Draft for Review Comment

City of South Bend, Indiana

Post-Flooding Investigation of Four Neighborhoods Along the St. Joseph River

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LAWSON-FISHER ASSOCIATES P.C.
CONSULTING ENGINEERS
525 WEST WASHINGTON AVENUE · SOUTH BEND, IN 46601
PH: (574) 234-3167 FAX: (574) 236-1330

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1.0 EXECUTIVE SUMMARY

The goal of this study was to investigate and validate the infrastructure within several neighborhoods along the river that experienced flooding during the historic event that occurred in February 2018 and to research potential options to reduce flooding during potential future extreme events. The areas that were included in this study are in Figure 1-1 located in Appendix A.

A questionnaire was made available to residents within the target neighborhoods so that data could be gathered pertaining to basement flooding, surface flooding, residential infrastructure, etc. for the February 2018 event, the August 2016 event, and more frequent storm events. This data was tabulated and input into GIS to aid in the data assessment and development of potential remediation options. There were 200 responses to the questionnaire.

Existing data such as the City GIS and sewer system as-built drawings were compared and utilized to identify potential physical issues with the systems in each study area. This information was correlated with the data from the resident survey along with videos of the sewer system that was available for some of the study area. After review and assessment of all of this information a field assessment and verification plan was prepared and executed. The goal of this plan was to verify the in-house information with field survey measurements and to investigate areas where the actual in-office data was unclear or where a potential issue was suspected.

As previously mentioned, the questionnaire provided to the residents asked for the homeowners' experiences with the February 2018 Event and the August 2016 event. These events were very different types of storms with the February 2018 event being a product of heavy snowfall, with unseasonable temperatures, followed by heavy rainfall. This event, while causing some issues within the upper watersheds, mainly impacted the St. Joseph River Levels which reached about a 0.2% Annual Chance Flood Level (500-year event). The August 2016 event was attributed to heavy rainfall which occurred over a short duration. This rain fell over a portion of the St. Joseph River Watershed and caused localized flooding throughout South Bend and St. Joseph County. Some areas during the 2016 event saw rainfall amounts of about 8.5-inches over a 12 hour duration. The 2016 storm was very different from the 2018 event in that the flooding was in the upper portions of the watersheds with very little, if any, flooding attributed to the river, while the 2018 event saw the river at historic levels which caused much of the flooding issues attributed to this particular event. While these storms were different, both were extreme, record-setting flood events that caused damage throughout Northern Indiana.

The February 2018 event resulted in river levels that coincided with the 0.2% Annual Chance Flood (ACF) Level or 500-year event boundary noted on the Federal Emergency Management (FEMA) Flood Insurance Maps. The August 2016 event, from a rainfall amount perspective, was estimated to correspond to a 0.1% ACF or 1,000-year event. Due to the difference of the how theses storm events occurred, the return intervals were determined utilizing different variables. The design storm event used for storm sewers throughout the City of South Bend, and common in many other municipalities, is that the 10-year, 6-hour duration storm should not be above the crown of the sewer pipe (therefore placing it into pressure flow). For comparison with the 2016 and 2018 events, the 10-year, 6-hour duration event for the South Bend Area is 3.1 inches. More info regarding the various storm events can be located in Section 2 of this Report.

1.1 Resident Questionnaire Results

The questionnaire also requested information of what the residents may have experienced during more frequent storm events in the area. They were also asked about whether they had cracks in their basements, backflow prevention devices, and other questions to assist with the investigation. Table 1-1 contains some of the questions asked in the survey with the percentages based on the respondents from each study area.

Table 1-1
Abbreviated Questionnaire Response Summary

	Keller	Northshore Triangle	Riverside	Emerson Ave.	Other
Total Survey Responses	32	105	10	5	48
2016 & 2018 Flood-Event Basement Flooding					
August 2016 Basement Flooding (%)	6%	7%	0%	0%	-
February 2018 Basement Flooding (%)	56%	19%	50%	60%	-
August 2016 & February 2018 Basement Flooding (%)	22%	61%	0%	0%	-
Non-Extreme Event Basement Flooding Frequency					
Less Than 2 Times per Year	38%	28%	30%	40%	-
Between 2 - 4 Times per Year	13%	4%	0%	20%	-
More Than 4 Times per Year	3%	2%	0%	0%	-
No Flooding Occurs	47%	60%	70%	40%	-
Have a Basement Bathroom					
Yes	9%	24%	20%	0%	-
Water Type Observed in Basement During Flooding					
Clear Groundwater/ Rainwater	63%	43%	40%	60%	-
Clear with Some Sewage	16%	29%	20%	0%	-
Sewage	3%	5%	0%	0%	-
Have a Sump Pump					
Yes	28%	24%	30%	20%	-
Downspouts are Disconnected					
Yes	66%	64%	50%	60%	-
Have Backflow Prevention Device(s) Installed					
Yes	44%	33%	0%	20%	-
Backflow Prevention Device Functioned Properly					
Yes	34%	20%	N/A	20	-

Based on the resident survey responses there were several similarities between the study areas. They all had some impact from the 2018 flood however there was a smaller impact if any from the 2016 event. This can be attributed to the impact that the river had on the 2018 event and how it flooded into neighborhoods, and the impact on the functionality of the City's sewer network.

Based on the responses, during events other than those in 2016 and 2018, the frequency of basement flooding decreases significantly. This could be an indicator that the sewer systems function as intended during the less extreme storm such as a typical design event which as previously stated has a much smaller recurrence interval than the events of 2016 and 2018.

Another item of note is that the majority of the respondents noted that the water observed in their basement during the 2018 event was mostly clear water. There were some that noted clear with some sewage while there was a smaller percentage that noted just sewage. The groundwater in the study areas is high and many of the respondents noted that they had cracks in their basement walls, floor, or both. The groundwater responds to the River level and rain and is a potential source for some of the flooding that was identified. Less than half of the respondents in all of the study areas had a backflow prevention device installed. This device, when operated and maintained properly, can eliminate sewage from backing up into a home when the combined or sanitary sewer is beyond its hydraulic capacity and begins to back up. The City has been conducting a program to cost-share with residents in the installation of backflow prevention devices. More information regarding the resident survey and responses is located in later sections of this report.

Some of the properties in the study areas were located within the 1% ACF zone (100-year). Floodplain ordinance which vary from community to community and have changed considerably over the years attempt to discourage building in these zones. However, these ordinances were not in place when most of the home along the river in the City were constructed. Therefore, inundation of these properties during a historic event along the River such as the February 2018 can be expected based as shown in FEMA flood maps.

1.2 <u>Common Observations Within the Study Areas</u>

- For the most part, the GIS and As-builts were accurate for the study areas.
- The flooding in 2018 inundated mostly all of the Combined Sewer Overflows (CSO) and the separated stormwater outlets. This provided no positive outlet for these sewers. These outlet were inundated for an extended duration. Also, the areas downstream of these areas was at or above capacity not allowing flow to constantly flow until the downstream systems had drained.
- A large percentage of those that reported basement flooding also reported having cracks in their basement walls, floors or both. All of the study areas have high groundwater elevations under normal situations due to the proximity to the river. During flooding conditions the groundwater increases. This could lead to ground water flowing through the cracks and flooding a basement.
- Less than 50% of the respondents noted having backflow prevention devices. These devices could have eliminated potential sewer backups into basements.
- While less than 50% noted having backflow prevention devices, a smaller percentage of those with them noted that they worked properly.
- A large percentage of the respondents noted that their downspouts had been disconnected. This helps reduce flow to the sanitary or combined sewer.

- Several residents from the study areas noted that an earlier notification would have been helpful during the 2018 event.
- The City is currently working to renegotiate the consent decree and Long-Term Control Plan that would most likely contain projects that would potentially reduce the amount of runoff to the interceptor pipes in the study areas. Any decrease in flow in the existing trunk sewers would be a benefit to the sewers in the study areas.

1.3 Study Area Specific Items

Many of the observations and conclusions, as noted above, were the same throughout the study areas, however there were some items that were specific to just one or two of the neighborhoods.

- Both the Keller Park and Emerson Avenue Areas had properties that were within the 1% ACF zone. These properties have a higher risk of flooding due to the River more frequently than those outside of the boundary.
- A majority of the pipes within the North Shore Triangle Area had been televised. This provided an opportunity to view for pipe defects, blockage etc. There were some stretches of pipe where a portion of the pipe was blocked obstructing flow. The pipes were categorized and recommended for assessment and cleaning. Televising and assessing the pipes is recommended for all of the Study Areas.
- In the Riverside (South of Bartlett) Area the combined sewer is conveyed through a 12-inch throttle pipe. During high flows whatever cannot flow through the 12-inch throttle pipe overflows through CSO 10 into the River. It is recommended that the City research the option and impacts of increasing this throttle line which could reduce the stress on the combined sewer in this area.
- During review of the GIS data, as-builts, discussions with City Staff and a field investigation it was observed that in the Northshore Triangle there are some 18-inch sanitary sewer pipes that flow into a 10-inch sanitary sewer pipe that runs along Angela. Typically, pipe size increases as it progresses downstream and collects flow from other pipes. Most of the Northshore Triangle Area is a separated system have both sanitary and storm sewers. Based on as-builts the storm sewers were installed around 1965. At that time, the original combined sewer, which was installed in the early 1900's was utilized for the sanitary while new storm sewer lines was installed to carry storm runoff. The original lines would have most likely been sized to carry sanitary and stormwater. Therefore they are potentially bigger than they need to be for just the sanitary flow that they currently convey. It is recommended that the City further research this assumption to verify that the 10-inch along Angela is appropriately sized for the sanitary flow it conveys.
- Many respondents north of Angela noted heavy flow and flooding from the area north of their residences. This area was inspected and stormwater runoff is flowing from the private property to the North and collecting into the area North of Angela Boulevard near Iroquois and Marquette.
- There are several storm outlets along the river in the north shore triangle area. None of these outlets are outfitted with backflow prevention device. This allows the River to flow into the storm sewer when river levels rise above the outlets.

1.4 Recommendations Common For all Study Areas

- City: Evaluate the current design criteria for determining sewer capacity and stormwater storage. While the City's criteria is in-line with other municipalities, given recent storm data and events, evaluation of the existing criteria seems appropriate.
- City: Continue to offer residents the Basement Valve Program.
- Homeowners: Participation in the Basement Valve Program by homeowners will assist with the basement flooding from potential backflow of the sewer line.
- Homeowners: Address the cracking within basement walls and floors. This is an entry point for groundwater to enter and flood basements. The exact repair and cost will vary depending on items such as location and size of cracking.
- Homeowners: Continue the disconnection of downspouts so as to divert rain away from the sewer system.
- City: As part of the routine videoing, cleaning, and repairing of South Bend's sewer system, it is suggested that the City place particular emphasis on the neighborhoods featured in this report.
- Homeowners: Homeowners that experience frequent basement sewer backup issues are encouraged to have the service line on their property inspected and/or cleaned.
- City: Research the possibility of a notification system along multiple media platforms to provide residents with notification and information during flood events.

1.5 Recommendations For Specific Areas

- City: In certain circumstances FEMA provides grant assistance for the purchase of homes that are within particular flood zones. The City should research these FEMA requirements and ascertain their applicability to South Bend.
- City: Evaluate the 12-inch throttle pipe in the Riverside Drive (South of Bartlett) area to see if it could be increased to allow more flow to leave the area quicker. The effect on the downstream system should be evaluated along with the actual impact on the Riverside area.
- City: Further research to determine that the 10-inch sewer along Angela is appropriately sized for the sanitary flow it conveys (due to the larger pipes flowing into the 10-inch pipe)
- City: Discuss options to control runoff with the private landowner(s) of the 40-acres that is contributing stormwater runoff to the area north of Angela near Iroquois and Marquette.
- City: Install backflow prevention measures on the stormwater outlets to the St. Joseph River within the Northshore Triangle.

More detailed discuss of the findings and recommendations are covered in subsequent sections of this Report.

2.0 PROJECT BACKGROUND

In February 2018, historic flood levels occurred on the St. Joseph River. These levels were the result of a combination of unprecedented snowfall, temperatures, and rainfall for the month of February. The combination of snowfall, temperature and rainfall created record water levels on the St. Joseph River and caused flooding in some residential areas along the river. The focus of this study was to investigate the flooding that occurred in three areas (Riverside Drive (South of Bartlett), Northshore Triangle, Keller Park Area, and the Emerson Avenue Area) along the river. These areas are noted in Figure 1-1 in the Executive Summary. The goal of the study was to survey the residents in the areas to determine details of the flooding, verify Geographic Information System (GIS), as-built and field data, provide an opinion on how the systems in each area operated during this historic event, and identify possible programs or projects that may be of benefit to these areas in the event of future flooding.

2.1 St. Joseph River Basin

The St. Joseph River Basin has a drainage area of 4,865 mi^2 and a length of about 206 miles from the headwaters in Hillsdale, Michigan to where it flows into Lake Michigan. The River has a slope from the headwaters to Lake Michigan of about 3 ft per mile. The land use within the watershed consists mainly of agricultural with several urban areas.

There are twelve (12) dams located along the length of the River. The dams were originally constructed for power generation. Currently ten (10) of the twelve (12) dams are still generating power. Of those ten (10) still generating power, eight (8) are under the regulatory authority of, and have a license through, the Federal Energy Regulatory Commission (FERC). It should be noted that these dams were constructed for power generation and are not flood control structures. The dams regulated by the FERC are required, per their license, to maintain a water surface elevation (within a small operating envelope) in their respective impoundments. This requires the Licensee to operate such that water must be released at the same rate it enters the impoundment and cannot be stored. For most of the FERC licensed projects, this is standard operation, even in flooding situations.

2.2 February 2018 Storm Event

The month of February 2018 saw unusual weather patterns progress through the area. The month began with a fluctuation of temperatures with daily highs in the first part of the month ranging from 10˚F to about 50˚F. During this part of February about 30-inches of snowfall was recorded. Based on records from the National Weather Service (NWS), the first 10 out of 11 days in February saw measurable snowfall. The 29.6-inches of snow that fell during this time was about 14.6-inches above normal levels for the month. Figure 2-1 in Appendix A shows the snowfall amounts over time for the month of February.

Also, Figure 2-2 in Appendix A contains an image created by the NWS that shows snow depths within the St. Joseph River Basin ranging from 8-inches to 16-inches.

The combination of temperature, snowmelt, and rainfall led to increased runoff causing rising water surface elevation in the St. Joseph River. As shown in Figure 2-1 of Appendix A, the heavy snowfall in early February 2018 coincided with normal temperatures. After the majority of the snow had fallen by February 11th, there was a gradual increase in temperature for the month with all recorded daily, high temperatures above freezing. This resulted in the snow beginning to melt. Temperatures dipped and an additional 1.8 inches of snowfall was recorded on February 17th. Following this snowfall, the temperatures were unseasonably high for February and from February 19th to February 21st, 5.61 inches of rain was recorded. This rainfall fell while snow was still melting and on saturated ground. With the ground being saturated, the rainfall was not able to infiltrate into the ground resulting into direct runoff to the rivers and streams. This chain of meteorological events is shown graphically in Figure 2-1 of Appendix A.

The runoff generated from this event caused some flooding issues in the watershed but resulted in record flooding along the entire length of the St. Joseph River. Figure 2-3 in Appendix A contains the stage hydrograph at the National Weather Service (NWS) Staff Gage on the River near Pinhook Park.

As can be seen by the hydrograph, the River at this location reached its historic crest on February 22, 2018 however, given the large size of the drainage area, the River elevations did not fall below “major flood” levels until February 26th. This is critical in that most of the outfalls to the sewer system were inundated into the month of March.

Based on observed water surface elevations during the event, the flood levels equated to a 0.2% Annual Chance Flood (ACF) or 500-year flooding event. Figures 2-4 through 2-7 in Appendix A shows an estimate of the extent to which flood waters covered each study area during the February 2018 event. Figures 2-8 through 2-11 in Appendix A show profiles for each study area and the critical infrastructure within each area is noted within the profile. These profiles include the Combined Sewer Overflow (CSO) and storm outfall elevations in relation to approximate water surface elevations observed during the February 2018 event. As noted, these outfalls and pipes were inundated for an extended period of time while the River receded below flood levels.

2.3 <u>August 2016 Storm Event</u>

Another recent storm of note resulting in significant flooding observed throughout the City was the event that occurred in August 2016. During this event about 10.7-inches of rain fell in the area from August 12, 2016 to August 16, 2016. As can be seen from Figure 2-12 in Appendix A, approximately 2.2-inches of rainfall occurred on August 12th and August 13th while no rainfall was recorded on August 14th. Over the period of 24-hours from 11:00 AM on August 15th to 11:00 AM on August 16th 8.49-inches of rain was recorded. Based on the National Weather Service (NWS), the recorded rainfall depth over the 24-hour period had an average recurrence interval of 1 in 1000 years while the 6.15-inches the fell on August 15th from 6:00 PM to midnight had an average recurrence interval of 1 in 500 years.

This storm caused significant flooding in many neighborhoods and tributaries to the St. Joseph River however due to the timing of the storm and the distribution of the rainfall throughout the watershed, the river levels, according to the NWS staff gage at Pinhook Park, were not within the top 25 highest on record.

2.4 Design Storms

When designing a sewer system, a design storm is used in order to properly size the conveyance system to carry the necessary flow generated from a predetermined event. The current design storm for the City of South Bend is the 10-year, 6-hour duration storm event which is about 3.10 -inches of rainfall. The sewer must be sized so that the runoff generated from this event is below the crown of the pipe. This criteria may vary by municipality however the above noted requirements are common.

As can be seen by the rainfall amounts and durations, the August 2016 event saw rainfall well in excess of the design storm. This was evident by the flooding in areas within the upper reaches of the watershed. While the 2018 rainfall amount of 5.61-inches was above the design amount of 3.10, this rainfall was distributed over a longer period of time than 6-hours and had the addition of the runoff from the snow. While there was some flooding in the upper parts of the watershed, the major flooding of this event was along the river.

Design storms are the benchmark that is utilized to determine storm sewer and detention basin sizes. These items are designed for specific amounts of rainfall to occur over a set distribution. As can be seen by the above storm events, runoff can be generated from many factors and also rain can fall in many different durations and patterns than is specified in a design storm criteria. All of these factors contribute to flooding during a specific event within a certain area. An area can experience flooding when a system is designed to convey the required design storm due to the capacity being exceeded, due to increased runoff from a greater rainfall depth or duration than the design criteria or the introduction of another source of runoff such as snowmelt. While systems can be designed to convey these less probable events there can be significant costs associated with the construction of such infrastructure. Although the City's design criteria is similar to other municipalities it is recommended that the City evaluate the current standards to determine if revisions may be necessary given recent storm data.

In addition, when evaluating a sewer system, the entire network must be considered. This is because changes to one area of the system could have an effect on areas of the sewer network upstream or downstream of where the improvements may have occurred. Also, constrictions to a sewer network that are located downstream of improvements may negate the benefits if the downstream constriction is not addressed.

3.0 EXISTING SEWER NETWORKS WITHIN STUDY AREAS

3.1 Riverside Drive

The existing Riverside Drive sewer network is a combined system (both storm and sanitary flow through the same pipe). Photo 3-1 below shows an aerial of the sewer network as indicated by the City of South Bend's Geographic Information System (GIS).

Photo 3-1
Overview of Riverside Drive Sewer Network

The yellow lines indicate combined sewer pipes. In general, flow travels from southwest to northeast within Riverside Drive. Once flow reaches the intersection of Riverside Drive and Bartlett Street, it flows through a 12" diameter throttle pipe that conveys flow to the combined sewer network along Michigan Street. If flow exceeds the capacity of the 12" diameter throttle line, overflow from the system will discharge into the St. Joseph River through Combined Sewer Overflow (CSO) 10 (indicated by the red icon along river).

3.2 Northshore Triangle

A majority of the existing sewer network within the Northshore Triangle area consists of separate storm and sanitary pipes. The area northeast of Hillcrest Road is currently a combined system. Photo 3-2 below shows an aerial of the sewer network as indicated by the City of South Bend's Geographic Information System (GIS).

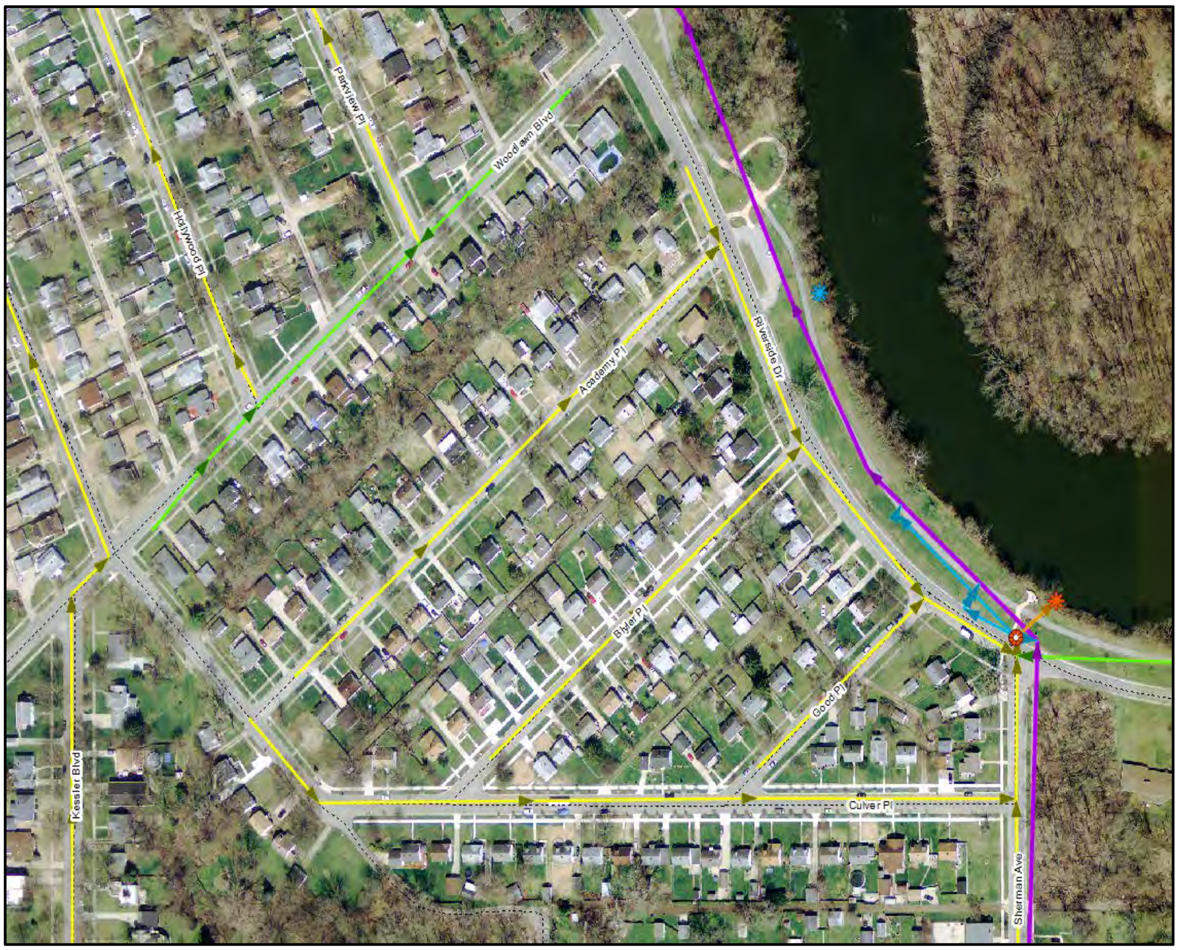
Photo 3-2
Overview of Northshore Triangle Sewer Network

The green lines indicate sanitary pipes while the blue lines indicate sanitary pipes. For a majority of the areas, storm and sanitary lines run parallel to each other and run underneath existing roadways. The yellow lines indicate combined pipes. There is an 84" diameter combined trunk sewer (indicated by the yellow line) that runs parallel to the Saint Joseph River. Stormwater pipes convey flow from northeast to southwest within the area and discharge into the river through storm outfalls (indicated by the blue icons along river). Sanitary pipes convey flow from northeast to southwest and discharge into the 84" diameter combined trunk line. The combined pipe conveys flow towards the intersection of Angela Boulevard and North Shore Drive where River Crossing 5 and CSO 5 (indicated by the red icon near the intersection of Angela Boulevard and North Shore Drive) are located. This trunk sewer also carries flow from the south side of the river that crosses at River Crossing Number 4. Under normal conditions, flow is conveyed across the river and continues to the South Bend Wastewater Treatment Plant (WWTP). If flow exceeds the capacity of River Crossing 5, flow within the 84” diameter combined pipe will discharge directly into the St. Joseph River via CSO 25 (red icon near intersection of Lafayette Boulevard and North Shore Drive) and CSO 5.

3.3 Keller Park

The existing sewer network in the Keller Park area is a combined system (both storm and sanitary flow through the same pipe). Photo 3-3 below shows an aerial of the sewer network as indicated by the City of South Bend’s Geographic Information System (GIS).

Photo 3-3
Overview of Keller Park Sewer Network



The yellow lines indicate combined sewer pipes. In general, flow travels from southwest to northeast within Keller Park. Once flow reaches the intersection of Sherman Avenue and Riverside Drive, it flows through a 21” diameter pipe (indicated in blue) and continues to the 96” combined sewer trunk line (indicated in purple) that runs parallel to the St. Joseph River. If flow exceeds the capacity of the 21” diameter pipe, the combined system will discharge into the Saint Joseph River through CSO 2 (indicated by the red icon along river).

The GIS data in these three areas were checked with available as-built data to determine if there were any contradictions or evidence of potentially, unknown bottlenecks in the system.

3.4 Emerson Drive

The existing sewer network in the Emerson Avenue area is a combined system (both storm and sanitary flow through the same pipe). Photo 3-4 below shows an aerial of the sewer network as indicated by the City of South Bend's Geographic Information System (GIS).

Photo 3-4
Overview of Emerson Avenue Sewer Network

The yellow lines indicate combined sewer pipes. In general, flow travels from north to south. Once flow reaches Northside Boulevard, it flows through a 36" diameter pipe (yellow line that runs parallel to the river) and continues northwest. If flow exceeds the capacity of the 36" diameter pipe, the combined system will discharge into the St. Joseph River through CSO 33 (indicated by the red icon near Emerson Avenue) and CSO 35 (indicated by red icon near Clover Street).

4.0 FIELD VERIFICATION

As part of the study, areas within the Northshore Triangle, Riverside Drive (South of Bartlett, Keller Park Area, and the Emerson Avenue Area were selected to conduct visual inspections, field survey and structure inspections. The purpose of investigations was to verify as-built and GIS data, gain a better understanding of how the sewer systems interact with one another and identify any issues that could have attributed to increased flooding within the study areas. Nine (9) total locations were selected based on their importance within the combined, sanitary, and storm sewer networks. The locations were visited to verify the structure configuration and elevations.

4.1 Location 1 - Intersection of West North Shore Drive and West Angela Boulevard

This location was selected due to its proximity to combined sewer outfall (CSO) 5 and river crossing 5. The 54” diameter combined sewer trunk line brings flow into the structure. It also appeared that a 24” diameter combined pipe was actively conveying flow into the structure as well. Additionally, it is assumed that this 24” diameter combined pipe is connected to Location 8. There are two gate valves installed within the structure. One gate valve is aligned with the 36” diameter CSO 5 outfall pipe and the other is aligned with the 54” diameter river crossing 5 pipe. The CSO 5 outfall, located along the east bank of the St. Joseph River, was significantly buried by sediment, impeding its ability to open and relieve the sewer network (See Photo 4-1). The outfall structure had a steel flap gate installed to help prevent the backflow of river water into the sewer network.

Photo 4-1
View of CSO 5 Outfall

A diagram of the structure and all pipes can be found in Appendix B along with photos obtained during the field visit.

4.2 Location 2 - Intersection of West North Shore Drive and Parkovash Avenue

This location was selected due to its proximity to a storm outfall. Within the structure there is a 36” diameter storm inflow and corresponding outflow line along with two 12” diameter storm inflow pipes from nearby street inlets. The flow travels south and ultimately discharges out of the storm outfall into the St. Joseph River. The headwall and outfall appear to be functional and in good condition. The structure and sewer configuration matched the as-built data. This outfall was not outfitted with a backflow prevention device.

Photo 4-2
View of Storm Outfall

A diagram of the structure and all pipes can be found in Appendix B along with photos obtained during the field visit.

4.3 Location 3 - Intersection of Marquette Avenue and Parkovash Avenue

Two structures were inspected at this location to verify the sewer separation. The first structure, 3-1 in Appendix B, is a sanitary structure. A total of seven pipes were identified within the structure. Four of the pipes were 8" diameter and were assumed to be plugged inflows from old street inlets. During the site visit in this area personnel were not able to locate any street inlets that would feed into the sanitary structure. One of the remaining lines was purposely plugged and assumed to be part of the sewer separation. The two remaining lines were both outlets, one being a 12" diameter pipe going northeast along Parkovash Avenue and the other being a 15" diameter pipe going southeast along Marquette Avenue. The other structure at this location, 3-2 in Appendix B, was a storm structure. There were four total pipes within the structure. Two main inflows were measured as 27" and 21" in diameter coming from the northwest and southeast, respectively, along Marquette Avenue. Additionally, a 36" diameter outlet pipe conveying flow towards Parkovash Avenue and a 12" diameter storm inlet, that is assumed to be from a nearby street inlet, were observed within the structure.

4.4 Location 4 - Intersection of West North Shore Drive and Iroquois Street

Two structures were selected in this area due to the complex network of piping shown on the City of South Bend's Geographic Information System (GIS) and their proximity to CSO 24. The first structure, 4-1 in Appendix B, had two defined pipes, one inlet and one outlet. According to the GIS, a 6" diameter throttle line should also have been present, but the presence of the throttle line could not be confirmed by visual inspection from the top.

According to the GIS, CSO 24 has been abandoned and is no longer in use. It appeared that a backflow preventer had been installed on the 24” diameter inlet pipe, but appeared to have been removed. The 24” diameter outlet pipe appeared to convey flow to the 84” diameter combined trunk line that runs parallel to the St. Joseph River. The second structure, 4-2 in Appendix B, was located along the 84” diameter combined sewer trunk line. There were two inflow pipes, an 84” diameter combined and a 24” diameter combined, along with two outflow pipes, an 84” diameter combined and a 24” diameter combined, observed within the structure. The 24” diameter outflow pipe appeared to be the old connection to the CSO 24 outfall structure. However, the old CSO outfall structure was broken into two separate pieces and did not appear to be functional.

Photo 4-3
View of abandoned CSO 24 Outfall

Based on visual inspection, it could not be confirmed that the 24” diameter outlet pipe has been plugged to prevent flow from exiting the structure and discharging into the river. There was evidence of debris along the rim of the structure indicating that the water level has been high in the past at this location.

4.5 Location 5 - Intersection of West North Shore Drive and Lafayette Boulevard

This location was selected based on the complicated pipe network shown on the City of South Bend’s GIS and its proximity to CSO 25. The structure that was inspected had a 24” diameter combined inflow pipe with three outflow pipes. The main outflow pipe was a 12” diameter combined sewer line that appeared to convey flow to the 84” diameter trunk line along the river. There is a 6” diameter throttle line that also connects to the 84” diameter trunk line further downstream in the sewer network. A 1.25-ft high weir prevents normal combined flow from entering the 24” diameter overflow line that is connected to CSO 25. This weir will only discharge flow to the river during high flow events when water levels exceed the weir height. Based on visual inspection, a backflow prevention device was installed on the outlet side of the 24” diameter outfall pipe to prevent river water from entering the sewer network through CSO 25. A diagram of the structure and all pipes can be found in Appendix B along with photos obtained during the field visit.

4.6 Location 6 - Intersection of Riverside Drive and Bartlett Street

Two structures were inspected at this location due to the complex pipe network shown on the City of South Bend's GIS and their proximity to CSO 10. The first structure, 6-1 in Appendix B, is the diversion chamber for CSO 10. It has two inflow pipes, a 24" diameter combined and a 15" diameter combined, along with a 12" diameter outflow throttle pipe that appears to connect to the Michigan Street combined sewer network. There is a 24" diameter outflow pipe that flows towards the CSO 10 outfall structure and there is a 1-foot high wooden weir. The weir helps divert normal flow, but will allow flow to go through the CSO 10 outfall structure during high flow events when the water level exceeds the weir height. The second structure, 6-2 in Appendix B, has 3 inflow pipes and an 18" diameter outflow pipe that leads to the CSO 10 outfall structure. The 24" diameter combined inflow pipe has a Larflex backflow prevention device installed to prevent river water from entering the sewer network through the CSO 10 outfall structure. There is another 24" diameter inflow pipe assumed to be a storm line coming from the area north of the structure. There is also a 10" diameter storm inflow pipe that appears to come from a nearby street inlet.

4.7 Location 7 - Intersection of Riverside Drive and Sherman Avenue

Two structures were inspected at this location due to their proximity to CSO 2. The first structure, 7-1 in Appendix B, is the diversion chamber for CSO 2. There is a 24" diameter combined inflow pipe that conveys flow through a concrete channel and exits the structure through a 21" diameter combined outflow pipe. There is a 12" diameter combined outflow pipe that is elevated and is assumed to gather flow when the water level is higher than the concrete channel. The 21" diameter and 12" diameter outflow pipes ultimately connect back into the 96" diameter combined trunk line that runs parallel to the St. Joseph River. There is an additional 24" diameter combined outflow pipe that leads towards the CSO 2 outfall structure. It is elevated 1' higher than the rest of the piping which acts as a weir to only allow flow from high flow events to discharge towards the CSO 2 outfall structure. The second structure, 7-2 in Appendix B, has a Larflex backflow prevention device installed on the 24" diameter combined pipe. This is to prevent river water from flowing into the sewer network through the CSO 2 outfall structure. Additionally, a 24" diameter combined outflow line that conveys flow towards the CSO 2 outfall structure was observed.

4.8 Location 8 - Area north of Angela Boulevard between North Shore Drive and the old St. Joseph High School Campus

The area north of Angela Boulevard was inspected to locate any existing ditches and to identify potential sources of runoff that contribute to the flow going to this area. The City of South Bend's GIS also showed a 24" diameter combined sewer line running along the alley north of Angela Boulevard that was verified during the investigation.

The field investigation started by walking an existing ditch that began near the parking lot of the old St. Joseph High School Campus. Initially, the ditch was relatively flat and lined with stone/riprap. About 200 feet into the tree line, the ditch had some step features made out of stone and a 14" diameter PVC pipe that was actively discharging into the channel. There were also two CMP pipes projecting from the southern bank. The sources of the pipes were unable to be determined during the field investigation nor after review of drawings from the area. Immediately past the pipes, the channel widens dramatically.

After 500 feet, a 24" diameter CMP pipe sits on the surface and appeared to have been installed to help direct flow within the channel. The channel showed signs of severe erosion around the pipe and appeared to have bypassed the pipe in the present condition.

Photo 4-4
View of Erosion near 24" Diameter CMP Pipe

Beyond the CMP pipe the channel narrows and flattens until it ultimately discharges to the alley north of the intersection of Angela Boulevard and Iroquois Street.

A second distinguished ditch exists near the old railroad line/path. The field investigation identified a ditch that seemed to start near a foot trail that runs parallel to the old railroad line. It appeared that much of the flow was due to runoff from the cleared foot paths being concentrated into one location. The survey team walked along the ditch for approximately 850 feet until the ditch became flat and appeared to end in the alley north of Angela Boulevard between Iroquois Street and Marquette Avenue.

The 24" diameter sewer line was investigated by conducting structure inspections of manholes along the designated path indicated on the City of South Bend's GIS. The survey team was able to open a manhole along North Shore Drive north of Angela Boulevard that appeared to have a 24" diameter sanitary or combined inflow and corresponding outflow pipe. The inflow appeared to be coming from the direction of the alley north of Angela Boulevard while the outflow appeared to flow towards the CSO 5 and river crossing 5 junction. A second manhole was able to be located and opened behind the 525 Angela Boulevard residence. This structure also had a 24" diameter inflow and corresponding outflow pipe. In an attempt to determine where the flow originated from, the pipe was traced into the wooded area as indicated on the GIS map. An elevated manhole casting was located within the wooded area, but was unable to be opened due to it being bolted and in a rusted condition. After reviewing drawings, it is assumed that the flow is coming from the Holy Cross Campus to the north. A diagram of all of the pipes within the structure along North Shore Drive can be found in Appendix B along with photos obtained during the field visit.

4.9 Location 9 - Intersection of Angela Boulevard and Marquette Avenue

This location was selected based on the complicated pipe network shown on the City of South Bend's GIS. The structure that was inspected had two inflow pipe and one outflow pipe. The outflow pipe was a 10" diameter sanitary sewer line that appeared to convey flow towards the 84" diameter trunk line along the river. There was a 10" and 18" diameter inflow pipe as well. It is not common to have a larger diameter pipe flow into a smaller diameter pipe. After reviewing the as-built drawings and GIS data, it appears that the Northshore Triangle area was separated in 1965. As part of the separation process, the existing combined pipe network that was installed in the early 1900's was converted to a sanitary system. A separate storm pipe network and an additional 10" diameter sanitary pipe along Angela Boulevard were installed in 1965 to complete the sewer separation. Based on visual inspection, there wasn't a visible high water mark or debris line to indicate the system had backed up in the structure. A diagram of the structure and all pipes can be found in Appendix B along with photos obtained during the field visit.

5.0 RESIDENT SURVEY SUMMARY

The City of South Bend distributed Sewer Study Questionnaires targeted toward the residents of the Keller Park, Northshore Triangle, Riverside Drive, and the Emerson Avenue areas in the Spring of 2018. The survey was made available online to all residents of the City. The questionnaires were made available in an electronic and physical format; the physical surveys were delivered to residences in the above-mentioned areas. Overall, 200 Sewer Study Questionnaires were submitted. Of the submittals approximately 105 (52.5%) responses were received from the Northshore Triangle area, 32 (16%) were received from the Keller Park area, 10 (5%) were received from the Riverside area, and 5 (2.5%) were from the Emerson Avenue area. Approximately 48 (24%) out of the 200 questionnaires were submitted by residents from outside of the targeted areas of study. Please note, the responses received from areas other than the targeted areas of study were not included in the analysis of the targeted study areas however the data was downloaded and put in GIS format for potential future use.

5.1 Basement Flooding

The questionnaire focused on gathering historic as well as recent flooding data. Historic non-extreme flood (not the 2018 or 2016 events) event basement flooding frequency data were surveyed to establish baseline flooding activity in each study area. Table 5-1 demonstrates the number of respondents that reported the frequency of basement flooding outside of the 2016 and 2018 flooding events. The two recent flooding events surveyed were the August 2016 and February 2018 flood events. Table 5-2 demonstrates the number of respondents that reported basement flooding during the August 2016, February 2018, or both flooding events. It should be noted that the numbers may not necessarily add up to the total responses due to some respondents leaving some questions blank and some checking multiple boxes on the survey. This was most evident in the questions regarding the basement flooding during the 2016 and 2018 event.

Table 5-1
Basement Flooding Frequency
(Not including the 2016 and 2018 Events)

	Keller	Northshore Triangle	Riverside Dr.	Emerson Ave.	Other
Total Survey Responses	*32*	*105*	*10*	*5*	*48*
Less Than 2 Times per Year	12	29	3	2	-
Between 2 - 4 Times per Year	4	4	0	1	-
More Than 4 Times per Year	1	2	0	0	-
No Flooding Occurs	15	63	7	2	-

Based on the data, only a small number of the homes within the study areas experience basement flooding during a typical year when not including the major storm events that have recently occurred. About 30% from each area experience basement flooding less than twice a year. This flooding could be due to several reasons ranging from high groundwater entering crack in the basement, grading near the home, localized problems with the service lines, etc.

Table 5-2
2016 & 2018 Flood-Event Basement Flooding

	Keller	Northshore Triangle	Riverside Dr.	Emerson Ave.	Other
Total Survey Responses	*32*	*105*	*10*	*5*	*48*
August 2016 Basement Flooding	2	7	0	0	-
February 2018 Basement Flooding	18	20	5	3	-
Both August 2016 & February 2018 Basement Flooding	7	64	0	0	-

As can be seen by the data, a large number of the respondents experienced flooding in their basements during the February 2018 event. This event saw extreme river levels where the actual ground around some of these homes was inundated. In addition, the sewer system in this area was backed up for an extended period of time due to the lagging recession of the river. This provided little relief to the system as a whole and also increased the issues with an already high groundwater.

5.2 Floodwater Source and Type

Respondents were asked to identify the primary sources of their basement flooding. The questionnaire also surveyed for the composition of the basement floodwater. Tables 5-3 and 5-4 show the responses gathered from this inquiry.

Table 5-3
Primary Source of Basement Flooding

	Keller	Northshore Triangle	Riverside Dr.	Emerson Ave.	Other
Total Survey Responses	*32*	*105*	*10*	*5*	*48*
Crack in Floor	20	40	2	0	-
Crack in Wall	11	32	4	2	-
Floor Drain	18	69	5	0	-
Sink	6	10	0	0	-
Toilet	2	10	1	0	-
Other	7	26	3	0	-

Table 5-4
Water Type Observed in Basement During Flooding

	Keller	Northshore Triangle	Riverside Dr.	Emerson Ave.	Other
Total Survey Responses	*32*	*105*	*10*	*5*	*48*
Clear Groundwater/ Rainwater	20	45	4	3	-
Clear with Some Sewage	5	30	2	0	-
Sewage	1	5	0	0	-

5.3 Flood Prevention Initiatives

The questionnaire asked residents about the status of their downspout connection and backflow prevention device installation. Table 5-5 shows the number of respondents whose downspouts are disconnected. Table 5-6 shows the number of respondents who indicated they have a backflow prevention device installed.

Table 5-5
Downspouts are Disconnected

	Keller	Northshore Triangle	Riverside	Emerson Ave.	Other
Total Survey Responses	*32*	*105*	*10*	*5*	*48*
Yes, Downspouts are Disconnected	21	67	5	3	-

Table 5-6
Backflow Prevention Device(s) Installed

	Keller	Northshore Triangle	Riverside	Emerson Ave.	Other
Total Survey Responses	*32*	*105*	*10*	*5*	*48*
Yes	14	35	0	1	-
Type of Back Flow Device Installed					
Ball Valve	4	13	N/A	N/A	-
Check Valve	5	12	N/A	N/A	-
Gate Valve	1	3	N/A	N/A	-
Plug Valve	6	12	N/A	1	-
Other Device	4	12	N/A	N/A	-
Backflow Prevention Device Functioned Properly					
Yes	11	21	N/A	1	-

6.0 FINDINGS FROM INVESTIGATIONS

The following is a summary, by area, of the findings and opinions that were developed based on reviewing the physical infrastructure and the data acquired from the resident questionnaire. This study did not include any hydrologic/hydraulic modeling but utilized available data. In addition, it should be noted that during the larger storm events, such as the February 2018 and August 2016 events, there are things occurring system-wide and city-wide that can effect how the sewers react within a totally separate area of the system. A capacity issue at the downstream end of the system can have cascading effects throughout the upper reaches. This should be taken into consideration when reviewing these conclusions.

6.1 Riverside Drive (South of Bartlett)

The field verification and survey did not show signs that the sewer network in the Riverside Drive area had failed or was limited in its as-designed performance. This is also represented by the relatively low frequency of flooding during normal, non-extreme flooding events. Based on the data from the resident survey of the reported flooding it was noted that there were cracks within the basement infrastructure which provides a path for water to enter when the groundwater increases. This could be a source for the flooding given the river levels. In addition, the groundwater in this area high during normal conditions given the proximity to the river.

There was no flooding reported during the August 2016 event in this area. During the February 2018 event, five (5) residents reported flooding. Many municipalities, including the City of South Bend, design criteria for call for storm and combined sewer networks to convey a 10-year,6 hour storm event without the hydraulic grade line exceeding the crown of the pipe. The February 2018 event, being estimated as a 500-year flood, exceeded the design capacity of the sewer network. Figure 2-8 in Appendix A shows that the relief points (CSO 26, CSO 10, and storm outfalls) for the Riverside Drive area were below the river water surface level and were unable to adequately relieve the storm and sewer networks for an extended period of time. Since the February 2018 storm was such an extreme flooding event as shown in Figure 2-4 in Appendix A, it is concluded that the flooding experienced during this time was due to the high water surface elevation of the St. Joseph River not allowing the relief for the system rather than an inadequate sewer system. It should also be noted that out of the five residents that noted flooding during 2018, none of them had backflow prevention devices installed and all but two (2) had identified some sort of cracking within either their basement walls, floor, or both.

6.2 Northshore Triangle

The field verification and survey did not indicate that the sewer network in the Northshore Triangle area had failed or was limited in its designed performance due to an issue within the system itself. This is also represented by the relatively reported low frequency of flooding during normal, non-extreme flooding events. Most of the residents noted that their basement flooded less than two (2) times per year with a small number noting flooding more than two times per year. The groundwater in this area is high due to the proximity to the river and a small increase in groundwater could cause flooding in basements that have cracks within the basement infrastructure. This flooding could also be an issue with a clogged or damaged service line.

Backflow prevention devices can play a big role in reducing/eliminating basement flooding due to sewer backup. Many of the homes that were flooded during the 2018 had backflow prevention devices however if they were within the area flooded by the river and/or had cracks within the basement infrastructure, there was still a chance of the basement flooding due to the high groundwater in the area. Also, given the duration that the system was backed up, any use of facilities producing sewage would have remained in the homes piping system and possibly overflowed unless the backflow preventer was opened and/or the hydraulic head was relieved. However, opening of the backflow prevention device would allow flow into the home from the sewer system.

In addition, sewer video was made available for several stretches of pipe within this area. Lawson-Fischer and Associates (LFA) reviewed the video and categorized the pipes as either “Good”, “OK”, or “Bad Condition”. These ratings can be seen in Figure 6-1 in Appendix A. A pipe was assigned a “Bad” rating when cracking and/or significant blockage (i.e. roots, debris, etc.) was observed, an “OK” condition rating was given when there may be some minor buildup or blockage in the pipe, and a “Good” condition rating was applied where there was no issues identified in the video within the pipe. It should be noted that the video was only available for the North Shore Triangle area and that video of the whole area was not available. Cleaning and possible repair of some of the pipes identified as “Bad” could provide for better flow throughout those portions of sewer systems.

As previously stated, most municipalities, including the City of South Bend, design storm and combined sewer networks to withstand a 10 year-6 hour storm event. The February 2018 event, being estimated as a 500-year flood, greatly exceeded the design capacity of the sewer network. Figure 2-9 in Appendix A shows that the relief points (CSO 25, CSO 5 and storm outfalls) for the Northshore Triangle area were below the river water surface level and were unable to adequately relieve the storm and sewer networks for a considerable amount of time. Based on the as-built data of the inverts of the pipes within the NST network, the sewer pipes would have most likely been completely full to the elevation of the river. Figure 2-5 in Appendix A shows the line for the 500-year event. This would have greatly limited any stormwater and sewage getting to the interceptor.

As stated above, during the larger storm events, such as the February 2018 and August 2016 events, there are things occurring system-wide and city-wide that can affect how the sewers react within a totally different separate area of the system. A capacity issue at the downstream end of the system can have cascading effects throughout the upper reaches. This occurred along the interceptor that the North Shore Triangle neighborhood drains to. Based on data from the EmNet network, the interceptor downstream of the area near CSO 4 on the west side of the river was at or near capacity for an extended duration. This can be seen by the plots in Figure 6-2 of Appendix A. This limited the flow that could discharge from the upstream area during and after the event.

Based on the comments received from the questionnaire and the field investigation, there appears to be stormwater runoff flowing from the old St. Joseph High School property into a small ditch near the alley behind the properties on W. Angela Blvd. This runoff appears to flow down from the school property and into a ditch and then finds its way onto Angela and eventually into the inlets in that area. Erosion along this non-engineered channel is evident. The drainage area for this runoff was calculated to be approximately forty acres. With no storage and an undefined place to outlet, this runoff most likely flows through the properties during larger storms as can be seen by the data from the 2018 storm event.

6.3 Keller Park

The field verification and survey did not show signs that the sewer network in the Keller Park area had failed or was limited in its designed performance. This is also represented by the relatively low frequency of flooding during normal, non-extreme flooding events as identified in the resident survey responses.

When looking at the Keller Park area, for this report the study looked at the area west and east of Keller Park. The area east of Keller Park has no identified storm sewer system and relies on surface flow to convey storm runoff. There a few homes in this area that sit on rather large lots that are located within the 1% ACF (100-year) flood fringe. This can be seen in Figure 2-6 in Appendix A. The flooding of these properties can be attributed to the river levels. Also, based on the survey, none of the residents in this area noted the presence of a backflow prevention device which could have eliminated/reduced the amount of flooding in the basements.

The neighborhood west of Keller Park with Academy Pl. to the north Inglewood Pl. to the west and Riverside to the East, had several homes that have experienced flooding during the non-extreme flooding events. There were nine (9) that noted flooding two (2) or less times per year and five (5) that noted flooding more than twice a year. Several of these noted cracks in the basement and some of them noted that they had no backflow prevention installed.

A majority of this neighborhood is located within the FEMA 1% ACF (100-year) flood fringe. The ground in this area was most likely flooded during the May event and leading to high groundwater which would have most likely seeped through basement cracks and flooding basements. The sewers in this area are combined and based on review of the available data the CSO is operating as intended. During the larger storm events, such as the February 2018 and August 2016 events, there are things occurring system-wide and city-wide that can affect how the sewers react within a totally different separate area of the system. A capacity issue at the downstream end of the system can have cascading effects throughout the upper reaches. Based on data from the Emnet network, the interceptor was at or near capacity for a long duration. This can be seen by the plots in Figure 6-3 of Appendix A. This limited the flow that could discharge from the upstream area during and after the event.

6.4 Emerson Avenue

The review of the GIS Data and as-built data did not show signs that the sewer network in the Emerson Avenue area had failed or was limited in its designed performance. This neighborhood is mostly situated within a low area by the river with a portion in the 1% ACF (100-year) FEMA flood zone. Of the five (5) residents that participated in the survey, four (4) of the homes were within the 1% ACF boundary. Of the homes that responded, three noted basement flooding and were within the approximated inundation area. One of the homes that noted flooding also commented that the water was entering through the joint between the basement floor and wall. This area is typically the first area to flood along the river in South Bend. If flooding occurs it is usually confined along a small area on Northshore Drive however with the magnitude of the historic February 2018 flood the river rose significantly higher than in the past.

Of the residents in this area that submitted a response to survey, only one of the five noted that they had a backflow prevention device in place. This home was one of the three that noted having basement flooding however it is also the home that described the water as entering through the joint between the basement floor and wall. The three respondents also noted that the water was clear which would be a sign that the flooding was most likely from groundwater.

One of the five respondents furthest north within the study area noted surface flooding on the streets during large rain events. They also that their during heavy rainfall that they sometimes had small amounts of water in their basement. This was the only respondent in the northern part of the study area so there was no other data available for comparison.

7.0 POTENTIAL IMPROVEMENTS AND RECOMMENDATIONS

The below improvements and recommendations are based on the findings from the review of the existing infrastructure data, limited field survey, and the responses received from the residential questionnaire. It should be noted that the February 2018 storm event was one of historic magnitude and while the improvements and recommendations noted below, by study area, would not eliminate flooding in a similar event, they would potentially reduce the amount of flooding.

The potential improvements and recommendations are summarized by study area. It is also recommended that the City review the existing design criteria for sewer systems to determine if revisions are necessary.

7.1 Riverside Drive (South of Bartlett)

- It is recommended that backflow prevention devices be installed in the homes within this area. The continuation of the backflow prevention device program and also participation by the residents will assist with the basement flooding from potential backflow of the sewer line. Also, there should be a detailed educational program that conveys to residents that the installation of the backflow device alone will not eliminate/reduce flooding. Backflow prevention devices are intended to inhibit water/sewage from a storm/sanitary sewer system from getting into basements and houses. However, when a backflow prevention device is in the shut or closed position, water can neither enter nor exit the home. Therefore, flushing toilets, taking a shower, operating a dishwasher or washing machine all contribute to water/sewage entering a basement without an ability to drain to the storm/sanitary system. Water/sewage will continue to accumulate in the basement until the backflow prevention device is opened. Residents that have a backflow prevention device installed should review and understand the operation of their individual device.

- Cracks in basements can allow groundwater to penetrate and enter basements, especially during more intense storm events that cause the groundwater level to rise significantly. Clear water found within the basement is a good indication that the source is likely groundwater instead of storm or sanitary systems. Residents that have cracks (floor, wall or both) in their basement should consult with a company who specializes in this type of repair. The exact repair and cost will vary depending on items such as location and size of cracking.

- Disconnecting downspouts will greatly reduce the stress put on the sanitary/storm sewer. By disconnecting downspouts from the storm/sewer network, runoff and drainage from gutters is given the chance to be absorbed into the ground naturally instead of relying on the storm/sewer network to convey the flow. By diverting stormwater from downspouts, the storm/sewer network will have more capacity to effectively convey flow from street inlets and thus reduce the likelihood of street and surface flooding. The City of South Bend requires all property owners to have downspouts disconnected by the year 2020. It is recommended that the downspout disconnection program continue on the current timeline.

- The existing storm/sanitary network has a 12" diameter throttle pipe that conveys flow from the Riverside Drive area to the Michigan Street combined sewer line. Increasing the diameter of the throttle line could help increase flow leaving the Riverside Drive area. However, a detailed study to include modeling of the sewer system in this area and evaluation of its impact to downstream sewer network would need to be conducted. It is recommended that the City research this option.

- It is recommended that the City video the sewers within this neighborhood to determine the condition and assess the need for repairs. Blockage of the lines and/or excessive inflow/infiltration could be a potential cause of sewer backups. These items can be identified with videoing the sewer system.

7.2 Northshore Triangle

- It is recommended that backflow prevention devices be installed in the homes within this area. The continuation of the backflow prevention device program and also participation by the residents will assist with the basement flooding from potential backflow of the sewer line. Also, there should be a detailed educational program that conveys to residents that the installation of the backflow device alone will not eliminate/reduce flooding. Backflow prevention devices are intended to inhibit water/sewage from a storm/sanitary sewer system from getting into basements and houses. However, when a backflow prevention device is in the shut or closed position, water can neither enter nor exit the home. Therefore, flushing toilets, taking a shower, operating a dishwasher or washing machine all contribute to water/sewage entering a basement without an ability to drain to the storm/sanitary system. Water/sewage will continue to accumulate in the basement until the backflow prevention device is opened. Residents that have a backflow prevention device installed should review and understand the operation of their individual device.

- Cracks in basements can allow groundwater to penetrate and enter basements, especially during more intense storm events that cause the groundwater level to rise significantly. Clear water found within the basement is a good indication that the source is likely groundwater instead of storm or sanitary systems. Residents that have cracks (floor, wall or both) in their basement should consult with a company who specializes in this type of repair. The exact repair and cost will vary depending on items such as location and size of cracking.

- Disconnecting downspouts will greatly reduce the stress put on the sanitary/storm sewer. By disconnecting downspouts from the storm/sewer network, runoff and drainage from gutters is given the chance to be absorbed into the ground naturally instead of relying on the storm/sewer network to convey the flow. By diverting stormwater from downspouts, the storm/sewer network will have more capacity to effectively convey flow from street inlets and thus reduce the likelihood of street and surface flooding. The City of South Bend requires all property owners to have downspouts disconnected by the year 2020. It is recommended that the downspout disconnection program continue on the current timeline.

- There were several residents that noted that an earlier notification of potential flooding would have been desired and helpful. A notification system could help warn residents when a major storm event is imminent. The notification system would ideally notify residents of a potential severe event that could lead to flooding and direct them to a location (website) with more information on steps to take to protect personnel and property. The exact method of notification method (text, call, email, etc.) and information contained within the message will need to be evaluated based on accuracy, effectiveness, and potential cost. It is recommended that the City research potential measures of notification for residents during potential flooding situations.

- Backflow prevention devices should be installed on all storm outfalls if not currently in place. These backflow prevention devices will help prevent river water from filling the storm pipe network. However, backflow prevention devices will only allow water to enter the river when the river water surface elevation is below the outfall elevation. If the river water surface elevation is higher than the storm outfall, the backflow prevention will not allow river water to enter the storm network nor allow stormwater to exit the storm network.

- It is recommended that the video monitoring of the sewer system continue based on the findings from the video inspections. The maintenance of storm and sewer pipes within the Northshore Triangle area can be prioritized and conducted to ensure proper operation of the sewer system. The City of South Bend conducted video inspections on many of the pipes within the Northshore Triangle area during Spring 2018. Some areas showed signs of sedimentation and blockages that could affect the system's performance.

- Service lines from homes can also fail or become blocked, therby reducing their capacity to operate. It is recommended that homeowners who have experienced frequent basement sewage flooding should have their service lines inspected and/or cleaned or repaired.

- The intersection of Angela Boulevard and Marquette Avenue has an 18 inch diameter sanitary pipe going into a 10 inch diameter pipe. It is not common to have a larger diameter pipe flow into a smaller diameter pipe. After reviewing the as-built drawings and GIS data, it appears that the Northshore Triangle area was separated in 1965. It appears that as part of the separation process, the existing combined pipe network that was installed in the early 1900's may have been utilized as the new sanitary pipe. It appears that a separate storm pipe network and additional 10 inch diameter sanitary pipe along Angela Boulevard were installed in 1965 to complete the sewer separation. This is LFA's opinion based on the available as-built data and field reconnaissance, however, there was no other data to verify our assumptions. It is recommended that City further investigate this area to evaluate whether the 10 inch diameter pipe is an adequate size to convey the required sanitary flow.

- It is recommended that the City work with the private property owner to control the runoff from the old St. Joseph High School Property. A drainage area of approximately 40 acres was delineated based on existing topography and storm infrastructure in the area. This area and the estimated flow paths can be seen in Figure 7-1 of Appendix A. As can be seen from the figure this property drains from the northeast corner southwest towards the river. Based on field inspection and survey data, runoff from the east side of 933 does not flow into this area.

- The City of South Bend is currently working to renegotiate the Consent Decree and Long-Term Control Plan (LTCP) that will include several projects that would reduce the amount of runoff within the interceptor in this area. Any decrease in flow to the existing trunk sewer would be a benefit to tributary lines to the system.

7.3 Keller Park

- Several of the properties are located within the 1% Annual Chance Flood (100-Year) Flood fringe. A buyout program could be considered for those properties that reside within the defined floodplain. There is a high possibility that these properties will be affected in the future by flooding events. The Federal Emergency Management Agency (FEMA) offers a grant program for a voluntary floodplain buyout program. The resulting area could be converted to a park or other recreational purpose. It is recommended that the possibility of a buyout program be discussed with the homeowners in this area.

- It is recommended that backflow prevention devices be installed in the homes within this area. The continuation of the backflow prevention device program and also participation by the residents will assist with the basement flooding from potential backflow of the sewer line. Also, there should be a detailed educational program that conveys to residents that the installation of the backflow device alone will not eliminate/reduce flooding. Backflow prevention devices are intended to inhibit water/sewage from a storm/sanitary sewer system from getting into basements and houses. However, when a backflow prevention device is in the shut or closed position, water can neither enter nor exit the home. Therefore, flushing toilets, taking a shower, operating a dishwasher or washing machine all contribute to water/sewage entering a basement without an ability to drain to the storm/sanitary system. Water/sewage will continue to accumulate in the basement until the backflow prevention device is opened. Residents that have a backflow prevention device installed should review and understand the operation of their individual device.

- Cracks in basements can allow groundwater to penetrate and enter basements, especially during more intense storm events that cause the groundwater level to rise significantly. Clear water found within the basement is a good indication that the source is likely groundwater instead of storm or sanitary systems. Residents that have cracks (floor, wall, or both) in their basement should consult with a company who specializes in this type of repair. The exact repair and cost will vary depending on items such as location and size of cracking.

- Disconnecting downspouts will greatly reduce the stress put on the sanitary/storm sewer. By disconnecting downspouts from the storm/sewer network, runoff and drainage from gutters is given the chance to be absorbed into the ground naturally instead of relying on the storm/sewer network to convey the flow. By diverting stormwater from downspouts, the storm/sewer network will have more capacity to effectively convey flow from street inlets and thus reduce the likelihood of street and surface flooding. The City of South Bend requires all property owners to have downspouts disconnected by the year 2020. It is recommended that the downspout disconnection program continue on the current timeline.

- There were several residents that noted that an earlier notification of potential flooding would have been desired and helpful. A notification system could help warn residents when a major storm event is imminent. The notification system would ideally notify residents of a potential, severe event that could lead to flooding and direct them to a location (website) with more information on steps to take to protect personnel and property. The exact method of notification method (text, call, email, etc.) and information contained within the message will need to be evaluated based on accuracy needed, effectiveness and potential cost. It is recommended that the City research potential measures for notification of residents during potential flooding situations.

- It is recommended that the City video the sewers within this neighborhood to determine the condition and assess the need for repairs. Blockage of the lines and/or excessive inflow/infiltration could be a potential cause of sewer backups. These items can be identified with videoing the sewer system.

- Service lines from homes can also fail or become blocked reducing their capacity to operate. It is recommended that homeowners that have experienced frequent basement sewer flooding should have their service lines inspected and/or cleaned or repaired.

- The City of South Bend is currently working to renegotiate the Consent Decree and Long-Term Control Plan (LTCP) that will include several projects that would reduce the amount of runoff within the interceptor in this area. Any decrease in flow to the existing trunk sewer would be a benefit to tributary lines to the system.

7.4 Emerson Avenue

- Several of the properties are located within the 1% Annual Chance Flood (100-Year) Flood fringe. A buyout program could be considered for those properties that reside within the defined floodplain. There is a high possibility that these properties will be affected in the future by flooding events. The Federal Emergency Management Agency (FEMA) offers a grant program for a voluntary floodplain buyout program. The resulting area could be converted to a park or other recreational purpose. It is recommended that the possibility of a buyout program be discussed with the homeowners in this area.

- Cracks in basements can allow groundwater to penetrate and enter basements, especially during more intense storm events that cause the groundwater level to rise significantly. Clear water found within the basement is a good indication that the source is likely groundwater instead of storm or sanitary systems. Residents that have cracks (floor, wall, or both) in their basement should consult with a company who specializes in this type of repair. The exact repair and cost will vary depending on items such as location and size of cracking.

- It is recommended that the City video the sewers within this neighborhood to determine the condition and assess the need for repairs. Blockage of the lines and/or excessive inflow/infiltration could be a potential cause of sewer backups.

APPENDIX A

FIGURES

Figure 1-1
Study Area Locations

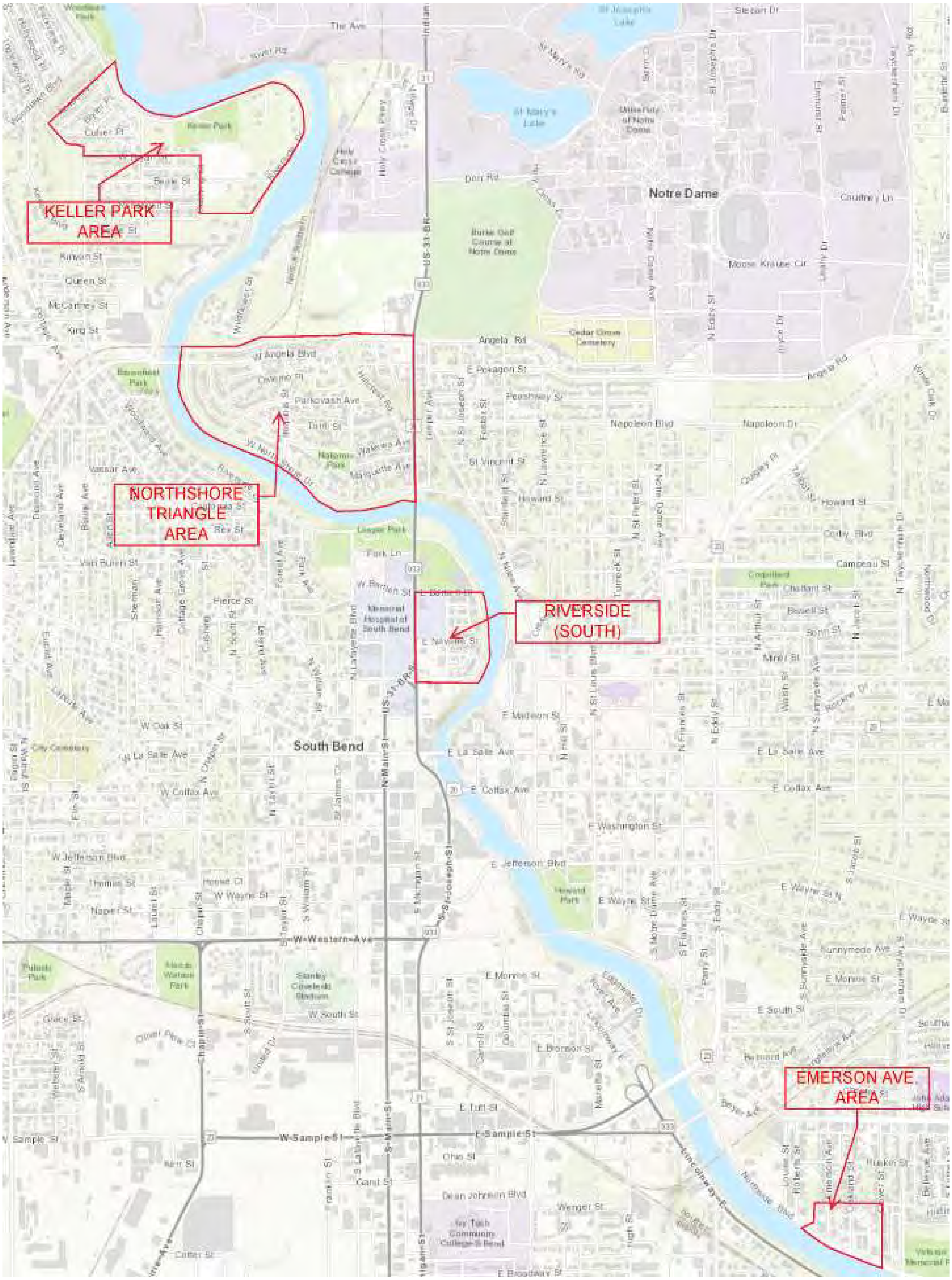
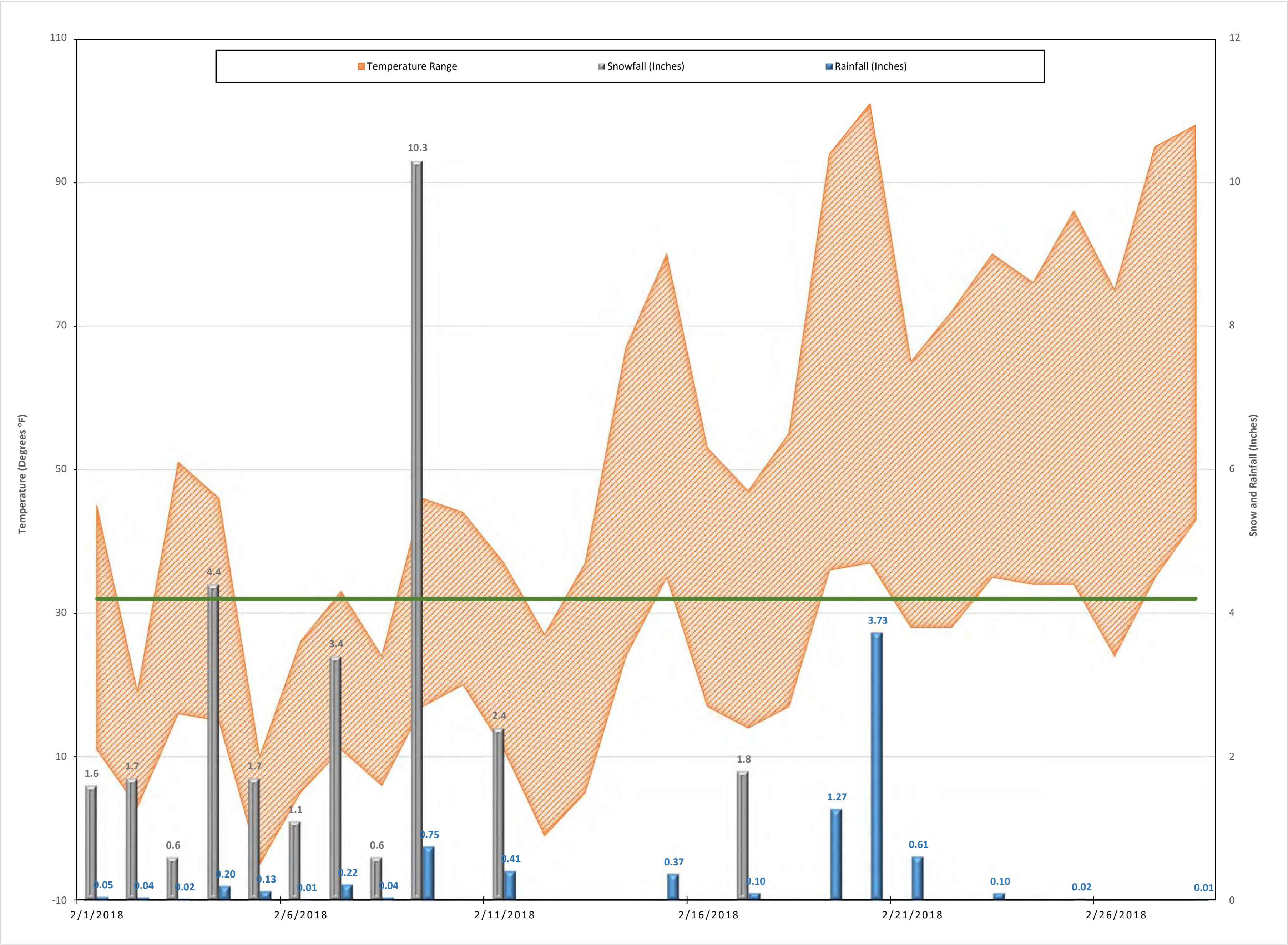


FIGURE 2-1
February 2018 Snowfall/Rainfall Depths



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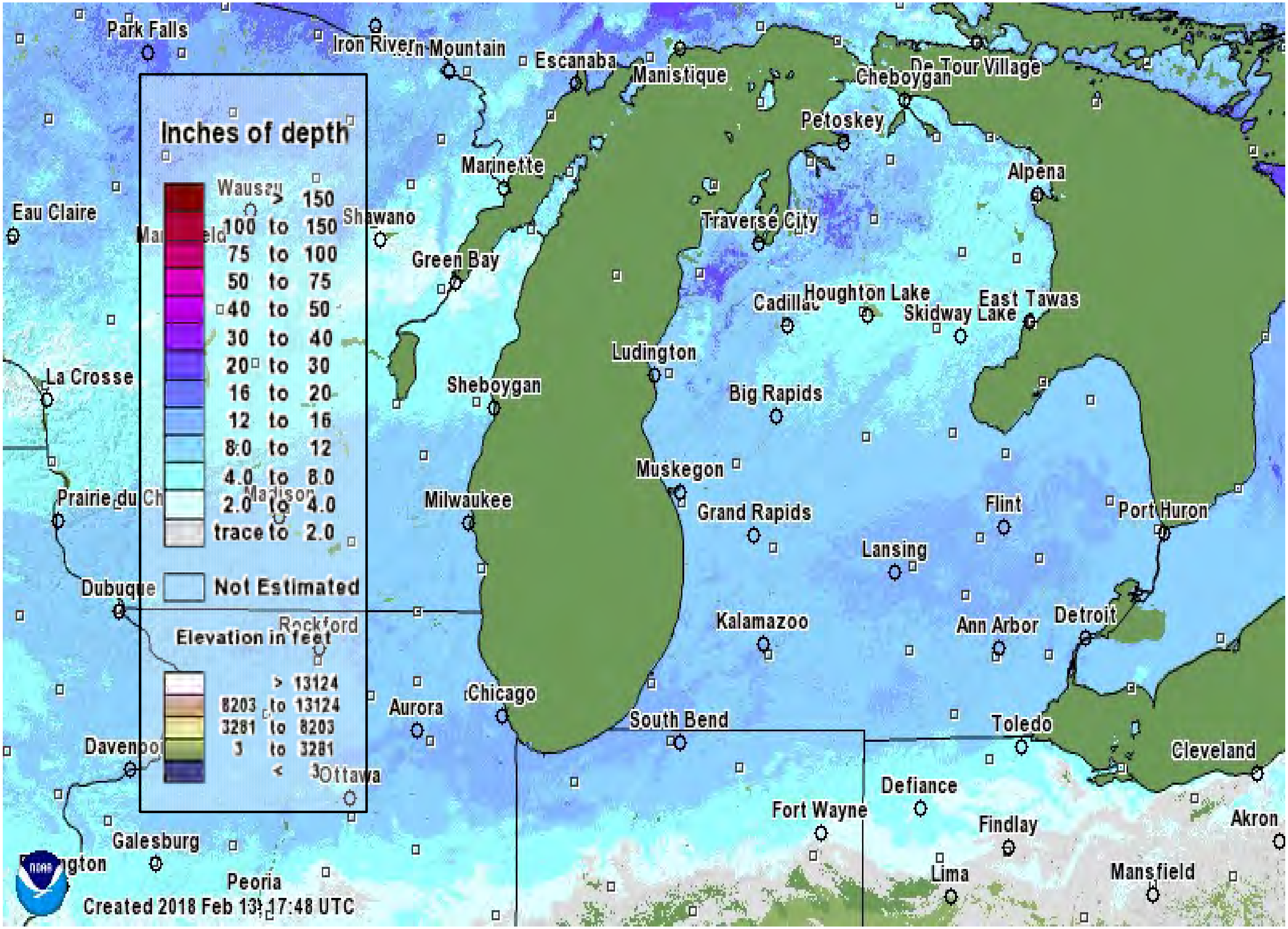
Project File No. 201821.00
8/7/2018

FIGURE 2-2
NWS Snowfall Depth with St. Joseph River Basin



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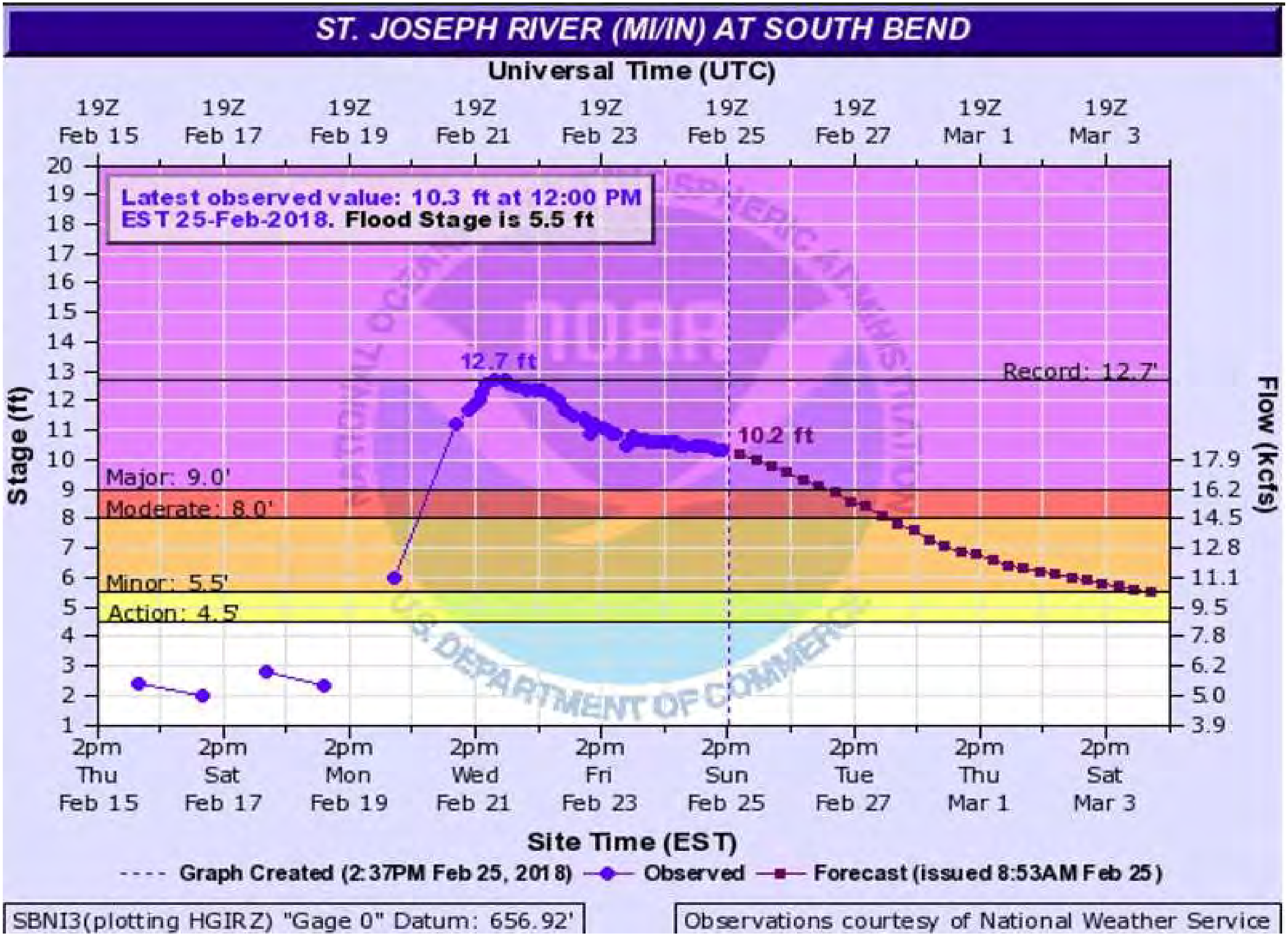
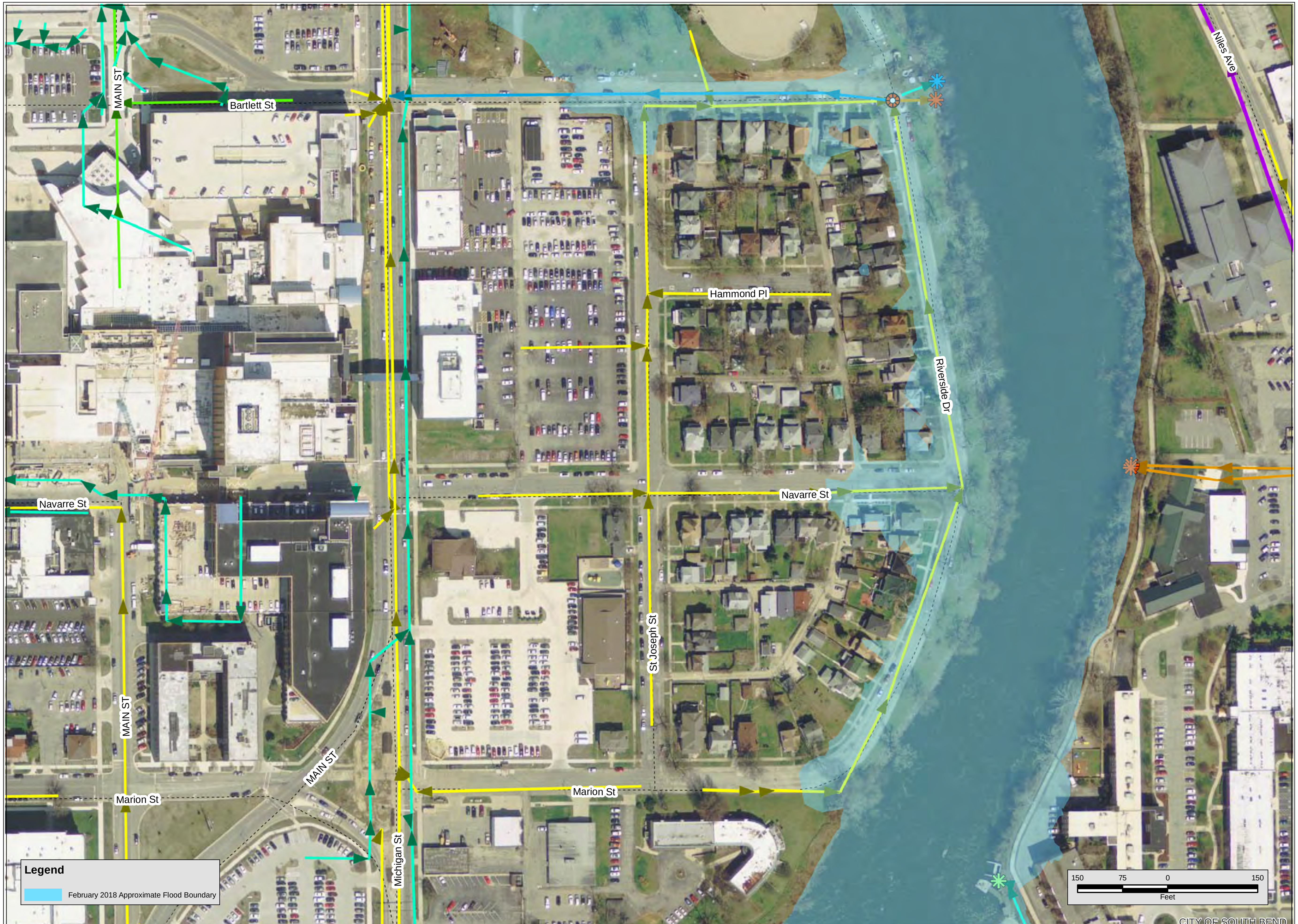
8/7/2018

Figure 2-3
NWS St. Joseph River Staff Gage Hydrograph





City of South Bend, Indiana
Sewer Study

Riverside Drive Flood Inundation

LFA LAWSON-FISHER ASSOCIATES P.C.
525 W WASHINGTON AVENUE
SOUTH BEND, INDIANA 46601
PH. (574) 234-3167

Figure 2-4

201821.00

August, 2018

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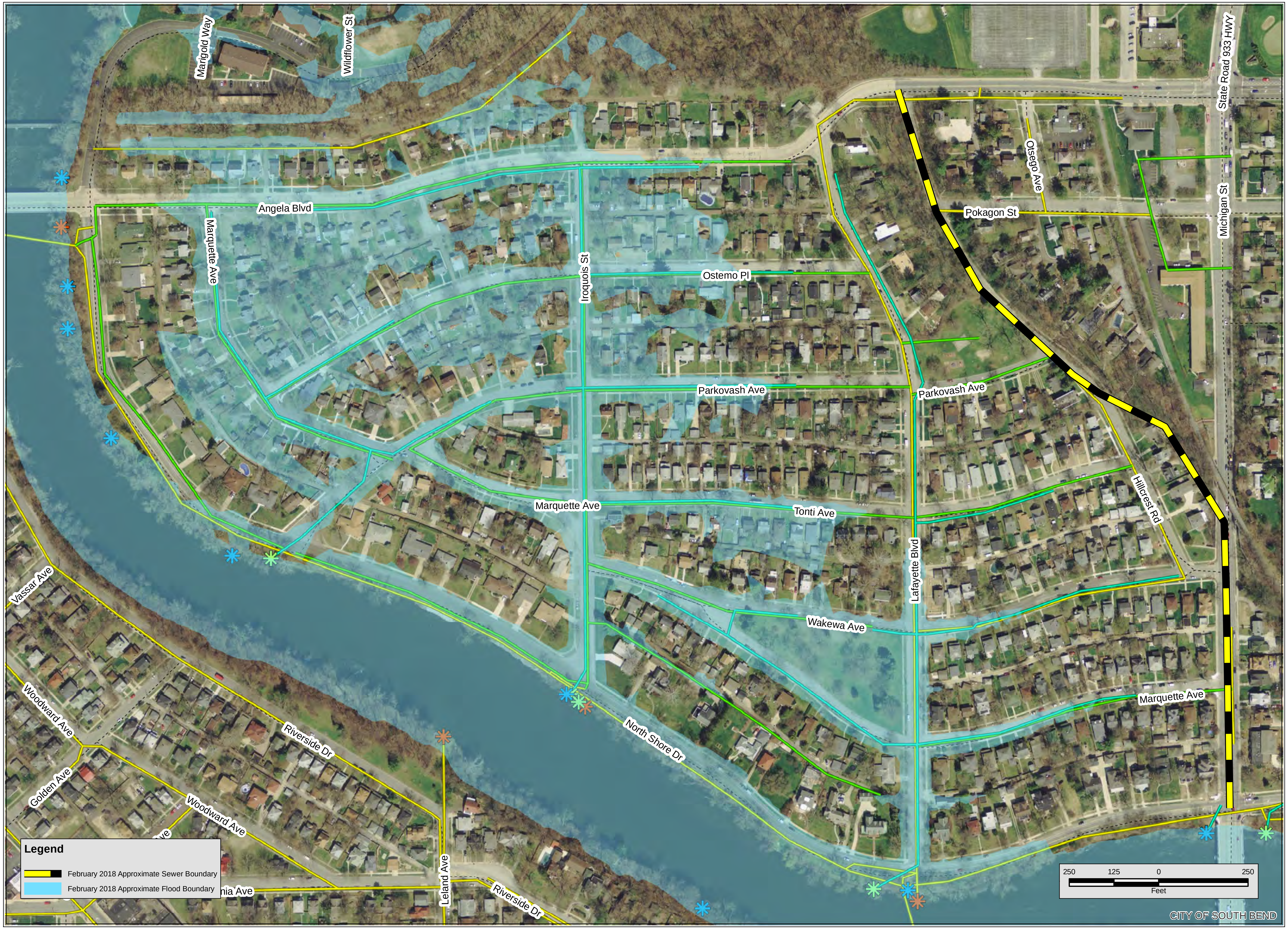

City of South Bend, Indiana
Sewer Study

Northshore Triangle Flood Inundation

LFA
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525 W WASHINGTON AVENUE
SOUTH BEND, INDIANA 46601
PH. (574) 234-3167

Figure 2-5

201821.00

August, 2018

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City of South Bend, Indiana
Sewer Study

Keller Park Flood Inundation

N
W E
S

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525 W WASHINGTON AVENUE
SOUTH BEND, INDIANA 46601
PH. (574) 234-3167

Figure 2-6

201821.00

August, 2018

Path: \\lfa-fs1\Projects\2018\201821 SBN Sewer Asmt\GIS\MXD\Final Report Figures\11x17\2018 Flood Inundation.mxd
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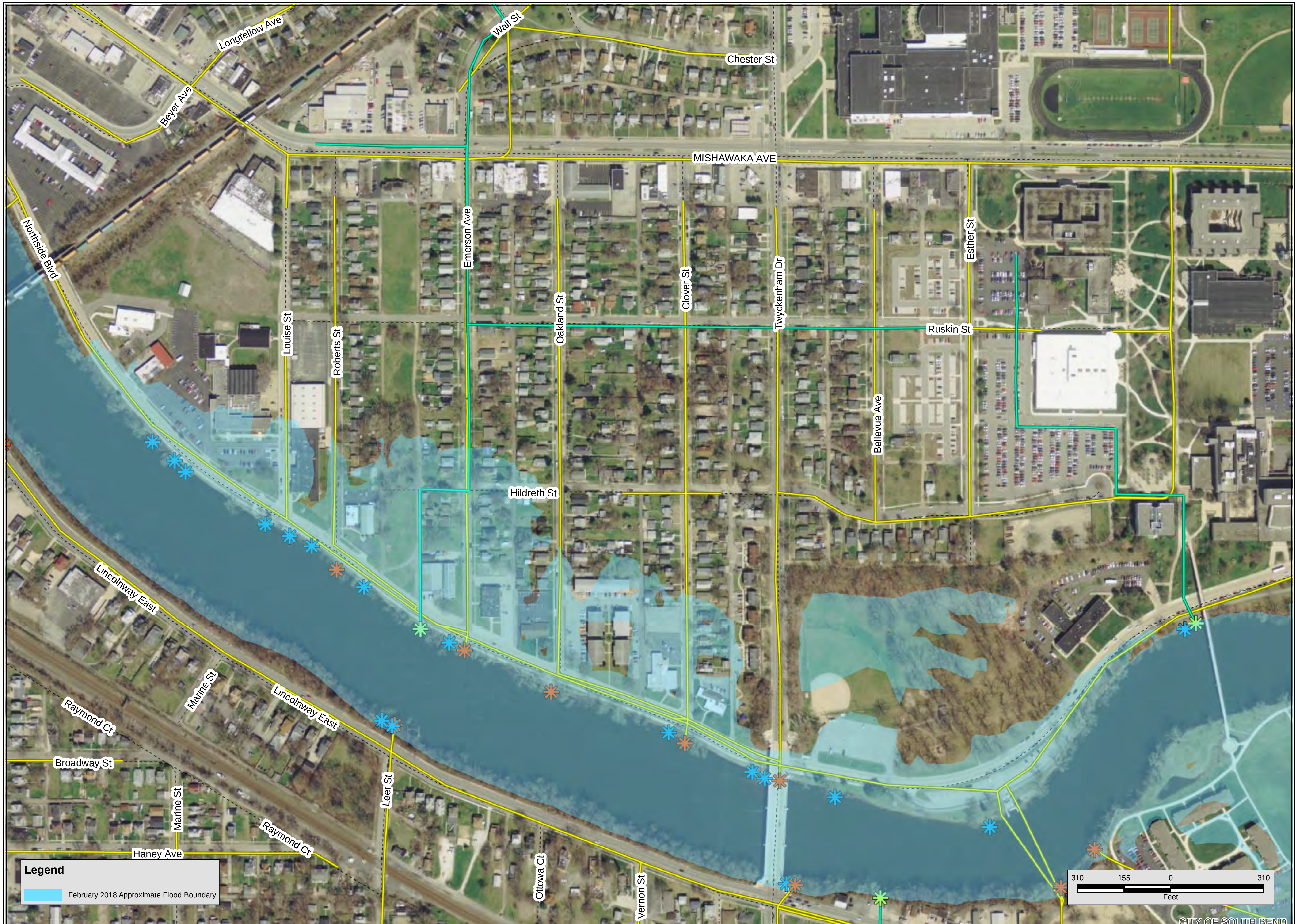

City of South Bend, Indiana
Sewer Study

Emerson Avenue Flood Inundation

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SOUTH BEND, INDIANA 46601
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Figure 2-7

201821.00

August, 2018

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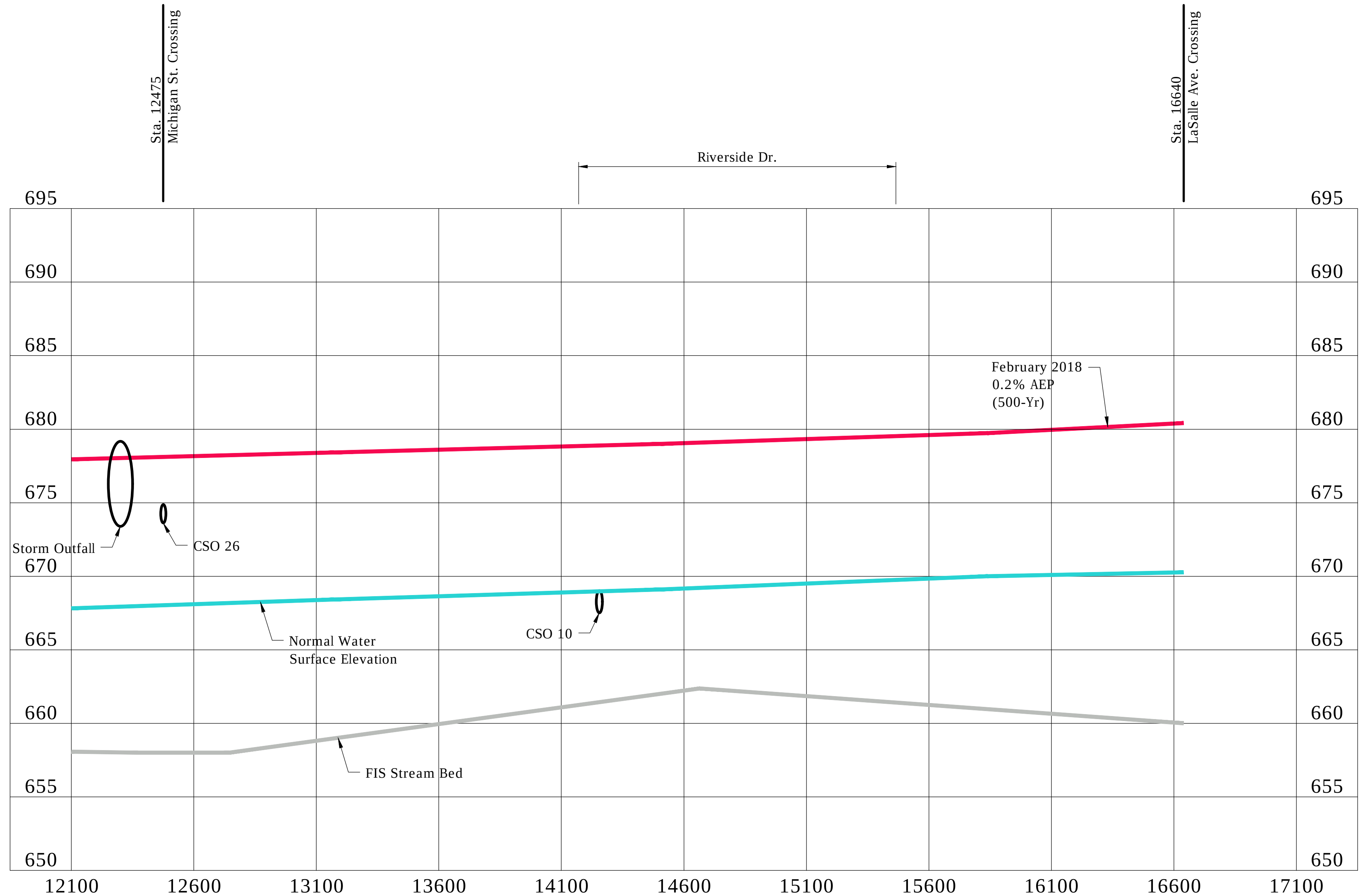

NOTE:
Annual Exceedance Probability (AEP) Refers to the Probability of a Flood Event Occurring in any Year. (1% = 1/100 Chance)

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Figure 2-8

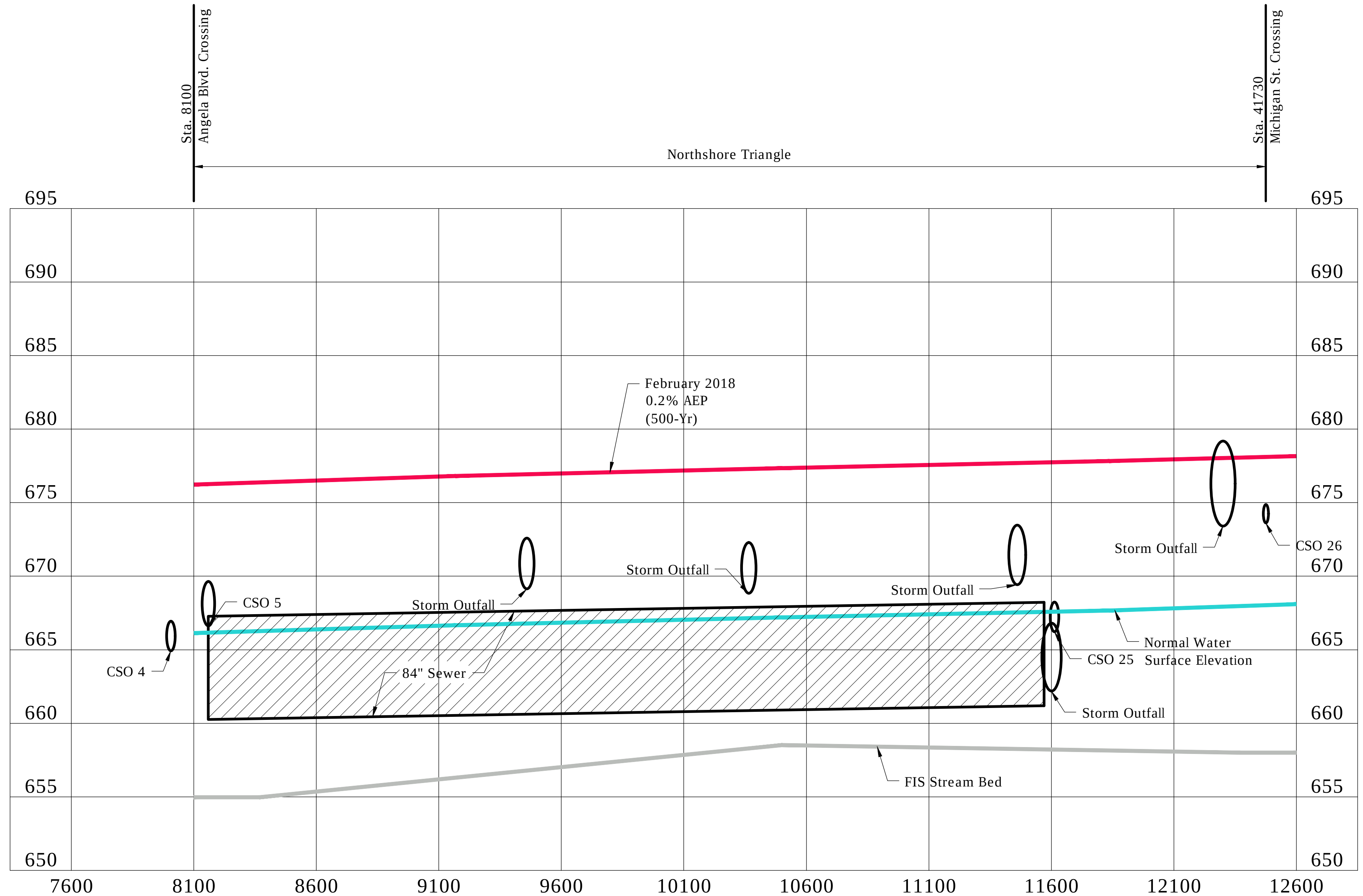
SIGNATURE DATE

NOT FOR CONSTRUCTION

CITY OF SOUTH BEND
SEWER STUDY

RIVERSIDE PROFILE

REVISIONS	HORIZONTAL SCALE	PROJECT NUMBER
	1" = 600'	201821.00
	VERTICAL SCALE	
	1" = 10'	
DRAWN: BJS	SURVEY BOOK	SHEETS
CHECKED: TRT	DATE JULY 2018	1 OF 1



NOTE:
Annual Exceedance Probability (AEP) Refers to the Probability of a Flood Event Occurring in any Year. (1% = 1/100 Chance)

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Figure 2-9

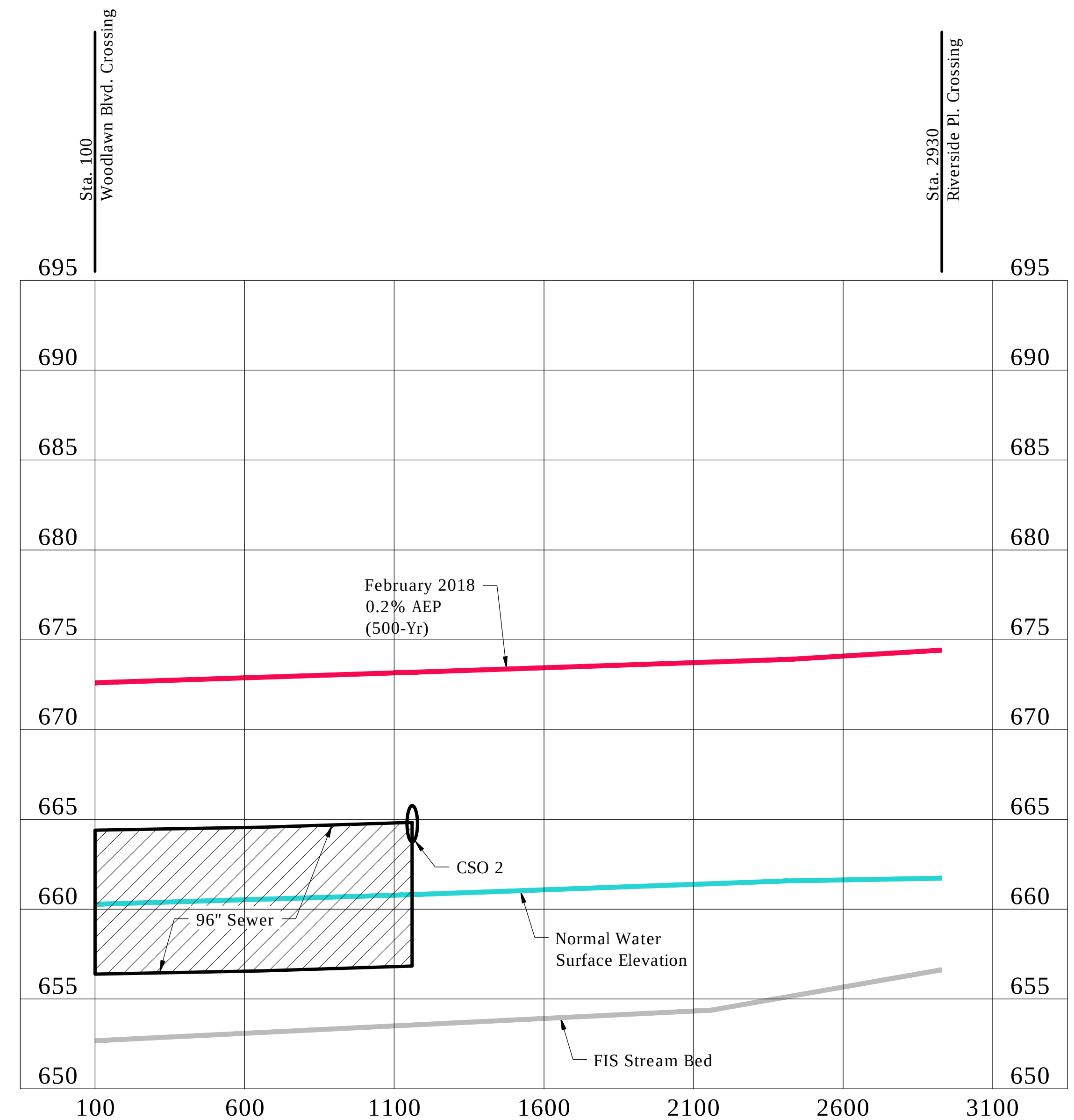
SIGNATURE DATE

NOT FOR CONSTRUCTION

CITY OF SOUTH BEND
SEWER STUDY

NORTHSHORE TRIANGLE PROFILE

REVISIONS	HORIZONTAL SCALE	PROJECT NUMBER
	1" = 600'	201821.00
	VERTICAL SCALE 1" = 10'	
DRAWN: BJS	SURVEY BOOK	SHEETS
CHECKED: TRT	DATE JULY 2018	1 OF 1



NOTE:
Annual Exceedance Probability (AEP) Refers to the Probability of a Flood Event Occurring in any Year. (1% = 1/100 Chance)

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Figure 2-10

SIGNATURE DATE

NOT FOR CONSTRUCTION

CITY OF SOUTH BEND
SEWER STUDY

KELLER PARK PROFILE

REVISIONS	HORIZONTAL SCALE	PROJECT NUMBER
	1" = 600'	201821.00
	VERTICAL SCALE	
	1" = 10'	
DRAWN: BJS	SURVEY BOOK	SHEETS
CHECKED: TRT	DATE JULY 2018	1 OF 1

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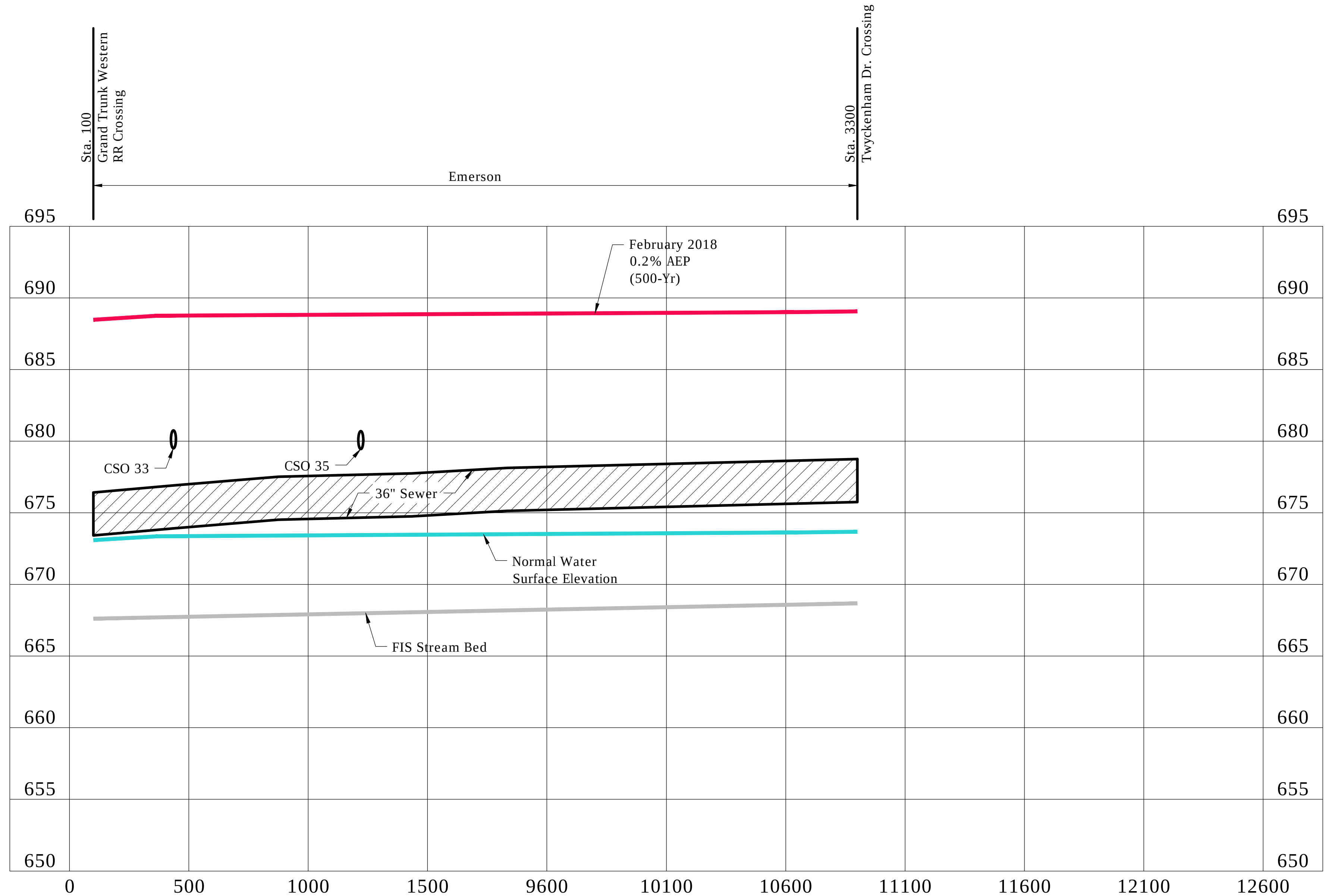

NOTE:
Annual Exceedance Probability (AEP) Refers to the Probability of a Flood Event Occurring in any Year. (1% = 1/100 Chance)

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Figure 2-11

SIGNATURE DATE

NOT FOR CONSTRUCTION

CITY OF SOUTH BEND
SEWER STUDY

EMERSON PROFILE

REVISIONS	HORIZONTAL SCALE	PROJECT NUMBER
	1" = 600'	201821.00
	VERTICAL SCALE	
	1" = 10'	
DRAWN: BJS	SURVEY BOOK	SHEETS
CHECKED: TRT	DATE JULY 2018	1 OF 1

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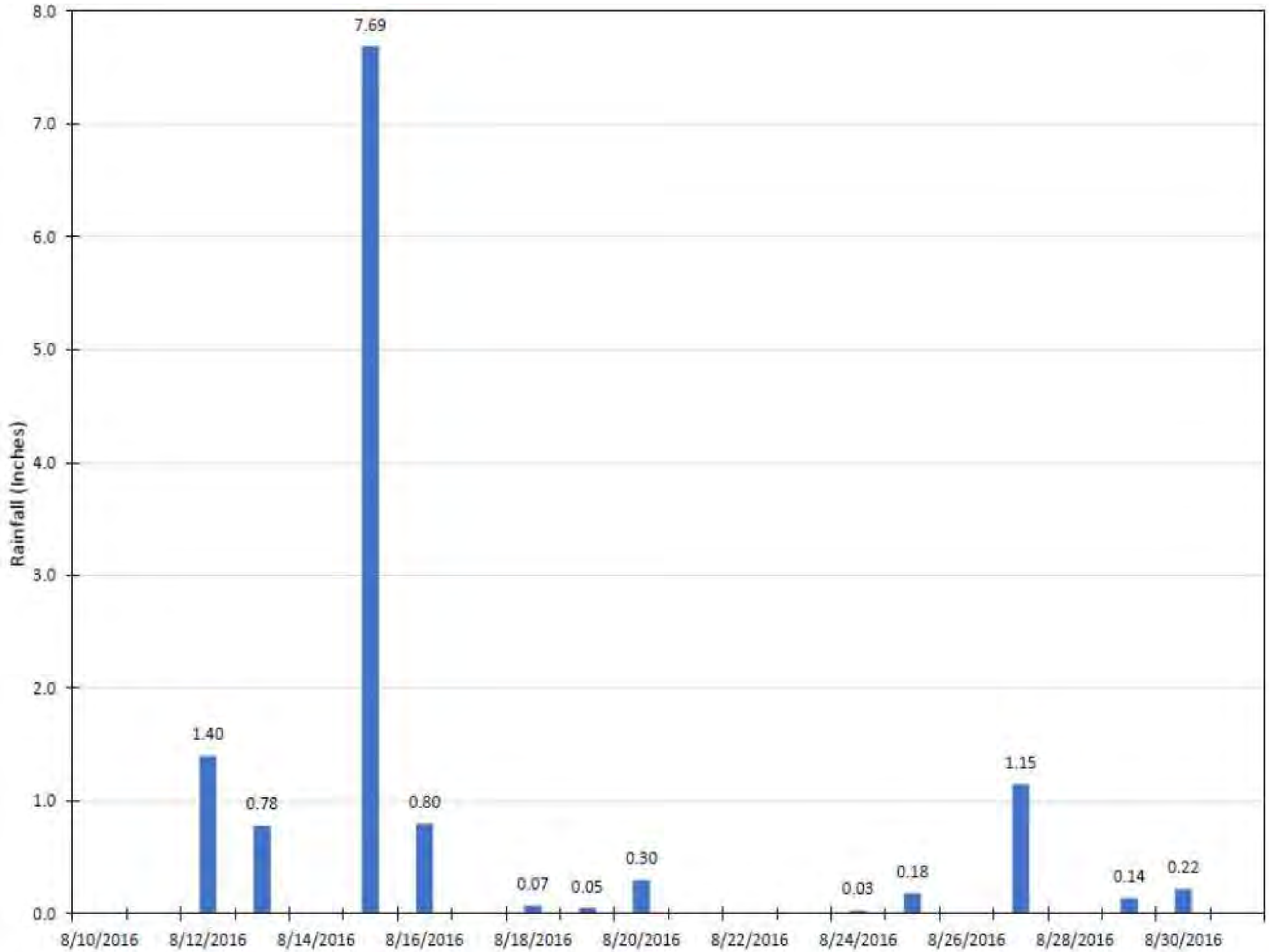
Figure 2-12
August 2016 Rainfall



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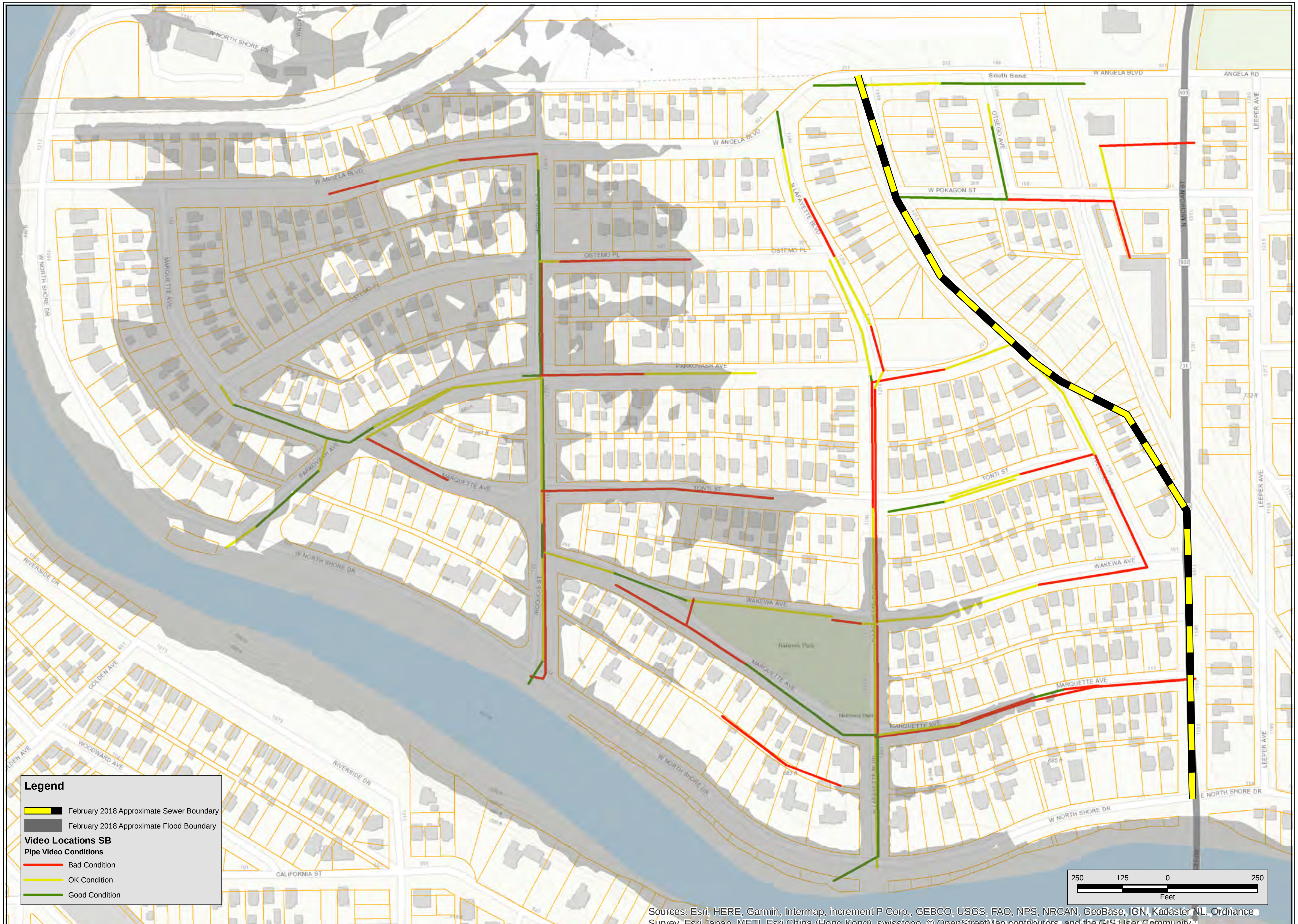
Project File No. 201821.00
8/15/2018



City of South Bend, Indiana
Sewer Study

Northshore Triangle
Pipe Conditions

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525 W WASHINGTON AVENUE
SOUTH BEND, INDIANA 46601
PH. (574) 234-3167

Figure 6-1

201821.00

August, 2018

Path: U:\2018\201821 SBN Sewer Asmt\GIS\MXD\Final Report Figures\11x17\NST Pipe Conditions.mxd
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Figure 6-2
Northshore Triangle Sewer Depth

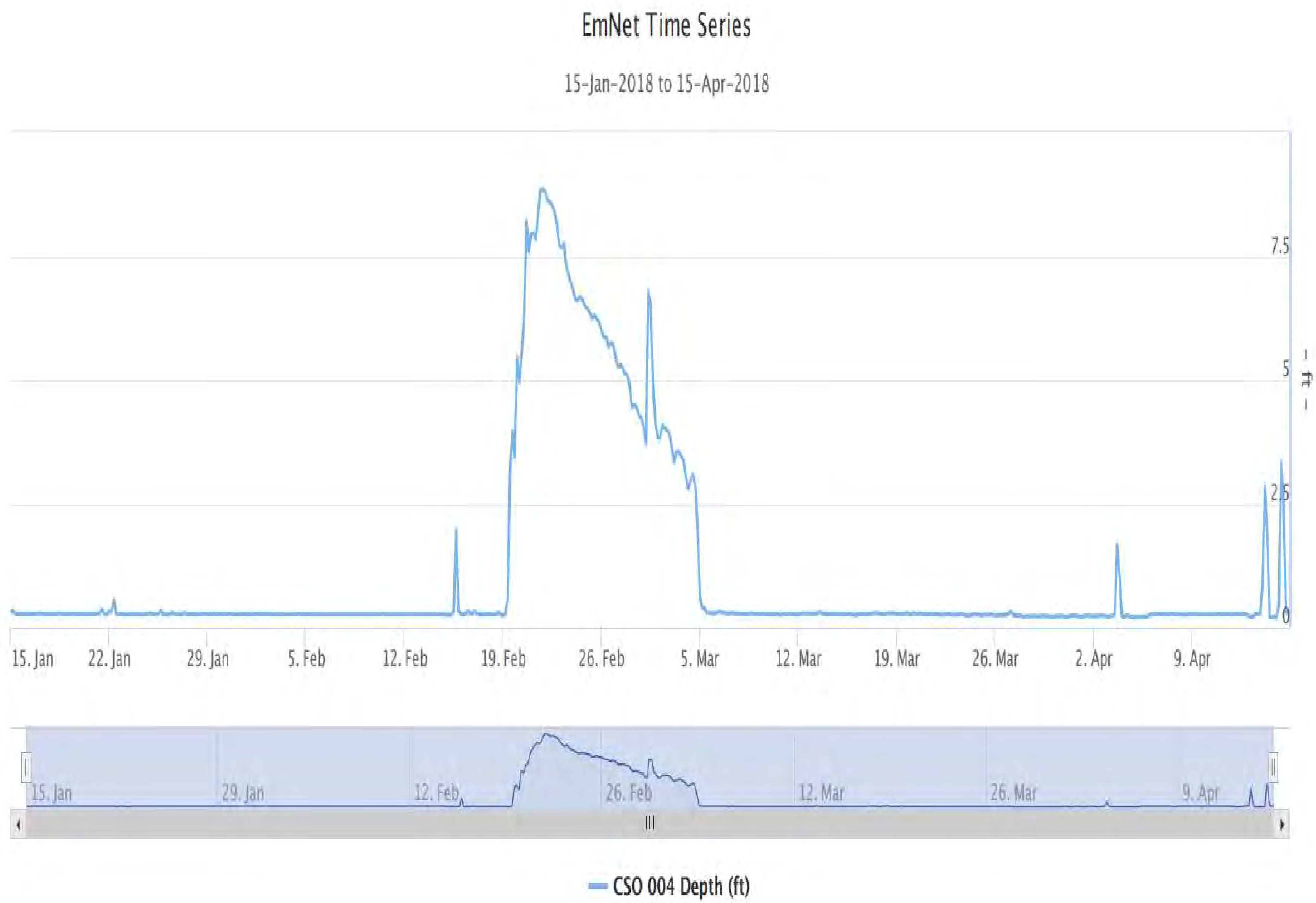
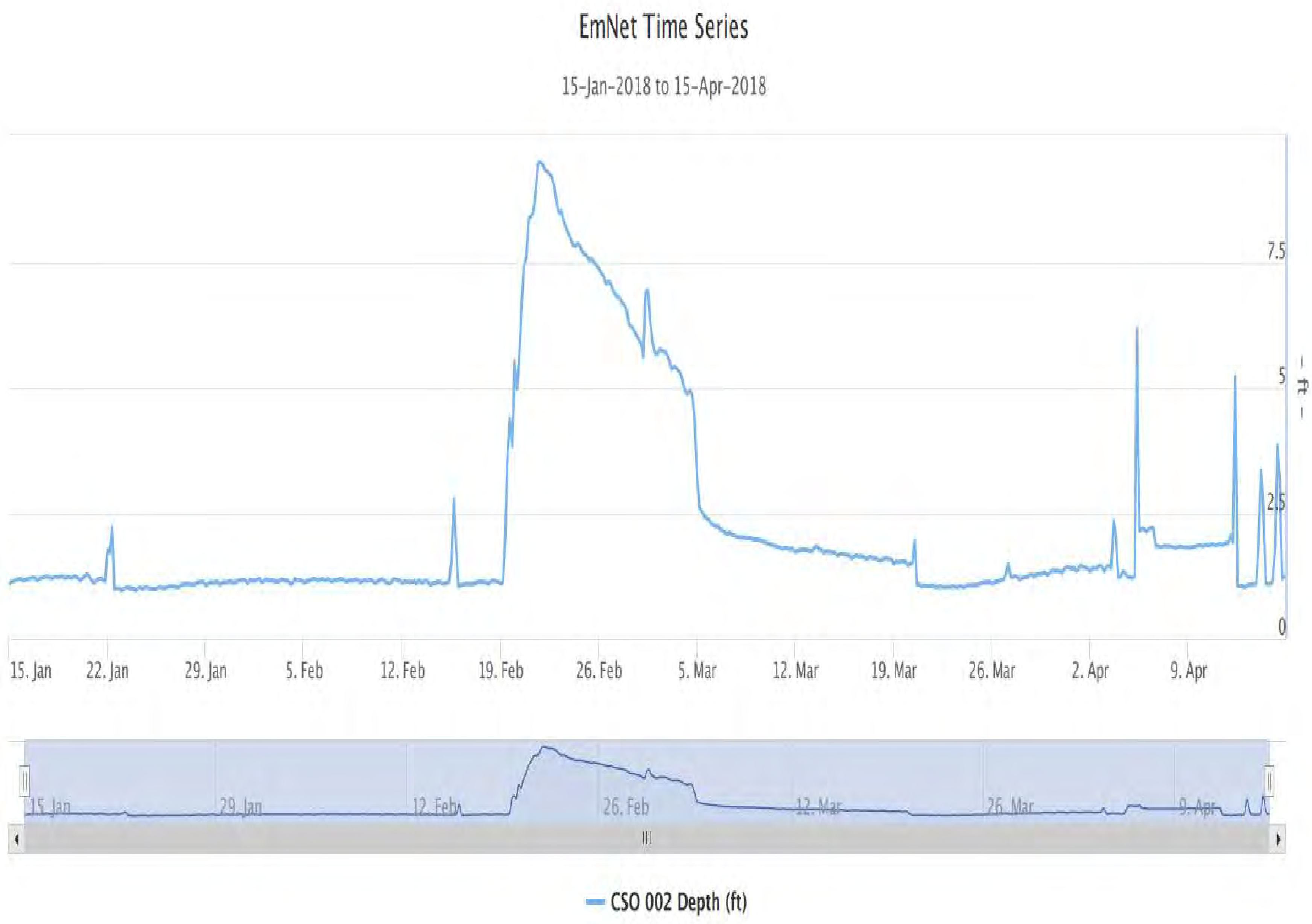


Figure 6-3
Keller Park Sewer Depth



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City of South Bend, Indiana
Sewer Study

Northshore Triangle Watershed

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Figure 7-1

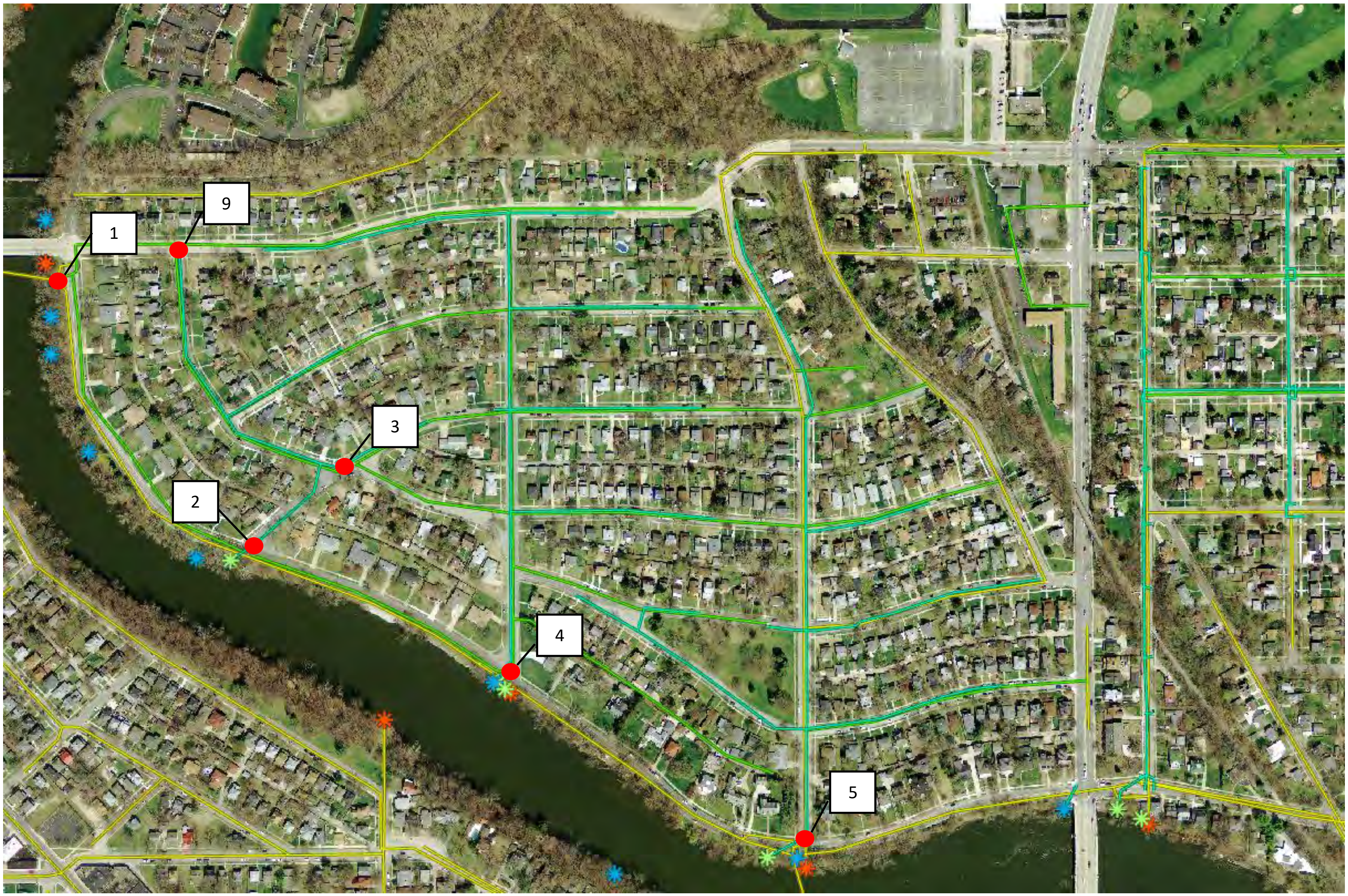
201821.00

August, 2018

APPENDIX B

FIELD INVESTIGATION INFORMATION

Overview of Northshore Triangle Field Verification Locations

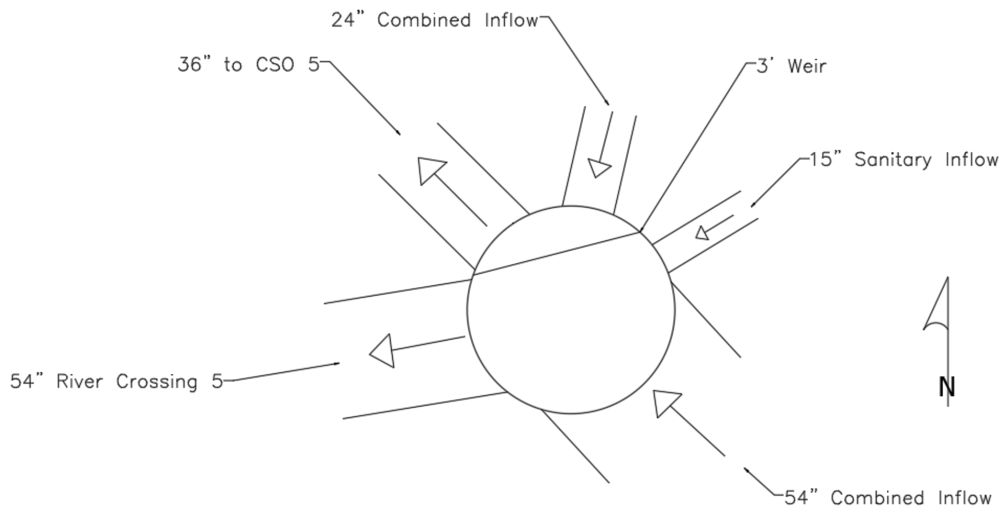


Overview of Riverside Drive Field Verification Location

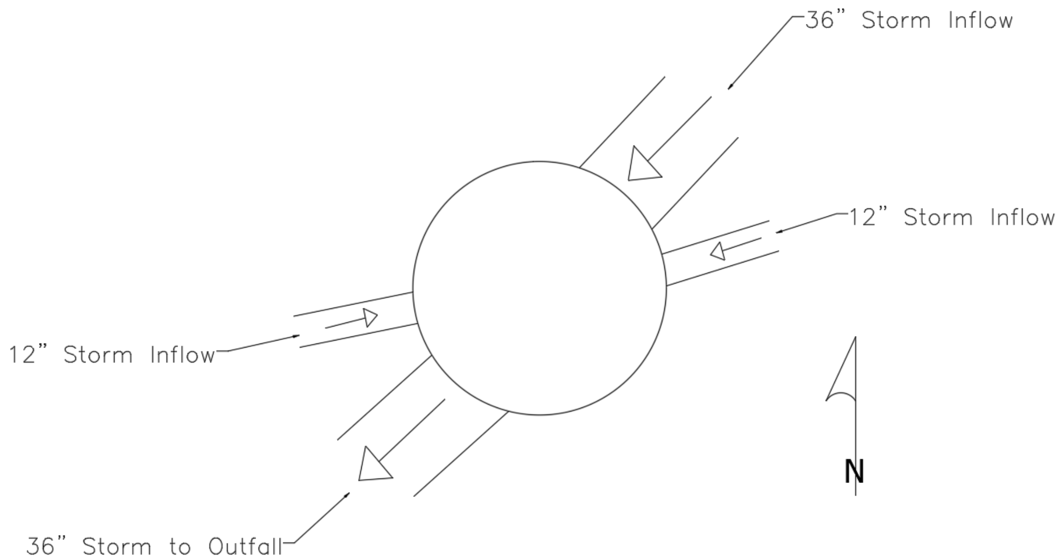
Overview of Keller Park Field Verification Location

Overview of Field Verification Location and Ditches North of Angela Boulevard in near Northshore Triangle

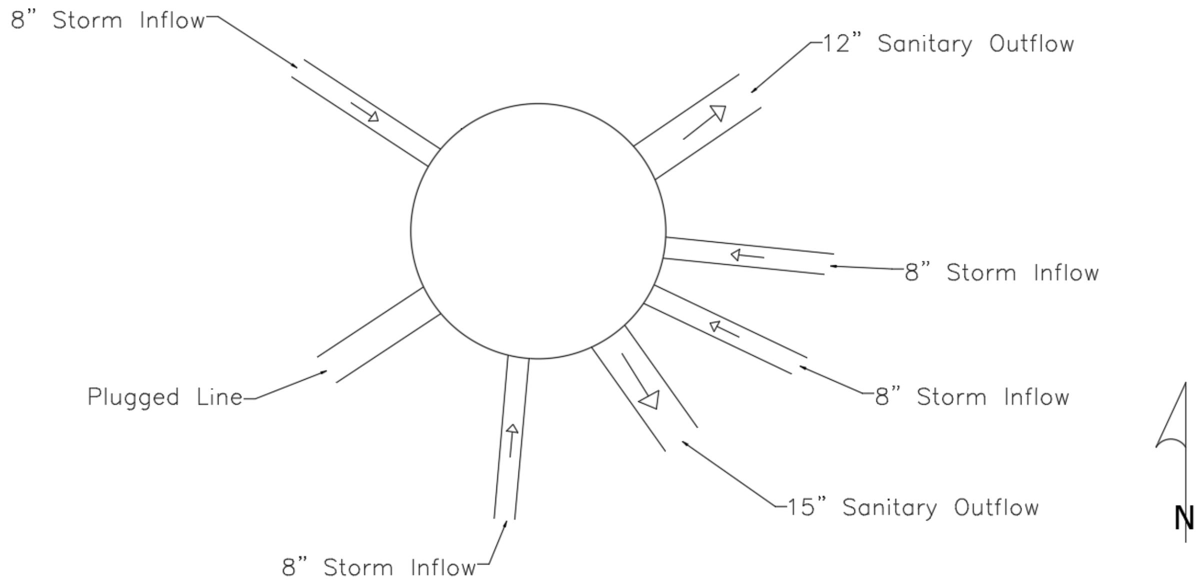
Location 1:


24" Combined Inflow
36" to CSO 5
3' Weir
15" Sanitary Inflow
N
54" River Crossing 5
54" Combined Inflow

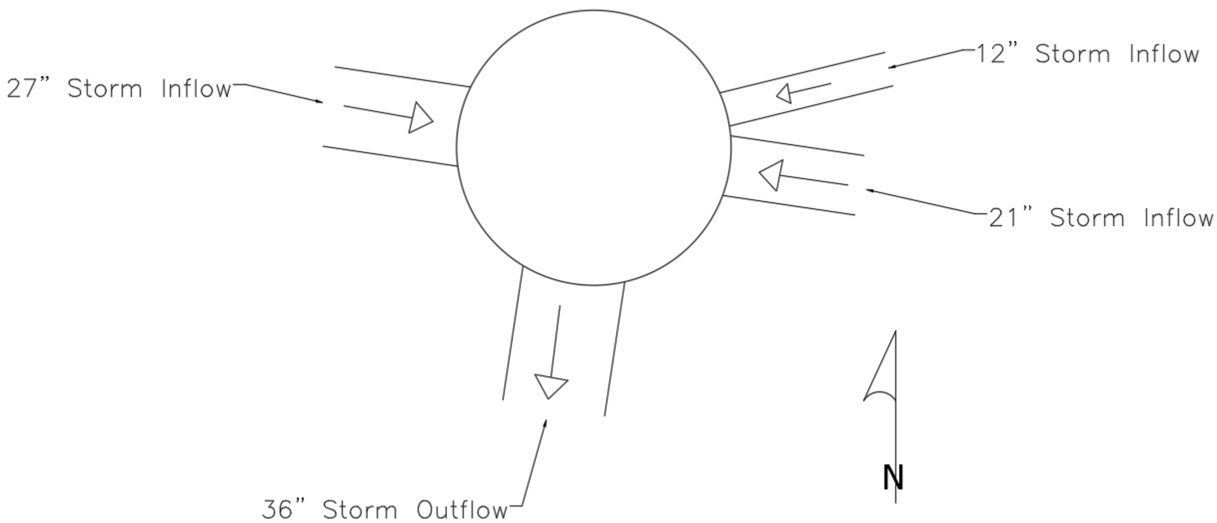
Location 2:


36" Storm Inflow
12" Storm Inflow
12" Storm Inflow
36" Storm to Outfall
N

Location 3-1:

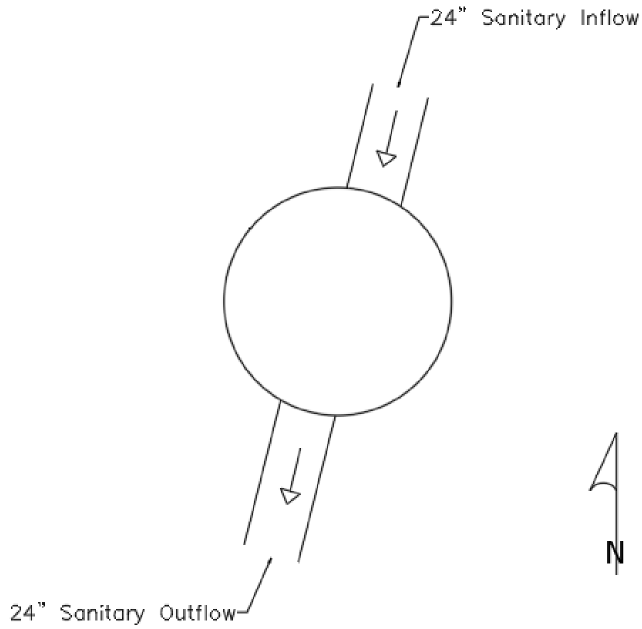

8" Storm Inflow
12" Sanitary Outflow
8" Storm Inflow
8" Storm Inflow
Plugged Line
15" Sanitary Outflow
8" Storm Inflow
N

Location 3-2:

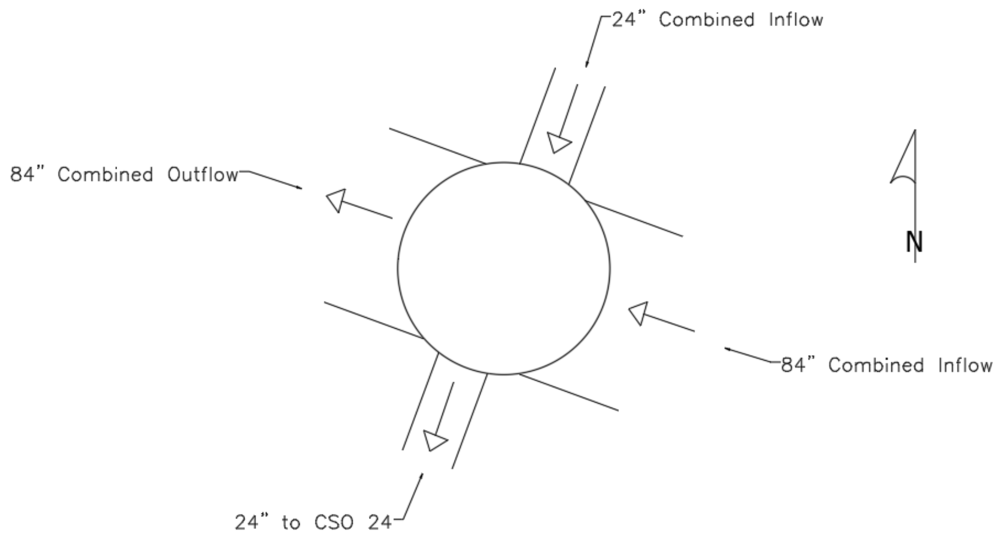


27" Storm Inflow
12" Storm Inflow
21" Storm Inflow
36" Storm Outflow
N

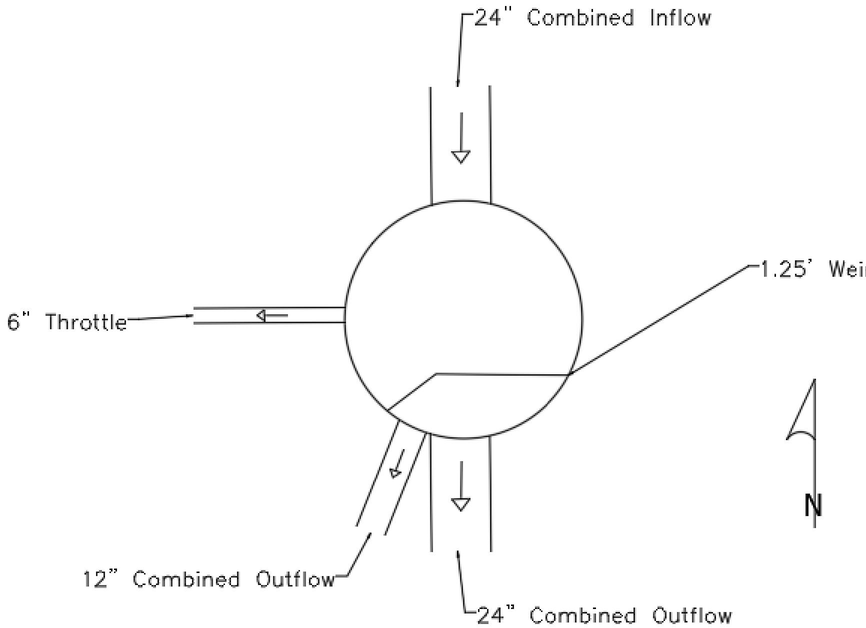
Location 4-1:



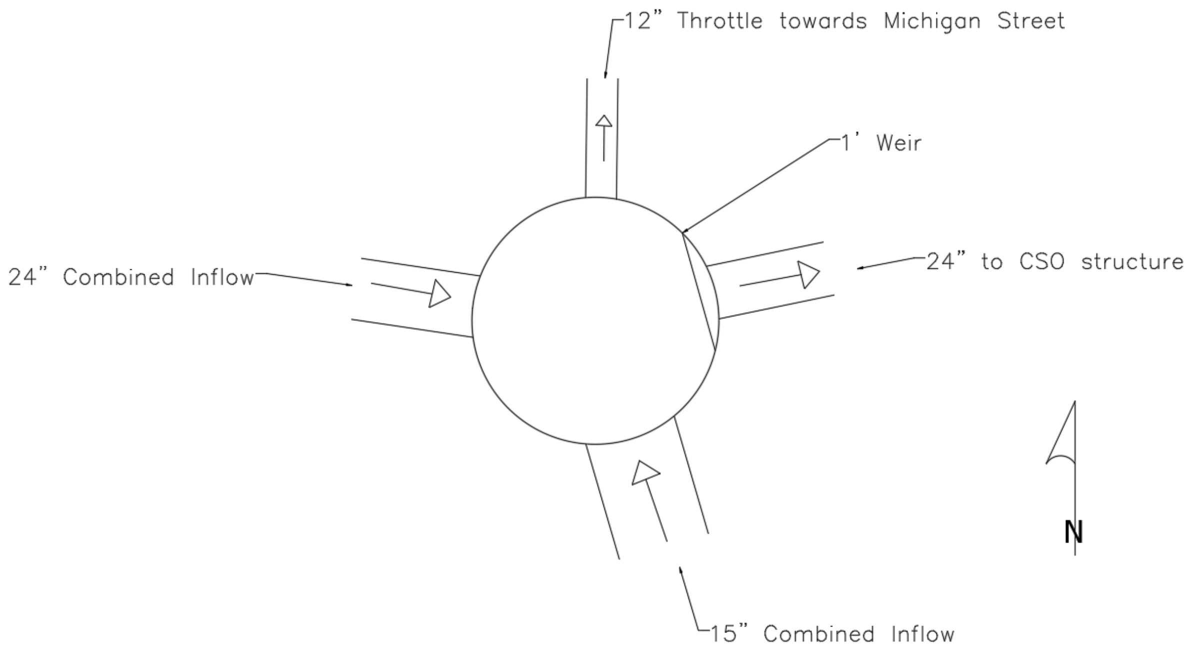
Location 4-2:


24" Combined Inflow
84" Combined Outflow
N
84" Combined Inflow
24" to CSO 24

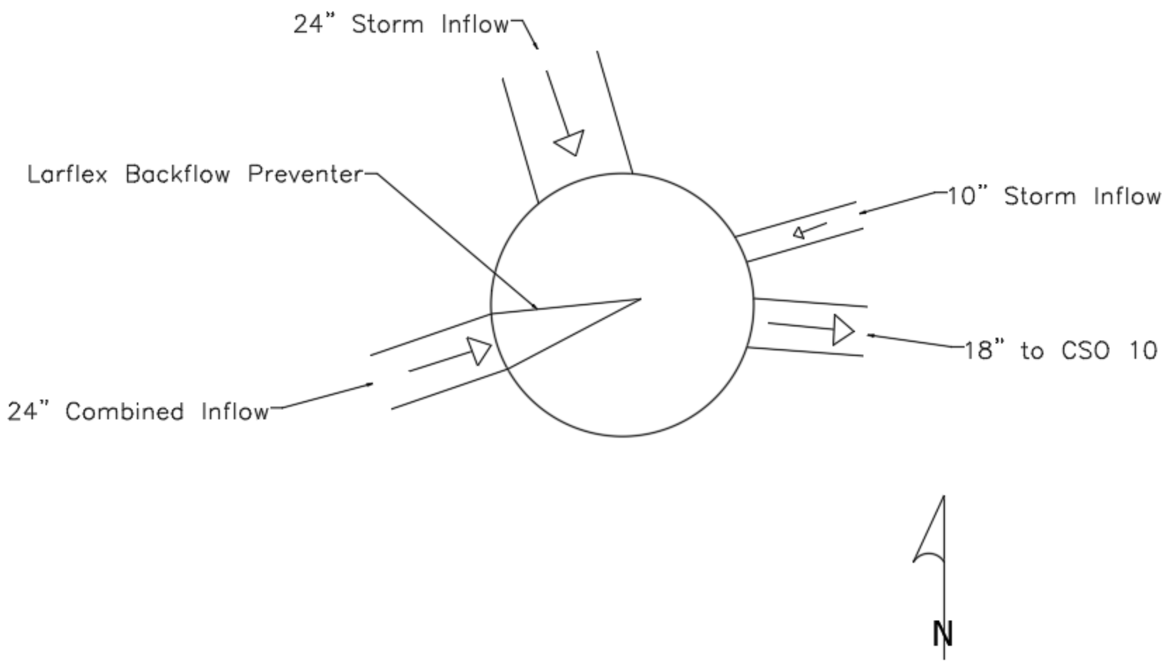
Location 5:


24" Combined Inflow
1.25' Weir
6" Throttle
N
12" Combined Outflow
24" Combined Outflow

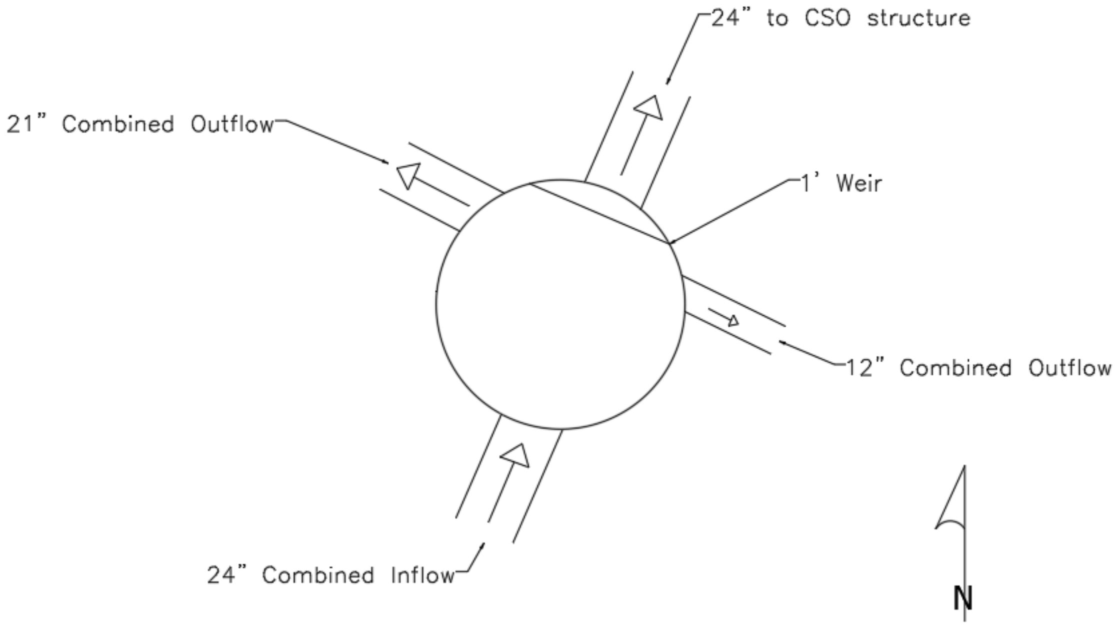
Location 6-1:


12" Throttle towards Michigan Street
1' Weir
24" Combined Inflow
24" to CSO structure
N
15" Combined Inflow

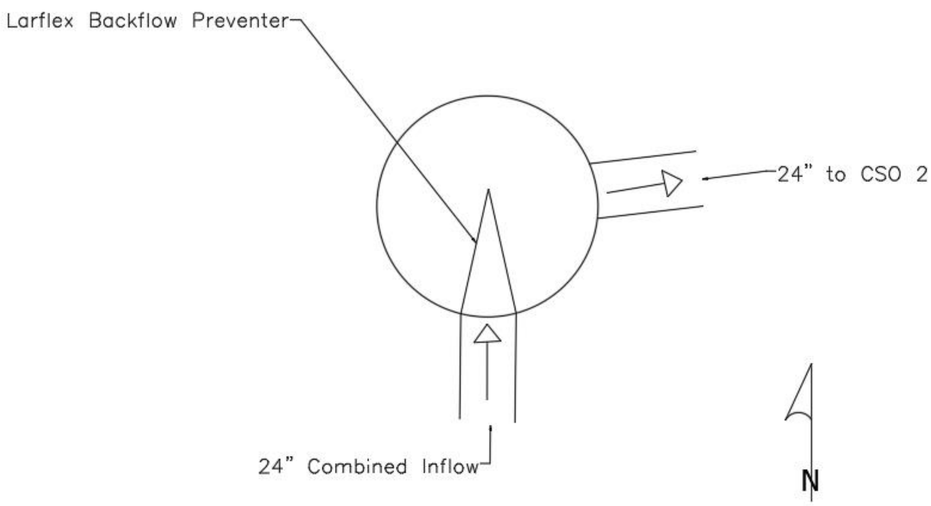
Location 6-2:


24" Storm Inflow
Larflex Backflow Preventer
10" Storm Inflow
18" to CSO 10
24" Combined Inflow
N

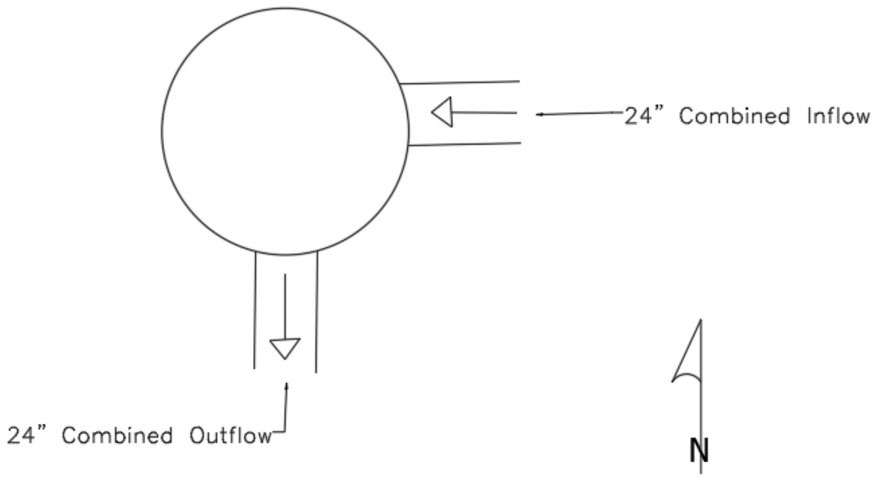
Location 7-1:


24" to CSO structure
21" Combined Outflow
1' Weir
12" Combined Outflow
24" Combined Inflow
N

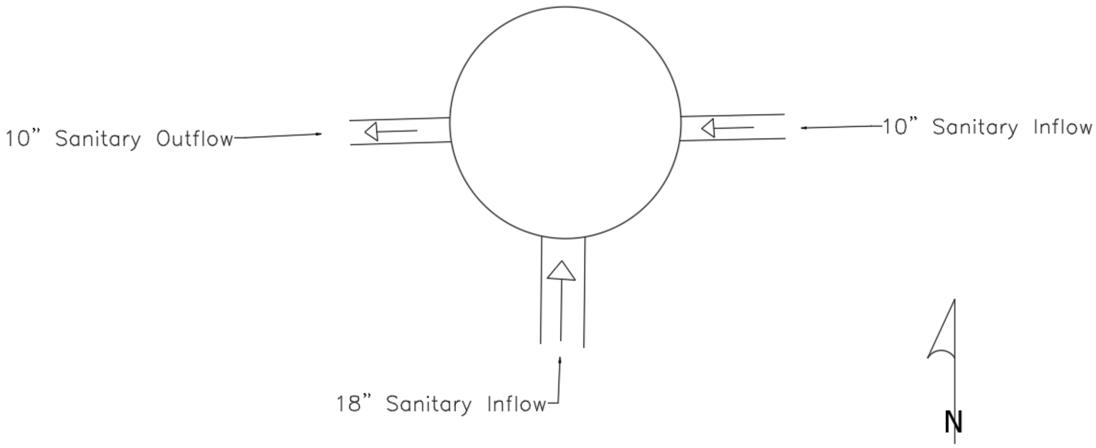
Location 7-2:



Location 8:



Location 9:


10" Sanitary Outflow
10" Sanitary Inflow
18" Sanitary Inflow
N