



LOWELL REGIONAL WASTEWATER UTILITY

WASTEWATER COLLECTION AND TREATMENT



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SUBJECT: Infiltration and Inflow Abatement Plan

DATE: 12/30/2022

Mrs. King and Mr. Koopman

With this correspondence, the City of Lowell is submitting this Infiltration and Inflow Identification and Removal Program to comply with Massachusetts Department of Environmental Protection regulations at 314 CMR 12.04(2).

The Infiltration and Inflow Abatement Plan layouts a comprehensive approach and schedule to identify and investigate locations of excessive infiltration and inflow (I/I) within the Lowell Regional Wastewater Utility's (LRWWU) sewer system. Through comprehensive review, the LRWWU experiences significant I/I in several areas and will proceed with the following work in 2023:

1. Conduct a City-wide Flow Metering Program and summarize findings and recommendations in an I/I Analysis Report in accordance with MassDEP Guidelines.
2. Conduct CCTV and manhole inspections during high groundwater periods in subareas 7, 9, 19, 20 (as defined in 1990 I/I Study). Includes approximately 60,100 feet (5% of system) of sewer inspections and 330 manhole inspections (5% of system).
3. CCTV inspections of River-front interceptors (up to 10,000 feet) and siphon (at least one priority location).
4. Repair of Kearney Square sewer.

Should you have any questions, please do not hesitate to call me at 978-674-1604.

Respectfully,

A handwritten signature in black ink, appearing to read "Aaron Fox".

Aaron Fox, Operations Manager
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**LOWELL REGIONAL WASTEWATER UTILITY
CITY OF LOWELL, MA
INFILTRATION AND INFLOW ABATEMENT PLAN
KLEINFELDER PROJECT #20220166.003A**

DECEMBER 30, 2022

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REPORT WAS PREPARED.**

A Report Prepared for:

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**LOWELL INFILTRATION AND INFLOW ABATEMENT PLAN
CITY OF LOWELL, MA**

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**LOWELL REGIONAL WASTEWATER UTILITY
CITY OF LOWELL, MA
INFILTRATION AND INFLOW ABATEMENT PLAN**

1 EXECUTIVE SUMMARY

The City of Lowell (the City) has proactively developed this Infiltration/Inflow Identification and Removal Program to comply with Massachusetts Department of Environmental Protection (MassDEP's) regulations at 314 CMR 12.04(2).

Lowell Regional Wastewater Utility (LRWWU) contracted with Kleinfelder to develop an Infiltration/Inflow Abatement Plan to provide a comprehensive approach and schedule to identify and investigate locations of excessive infiltration and inflow (I/I) within the LRWWU's sewer system. Kleinfelder performed a review of LRWWU's available data, past reports, existing conditions of sewer system, and an I/I analysis of LRWWU's available sewer system meter data collected in 2018 in support of Lowell's 2019 Integrated Capital Plan.

Through comprehensive review, the LRWWU experiences significant I/I in several areas and will proceed with the following work in 2023:

1. Conduct a City-wide Flow Metering Program and summarize findings and recommendations in an I/I Analysis Report in accordance with MassDEP Guidelines.
2. Conduct CCTV and manhole inspections during high groundwater periods in subareas 7, 9, 19, 20 (as defined in 1990 I/I Study). Includes approximately 60,100 feet (5% of system) of sewer inspections and 330 manhole inspections (5% of system).
3. CCTV inspections of River-front interceptors (up to 10,000 feet) and siphon (up to 1 location).
4. Repair of Kearney Square sewer.

It is anticipated that a draft I/I Analysis Report would be developed within 6 months of the completion of the flow metering and infiltration/inflow inspections. This assumes we have appropriate antecedent rainfall as well as qualifying rainfall events during the flow metering period. The I/I Analysis Report will include the following: a road map for LRWWU to implement an ongoing plan to execute ongoing I/I investigations and reduction efforts; estimated costs and draft schedule of subsequent SSES phases; and budgeting for the anticipated SSES efforts.

2 BACKGROUND

The City of Lowell (the City) will develop and implement an ongoing Infiltration/Inflow (I/I) Identification and Removal Program compliant with Massachusetts Department of Environmental Protection (MassDEP's) regulations at 314 CMR 12.04(2). In April 2014, MassDEP implemented regulations requiring all sewer authorities to develop and implement an ongoing program to control extraneous flow entering sewer systems. 314 CMR 12.04(2) requires phased I/I evaluations of sewer systems consistent with MassDEP's *Guidelines for Performing Infiltration/Inflow Analyses and Sanitary Sewer Evaluation Surveys, May 2017*. As such, Kleinfelder has performed a review of the Lowell Regional Wastewater Utility (LRWWU) available data, past reports, and existing conditions to develop a comprehensive approach and schedule to identify and investigate locations of excessive I/I within the LRWWU's sewer system. **Figure 1** illustrates the LRWWU's sewer system.

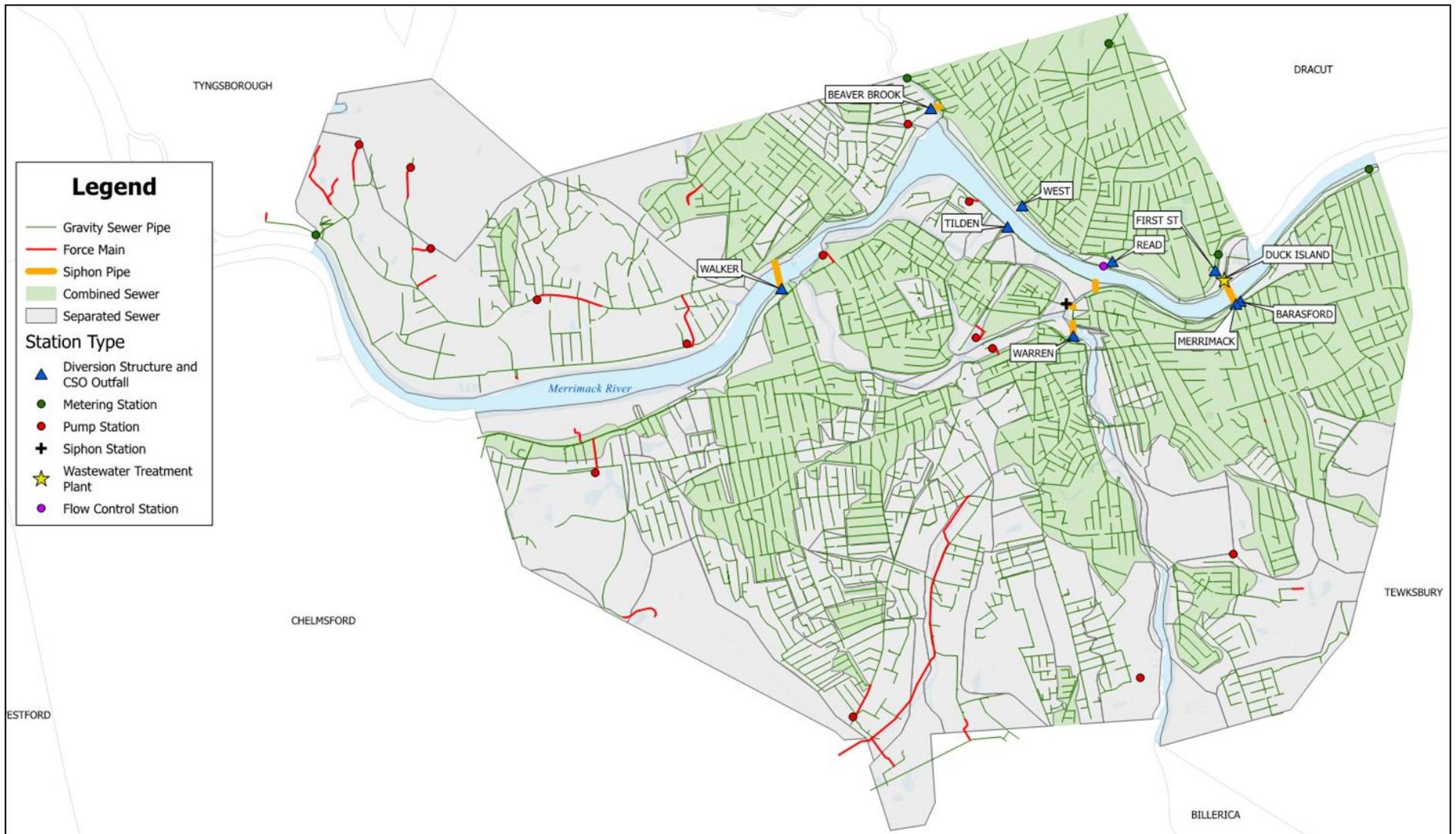


Figure 1: Lowell Regional Wastewater Utility Sewer System

2.1 SEWER COLLECTION AND CONVEYANCE SYSTEM

The LRWWU's sewer system is 226 miles of sewer pipe comprised of portions of combined (approximately 52%) and separated (approximately 48%) sewers by linear foot dating back to the 1830s and largely developed from 1870s to the 1970s. The pipes range from 8-inch to 120-inch in diameter, with the majority of 36-inch in size or smaller. The sewer system is predominantly Vitriified Clay (VC), Concrete, Brick, and Asbestos Cement (AC) with the remaining materials including Cast Iron (CI), Ductile Iron (DI), and Polyvinyl Chloride (PVC). The system also includes six siphons (double or triple barrel), 5 miles of force main, 14 pump stations, nine diversion structures, one siphon station, five meter stations, one flow control station, three permanent rain gauges and the Duck Island Wastewater Treatment Facility (WWTF). There are six metering stations bordering the City that are not owned or operation by the LRWWU. The LRWWU collects and treats flows from the neighboring member communities of Chelmsford, Dracut, Tewksbury, and Tyngsborough utilizing Inter-Municipal Agreements (IMAs).

3 EXISTING INFORMATION REVIEW

Kleinfelder reviewed various past reports and available data provided by the LRWWU to better understand the history of sewer system evaluations and investigations under previous sewer system studies, and the sewer system improvements completed with I/I reduction benefits.

3.1 PREVIOUS REPORTS

A review of the following reports was performed:

1. Phase 1 I/I Report (CDM Smith, 1990),
2. Humphrey's Brook CSO Separation PDR (CDM Smith, 2000),
3. Warren Street CSO Separation Report PDR (CDM Smith, 2004),
4. CSO Phase 2 Long Term Control Plan (LTCP) (CDM Smith, 2014),
5. I/I Control Plans,
6. Capacity, Management, Operation, and Maintenance (CMOM) Reports,
7. NPDES Reports.

3.1.1 1990 Phase 1 I/I Report

The 1990 Phase 1 I/I program included a comprehensive City-wide flow metering program, dividing the City into 48 sewer catchments to identify those areas with excessive amounts of I/I. Sewer catchments ranged in size from 4,560 feet to 44,740 feet of sewer pipe. The 1990 Phase 1 I/I Report followed the 1989 Sanitary Sewer Evaluation Survey (SSES) guidelines where MassDEP classifies "high" infiltration rates as equal to, or higher than, 5,000 gallons per day per inch-diameter-mile (gpd/idm). Thirty out of the 48-meter areas were identified as high-infiltration contributors and recommended for further investigations including flow isolation, closed-circuit television (CCTV) inspections, and manhole inspections. For the purposes of development of LRWWU's I/I Abatement Plan, the six highest I/I areas from the 1990 I/I study were evaluated and considered for further investigation. The nine subareas listed in **Table 1** detail the six highest infiltration areas and the six highest inflow areas from the 1990 I/I study, shown in **Figure 2**. Note that CSO portions of the collection system are expected to have high inflow rates given the design of the combined sewer system. Nevertheless, addressing high I/I areas can provide cost-effective flow and sewer overflow reductions.

Table 1: 1990 I/I Study Priority Subareas

CSO Area	Sewer Sub-Area	Total Sewer Length (LF)	Peak Infiltration Rate (GPD/inch-mi)	Peak Inflow (GPD/inch-mi)
Warren	19	11,880	59,700	72,800
Warren	10	42,203	41,100	51,400
Tilden	20	9,423	38,200	N/A
Warren	14	12,699	21,900	N/A
Merrimack	7	12,857	21,000	N/A
Merrimack	9	5,421	18,500	60,400
Tilden	21	25,497	N/A	115,900
Warren	17	30,703	N/A	39,900
Merrimack	43	12,857	N/A	39,200

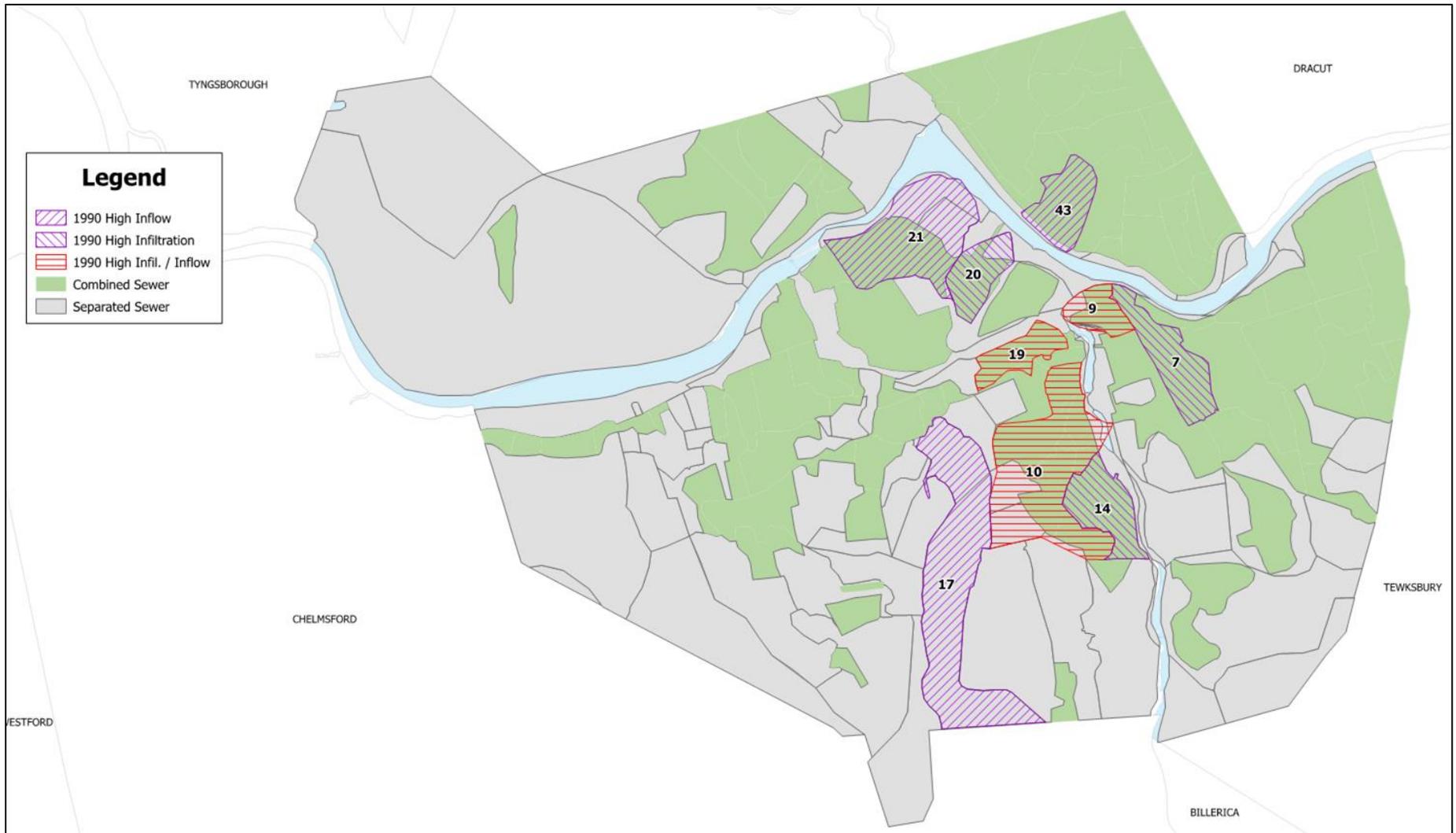


Figure 2: 1990 High I/I Subareas

3.1.2 2000 Humphrey's Brook CSO Separation PDR

The 2000 Humphrey's Brook CSO Separation PDR identified two major sources of inflow: Humphrey's Brook (estimated to contribute 0.5 million gallons per day (MGD)) and Billing's Brook (estimated to contribute 0.3 MGD). The project includes Sewer Subareas 41, 42 and 43, which serve portions of the Centralville and Christian Hill neighborhoods of the City. Subareas 41, 42 and 43 convey combined flow to the West Street CSO structure, where flows may be discharged as CSOs during significant rain events. The tributary drainage area, including Humphrey's and Billing's Brook catchment areas, encompasses approximately 700 acres. Approximately 400 acres of the drainage area is located within the City of Lowell, with the remaining area of basin located in the Town of Dracut. The 1990 I/I Study reported infiltration over 10,000 gpd/idm in all three of the Humphrey's Brook sewer subareas.

3.1.3 2004 Warren Street CSO Separation PDR

The 2004 Warren Street CSO Separation PDR focused on the Warren Street CSO area and identified 11 out of 12 metered areas as high infiltration contributors (greater than 5,000 gpd/idm). This PDR included the design of 12 key sewer separation projects to reduce CSO volumes and sewer surcharging and to mitigate I/I contributions including: Industrial-Wellman, Weed Street, Plain Street, Bolt Street, Newhall Street South, Lincoln Street West, Middlesex Street East, Crosby Avenue, Newhall Street North, Sanders Avenue, Gorham Street South, and Boston Road.

3.1.4 2014 CSO Long Term Control Plan (LTCP)

The 2014 CSO LTCP summarized completed sewer separation projects shown in **Table 2**, as well as the University Crossing Sewer Separation Project (Tilden CSO Area).

Table 2: 2014 CSO LTCP Summary of Completed Sewer Separation Projects

Sewer Separation Project Area	Approximate Acres Separated	Sewer Replaced (LF)	Sewer Rehabilitated (LF)	New Drainage (LF)
Varnum/LaPlume/West Meadow	30	1,500	0	4,100
Sixth and Emery	164	3,084	0	11,881
Weed Street and Wellman Street (Part 1)	103	5,443	8,810	15,004
Lincoln Street East, Lincoln Street West (Part 1) and Gorham Street South	282	7,031	5,984	20,271
Lincoln Street West (Part 2) and Wellman Street (Part 2) and Sewer Areas 24/25	320	3,845	4,530	28,716
Cabot Street Area & Third & Ellis	50	3,250	4,400	4,900
Total	949	22,653	23,724	80,772

Through these sewer separation efforts, the LRWWU carried out an aggressive sump pump identification and removal program, disconnecting approximately 331 sump pumps to further reduce inflow into the sanitary sewer system, shown in **Figure 3**.

3.1.5 I/I Control Plans, CMOM Reports, and NPDES Reports

Kleinfelder reviewed LRWWU’s available I/I Control Plans, CMOM Reports, and NPDES Reports to better understand the LRWWU’s operation and maintenance activities, reported sanitary sewer overflows (SSOs), and additional system investigations efforts. In addition to the sewer separation work noted in Section 3.1.4, the LRWWU has completed CCTV inspections, manhole inspections, lining projects, and sewer repairs and replacements in recent years. The LRWWU purchased a CCTV truck in 2012 with an equipment upgrade in 2022 allowing for sewer pipeline inspections to be conducted in-house. The LRWWU, and its subcontractors, has inspected roughly 49% of their pipelines from 2007 to date, as shown in **Figure 4**. Lowell rehabilitated approximately 46,000 feet of sewer pipe with Cured-in-Place Pipe (CIPP) lining and installed 53,300 feet of new sewer pipe since 2000, shown in **Figure 5**. **Figure 5** also depicts a portion of the aforementioned 2014 LTCP completed separation projects.

The City has experienced SSOs at six locations within combined and separated areas of the collection system due to peak system capacity during wet weather, shown in **Table 3**. In an effort to identify potential inflow sources, the City performed conductance surveys through a field program. As described in the 2022 I/I Control Plan, conductance is a measure of electrical conductivity (or dissolved ions) in

water. Typically, sewage has a high specific conductivity in the range of 1,000 micro-Siemens per centimeter ($\mu\text{S}/\text{cm}$). Sections of the collection system with high I/I tend to dilute the sewage and lower the conductance, offering a low-effort screening tool to identify areas of the system in need of further inspection and repair. **Figure 6** displays the spatial relationship between SSO locations and the locations of potential inflow problems within the City.

Table 3: SSOs Related to Sewer System Capacity Issues during Wet Weather

Year	Occurrences	Location
2016	1	15 Sayles Street
2016, 2017	5	1371 Middlesex Street
2022	1	67 Payne Street
2017, 2020, 2021	4	35 Eagle Court
2017	1	174 Boylston Street
2017, 2020, 2021	5	35 Windward Road

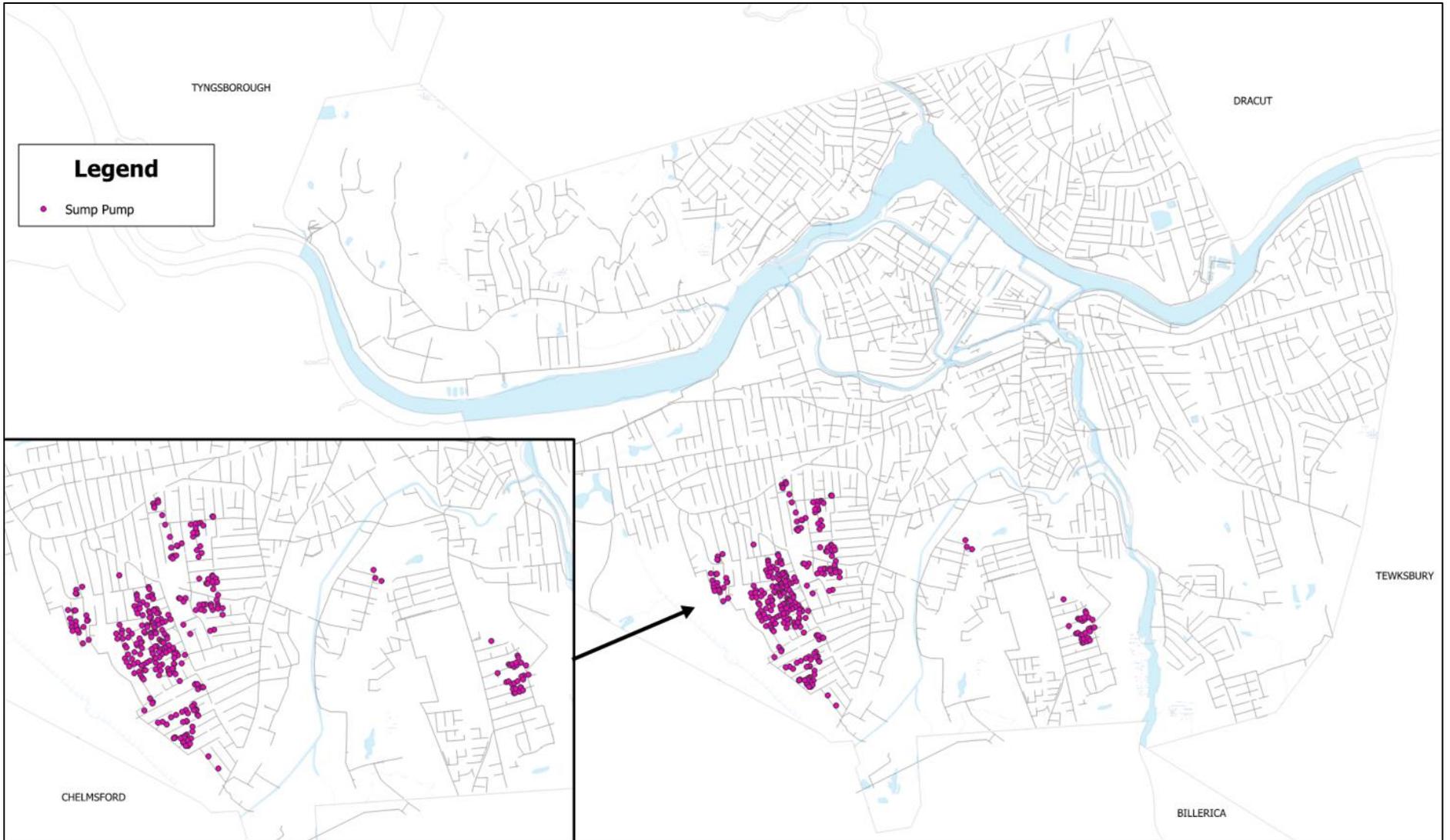


Figure 3: Sump Pump Disconnections

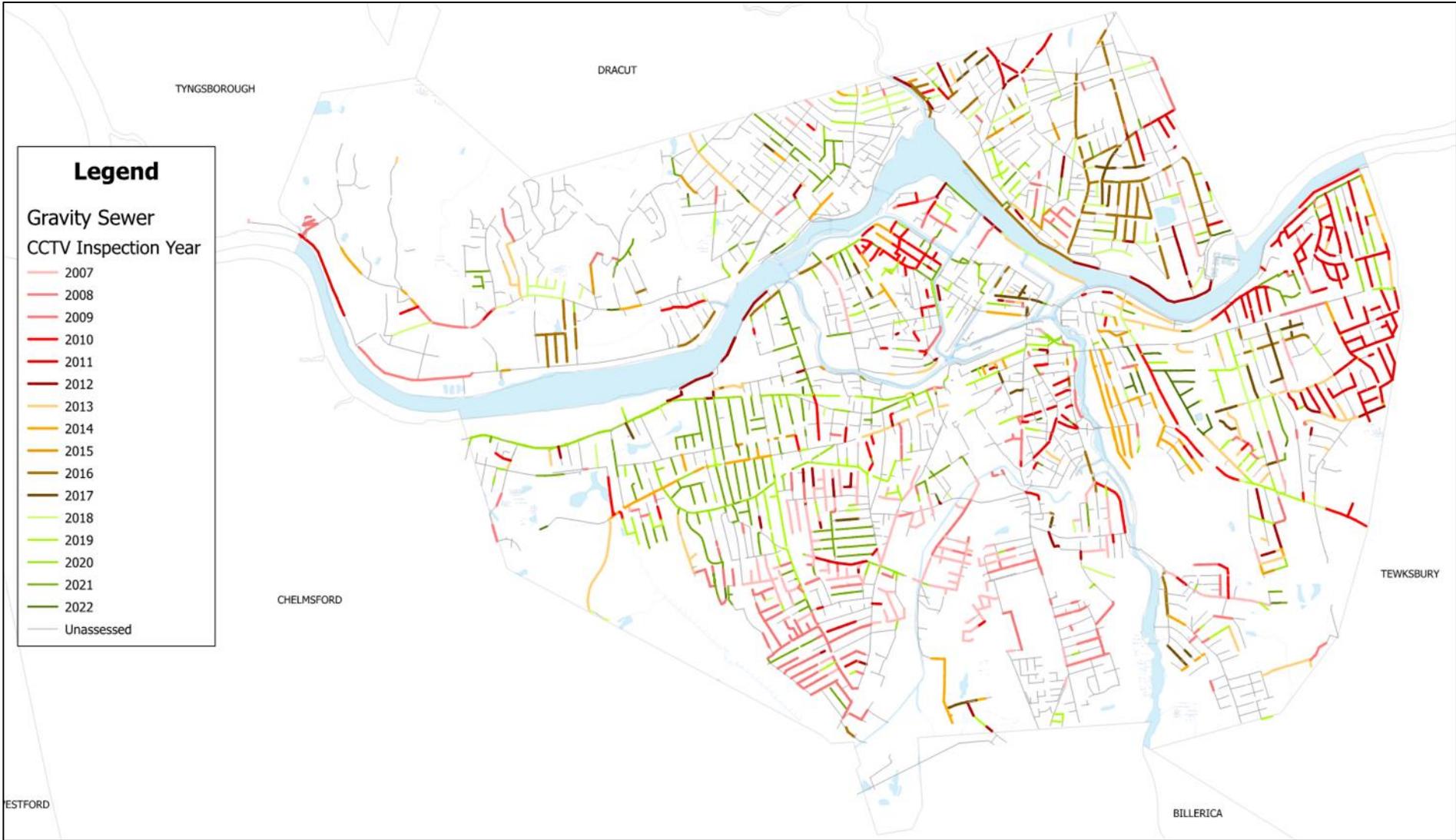


Figure 4: Completed Sewer System CCTV Inspections

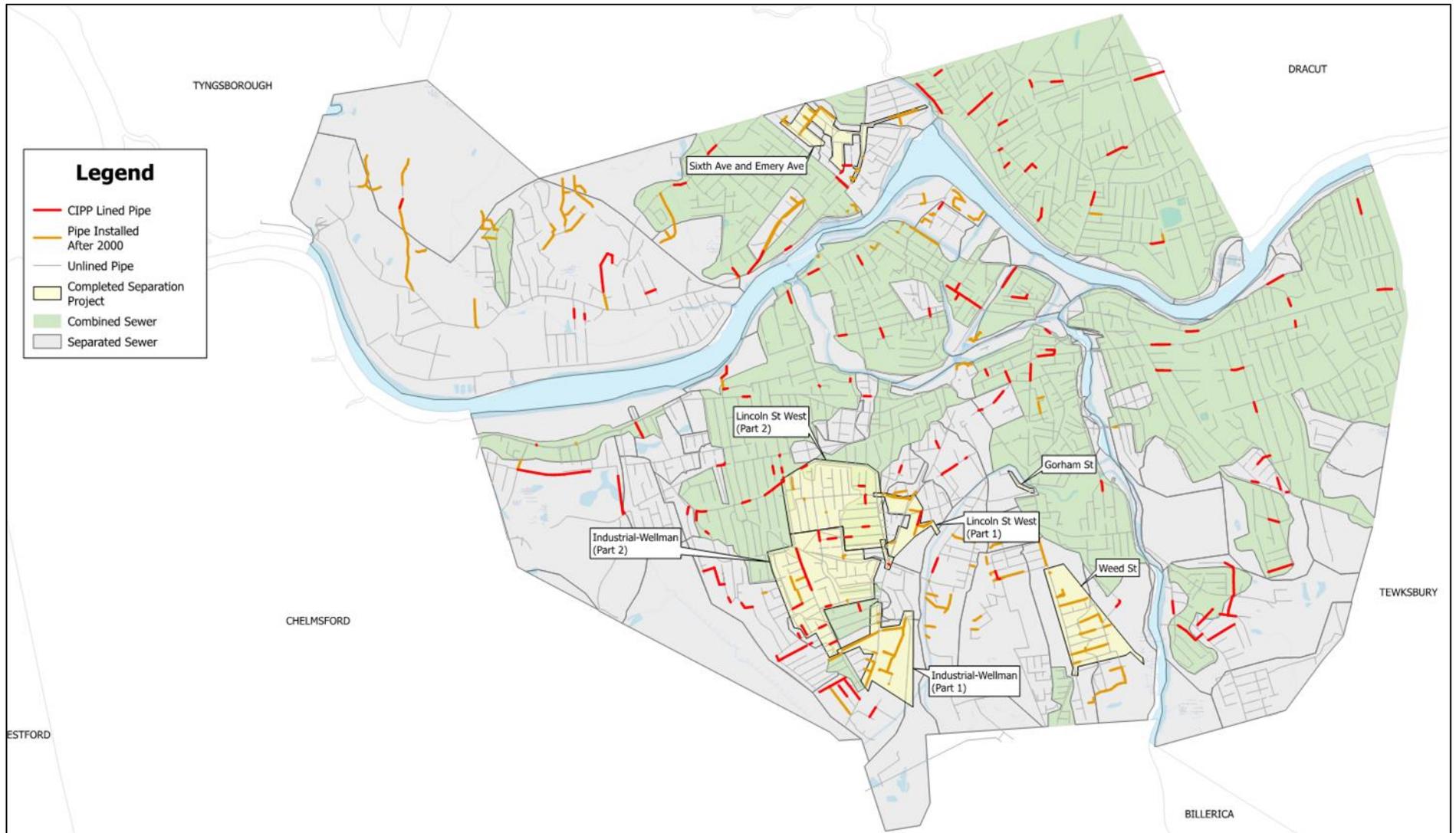


Figure 5: Completed Sewer System Improvements

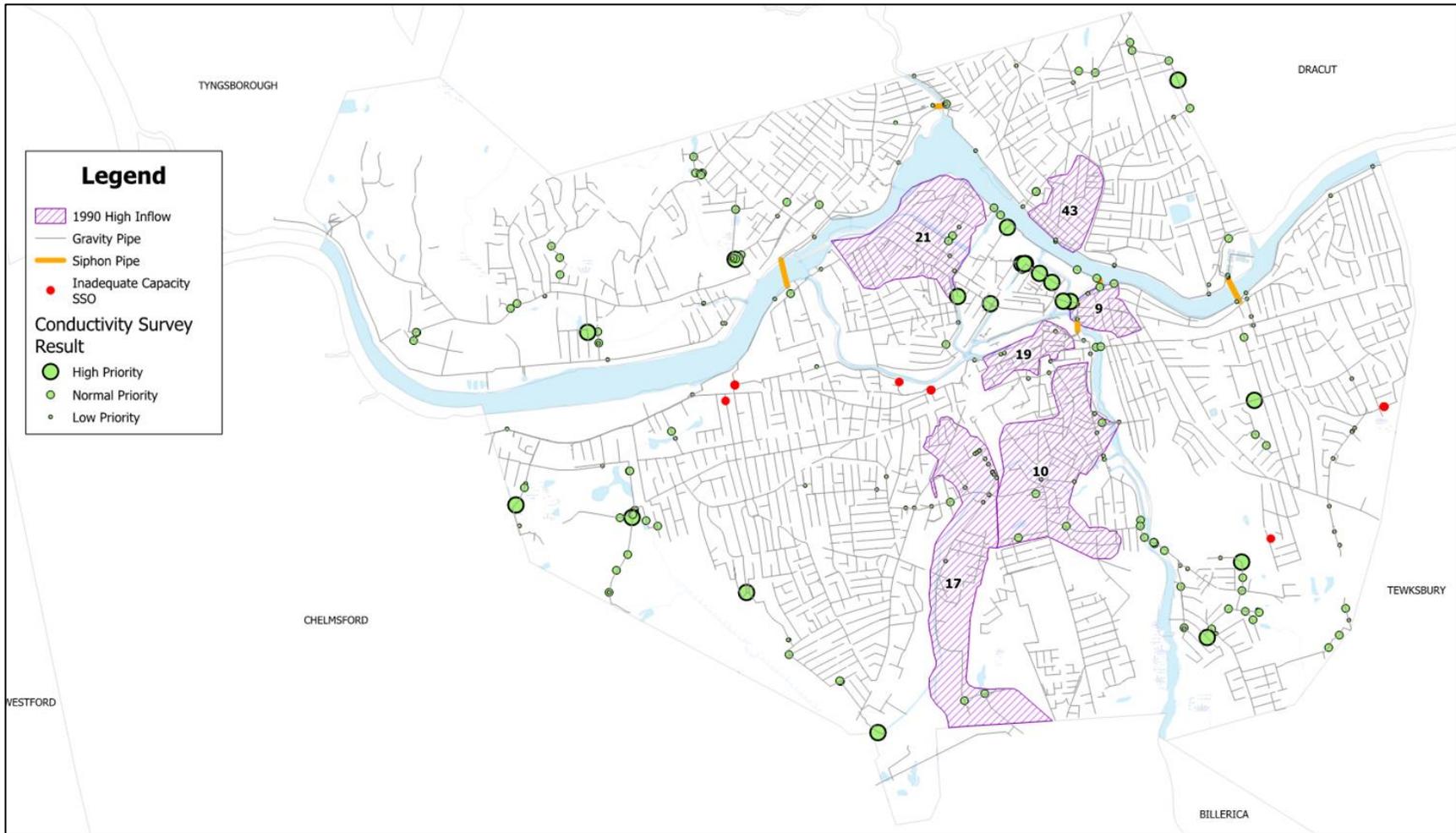


Figure 6: Peak Wet Weather System Capacity vs. Conductance Surveys

3.2 MEMBER COMMUNITIES

LRWWU collects, transports, and treats sewer flows from bordering member communities including Chelmsford, Dracut, Tewksbury, and Tyngsborough through established Inter-Municipal Agreements (IMAs). Below is a summary of the more recent community specific I/I efforts noted by each member community.

3.2.1 Chelmsford

The Town of Chelmsford recently completed an I/I Plan in 2021. The 2021 I/I Plan summarized a flow meter program conducted in 2019 which resulted in all meter areas with infiltration rates under MassDEP's 4,000 gpd/idm threshold. Chelmsford has approximately 167 miles of PVC and ductile iron (DI) sewer estimated to be 40 years old or newer. Subareas with inflow contributions were identified and recommended for further investigation and/or removal. The I/I Plan also included a 10-year CCTV inspection plan for sanitary sewers.

3.2.2 Dracut

The Town of Dracut completed I/I Reports in 2017 and 2018. Dracut has approximately 125 miles of sewer ranging from 8-inch to 42-inch in diameter. Their system is mostly PVC with some cross-country DI pipe and some larger Concrete and AC pipe. All pipe is estimated to be 50 years old or newer. The majority of wastewater flows are conveyed to Lowell, except for a portion of East Dracut conveyed to the Greater Lawrence Sewer District (GLSD). The 2017 and 2018 I/I Reports detailed the use of four permanent meter stations to review monthly flow data in lieu of temporary flow metering. This method showed there was no significant I/I dependent on rainfall, however groundwater infiltration is occurring. As discussed in Section 3.1.2, it is important to note that approximately 300 acres of the Humphrey's and Billing's Brook drainage area, tributary to Lowell's West Street CSO, is in the Town of Dracut. The 2017 and 2018 I/I Reports presented a schedule of phased sewer inspection and rehabilitation efforts from 2012 through 2031.

3.2.3 Tewksbury

The Town of Tewksbury has approximately 158 miles of sewer pipe that is estimated to be 40 years old or newer. Tewksbury's 2012 I/I Study was based on the analysis of pump station flow data and demonstrated significant I/I reported. A 2018 I/I Report called for further I/I investigations and recommended several system repairs.

3.2.4 Tyngsborough

The Town of Tyngsborough completed an I/I report in 2017. The Town has approximately 22 miles of sewer pipe that is mostly AC or DI and is estimated to be 50 years old or newer. All flow is conveyed to the Lowell's WWTF. There were 17 defects flagged in 2017 contributing 14,000 gallons per day of infiltration to be addressed as soon as possible. The report included recommendations for a 2018 system-wide flow metering program. The Town completed a sewer rehabilitation project in 2021/2022 that included various sewer pipe and manhole rehabilitation and repairs.

4 2018 FLOW METER I/I ANALYSIS

A flow metering program was conducted in 2018 in support of the LRWWU's Integrated Capital Planning efforts. Twenty flow meters were installed for the purposes of calibrating LRWWU's hydraulic model, quantifying CSO discharge volumes, and conducting an alternative analysis for reducing CSOs. Most of the meters were installed in early April 2018 but were analyzed from May 7th, 2018, to August 20th, 2018, due to the poor quality prior to that timeframe. Although the flow meter data was not initially intended for an I/I analysis, the data was able to yield infiltration and inflow values for the majority of the City. MassDEP's 2017 *Guidelines for Performing Infiltration/Inflow Analyses and Sewer System Evaluation Surveys* (MassDEP Guidelines) recommend meter areas of 20,000 linear feet of sanitary sewer to accurately measure flows to quantify infiltration during high groundwater periods and for rainfall-related inflow during wet weather periods. Eleven of out the 20 meter-areas were above 20,000 linear feet of tributary sewer. Larger metering areas do not allow for targeted field investigations to identify the sources of I/I within follow-up SSES phases as discussed in MassDEP Guidelines. It is also noted that the majority of the quality metering data used for this I/I analysis was captured during the summer months, which is historically a low-groundwater period. MassDEP Guidelines recommend that determination of infiltration quantities in the sewer system should be based on the flow data collected during high groundwater periods. With these considerations, this analysis should be viewed as a means of insight to identify potential problem areas and to corroborate the areas identified in the 1990 I/I study with excessive I/I is largely limited to that intention solely. **Figure 7** depicts the respective flow meter relationships, and the Duck Island (DIRG) and Warren (WRG) rain gauge locations. **Table 4** shows the pipe inventory and analysis related characteristics.

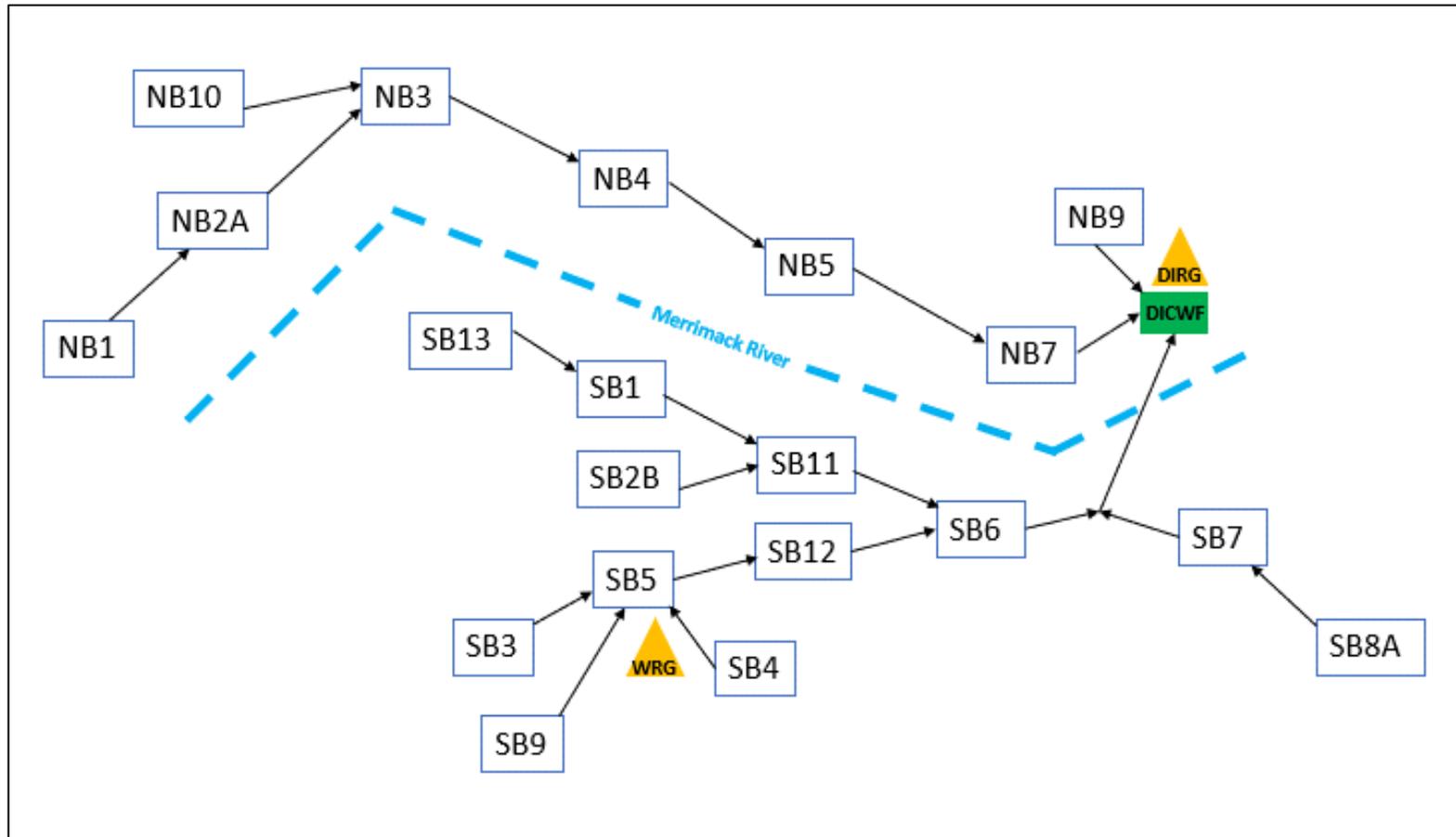


Figure 7: 2018 Flow Meter Schematic

Table 4: 2018 Flow Meter Inventory

Meter Area	Units	Diameter (inches)												Total Length (LF)	Total Meter Area (idm)
		6 to 8	10 to 12	13 to 15	16 to 20	21 to 25	26 to 30	31 to 36	37 to 42	45 to 52	54 to 63	72-78	84 to 96		
NB1	LF	19,923	33,868	9,703	2,509	1,916	6,749	414	-	6,062	-	-	-	81,145	240.84
	idm	29	71	28	9	9	38	3	-	55	-	-	-		
NB2A	LF	1,639	5,092	602	2,438	609	496	511	-	882	-	-	-	12,269	40.50
	idm	2	11	2	9	3	3	3	-	8	-	-	-		
NB3	LF	13,164	22,661	1,818	2,456	1,782	-	1,277	-	1,185	465	-	4,793	49,603	191.91
	idm	19	48	5	9	8	-	9	-	11	6	-	78		
NB4	LF	3,593	7,837	724	646	593	-	-	1,636	69	-	-	1,736	16,834	72.96
	idm	5	16	2	2	3	-	-	13	1	-	-	32		
NB5	LF	9,423	45,036	8,912	3,605	3,783	3,725	1,765	1,344	6,523	2,852	-	1,043	88,012	316.00
	idm	13	97	25	12	17	20	12	10	59	31	-	19		
NB7	LF	8,002	18,657	2,568	1,092	3,023	287	2,619	953	-	227	-	2,542	39,970	149.42
	idm	10	41	7	4	13	2	18	7	-	3	-	46		
NB9	LF	4,948	1,362	1,268	1,314	-	-	511	-	396	-	-	-	9,798	25.40
	idm	7	3	4	4	-	-	3	-	4	-	-	-		
NB10	LF	72,037	48,973	8,600	14,955	1,598	1,301	-	-	4,469	1,287	-	-	153,220	354.79
	idm	108	100	24	52	7	7	-	-	40	15	-	-		
SB1	LF	3,196	1,729	587	-	351	-	-	535	1,495	-	1,791	-	9,683	54.71
	idm	5	3	2	-	2	-	-	4	15	-	24	-		
SB2B	LF	472	3,416	2,167	2,283	715	2,762	199	-	-	-	-	-	12,015	40.84
	idm	1	7	6	8	3	14	1	-	-	-	-	-		
SB3	LF	5,053	33,008	5,057	3,195	367	982	7,050	2,950	5,876	-	-	267	63,805	242.58
	idm	7	73	14	11	2	5	46	23	56	-	-	5		
SB4	LF	74,311	183,109	30,789	17,602	11,428	8,572	16,092	3,744	11,817	4,301	3,272	6,055	371,092	1171.48
	idm	107	390	87	60	51	48	108	27	104	44	46	97		
SB5	LF	1,291	1,611	3,403	-	51	-	77	-	549	-	490	360	7,832	33.27
	idm	2	4	10	-	0.2	-	1	-	5	-	7	6		
SB11	LF	296	-	-	-	-	-	2,255	-	229	-	357	41	3,179	23.32
	idm	0.3	-	-	-	-	-	15	-	2	-	5	1		
SB6A	LF	1,284	11,800	3,256	5,010	1,591	218	2,083	-	-	-	-	163	25,406	79.33
	idm	2	27	9	18	7	1	13	-	-	-	-	3		
SB7	LF	14,499	14,652	1,861	1,800	2,133	2,479	1,077	-	515	-	-	5,012	44,029	177.86
	idm	22	29	5	6	10	14	7	-	5	-	-	80		
SB8A	LF	28,702	46,018	7,818	6,222	1,677	1,288	1,127	2,071	6,010	682	-	-	101,614	279.12
	idm	40	95	22	21	8	7	8	16	54	8	-	-		
SB9	LF	46	478	854	622	-	173	315	-	-	-	-	-	2,488	8.32
	idm	0.1	1	2	2	-	1	2	-	-	-	-	-		
SB12	LF	1,486	2,924	1,897	2,424	1,034	1,491	1,967	935	-	-	-	393	14,550	60.79
	idm	2	6	5	8	5	8	13	7	-	-	-	7		
SB13	LF	2,791	26,235	4,705	5,713	2,188	3,216	2,129	4,322	3,770	-	-	-	55,070	200.99
	idm	4	58	13	20	9	18	13	30	35	-	-	-		

4.1 RAINFALL MONITORING

Kleinfelder utilized rainfall data from LRWWU’s permanent rain gauges at Warren Street Pump Station (90 Warren Street) and at the WWTF (451 First Street Blvd). **Table 5** shows the dry and wet weather periods with associated storm characteristics recorded from the Warren Street Rain Gauge during the metering period.

Table 5: 2018 Recorded Rain Events

No.	Duration (hrs)	Rain Event	Average Intensity (in/hr)	Peak Intensity (in/hr)	Sum (in)	No.	Duration (hrs)	Rain Event	Average Intensity (in/hr)	Peak Intensity (in/hr)	Sum (in)
	~1.5 days	4/01 @ 00:00 - 4/02 @ 11:00	DRY			15	26	5/19 @ 13:00 - 5/20 @ 14:00	0.01	0.06	0.33
1	1	4/02 @ 12:00 - 4/02 @ 13:00	0.05	0.05	0.05		~6.4 days	5/20 @ 15:00 - 5/26 @ 23:00	DRY		
	~1.1 days	4/02 @ 13:00 - 4/03 @ 15:00	DRY			16	24	5/27 @ 00:00 - 5/27 @ 23:00	0.01	0.08	0.21
2	25	4/03 @ 16:00 - 4/04 @ 17:00	0.02	0.09	0.58		~7.2 days	5/28 @ 00:00 - 6/04 @ 04:00	DRY		
	~1.8 days	4/04 @ 18:00 - 4/06 @ 12:00	DRY			17	35	6/04 @ 05:00 - 6/05 @ 15:00	0.01	0.14	0.42
3	17	4/06 @ 13:00 - 4/07 @ 06:00	0.03	0.06	0.47		~13.1 days	6/05 @ 16:00 - 6/18 @ 17:00	DRY		
	~5.5 days	4/07 @ 07:00 - 4/12 @ 18:00	DRY			18	19	6/18 @ 18:00 - 6/19 @ 12:00	0.01	0.06	0.22
4	2	4/12 @ 19:00 - 4/12 @ 20:00	0.07	0.12	0.13		~2 days	6/19 @ 13:00 - 6/21 @ 13:00	DRY		
	~3.2 days	4/12 @ 21:00 - 4/16 @ 00:00	DRY			19	1	6/21 @ 14:00 - 6/21 @ 14:00	0.04	0.04	0.04
5	20	4/16 @ 01:00 - 4/16 @ 20:00	0.12	0.33	2.40		~1.8 days	6/21 @ 15:00 - 6/23 @ 10:00	DRY		
	~2.4 days	4/16 @ 21:00 - 4/19 @ 06:00	DRY			20	1	6/23 @ 11:00 - 6/23 @ 11:00	0.03	0.03	0.03
6	11	4/19 @ 07:00 - 4/19 @ 17:00	0.02	0.08	0.17		~1.2 days	6/23 @ 12:00 - 6/24 @ 15:00	DRY		
	~5.5 days	4/19 @ 08:00 - 4/25 @ 06:00	DRY			21	46	6/24 @ 16:00 - 6/26 @ 13:00	0.01	0.04	0.42
7	24	4/25 @ 07:00 - 4/26 @ 07:00	0.04	0.21	0.88		~18.3 days	6/26 @ 14:00 - 7/14 @ 20:00	DRY		
	~1.2 days	4/26 @ 08:00 - 4/27 @ 12:00	DRY			22	8	7/14 @ 21:00 - 7/15 @ 04:00	0.02	0.08	0.19
8	14	4/27 @ 13:00 - 4/28 @ 02:00	0.03	0.16	0.39		~2.3 days	7/15 @ 05:00 - 7/17 @ 12:00	DRY		
	~1.2 days	4/28 @ 03:00 - 4/29 @ 06:00	DRY			23	11	7/17 @ 13:00 - 7/17 @ 23:00	0.12	0.38	1.37
9	8	4/29 @ 07:00 - 4/29 @ 14:00	0.03	0.07	0.21		~4.3 days	7/18 @ 00:00 - 7/22 @ 06:00	DRY		
	~1.1 days	4/29 @ 15:00 - 4/30 @ 17:00	DRY			24	34	7/22 @ 07:00 - 7/23 @ 16:00	0.01	0.05	0.43
10	5	4/30 @ 18:00 - 4/30 @ 22:00	0.01	0.02	0.07		~16.8 days	7/23 @ 17:00 - 8/09 @ 12:00	DRY		
	~2.6 days	4/30 @ 23:00 - 5/03 @ 13:00	DRY			25	5	8/09 @ 13:00 - 8/09 @ 17:00	1.02	1.61	5.08
11	1	5/03 @ 14:00 - 5/03 @ 14:00	0.04	0.04	0.04		~1.7 days	8/09 @ 18:00 - 8/11 @ 10:00	DRY		
	~2.7 days	5/04 @ 15:00 - 5/06 @ 07:00	DRY			26	81	8/11 @ 11:00 - 8/14 @ 19:00	0.04	0.79	3.34
12	17	5/06 @ 08:00 - 5/07 @ 00:00	0.03	0.14	0.59		~2.8 days	8/14 @ 20:00 - 8/17 @ 15:00	DRY		
	~5.5 days	5/07 @ 01:00 - 5/12 @ 11:00	DRY			27	26	8/17 @ 16:00 - 8/18 @ 17:00	0.05	0.68	1.25
13	6	5/12 @ 12:00 - 5/12 @ 17:00	0.02	0.04	0.09		~3.5 days	8/18 @ 18:00 - 8/22 @ 06:00	DRY		
	~2.9 days	5/12 @ 18:00 - 5/15 @ 15:00	DRY			28	9	8/22 @ 07:00 - 8/22 @ 15:00	0.07	0.38	0.59
14	4	5/15 @ 16:00 - 5/15 @ 19:00	0.12	0.22	0.48		~9.3 days	8/22 @ 16:00 - 8/31 @ 23:00	DRY		
	~3.7 days	5/15 @ 20:00 - 5/19 @ 12:00	DRY								

4.2 INFILTRATION ANALYSIS

Infiltration is extraneous water that enters the sewer system from defective pipes, pipe joints, broken service connections, or manholes. Groundwater infiltration occurs where components of the sewer system lie at or beneath the groundwater table elevation. Developing a synthetic diurnal curve representative of typical dry weather conditions is the first step in determining the infiltration rates for each metered area. For the synthetic diurnal curve to be most representative of a typical dry weather day, without significant influence from rain events or Rainfall-Induced Infiltration (RII), Kleinfelder identified a three-day period of dry weather with an antecedent dry-weather period. The dry weather periods utilized for this analysis were in early to mid-July 2018 as detailed in **Table 6**. Infiltration rates were then estimated from nighttime minimum flows for each metered area during these respective dry-weather periods. The percentage of the nighttime minimum flow attributable to sanitary flow contributions is assumed to be a small percentage during the hours of 0:00 to 05:00. Therefore, a high percentage of the nighttime minimum flow may be attributed to groundwater infiltration.

Sanitary flow is defined as the component of wastewater which includes domestic, commercial, institutional, and industrial sewage, and specifically excludes infiltration and inflow. For each metered area, nighttime minimum flows were analyzed for potential 24-hour industrial/commercial operations in addition to the small portion of domestic sanitary flows to determine an appropriate portion of the flow that can be attributed to infiltration versus sanitary flow. Sanitary flow is estimated by subtracting the infiltration portion of the nighttime minimum flow from metered wastewater flow during dry weather. **Figure 8** illustrates the diurnal sanitary flow curve and base flow attributed to infiltration during dry weather conditions. The corresponding dry weather hydrograph for each metered area is included in **Appendix A**.

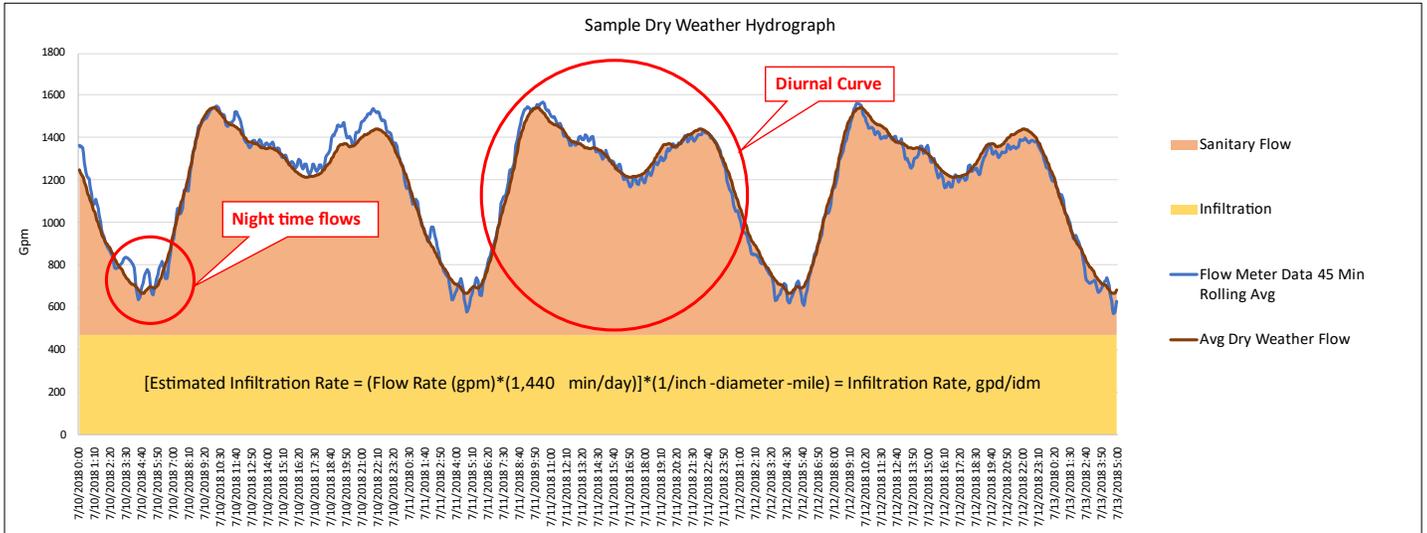


Figure 8: Sample Dry Weather Hydrograph

Seven out of the 20 metered areas exhibited high infiltration rates over the 4,000 gpd/idm threshold defined by MassDEP Guidelines, three areas were indeterminate based on unreliable data, and the remaining ten areas were under the 4,000 gpd/idm threshold. **Figure 9** depicts the 2018 meter areas using a heat color stylization (yellow to orange to red increases the level of infiltration) to visually represent the concentrated focus areas NB7, SB2B, SB5, and SB12 that corroborate with the 1990 priority subareas 7, 9, 19 and 20. **Table 6** also lists the estimated infiltration rates per meter area.

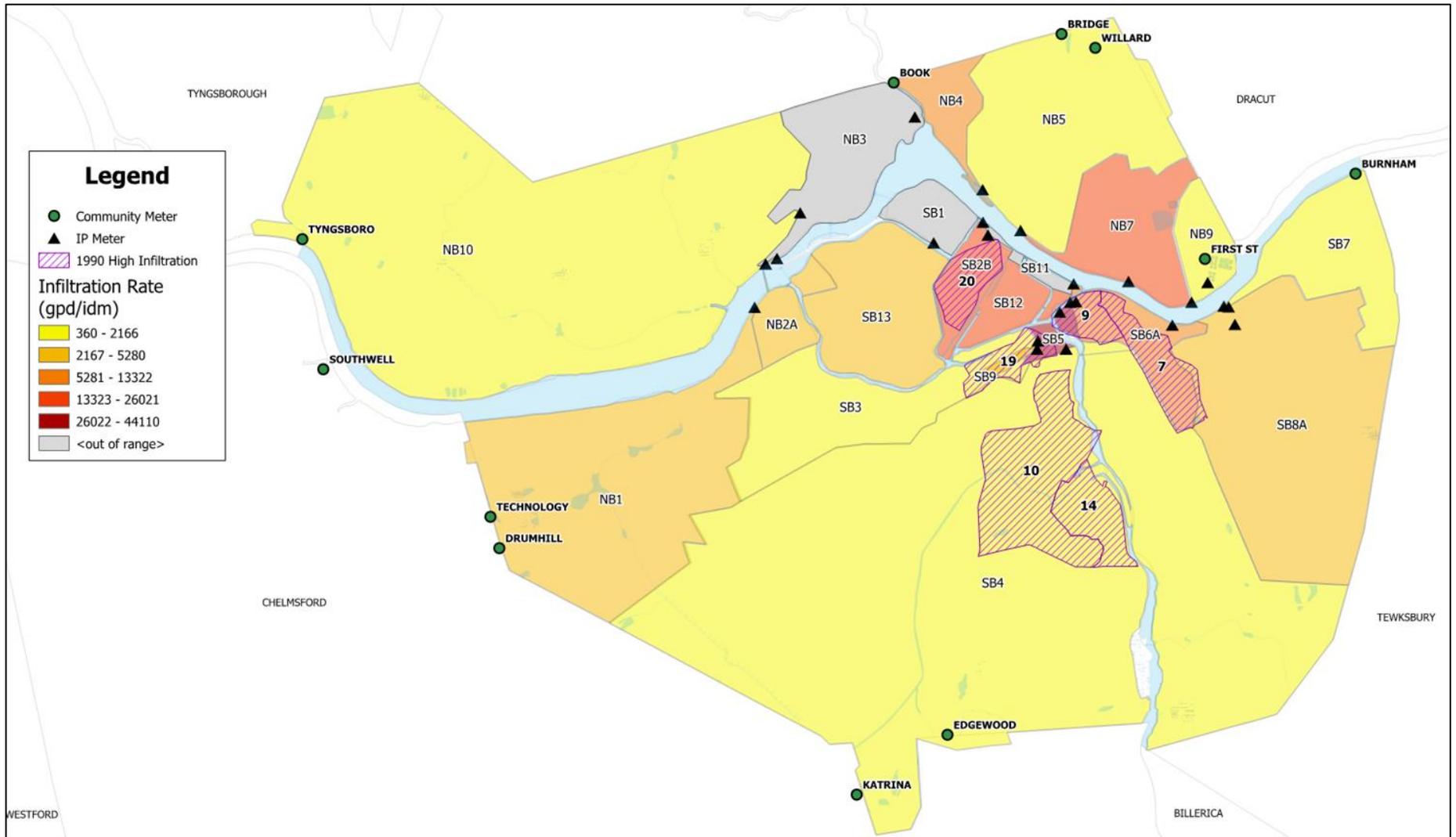


Figure 9: 2018 Flow Meter Infiltration

Table 6: 2018 Infiltration Summary

Meter	Type	Location	Pipe Length (LF)	IDM	³ Estimate Infiltration (gpm)	Estimate Infiltration (gpd)	Estimate Infiltration Rate (gpd/IDM)	Dry Weather Day Used	⁴ Zoning
NB1	¹ Separated	Off of 579 Pawtucket St, Lowell, MA	81,145	241	471	678,384	2,817	7/10 - 7/12	Industrial
NB2A	¹ Combined	90 Varnum Ave	12,269	41	149	213,840	5,280	7/10 - 7/12	Residential
NB3	¹ Separated	Martin St Pump Station	49,603	192	² IND	² IND	² IND	7/10 - 7/12	Residential
NB4	Combined	Bike Path on the North Bank of the Merrimack River	16,834	73	675	972,000	13,322	7/10 - 7/12	Residential
NB5	Combined	Bike Path on the North Bank of the Merrimack River	88,012	316	360	518,400	1,641	7/10 - 7/12	Residential
NB7	Combined	Walking path located off VFW Highway	39,970	149	2700	3,888,000	26,021	7/10 - 7/12	Residential
NB9	Combined	Duck Island WWTP, Lowell, MA	9,798	25	22	31,104	1,225	7/10 - 7/12	Residential
NB10	¹ Separated	Second Ave @ White St	153,220	355	534	768,528	2,166	7/10 - 7/12	Residential
SB1	Separated	End of Martin Luther King Jr. Way. Up path from Tilden CSO PS	9,683	55	² IND	² IND	² IND	7/8 - 7/10	Industrial
SB2B	¹ Combined	Martin Luther King Jr. Way	12,015	41	495	712,800	17,453	7/28 - 7/30	Residential
SB3	Combined	41 Hurd St Lowell, MA (In front of lower district court)	63,805	243	336	483,408	1,993	7/8 - 7/10	Residential
SB4	¹ Separated	151 Warren St Lowell, MA	371,092	1171	293	421,344	360	7/8 - 7/10	Industrial
SB5	¹ Combined	East Merrimack St in front of Lowell Auditorium	7,832	33	936	1,347,840	40,512	7/3 - 7/5	Residential
SB6A	Combined	Stackpole St at Corrigan Ave (over the bank)	25,406	79	576	829,440	10,456	7/8 - 7/10	Residential
SB7	Combined	Merrimack CSO Station off Merrimack St Lowell, MA	44,029	178	180	259,200	1,457	7/8 - 7/10	Residential
SB8A	¹ Combined	East Merrimack St at Barasford Ave	101,614	279	468	673,920	2,414	7/8 - 7/10	Residential
SB9	Combined	21 George St Lowell, MA	2,488	8	17	24,624	2,960	7/8 - 7/10	Residential
SB11	¹ Separated	Hall Street East at River Place	3,179	23	² IND	² IND	² IND	7/8 - 7/10	Residential
SB12	Combined	Stackpole St at Brown St	14,550	61	810	1,166,400	19,187	6/6 - 6/8	Residential
SB13	Combined	Cabot St	55,070	201	443	637,632	3,172	7/18 - 7/20	Residential

¹Mixed type comprised of at least 30% of the opposite type.

²IND = Indeterminate.

³Estimated infiltration includes contributions from upstream member communities.

⁴Industrial zones used an infiltration factor of 0.7 and residential zones used 0.9.

4.3 INFLOW ANALYSIS

Inflow is an element of wastewater flow largely influenced by precipitation. Inflow stems from sources such as sump pumps, roof leaders, foundation and surface drains, and cross connections with the storm-sewer system. Inflow is the area between the storm event hydrograph and the synthetic dry weather diurnal curve. Since inflow is derived from storm events, it is not present during prolonged dry weather. Inflow is characterized by two different components, direct and indirect inflow. Direct inflow quickly influences the flow in the sewer system, and it is therefore evident in the hydrograph. Direct inflow sources are typically direct connections from stormwater structures such as catch basins, drainpipe cross connections, as well as roof leaders. Significant direct connections can quickly increase wastewater flow causing a spike during storm events and put increased stress on the sewer system. Indirect inflow is shown in the hydrograph as a delayed response to the storm event. The influence of indirect inflow can be due RII as well as from sump pumps. It is not uncommon for indirect inflow to persist in a wastewater system for a week or longer after the end of the wet weather event.

Per MassDEP Guidelines, inflow is to be calculated using qualifying storm events with an intensity of at least 0.2 inches per hour that last at least six hours. During the metering analysis, no storm met these criteria. The MassDEP Guidelines further state that any storm producing a visual response to the flows in the system may be used for inflow analysis if there are no, or not enough, qualifying storm events. Storms selected for inflow evaluation in this study are summarized in **Table 7**, which summarizes average intensity, peak intensity, and total rainfall for each event.

Table 7: 2018 Selected Storm Events

Storm No.	Duration (hrs)	Rain Event	Average Intensity (in/hr)	Peak Intensity (in/hr)	Total Rainfall (in)
1	4	5/15/18 @16:00 – 5/15/18 @19:00	0.12	0.22	0.48
2	11	7/17/18 @13:00 – 7/17/18 @23:00	0.12	0.38	1.37
3	81	8/11/18 @11:00 – 8/14/18 @19:00	0.04	0.79	3.34

Direct and indirect inflow volumes were calculated for each of the metered areas. Inflow volumes were calculated by subtracting the synthetic dry weather diurnal curve from the storm event hydrograph. Inflow is observed when the storm event hydrograph diverges from the synthetic dry weather diurnal curve, both at the beginning of the storm event and after the storm has passed.

The hydrograph depicted in **Figure 10**, was selected to illustrate the sanitary curve and the system’s response to the storm event. The wet weather hydrographs for each metered area are included in **Appendix B**.

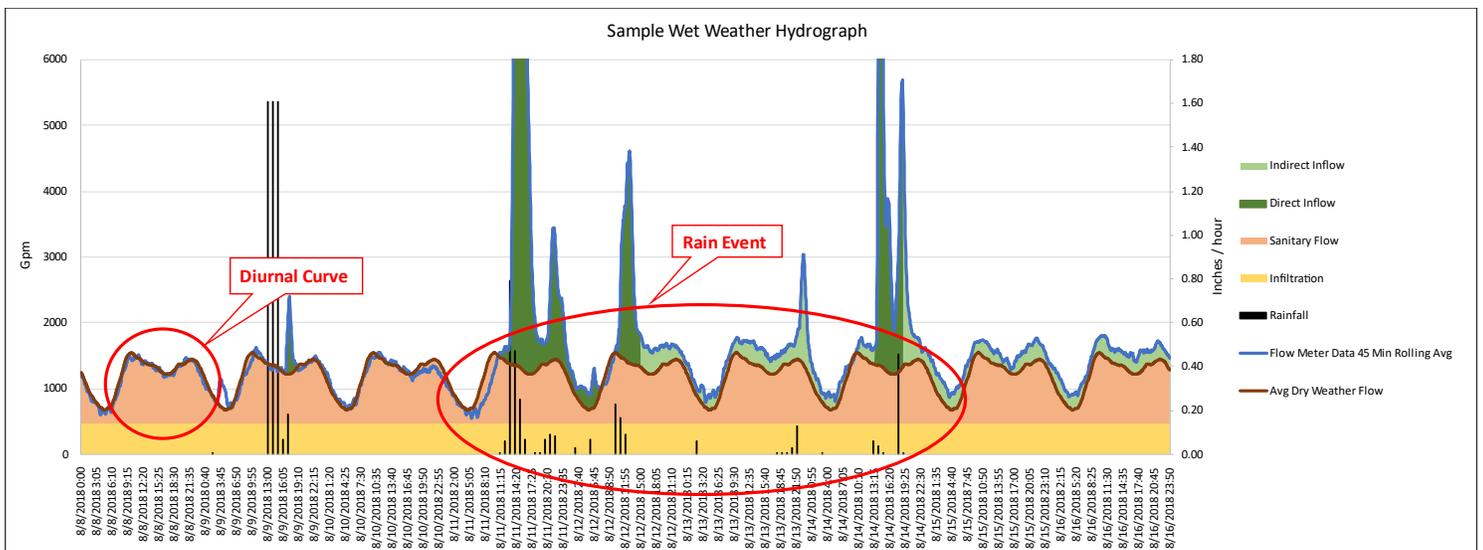


Figure 10: Sample Wet Weather Hydrograph

Design Storm inflows are estimated from a “best fit” curve line that is derived from the inflow data obtained by analyzing the varied rain events observed during the metering period. The Design Storm is defined in the MassDEP Guidelines as a 1-yr, 6-hour rain event of 1.72 inches. By plotting the “best fit” line between the storm events for each Meter Area, the resulting equation is used to calculate the inflow volume corresponding to the Design Storm. **Table 8** summarizes the inflow volumes from the analyzed storm events and the estimated inflow contributions from the 1-yr, 6-hour design storm event for each meter area.

According to MassDEP Guidelines, metered areas that account for 80% of the total inflow of the system should be prioritized for investigations. Metered areas NB7, SB4, SB7, SB6A, SB13, NB5, NB10, SB5, and SB8A account for 83% total of the inflow identified within the 20 metered areas. **Figure 11** depicts the 2018 meter areas using a heat color stylization (yellow to orange to red increases in level of total inflow) and overlays the six highest inflow areas from the 1990 I/I study for comparison. It is important to note that combined sewers within 1990 Study Subarea 17 and a portion of Subarea 21 were separated under the City’s Phase 1 Sewer Separation efforts (2005-2011).

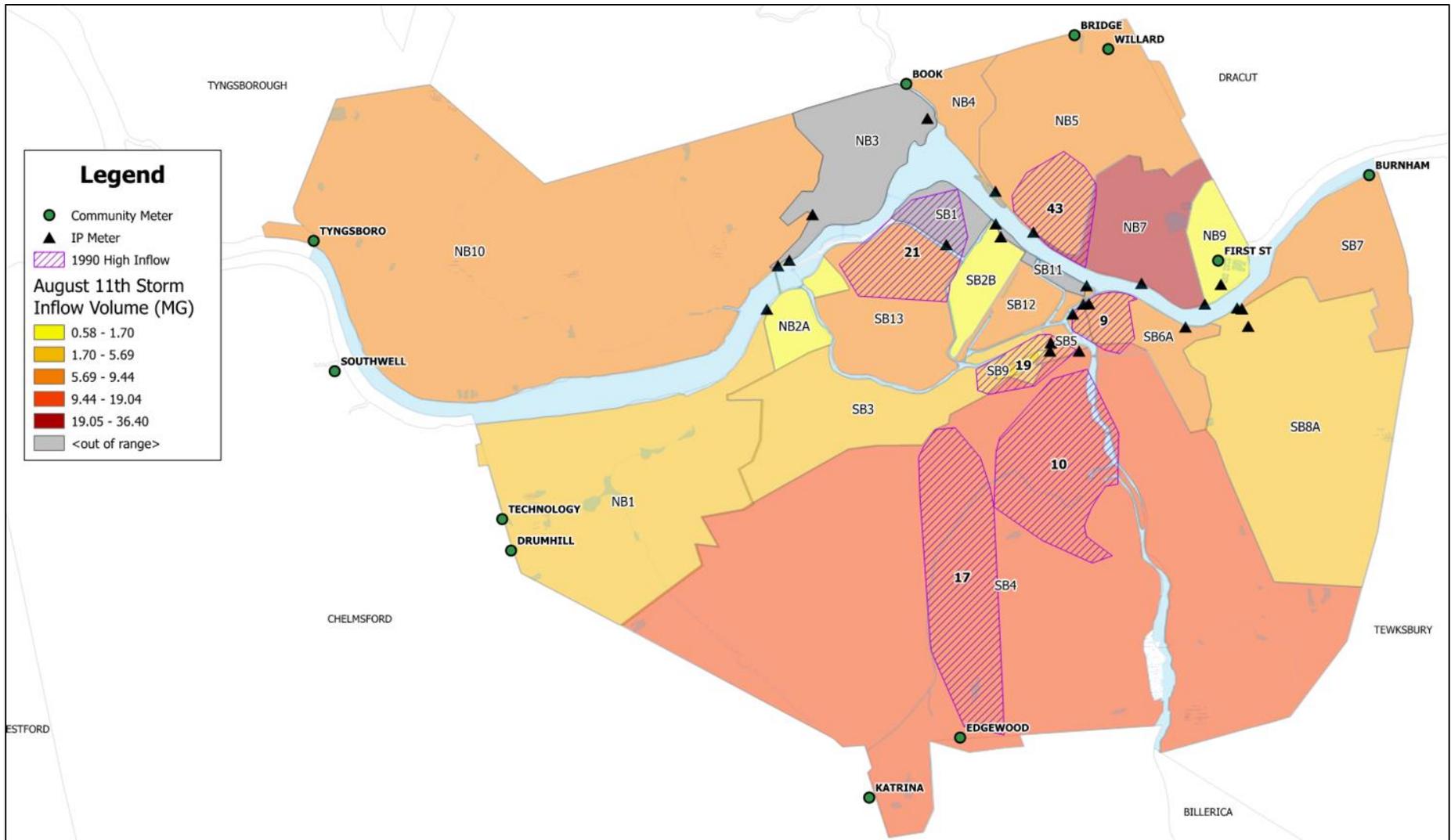


Figure 11: 2018 Flow Meter Inflow

Table 8: 2018 Inflow Summary

Meter	Type	Location	⁵ Storm Event Volume (MG)			Design Storm				Percent Inflow	Percent Cumulative Inflow
			5/15/2018	7/17/2018	8/11/2018	³ Design Storm Inflow (gal.)	Design Storm D/I Ratio (ave)	Design Storm Indirect Inflow (gal.)	Design Storm Direct Inflow (gal.)		
NB3	¹ Separated	Martin St Pump Station	N/A	N/A	N/A	-	-	-	-	-	-
SB1	Separated	End of Martin Luther King Jr. Way. Up path from Tilden CSO PS	N/A	N/A	N/A	-	-	-	-	-	-
SB11	² Separated	Hall Street East at River Place	N/A	N/A	N/A	-	-	-	-	-	-
NB7	Combined	Walking path located off VFW Highway	5.58	N/A	36.40	27,002,280	2.23	8,359,839	18,642,441	32.5%	32%
SB4	¹ Separated	151 Warren St Lowell, MA	3.53	6.81	19.05	9,680,504	6.40	1,308,176	8,372,328	11.6%	44%
⁴ SB7	Combined	Merrimack CSO Station off Merrimack St Lowell, MA	N/A	N/A	9.44	7,063,008	1.11	3,347,397	3,715,611	8.5%	53%
SB6A	Combined	Stackpole St at Corrigan Ave (over the bank)	N/A	2.65	7.52	5,472,696	5.71	815,603	4,657,093	6.6%	59%
⁴ SB13	Combined	Cabot St	N/A	N/A	9.24	4,760,616	7.64	550,997	4,209,619	5.7%	65%
NB5	Combined	Bike Path on the North Bank of the Merrimack River	4.36	N/A	8.42	4,561,956	3.71	968,568	3,593,388	5.5%	70%
NB10	¹ Separated	Second Ave @ White St	N/A	1.21	7.70	3,612,000	0.92	1,881,250	1,730,750	4.3%	75%
SB5	¹ Combined	East Merrimack St in front of Lowell Auditorium	0.98	N/A	6.85	3,526,688	0.76	2,003,800	1,522,888	4.2%	79%
⁴ SB8A	¹ Combined	East Merrimack St at Barasford Ave	N/A	N/A	4.61	3,446,536	1706.69	2,018	3,444,518	4.1%	83%
NB4	Combined	Bike Path on the North Bank of the Merrimack River	0.92	N/A	6.50	3,347,120	1.55	1,312,596	2,034,524	4.0%	87%
⁴ SB12	Combined	Stackpole St at Brown St	N/A	N/A	6.44	3,313,924	² IND	² IND	² IND	4.0%	91%
NB1	¹ Separated	Off of 579 Pawtucket St, Lowell, MA	0.67	1.67	5.69	2,804,460	3.89	573,509	2,230,951	3.4%	94%
SB3	Combined	41 Hurd St Lowell, MA (In front of lower district court)	0.43	1.14	4.09	2,001,392	11.83	155,993	1,845,399	2.4%	97%
NB2A	¹ Combined	90 Varnum Ave	0.34	N/A	1.70	884,424	4.20	170,082	714,342	1.1%	98%
SB2B	¹ Combined	Martin Luther King Jr. Way	N/A	0.85	1.31	732,204	29.81	23,765	708,439	0.9%	99%
SB9	Combined	21 George St Lowell, MA	0.14	0.40	1.09	551,432	35.56	15,083	536,349	0.7%	100%
NB9	Combined	Duck Island WWTP, Lowell, MA	N/A	0.16	0.58	407,296	3.47	91,118	316,178	0.5%	100%

¹Mixed type comprised of at least 30% of the opposite type.

²IND = Indeterminate, SB12 demonstrated no indirect inflow due to upstream relationship values.

³Using Assumed Design Storm of 1.72 inches.

⁴The Design Storm Inflow constant was derived from 8/11 storm event and origin of graph.

⁵Includes inflow contributions from upstream member communities.

5 RECOMMENDATIONS

Kleinfelder has thoroughly reviewed the LRWWU's prior reports and completed work to date to gain a comprehensive understanding of areas with historic I/I contributions and where targeted SSES efforts can be focused on in the near term. The 1990 I/I Study identified Subareas 7, 9, 19, 20 with some of the highest amounts of infiltration per inch-diameter-mile of sewer. In general, the infiltration analysis of the 2018 meter data also estimated high infiltration in these areas of the City, as shown in **Figure 9**. Conducting CCTV and manhole inspections to identify infiltration sources will offer a multi-benefit solution to the City by also providing a structural assessment of the City's aging infrastructure, a CMOM Program requirement to address preventative maintenance of the sewer system. CCTV and manhole inspections should be performed in accordance with National Association of Sewer Service Companies (NASSCO) guidelines, as described by the Pipeline Assessment & Certification Program (PACP) for CCTV inspections and by the Manhole Assessment & Certification Program (MACP) for manhole inspections. Kleinfelder recommends that the City inspect approximately 10% of the system annually over the next decade. This focused effort will discover potential defects to mitigate while building an inventory for better management of their assets and provide more current data for prioritization maintenance and rehabilitation purposes.

In addition to the CCTV of high infiltration areas discussed above, LRWWU will CCTV of some of their largest and most critical sewers. LRWWU has close to 47,000 feet of interceptor sewer located along the Merrimack River, Concord River, and Pawtucket Canal. These interceptors range in size from 36-inch to 120-inch in diameter and are LRWWU's most critical sewers for wastewater conveyance to the treatment facility. Given the proximity to the waterways, there is a higher potential for structural defects in these pipeline and manholes to be sources of both I/I, which would reduce system capacity and impact conveyance of wastewater flows to the treatment facility.

The river-bordering interceptor system also includes six siphons, double or triple barrel, which have not been evaluated or cleaned in recent years. Any structural defect within this infrastructure would be a significant source of infiltration/inflow into the sewer system, and a failure of these critical assets could negatively impact the water quality of the impacted waterways.

Infiltration/Inflow Source Repair

LRWWU's 2022 Infiltration and Inflow Control Plan reported a significant source of I/I that was identified through their conductance survey program. A large hole was observed through video inspection in the

sidewall of the 36-ductile iron sewer submerged under the Eastern Canal, near Kearney Square. The City observed excessive inflow contributions of canal water entering the sewer through this defect. The Kearney Square pipe is located just upstream of LRWWU’s East Merrimack siphon as shown in **Figure 12** and tributary to the Merrimack CSO Station. LRWWU will prioritize repair of Kearney Square pipe in 2023 to remove this known source of excessive I/I from the collection system.

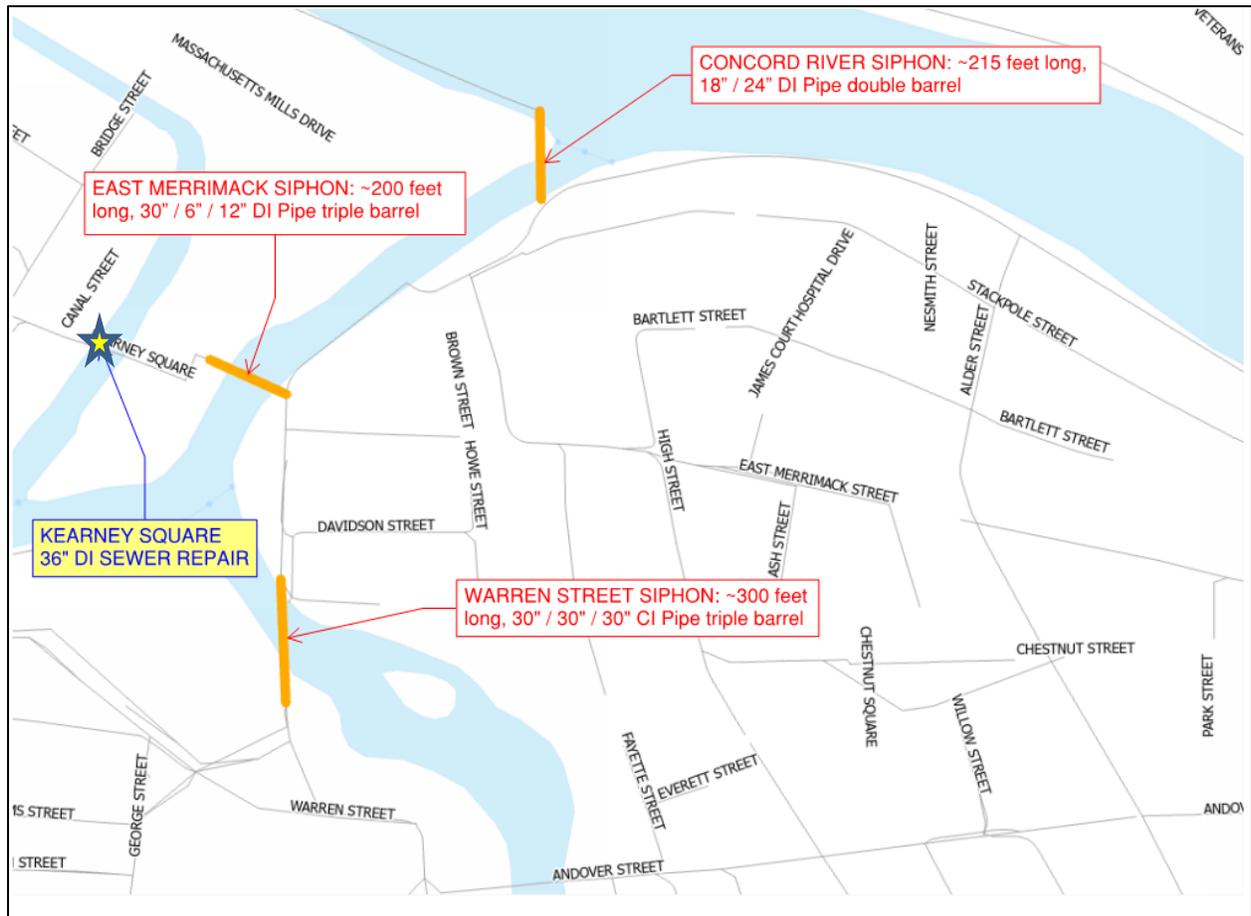


Figure 12: Kearney Square Sewer Repair

Infiltration/Inflow Analysis

Given the most reliable I/I flow metering data dates back to 1990, LRWWU will commence a City-wide, comprehensive flow metering program to better target I/I problems areas and understand current I/I conditions of the sewer system. This flow meter program will double as the established baseline before the potential sewer separation projects to be able to quantify the I/I reduction benefits of those projects. After completion of the I/I analysis, meter areas will be ranked based on the highest I/I volumes to develop a priority list for follow-up field investigations to identify I/I sources through a Sewer System Evaluation Survey (SSES). The SSES will include an investigation plan and rehabilitation/repair

recommendations in collaboration with other sewer system improvements such as the future CSO separation projects.

The I/I Analysis will also include the following components in accordance with MassDEP Guidelines:

- Groundwater monitoring
- Analysis of I/I contributions from member communities
- Risk assessment of sewer system overflows from a five-year, 24-hour storm event

LRWWU is evaluating system improvements and operational measures which will reduce the risk of sewer system surcharge/overflow events through a CMOM Program Self-Assessment. The assessment includes review of the City's existing sewer use ordinance which discuss permitted and unauthorized connections to the sewer system. As provided in 314 CMR 12.04(2)(d), impacts from new sewer connections and extensions to the sewer system shall be mitigated for sewer system authorities with NPDES permits for combined sewer overflows. LRWWU will update the City's existing sewer use ordinance to provide mitigation of new sanitary discharges through removal of I/I in accordance with 314 CMR 12.04(2)(d). This modification will be implemented in conjunction with other updates to the sewer use ordinance that are identified through the CMOM Program Self-Assessment.

Summary of 2023 I/I Analysis and Investigations

LRWWU will begin further infiltration/inflow analysis and targeted field investigations in Spring 2023. Below is a summary of the specific elements of the 2023 (Year 1) I/I Program. Items 2 through 4 are also illustrated in **Figure 13**.

1. Conduct a City-wide Flow Metering Program and summarize findings and recommendations in an I/I Analysis Report in accordance with MassDEP Guidelines.
2. Conduct CCTV and manhole inspections during high groundwater periods in subareas 7, 9, 19, 20 (as defined in 1990 I/I Study). Includes approximately 60,100 feet (5% of system) of sewer inspections and 330 manhole inspections (5% of system).
3. CCTV inspections of River-front interceptors (up to 10,000 feet) and siphon (at least one priority location).
4. Repair of Kearney Square sewer.

It is anticipated that a draft I/I Analysis Report would be developed within 6 months of the completion of the flow metering and infiltration/inflow inspections. The I/I Analysis Report will include a road map for LRWWU to implement an ongoing plan to execute continuous I/I investigations and reduction efforts, along with estimated costs, budgeting, and draft schedule of subsequent SSES phases.

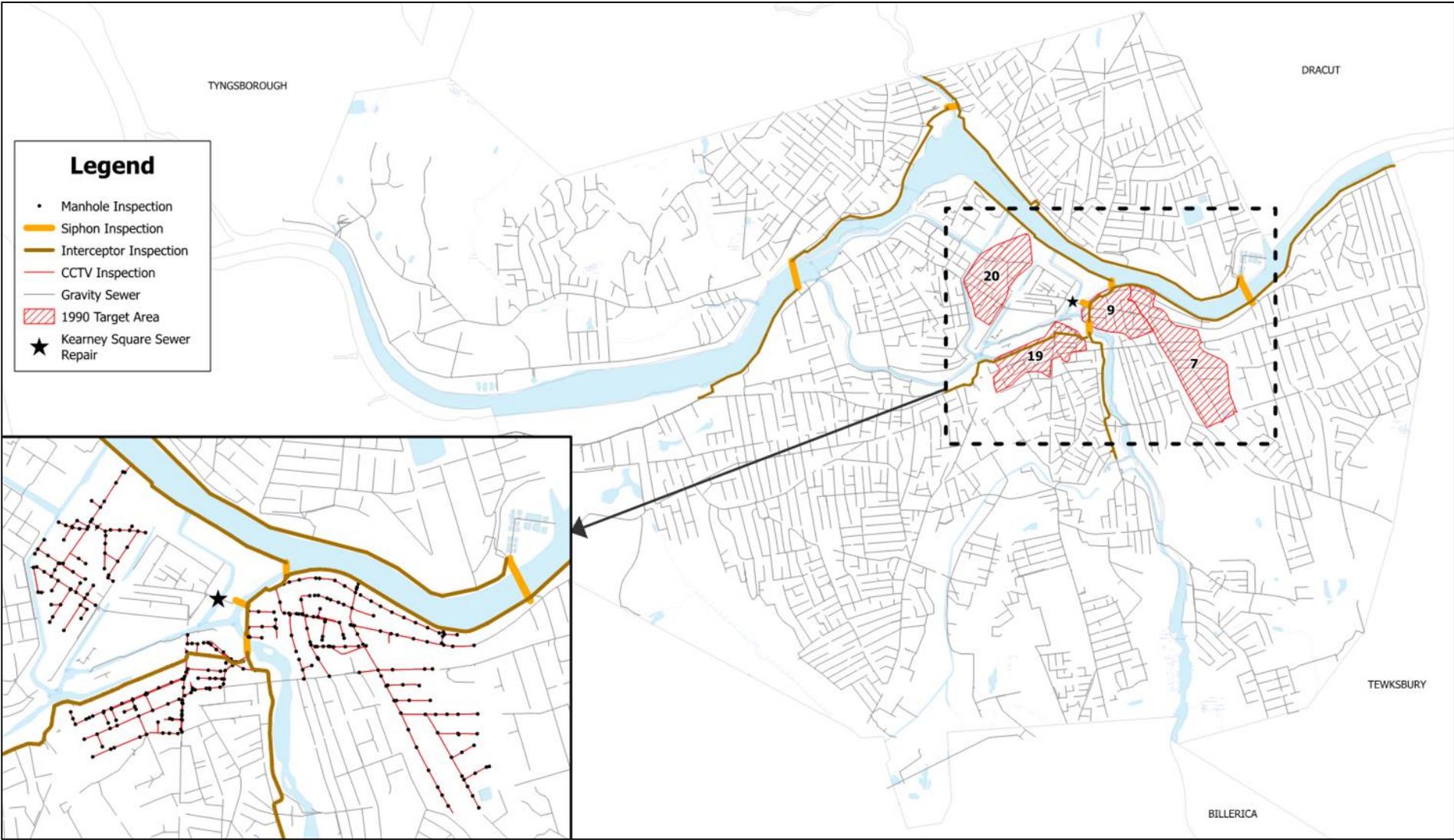
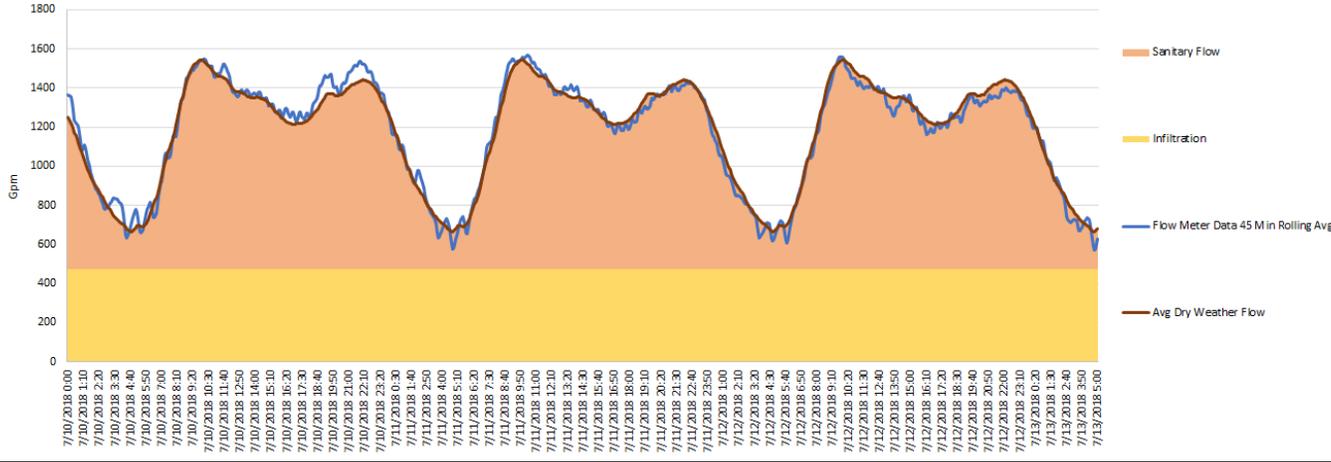


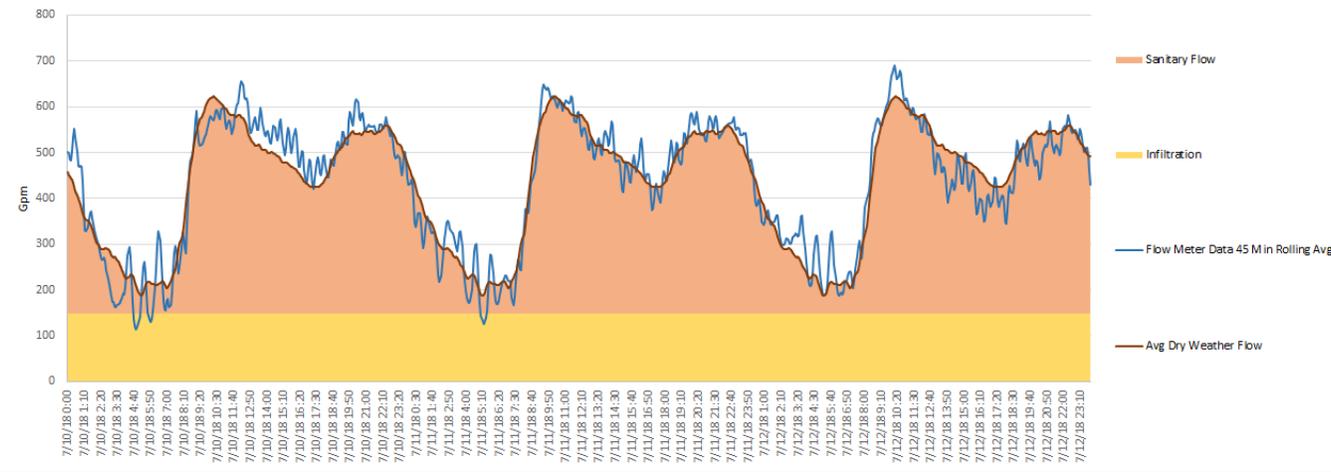
Figure 13: 2023 (Year 1) I/I Investigations and Repair

APPENDIX A:
2018 FLOW METER
DRY WEATHER
HYDROGRAPHS

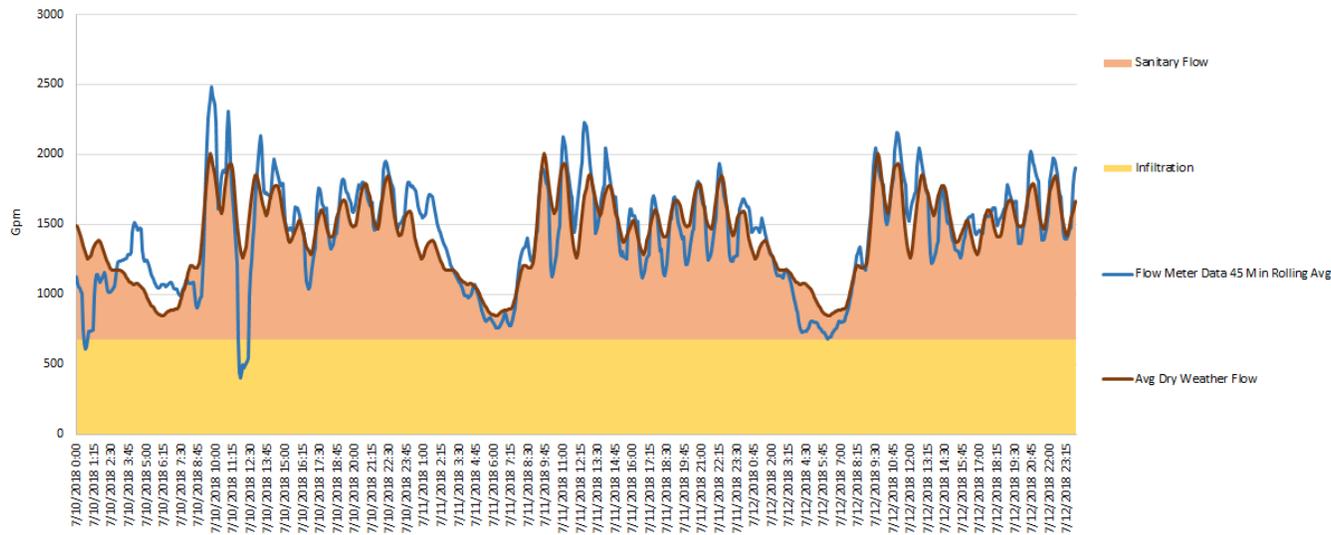
Meter NB1 (579 Pawtucket) - Dry Weather Hydrograph



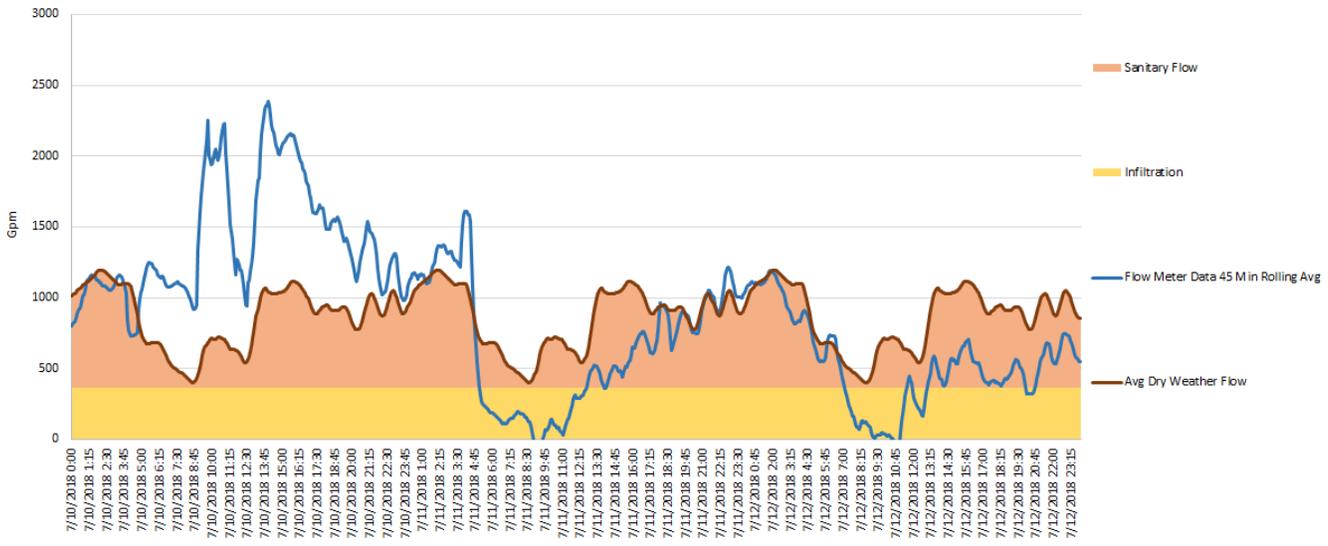
Meter NB2A (90 Varnum) - Dry Weather Hydrograph



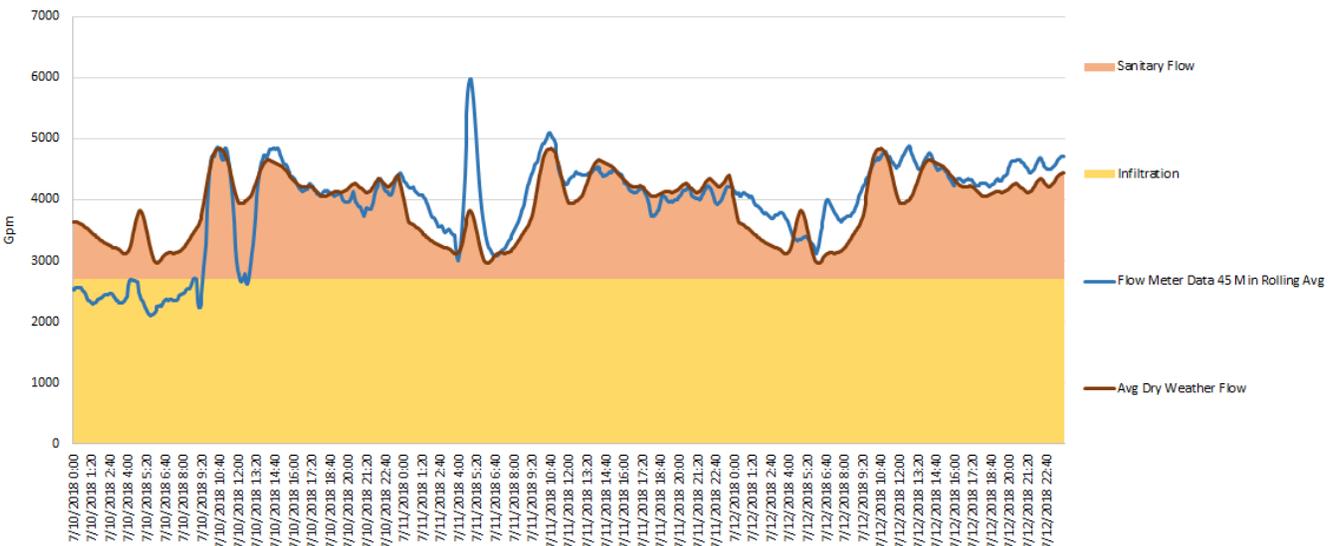
Meter NB4 (Bike Path Next to VFW Hwy) - Dry Weather Hydrograph



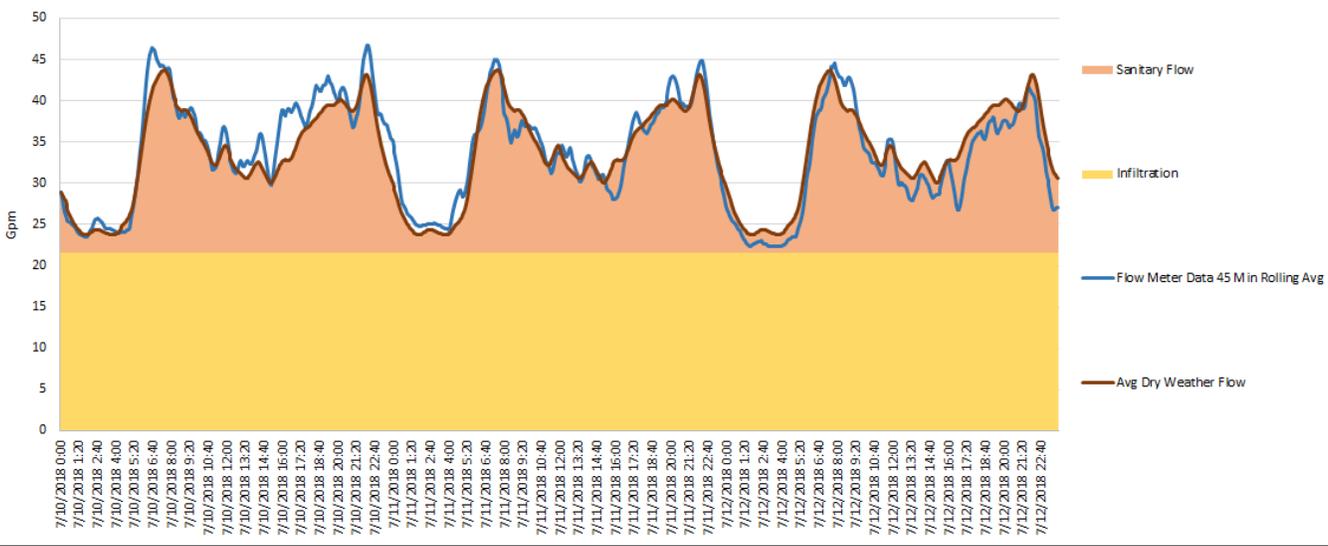
Meter NB5 (Bike Path Next to VFW Hwy) - Dry Weather Hydrograph

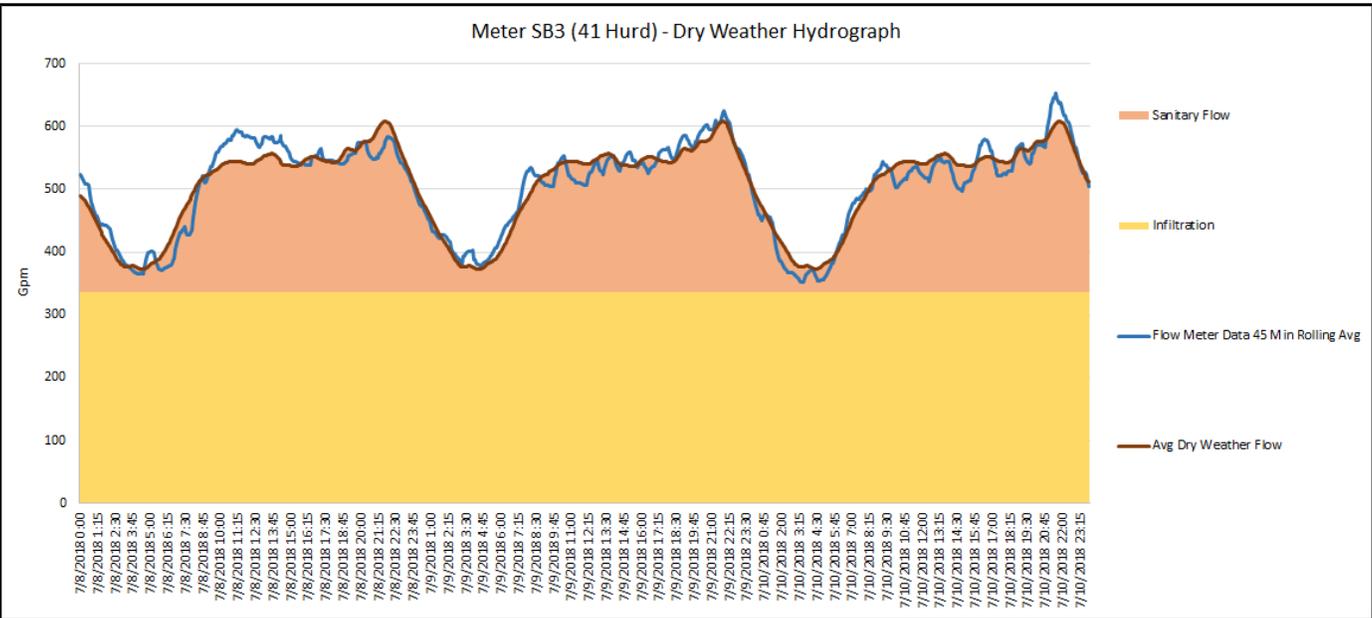
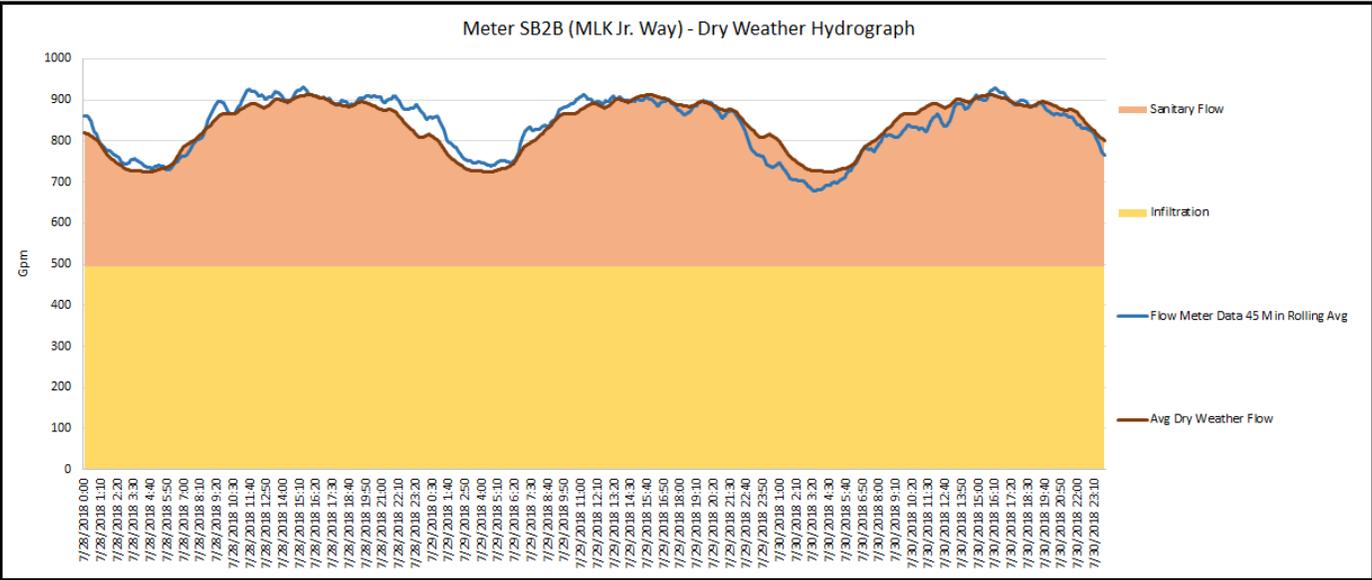
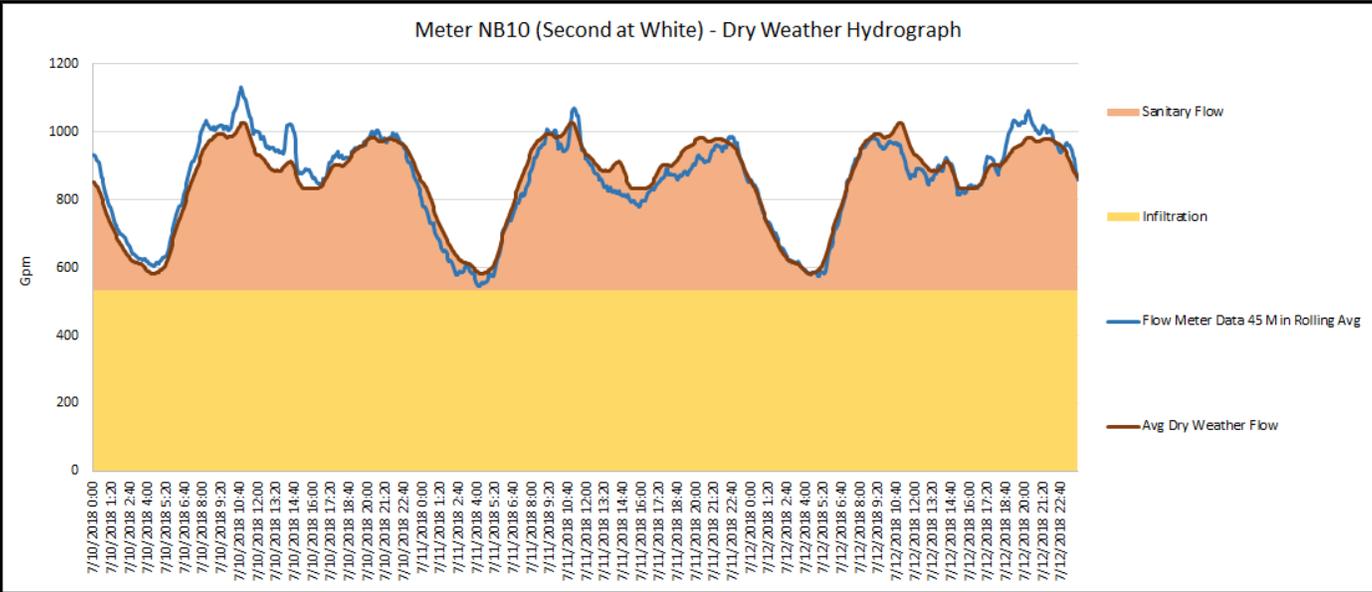


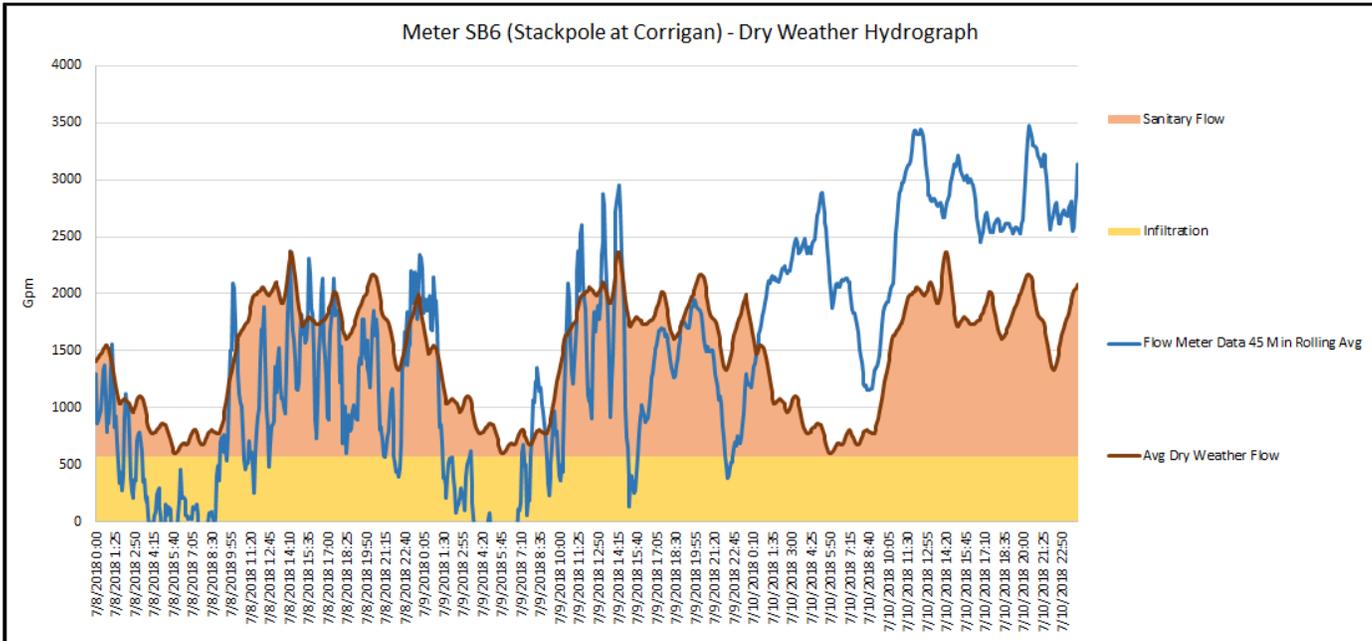
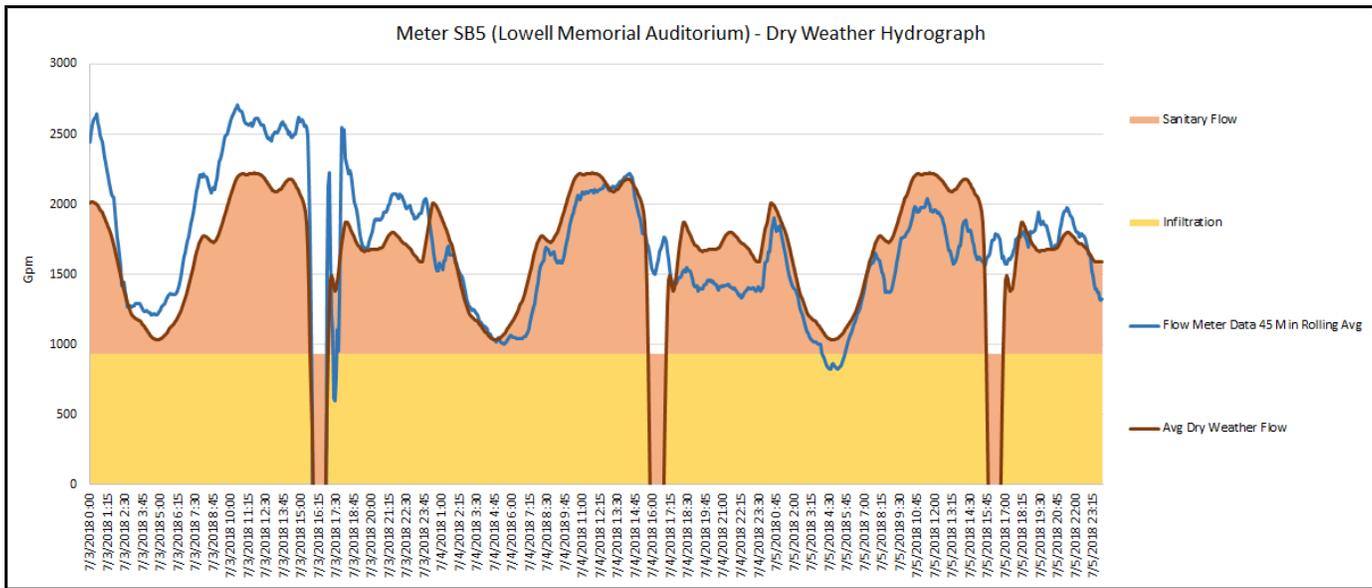
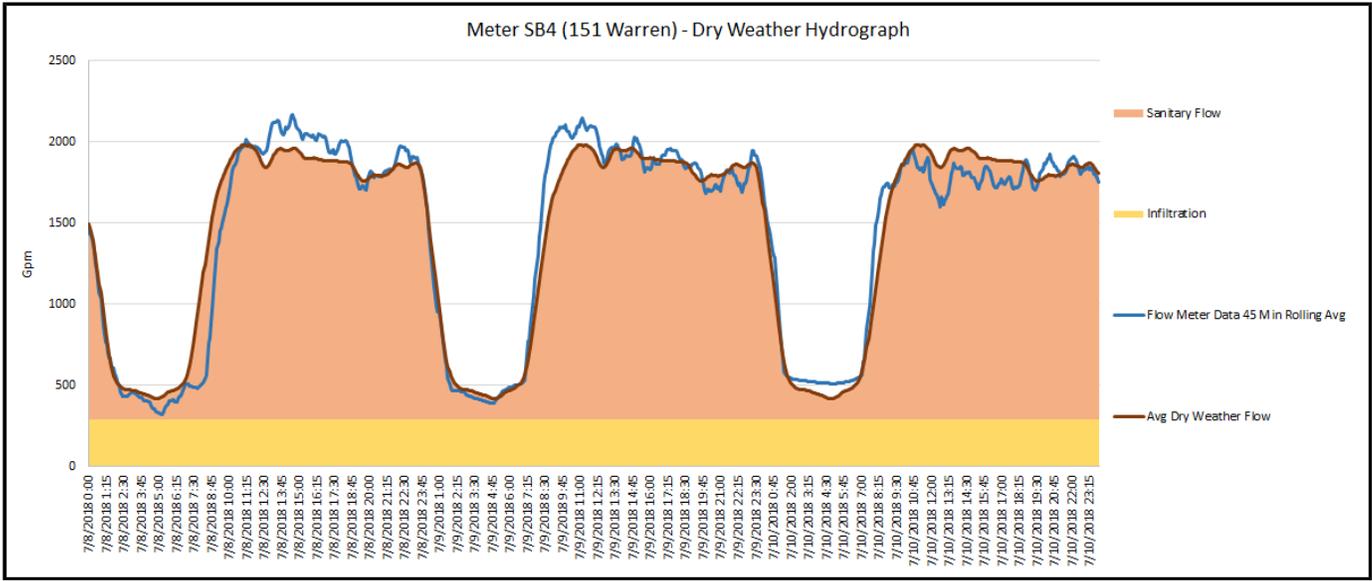
Meter NB7 (Walking Path Next to VFW Hwy) - Dry Weather Hydrograph

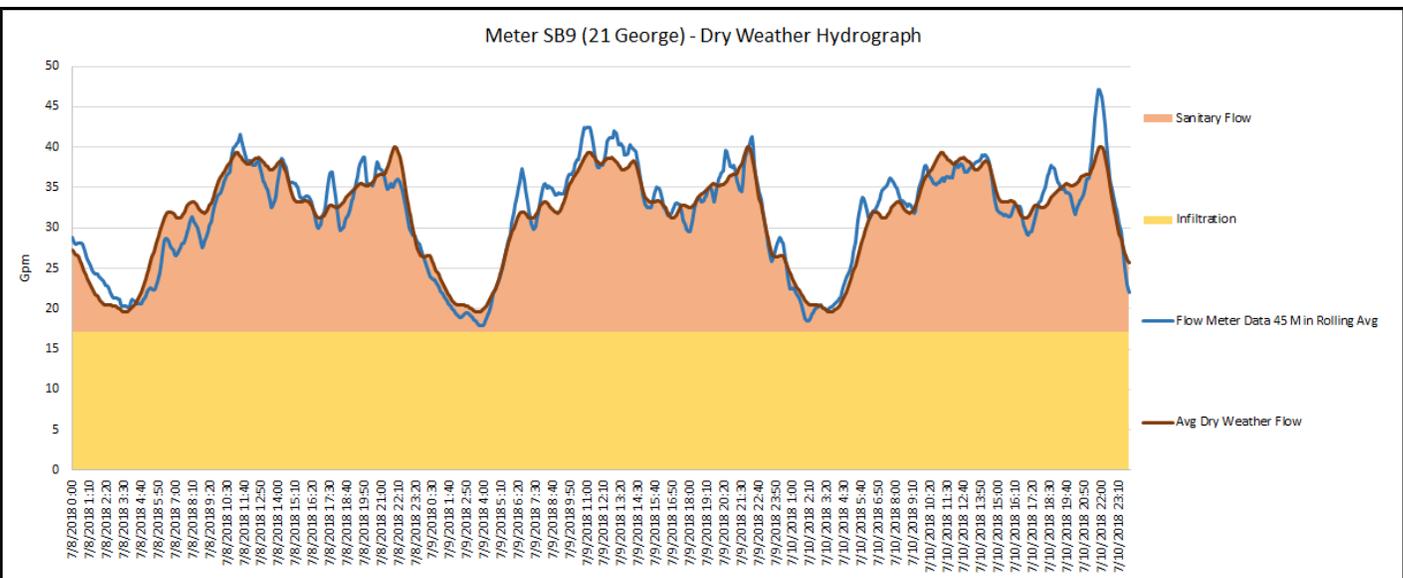
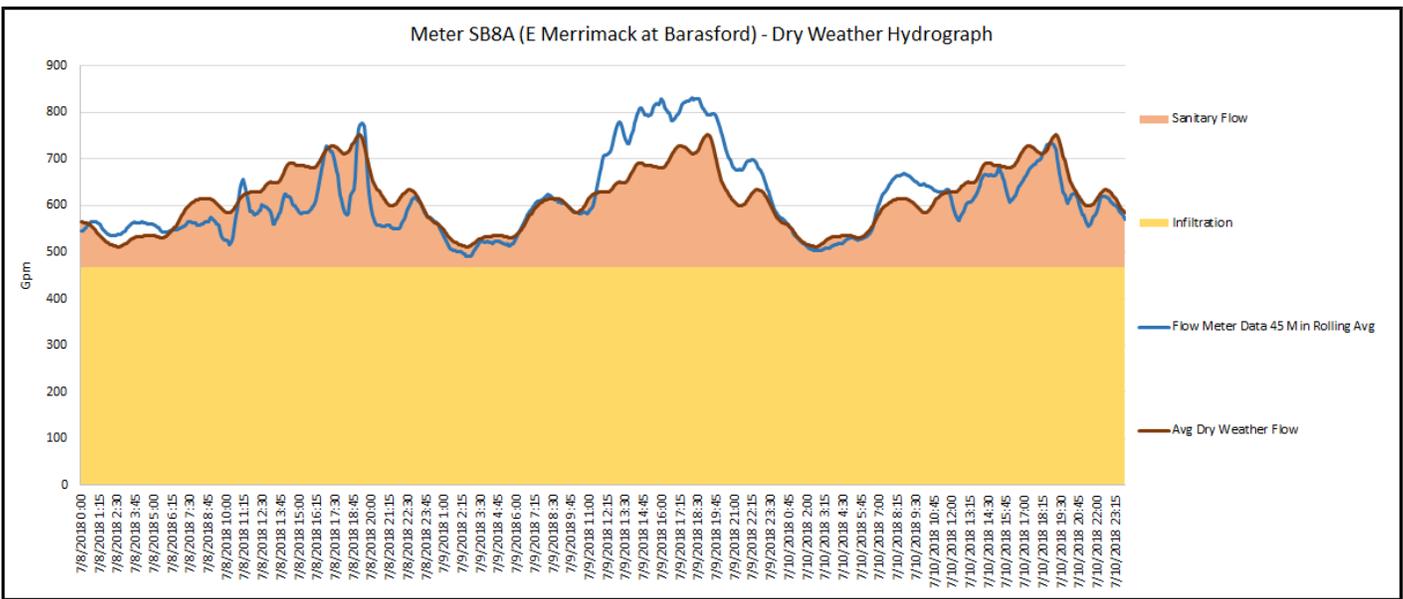
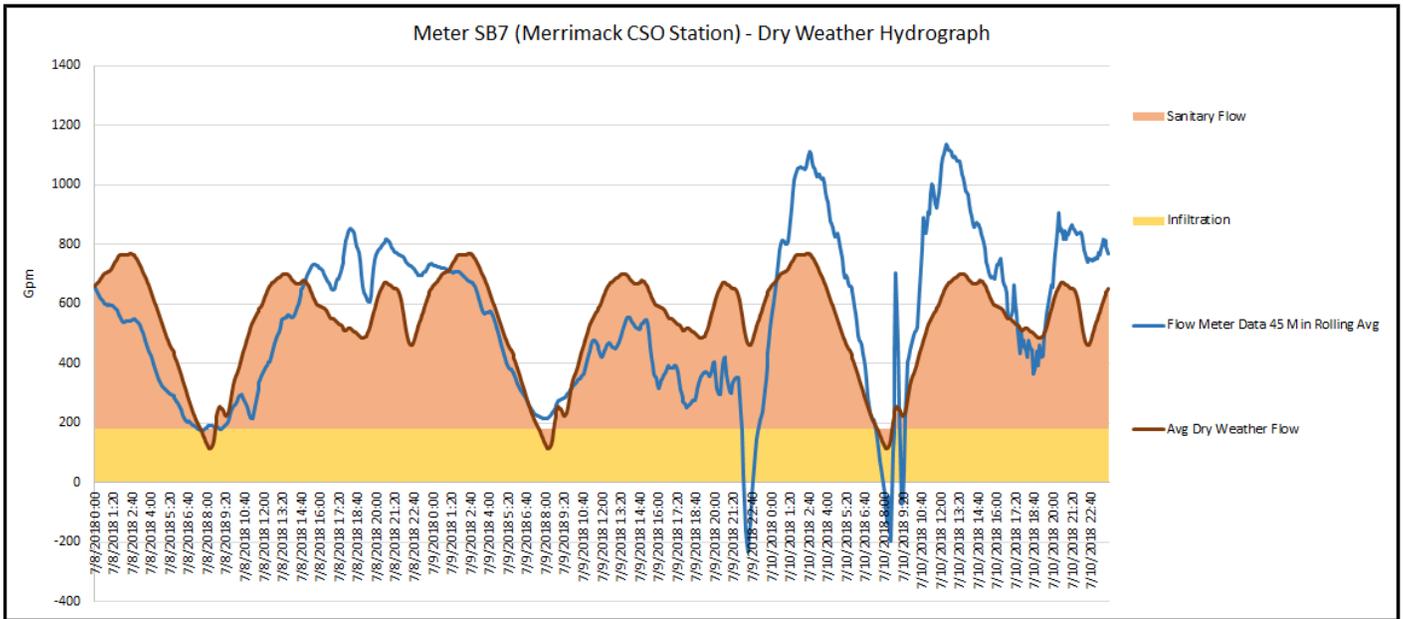


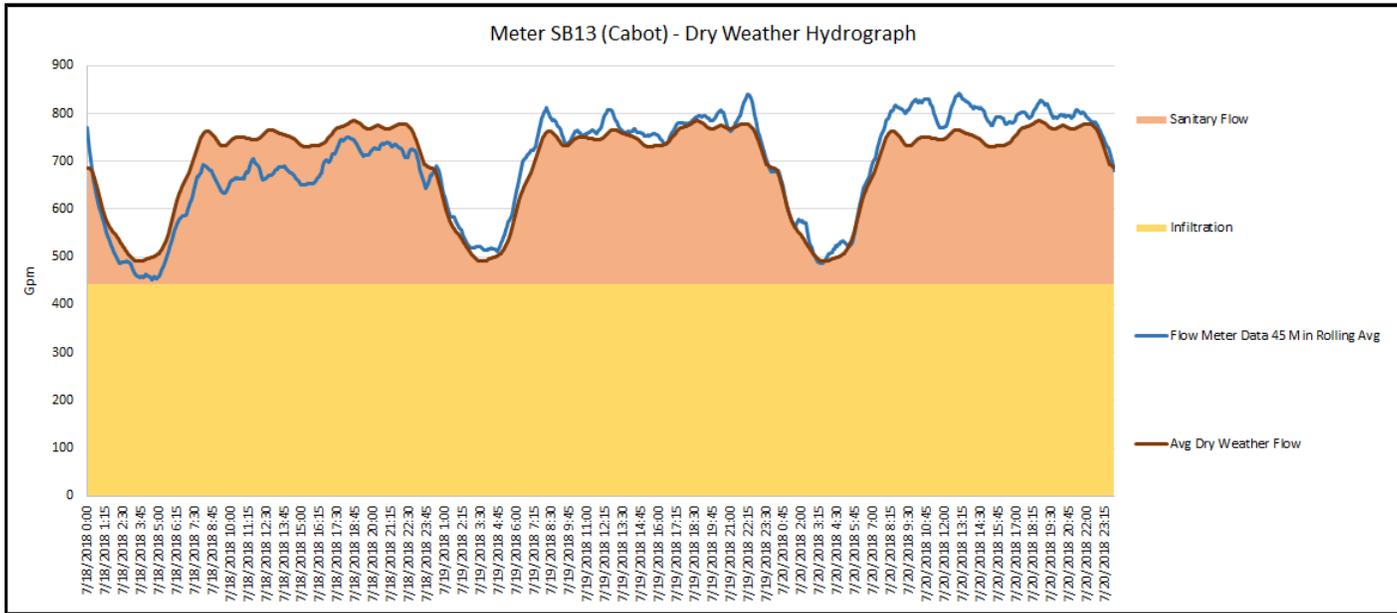
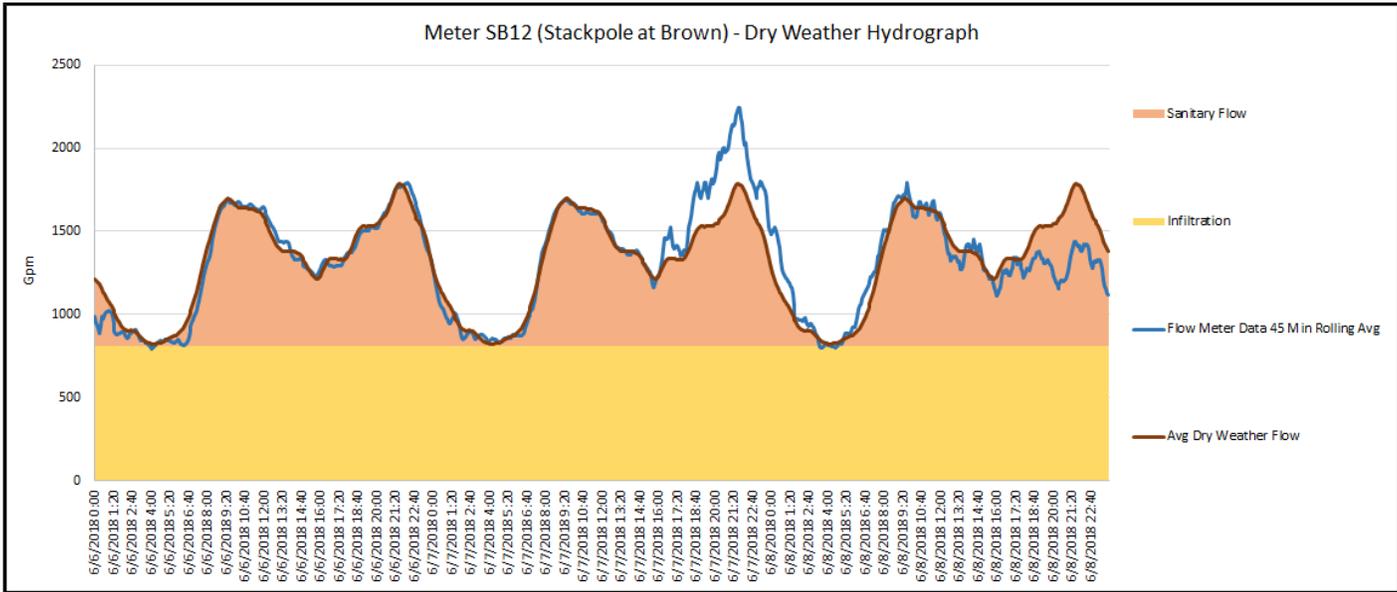
Meter NB9 (Duck Island WWTP) - Dry Weather Hydrograph







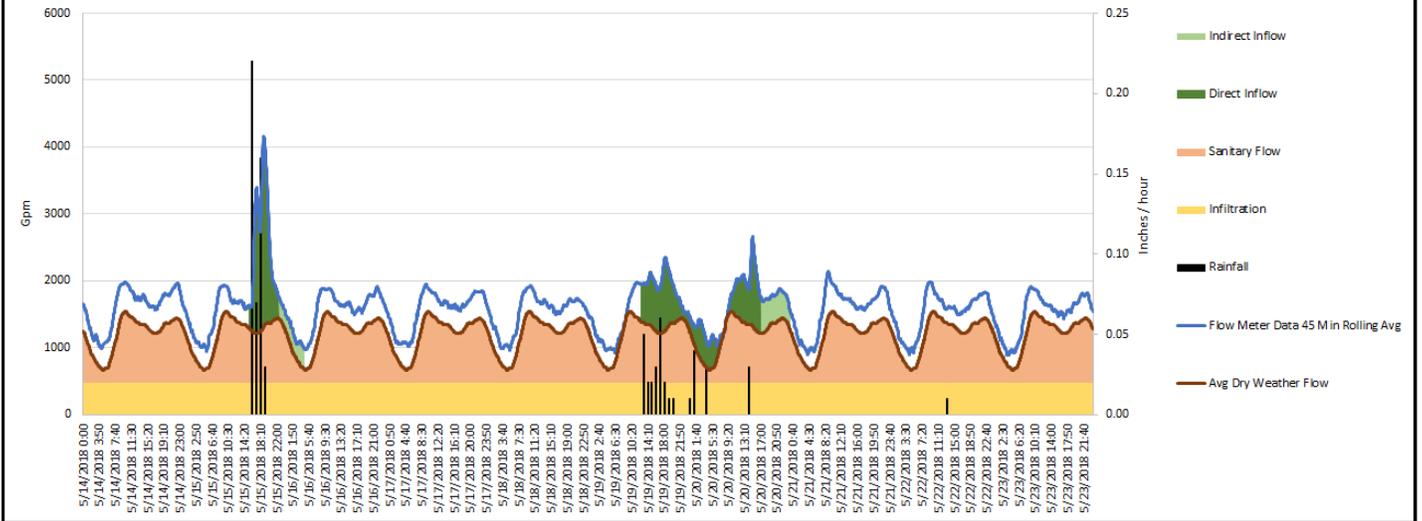




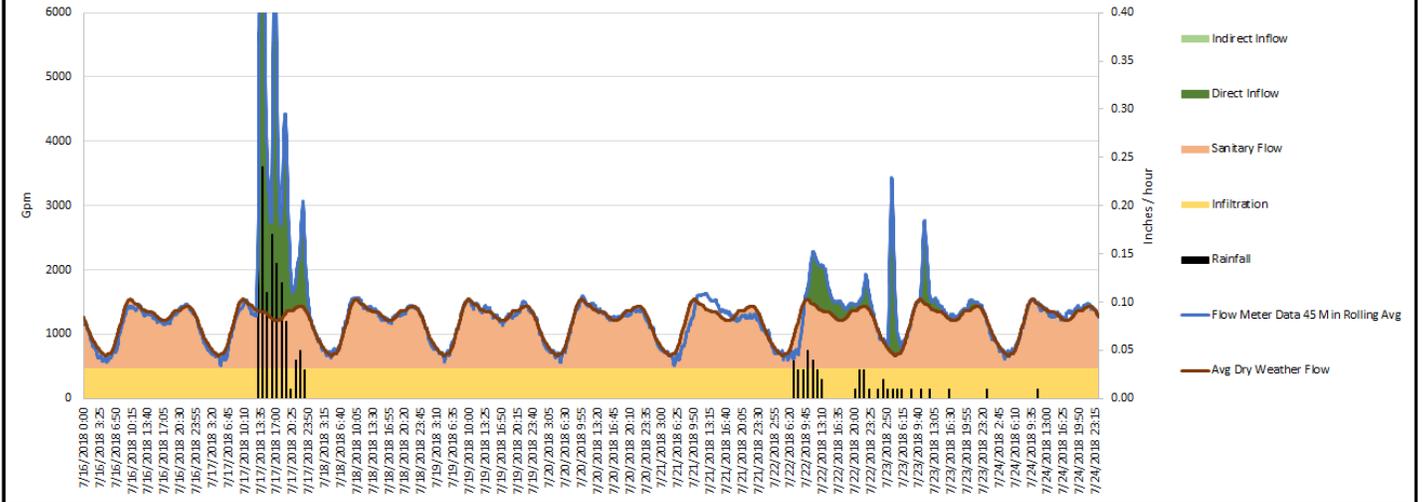
Hydrographs for NB3, SB1, and SB11 were indeterminate due to poor quality data.

APPENDIX B:
2018 FLOW METER
WET WEATHER
HYDROGRAPHS

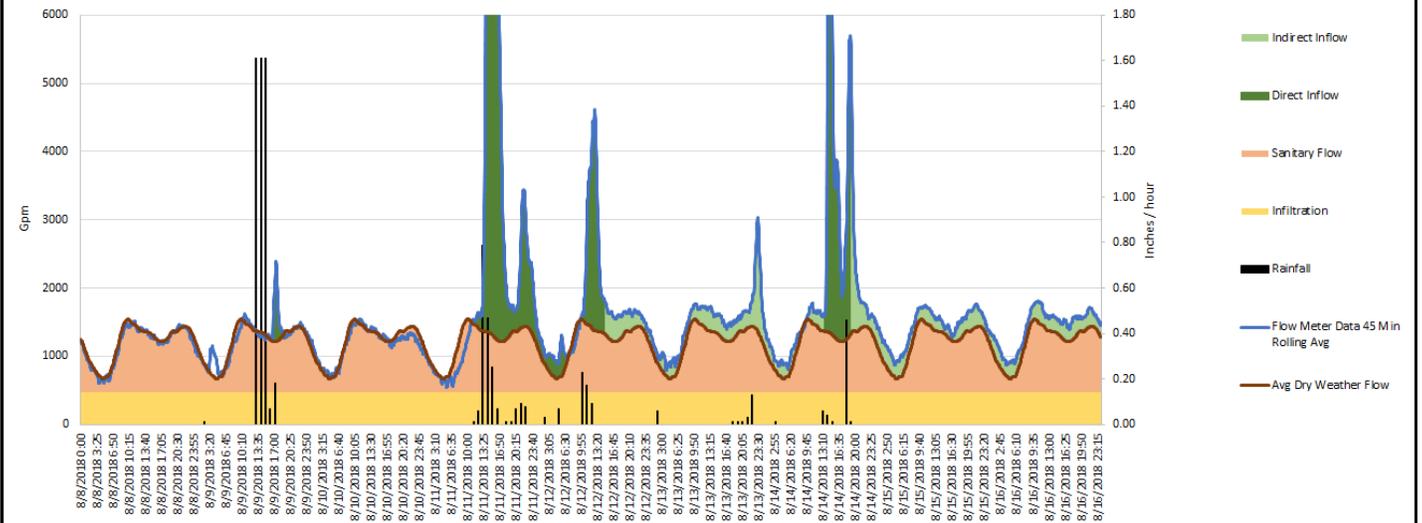
Meter NB1 (579 Pawtucket) - Wet Weather (5/15) Hydrograph



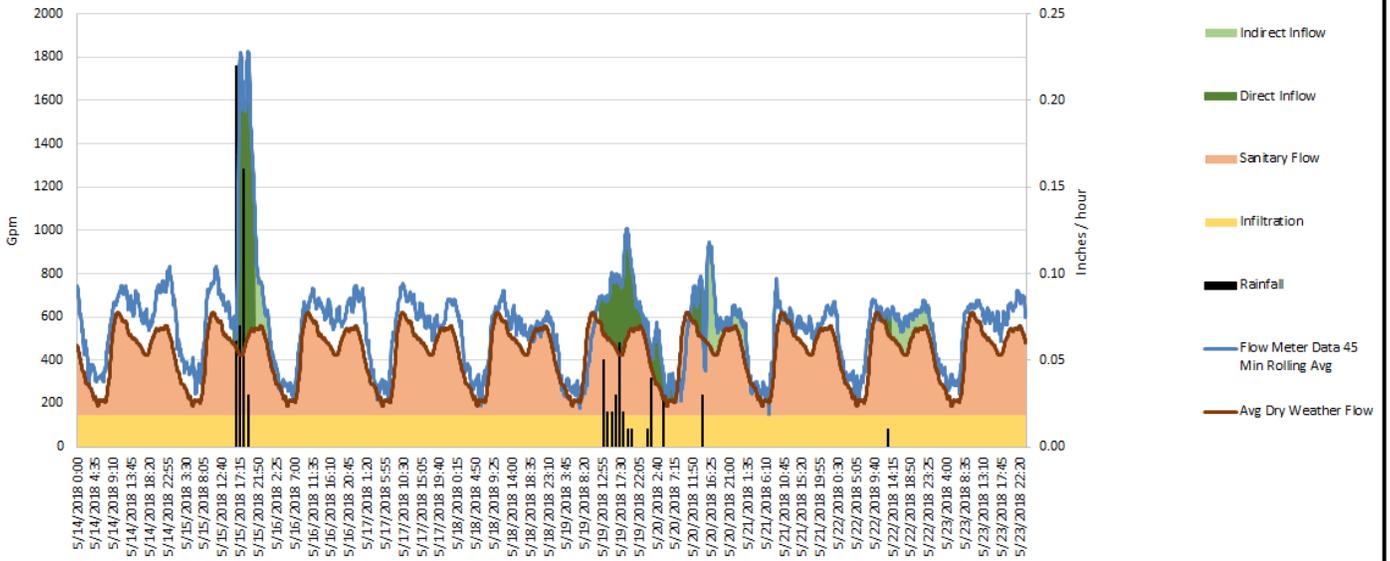
Meter NB1 (589 Pawtucket) - Wet Weather (7/17) Hydrograph



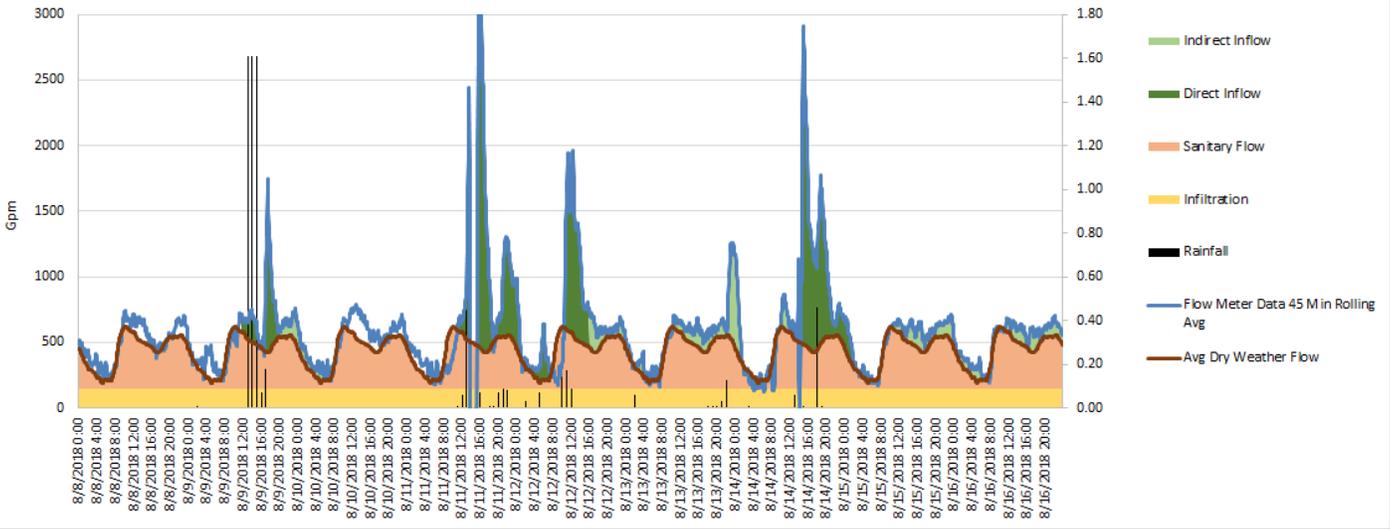
Meter NB1 (579 Pawtucket) - Wet Weather (8/11) Hydrograph



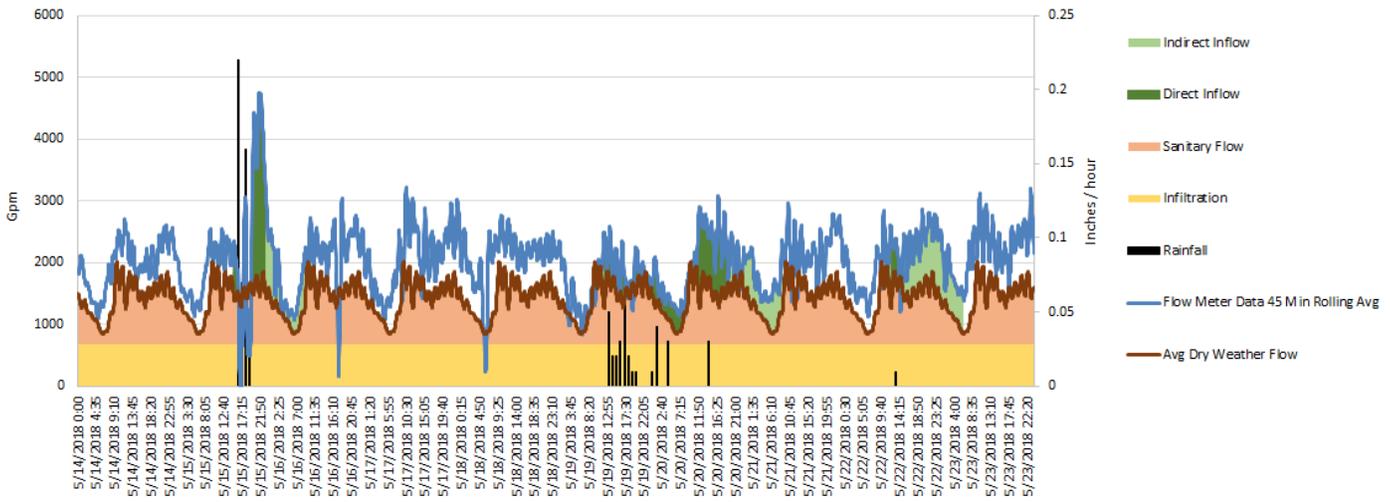
Meter NB2A (90 Varnum) - Wet Weather (5/15) Hydrograph



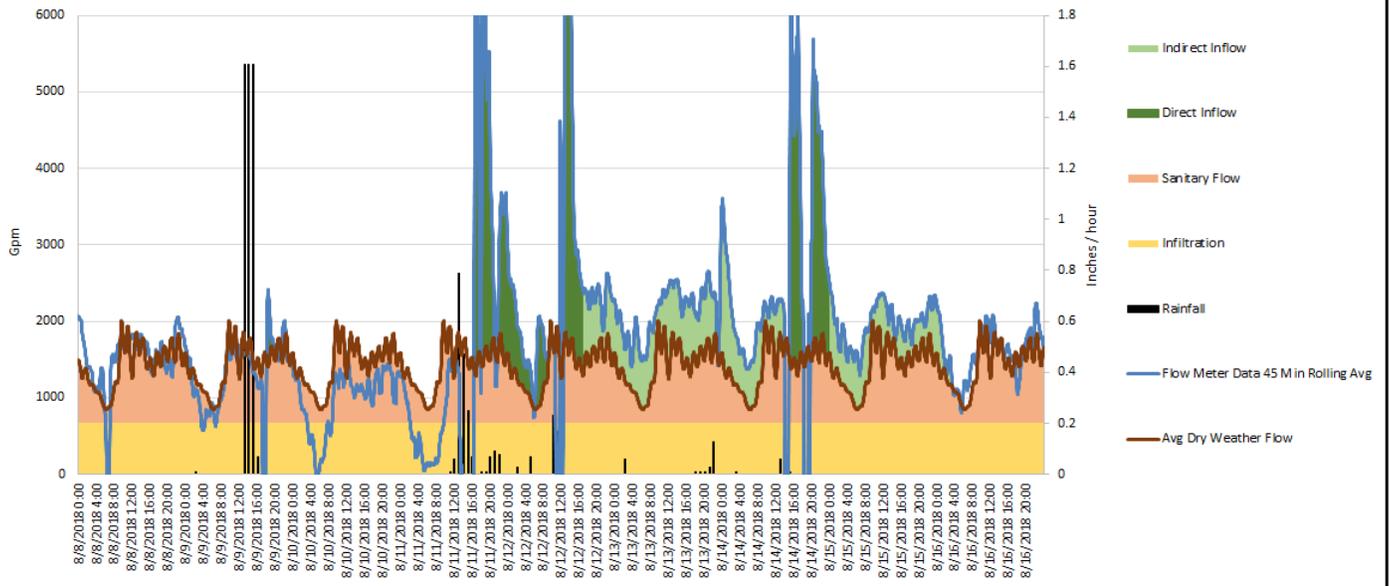
Meter NB2A (90 Varnum) - Wet Weather (8/11) Hydrograph



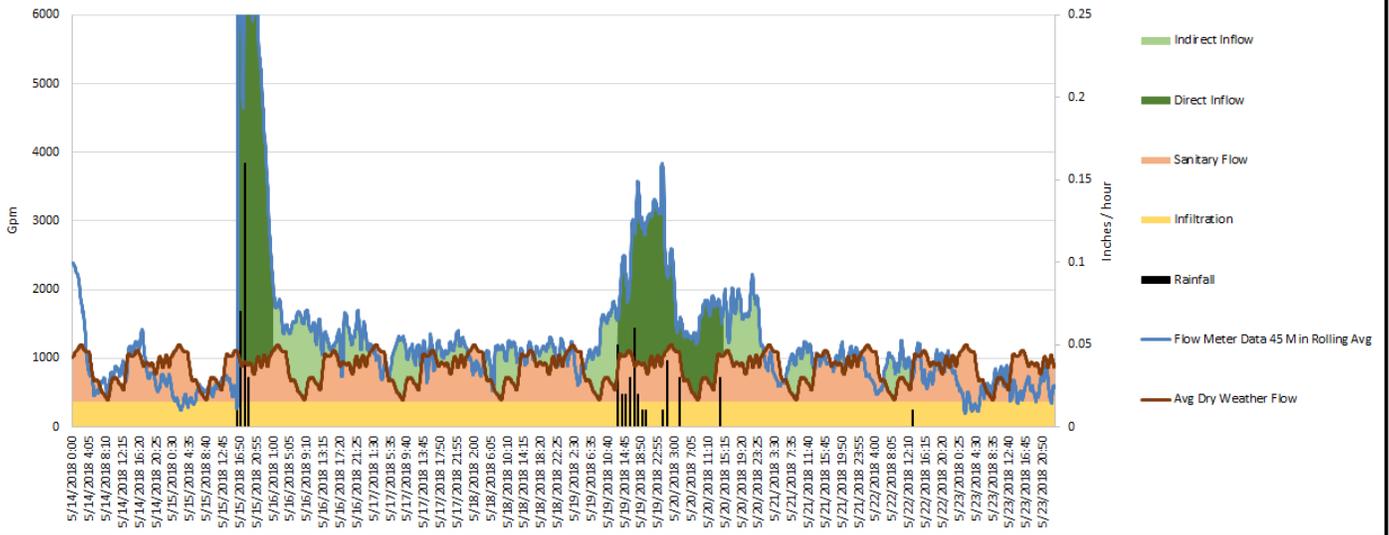
Meter NB4 (Bike Path Next to VFW Hwy) - Wet Weather (5/15) Hydrograph



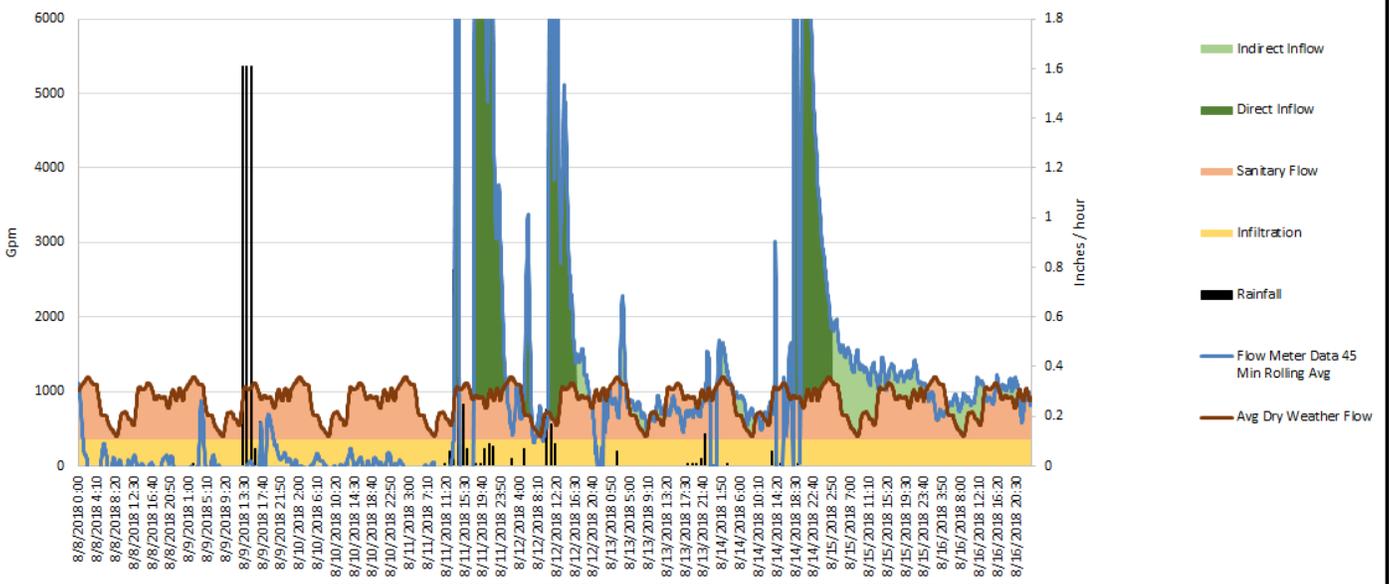
Meter NB4 (Bike Path Next to VFW Hwy) - Wet Weather (8/11) Hydrograph



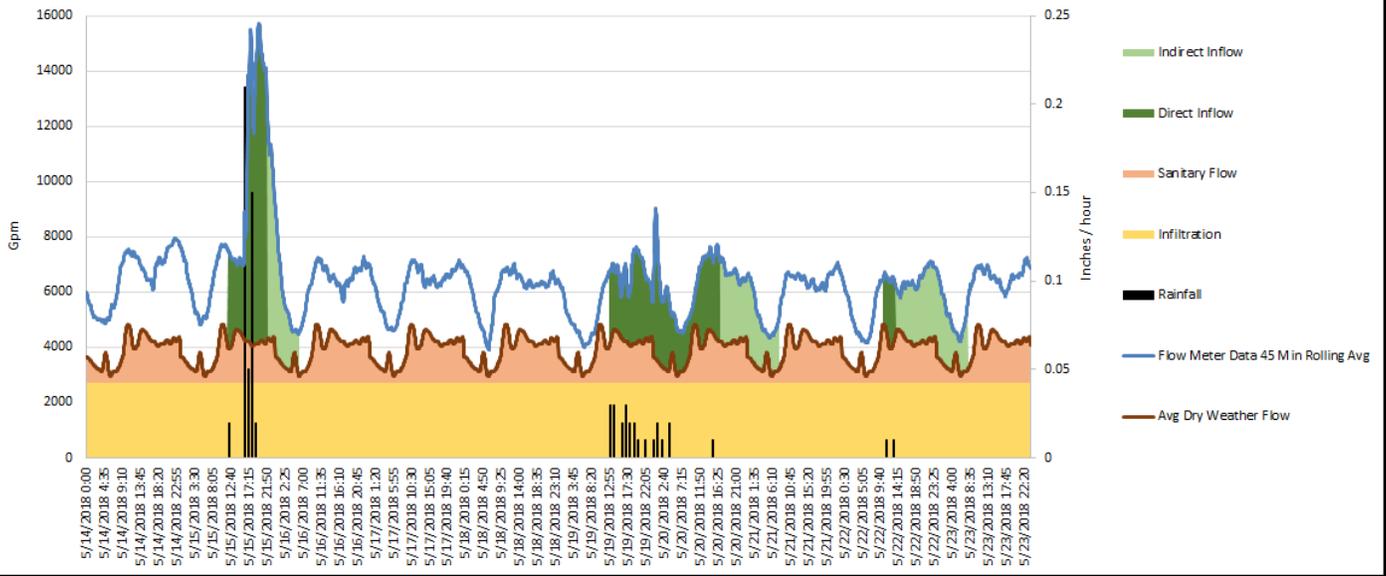
Meter NB5 (Bike Path Next to VFW Hwy) - Wet Weather (5/15) Hydrograph



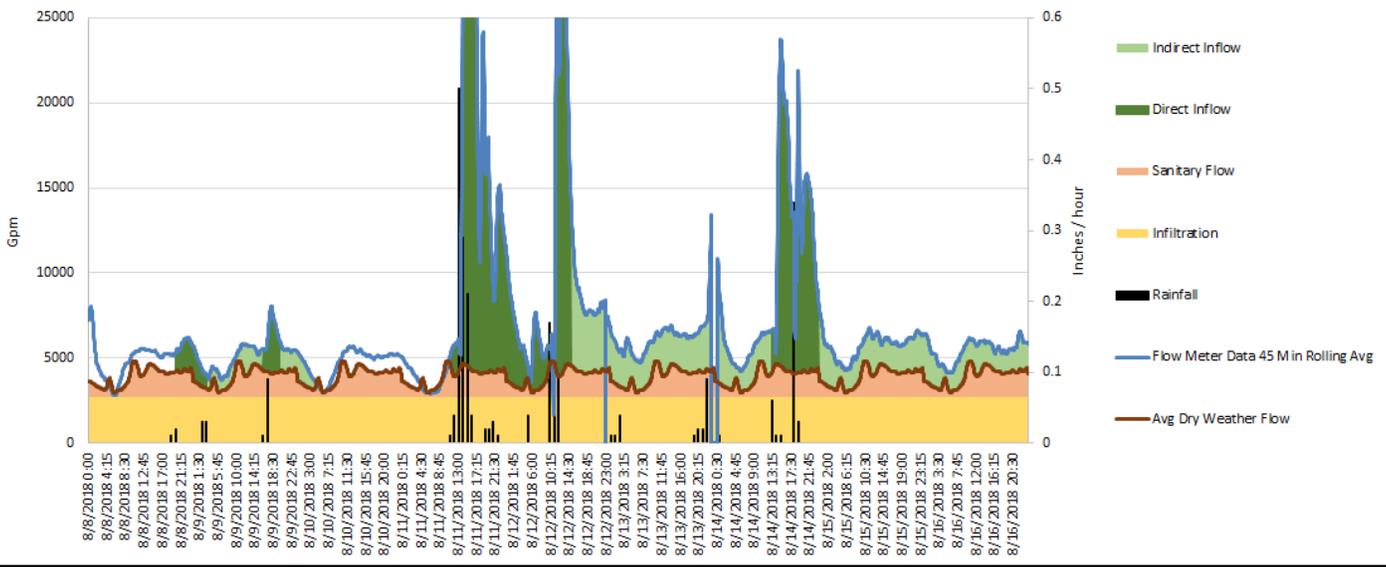
Meter NB5 (Bike Path Next to VFW Hwy) - Wet Weather (8/11) Hydrograph



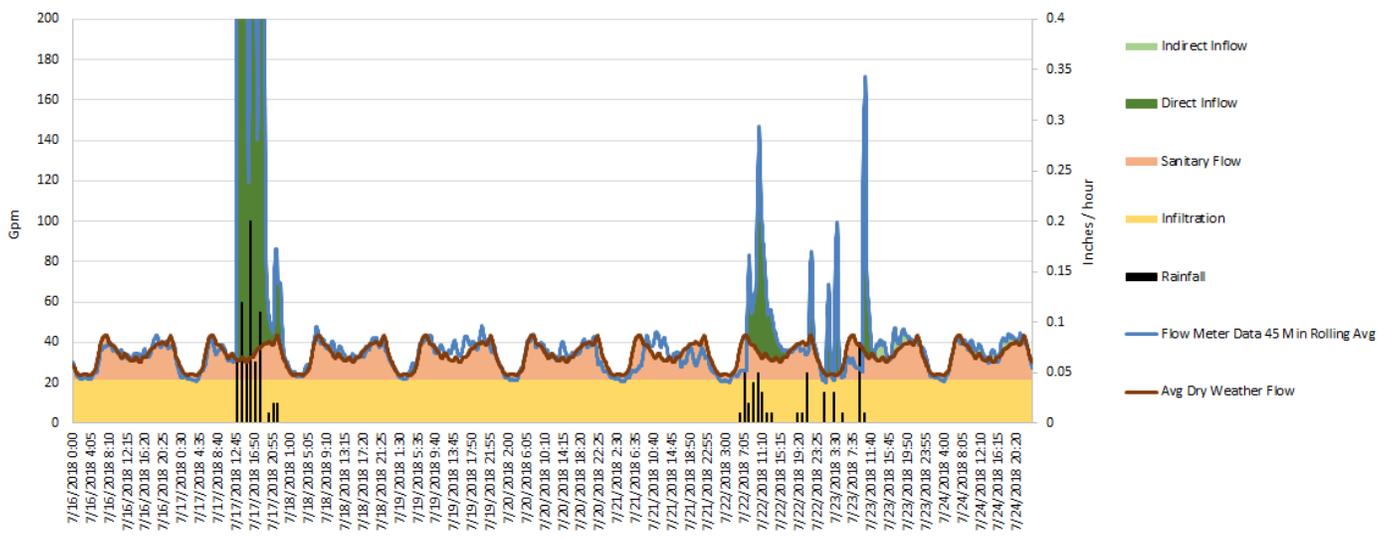
Meter NB7 (Walking Path Next to VFW Hwy) - Wet Weather (5/15) Hydrograph



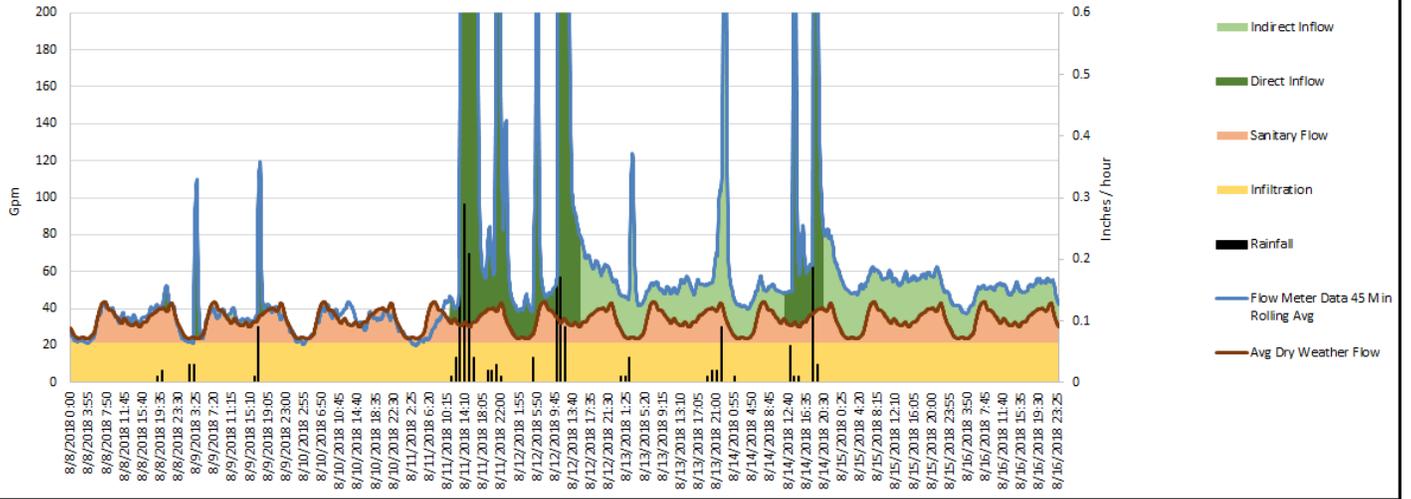
Meter NB7 (Walking Path Next to VFW Hwy) - Wet Weather (8/11) Hydrograph



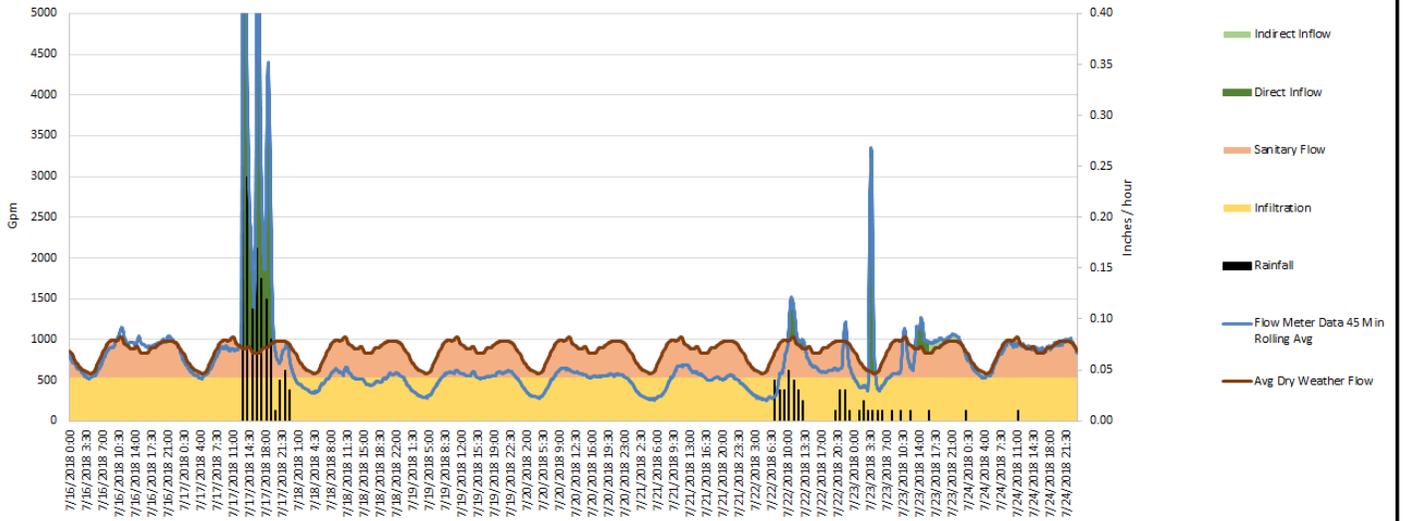
Meter NB9 (Duck Island WWTP) - Wet Weather (7/17) Hydrograph



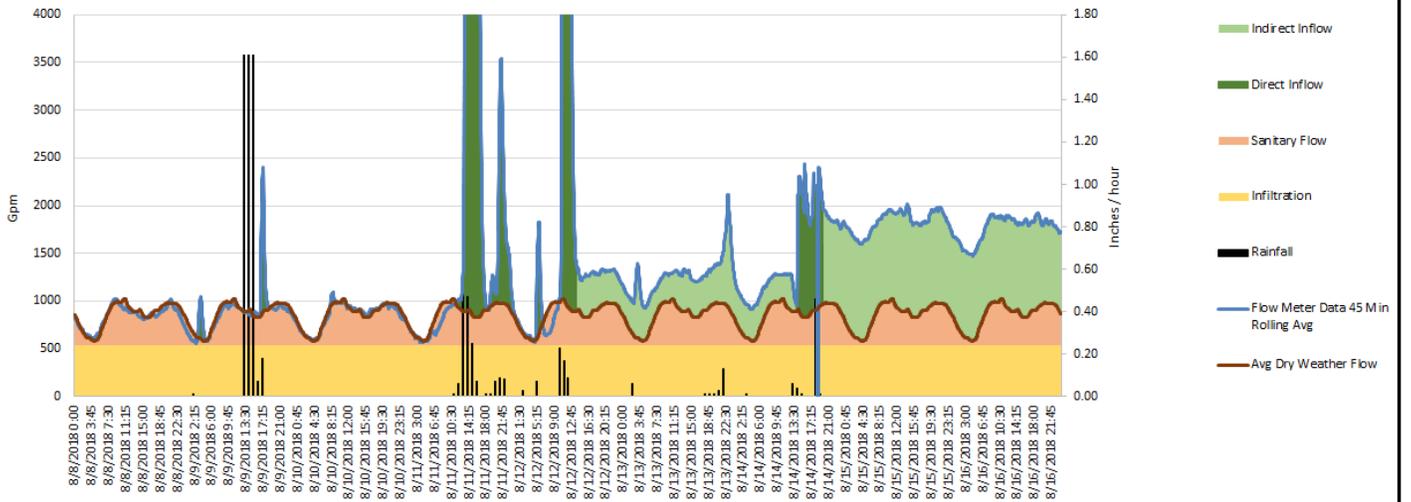
Meter NB9 (Duck Island WWTP) - Wet Weather (8/11) Hydrograph



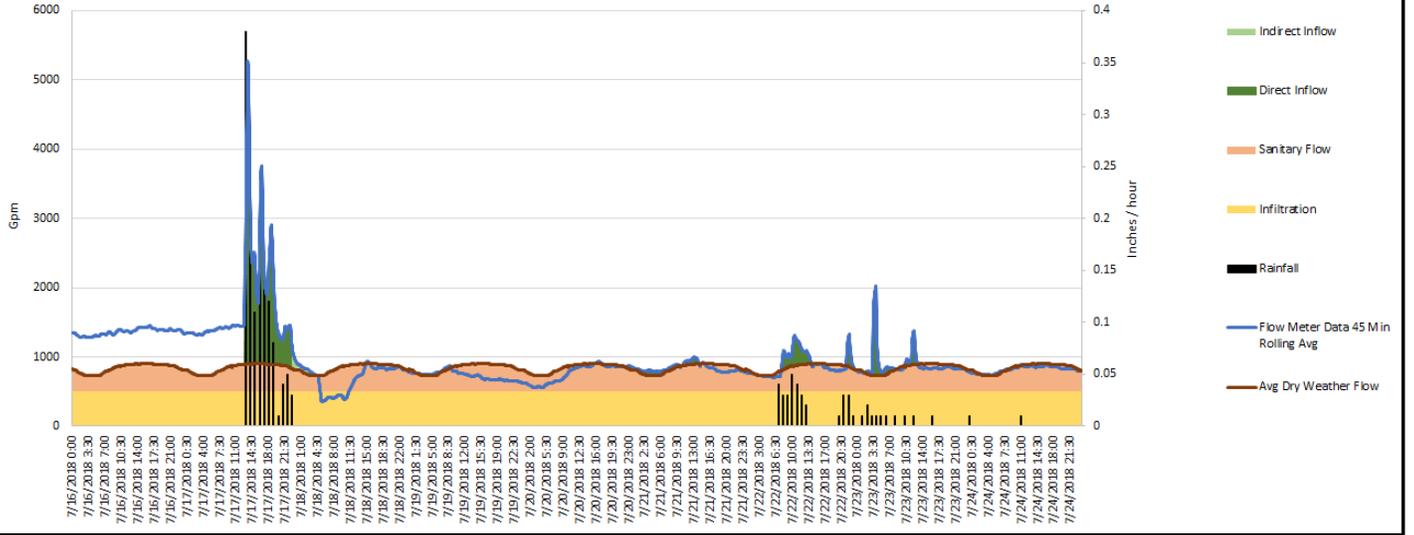
Meter NB10 (Second at White) - Wet Weather (7/17) Hydrograph



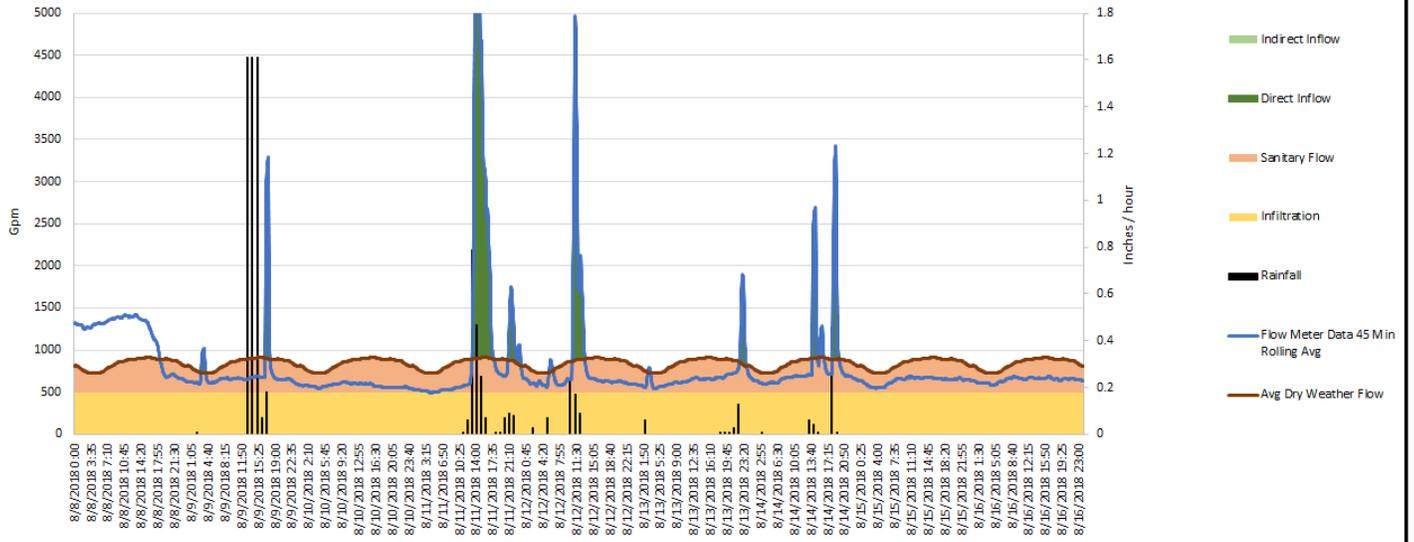
Meter NB10 (Second at White) - Wet Weather (8/11) Hydrograph



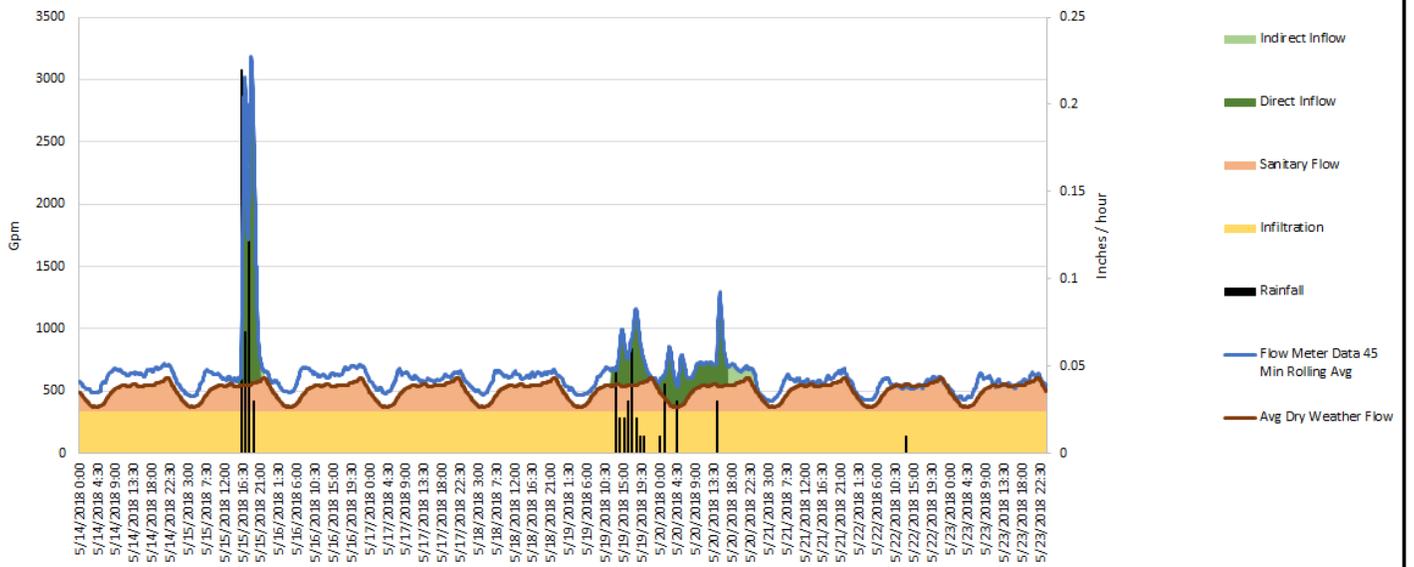
Meter SB2B (MLK Jr. Way) - Wet Weather (7/17) Hydrograph



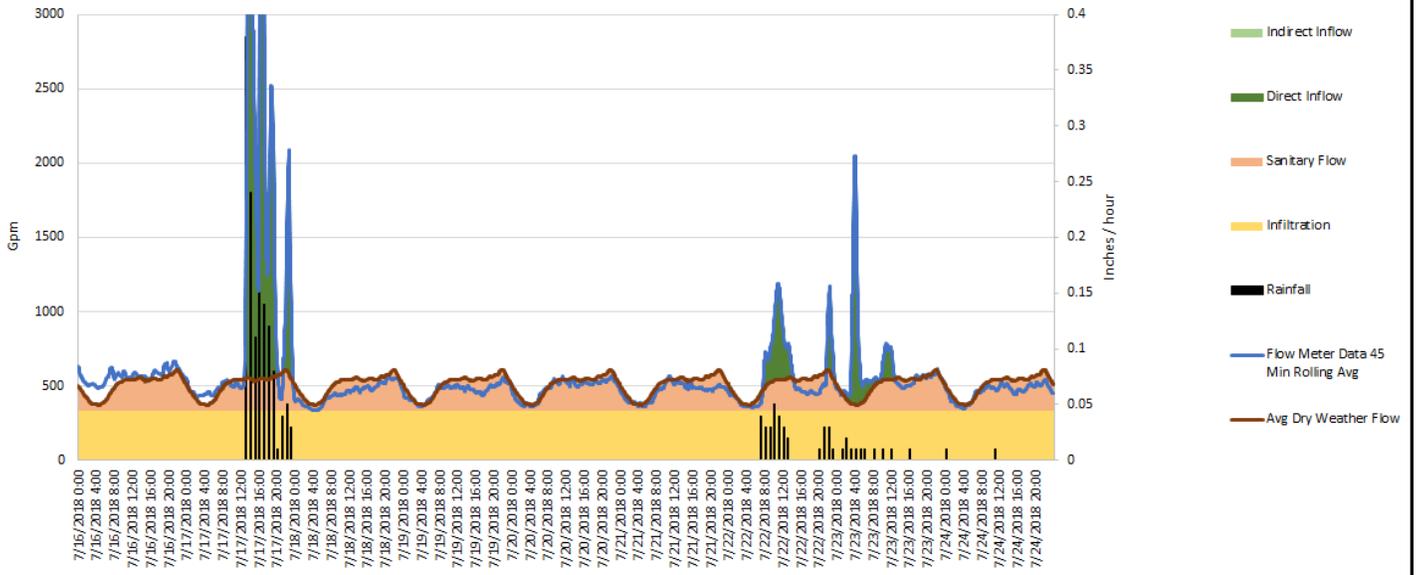
Meter SB2B (MLK Jr. Way) - Wet Weather (8/11) Hydrograph



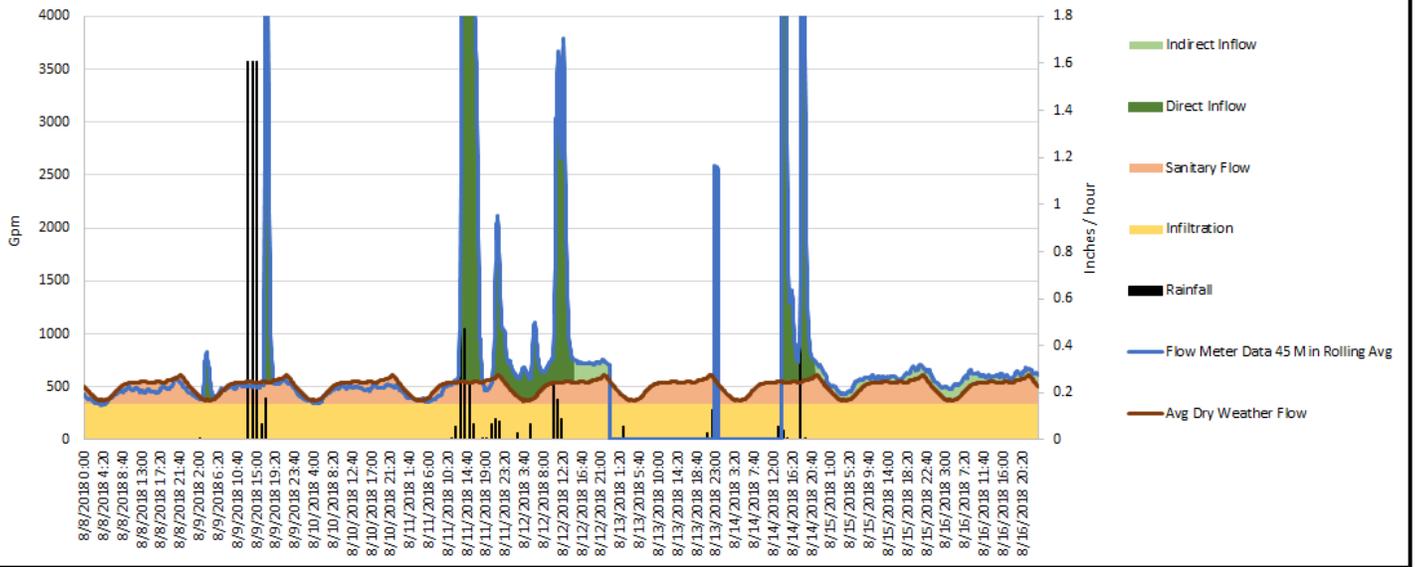
Meter SB3 (41 Hurd) - Wet Weather (5/15) Hydrograph



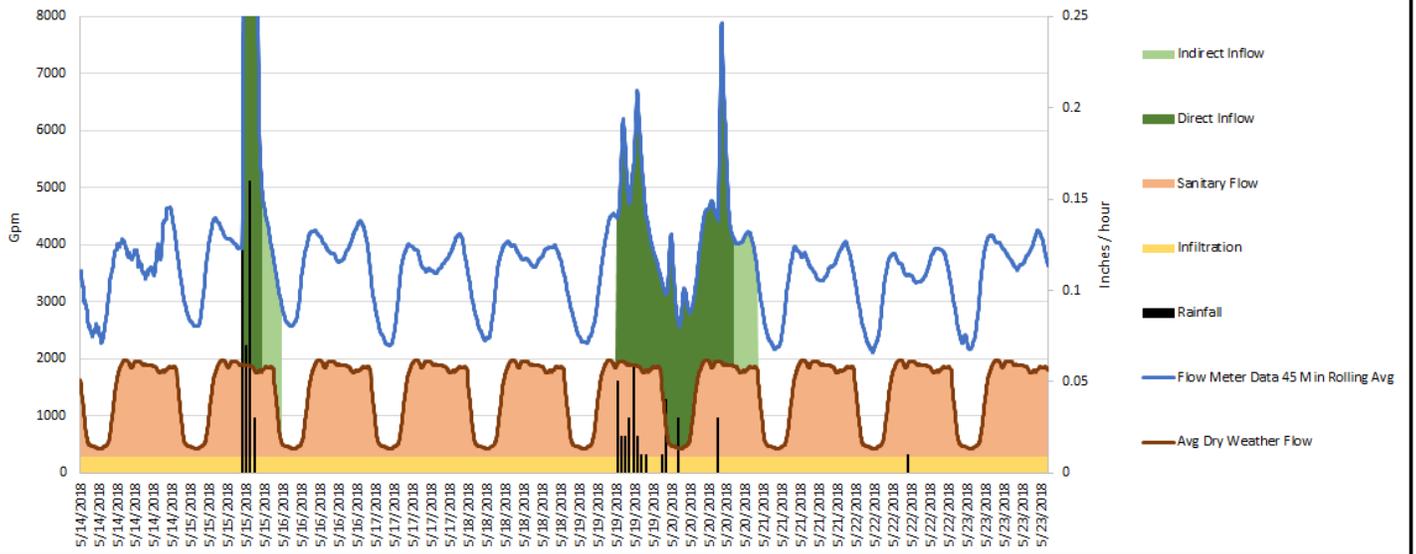
Meter SB3 (41 Hurd) - Wet Weather (7/17) Hydrograph



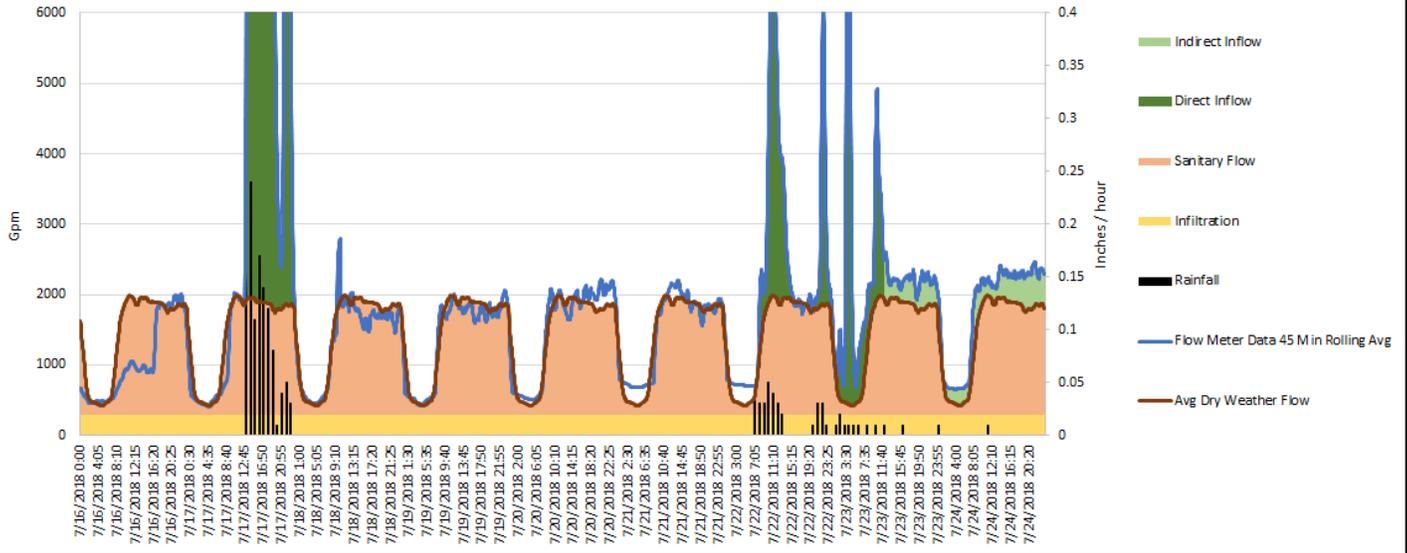
Meter SB3 (41 Hurd) - Wet Weather (8/11) Hydrograph



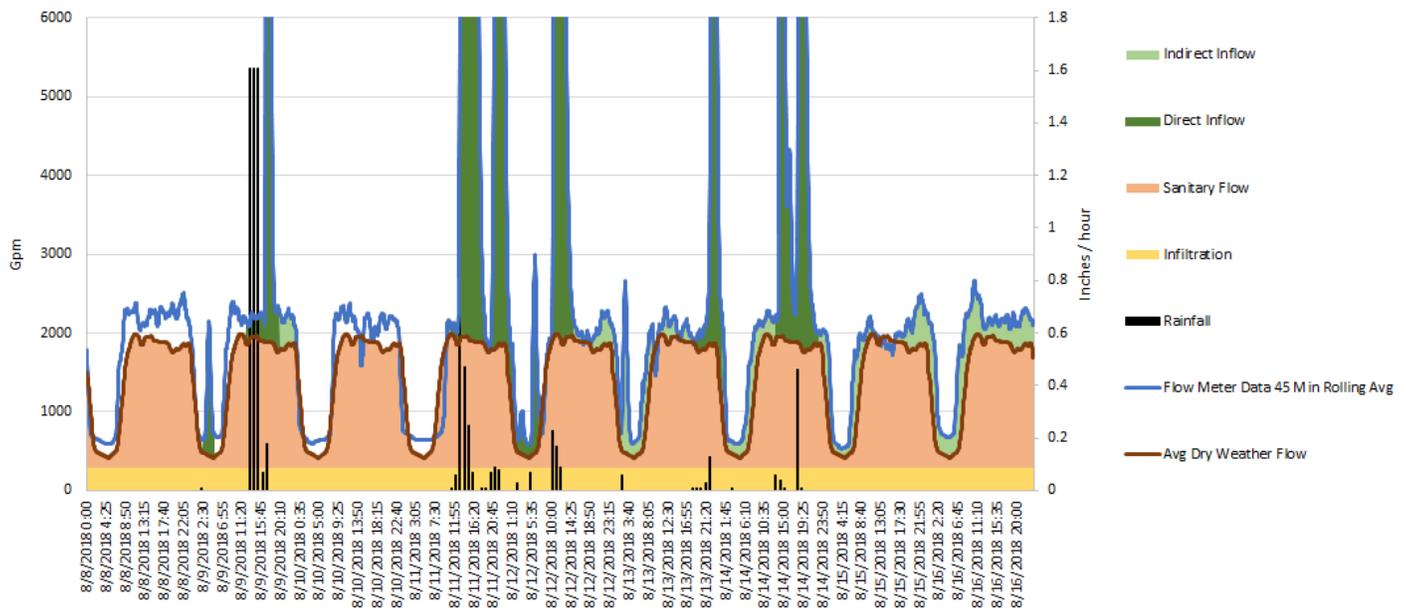
Meter SB4 (151 Warren) - Wet Weather (5/15) Hydrograph



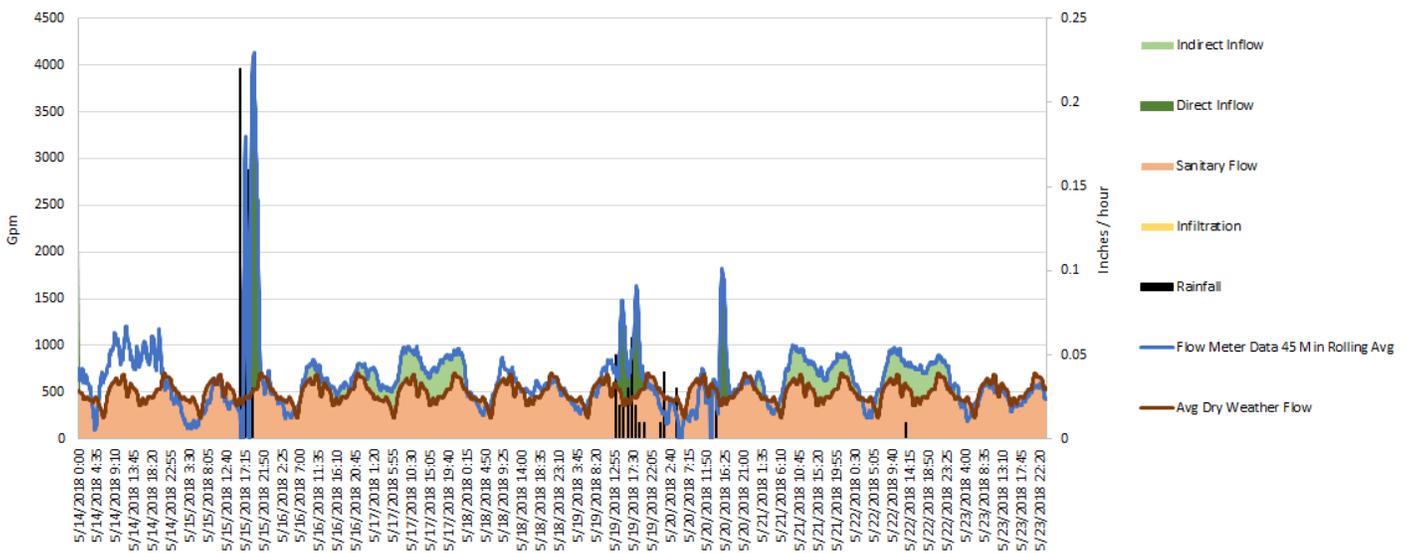
Meter SB4 (151 Warren) - Wet Weather (7/17) Hydrograph



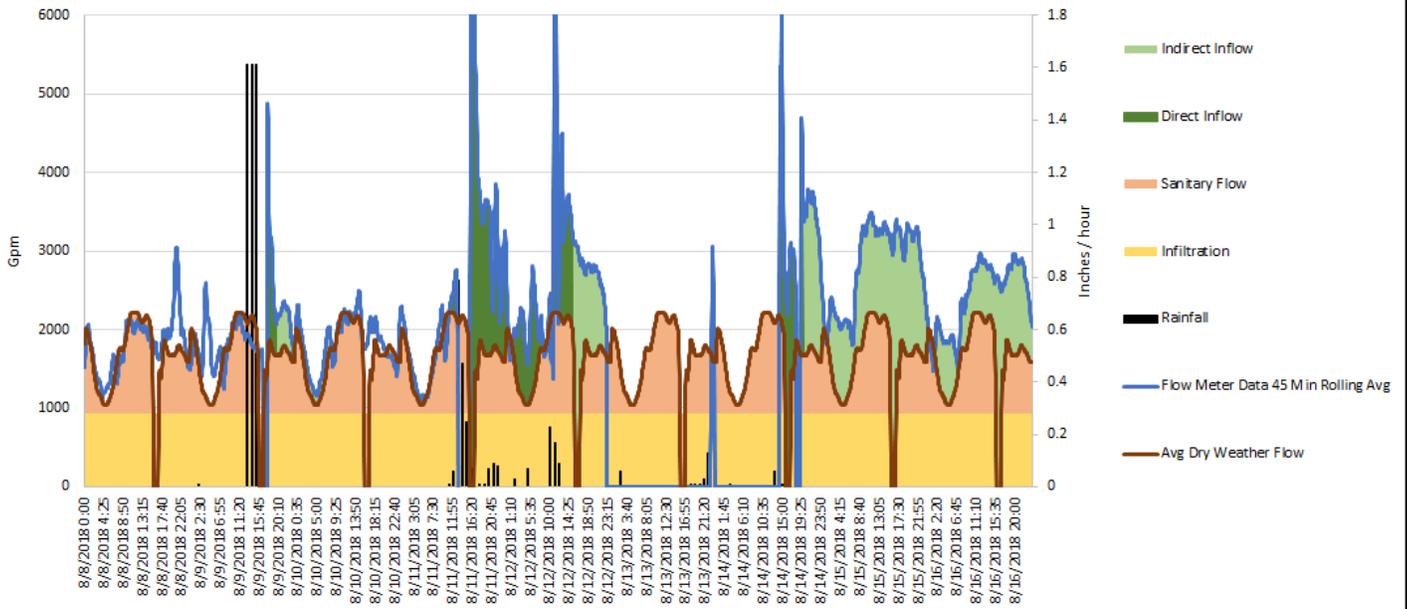
Meter SB4 (151 Warren) - Wet Weather (8/11) Hydrograph



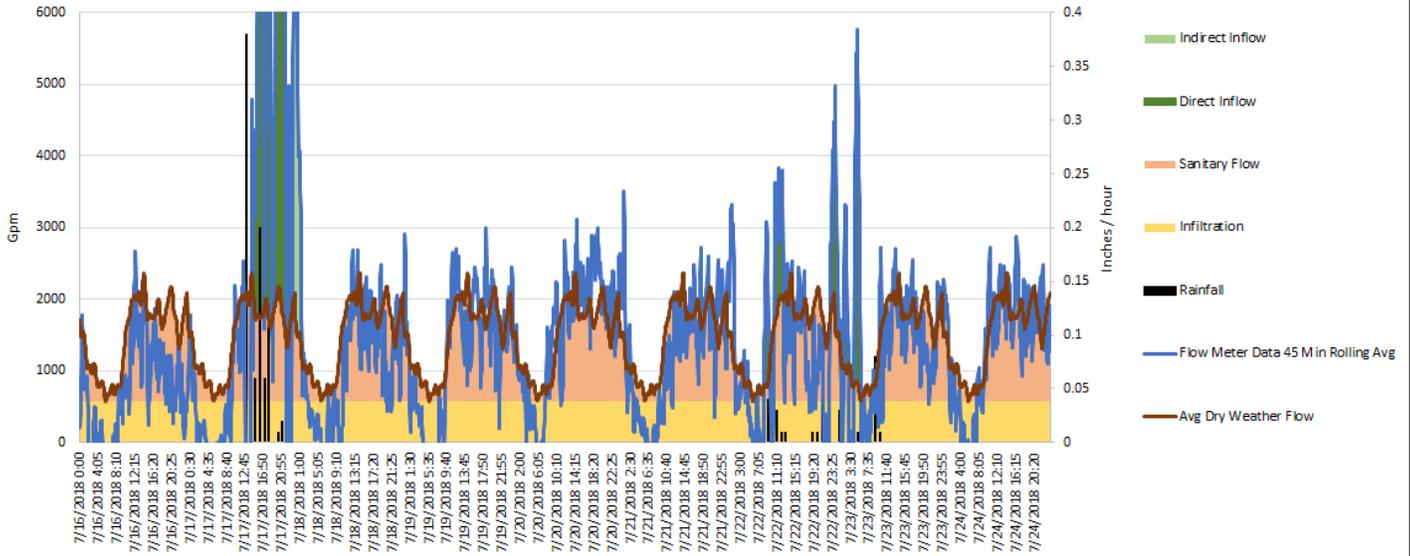
Meter SB5 (Lowell Memorial Auditorium) - Wet Weather (5/15) Hydrograph



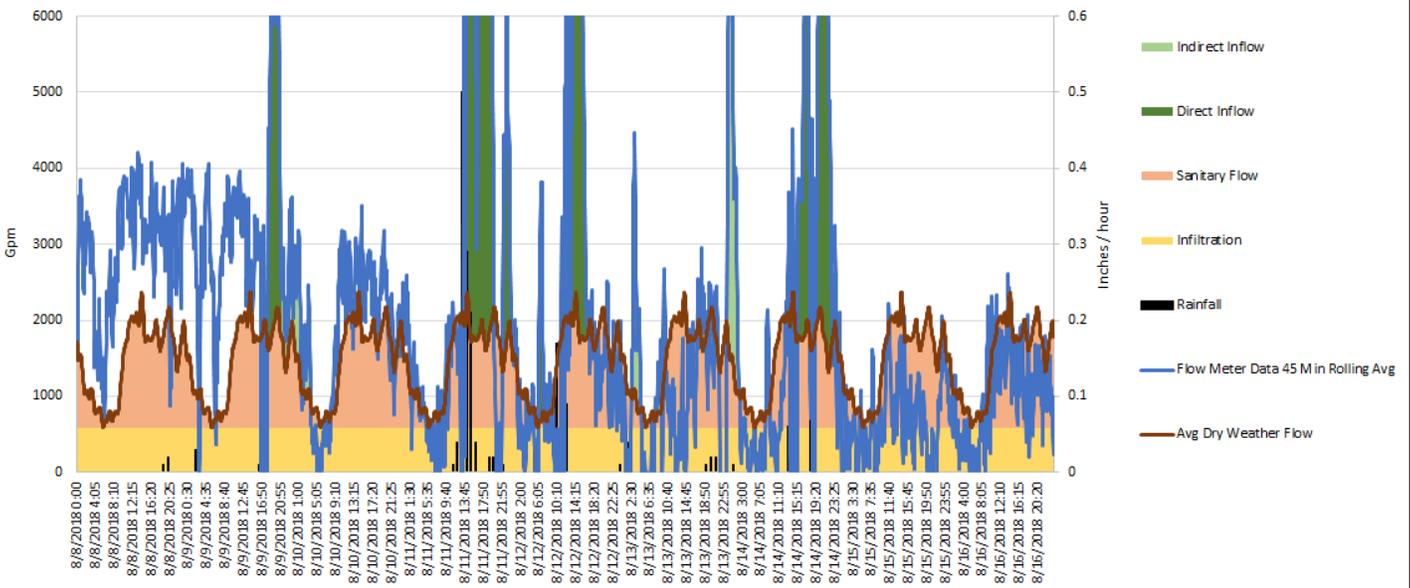
Meter SB5 (Lowell Memorial Auditorium) - Wet Weather (8/11) Hydrograph



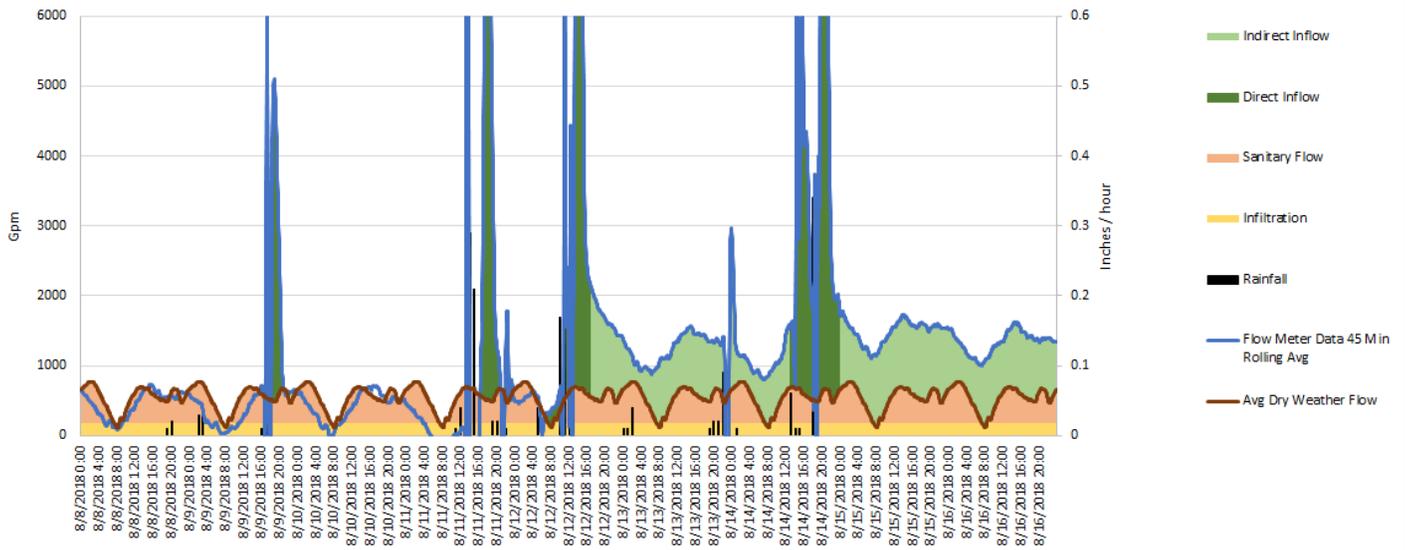
Meter SB6A (Stackpole at Corrigan) - Wet Weather (7/17) Hydrograph



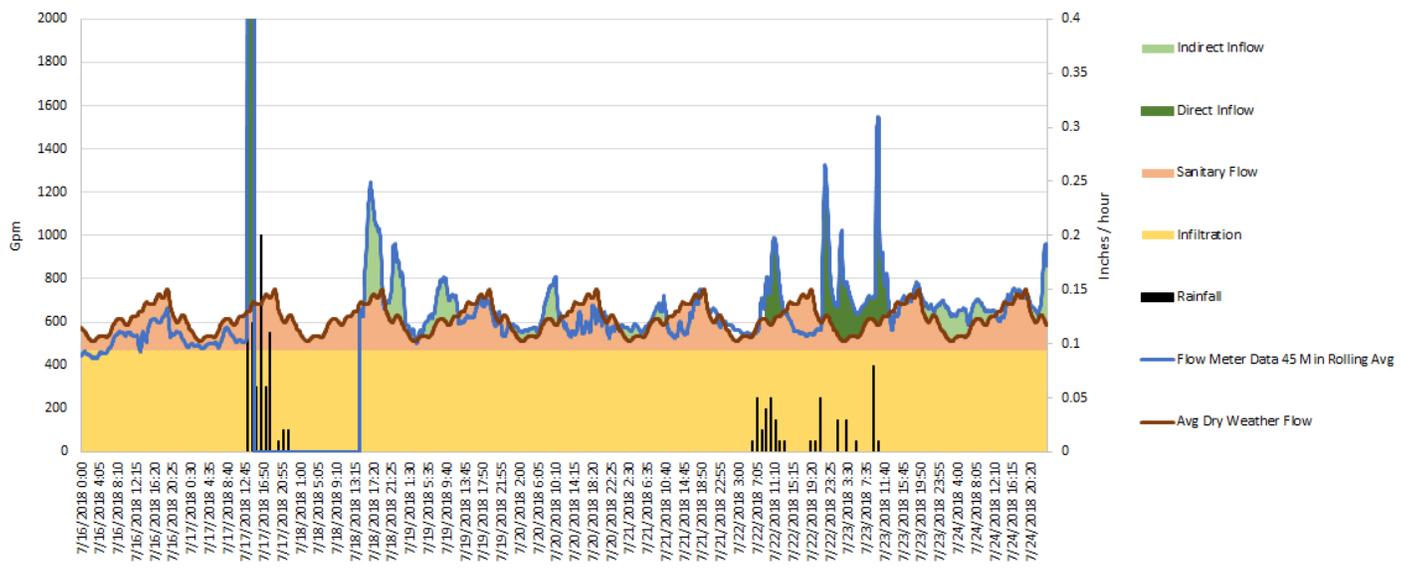
Meter SB6A (Stackpole at Corrigan) - Wet Weather (8/11) Hydrograph



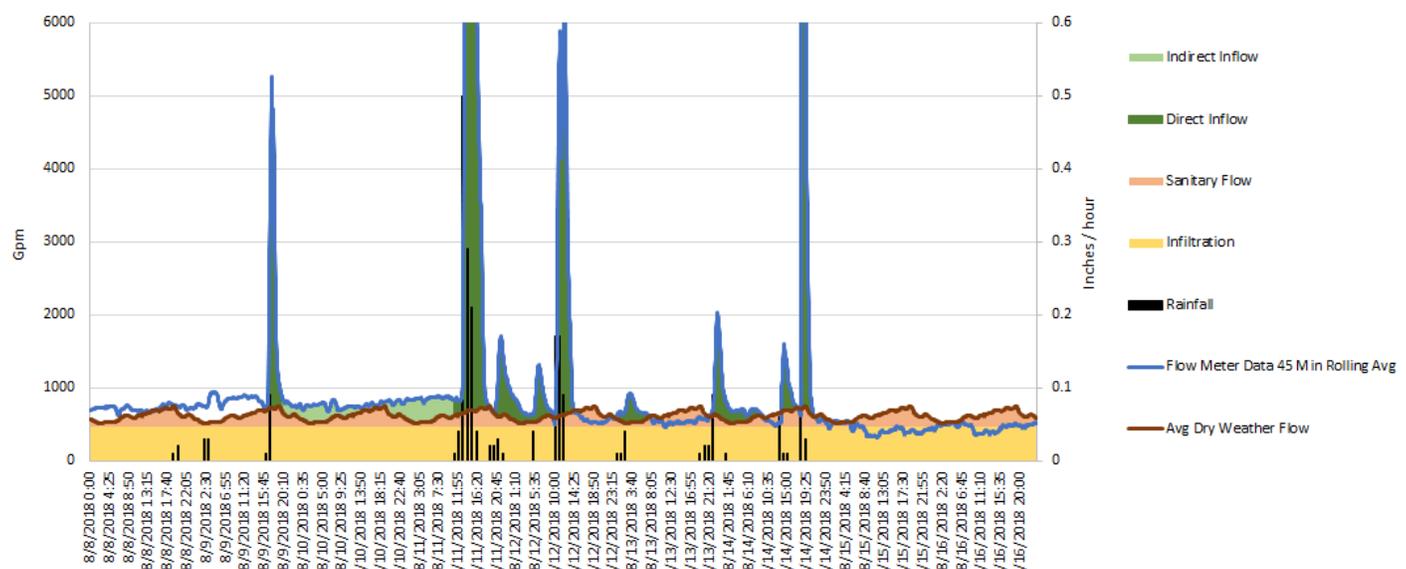
Meter SB7 (Merrimack CSO Station) - Wet Weather (8/11) Hydrograph



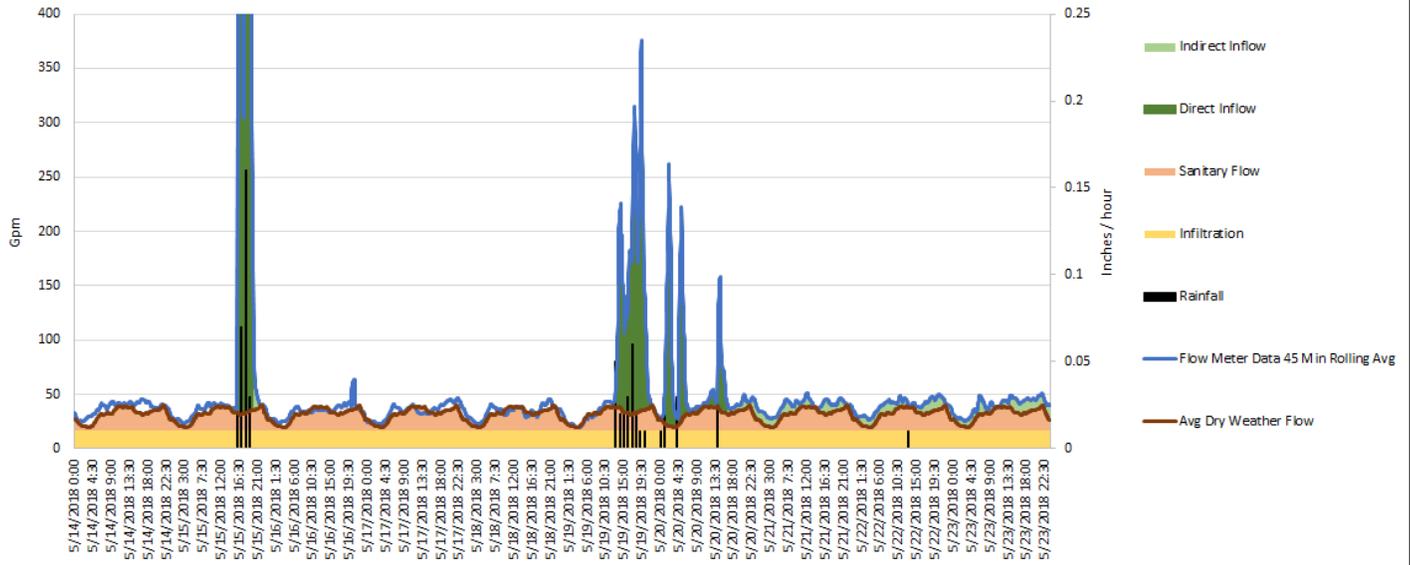
Meter SB8A (E Merrimack at Barasford) - Wet Weather (7/17) Hydrograph



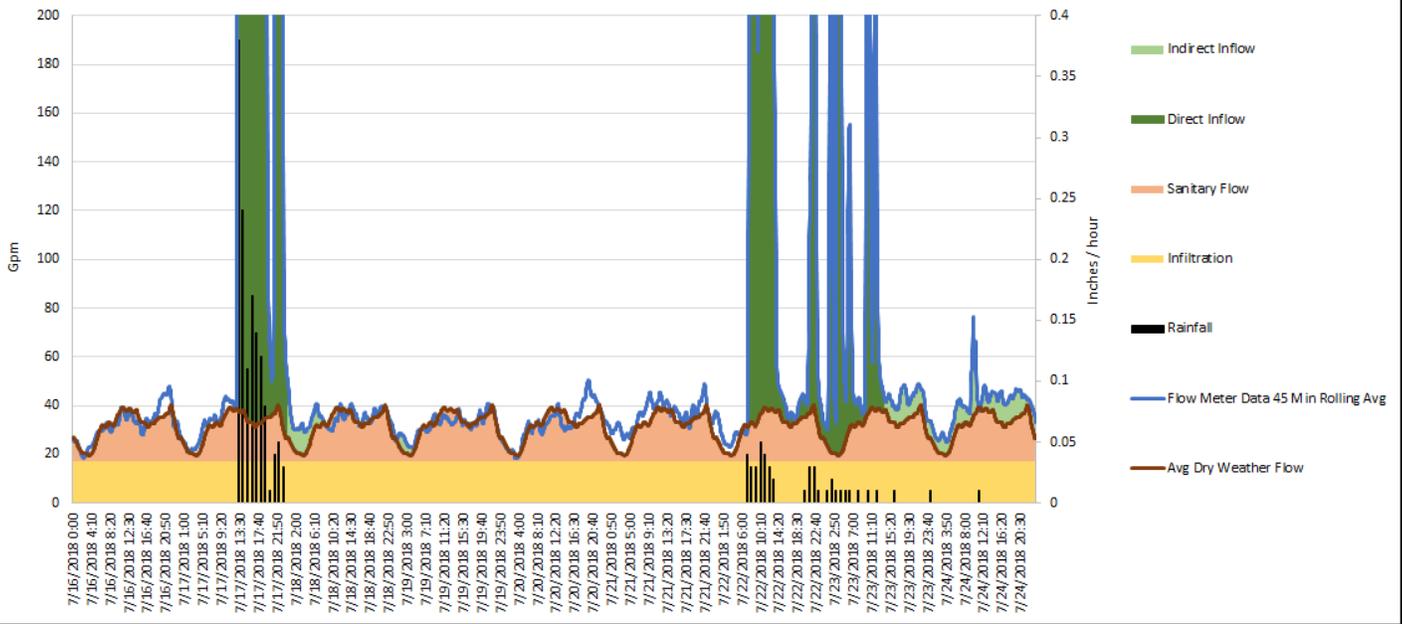
Meter SB8A (E Merrimack at Barasford) - Wet Weather (8/11) Hydrograph



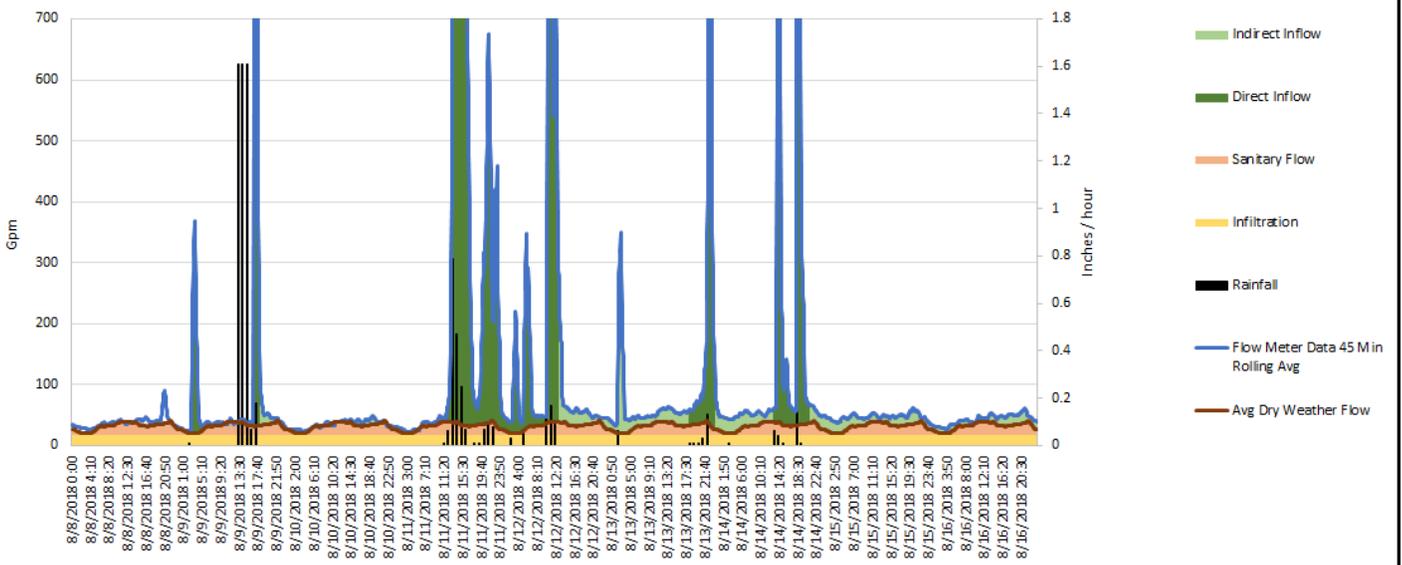
Meter SB9 (21 George) - Wet Weather (5/15) Hydrograph



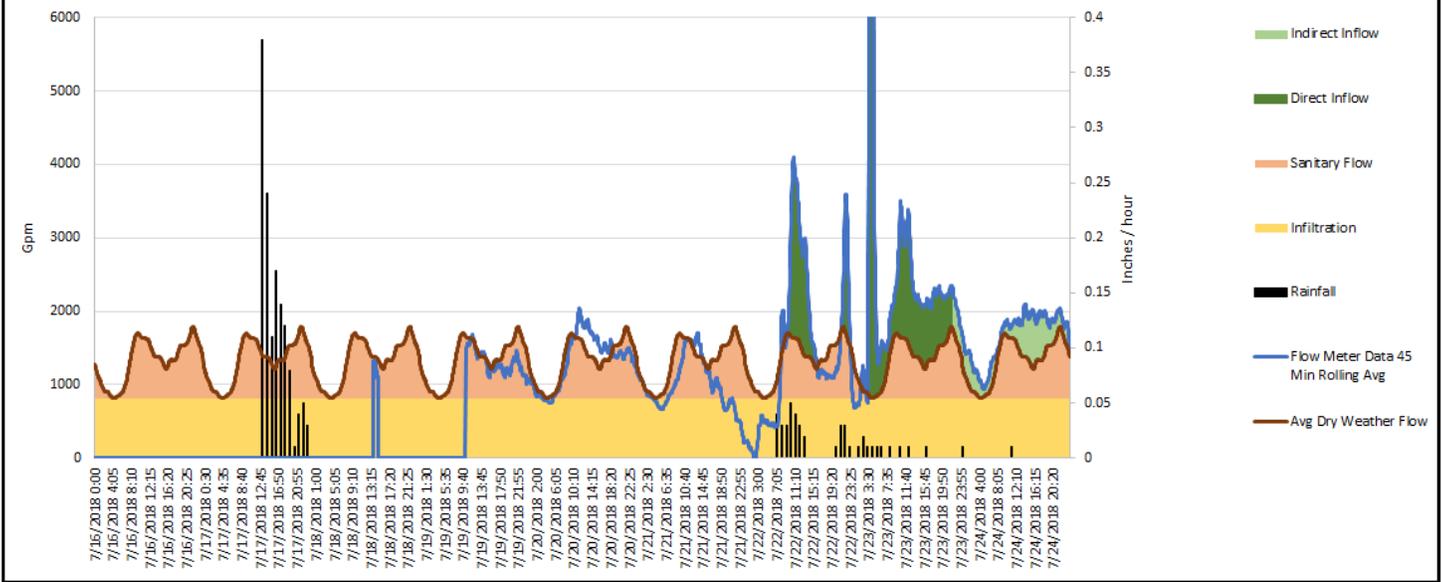
Meter SB9 (21 George) - Wet Weather (7/17) Hydrograph



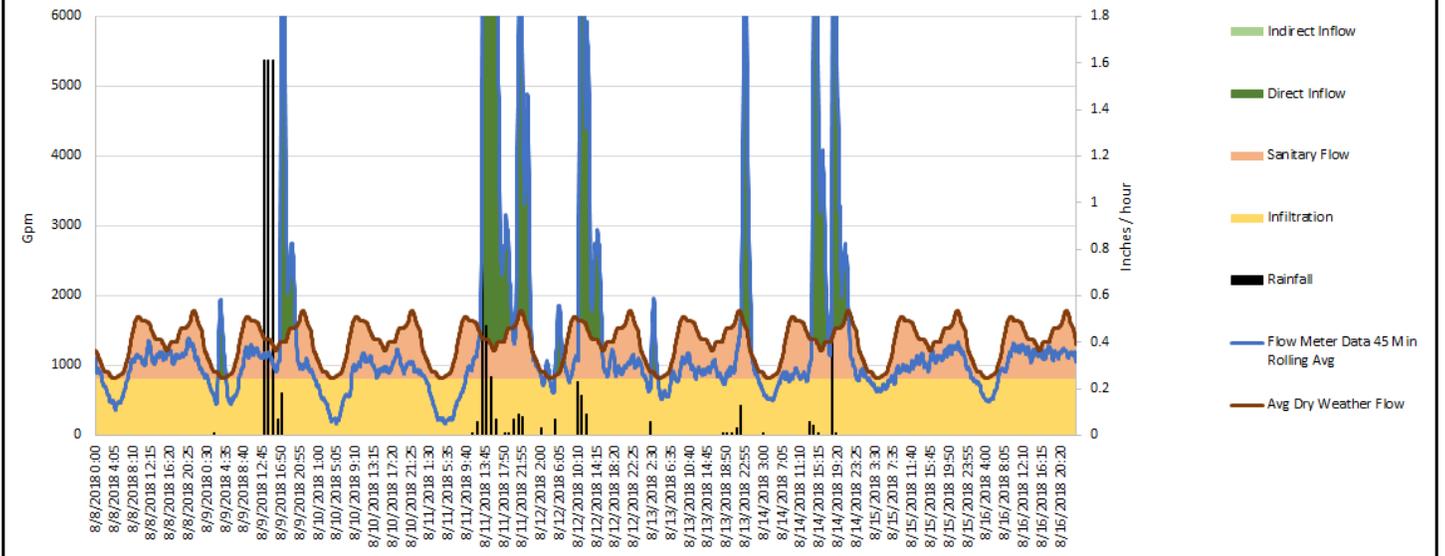
Meter SB9 (21 George) - Wet Weather (8/11) Hydrograph



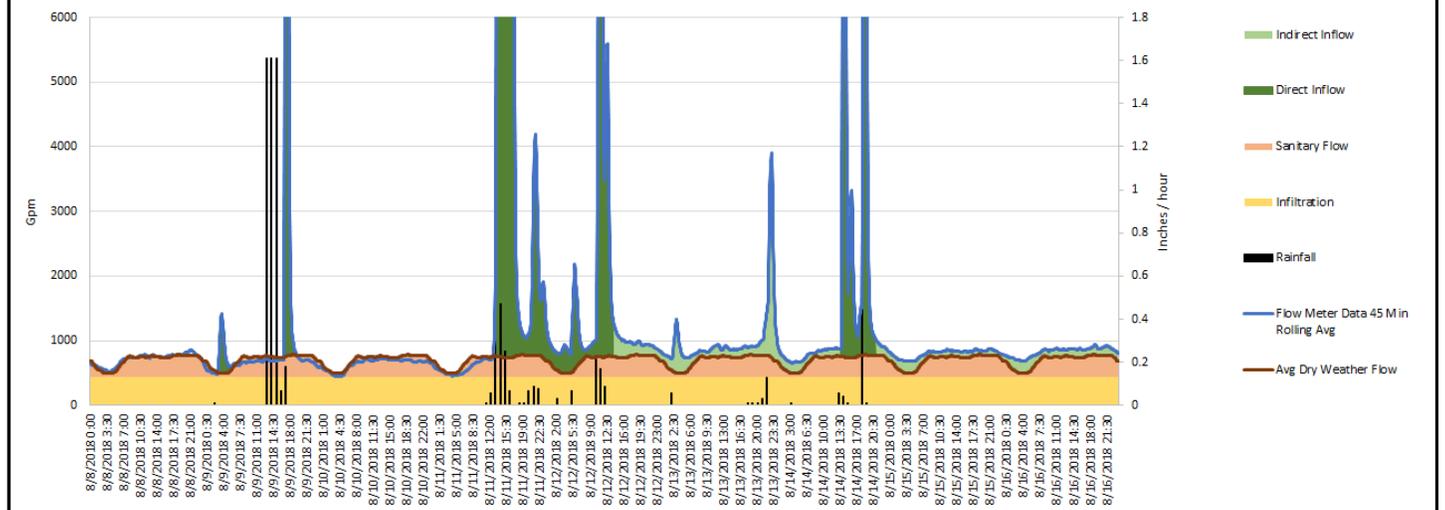
Meter SB12 (Stackpole at Brown) - Wet Weather (7/17) Hydrograph



Meter SB12 (Stackpole at Brown) - Wet Weather (8/11) Hydrograph



Meter SB13 (Cabot) - Wet Weather (8/11) Hydrograph



Hydrographs for NB3, SB1, and SB11 were indeterminate due to poor quality data.