100 cfs through the basin to the canal. The emergency relief gates can be opened up to 4 at a time.

The design flow rates are given on a hydraulic profile of the basin and connecting conduits provided in **Appendix 2**. For a 10-year, 1-hour design storm, the predicted peak flow rate through the basin will be 13,262 cfs. For a 10-year, 24-hour design storm, the predicted peak flow rate through the basin will be 13,963 cfs.

The Conner Creek canal levels will be about equal to the Detroit River levels. The canal levels used in the design of the basin range from an average level of 95 feet to a 25-year high level of 97.9 feet. For comparison, the Detroit River level during the July 8 and August 16, 2016 storm events were approximately 97 feet.

3.8 Fox Creek Enclosure

The Fox Creek Enclosure (FCE) and the DWSD-operated Ashland sewer are tributary to the GLWA operated Fox Creek regulator gate/backwater gate chamber. The Fox Creek regulator gates consist of 3 parallel 6-feet by 6-feet sluice gates that are currently fully open. The gates may be operated from a local control panel with electric motors. The Fox Creek regulator gates discharge wastewater into the East Jefferson Relief sewer which runs to the Conner Creek PS. If capacity is not available in the East Jefferson Relief sewer and/or the regulator gates are closed, overflow of wastewater to the Fox Creek canal is possible through 2 backwater gates. The backwater gates are two parallel 10-feet by 10-feet hinged gates that discharge wastewater to the Fox Creek canal whenever the upstream hydraulic grade line level exceeds the downstream canal level.

The FCE transports wastewater from the Southeast Macomb Sanitary District (SEMSD), the Wayne County Northeast Sanitary Disposal System (NESDS), Grosse Pointe Farms and the City of Grosse Pointe.

The FCE was constructed in about 1929 and begins at the Kerby Road PS and discharges into a short segment of box conduit at Ashland Road and Jefferson Avenue just upstream of the Fox Creek regulator chamber. The Ashland sewer and the FCE combine at this point. The FCE is owned by Wayne County and receives flow inputs from three pump stations: the Wayne County Kerby Road PS, the Grosse Pointe Farms PS which is also at Kerby Road, and the City of Grosse Pointe PS.

The FCE is a gravity sewer that does not normally operate under surcharge conditions. The open channel capacities range from 536 cfs at the upstream end to about 770 cfs at its downstream end. The FCE may operate under surcharged conditions under peak wet weather conditions. Hydraulic profiles for the FCE were taken from the Wayne County Fox Creek District Facility Plan and are provided in **Appendix 3**.

3.9 Wayne County Northeast Sewage Disposal System

The NESDS is tributary to the Wayne County Kerby Road PS and includes the Marter Road Booster PS (also known as the County Line PS) and the Grosse Pointe Interceptor (GPI). All of these facilities are owned and operated by Wayne County.

The SEMSD includes Eastpointe, Roseville and St. Clair Shores. The SEMSD includes two RTBs in St. Clair Shores (Martin and Chapaton) that are operated by the Macomb County Public Works Office (MCPWO) for SEMSD. The Martin and Chapaton RTBs can overflow to Lake St. Clair in wet weather. The SEMSD discharges to the Marter Road Booster PS. The Marter Road Booster PS discharges into the GPI. The GPI runs from Marter Road Booster PS to the Kerby Road Booster PS.

The Milk River District discharges wastewater into the GPI and is primarily served by combined sewers. The Milk River District provides wastewater capacity for most of Harper Woods and all of Grosse Pointe Woods. The Milk River District includes a pump station with sanitary and storm pumps and a RTB that can discharge into the Milk River Drain and Lake St. Clair in wet weather.

Grosse Pointe Shores is part of the NESDS and discharges through the Cook Road Pump Station into the GPI.

Figure 3.1: East Side Collection and Conveyance System Schematic

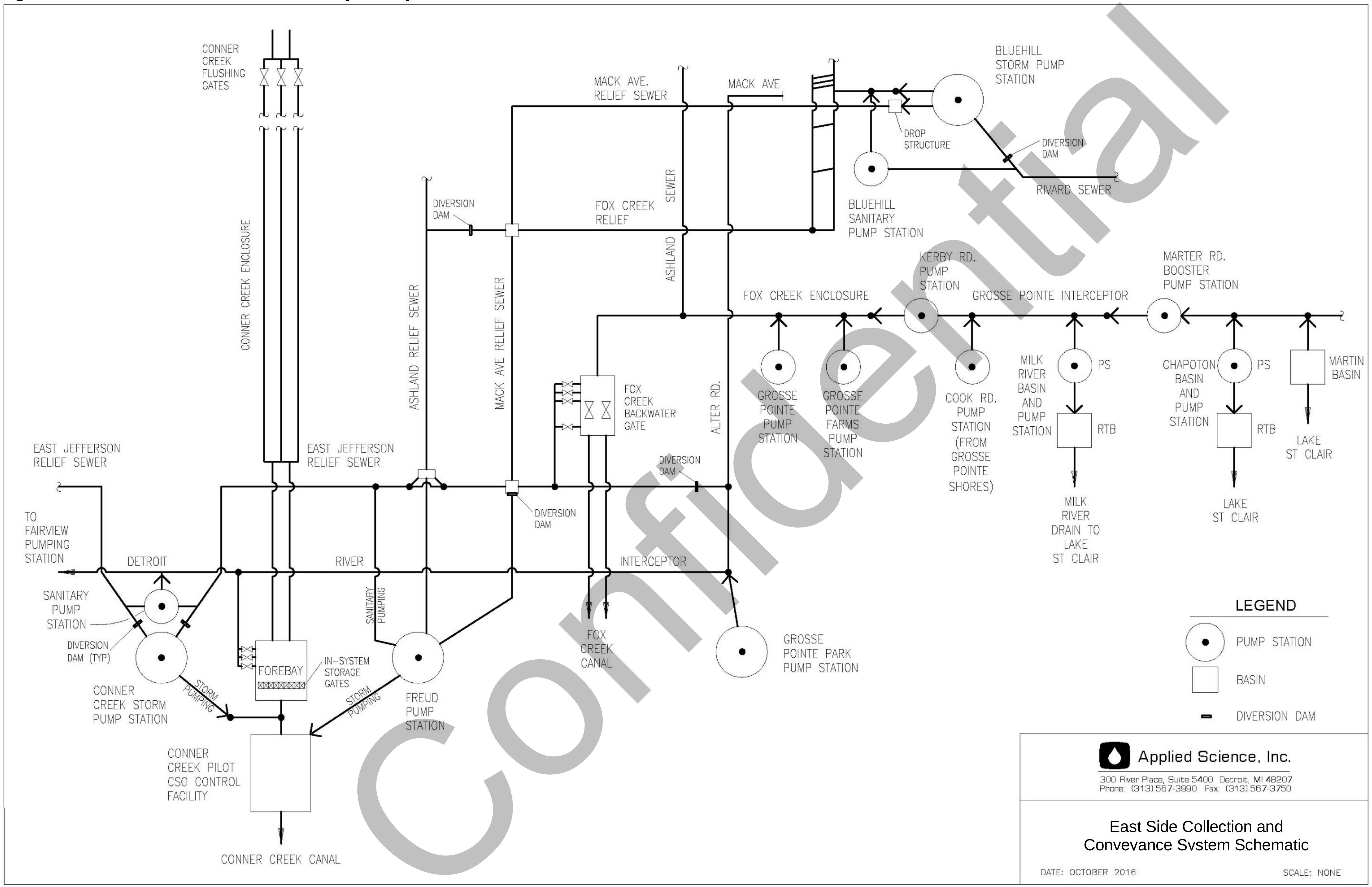


Figure 3.2: East Side Collection and Conveyance System Service Area

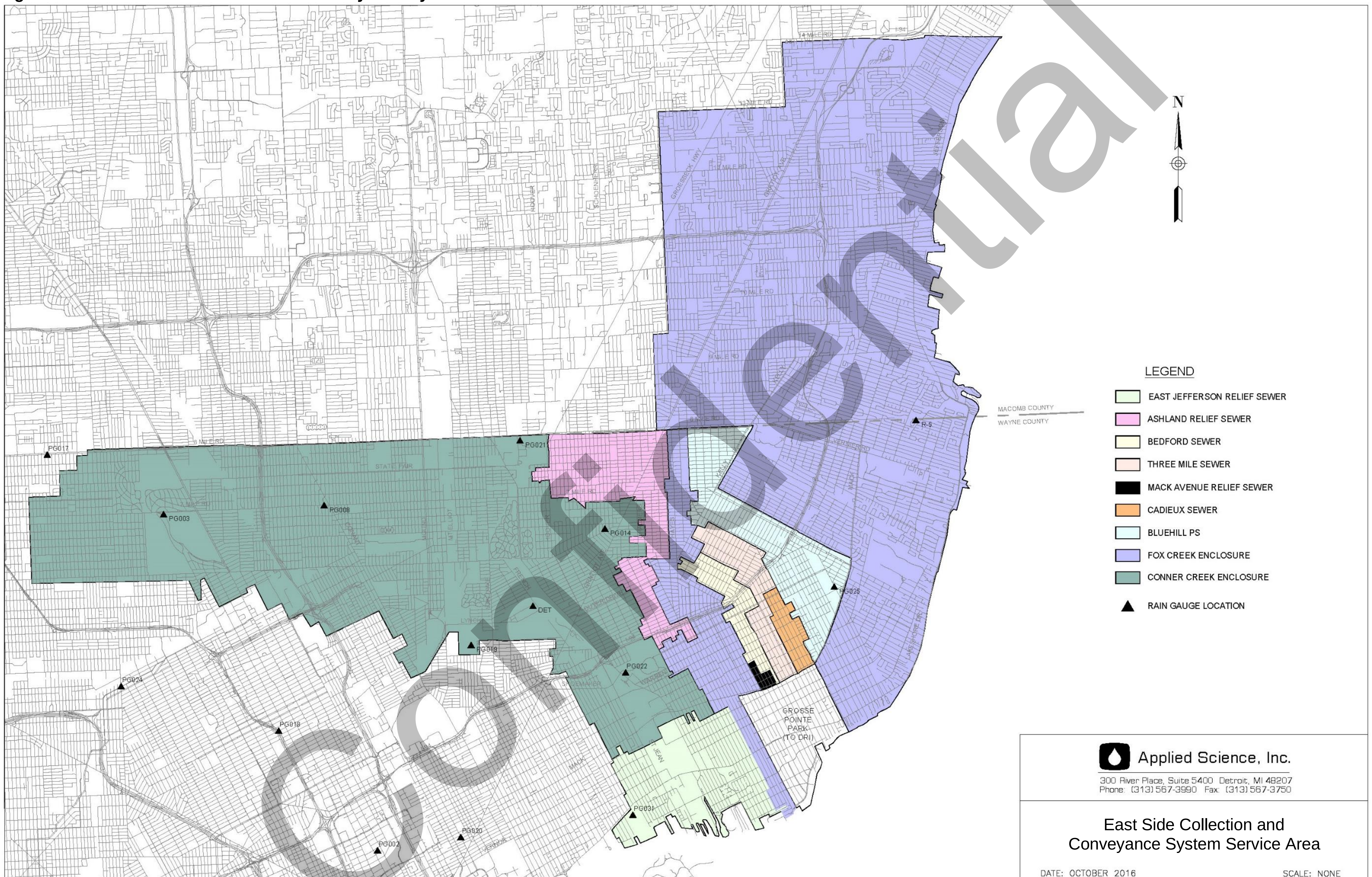
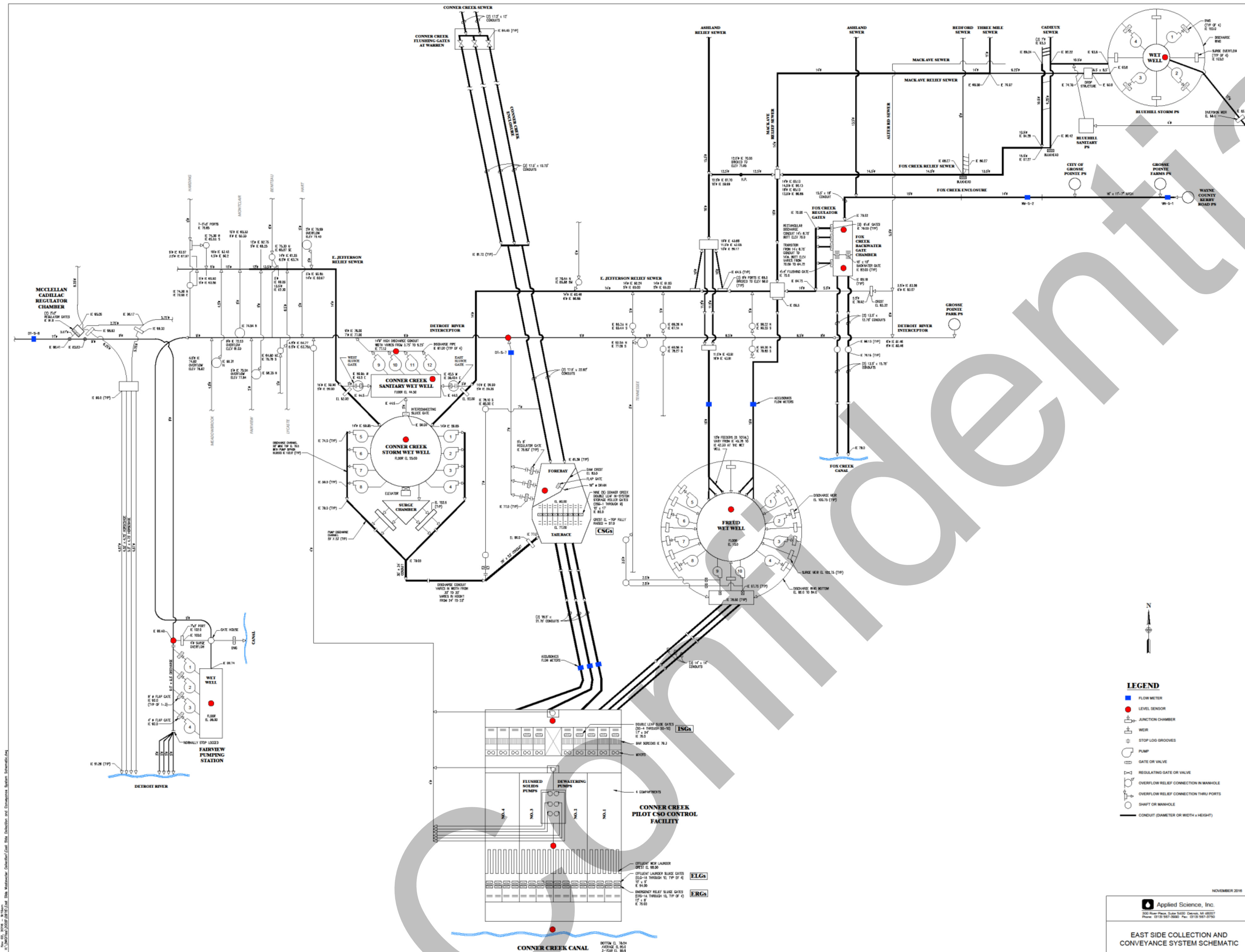


Figure 3.3: East Side Collection and Conveyance System Schematic



4.0 Event Response Timeline

The storms that occurred on July 8, and August 16, 2016 were severe thunderstorms with rainfall that exceeded the 10-year design storm. In addition to large rainfall totals, the intensity of the rainfall caused the system to respond quickly with rapid increases in flow and level within the system. In response, the GLWA operation staff quickly mobilized and prepared the system for rapid increases in flow. The response of the system and the operators to these storms can be understood through a review of sewer system and facility time-series data collected by GLWA, staff interviews, and operator logs. A subset of the event timeline focused on the facilities within the east side of Detroit is presented in this section for each storm; the full chronology of the July 8, and August 16, 2016 event timelines are included in **Appendix 4**.

4.1 July 8, 2016 Storm Timeline

Prior to the July 8, 2016 storm, the National Weather Service forecast predicted a 70% chance of rainfall with no indication of local flooding or heavy rainfall and no severe weather watches or warnings. A review of the live radar rainfall images shows moderate rainfall intensities as the storm approached the area. As the storm moved nearer to the east side of Detroit, the intensity of the storm rapidly increased. Starting at 1:18 am, the flow rates in the system began to increase causing automatic alarm notifications to be sent to the GLWA staff. In the period from 1:18 am to 2:09 am, the GLWA staff received auto alarms from seven separate CSO facilities in the system. A summary the alarm timeline is presented in **Figure 4.1**.

Using the level, pump operation and rainfall data collected from the instrumentation installed in the collection system and facilities in the east side of Detroit, a timeline of the system response and the response of the operators was developed and presented in **Figure 4.2, Figure 4.3** and **Table 4.1.**

Figure 4.1 Summary of CSO Facility Auto Alarm Notifications

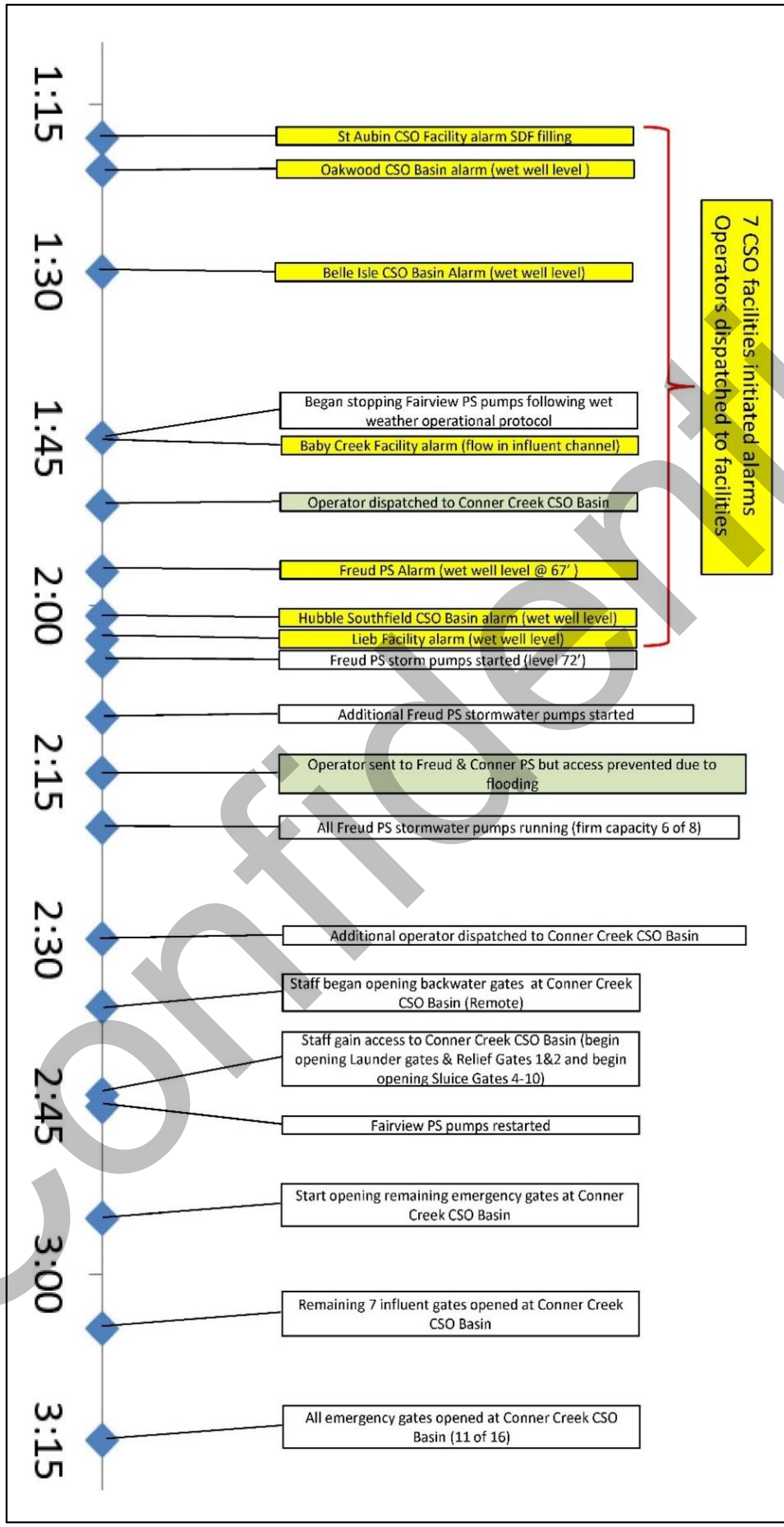


Figure 4.2: July 8, 2016 Storm Rainfall and Elevation Readings

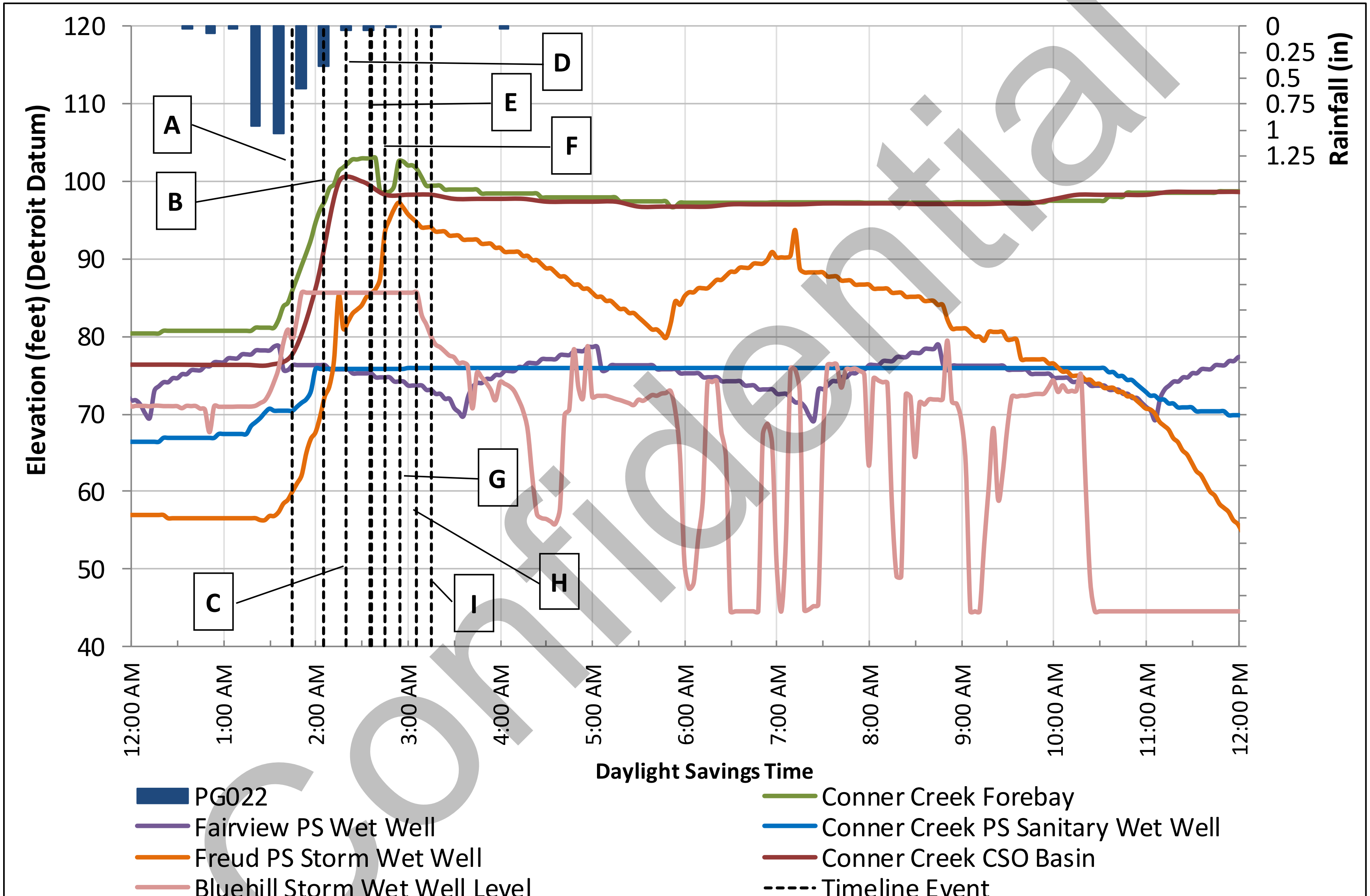


Figure 4.3: July 8, 2016 Number of Pumps In-Service

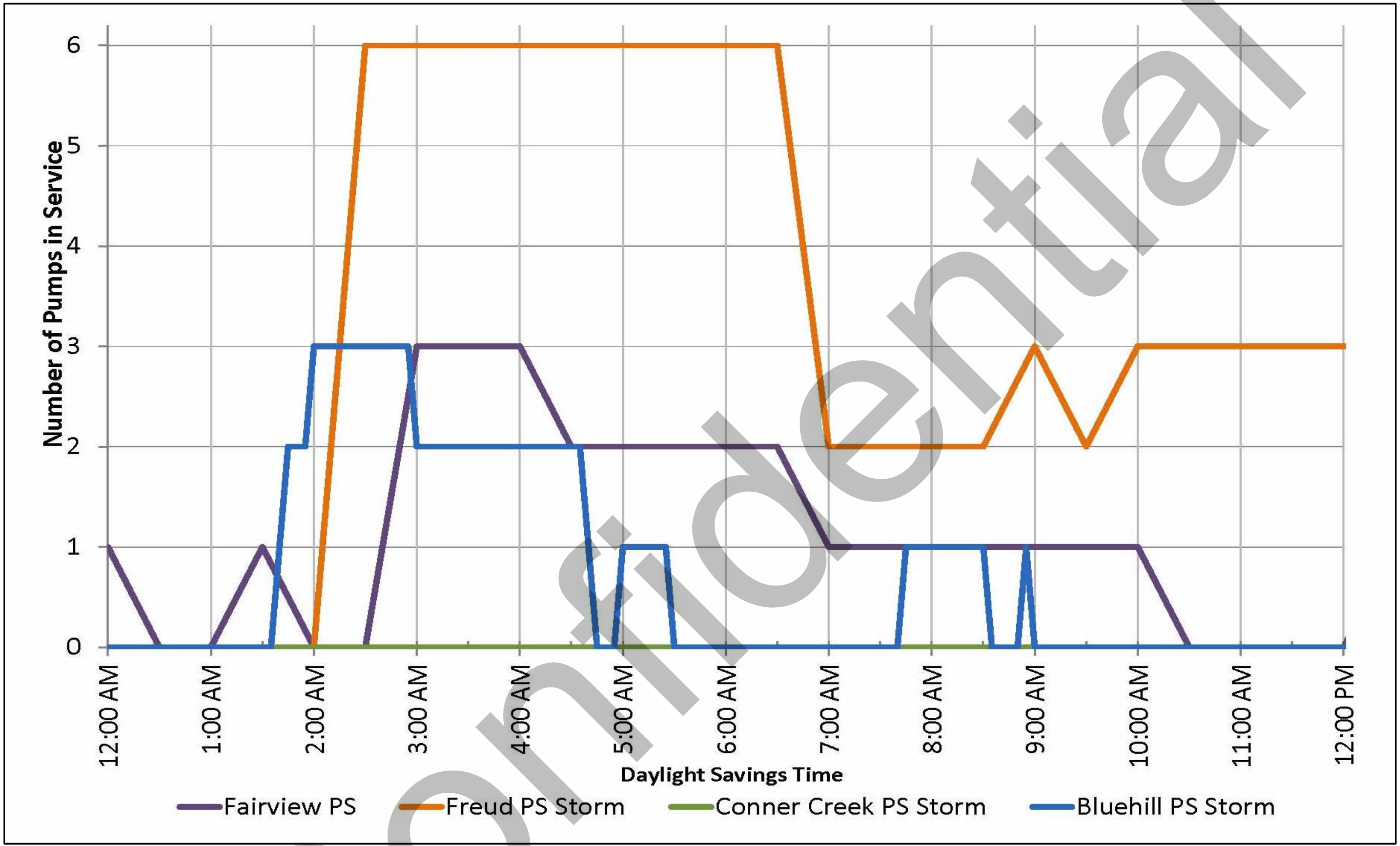


Table 4.1:
System and Operator Response to the July 8, 2016 Storm

Event	Time	Description
A	1:45	Pumping reduced at Fairview PS.
B	2:05	Freud PS storm pumps started. Freud PS wet well elevation at 71 feet.
C	2:20	Six storm pumps running at Freud PS.
D	2:35	Forebay elevation at 102 feet.
E	2:36	Surface flooding; access to facilities difficult. Conner Creek CSO facility backwater gate Nos. 1, 6, 7, 8 and 9 could not be opened remotely.
F	2:45	Fairview PS restarted.
G	2:55	Begin opening Conner Creek CSO facility emergency relief gates (only 2 open up to this time). 14 of 16 Conner Creek CSO facility launder gates open.
H	3:05	Remaining 7 Conner Creek CSO facility influent gates opened.
I	3:15	11 of 16 Conner Creek CSO facility emergency relief gates open.

Based on the information provided in **Figure 4.2, Figure 4.3** and **Table 4.1**, there are a number of observations that can be made. These observations are summarized below.

1. <u>Fairview Pump Station Shutdown and Restart</u>

   At 1:45 the Fairview PS was shutdown per wet weather protocol. This protocol required Fairview PS shutdown at the onset of wet weather operations. Onset of wet weather operations is based on observed flow at the WWTP or sewer levels within the DRI.

   As the storm progressed and wet well levels continued to rise, despite operation of six stormwater pumps at the Freud PS, the GLWA operators restarted the pumps at Fairview PS at 2:45. Restarting the Fairview PS was implemented by the operators to reduce the sewer levels in the lower east side area.

2. <u>Freud Pump Station</u>

   Per the operational protocol, the first stormwater pump at the Freud PS was started at 2:05 when the wet well rose to an elevation of 71 feet. As the wet well continued to rise during the storm, the operators quickly responded bringing six stormwater pumps on-line between 2:05 and 2:20. During this 15-minute period, the wet well level continued to rapidly increase from 71 to 82 feet. With 6 pumps running, the wet well continued to rise above 82 feet until reaching a peak level of 97.2 feet. These six storm pumps were running continuously for a four-and-a-half-hour period during the peak of the event.

3. <u>Conner Creek Pump Station Wet Well Levels</u>

The Conner Creek PS wet well level data shows that the wet well level sensors exceeded the top of their range. Due to this exceedance, the actual peak value and timing of this peak within the Conner Creek PS wet well is unknown. Although Conner Creek PS stormwater pumps were available, limitations of the vacuum priming system prevented operation of the Conner Creek PS stormwater pumps during the July 8, 2016 storm.

Conner Creek PS wet well level data for this event is not sufficient to determine the peak wet well level during the July 8th storm, however the Freud PS wet well level can be substituted due to sewer interconnections. Based on the Freud PS wet well level, we can assume the Conner Creek PS peak wet well level during this event was approximately 97 feet.

4. <u>Conner Creek CSO Basin Levels and Discharge</u>

The Conner Creek CSO Basin level measurement can be represented by level data collected in the Conner Creek CSO Basin or by level data collected in the forebay, which is upstream of the in-system storage gates. The forebay level readings are reflective of level in the Conner Creek CSO Basin when the in-system storage gates are open. With the in-system storage gates closed, the forebay level increased steadily from 82 feet to 102 feet over a 1-hour period. The forebay level remained at 102 feet for almost 2 hours. Field observations and observed damage to the access hatches following the storm, suggest that the forebay was flooding to grade during this period, preventing a further rise in the forebay level. The forebay level remained at 102 feet until 2:55. Over the period from 2:55 to 3:15, the operators were able to open 11 of the 16 emergency relief gates and all influent gates. A comparison of the forebay level and the Conner Creek CSO Basin level shows elevated depths at the forebay prior to the influent gates being opened. However, once the influent gates were opened, the forebay and Conner Creek CSO Basin level readings were in agreement.

Discharge from the Conner Creek CSO facility was recorded in the operator log book. A review of the Conner Creek CSO Basin log book shows that discharge began on July 8, 2016 at 2:40.

During the storm, GLWA operators arrived at the Conner Creek CSO basin at approximately 2:35 but were initially unable to enter the facility due to street flooding. By 2:44, a GLWA operator was able to access the facility and began opening the launder gates. Two of the emergency overflow gates were also opened at this time. Between 2:55 and 3:15, the GLWA operators unlocked and opened 11 of the 16 emergency gates.

5. <u>Bluehill Pump Station</u>

The Rivard sewer is an 11.75 diameter sewer with an invert elevation of 65.67 feet at the point of inflow to the Bluehill pump station. This pipe invert and diameter sets the pipe crown at 77.42 feet. If the wet well elevation in the Bluehill PS rises above 77.42 feet it will begin to surcharge the Rivard sewer. A review of the wet well data collected within the Bluehill PS wet well during the July 8, 2016 storm shows a sustained wet well level of approximately 85 feet for over a 1-hour period. This sustained 85 foot level measurement indicates that the level sensor hit its maximum level and the actual wet well level was above 85 feet. At 85 feet, the Bluehill PS imposes a surcharge on the Rivard sewer. During the storm, three of the four stormwater pumps were operating meeting the firm capacity of the pump station.

4.2 August 16, 2016 Storm Timeline

Prior to the August 16, 2016 storm, the National Weather Service forecast predicted a near 100% chance of rainfall with an indication of heavy rainfall and local flooding, but no severe weather watches or warnings. GLWA staff prepared for this storm following an updated operational protocol that is intended to maintain a more open Conner Creek CSO Basin. This protocol included keeping the launder gates and the influent gates in a fully open position and unlocking every forth emergency gate. GLWA staff was also on-site full time (24/7) at Conner Creek CSO facility, with additional staff deployed to the Conner Creek PS, and Freud PS. Using the level, pump operation and rainfall data collected from the instrumentation from the collection system and facilities in the east side system, a timeline of the system response and the response of the operators was developed and presented in **Figure 4.3, Figure 4.4** and **Table 4.2**.

Figure 4.3: August 16, 2016 Storm Rainfall and Elevation Readings

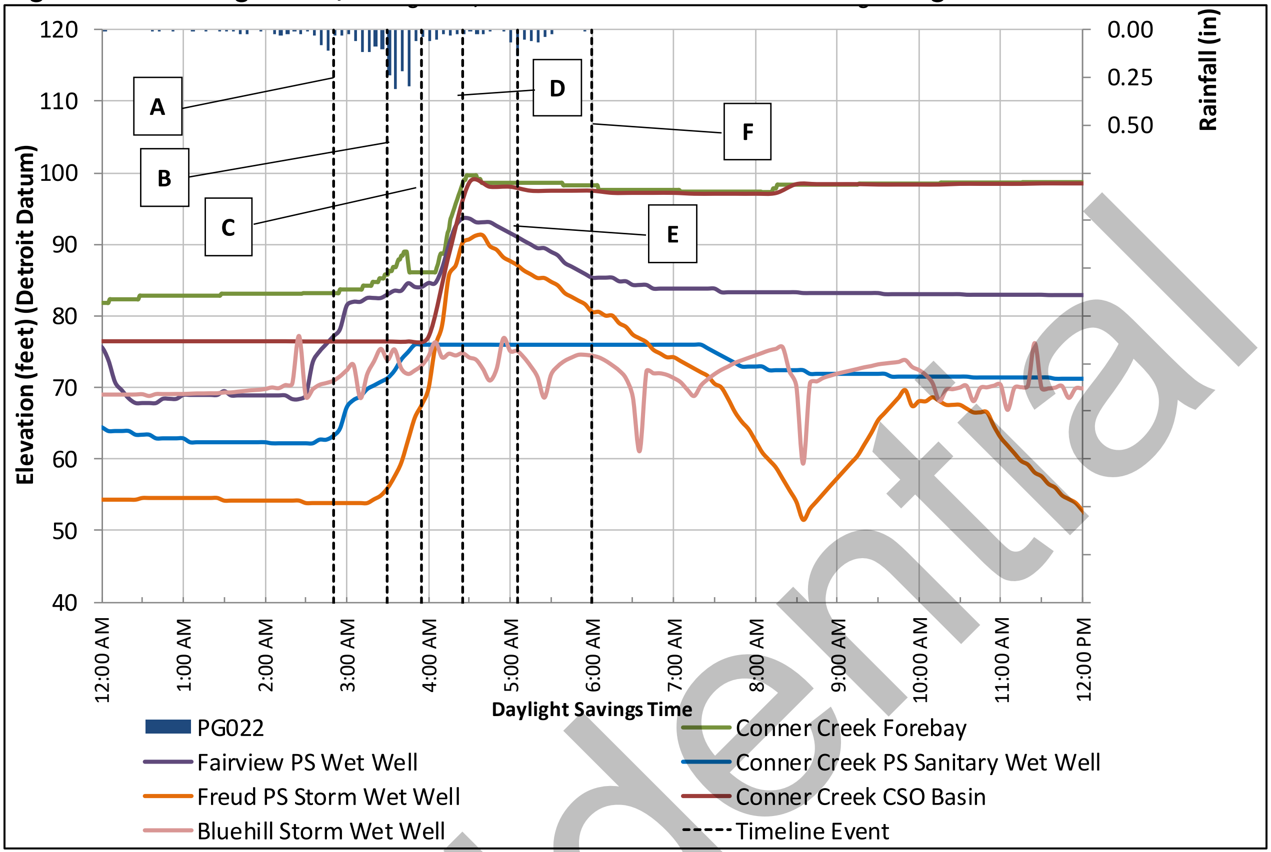


Figure 4.4: August 16, 2016 Number of Pumps In-Service

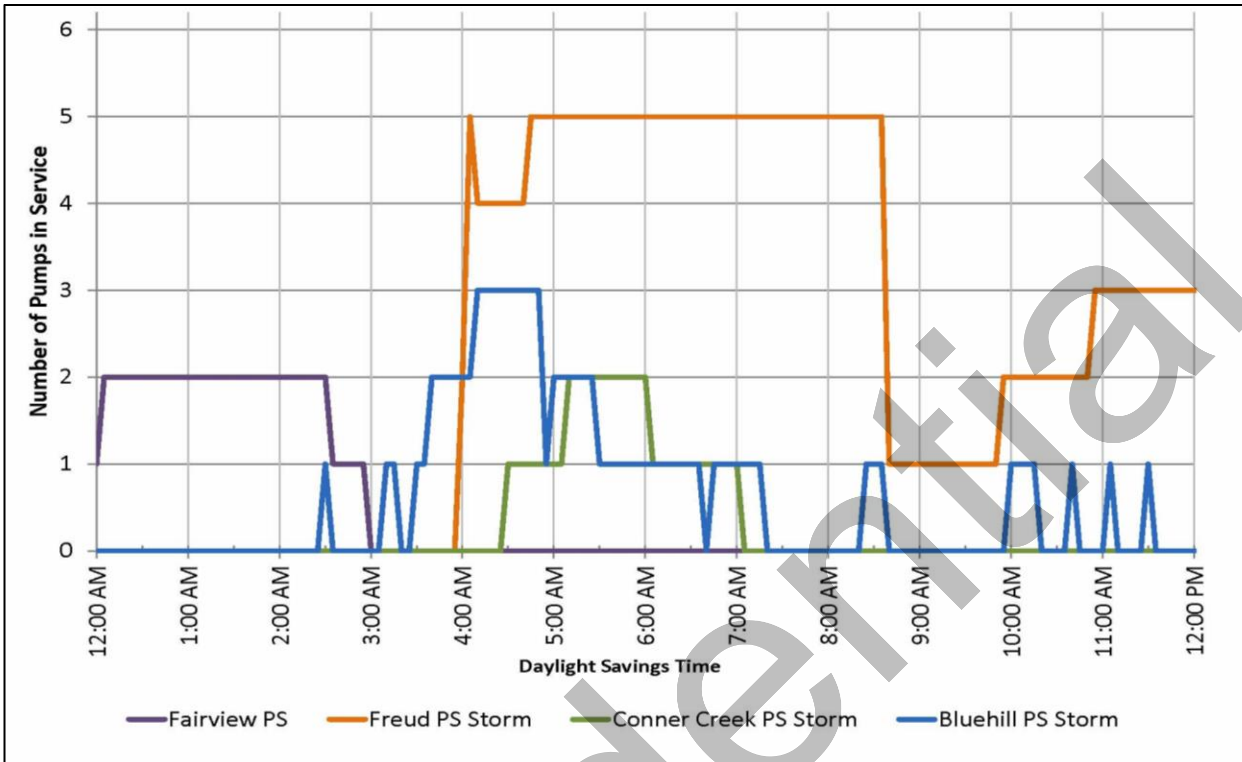


Table 4.2:
System and Operator Response to the August 16, 2016 Storm

Event	Time	Description
A	2:50	Sanitary pumps at Fairview PS, Conner Creek PS and Freud PS stopped.
B	3:30	Conner Creek CSO Basin backwater gates opened.
C	3:55	Five pumps running at Freud PS.
D	4:25	Sixteen relief gates opened at Conner Creek CSO Basin. 1 storm pump running at Conner Creek PS.
E	5:10	2 pumps running at Conner Creek PS.
F	6:00	One pump running at Conner Creek PS.

Based on the information provided in **Figure 4.3, Figure 4.4** and **Table 4.2** there are a number of observations that can be made. These observations are summarized below.

1. <u>Fairview Pump Station</u>

   Per normal protocol, all Fairview PS pumps were turned off when the GLWA system entered a wet weather mode of operation.

2. <u>Freud Pump Station</u>

Freud PS wet well data shows a peak level of 91.2 feet. Five stormwater pumps were operating simultaneously for a three-and-a-half-hour period during the peak of the storm (one pump dropped out for 30 minutes during this period).

3. <u>Conner Creek Pump Station Wet Well Levels</u>

The Conner Creek PS wet well level data shows that the wet well level sensors exceeded the top of their range for over 3 hours. Due to this exceedance, the actual peak value and timing of this peak within the wet well is unknown. Two of the Conner Creek PS stormwater pumps were operated for approximately 1.5 hours during the storm.

Conner Creek PS wet well level data for this event is not sufficient to determine the peak wet well level during the August 16th storm, however the Freud PS wet well level can be substituted due to sewer interconnections. Based on the Freud PS wet well level, we can assume the Conner Creek PS peak wet well level during this event was approximately 91.2 feet.

4. <u>Conner Creek CSO Basin</u>

The Conner Creek CSO Basin level measurement can be represented by level data collected in the Conner Creek CSO Basin or by level data collected in the forebay, which is upstream of the in-system storage gates. The forebay level readings are reflective of level in the Conner Creek CSO Basin when the in-system storage gates are open. All Conner Creek CSO Basin gates were opened for this storm. All launder and influent gates were left in an open position prior to the start of the storm. The level data collected in the Conner Creek CSO Basin and at the forebay are in good agreement from the time the Conner Creek CSO Basin began filling through the end of the storm. The log book shows that the backwater gates were opened on August 16, 2016 by 3:30 and relief gates were opened on August 16, 2016 by 4:25.

Discharge from the Conner Creek CSO Basin was recorded in the operator log book. A review of the Conner Creek CSO Basin log book shows that emergency discharge from the launder gates or from the emergency relief gates began on August 16, 2016 at 4:30.

5. Bluehill Pump Station

   The maximum level in the Bluehill PS wet well during this storm was 77.3 feet, is below the 77.4 foot crown of the Rivard sewer. Therefore, the wet well did not impose a surcharge on the Rivard sewer during this storm.

4.3 Summary of available and In-Service Pumps

Stormwater pumps available and in-service at Conner Creek PS and Freud PS are a factor in the ability to address wet weather flow rates in the east side system. **Table 4.3** summarizes the stormwater pumps available at these pump stations during the July 8, and August 16, 2016 events and since October 31, 2016.

Table 4.3:
Storm Water Pump Availability and Service at Conner Creek PS and Freud PS

		July 8, 2016	August 16, 2016	Since October 31, 2016
Conner Creek PS	Pump Nos. Out of Service	4 & 8	4 & 8	1, 4 & 8
	Count Available	6	6	7
	Count In-Service	0	2	NA
Freud PS	Pump Nos. Out of Service	5 & 7	5 & 7	5
	Count Available	6	6	7
	Count In-Service	6	5	NA

5.0 Flood Mitigation Actions

In response to the recent events occurring during the July 8 and August 16, 2016 storms, the GLWA has implemented immediate system improvement modifications to the operating protocols for the Fairview, Conner Creek and Freud Pump Stations and the Conner Creek CSO Basin.

In addition, GLWA is currently in the process of implementing immediate and near-term system improvements that will provide additional hydraulic relief for the east side system during storm events. GLWA has already begun implementing immediate improvements to the system that are directed at providing relief to the system more quickly and reducing the reliance on operator response.

These immediate and near term system improvement projects have an estimated total infrastructure investment in excess of $12,000,000. These projects have been moved forward in the FY 2017-21 approved Capital Improvement Plan (CIP) and the funding source has been secured. These system improvements are described in detail below.

5.1 Immediate System Improvements

Immediate system improvements include protocols and projects that were implemented without any detailed analysis of the system or new construction. Below is a summary of system changes that have been implemented by GLWA staff since the July 8, 2016 storm.

1. **Conner Creek CSO Basin Staffing**

   Prior to the July 8, 2016 storm, staffing for the Conner Creek CSO Basin (as well as the eight other CSO control facilities) was deployed in anticipation of major storms or in response to lesser storms. None of the CSO control facilities were staffed on a full-time basis. During the July 8, 2016 storm, staff that had been called to the facility were delayed access due to substantial street flooding caused by the storm. This delay in staff arriving at the basin delayed the opening of the in-system influent and discharge gates. As part of the system improvement strategy, the GLWA has assigned full-time staff to the Conner Creek CSO Basin. Having staff on site 24 hours a day and 7 days per week eliminates facility access issues and prevents any delay in gate operation.

2. Launder Gate Settings

The launder gates are the upper point of discharge from the Conner Creek CSO Basin to the Detroit River. These gates are intended to prevent high river levels greater than 98 feet from backfilling the Conner Creek CSO Basin, while also preventing fish and foreign objects from entering the launder channels. When opened, these gates allow flow to be discharged from the Conner Creek CSO Basin up to a design flow rate of 4,100 cfs. Prior to the July 8, 2016 storm, the launder gates were normally kept in the closed position. To prevent any risk of delay opening the launder gates, the launder gates will be kept in an open position through the summer and fall storm season.

3. Influent Gate Settings

The influent gates are located in channels just upstream of the mechanical screens and are used to isolate the screening equipment and Conner Creek CSO Basin storage from the upstream system. Prior to the July 8, 2016 storm, 7 of the 10 gate openings were in a normally closed position. The 3 remaining channels do not have gates and therefore are always open. To prevent delays in opening these gates, all influent gates are now in a normally open position.

4. Emergency Relief Gates

The 16 emergency relief gates are located below the launder gates and are used as a secondary point of discharge from the Conner Creek CSO Basin to the Detroit River. These gates are intended to be opened when the hydraulic head in the facility requires relief. This hydraulic head is generated when flow into the Conner Creek CSO Basin exceeds 4,100 cfs (maximum capacity of the launder weirs). These gates extend more than 20 feet below the Detroit River level. Due to the high differential hydraulic head when the Conner Creek CSO Basin is empty, considerable damage to the basin can occur if the emergency gates are opened prematurely. To prevent accidental damage to the facility, the emergency gates were kept locked prior to the July 8, 2016 storm and required a key to open the gates. To prevent delays in opening these emergency gates, the GLWA staff is now maintaining every fourth gate (one gate for each of the 4 bays comprising the basin) in an unlocked condition. These unlocked gates can be operated locally without a key to provide relief from the Conner Creek CSO Basin and upstream system more quickly.

5. Fairview Pump Station

The Fairview PS operating protocol has been modified to continue pumping operations during storms. This update to the operational protocol was put in place after the August 16, 2106 storm. The intent of this operational change is to increase the amount of pumped flow from the DRI and Jefferson Relief sewers.

6. Freud Pump Repair

At the Freud PS there were two pumps that required repair and were not available for service. Pump No. 7 has been repaired and returned to service. Pump No. 5 has already been removed and sent to the manufacturer for repair. Pump No. 5 is expected to be repaired and returned to service within the next 4 weeks.

7. Interceptor Sewer Inspection

Restrictions in the interceptors can cause increased head loss in the collection system resulting in higher than expected sewer hydraulic gradient levels. Restrictions in the sewer can be the result of sediment buildup, damage to the sewer, or even historical bulkheads. To address if there are any restrictions in the interceptors, the GLWA has initiated an investigation of the major interceptor sewers within the east side system. This investigation will include a review of recently completed sewer inspections and additional supplemental inspections.

8. Conner Creek Pump Station – Priming System

The large stormwater pumps at the Conner Creek Pump Station require vacuum priming before starting. This priming sometimes does not function effectively and prevents, or otherwise hinders, the startup of the stormwater pumps. The GLWA is currently exploring approaches to enable priming of these pumps. These approaches will provide relief until permanent modifications are made to the Conner Creek Stormwater Pump Station through a longer-term capital improvement project.

8. Sewer Inspection

The major trunk sewers within the east side system were constructed over a half century ago, many nearly a century ago. Although several of these sewers have been inspected in the past, the GLWA has implemented additional inspections of the sewers to ensure that the sewer conditions are not contributing to flooding problems within the east side system. These inspections will look for structural defects in the system and possible buildup of sediment.

5.2 Near-Term System Improvements

Near term improvements to the system require some level of analysis to verify that they will provide the intended benefit, can be implemented quickly without long-lead time, fabrication or procurement, require minimal modification to the system to implement, do not cause harm or detriment to other systems, facilities or equipment, and can be implemented safely. Below is a summary of these near-term system improvements.

1. System Analysis

To better understand the causes of the flooding during the July 8, and August 16, 2016 storms and to analyze possible solutions to prevent the flooding, GLWA has engaged two separate consultants to collect data, analyze the system performance (during the July 8, and August 16, 2016 storms and during design storm conditions), and develop and test short-term and long-term system relief options. These analyses are ongoing and some of the initial findings are included in this report. Additional analysis will continue and the findings presented to the GLWA. The focus of this analysis is on the physical features, equipment and hydraulics at the Conner Creek CSO basin, Conner Creek PS, Fairview PS, Freud PS, Bluehill PS, interceptor and trunk sewers tributary to these pump stations, and local existing and former overflow relief points.

2. Conner Creek CSO Basin Instrumentation

Many of the operations at the Conner Creek CSO Basin were originally intended to be operated remotely from the SCC. Since the time of the facility's commissioning, some of the instrumentation and control systems have been damaged and unavailable for use. Known damage impacts include remote control of the influent basin gates, launder gates, and emergency relief gates. These systems are currently dependent on human operators on-site for operation. To provide for remote control, the GLWA has begun a program to inventory the instrumentation and control systems and begin preparation for repair and/or replacement as needed. As these instrumentation and control systems are addressed, a separate uninterruptable power supply (UPS) will be added to the system in case of power failure.

To supplement the existing equipment and to provide improved monitoring of the system, additional monitoring equipment will be installed. This monitoring equipment will include additional level sensors and flow meters.

3. Conner Creek PS – Priming System

GLWA will implement modification to the discharge channel for the Conner Creek PS to provide for sufficient depth of wastewater to enable the vacuum priming system to operate more reliably. This modification will provide for pump station operation until permanent modifications are made to Conner Creek PS through the long-term CIP.

4. Fox Creek Regulator Overflow – System Relief

The Fox Creek regulator chamber regulates flow from the Fox Creek Enclosure and Ashland Sewer into the East Jefferson Relief Sewer. This chamber includes three-6'x6' regulator gates. Due, in part, to the head required in the chamber to overcome the Detroit River levels, this regulator chamber rarely overflows. The GLWA is investigating the option of throttling the three-6'x6' regulator gates and limiting the flow into the East Jefferson Relief sewer to relieve the downstream system.

5. Continuation of Sewer Inspection

To ensure no problems with wastewater conveyance through the major trunk sewers, the GLWA will continue inspection of the sewers.

6.0 Future Flood Mitigation Actions

The focus of the GLWA's long-term flood mitigation actions for the east side system is centered on the rehabilitation of the Conner Creek and Freud Pump Stations to provide for reliable firm pumping capacity. These are long-term projects will require detailed engineering study, design and construction. The following is a list of these future flood mitigation projects.

1. **Conner Creek Pump Station Facility, Pumping and Priming System Rehabilitation/Replacement**

   The pumps at the Conner Creek PS were installed in the 1920's when the pump station was originally constructed. These pumps and the pump priming system will be evaluated to determine if it is necessary to modify, rehabilitate or replace the components of the pumping systems.

2. **Freud Pump Station Facility Rehabilitation**

   The Freud PS facility, including the power system and instrumentation, will be evaluated to determine if it is necessary to modify, rehabilitate or replace components of the station to improve reliability and level of service. All eight stormwater pumps will be retrofitted to allow future repairs to be performed locally more quickly and efficiently.

3. **Emergency Overflow**

   The Freud and Conner Creek Pump Stations and Conner Creek Enclosure were originally constructed with an emergency overflow to the Detroit River. During the construction of the Conner Creek CSO Basin, these emergency overflows were eliminated. The GLWA will investigate whether emergency overflows could be restored to provide system relief during emergency conditions when the system is operating above design conditions and the potential exists for flooding of neighborhoods.

7.0 Conclusions

This report was developed to provide an understanding of the circumstances that occurred during storms that caused basement flooding on July 8, and August 16, 2016 in the east side of Detroit. An analysis of the rainfall that occurred during these storms was provided. Although the GLWA collection system in this portion of Detroit is complex, a detailed discussion of the system components has been provided to help the reader understand the system. This report did not include an analysis or discussion of the local Detroit sewer system or property sewer leads. Details of both the physical response of the system equipment and facilities to the storms and the response of the GLWA staff were provided. Finally, a plan by the GLWA to provide improvements to the system has been laid out. These improvements include immediate, near-term, and future flood mitigation actions. Based on the information provided in this report, the following conclusions can be made:

1. The July 8, and August 16, 2016 storms were large and intense. The rainfall from these storms had an annual probability of occurrence considerably less that the 10% design storm. The flow rates in the sewer system generated from these storms exceeded or approached the design capacity of the collection system. The interceptor and major trunk collection system and associated pump stations, gates, and diversion chambers were designed for storms with not less than a 10% annual probability of occurrence. The decision to design the system to a 10% annual probability of occurrence level of service is typical for large municipalities servicing combined sewer systems to balance the cost of infrastructure with the level of service.

2. The GLWA staff mobilized and responded rapidly to the July 8th storm in accordance with established protocol and procedures. Weather forecasts for the late evening and early morning of the 8th projected a 70% chance of rain with no flood watch or severe weather warning. The intensity of the rainfall caused widespread flooding which delayed staff access to the Conner Creek CSO Basin, and concurrently caused the flow rates and levels in the system to increase rapidly.

3. Following the July 8th storm, the GLWA responded by assigning staff to the Conner Creek CSO Basin on a full-time basis, 24 hours per day and 7 days per week. Staff members will also be dispatched to both the Conner Creek and Freud Pump Stations in

anticipation of a storm. Further, the discharge launder gates and all influent gates will be maintained in an open position as a standard operation procedure.

4. For the August 16th storm, staff were already onsite in advance of the storm, therefore access to the Conner Creek CSO Basin or pump stations was not a factor. Further, with the basin influent and launder gates opened and staff onsite to open the emergency relief gates, discharge from the facility was not be a constraining factor in flooding problems.

5. The post storm analysis of basement flooding claims from the August 16, 2016 storm shows significantly reduced flooding when compared to the July 8, 2016 basement flooding claims. Based on implementation of the new procedures (identified in Conclusion No. 3), GLWA staff responded appropriately and in accordance with established protocol and procedures. Although the August storm was less intense, the immediate operational changes implemented after the July storm have been beneficial to the system operation. Flooding claims from the August 16, 2016 storm in Grosse Pointe and Saint Clair Shores are upstream of pump stations that pump into the Fox Creek Enclosure and therefore are hydraulically isolated by the pump stations. These basement flooding claims are believed to be the result of local system problems. During this storm, the Bluehill PS was operated in accordance with the operational protocol and was able to maintain a wet well elevation that prevented surcharge of the Rivard sewer. Therefore, any basement flooding claims within the Cornerstone neighborhood are believed to be the results of the local system and not the result of the regional system operations.

6. The area with the most significant occurrence of basement flooding for both events is topographically very low and therefore vulnerable to both surface and basement flooding. Large tracts of land in this area are within the 100-year floodplain boundary as established by Federal Emergency Management Agency with some areas lying at or below the current water level of the Detroit River. The Detroit River is the water body to which wet weather flows are discharged. Homes having a ground elevation, and therefore basement elevations, below the receiving water level is very uncommon because they are more susceptible to flooding.

7. The local collector sewers serving the areas of the basement flooding, which are owned and operated by the DWSD, have not been inspected and therefore their condition at the time of the July and August events is unknown. Further, it is known and has been reported that some areas in the city have local sewers that are not sized or properly installed to convey the 10-year, one-hour design storm. Together these two facts call into question the adequacy of the local sewers to convey flows as designed during the both the July and August storm events.

8. Every storm event, including the July 8, and August 16, 2016 storms, is unique and provides a unique system response. These two storms had large rainfall totals and intensity. The GLWA has collected a significant amount of information about the impact these storms had on the system to better understand the system response. Based on this analysis, the GLWA has identified areas for improvement and has begun implementation of immediate, near term, and future flood mitigation actions. These improvements include changes in the operational protocol, repairs to the existing system components, and major capital improvements.

9. Although the rainfall from the July 8, and August 16, 2016 storms have been found to exceed the design rainfall of the system, the GLWA recognizes that there are opportunities to improve the level of service and further mitigate system flooding. The extenuating circumstances associated with staff inability to access the Conner Creek CSO Basin (upon arrival at the facility due to widespread flooding throughout the area during the July 8th storm) has been addressed via full-time facility staffing. Planned remote control of gates will further enhance system operations and level of service. In addition, planned near-term and long-term improvements to the Conner Creek and Freud Pump Stations will focus directly on the capacity to dewater the collection system, lower the hydraulic gradient and substantially reduce the probability of flooding throughout the east side system.

Appendix 1

Event Rainfall Maps

Appendix 2

Conner Creek CSO Basin Hydraulic Profile

Appendix 3

Fox Creek Enclosure Hydraulic Profile

Appendix 4

Detailed Time Series Data