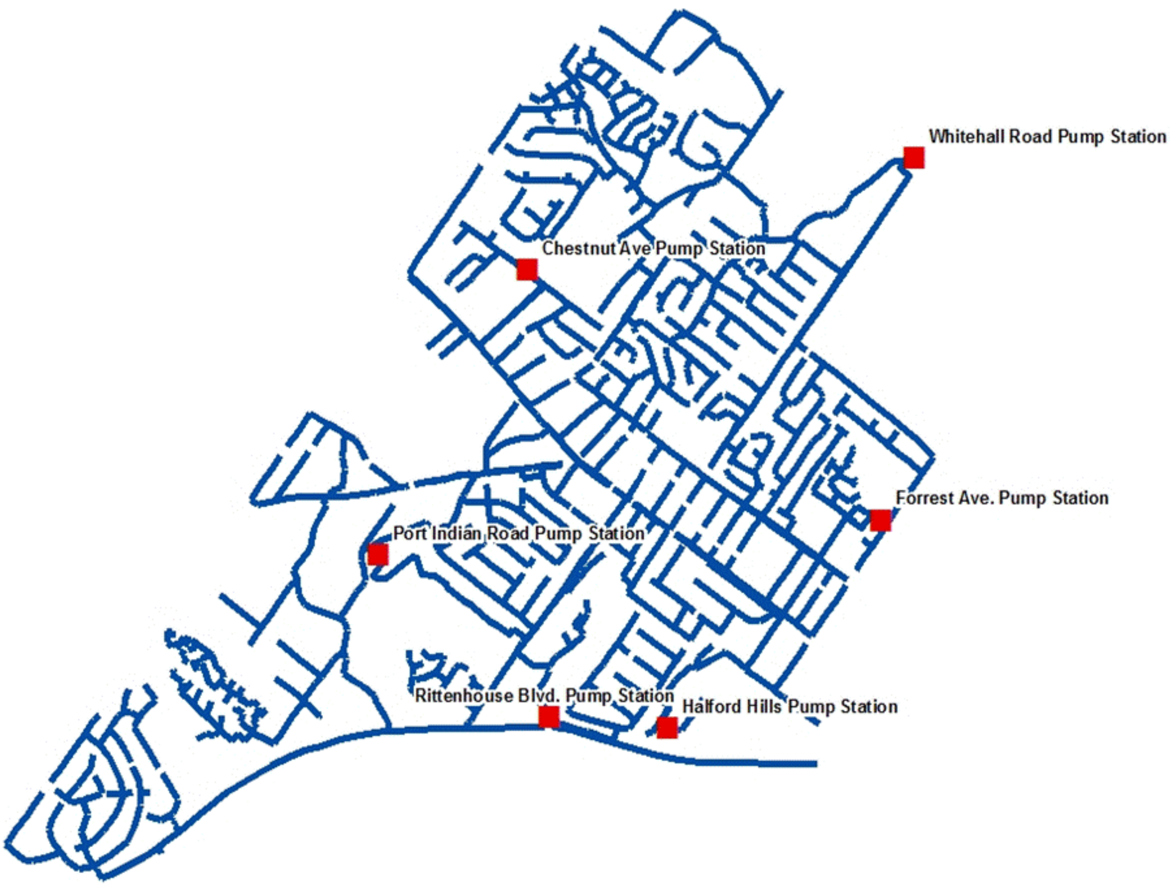
WEST NORRITON TOWNSHIP

SANITARY SEWER SYSTEM
INFLOW AND INFILTRATION STUDY



November 2013

Rettew Associates, Inc.
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Lancaster, PA 17603

RECOMMENDATIONS

The top four priorities for inflow and infiltration reduction based on this study are listed below with the highest priority listed first. The full table of prioritized meter areas is on Table 1 on the following page. Table 2 on page 3 summarizes the possible sources of I&I within each meter area, as identified in the characterization of flows within the discussions for each individual meter.

1. Investigate the sewershed contributing to Meter 14, which consists of only 14 manholes located mostly in Mystic Lane. Current metering identifies an average daily dry weather flow of approximately 40 gpm; expected values are 4 gpm. A field investigation of the piping at the meter site in the early morning hours should show flows very close to zero. If significant flows are occurring, their source should be identified and repaired. Additionally, this sewershed has the highest rate of I&I (Inflow and Infiltration) per manhole of any of the metered areas. During a 2-year storm event, peak inflows of 14.3 gpm per manhole were experienced. The potential sources are most likely to include flow into manhole lids, sewer vents, and into manholes through the stone subbase of roadways.

2. Investigate a single 7-manhole run in School Lane, contributory to Meter 11(1) for inflow and infiltration. During a 2-year storm event, peak inflows reached 10 gpm per manhole. Both inflow and infiltration are clearly evident for this sewer run. Except for downspout connections, all other typical sources are possible contributors, such exterior drain connections, low sewer vents, flow directly into manhole lids, flow into manholes through the stone subbase of roadways, and infiltration into the pipe or manholes from groundwater.

3. Investigate the sewershed contributory to Meter 1, which is located in the manhole at 360 Burnside Avenue. This sewershed generally extends from Burnside Avenue to Trooper Road on each side of Oakland Drive. Inflow levels reached 5.7 gpm per manhole during a 2-year storm event, which results in a tremendous amount of extra flow due to 141 contributing manholes. The inflow was characterized as likely coming from exterior drain connections to the sewer lateral, surface flow passing directly through manhole lids, flow into manholes through the stone subbase of roadways, and bad laterals. Groundwater Infiltration appeared to be minimal.

4. Investigate the sewershed contributory to Meter 4 (essentially the sewershed to the Whitehall Road +Pump Station), which includes the areas flowing through Meter 18, Meter 3, and Meter 17. The peak inflow and infiltration from this sewershed was estimated at 4.2 gpm per manhole, from a total of 236 manholes. Except for downspout connections, all other typical sources are possible contributors, such as exterior drain connections, low sewer vents, flow directly into manhole lids, flow into manholes through the stone subbase of roadways, and infiltration into the pipe or manholes from groundwater. The Meter 17 sewershed's flow had different characteristics; its likely sources of rain-induced flow did not include downspout or exterior floor drain connections, sump pump connections, stone subbase flow into manholes, nor infiltration.

Table 1

WEST NORRITON TOWNSHIP

Meter Area Prioritization for I & I Repair Projects

Priority Number	Meter #	Meter Name	Contributing MHs	Estimated June 7 I & I (GPM)	June 7 I & I per Manhole (GPM)	Estimated July 23 I & I (GPM)	July 23 I & I per Manhole (GPM)
1	14	West Indian Woods	14	200	14.3	50	3.6
2	11(1)	School at Driveway	7	70	10	17	2.1
3	1	360 Burnside	141	800	5.7	300	3
4	4	Whitehall	42	1000(4)	4.2(5)	650(6)	7.1(7)
5	18(1)	Burnside Avenue	50	(2)	(2)	NF(3)	NF
6	11(2)	Off School	124	NF	NF	500	4
7	7	498 Port Indian	84	700(8)	3.9(9)	NF	NF
8	8	367 Port Indian	23	400(10)	3.14(11)	0	0
9	17	Paddock	38	80	2.1	0	0
10	10	Port Indian Detention	108	450(12)	1.9(13)	NF	NF
11	3	Wayne Drive	106	NF	NF	220	2.1
12	9	General Armistead	96	NF	NF	200	2.1
13	5	Sheridan/Hartranft	86	NF	NF	NF	NF
14	15	Riverview	90	NF	NF	0	0
15	2	711	153	0	0	0	0
16	13	Beaver Hollow	55	0	0	0	0

(1) Prioritized based on July 23 Flow Analysis of Meter 4
(2) Calculated with Meter 4
(3) Non-Functioning
(4) Assumed to come from Meter 18, Meter 3, Meter 17 and Meter 4
(5) Based on a total of 236 manholes in the total contributing sewershed
(6) Assumed to come from Meter 18 and Meter 4
(7) Based on a total of 92 manholes in the total contributing sewershed
(8) Assumed to come from Meter 7 and from Meter 9
(9) Based on a total of 180 manholes in the total contributing sewershed
(10) Assumed to come from Meter 14, Meter 15, and from Meter 8
(11) Based on a total of 127 manholes in the total contributing sewershed
(12) Assumed to come from Meter 11(2) and from Meter 10
(13) Based on a total of 232 manholes in the total contributing sewershed

WEST NORRITON TOWNSHIP

Meter Area Possible I & I Sources

Priority Number	Meter #	Meter Name	Possible I & I Sources								
			Sump Pump Connections	Manholes in low points of paved areas	Manholes adjacent to drainage paths	Exterior surface drains connected to sewer lateral	Sewer vents at ground level and in drainage path	Low sewer vent adjacent to drainage path	Downspout connections to sewer lateral	Manhole inflow from road stone subbase	Infiltration from groundwater
1	14	West Indian Woods	N	N	Y	N	Y	Y	N	Y	N
2	11(1)	School at Driveway	Y	Y	Y	Y	Y	Y	N	Y	Y
3	1	360 Burnside	Y	Y	N	Y	Y	N	Y	Y	N
4	18[1]	Burnside Avenue	Y	N	Y	N	Y	Y	N	Y	Y
5	4	Whitehall	Y	N	Y	N	Y	Y	N	Y	Y
6	11(2)	Off School	Y	Y	Y	Y	Y	Y	Y	Y	Y
7	7	498 Port Indian	Y	N	Y	N	N	Y	N	Y	Y
8	8	367 Port Indian	N	N	Y	N	N	Y	N	N	N
9	17	Paddock	N	N	Y	N	N	Y	N	N	N
10	10	Port Indian Detention	U	U	U	U	U	U	U	U	U
11	3	Wayne Drive	N	Y	N	Y	N	N	Y	Y	N
12	9	General Armistead	N	N	Y	N	Y	Y	N	N	N
13	5	Sheridan/Hartranft	U	U	U	U	U	U	U	U	U
14	15	Riverview	N	Y	Y	Y	Y	Y	Y	Y	N
15	2	711	N	N	N	N	N	N	N	N	N
16	13	Beaver Hollow	N	N	N	N	N	N	N	N	N

Note: Y = Yes, which means possibly present, and N = No, which means not likely to be present, based on metering results; U means Unknown

COMPUTER MODELING

Computer Model Development

This Inflow and Infiltration Study consisted of two components: metering of the sewage flows throughout the system; and, development of a computer model of the entire West Norriton Township sewer system. Prior to the development of the sewer system computer model, Geographic Information System (GIS) mapping of the sewer system was completed. The GIS mapping was developed by gathering information from the Township's sewer system drawings, and incorporating it by computer in digital aerial photography and parcel mapping of the Township.

A full system hydraulic computer model was developed using Bentley SewerCAD Version 8i modeling software. Gravity sanitary sewer mains, force mains and manholes were developed for the model by linking and integrating the GIS database within the SewerCAD program. The Township's six pump stations (Rittenhouse Boulevard, Whitehall Road, Port Indian Road, Chestnut Avenue, Halford Hills, and Forest Avenue) were created using record drawings and pump flow curves. Each pump station consists of a wet well, lead and lag pumps. The pumps are controlled by the water level in their respective wet well.

The daily flow data collected from the system flow meters was analyzed to determine the typical variation of flow through a 24-hour period during dry weather conditions. From census data, the typical household in West Norriton Township consists of an average of 2.25 persons. With a typical average sanitary flow of 100 gallons per day per person, the typical average flow per household is assumed to be 225 gallons per day. To mimic the typical flow from each household in the Township, the flow curve shown in Figure 1 was developed, which utilizes the typical variation of flow based on metering and equates to a 24-hour total flow of 225 gallons.

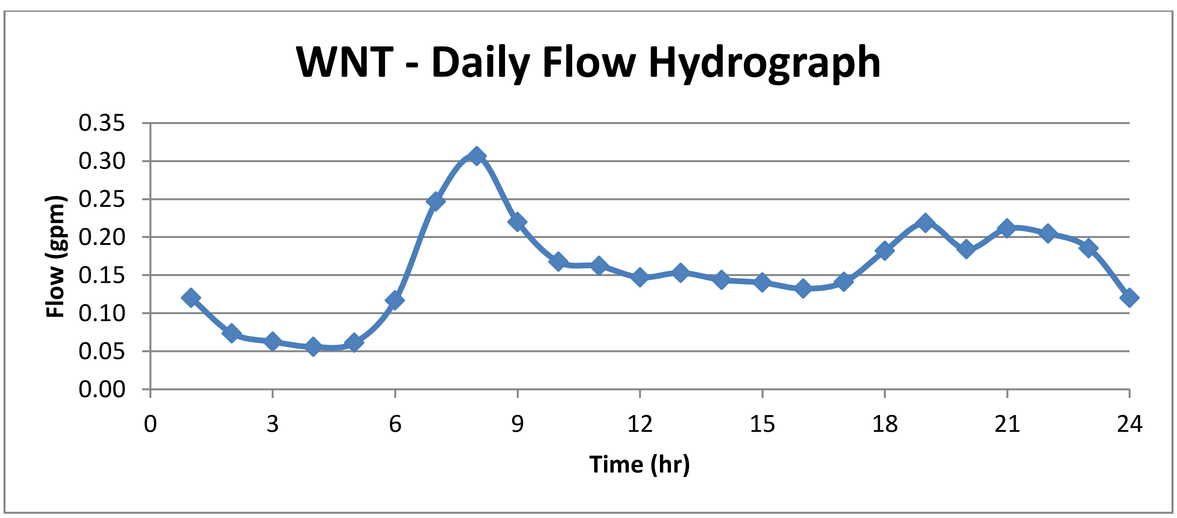


Figure 1: West Norriton Township daily flow hydrograph used for each sewer connection in the hydraulic model.

The sewer modeling software was utilized to assign each parcel in the Township to the closest sanitary sewer manhole. Significant non-residential customers in the sewer system, defined as contributing more than 7200 gallons per day or 5 gallons per minute, were identified from past water use records, and their sewage flow (assumed the same as the water usage) was input into the sewer system model at the appropriate location.

The computer model was utilized to develop the anticipated dry weather flows at the flow meter locations. This provides quality control for the collected meter data, assisting in the determination of meter accuracy as well as identifying meter locations with excessive flows which could identify high levels of infiltration. Future phases of sewer system analysis can utilize the computer model to analyze storm flows, to determine potential undersized pipes and pump stations, and to appropriately size upgrade facilities.

<u>Computer Model Results</u>

The accuracy of the computer model is best illustrated through Table 3, Model Results – Pump Station/System Comparisons, on Page 6. This table shows the 2012 Chapter 94 Report flow values for the Township pump stations, the Jackson Street Diversion Chamber, and for the total flow to Norristown, as well as the flow results for these same locations from the computer model. It should be noted that the average daily flows from the Chapter 94 Report include all wet-weather as well as dry weather flows, whereas the computer model flows are only dry-weather flows. The Chapter 94 report flows would be expected to be higher than the computer model flows in most cases, as can be seen to be true in this table. The results shown on this table provide a high level of confidence in the accuracy of the computer model. The comparisons of the total flow to Norristown indicates that approximately 13% of the of the sewage flow is due to inflow and infiltration, based on the computer modeling.

To evaluate the apparent accuracy of the flow data collected by the installed flow meters, we have developed Table 4, Model Results – Flow Meter Comparisons, on Page 7. This table provides a clear illustration of the challenges of obtaining accurate flow meter data, as shown through the variability of the comparison at each meter site. The table does provide a valuable tool in the analysis of the flow meter data when evaluating inflow and infiltration levels, by allowing upward or downward adjustments of flow data based on comparisons with anticipated levels from the computer modeling results.

Model Results – Pump Station/System Comparisons

Pump Station Name	Average Daily Flow (gpm)	
	2012 Chapter 94 Report	Model Dry Weather
Rittenhouse Blvd	985.1	852.3
Whitehall Road	307.7	312.1
Port Indian Road	226.5	184.7
Forest Avenue	124.3	150.4
Chestnut Avenue	40.9	34.2
Halford Hills	1.7	2.0
Jackson Street	651.6	577.7
Flow to Norristown	1,636.7	1,430.0

gpm = gallons per minute

Model Results – Flow Meter Comparisons

Meter #	Meter Name	Average Daily Flow (gpm)	
		Metered Dry Weather	Model Dry Weather
1	360 Burnside	70.0	133.9
2	7-11	300.0	571.6
3	Wayne Drive	75.0	62.0
4	Whitehall	200.0	308.7
5	Sheridan/Hartranft	60.0	231.3
7	498 Port Indian	0	166.4
8	367 Port Indian	60.0	39.0
9	General Armistead	75.0	71.7
10	Port Indian Detention	50.0	184.7
11(1)	School at Driveway	4.0	2.8
11(2)	Off School	100.0	130.4
13	Beaver Hollow	1.0	22.9
14	W Indian Woods	40.0	3.6
15	Riverview	2.0	14.2
17	Paddock	0.2	49.7
18	Burnside Avenue	120.0	155.4

gpm = gallons per minute

STORM ANALYSIS

Two recent storms of significance were analyzed for this report, June 7, 2013, and July 23, 2013, which occurred during flow monitoring within the West Norriton Township sewer system. All meters were in place during these two storms, allowing comparisons between the meters and prioritization based on those comparisons. These storms are described within this section, and the effect of these storms on each individual flow meter is described in Meter Results, beginning on page 15.

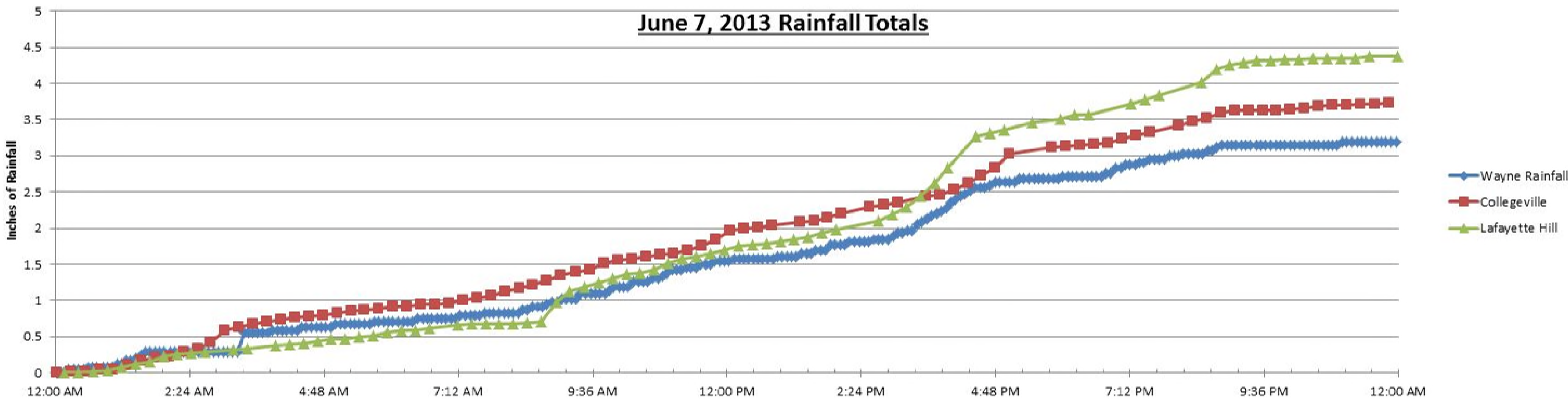
Storm of June 7, 2013

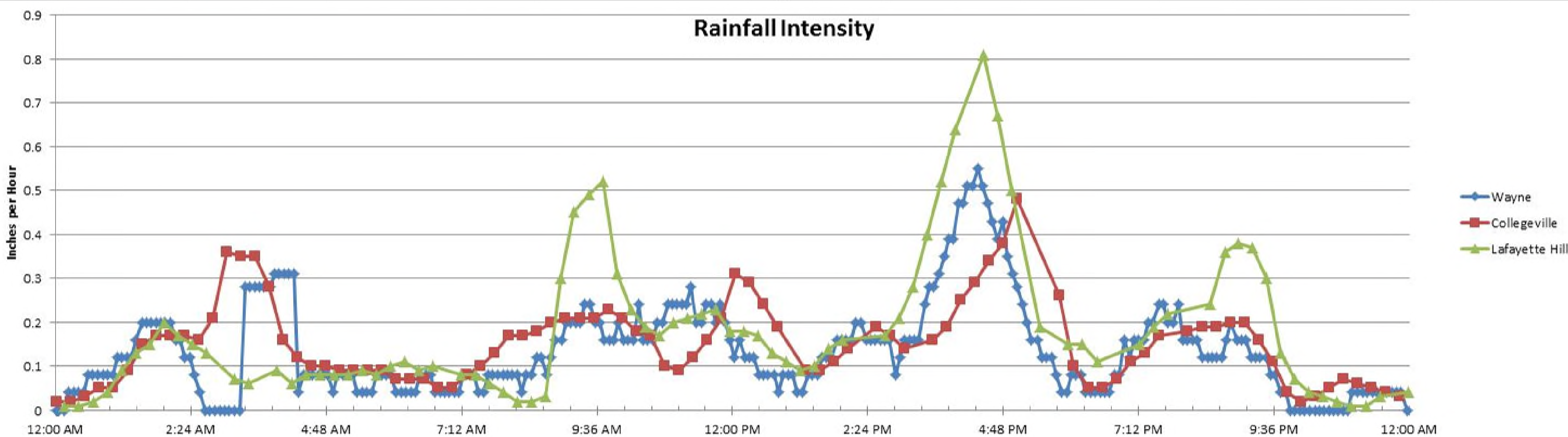
From midnight on the morning of June 7, 2013, to the end of rainfall approximately 24 hours later, West Norriton Township received a total of between 3 and 4 inches of rainfall following approximately 0.16" of rain through the evening of June 6. This rainfall for three nearby rain gages is depicted on Figure 1 which shows both the accumulation of total rainfall as well as the intensity of the rainfall throughout the day. These three rain gages surround the Township as shown on Figure 2, and were utilized for analysis since no functioning raingage was located within the Township during this storm. The storm traveled in a southwest to northeast direction. The Wayne raingage lies directly in front of the Township for the path of this storm, and based on the speed of the storm track, it would take approximately 5 minutes for rain at the Wayne gage to travel to the center of the Township. Due to the proximity of the Wayne raingage, it was utilized for the comparison of rainfall to flow for the Township. For reference, the Collegeville and Lafayette Hill rain gages may provide an indication of how the rainfall is changing as it travels across the Township.

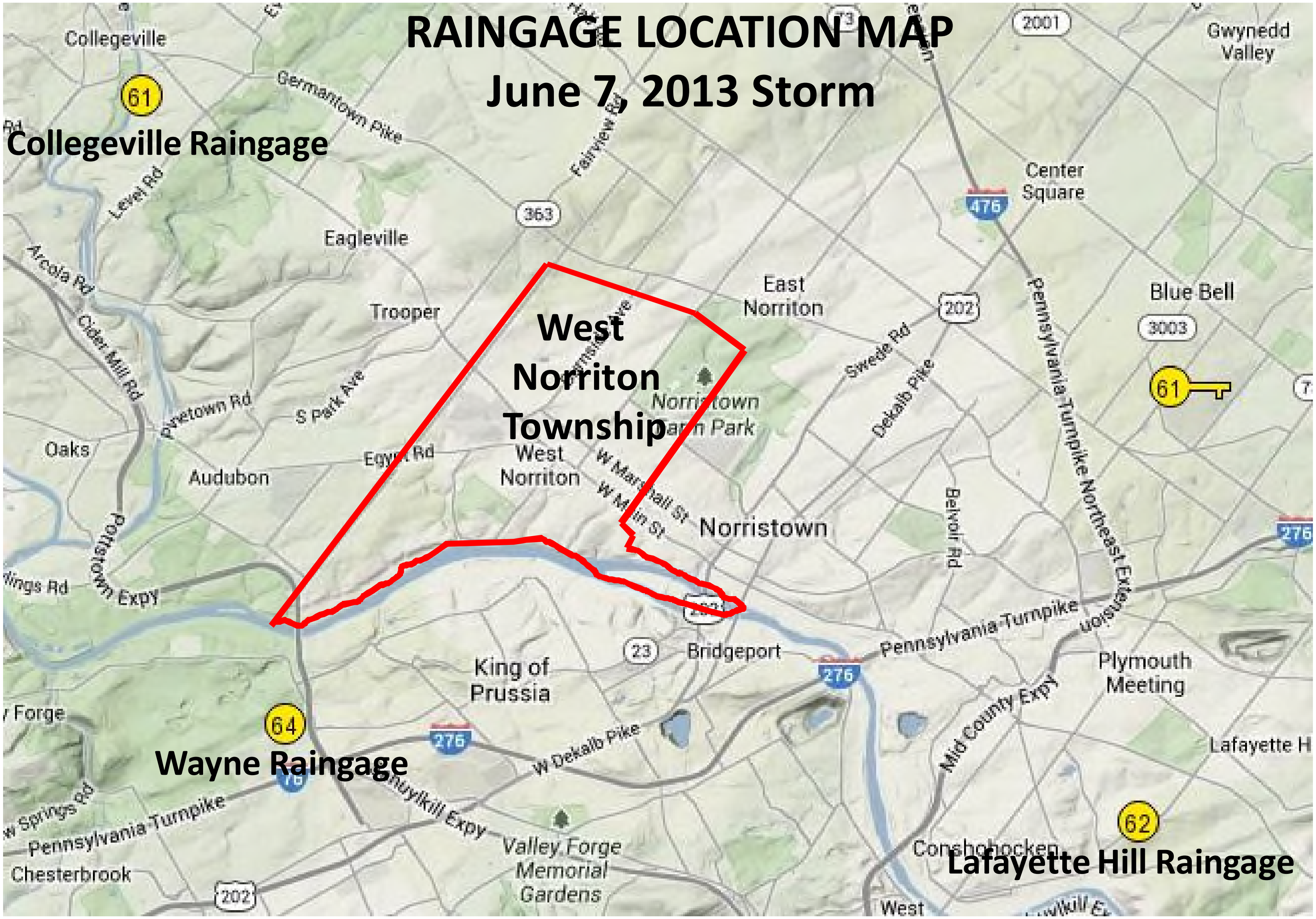
The Wayne raingage received a total rainfall in the 24-hour period of June 7 of 3.19 inches, which would represent a 2-year storm based on the latest NOAA Point Precipitation Frequency Estimates. A 2-year storm event happens on the average once every two years. If the rainfall on the Township increased to 4 inches as possible based on the Collegeville and Lafayette Hill rain gages, then the Township would have experienced a 5-year storm event. The maximum intensity of rainfall during this rainfall event was 0.55 inches per hour, which occurred between 4 pm and 5 pm.

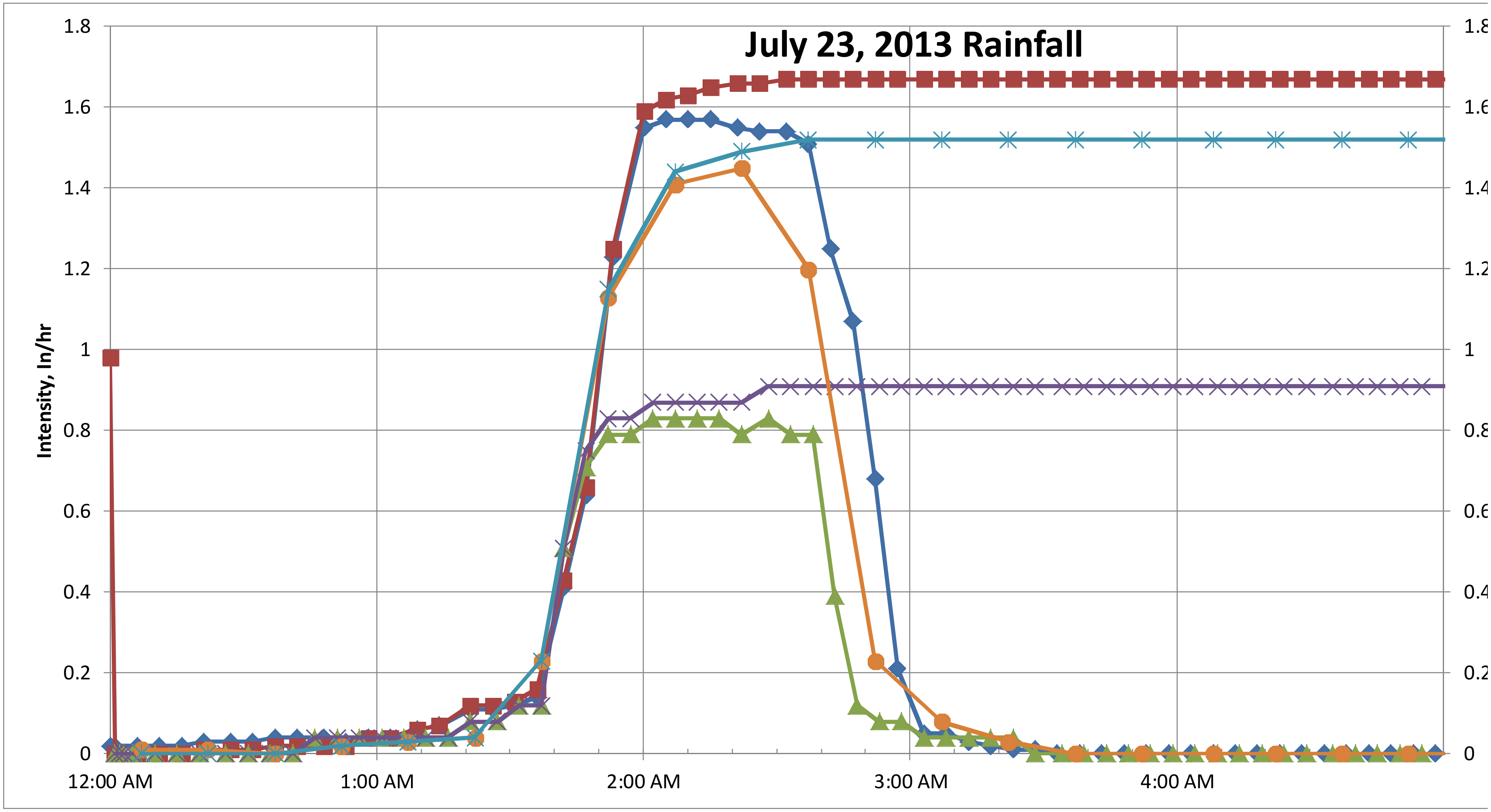
Storm of July 23, 2013

The storm of July 23 was a very short, high intensity event which occurred in the early morning hours between 1 am and 3 am, as depicted on Figure 3. The Eagleville raingage, located as shown on Figure 4, which lies closer to the Township than the Collegeville raingage, was functioning during this storm. The storm tracked almost directly from west to east, such that the rainfall at the Township would most likely lie between the values of the Wayne and the Eagleville rain gages. For this storm, the Wayne raingage received 0.91 inches of rain, and the Eagleville raingage received 1.67 inches of rain. The Lafayette Hill raingage received 1.52 inches of rain; with the storm track being almost directly from the Wayne raingage to the Lafayette Hill raingage, it appears that the storm intensified as it traveled over the Township from the Wayne raingage. The peak storm intensity over the Township was most likely somewhere between 0.83 inches per hour at the Wayne raingage and 1.57 inches per hour at the Eagleville raingage. This would represent approximately a 2-year storm event.

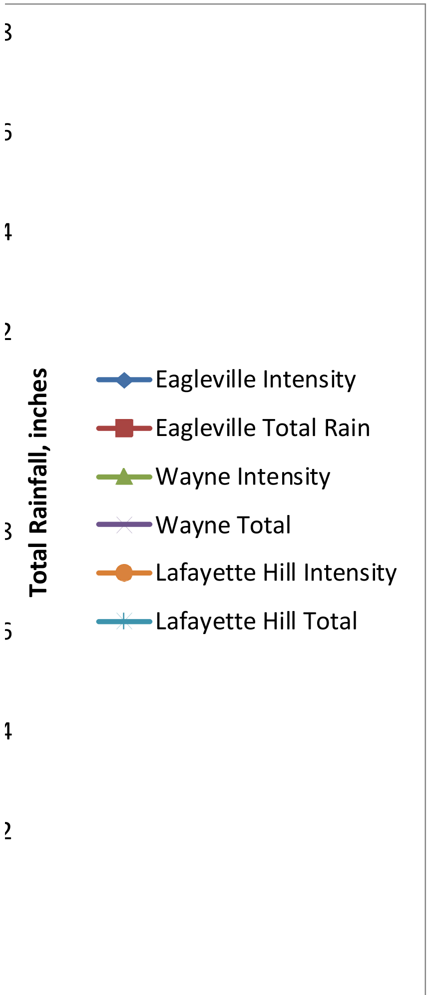

June 7, 2013 Rainfall Totals
Inches of Rainfall
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
12:00 AM
2:24 AM
4:48 AM
7:12 AM
9:36 AM
12:00 PM
2:24 PM
4:48 PM
7:12 PM
9:36 PM
12:00 AM
Wayne Rainfall
Collegeville
Lafayette Hill

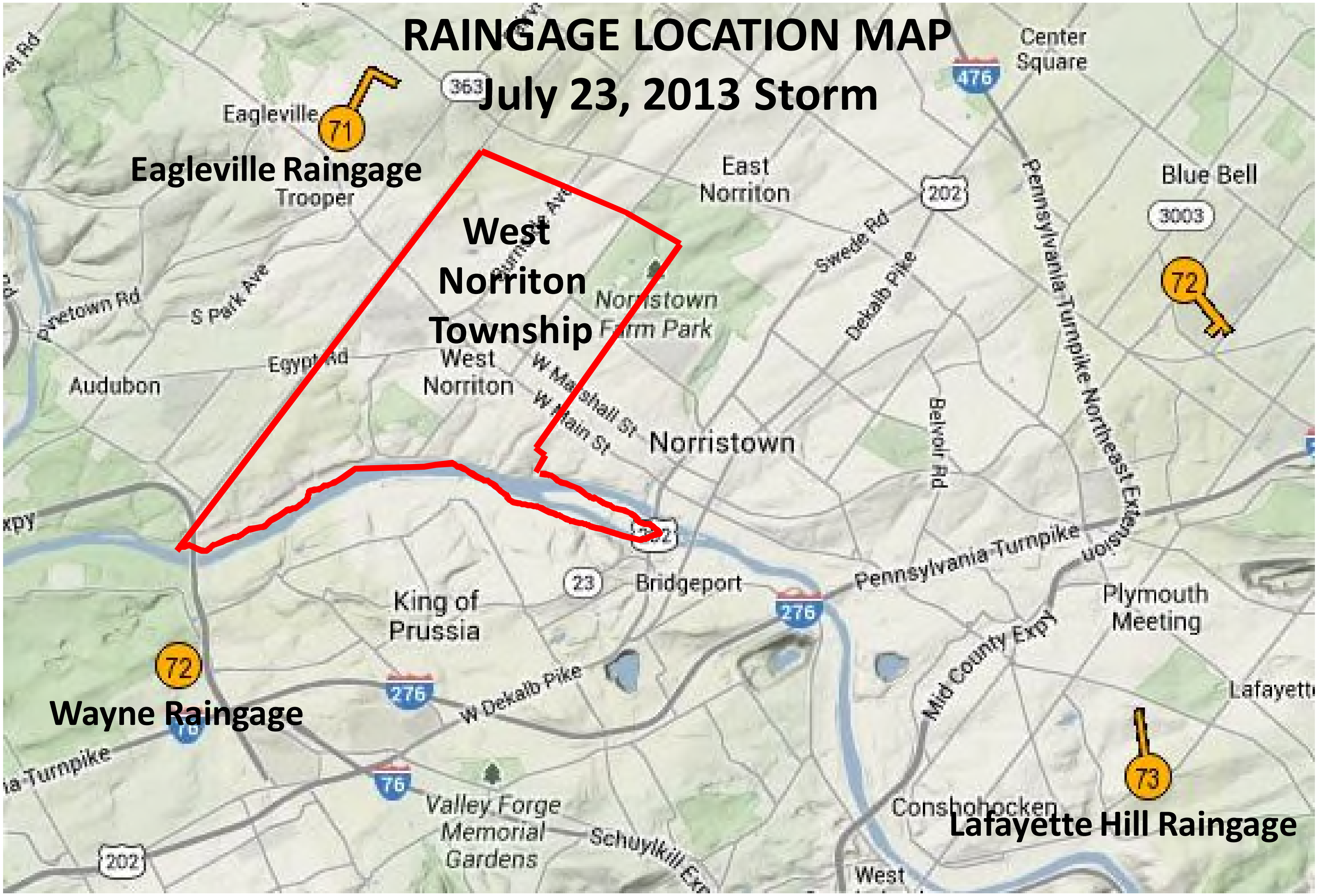

Rainfall Intensity
Inches per Hour
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
12:00 AM
2:24 AM
4:48 AM
7:12 AM
9:36 AM
12:00 PM
2:24 PM
4:48 PM
7:12 PM
9:36 PM
12:00 AM
Wayne
Collegeville
Lafayette Hill


RAINGAGE LOCATION MAP
June 7, 2013 Storm
Collegeville Raingage
61
West
Norriton
Township
Wayne Raingage
64
Lafayette Hill Raingage
62
Collegeville
Eagleville
Trooper
Oaks
Audubon
West
Norriton
East
Norriton
Norristown
Norristown
Farm Park
Bridgeport
King of
Prussia
Center
Square
Blue Bell
Gwynedd
Valley
Plymouth
Meeting
Chesterbrook
Valley Forge
Memorial
Gardens
Conshohocken
Germantown Pike
Pennsylvania Turnpike
Pennsylvania Turnpike Northeast Extension
Mid County Expy
W Dekalb Pike
Swede Rd
Dekalb Pike
Belvoir Rd
W Marshall St
W Main St
Egypt Rd
S Park Ave
Level Rd
Arcola Rd
Cider Mill Rd
Pottstown Expy
363
476
202
3003
2001
276
23



July 23, 2013 Rainfall
Intensity, In/hr
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM


Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total

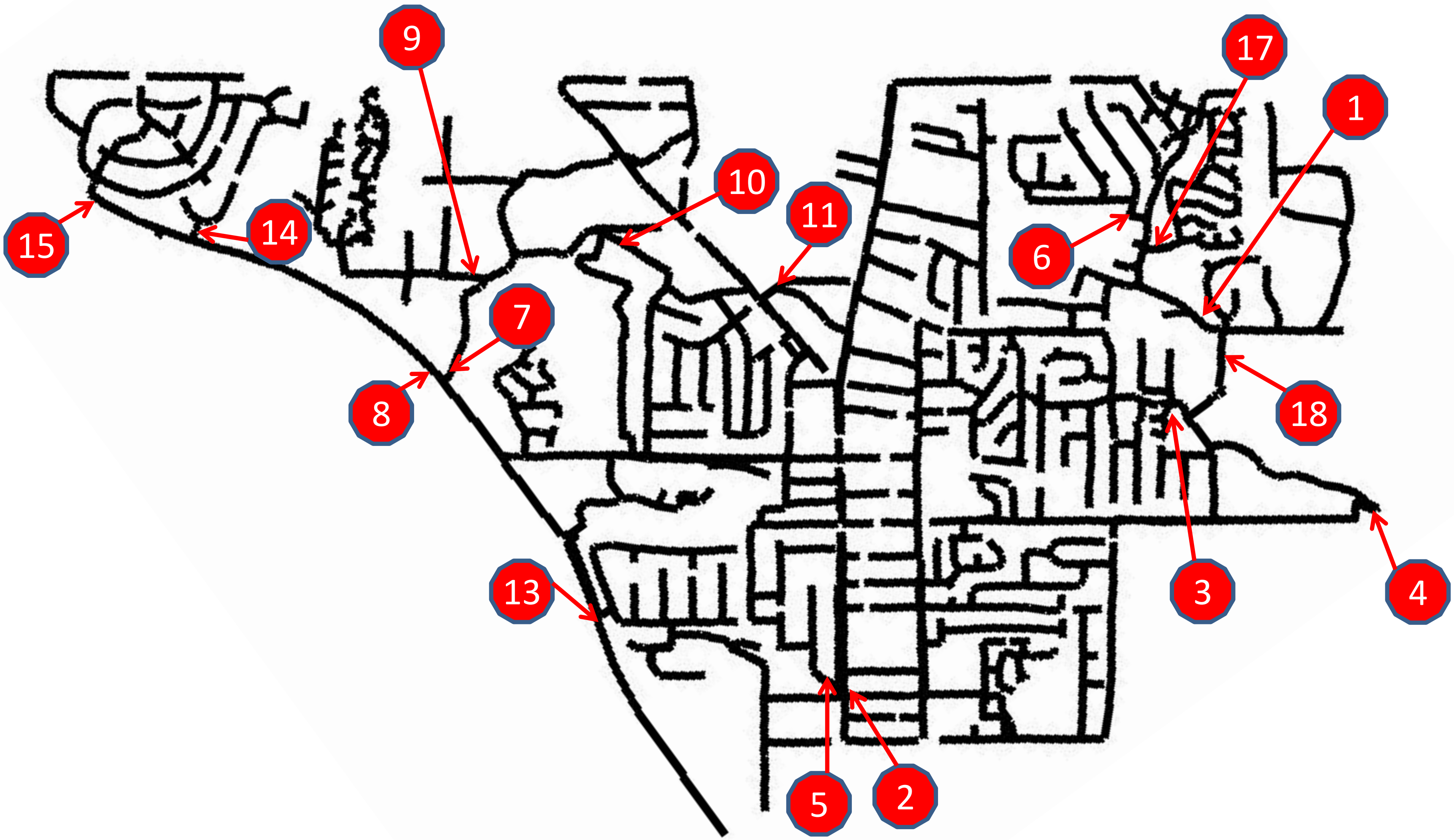

RAINGAGE LOCATION MAP
July 23, 2013 Storm
Eagleville Raingage
West Norriton Township
Wayne Raingage
Lafayette Hill Raingage
Eagleville
71
72
72
73
Trooper
Audubon
East Norriton
Center Square
Blue Bell
Norristown Farm Park
West Norriton
Norristown
King of Prussia
Bridgeport
Plymouth Meeting
Conshohocken
Valley Forge Memorial Gardens
Pennsylvania Turnpike
Pennsylvania Turnpike Northeast Extension
Mid County Expy
W Dekalb Pike
Schuylkill Expy
Egypt Rd
S Park Ave
Swede Rd
Dekalb Pike
Belvoir Rd
W Marshall St
W Main St
363
476
202
3003
23
276
76

METER RESULTS

Fifteen flow meters have collected flow information in the West Norriton Township sewer system through the summer of 2013. The meters are Greyline Loggers, which gather and store information on the velocity and depth of the sanitary sewer flow, with values obtained continuously at 5- or 10-minute intervals. Based on the diameter of the pipe in which the meter is installed, the flow can be determined from the velocity and depth readings. The location of the meters is shown on Figure 6, page 14. A description of the effects of the June 7 and July 23 rainfall events on each of these meters follows Figure 6, along with a discussion of the probable causes of those effects, also known as the characterization of the storm event flows. It should be noted that different graphs utilize different flow increments, so that peak flows shown at the same time for the same meter can be quite different; some charts contain average daily flow, whereas others show instantaneous flows at 5-minute increments.

Based on an analysis of the individual metering information shown on pages 15 through 83, inflow and infiltration (I&I) levels have been estimated at each meter location for the two analyzed storms, and prioritizations have been established for I&I repair efforts. Table 1 on page2 presents the estimated I&I values as well as the results of the prioritization. Table 2 on page 3 summarizes the possible sources of the I&I within each prioritized meter area, as discussed in the characterization of flow contained within the analysis of each individual meter.

METER LOCATIONS



METER 1 – 360 BURNSIDE AVENUE

Meter 1 is located in Township manhole 1299 at 360 Burnside Avenue, in the 12-inch influent pipe to that manhole. Meter 17 flows through this meter; based on computer modeling, it is expected to contribute approximately 1/3 of the dry weather flow to Meter 1.

Period of Record

From Figure 7, it can be seen that the approximate average daily flow at this meter is 70 gallons per minute (gpm) for non-rainfall days. It is important to note that the anticipated average daily flow for dry-weather days is 150 gpm based on computer modeling; it therefore appears that the meter is reading too low in general. The average daily flow can be seen in Figure 6 to have clear increases which occur on days related to high rainfall events.

June 7, 2013 Event

On June 7, following approximately 3 inches of rainfall, the instantaneous peak flow reached 873 gpm, as shown on Figure 7. A gradual, steady increase in flow began at 1 am, after 0.24 inches of rainfall with intensities of only 0.08 inches per hour. Flows continued to increase or stay at the highest levels until the rainfall intensity dropped to below 0.15 inches per hour around 10 pm. From Figure 8, it can be seen that flows dropped close to pre-storm levels approximately 1 day following the end of rainfall.

July 23, 2013 Event

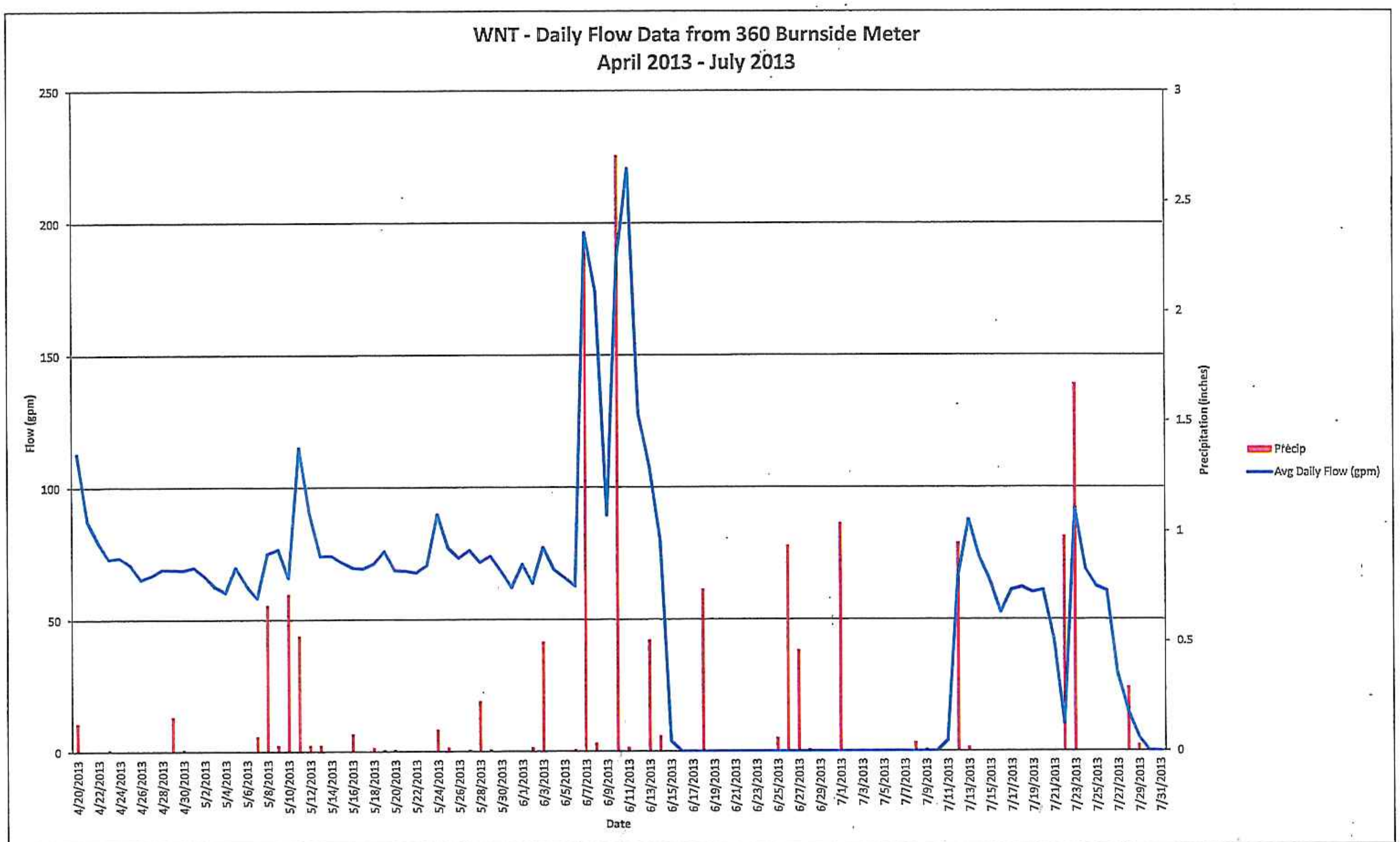
Based on Figure 9, it can be seen that the meter transitioned from a non-functioning position to a flow of 100 gpm within 30 minutes following the start of significant intensities of rainfall. Based on the results of the June 7 event where flow increased essentially concurrently with the start of rainfall and reached 100 gpm after intensities reached 0.2 inches per hour, it is probable that the period of meter non-function at the beginning of this storm included instantaneous increases in flow with the start of rainfall. The July 23 peak flow was 385 gpm. Flows rapidly decreased following a decrease in rainfall intensity until the rain ended at 3 am. From that point, with a flow of 250 gpm, flows gradually decreased, falling nearly to pre-storm levels approximately 1 day following the end of rainfall, as seen on Figure 10.

Flow Characterization

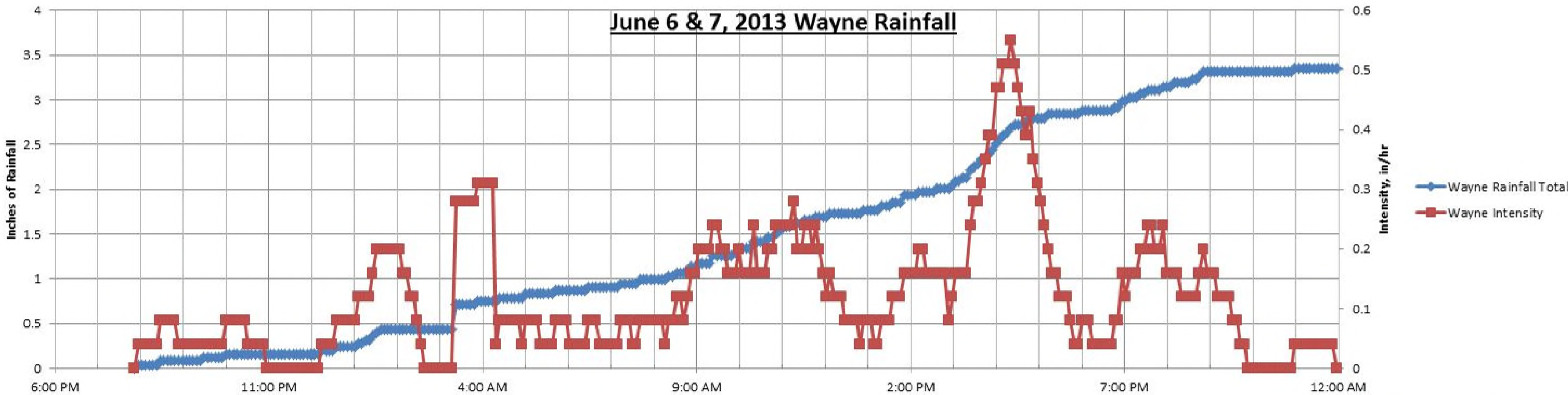
Based especially on Figures 8 and 9, it appears that there are two components to the storm-induced flows to this flow meter: a direct inflow; and a delayed inflow. It appears that infiltration is a very minor component for the pipes contributing to meter 1, since increased flows last essentially only a day following the end of rainfall. Pipes experiencing significant levels of infiltration would typically experience increased flows for many days after a storm event, especially after a 3-inch rainfall event.

With sewage flows apparently increasing immediately with the onset of significant rainfall, it would be indicative of downspout or exterior surface drain connections directly to sewer laterals, or having manholes without lid inserts located in drainage low points which receive flow from paved areas (such as near curb lines within paved streets.) All of the flow from these sources would experience a rapid decline following the end of rainfall. The point at which these direct flows become less than the flow from delayed sources can be seen at 3 am on Figure 9 and 6 am on Figure 8, where the slope of the line showing decreasing flows changes abruptly.

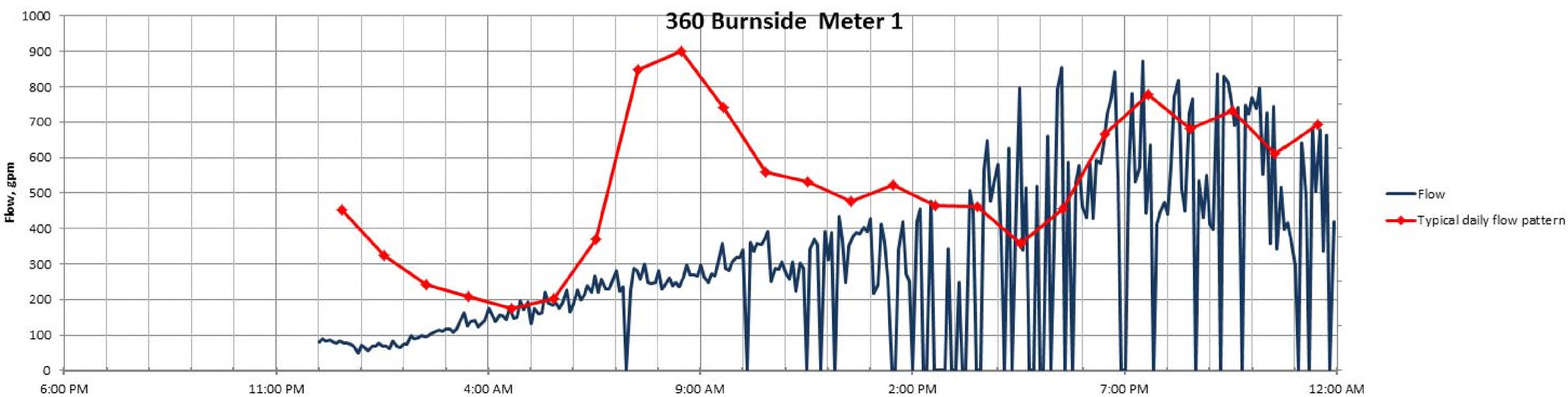
The sources of the delayed inflows can be such things as sump pump connections, flow into manholes through the stone subbase of paved roads, and flow into low-lying sewer vents.



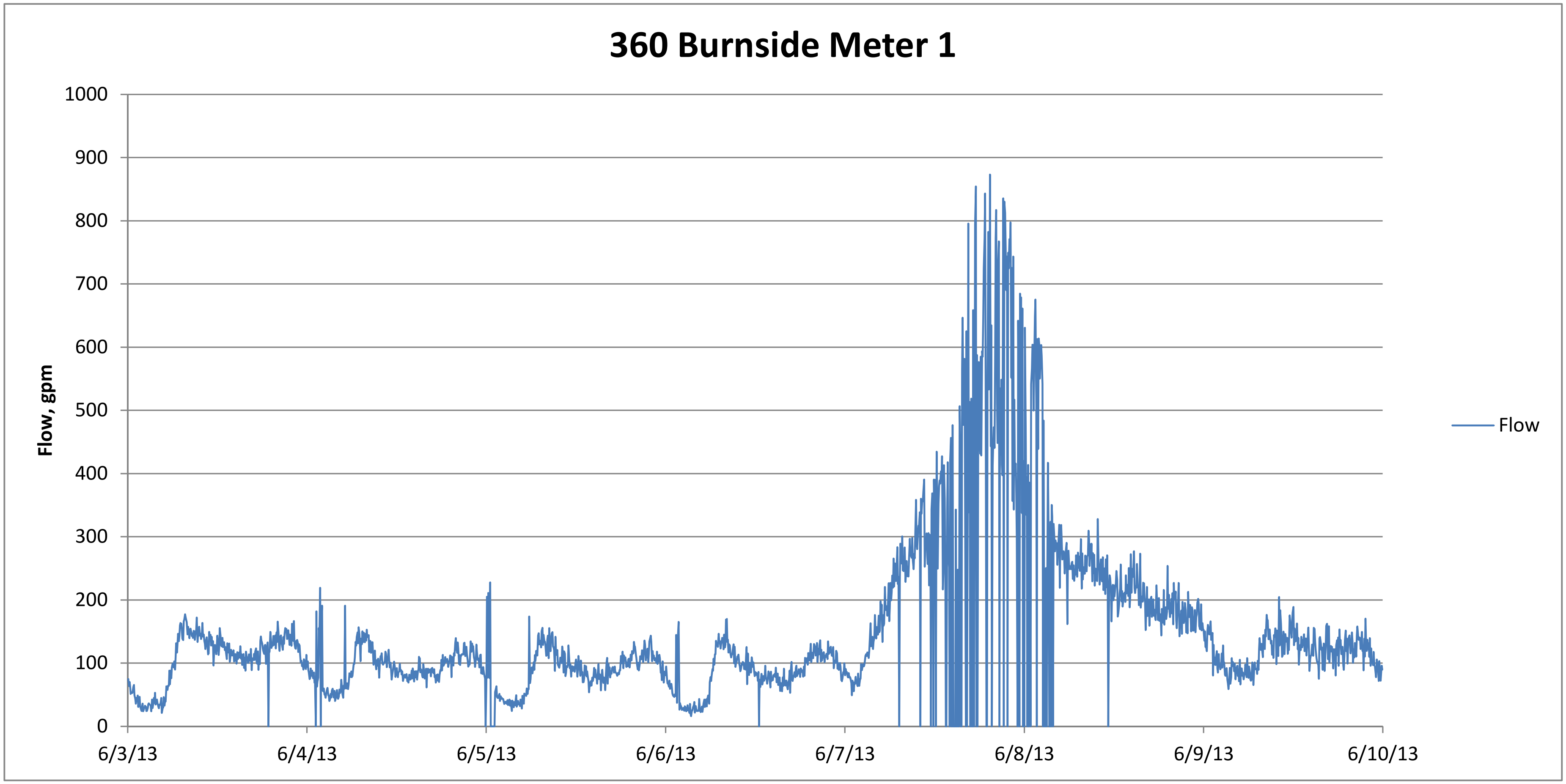
WNT - Daily Flow Data from 360 Burnside Meter
April 2013 - July 2013
Flow (gpm)
Precipitation (inches)
Date
Precip
Avg Daily Flow (gpm)



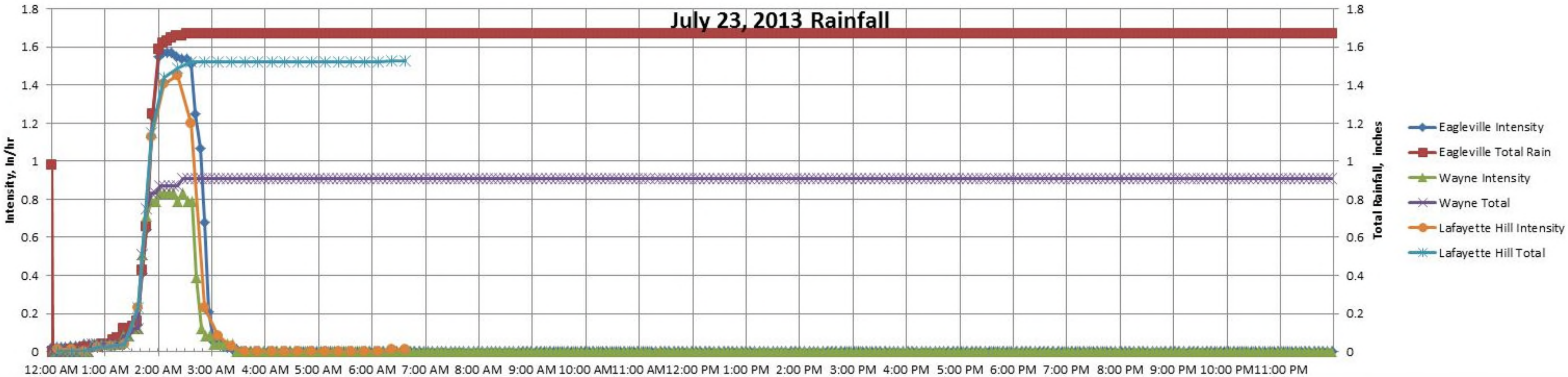
June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM

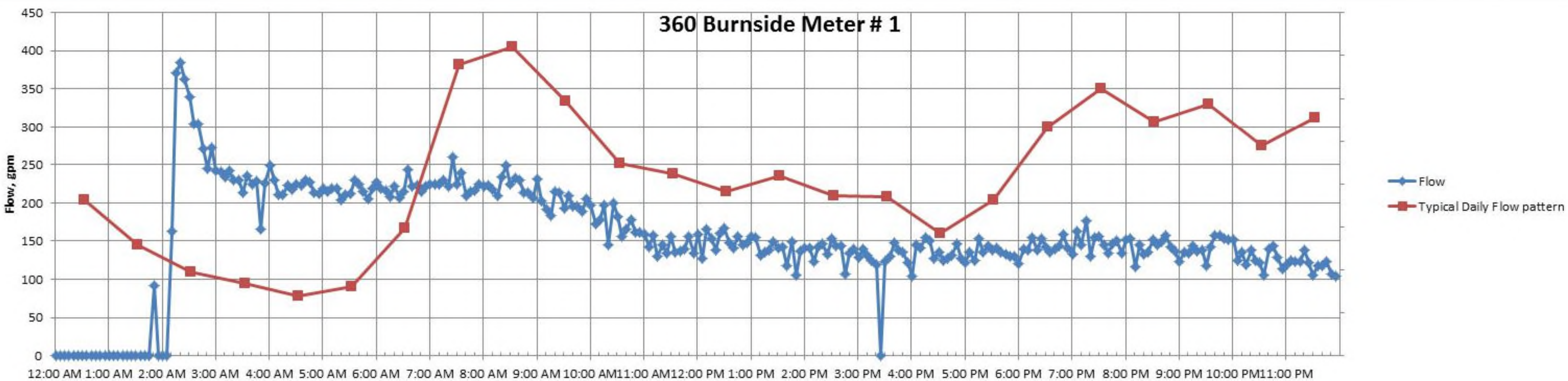


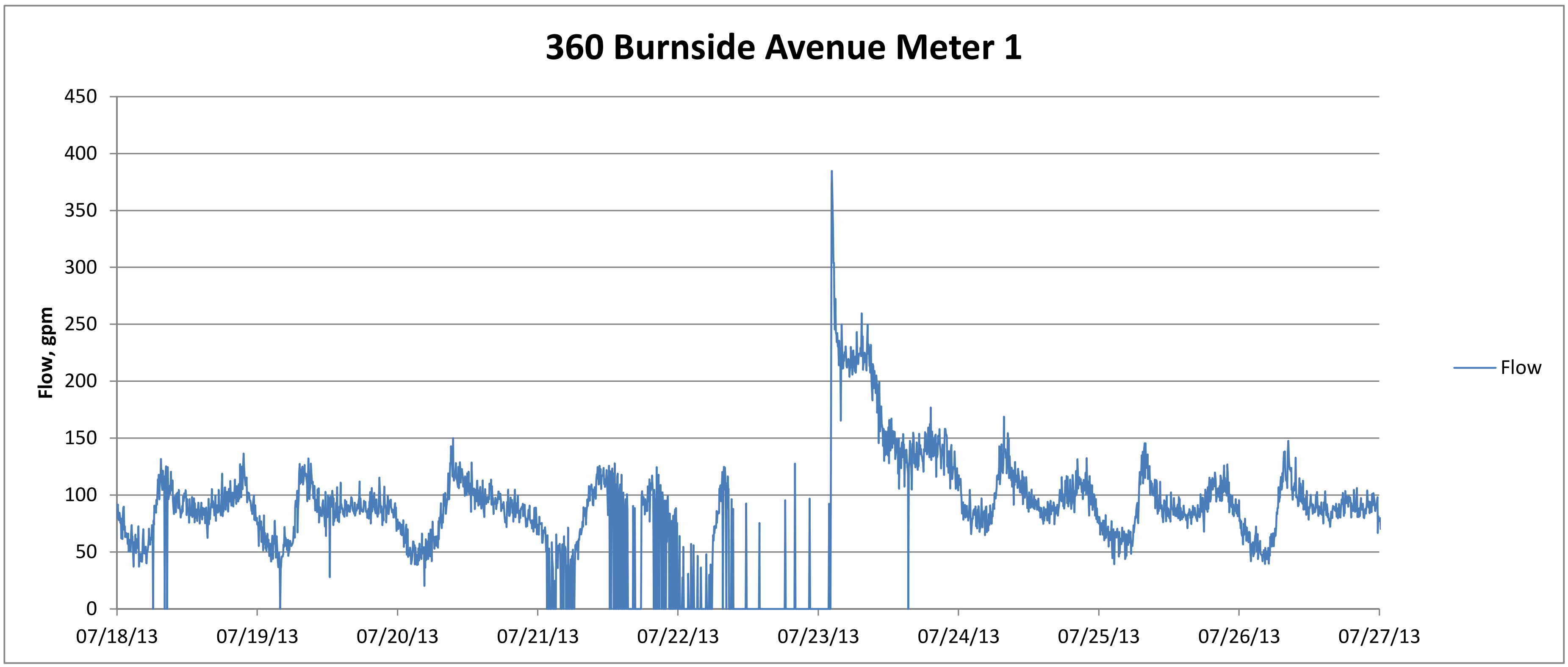
360 Burnside Meter 1
Flow, gpm
Flow
Typical daily flow pattern
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM



360 Burnside Meter 1
Flow, gpm
1000
900
800
700
600
500
400
300
200
100
0
6/3/13
6/4/13
6/5/13
6/6/13
6/7/13
6/8/13
6/9/13
6/10/13
Flow


July 23, 2013 Rainfall
Intensity, in/hr
Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM


360 Burnside Meter # 1
Flow, gpm
Flow
Typical Daily Flow pattern
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM


360 Burnside Avenue Meter 1
Flow, gpm
450
400
350
300
250
200
150
100
50
0
07/18/13
07/19/13
07/20/13
07/21/13
07/22/13
07/23/13
07/24/13
07/25/13
07/26/13
07/27/13
Flow

METER 17 – PADDOCK CIRCLE

Meter 17 is located in Township manhole 1254 near Paddock Circle, in an 8-inch pipe at that manhole. There are no other meters which flow to this meter.

Period of Record

Figure 11 would indicate that the average daily flow through this meter for non-rainfall days would be less than 1 gpm. This is an unrealistically low value considering the number of households which flow through this meter; the anticipated average daily flow for dry-weather days is 55 gpm based on computer modeling. An important observation from Figure 11 is that there appears to be very little correlation between rainfall events and the average daily flow, except for the very highest rainfall events, where there is a significant increase in average daily flows.

June 7, 2013 Event

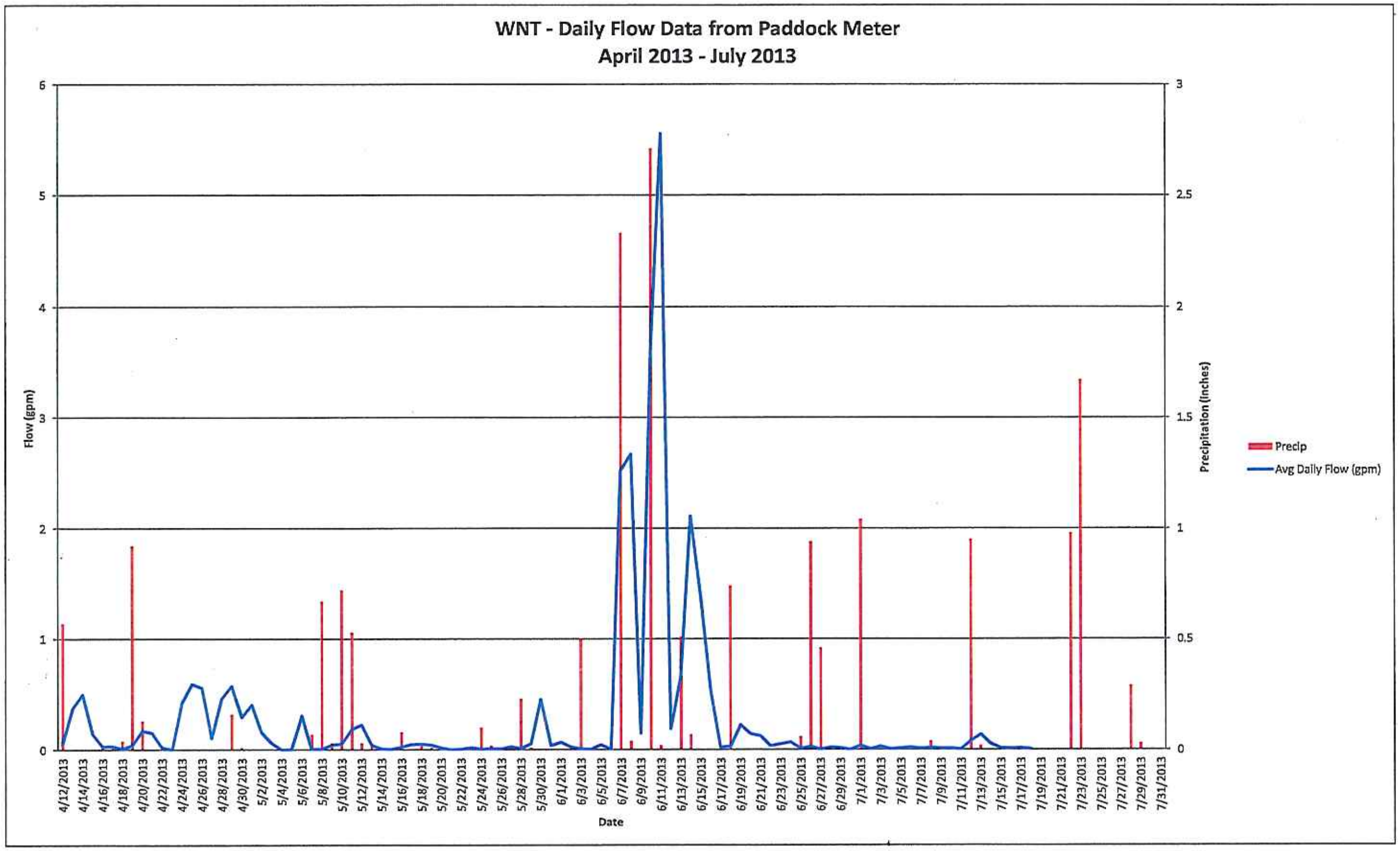
This meter shows a peak instantaneous flow of 80 gpm on June 7 as shown on Figure 12. It occurs at the end of the significant rainfall. However, throughout this storm, short periods of increased flow only appear to occur in general after the most intense periods of rainfall, and not as a steadily increasing effect through the storm.

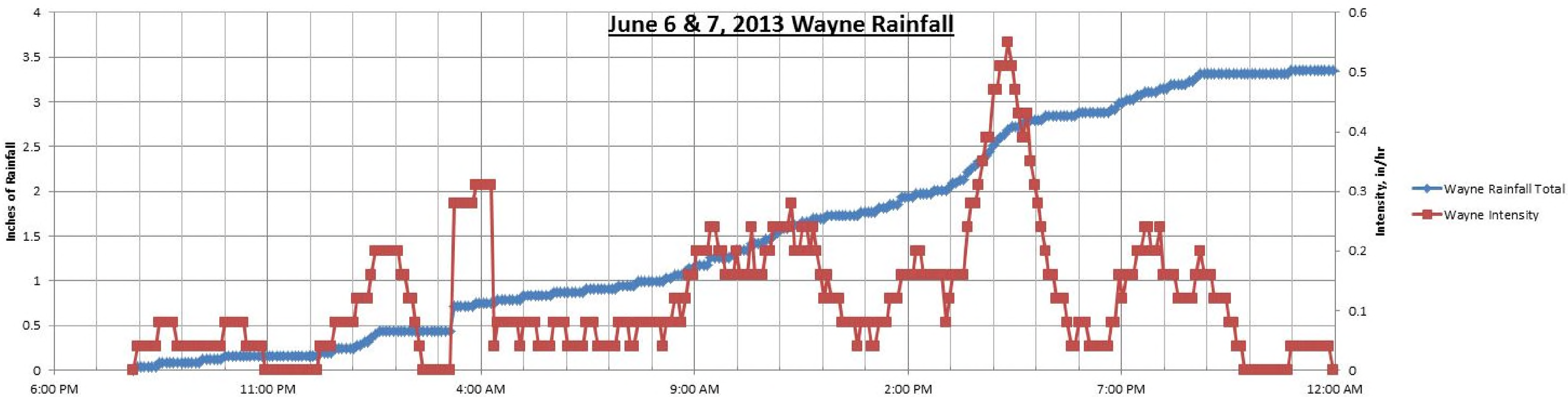
July 23, 2013 Event

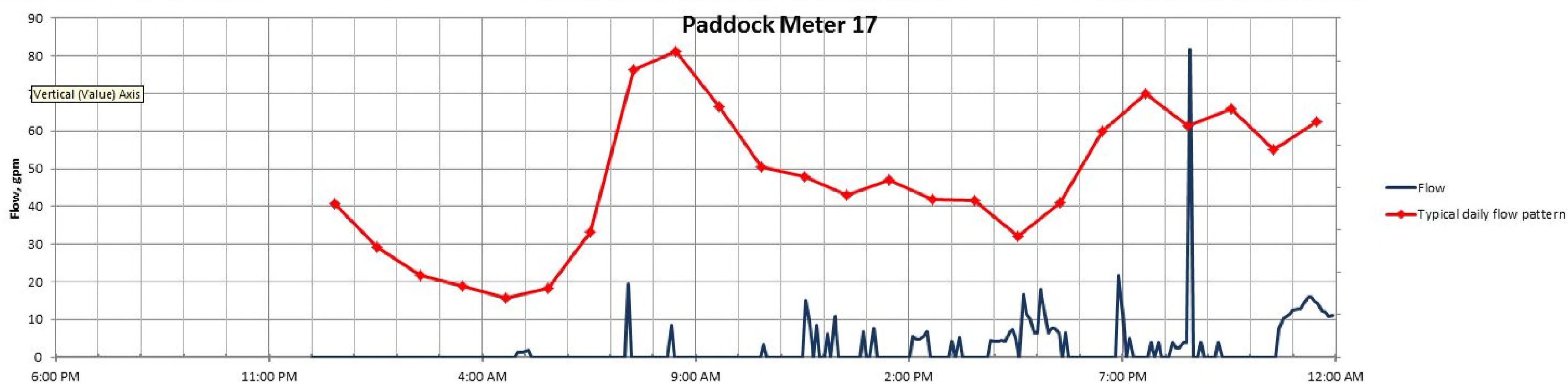
A very short duration high flow appears to occur immediately upon the occurrence of the highest intensity rainfall, just after 2 am, as shown on Figure 13. A higher short duration appears to occur just after 7 am, but with the rainfall ending at 3 am, it does not appear possible that this flow would be rainfall-induced. It appears that this would be a peak flow based on the typical morning flows through this meter; its magnitude is consistent with anticipated normal peak flows through this meter.

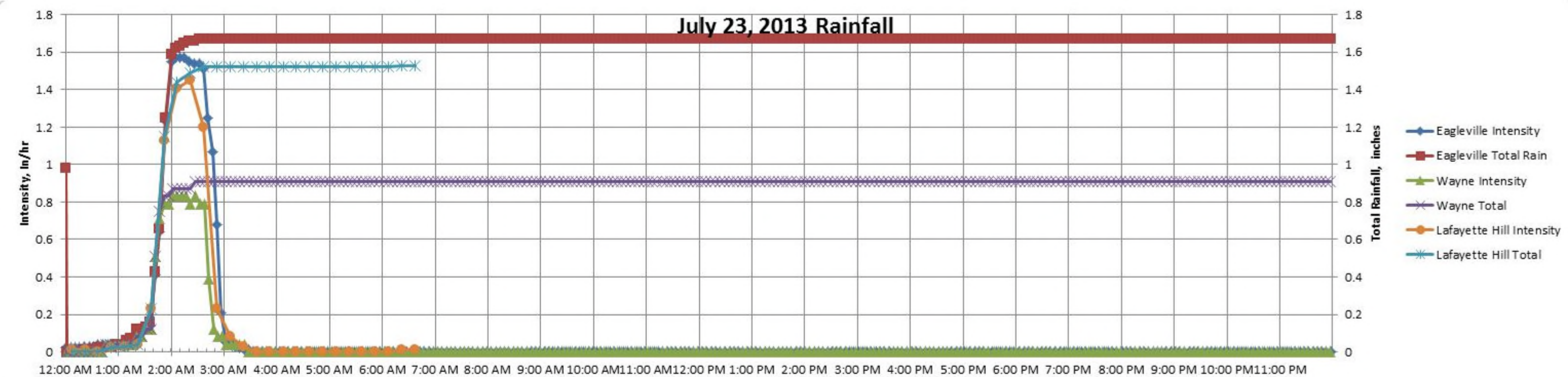
Flow Characterization

Analysis of the three figures related to this meter indicate that only the very highest rainfall intensities from significant rainfall events contribute rainfall-induced flows to this meter. This would mean that the rainfall would need to be producing very high surface runoff flows. These flows are apparently high enough to reach direct inflow points to the sewer which are normally unaffected by typical surface runoff. This could be sewer vents which are above ground level but are low enough to collect higher surface flows; it could also be street manholes which are not along the curbline, but are close enough to be affected by higher and wider curb flows; or, manholes which are along a surface drainage channel, but are only high enough to be above the majority of surface flow. These peak sewer flows would not be the result of roof drain connections, floor drain connections, sump pumps, subbase flows, nor infiltration.

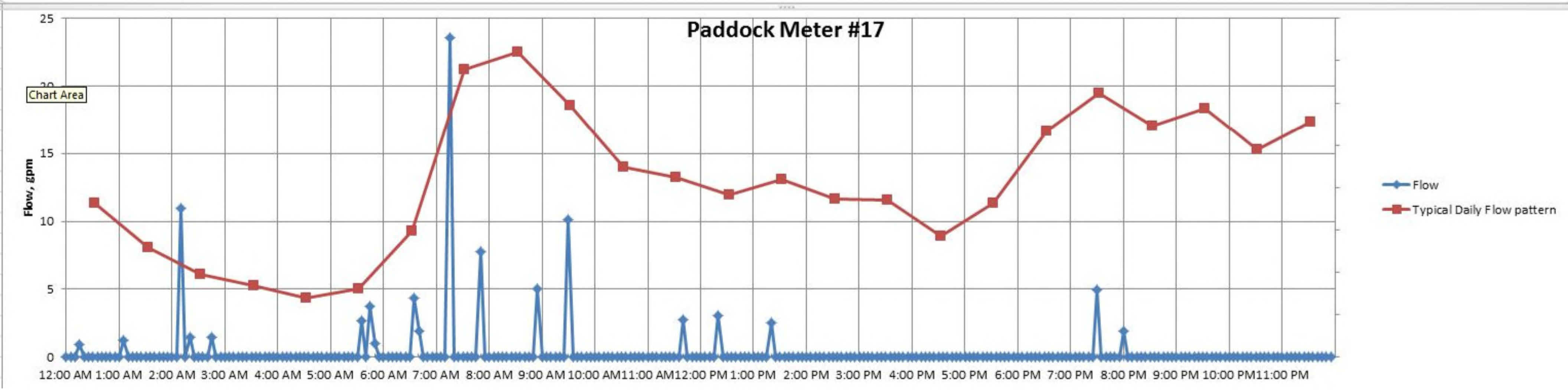

WNT - Daily Flow Data from Paddock Meter
April 2013 - July 2013
Flow (gpm)
Precipitation (inches)
Date
Precip
Avg Daily Flow (gpm)


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


Paddock Meter 17
Vertical (Value) Axis
Flow, gpm
Flow
Typical daily flow pattern
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM



July 23, 2013 Rainfall
Intensity, in/hr
Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM



Paddock Meter #17
Chart Area
Flow, gpm
Flow
Typical Daily Flow pattern
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM

METER 3 – WAYNE DRIVE

Meter 3 is located in Township manhole 1153 behind 1909 and 1911 Wayne Drive, in an 8-inch pipe at that manhole. There are no other meters which flow to this meter.

Period of Record

Meter 3 has been in place since April of 2012, but has recorded flows of zero for much of that time. Figure 14 shows some recorded flows in June and July of 2013. It can be seen that the highest recorded flow occurred on a day with no rainfall. From approximately July 17 to July 21, a typical flow pattern can be seen which would be representative of base flows with no inflow or infiltration. This base flow, or apparent dry-weather average flow value is 75 gpm, compared to the anticipated value of 69 gpm from computer modeling; this is considered a very good comparison.

June 7, 2013 Event

As seen on Figure 15, a single recorded peak flow occurs at 9 am, in the middle of the storm after a period of relatively low rain intensity. It is possible that the meter was not functioning before or after this peak, so no specific information can be assumed from this graph.

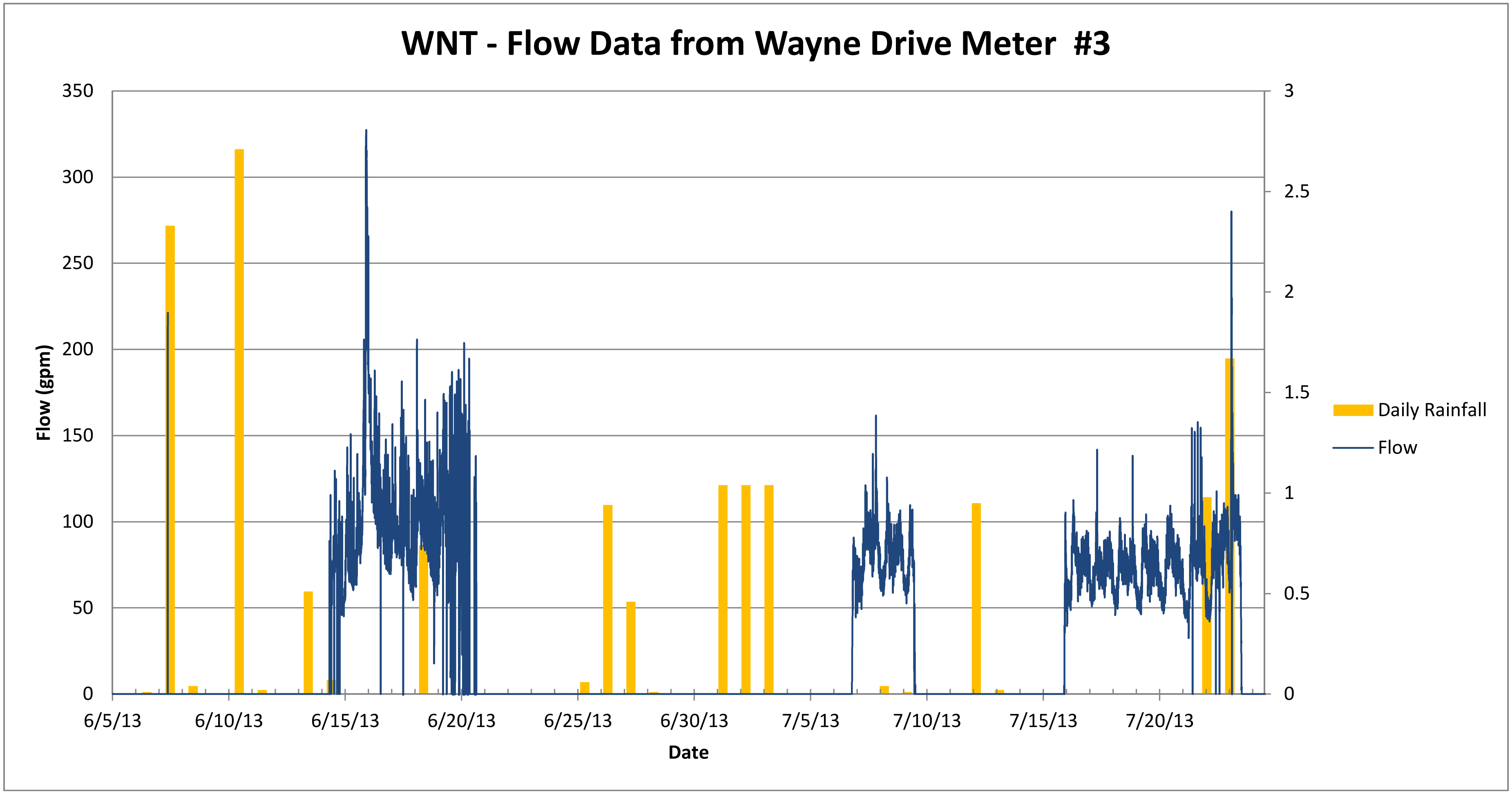
July 23, 2013 Event

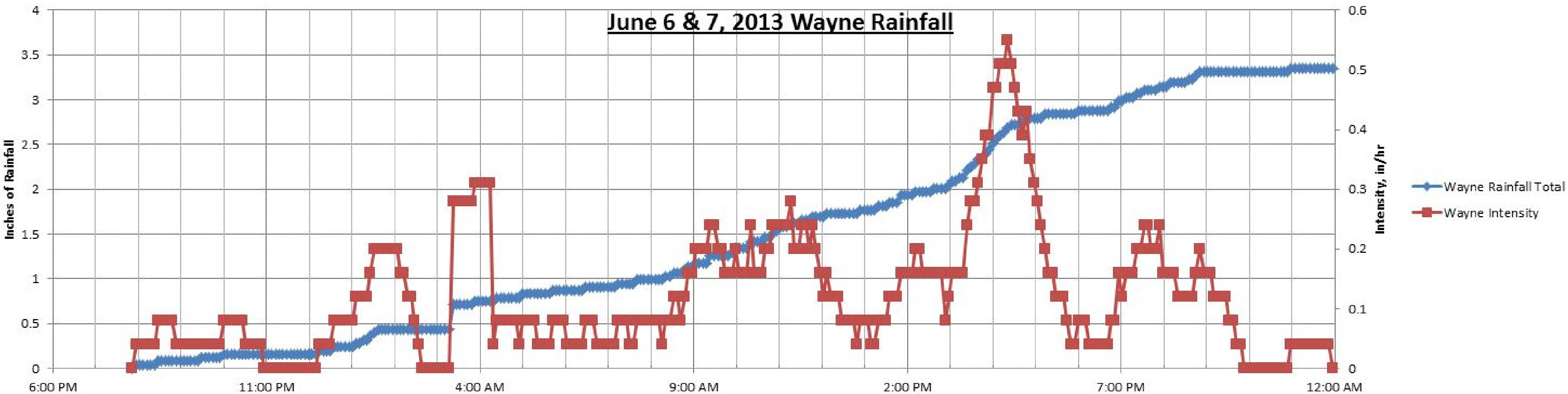
Based on Figure 16, it can be seen that increases in flow began immediately with the occurrence of significant rainfall, and continued to increase with the increase in rainfall intensity, followed by a rapid decline with the passing of the peak rainfall. Flows increased by a factor of 4; as with Figure 14, all of the actual flow values on Figure 16 are too high, but the magnitude of the increase in flows is appropriately depicted. It appears that the rainfall-induced flows ended by approximately 5 am (2 hours after the end of rainfall, at which point the higher flows related to the increase of the typical daily flow curve take over.

Flow Characterization

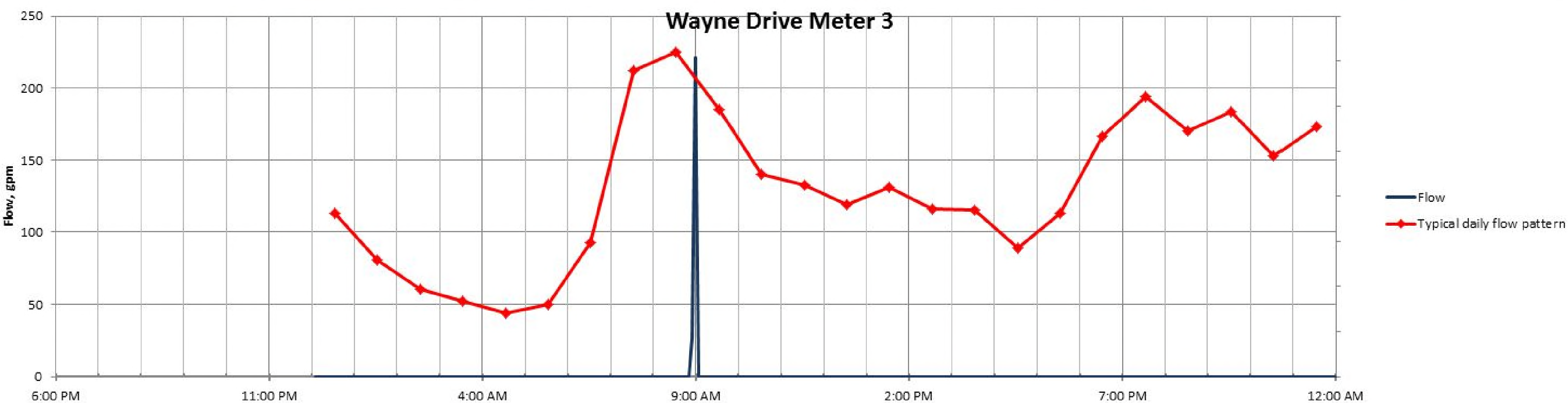
Based specifically on Figure 16, it is clear that there is direct inflow of the rainfall runoff into the sewer system, such as downspout or exterior floor drain connections directly to sewer laterals, or having manholes without lid inserts located in drainage low points which receive flow from paved areas (such as near curb lines within paved streets.) All of the flow from these sources would experience a rapid decline following the end of rainfall as can be seen in Figure 16. There is also a delayed inflow component within this meter area which only lasts a couple of hours after the storm. The sources of the delayed inflows at this meter would most likely be flow into manholes through the stone subbase of paved roads. It appears that infiltration is a very minor component or non-existent for the pipes contributing to meter 3, since increased flows last such a short time following the end of rainfall.

Additional discussion concerning rain-induced flows at Meter 3 can be found in the discussions of downstream Meter 4.

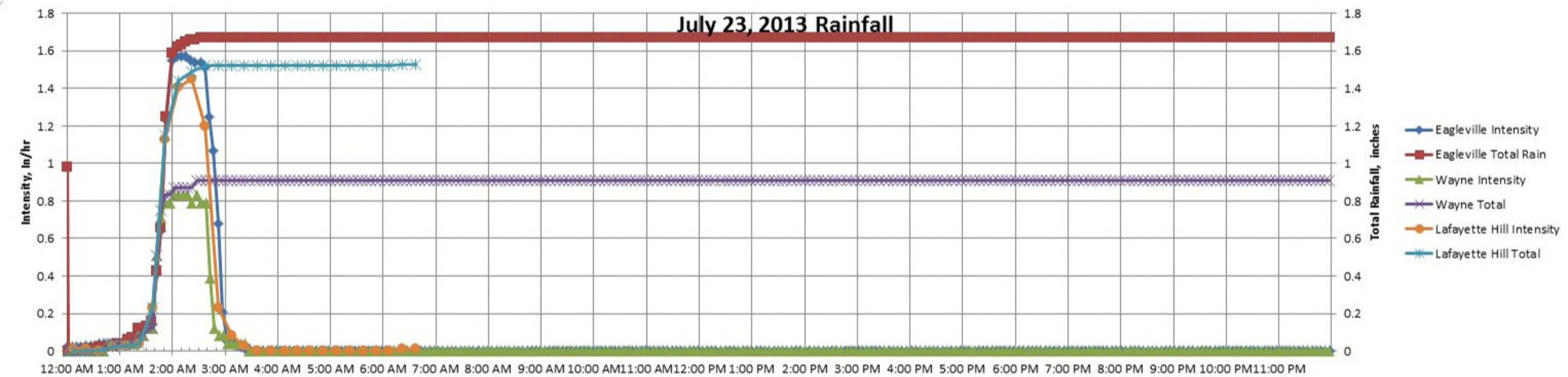

WNT - Flow Data from Wayne Drive Meter #3
Flow (gpm)
350
300
250
200
150
100
50
0
3
2.5
2
1.5
1
0.5
0
6/5/13
6/10/13
6/15/13
6/20/13
6/25/13
6/30/13
7/5/13
7/10/13
7/15/13
7/20/13
Date
Daily Rainfall
Flow

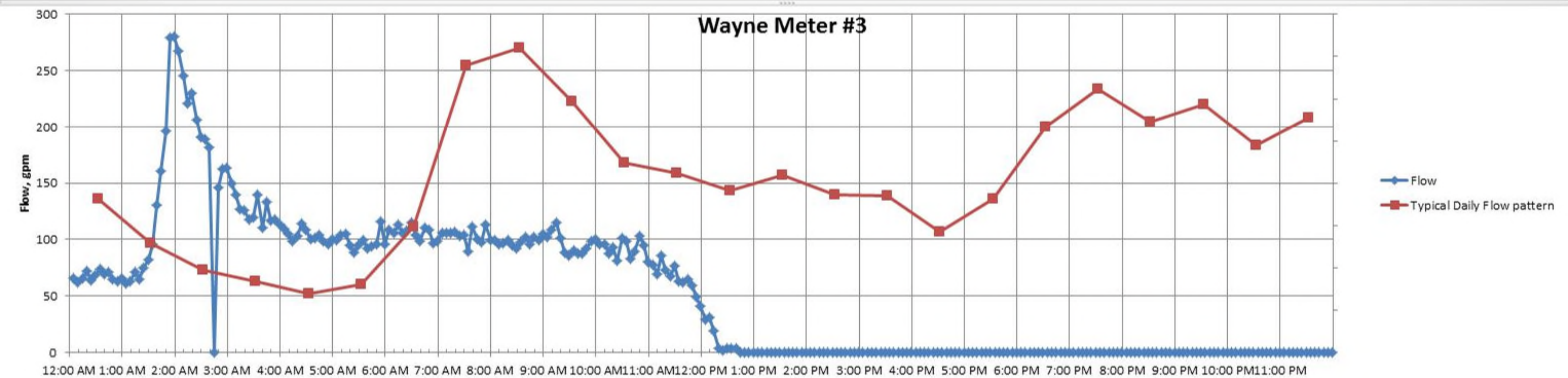


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
0
0.5
1
1.5
2
2.5
3
3.5
4
0.1
0.2
0.3
0.4
0.5
0.6
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM



Wayne Drive Meter 3
Flow, gpm
Flow
Typical daily flow pattern
0
50
100
150
200
250
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


July 23, 2013 Rainfall
Intensity, in/hr
Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM


Wayne Meter #3
Flow, gpm
Flow
Typical Daily Flow pattern
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM

METER 9 – GENERAL ARMISTEAD

Meter 9 is located in Township manhole 505 near the intersection of Boulevard of the Generals and General Arnold Avenue, in an 8-inch pipe at that manhole. There are no other meters which flow to this meter.

Period of Record

Meter 9 has been functional for portions of the time since May of 2013 as shown in Figure 17. It can also be seen that there is very little effect of rainfall events on average daily flows. When the meter is functioning, its accuracy appears good, in that the actual dry-weather average daily flow appears to be 75 gpm, and the anticipated flow is 80 gpm from computer modeling.

June 7, 2013 Event

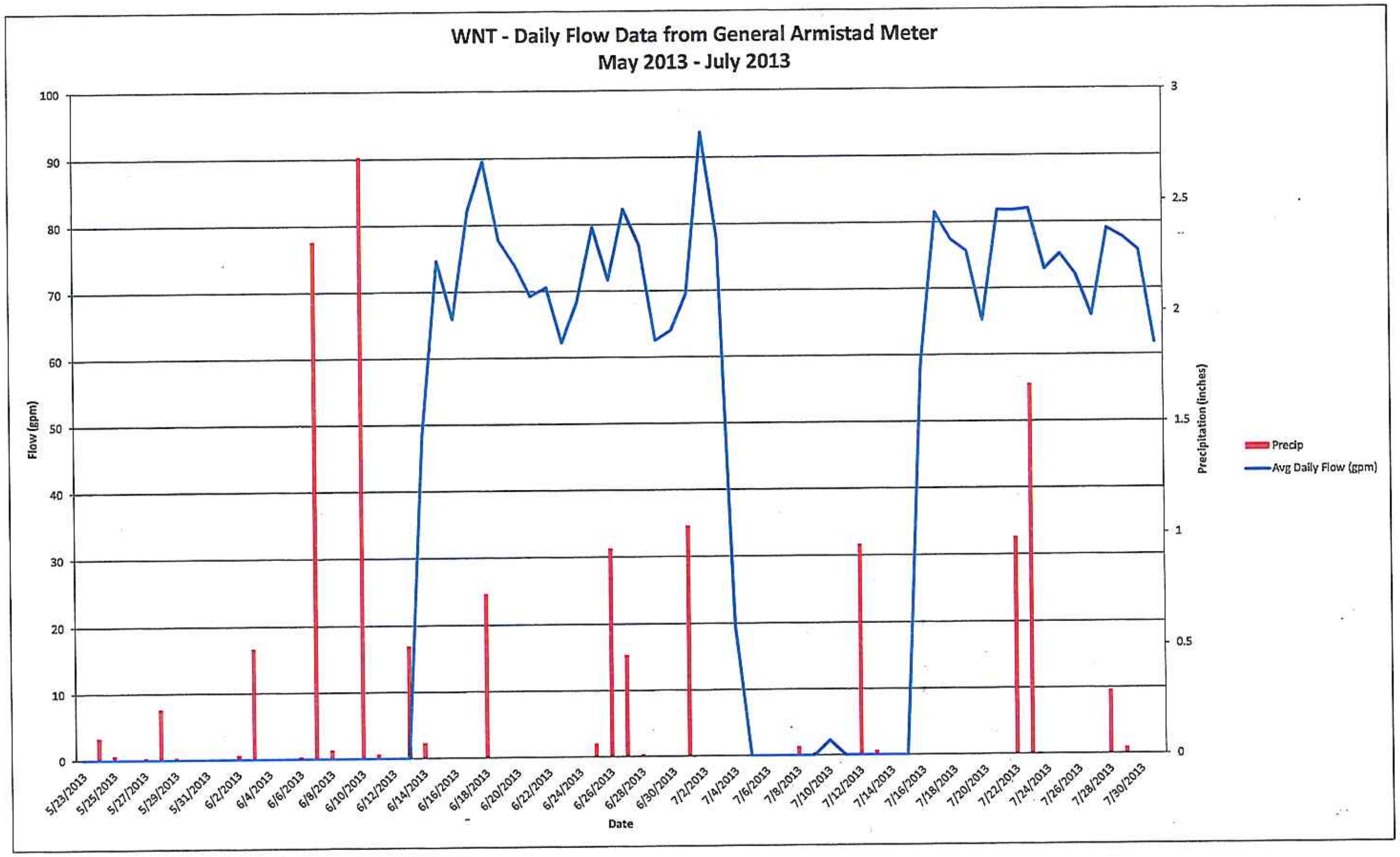
The meter was not functioning during this rain event.

July 23, 2013 Event

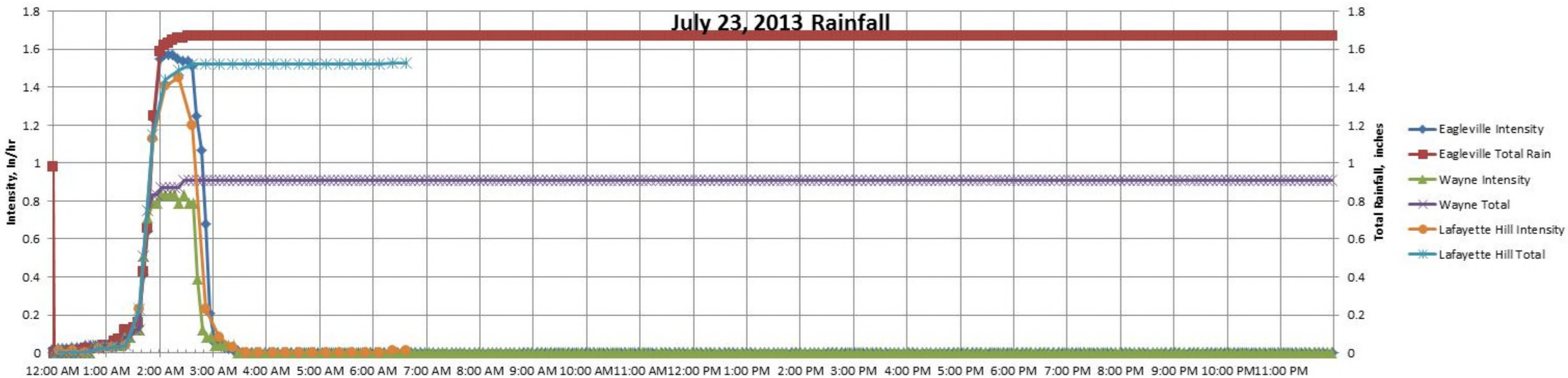
From Figure 18, it can be seen that increases in flow began approximately ½ hour after the occurrence of significant rainfall, and continued to increase with the increase in rainfall intensity, followed by a rapid decline with the passing of the peak rainfall. It appears that the rainfall-induced flows ended by approximately 4 am (1 hour after the end of rainfall, at which point the flows have returned to the typical daily flow curve.)

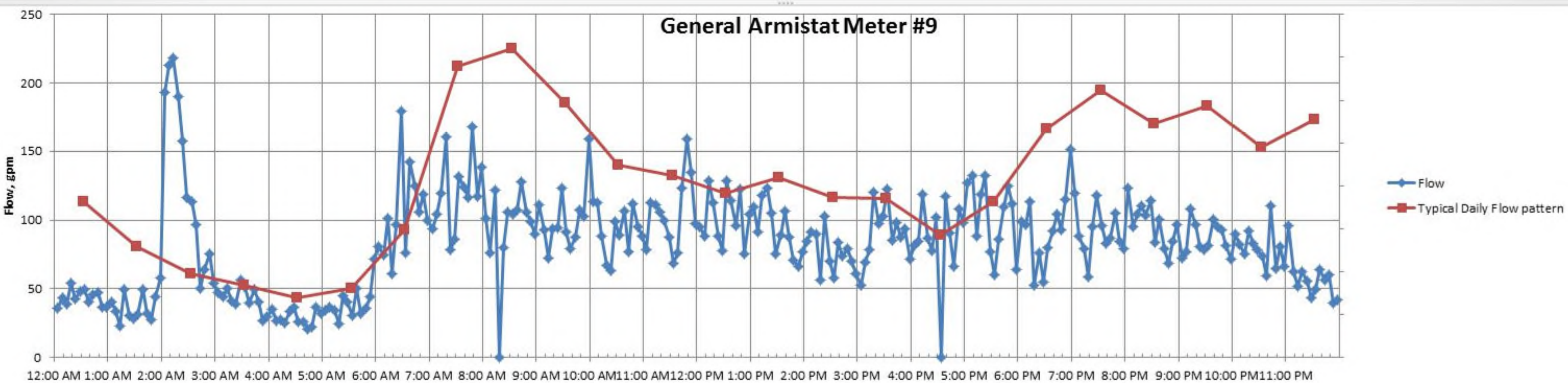
Flow Characterization

From Figure 18, it is clear that there is direct inflow of the rainfall runoff into the sewer system, although it is delayed such that it would not be due to downspout connections which provide an instantaneous response. It could be due to low sewer lateral vents, or to manholes without lid inserts which are adjacent to drainage low areas and are affected after a buildup of surface flows. The flow from these sources would experience a rapid decline following the end of rainfall as can be seen in Figure 18. The delayed inflow component within this meter area lasts approximately only an hour after the storm and is very minor.



WNT - Daily Flow Data from General Armistad Meter
May 2013 - July 2013
Flow (gpm)
Precipitation (inches)
Date
Precip
Avg Daily Flow (gpm)


July 23, 2013 Rainfall
Intensity, in/hr
Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM


General Armistat Meter #9
Flow, gpm
Flow
Typical Daily Flow pattern
0
50
100
150
200
250
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM

METER 14 – WEST INDIAN WOODS

Meter 14 is located in Township manhole 480 behind 922 Mystic Lane, in an 8-inch pipe at that manhole. There are no other meters which flow to this meter.

Period of Record

Meter 14 was providing mostly zero flow readings prior to the storm of June 7, 2013, as illustrated in Figure 19. Following the storms of June 7 and June 10, flows returned closer to zero, but then gradually increased to an average daily flow of approximately 40 gpm. For this relatively small sewershed of residential housing, an average daily flow of 40 gpm is too high, with anticipated averages at 4 gpm based on computer modeling. Figure 20 shows more detail with hourly flows for the period of June 7 through June 23. While the peak flows from June 15 through June 23 appear too high, the daily flow pattern with many flows dropping to zero would be expected; the general flow pattern in this time period therefore appears appropriate. This implies that the flows between June 8 and June 14, which are followed by an apparent instantaneous and large drop in flows, are unrealistically high.

June 7, 2013 Event

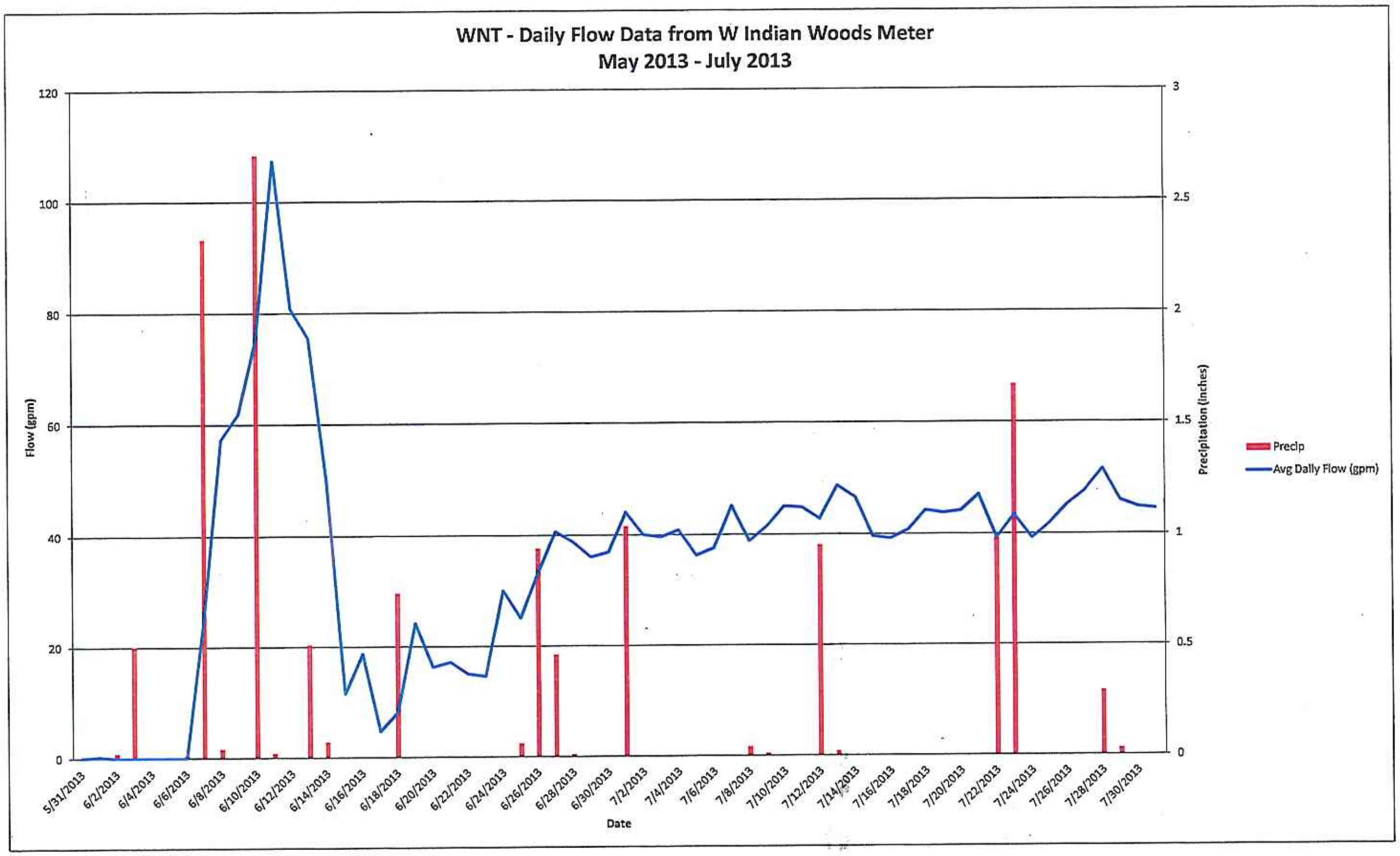
Figure 21 shows negligible flows until over 2.5 inches of rainfall has occurred and after the highest storm intensities, and flows rapidly dropping to zero after the higher rainfall intensities have ceased. The recorded peak flows appear to be unrealistically high. It is also unknown if the rapid drop to zero flow from the high peaks is accurate or represents a non-functioning meter.

July 23, 2013 Event

Based on Figure 22, it is clear that this storm has caused rainfall-induced sewer flows. It is unclear whether the drop in flows after the initial rise at 2 am is accurate, since high increases occur again at 2:30 am; whereas the high intensity rainfall continues to increase through this time period, it would be expected that flows would continue to increase. Following the end of rainfall, flows in general gradually decrease back to normal sewer flows over a period of approximately 2 hours.

Flow Characterization

It was noted that in both storms sewage flows do not appear to increase until significant surface flows are experienced. For June 7, since storm intensities were not very high, it took 2.5 inches of previous rainfall to develop sufficient surface flows to cause sewer inflow. For July 23, sewer inflows didn't occur until after a storm total of over 0.5 inches and storm intensities exceeded 0.5 inches per hour. In each case, it appears that sufficient rainfall occurred as needed to produce significant surface flows. It is likely therefore that the inflow is due to low sewer lateral vents, or to manholes without lid inserts which are adjacent to drainage low areas and are affected after a buildup of sufficient surface flows. These inflows would not be due to downspout connections which provide an instantaneous response. From Figure 22, it is clear that there is a delayed inflow which occurs a short period after the rainfall event. The sources of the delayed inflows at this meter would most likely be flow into manholes through the stone subbase of paved roads. It appears that infiltration is a very minor component or non-existent for the pipes contributing to meter 14, since increased flows last such a short time following the end of rainfall. A field investigation should be made of the contributing sewershed to this area to verify that the metered flows are erroneously high, and that there is not an intercepted spring, continuous high capacity sump pump connection, or some other significant flow source somewhere in the system.



WNT - Daily Flow Data from W Indian Woods Meter
May 2013 - July 2013
Flow (gpm)
Precipitation (inches)
Date
Precip
Avg Daily Flow (gpm)
0
20
40
60
80
100
120
0
0.5
1
1.5
2
2.5
3
5/31/2013
6/2/2013
6/4/2013
6/6/2013
6/8/2013
6/10/2013
6/12/2013
6/14/2013
6/16/2013
6/18/2013
6/20/2013
6/22/2013
6/24/2013
6/26/2013
6/28/2013
6/30/2013
7/2/2013
7/4/2013
7/6/2013
7/8/2013
7/10/2013
7/12/2013
7/14/2013
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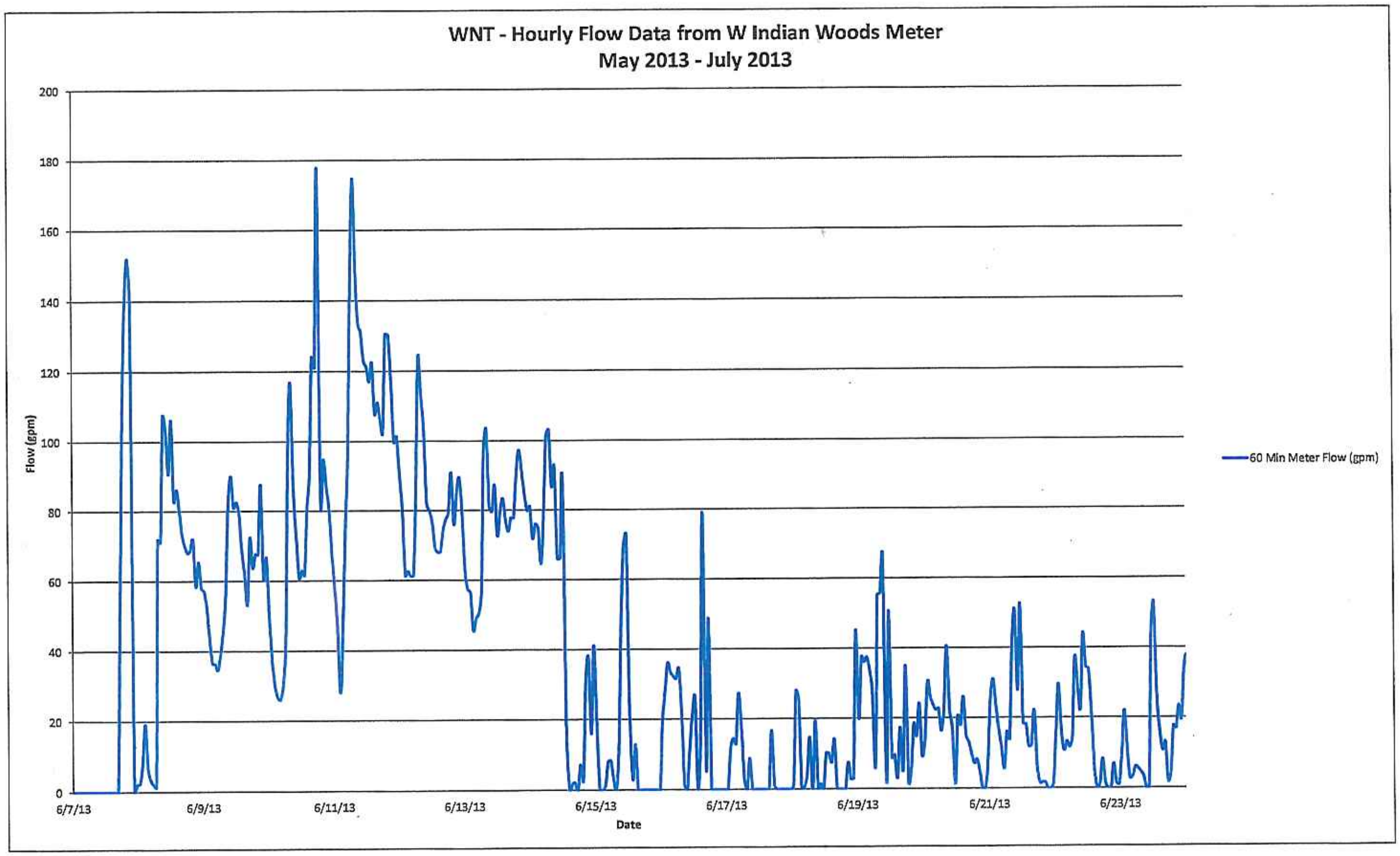
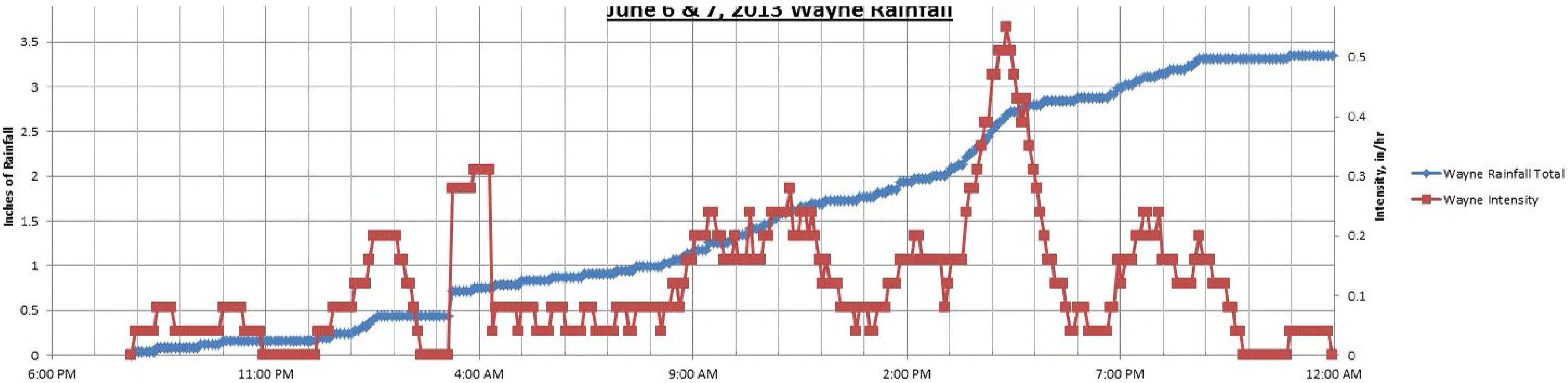
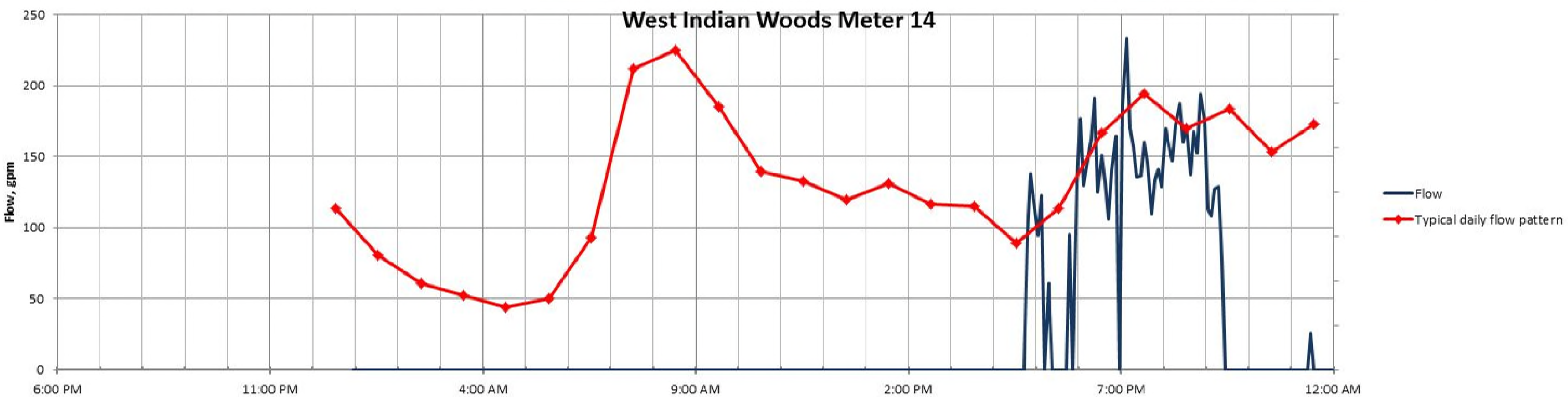
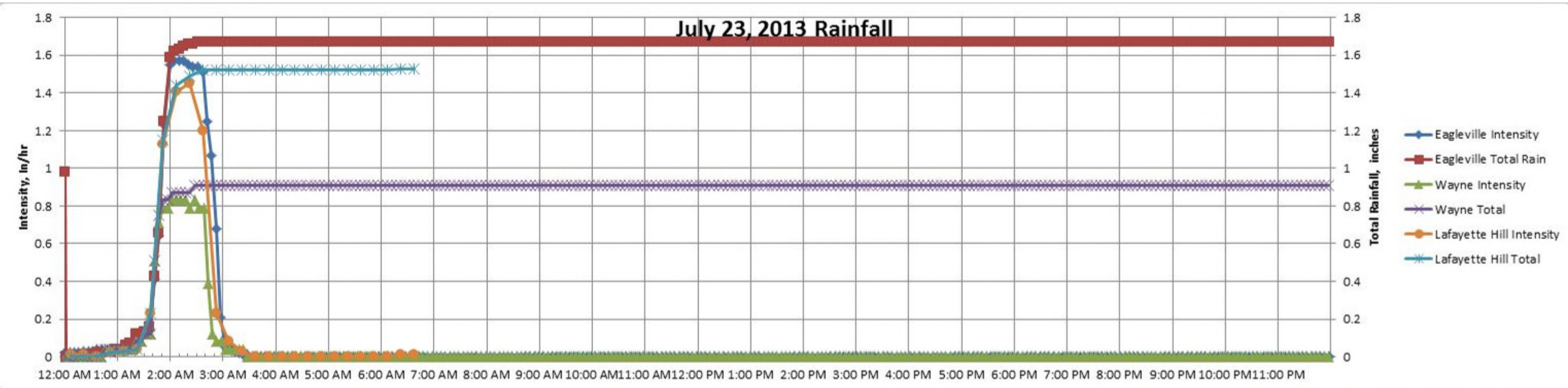
7/26/2013
7/28/2013
7/30/2013



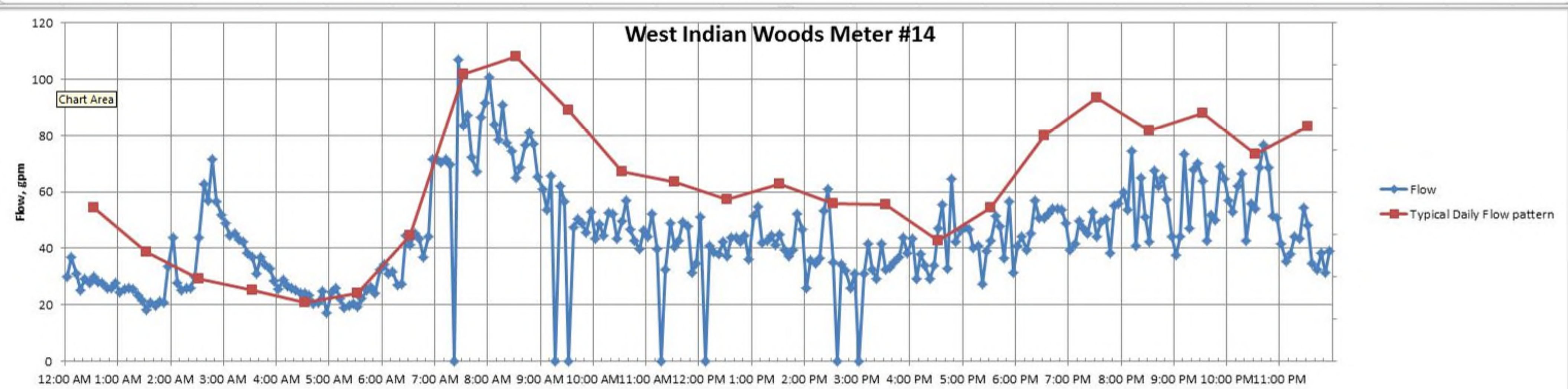
WNT - Hourly Flow Data from W Indian Woods Meter
May 2013 - July 2013
200
180
160
140
120
100
80
60
40
20
0
Flow (gpm)
6/7/13
6/9/13
6/11/13
6/13/13
6/15/13
6/17/13
6/19/13
6/21/13
6/23/13
Date
60 Min Meter Flow (gpm)


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
3.5
3
2.5
2
1.5
1
0.5
0
0.5
0.4
0.3
0.2
0.1
0
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


West Indian Woods Meter 14
Flow, gpm
Flow
Typical daily flow pattern
250
200
150
100
50
0
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM



July 23, 2013 Rainfall
Intensity, In/hr
Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM



West Indian Woods Meter #14
Chart Area
Flow, gpm
Flow
Typical Daily Flow pattern
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM

METER 15 – RIVERVIEW

Meter 15 is located in Township manhole 390 on Riverview Boulevard, in the 10-inch pipe discharging from that manhole. There are no other meters which flow to this meter.

Period of Record

Meter 15's contributing sewershed is a residential area for which anticipated dry-weather average daily flows would be 47 gpm based on computer modeling; Figure 23 shows an actual average daily flow of approximately 2 gpm, indicating that the meter is reading significantly too low. While it appears that most rain events cause an increase in average daily flows, there are non-rain event peak flows as least as large as the rain event peak flows, other than those occurring on June 7 and June 10. It appears therefore that very large rain events (2 inches and greater) are required to see any appreciable increase in average daily sewer flows.

June 7, 2013 Event

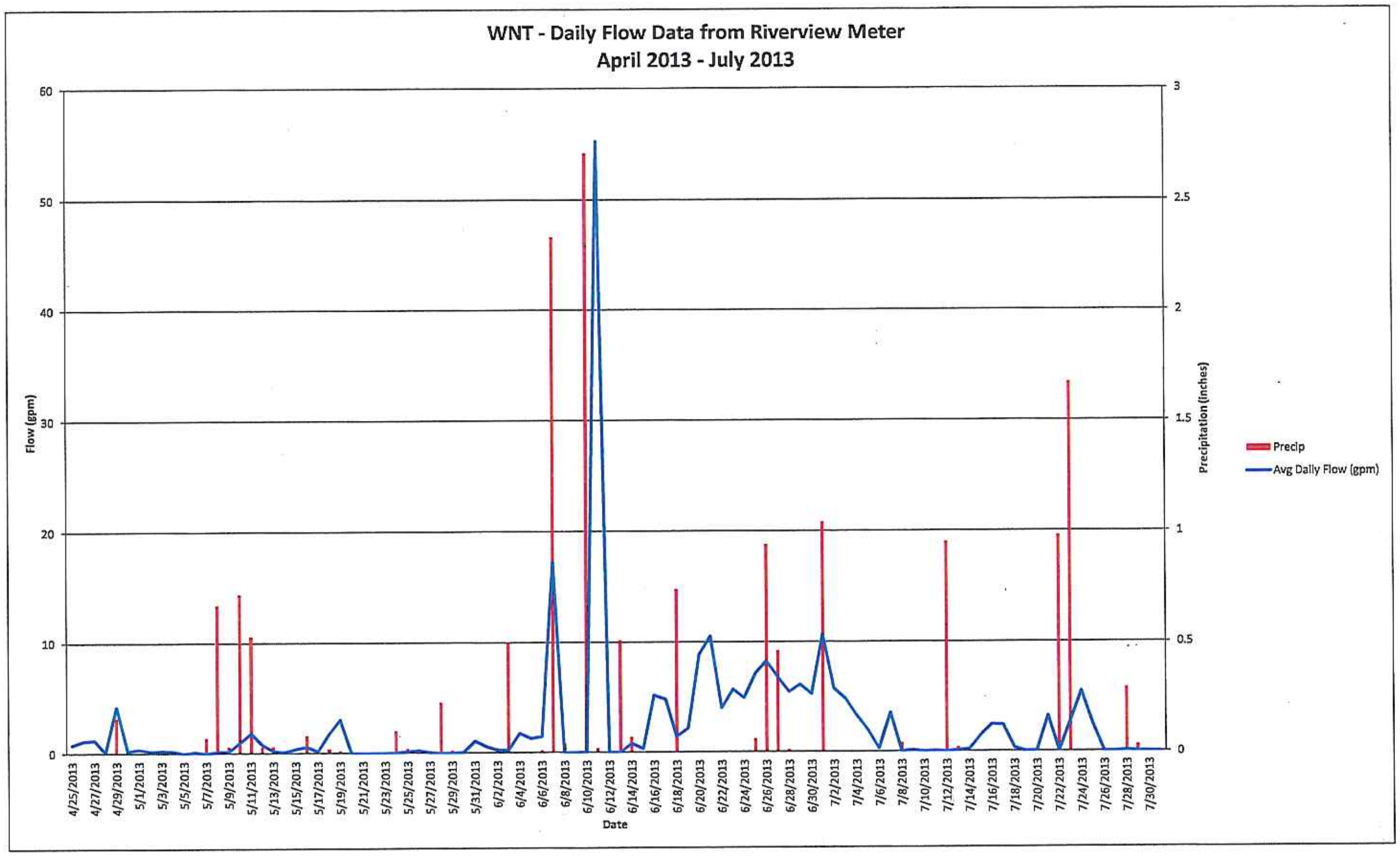
Figure 24 shows a very high (over 500 gpm), short duration peak flow occurring at 3 pm. However, there is no basis for this peak to occur at this particular time based on the rainfall patterns. Also, meter 8, which is the next meter downstream from meter 15, shows no such comparable peak flow. It appears that this peak is therefore erroneous. The smaller, although significant flows occurring from 2 to 5 am are relatively consistent in timing and magnitude with flows at downstream meter 8.

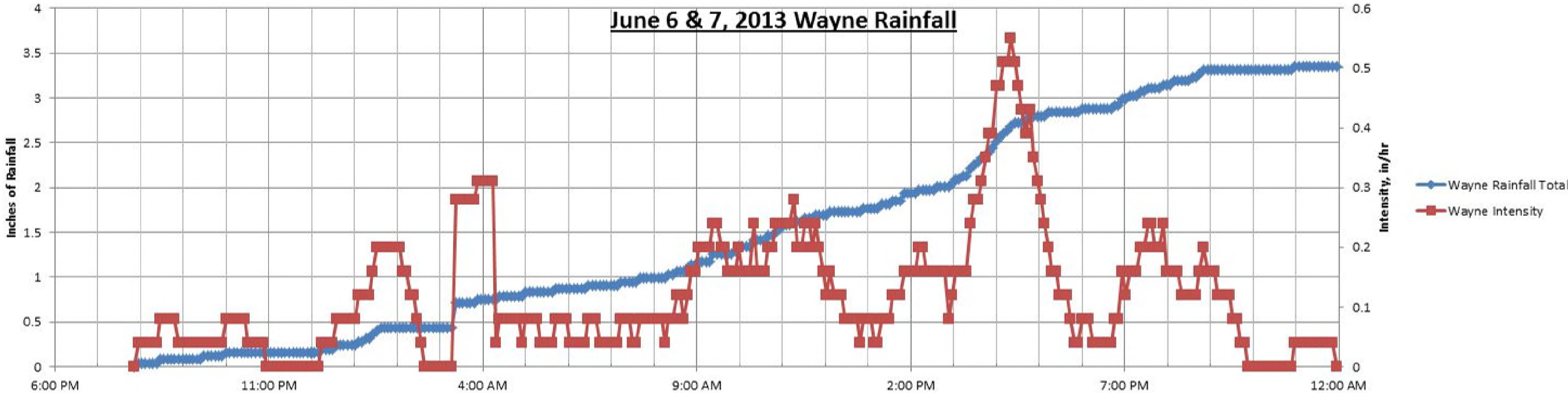
July 23, 2013 Event

There are multiple very short duration peaks shown to have occurred throughout the day as shown on Figure 25. These peaks are relatively consistent in magnitude and are not limited to occurrence with the early morning rainfall event. They also do not appear to be consistent with flows at downstream meter 8. It is assumed that these flows are in error and provide no worthwhile information concerning rain-induced flows.

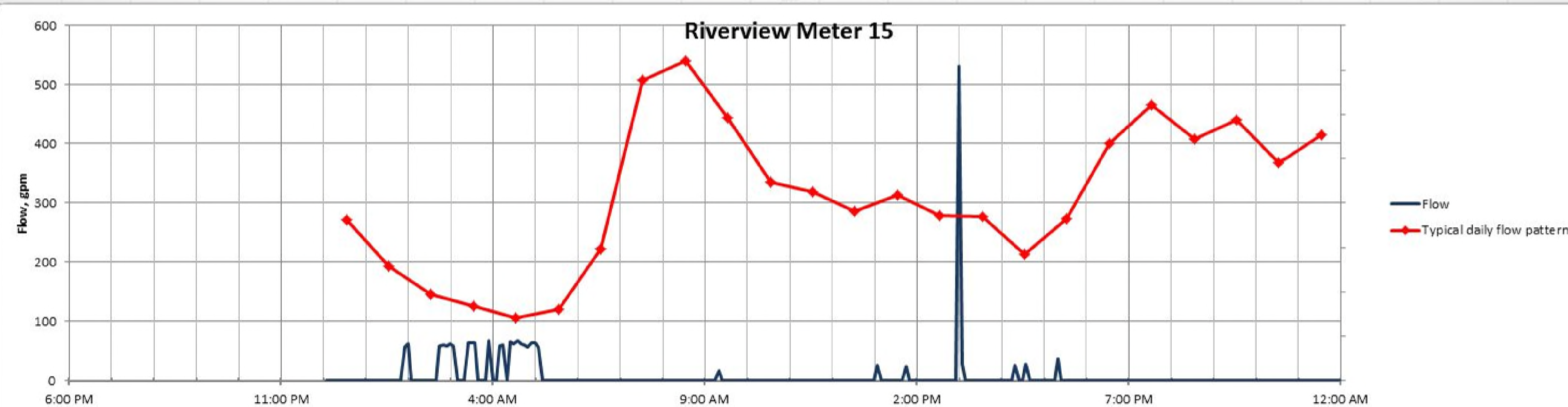
Flow Characterization

The metering results for these two storm events provide no information concerning the types of inflow which might be occurring within the contributing sewershed. It seems like the significant increases in average daily flow for the June 7 and June 10 rainfall events indicates that direct and/or indirect inflow is occurring. Whereas the average daily flows appear to drop to zero within one day following the rainfall events, infiltration and sump pumps would not appear to be a significant contributor of rain-induced sewage flows. All other sources of potential inflow could be considered, including downspout and exterior surface drain connections to sewer laterals, low lying sewer vents, direct surface flow into non-lined manhole covers, and subbase drainage into manholes.

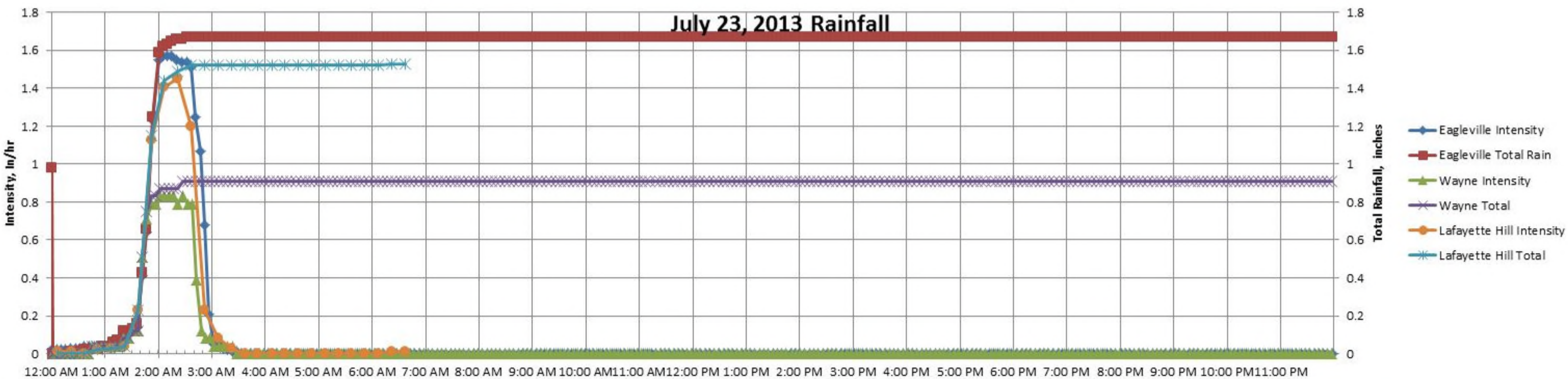

WNT - Daily Flow Data from Riverview Meter
April 2013 - July 2013
Flow (gpm)
Precipitation (inches)
Date
Precip
Avg Daily Flow (gpm)

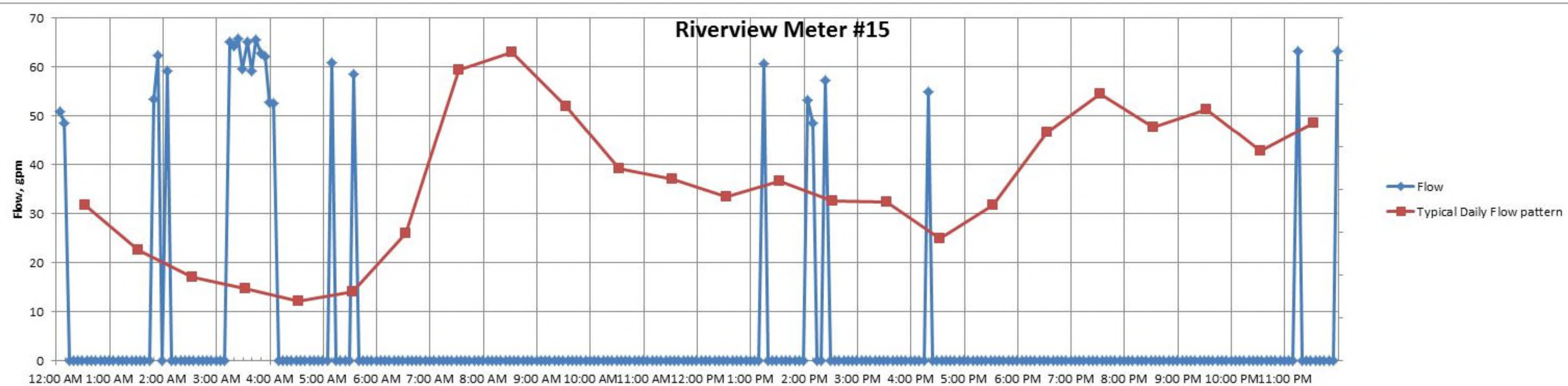


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM



Riverview Meter 15
Flow, gpm
Flow
Typical daily flow pattern
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


July 23, 2013 Rainfall
Intensity, in/hr
Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM


Riverview Meter #15
Flow, gpm
Flow
Typical Daily Flow pattern
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM

METER 8 – 367 PORT INDIAN

Meter 8 is located in Township manhole 367 on West Indian Lane, just west of the intersection with Port Indian Road, in the 15-inch pipe at that manhole. Meter 14 and Meter 15 both flow to Meter 8, along with a large apartment complex.

Period of Record

Figure 26 shows small impacts to average daily sewage flows for most rainfall events, with significant impacts for the June 7 and June 10 rain events. The apparent impacts for normal rain events are not significantly higher than high flows for non-rainfall event days. This is consistent with both contributing meters to this site, ie, that only very large rainfall events have a significant impact on sewage flows. It should be noted that the meter appears generally accurate, with actual dry-weather average daily flows at 60 gpm compared to anticipated flows between 64 and 75 gpm based on computer modeling.

June 7, 2013 Event

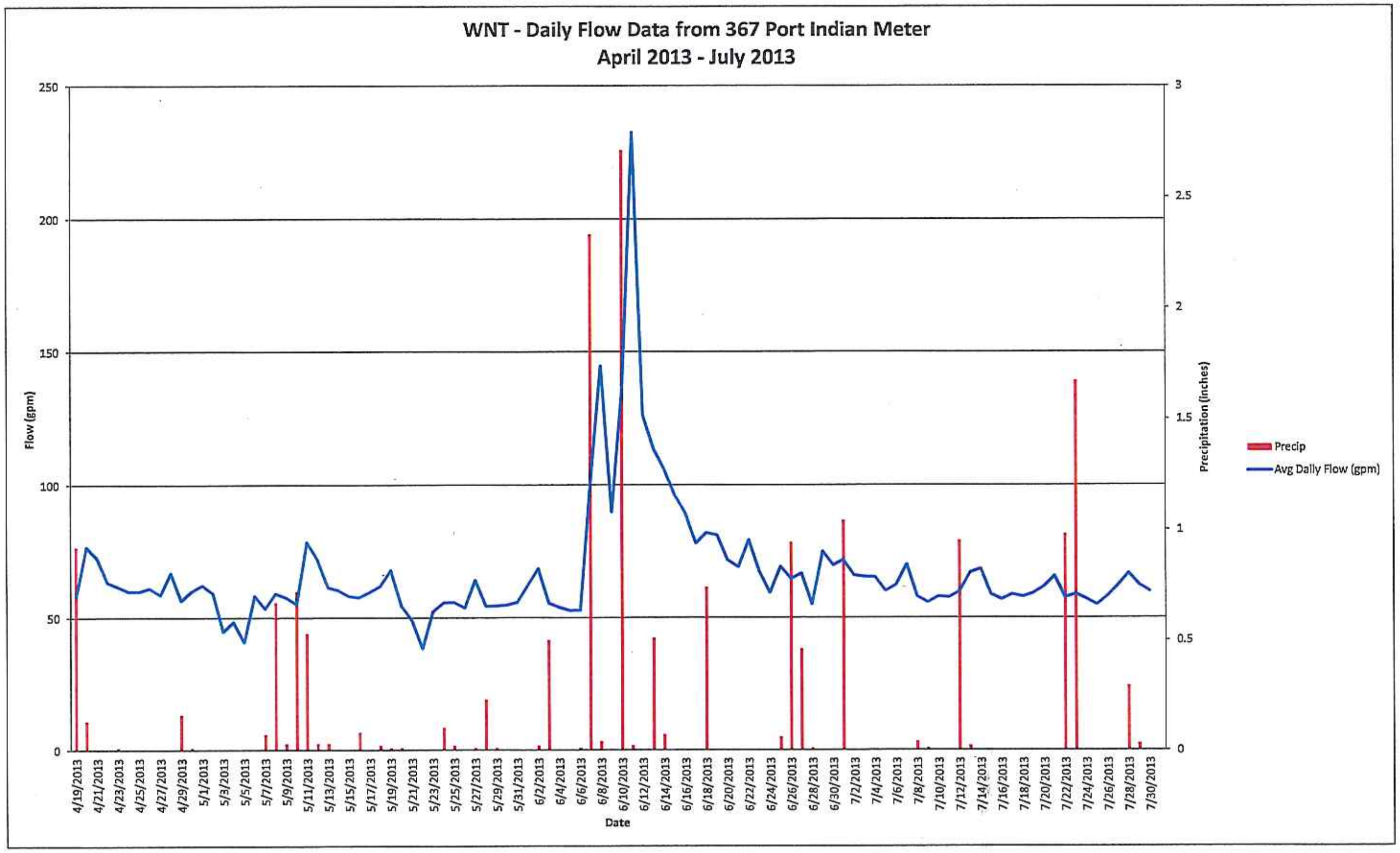
It appears from Figure 27 that the increased flows from 2 am to 3:30 am come from upstream meter 15, but that rain-induced flows appear at Meter 8 around 6 am. These rain-induced flows do not appear at Meter 14 or Meter 15, and would therefore appear to originate in the direct sewershed contributing to Meter 8. The peak sewage flow which occurs at approximately 7:30 pm is consistent with the peak flow at Meter 14, although twice as high. The travel time for sewage flows from Meter 14 and Meter 15 to Meter 8 is approximately 20 minutes, which is the difference in time between the peak occurrence at Meter 14 and Meter 8. Therefore, although the peak flow from Meter 14 passes through Meter 8, there is also a very significant contribution from the direct Meter 8 sewershed.

July 23, 2013 Event

The flows shown on Figure 28 for Meter 8 show a nearly identical curve to the flows from Meter 14, which is the typical daily flow curve for non-rainfall days. The rain-induced peak from Meter 14 which occurred at 2:45 am shows up at Meter 8 approximately ½ hour later. The difference in the magnitude of the peak at the two meters appears to be consistent with the difference in normal flows from the direct sewershed to Meter 8. The differences in flow throughout the day would be consistent with normal flows between the two meters. What this would imply is that there was essentially no rain-induced flow contribution from Meter 8's direct sewershed as a result of this storm.

Flow Characterization

It was noted that in both storms sewage flows do not appear to increase until significant surface flows are experienced. For June 7, significant flow increases didn't occur until after 3 inches of rainfall was received. For July 23, it appears that no inflow occurred even after more than one inch of rain had fallen. In each case, it appears that sufficient rainfall has to occur as needed to produce surface flows which are large enough to flood areas which are not affected by smaller rainfall events. It is likely therefore that the inflow is due to low (but not flush) sewer lateral vents, or to manholes without lid inserts which are adjacent to drainage low areas and are affected after a buildup of sufficient surface flows. These inflows would not be due to downspout connections which provide an instantaneous response. It also appears that most of the delayed inflows at Meter 8 originate from Meter 14.



WNT - Daily Flow Data from 367 Port Indian Meter
April 2013 - July 2013
Flow (gpm)
Precipitation (inches)
Date
Precip
Avg Daily Flow (gpm)
250
200
150
100
50
0
3
2.5
2
1.5
1
0.5
0
4/19/2013
4/21/2013
4/23/2013
4/25/2013
4/27/2013
4/29/2013
5/1/2013
5/3/2013
5/5/2013
5/7/2013
5/9/2013
5/11/2013
5/13/2013
5/15/2013
5/17/2013
5/19/2013
5/21/2013
5/23/2013
5/25/2013
5/27/2013
5/29/2013
5/31/2013
6/2/2013
6/4/2013
6/6/2013
6/8/2013
6/10/2013
6/12/2013
6/14/2013
6/16/2013
6/18/2013
6/20/2013
6/22/2013
6/24/2013
6/26/2013
6/28/2013
6/30/2013
7/2/2013
7/4/2013
7/6/2013
7/8/2013
7/10/2013
7/12/2013
7/14/2013
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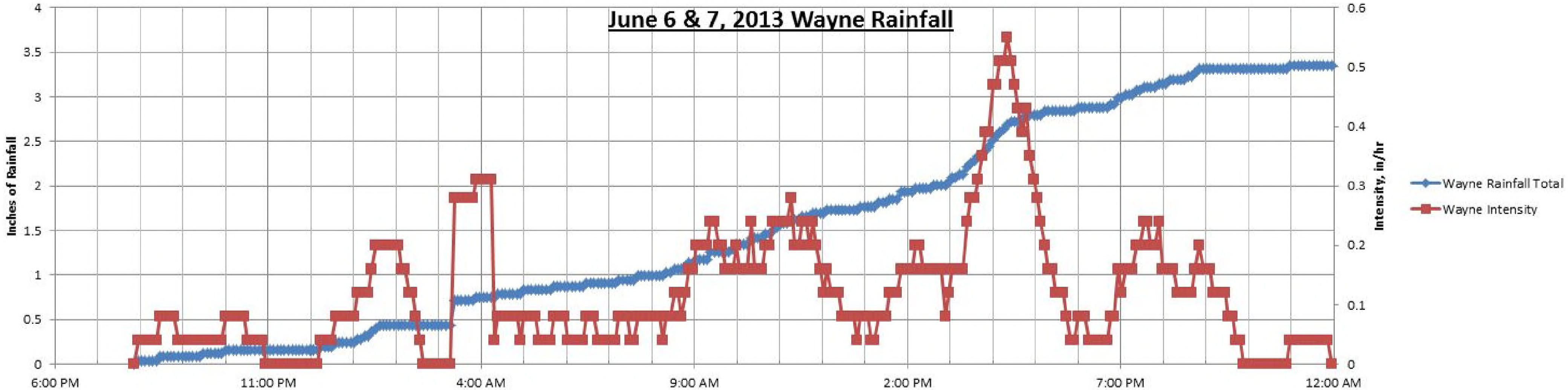
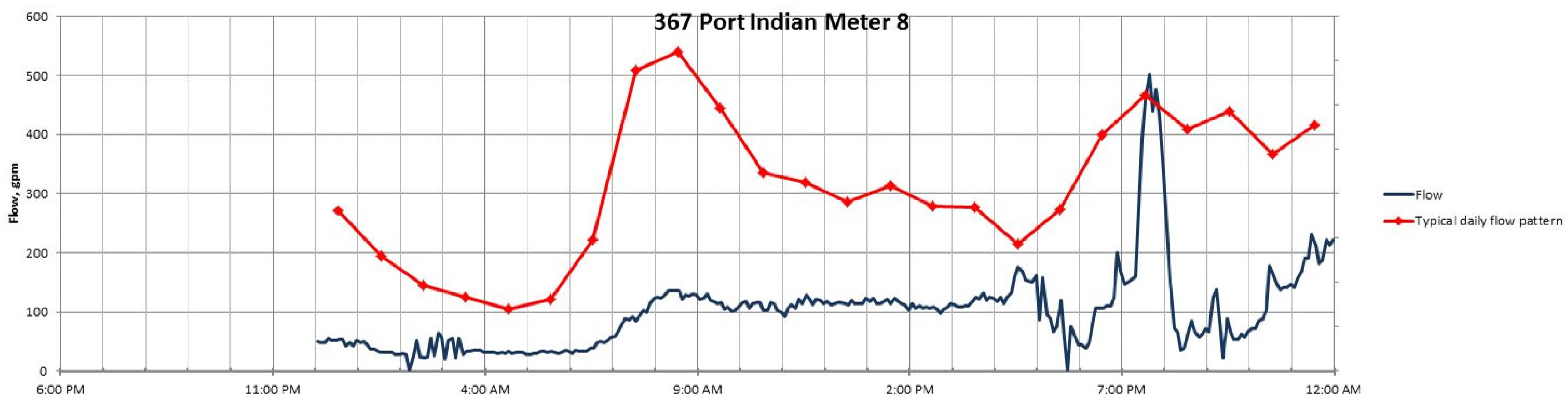
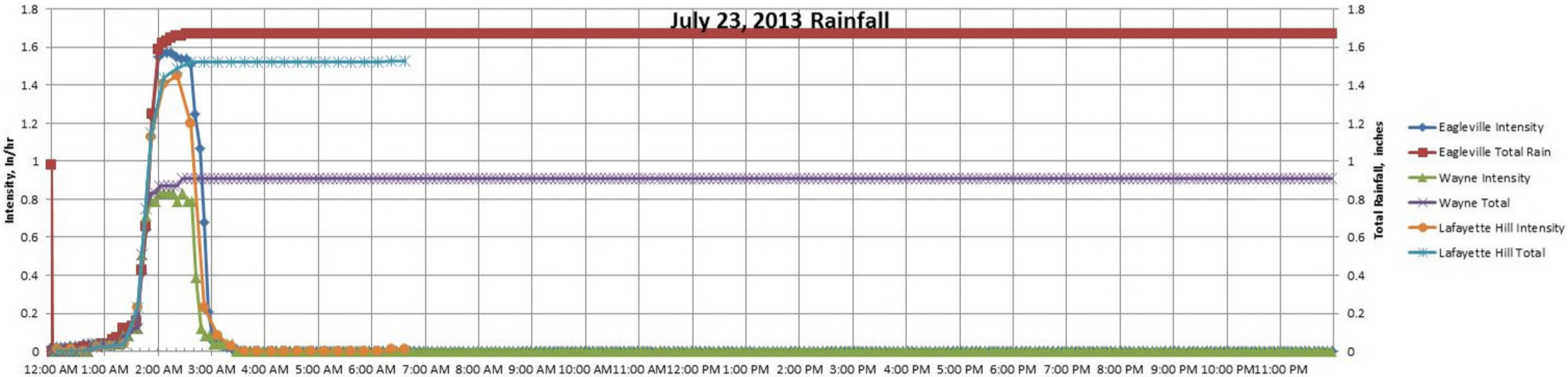
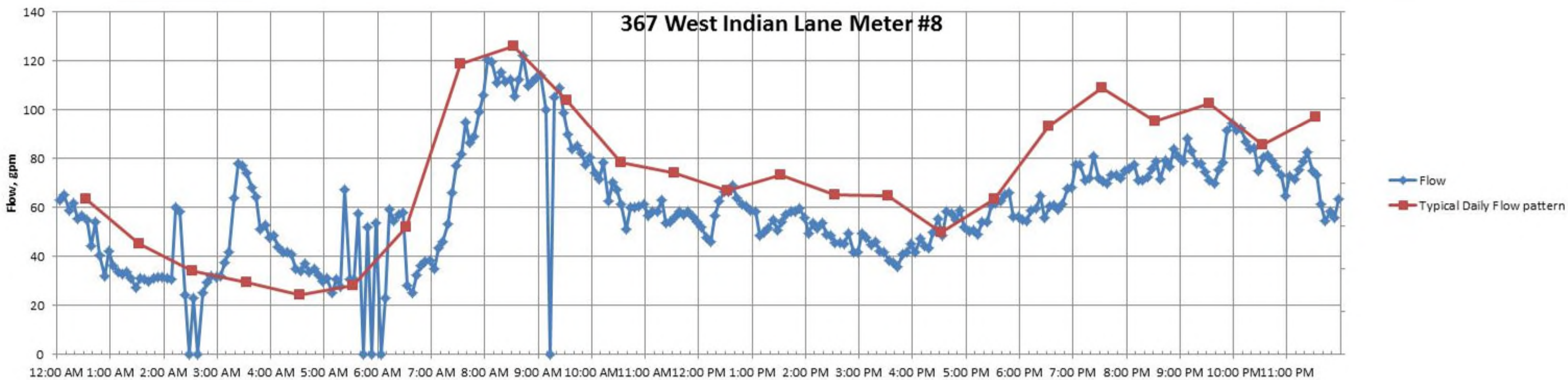
7/26/2013
7/28/2013
7/30/2013


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
0
0.5
1
1.5
2
2.5
3
3.5
4
0.1
0.2
0.3
0.4
0.5
0.6
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


367 Port Indian Meter 8
Flow, gpm
Flow
Typical daily flow pattern
0
100
200
300
400
500
600
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


July 23, 2013 Rainfall
Intensity, in/hr
Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM


367 West Indian Lane Meter #8
Flow, gpm
Flow
Typical Daily Flow pattern
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM

METER 7 – 498 PORT INDIAN

Meter 7 is located in Township manhole 498 on Port Indian Road, in the 15-inch pipe at that manhole. Meter 9 flows to Meter 7.

Period of Record

The only recorded flows at Meter 7 occurred on the high rainfall events of June 7 and 10, 2013, as shown on Figure 29. This was due to a non-functioning meter and not representative of zero flow, as a comparison with Meter 9, which flows to Meter 7, makes clear. Anticipated dry-weather average daily flows at this meter range from 112 to 184 gpm based on computer modeling.

June 7, 2013 Event

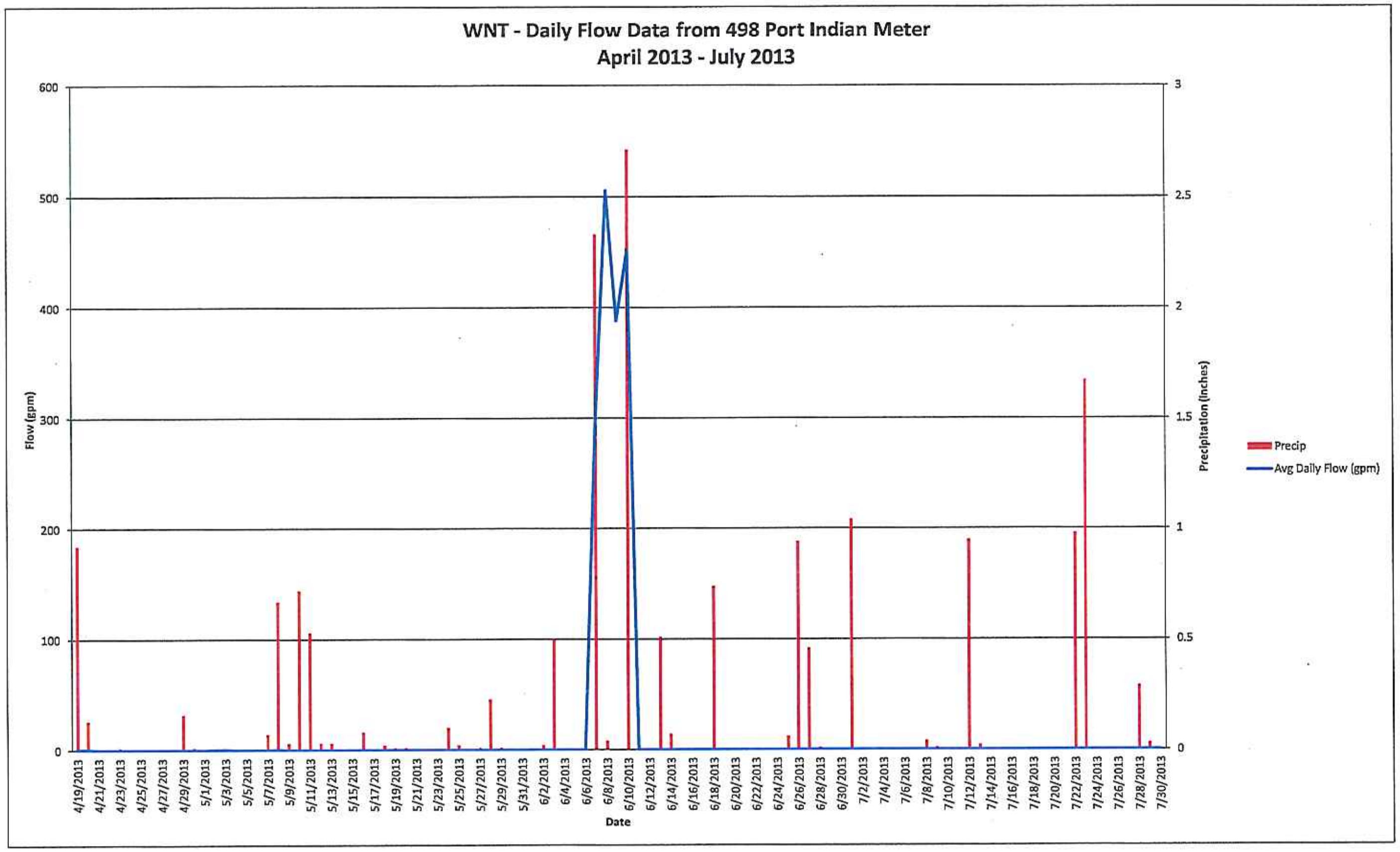
Figure 30 shows the hourly flows for the period of June 7 through June 12, while Figure 31 shows the flows at 5 minute increments for June 7. Whereas sufficiently high flows apparently needed to occur to coax this meter into flow readings, it is assumed that high flows didn't occur until over 1½ inches of rain occurred on June 7. As hinted at on Figure 31, and as seen more clearly on Figure 30, flows declined slowly following the end of rainfall, and were still at half of the highest peak flow a full day after the end of the rainfall.

July 23, 2013 Event

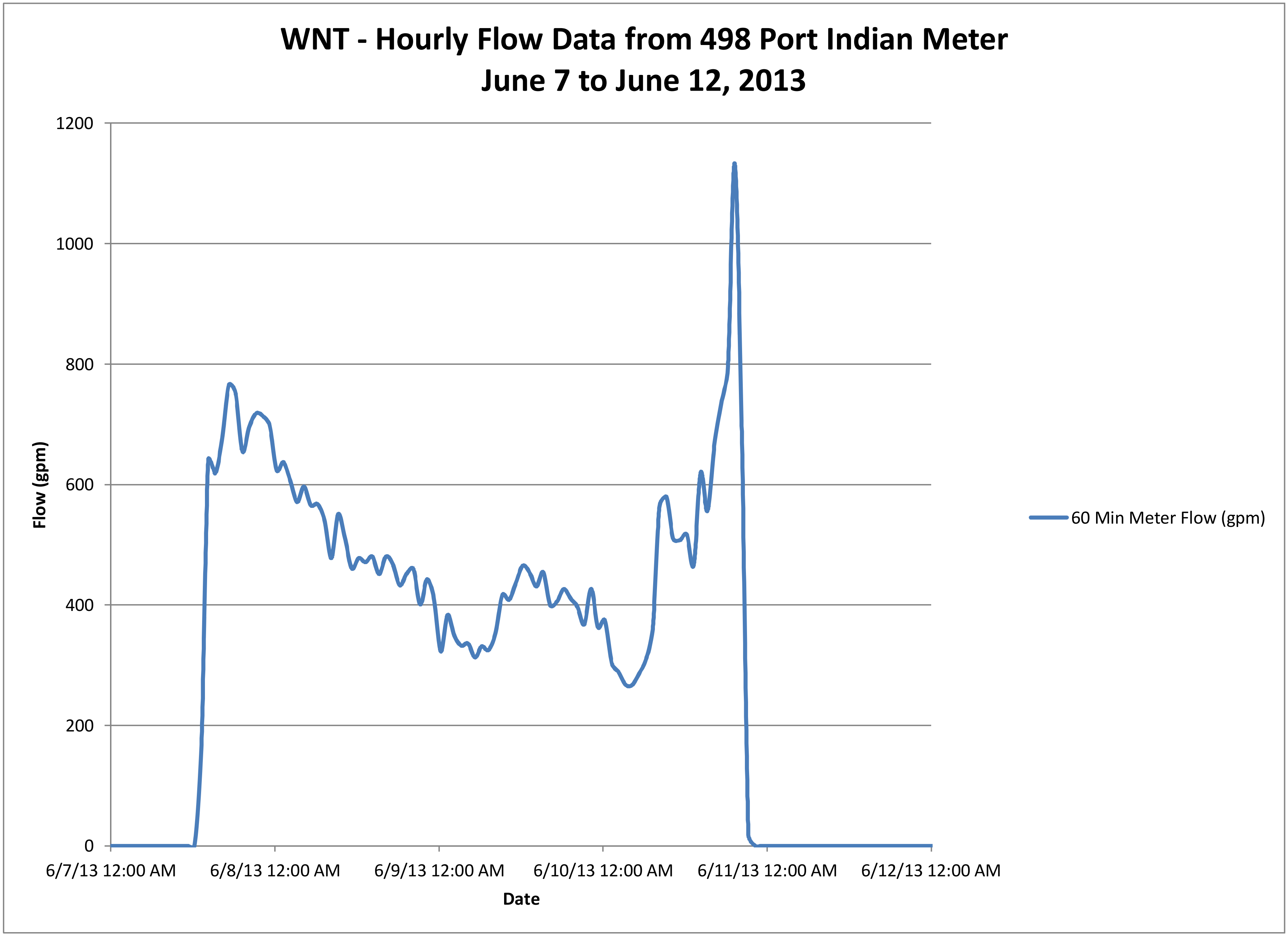
This meter was not functional during the July 23 rain event.

Flow Characterization

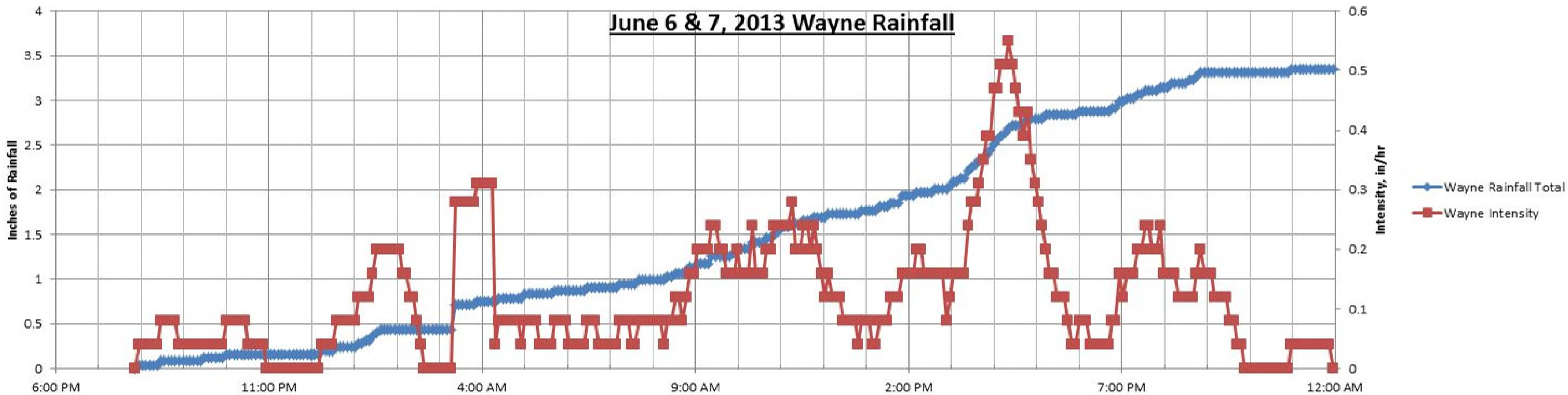
Similar to Meter 9 as evidenced by its July 23 flow chart, it appears that significant rain-induced sewage flows to meter 7 do not occur until sufficient rainfall occurs as needed to produce high surface flows. There apparently is very little direct inflow to the sewershed contributing to Meter 7. This is further illustrated by the fact that there is no rapid reduction in sewage flows following the end of the rainfall event. Direct surface inflow to manhole lids, direct connection of downspout or exterior area drains to sewer laterals, and low sewer vents would not be expected to be significant contributors to sewage flows in the contributing sewershed. Flow into manholes through the stone subbase of streets, and groundwater infiltration would be expected to be the sources of rain-induced sewage flows in this case.

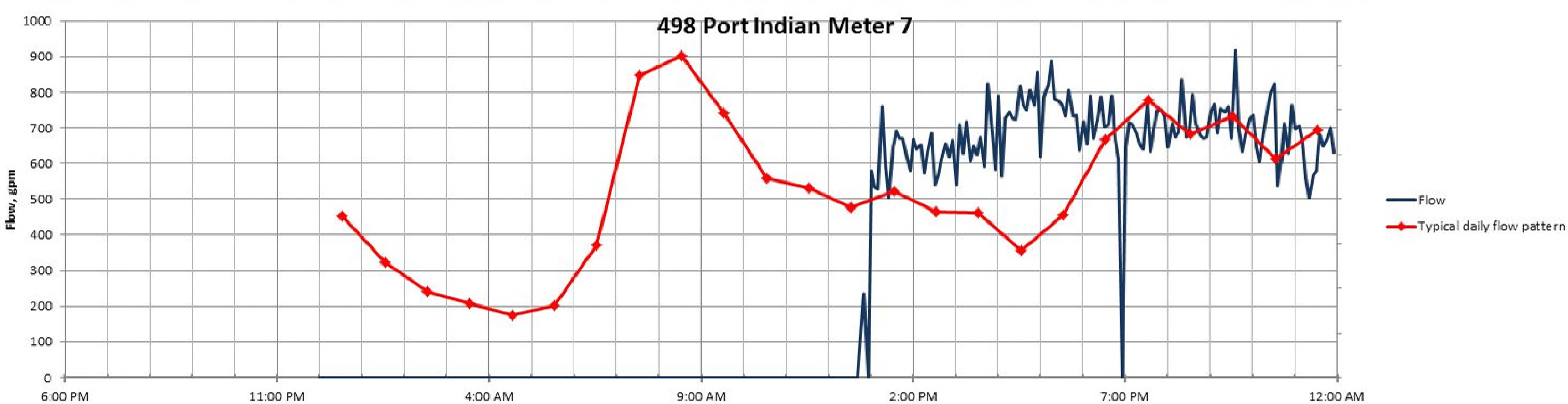


WNT - Daily Flow Data from 498 Port Indian Meter
April 2013 - July 2013
Flow (gpm)
Precipitation (inches)
Date
Precip
Avg Daily Flow (gpm)



WNT - Hourly Flow Data from 498 Port Indian Meter
June 7 to June 12, 2013
1200
1000
800
600
400
200
0
Flow (gpm)
6/7/13 12:00 AM
6/8/13 12:00 AM
6/9/13 12:00 AM
6/10/13 12:00 AM
6/11/13 12:00 AM
6/12/13 12:00 AM
Date
60 Min Meter Flow (gpm)


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


498 Port Indian Meter 7
Flow, gpm
Flow
Typical daily flow pattern
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM

METER 11(1) – SCHOOL AT DRIVEWAY

Meter 11(1) is located in Township manhole 701 on School Lane, in the 8-inch pipe at that manhole.

Period of Record

Figure 32 shows small impacts to average daily sewage flows for most rainfall events, with significant impacts for the June 7 and June 10 rain events. Another feature apparent from this figure is that following each rise related to a rain event, there is a gradual decline in flows until the next rain event. It is also worthwhile to note that even though the rainfalls were generally comparable on June 7 and June 10, the average daily flow for the June 10 event was much higher than the June 7 event. It should be noted that the meter appears to be providing fairly accurate data, since the actual dry-weather average daily flows are approximately 4 gpm compared to the anticipated value of 2 gpm based on computer modeling.

June 7, 2013 Event

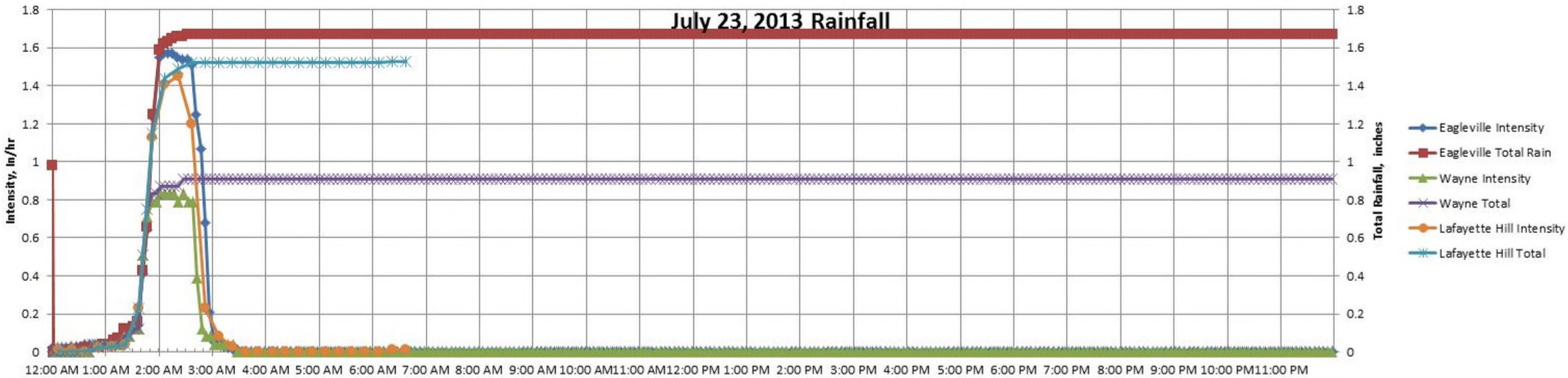
Figure 33 shows the hourly flows from June 6 through June 10 related to this storm, and Figure 34 shows the flows at 5-minute increments through June 7. It appears that rain-induced flows began after only 0.2 inches of rainfall, showing gradual increases with the higher rain intensities, until approximately 3:40 pm, approximately ½ hour after the highest rainfall intensities began. The subsequent flows drop with the drop in rainfall intensity. Following the end of rainfall, the flows drop fairly rapidly for approximately two hours, at which point the drop changes to a very slow decrease over the following two days (as seen in Figure 33).

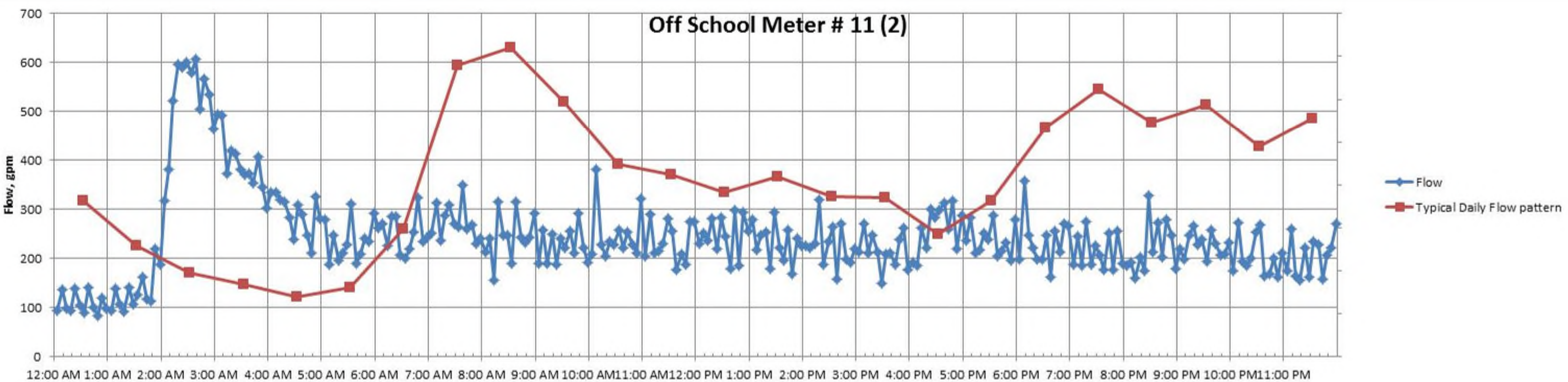
July 23, 2013 Event

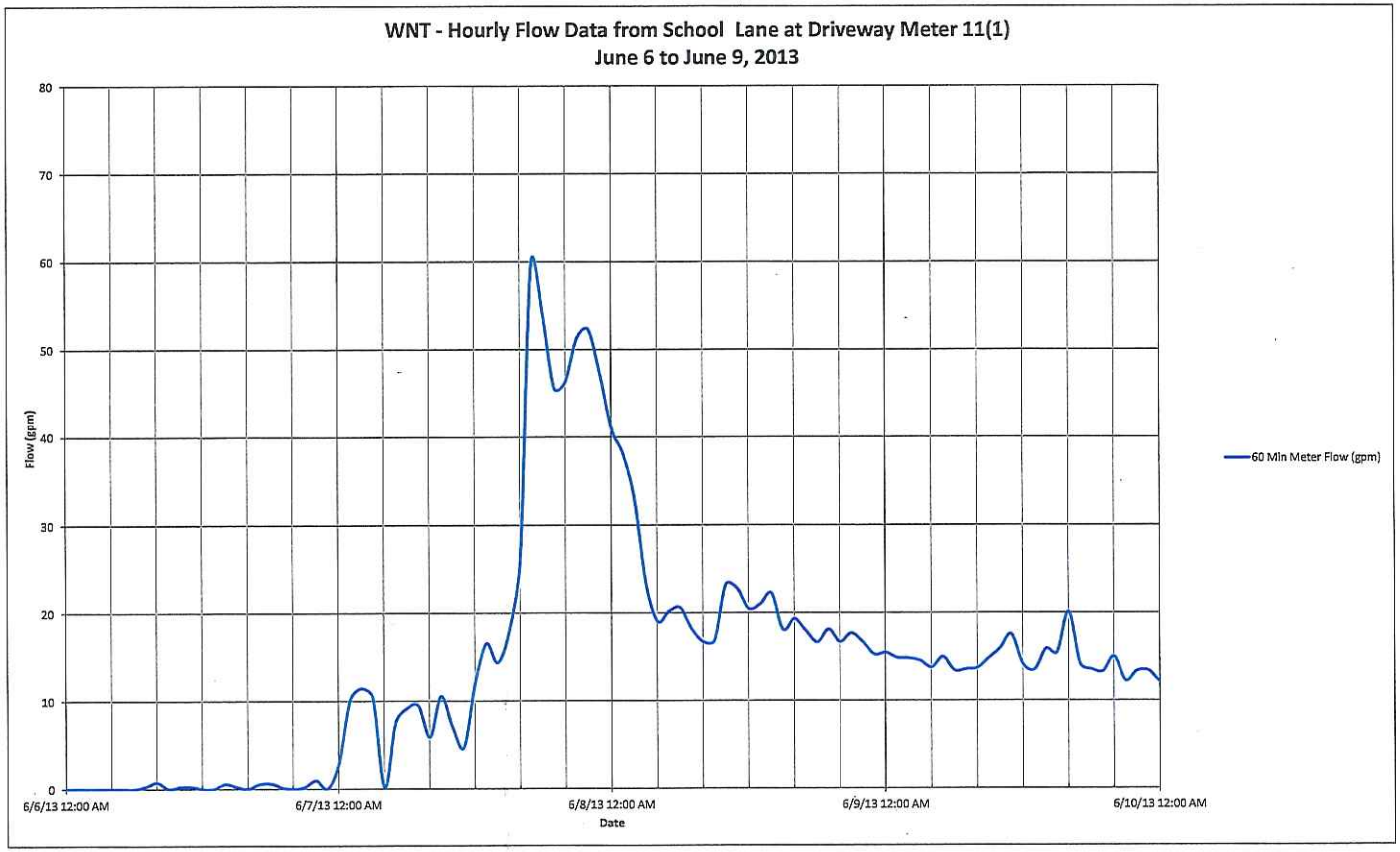
From Figure 35, it can be seen that rain-induced sewage flows begin shortly after the start of significant rainfall intensities, and the flows continue to increase through the end of rainfall. The drop in flows is similar to the June 7 event, although to a much lesser magnitude. There is a sharp, short drop following the end rainfall, followed by a 3 hour gradual decline, followed by a very gradual decrease through the end of the day.

Flow Characterization

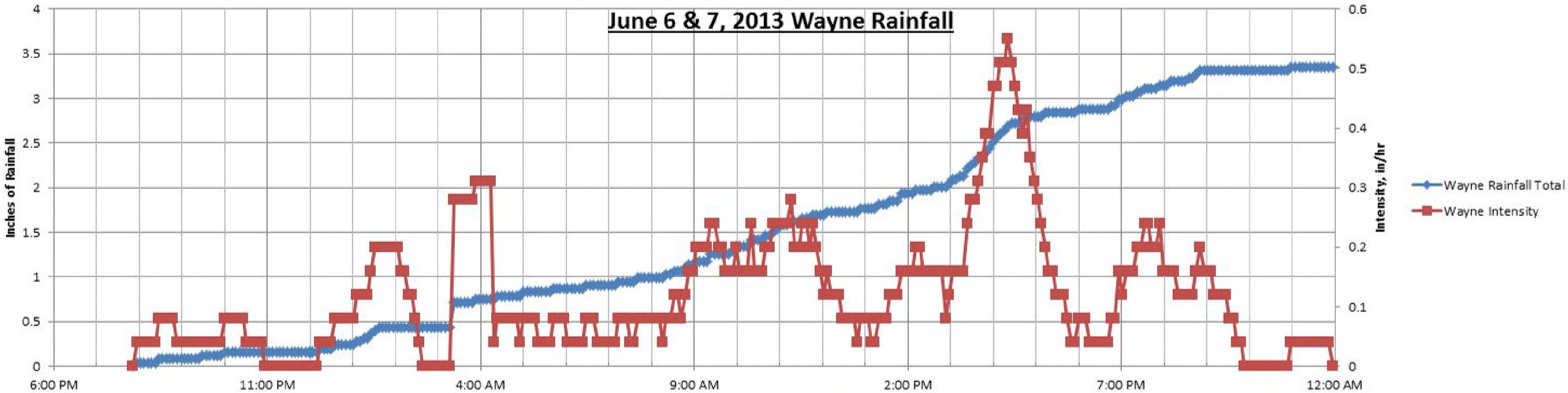
It appears that this sewershed has some elements of each type of inflow and infiltration: direct inflow, delayed direct inflow, and infiltration. The least likely direct inflow source would be direct downspout connections. Inflow through manhole lids and low sewer vents, are all likely, as is inflow to manholes through the stone subbase of the road. Of all the meters analyzed thus far in this report, this one is the most likely candidate for receiving infiltration from groundwater. The fact that the flows increased so significantly for the June 7 storm event compared to the June 10 storm event, even though they were generally comparable rainfall events, is almost surely due to a rise in the groundwater level due to the two close, large rain events. The sewershed contributing to this meter consists of only 6 manholes, approximately 1150 feet of 8” pipe, and less than 10 homes and small businesses. For it to contribute over 70 gpm of average daily flow due to the June 10 storm event is a tremendous amount of rain-induced flows for such a small area.

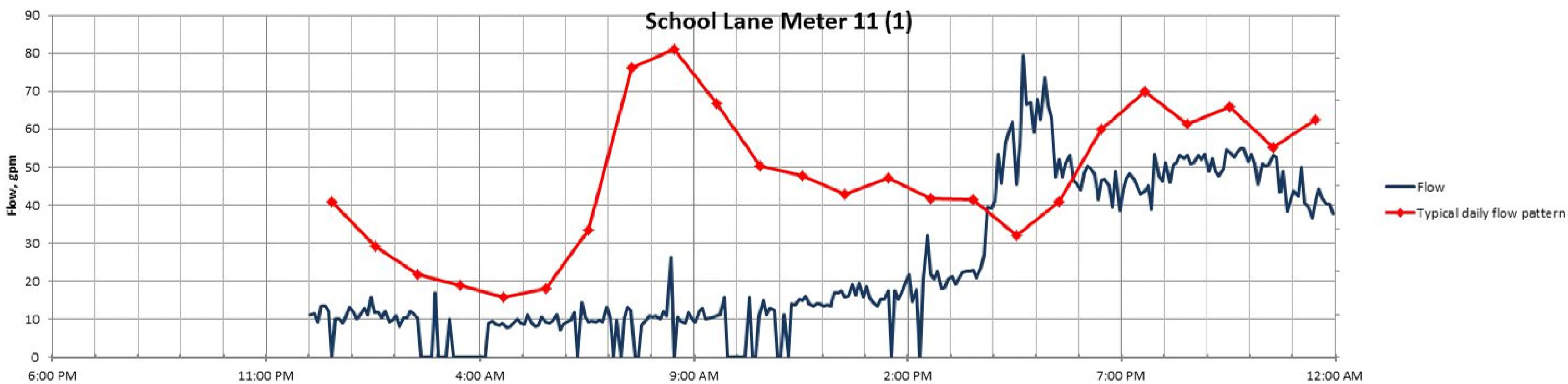

July 23, 2013 Rainfall
Intensity, in/hr
Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM

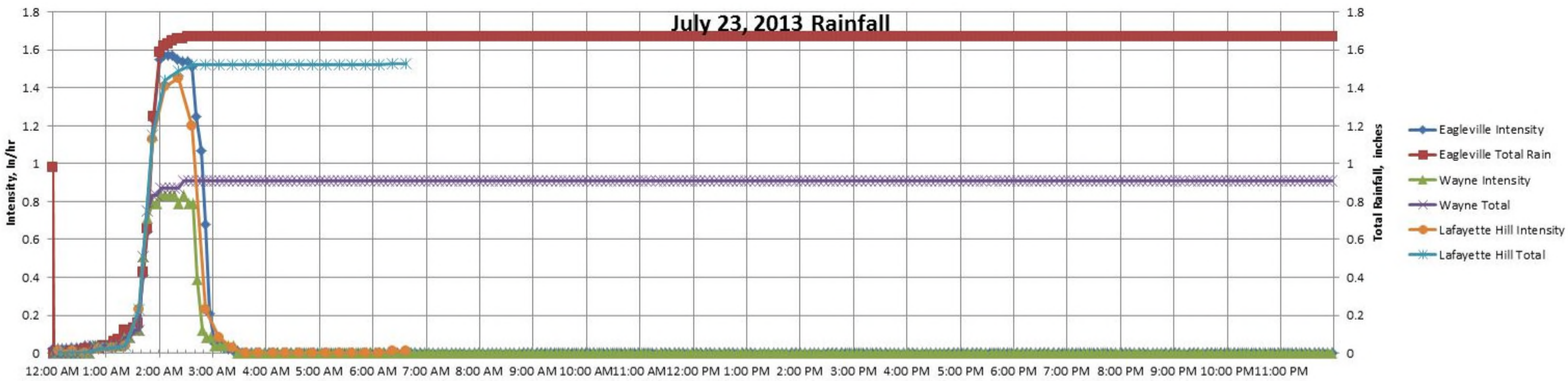

Off School Meter # 11 (2)
Flow, gpm
Flow
Typical Daily Flow pattern
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM

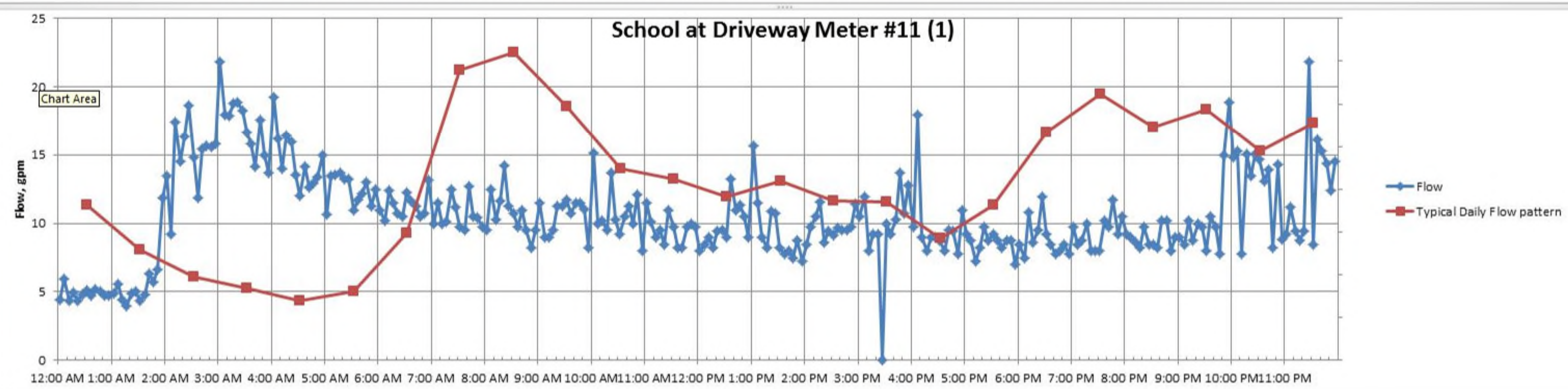


WNT - Hourly Flow Data from School Lane at Driveway Meter 11(1)
June 6 to June 9, 2013
Flow (gpm)
80
70
60
50
40
30
20
10
0
6/6/13 12:00 AM
6/7/13 12:00 AM
6/8/13 12:00 AM
6/9/13 12:00 AM
6/10/13 12:00 AM
Date
60 Min Meter Flow (gpm)


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


School Lane Meter 11 (1)
Flow, gpm
Flow
Typical daily flow pattern
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


July 23, 2013 Rainfall
Intensity, In/hr
Total Rainfall, inches
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total


School at Driveway Meter #11 (1)
Chart Area
Flow, gpm
25
20
15
10
5
0
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM
Flow
Typical Daily Flow pattern

METER 11(2) – OFF SCHOOL

Meter 11(2) is located in Township manhole 708 just off of School Lane, in a 12-inch pipe at that manhole.

Period of Record

This meter was functioning after June 12, 2013. From Figure 36, there is a clear increase in average daily sewage flow at this meter for essentially every rain event. The other thing that is clearly illustrated in this figure is that following the increases due to each rain event, there is a gradual decline in flows, with the downward trend continuing until the next rain event. The gradual drop in flows from the June 10 event can be seen in the beginning of this figure. It should be noted that this meter appears to be reading too low, since the apparent dry-weather average daily flow is 100 gpm, with an anticipated value between 122 and 145 gpm based on computer modeling.

June 7, 2013 Event

This meter was not functioning during the June 7 event.

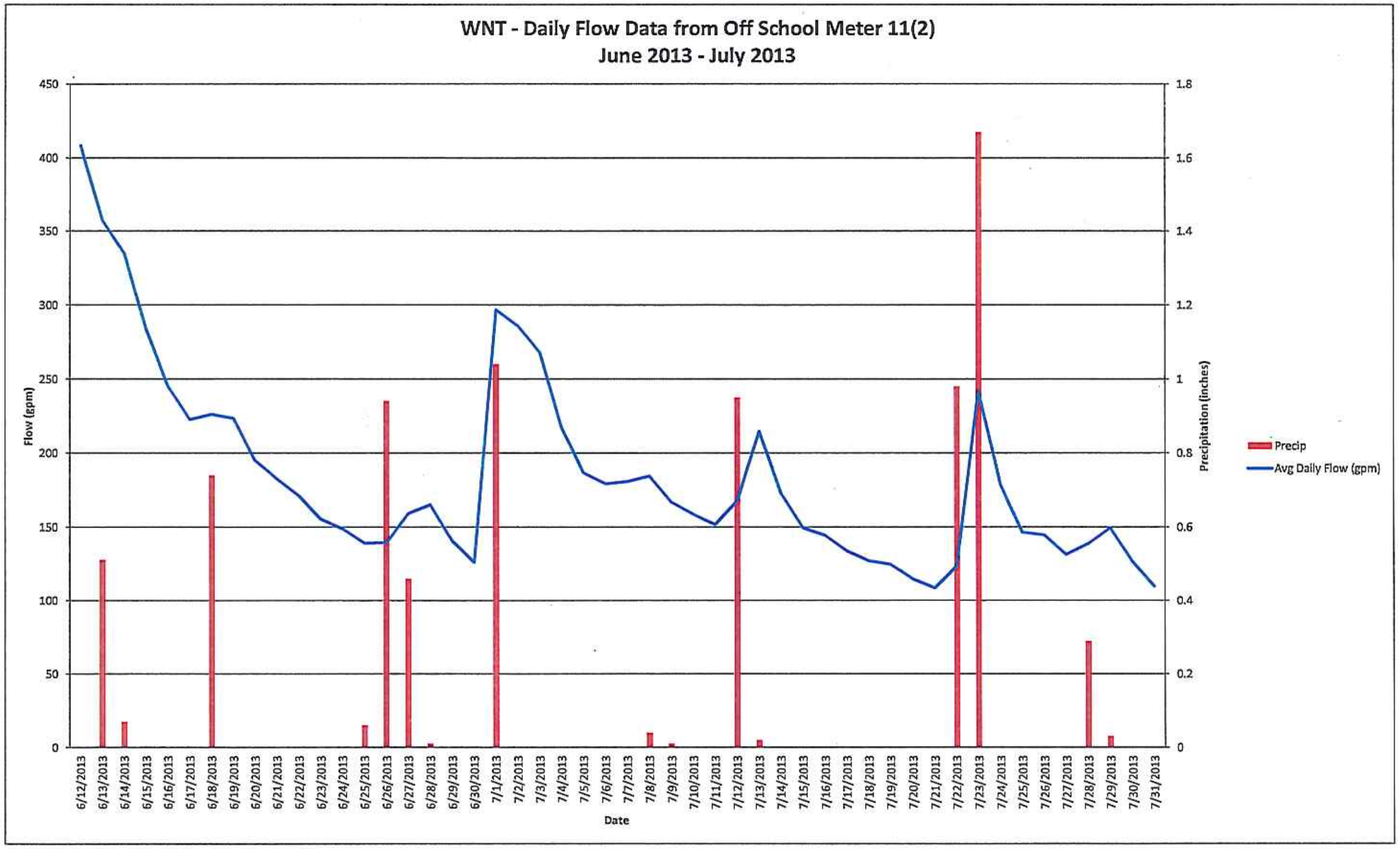
July 23, 2013 Event

From Figure 37, it can be seen that rain-induced sewage flows begin shortly after the start of significant rainfall intensities, and the flows continue to increase along with the increase in rainfall intensities. There is a relatively steady drop in flow for the next two hours, to a flow just over 1/3 of the peak flow, at which point the drop in flows is much more gradual over much more time.

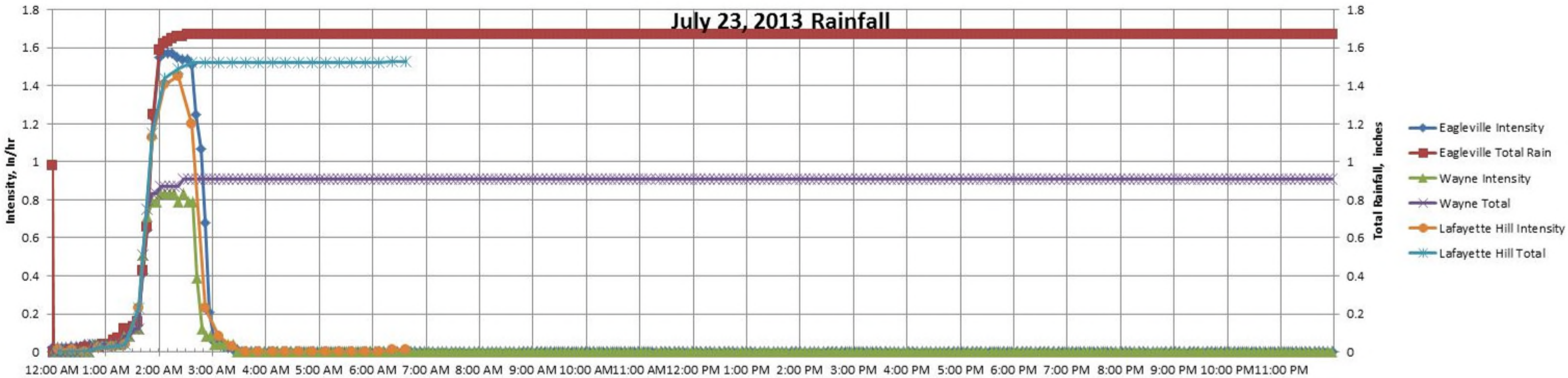
Flow Characterization

The sewershed through this meter includes the Chestnut Hill Pump Station. As such, peak flows through this pump station are reduced, and the timing of the arrival at the meter is delayed. Characterization of the flows at the meter therefore must be much more generalized since there is no method of differentiating the timing of those various flows. It is clear that there is a source of direct surface inflow to the meter which does not pass through the pump station, due to its nearly immediate arrival with the onset of significant rainfall; the sewage flows can be seen to rise In Figure 37 at the same time as the beginning of rainfall. This could be due to downspout connections and sewer manholes without lid inserts located close to the low point of surface flow areas. Additionally, it appears that there are sources of significant delayed inflow, such as low sewer vents, and external drain connections. Most clearly, there is significant infiltration occurring within this sewershed, best illustrated by Figure 36, which shows continual drops in average daily flows for days following rain events.

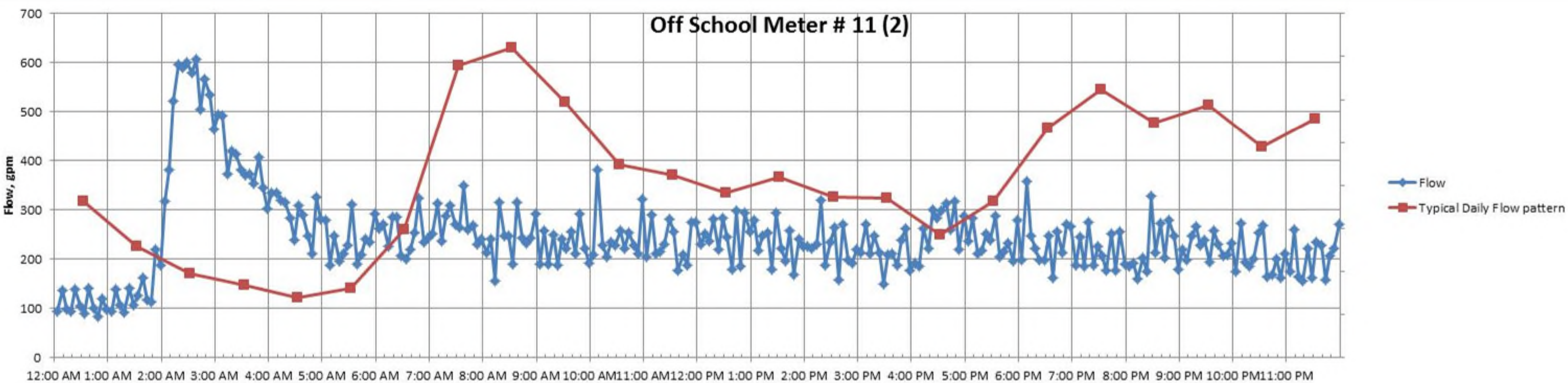
This sewershed would be a good candidate for additional metering, with meters strategically placed to narrow down the sources and their likely type of inflow or infiltration.



WNT - Daily Flow Data from Off School Meter 11(2)
June 2013 - July 2013
Flow (gpm)
Precipitation (inches)
Date
Precip
Avg Daily Flow (gpm)



July 23, 2013 Rainfall
Intensity, in/hr
Total Rainfall, inches
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total



Off School Meter # 11 (2)
Flow, gpm
700
600
500
400
300
200
100
0
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM
Flow
Typical Daily Flow pattern

METER 10 – PORT INDIAN DETENTION

Meter 10 is located in Township manhole 676 just off of Port Indian Road near the Port Indian Road Pump Station, in a 10-inch pipe at that manhole. Meter 11(1) and Meter 11(2) both flow to this meter.

Period of Record

Figure 38 shows the average daily flows through Meter 10. The high flows from 7/12 through 7/24 are surely erroneous, as they are extremely high. This is the opposite of the meter accuracy, which generally appears low, with apparent dry-weather average daily flows of 50 gpm compared to anticipated flows of 178 to 205 gpm based on computer modeling. Many rainfall events appear to cause a clear increase in flow, followed by a long steady decrease in flows until the next rainfall event.

June 7, 2013 Event

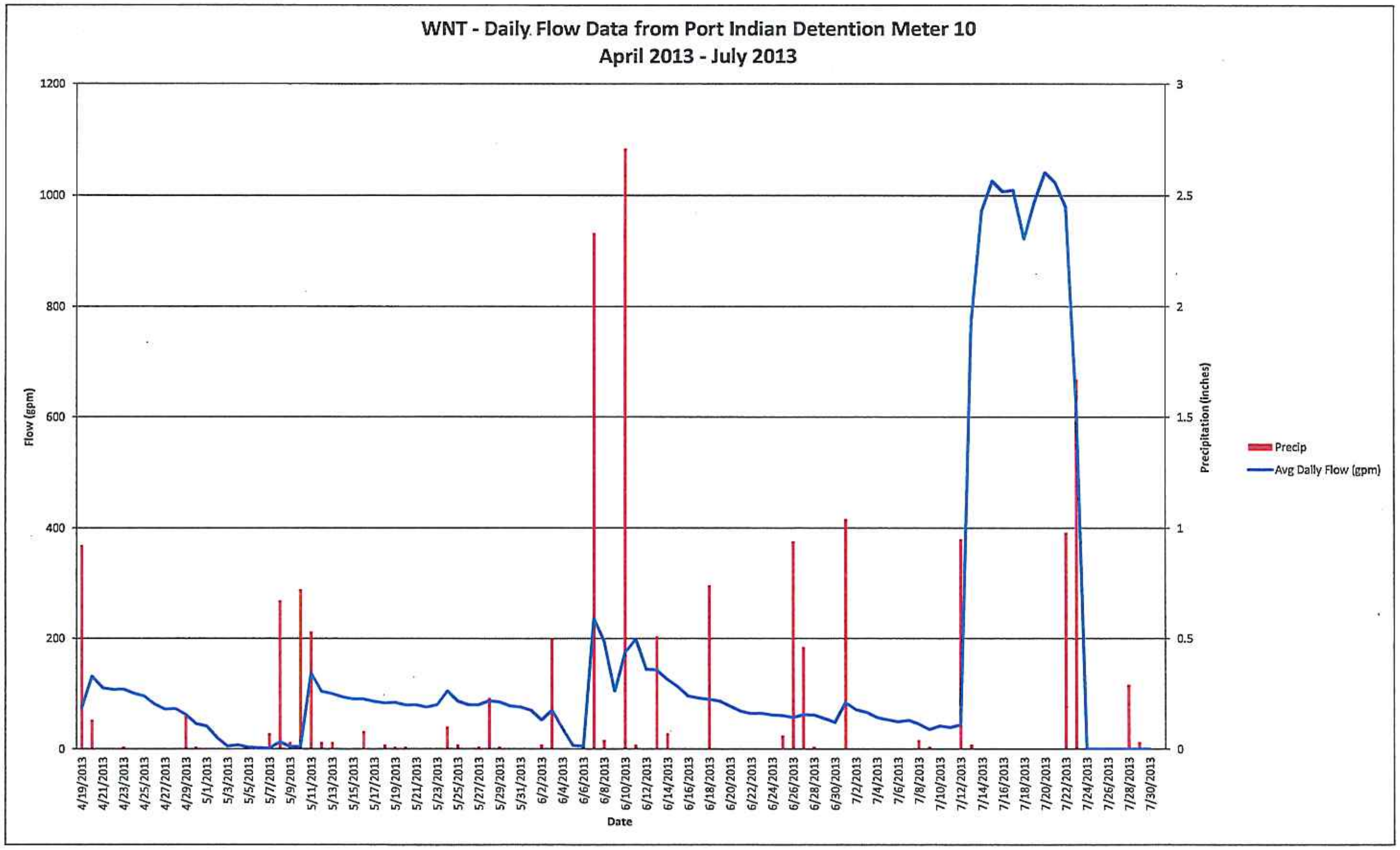
Figure 39 shows a clear increase in sewage flows upon occurrence of higher rainfall intensities. The flow generally steadily increases, until a peak flow is reached several hours after the peak rainfall intensities.

July 23, 2013 Event

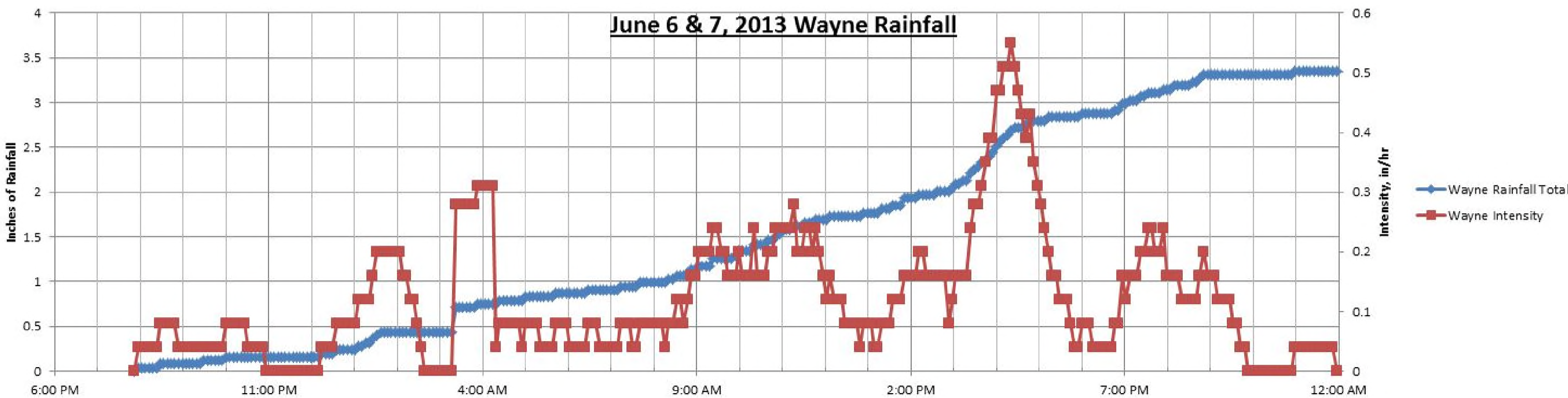
This meter was not functioning correctly during the July 23 event, as illustrated by Figure 40. The very high flows remain essentially the same before, during, and after the rain event, until the sudden drop to zero flow 12 hours after the storm ends.

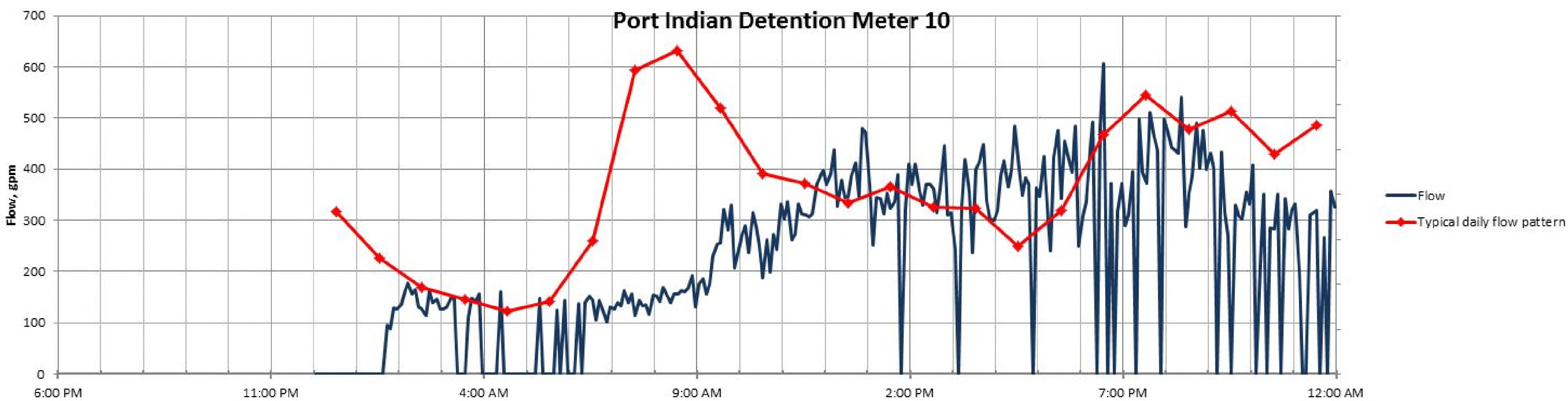
Flow Characterization

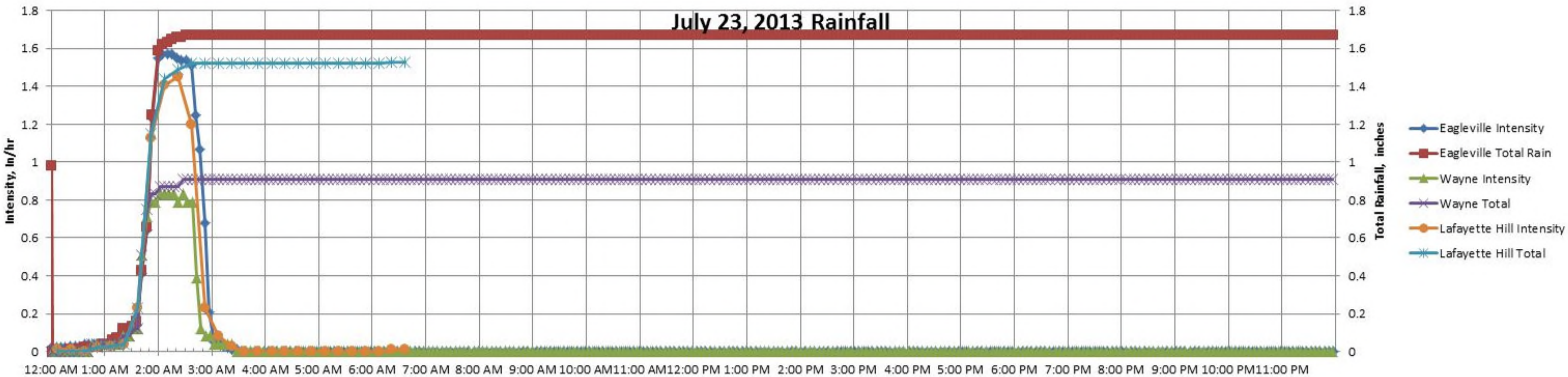
Meter 11(1) and Meter 11(2) both flow through Meter 10. Meter 11(2)'s average daily flows by themselves are significantly higher than Meter 10's flows, for both rain days and non-rainfall days. While Meter 11(2)'S flows appear too high, a logical assumption is that most of the flows to Meter 10 come from Meter 11(2), including the rain-induced flows. Without metering which shows more logical comparisons for Meter 11(2) and Meter 10, no other conclusions can be determined for the sewershed contributing directly to Meter 10.

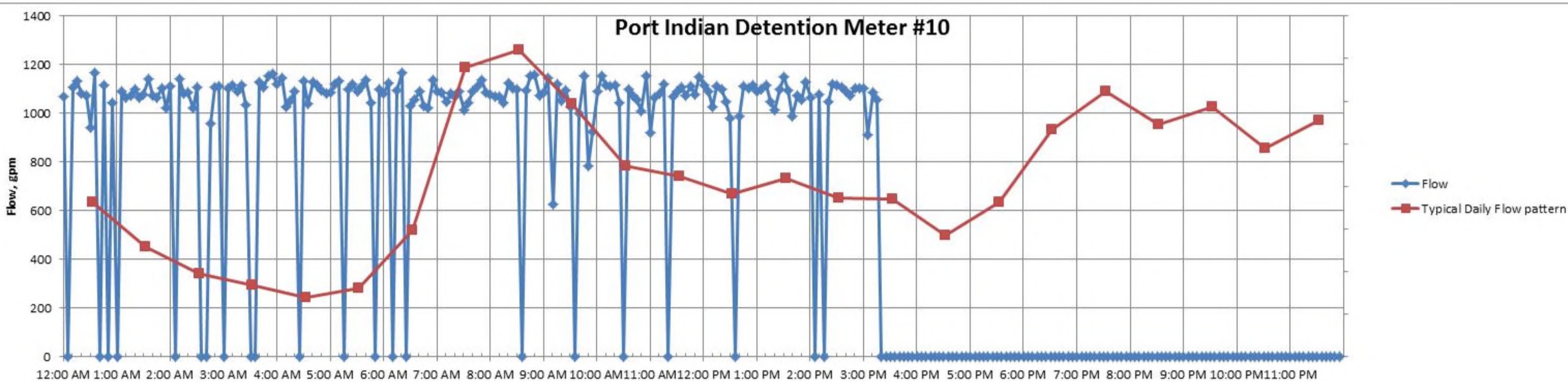


WNT - Daily Flow Data from Port Indian Detention Meter 10
April 2013 - July 2013
Flow (gpm)
Precipitation (inches)
Date
Precip
Avg Daily Flow (gpm)


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


Port Indian Detention Meter 10
Flow, gpm
Flow
Typical daily flow pattern
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


July 23, 2013 Rainfall
Intensity, In/hr
Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM


Port Indian Detention Meter #10
Flow, gpm
Flow
Typical Daily Flow pattern
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM

<u>METER 13 – BEAVER HOLLOW</u>

Meter 13 is located in Township manhole 336, in the back of the property at 1710 Beaver Hollow Drive, in an 18-inch pipe at that manhole. Flows over 700,000 gallons per day at the Jackson Street Diversion Chamber are diverted such that they flow through this meter. The Halford Hills Pump Station contributes flow to this meter.

<u>Period of Record</u>

Figure 41 shows the average daily flows through Meter 13, which for dry-weather days are approximately 1 gpm; anticipated flows are ?????? based on computer modeling. It is likely that the Jackson Street Diversion Chamber is the source of the high average daily flows on June 7 through June 10. It is possible that the Diversion Chamber was sending non-rainfall flows through Meter 13 on June 19 through June 25. For the rest of the period of record, there is no obvious correlation between rainfall events and high flows: peaks on non-rainfall days are as high as the peaks for rain events, other than the June 7 and June 10 events.

<u>June 7, 2013 Event</u>

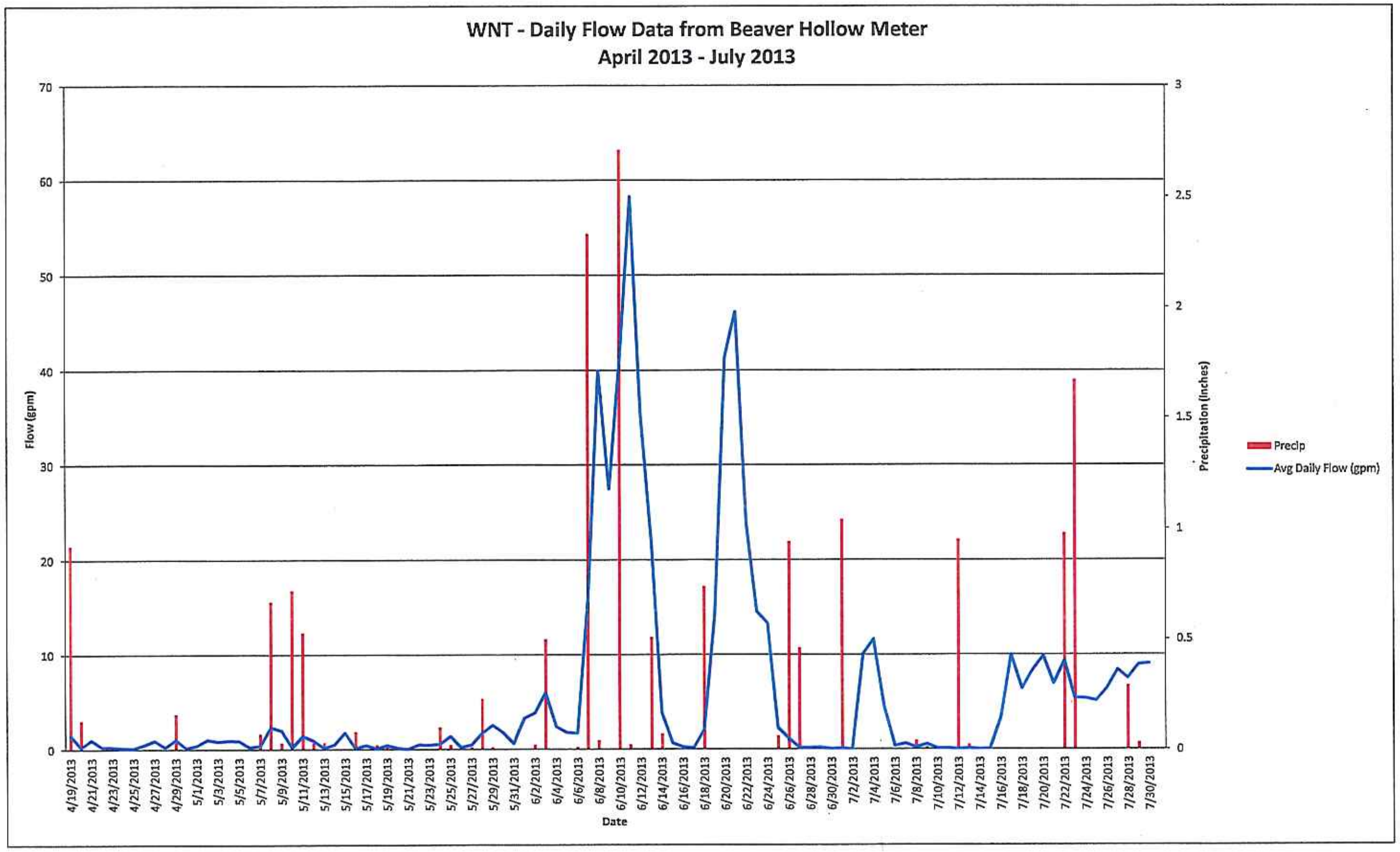
The high flows seen on Figure 42 appear to be flows from the diversion chamber, especially since the very short duration high peak flows occur an hour after the peak rainfall intensities. The likelihood of this flow being generated within the very small sewershed to Meter 13 is extremely low, since it would not take an hour for peak flows generated within the directly contributing sewershed to reach the meter.

<u>July 23, 2013 Event</u>

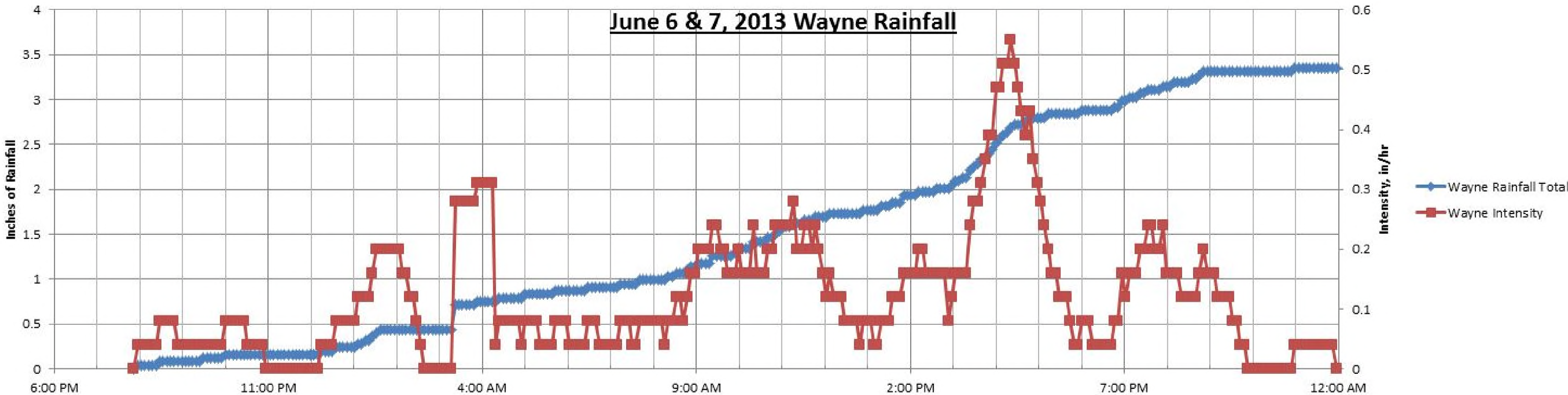
This storm event appears to generate no rainfall-induced flows to Meter 13. A review of Figure 43 shows flows through the day generally following the typical daily flow pattern expected throughout the system. Additionally, the highest recorded peak flow for the day occurs 8 hours after the end of rainfall.

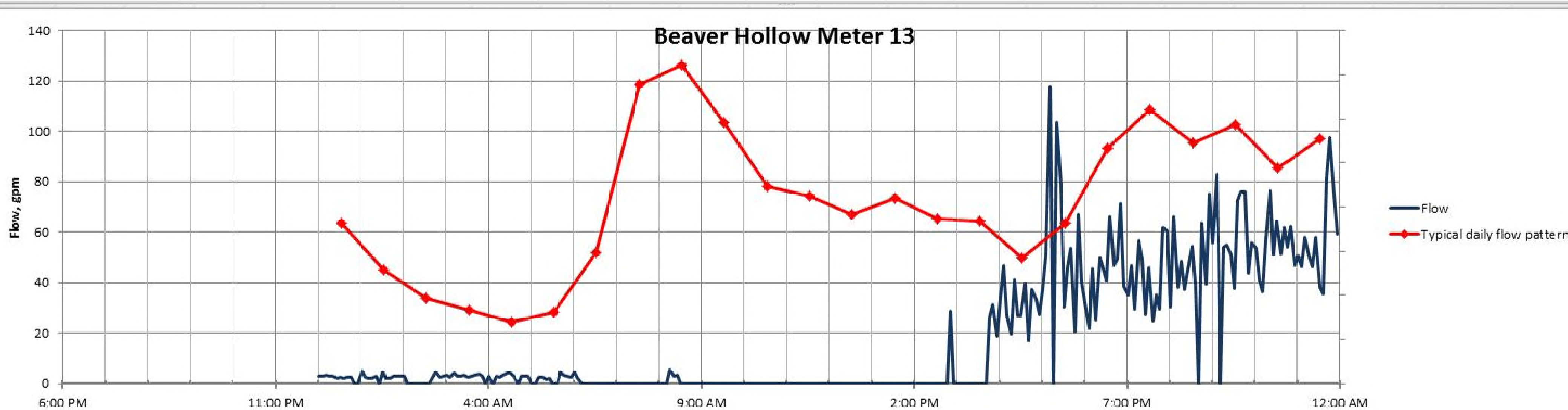
<u>Flow Characterization</u>

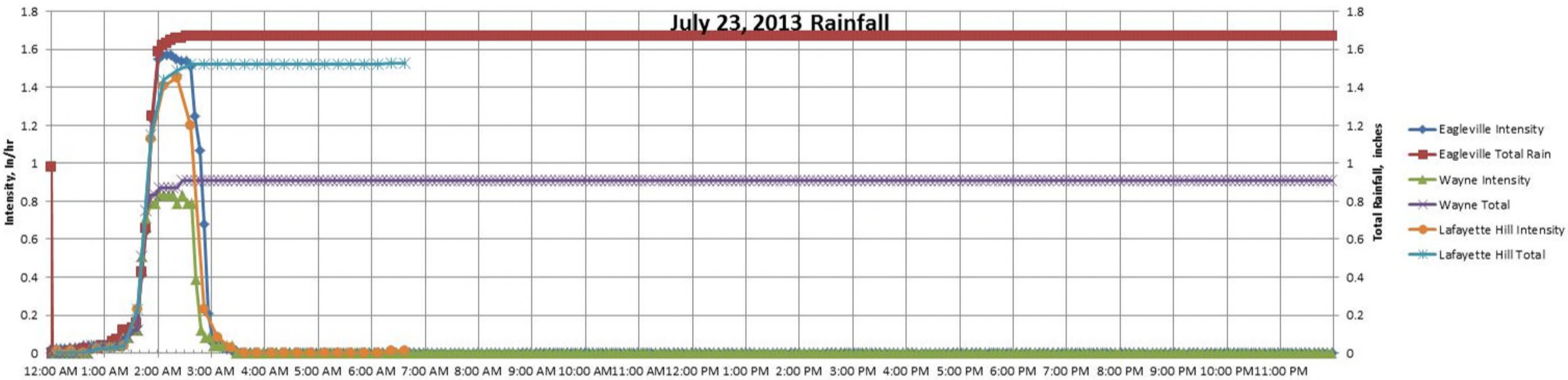
From Figures 41, 42, and 43, the conclusion is that the sewershed contributing to Meter 13 does not have any significant sources of inflow or infiltration. This excludes the flow which passes through the meter from the Jackson Street Diversion Chamber.



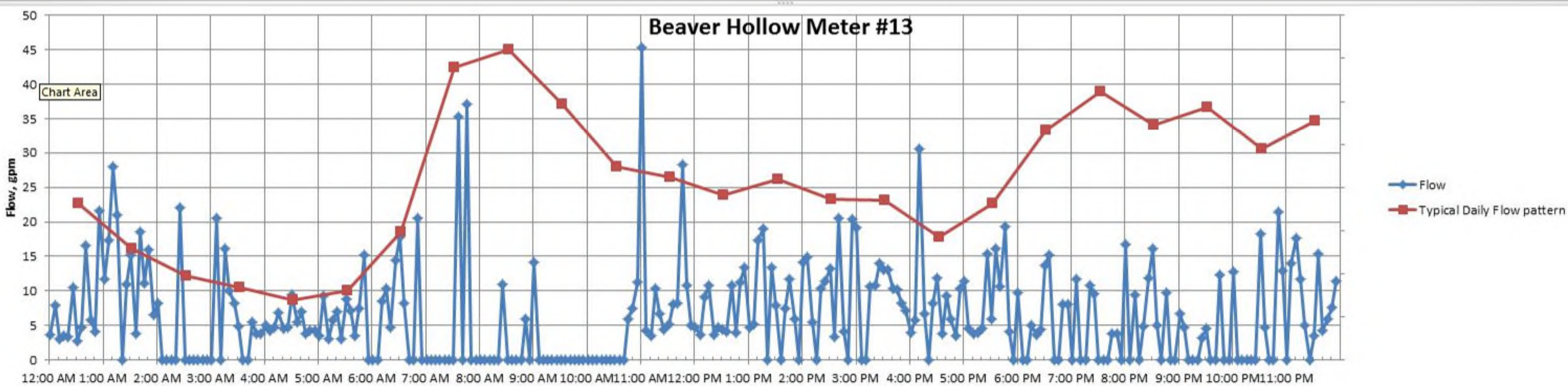
WNT - Daily Flow Data from Beaver Hollow Meter
April 2013 - July 2013
Flow (gpm)
Precipitation (inches)
Date
Precip
Avg Daily Flow (gpm)


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
4
3.5
3
2.5
2
1.5
1
0.5
0
0.6
0.5
0.4
0.3
0.2
0.1
0
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


Beaver Hollow Meter 13
Flow, gpm
Flow
Typical daily flow pattern
140
120
100
80
60
40
20
0
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM



July 23, 2013 Rainfall
Intensity, in/hr
Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM



Beaver Hollow Meter #13
Chart Area
Flow, gpm
Flow
Typical Daily Flow pattern
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM

METER 18 – BURNSIDE AVENUE

Meter 18 is located in Township manhole 1349, behind the property at 380 Burnside Avenue, in a 15-inch pipe at that manhole. Meter 1, which includes Meter 17's flow, flows through Meter 18.

Period of Record

Figure 44 shows the average daily flows through Meter 18. This figure provides no decisive results for the impact of rainfall events. In 2012 and for the July 23, this figure indicates significant increases in average daily flow for larger rain events; however, no effect is seen for the very significant June 7 and June 10 rainfall events. The total average daily flow for Meter 1 for the June 7 rainfall event is approximately 200 gpm; the total shown for Meter 18 is approximately 140 gpm. Meter 18's flow must be higher than Meter 1's, so Meter 18 must be reading significantly too low. This is also evidenced by the metered dry-weather average daily flow of 120 gpm compared to the anticipated flow of 170 gpm based on computer modeling.

June 7, 2013 Event

Meter 1 is showing peak sewage flows on June 7 of almost 900 gpm, while the peak flow at Meter 18 can be seen on Figure 45 to be just over 400 gpm. The Meter 18 peak flows which occur at the comparable time to Meter 1's peak is even lower, at just over 350 gpm. It is clear that one of the meters is providing inaccurate data.

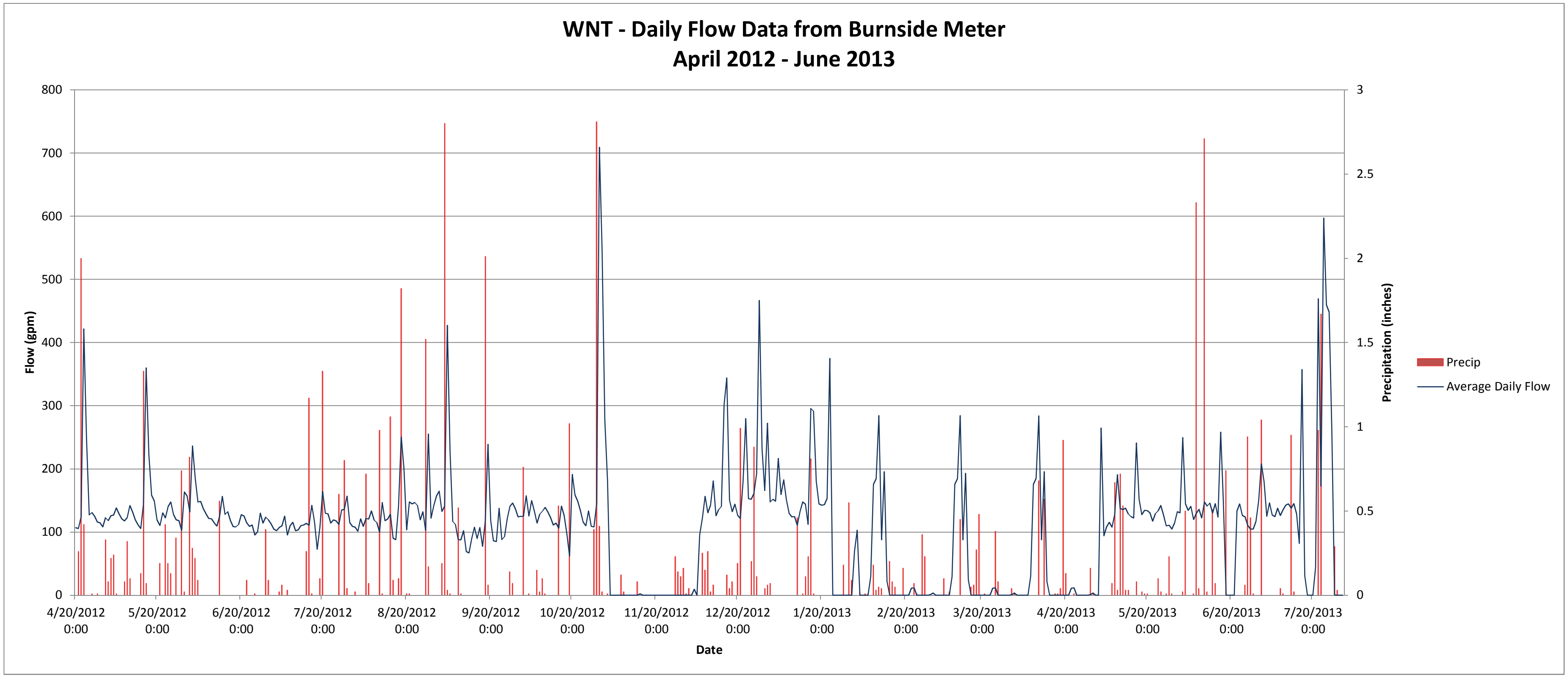
July 23, 2013 Event

Even though the average daily flow for July 23, 2013 is shown to greatly increase on Figure 44, Figure 46 identifies erroneous metering for this day. From Figure 46, it can be seen that the meter is showing very high, constant peaks occurring for 4½ hours, but not until 15 hours after the end of the storm event. These erroneous flows are large enough to provide a significant impact to the average daily flow, but it is clear that this is in error. The meter recorded no flows during the actual rain event.

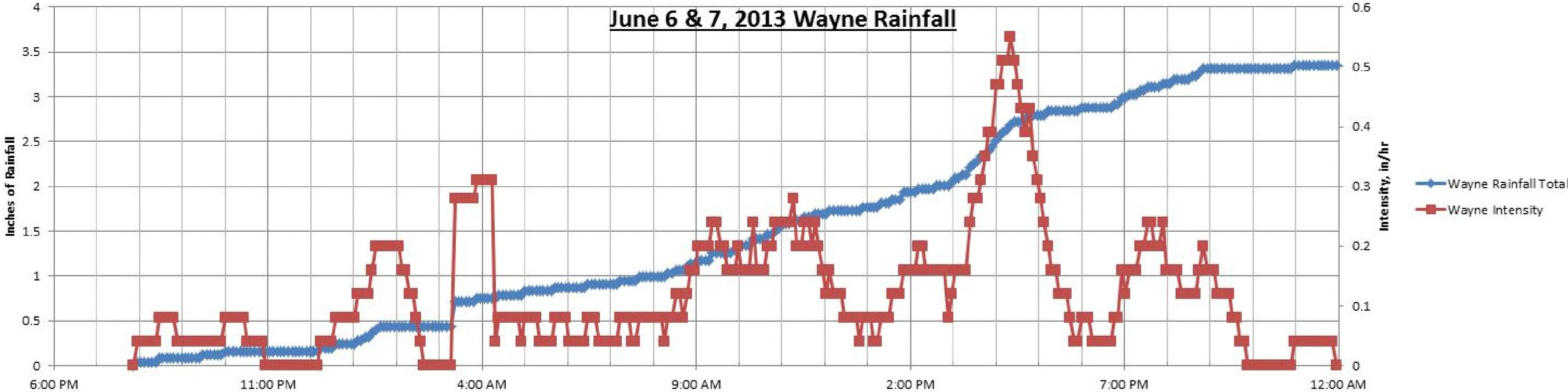
Flow Characterization

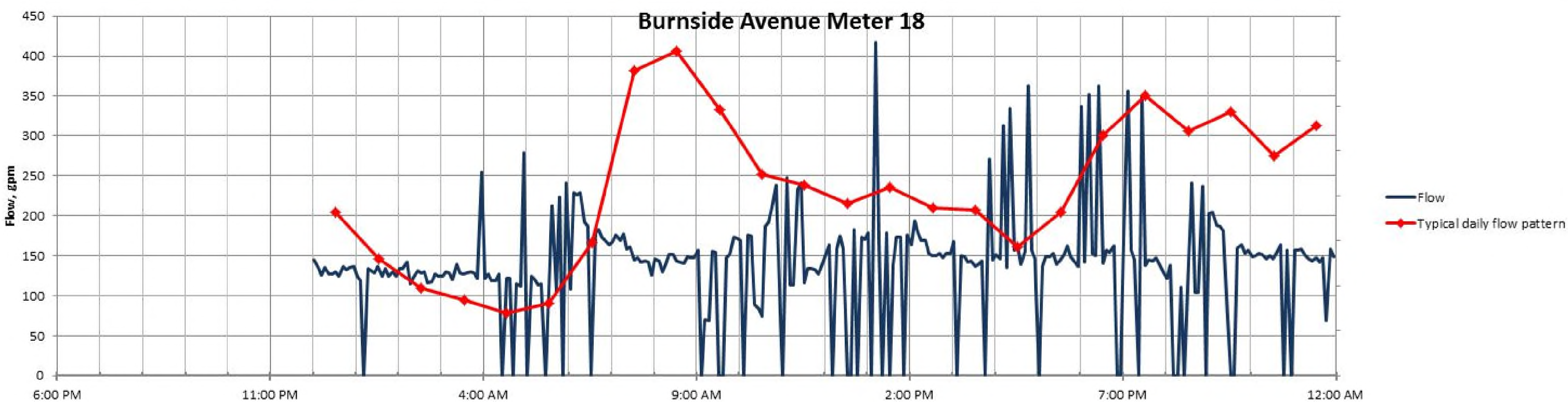
The 2013 meter data, as shown in Figures 44, 45, and 46, provides no worthwhile information concerning the impact or existence of rain-induced flows to Meter 18. Replacement or rehabilitation of the meter should be completed, with future data compared to upstream flow meters for consistency.

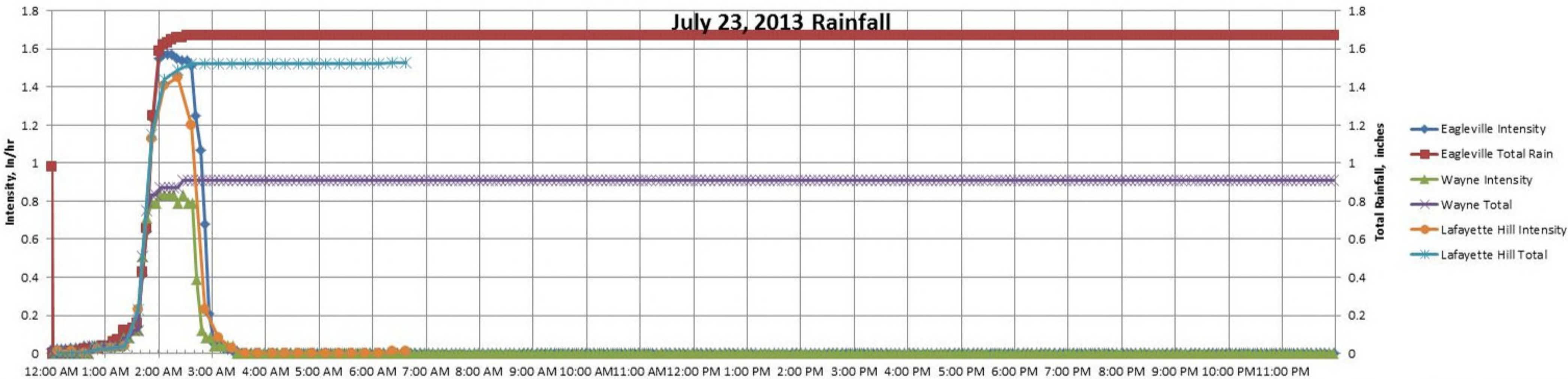
Additional discussion concerning rain-induced flows at Meter 18 can be found in the discussions of downstream Meter 4.



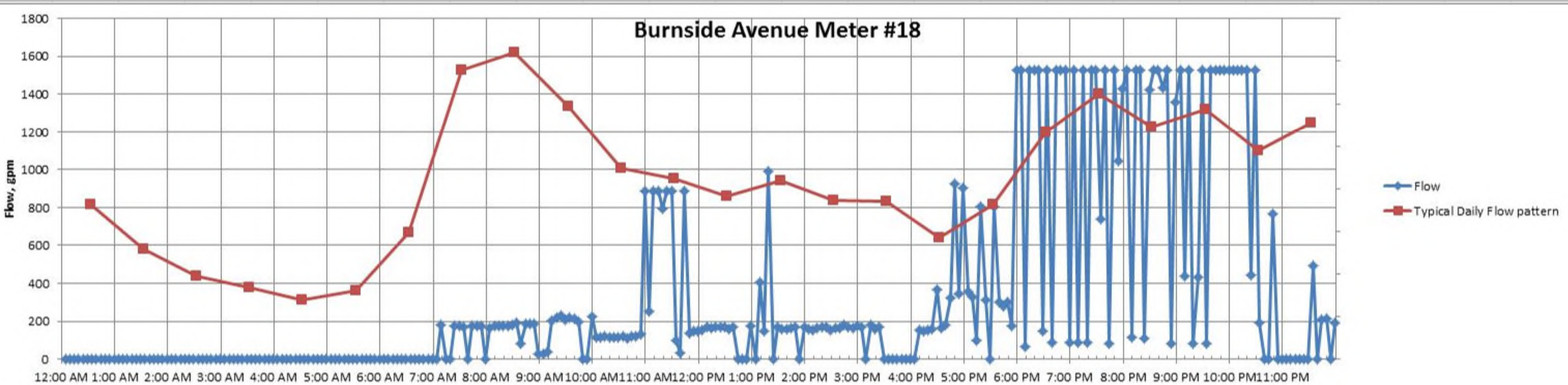
WNT - Daily Flow Data from Burnside Meter
April 2012 - June 2013
Flow (gpm)
Precipitation (inches)
Date
800
700
600
500
400
300
200
100
0
3
2.5
2
1.5
1
0.5
0
4/20/2012 0:00
5/20/2012 0:00
6/20/2012 0:00
7/20/2012 0:00
8/20/2012 0:00
9/20/2012 0:00
10/20/2012 0:00
11/20/2012 0:00
12/20/2012 0:00
1/20/2013 0:00
2/20/2013 0:00
3/20/2013 0:00
4/20/2013 0:00
5/20/2013 0:00
6/20/2013 0:00
7/20/2013 0:00
Precip
Average Daily Flow


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
4
3.5
3
2.5
2
1.5
1
0.5
0
0.6
0.5
0.4
0.3
0.2
0.1
0
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


Burnside Avenue Meter 18
Flow, gpm
Flow
Typical daily flow pattern
450
400
350
300
250
200
150
100
50
0
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM



July 23, 2013 Rainfall
Intensity, In/hr
Total Rainfall, inches
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM



Burnside Avenue Meter #18
Flow, gpm
Flow
Typical Daily Flow pattern
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM

METER 4 – WHITEHALL

Meter 4 is located in Township manhole 1218, behind the Whitehall Pump Station, in a 15-inch pipe at that manhole. Meter 18 (which includes Meter 1, which includes Meter 17) and Meter 3 both flow through Meter 4.

Period of Record

Figure 47 shows a clear relationship between rain events and increased average daily flows throughout the 15-month period of record for this meter. Another very well illustrated tendency is the rapid drop in average daily flows in the day following the rain event, followed by a much more gradual decline in flows for all of the following days until the next rain event. Meter 4 actually appears to be reading too low, with apparent dry-weather average daily flows of 200 gpm compared to anticipated flows of 282 to 343 gpm based on computer modeling.

June 7, 2013 Event

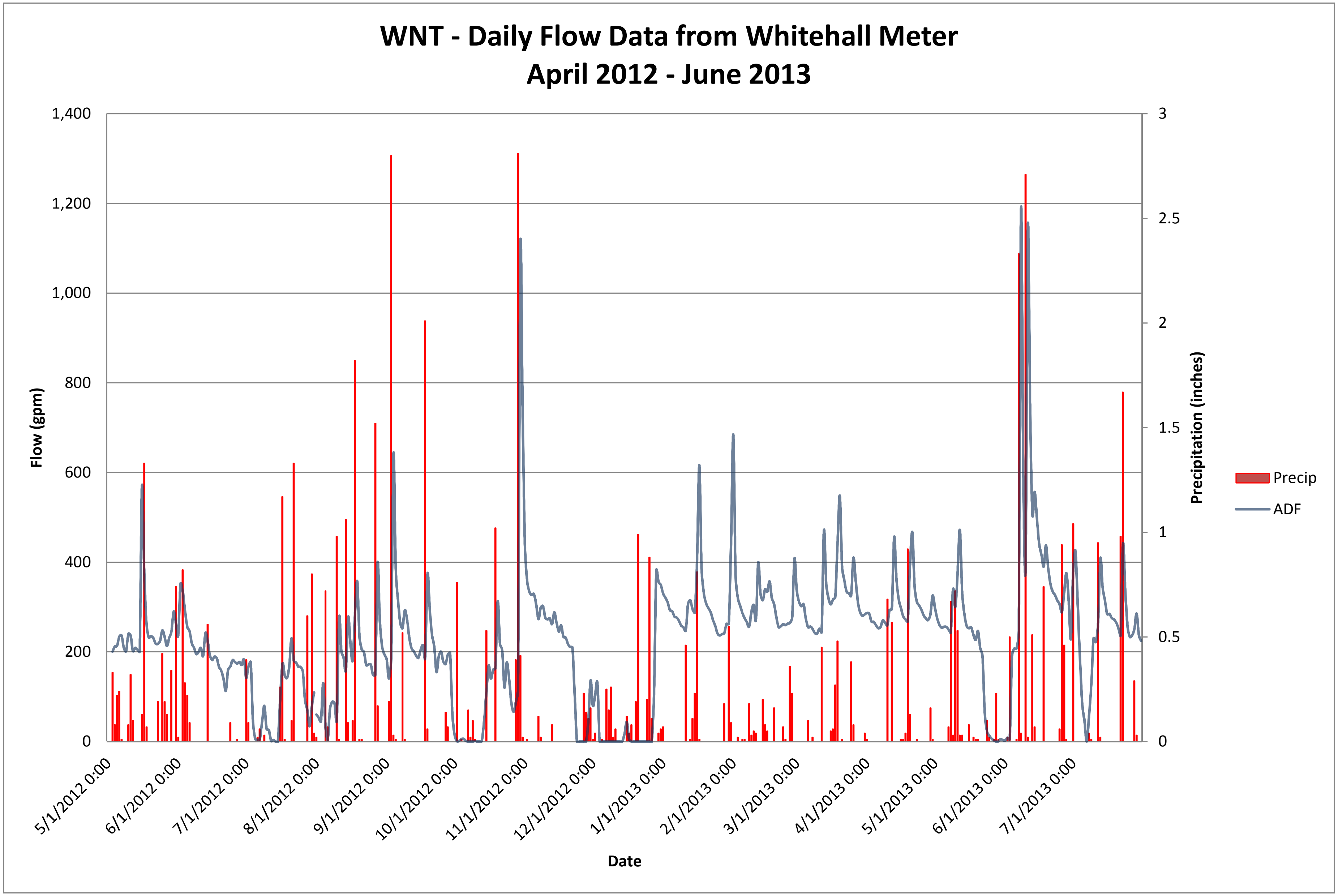
It can be seen in Figure 48 and Figure 49 that the sewage flow due to the storm on June 7 peaks around 1700 gpm at Meter 4 just before midnight, with this peak flow occurring at least an hour following the end of significant rainfall. From Figure 49, it can also be seen that the very high flows continue until approximately 7:00 am on the morning of June 8, with a fairly rapid drop of about 70 gpm over the next 5 hours, and a subsequent slower drop over the next 24 hours.

July 23, 2013 Event

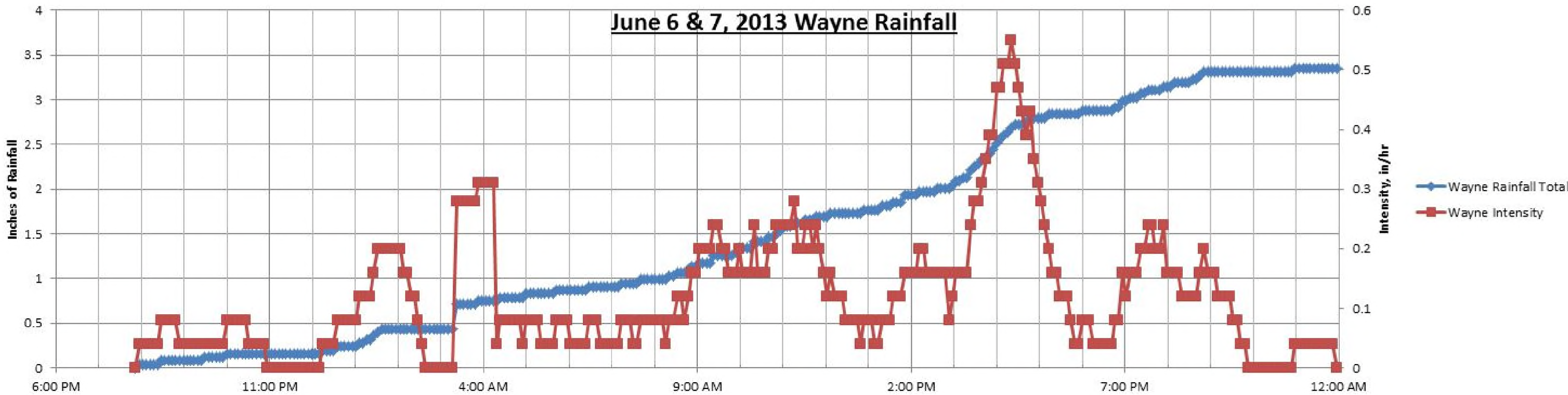
Flows didn't begin to increase on July 23 until approximately ½ hour after the start of significant rainfall, as can be seen in Figure 50. The flows continue to rise to 1000 gpm until the end of rainfall, and remain high for approximately ½ hour. A fairly rapid drop of 200 gpm occurs in the next ½ hour, followed by a slow decline in flow for the remainder of the day.

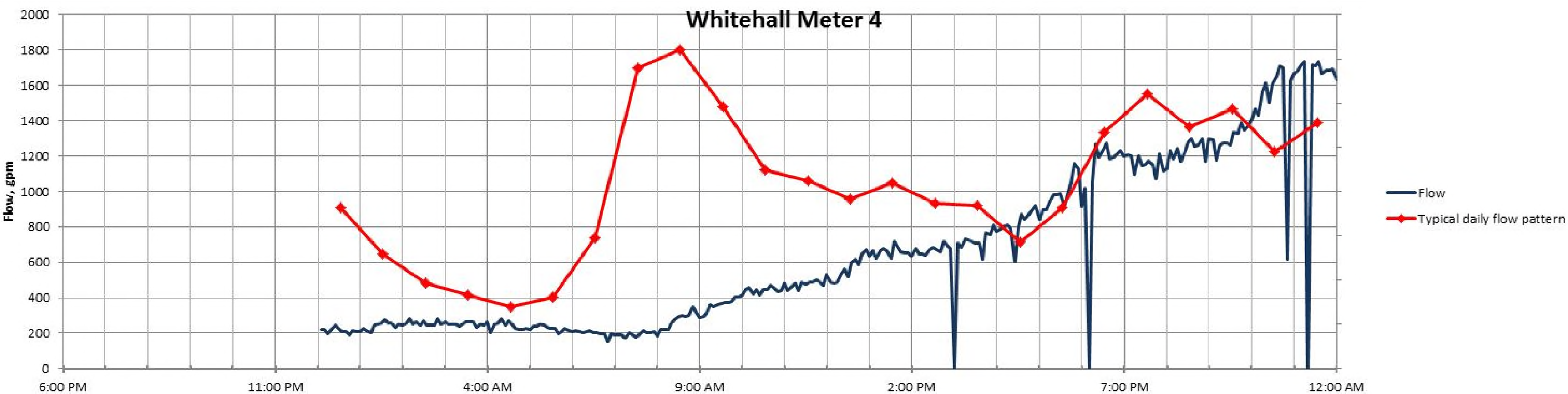
Flow Characterization

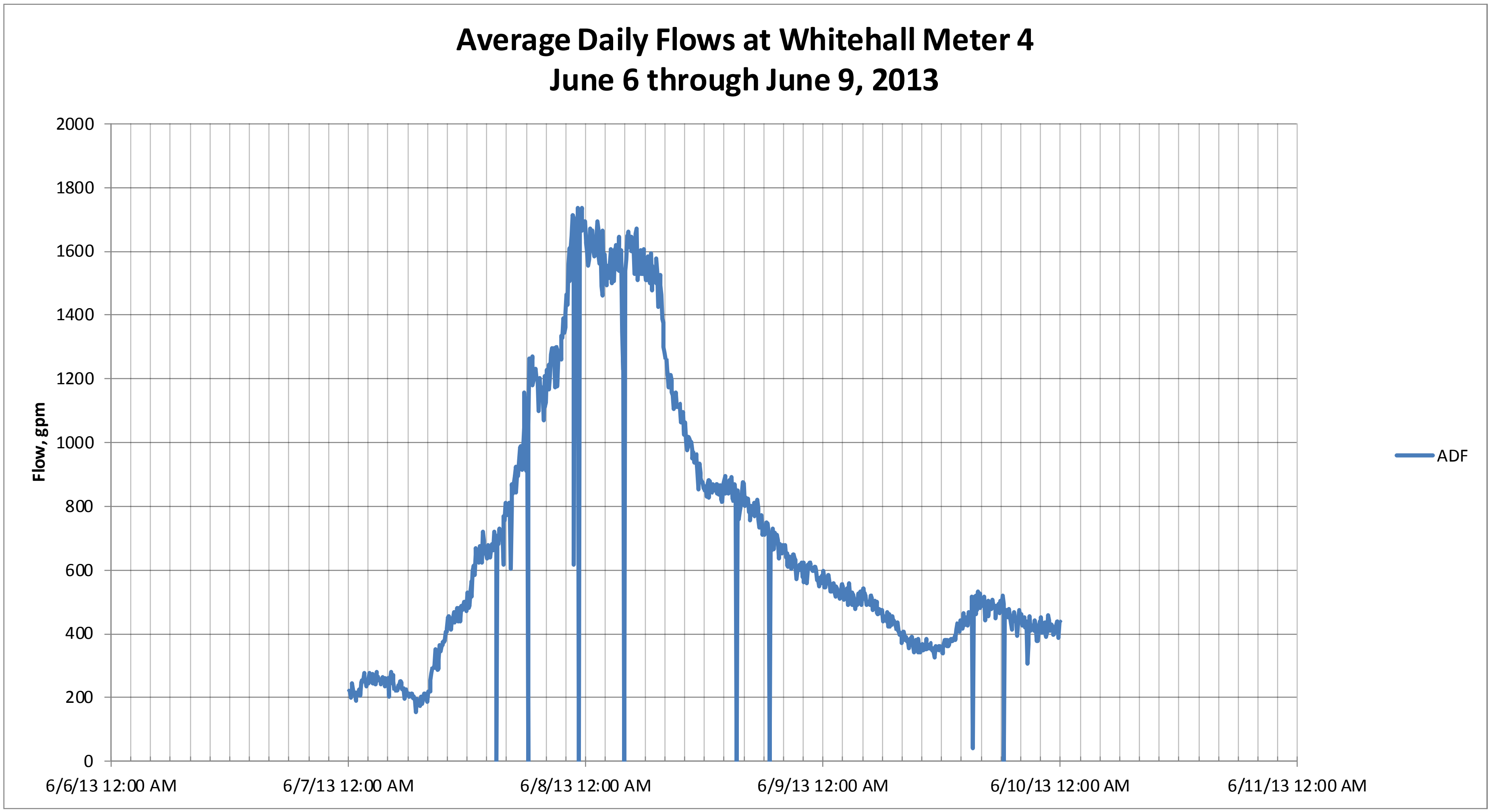
Meter 18, which includes Meter 1, and Meter 3, both contribute flow to Meter 4. The full sewershed to Meter 4 is quite large, with anticipated dry weather flows of around 300 gpm. It is expected therefore that flows from the outer limits of the sewershed could take approximately 1½ to 3 hours to flow to Meter 4. From a comparison of Figure 48 to Figure 7, it can be seen that until approximately 10:30 am, Meter 1 is contributing most of the rain-induced flows to Meter 4. This implies that Meter 4's and Meter 18's directly contributing sewer sheds have very little direct inflow such as downspout connections and un-lined manhole lids in low drainage areas. Meter 3 was already identified as having significant direct inflows. However, since Meter 1's peak flows only represents approximately ½ of Meter 4's peak flows, these other areas are contributing significant amounts of delayed direct inflow, such as low sewer vents, flow into manholes through road stone subbase, and flow into un-lined manhole lids along drainage areas, but which are unaffected by lower surface flows. Whereas Meter 1's flows following the storm represent less than ½ of the flows at Meter 4, the other areas are contributing the bulk of the longer delayed inflows such as sump pump flow, and are contributing significant amounts of infiltration causing the slowly declining flows so evident in Figure 47.

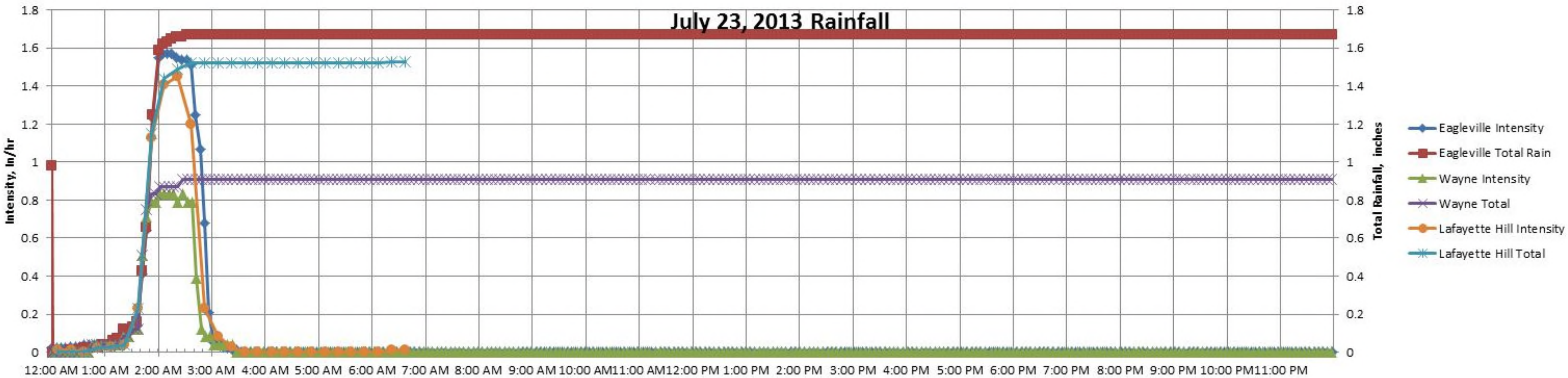


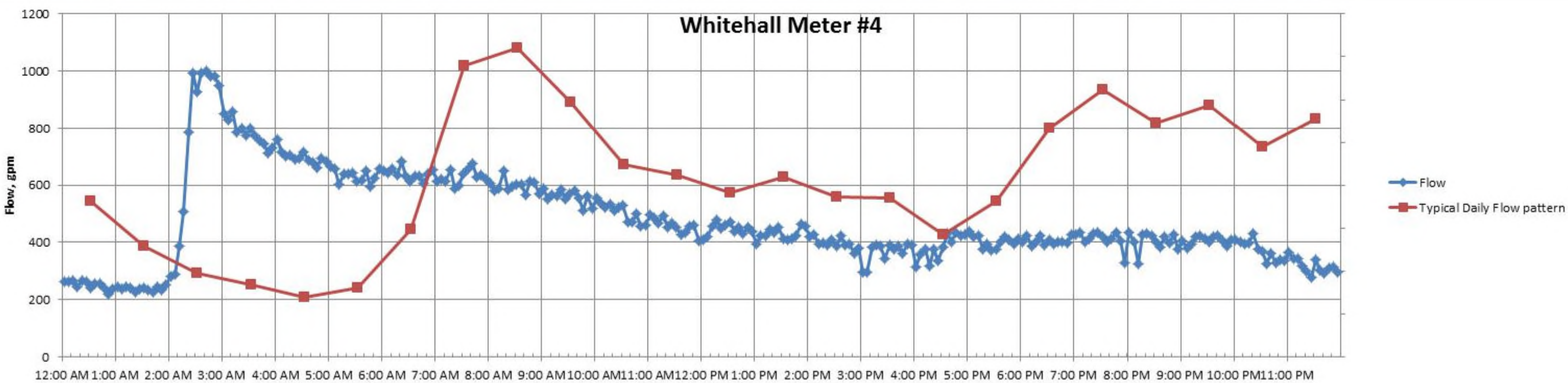
WNT - Daily Flow Data from Whitehall Meter
April 2012 - June 2013
Flow (gpm)
1,400
1,200
1,000
800
600
400
200
0
Precipitation (inches)
3
2.5
2
1.5
1
0.5
0
5/1/2012 0:00
6/1/2012 0:00
7/1/2012 0:00
8/1/2012 0:00
9/1/2012 0:00
10/1/2012 0:00
11/1/2012 0:00
12/1/2012 0:00
1/1/2013 0:00
2/1/2013 0:00
3/1/2013 0:00
4/1/2013 0:00
5/1/2013 0:00
6/1/2013 0:00
7/1/2013 0:00
Date
Precip
ADF


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


Whitehall Meter 4
Flow, gpm
Flow
Typical daily flow pattern
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


Average Daily Flows at Whitehall Meter 4
June 6 through June 9, 2013
Flow, gpm
2000
1800
1600
1400
1200
1000
800
600
400
200
0
6/6/13 12:00 AM
6/7/13 12:00 AM
6/8/13 12:00 AM
6/9/13 12:00 AM
6/10/13 12:00 AM
6/11/13 12:00 AM
ADF


July 23, 2013 Rainfall
Intensity, in/hr
Total Rainfall, inches
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM
Eagleville Intensity
Eagleville Total Rain
Wayne Intensity
Wayne Total
Lafayette Hill Intensity
Lafayette Hill Total


Whitehall Meter #4
Flow, gpm
1200
1000
800
600
400
200
0
12:00 AM 1:00 AM 2:00 AM 3:00 AM 4:00 AM 5:00 AM 6:00 AM 7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM 12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM 6:00 PM 7:00 PM 8:00 PM 9:00 PM 10:00 PM 11:00 PM
Flow
Typical Daily Flow pattern

<u>METER 2 – 7-11</u>

Meter 2 is located in Township manhole 98, in front of the 7-11 in Main Street, near the intersection of Montgomery Avenue, in a 15-inch pipe at that manhole. Meter 2 receives flow from the Whitehall Road Pump Station (essentially the same flow as Meter 4) as well as its own directly contributing sewershed.

<u>Period of Record</u>

For the periods when this meter was functioning, Figure 51 shows a clear relationship between rain events and increased average daily flows. Another very well illustrated tendency is the rapid drop in average daily flows in the day following the rain event, followed by a much more gradual decline in flows for all of the following days until the next rain event. It should be noted that Meter 2 appears to be reading too low, since apparent dry-weather average daily flows are 300 gpm compared to anticipated flows of 428 to 635 gpm based on computer modeling.

<u>June 7, 2013 Event</u>

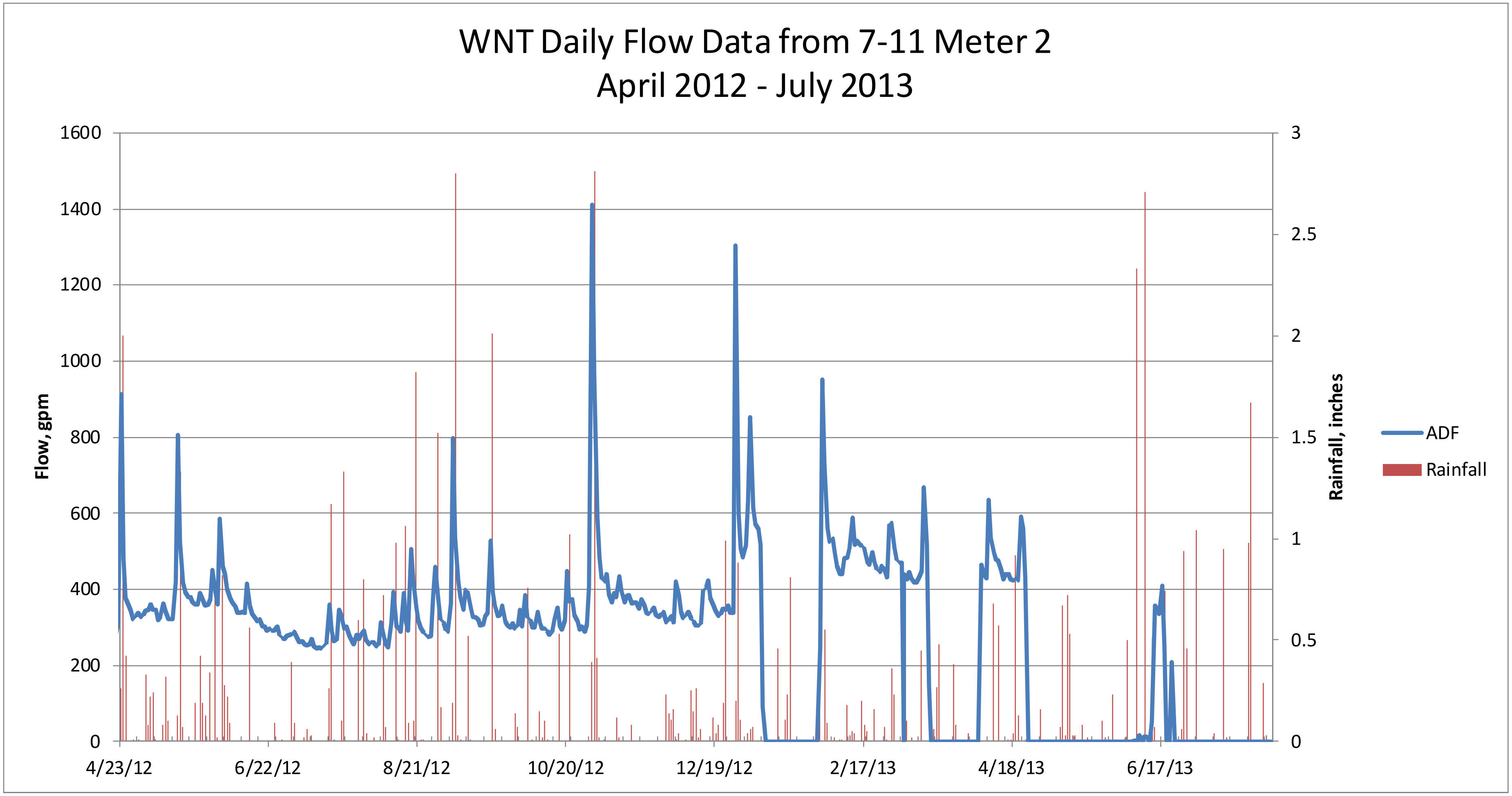
This meter was not functioning during the June 7 event.

<u>July 23, 2013 Event</u>

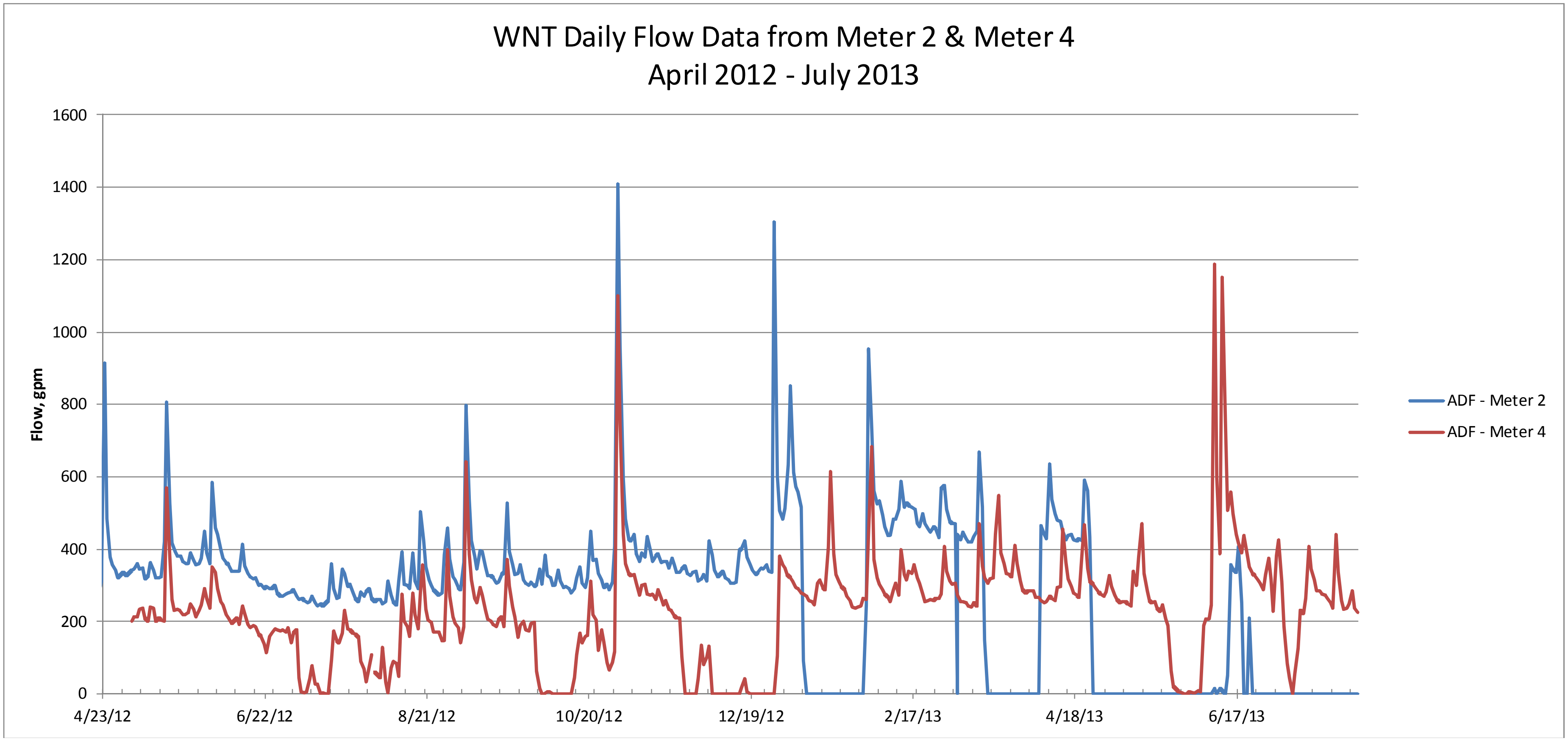
This meter was not functioning during the July 23 event.

<u>Flow Characterization</u>

Meter 4 flows through Meter 2, and is expected to provide over half of its average daily dry weather flows based on computer modeling. To obtain an indication of how much of the rain-induced flow at Meter 2 comes from Meter 4, Figure 52 was developed for a direct correlation. Based on this figure when both meters were functioning, it appears that essentially all of the rain-induced flows come from Meter 4. For instance, in the October, 2012, rain event of approximately 2.8 inches (from Figure 51), the average daily flows at Meter 4 increased from approximately 100 gpm to approximately 1100 gpm; at Meter 2, the flows increased from 300 gpm to 1400 gpm. Of the 1100 gpm increase at Meter 2, 1000 gpm came from Meter 4. The 100 gpm increase apparently from Meter 2's directly contributing sewershed represents less than a 25% increase over dry weather flows, and indicates that inflow and infiltration control efforts should be directed to other areas of the system.



WNT Daily Flow Data from 7-11 Meter 2
April 2012 - July 2013
Flow, gpm
Rainfall, inches
0
200
400
600
800
1000
1200
1400
1600
0
0.5
1
1.5
2
2.5
3
4/23/12
6/22/12
8/21/12
10/20/12
12/19/12
2/17/13
4/18/13
6/17/13
ADF
Rainfall



WNT Daily Flow Data from Meter 2 & Meter 4
April 2012 - July 2013
Flow, gpm
1600
1400
1200
1000
800
600
400
200
0
4/23/12
6/22/12
8/21/12
10/20/12
12/19/12
2/17/13
4/18/13
6/17/13
ADF - Meter 2
ADF - Meter 4

METER 5 – SHERIDAN-HARTRANFT

Meter 5 is located in Township manhole 209, at the intersection of Sheridan Lane and Hartranft Drive, in a 15-inch pipe at that manhole. The Port Indian Road Pump Station (the same as Meter 10) flows through Meter 5 when its flow is not diverted to the Rittenhouse Pump Station; this diversion is typically only done during rain-induced high flow periods.

Period of Record

Figure 52 shows the metering record for Meter 5; it was operating correctly less than half of the installation period. Dry weather average daily flows to this meter should be approximately 250 gpm based on computer modeling; it can be seen from Figure 52 that when the meter was operating, the average of its flows was approximately 60 gpm. The highest recorded average daily flow was on a non-rainfall event day.

June 7, 2013 Event

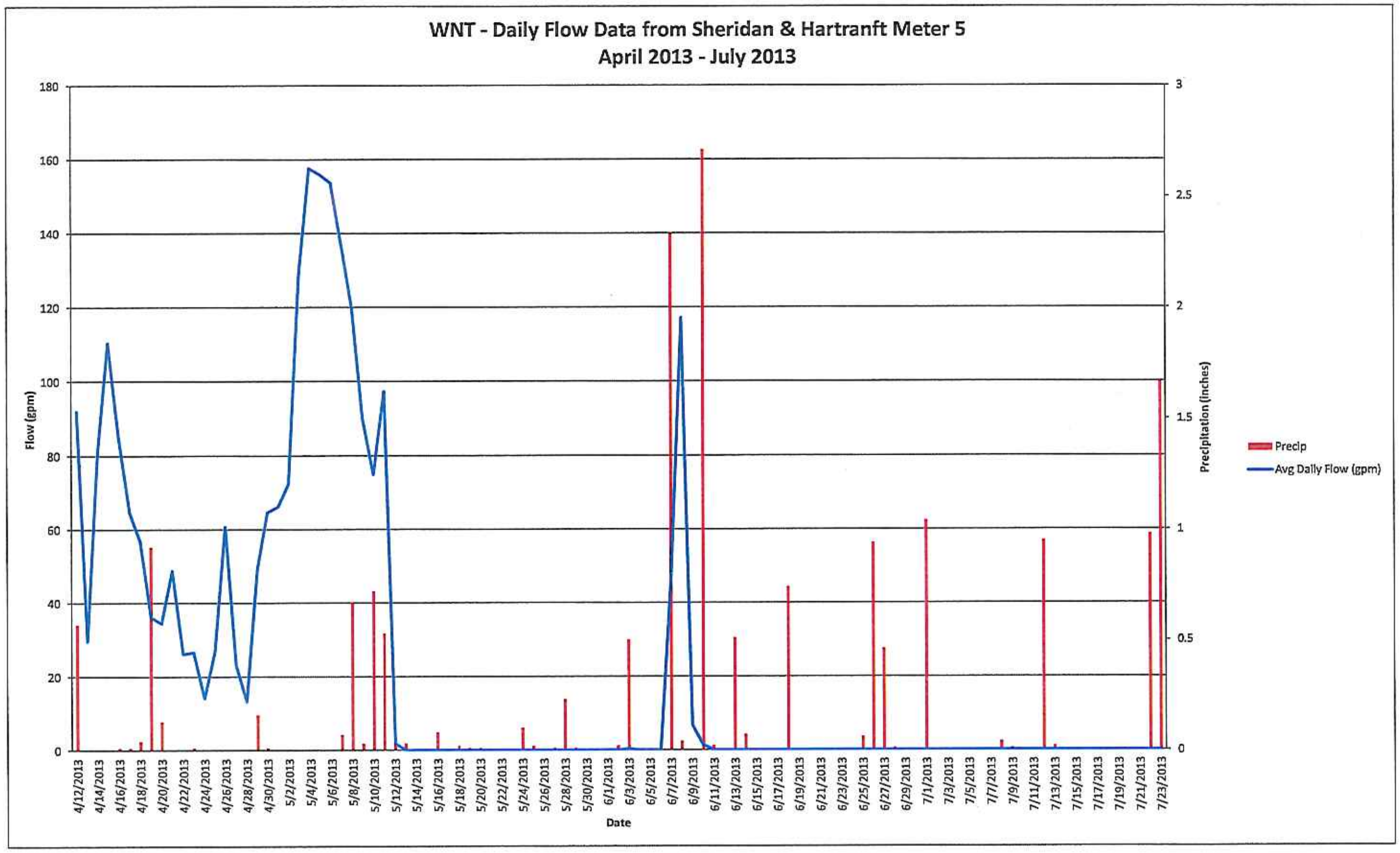
It can be seen in Figure 53 that the reason for the insignificant average daily flow on June 7 which appeared on Figure 52 was due to the fact that the recorded peak instantaneous flows were for a very short period while most of the day had zero flow. It is estimated that the pumps at the Port Indian Pump Station should have cycled on approximately every 10 minutes based on the high flows from Meter 10. The pumps produce a flow of approximately 1000 gpm, so the total flow through Meter 5 should be over 1000 gpm unless diversion is occurring, and should reach that flow approximately every 10 minutes from noon to 9 pm. The highest that the Meter 5 flow reached was 740 gpm, and this was only for two instantaneous readings over the 9-hour period.

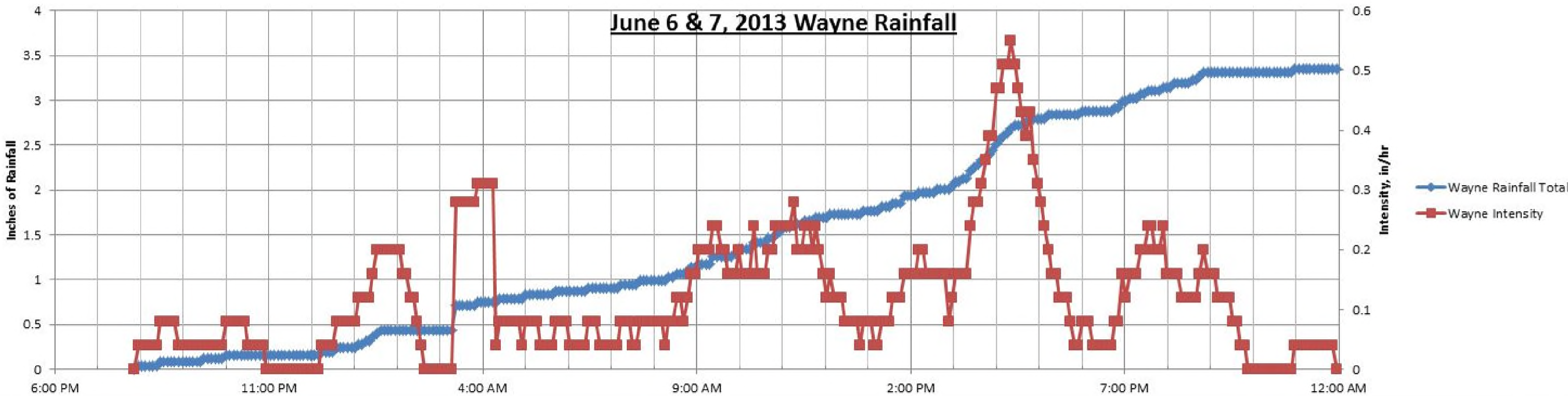
July 23, 2013 Event

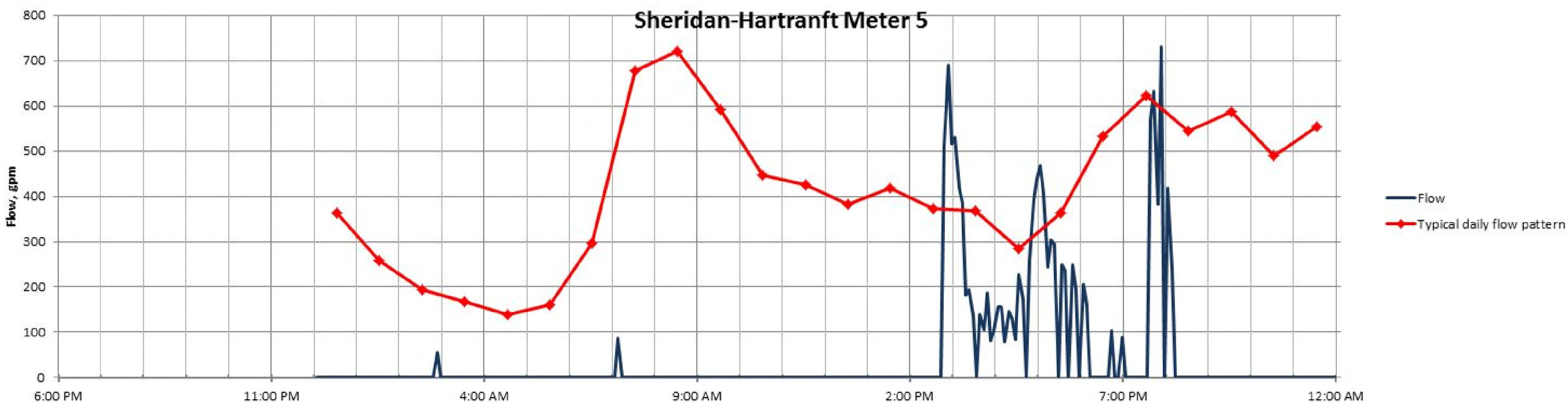
This meter was not functioning during the July 23 event.

Flow Characterization

Based on comparisons with expected flows from the Port Indian Pump Station, the only conclusion that can be drawn from Figure 54 is that the directly contributing sewershed to Meter 5 contributes very little rain-induced sewage flows. However, it appears that the metering data is inaccurate, since average daily flows on Figure 53 are well below what should flow through this meter. Additionally, the peak flows on Figure 54 are generally well below the flows which would come from the pumping rates at the Port Indian Pump Station. It is recommended that the metering location be revised or the meter be rehabilitated.


WNT - Daily Flow Data from Sheridan & Hartranft Meter 5
April 2013 - July 2013
Flow (gpm)
Precipitation (inches)
Date
Precip
Avg Daily Flow (gpm)


June 6 & 7, 2013 Wayne Rainfall
Inches of Rainfall
Intensity, in/hr
Wayne Rainfall Total
Wayne Intensity
4
3.5
3
2.5
2
1.5
1
0.5
0
0.6
0.5
0.4
0.3
0.2
0.1
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM


Sheridan-Hartranft Meter 5
Flow, gpm
Flow
Typical daily flow pattern
800
700
600
500
400
300
200
100
0
6:00 PM
11:00 PM
4:00 AM
9:00 AM
2:00 PM
7:00 PM
12:00 AM