memorandum

Date:	April 27, 2022
To:	Troy Baughman, Project Manager
cc:	Molly Maciejewski, Public Works Manager Jerry Hancock, Stormwater / Floodplain Coordinator Jennifer Lawson, Water Quality Manager Evan Pratt, Washtenaw County Water Resources Commissioner Harry Sheehan, Chief Deputy Water Resources Commissioner
From:	Robert Czachorski, OHM Advisors Mackenzie Johnson, OHM Advisors
Re:	**June 25-26, 2021 Storm Event Analysis**

Project Background

A large rain event occurred on the evening of June 25, 2021 into the early morning hours of June 26, 2021 resulting in numerous reports of flooding and basement backups in Washtenaw and Wayne Counties, including portions of the City of Ann Arbor. The rain was so significant that states of disaster were declared at the regional, state, and federal levels. The Pittsfield Village neighborhood and surrounding streets were the most impacted areas in the City of Ann Arbor, although scattered flooding and backups were reported throughout the City.

The City of Ann Arbor (City) requested OHM Advisors to perform an engineering analysis to better understand the cause of the basement backups and flooding issues in the City, and provide recommendations on what, if anything, can be done to minimize the potential for similar occurrences in the future. This technical memorandum details the various analyses performed and presents findings and recommendations.

Project Area

While basement backups and flooding were reported throughout the City of Ann Arbor, the Pittsfield Village neighborhood and surrounding streets contained the majority of the reported issues. Thus, this analysis focused on the southeastern portion of the City, bounded to the north by Washtenaw Avenue, the east by US-23, the south by Packard Rd., and the west by Malletts Creek. The defined project area is depicted in Figure 1 of Appendix A. Locations of reported basement backups and surface flooding within the project area are shown in Figure 2 of Appendix A.

June 25-26, 2021 Storm Event

The City of Ann Arbor maintains five (5) active rain gauges throughout the City. In addition to the five City rain gauges, an additional rain gauge near the project area, named the “Southeast” rain gauge, was installed by a professional meteorologist at his home and was in place during the June storm event. The locations of the City and private rain gauges are shown in Figure 1 of Appendix A. The total rainfall recorded by each of these rain gauges during the June storm event is summarized in Table 1 below. Detailed rainfall data is provided in Appendix B. Based on the rain data, the rain event began around 8:00AM on June 25, 2021 and ended around 5:30AM on June 26, 2021. The heaviest rainfall occurred around the midnight hour.

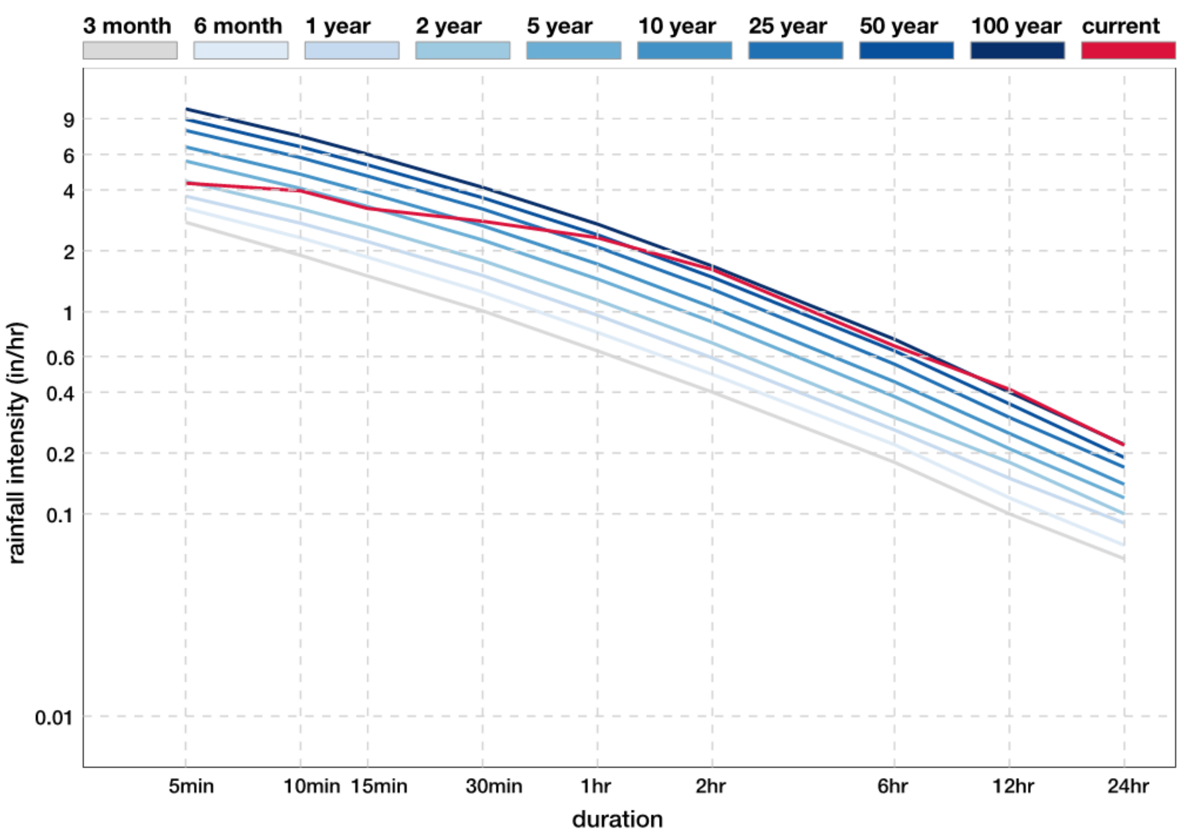
Rain Gauge	Total Rainfall (inches)
Barton Pond	2.01”
City Hall	2.99”
Jackson Road	2.94”
North Campus	3.05”
South Industrial	3.51”
Southeast Rain Gauge	5.25”

Table 1: Rainfall Totals by Rain Gauge

The data in the table above suggests that more rain fell in the southern and southeastern portions of the City than in the northern portion of the City. This was verified with radar data, which is discussed below.

Intensity-Duration-Frequency (IDF) curves were developed for each of these rain gauges, and are provided in Appendix B. IDF curves show the probability that a given rainfall intensity (inches/hour) will occur within a given period of time. Given the rainfall intensity recorded by the rain gauges during the June storm, the IDF curves show that the June storm had higher recurrence intervals, or lower probabilities of occurring, for the longer durations (12-24 hours), and lower recurrence intervals, or higher probabilities of occurring, for the shorter durations (15-30 minutes). The Southeast rain gauge located near the project area had a 100-year recurrence interval for a 24-hour period, as shown by the intersection of the red line and dark blue line at the 24-hour mark in Figure 1 below. This was the highest recurrence interval recorded by any of the rain gauges.

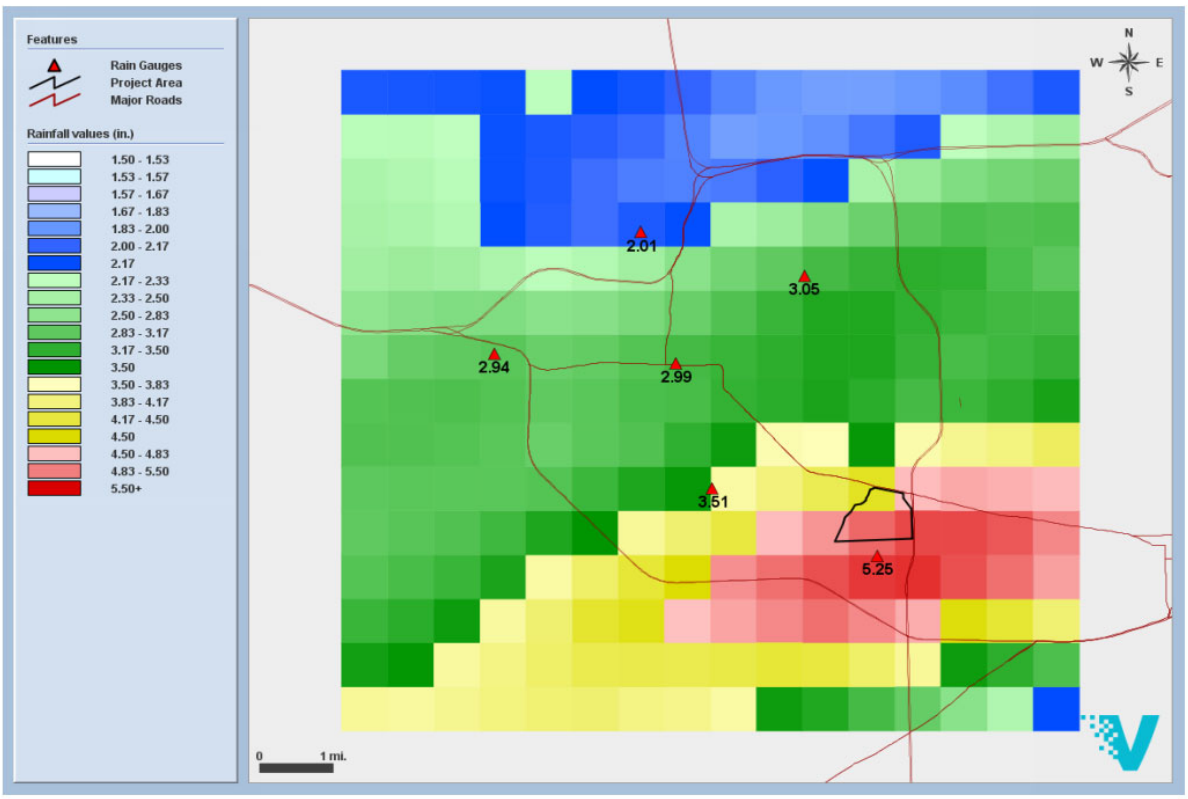
Figure 1: IDF Curve for Southeast Rain Gauge



This recurrence interval suggests that the intensity of rain recorded by this rain gauge has a 1% chance of occurring in any given year (100-year storm). A storm event of this magnitude exceeds the City's design standards of both the stormwater system and sanitary sewer system.

In addition to the rain gauge data, ground-truthed radar rainfall data was also obtained to better understand the spatial variability of the rainfall. Radar data produced by the National Weather Service Next Generation Radar system and local rain gauge data were quality controlled to provide gauge-adjusted radar rainfall (GARR). In the production of GARR, any biases, or systematic errors, in the radar rainfall are corrected through comparison with rain gauge accumulations. The spatial variability of rainfall throughout the City of Ann Arbor is shown in Figure 2 below. The project area is outlined in black.

Figure 2: Radar Rainfall Totals



As can be seen from Figure 2 above, more rain fell in the southeastern part of the City compared to the northern part of the City. The GARR shows that the project area received 4.821 inches of rainfall, as shown in Figure 1 in Appendix C. The full radar rainfall analysis report developed by Vieux is provided in Appendix C.

Public Engagement

Public Meetings
As part of the project initiation, two virtual public meetings were held with the project area community members to introduce the June storm event analysis project as well as to help the project team better understand the experiences of the community members during the rain event. The project team included Troy Baughman, Molly Maciejewski, Ron Hoeft, Jennifer Lawson, and Kayla Coleman from the City of Ann Arbor as well as Evan Pratt and Harry Sheehan from the Washtenaw County Water Resources Commissioner's Office (WCWRC). Robert Czachorski and Mackenzie Johnson from OHM Advisors were also a part of the project team.

These two public meetings covered the same information, but were held one week apart at different times to accommodate schedules of those who wished to attend. Each of the public meetings included breakout rooms where community members had direct communication with members of the project team to learn more about the June storm event and the forthcoming project, to learn about the local Washtenaw County creeks and watersheds, and to share their personal experiences during the June rain event. The presentation slides from the public meetings are provided in Appendix D. During the breakout room sessions, many community members reported instances of localized yard and street flooding, flooding near Malletts Creek and Swift Run (as shown in Figure 1 of Appendix E), as well as basement flooding due to floor drains backing up and from seepage through walls and windows.

Pittsfield Village Condo Association Interview and Field Reconnaissance
Following the public meetings, an interview was held with staff from the Pittsfield Village Condo Association (Pittsfield Village) to learn about their experiences during the June rain event. After the interview, a field reconnaissance was performed with the Condo staff that included an inspection of a condo unit basement and a walk-through of the areas that flooded. Highlights from the interview and field reconnaissance are summarized below:

- The greenspace near the intersection of Norwood and Whitewood collects most of the stormwater from Pittsfield Village (as shown in Figure 1 of Appendix E), and the level of flooding in this area approached the foundations of nearby homes.
    - There appeared to be three sanitary manholes in this area that had open pick holes where surface water could get in, and approximately 3-4 ft. of water was covering these sanitary manholes.
    - Water was coming up through manholes and catch basins in this area.
- The Swift Run creek flooded over Packard Road by about two to three feet causing Packard Road to be closed. The flood waters collected in the greenspace near the intersection of Norwood and Whitewood.
- Street flooding was witnessed on Fernwood/Berkwood, Norwood/Whitewood, Parkwood, and Edgewood/Richard.
- The sanitary sewers are not buried very deep in Pittsfield Village.
- It is typically uncommon for Pittsfield Village community members to experience sanitary sewer backups except for those living near the greenspace area near the intersection of Norwood and Whitewood.
- Every unit has a basement and a crawl space, and basement surveys showed basements to be about four (4) feet below ground level.
- Approximately 66 out of 422 units have sump pumps, and the rest have connected footing drains.
    - Several community members with operating sump pumps reported basement flooding due to water seeping through cracks in the basement walls or due to the inability of the sump pump to keep up with the flows received.
    - Sump pumps have helped reduce basement backup occurrences, and the Pittsfield Village Condo Association would like to continue performing footing drain disconnections, however it is difficult to get all community members to agree as some community members do not want sump pumps installed in their basements due to the additional maintenance required.
    - Perimeter has been contracted to perform the footing drain disconnection work as a part of the City's Developer Offset Mitigation (DOM) program.
        - The purpose of the DOM program is to reduce the overall flow to the sanitary sewer system, which will reduce sanitary sewer overflows and unnecessary treatment of stormwater. The DOM program requires developers to offset the additional flow that a new development is expected to add to the sanitary sewer system by removing existing flow from the sanitary sewer system for a net zero impact. Most developers pursue the footing drain disconnection option to remove the necessary flow from the

sanitary sewer system. Costs related to the footing drain disconnection, sump pump installation, and stormwater connection are negotiated directly with the developer.

        - Many streets in Pittsfield Village do not have City-owned stormwater pipes, so Perimeter has struggled to find acceptable sump pump discharge locations, and in some cases, has had to install lengthy discharge piping.
    - The sump pump is the resident's responsibility, and the sanitary lateral to the sewer main is Pittsfield Village's responsibility.
- Pittsfield Village staff provided information on which residences have gutters, sump pumps, and reported roots in service laterals, and these are shown along with the locations of reported sewer backups in Figures 3, 4, and 5, respectively, of Appendix A.
    - No gutters previously existed within the Pittsfield Village Condo Association, but Pittsfield Village has been working on adding gutters to residential units to facilitate stormwater drainage.

Resident Survey and Interviews

In addition to the public meetings and interview, an online resident survey was conducted to learn more about the flooding and basement backup experiences of the community members within the project area. Postcards were mailed to the project area community members notifying them of the resident survey. Community members had approximately two weeks to complete the survey, which is provided in Appendix E. A summary of the resident survey results is provided below:

- 35/57 respondents reported water in their basements.
- 34/57 respondents reported surface flooding near their homes.
- 32/57 respondents reported that their homes have experienced basement backups/flooding before.
- Manholes near the intersections of Norwood/Whitewood and Oakwood/Parkwood were reported to have water/sewage backing up out of the manhole covers.
- Four (4) community members requested a follow-up meeting in person.
- Eleven (11) community members requested a follow-up phone call.
- There were not widespread reports of surface water entering homes.
- The primary path of basement flooding appears to be from backups from the sanitary sewer with some instances of water seeping in through walls and windows.

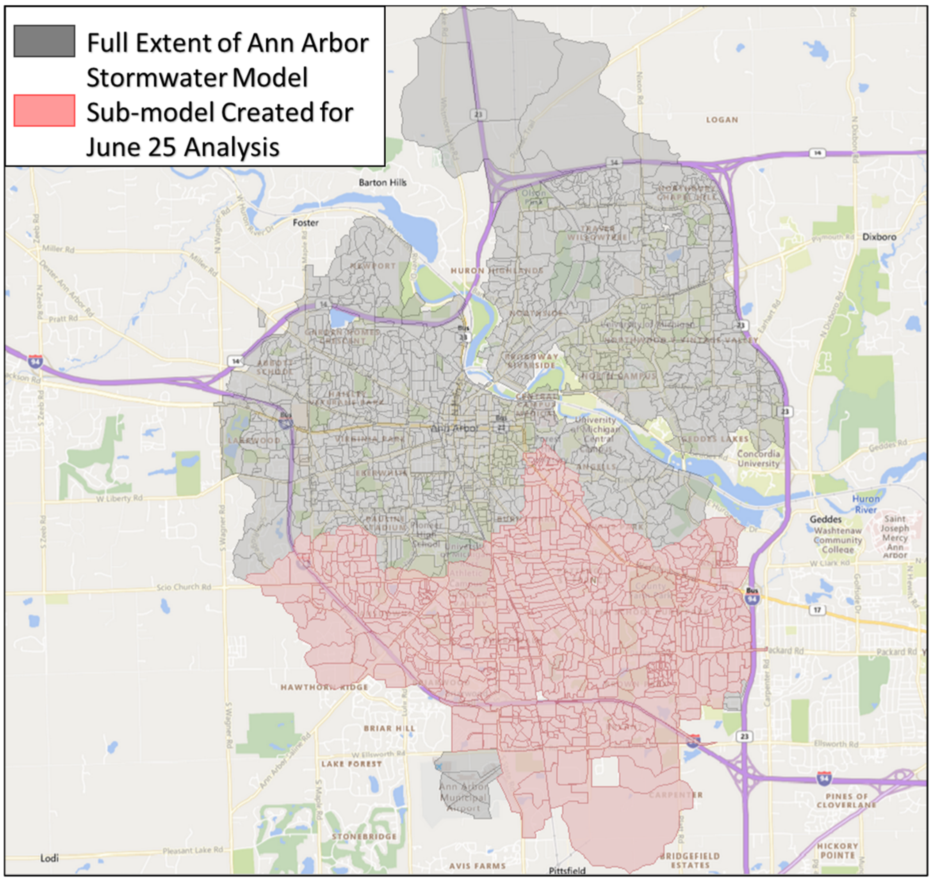
A summary of the survey results is provided in Appendix E.

Follow-up meetings and phone calls were held with specific community members as requested to address their various concerns. Many of the observations made by community members supported the information gathered during the Pittsfield Village Condo Association interview, including reports of several feet of flooding in the greenspace area north of Packard Road and evidence of sanitary sewer surcharging near the intersection of Norwood and Whitewood. Some community members witnessed water coming out of manholes in this area. One community member noted that several of the sanitary sewer manholes near the greenspace area are below grade or in low-lying places and have open pick holes allowing for surface water to enter. Additionally, this community member suggested that the Swift Run creek may be constricted in the 42-inch pipe under the greenspace area, resulting in surface flooding during wet weather events. This item is further evaluated in the next section.

Stormwater Model Analysis

Analysis of the stormwater system during the June rain event was performed using version 7 of the City's calibrated stormwater model. The model was converted from its original form in InfoSWMM to an EPA SWMM v5 model. The model was truncated from its full extents to cover only the portion of the conveyance system related to this analysis, as shown in Figure 3 below.

Figure 3: Stormwater Model Extents



Evaluation of the June rain event began by simulating the model with rainfall observed at local gauges during the event. The rain gauge titled "Southeast" was in closest proximity to the project area, and therefore was used for simulating the June rain event in the truncated SWMM model. The other rain gauges were too far from the project area to provide representative rainfall. This simulation provided the predicted hydrologic and hydraulic response in the stormwater collection system from the June rain event, which was comparable to a storm with a 1% chance of occurring in any given year based on the amount of rainfall received in a 24-hour period (100-year, 24-hour storm).

Model results suggest that the project area experienced widespread stormwater pipe surcharging and several hours of flooding during the June rain event as shown in Figures 4 and 5 below. The magnitude and frequency of flooding predicted by the model during the June 25-26th rain event is consistent with observations made by City staff and community members during the event, which supports the model results.

Figure 4: Modeled Stormwater Pipe Capacities During the June Rain Event

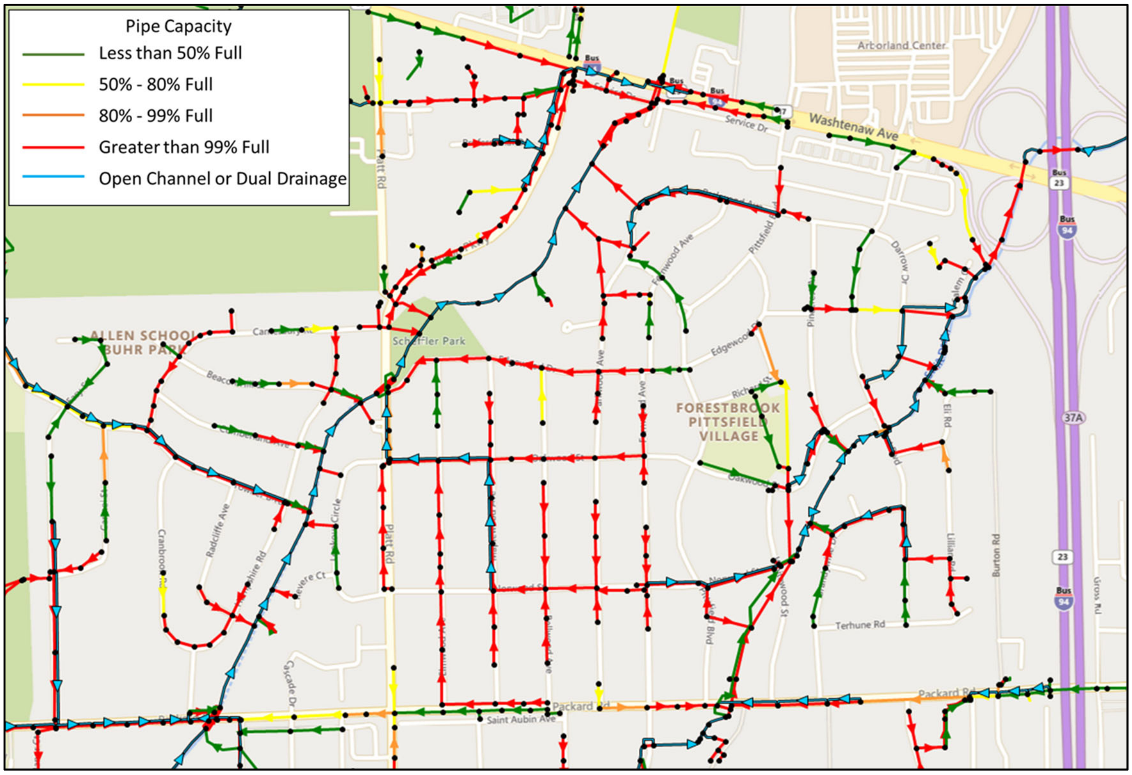
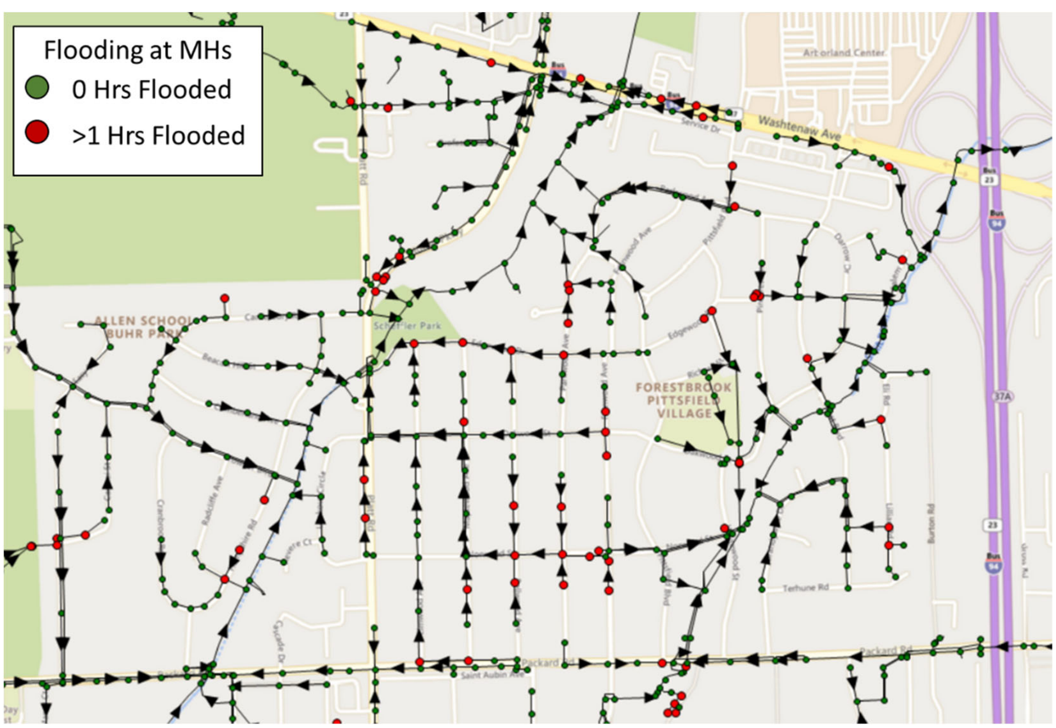
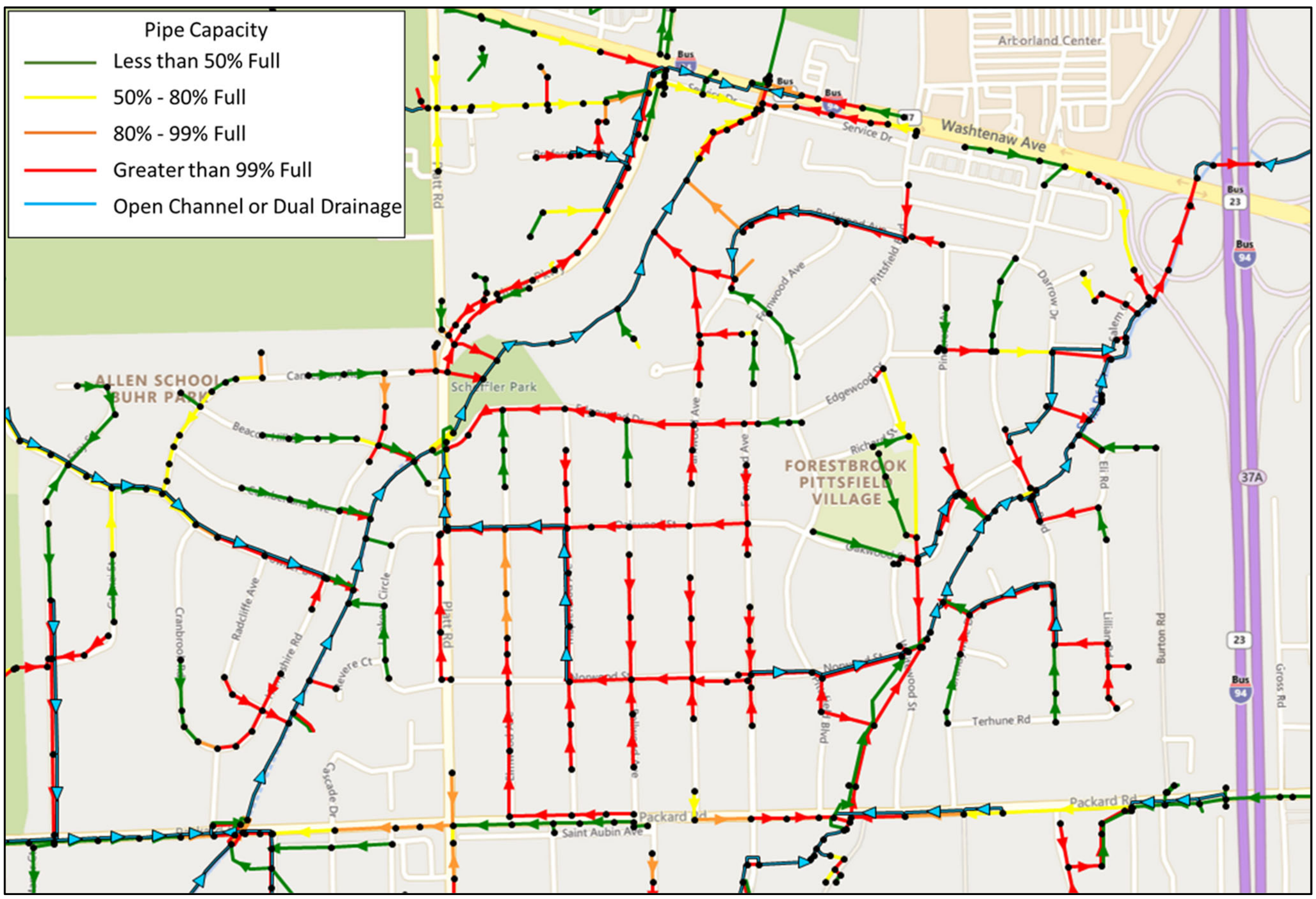


Figure 5: Modeled Stormwater Surface Flooding During the June Rain Event



The June storm was significantly larger than the standard design storm used by the City for sizing improvements to the stormwater collection system. The City's design storm is equal to a storm that has a 10% chance of occurring in any given year based on the amount of rainfall received in a 12-hour period (10-year, 12-hour storm). This design storm meets the Michigan Department of Environment, Great Lakes, and Energy's (EGLE's) regulatory design event standards. Despite the design storm being a smaller, more frequent storm event than the June storm, the model also predicted flooding throughout the project area during the design storm, but at a lesser magnitude than what was predicted and observed during the June 25th event, as shown in Figure 6 below. Since the predicted level of flooding for the June storm was similar to that of the City's design storm, the stormwater system performed as expected during the June rain event. In other words, the sheer volume of flow resulted in the surcharging of the stormwater system in this area as opposed to any pipe failures or obstructions in the pipes.

Figure 6: Modeled Stormwater Capacities During the Design Storm



Specific Areas of Concern
Additional analyses were performed in three specific areas of concern identified by City staff and community members. These areas either experienced significant flooding during the June 25-26th storm and/or have a history of flooding during large rain events. The results from the additional analyses are detailed below.

Swift Run & Packard:
The model predicted approximately 0.7 feet of flooding during the June 25-26th storm along Packard Road, east of the Swift Run crossing, as shown in Figure 7 below. The greenspace between Pittsfield and Whitewood, north of Packard Road, was predicted to have about 2 feet of flooding during the June rain event as shown in Figure 8. These flooding predictions are consistent with what was reported by community members in the area. Furthermore, model results showed that this greenspace was predicted to have about 1.5 feet of flooding during the design event, which is a smaller magnitude storm than the June event. This suggests that this greenspace area may have been intended to provide some level of surface storage during rain events, especially considering that it is located within the Swift Run floodplain as shown by the circled area in Figure 9.

Figure 7: Hydraulic Profile of the Swift Run Enclosure at Packard During the June Storm

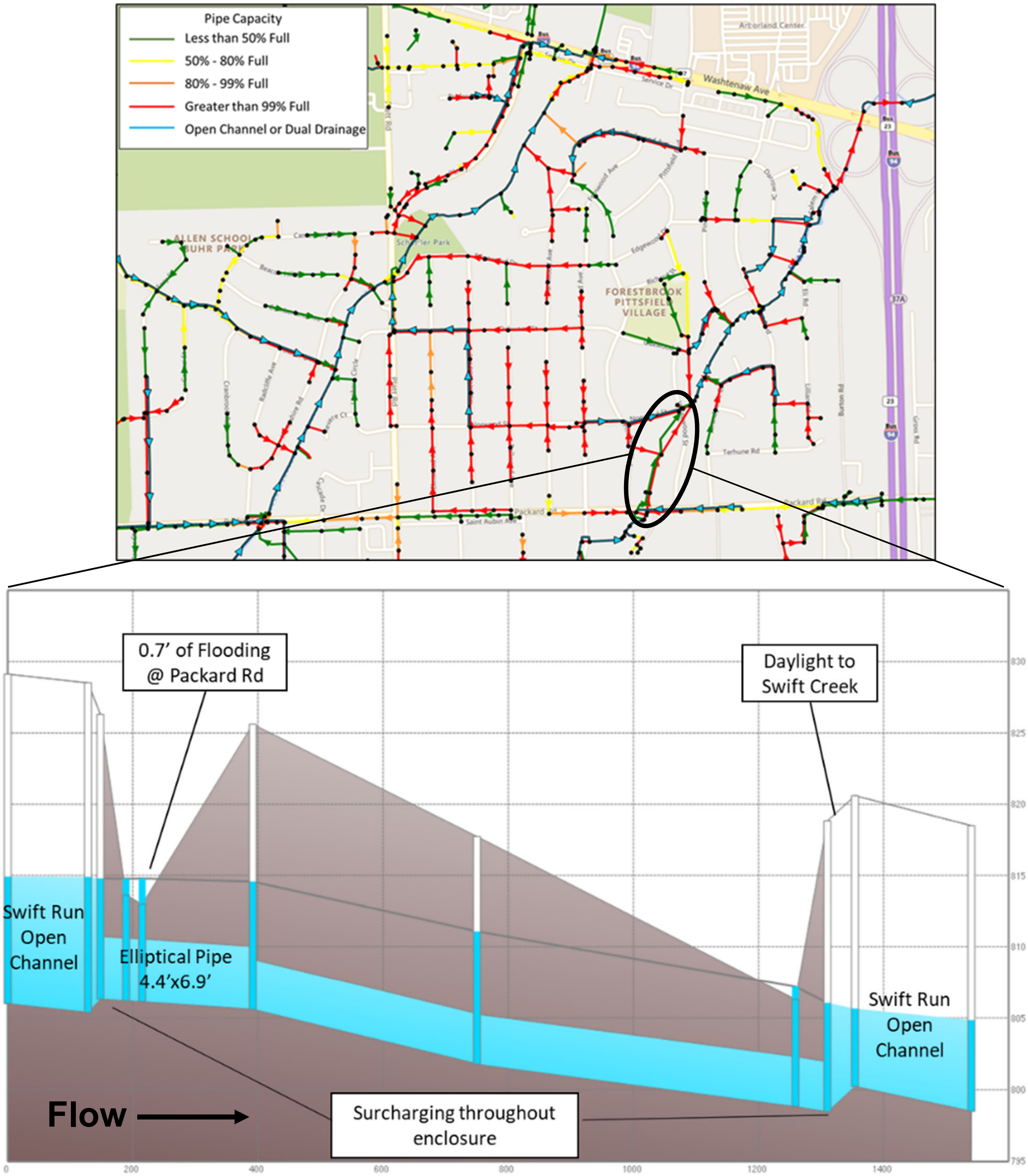


Figure 8: Hydraulic Profile of the Overland Flow in the Greenspace During the June Storm and Design Storm. The model has 'dual drainage flow' in this stretch that is not displayed in the profile below.

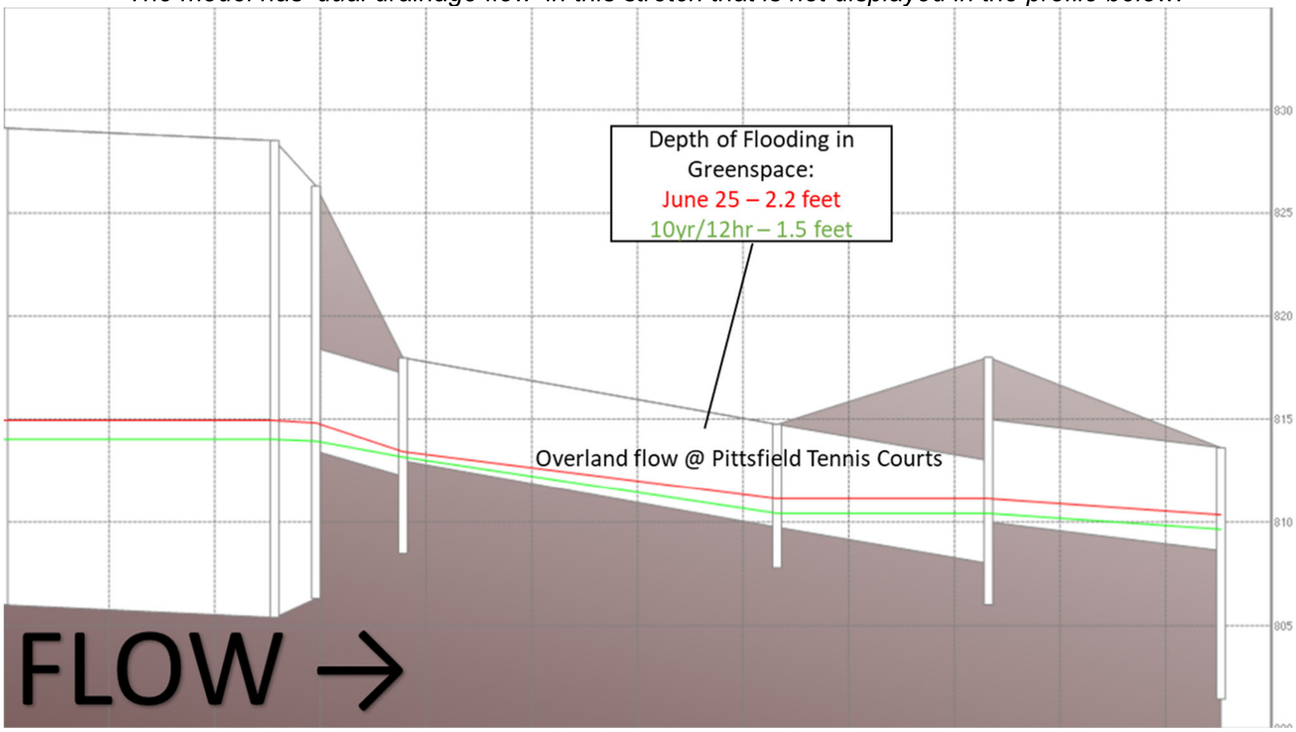
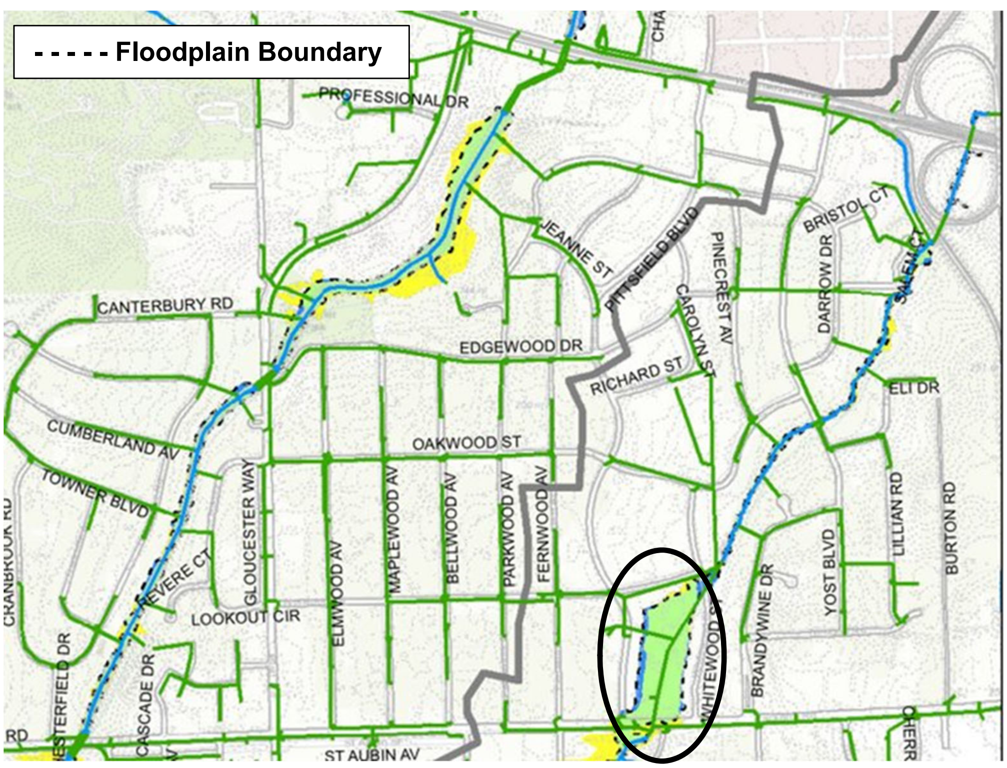


Figure 9: FEMA Floodplain Map of Project Area



Pinecrest & Yost:
The Pinecrest and Yost Blvd. area is located within the project area between Washtenaw and Packard, west of Swift Run. Recent reports from homeowners have revealed flooding from inlets near Carolyn Street. A model simulation of the design event confirmed these claims and suggest the stormwater pipes between Pinecrest and Darrow have insufficient capacity to transport local runoff, as shown in Figure 10. The model suggests that the flooding predicted in this area during a design rain event could be addressed by upsizing the stormwater pipes to 24-inches in diameter from Pinecrest to Darrow. Preliminary model results show that upsizing these stormwater pipes would have negligible impacts downstream in the open channel of Swift Run, as shown in Figure 11, however a more detailed analysis of the downstream impacts and potential for green infrastructure should be completed before upsizing these pipes.

Figure 10: Map and Hydraulic Profile from Pinecrest & Yost to Swift Run During the Design Storm

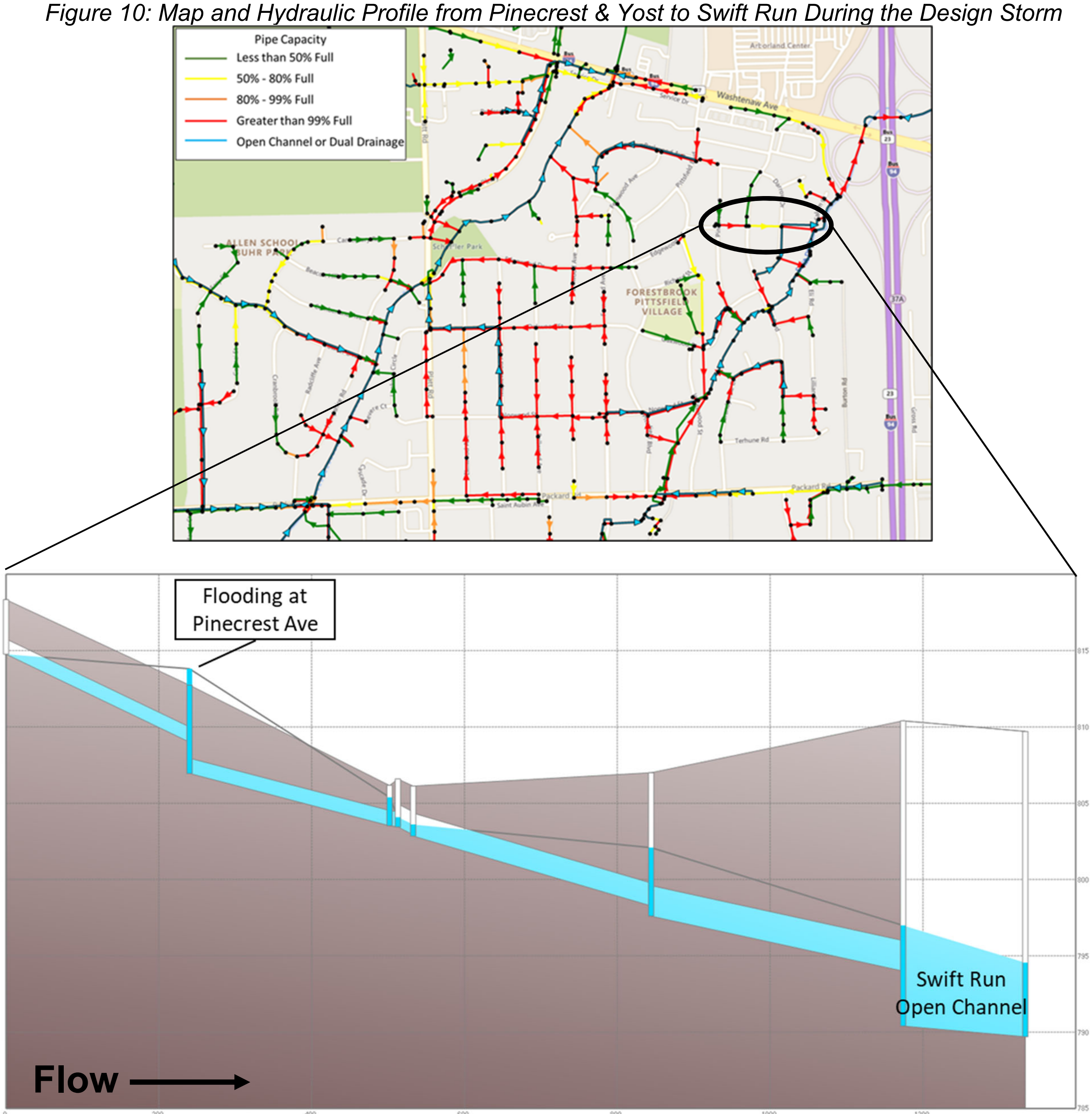
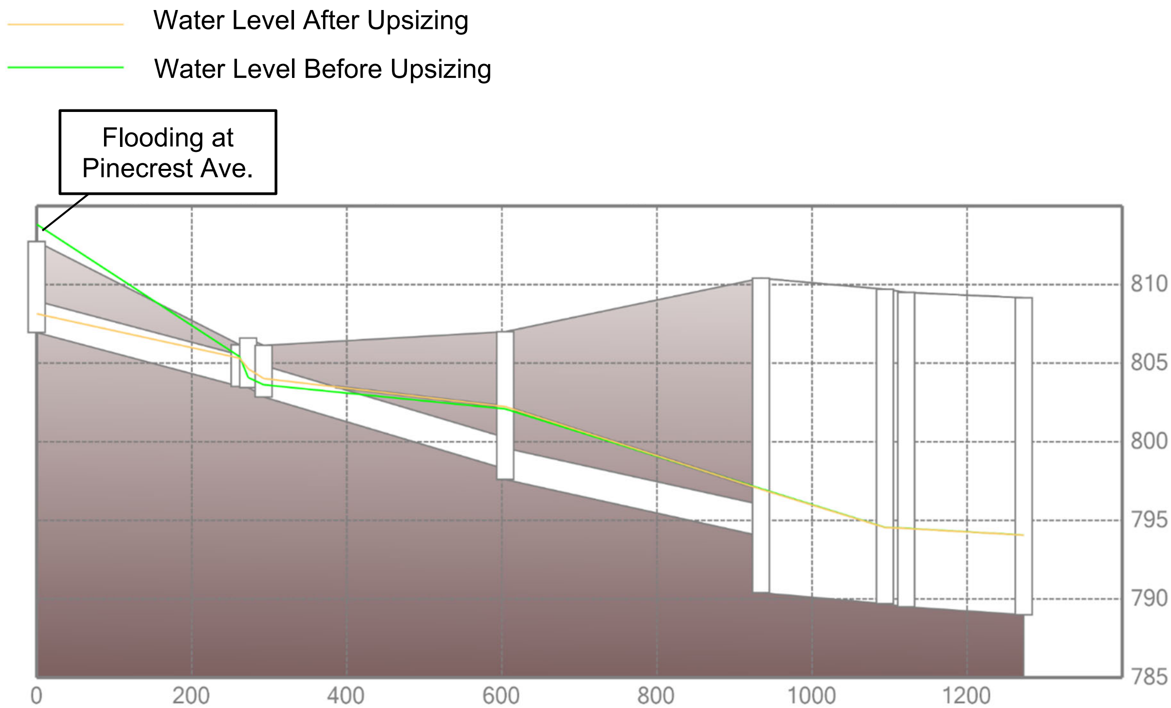
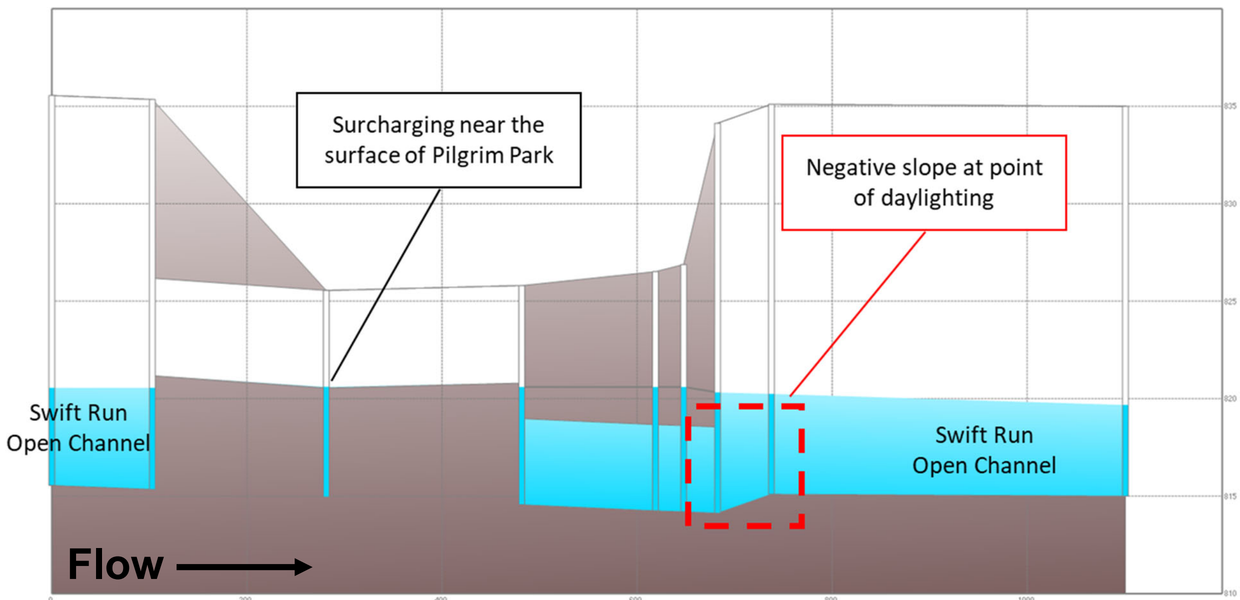


Figure 11: Design Storm Hydraulic Profile from Pinecrest & Yost to Swift Run Before and After Pipe Upsizing



Pilgrim Park:
Pilgrim Park is located on the upstream end of the Swift Run watershed, just north of I-94 along Platt Road. Pilgrim Park is unrelated to other areas considered in this analysis (Packard Rd and Pinecrest), but City staff expressed interest in understanding the extent of flooding in this area during large events. During the June rain event, the model predicts nearly two (2) feet of flooding in the park immediately upstream of the Swift Run enclosure, which is west of Platt Road. For the design storm, the model shows significant surcharging throughout Pilgrim Park, but does not predict any flooding in the park or surrounding area as shown in Figure 12. Although surface flooding is not predicted, the magnitude of surcharging during the design event may suggest the need for improvements to the local collection system in this area. It should also be noted that the first segment of open channel, following the enclosure under Platt Road, has a negative slope in the model. This characteristic is contributing to the predicted flooding and should be confirmed by the City with a field visit, then corrected in the model if necessary.

Figure 12: Hydraulic Profile of Pilgrim Park during the Design Storm



Sanitary Sewer Model Analysis

The June storm was significantly larger than the standard design storm used by the City for sizing improvements to the sanitary sewer system. The City's design storm for the sanitary sewer system was developed in collaboration with a Citizens Advisory Committee (CAC) during the Sanitary Sewer Wet Weather Evaluation Project from 2013-2015. The selected design event was based on future growth projections with peak flows from the 25-year recurrence interval event, plus an additional 10% peak flow. This additional peak flow was included to provide the City with flexibility to allow for changes in future growth, climate change, or a more infrequent design event (50-year peak flow). This design storm exceeds the Michigan Department of Environment, Great Lakes, and Energy's (EGLE's) regulatory design event standards.

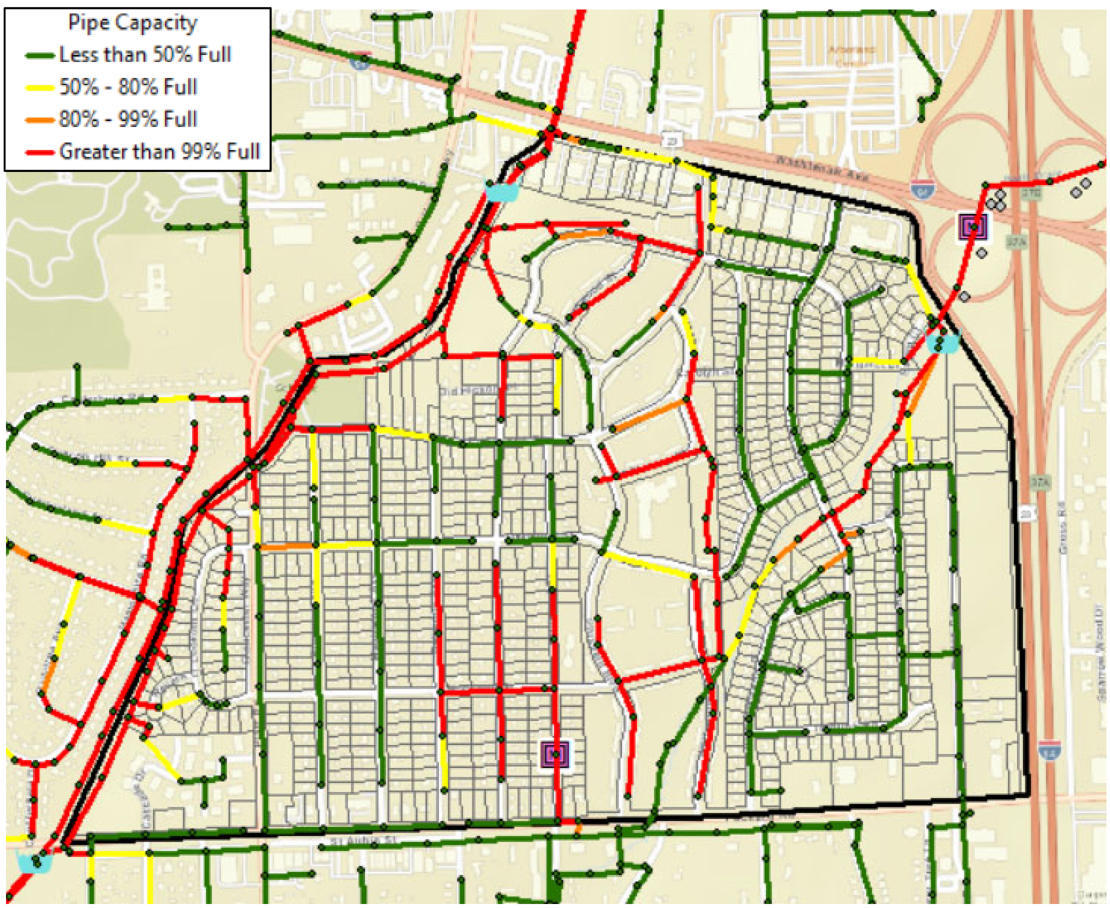
The City currently maintains twelve (12) flow meters throughout the sanitary sewer system to continuously monitor flows. The locations of these flow meters are shown in Figure 1 of Appendix A. The flow meter data from the June rain event is provided in Appendix F. This data was compared to the design flows developed during the Ann Arbor Antecedent Moisture Model (AMM) development in 2013 to verify that the metered flows are what would be expected for a storm of this size. A different set of flow meters were used for the 2013 AMM development than those that are in place now. Flow meter G1 was analyzed during the 2013 AMM development, and was located in the same geographical area of the current project area. The base flow at meter G1 was 2.4 cfs. The frequency analysis from the 2013 AMM analysis yielded a 10-year flow of 13.5 cfs and a 100-year flow of 18.5 cfs. These annual probabilities yield a 5.6 peaking factor and 7.7 peaking factor for the 10-year and 100-year events, respectively. A peaking factor is the ratio of the peak flow to the average flow. The flow meter in place during the June storm event near the US-23/Washtenaw Avenue interchange yielded a peaking factor of 15.8 during June's 100-year rain event. This peaking factor is much higher than what would be expected based on the AMM. This suggests that additional flow beyond what was expected entered into the sanitary sewer system during the June rain event. The source of this additional flow was likely higher rates of inflow and infiltration into the public sewers and footing drains during the June 25-26, 2021 rain event as a result of the surface water flooding in the area.

The hydraulic model was updated to reflect the conditions present during the June rain event per discussions with City staff. The flows in the model were calibrated to simulate observed flooding conditions. In order to better simulate the reported field conditions, additional flow was added to the model in the Pittsfield Village Condo Association as this area accounted for the majority of the reported basement backups. The typical flow per connected footing drain is 1 gallon per minute (gpm) per 1-inch of rain. Considering that the June rain event produced approximately 5 inches of rain, it would be expected that each connected footing drain would normally contribute about 5 gpm to the sanitary sewer system. However, an additional flow equal to approximately 15 gpm per connected footing drain had to be added to this area in the model to produce similar results to what were witnessed, as shown in Figure 13 below. This is substantially more inflow than what would be expected from footing drains for a storm of this size. It should be noted that while additional flow, equivalent to 15 gpm per connected footing drain, had to be added to the model to replicate observed conditions, not all of this flow into the sanitary sewer system actually came from connected footing drains. It is expected that a portion of the flow also came from public inflow and infiltration sources, such as through cracks and root intrusions in pipes and manholes. The model results confirm that surface water flooding caused a significant amount of inflow and infiltration, both from connected footing drains and public sources, into the sanitary sewer system causing basement backups. The locations of the reported sewer backups in relation to the modeled pipe capacities are shown in Figure 1 of Appendix G.

It is recommended that the City perform a sanitary sewer investigation to identify and remove public inflow and infiltration sources. As a part of this effort, the City may perform smoke testing, manhole lining, and pipe rehabilitation to remove excess flow from the system. It should be noted that the City plans to conduct a Utility Improvements Evaluation project in 2023, which will include a public sewer inflow and infiltration investigation involving some of the tasks identified above. Certain components of this public sewer investigation have already begun. It is also recommended that roof downspouts be extended far enough away from the house to reduce the flow into footing drains.

Hydraulic profiles of the sanitary sewer pipes in this area during the June rain event are shown in Appendix G. The estimated elevations of the basement floors in this area are marked on the profiles in Appendix G to indicate where the model predicts basement backups to have occurred. The locations are consistent with the actual locations where basement backups were reported. Recent basement surveys conducted in the Pittsfield Village neighborhood showed basement floors to be about four feet below ground level. Basement backups are predicted to occur where the hydraulic grade line (HGL) is higher than the basement elevation.
It should also be noted that the 24-inch sanitary sewer interceptor along Swift Run splits into parallel 27-inch and 15-inch sewer interceptors near the US-23/Washtenaw Avenue interchange. The 15-inch interceptor was not in service during the June rain event, however model results suggest that basement backups in the Pittsfield Village neighborhood would still have occurred even with the 15-inch sewer in service due to its lengthy distance downstream from Pittsfield Village. Model results show that while the local sanitary sewer mains in the Pittsfield Village neighborhood have sufficient capacity to convey the flows from the City's design storm, they did not have sufficient capacity to convey the peak flows produced by the June rain event resulting in sewer surcharging and basement backups.

Figure 13: Modeled Sanitary Sewer Pipe Capacities with Additional Flow Added



Conclusions

According to the radar rainfall data, the project area received approximately 4.8 inches of rain during the June 25-26, 2021 rain event, which equates to a storm with a 1% chance of occurring in any given year based on the amount of rainfall received in a 24-hour period (100-year, 24-hour storm). A storm of this magnitude exceeds the City's design standards for sizing both the stormwater system and sanitary sewer system.

Widespread stormwater pipe surcharging and several hours of flooding were observed during the June rain event, and these observations are consistent with the stormwater model predictions for a storm of this magnitude. While the City's design storm is a smaller storm event, the model also predicted flooding throughout the project area during the design storm, but at a lesser magnitude than what was predicted and observed during the June 25th event. Since the predicted level of flooding for the June storm was similar to that of the City's design storm, the stormwater system performed as expected during the June rain event. Additionally, the stormwater model analysis showed that surface flooding was expected to occur in the greenspace bound by Pittsfield, Norwood, and Whitewood during both the June storm and the design storm, which suggests that this greenspace area may have been intended to provide some level of surface storage during rain events, especially considering it is located within the Swift Run floodplain.

The flows in the sanitary sewer model were calibrated to simulate observed flooding conditions. A considerable amount of flow, equating to about 15 gpm per connected footing drain, had to be added to the project area in the model to replicate the extent of basement backups and surcharging reported during the June rain event.

A "best working hypothesis" for the cause of the basement backups was formed from the results of this investigation. The stormwater system backed up as would be expected for a storm of this size, resulting in surface flooding. The level of surface water approached the foundation of homes. The surface water flooding appears to have caused a significant amount of inflow and infiltration, both from footing drains and public sources, into the sanitary sewer system causing basement backups. This is supported from community member feedback, data analysis, and modeling efforts.

Recommendations

In order to reduce the risk for basement backups and flooding in the project area in the future, the following items are recommended.

The stormwater model results show that surface flooding is predicted in the project area during the City's design storm, which suggests that some stormwater pipes in this area may have insufficient capacities to convey the current design storm peak flows. In particular, it is recommended that the stormwater pipes between Pinecrest and Darrow be upsized to 24 inches in diameter as there have been multiple reports of flooding in this area during rain events. Preliminary model results show that upsizing these stormwater pipes would have negligible impacts downstream in the open channel of Swift Run, however a more detailed analysis of the downstream impacts and potential for green infrastructure should be completed before implementing this recommendation.

Additionally, although surface flooding is not predicted in the Pilgrim Park area, it is recommended that the City further evaluate the stormwater infrastructure in the Pilgrim Park area to confirm pipe slopes and to determine the need to upsize the pipes to reduce the level of surcharging predicted during the design storm. Considering that the Swift Run creek traverses through both Pilgrim Park and the project area, it is recommended that a study of the Swift Run watershed be performed by the WCWRC to better understand its behavior during dry and wet weather.

As a best practice for operation and maintenance of the sanitary sewer system, the City should perform a sanitary sewer investigation within the project area to identify and remove inflow and infiltration sources. This investigation may include televising the sanitary sewer pipes, smoke testing, and/or performing manhole inspections. Removal of inflow and infiltration sources may require repairing structural defects within the sanitary sewer pipes and manholes as well as addressing any smoke sources identified during smoke testing.

It should be noted that the City plans to conduct a Utility Improvements Evaluation project in 2023, which will include a public sewer inflow and infiltration investigation involving some of the tasks identified above. Certain components of this public sewer investigation have already begun. Additionally, considering that there were numerous reports of surface water flooding over the top of sanitary sewer manholes, it is also recommended that the pick holes in the manholes be plugged or bolted to prevent surface water from entering.

It is also recommended that the City extend the curb drains within the Pittsfield Village Condo Association to allow for sump pump discharge connections, as the existing private 4-inch yard drains may not have sufficient capacity to convey flows from both surface runoff and footing drains. It is recommended that the City then encourage the project area community members, particularly in the Pittsfield Village neighborhood, to disconnect their footing drains from the sanitary sewer system as a part of the City's DOM program. Under this program, developers would negotiate the cost for the footing drain disconnections with the community members who wish to participate. Connected footing drains typically account for a significant portion of inflow into the sanitary sewer system, and removing a majority of this flow would reduce the risk for sanitary sewer surcharges and basement backups. It should be noted that participation in the DOM program will help reduce the risk of basement backups from the sanitary sewer system, but will not reduce the risk of basement flooding from water seepage through the basement walls or windows. It is important that the source of flooding is identified for each individual home to ensure the appropriate solution is implemented. More information on the City's DOM program can be found at <a2gov.org/DOM>.

As a long-term task, it is recommended that the City initiate a project to redevelop the design storms for both the storm and sanitary sewer systems to account for climate change. Once the design storms are updated, the City will use these as the new standard to size improvements to the storm and sanitary sewer systems to ensure these networks can adequately convey the design storm flows. It is expected that this project will take some time to develop and implement, thus it should be initiated after the previously recommended items are addressed.

As many of the community members who experienced flooding and basement backups reside within the Pittsfield Village Condo Association, there are several recommendations that Pittsfield Village management can implement to better prepare their community members for future large rain events. It is recommended that Pittsfield Village management continue adding gutters to the residential units to facilitate stormwater drainage. Additionally, Pittsfield Village management can assist community members with ensuring their soil is sloped away from the foundations of their homes and can assist with enrolling community members in the City's DOM program. Cleaning and televising of sanitary sewer leads should also be conducted throughout the Pittsfield Village neighborhood to ensure the full sanitary sewer lead capacities are being utilized during rain events. It is recommended that Pittsfield Village management perform a capacity analysis on the private stormwater infrastructure to ensure it is adequately sized for the desired level of service.

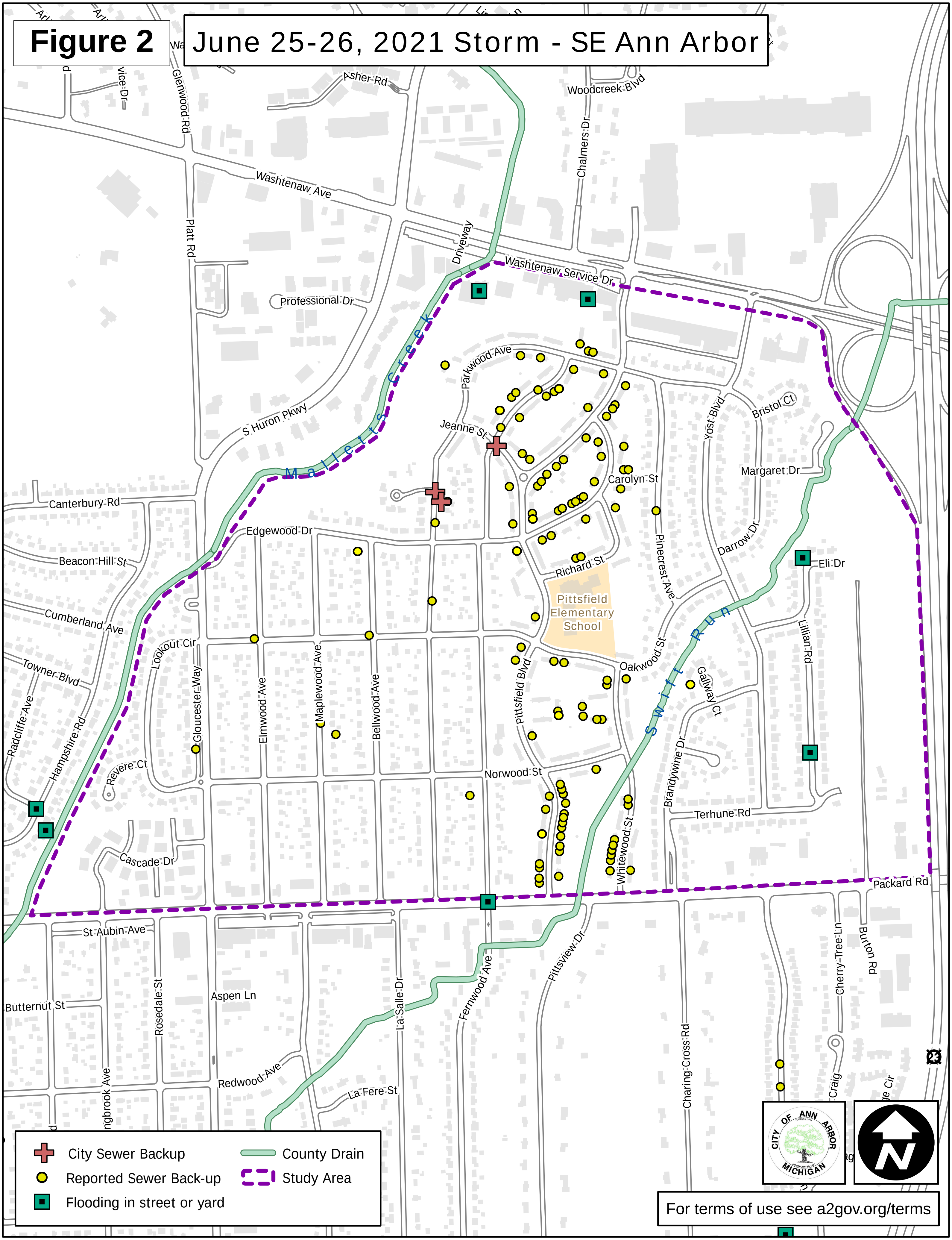
There are also several best practices that homeowners can implement themselves to reduce their risk for basement backups and flooding. Some best practices include ensuring that soil is graded/sloped away from the house, extending downspouts away from the house, and installing a check valve on the sanitary sewer lateral. A list of recommended best practices is documented in Appendix H.

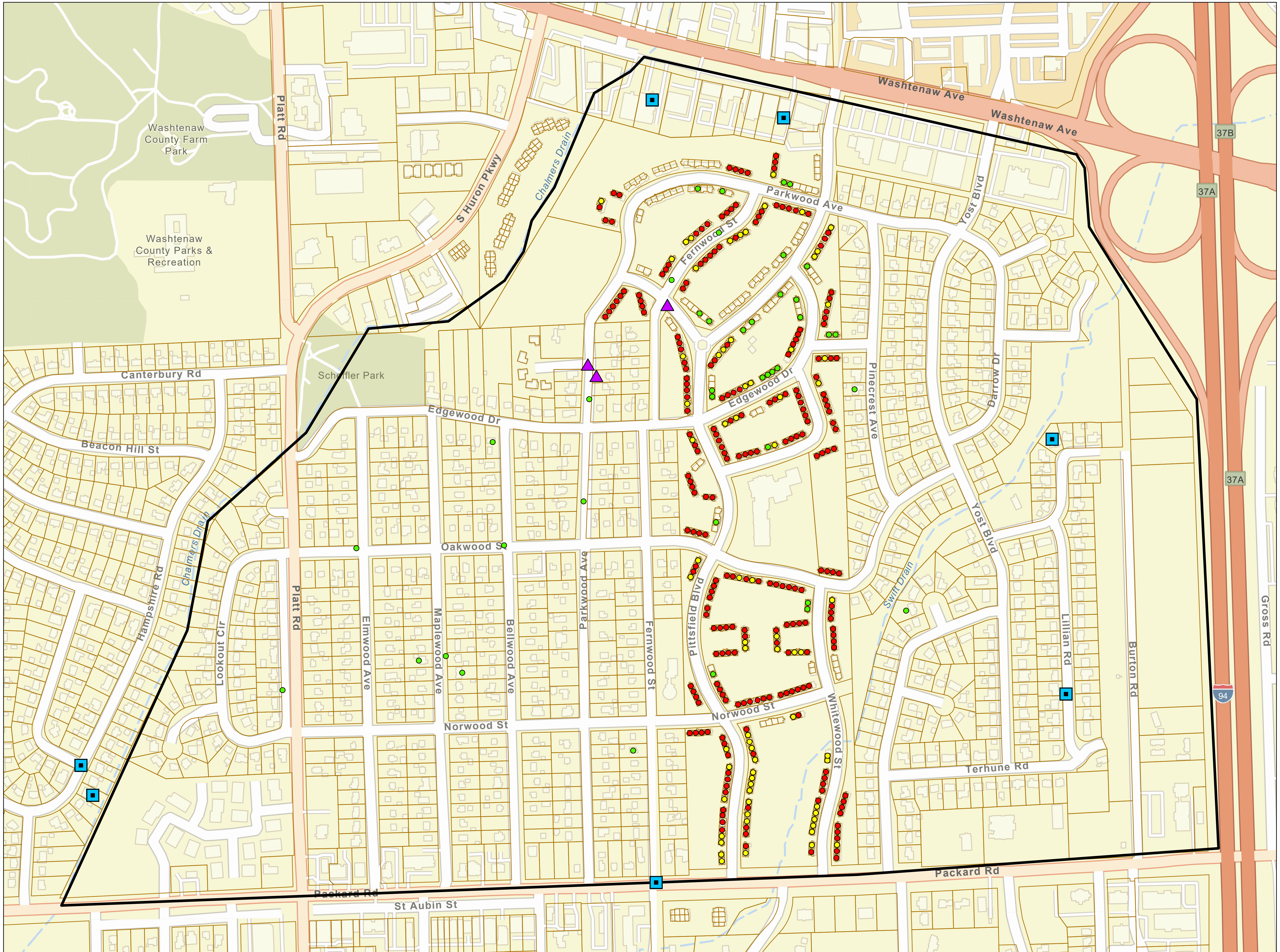
List of Appendices

Appendix A

Figure 2

June 25-26, 2021 Storm - SE Ann Arbor





Ann Arbor Addresses with Gutters

Figure 3

- Gutters
- Reported Sewer Backups
- Gutters and Reported Sewer Backups
- City Sewer Backups
- Street/Yard Flooding
- Project Area
- Ann Arbor Parcels

N

0 450 900
Feet

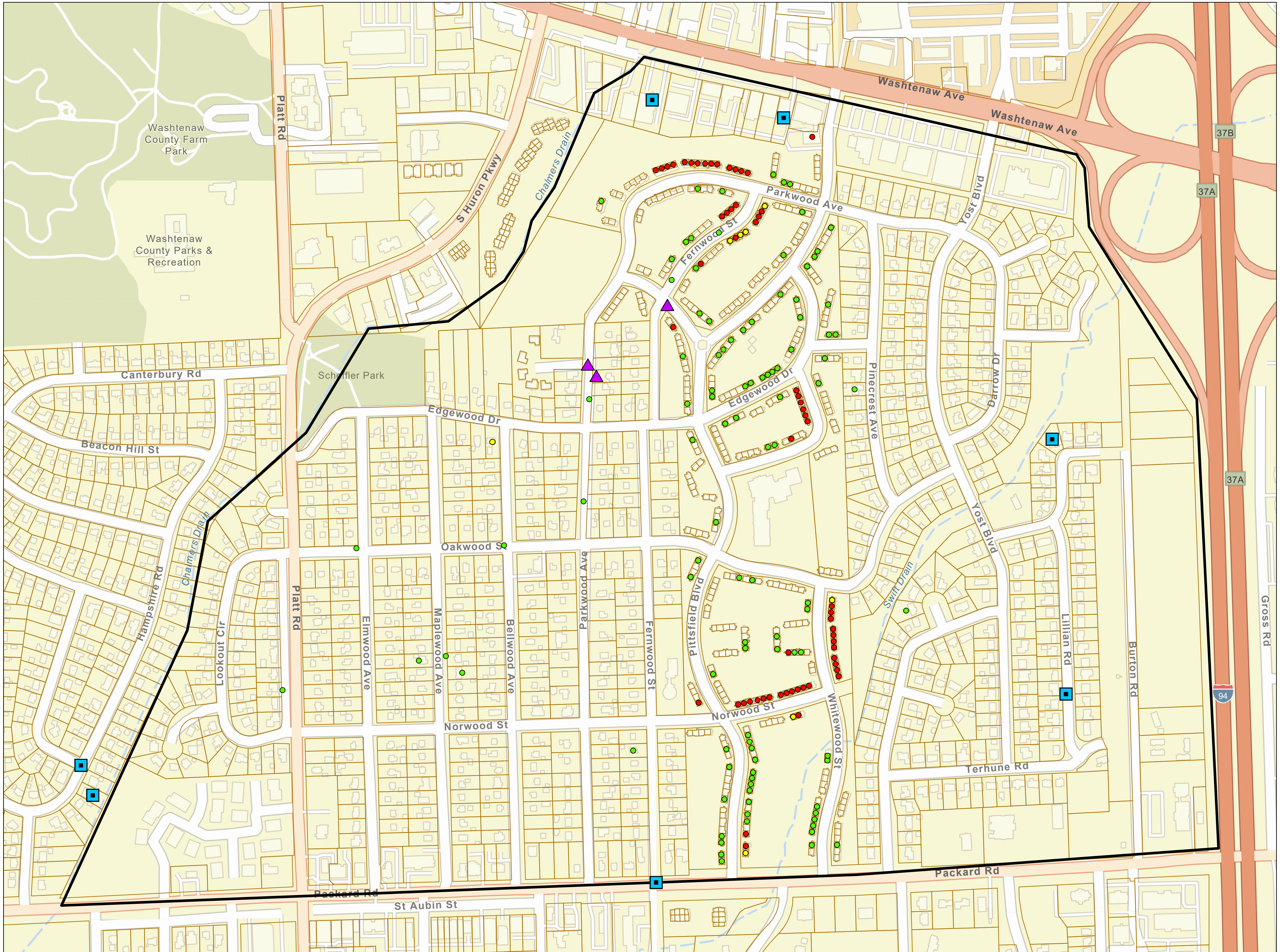
1″ = 450′

Source: Data provided by Ann Arbor, OHM Advisors, and Esri. OHM Advisors does not warrant the accuracy of the data and/or the map. This document is intended to depict the approximate spatial location of the mapped features within the Community and all use is strictly at the user's own risk.

Coordinate System: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl

Map Published: February 7, 2022

OHM



Ann Arbor Addresses with Sump Pumps

Figure 4

- Sump Pumps
- Reported Sewer Backups
- Sump Pumps and Reported Sewer Backups
- City Sewer Backups
- Street/Yard Flooding
- Project Area
- Ann Arbor Parcels

N

0 450 900

Feet

1″ = 450′

Source: Data provided by Ann Arbor, OHM Advisors, and Esri. OHM Advisors does not warrant the accuracy of the data and/or the map. This document is intended to depict the approximate spatial location of the mapped features within the Community and all use is strictly at the user's own risk.

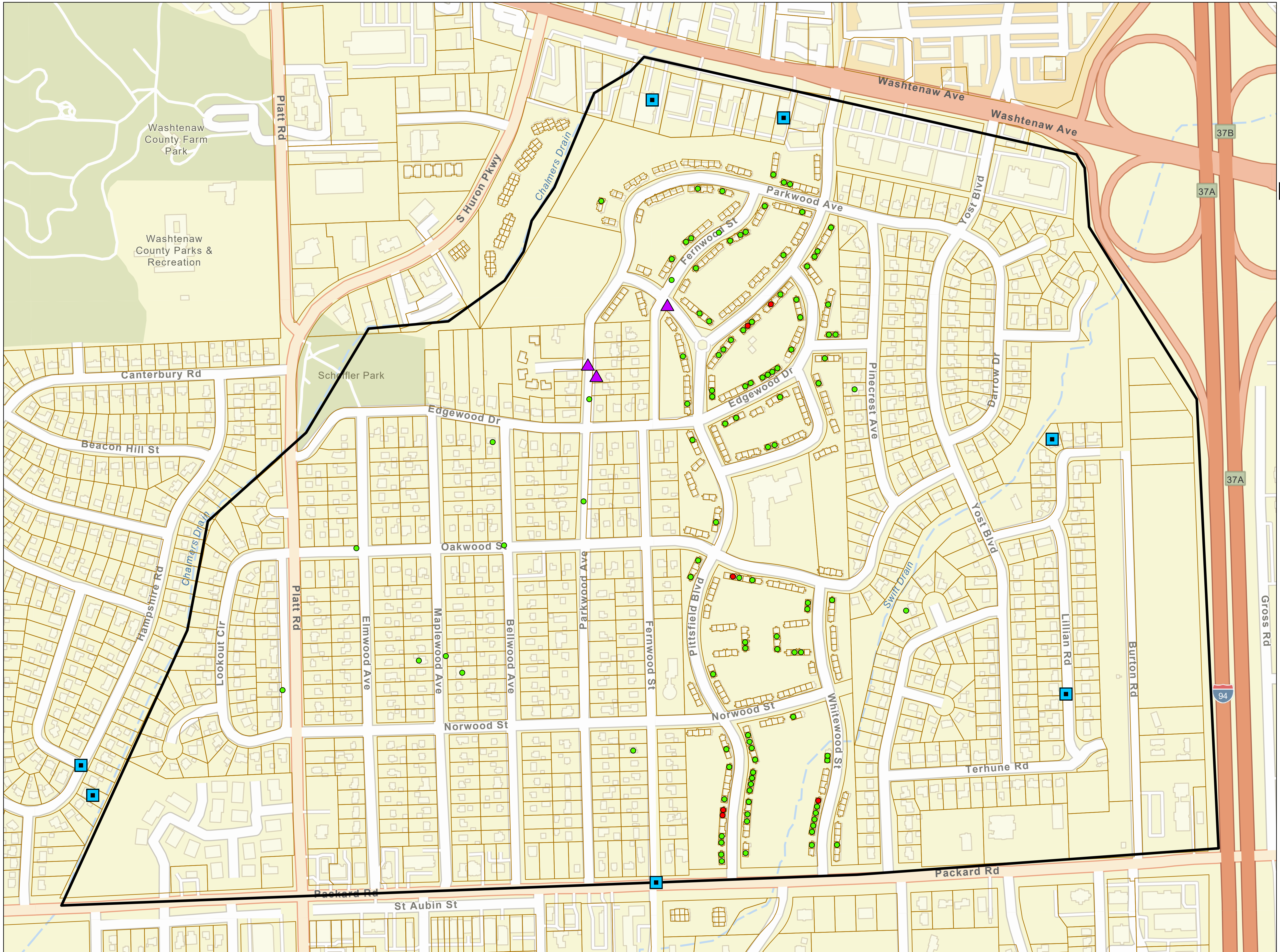
Coordinate System: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl

Map Published: February 7, 2022

OHM

Ann Arbor Addresses with Roots in Sewer Leads

Figure 5



- Roots in Sewer Leads
- Reported Sewer Backups
- City Sewer Backups
- Street/Yard Flooding
- Project Area
- Ann Arbor Parcels

N

0 450 900

Feet

1″ = 450′

Source: Data provided by Ann Arbor, OHM Advisors, and Esri. OHM Advisors does not warrant the accuracy of the data and/or the map. This document is intended to depict the approximate spatial location of the mapped features within the Community and all use is strictly at the user's own risk.

Coordinate System: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl

Map Published: February 1, 2022

OHM

Appendix B

H2Ometrics

Rainfall Pattern: City Hall Rain

City Hall Rain

hour

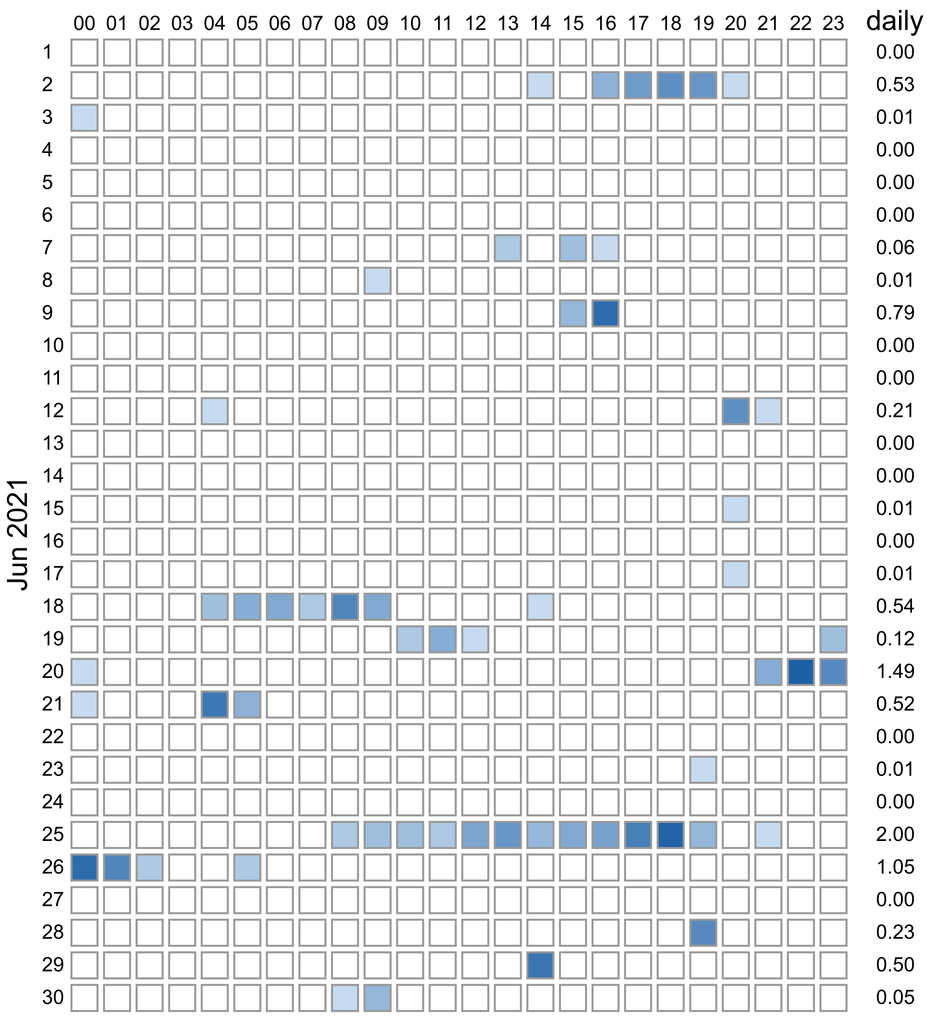
Jun 2021	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	daily
1																									0.00
2																	3	11	18	14		1			0.47
3	1																								0.01
4																									0.00
5																									0.00
6																									0.00
7																8	6								0.14
8																									0.00
9																	63								0.63
10																									0.00
11																					1	1			0.02
12																					22				0.22
13		1																							0.01
14																									0.00
15																									0.00
16																									0.00
17																									0.00
18					1	4	5	2	29	6															0.47
19												5													0.05
20																						7	91	19	1.17
21	1	3			39	3	1																		0.47
22																									0.00
23																									0.00
24																									0.00
25									1	2	2	2	7	12	5	3	7	36	98	5					1.80
26	97	20	1			1																			1.19
27																									0.00
28																				24					0.24
29															41										0.41
30									1	3															0.04

monthly 7.34

H2Ometrics

Rainfall Pattern: N Campus Rain

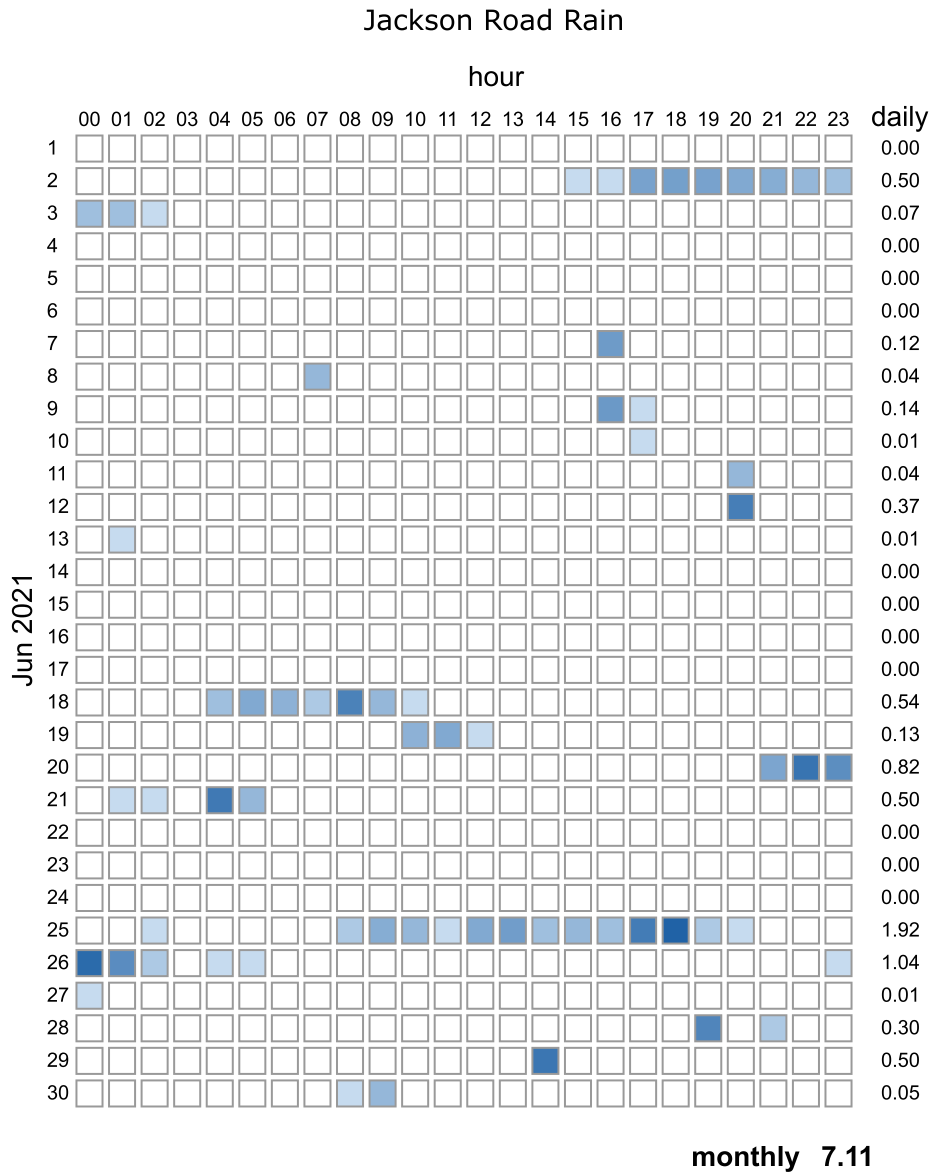
N Campus Rain



monthly 8.14

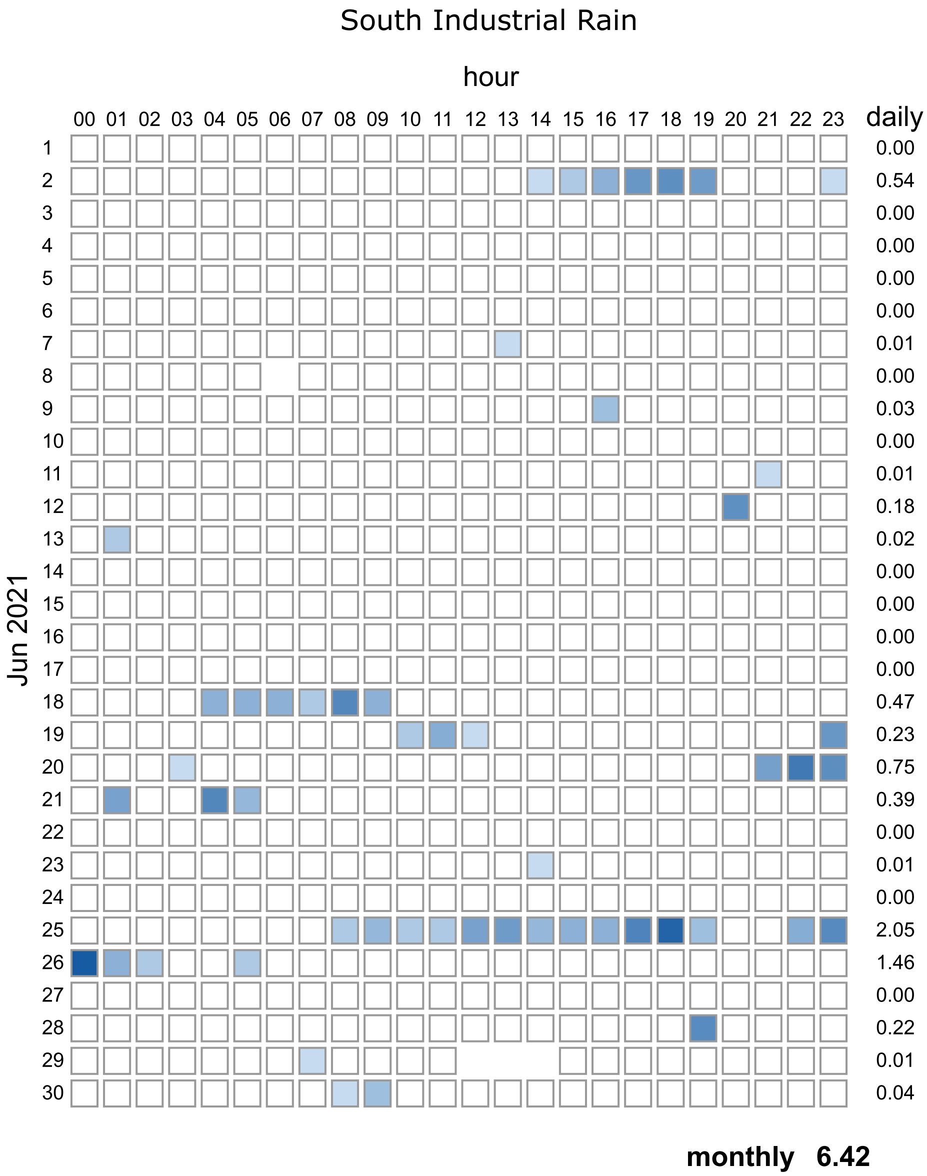
H2Ometrics

Rainfall Pattern: Jackson Road Rain

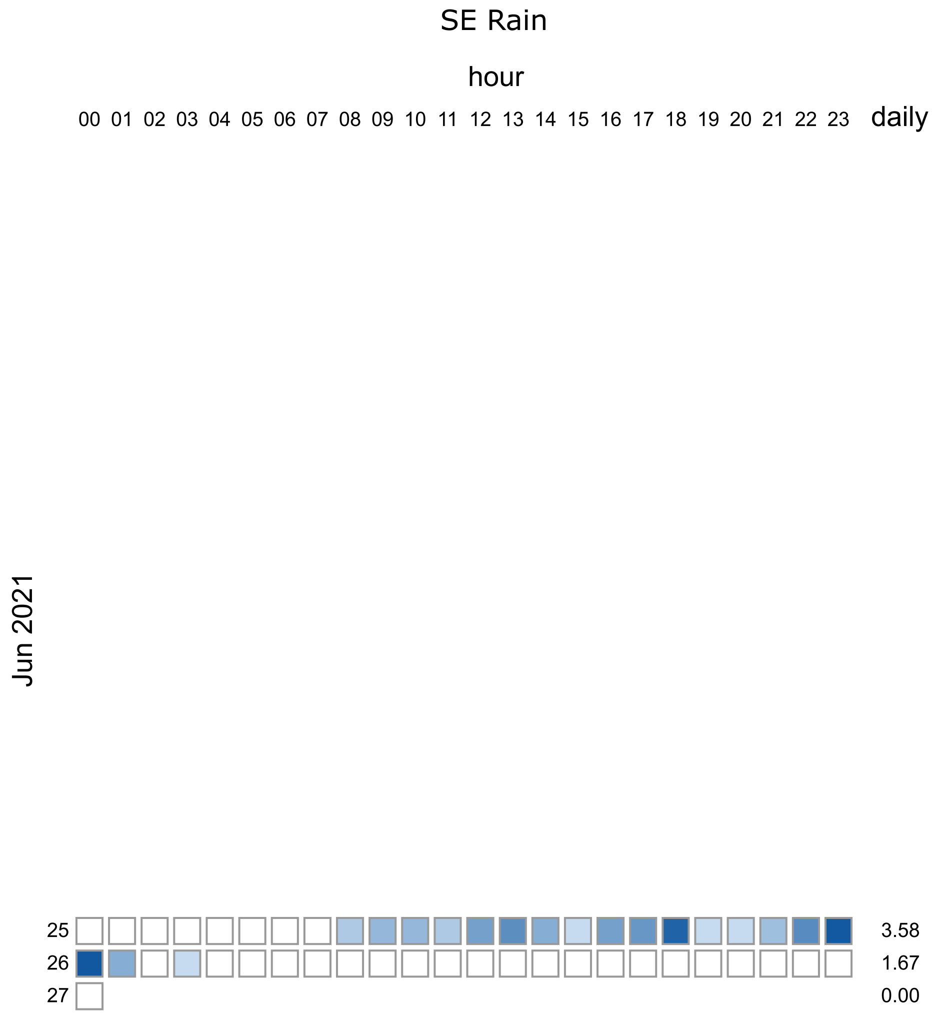


H2Ometrics

Rainfall Pattern: South Industrial Rain



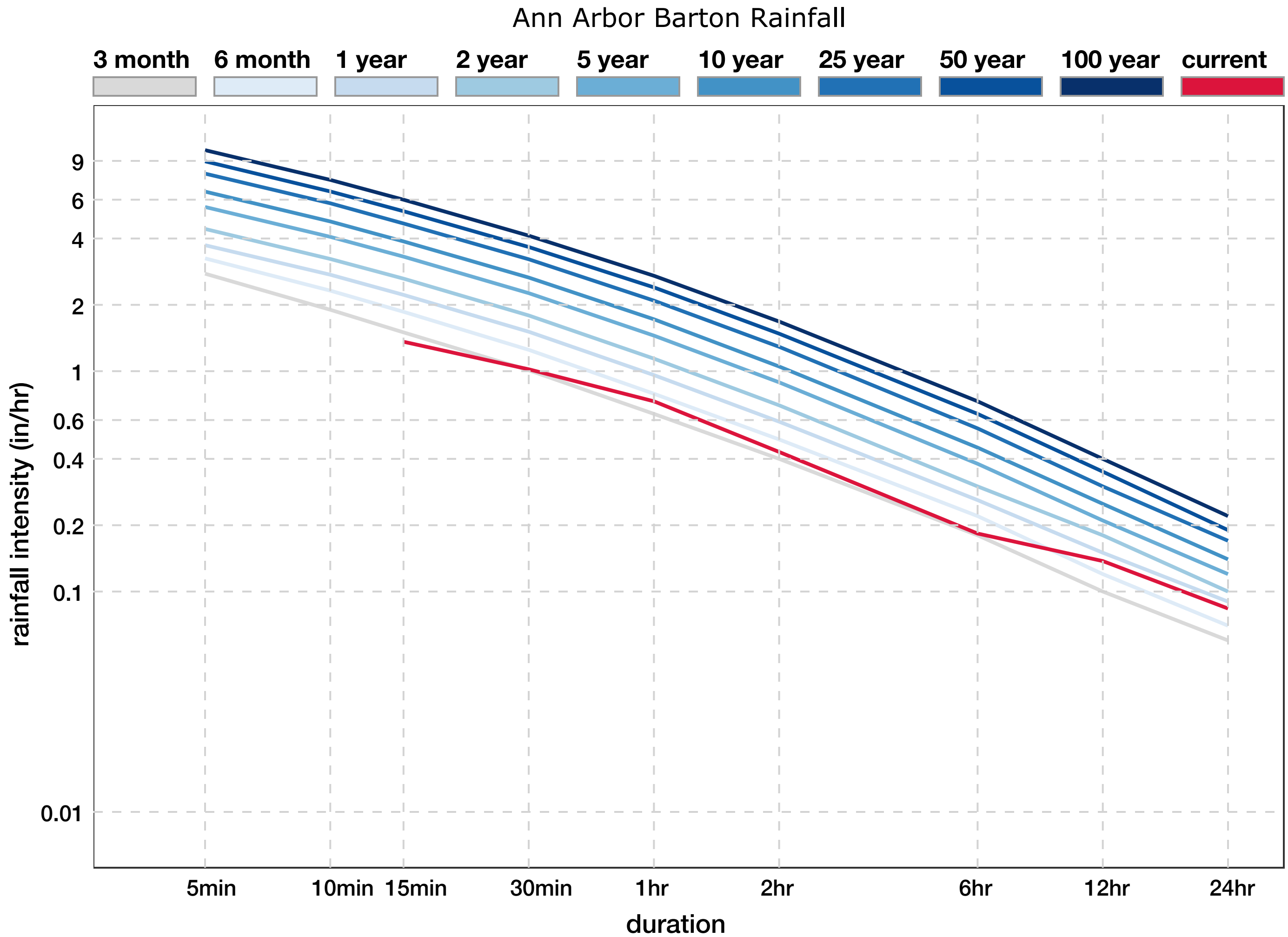
Rainfall Pattern: SE Rain



monthly 5.25 in

H2Ometrics

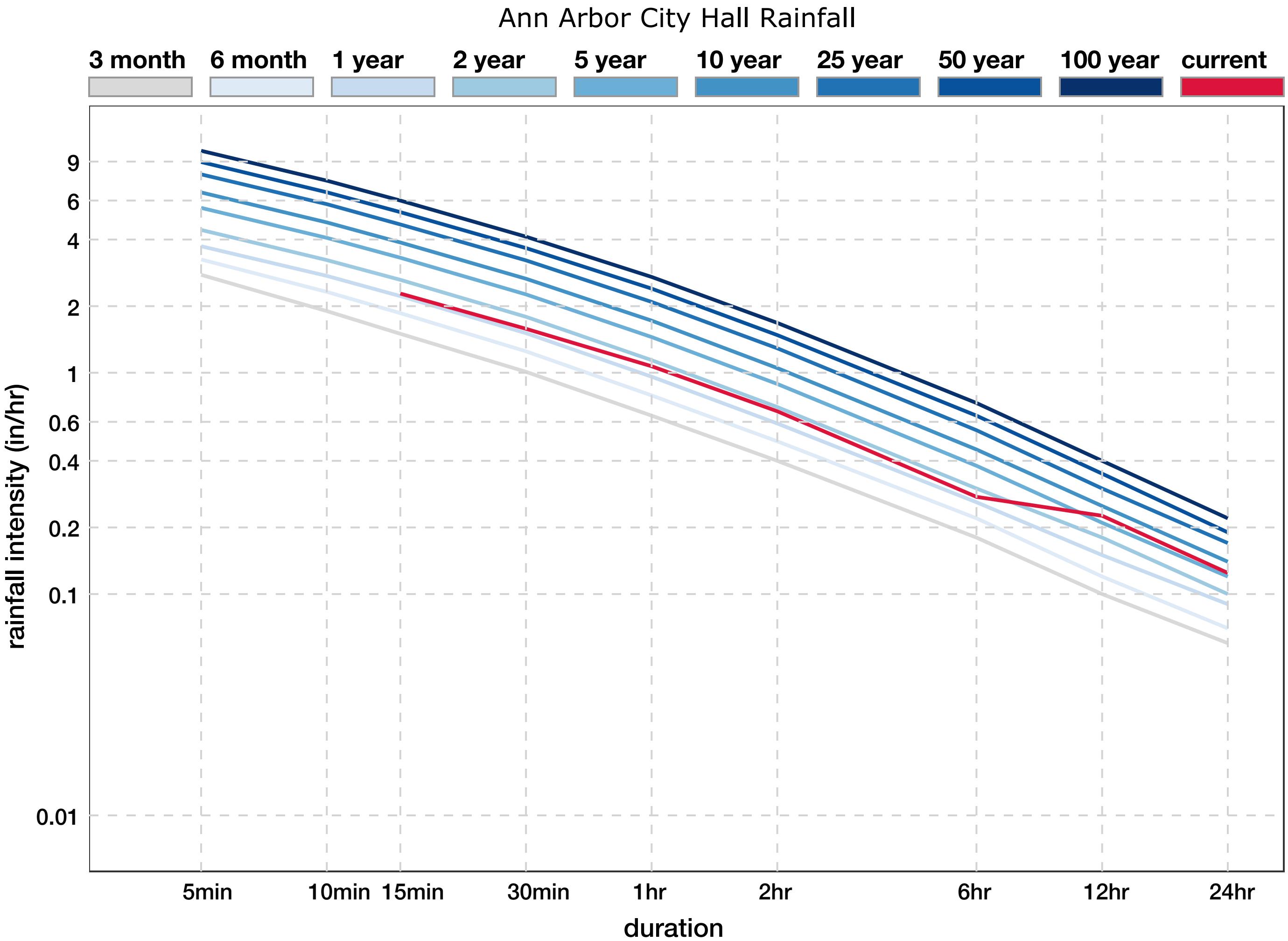
Rainfall IDF: Ann Arbor Barton Rainfall
25 Jun 2021 06:15 - 26 Jun 2021 06:00



	5min	10min	15min	30min	1hr	2hr	6hr	12hr	24hr
current rainfall (in)	--	--	0.340	0.510	0.730	0.860	1.100	1.650	2.010
current intensity (in/hr)	--	--	1.360	1.020	0.730	0.430	0.183	0.138	0.084
3 month intensity (in/hr)	2.77	1.9	< 1.5	1.01	<0.64	0.4	<0.18	0.1	0.06
6 month intensity (in/hr)	3.25	2.32	1.86	1.25	0.79	0.49	0.22	0.12	0.07
1 year intensity (in/hr)	3.73	2.74	2.22	1.51	0.96	0.59	0.26	0.15	0.09
2 year intensity (in/hr)	4.42	3.23	2.63	1.79	1.14	0.7	0.3	0.18	0.1
5 year intensity (in/hr)	5.56	4.07	3.31	2.26	1.45	0.89	0.38	0.21	0.12
10 year intensity (in/hr)	6.53	4.78	3.88	2.66	1.72	1.05	0.45	0.25	0.14
25 year intensity (in/hr)	7.88	5.78	4.68	3.22	2.09	1.29	0.55	0.3	0.17
50 year intensity (in/hr)	8.96	6.54	5.32	3.66	2.4	1.48	0.64	0.35	0.19
100 year intensity (in/hr)	10.07	7.38	6	4.12	2.71	1.68	0.73	0.4	0.22

H2Ometrics

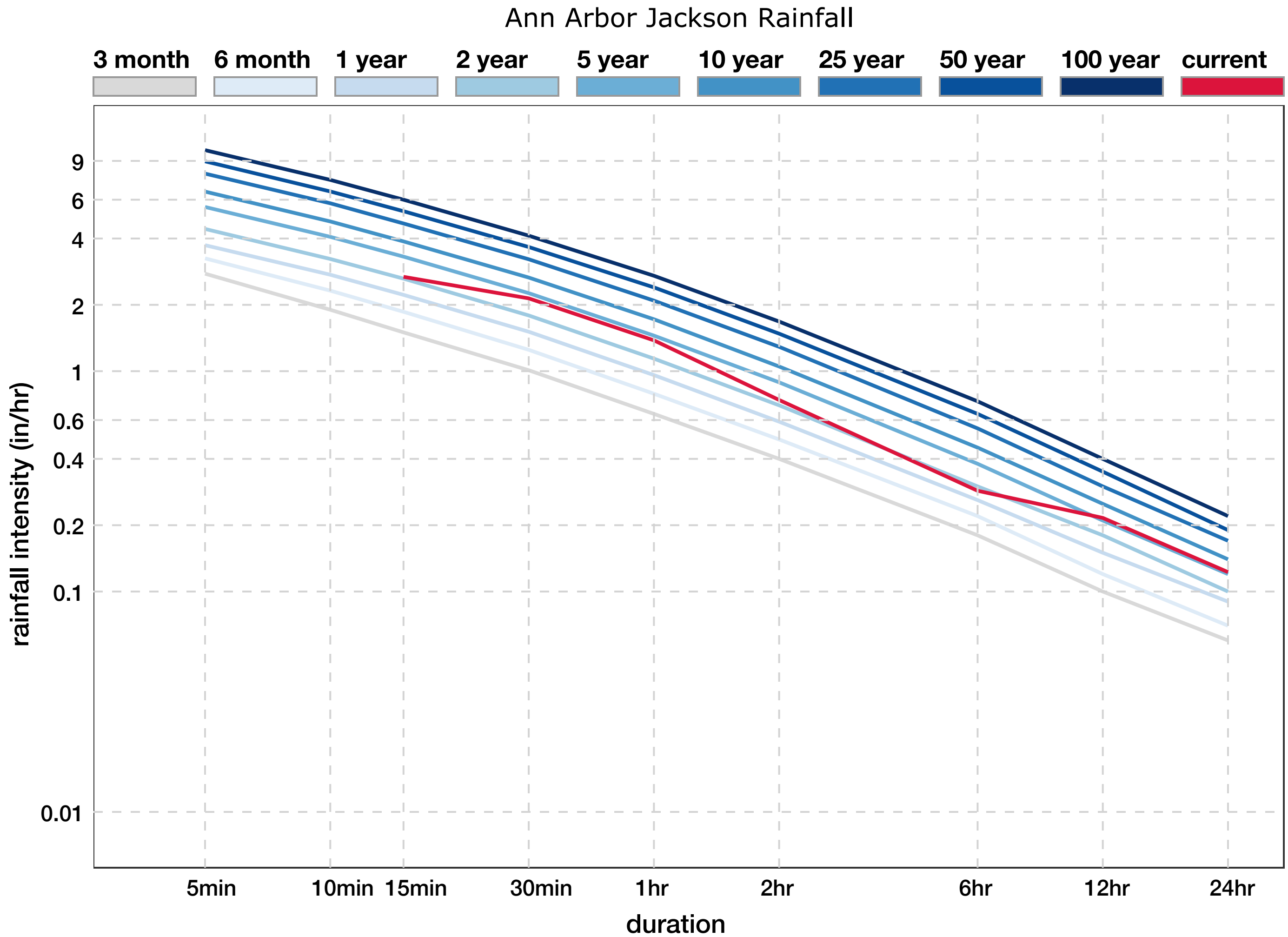
Rainfall IDF: Ann Arbor City Hall Rainfall
25 Jun 2021 06:15 - 26 Jun 2021 06:00



	5min	10min	15min	30min	1hr	2hr	6hr	12hr	24hr
current rainfall (in)	--	--	0.570	0.790	1.070	1.340	1.650	2.710	2.990
current intensity (in/hr)	--	--	2.280	1.580	1.070	0.670	0.275	0.226	0.125
3 month intensity (in/hr)	2.77	1.9	1.5	1.01	0.64	0.4	0.18	0.1	0.06
6 month intensity (in/hr)	3.25	2.32	1.86	1.25	0.79	0.49	0.22	0.12	0.07
1 year intensity (in/hr)	3.73	2.74	2.22	1.51	0.96	0.59	0.26	0.15	0.09
2 year intensity (in/hr)	4.42	3.23	2.63	1.79	1.14	0.7	0.3	0.18	0.1
5 year intensity (in/hr)	5.56	4.07	3.31	2.26	1.45	0.89	0.38	0.21	0.12
10 year intensity (in/hr)	6.53	4.78	3.88	2.66	1.72	1.05	0.45	0.25	0.14
25 year intensity (in/hr)	7.88	5.78	4.68	3.22	2.09	1.29	0.55	0.3	0.17
50 year intensity (in/hr)	8.96	6.54	5.32	3.66	2.4	1.48	0.64	0.35	0.19
100 year intensity (in/hr)	10.07	7.38	6	4.12	2.71	1.68	0.73	0.4	0.22

H2Ometrics

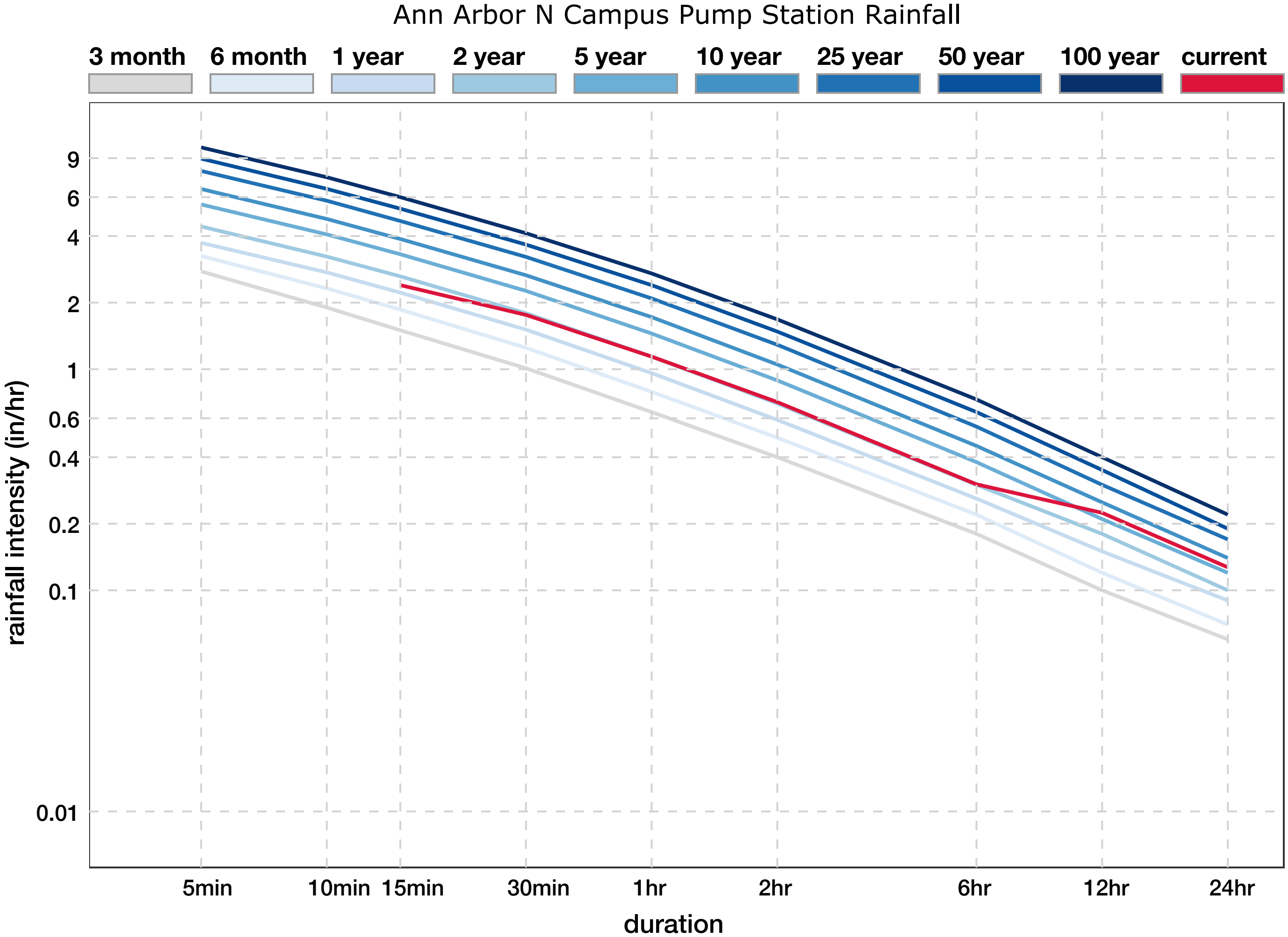
Rainfall IDF: Ann Arbor Jackson Rainfall
25 Jun 2021 06:15 - 26 Jun 2021 06:00



	5min	10min	15min	30min	1hr	2hr	6hr	12hr	24hr
current rainfall (in)	--	--	0.670	1.070	1.380	1.480	1.720	2.590	2.940
current intensity (in/hr)	--	--	2.680	2.140	1.380	0.740	0.287	0.216	0.122
3 month intensity (in/hr)	2.77	1.9	1.5	1.01	0.64	0.4	0.18	0.1	0.06
6 month intensity (in/hr)	3.25	2.32	1.86	1.25	0.79	0.49	0.22	0.12	0.07
1 year intensity (in/hr)	3.73	2.74	2.22	1.51	0.96	0.59	0.26	0.15	0.09
2 year intensity (in/hr)	4.42	3.23	2.63	1.79	1.14	0.7	0.3	0.18	0.1
5 year intensity (in/hr)	5.56	4.07	3.31	2.26	1.45	0.89	0.38	0.21	0.12
10 year intensity (in/hr)	6.53	4.78	3.88	2.66	1.72	1.05	0.45	0.25	0.14
25 year intensity (in/hr)	7.88	5.78	4.68	3.22	2.09	1.29	0.55	0.3	0.17
50 year intensity (in/hr)	8.96	6.54	5.32	3.66	2.4	1.48	0.64	0.35	0.19
100 year intensity (in/hr)	10.07	7.38	6	4.12	2.71	1.68	0.73	0.4	0.22

H2Ometrics

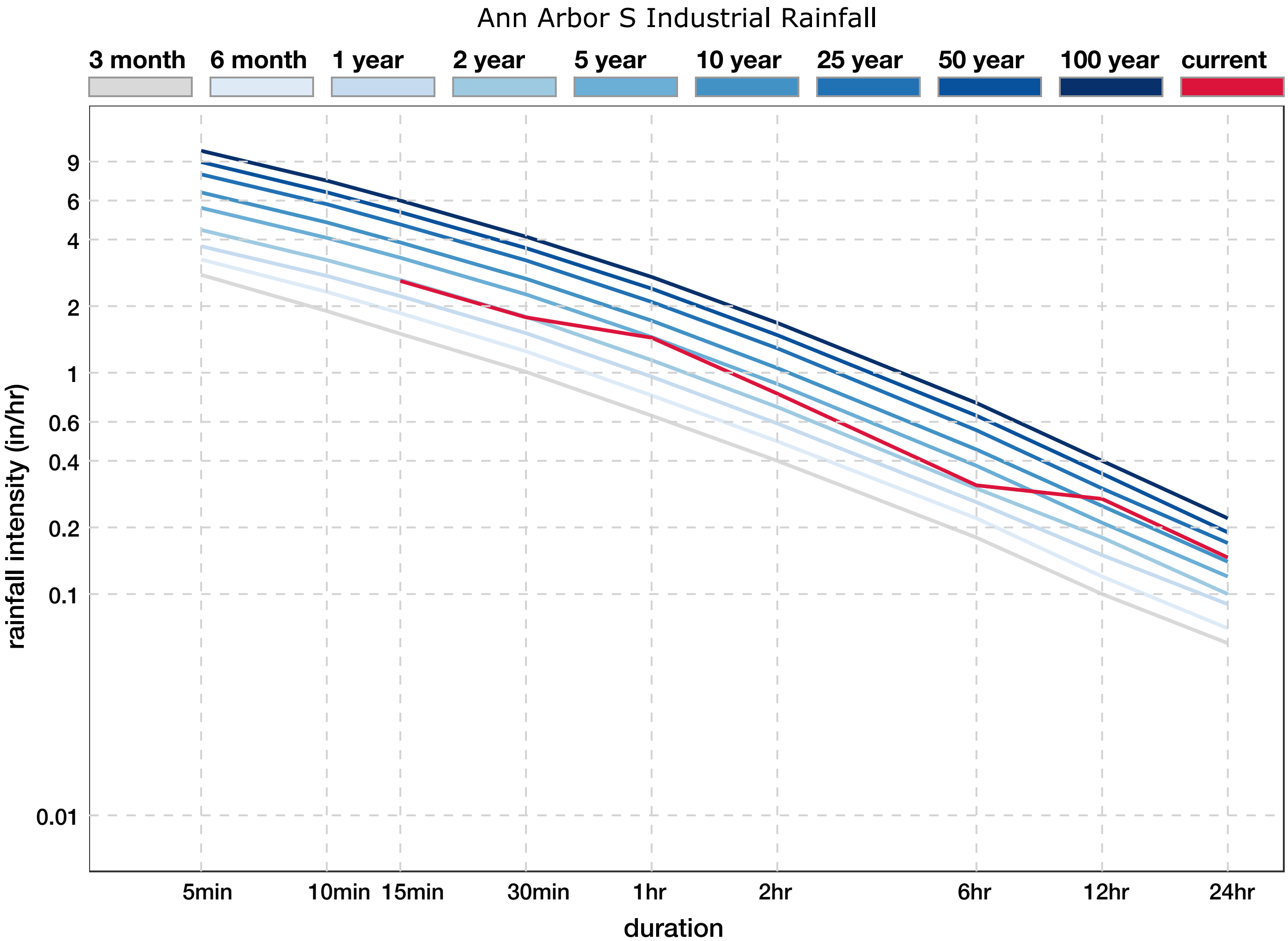
Rainfall IDF: Ann Arbor N Campus Pump Station Rainfall
25 Jun 2021 06:15 - 26 Jun 2021 06:00



	5min	10min	15min	30min	1hr	2hr	6hr	12hr	24hr
current rainfall (in)	--	--	0.600	0.880	1.140	1.420	1.810	2.690	3.050
current intensity (in/hr)	--	--	2.400	1.760	1.140	0.710	0.302	0.224	0.127
3 month intensity (in/hr)	2.77	1.9	1.5	1.01	0.64	0.4	0.18	0.1	0.06
6 month intensity (in/hr)	3.25	2.32	1.86	1.25	0.79	0.49	0.22	0.12	0.07
1 year intensity (in/hr)	3.73	2.74	2.22	1.51	0.96	0.59	0.26	0.15	0.09
2 year intensity (in/hr)	4.42	3.23	2.63	1.79	1.14	0.7	0.3	0.18	0.1
5 year intensity (in/hr)	5.56	4.07	3.31	2.26	1.45	0.89	0.38	0.21	0.12
10 year intensity (in/hr)	6.53	4.78	3.88	2.66	1.72	1.05	0.45	0.25	0.14
25 year intensity (in/hr)	7.88	5.78	4.68	3.22	2.09	1.29	0.55	0.3	0.17
50 year intensity (in/hr)	8.96	6.54	5.32	3.66	2.4	1.48	0.64	0.35	0.19
100 year intensity (in/hr)	10.07	7.38	6	4.12	2.71	1.68	0.73	0.4	0.22

H2Ometrics

Rainfall IDF: Ann Arbor S Industrial Rainfall
25 Jun 2021 06:15 - 26 Jun 2021 06:00

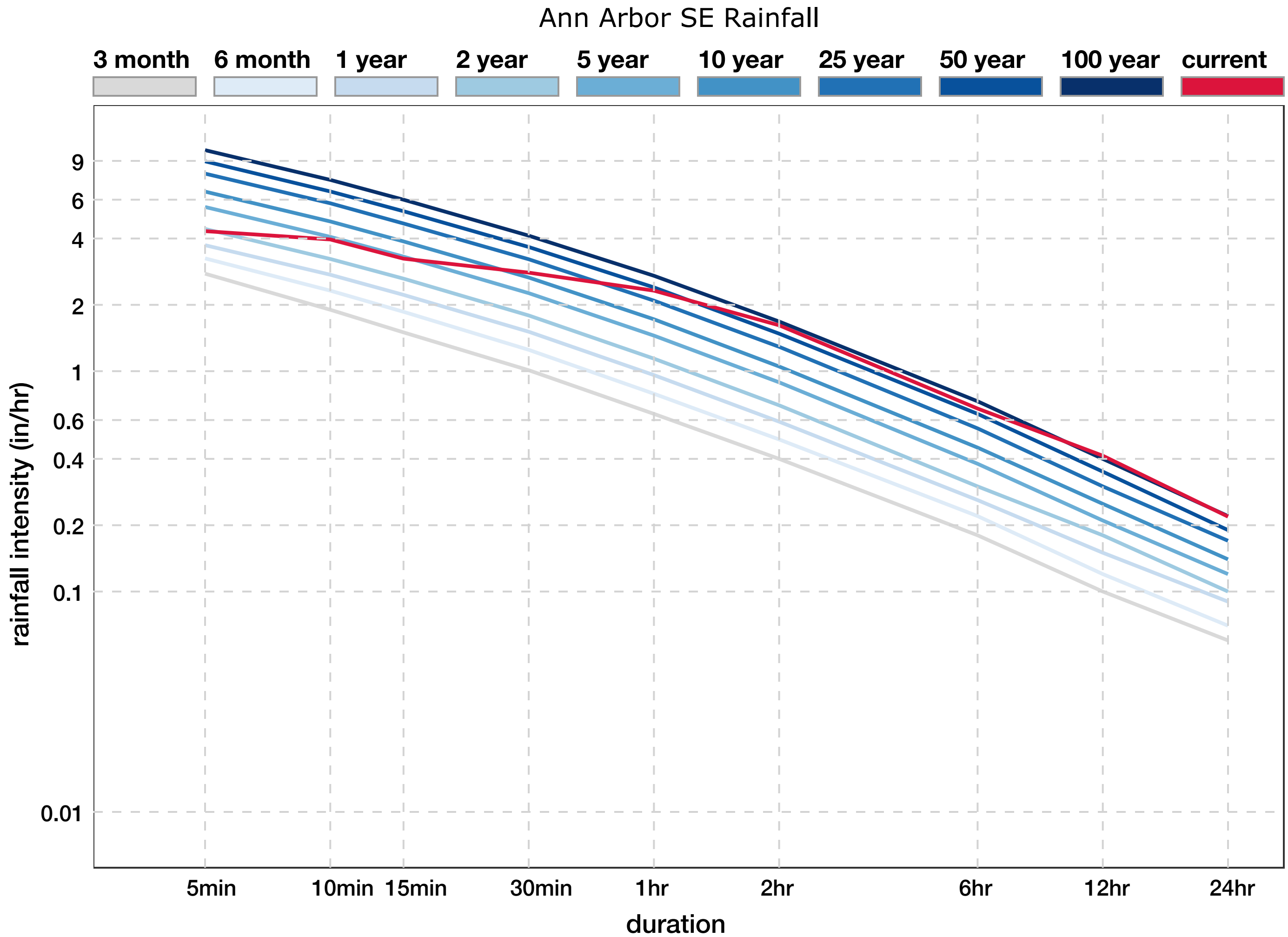


	5min	10min	15min	30min	1hr	2hr	6hr	12hr	24hr
current rainfall (in)	--	--	0.650	0.890	1.440	1.610	1.860	3.230	3.510
current intensity (in/hr)	--	--	2.600	1.780	1.440	0.805	0.310	0.269	0.146
3 month intensity (in/hr)	2.77	1.9	1.5	1.01	0.64	0.4	0.18	0.1	0.06
6 month intensity (in/hr)	3.25	2.32	1.86	1.25	0.79	0.49	0.22	0.12	0.07
1 year intensity (in/hr)	3.73	2.74	2.22	1.51	0.96	0.59	0.26	0.15	0.09
2 year intensity (in/hr)	4.42	3.23	2.63	1.79	1.14	0.7	0.3	0.18	0.1
5 year intensity (in/hr)	5.56	4.07	3.31	2.26	1.45	0.89	0.38	0.21	0.12
10 year intensity (in/hr)	6.53	4.78	3.88	2.66	1.72	1.05	0.45	0.25	0.14
25 year intensity (in/hr)	7.88	5.78	4.68	3.22	2.09	1.29	0.55	0.3	0.17
50 year intensity (in/hr)	8.96	6.54	5.32	3.66	2.4	1.48	0.64	0.35	0.19
100 year intensity (in/hr)	10.07	7.38	6	4.12	2.71	1.68	0.73	0.4	0.22

H2Ometrics

Rainfall IDF: Ann Arbor SE Rainfall

25 Jun 2021 06:15 - 26 Jun 2021 06:00

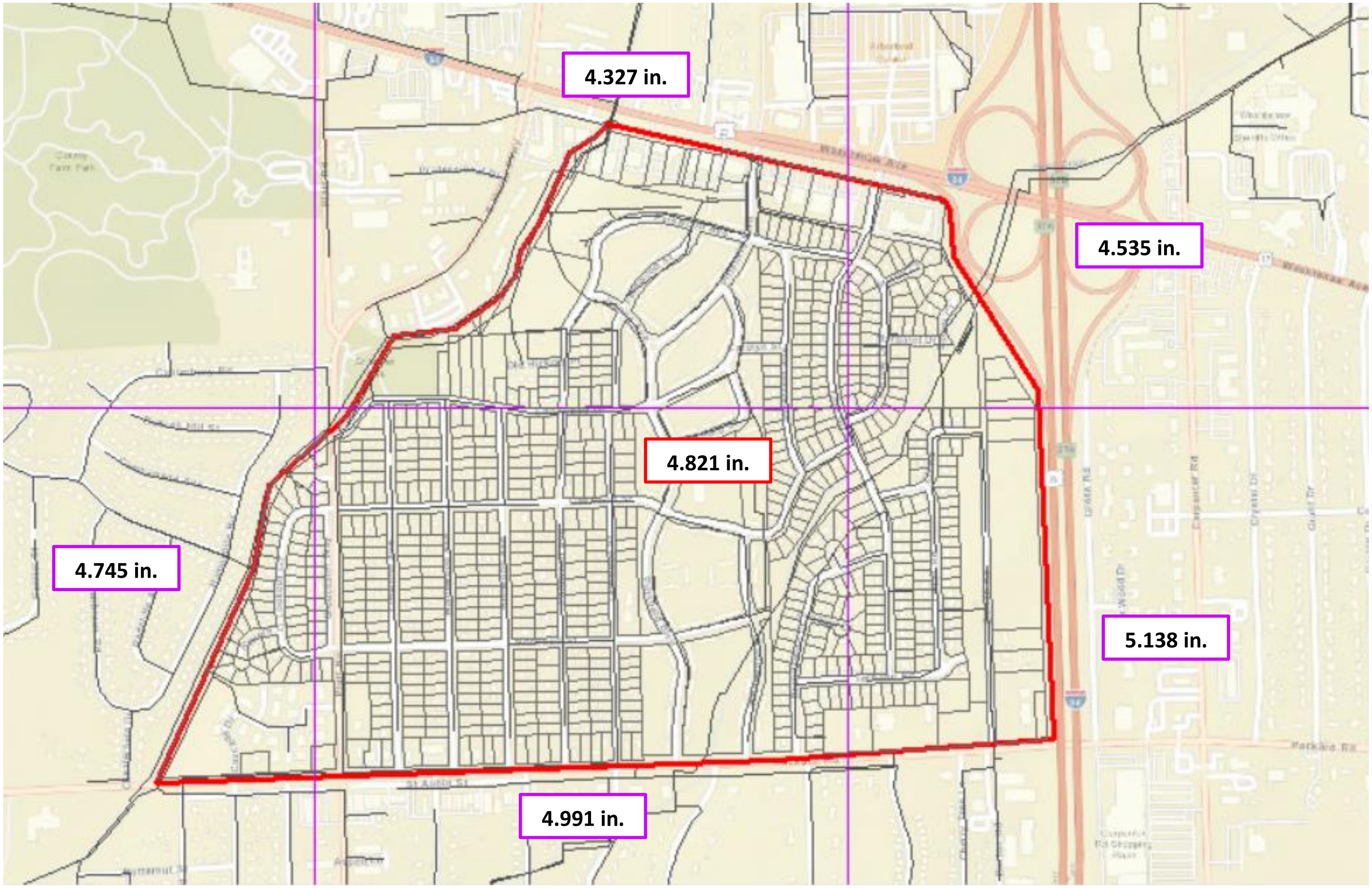


	5min	10min	15min	30min	1hr	2hr	6hr	12hr	24hr
current rainfall (in)	0.360	0.660	0.810	1.400	2.320	3.230	4.060	4.960	5.250
current intensity (in/hr)	4.320	3.960	3.240	2.800	2.320	1.615	0.677	0.413	0.219
3 month intensity (in/hr)	2.77	1.9	1.5	1.01	0.64	0.4	0.18	0.1	0.06
6 month intensity (in/hr)	3.25	2.32	1.86	1.25	0.79	0.49	0.22	0.12	0.07
1 year intensity (in/hr)	3.73	2.74	2.22	1.51	0.96	0.59	0.26	0.15	0.09
2 year intensity (in/hr)	4.42	3.23	2.63	1.79	1.14	0.7	0.3	0.18	0.1
5 year intensity (in/hr)	5.56	4.07	3.31	2.26	1.45	0.89	0.38	0.21	0.12
10 year intensity (in/hr)	6.53	4.78	3.88	2.66	1.72	1.05	0.45	0.25	0.14
25 year intensity (in/hr)	7.88	5.78	4.68	3.22	2.09	1.29	0.55	0.3	0.17
50 year intensity (in/hr)	8.96	6.54	5.32	3.66	2.4	1.48	0.64	0.35	0.19
100 year intensity (in/hr)	10.07	7.38	6	4.12	2.71	1.68	0.73	0.4	0.22

>

Appendix C

Radar Rainfall (GARR) Results



Radar Rainfall Analysis
Ann Arbor, Michigan
June 25 – 26, 2021

Prepared for OHM Advisors
In support of the City of Ann Arbor, MI

November 15, 2021

301 David L. Boren Blvd., Suite 3050
Norman, Oklahoma 73072
(405) 325-1818
www.vieuxinc.com

TABLE OF CONTENTS

Glossary

Average Difference (AD) – Average of the absolute percentage differences between the rain gauge data and uncalibrated radar data sampled over the gauges.

Bias Correction Factor – Bias is a systematic error that can be corrected through calibration. The correction factor is the sum of the gauges divided by the sum of the sampled radar values over the gauges.

Calibrated Average Difference (CAD) – Average of the absolute percentage differences between the rain gauges and local bias calibrated radar data sampled over the gauges.

Cumulative Distribution Plot (CDP) – A graph depicting the accumulation of a rain gauge and the unadjusted/adjusted radar over that gauge.

Decibels of Reflectance (dBZ) – The logarithmic scale for measuring radar reflectivity factor or a measure of reflectivity of a radar signal off a remote object.

Gauge-Adjusted Radar Rainfall (GARR) – Bias corrected radar rainfall through comparison with rain gauges.

KDTX – Federal Communications Commission (FCC) call sign for the NEXRAD near Detroit, MI.

Level II – The Level II radar products are the highest resolution, and consist of the base data that includes reflectivity measured in decibels of reflectance (dBZ) among Doppler velocity and spectrum width.

Local Bias (LB) – An approach to adjusting radar rainfall that uses the ratio of gauge to radar accumulations from surrounding gauges, with the closest gauge having the most weight.

Minimum Storm Total Threshold (MSTT) – A check used to remove radar/gauge pairs whose cumulative radar and/or gauge values for a given event period were below 0.05 inches.

Next Generation RADAR (NEXRAD) – A network of S-band (10.5-cm wavelength) radars operated by the National Weather Service.

Radio Detection and Ranging (RADAR) – An electronic instrument used for the detection and ranging of distant objects of such composition that they scatter or reflect radio energy.

Radar-Gauge (RG) – A pair of rainfall accumulations measured by the rain gauge and the radar rainfall accumulation sampled above the gauge.

Z-R relationship – An empirical relationship between radar reflectivity factor Z ($mm^6\ m^{-3}$) and rain rate R ($mm\ hr^{-1}$). Radar reflectivity factor is dependent on the rain drop size distribution. [$Z = aR^b$, where a and b are empirically derived constants]

- **Convective** – generally used for convective (i.e. thunderstorms) rainfall [$Z = 300R^{1.4}$]

Overview

Vieux and Associates, Inc. (Vieux) processed radar and rain gauge data for OHM Advisors (OHM) in support of the City of Ann Arbor, MI. Radar and rain gauge data are quality controlled (QC) to produce QC gauge-adjusted radar rainfall (GARR) for a historical rainfall event that occurred on June 25 – 26, 2021. To produce QC GARR, both radar and rain gauge data are reviewed manually to remove inconsistent data.

Radar data used in production of GARR is produced by the National Weather Service (NWS) Next Generation Radar (NEXRAD) system. NEXRAD Level II radar data are often referred to as Base Data and contain the full spatial/temporal/data resolution data from the radar. Level II radar data measures reflectivity in decibels of reflectance (dBZ), and at a spatial resolution of 0.5-degree by 0.25-km every 4 – 10 minutes with a data resolution of 0.5 dBZ amounting to 256 data levels of data. The radar data source used to process this period was Level II NEXRAD data from KDTX located near Detroit, MI. All radar data were processed into 15-minute increments.

Because the radar measures reflectivity in polar coordinates centered on the radar installation, the 1-degree azimuth increases in width as range increases from the radar. Range resolution of Level II is 1-km and is measured out to 230-km from the radar. Due to the location of KDTX in relation to the target area, the polar coordinates defining resolution range in width from 0.7 to 1.0-km. The radar data represented in these polar coordinates are sampled through spatial averaging into a Cartesian grid of uniform resolution, i.e. 1x1 km. An advantage of the Cartesian grid is that one radar can be substituted for the other without changing the grid resolution, as would be necessary if polar coordinates were used for output of rainfall information at 1x1 km spatial resolution. The Cartesian grid used was defined by a 1-km^2 grid domain shapefile containing 240 1-km^2 pixels covering the study area. OHM provided shapefiles of the City of Ann Arbor and the project area.

Rainfall data from as many as 7 gauges were used to adjust the radar. OHM provided locations and data for 5 City of Ann Arbor rain gauges and for another gauge located nearby the project area. In addition, rain gauge data were obtained from one NWS Automated Surface Observing System (ASOS) station. Figure 1 depicts the spatial distribution of the rain gauges, 1-km^2 pixels, and project area. For the gauges shown in Figure 1, the ID, name, and source of each gauge is listed in Table 1.

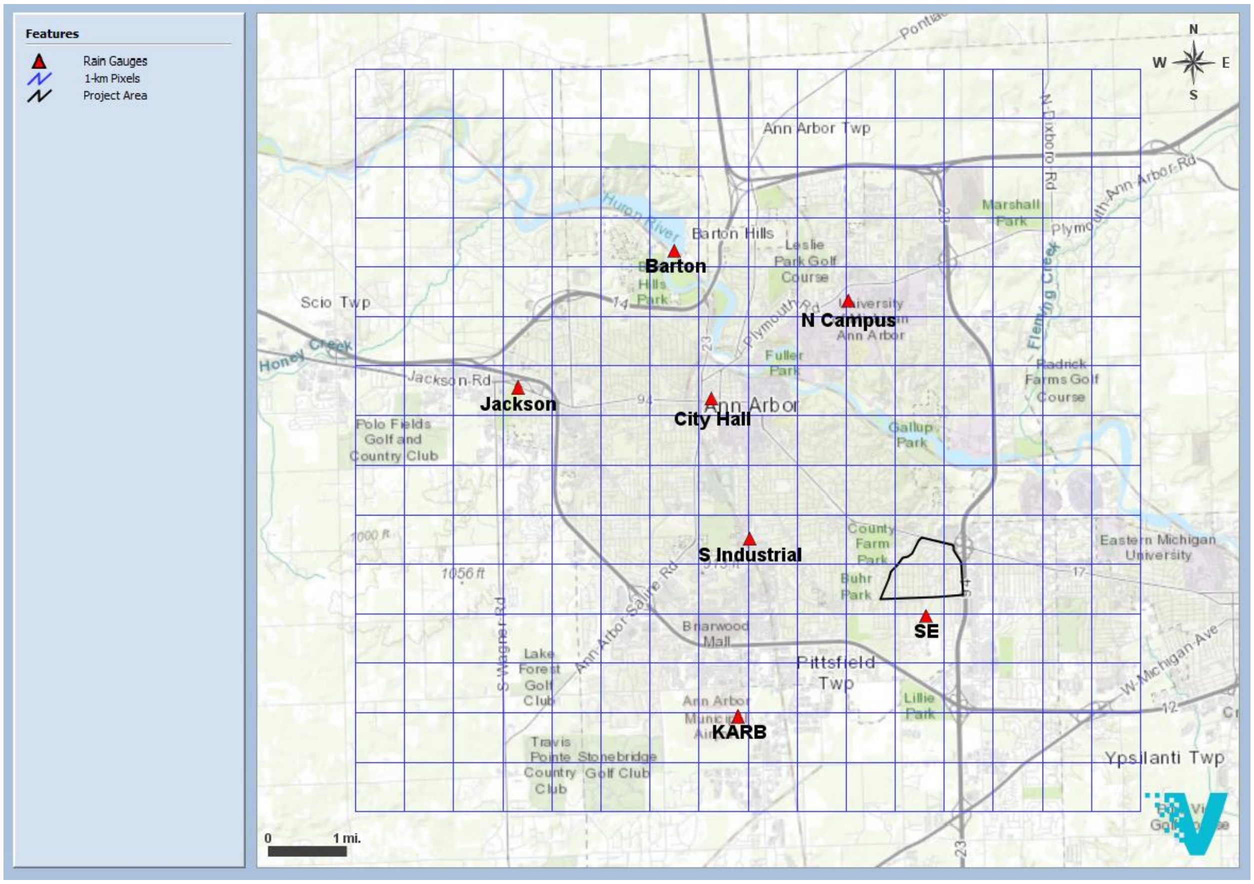


Figure 1 Spatial Distribution of the Rain Gauges, 1-km^2 Pixels, and Project Area

Table 1 Rain Gauge ID, Name, and Source

Gauge ID	Gauge Name	Source
Barton	Barton Pond	City of Ann Arbor
City Hall	City Hall	City of Ann Arbor
Jackson	Jackson Road	City of Ann Arbor
N Campus	N Campus Pump Station	City of Ann Arbor
S Industrial	S Industrial	City of Ann Arbor
KARB	Ann Arbor Municipal Airport	NWS - ASOS
SE	3200 Pittsview Dr.	OHM

Radar data review, preparation and sampling the radar over the gauges, 1-km^2 pixels, and project area were achieved using software developed at Vieux, Inc. The 7 rain gauges and the KDTX NEXRAD radar are used to produce GARR for the analysis period.

Methodology

Statistical control of the data makes radar rainfall measurements more accurate. By statistical comparison between the radar and rain gauge accumulations during a calibration interval, statistical outliers may be identified. Radar data is enhanced by correcting it for systematic errors called bias, which helps improve the accuracy of the rainfall product. The bias correction factors are multiplicative factors applied to the radar that enhances the accuracy of the radar rainfall for any accumulation period. By adjusting the radar data with rain gauge data, better maps of rainfall are produced than either sensor system could produce alone.

In the production of GARR, radar rainfall is bias corrected through comparison with rain gauge accumulations. To the extent possible, individual gauges are combined to cover the target area for use in bias adjustment. The method of adjustment depends on the hydrologic application and the spatial extent of the area of interest. The local bias (LB) approach to adjusting the radar rainfall uses the ratio of gauge to radar accumulations from surrounding gauges with the closest gauge having the most weight. The LB approach distributes the variation of bias over the region, and is computed and applied within each event period.

The LB uses the ratio between the sum of each gauge divided by the sum of the sampled radar values over each gauge. Gauge and radar accumulations were computed for each event period. A minimum storm total threshold (MSTT) check was used to remove radar/gauge (RG) pairs whose R or G cumulative values for a given event period were below a chosen threshold (i.e. 0.05 inches for this study). The remaining RG pairs were then checked for statistical outliers. Those RG pairs with individual bias (G/R) or average difference ((G-R)/G)) values greater than three standard deviations from the mean were then excluded from being used to adjust the radar.

After RG pairs have been removed by either the MSTT, outlier check or gauge performance review, there must be at least two remaining RG pairs to proceed with gauge-adjustment of the radar. The individual biases of the remaining RG pairs are then distributed spatially over the analysis area using the LB weighted distance method. The resulting LB value over each radar bin is the multiplicative factor that adjusts the radar. For example, a bias of 1.5 can be interpreted as a 33% underestimation by the radar. The statistical measures reported are 1) average difference (AD) and 2) calibrated average difference (CAD). Both of these statistical measures are expressed as an absolute percentage about the mean of G/R accumulations for each event period. GARR is then spatially aggregated from the final adjusted radar bins to the 1-km^2 pixels and project area using an area-averaged technique.

After bias correction, though generally small, differences between rain gauge and radar rainfall accumulations still exist due to sampling differences or local meteorological conditions among other reasons. A major reason for departures is that radar collects data by averaging reflectivity over a 1-degree by 1-km sample volume, while rain gauges measure at a point. Another source of difference is that radar measures above the ground, while rain gauges measure close to the ground. Further, updrafts and downdrafts during storms can decrease or increase rain rates, respectively. However, radar cannot detect local wind effects, while rain gauges can be affected. Differences between the radar data and the rain gauge data are also affected by precipitation processes associated with the type of storm, which also are affected by the season of the year.

Gauge-Adjusted Radar Rainfall (GARR)

GARR was processed continuously at fifteen-minute increments and covers the period from 2021-06-25 01:00 EDT to 2021-06-26 07:00 EDT. A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. The rainfall event was split into 7 sub-event periods to improve gauge-adjustment of the radar. The sub-event periods are shown in Table 2 under the **Sub-Event Period** column.

Table 2 Sub-Event Ranges

Sub-Event Period	Start Time (EDT)	End Time (EDT)
E01a	2021-06-25 01:00	2021-06-25 10:00
E01b	2021-06-25 10:00	2021-06-25 12:00
E01c	2021-06-25 12:00	2021-06-25 15:00
E01d	2021-06-25 15:00	2021-06-25 19:15
E01e	2021-06-25 19:15	2021-06-25 23:30
E01f	2021-06-25 23:30	2021-06-26 01:15
E01g	2021-06-26 01:15	2021-06-26 07:00

The GARR statistics for each sub-event period are listed in Table 3. The **Source** column shows what rainfall source was used to produce GARR for each sub-event period. The **Bias** value shown in Table 3 is the sum of the gauges divided by the sum of the sampled radar values over the gauges and represents the average bias correction factor applied to the unadjusted radar for each sub-event period. Those sub-event periods with the lowest CAD values shown in Table 3 represent the best agreement between GARR and gauge values for all radar/gauge pairs used to adjust the radar. On average, lower values of CAD imply higher statistical confidence in the reliability of the dataset. Typically, stratiform rainfall events (i.e., low spatial variability) have lower CAD values than convective rainfall events (i.e., high spatial variability). Based on all 7 sub-event periods, the event CAD averaged 5.9%, indicating that the mean GARR agrees with the mean gauge accumulation to within ±2.9%.

Table 3 Sub-Event GARR Statistics

Sub-Event Period	Source	Gauges Used (7)	Bias	AD (%)	CAD (%)
E01a	KDTX LII	5	1.121	10.4	5.5
E01b	KDTX LII	3	0.918	8.6	3.6
E01c	KDTX LII	6	2.672	61.8	6.9
E01d	KDTX LII	6	2.037	50.7	4.8
E01e	KDTX LII	3	0.889	18.9	9.5
E01f	KDTX LII	6	1.752	43.5	5.5
E01g	KDTX LII	5	1.375	27.9	5.4

Statistical review of the data can provide an indication of data quality. Depending on the quality of the radar and gauge data, CAD values for individual events less than 10% are considered excellent, 10 - 20% are considered good, and 20 - 30% are considered fair. However, CAD may not serve as a reliable indicator of data quality when abrupt changes in bias occur within the analysis period, particularly when compensating over- and under-estimation results due to using an assumed Z-R relationship throughout the period while atmospheric conditions merit different Z-R coefficients. The effects from abrupt changes in Z-R are mitigated by splitting the event into sub-event periods.

Rain gauges were analyzed to identify those that were not consistent with the radar or surrounding gauges. Cumulative Distribution Plots (CDPs) at each gauge location showing gauge, unadjusted radar and GARR values were produced for each rainfall event and are presented in Appendix C. CDPs are useful for visualizing rain gauge performance. Figure 2 shows the rainfall accumulation at the 3200 Pittsview Dr. (SE) gauge during the event as measured by the gauge (green), unadjusted radar (blue), and gauge-adjusted radar (red). Rain gauges that are not performing consistently with the radar or surrounding gauges have characteristics such as clogs, synchronization or other mechanical/transmission malfunctions that can be visually identified in the CDP graph.

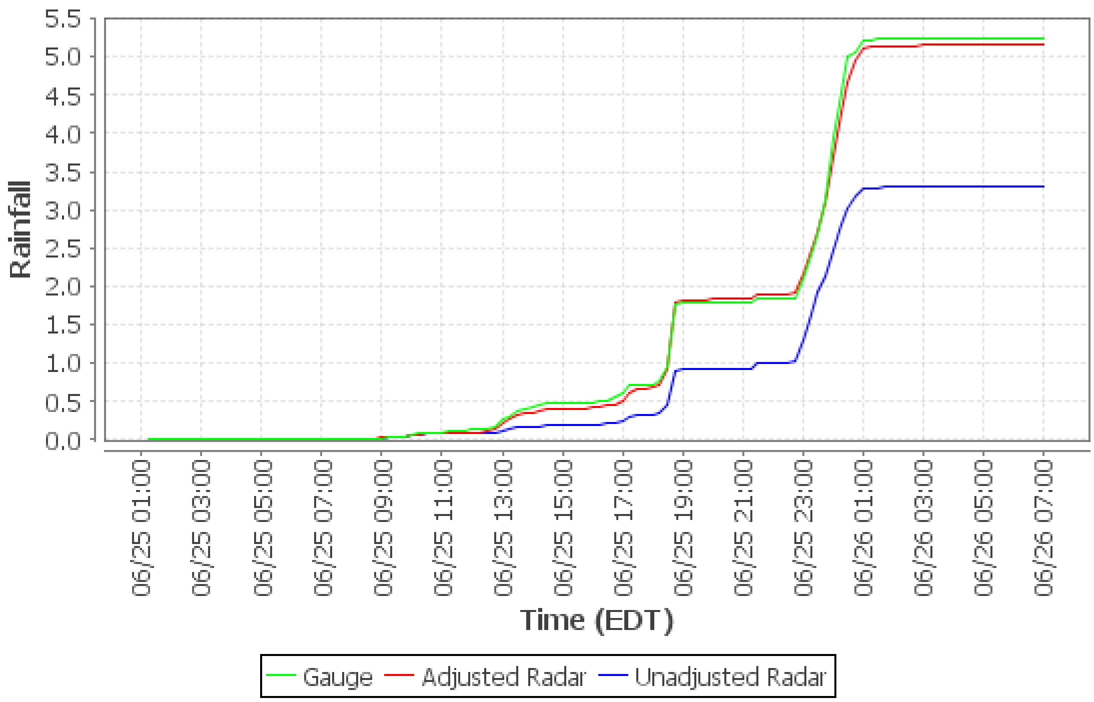


Figure 2 CDP Showing Rain Gauge Versus Unadjusted Radar Versus GARR

Reasons for not using gauges in rainfall analysis include clogs, significant under- or over-reporting of rainfall, gauges that stop reporting during rainfall, or a combination of these reasons. A list of possible reasons for not using a gauge based on CDP analysis is shown in Table 4. Those gauges that were excluded from analysis based on gauge performance are shown in Appendix A. Additional gauges were not used to adjust the radar for a given event or sub-event period if they did not meet the statistical criteria outlined in the Methodology section. A list of reasons for not using a gauge based on statistical criteria is shown in Table 5. The gauges listed in Appendix B did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar.

Table 4 Reasons for Gauge Exclusion Based on Performance

Reason	Explanation
Clog (C)	Gauge appeared to be clogged
Zero (Z)	Gauge did not report any rainfall while radar rainfall estimates reported significant rainfall
Stop (S)	Gauge appeared to stop reporting rainfall while radar rainfall estimates reported significant rainfall
Over (O)	Gauge appeared to significantly over-report rainfall as compared to radar rainfall estimates and surrounding gauges (e.g. anomalously high rainfall values caused by field calibration, data transmission error, or switch malfunctions)
Under (U)	Gauge appeared to significantly under-report as compared to radar rainfall estimates and surrounding Gauges (e.g. half-tipper)
Sync (SY)	Gauge appeared to be reporting out-of-sync with the radar rainfall estimates
Frozen/Melt (F/M)	Gauge not reporting properly due to frozen or melting precipitation
Other (T)	Combination of multiple reasons
No Data (ND)	Gauge reported "no data" for a significant amount of time

Table 5 Reasons for Gauge Exclusion Based on Statistical Criteria

Reason	Explanation
Minimum Storm Total Threshold (MSTT)	The radar or gauge cumulative sum during the event or sub-event period was less than MSTT
Outlier Based on Mean Field Bias (OMFB)	The RG pair bias (G/R) was greater than three standard deviations from the mean bias (e.g. G>>R)
Outlier Based on Average Difference (OAD)	The RG pair average difference ((G-R)/G)) was greater than three standard deviations from the mean average difference (e.g. G<<R)

Tables 6 - 12 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i* is the GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Those gauges not used to adjust the radar are shown at the bottom of the table and are highlighted in red. The specific reason for gauge exclusion is displayed in the Flag column. Figures 3 - 9 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 10 depicts the GARR storm total over the 1-km^2 pixels. The GARR amounts for the 240 1-km^2 pixels range from 1.8 - 5.3 inches with a mean of 3.1 inches. The GARR amount for the project area is 4.8 inches.

Table 6 Summary of Individual RG Pairs for Event 1a

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)	Flag
Barton	Barton Pond	0.06	0.06	0.07	-0.01	-16.7	
N Campus	N Campus Pump Station	0.05	0.05	0.05	0.00	0.0	
S Industrial	S Industrial	0.06	0.05	0.06	0.00	0.0	
SE	3200 Pittsview Dr.	0.06	0.05	0.06	0.00	0.0	
Jackson	Jackson Road	0.08	0.06	0.07	0.01	12.5	
City Hall	City Hall	0.03	---	---	---	---	MSTT
KARB	Ann Arbor Municipal Airport	0.00	---	---	---	---	Z

Table 7 Summary of Individual RG Pairs for Event 1b

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)	Flag
Barton	Barton Pond	0.06	0.07	0.06	0.00	0.0	
Jackson	Jackson Road	0.05	0.06	0.05	0.00	0.0	
N Campus	N Campus Pump Station	0.05	0.05	0.05	0.00	0.0	
City Hall	City Hall	0.04	---	---	---	---	MSTT
KARB	Ann Arbor Municipal Airport	0.00	---	---	---	---	Z
S Industrial	S Industrial	0.04	---	---	---	---	MSTT
SE	3200 Pittsview Dr.	0.07	---	---	---	---	MSTT

Table 8 Summary of Individual RG Pairs for Event 1c

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)	Flag
Barton	Barton Pond	0.22	0.09	0.24	-0.02	-9.1	
S Industrial	S Industrial	0.25	0.10	0.27	-0.02	-8.0	
Jackson	Jackson Road	0.21	0.09	0.22	-0.01	-4.8	
City Hall	City Hall	0.24	0.09	0.24	0.00	0.0	
SE	3200 Pittsview Dr.	0.35	0.11	0.32	0.03	8.6	
N Campus	N Campus Pump Station	0.27	0.09	0.24	0.03	11.1	
KARB	Ann Arbor Municipal Airport	0.00	---	---	---	---	Z

Table 9 Summary of Individual RG Pairs for Event 1d

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)	Flag
SE	3200 Pittsview Dr.	1.30	0.73	1.42	-0.12	-9.2	
Barton	Barton Pond	0.92	0.46	0.95	-0.03	-3.3	
City Hall	City Hall	1.44	0.71	1.47	-0.03	-2.1	
N Campus	N Campus Pump Station	1.58	0.80	1.61	-0.03	-1.9	

Gauge ID	Name	G_i (in)	R_i (in)	R_i* (in)	Diff* (in)	Diff* (%)	Flag
Jackson	Jackson Road	1.54	0.69	1.48	0.06	3.9	
S Industrial	S Industrial	1.38	0.61	1.26	0.12	8.7	
KARB	Ann Arbor Municipal Airport	ND	---	---	---	---	ND

Table 10 Summary of Individual RG Pairs for Event 1e

Gauge ID	Name	G_i (in)	R_i (in)	R_i* (in)	Diff* (in)	Diff* (%)	Flag
S Industrial	S Industrial	0.11	0.15	0.13	-0.02	-18.2	
City Hall	City Hall	0.05	0.05	0.05	0.00	0.0	
SE	3200 Pittsview Dr.	0.90	0.99	0.89	0.01	1.1	
Barton	Barton Pond	0.01	---	---	---	---	MSTT
Jackson	Jackson Road	0.03	---	---	---	---	MSTT
KARB	Ann Arbor Municipal Airport	ND	---	---	---	---	ND
N Campus	N Campus Pump Station	0.05	---	---	---	---	MSTT

Table 11 Summary of Individual RG Pairs for Event 1f

Gauge ID	Name	G_i (in)	R_i (in)	R_i* (in)	Diff* (in)	Diff* (%)	Flag
S Industrial	S Industrial	1.59	1.04	1.77	-0.18	-11.3	
City Hall	City Hall	1.01	0.58	0.99	0.02	2.0	
N Campus	N Campus Pump Station	0.82	0.45	0.79	0.03	3.7	
Barton	Barton Pond	0.47	0.25	0.45	0.02	4.3	
SE	3200 Pittsview Dr.	2.54	1.37	2.41	0.13	5.1	
Jackson	Jackson Road	0.78	0.42	0.73	0.05	6.4	
KARB	Ann Arbor Municipal Airport	0.00	---	---	---	---	ND

Table 12 Summary of Individual RG Pairs for Event 1g

Gauge ID	Name	G_i (in)	R_i (in)	R_i* (in)	Diff* (in)	Diff* (%)	Flag
Barton	Barton Pond	0.27	0.22	0.29	-0.02	-7.4	
Jackson	Jackson Road	0.25	0.19	0.25	0.00	0.0	
S Industrial	S Industrial	0.08	0.06	0.08	0.00	0.0	
N Campus	N Campus Pump Station	0.23	0.16	0.22	0.01	4.3	
City Hall	City Hall	0.18	0.12	0.16	0.02	11.1	
KARB	Ann Arbor Municipal Airport	0.02	---	---	---	---	MSTT
SE	3200 Pittsview Dr.	0.03	---	---	---	---	MSTT

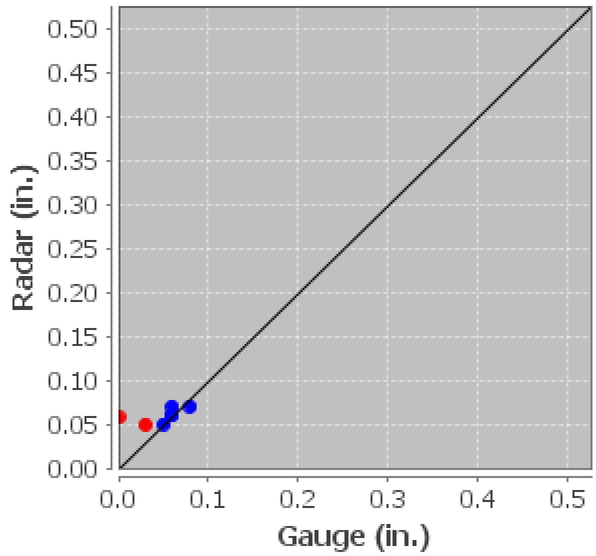


Figure 3. Scatter Plot of RG Pairs for Event 1a

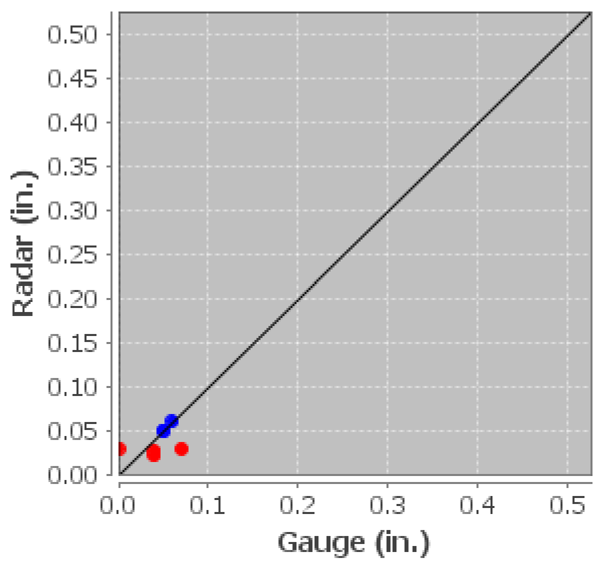


Figure 4. Scatter Plot of RG Pairs for Event 1b

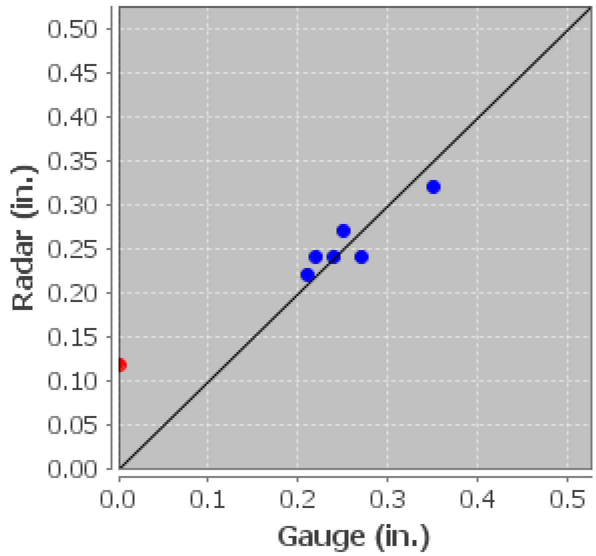


Figure 5. Scatter Plot of RG Pairs for Event 1c

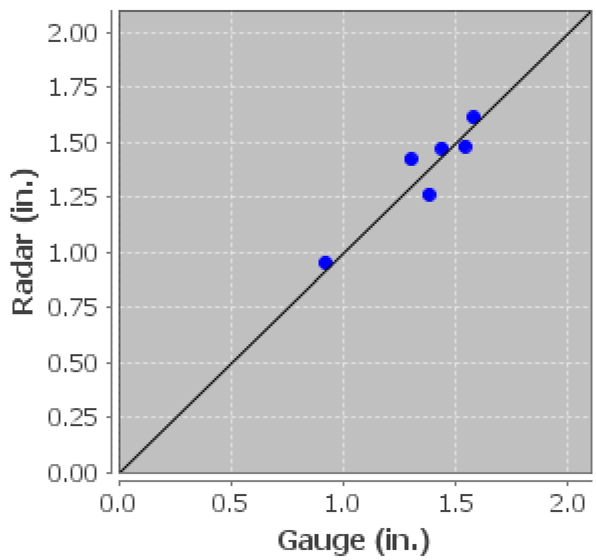


Figure 6. Scatter Plot of RG Pairs for Event 1d

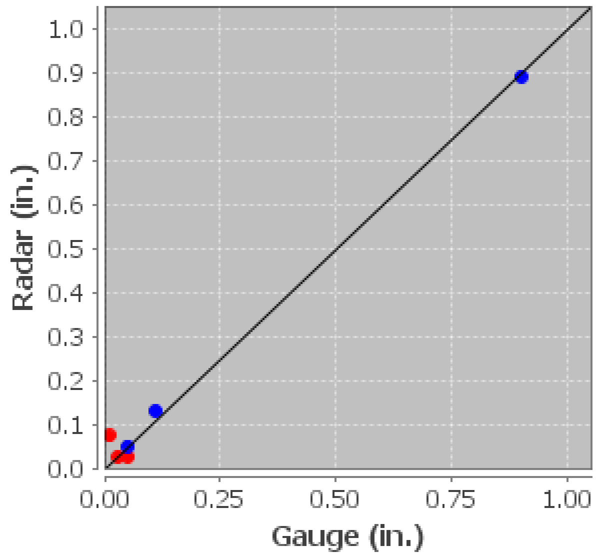


Figure 7. Scatter Plot of RG Pairs for Event 1e

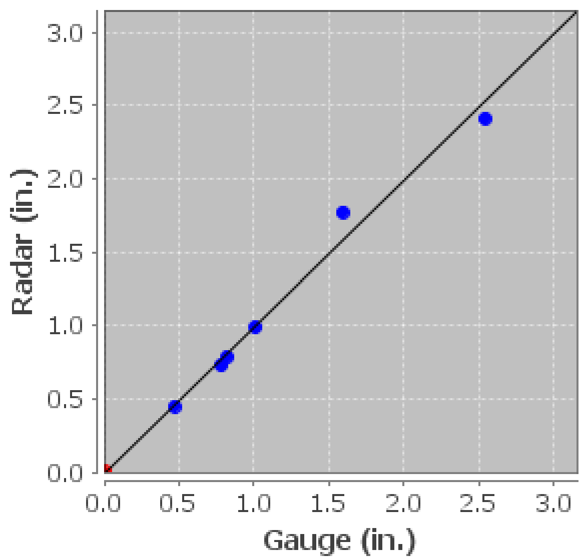


Figure 8. Scatter Plot of RG Pairs for Event 1f

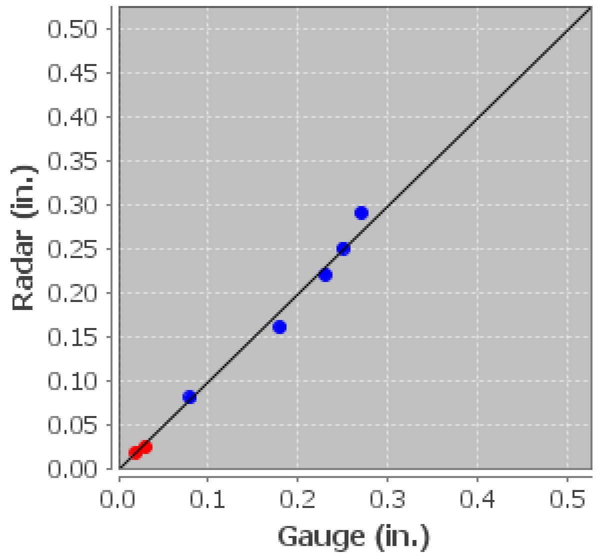


Figure 9. Scatter Plot of RG Pairs for Event 1g

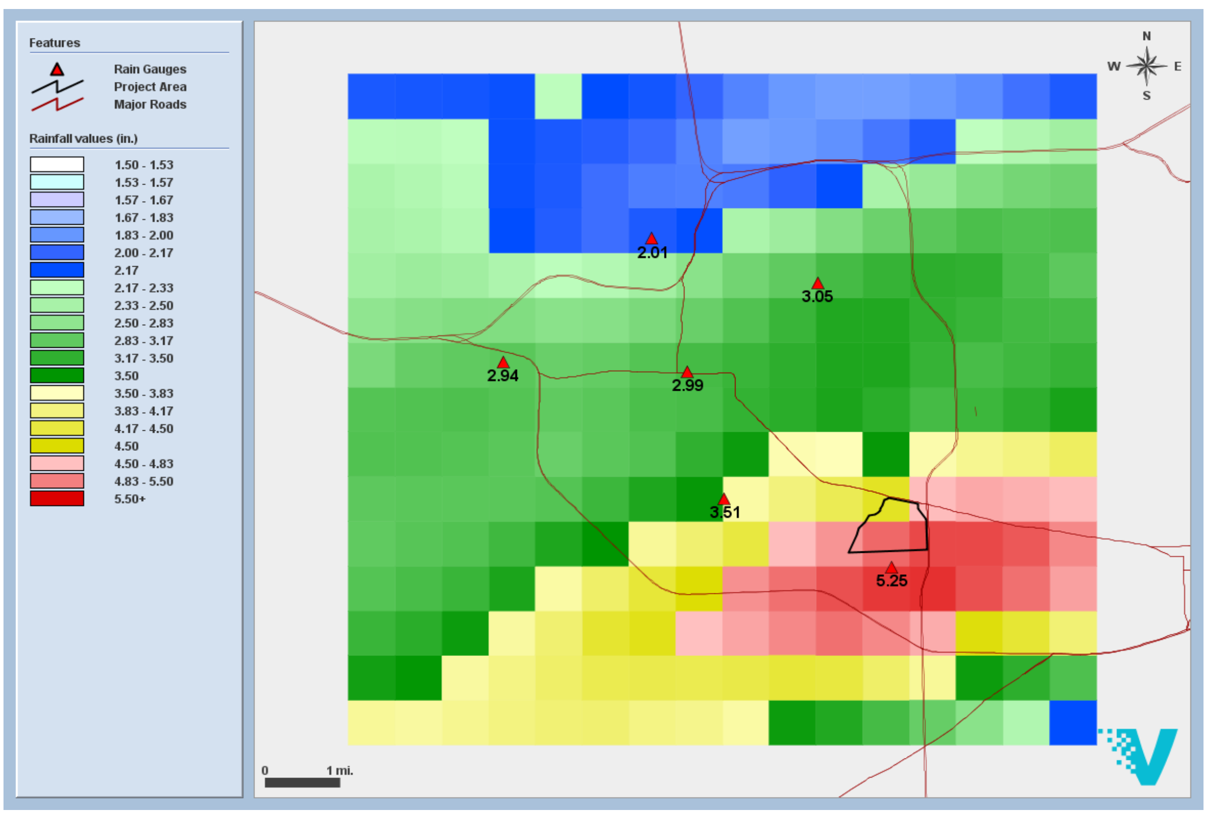


Figure 10. GARR Storm Total

Metadata

Data accompanying this document provides a continuous rainfall record of all 240 1-km^2 pixels and the project area in 15-min intervals. Shapefiles of the 1-km^2 pixels and project area are located in the Shapefiles subfolder.

Rainfall Event:

- 2021-06-25 01:00 EDT - 2021-06-26 07:00 EDT

CSV format:

- Comma delimited file with IDs across the columns and time down the rows.
- Time stamps (yyyy/mm/dd hh:mm:ss) are in EDT.
- Data values represent 15-min accumulation (inches) at end of interval.
- 1-km^2 pixel ID field that was used from the shapefile DBF is "ID".
- Project area ID field that was used from the shapefile DBF is "ID".

Shapefile metadata:

- NAD 1983, State Plane Michigan South (feet).

Appendices

Appendix A - Gauge Performance Exclusion Table
Appendix B - Gauge Statistical Criteria Exclusion Table
Appendix C - Event CDPs

Appendix A - Gauge Performance Exclusion Table

Reason	Explanation
Clog (C)	Gauge appeared to be clogged
Zero (Z)	Gauge did not report any rainfall while radar rainfall estimates reported significant rainfall
Stop (S)	Gauge appeared to stop reporting rainfall while radar rainfall estimates reported significant rainfall
Over (O)	Gauge appeared to significantly over-report rainfall as compared to radar rainfall estimates and surrounding gauges (e.g. anomalously high rainfall values caused by field calibration, data transmission error, or switch malfunctions)
Under (U)	Gauge appeared to significantly under-report as compared to radar rainfall estimates and surrounding Gauges (e.g. half-tipper)
Sync (SY)	Gauge appeared to be reporting out-of-sync with the radar rainfall estimates
Frozen/Melt (F/M)	Gauge not reporting properly due to frozen or melting precipitation
Other (T)	Combination of multiple reasons
No Data (ND)	Gauge reported "no data" for a significant amount of time

Event #	E1a	E1b	E1c	E1d	E1e
Event Date	**2021-06-25**	**2021-06-25**	**2021-06-25**	**2021-06-25**	**2021-06-25**
Start Time (EDT)	2021-06-25 01:15	2021-06-25 10:15	2021-06-25 12:15	2021-06-25 15:15	2021-06-25 19:30
End Time (EDT)	2021-06-25 10:00	2021-06-25 12:00	2021-06-25 15:00	2021-06-25 19:15	2021-06-25 23:30
Barton					
City Hall					
Jackson					
N Campus					
S Industrial					
KARB	Z	Z	Z	ND	ND
SE					

Event #	E1f	E1g
Event Date	**2021-06-25**	**2021-06-25**
Start Time (EDT)	2021-06-25 23:45	2021-06-26 01:30
End Time (EDT)	2021-06-26 01:15	2021-06-26 07:00
Barton		
City Hall		
Jackson		
N Campus		
S Industrial		
KARB	ND	
SE		

Appendix B - Gauge Statistical Criteria Exclusion Table

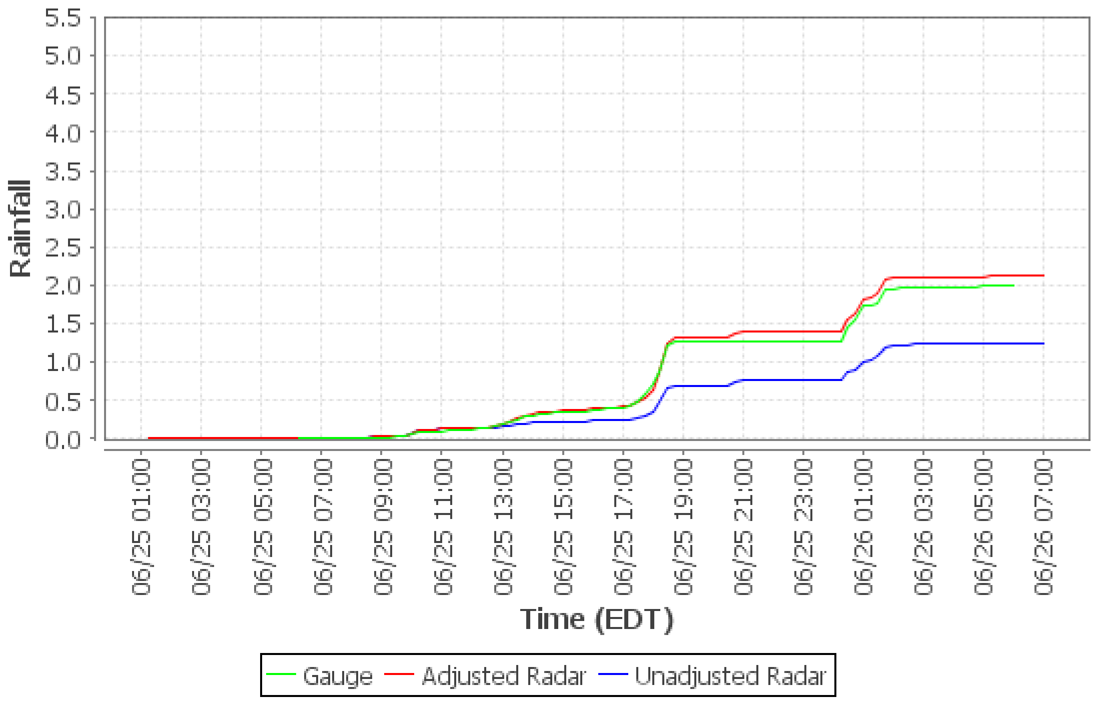
Reason	Explanation
Minimum Storm Total Threshold (MSTT)	The radar or gauge cumulative sum during the event or sub-event period was less than MSTT
Outlier Based on Mean Field Bias (OMFB)	The RG pair bias (G/R) was greater than three standard deviations from the mean bias (e.g. G>>R)
Outlier Based on Average Difference (OAD)	The RG pair average difference ((G-R)/G)) was greater than three standard deviations from the mean average difference (e.g. G<<R)

Event #	E1a	E1b	E1c	E1d	E1e
Event Date	**2021-06-25**	**2021-06-25**	**2021-06-25**	**2021-06-25**	**2021-06-25**
Start Time (EDT)	2021-06-25 01:15	2021-06-25 10:15	2021-06-25 12:15	2021-06-25 15:15	2021-06-25 19:30
End Time (EDT)	2021-06-25 10:00	2021-06-25 12:00	2021-06-25 15:00	2021-06-25 19:15	2021-06-25 23:30
Source	KDTX LII	KDTX LII	KDTX LII	KDTX LII	KDTX LII
Barton					MSTT
City Hall	MSTT	MSTT			
Jackson					MSTT
N Campus					MSTT
S Industrial		MSTT			
KARB					
SE		MSTT			

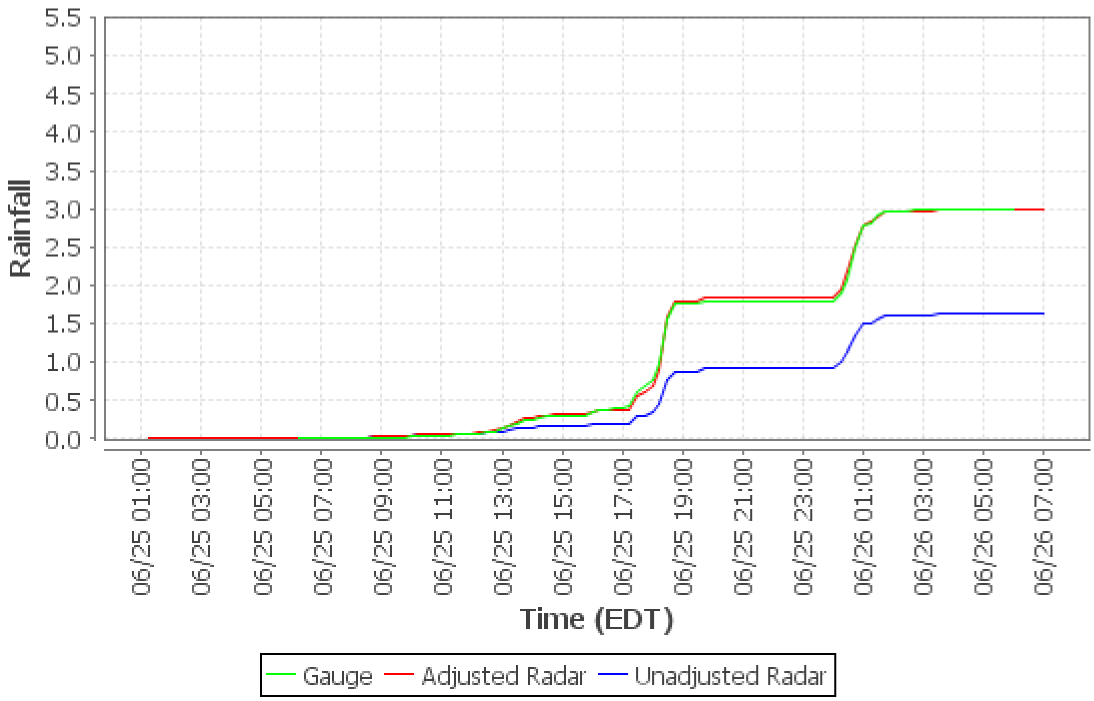
Event #	E1f	E1g
Event Date	**2021-06-25**	**2021-06-25**
Start Time (EDT)	2021-06-25 23:45	2021-06-26 01:30
End Time (EDT)	2021-06-26 01:15	2021-06-26 07:00
Source	KDTX LII	KDTX LII
Barton		
City Hall		
Jackson		
N Campus		
S Industrial		
KARB		MSTT
SE		MSTT

Appendix C - Event CDPs

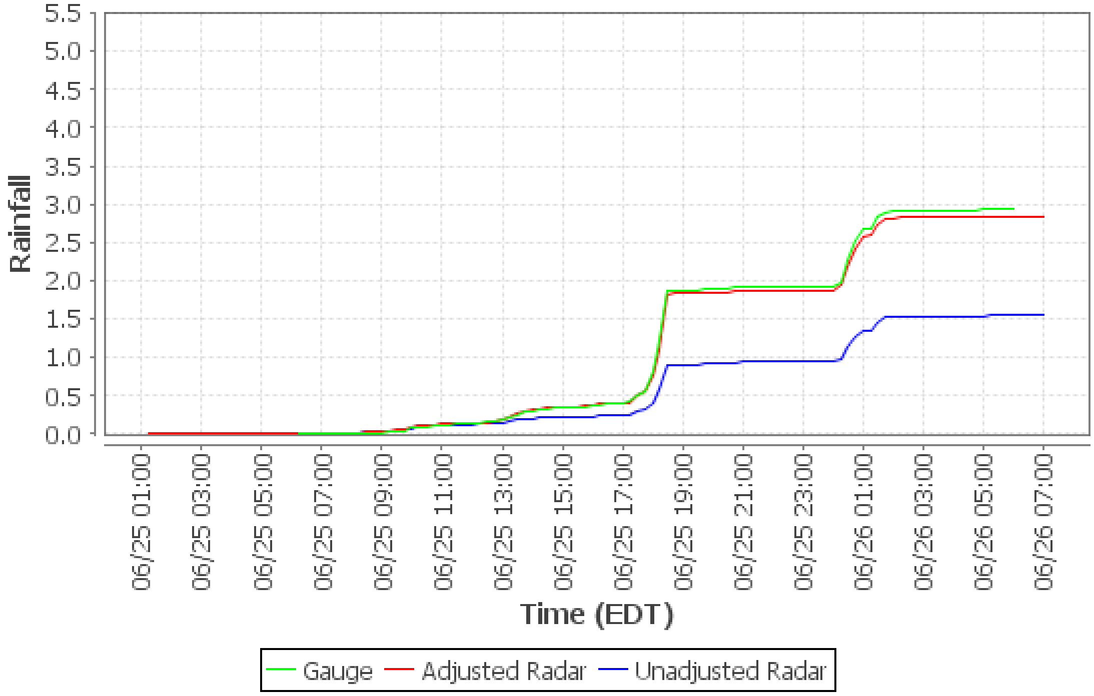
Cumulative Distribution Plot - Barton Pond (Barton)



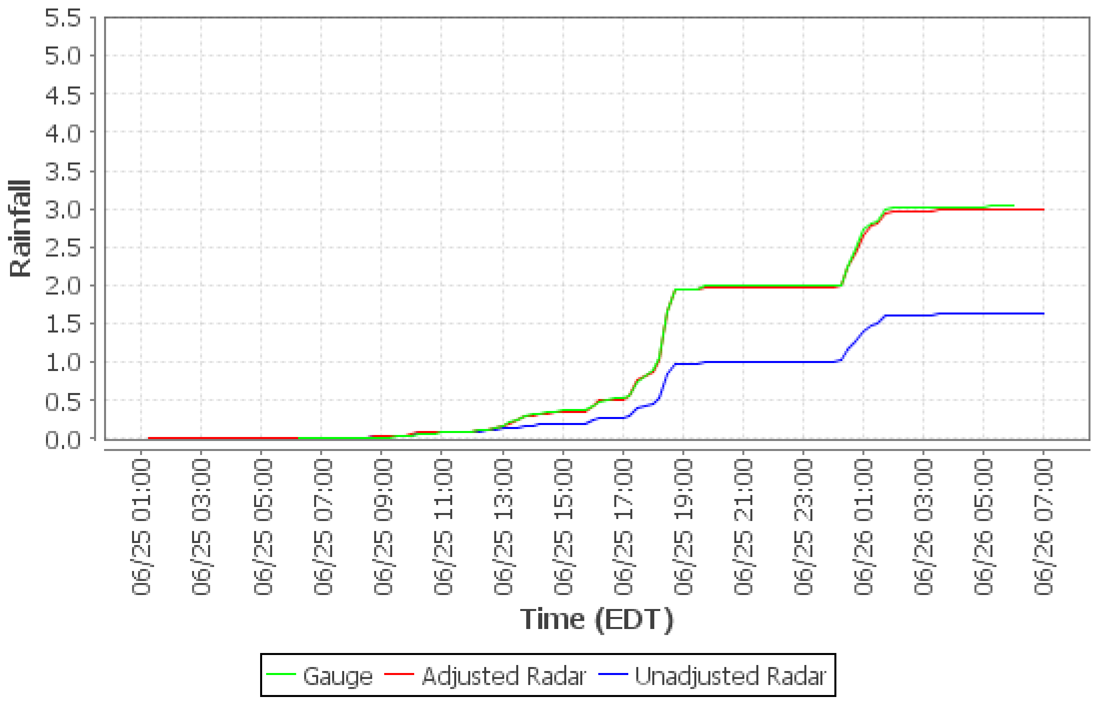
Cumulative Distribution Plot - City Hall (City Hall)



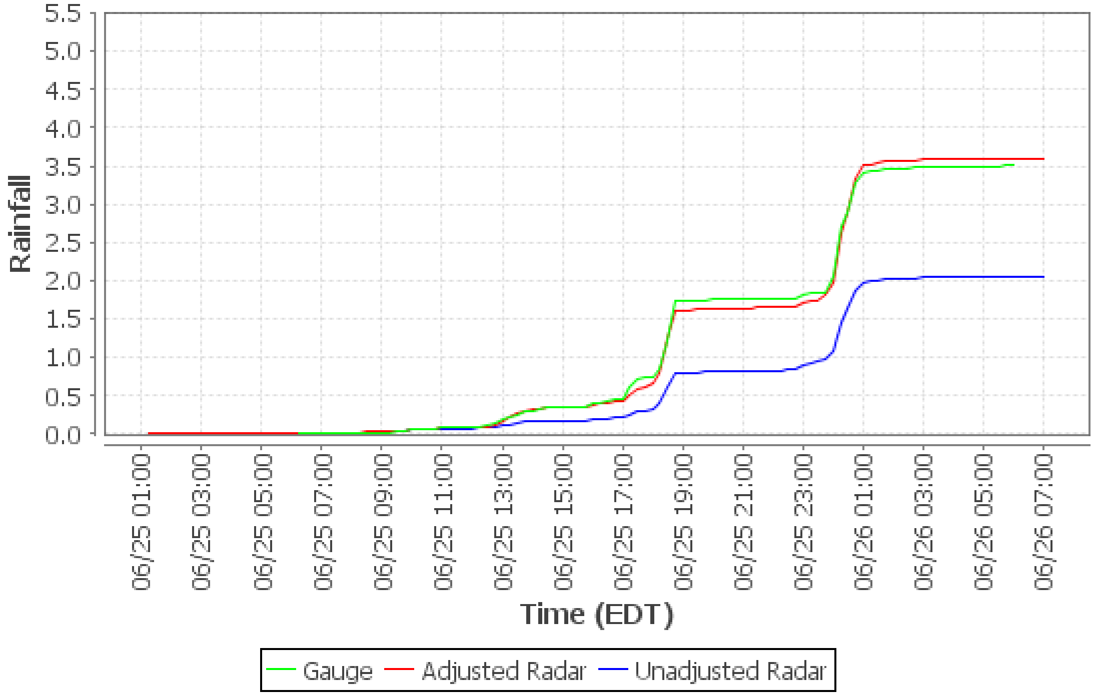
Cumulative Distribution Plot - Jackson Road (Jackson)



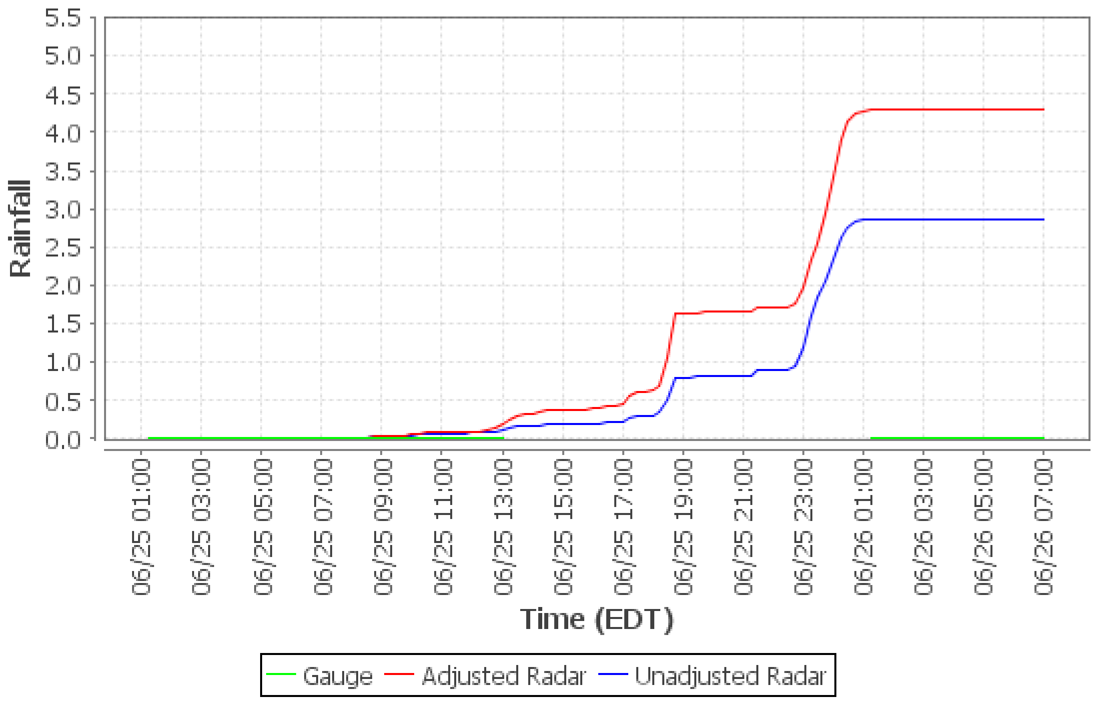
Cumulative Distribution Plot - N Campus Pump Station (N Campus)



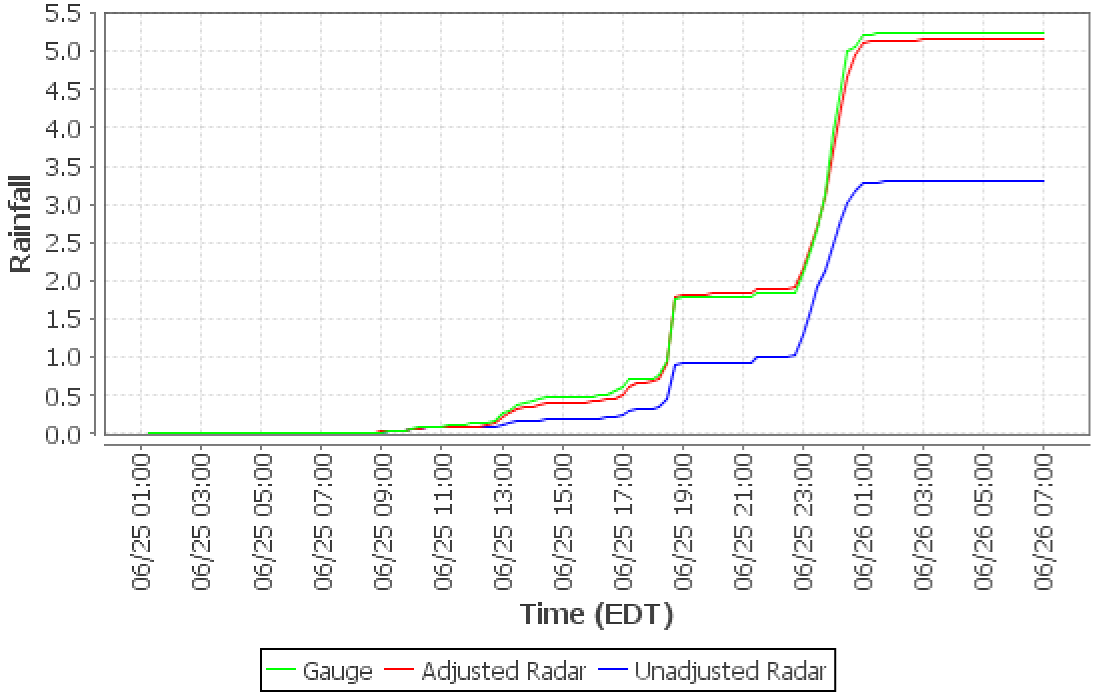
Cumulative Distribution Plot - S Industrial (S Industrial)



Cumulative Distribution Plot - Ann Arbor Municipal Airport (KARB)



Cumulative Distribution Plot - 3200 Pittsview Dr. (SE)



Appendix D

Things to Know

- You can leave and rejoin the meeting at any time (unless the meeting is at capacity or you are removed for inappropriate behavior).
- Multiple opportunities for questions will be provided throughout today's session.
- The meeting presentation will be posted at www.a2gov.org/JuneStorm
- All attendees are muted (instructions to unmute will be covered).
- Please keep video off throughout today's session.
- Attendee screen share is prohibited.
- Chat feature is not available during today's session; written comments can be submitted to TBaughman@a2gov.org

June 25-26 Storm Event

September 1 and 8, 2021

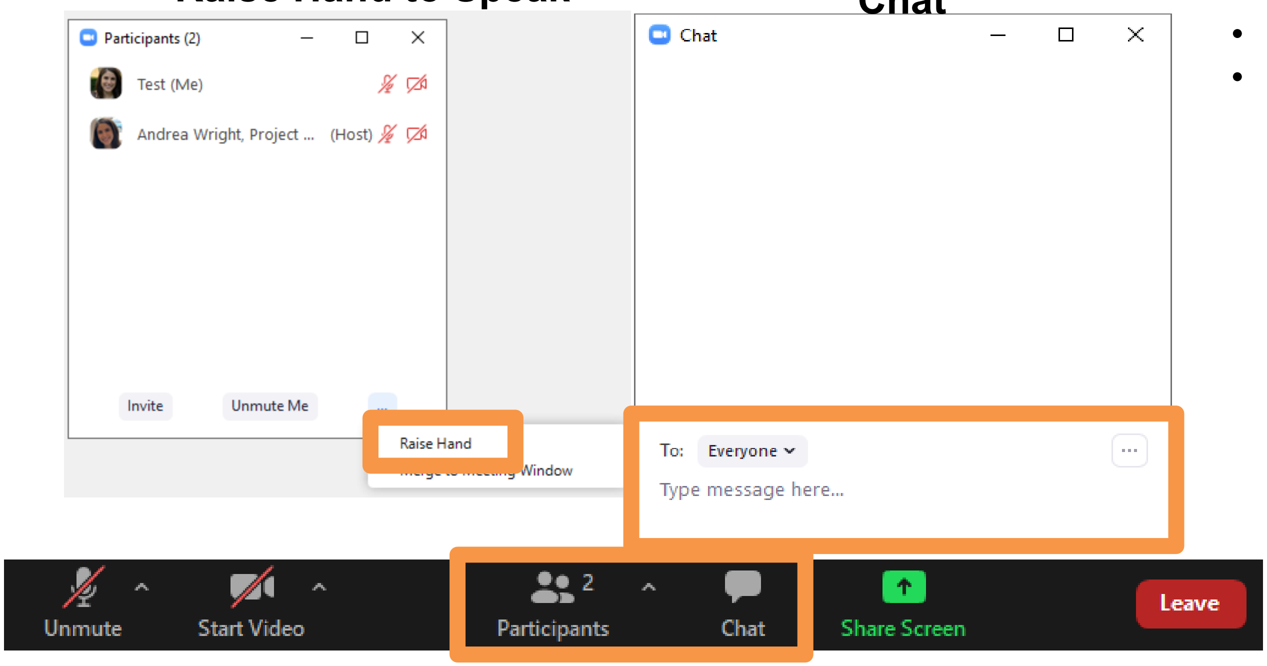
Technology Overview

Ask a Question or Share a Comment

Computer

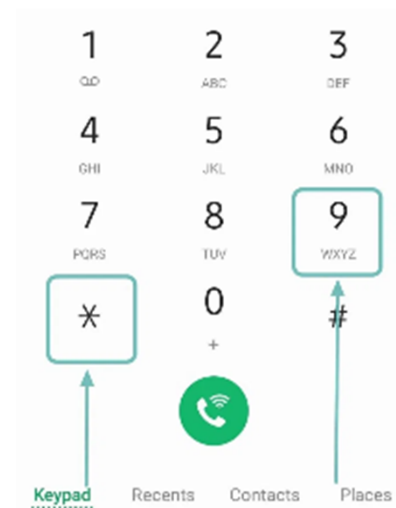
Raise Hand to Speak

Chat



Phone

- Select *9 to raise your hand
- You will be identified by the last 3 digits of your phone number



Zoom Meeting Guidelines

- **Commit to learning and avoid speculation** – we encourage you to ask questions so we can explore the issue together.
- **We want to hear from each of you!**
  - Raise your hand and be recognized to speak; there will be one speaker at a time.
  - When speaking, please move to a quiet area and silence any background sounds.
  - Speak loud and clearly.
  - Everyone will be provided a change to speak before a repeat speaker.
- **Please remember the importance of rights and the dignity of other people:**
  - Critique ideas, not people.
  - Be thoughtful about your language so this can be a comfortable and respectful forum for all participants - inappropriate written and/or verbal comment or language, including personal attacks and accusations, will result in the attendee being removed from the meeting.

Is there anything else anyone would like to add?

Agenda

- Introductions
- Purpose of meeting
- Efforts to date
- System overview
- Follow Up Steps
- Breakout Rooms
  - Review of storm event
  - Engineering study details
  - Washtenaw County Q&A
  - Neighborhood conditions

Welcome and Introductions

- **City of Ann Arbor**
  - Troy Baughman
  - Molly Maciejewski
  - Ron Hoeft
  - Jennifer Lawson
  - Kayla Coleman

- **Washtenaw County Water Resources Commissioner**
  - Evan Pratt
  - Harry Sheehan

- **OHM Advisors**
  - Robert Czachorski
  - Mackenzie Johnson

Purpose

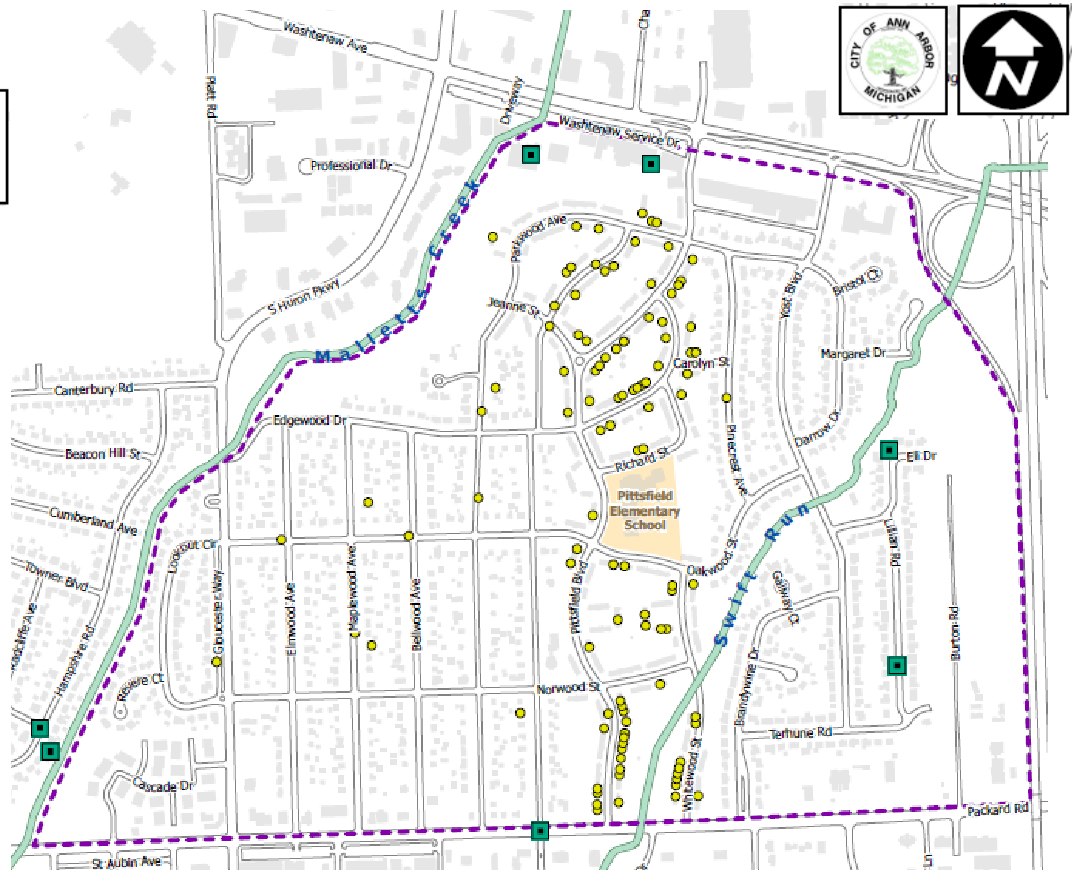
- Begin to discuss and share experiences during the June 25-26 storm event
- Review efforts to date
- Introduce the storm event analysis project
- Help the project team learn more about neighborhood conditions during the storm

Project Location

June 25-26 Storm – Southeast Ann Arbor

For terms of use visit a2gov.org/terms

Reported Back-up/Water Issue
Flooding in street or yard
County Drain
Study Area



- Pittsfield Village
- Darlington
- Forestbrooke
- And other surrounding neighborhoods in Southeast Ann Arbor

Actions to Date

- FEMA State of Emergency
  - https://www.a2gov.org/news/pages/article.aspx?i=810
- Insurance Claims
- Pittsfield Village Condo Board Meeting
- Public Works activities
- Capital Improvement Plan (CIP) Projects
- Contracted with engineering consultant, OHM Advisors, for Storm Event Analysis

System Overview

Stormwater System Infrastructure

- Collects stormwater runoff from the ground surface
- Discharges to rivers, streams, or lakes without treatment

Sanitary Sewer Infrastructure

- Collects wastewater from the use of toilets, dishwashers, faucets, etc.
- Discharges to a wastewater treatment plant before discharging to a river, stream, or lake

Important to Note:

- Sanitary sewer pipes are designed for expected sanitary sewer flow, not stormwater flow.
- Excessive stormwater entering the sanitary sewer system can cause basement backups and sewer overflows.

System Overview

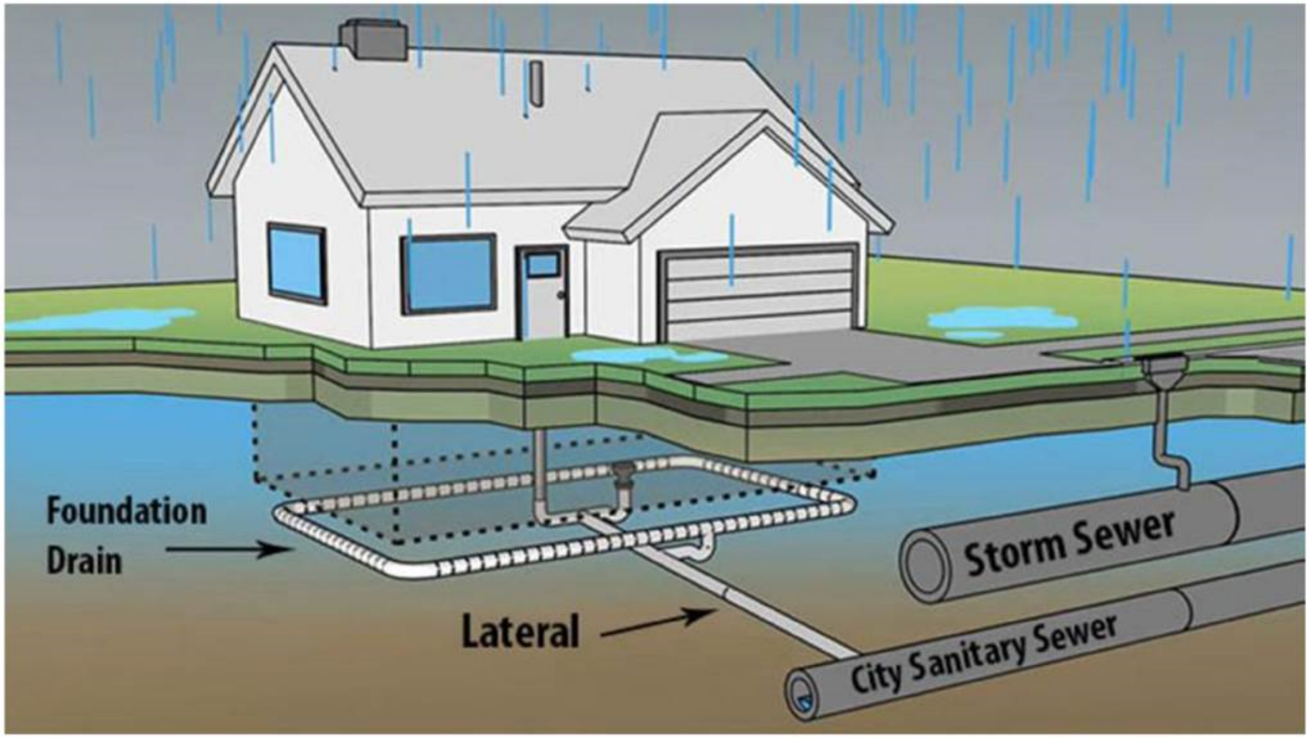
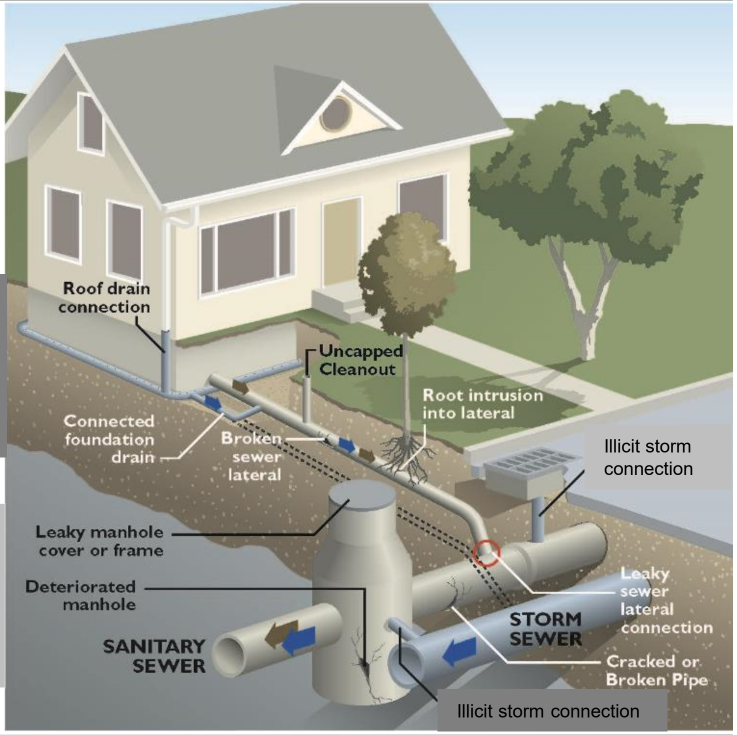


Image Credit:
Milwaukee
Metropolitan
Sewerage District

How stormwater may enter the sanitary sewer system:

Infiltration:
Connected footing drain
Broken sewer lateral
Root intrusion into lateral
Cracked or broken pipe

Inflow:
Roof drain connection
Uncapped cleanout
Illicit storm connection
Deteriorated manhole



Jurisdictions

- City of Ann Arbor owns and maintains public stormwater and sanitary sewer systems throughout the City
- The Pittsfield Village Condo association owns and maintains some backyard stormwater pipes and private sanitary sewer pipes
- Washtenaw County Water Resources Commissioner's Office (WCWRC) is responsible for the County Drains that traverse through the City (e.g., Swift Run and Malletts Creek)

Storm Event Magnitude

- The amount of rain that fell within the City during the June 25-26 storm had a 1-2% annual probability of occurring
- Utility systems are typically designed to handle approximately 3 inches of rainfall over 24 hours
  - The rainfall on June 25-26, 2021 totaled over 5 inches in some areas of the City
- The focus of the Storm Event Analysis study will be to identify best practices to minimize property damage for future large rain events

Follow Up Steps

- Public engagement
  - Meeting summaries are planned to be posted within two weeks of meeting
  - Individual interviews/questionnaires to share flooding experiences
  - Additional community discussions

- Technical engineering review, including:
  - Flow meter and rain gauge data
  - Stormwater and sanitary sewer hydraulic models

- Determine whether any recommendations could minimize future flooding and/or basement backup risks
  - Considering community input and engineering analysis

Contact the project team at any time to request an individual meeting or discussion.

Questions and Discussion

June 25-26 Storm Event

… Details

What questions do you have about the storm?

Talk to the City's Project Manager

Project Details/Study

… Engineering analysis

… Public engagement process

What questions do you have about next steps?

Share feedback on the draft questionnaire

Neighborhood conditions related to the storm event

… What we've heard so far.

What did you experience during the storm?

County Q&A

…Overview of County Drains

What questions do you have about jurisdiction of storm and sanitary infrastructure ?

Breakout Room:
Storm Event Details

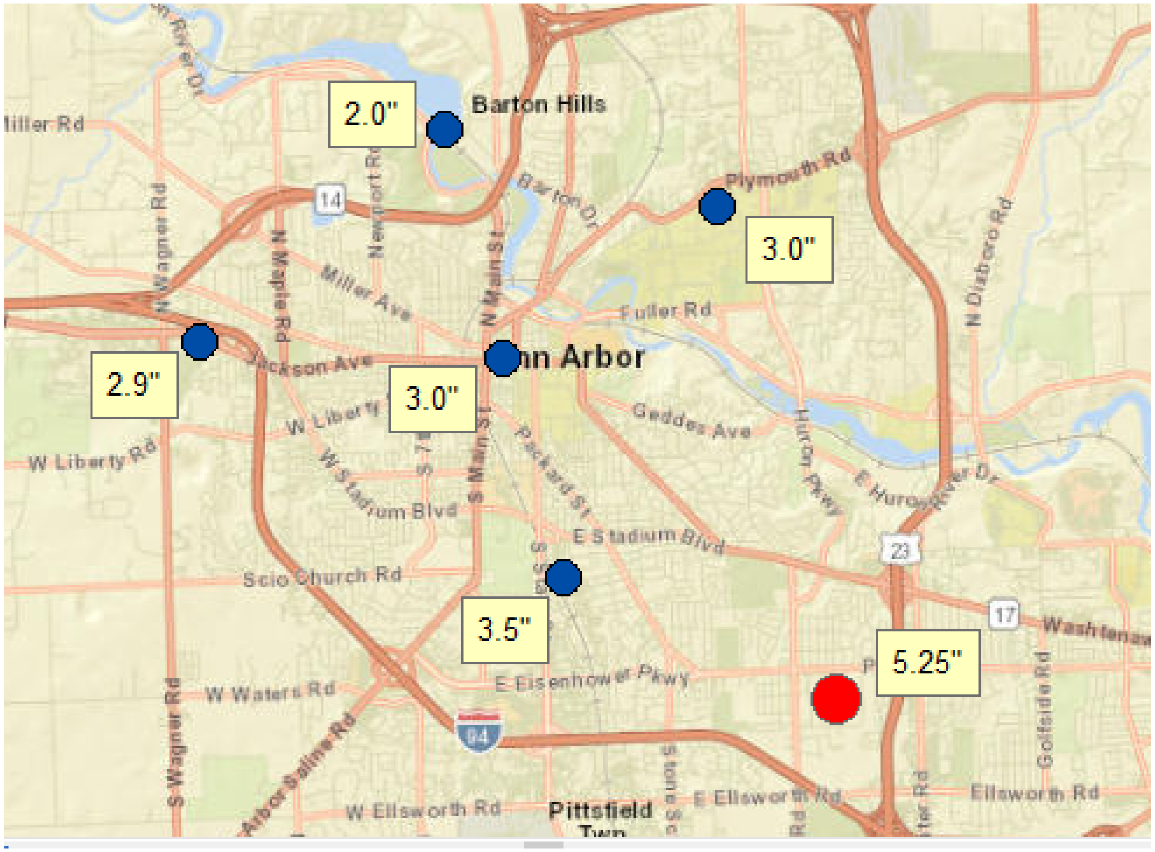
June 25-26 Storm Event

… Details

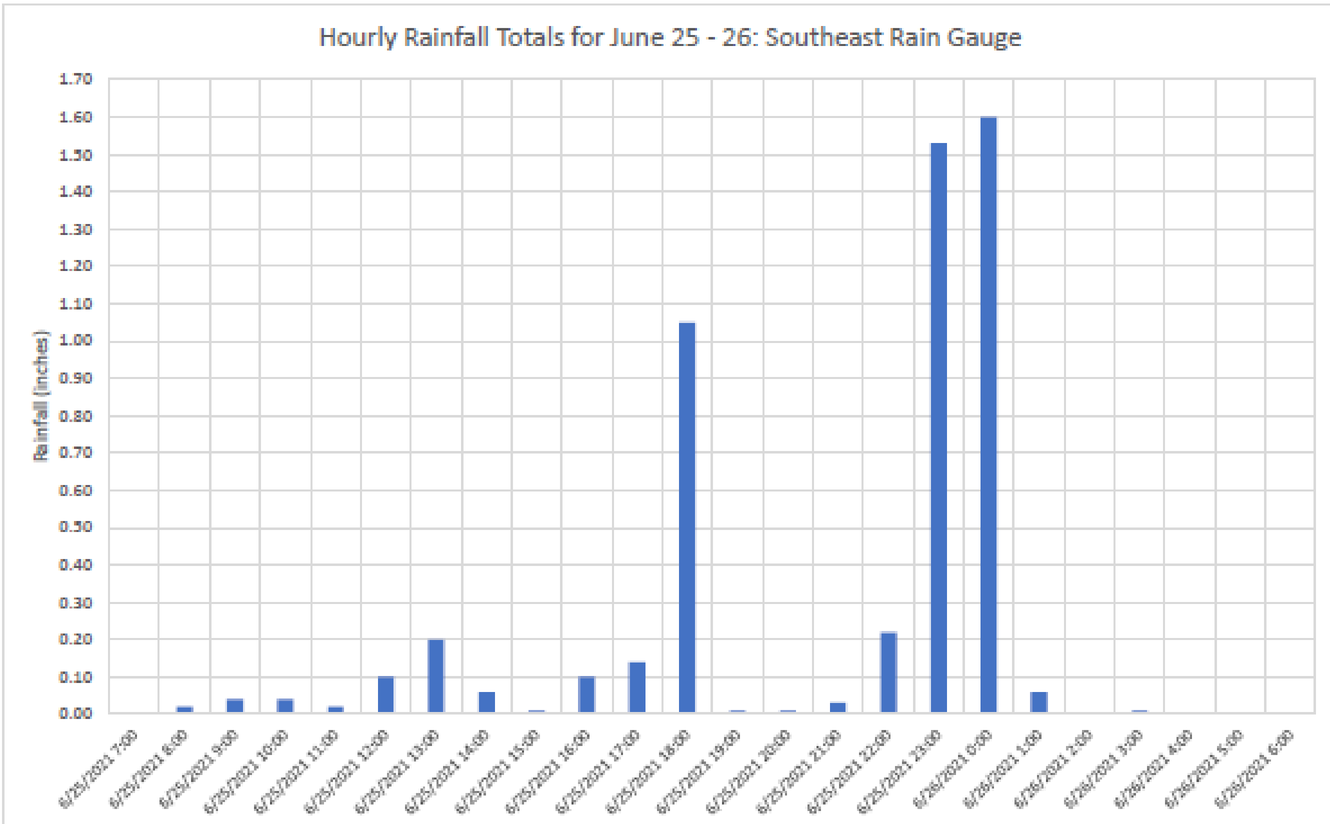
What questions do you have about the storm?

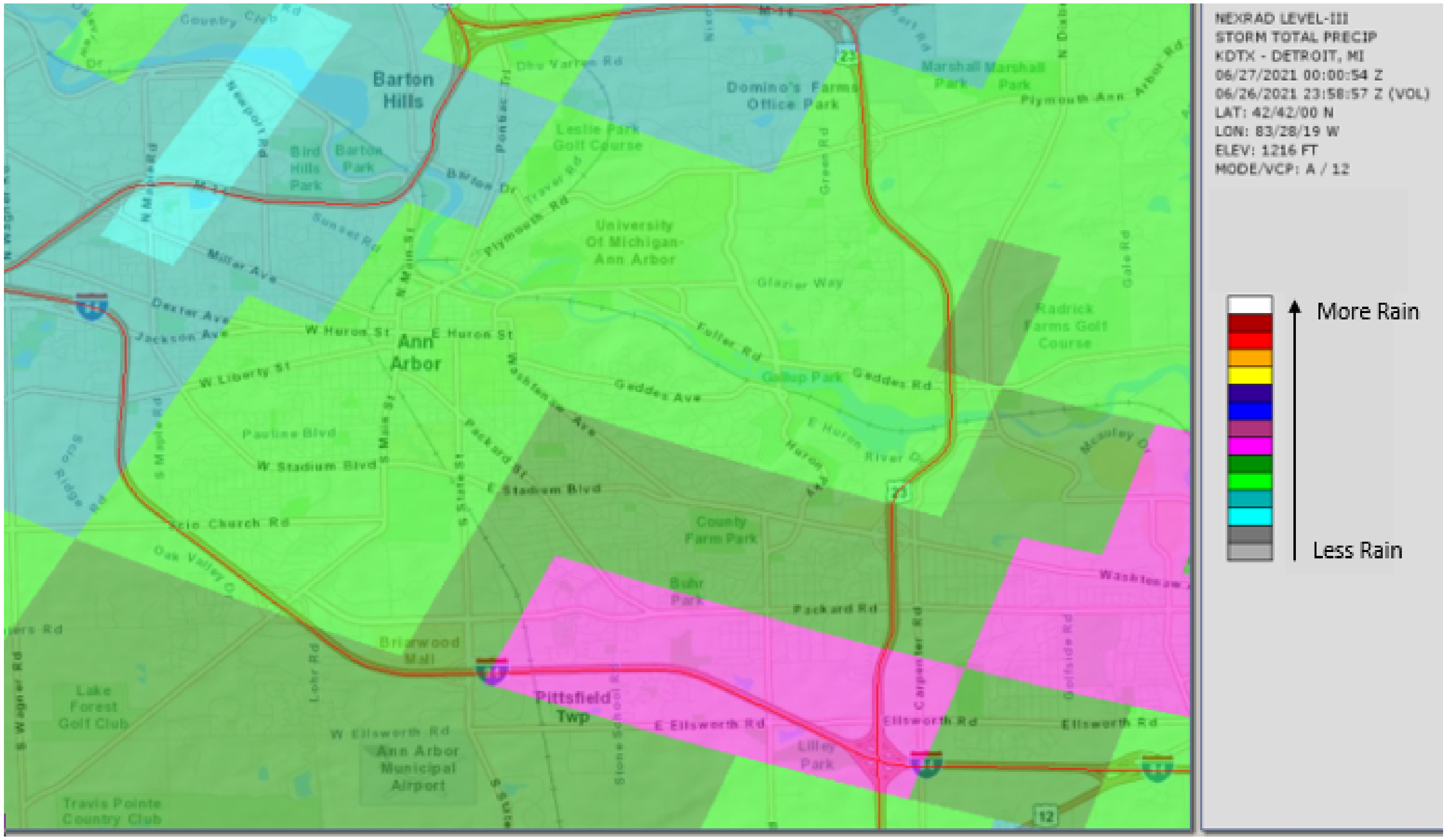
Talk to the City's Project Manager

June 25-26 Rainfall Totals



Hourly Rainfall Totals – SE Ann Arbor





June 25-26 NOAA Radar Rainfall Data

*This map shows the spatial variability of the rainfall. It can be seen that more rain fell in the south and southeastern parts of the City compared to the northern part of the City.

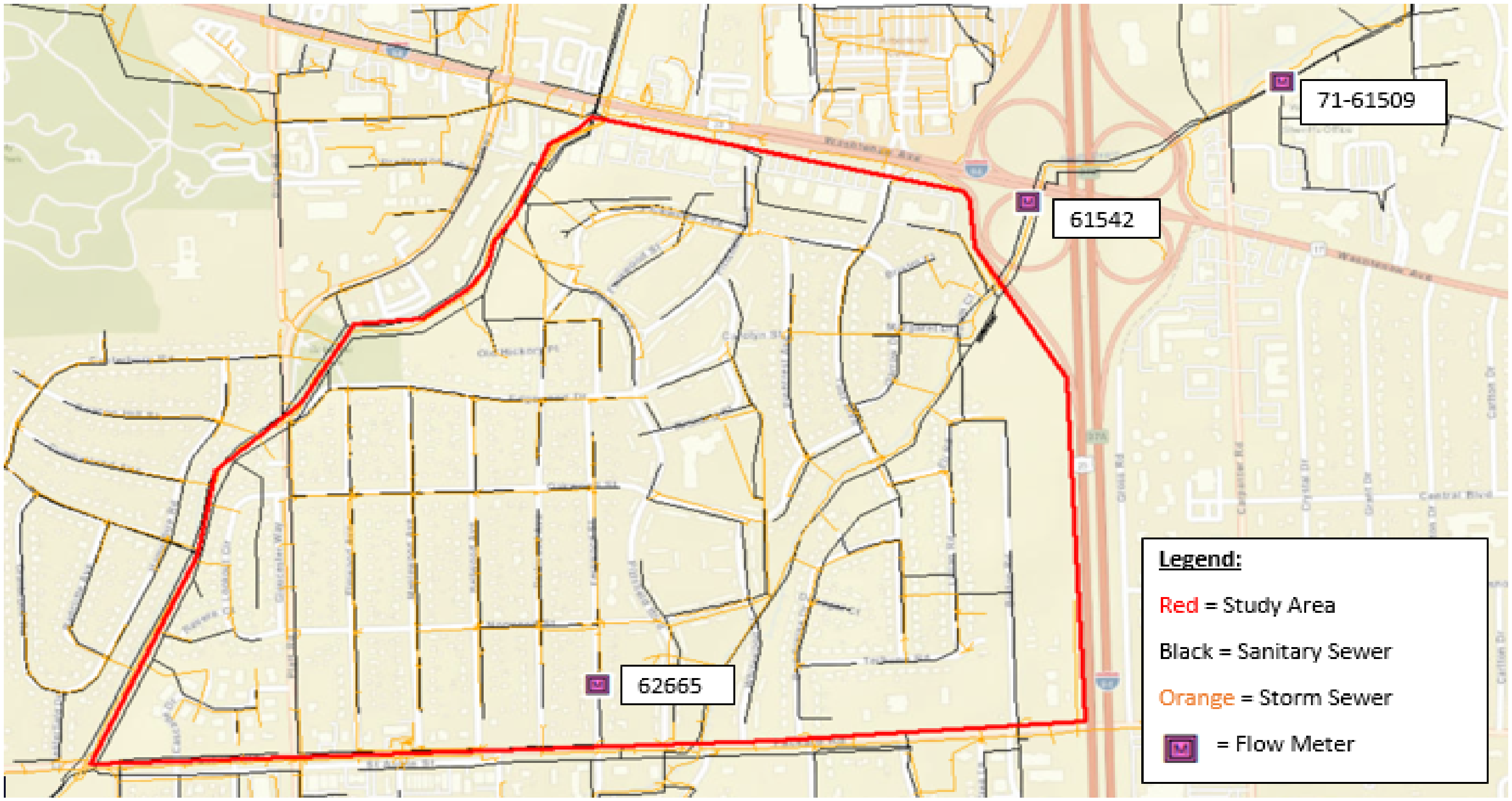
What is Annual Exceedance Probability ?

- An annual exceedance probability (AEP) is the probability of an event occurring in any given year.
  - 1% AEP (100 yr storm)
  - 2% AEP (50 yr storm)
  - 4% AEP (25 yr storm
  - 10% AEP (10 yr storm)

June 25-26 Storm Event

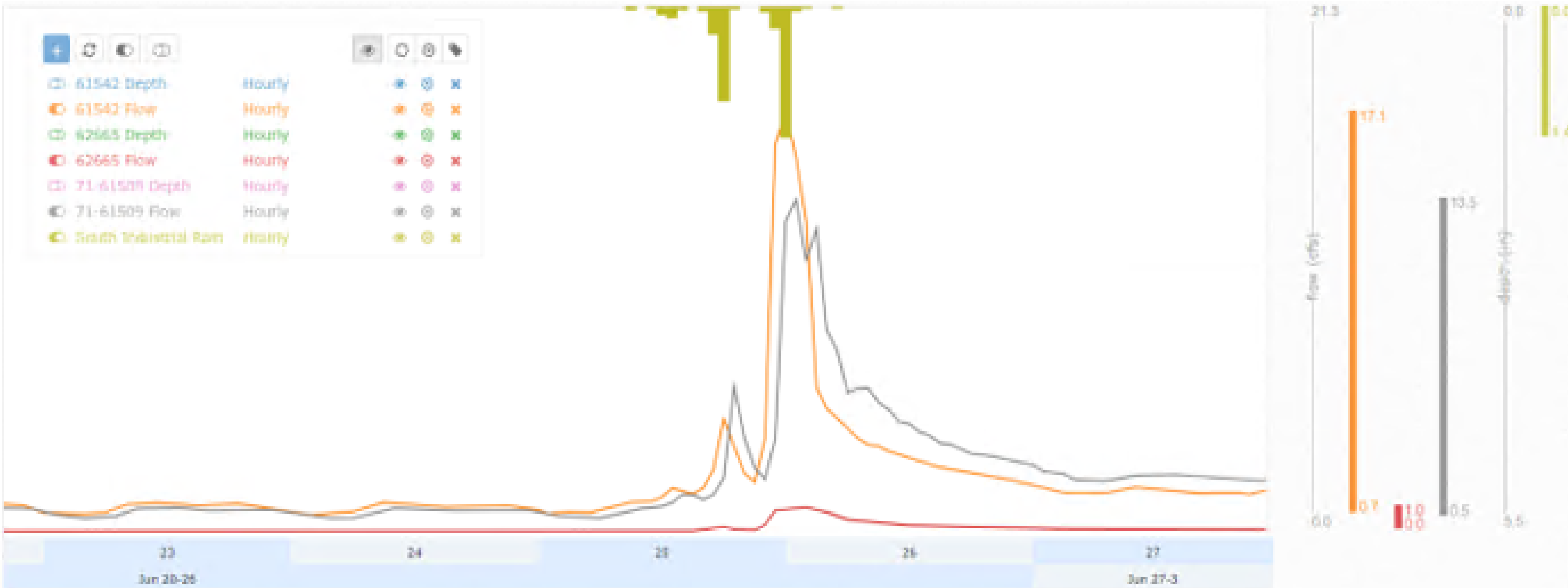
- 5.25” in approximately 19 hours
- For 12hr period, storm event intensity exceeded 1% probability (100-yr) storm

Sanitary Flow Meters



Locations of Flow Meters Near Study Area

Sanitary Flow Meters



Flow Data of 3 Flow Meters Near Study Area

Breakout Room:
Project Study Details

Project Details/Study

… Engineering analysis

… Public engagement process

What questions do you have about next steps?

Share feedback on the draft questionnaire

Meetings

Updates at a2gov.org/JuneStorm

Open communications

On-going Public Engagement

August-September

Understand what happened:

- Public meeting input
- Resident interviews
- Community survey
- Interview staff (City, County, Pittsfield Village maintenance)
- Data collection (rains, flows, locations)

October

Evaluation:

- Maps
- Rain and flow data analysis
- Simulate event with City's storm and sanitary models
- Look for trends, explanations, causes

November-December

Recommendations:

- Improvement(s) to minimize future flooding and/or basement backups
- Follow-up task(s) based on findings
- Technical memorandum
- Plan for next steps

DRAFT Survey questions:

1. Do you have a basement?

   No → Did you experience flooding in your home?

   Yes → Did you have water in your basement?

   - How much water (depth)?
   - Coming from inside the house or outside the house?
   - Coming from the walls/windows?
   - Coming from a floor drain or sump pump?

2. Did you lose power? Time frame?

3. Do you have a sump pump? Did it operate during the June 25-26 storm?

4. Has this home experienced basement backups or flooding before?
   - When ?
   - How much water (depth)?

DRAFT Survey questions:

5. Is your footing/foundation drain connected to the sanitary sewer system?

No → when was the footing drain disconnected from the sanitary sewer system?

6. Do you have a check valve installed on your sanitary sewer service line?

Yes → when was the check valve installed?

- Footing/Foundation Drain = Pipes that are installed under the building foundation or basement floor to collect water and drain it away from the building.
- Check Valve = Valve installed on a sewer line that opens to allow sewage to flow out, but then closes to prevent sewage from flowing in the reverse direction (backing up into the house).

DRAFT Survey Feedback

- Do these questions make sense?
- What other questions should we ask?
- Other feedback/input on the questionnaire?

Breakout Room:
Neighborhood Conditions

Jam Board – September 1, 2021 Meeting

Jam Board – September 8, 2021 Meeting

Project Website: a2gov.org/JuneStorm

Phone: 734.794.6430 ext. 43798

Email: **TBaughman@a2gov.org**
Mackenzie.Johnson@ohm-advisors.com

Thank you!

Internal Resource Slide

Sump pump info: www.a2gov.org/sumppumps

Developer Offset Mitigation (DOM) Program:
www.a2gov.org/DOM

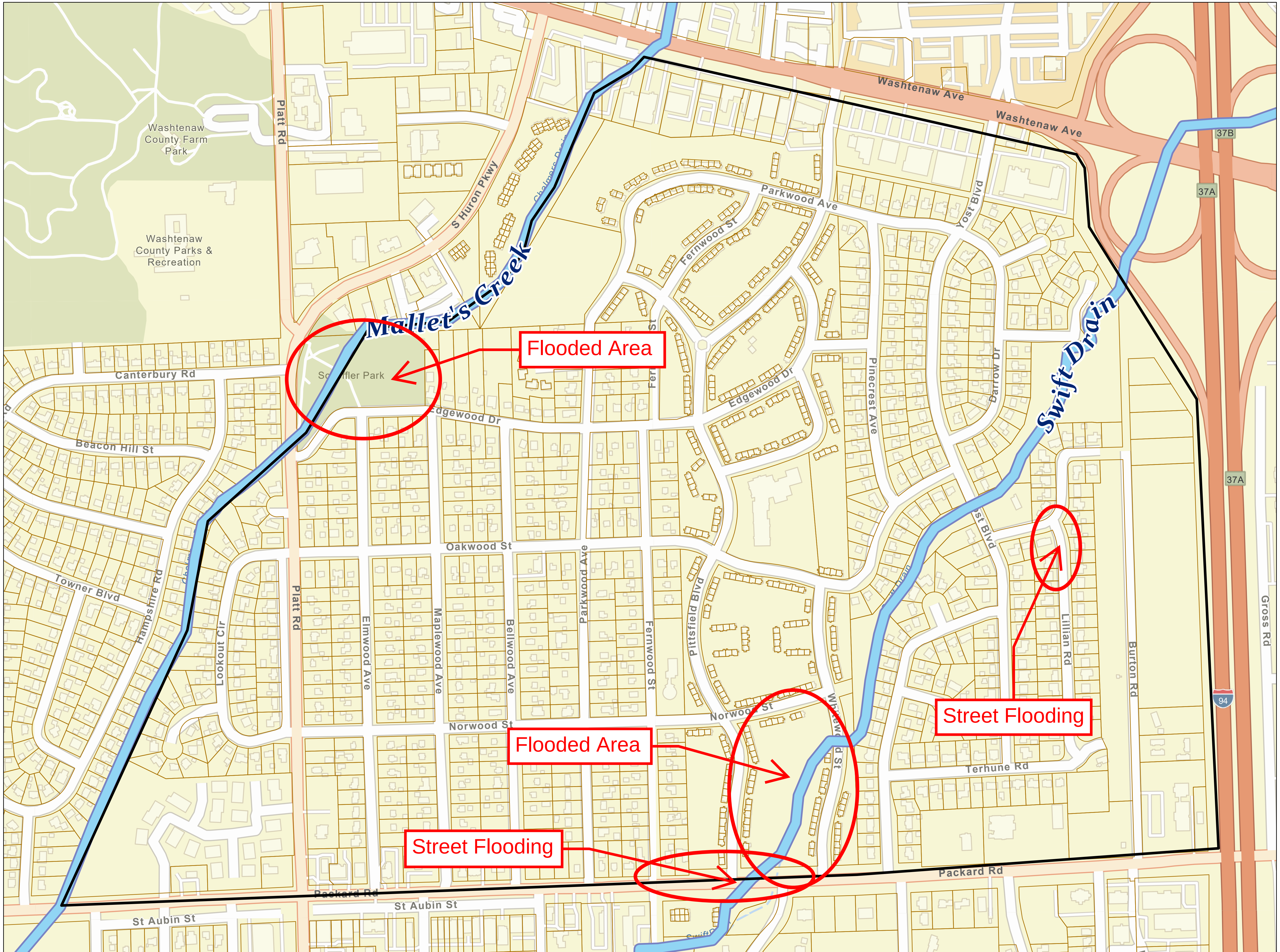
FEMA Info: www.a2gov.org/news/pages/article.aspx?i=810

City Claim Info: www.a2gov.org/departments/finance-admin-services/treasury/Pages/Filing-a-Claim-Against-the-City-.aspx

Appendix E

Ann Arbor Drains Within Project Area

Figure 1



Drains

Project Area

Ann Arbor Parcels

N

0 450 900

Feet

1" = 450'

Source: Data provided by Ann Arbor, OHM Advisors, and Esri. OHM Advisors does not warrant the accuracy of the data and/or the map. This document is intended to depict the approximate spatial location of the mapped features within the Community and all use is strictly at the user's own risk.

Coordinate System: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl

Map Published: February 1, 2022

OHM

June Storm Event Survey

The City of Ann Arbor is working with their engineering consultant, OHM Advisors, to conduct a study related to the June 25-26, 2021 rain event that resulted in numerous reports of flooding and basement backups throughout Washtenaw and Wayne Counties, including portions of the City of Ann Arbor.

The City of Ann Arbor would like to hear from you, and other project area neighbors, about your experiences during the June storm event. Please use this form to share your experiences by **November 5, 2021**. We expect this will take 10-15 minutes to complete.

Additional background, including presentation slides and a recording of the September 1st and 8th public discussions on this topic, is available at a2gov.org/JuneStorm (http://a2gov.org/JuneStorm).

* Required

1. Do you have a basement?

   ◯ Yes

   ◯ No

2. Did you experience flooding in your home?

   ◯ No

   ◯ Yes

3. Where was the water coming from?

4. How much water (depth) did you have in your home? Please provide the water depth in inches.

5. Did you have water in your basement?

- ◯ Yes
- ◯ No

6. If you had water in your basement, check all that apply:

- ☐ Water was coming from inside the house
- ☐ Water was coming from outside the house
- ☐ Water was coming from walls/windows
- ☐ Water was backing up from a floor drain or sump pump
- ☐ Unsure of where water was coming from

7. If water was coming from outside the house, describe the flooding that occurred.

8. How much water (depth) did you have in the basement? Please provide the water depth in inches.

9. How long was water pooled in the basement?

- ◯ Less than 1 hour
- ◯ 1-2 hours
- ◯ 2-4 hours
- ◯ 4-6 hours
- ◯ 6-8 hours
- ◯ Over 8 hours
- ◯ Unsure

10. Did you experience surface flooding near your home (yard, street, etc.)?

- ◯ Yes
- ◯ No

11. Where did the flooding occur?

- ☐ Your street
- ☐ Your yard
- ☐ Against the home
- ☐ Other

12. How long was water pooled in the area(s) near your home?

- ◯ Less than 1 hour
- ◯ 1-2 hours
- ◯ 2-4 hours
- ◯ 4-6 hours
- ◯ 6-8 hours
- ◯ Over 8 hours
- ◯ Unsure

13. Describe the flooding that occurred.

14. Did you witness flooding in areas not near your home (creeks, streets, open areas, etc.)?

- ◯ Yes
- ◯ No

15. Did you witness flooding in any of the following areas? Check all that apply:

- ☐ Creeks
- ☐ Streets
- ☐ Open Areas
- ☐ I did not witness flooding in any of these areas
- ☐ Other

16. How long was water pooled in these areas?

- ◯ Less than 1 hour
- ◯ 1-2 hours
- ◯ 2-4 hours
- ◯ 4-6 hours
- ◯ 6-8 hours
- ◯ Over 8 hours
- ◯ Unsure

17. Describe the flooding that occurred.

18. Did you see water/sewage flow coming out of any manholes onto the ground surface?

- ◯ Yes
- ◯ No

19. Where were these manholes located? Please provide addresses or intersections.

20. Did you lose power?

- ◯ Yes
- ◯ No

21. What was the time frame that the power was out?

22. Do you have a sump pump?

- Yes
- No

23. Did your sump pump operate during the June 25-26, 2021 rain event?

- Yes
- No
- I don't know

24. Where does the sump pump discharge (on lawn, into a pipe, etc.)?

25. When was the sump pump installed?

26. Do you have a check valve* installed on your sanitary sewer service line?

*A check valve is a valve installed on a sewer line that opens to allow sewage to flow out, but then closes to prevent sewage from flowing in the reverse direction (backing up into the building).

- ◯ Yes
- ◯ No
- ◯ I don't know

27. When was the check valve installed?

28. Has this home experienced basement backups or flooding before?

- ◯ Yes
- ◯ No
- ◯ I don't know

29. When was the last time this home experienced a basement backup or flooding?

30. How much water (depth) was in the home or basement the last time this home experienced a basement backup or flooding?

31. Please provide any additional comments related to the June storm event.

32. Would you like to meet or have a phone call with the City and OHM Advisors to further discuss your flooding experiences? If so, please provide your contact information in the question below.

- ◯ Yes - Meet
- ◯ Yes - Phone Call
- ◯ No

33. Please provide your address so we can associate your responses with your location within the storm and sanitary sewer systems. *

34. Please provide the following contact information for follow-up as needed (email addresses provided will be subscribed to receive project updates - you will have the option to unsubscribe).
Name
Address
Phone Number
Email Address *

Forms(https://www.office.com/launch/forms?auth=2)

June Storm Event Survey

57
Responses

09:10
Average time to complete

Active
Status

1. Do you have a basement?

Insights

Yes	50
No	5

2. Did you experience flooding in your home?

Yes	4
No	1

3. Where was the water coming from?

4
Responses

Latest Responses

4. How much water (depth) did you have in your home? Please provide the water depth in inches.

3
Responses

Latest Responses

5. Did you have water in your basement?

Insights

Yes	35
No	15

6. If you had water in your basement, check all that apply:

Water was coming from inside...	3
Water was coming from outsi...	15
Water was coming from walls/...	5
Water was backing up from a f...	25
Unsure of where water was co...	4

7. If water was coming from outside the house, describe the flooding that occurred.

Insights

20

Responses

14 respondents (**70**%) answered **water** for this question.

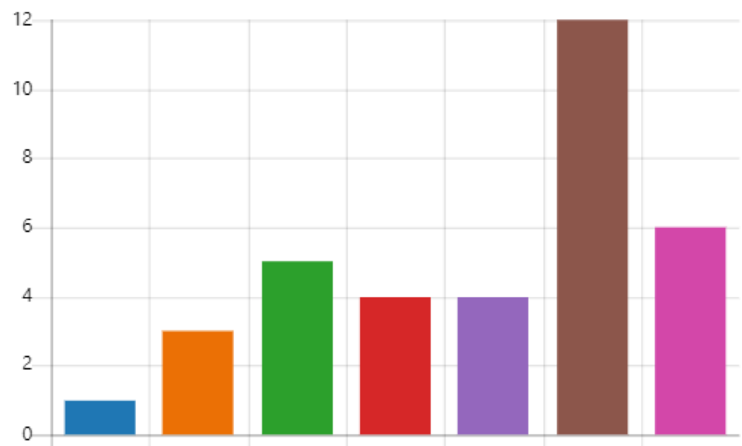
8. How much water (depth) did you have in the basement? Please provide the water depth in inches.

Insights
35
Responses

16 respondents (**47**%) answered **inches** for this question.

9. How long was water pooled in the basement?

Less than 1 hour	1
1-2 hours	3
2-4 hours	5
4-6 hours	4
6-8 hours	4
Over 8 hours	12
Unsure	6



10. Did you experience surface flooding near your home (yard, street, etc.)?

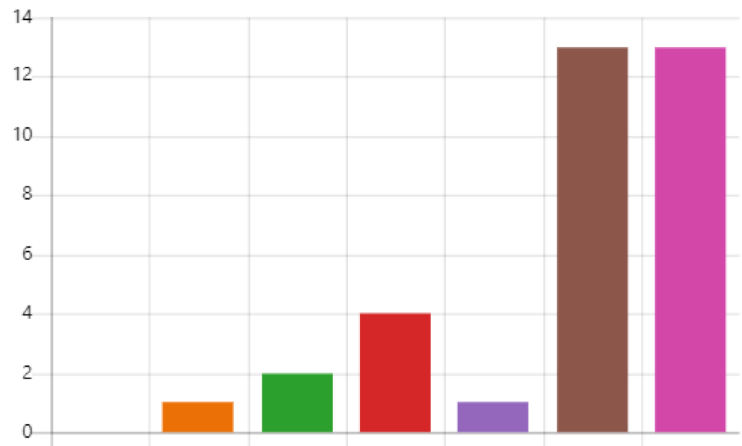
Yes	34
No	21

11. Where did the flooding occur?

Your street	14
Your yard	28
Against the home	9
Other	5

12. How long was water pooled in the area(s) near your home?

Less than 1 hour	0
1-2 hours	1
2-4 hours	2
4-6 hours	4
6-8 hours	1
Over 8 hours	13
Unsure	13



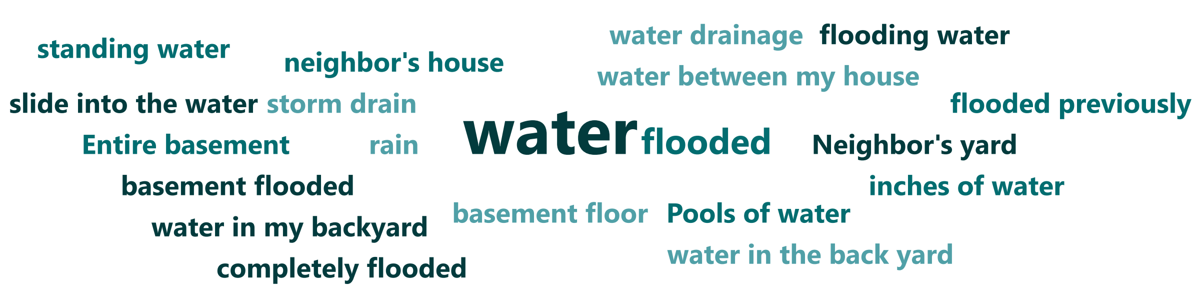
13. Describe the flooding that occurred.

30 Insights

Responses

Latest Responses

22 respondents (**73**%) answered **water** for this question.



14. Did you witness flooding in areas not near your home (creeks, streets, open areas, etc.)?

Insights

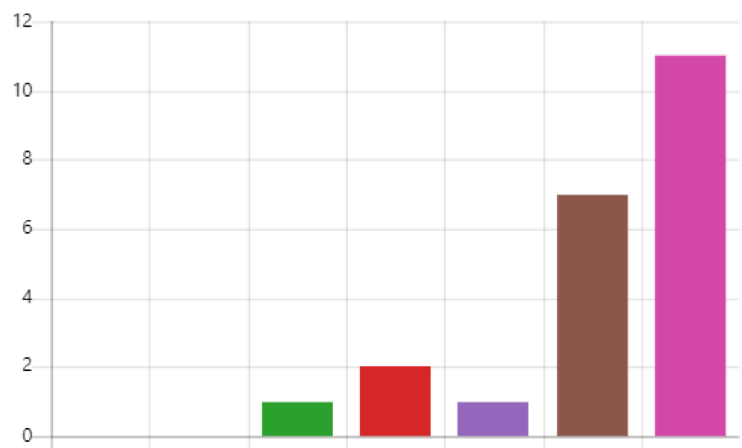
Yes	22
No	33

15. Did you witness flooding in any of the following areas? Check all that apply:

Creeks	10
Streets	15
Open Areas	18
I did not witness flooding in a...	0
Other	0

16. How long was water pooled in these areas?

Less than 1 hour	0
1-2 hours	0
2-4 hours	1
4-6 hours	2
6-8 hours	1
Over 8 hours	7
Unsure	11



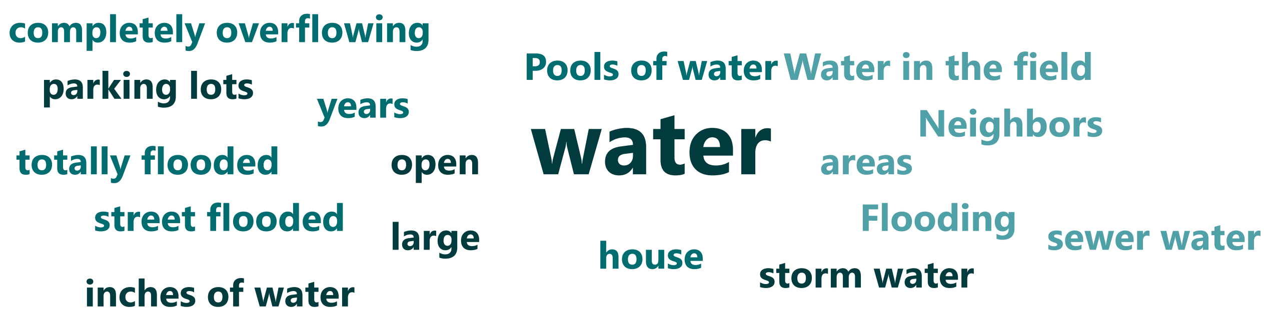
17. Describe the flooding that occurred.

16 Insights

Responses

Latest Responses

8 respondents (**50**%) answered **water** for this question.



18. Did you see water/sewage flow coming out of any manholes onto the ground surface?

Yes	2
No	50

19. Where were these manholes located? Please provide addresses or intersections.

2

Responses

Latest Responses

20. Did you lose power?

Insights

Yes	17
No	35

21. What was the time frame that the power was out?

Insights

17

Responses

10 respondents (**59**%) answered **hours** for this question.

22. Do you have a sump pump?

Insights

Yes	18
No	34

23. Did your sump pump operate during the June 25-26, 2021 rain event?

Yes	12
No	3
I don't know	3

24. Where does the sump pump discharge (on lawn, into a pipe, etc.)?

18 Insights

Responses

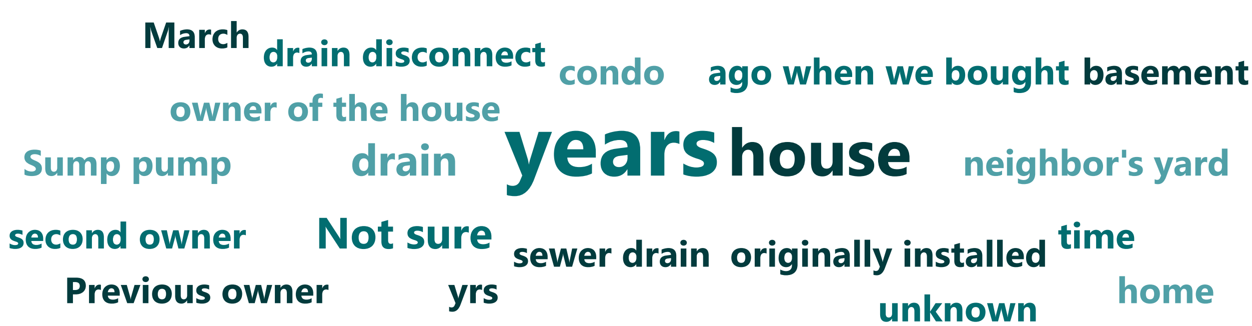
8 respondents (**47**%) answered **pipe** for this question.

25. When was the sump pump installed?

18 Insights

Responses

4 respondents (**24**%) answered **years** for this question.



26. Do you have a check valve* installed on your sanitary sewer service line?

*A check valve is a valve installed on a sewer line that opens to allow sewage to flow out, but then closes to prevent sewage from flowing in the reverse direction (backing up into the building).

Insights

Yes	0
No	10
I don't know	42

27. When was the check valve installed?

0

Responses

Latest Responses

28. Has this home experienced basement backups or flooding before?

Insights

Yes	32
No	14
I don't know	6

29. When was the last time this home experienced a basement backup or flooding?

Insights

32

Responses

7 respondents (**23**%) answered **years ago** for this question.

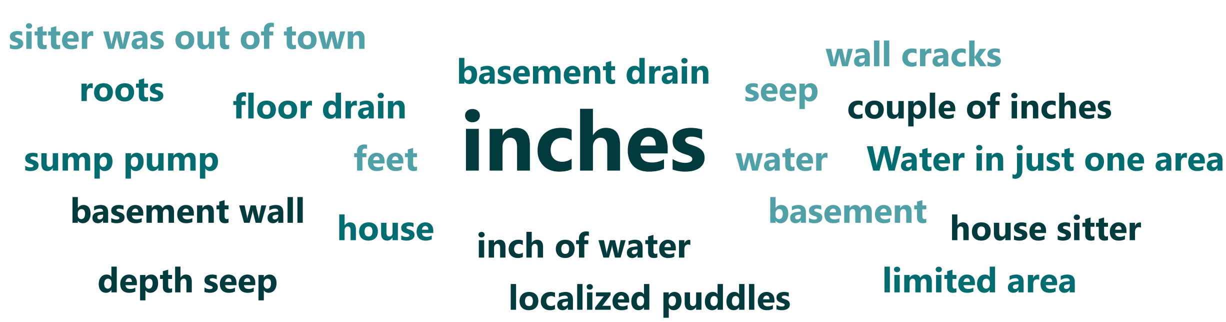
30. How much water (depth) was in the home or basement the last time this home experienced a basement backup or flooding?

Insights

32

Responses

14 respondents (**45**%) answered **inches** for this question.



31. Please provide any additional comments related to the June storm event.

21 Insights

Responses

11 respondents (**52**%) answered **water** for this question.

32. Would you like to meet or have a phone call with the City and OHM Advisors to further discuss your flooding experiences? If so, please provide your contact information in the question below.

Yes - Meet	4
Yes - Phone Call	10
No	36

33. Please provide your address so we can associate your responses with your location within the storm and sanitary sewer systems.

Insights

24

Responses

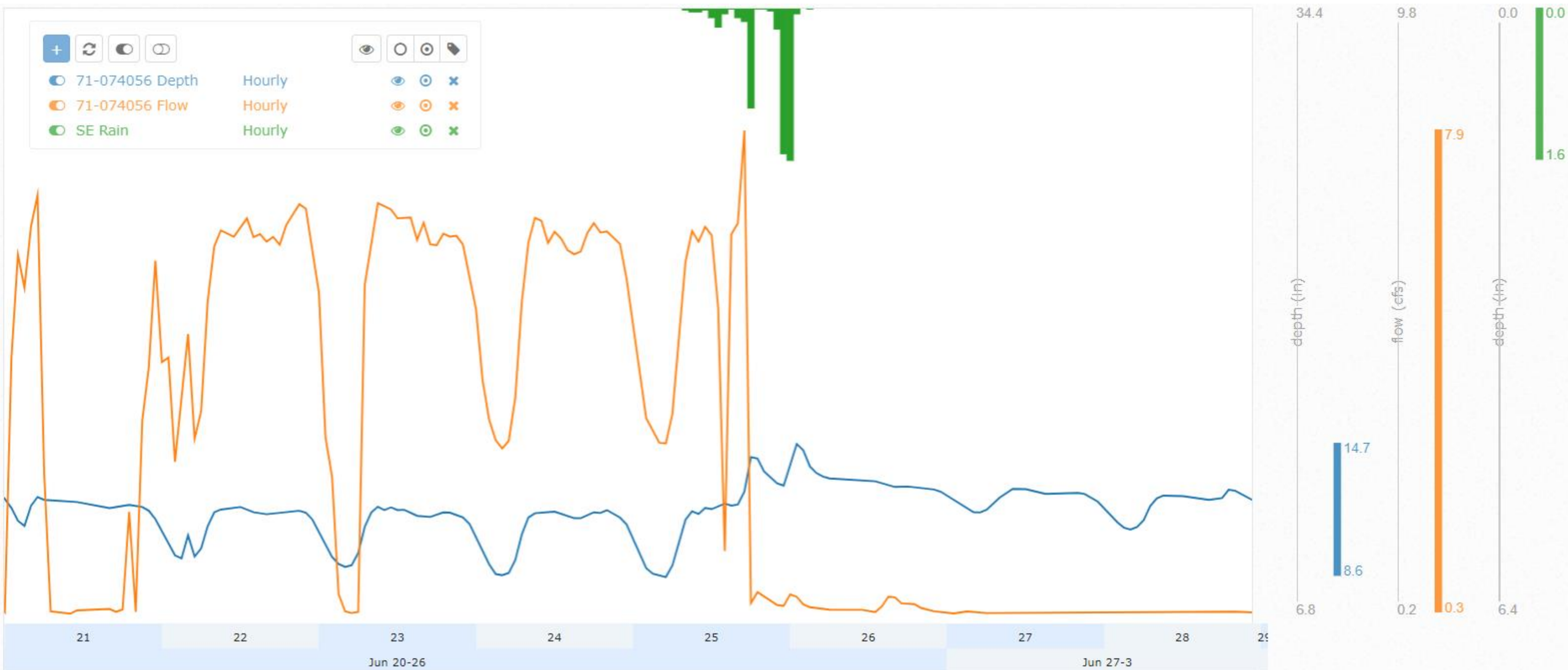
34. Please provide the following contact information for follow-up as needed (email addresses provided will be subscribed to receive project updates - you will have the option to unsubscribe).
Name
Address
Phone Number
Email Address

Insights

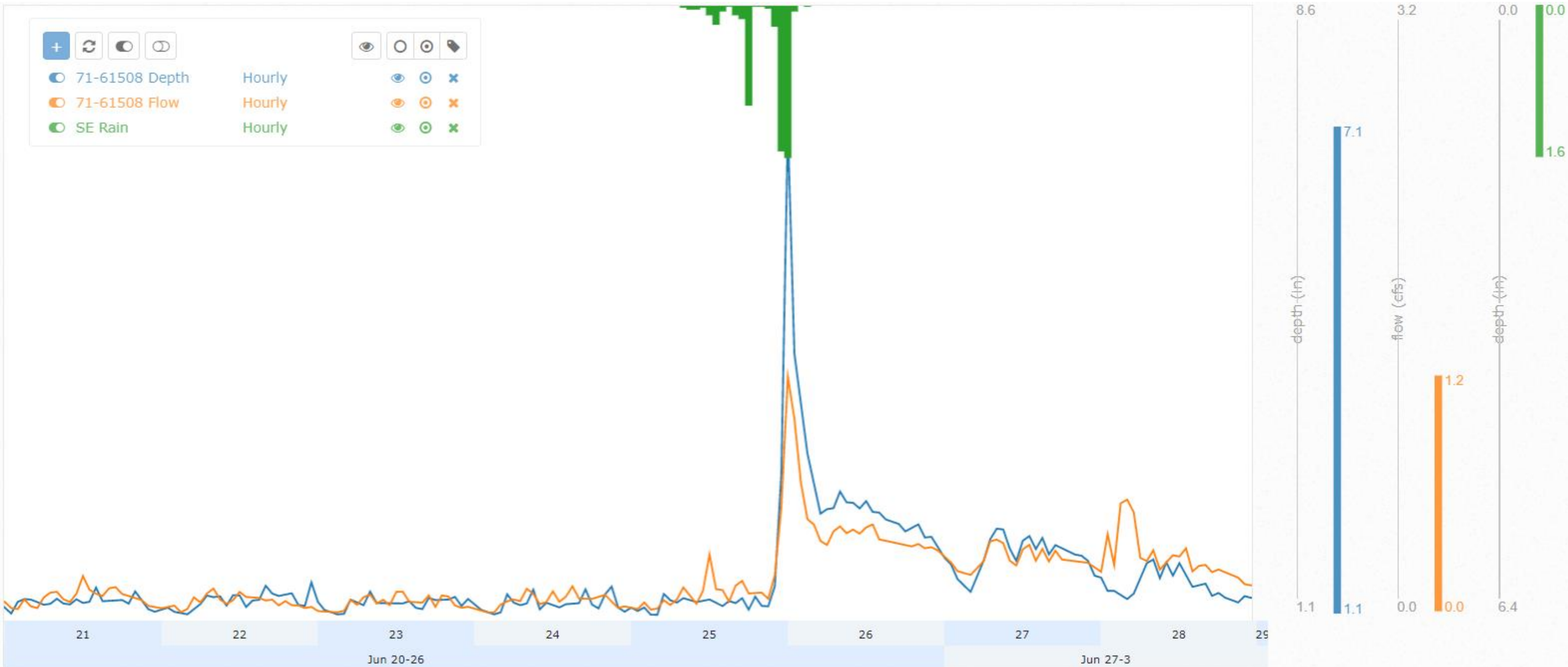
46
Responses

Appendix F

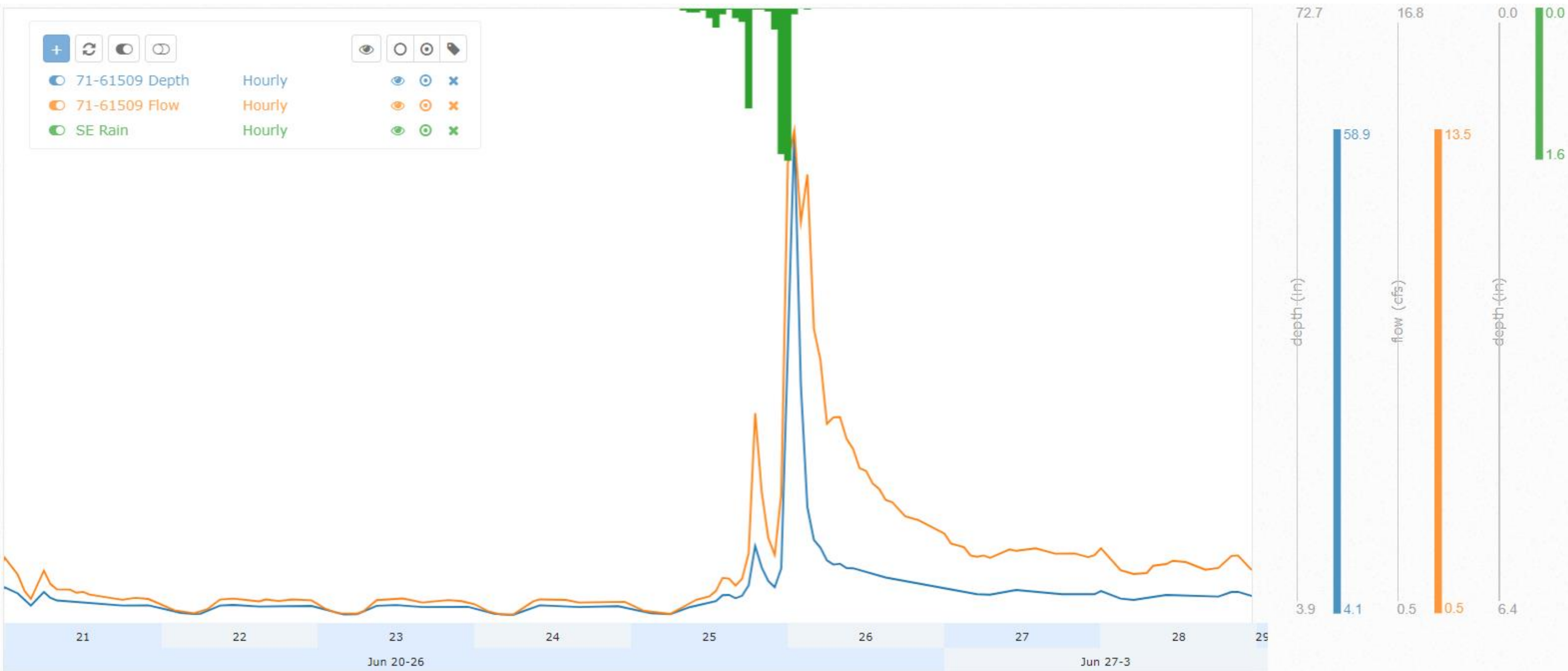
Flow Meter 71-074056



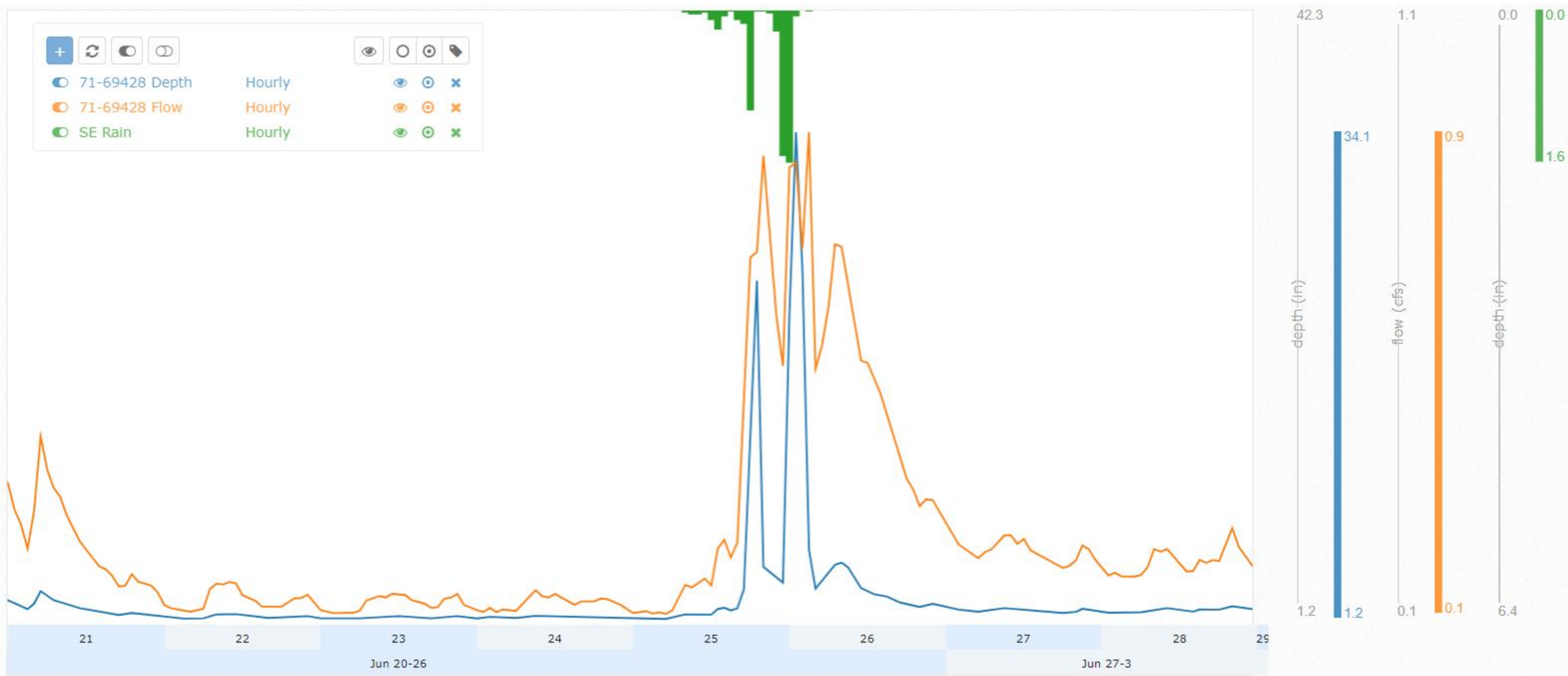
Flow Meter 71-61508



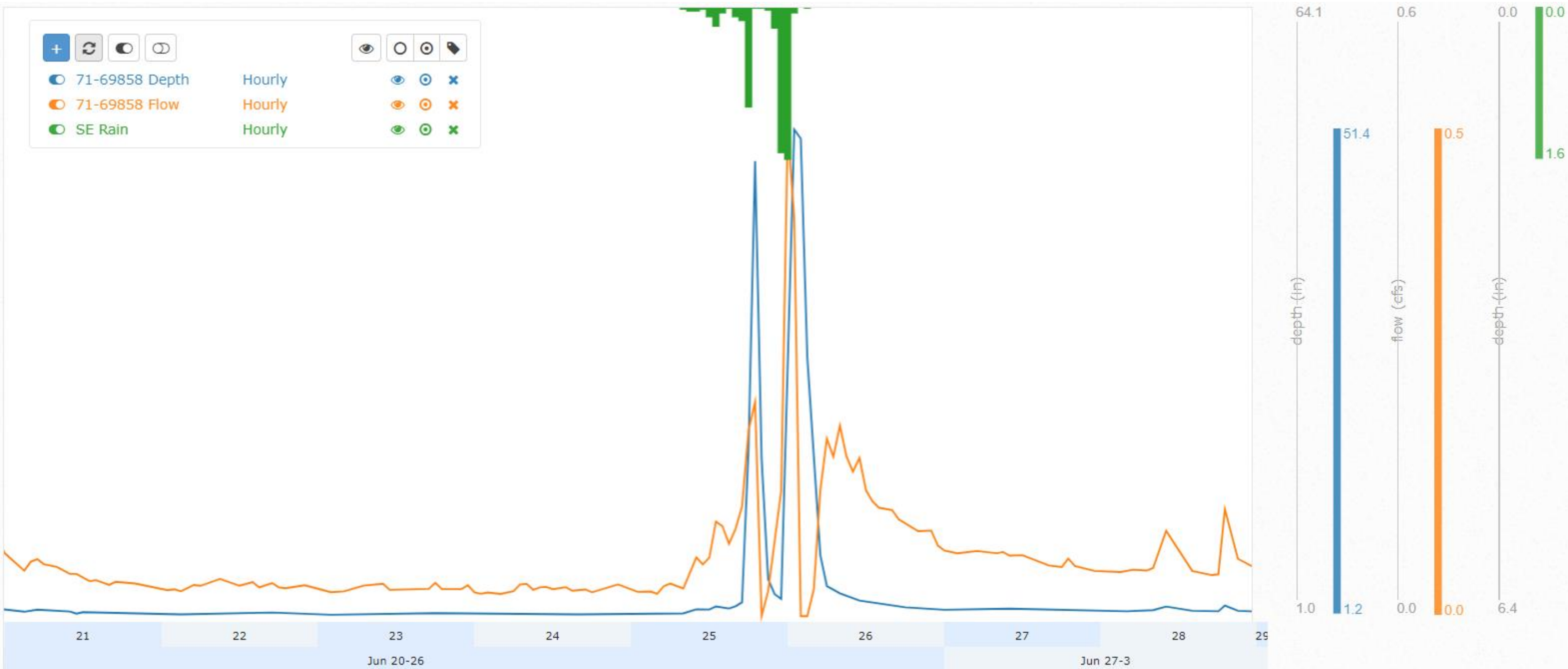
Flow Meter 71-61509



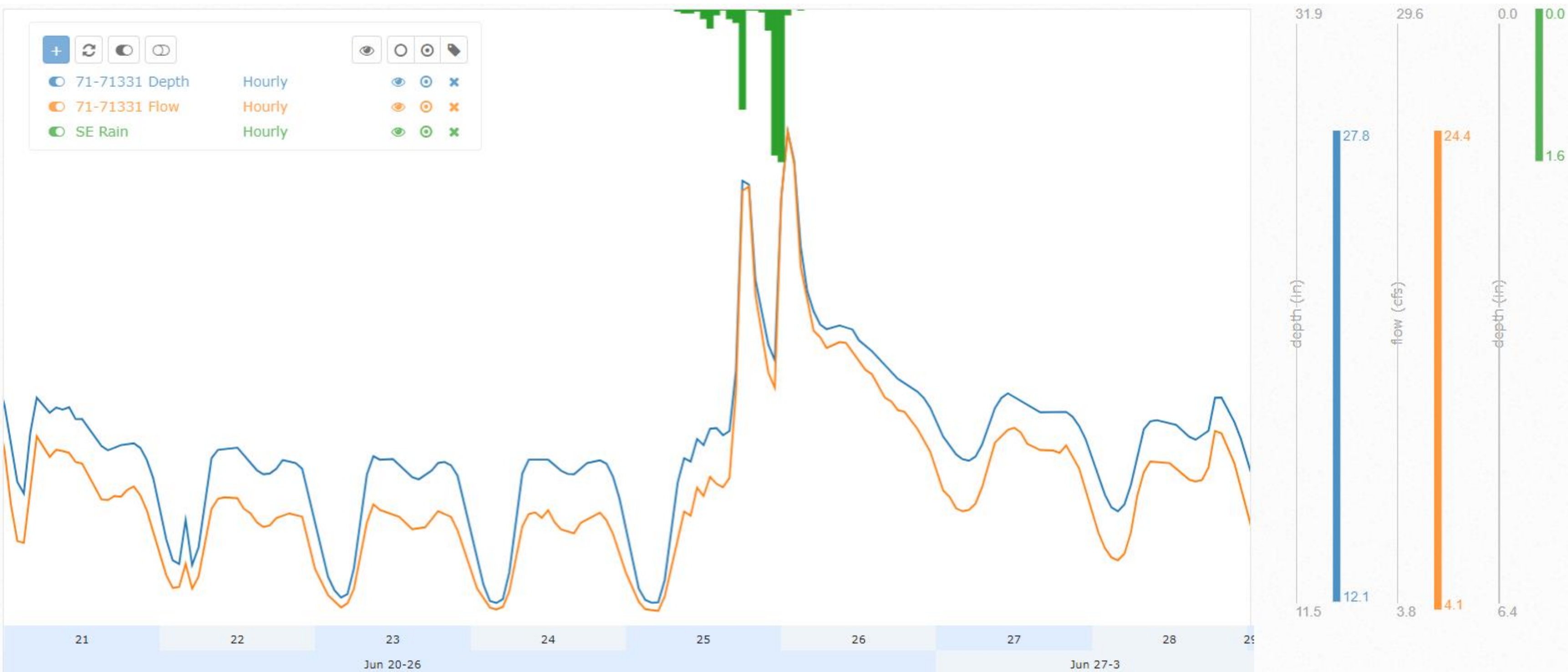
Flow Meter 71-69428



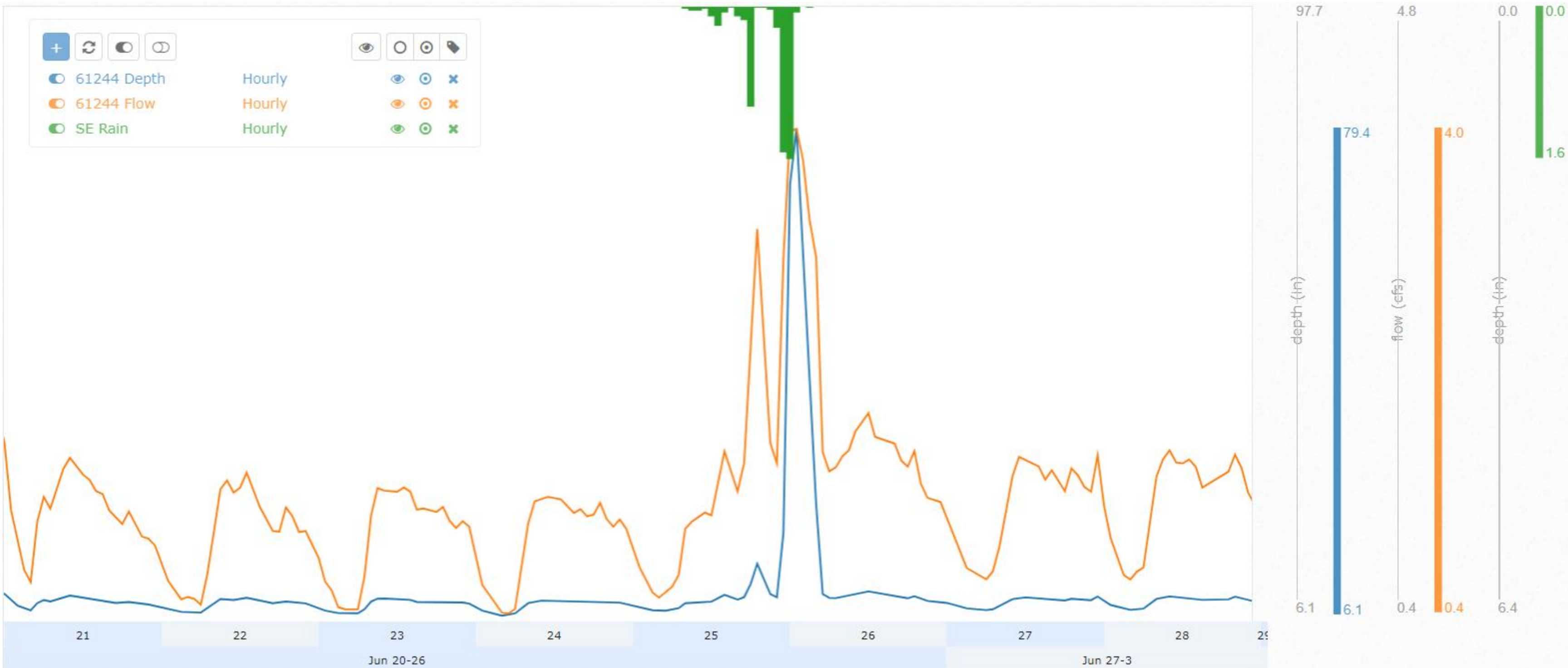
Flow Meter 71-69858



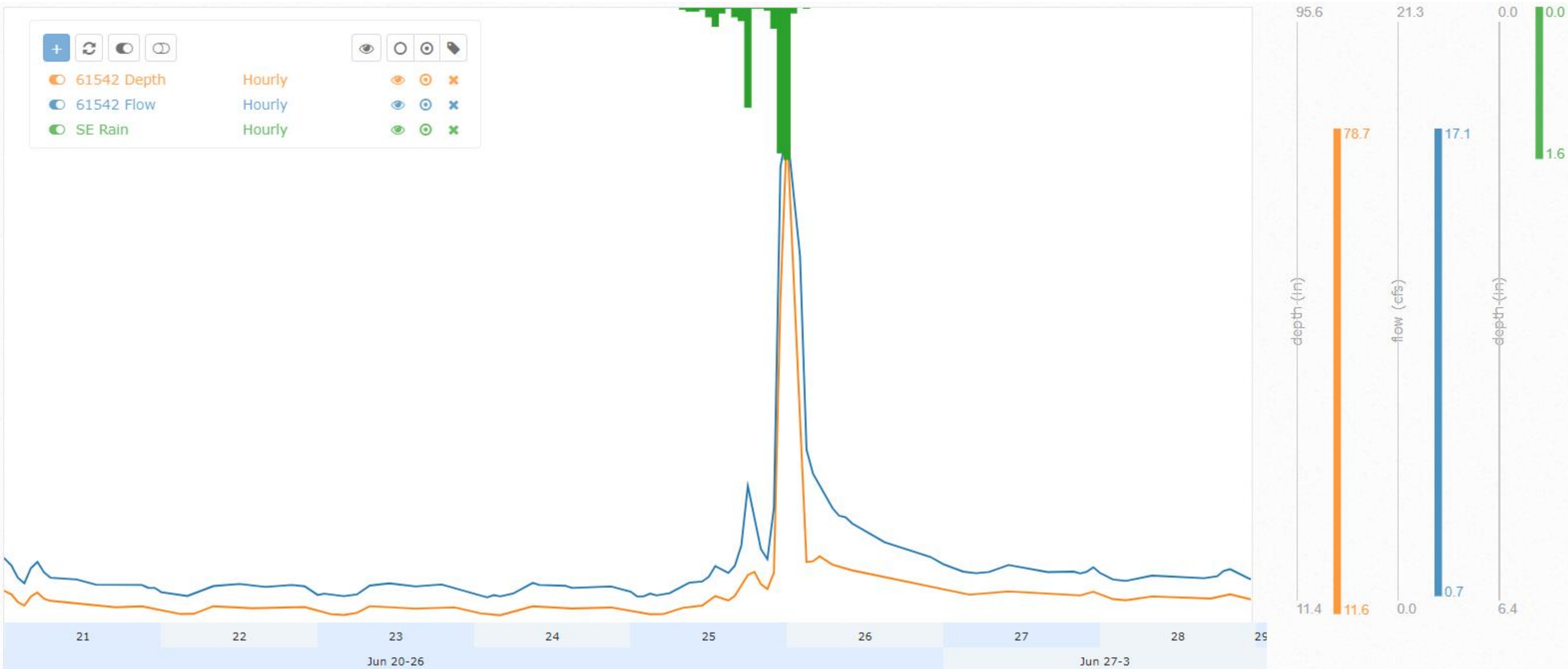
Flow Meter 71-71331



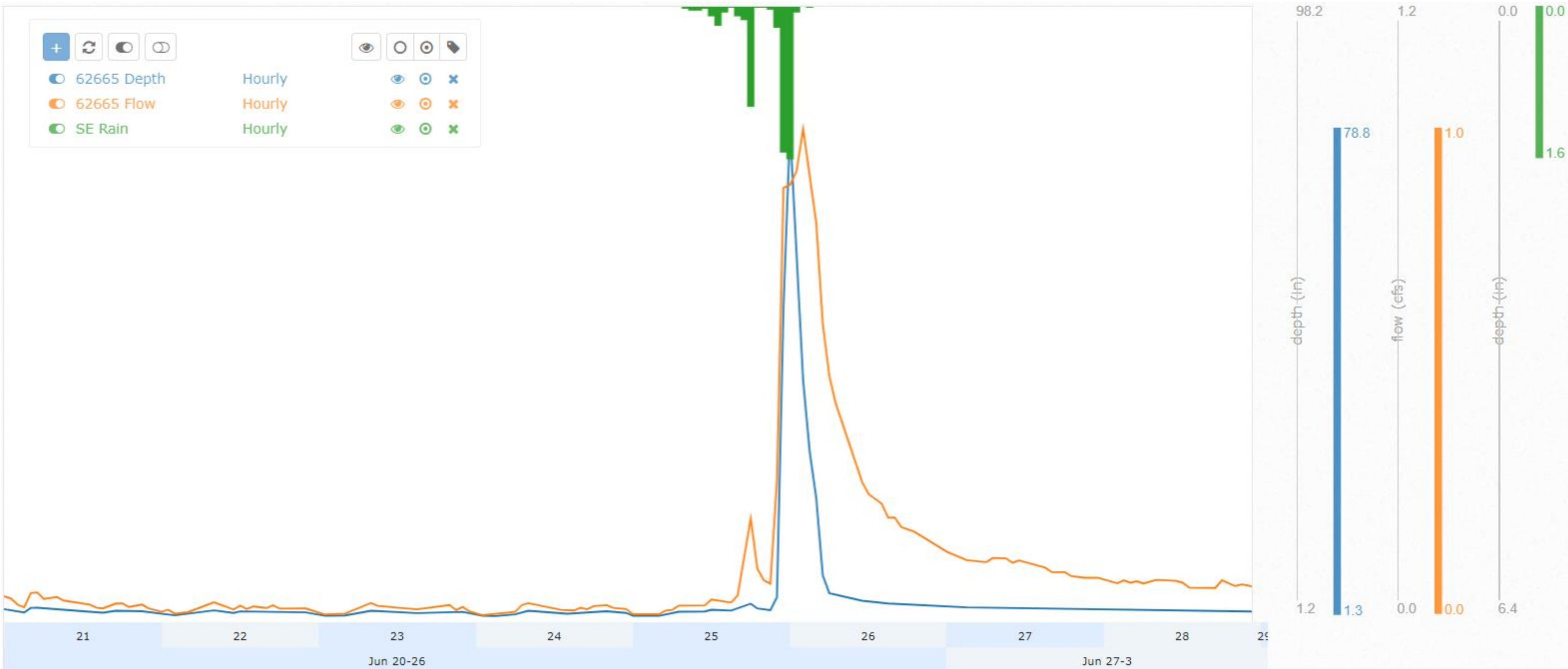
Flow Meter 71-61244



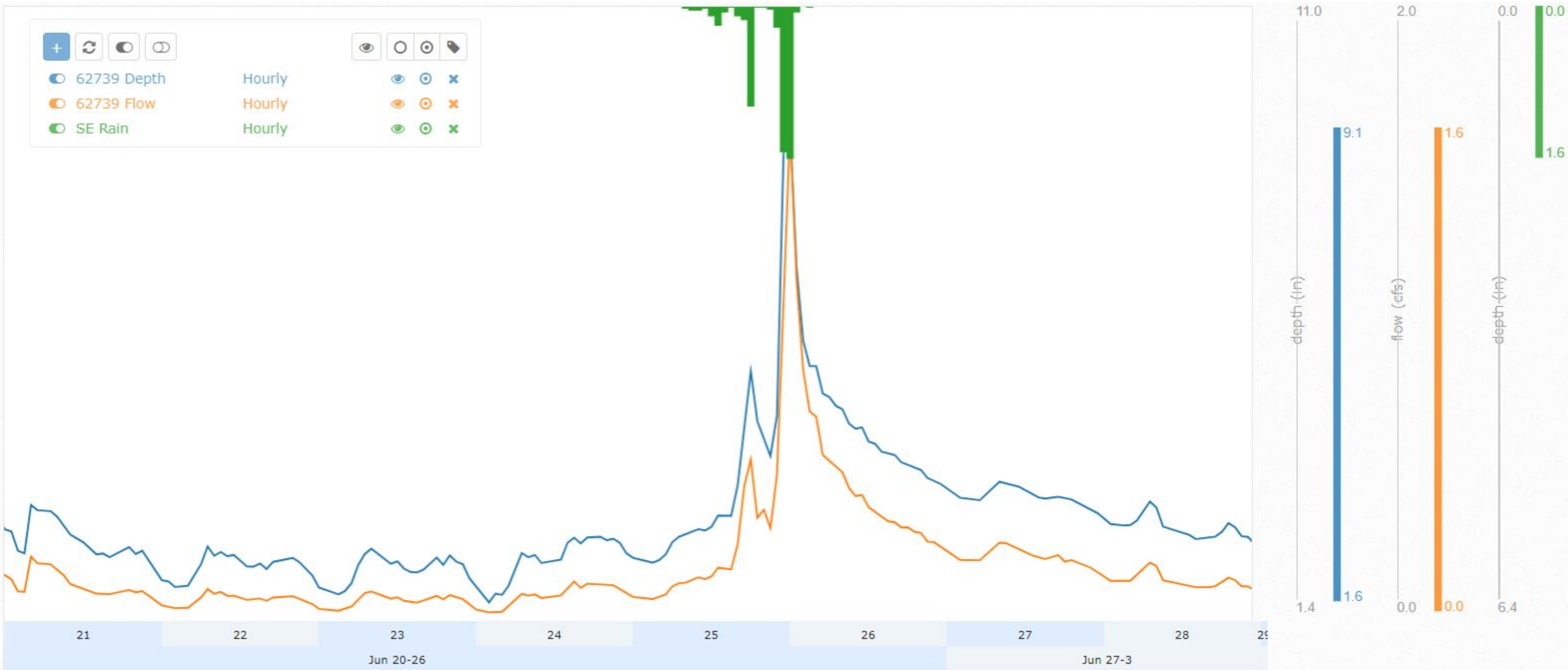
Flow Meter 71-61542



Flow Meter 71-62665



Flow Meter 71-62739



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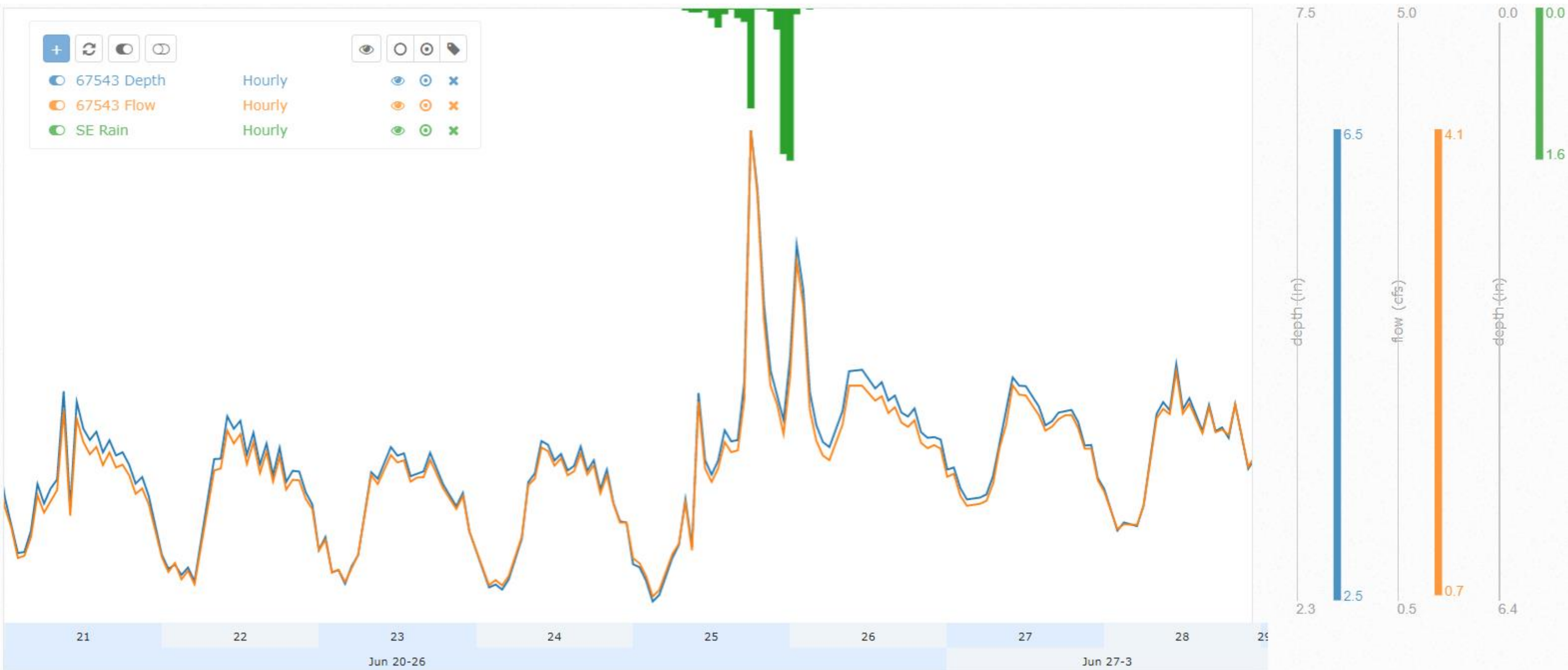

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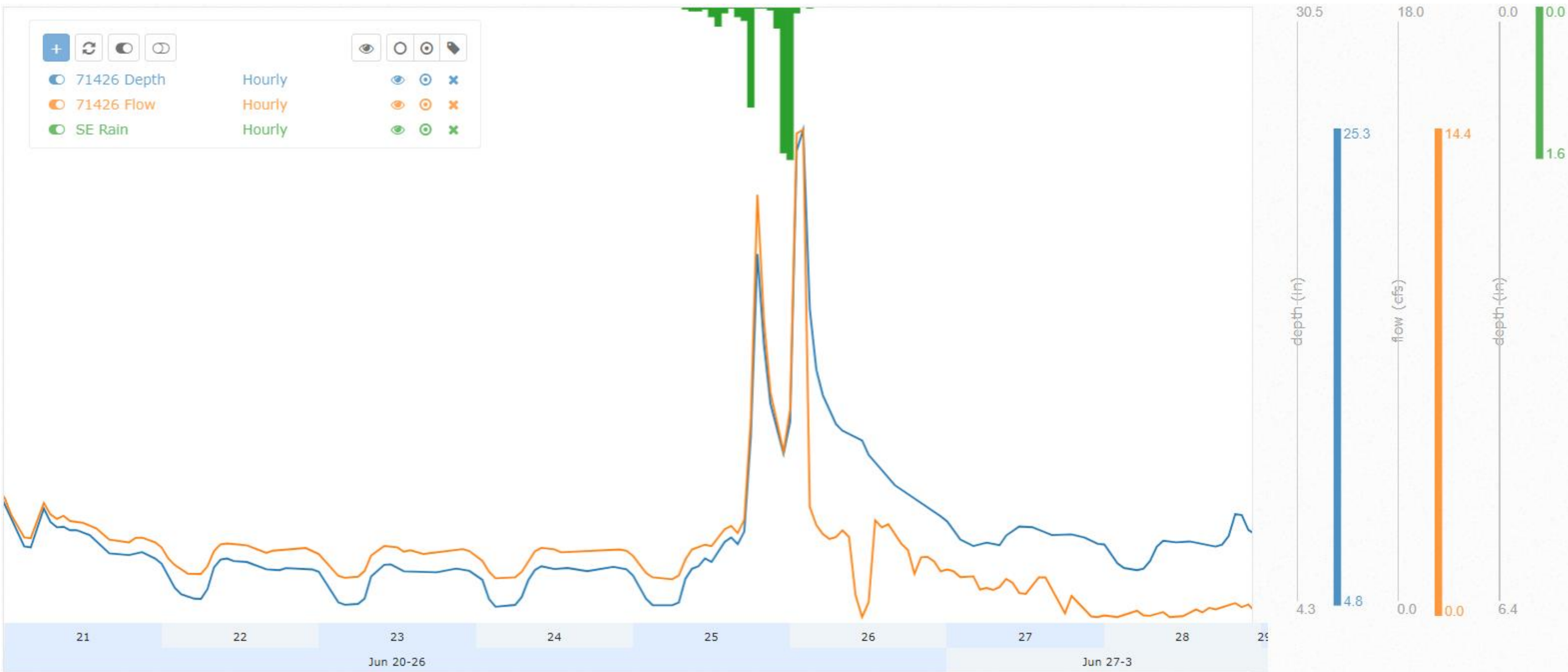
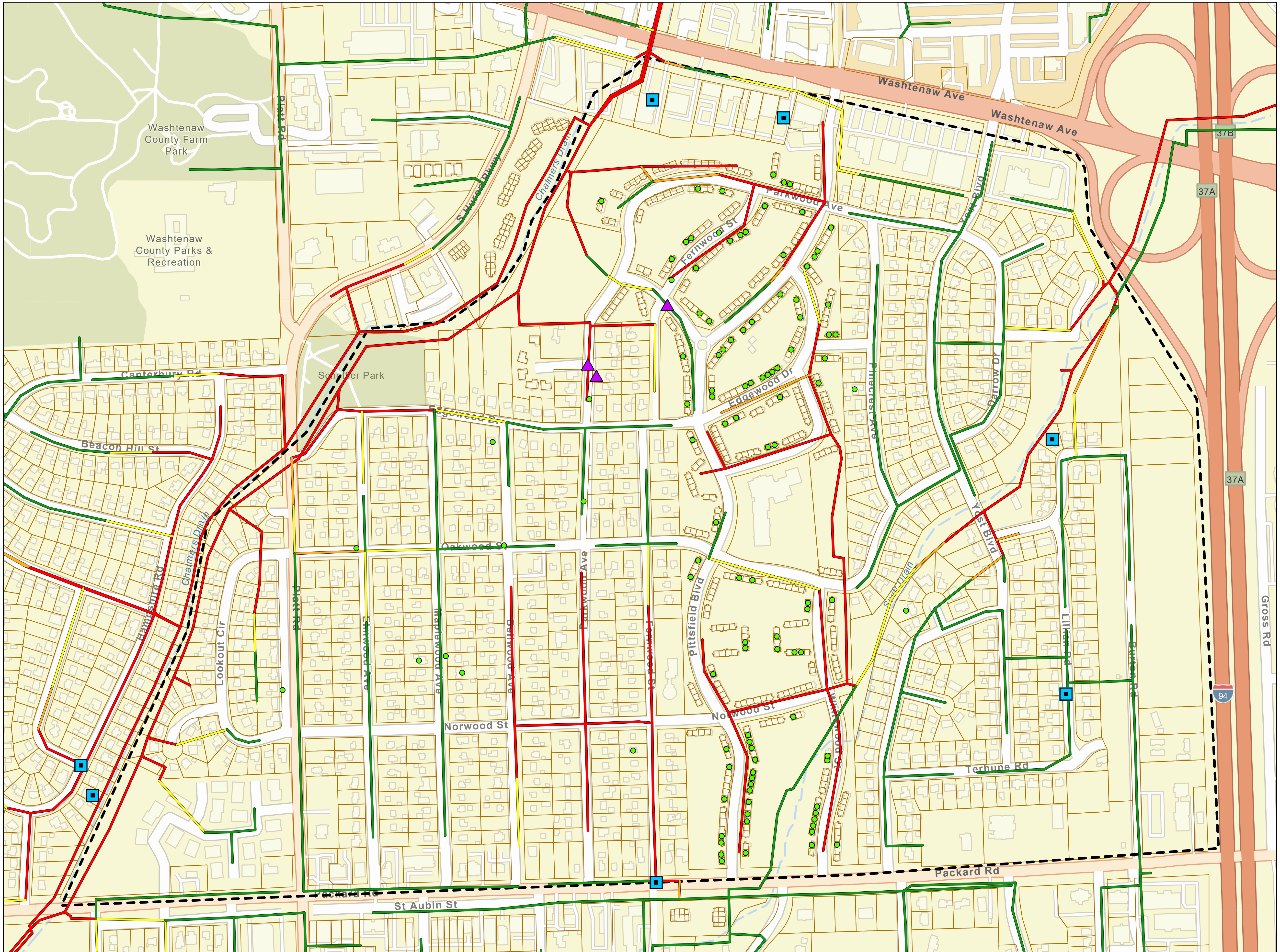


Appendix G



Ann Arbor Sanitary Sewer Capacity

Figure 1

Pipe Capacity

- Less than 50% Full
- 50% - 80% Full
- 80% - 99% Full
- Greater than 99% Full
- Street/Yard Flooding
- Reported Sewer Backups
- City Sewer Backups
- Project Area
- Ann Arbor Parcels

N

0 450 900

Feet

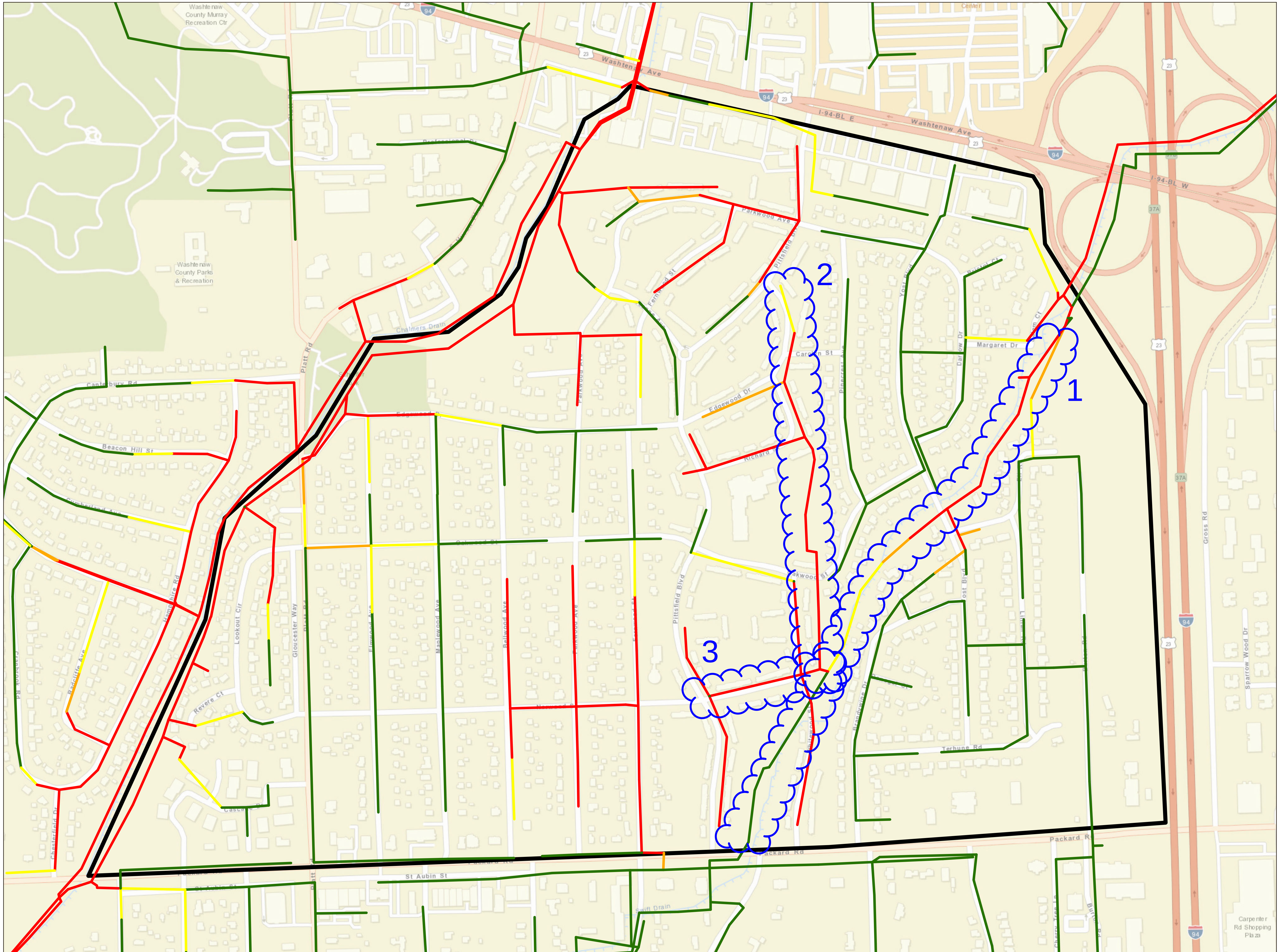
1″ = 450′

Source: Data provided by Ann Arbor, OHM Advisors, and Esri. OHM Advisors does not warrant the accuracy of the data and/or the map. This document is intended to depict the approximate spatial location of the mapped features within the Community and all use is strictly at the user's own risk.

Coordinate System: NAD 1983 StatePlane Michigan South FIPS 2113 Feet Intl

Map Published: February 7, 2022

OHM



City of Ann Arbor Michigan

City of Ann Arbor

Hydraulic Profile Locations

Legend

Pipe Capacity

- Less than 50% Full
- 50% - 80% Full
- 80% - 99% Full
- Greater than 99% Full
- Project Area
- Numbered based on order of subsequent hydraulic profiles

N

0 500 1,000
Feet

1″ = 483′

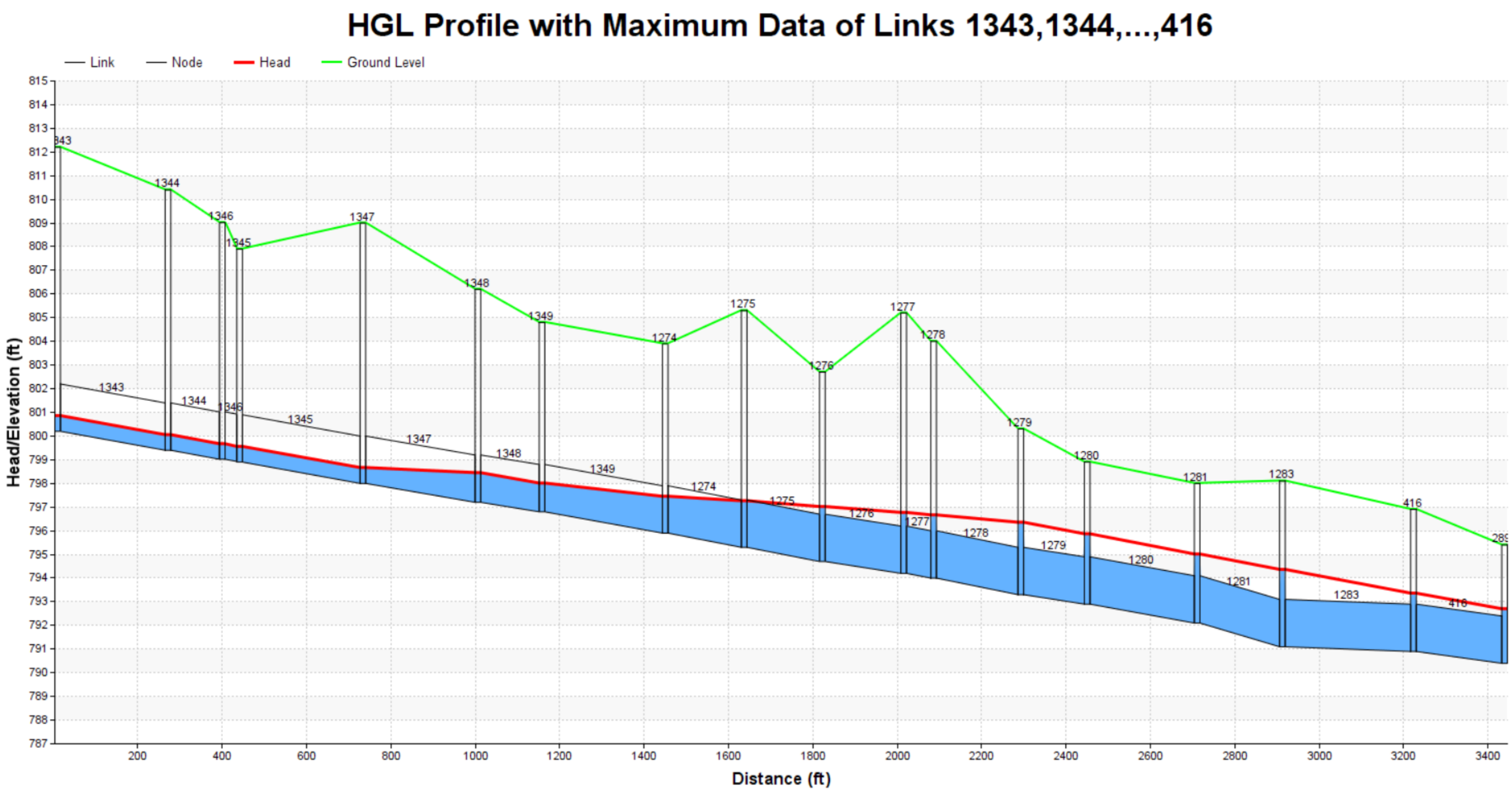
Source: Data provided by /INSERT DATA SOURCE\. OHM Advisors does not warrant the accuracy of the data and/or the map. This document is intended to depict the approximate spatial location of the mapped features within the Community and all use is strictly at the user's own risk.

Coordinate System: NAD 1983 StatePlane Michigan South FIPS 2113 Feet

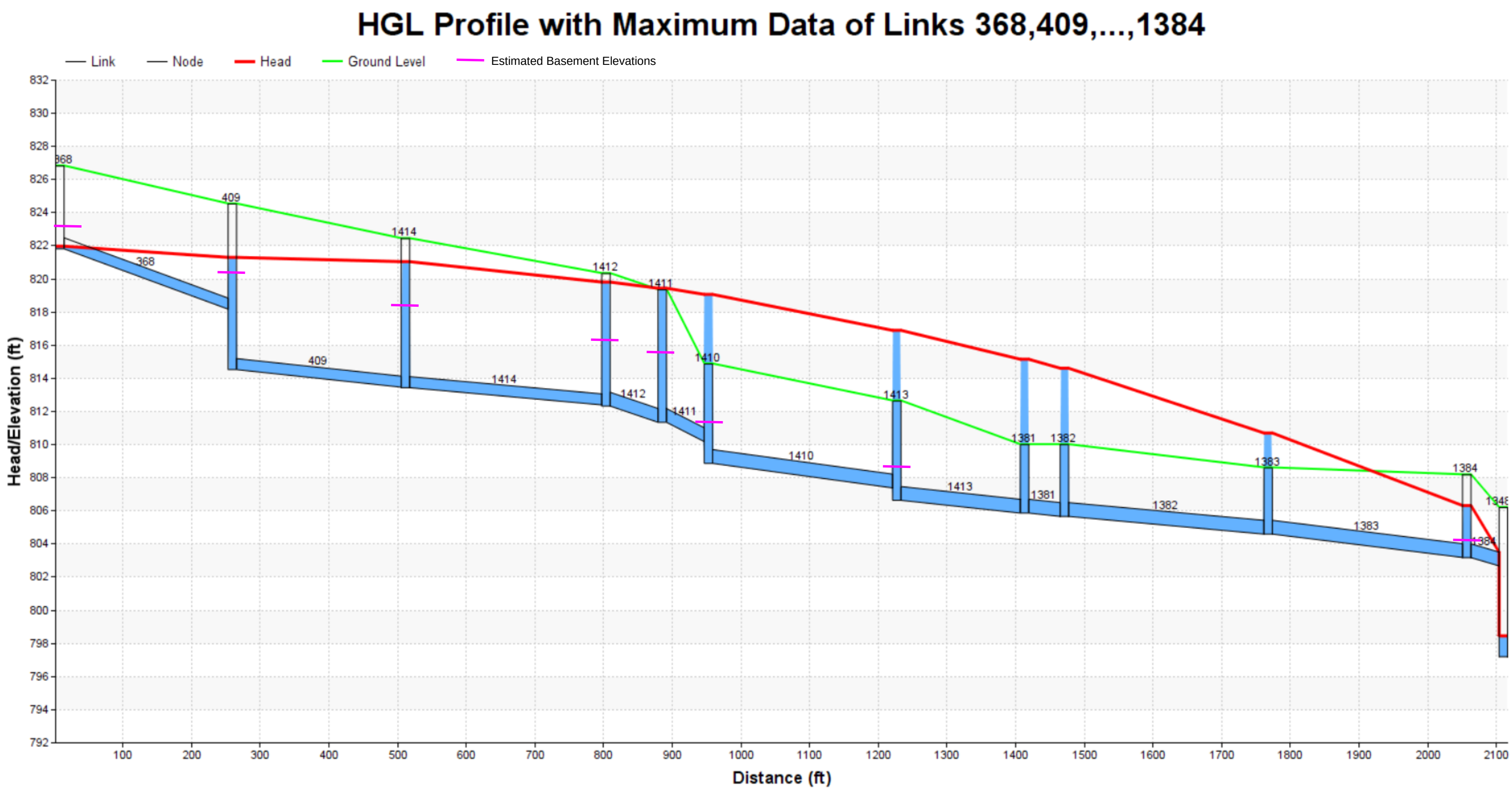
Map Published: January 26, 2022

OHM

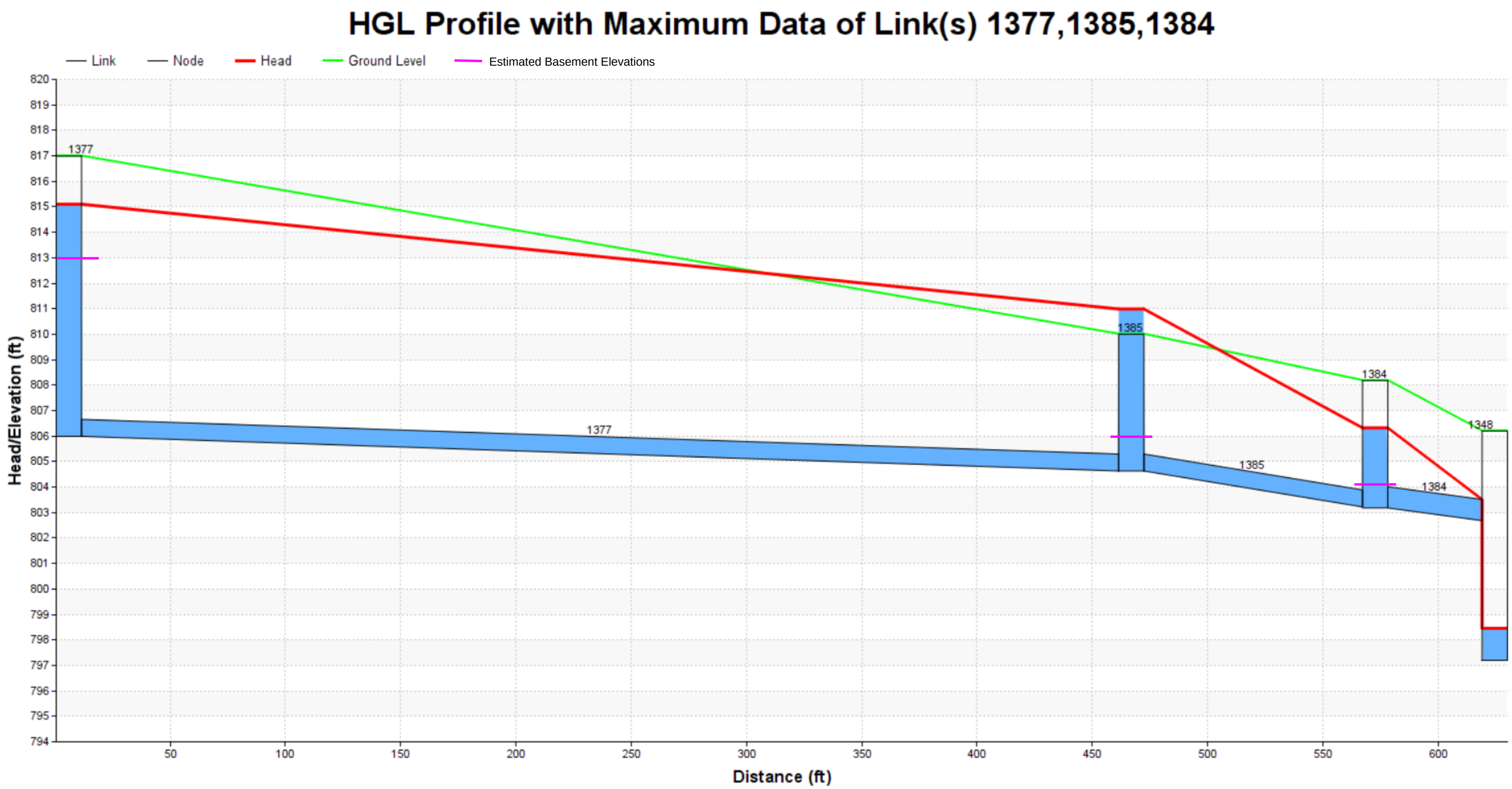
Model Results – Hydraulic Profiles with Added Flow



1. **Along Swift Run (from Packard to M-23/I-94 Interchange)**



2. Whitewood (from Pittsfield to Norwood)



3. Norwood (from Pittsfield to Swift Run)

Appendix H

What can residents do now to reduce the risk of basement flooding?

Around the House

Top priority:

- Ensure soil is graded (sloped) away from the house. Ensure there are no low spots or areas that trap water within 10 feet of the basement foundation. It is imperative that water is drained away from the foundation of the home.

Other important items:

- Downspouts should be extended away from the house.
- Ensure gutter system is working correctly. Identify where and how it is discharging to ensure water is draining away from the foundation.
- If there are external stairwells or basement egress windows, consider covering or enclosing them to ensure surface water is not entering. This water will go directly into the footing drains around the home. External stairwells often have drains in the bottom. If the drain clogs with leaves or debris, water will back up at the bottom, breach the threshold, and enter the basement.

- Perform a camera inspection of the sanitary sewer lead/lateral. If roots, cracks, offsets, etc. are identified, replace or line the service lateral to limit infiltration into the system as well as prevent backups. The sanitary lead for the home includes the tap into the City of Ann Arbor's sanitary sewer main.

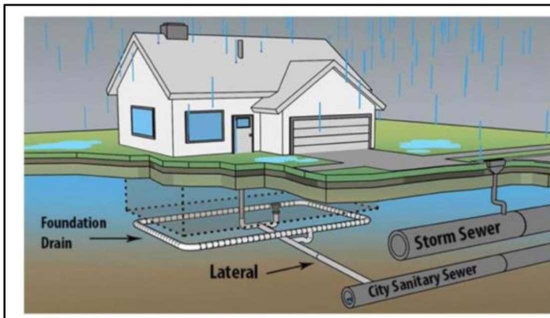
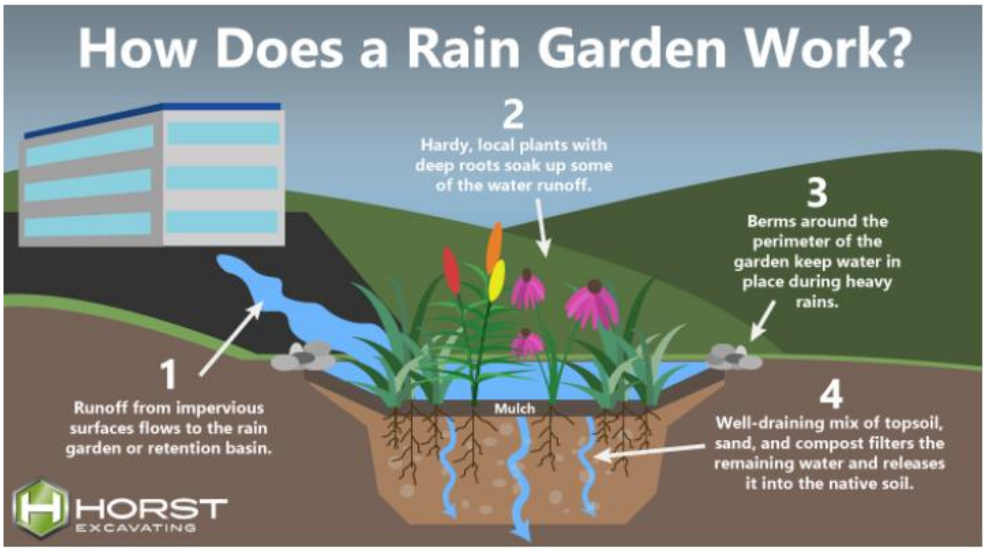


Image Credit: Milwaukee Metropolitan Sewerage District

Items that will help the overall system:

- Direct water from poorly drained surfaces to grassy or landscaped areas to allow the water to soak into the ground before running off the property.
- If possible, treat the runoff water with rain gardens or other stormwater treatments. Install rain gardens in as many places as possible, both on the property and in the right of way.

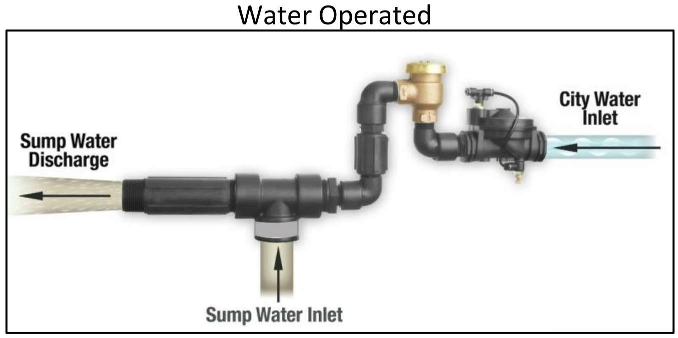


In the Basement

Sump pump items:

- Backup the sump pump with a battery or other backup system (water operated, second pump system at a higher point, extra pump ready, and/or generator for home, etc.).

Water Operated



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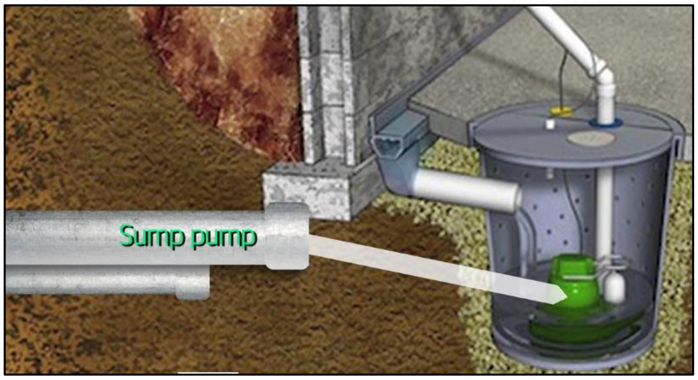
- Maintain sump systems and test them at least twice a year.



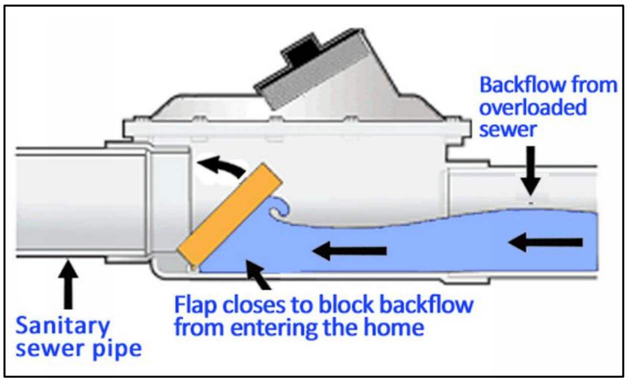
- If there is no backup for the sump pump, consider the next pump and check valve assembly being present next to the sump for quick replacement in the case of failure.
- Install a water alarm in the basement at the lowest point. Consider installing a second water alarm in the sump basin or footing drain cleanout.

- Install a generator system considering its ability to operate key parts of the home (sump, refrigerator, lights, etc.). This can be a key function during extended power outages.

- Additional information regarding basements and sump pumps can be found here: https://www.a2gov.org/departments/engineering/pages/basements-and-sump-pumps.aspx

Other basement items:

- Ensure drains are accessible in the basement. Locate clean outs for the sanitary system and footing drains if present. Understand where the floor drains in the basement discharge for both the sanitary system and sump system.
- Ensure valuable items are stored in an elevated area or off the floor.
- Utilize plastic bins for storage.
- Avoid installing carpet in the basement. Consider using tile, removable flooring, and/or area rugs to minimize the cleanup effort and cost.
- Install a whole home check valve (swing or gate style). If installing, make sure footing drains are disconnected.



- Determine whether water in the basement is covered by insurance (rider). Ensure the different kinds of backups are covered as appropriate, including sanitary, footing drain, surface water, and municipal source leak.

Glossary:

Sump pump – A pump used to remove water that has accumulated in the basement.
Rain Garden – A rain garden, comprised of native plants and flowers, collects rain water from roofs, driveways, and streets and allows it to soak into the ground, reducing runoff from the property.
Check Valve/Backflow Preventor – Valve installed on a sewer line that opens to allow sewage to flow out, but then closes to prevent sewage from flowing in the reverse direction (backing up into the building).
Footing/Foundation Drain – Pipes that are installed under the building foundation or basement floor to collect water and drain it away from the building.
Sewer Lead/Lateral – A pipe that transports wastewater from the building's plumbing system to the public sewer main.