Agenda Report

Subject: **Sanitary Sewer Evaluation Survey – Report and Next Steps**

Prepared By: Steven M. Saunders, Director of Public Works/Village Engineer

Ref: February 21, 2012 Council Meeting
July 17, 2012 Council Meeting

Date: August 15, 2012

Background and Prior Discussions

On February 21, 2012, the Village Council awarded a contract to Strand Associates to complete a flow monitoring analysis of the Village's sanitary sewer system to identify areas of the Village subject to inflow and infiltration (I/I). I/I is stormwater or groundwater that enters the Village's separate sanitary sewer system, which is designed and intended to handle solely wastewater. Excessive I/I in the sanitary sewer system can lead to basement backups.

Strand Associates installed 30 flow meters to record flow information for the majority of the Village's sanitary sewer system. Flow monitoring took place for the period April 9 to June 8, 2012. Following completion of the flow monitoring work, Strand Associates compiled and analyzed the data and provided some preliminary recommendations on prioritizing basins for detailed study and analysis. Strand's data analysis consisted of identifying average dry-weather flow as a baseline, and calculating the observed increases between wet-weather flow and dry-weather flow during and immediately after a measured rain event. Inflow and infiltration data were evaluated, quantified and tabulated for each of the 30 metering basins.

Inflow was characterized by two methods. In the first method, a ratio of wet-weather flow to dry-weather flow, known as "peaking factor", was calculated for each metering location. The higher the peaking factor, the more susceptible the metering basin is to inflow. In the second method, inflow for the entire system was calculated, and each basin was ranked based on the percentage of inflow it contributed to the entire system. Infiltration for each basin was calculated using the flow volume beginning 30 minutes after the conclusion of each rainfall event and ending when the flow volume returned to the baseline dry weather flow.

Strand provided some preliminary recommendations on how to rank basins for prioritizing future actions, based on a data-driven, empirical evaluation of the system. These preliminary recommendations were discussed by the Village Council on July 17, 2012. At that meeting, the Council directed staff and Strand Associates to finalize their recommendations concerning areas subject to further detailed survey and evaluation. These areas should be selected by focusing on basins most susceptible to I/I (based on flow metering results) and areas shown to be susceptible to basement flooding ("clusters" shown in the 2011 flooding survey).

Immediate Next Steps

Strand Associates has identified immediate next steps for consideration by the Village. This activity consists of performing a pilot SSES study entailing detailed evaluations of the sanitary sewer system in certain high-priority basins and cluster areas discussed at the July 17, 2012 Council Meeting. Strand Associates has recommended that basins 14, 15, and 20 be evaluated, along with a portion of basin 26, previously unmetered areas of Oak Street and Sunview Lane and five clusters of reported flooding east of Green Bay Road. These recommended areas are shown in Figure 5.03-1 of the Strand Report, and represent the highest priority areas based on measured I/I and the results of the September 2011 flood survey. Detailed analysis in these areas would consist of manhole evaluations, smoke testing, and, depending on the results of the smoke testing, television inspection of sewer lines showing potential defects.

In basins 14, 15, and 20, these detailed evaluations would start in the portions of the basins where flooding clusters were observed, however these detailed studies would expand to the remaining areas of these basins as well. This approach is recommended because the cause of basement flooding may not originate in the area where flooding was reported. However, starting in the vicinity of the flooding clusters and working back through the remainder of the basin allows for the possibility of discovering problems early in the process and possibly minimizing the level of effort to be expended. In the limited cluster areas, the detailed investigations will be limited to the vicinity of the flooding clusters, again in order to minimize the level of effort to be expended on the program.

Strand Associates has estimated that this pilot SSES study can be completed for $75,000, including $28,100 for potentially televising up to 50% of the evaluated portions of the sewer system. The amount and location of sewer main to be televised will depend on the conditions uncovered during the detailed evaluation. The Village does have the capability of video-inspecting sewers in-house and depending on the amount of television inspection needed, may complete this television inspection with Public Works crews.

This initial detailed evaluation approach presents the Village with several advantages when compared to a broader initial approach of evaluating all of the higher priority areas. First, it focuses the Village's resources on initially addressing the highest priority areas, as evidenced both by I/I evaluation and by the Village's flood survey. Second, it allows the Strand Associates to further refine their estimated costs for future detailed investigations based on direct field inspections in Winnetka. Finally, it will provide the Village with some hard data on the amount and type of defects or needed repairs in the public and portions of private systems in the pilot study areas that can be extrapolated across the remainder of the Village's system to predict the level of capital expenditures needed to address I/I and basement flooding in the remainder of the Village.

Future Actions

Strand Associates has also identified a program of future actions for consideration by the Village, to provide a complete evaluation to identify future improvements to the Sanitary

Sewer System. This program includes performing detailed evaluations of all of the remaining metering basins over a two year period at an estimated cost of $340,500.

Strand Associates also recommends for consideration a program that would examine the Village's sanitary sewer system for susceptibility to backups associated with the MWRDGC's intercepting sewer system. This program would consist of the Village purchasing three flow meters (and associated software and staff training) that could be installed in proximity to key points where the Village's system connects to the MWRDGC's system. These meters could be monitored on a long-term basis by Village staff to identify if and when back-up conditions exist in the MWRDGC's system. These meters would also be useful on a long-term basis to evaluate the effectiveness of any future I/I elimination activities by way of before-and-after flow metering. The estimated cost to purchase three flow meters, the evaluation software, and to receive operational training is approximately $24,500. Strand has also suggested undertaking a hydraulic analysis of the Village's sewer system in the vicinity of its connections to the MWRDGC's interceptor system to identify areas where the Village's system might be hydraulically susceptible to backflow from the MWRDGC system. This hydraulic investigation is estimated to cost approximately $30,000, but is not recommended by staff at this time. It is less expensive and more reliable for the Village to monitor its system in the vicinity of the MWRDGC connections to obtain hard evidence of potential backflows into the Village system than to expend a significant sum to determine if the MWRDGC's system can theoretically surcharge into the Village's system.

Summary and Recommendations

Strand Associates has proposed a program of actions that, if implemented in its entirety, would complete a detailed evaluation of most of the Village's sanitary sewer system, and a determination of the susceptibility of the Village's system to backup from the MWRDGC intercepting system, by the end of 2014, at a cost of approximately $470,000. What is missing from this estimate, however, is the timeline and cost of making identified repairs. It is impossible at this time to provide anything more than a guess as to the nature and cost of potential repairs. Staff is recommending that the Council consider an alternate, more deliberate approach that would immediately address three pressing issues. This approach consists of immediately proceeding with detailed investigations of very targeted areas, consisting of three basins that exhibit significant I/I and basement flooding, plus clusters of identified basement flooding in 8 other limited areas. This approach also includes budgeting for and obtaining three flow meters (and staff training) to be used by staff to identify whether the MWRDGC interceptor system does contribute backup to areas of the Village's sanitary sewer system.

This approach will provide an initial estimate of the nature, scope, and cost of necessary repairs in the most critical areas of the Village's sanitary sewer system, which could be extrapolated to provide an idea of what might be encountered in other areas of the Village. This approach will also indicate if the MWRDGC system backs up to the Village, and could be accomplished for a total estimated cost of approximately $100,000, or less depending on the amount of television inspection required. This approach is detailed below.

Recommended Actions	Estimated Timeframe	Estimated Cost
Detailed Investigation of First Priority Areas (including possible television inspection)	Fall 2012	$75,000
Budget for Improvements identified during Detailed Investigation of First Priority Areas	Winter 2012-13	N/A
Flow Meter Purchase	Spring 2013	$24,500
Engineering and Construction of improvements – first priority areas	Spring – Summer 2013	Unknown
Possible Additional Actions for Future Consideration	**Estimated Timeframe**	**Estimated Cost**
Detailed Investigation of Remaining Priority Areas (including possible television inspection)	2013	$105,500
Engineering and Construction of improvements – remaining priority areas	2014	Unknown
Detailed Investigation of Lower Priority Areas (including possible television inspection)	2014	$235,000
Engineering and Construction of improvements – lower priority areas	2015	Unknown

Budget Evaluation:

The FY 2012-13 Capital Budget contains $350,000 in the sewer fund for three line items – Sanitary Sewer Evaluation Studies, Trenchless Lining, and System I/I Repairs. The current status of capital items in this fund is as follows:

Item	Budget	Estimate	Variance
Sanitary Sewer Evaluation Studies	$100,000	$108,000 (Strand flow metering contract)	$8,000
Trenchless Lining	$150,000	$166,000 (contract awarded to Michels construction May 2012)	$16,000
System I/I Repairs	$100,000	$75,000 (proposed detailed investigation of priority areas and clusters)	($25,000)
Total	***$350,000***	***$349,237***	***($1,000)***

As a result, funding is available to implement the first portions of this approach in the current budget.

Recommendation:

Consider the next steps recommended by Strand Associates and presented in their August 2012 report to the Village of Winnetka:

1. Consider directing staff to obtain contractual pricing for Strand Associates to perform detailed investigations of metering basins 14, 15, and 20, and the flooding cluster areas identified in figure 5.03-1 of Strand Associates' report dated August, 2012, and;

2. Consider directing staff to obtain budgetary pricing for purchase of 3 flow meters, associated software, and operational training, for use in evaluating possible backflow from the MWRDGC's intercepting sewer system.

Attachments:

1. Strand Associates August 2012 Report

Sanitary Sewer Evaluation Survey–Flow Monitoring Study

Report

Village of

Winnetka, IL

August 2012

Report

Village of

Winnetka, IL

August 2012

Report for

Village of Winnetka, Illinois

Sanitary Sewer Evaluation Survey
Flow Monitoring Study

Prepared by:

STRAND ASSOCIATES, INC.®
IDFPR No. 184-001273
1170 South Houbolt Road
Joliet, IL 60431
www.strand.com
August 2012

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EXECUTIVE SUMMARY

The Village of Winnetka, Illinois (Village) owns and operates its own separate sanitary sewer system. Sanitary flow generated within the Village is collected in local sewers that discharge to a network of interceptor sewers owned and operated by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) before being treated at an MWRDGC wastewater treatment plant (WWTP).

As the Village's separate sanitary sewer system ages, there is potential for wet weather flows to enter into the sewer system. These wet weather flows are known as infiltration and inflow (I/I). The affect of I/I is to increase flow in the sewer much higher than the average dry weather flow, potentially causing sanitary sewer surcharging and basement backups.

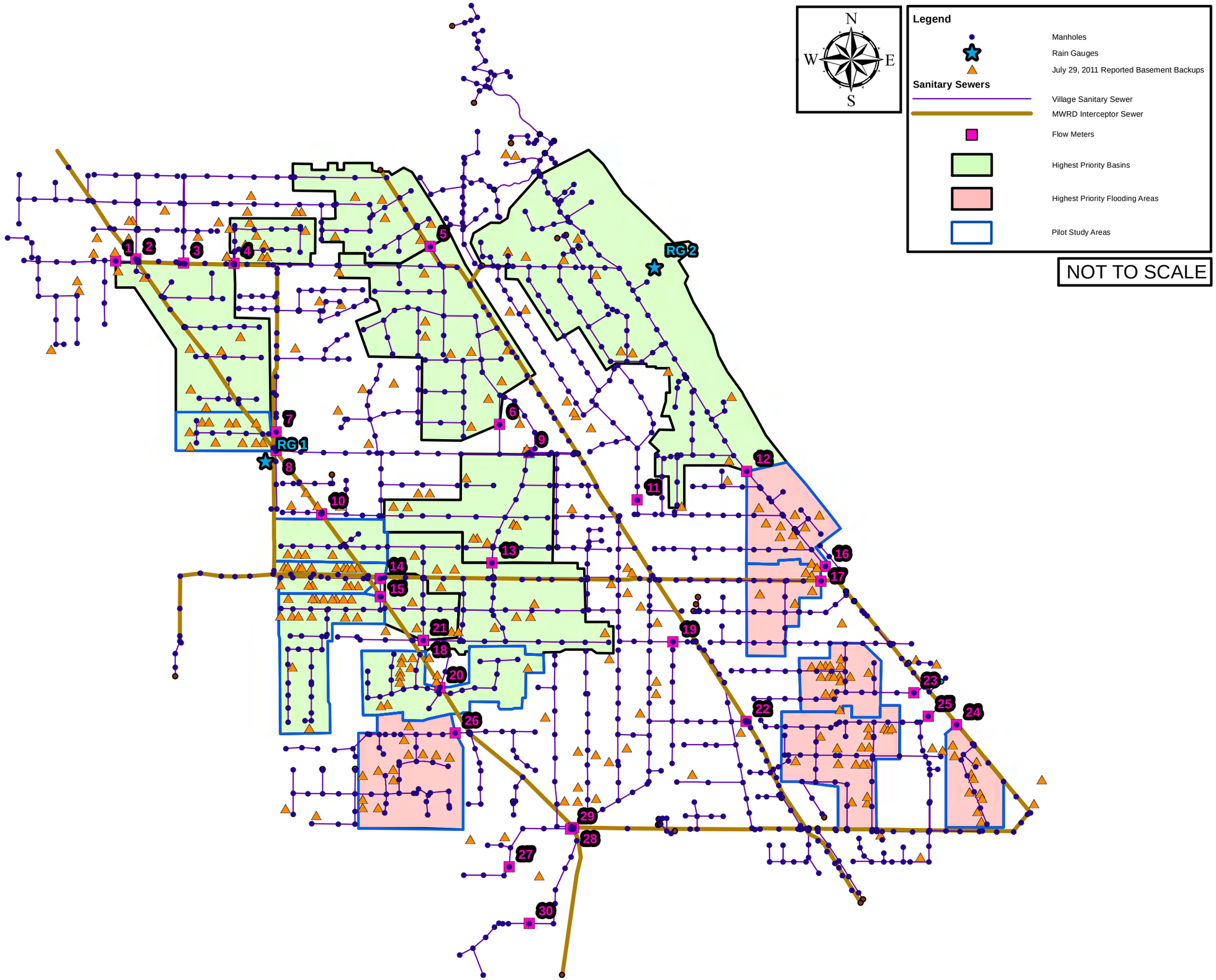
On July 23, 2011, a significant wet weather event subjected the Village to over six inches of rain in less than three hours causing severe street flooding and basement backups. In response to this event, the Village conducted a survey of all residents to determine the extent of the flooding. Of the responses received, 276 residents indicated they experienced a basement backup. The results of this survey prompted the Village to undertake a sanitary sewer evaluation survey (SSES).

Section 1 of this study describes the purpose and scope of the SSES. A flow monitoring program was developed to identify and prioritize areas within the system that experience high levels of I/I. The system was divided into 30 basins with data collected at 30 flow monitoring locations. An existing Illinois State Water Survey (ISWS) rain gauge and an additional installed rain gauge were used to collect simultaneous rainfall data during the flow monitoring period from April 13, 2012, through June 8, 2012. Section 2 describes the flow monitoring program. Figure ES-1 shows the 30 flow metering locations along with the rain gauge locations.

Flow meter and rain gauge data were used to conduct a number of analyses in order to identify which basins were most susceptible to I/I. These analyses are described in Section 3. Several areas within the Village were prioritized for future SSES investigations based on the flow metering analyses and results of the Village flood survey. Figure ES-1 shows the priority areas and the results of the flood survey by the Village.

Section 4 describes a series of investigations intended to identify potential defects in the sewer system and potential sources of I/I. These investigations include traditional SSES investigations such as manhole inspections, smoke testing, televising, and dye testing.

While I/I appears to be an issue throughout the Village's sanitary sewer system, some areas that reported flooding in July 2011 were not identified by the flow metering data as susceptible to excessive I/I. The reported flooding could be a result of other influences, and Section 4 also identifies additional investigations aimed at determining if influence from the MWRDGC interceptor system impacts the Village's sewer system. These investigations include a hydraulic analysis of the MWRDGC interceptor system relative to the Village's system and an extended flow monitoring program at key locations where the two systems interact to capture a large enough event to evaluate the influence from the MWRDGC interceptors.



HIGHEST PRIORITY BASINS

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VILLAGE OF WINNETKA
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FIGURE ES-1

Section 5 presents a recommended plan moving forward including costs and a schedule for implementing the plan. The plan starts with a pilot study implemented in the fall of 2012 to provide the Village with a sampling of defects in the system and perspective on potential rehabilitation efforts needed. This information would be used to project rehabilitation efforts required to be put into the Village's Capital Improvement budget. The rest of the plan entails continuing SSES investigations throughout the entire Village in the years 2013 and 2014 to identify specific rehabilitation needs.

The plan also includes performing a hydraulic analysis of the MWRDGC interceptor system and the extended flow monitoring program in 2013. As an alternative to the Village using a consultant for the extended flow monitoring, Village purchase of its own flow metering equipment is suggested in Section 5 to provide a reduction in cost and added flexibility.

Table ES-1 summarizes the recommended SSES plan, schedule, and opinion of costs.

Year	Investigations	Cost	Total Annual Cost
2012	SSES Pilot Study	$46,900	$75,000
	Pilot Study Televising	$28,100	
2013	SSES Investigations of Remaining Priority Areas	$56,100	$160,000
	Televising of Remaining Priority Areas	$49,400	
	Hydraulic Analysis	$30,000	
	Purchase Flow Meters and Training	$24,500	
2014	SSES Investigations of Remaining Basins	$135,000	$235,000
	Televising of Remaining Basins	$100,000	

Table ES-1 Recommended Plan and Schedule

SECTION 1
INTRODUCTION

1.01 PURPOSE

The Village of Winnetka, Illinois (Village), owns and maintains its own sanitary sewer system. Sewerage from the Village's sanitary sewer system flows into an interceptor sewer system owned and maintained by the Metropolitan Water Reclamation District of Great Chicago (MWRDGC) and is transported to the North Side Wastewater Treatment Plant (WWTP).

Over the years the Village has experienced a number of large rainfall events resulting in significant surface flooding and backup of the sanitary sewer system into basements. One particular event occurred on July 23, 2011, when over 6 inches of rain fell in less than three hours. In response to the July 23 event, the Village conducted a survey of all residents to determine the extent of flooding and basement backups. Of the responses received, 276 residents indicated they experienced a basement backup. While the July 23 event was an extreme event, the results of the survey suggest the presence of infiltration and inflow (I/I) prompting development of a sanitary sewer evaluation survey (SSES).

The purpose of a SSES study is to identify locations of I/I into the sanitary sewer system and determine means for reducing I/I. Infiltration is groundwater that enters the sanitary sewer system through defective sewer joints, cracked or broken sewers, or manhole walls. Inflow is surface water directly entering the sanitary sewer system because of rainfall or surface runoff through roof drains, yard or area drains, foundation drains, manhole covers, and cross-connections with storm sewers. Excessive I/I into the sewer system can exceed the sewer's capacity and result in system backups.

The purpose of this flow monitoring study was to analyze the dry and wet weather flow characteristics of the Village's sanitary sewer system, isolate the areas within the system where I/I is most prolific, and provide the Village with recommendations on moving forward with further investigations to pinpoint and reduce the sources of I/I.

1.02 SCOPE

The scope of the Flow Monitoring Study includes the following:

1. Division of the Village into 30 flow metering basins and installation of flow meters for a period of approximately seven weeks from April 13 to June 8, 2012.

2. Installation of one rain gauge to supplement the existing Illinois State Water Survey (ISWS) rain gauge within the Village and collect simultaneous rainfall data over the flow metering period.

3. Analysis of the flow monitoring data for sanitary sewer system I/I characteristics in each flow metering basin.

4. Prioritization of the flow metering basins based on I/I characteristics.

5. Recommendations for continued investigations to pinpoint and reduce sources of I/I.

1.03 ABBREVIATIONS

Village	Village of Winnetka
FM	flow meter
GIS	geographical information system
gpm	gallons per minute
I/I	infiltration and inflow
in	inch
MWRDGC	Metropolitan Water Reclamation District of Greater Chicago
RG	rain gauge
WWTP	wastewater treatment plant
ISWS	Illinois State Water Survey
SSES	sanitary sewer evaluation study
SSO	sanitary sewer overflow

SECTION 2
FLOW MONITORING PROGRAM

2.01 EXISTING COLLECTION SYSTEM

The Village currently owns, operates, and maintains a sanitary sewer system that serves residential, commercial, and public users. These sewers were designed to convey wastewater for the existing users and also for future growth. The Village-owned sewers flow into MWRDGC-owned interceptor sewers that convey flow to MWRDGC's North Side WWTP.

The Village's sanitary system is a separate sanitary sewer system. A separate sanitary sewer system is a two-pipe system where wastewater flows through one network of pipes and stormwater flows through a separate network of pipes. However, because of the grade separation at the railroad tracks along Green Bay Road storm sewers are prevented from crossing the tracks. As a result, some of the separate storm sewers on the west side of the village discharge directly into the MWRDGC interceptors.

2.02 BASIN DELINEATION AND FLOW METERING LOCATIONS

The Village's sanitary sewer system is unique in that there are over 26 points of discharge into the MWRDGC interceptor sewer system. This made developing a metering program challenging and resulted in having a much higher number of flow meters than normally would be required for a system of similar size.

Ultimately, a total of 30 flow meters were installed in the Village's sanitary sewer system creating 30 sewershed basins with each basin monitored by a flow meter. The flow meters were maintained and data collected over an approximately seven-week monitoring period from April 13 through June 8. Table 2.02-1 provides an inventory of the flow metering locations and the upstream pipe sizes (flow meter sizes). Figure 2.02-1 shows the locations of each flow meter and the resulting metered areas or sewershed basins.

On July 23, 2011, the Village experienced an extreme rainfall event that produced over 6 inches of rain in less than 3 hours. In response to that event, the Village conducted a flood survey in September 2011 to identify how many residents and at what locations basement backups occurred. The results of this survey are shown in Figure 2.02-1.

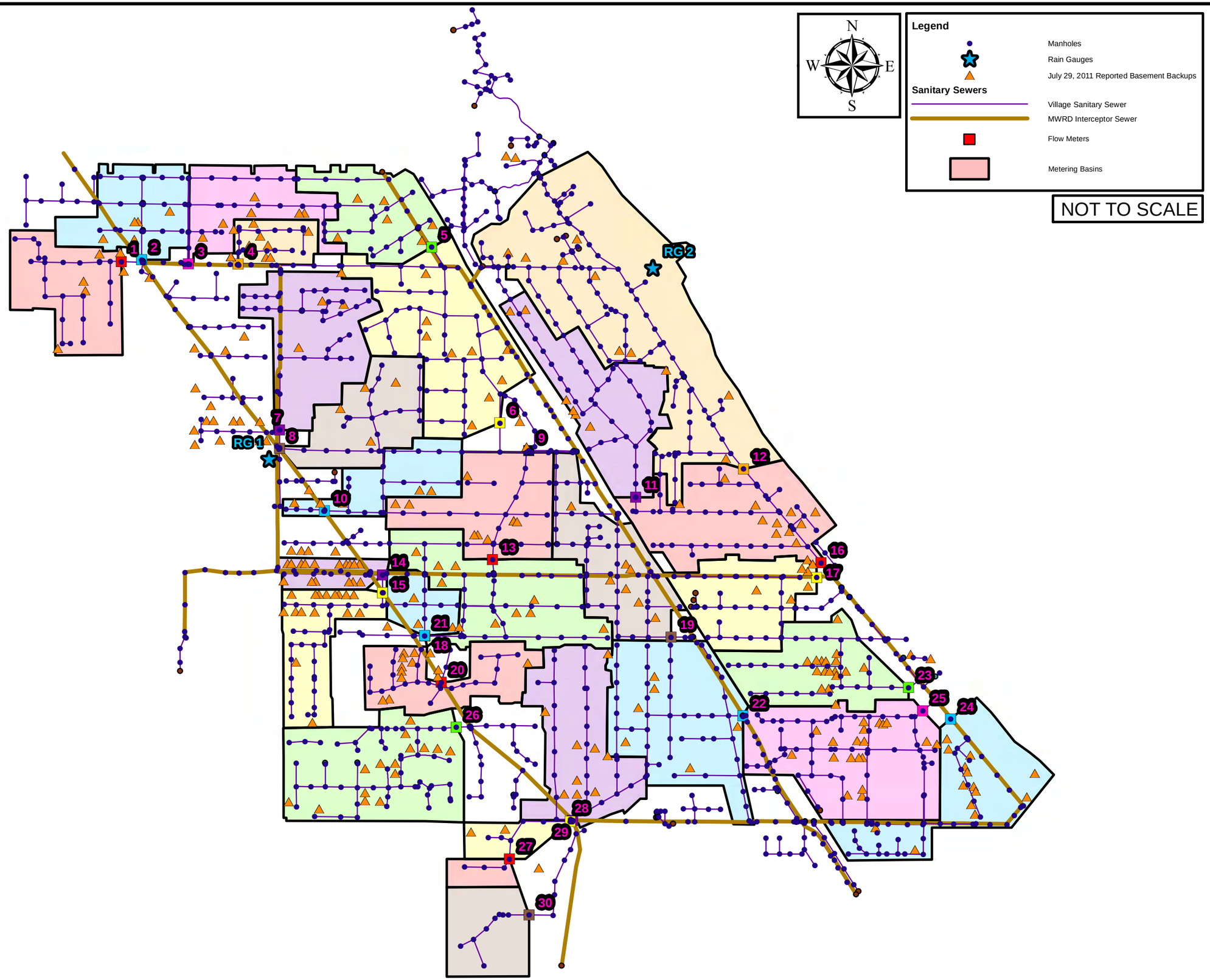
The flow metering program was developed to monitor as much of the system as practical, especially the areas that experienced basement backups according to the Village survey. However, a few areas of the Village were not metered. Because of the numerous MWRDGC connection points, including these unmetered areas would have required significantly more flow meters. Additionally, in many cases there was not a manhole suitable for meter installation or the tributary areas were too small to allow for reliable data collection. Areas not metered under this program are unshaded in Figure 2.02-1. Some of these areas did report basement backups, which was taken into consideration in making recommendations for future investigations.

Figure 2.02-2 shows a schematic of the flow meters in the conveyance system. This figure provides perspective on how the meters were interconnected and their position relative to the MWRDGC Interceptor sewer system.

TABLE 2.02-1

FLOW METER LOCATIONS AND SIZES

Meter	Meter Location	Sewer Size (inches)
M01	In the westbound lane of Tower Road just east of Boar Parkway	8
M02	At the intersection of Tower Road and Greenwood Avenue	10
M03	In the parkway south of the intersection of Tower Road and Vernon Avenue	15
M04	In the eastbound lane of Tower Road between Bell Lane and Forest Glen Drive	8
M05	Green Bay Road just north of Tower Road	12
M06	East parkway of Blackthorn Road north of Pine Street	15
M07	Northbound lane of Hibbard Avenue just north of Pine Street	10
M08	At the intersection of Hibbard Avenue and Pine Street	15
M09	North parkway of Pine Street between Provident Avenue and Walden Road	18
M10	Westbound lane of Elm Street east of Hibbard Avenue	10
M11	In the middle of Lincoln Avenue north of Elm Street	15
M12	In the middle of Sheridan Road between Pine and Spruce Street	27 x 18 Egg Shape
M13	Northbound lane of Provident Avenue between Oak and Cherry Street	15
M14	At the intersection of Ash Street and Glendale Avenue	10
M15	In the southbound lane of Glendale south of Ash Street	15
M16	In the middle of Sheridan Road between Cherry and Oak Street	36 x 24 Egg Shape
M17	Just west of the intersection of Cherry Street and Sheridan Road	32 x 21 Egg Shape
M18	Intersection of Rosewood Avenue and Willow Road (Same MH as M21)	15
M19	Intersection of Willow Road and Forest Street	27 x 18 Egg Shape
M20	Just north of the intersection of Locust Road and Mt. Pleasant Street	10
M21	Intersection of Rosewood Avenue and Willow Road (Same MH as M18)	8
M22	Outside northbound lane of Green Bay Road between Sunset Street and Church Road	18
M23	In the middle of Hawthorn Lane just West of Sheridan Road	18
M24	In the middle of Sheridan Road between Elder Lane and Fuller Lane	27 x 20 Egg Shape
M25	In the middle of Elder Lane between Sheridan and Essex Road	28 x 21 Egg Shape
M26	The intersection of Sunset and De Windt Road	12
M27	Northbound Lane of Fox Lane south of Hill Road	12
M28	MWRDGC manhole at the intersection of Hill and N. Indian Hill Road	10
M29	Just west of the intersection of Hill and N. Indian Hill Road	15
M30	Front yard of 40 Indian Hill Road	8



FLOW METERING BASINS

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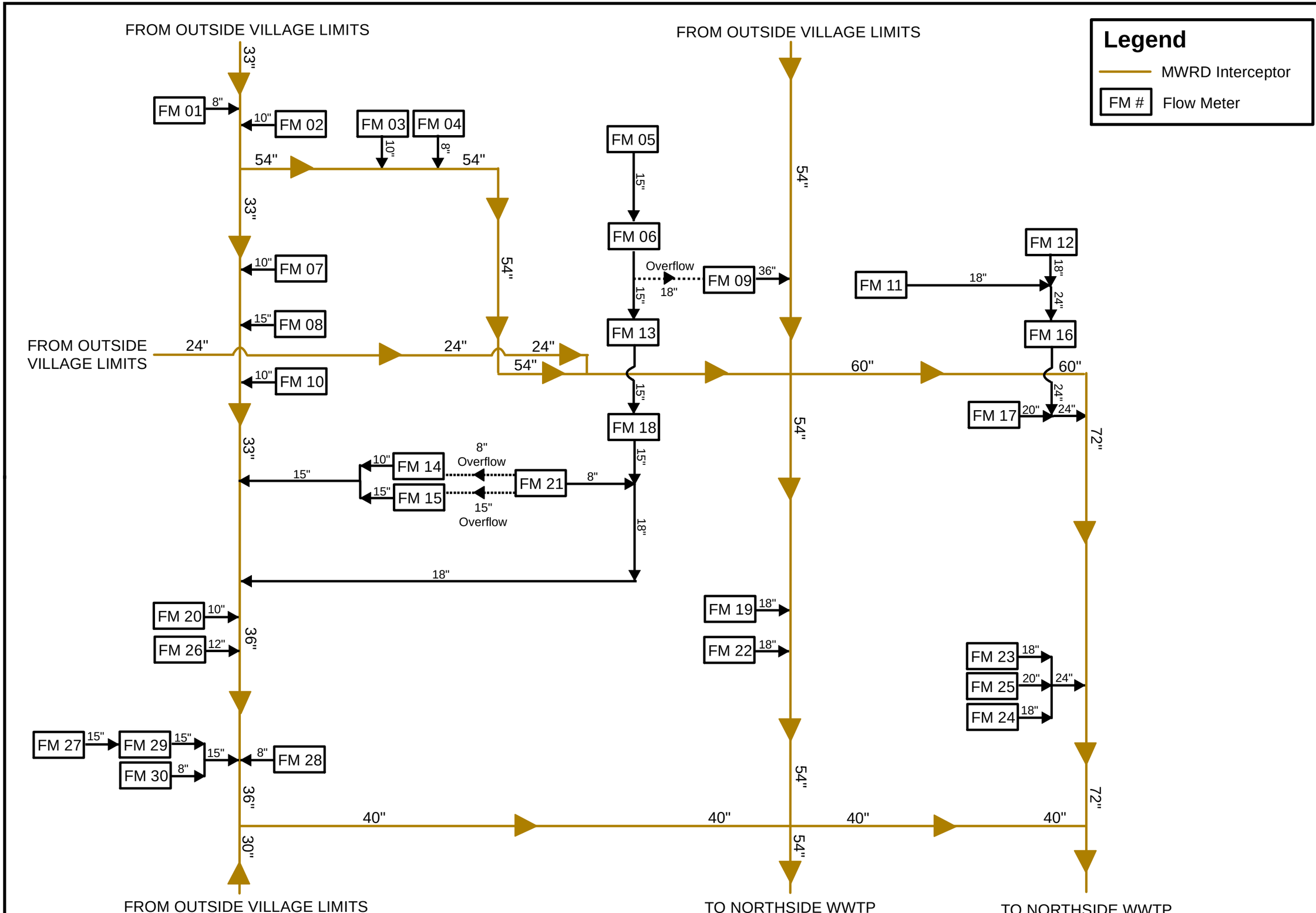
FIGURE 2.02-1



SYSTEM SCHEMATIC

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FIGURE 2.02-2

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In preparation for evaluating the flow metering data collected, it was recognized that sewershed size and pipe diameters were not consistent between basins, which could skew comparison of flow characteristics between basins. For example, evaluation of infiltration into a sewer system looks at groundwater entering the sanitary sewer system through sewer defects, which is directly related to sewer length and diameter. It is expected that a large sewershed basin with large diameter pipes will have a higher volume of infiltration than a small basin with small diameter pipes. However, a larger total infiltration volume does not necessarily indicate a larger infiltration problem. Therefore, to equalize basin size and pipe diameter variables between the basins, each basin was quantified by inch-miles of sewer. Table 2.02-2 is a summary of this quantification. A detailed quantification is included in Appendix A.

In Table 2.02-2 there is no quantification for Basins 09, 27, and 30. FM 09 was installed to measure any overflows from Basin 13. As a result, there was no associated basin with a network of pipes that required quantification.

Flow meters 27 and 30 were installed to measure and quantify the flow that enters the Village's system from an unincorporated portion of Cook County serviced by the Woodley Road Sanitary District located west of Locust Road. Since it is not part of the Village system, the details of the basins were not studied in this report.

Metering Basin	Length of Sewer		Equivalent Sewer Length
	(feet)	(miles)	(inch dia-mile)
M 01	5,440	1.03	8.24
M 02	4,768	0.90	7.52
M 03	5,819	0.94	11.24
M 04	2,594	0.49	3.93
M 05	5,899	1.12	9.98
M 06	14,240	2.11	25.93
M 07	10,881	2.06	16.88
M 08	4,708	0.89	10.27
M 09			
M 10	5,207	0.99	9.87
M 11	7,023	1.33	13.87
M 12	18,261	3.46	33.95
M 13	8,050	1.52	15.43
M 14	1,413	0.27	2.42
M 15	5,391	1.02	10.23
M 16	8,494	1.49	20.96
M 17	6,061	1.15	14.81
M 18	11,571	2.19	20.35
M 19	5,308	1.01	22.04
M 20	4,514	0.85	7.25
M 21	2,437	0.46	3.69
M 22	11,152	2.07	20.22
M 23	4,636	0.88	14.96
M 24	6,592	1.25	16.06
M 25	13,668	2.34	31.43
M 26	10,147	1.92	16.88
M 27			
M 28	7,017	1.33	10.64
M 29	1,604	0.30	4.03
M 30			

Table 2.02-2 Quantification of Flow Metering Basins

2.03 RAIN GAUGE LOCATIONS

Rainfall data was collected from two rain gauges located within the Village. Rain Gauge 1 (RG 1) is an existing ISWS-maintained rain gauge located in the southwest corner of the Village. The data from RG 1 was collected, maintained, and made available via the internet by the ISWS during the flow monitoring period.

The second rain gauge, Rain Gauge 2 (RG 2), was installed for the flow monitoring period at the Village's electric plant located at the intersection of Tower Road and Sheridan Road along the lakeshore.

The rain gauges collected rainfall over the seven-week period. The data collected was used to develop a relationship between rainfall totals, rainfall intensity, and wastewater flows in the collection system.

2.04 FLOW MONITORING OPERATIONS

The flow monitoring operations began with installation of 30 ISCO 2150 area-velocity flow meters and one ISCO 675 tipping-bucket rain gauge between April 9, 2012 and April 13, 2012. Figures 2.04-1 and 2.04-2 show photographs of the equipment used. The flow meters used a pressure transducer to detect water level and Doppler radar to detect velocity of flow over the top of the sensor, which is set at or near the bottom of the sewer pipe entering a selected flow metering manhole. The diameter and shape of the sewer were programmed into the flow meter, and the level reading was converted within the flow meter into a cross-sectional area of flow. Flow was calculated by multiplying the velocity readings by the flow meter's calculated flow area. Figure 2.04-3 shows a typical installation.

Figure 2.04-1 ISCO 2150 Flow Meter

Figure 2.04-2 ISCO Tipping Bucket Rain Gauge

Figure 2.04-3 Flow Meter Installation

After the initial installation, each of the flow meters and the rain gauge were monitored on a weekly basis. The stored data was downloaded from the meters and rain gauge to a laptop and a visual check of the data and site conditions was made to verify the meters were operating correctly. A manhole entry was made to correct any problems detected with the flow meters. Figure 2.04-4 shows a photograph of downloading data.

Following each week's data collection, a more thorough evaluation of the data was performed. This evaluation included a mass balance of flows comparing upstream and downstream data to confirm meters were working properly relative to each other.

The meters were removed June 7 and 8, 2012.

Figure 2.04-4 Flow Meter Data Download

SECTION 3
FLOW MONITORING DATA ANALYSIS

3.01 RAINFALL DATA ANALYSIS

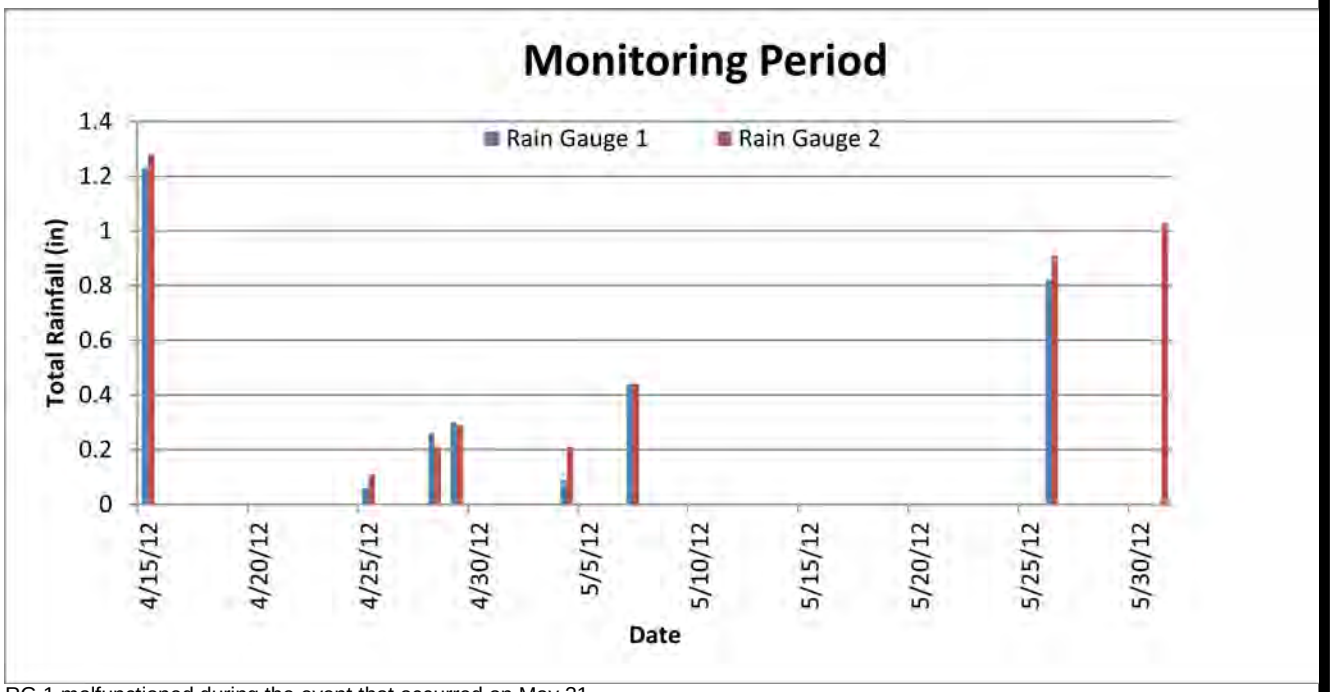
There were eight rainfall events evaluated over the seven-week flow monitoring period. There were additional smaller events during the study period, but for an event to be considered, more than 0.10 inch of rain was required. The eight rainfall events are detailed in Table 3.01-1. The rainfall distribution over the monitoring period is shown in Figure 3.01-1.

Date	Rain Gauge 1				Rain Gauge 2			
	Total Rainfall (in)	Total Duration (hrs)	Maximum Rainfall Intensity	Maximum Rainfall Recurrence Interval	Total Rainfall (in)	Total Duration (hrs)	Maximum Rainfall Intensity	Maximum Rainfall Recurrence Interval
4/15	1.23	24	.78 in/3 hour	<2 months, 3 hour	1.28	24	.37 in/1 hour	<2 months, 1 hour
4/25	0.06	9	.02 in/10 min	<2 months, 10 min	0.11	8.5	.04 in/1 hour	<2 months, 1 hour
4/28	0.26	1.67	.19 in/30 min	<2 months, 30 min	0.21	2	.11 in/1 hour	<2 months, 1 hour
4/29	0.30	5	.11 in/30 min	<2 months, 30 min	0.29	4.33	.12 in/30 min	<2 months, 30 min
5/4	0.09	2	.02 in/10 min	<2 months, 10 min	0.21	2.67	.13 in/30 min	<2 months, 30 min
5/7	0.44	2.5	.26 in/1 hour	<2 months, 1 hour	0.44	3	.2 in/30 min	<2 months, 30 min
5/26	0.82	1.5	.55 in/10 min	1.2 year, 10 min	0.91	1	.59 in/10 min	1.25 year, 10 min
5/31					1.03	8.5	.44 in/2 hour	<2 months, 2 hour

The shaded light gray indicates the events chosen for analysis.
The shaded dark gray indicates a period when the associated rain gauge was not working properly.

Table 3.01-1 Rainfall Event Details

The data collected at each rain gauge was used to analyze each rainfall event. The rainfall intensity for the most intense portion of the rainfall event was used to estimate a recurrence interval in accordance with the *Rainfall Frequency Atlas of the Midwest* by Huff and Angel. Rainfall recurrence intervals consider both magnitude and duration of a rainfall event and are based on a statistical analysis representing the probability that the given event will be equaled or exceeded in any given year. For example, in any given year statistically there is a 1 in 2 chance that 0.67 inches of rain will fall in 10 minutes in the Village. Therefore, the event is said to have a 2-year recurrence interval. Furthermore, in any given year statistically there is a 1 in 1 chance that 0.55 inches of rain will fall in 10 minutes. This is considered to have a 1-year recurrence interval. On May 26, RG 2 recorded 0.59 inches of rain in 10 minutes. Since this amount of rainfall is between the 1- and 2-year storms for a 10-minute duration, we interpolated to estimate the event at a 1.25-year recurrence interval.



RG 1 malfunctioned during the event that occurred on May 31.

Figure 3.01-1 Rainfall Events

A rainfall event used for data analysis would ideally be uniform across the Village. A uniform event would result in approximately equal rain gauge data at each gauge location. If the data collected at each rain gauge is approximately equal, it can be inferred that the rainfall between the rain gauges was also approximately equal. This allows us to assume that sewershed basins not next to a rain gauge received approximately the same rainfall observed at a rain gauge which, in turn, allows for a more equal comparison between basins when evaluating the severity of I/I into the system. Each sewershed basin was assigned to one of the two rain gauges.

The most significant events observed during the monitoring period occurred on April 15, May 26, and May 31. The April 15 and May 31 events were characterized by long low-intensity soaking events. While these two events had recurrence intervals less than two months, over 1 inch of rain fell and the flow monitoring data suggest they impacted flow characteristics in the sanitary sewer system.

The May 26 event was a short, but intense, event that occurred after a prolonged period of dry weather. This type of event is a good indicator of sources of inflow in the system because the long period of dry weather before the event most likely resulted in more absorption by the dry soils and may have reduced the impacts of infiltration. With the impact of infiltration reduced, the increase in flows observed as a result of this event was most likely inflow. This inference seems to be supported by the data collected.

3.02 FLOW METER DATA EVALUATIONS

On a weekly basis over the flow monitoring period, the flow metering data was compiled and evaluated to determine two things: (1) the quality of the data collected at each individual flow metering location and (2) how the meters were working relative to each other.

To determine the quality of the data collected, a scatter graph was created for each flow meter each week. The scatter graphs consisted of plotting the velocity data vs. the level data on the same graph. The shape and pattern of the scatter graph provided valuable insight into how the flow meter was functioning and the quality of the data it was collecting as well as how the hydraulic conditions in the sewers were changing during rain events. Figure 3.02-1 shows an example scatter graph created for data evaluation. As should be expected, the data points generally fall into a relatively tight line. This scatter graph suggests the flow meter is collecting good data and the sewer did not surcharge during the month of April.

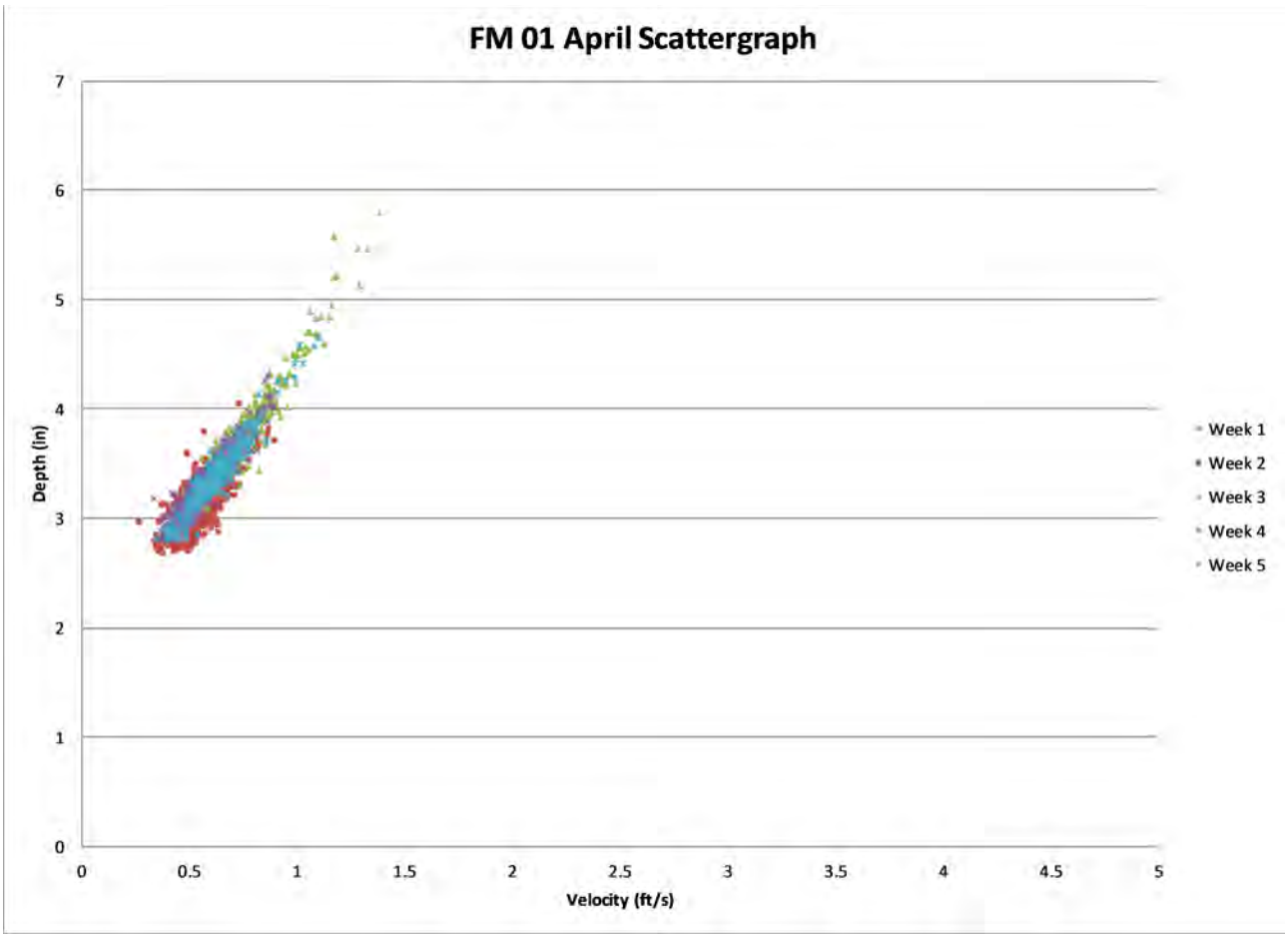


Figure 3.02-1 Example Scatter Graph

To determine how the meters were working relative to each other, a mass balance was calculated between certain flow meters. A mass balance analysis is a comparison between downstream flow data and flow data collected directly upstream. While most flow meters were installed directly upstream of the MWRDGC intercepting sewers, there were some meters upstream of other meters. In these situations, flow meter data was evaluated by removing the influence of upstream meters by subtracting the upstream flow meter data from the downstream data, taking time of travel into account. In theory, any flow generated in an upstream basin should be measured at the flow meter location downstream. Furthermore, additional sewerage collected from within the downstream basin should also be measured at the downstream flow meter. This means the flow rates observed at the downstream meter should always be higher than the flows observed at the upstream meter.

If the results of the data evaluation suggested a flow meter was not working properly, a specific maintenance trip was made to correct the flow meter in question, or the meter was adjusted during the next weekly download.

Appendix B discusses the flow meter data evaluation in more detail providing a narrative description of each flow metering location and the quality of data collected, specifically during the three study events. Appendix B also provides flow response graphs for each flow metering location during each of the three study rainfall events.

3.03 BASELINE FLOW ANALYSIS

A baseline flow analysis was performed to determine the baseline flow characteristics of each sewershed basin.

To determine the baseline flow at each meter, dry weather flow values collected at 10-minute intervals over each dry weather day were averaged to create a 24-hour baseline flow consisting of 144 data points for each basin. For a day to be considered a “dry weather” day, it had to satisfy two criteria: (1) it had to have less than 0.10 inches of rain and (2) there had to be at least 48 hours of dry weather preceding it. Table 3.03-1 shows the results of the baseline flow analysis.

Flow Meter	Baseline Flow (gpm)		
	Minimum	Average	Maximum
FM 01	21.5	32.7	47.2
FM 02	27.1	46.4	83.8
FM 03	6.8	12.5	20.9
FM 04	8.5	16.2	31.7
FM 05	29.2	46.0	60.9
FM 06	8.6	24.8	48.6
FM 07	6.6	8.2	12.2
FM 08	48.7	62.2	83.8
FM 09	27.6	43.2	65.8
FM 10	13.6	16.5	21.0
FM 11	25.9	47.5	69.2
FM 12	55.2	114.0	172.5
FM 13	11.5	25.7	43.2
FM 14	19.1	29.8	51.0
FM 15	16.9	25.2	36.6
FM 16	18.4	72.6	111.3
FM 17	29.1	43.2	70.7
FM 18	36.8	56.5	92.4
FM 19	64.9	89.5	110.9
FM 20	36.2	47.4	56.8
FM 21	13.3	16.6	22.4
FM 22	82.6	122.9	162.1
FM 23	39.0	60.0	91.0
FM 24	48.5	61.8	77.2
FM 25	16.0	24.0	35.5
FM 26	43.1	61.2	87.3
FM 27	95.0	108.9	127.1
FM 28	15.3	28.4	48.9
FM 29	12.6	26.2	61.0
FM 30	46.8	57.2	69.9

Table 3.03-1 Baseline Flow Analysis

The flows presented in Table 3.03-1 represent the baseline flow characteristics for each individual sewershed basin and were used for the wet weather analyses in the next section.

3.04 WET WEATHER FLOW ANALYSIS

A wet weather flow analysis was performed for each sewershed basin for each of the three rain events that occurred on April 15, May 26, and May 31. There were two analyses performed on each basin.

A. Inflow Analysis

The inflow analysis determined the peaking factor of each basin for each event by taking the peak flow observed during the rain event and dividing it by the baseline flow value that occurred at the same time of day. For example, if the peak flow occurred at 2:20 A.M., then the peaking factor was determined by taking the peak flow value and dividing by the baseline flow value at 2:20 A.M. as calculated in the baseline flow analysis. Peaking factor is generally a good analysis of inflow because it quantifies the quick response observed within the system directly caused by rainfall. When there are inflow problems, it tends to cause flows to peak quickly to multiple times higher than the baseline dry weather flows.

Table 3.04-1 shows the results of the peaking factor analysis. Figure 3.04-1 graphically presents the results for each flow meter location. The peaking factors determined for each rainfall are depicted by the three different colored bars. This graphic contrasts the peaking factors at each flow meter providing perspective as to which basins are most susceptible to inflow.

TABLE 3.04-1

INFLOW ANALYSIS–PEAKING FACTORS

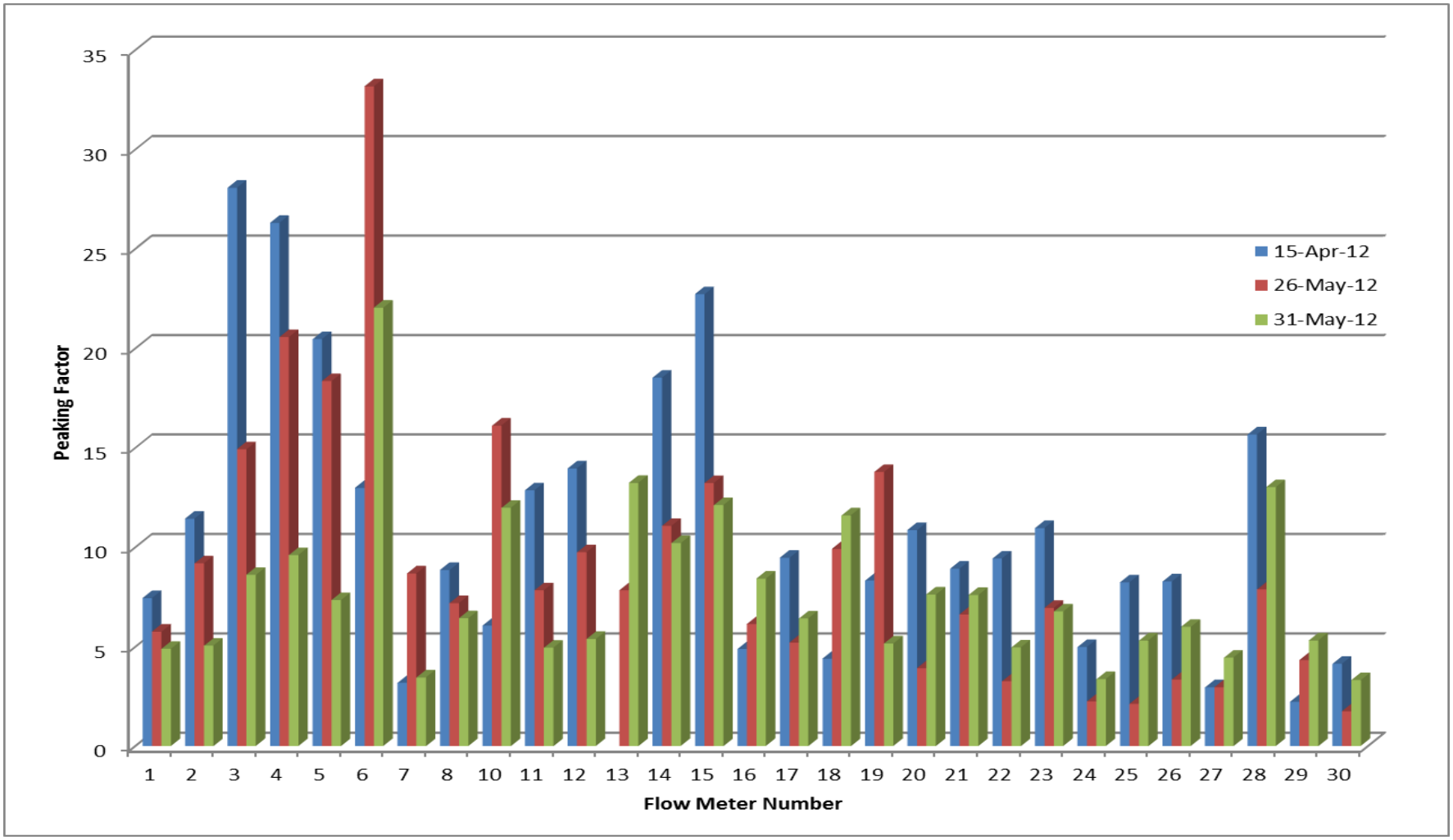
Metered Basin[1]	April 15, 2012			May 26, 2012			May 31, 2012		
	Corresponding Baseline Flow (gpm)	Peak Flow (gpm)	Peaking Factor	Corresponding Baseline Flow (gpm)	Peak Flow (gpm)	Peaking Factor	Corresponding Baseline Flow (gpm)	Peak Flow (gpm)	Peaking Factor
1	22.6	168.3	7.4	35.4	203.3	5.8	34.0	166.4	4.9
2	28.1	321.1	11.4	57.5	528.7	9.2	46.0	232.7	5.1
3	7.2	202.6	28.1	14.8	220.6	14.9	13.1	113.0	8.6
4	9.3	244.3	26.3	21.2	435.9	20.6	18.0	172.5	9.6
5	31.0	635.2	20.5	52.3	959.6	18.4	52.7	386.8	7.3
6	17.0	220.9	13.0	38.9	1288.8	33.2	26.1	576.1	22.0
7	9.7	31.0	3.2	10.4	90.4	8.7	9.1	31.2	3.5
8	50.6	448.1	8.9	69.0	496.5	7.2	64.3	413.4	6.4
9	18.6	406.0	12.5	17.2	549.0	10.2		441.0	7.6
10	18.6	112.8	6.1	17.2	276.8	16.1	14.7	176.3	12.0
11	27.1	348.7	12.9	63.7	498.4	7.8	60.2	297.8	5.0
12	64.1	894.3	14.0	149.7	1458.7	9.8	133.8	720.6	5.4
13[2]				26.5	207.6	7.8	33.4	441.6	13.2
14	19.7	364.1	18.5	32.1	355.1	11.1	31.6	322.7	10.2
15	17.3	393.9	22.7	29.3	386.9	13.2	26.1	316.7	12.1
16	81.4	397.1	4.9	67.3	413.2	6.1	89.9	756.6	8.4
17	29.6	280.3	9.5	48.8	254.2	5.2	44.1	283.4	6.4
18	131.5	577.3	4.4	65.0	644.3	9.9	58.5	678.3	11.6
19	67.8	563.8	8.3	103.6	1427.6	13.8	100.0	516.1	5.2
20	37.2	403.8	10.9	53.0	207.3	3.9	52.4	399.1	7.6
21	13.7	122.5	8.9	17.6	116.7	6.6	16.7	127.2	7.6
22	83.2	784.7	9.4	137.9	450.0	3.3	131.7	653.2	5.0
23	39.6	434.5	11.0	67.3	468.3	7.0	64.6	437.9	6.8
24	49.2	244.9	5.0	67.6	152.5	2.3	65.0	219.3	3.4
25	16.2	133.6	8.2	26.2	55.5	2.1	25.0	132.9	5.3
26	43.4	359.0	8.3	70.1	234.0	3.3	67.9	407.5	6.0
27	96.1	374.8	3.0	109.2	323.0	3.0	115.7	514.5	4.5
28	16.5	259.2	15.7	32.8	258.5	7.9	30.0	390.6	13.0
29	58.8	131.2	2.2	7.6	33.1	4.3	11.0	58.4	5.3
30	40.7	168.3	4.1	61.6	108.0	1.8	57.8	191.5	3.3

[1] FM9 was omitted from the analysis because it was installed to capture overflows from Basin 13. See Section 3.05 for details.

[2] Gray shading indicates the meter was not functional. Refer to Section 3.05 for details.

FIGURE 3.04-1

PEAKING FACTORS AT FLOW METERS



B. Infiltration Analysis

The infiltration analysis looked at the elevated flows in the system over a period of time following the rainfall event and involved calculating an infiltration volume for each sewershed basin for each wet weather event and normalizing the volume based on inch-diameter miles of sewer in each basin. The volume of infiltration for each basin was determined by calculating the flow volume starting 30 minutes after the conclusion of the rainfall event until the flow in the sewer returned to baseline flow levels and then subtracting the baseline volume over the same period of time. The reason for waiting 30 minutes after the rainfall event was to isolate the infiltration portion of the sewer flow response. If the analysis was performed starting at the beginning of the event, it would include the effects of inflow into the system. A 30-minute delay was used because most of the sewershed basin areas are small enough that surface flow and runoff, which represents inflow, would have enough time to get in the system and not skew the results of the analysis. Furthermore, the shapes of the hydrographs presented in Appendix B show a majority of the peak flows have significantly dropped off after approximately 30 minutes suggesting the delay appropriately isolates the sources of infiltration.

The final step of the analysis divided the volume calculated as described above by the inch diameter-miles calculated for each basin, as presented in Table 2.02-2. Table 3.04-2 shows the results of the infiltration analysis.

Figure 3.04-2 graphically presents the results for each flow meter location. The infiltration rate determined for each rainfall is depicted by the three different colored bars. This graphic contrasts the infiltration rate at each flow meter, providing perspective as to which basins are most susceptible to infiltration.

TABLE 3.04-2

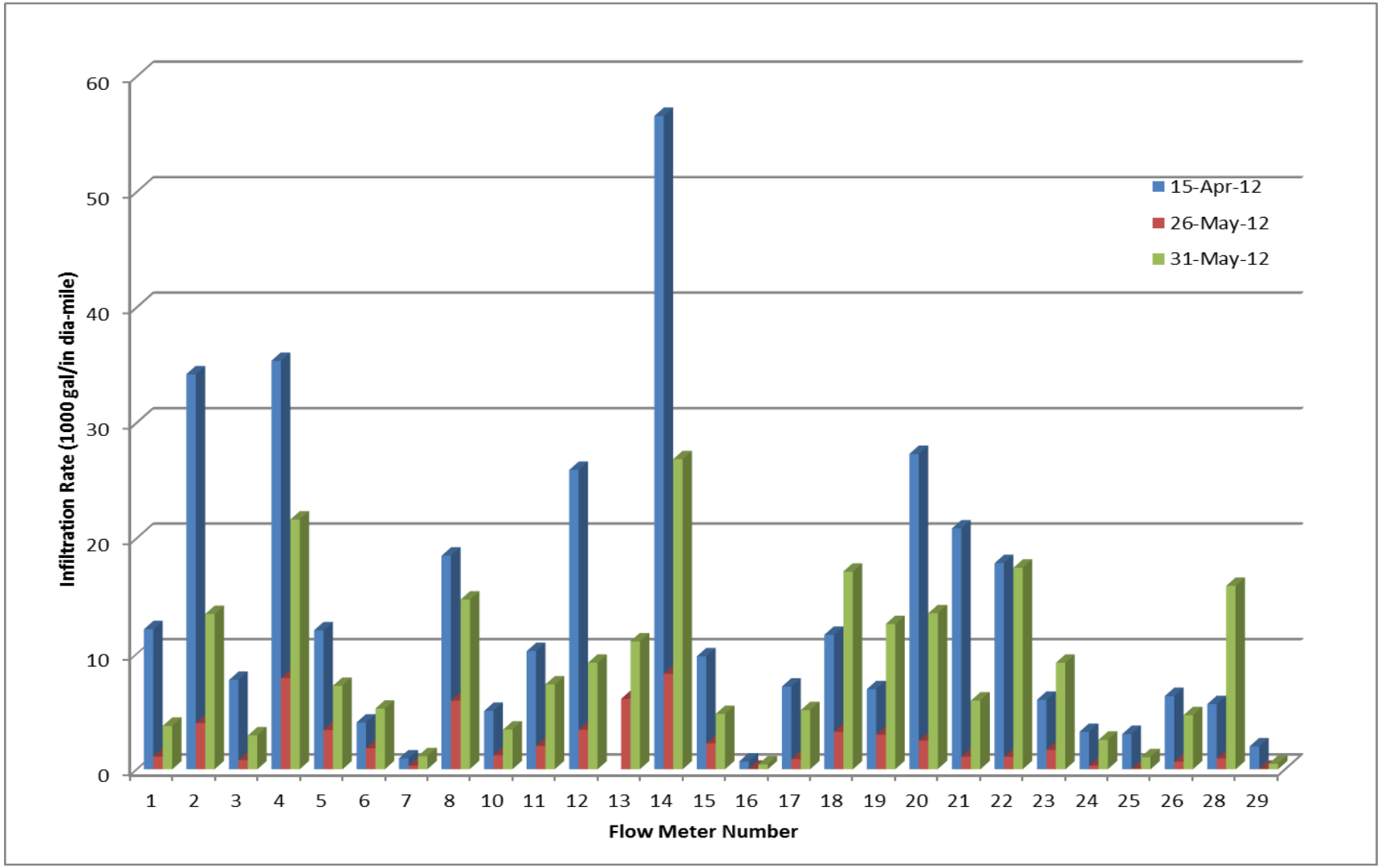
INFILTRATION ANALYSIS

Metered Basin[1]	April 15, 2012		May 26, 2012		May 31, 2012	
	Infiltration Volume (1000 gal)	Infiltration Rate (1000 gal/inch dia.-mile)	Infiltration Volume (1000 gal)	Infiltration Rate (1000 gal/inch dia.-mile)	Infiltration Volume (1000 gal)	Infiltration Rate (1000 gal/inch dia.-mile)
1	99.93	12.12	8.95	1.09	31.15	3.78
2	256.99	34.19	30.14	4.01	100.56	13.38
3	87.23	7.76	8.54	0.76	32.8	2.92
4	139.47	35.49	31	7.89	84.92	21.61
5	119.94	12.02	33.54	3.36	72.47	7.26
6	104.67	4.04	46.9	1.81	135.69	5.23
7	15.8	0.94	5.49	0.33	18.67	1.11
8	190.2	18.52	60.73	5.91	150.76	14.68
10	50.02	5.07	11.75	1.19	33.99	3.44
11	141.96	10.23	27.55	1.99	101.71	7.33
12	879.53	25.91	116.4	3.43	313.04	9.22
13[2]			94.05	6.10	170.57	11.06
14	136.92	56.54	19.68	8.13	64.7	26.72
15	99.85	9.76	22.64	2.21	48.67	4.76
16	14.22	0.68	0.96	0.05	9.42	0.45
17	106.33	7.18	12.69	0.86	76.5	5.17
18	416.11	11.63	66.25	3.26	348.09	17.11
19	152.6	6.92	66.01	2.99	276.68	12.55
20	198.03	27.31	18.19	2.51	97.81	13.49
21	77.07	20.87	4.29	1.16	21.99	5.96
22	360.53	17.83	21.58	1.07	353.29	17.47
23	90.26	6.03	24.68	1.65	138.33	9.24
24	52.02	3.24	5.17	0.32	41.01	2.55
25	96.25	3.06	1.53	0.05	32.56	1.04
26	106.68	6.32	11.09	0.66	79.28	4.70
28	59.69	5.61	9.77	0.92	168.86	15.86
29	7.86	1.95	0.17	0.04	1.94	0.48

[1] FM9, FM27, and FM30 were omitted from this analysis. See Section 3.05 for details.
[2] Gray shading indicates the meter was not functional. Refer to Section 3.05 for details.

FIGURE 3.04-2

INFILTRATION RATES AT FLOW METERS



3.05 ANALYSIS ANOMALIES

Overall, the data collected by the flow meters was generally of good quality and analyses of I/I were successful for all of the sewershed basins. However, as evident from the tables and figures presented in Sections 3.03 and 3.04, there were a few basins not included in the analyses. This section explains why some data was omitted from the analyses.

A. FM 09

Flow meter (FM) 09 was installed in a relief sewer that acted as an overflow from Basin 13 (see Figure 2.02-2). As a result, the data collected from FM 09 was used to supplement the data collected at FM 13 and FM 18. The flow recorded at FM 09 had to be added to the data collected at FM 13 and FM 18 to quantify the actual flow rates generated within those sewershed basins because it overflowed from the basin before being recorded by the respective flow meters.

Since this flow meter was installed strictly as a supplement to other meters, it was not analyzed directly. However, the data was incorporated for both the I/I analyses for Basins 13 and 18.

B. FM 13

All flow metering equipment was calibrated and certified by the manufacturer before beginning the flow metering program. However, as sometimes happens with electrical equipment, an error occurred at FM 13 shortly after it was installed on April 9 causing it to not record data. The error was discovered and addressed during recalibration of the meter on April 11 and verified to be working properly during data download on April 14. Unfortunately, the meter once again failed and did not record data during the April 15 wet weather event. The meter was replaced and worked properly for the remainder of the flow metering period.

Since data was not obtained for the April 15 event at FM 13, that basin was not analyzed for the April 15 event. Instead, Basin 18 was expanded to include Basin 13 for the analyses of the April 15 event.

C. FM 27 and 30

These meters were installed to monitor the flow into the Village system from an unincorporated development outside the Village limits served by the Woodley Road Sanitary District. They were installed to quantify the outside impacts to the Village's system. These basins were included in the inflow analysis but not the infiltration analysis because information regarding the length and size of pipes within these basins was not available.

3.06 CONCLUSIONS

The reports of basement backups during the July 23, 2011 storm event suggest the Village's sanitary sewer system is susceptible to I/I that could have contributed to the basement backups. While none of the metered rainfall events between April 9, 2012, and June 8, 2012, were large enough to mirror the conditions that occurred during the July 23, 2011 event, the flow metering data collected during this

study affirms the presence of I/I within the system. Additionally, the data presented in the figures from Section 3.04 suggest the sources of I/I are widespread throughout most of the system.

Ideally the flow monitoring data would identify a group of specific basins where the sources of I/I are significantly more pronounced than the rest of the basins making it clear which basins are priorities for further investigations and focused attention on reduction of I/I. In the Village's case, this identification is not as clear cut. Therefore, a ranking methodology was used to quantify the relative magnitude of I/I produced in each sewershed basin.

A. Ranking Methodology

The results of the I/I analyses were used to rank the basins. Considering the inflow analysis results, each basin was given a score of 1 through 29 (Basin 09 was not included in the ranking) with the basin having the highest peaking factor receiving a score of 1 and the lowest peaking factor receiving a score of 29. Considering the infiltration analysis, each basin was given a score of 1 through 27 (Basins 09, 27, and 30 were not included in the ranking) with the basin having the highest infiltration rate receiving a score of 1 and the basin with the lowest infiltration rate receiving a score of 27.

Once scores were given for each basin for each event and for each analysis, an overall score was calculated by adding the two average scores together. The basins were then ranked based on the overall average score.

As previously noted, Basin 13 was not functioning during the April 15 event. Therefore, the overall score for Basin 13 was based on four individual scores rather than six.

B. Ranking Results

Tables 3.06-1, 3.06-2, and 3.06-3 show the results of the three sets of rankings. Table 3.06-1 shows rankings based on the peaking factor analysis. Table 3.06-2 shows the rankings based on the infiltration analysis. Table 3.06-3 is the overall basin rankings taking into account both the I/I analyses.

TABLE 3.06-1

PEAKING FACTOR RANKINGS

Rank	Flow Metering Basin	Average Score	April 15, 2012		May 26, 2012		May 31, 2012	
			Peaking Factor	Score	Peaking Factor	Score	Peaking Factor	Score
1	6	3.33	12.98	8	33.16	1	22.04	1
2	4	4	26.3	2	20.56	2	9.6	8
3	15	4.67	22.72	3	13.22	7	12.12	4
4	3	5	28.07	1	14.92	5	8.61	9
5	14	6.67	18.52	5	11.07	8	10.21	7
6	5	7	20.46	4	18.35	3	7.34	14
7	28	7.67	15.67	6	7.88	14	13.02	3
8	13	8.5			7.83	15	13.23	2
9	10	10.33	6.06	22	16.11	4	11.98	5
10	12	12.33	13.96	7	9.75	11	5.39	19
11	18	13.67	4.39	25	9.91	10	11.6	6
12	23	15	10.96	12	6.95	18	6.77	15
13	19	15.33	8.32	18	13.78	6	5.16	22
13	2	15.33	11.43	11	9.19	12	5.05	23
15	21	15.67	8.92	16	6.62	19	7.6	12
16	20	16	10.86	13	3.91	24	7.62	11
17	11	16.33	12.86	9	7.83	15	4.95	25
18	8	16.67	8.85	17	7.19	17	6.43	16
19	17	17.67	9.47	14	5.2	22	6.42	17
20	16	18	4.88	24	6.14	20	8.42	10
21	26	20.67	8.28	19	3.34	25	6	18
22	22	21.67	9.43	15	3.26	26	4.96	24
23	1	22.67	7.44	21	5.75	21	4.89	26
23	7	22.67	3.18	27	8.68	13	3.45	28
25	25	23	8.23	20	2.12	29	5.31	20
26	29	24	2.23	29	4.32	23	5.31	20
27	24	26.67	4.98	23	2.25	28	3.37	29
28	27	27.33	2.96	28	2.96	27	4.45	27
29	30	28.67	4.14	26	1.75	30	3.32	30

TABLE 3.06-2

INFILTRATION ANALYSIS RANKINGS

Rank	Flow Metering Basin	Average Score	April 15, 2012		May 26, 2012		May 31, 2012	
			Infiltration Rate	Score	Infiltration Rate	Score	Infiltration Rate	Score
1	14	1	56.57	1	8.26	1	26.84	1
2	4	2	35.37	2	7.89	2	21.63	2
3	2	5.33	34.19	3	3.99	5	13.44	8
4	8	5.67	18.5	7	5.94	4	14.7	6
5	13	6.5			6.09	3	11.08	10
6	20	7	27.3	4	2.48	10	13.51	7
7	12	7.33	25.92	5	3.42	6	9.22	11
8	18	7.67	11.63	11	3.24	8	17.1	4
9	22	9	17.85	8	1.09	16	17.45	3
10	5	10.33	12.03	10	3.41	7	7.22	14
11	19	11.33	6.94	16	2.99	9	12.57	9
12	11	12.33	10.23	12	2.02	12	7.35	13
13	21	13	20.85	6	1.08	18	5.96	15
14	15	14	9.78	13	2.25	11	4.79	18
15	23	14.33	6.01	18	1.67	14	9.22	11
15	28	14.33	5.64	19	0.94	19	15.88	5
17	1	15	12.13	9	1.09	16	3.76	20
18	6	16.67	4.05	21	1.81	13	5.25	16
19	17	17.33	7.16	15	0.88	20	5.13	17
20	10	18.67	5.07	20	1.22	15	3.44	21
21	3	19	7.74	14	0.8	21	2.94	22
22	26	19.33	6.34	17	0.65	22	4.68	19
23	24	22.67	3.24	22	0.31	23	2.55	23
24	7	24.33	0.95	25	0.3	24	1.13	24
24	25	24.33	3.05	23	0.06	25	1.05	25
26	29	25.67	1.98	24	0.04	27	0.48	26
27	16	26.33	0.67	26	0.05	26	0.43	27

TABLE 3.06-3

OVERALL BASIN RANKINGS

Rank	Flow Metering Basin	Overall Score	Peaking Factor Average Score	Infiltration Rate Average Score
1	4	6	4	2
2	14	7.67	6.67	1
3	13	15	8.5	6.5
4	5	17.33	7	10.33
5	15	18.67	4.67	14
6	12	19.66	12.33	7.33
7	6	20	3.33	16.67
8	2	20.66	15.33	5.33
9	18	21.34	13.67	7.67
10	28	22	7.67	14.33
11	8	22.34	16.67	5.67
12	20	23	16	7
13	3	24	5	19
14	19	26.66	15.33	11.33
15	11	28.66	16.33	12.33
16	21	28.67	15.67	13
17	10	29	10.33	18.67
18	23	29.33	15	14.33
19	22	30.67	21.67	9
20	17	35	17.67	17.33
21	1	37.67	22.67	15
22	26	40	20.67	19.33
23	16	44.33	18	26.33
24	7	47	22.67	24.33
25	25	47.33	23	24.33
26	24	49.34	26.67	22.67
27	29	49.67	24	25.67

3.07 BASIN PRIORITIZATION

Table 3.06-3 presents overall basin rankings solely based on the I/I observed during the flow monitoring period. However, there are other factors that contribute to prioritization of the basins that can not necessarily be quantified with data analysis. One such factor is the results of the flooding survey presented in Figure 2.02-1. In addition, sources of inflow are traditionally both easier and less expensive to locate and repair. As a result, the ranking system combined with engineering judgment accounting for the flooding survey results and potential future costs, help determine the prioritization and schedule for future investigations.

A. Highest Priority Basins

Figure 3.07-1 shows the basins given the highest priority for future investigations. The following discusses why each basin was chosen.

Basin 04 was included as a high priority because of how high it ranked based on the data collected during the flow metering period supported by the flooding reported as a result of the July 23, 2011 event.

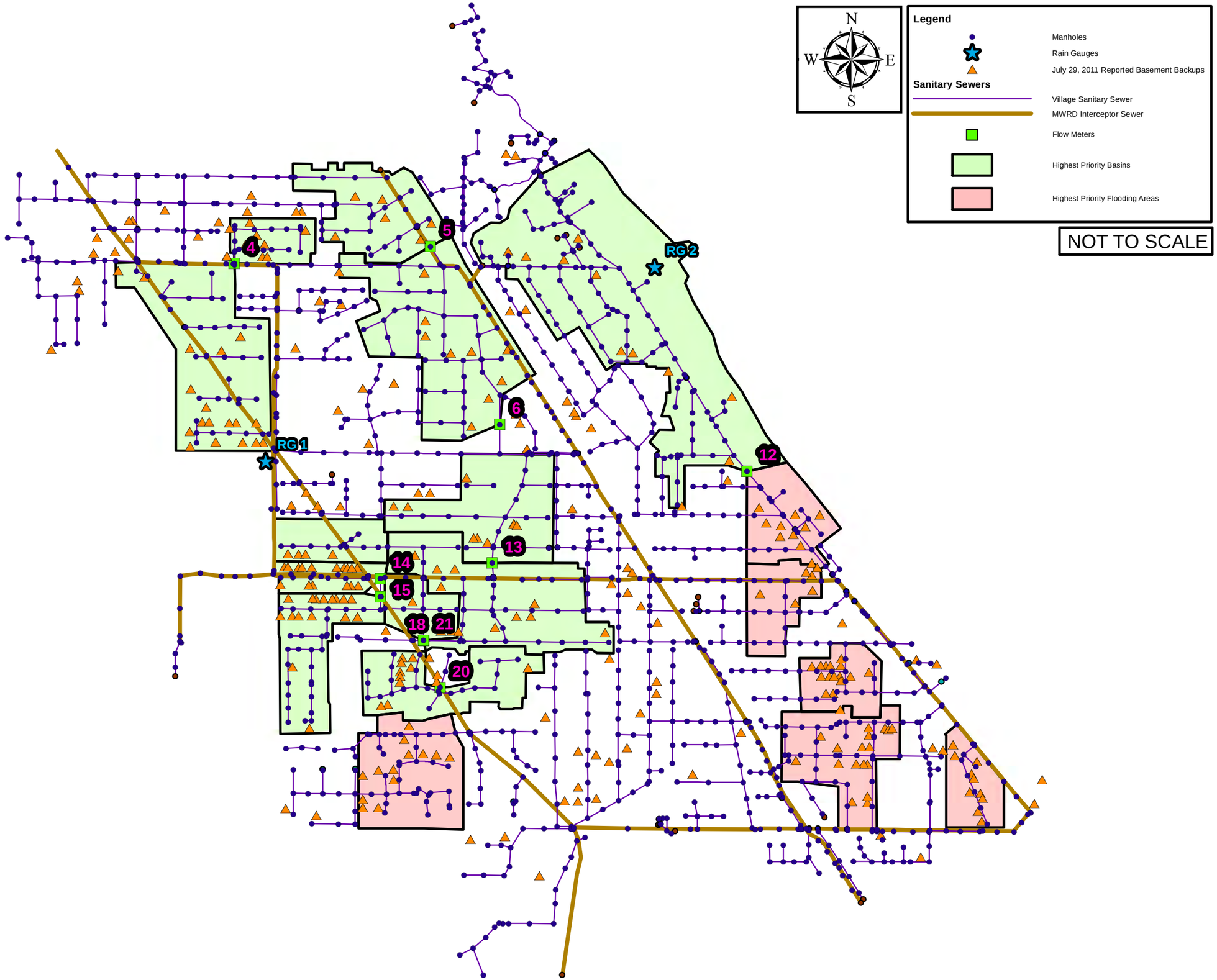
Basin 14 exhibited high values of both inflow and infiltration and was ranked second highest in the ranking system, and it also showed significant flooding according to the flood survey results.

Basin 15 was prioritized because it is a top ten basin according to the rankings, but more importantly the flooding survey suggests extensive flooding in this area. Also, its proximity to Basin 14 makes it a logical basin for future investigation.

Basins 05, 06, 13, and 18 were included in the highest priority group because each basin ranked high in the overall rankings and the peaking factor rankings. In addition, flooding was reported in each of those basins according to the survey results. Most importantly however, these basins interact very closely because they are in series (see Figure 2.02-2). Furthermore, the presence of a relief sewer from Basin 13, which also relieves Basin 18, suggest that excess flow has historically been an issue throughout these basins.

Basin 21 was included as a high priority basin not because the rankings suggest this basin is subject to extensive I/I but because it includes an overflow to Basins 14 and 15 and future investigations appear warranted throughout this area.

Basin 12 was included as a high priority basin because it ranked high in the overall rankings. While the risk of basement backups in this area appears low because of the topography of the basin and relatively few basement backups indicated in the flood survey, removing the excess flow would provide added capacity downstream and could benefit Basin 16. According to the flow metering data, Basin 16 does not appear to be a basin with high I/I; however, the flooding survey suggests there is a problem with basement backups along the main sewer on Sheridan Road. This could be because I/I from Basin 12 is reducing the capacity of the sewers within Basin 16 and it is the lack of capacity causing the reported problems in Basin 16.



HIGHEST PRIORITY BASINS

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WINNETKA, IL

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FIGURE 3.07-1

There are several areas of the Village that were not metered that reported basement backups in the flood survey, specifically the areas west of Basin 07 and north of Basin 14. These areas are also recommended to be included as high priority areas.

The results of the flood survey indicate there were several clusters of heavy flooding located within basins that, from a flow metering perspective, do not appear to have significant sources if I/I. Specifically these clusters appear within Basins 16, 17, 20, 23, 24, 25, and 26. Despite the flow metering data suggesting these basins do not require high priority, the specific cluster areas should be treated as a high priority to identify potential specific sources of I/I concentrated in these areas.

B. Remaining Basins

The flood survey report and the results of the flow metering analyses indicate there are other areas of the Village that have concerns with I/I and potential for basement backups. The intention of the highest priority basin ranking is not to exclude these other areas but to give the Village focus on where to start further investigations. As discussed in Section 5, the remaining basins will be addressed following the further investigation of the priority areas and follow-up evaluations of I/I removal success.

SECTION 4
FURTHER INVESTIGATIONS

4.01 MOVING FORWARD

The purpose of the flow monitoring study was to identify areas of the Village's sanitary sewer system where I/I is most prolific. The study findings, as well as the results of the Village's flood survey for the July 23, 2011 event, have provided an understanding of where the Village's sanitary sewer system is susceptible to excess flow because of wet weather conditions. Moving forward, this information will be used to guide investigations to pinpoint the sources of excess flow into the system and develop a plan for eliminating these sources and reducing excess flow.

Sources of I/I are identified through a series of physical investigations described in the following section.

4.02 INVESTIGATION METHODS

The following methods are used to locate sources of I/I. Although both inflow and infiltration are important contributors to excess flow in the sewer system, sources of inflow are of immediate concern to the Village because they have the most direct impact on surcharging and basement flooding. Additionally, sources of inflow are often easier to find and less expensive to remove. For this reason, locating inflow sources is emphasized in this report. Assessments of infiltration will also come out of these investigations and will be used to provide insight into the condition of the sewer infrastructure.

A. Manhole Assessments

Manholes can be a large contributor of inflow into a sanitary sewer system. There are a number of defects within the top half of a manhole where inflow can enter in the system. For instance, open pick holes, missing bolts, torn gaskets, offset frames, and broken riser rings are not uncommon and all allow water to seep into the manhole. If a manhole is located in a low area that holds water or in the path of concentrated rainfall runoff, the impacts of these defects are significantly increased. A manhole assessment program involves visually inspecting manholes, their location, and identifying, categorizing, and quantifying the impacts of each manhole defect.

The data gathered during a manhole assessment program is entered into a database that conveniently stores the data, integrates with geographic information systems (GIS) and is a valuable tool for planning repairs. Physical investigations identify the defects and an overall condition of the manhole. The location and nature of each defect is recorded and given a severity rating of minor, moderate, or severe. Initial recommendations for rehabilitation are made by field staff performing the assessment. The magnitude of inflow associated with each defect is also estimated for use in predicting benefit versus cost for rehabilitation. Appendix C includes an example of an inspection form used for the assessment of manholes.

B. Smoke Testing

Smoke testing is a process that involves blowing a white, odorless simulated smoke into the sanitary sewer system, which, as opposed to water seeping into the system, allows smoke to seep out of the system. In locations where water enters the system, the smoke will exit the system. The smoke is nontoxic, does not leave a residue, and is produced chemically rather than with fire. Figure 4.02-1 provides a visual of this process. Field staff visually observe the areas surrounding the smoke testing operation to locate where smoke is leaving the system. Each instance of smoke is documented via photograph and on a Smoke Testing Field Log. Figure 4.02-2 provides an example photograph taken during smoke testing showing a cross-connection between the sanitary sewer system and the storm sewer system.

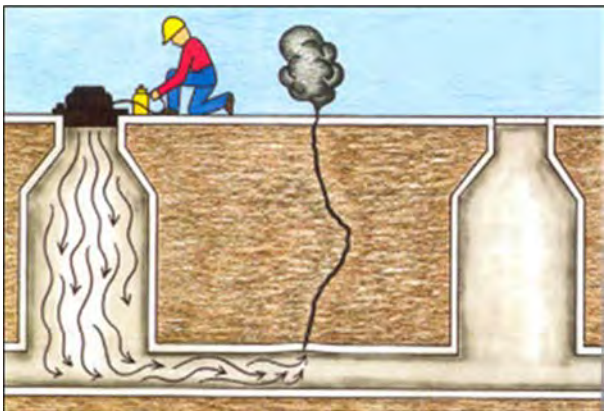


Figure 4.02-1 Smoke Testing Concept

Smoke testing serves multiple purposes. It can identify sources of inflow not directly related to the condition of the manholes in the system. Sources such as connected downspouts, foundation drains, sump pump connections, and storm sewer cross-connections are readily located. Smoke testing also confirms observations made during the manhole assessment program. If there are defects, such as broken riser rings, offset frames, or open pick holes, smoke will exit the system at these locations.

Figure 4.02-2 Example of a Storm Sewer Cross-Connection

Smoke testing is also a valuable tool for focusing other more expensive investigations such as televising and dye testing.

C. Sewer Televising

Sewer televising involves inserting a camera into the sanitary sewer system to observe the condition of the pipe system. Figure 4.02-3 shows a still shot from a televising project. Clear water entering the sanitary sewer system through a pipe defect is observed by the televising crew. Televising can be expensive and time-consuming. Therefore, this investigation technique is often done after a smoke testing program. Televising efforts are concentrated in locations where smoke showed evidence of defects making the operation more efficient from both a time and cost perspective.

Figure 4.02-3 Clear Water Entering a Separate Sanitary System During Televising

Televising generally identifies sources of infiltration from pipe defects. However, it can also be valuable in identifying inflow sources. For example, a connected sump pump could be indicated by intermittent or continual clear water flow from a lateral. Coupled with dye testing (discussed below), televising will identify where stormwater cross-connections enter the system. Televising also finds major defects such as collapsed pipes. A collapsed pipe can restrict flow in a sewer and the excess flow through the broken pipe reduces system capacity. The reduced capacity can cause a system bottleneck contributing to basement backups. Additionally, a sewer collapse can be the source of significant infiltration. While normally infiltration does not contribute much to basement backups, a significant sewer break can contribute so much infiltration volume relatively quickly that it acts similar to inflow.

D. Dye Testing

Dye testing is a method often done in conjunction with sewer televising. It involves flooding the storm sewer system with a bright-colored nontoxic dye that is used to both confirm and quantify inflow sources associated with storm sewer cross-connections.

Dye testing is another method that is both expensive and time intensive. Therefore, it is most appropriately done when the results of smoke testing suggest there is a cross-connection between the storm and sanitary sewer systems. Once the storm sewer system is flooded with dye, the adjacent sanitary sewers are televised. If there is a cross-connection between the systems, the dyed water appears in the sanitary sewer and is captured by the televising crew.

4.03 ADDITIONAL INVESTIGATIONS

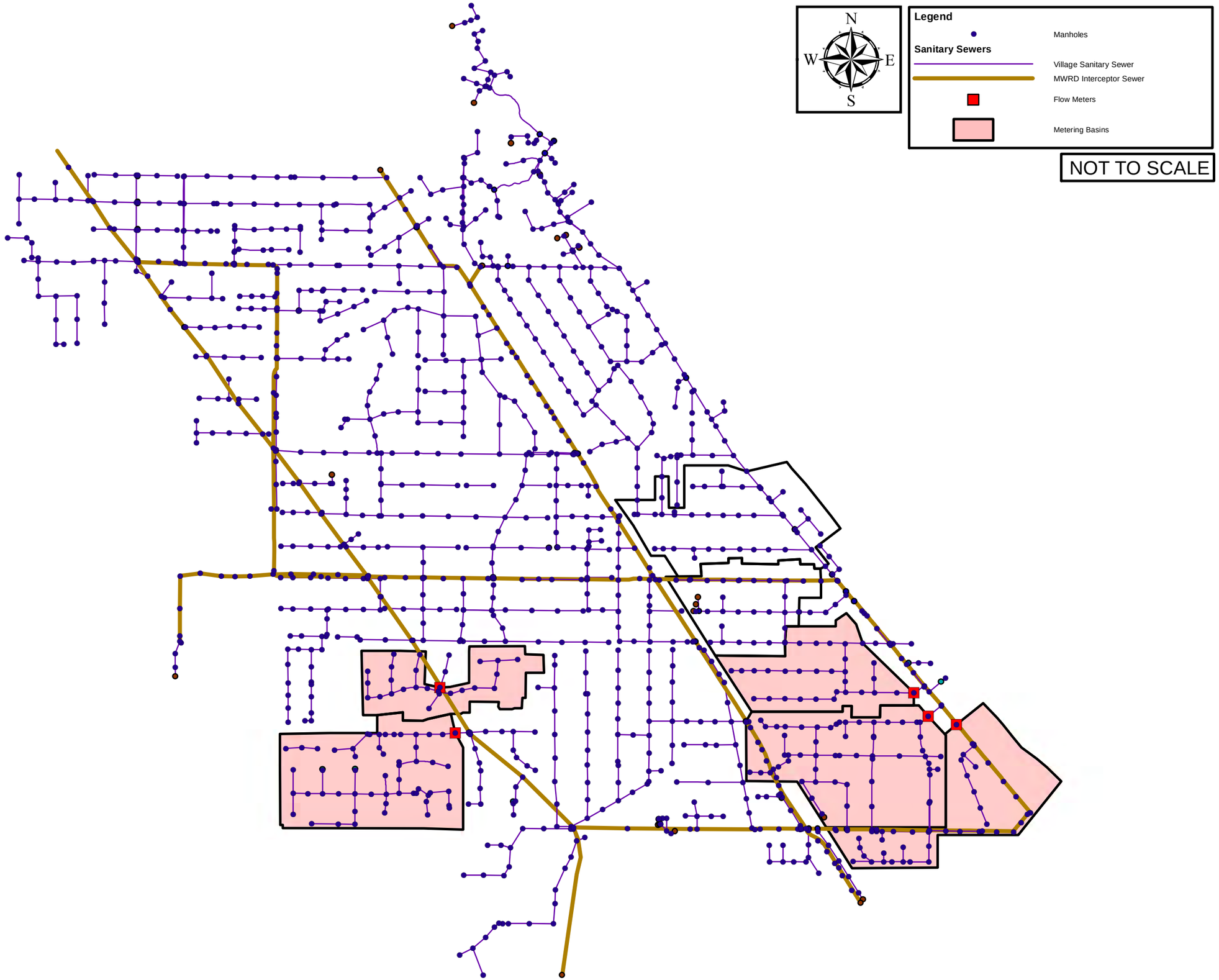
The investigations presented above are standard practices that are commonly used for all SSES studies regardless of system characteristics. However, the Village has some unique factors, as indicated by the July 23, 2011 flood study, that could be causing basement backups in the system. As discussed in Section 3, the flood study indicated large clusters of flooding in basins where the flow monitoring data did not suggest significant sources of I/I exist. This suggests there are other factors which contributed to the system flooding that are triggered during large events but not smaller ones.

Review of the flood study seems to indicate a number of the reported flooding clusters occurred fairly close to the MWRDGC intercepting sewers. It is possible these areas experienced basement backups as a result of surcharging in the MWRDGC intercepting sewers. There are a number of

reasons that could cause the MWRDGC interceptors to surcharge, including excessive wet weather flows from the surrounding communities such as Wilmette and Kenilworth that also discharge into the MWRDGC sewer system. Unfortunately, none of the rainfall events that occurred over the flow monitoring period were very significant and it is not believed that the capacity of the MWRDGC interceptors was exceeded. Additionally, none of the flow data studied indicated the MWRDGC interceptors backed up into the Village system.

To evaluate whether the MWRDGC is impacting Winnetka's sewer system, particularly where the flood clusters were identified, a cursory survey and hydraulic study of the MWRDGC interceptor system and the Village sewer system should be performed. This would include review of engineering drawings for the MWRDGC system as well as performing a cursory elevation survey of the Village system. The relationship of the MWRDGC system to the Village system would provide important insight into the potential for impact because of surcharging of the MWRDGC system.

Additionally, installation of flow meters at key locations and collection of flow and rain data for an extended period of time may result in capturing a large enough rainfall to evaluate from a flow metering standpoint whether the MWRDGC interceptors impact the Village's sewers. Figure 4.03-1 presents a suggested extended flow monitoring program that includes installation of five flow meters for an eight-month monitoring period from the beginning of March through the end of October. This schedule allows the meters to be installed during the wet spring months, during the summer thunderstorm season, and the traditionally wet fall season maximizing the potential of capturing an event that results in surcharged interceptors.



EXTENDED FLOW METERING PROGRAM

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VILLAGE OF WINNETKA
WINNETKA, IL

STRAND ASSOCIATES®

FIGURE 4.03-1

SECTION 5
RECOMMENDED SSES INVESTIGATION PLAN

5.01 NEXT STEPS

The next step in the Village's SSES is to plan for and undertake an investigation program to identify sources of excess flow. These investigations are generally performed in phases based on weather conditions. Figure 5.01-1 provides a graphic of typical phasing of investigations. Manhole assessments are performed during wet weather when susceptibility to runoff and sources of flow into the manholes will be most noticeable. Smoke testing is performed during dry weather when the ground is dry and will allow smoke to easily travel to the surface. Televising is typically performed during wet weather when sources of flow into the sewer are most noticeable and is often done in conjunction with dye testing.

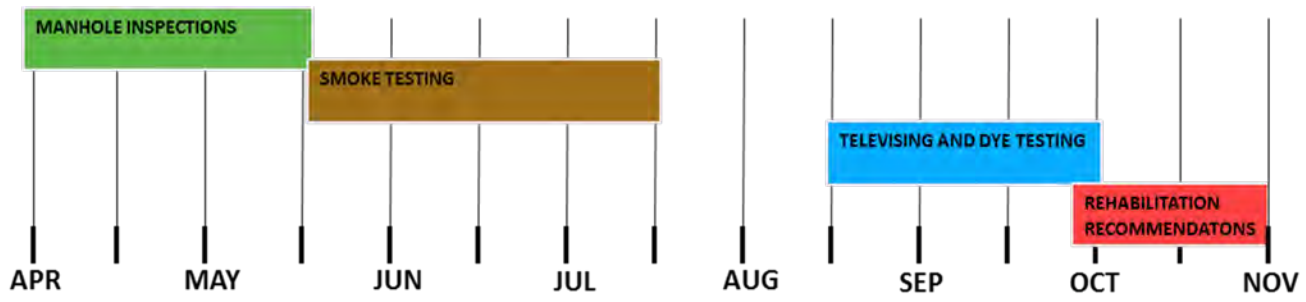


Figure 5.01-1 Typical Yearly Phasing of Further Investigations

5.02 OPINION OF PROBABLE COST

The cost to perform the SSES investigations and develop rehabilitation recommendations for the priority basins is approximately $180,500. This cost includes $77,500 in sewer cleaning and televising costs. Since the quantity of televising that may be necessary in each basin is not certain at this time, this opinion of cost anticipates 50 percent of each basin being televised. This estimate is based on past similar projects but may change based on results of the other SSES investigations.

The opinion of probable cost to perform SSES investigations on the remaining basins is approximately $235,000. This cost includes $100,000 in sewer cleaning and televising costs, anticipating 50 percent of each basin being televised.

The opinion of probable cost to perform SSES investigations over the entire Village is approximately $415,500. Appendix D provides a breakdown of these costs for each individual basin.

An opinion of probable cost was also developed for the additional investigations discussed in Section 4.03. The cost to perform a cursory elevation survey and hydraulic study of the MWRDGC interceptor sewer system and the Village's sanitary sewer system is approximately $30,000.

The opinion of probable cost to perform a supplemental flow monitoring program is approximately $134,000. This program includes installation of five flow meters for an eight-month period to study the areas shown in Figure 4.03-1 and anticipates the Village contracting with a consultant to supply, install, maintain, and remove the flow meters.

As an alternative to using a consultant, the option of the Village purchasing a number of meters and performing installation, calibration, interrogation, and removal of the meters itself was investigated. This alternative was determined to be advantageous to the Village because it significantly reduces costs and provides flexibility for the Village to install and rotate meter locations as desired. The opinion of probable cost for purchasing these flow meters is $24,500. This includes the cost of three 2150 ISCO area velocity flow meters, the associated ancillary equipment, including computer software, transducers, mounting rings, and training of Village staff by Strand Associates, Inc.®. This cost anticipates purchase of only three meters, which would be rotated as desired to study the five priority locations. After consideration of this alternative, the Village decided to proceed with this option.

5.03 RECOMMENDED INVESTIGATION PLAN

Planning for the SSES investigations and the resulting rehabilitation efforts needs to fit into the Village's capital improvements budget. Based on discussions with Village staff, it is recommended the Village proceed with a pilot SSES investigation program in the fall of 2012. The pilot program is designed to investigate a cross section of areas including priority basins and areas that reported significant flooding in July 2011. The intent of the pilot program is to provide the Village with a sample of defects found in the Village's system and the type of rehabilitation methods required to address the problems. From this information a projection of potential rehabilitation costs for the entire Village will be made and then programmed into the Village's Capital Improvement budget. Figure 5.03-1 shows the basins and areas chosen for the pilot SSES program.

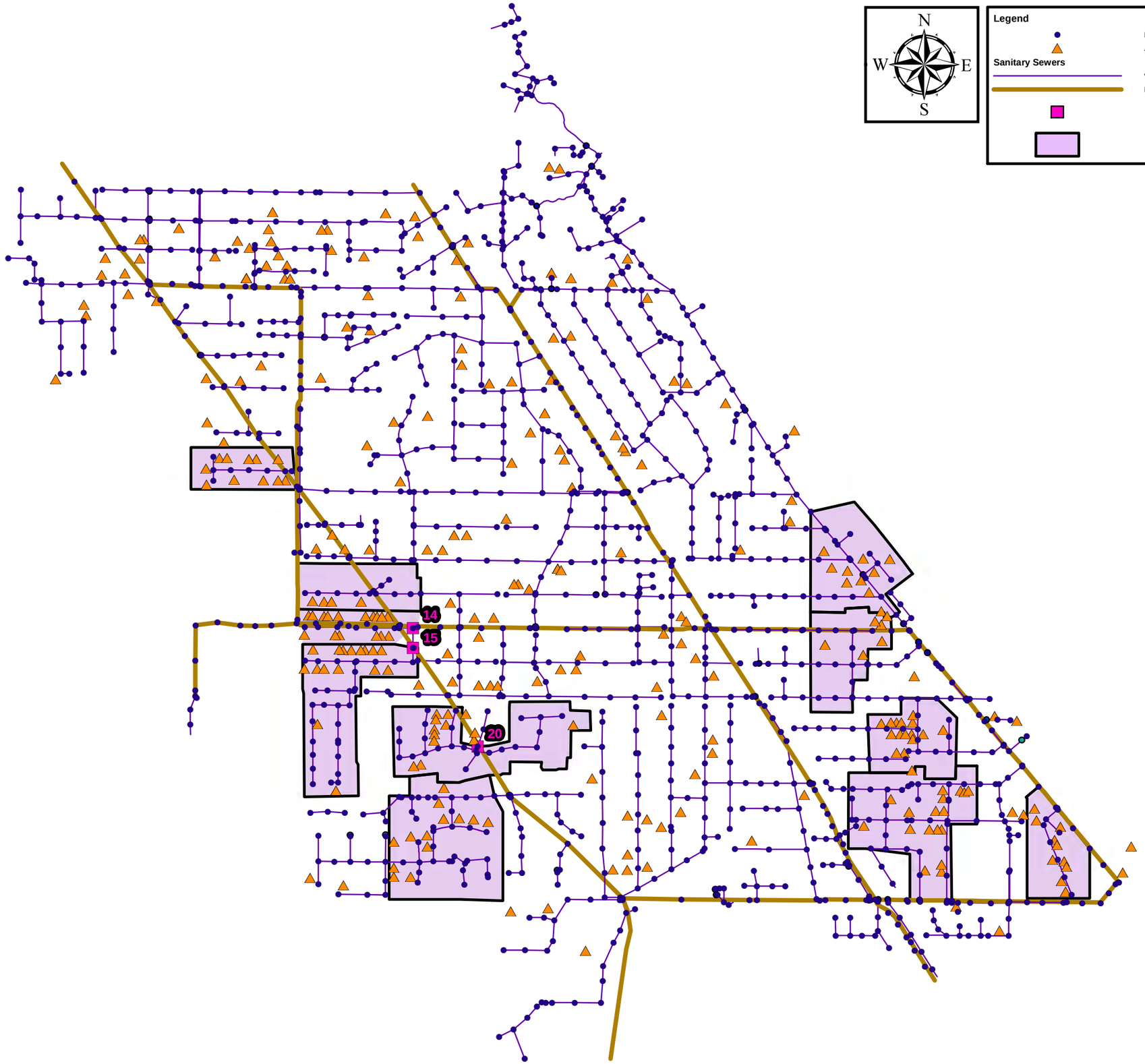
Over the subsequent two years, all the SSES investigations will be performed for the entire Village sanitary sewer system. The first year will include all the priority areas, the second year would include the remaining areas. Additionally, in the first year, the hydraulic analysis and extended flow metering program will be performed.

Table 5.03-1 presents the schedule and opinion of cost to undertake the SSES investigations. The table provides an opinion of cost for the pilot study and the resulting reduced cost for study of the priority basins. The table also includes the cost for the Village to purchase its own meters and perform an extended flow metering program.

Table 5.03-1 lays out the schedule and annual cost for the recommended SSES investigation plan. The results of the pilot study and remaining SSES investigations will determine the rehabilitation costs and schedule required. Rather than provide broad assumptions, the rehabilitation cost and schedule have been omitted and will be provided upon completion of the SSES investigations.

Year	Investigations	Cost	Total Annual Cost
2012	SSES Pilot Study	$46,900	$75,000
	Pilot Study Televising	$28,100	
2013	SSES Investigations of Remaining Priority Areas	$56,100	$160,000
	Televising of Remaining Priority Areas	$49,400	
	Hydraulic Analysis	$30,000	
	Purchase Flow Meters and Training	$24,500	
2014	SSES Investigations of Remaining Basins	$135,000	$235,000
	Televising of Remaining Basins	$100,000	

Table 5.03-1 Recommended Plan and Schedule



PILOT STUDY

SANITARY SEWER EVALUATION SURVEY
VILLAGE OF WINNETKA
WINNETKA, IL

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FIGURE 5.03-1

APPENDIX A
BREAKDOWN OF SANITARY SUBBASINS

APPENDIX A
BREAKDOWN OF SANITARY SUBBASINS

Meter	Sewer Diameter	Length of Sewer		Equivalent Sewer Length
	(in)	(ft)	(miles)	inch-mile
1	8	5440	1.03	8.24
Total		**5440**	**1.03**	**8.24**
Acreage		50.7		
2	8	3998	0.76	6.06
	10	770	0.15	1.46
Total		**4768**	**0.90**	**7.52**
Acreage		43.6		
3	8	959	0.18	1.45
	10	4013	0.76	7.60
	12	384	0.07	0.87
	15	463	0.09	1.32
Total		**5819**	**0.94**	**11.24**
Acreage		42.0		
4	8	2594	0.49	3.93
Total		**2594**	**0.49**	**3.93**
Acreage		17.4		
5	8	3969	0.75	6.01
	10	1118	0.21	2.12
	12	812	0.15	1.85
Total		**5899**	**1.12**	**9.98**
Acreage		45.8		
6	8	8970	1.70	13.59
	10	2159	0.41	4.09
	12	1036	0.20	2.35
	15	2075	0.39	5.89
Total		**14240**	**2.11**	**25.93**
Acreage		94.7		
7	8	9841	1.86	14.91
	10	1040	0.20	1.97
Total		**10881**	**2.06**	**16.88**
Acreage		67.2		
8	8	1934	0.37	2.93
	10	152	0.03	0.29
	12	696	0.13	1.58
	15	1926	0.36	5.47
Total		**4708**	**0.89**	**10.27**
Acreage		47.1		

Meter	Sewer Diameter	Length of Sewer		Equivalent Sewer Length
	(in)	(ft)	(miles)	inch-mile
9	Overflow for Basin 13			
10	8	1232	0.23	1.87
	10	2720	0.52	5.15
	12	1255	0.24	2.85
Total		**5207**	**0.99**	**9.87**
Acreage		33.4		
11	8	3036	0.58	4.60
	10	1928	0.37	3.65
	12	398	0.08	0.90
	15	1661	0.31	4.72
Total		**7023**	**1.33**	**13.87**
Acreage		66.3		
12	6	337	0.06	0.38
	8	10624	2.01	16.10
	10	2712	0.51	5.14
	12	2986	0.57	6.79
	15	1602	0.30	4.55
	18	291	0.06	0.99
Total		**18261**	**3.46**	**33.95**
Acreage		184.2		
13	8	5613	1.06	8.50
	15	2437	0.46	6.92
Total		**8050**	**1.52**	**15.43**
Acreage		47.8		
14	8	672	0.13	1.02
	10	741	0.14	1.40
Total		**1413**	**0.27**	**2.42**
Acreage		7.4		
15	8	455	0.09	`
	10	4008	0.76	7.59
	15	928	0.18	2.64
Total		**5391**	**1.02**	**10.23**
Acreage		39.4		

Meter	Sewer Diameter	Length of Sewer		Equivalent Sewer Length
	(in)	(ft)	(miles)	inch-mile
16	6	131	0.02	0.15
	8	3016	0.57	4.57
	10	1025	0.19	1.94
	15	2025	0.38	5.75
	18	1669	0.32	5.69
	24	628	0.12	2.85
Total		**8494**	**1.49**	**20.96**
Acreage		76.0		
17	8	2481	0.47	3.76
	10	1326	0.25	2.51
	20	2254	0.43	8.54
Total		**6061**	**1.15**	**14.81**
Acreage		47.5		
18	8	9233	1.75	13.99
	12	503	0.10	1.14
	15	1835	0.35	5.21
Total		**11571**	**2.19**	**20.35**
Acreage		72.8		
19	8	4383	0.83	6.64
	10	954	0.18	1.81
	12	448	0.08	1.02
	15	1305	0.25	3.71
	18	2601	0.49	8.87
Total		**5308**	**1.01**	**22.04**
Acreage		56.9		
20	8	3424	0.65	5.19
	10	1090	0.21	2.06
Total		**4514**	**0.85**	**7.25**
Acreage		41.6		
21	8	2437	0.46	3.69
Total		**2437**	**0.46**	**3.69**
Acreage		17.9		

Meter	Sewer Diameter	Length of Sewer		Equivalent Sewer Length
	(in)	(ft)	(miles)	inch-mile
22	8	6145	1.16	9.31
	9	703	0.13	1.20
	10	2044	0.39	3.87
	12	1220	0.23	2.77
	15	834	0.16	2.37
	18	206	0.04	0.70
Total		**11152**	**2.07**	**20.22**
Acreage		86.6		
23	8	1926	0.36	2.92
	10	393	0.07	0.74
	12	2581	0.49	5.87
	15	407	0.08	1.16
	18	1255	0.24	4.28
Total		**4636**	**0.88**	**14.96**
Acreage		54.0		
24	8	971	0.18	1.47
	9	1518	0.29	2.59
	10	1911	0.36	3.62
	12	2116	0.40	4.81
	18	1047	0.20	3.57
Total		**6592**	**1.25**	**16.06**
Acreage		65.9		
25	6	116	0.02	0.13
	8	6222	1.18	9.43
	12	2871	0.54	6.53
	15	599	0.11	1.70
	18	2571	0.49	8.76
	20	1289	0.24	4.88
Total		**13668**	**2.34**	**31.43**
Acreage		91.7		
26	8	8166	1.55	12.37
	12	1981	0.38	4.50
Total		**10147**	**1.92**	**16.88**
Acreage		85.5		
27	12	710	0.13	1.61
Total		**710**	**0.13**	**1.61**
Acreage		9.0		

Meter	Sewer Diameter	Length of Sewer		Equivalent Sewer Length
	(in)	(ft)	(miles)	inch-mile
28	8	6985	1.32	10.58
	10	32	0.01	0.06
Total		**7017**	**1.33**	**10.64**
Acreage		67.5		
29	12	925	0.18	2.10
	15	679	0.13	1.93
Total		**1604**	**0.30**	**4.03**
Acreage		14.9		
30	8	1563	0.30	2.37
Total		**1563**	**0.30**	**2.37**
Acreage		34.3		

APPENDIX B
FLOW METERING EVALUATIONS

B.01 FLOW METERING BASIN DESCRIPTIONS

The following evaluation provides a summary of each metering location, the data collected, and concerns identified based on the three study rainfall events. The information presented is best considered in conjunction with the dry and wet weather flow analyses presented in Section 3.

A. Basin 01

This basin was approximately 50.7 acres in area. It collected flow from the most northwest portion of the Village. The flow meter collected good data throughout the monitoring period. The sewerage from this basin flowed directly into the MWRDGC interceptor system.

B. Basin 02

This basin was approximately 43.6 acres in area, located north of Tower Road between Grove Street and Vernon Avenue. This flow meter collected good data throughout the monitoring period. The sewerage from this basin flowed directly into the MWRDGC interceptor system.

C. Basin 03

This basin was unique among some of the other basins in that it had a relief sewer located within it. There are two sewers that travel from north to south along Vernon Avenue. The eastern most line collects flow from the collector sewers along Scott and Asbury Avenues. However, there exists three overflow pipes connecting the eastern line to the western line. The inverts of these overflow pipes are set higher than the invert of the downstream sewers. When flows get too high and the water level rises it would reach the invert of the overflow sewers and flow into the adjacent sewer line. An analysis of the data and physical observations, such as the presence of debris in the overflow pipe flowline both before and after rainfall events, suggest that none of the events that occurred during the monitoring period caused an overflow.

This basin was 42 acres in area and the data collected was of good quality. The connection to the MWRDGC interceptor is located directly downstream.

D. Basin 04

This basin was approximately 17.4 acres in area, located north of Tower Road, collecting sewerage from the Forest Glen area. The meter functioned well during the monitoring period and the basin flows directly to the MWRDGC interceptor.

E. Basin 05

The flow metering data collected from Basin 05 was good. The basin was 45.8 acres in area encompassing the area north of Tower Road, west of the railroad tracks and East of Euclid Avenue. Sewerage from this basin continued downstream to Basin 06.

F. Basin 06

As stated above, Basin 06 received flow from the Basin 05 as well as sewerage from an 94.7 acre area. The data collected at this metering location was good throughout the metering period. Basin 06 was tributary to Basin 13.

G. Basin 07

This flow meter had some sediment issues that caused some data dropouts to occur. When velocities are low within sewers it causes solids to settle out. When these solids deposit on top of the flow meter sensor it prevents the meter from collecting a velocity reading. To combat this, every week during the data download process we made sure to clean this location. The diligent cleaning program for this metering location ensured that the data collected at this location was good.

This basin had an area of 67.2 acres and was directly upstream of an MWRDGC interceptor.

H. Basin 08

This flow meter collected good data. However, during the middle of the night during low flows the meter was having difficulty collecting data because the flow level was too low. We made a maintenance visit to this location during the monitoring period to push the meter further into the pipe and this solved the problem. Since the flow level was elevated during rainfall events, this did not affect any of the wet weather data collected.

This basin was 47.1 acres in size and was directly upstream of the MWRDGC interceptor.

I. Basin 09

This flow meter was installed in an 18 inch relief sewer designed to offload a small portion of dry weather and a significant portion of the wet weather flows from the Basin 13 towards an MWRDGC interceptor. All data collected at this flow meter actually represented flow generated upstream in Basins 13, 06, and 05. The data was used to adjust the data collected by Basin 13. As a result, the wet weather analyses described later in this section was not applied to Basin 09. This is described further in Section 3.05.

The dry weather flows at this metering location were fairly low since it was monitoring a relief sewer. This resulted in solid depositing on the flow metering sensor. This was another site that required cleaning every time the data was downloaded. The data collected at this location was generally good despite the solids deposits.

J. Basin 10

Basin 10 presented problems throughout the flow monitoring period. Firstly, the velocities within the sewer were very low resulting in severe solids depositing. We explored the option of moving the meter. However, the next manhole upstream was a junction point of two sewers, which would have required

the installation of an additional meter. Rather than moving the meter and increasing the cost, we were diligent in cleaning the solids deposits during each data download.

Despite the heavy solids deposits, the meter was functional during all of the rainfall events and provided generally good data throughout the monitoring period. The MWRDGC interceptor was directly downstream of this metering location.

The flow response graph at this location suggested that a backup occurred during the April 15 and May 26 events as evidenced by the negative flow observed during the event. It is unclear based on the flow metering data whether the backup was caused by the capacity of the sewer being exceeded or as a result of downstream influence from the MWRDGC intercepting sewer.

K. Basin 11

This meter was located east of the railroad tracks in the downtown area north of Elm Street. Its tributary area was 66.3 acres and the data collected at this location was good. Basin 11 was tributary to Basin 16.

L. Basin 12

This basin encompassed the northeastern portion of the Village and had the largest basin area at 184.2 acres. This flow metering location was unique in that the sewer was an egg-shaped brick sewer. The shape of the sewer was accounted for to accurately calculate flow rates.

The data collected at this location was good and this meter was also tributary to Basin 16.

M. Basin 13

This flow meter experienced a mechanical error and did not collect data during portions of the first few weeks of the monitoring period. As a result, this meter was not operational during the April 15 event. This is discussed in further detail in Section 3.05. Once the meter was replaced, it collected good data during the rest of the monitoring period including the final two study rainfall events.

This basin was 47.8 acres in size and was located downstream of Basin 06 and upstream of Basin 18. As discussed previously, the data collected at Basin 13 was adjusted using the data collected by Basin 09.

N. Basin 14

This flow meter provided good data during the monitoring period, especially during the study rainfall events. A maintenance trip was required early on in the monitoring period to push the flow meter deeper into the pipe to reduce turbulence. This resulted in better data the rest of the monitoring period.

This basin contained an overflow relief sewer from Basin 21. The flow metering data and physical observations, such as the presence of debris in the overflow pipe flow line both before and after rainfall events suggest an overflow did not occur during the flow monitoring period.

This flow metering basin was 7.4 acres and was directly tributary to the MWRDGC interceptor system.

O. Basin 15

This flow meter provided good data throughout the monitoring period. The basin was 39.4 acres. This basin also contains an overflow from Basin 21 and similar to Basin 14 the data and physical observations suggest an overflow did not occur during the metering event.

P. Basin 16

This flow meter was installed in a brick egg-shaped sewer. As a result, similar metering adjustments were required as described under Basin 12. This meter collected the sewerage from Basin 11 and Basin 12. The data collected here was good throughout the period. This basin was 76 acres in area and was tributary to the MWRDGC interceptor system.

Q. Basin 17

This flow meter was also installed in a brick egg-shaped sewer and required the adjustments described above. Overall the data collected at this location was good. The basin area was 47.5 acres and was directly connected to the MWRDGC interceptor system.

R. Basin 18

This flow meter was located downstream of Basin 13. The data collected at this location was good and it flowed to the MWRDGC interceptor system.

S. Basin 19

This flow meter was located in an egg-shaped brick sewer and the metering was adjusted accordingly. This location experienced severe solids deposition resulting in some lost data during dry weather. However, this was one location that was cleaned during each data download and therefore was fully operational for each study rainfall event. This basin was 56.9 acres in area and was directly upstream of the MWRDGC interceptor.

T. Basin 20

This basin was 41.6 acres in area and the data collected was good throughout the flow monitoring period.

U. Basin 21

This basin was 17.9 acres in area and was directly upstream of the MWRDGC interceptor. However, this metering basin has two overflows into other basins as described above (Basin 14 and Basin 15). Despite the presence of the overflow pipes, the data suggest there were no overflows during the flow monitoring period. We were able to make this determination by analyzing the level and flow data

collected by the meter. If an overflow occurred upstream the level data collected at this location would have leveled off at the elevation of the overflow pipes. Similarly, the shape of the flow curve, found later in this Appendix, would show evidence of an overflow.

V. Basin 22

Basin 22 was 86.6 acres in size. The flow meter at this location collected good data throughout the flow monitoring period. There were a few times some obstructions caused a loss in velocity data, however this did not occur during any of the study wet weather events. This meter was directly upstream of the connection to the MWRDGC interceptor.

W. Basin 23

This flow meter collected good data throughout the metering period. The basin had an area of 54 acres and was directly tributary to the MWRDGC interceptor system.

X. Basin 24

This flow meter collected good data throughout the monitoring period. This meter was also installed in an egg-shaped sewer and the metering was adjusted to account for that. The basin had an area of 65.9 acres. This basin was directly upstream of the MWRDGC connection.

Y. Basin 25

This flow meter was the last meter installed in an egg-shaped sewer and required adjustment for that reason. It was located directly upstream of the MWRDGC interceptor and collected good data throughout the monitoring period. The basin had an area of 91.7 acres.

Z. Basin 26

This flow meter collected sewerage from the southwest portion of the Village. The data collected was good for all three study events and throughout the monitoring period. This basin was 85.5 acres and was directly tributary to the MWRDGC interceptor system.

AA. Basin 27

This flow meter along with Basin 30 were unique among the other meters in that, it was installed to monitor flow entering the Village of Winnetka system from the Woodley Road Sanitary District. This is described in more detail in Section 3.05. The size of the tributary area to this flow meter is unknown because mapping information for this area was unavailable. The data collected at this location was good, however, on two occasions the meter needed to be cleaned free of rags. Neither incident affected any of the three study rainfall events.

AB. Basin 28

This meter was installed in a Village of Winnetka sewer that was directly connected to an MWRDGC owned manhole requiring a confined space entry. Before entering the MWRDGC manhole, however, we needed to receive permission.

Strand Associates and Village of Winnetka personnel met at the MWRDGC offices in downtown Chicago on April 4, 2012. The purpose of the meeting was to inform the MWRDGC of the intent and goals of the project and to receive permission to access their manhole. The result of the meeting was positive and we were able to install the flow meter.

This basin had an area of 67.5 acres.

AC. Basin 29

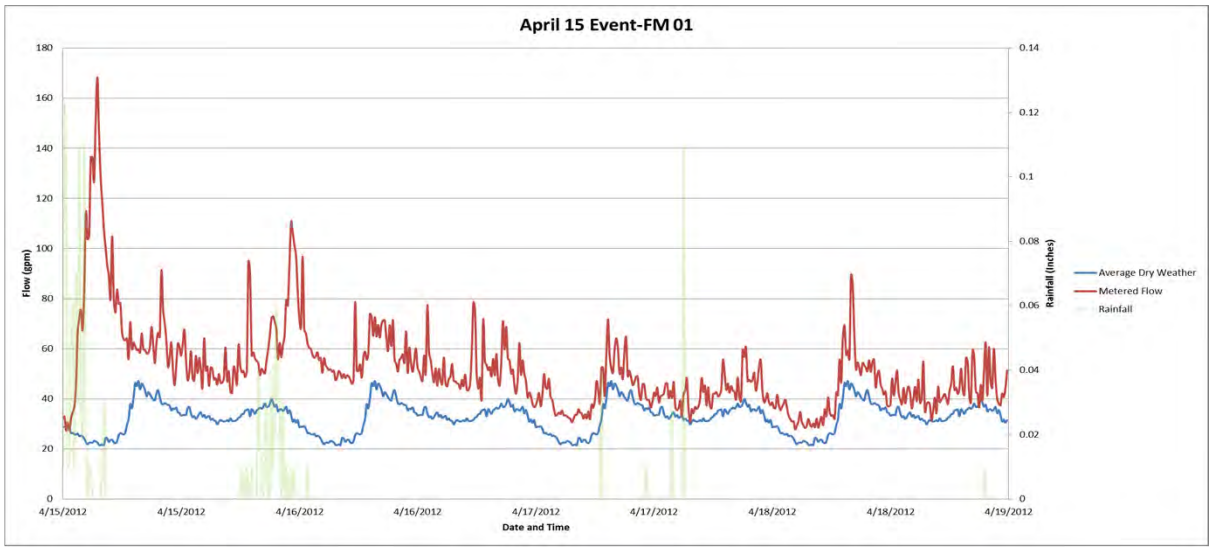
This basin was downstream of Basin 27. The data appeared to be good based on the quality control checks performed on the data. This basin was 14.9 acres and directly upstream of the MWRDGC interceptor system.

AD. Basin 30

This basin was similar to Basin 27. It was installed to monitor flows into the Village from the Woodley Road Sanitary District. This meter collected generally good data, although there were times when rags collected on the probe and caused erroneous data. This did not affect any of the study events, however. As was the case with Basin 27, the actual size of this basin is unknown because mapping was unavailable at the time of this report. See Section 3.05 for further details regarding this basin.

B.02 WET WEATHER FLOW RESPONSES

The following graphs represent the flow response at each metering location that occurred during the three study events that occurred on April 15, May 26, and May 31.


April 15 Event-FM 01
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
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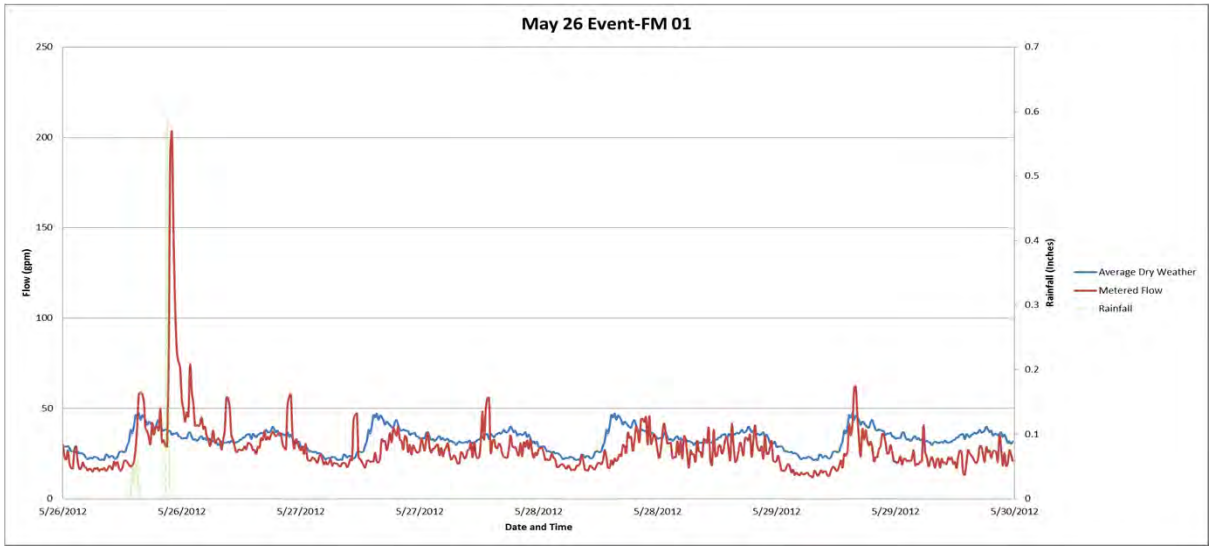
4/18/2012
4/19/2012


May 26 Event-FM 01
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
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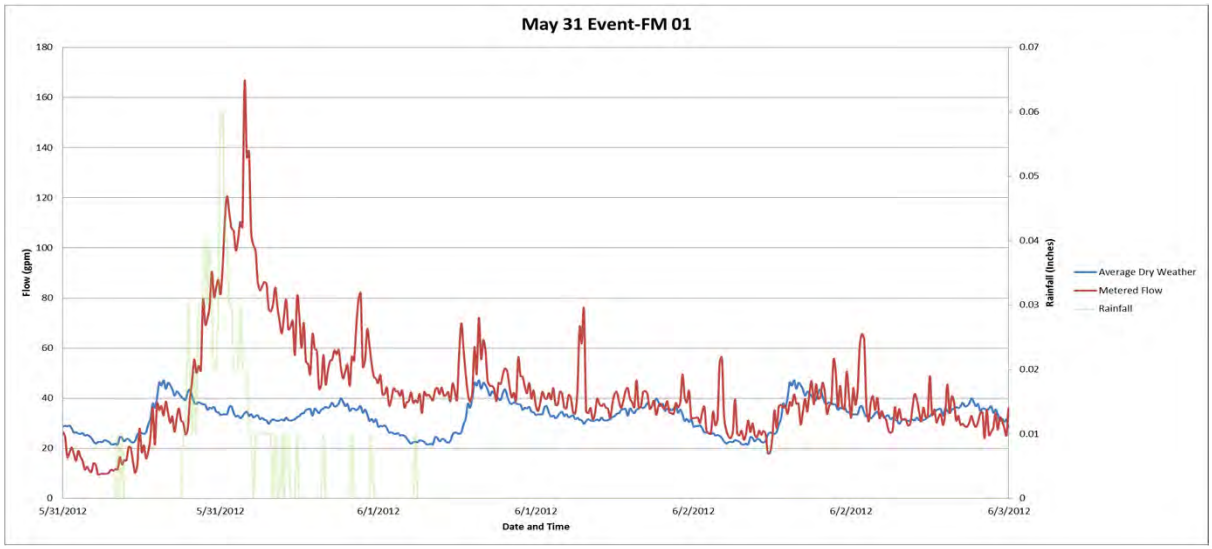
5/29/2012
5/30/2012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Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
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5/31/2012
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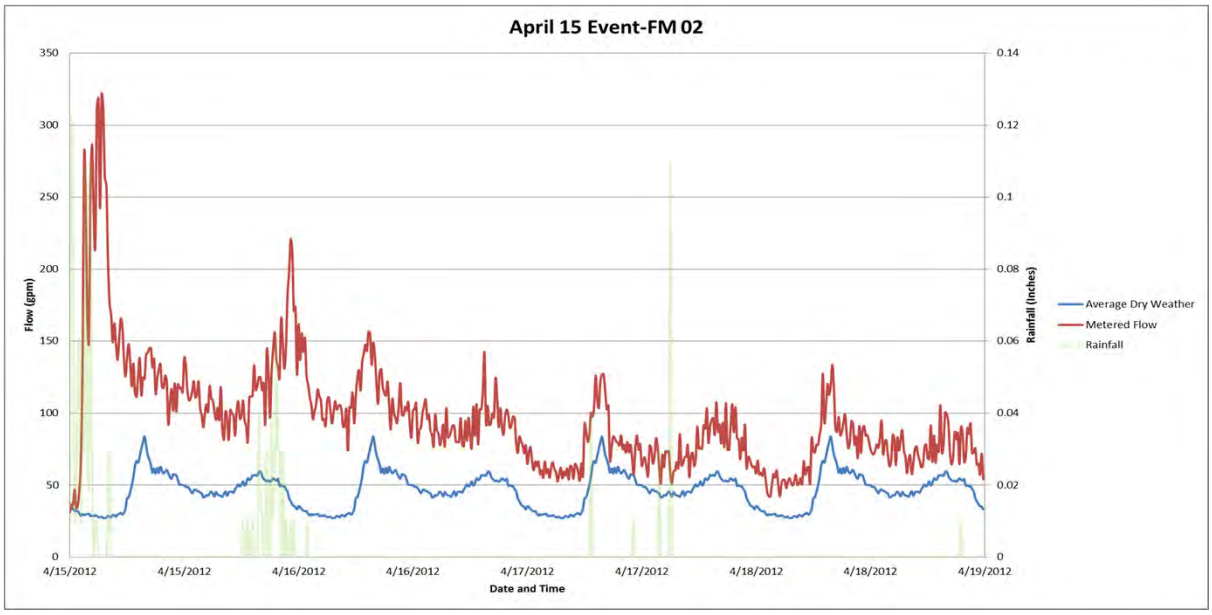
6/2/2012
6/3/2012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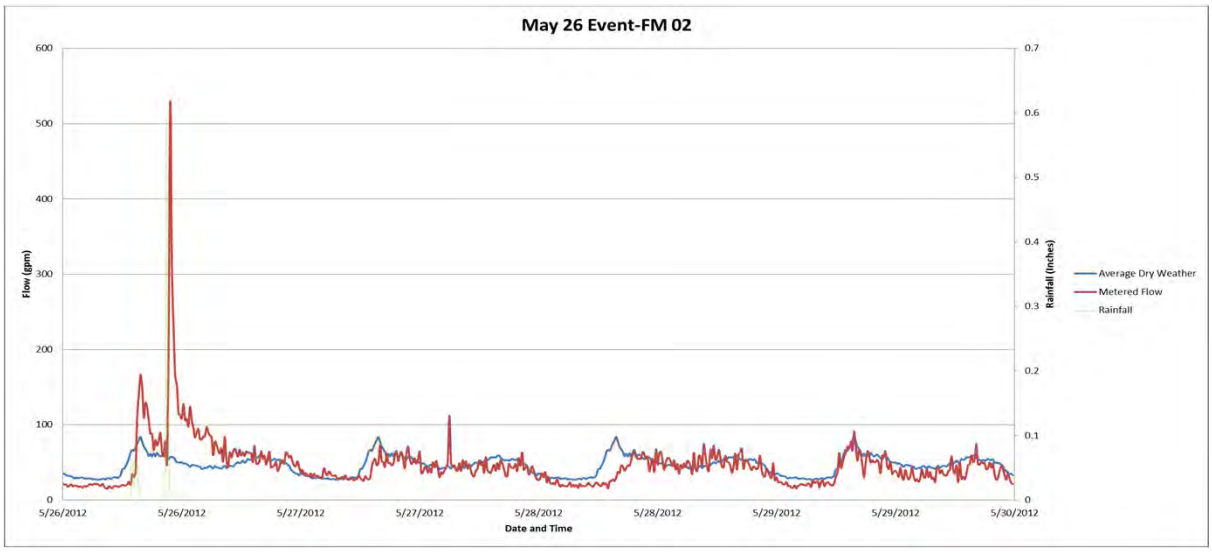
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
350
300
250
200
150
100
50
0
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012


May 26 Event-FM 02
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
600
500
400
300
200
100
0
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
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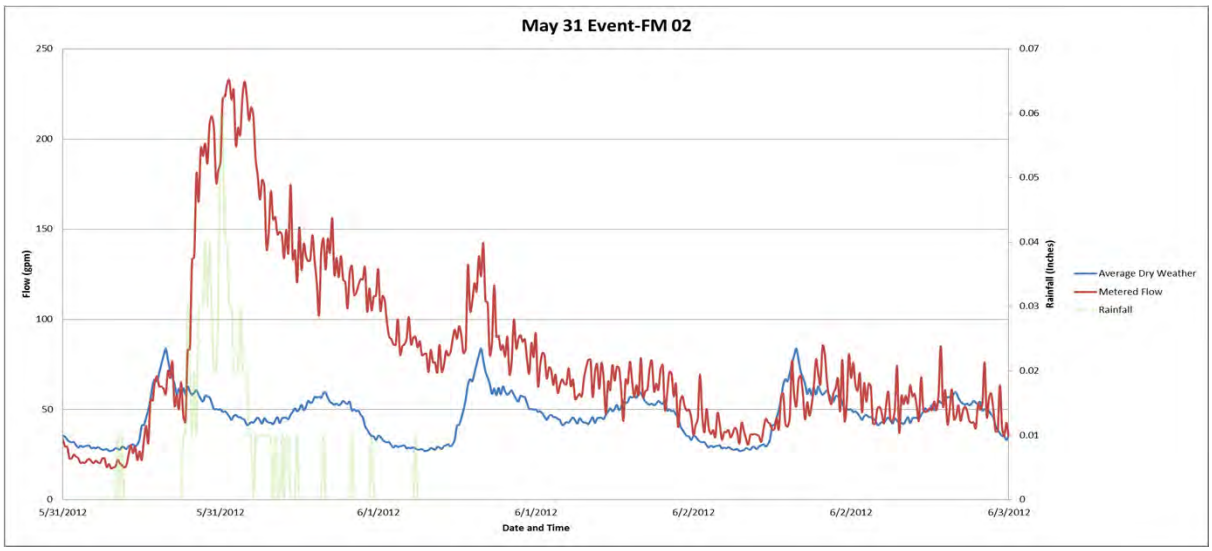
5/29/2012
5/30/2012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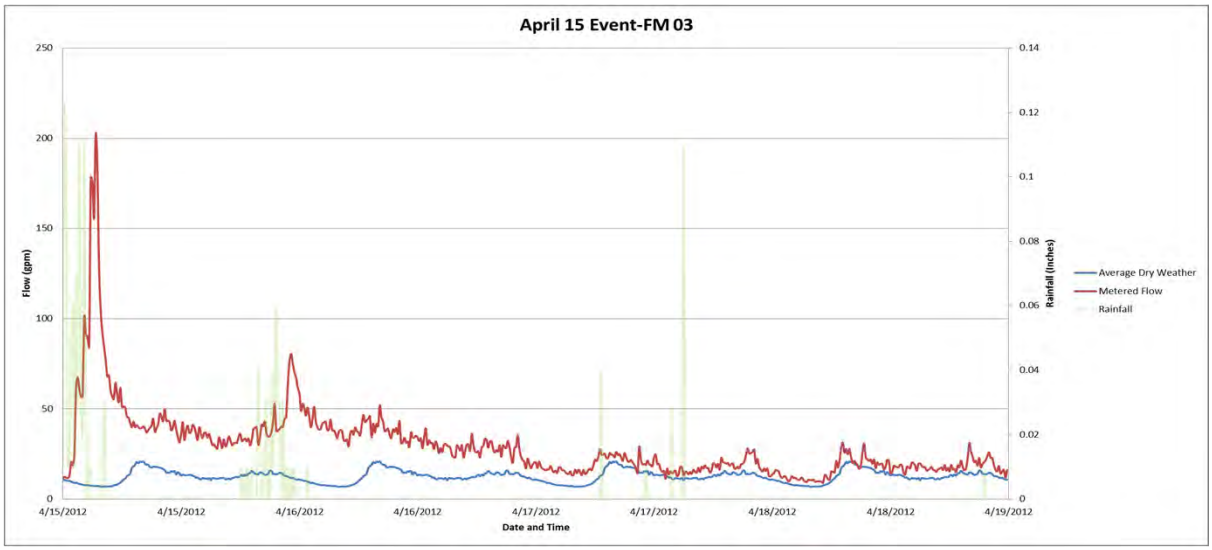
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
250
200
150
100
50
0
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012


April 15 Event-FM 03
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
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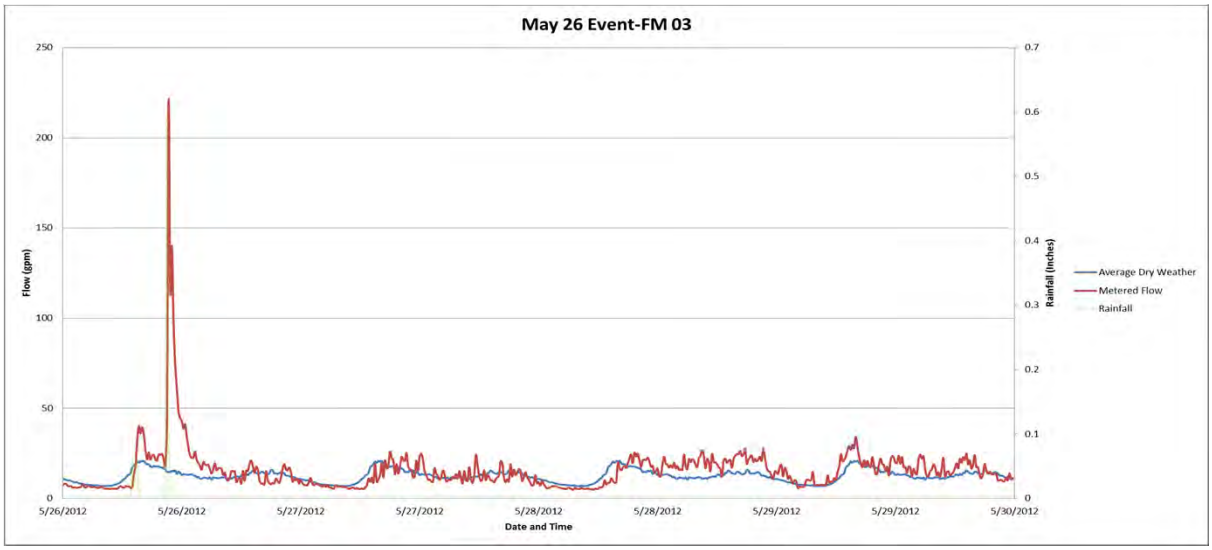
4/18/2012
4/19/2012


May 26 Event-FM 03
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
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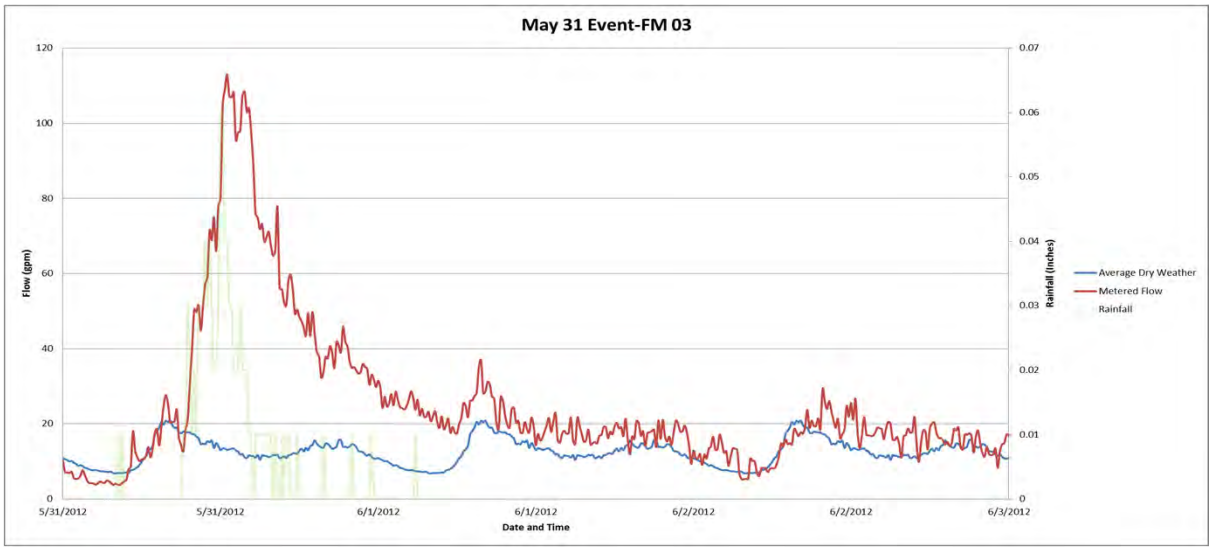
5/29/2012
5/30/2012


May 31 Event-FM 03
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
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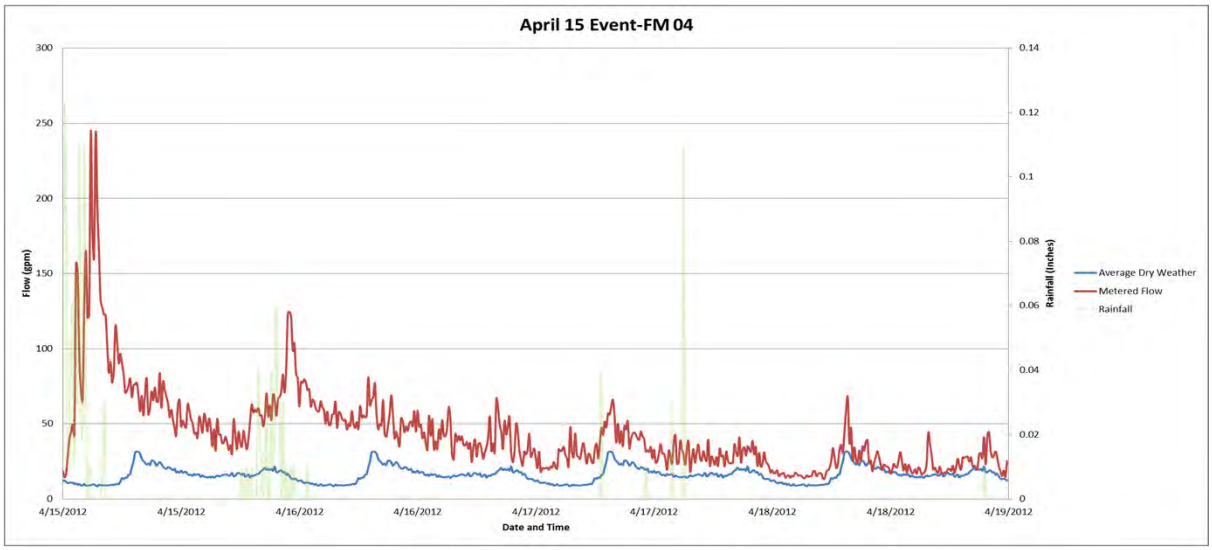
6/2/2012
6/3/2012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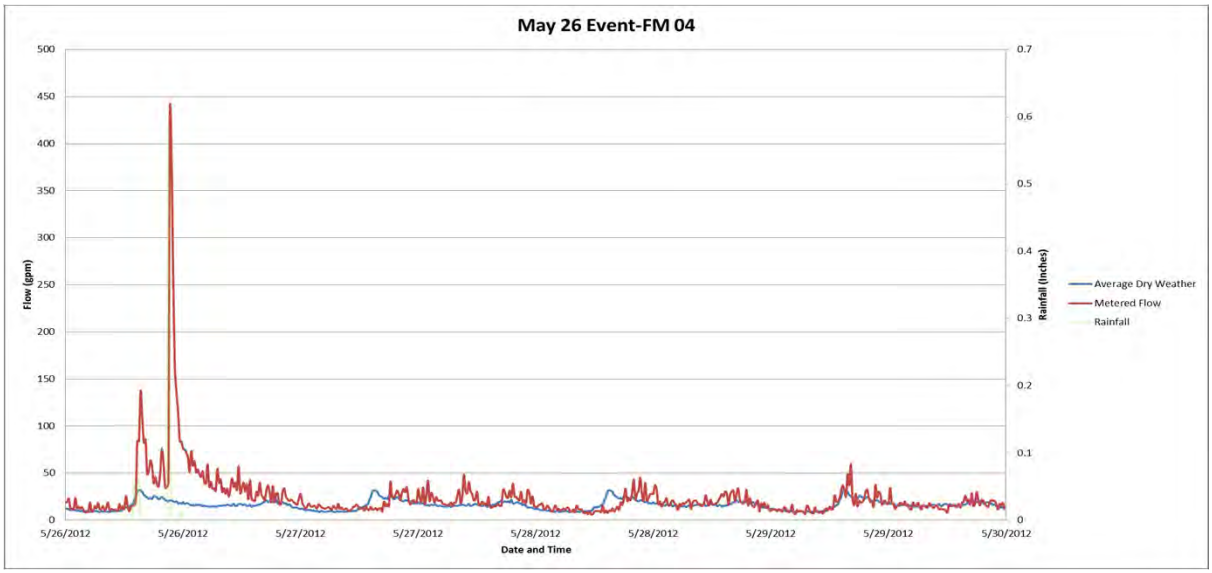
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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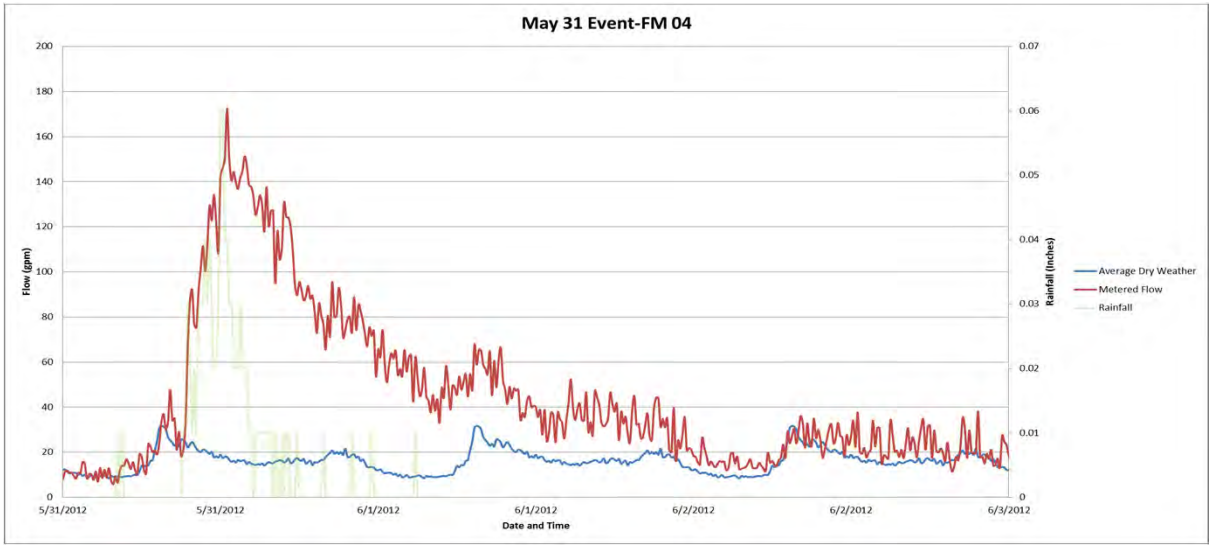
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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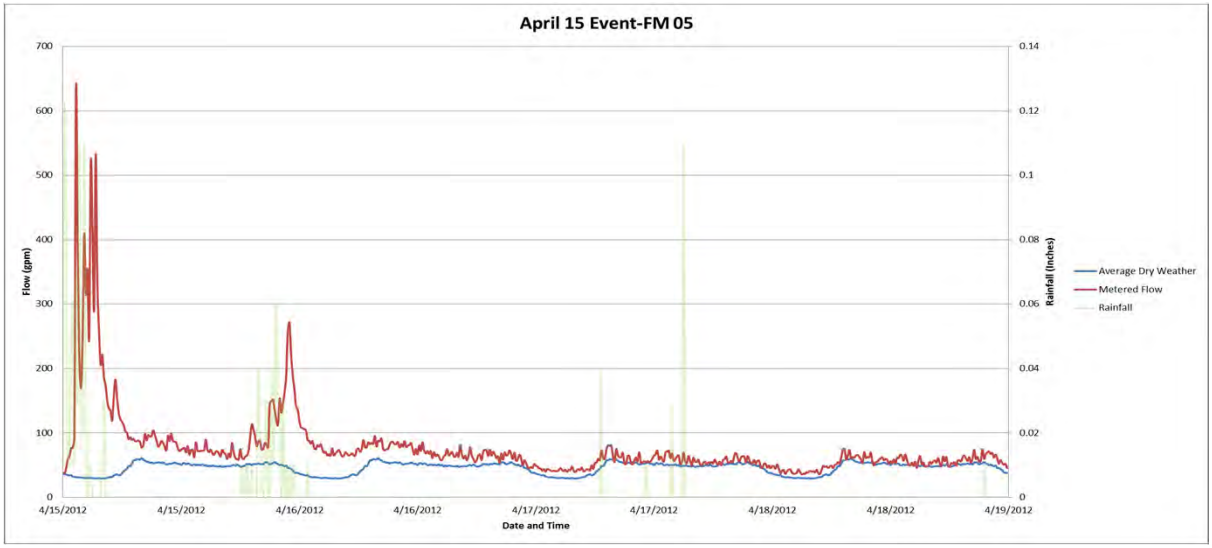
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall


April 15 Event-FM 05
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
0
100
200
300
400
500
600
700
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
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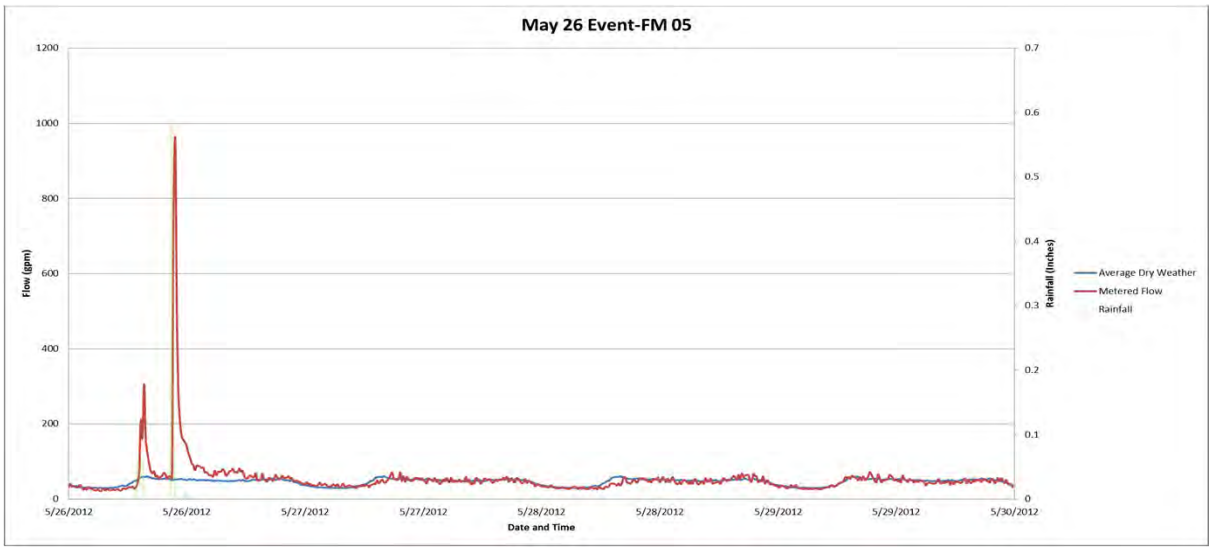
4/18/2012
4/19/2012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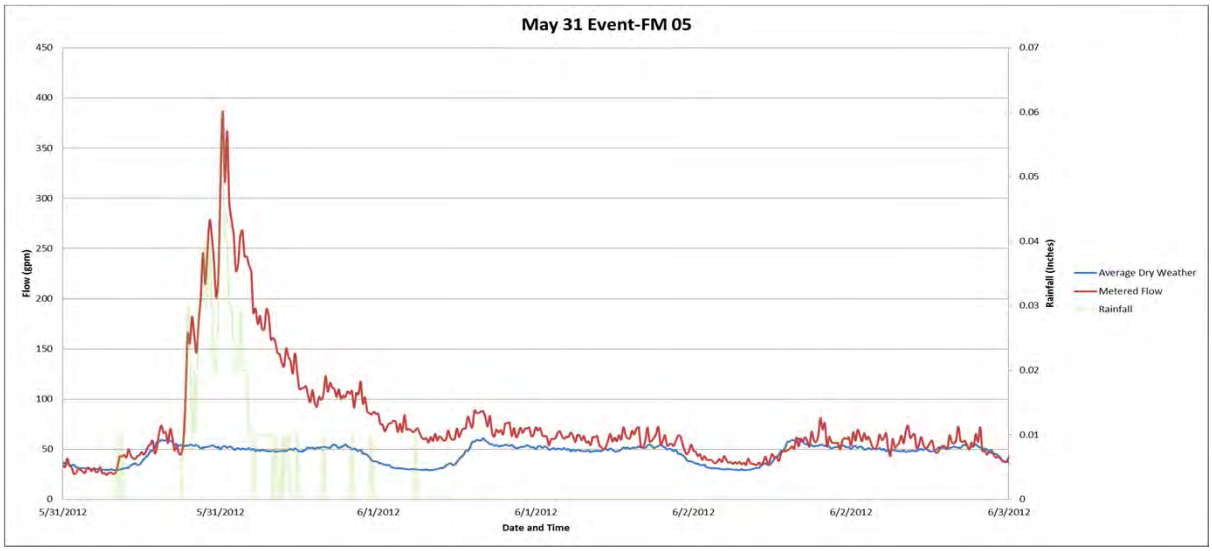
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
0
200
400
600
800
1000
1200
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012


May 31 Event-FM 05
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
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50
100
150
200
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300
350
400
450
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0.01
0.02
0.03
0.04
0.05
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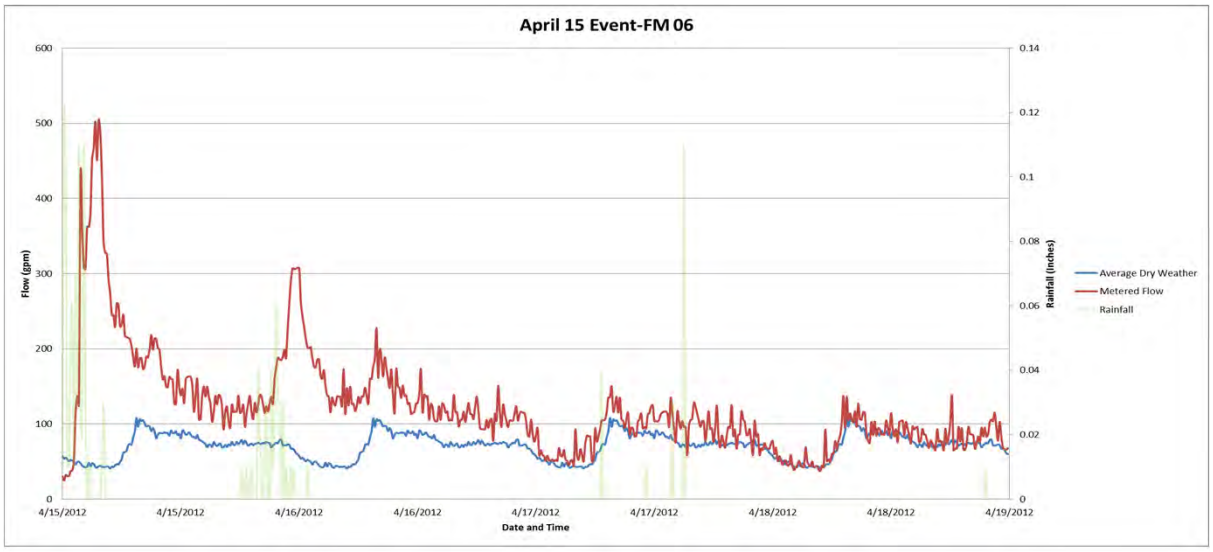
6/2/2012
6/3/2012


April 15 Event-FM 06
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
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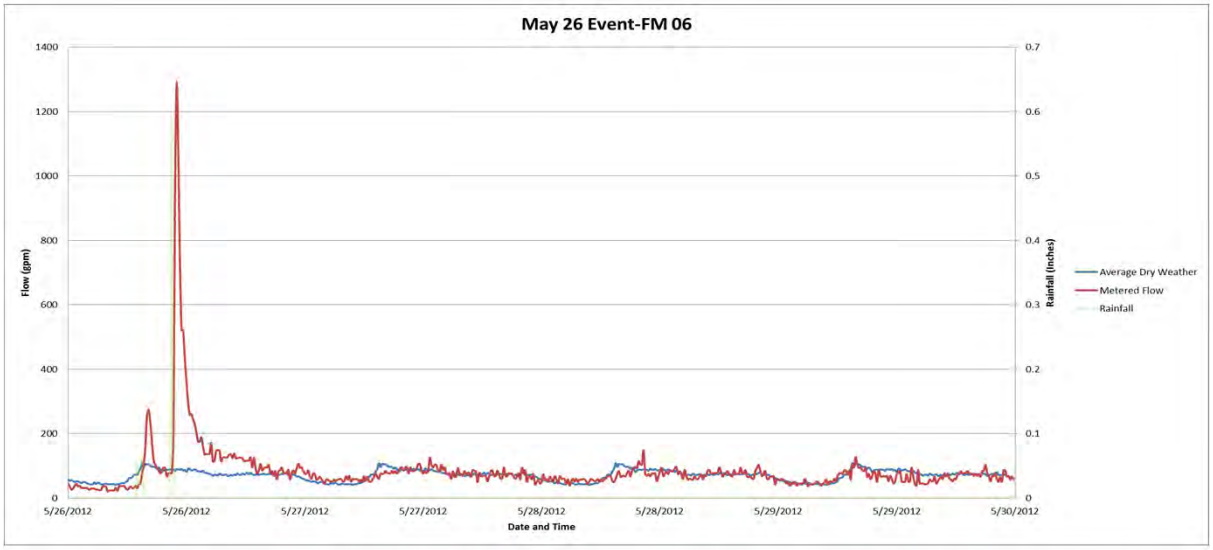
4/18/2012
4/19/2012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Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
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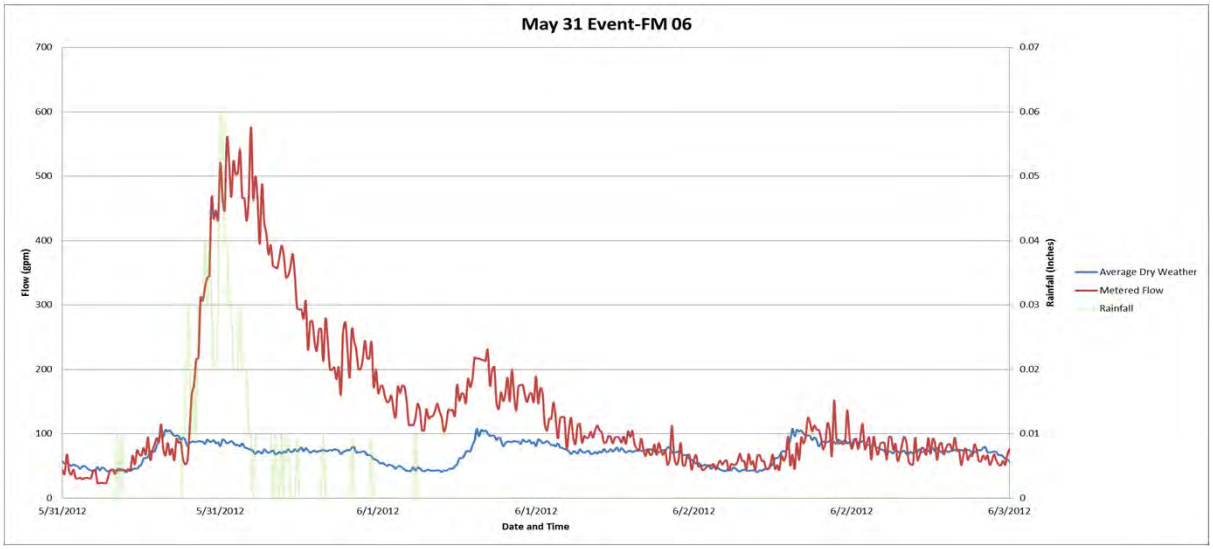
5/29/2012
5/30/2012


May 31 Event-FM 06
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
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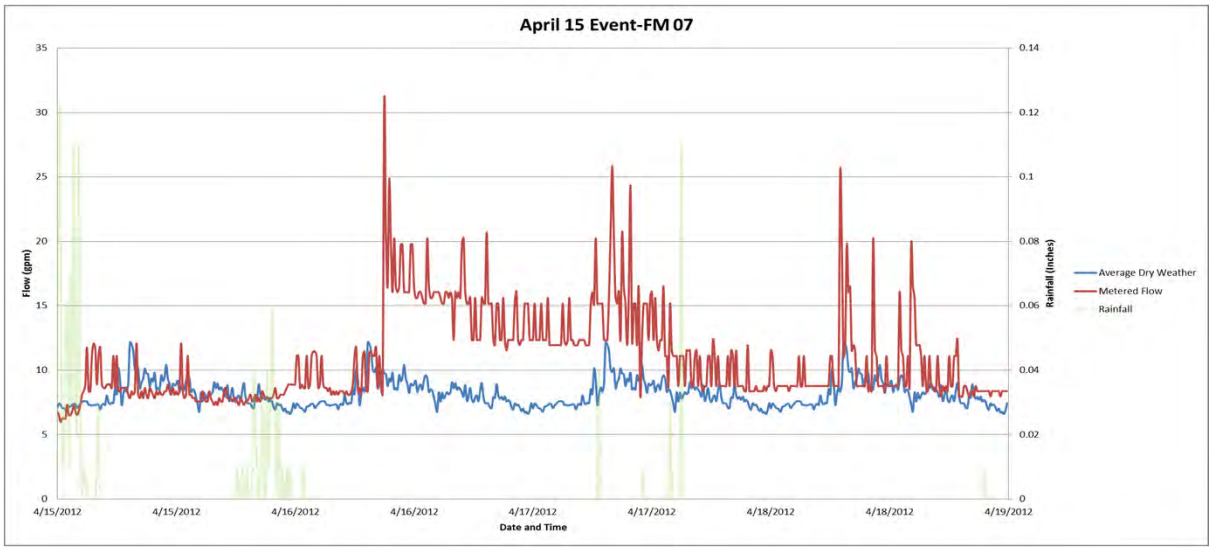
6/2/2012
6/3/2012


April 15 Event-FM 07
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
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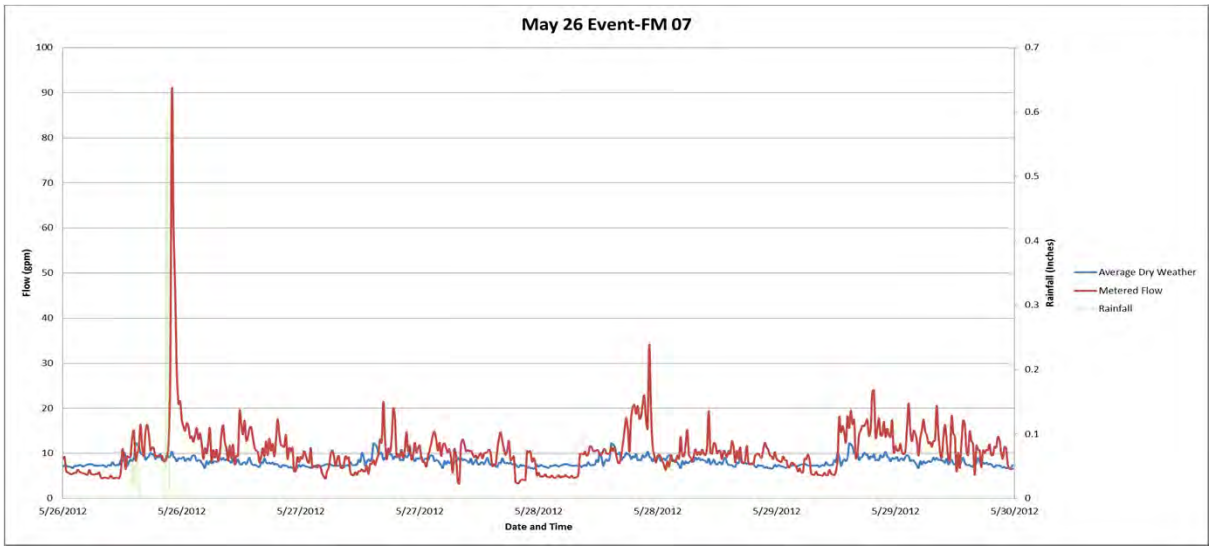
4/18/2012
4/19/2012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Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
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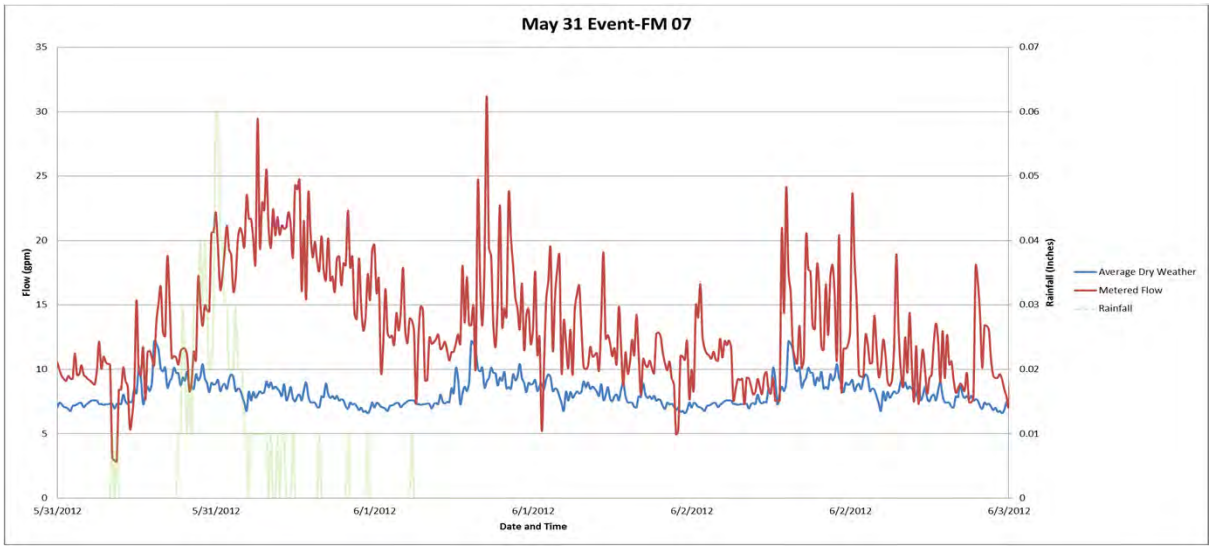
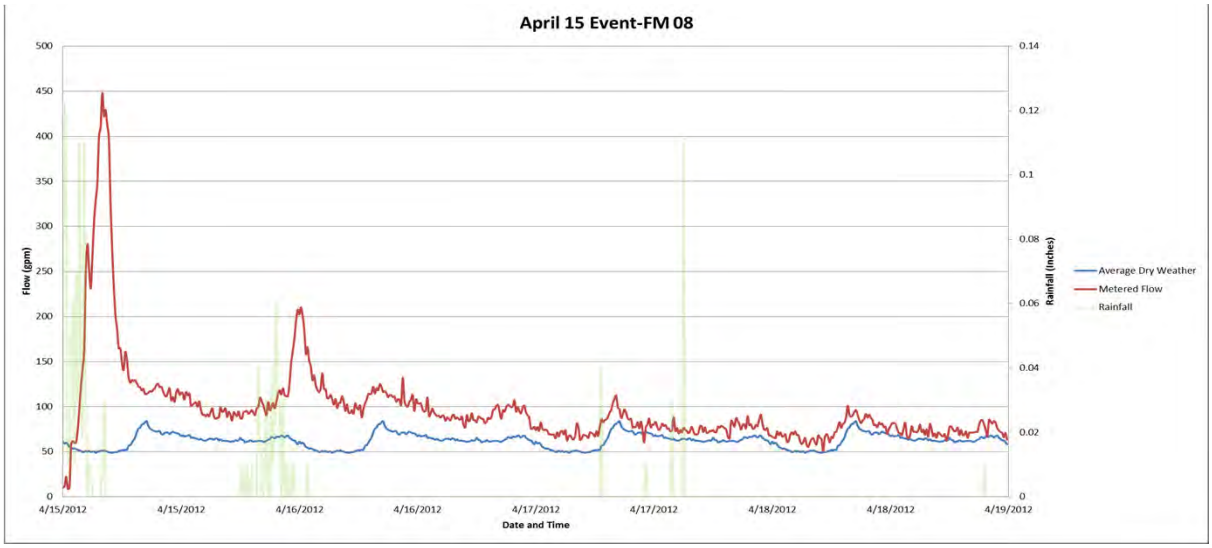
5/29/2012
5/30/2012


May 31 Event-FM 07
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012


April 15 Event-FM 08
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
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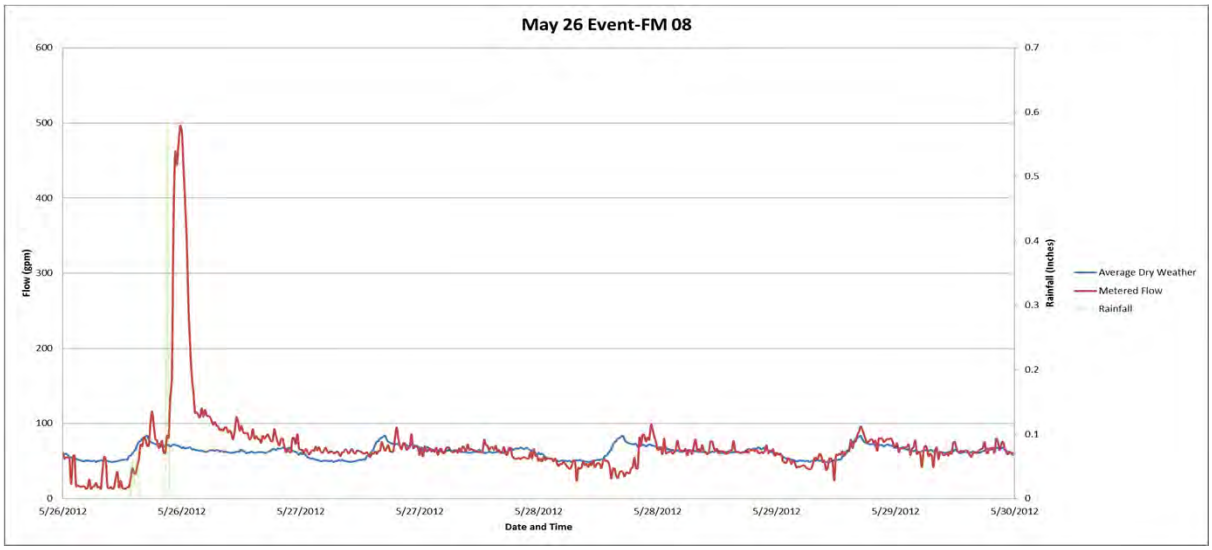
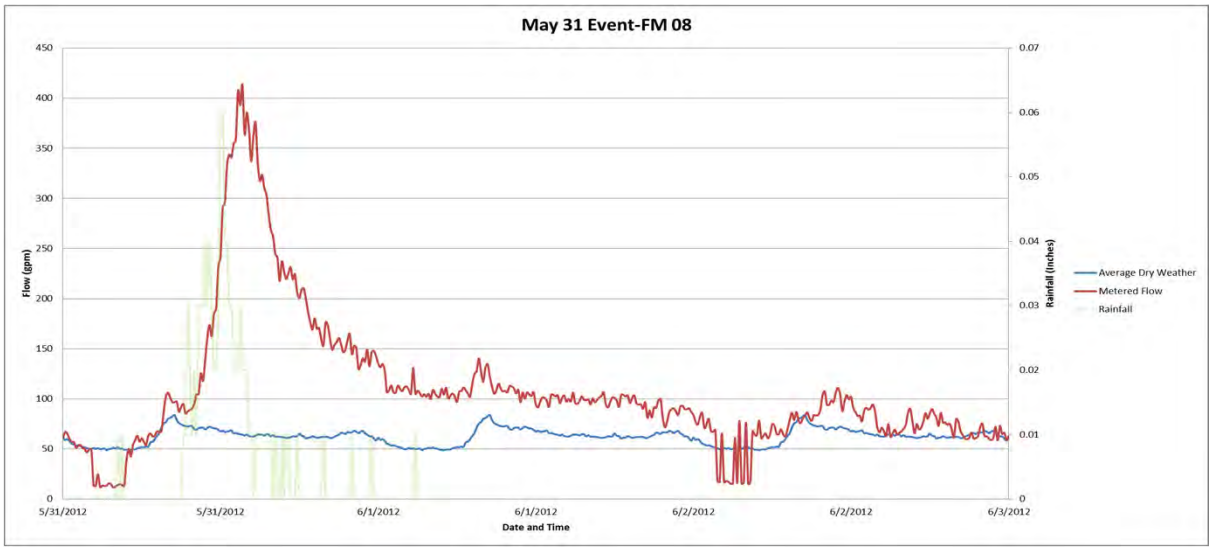
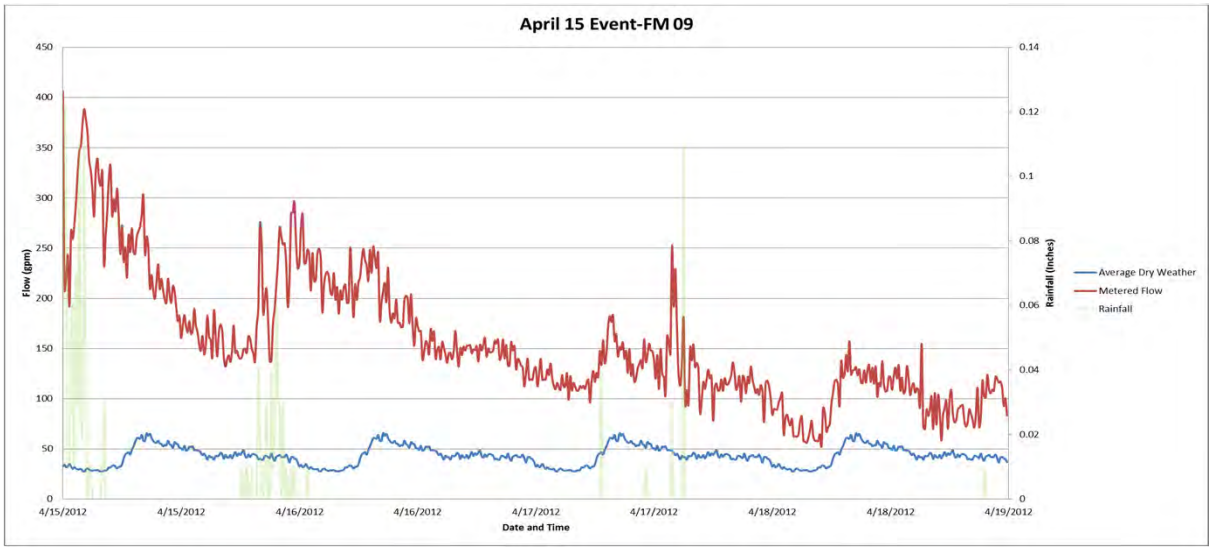
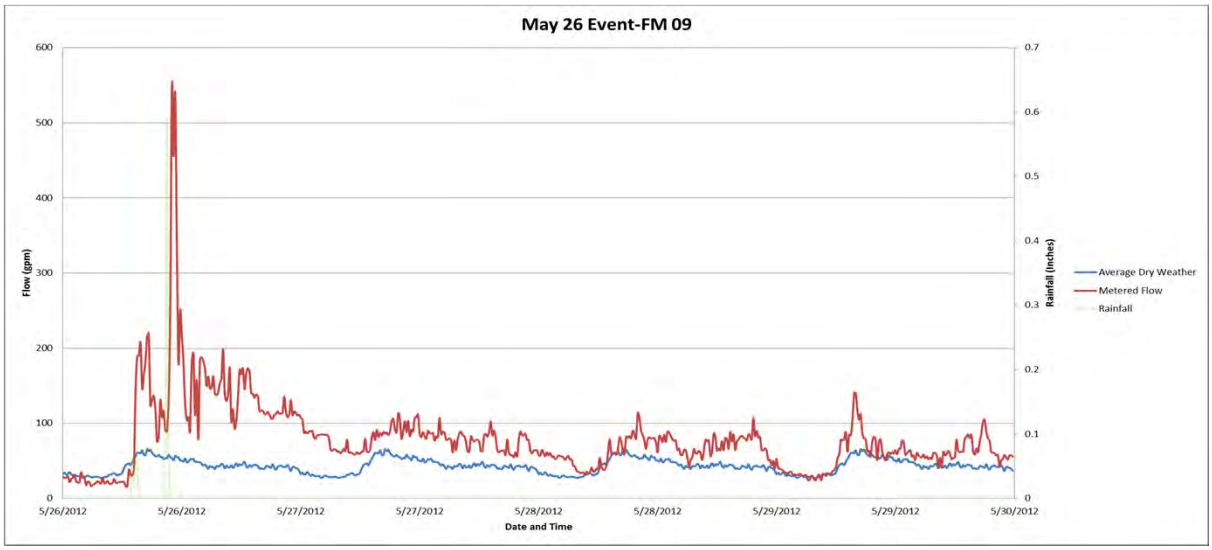
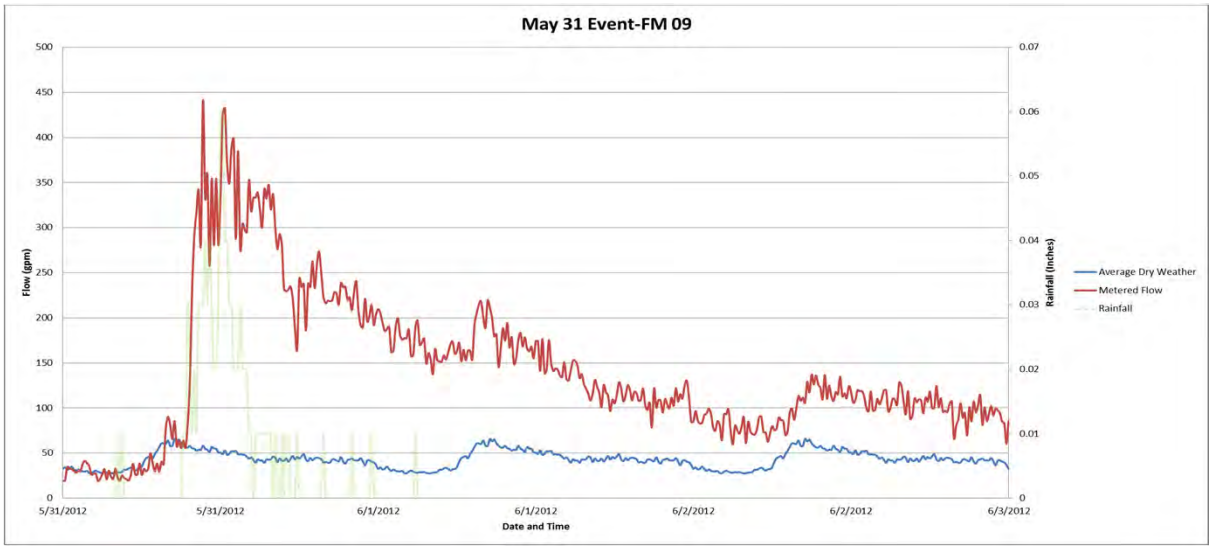
4/18/2012
4/18/2012
4/19/2012

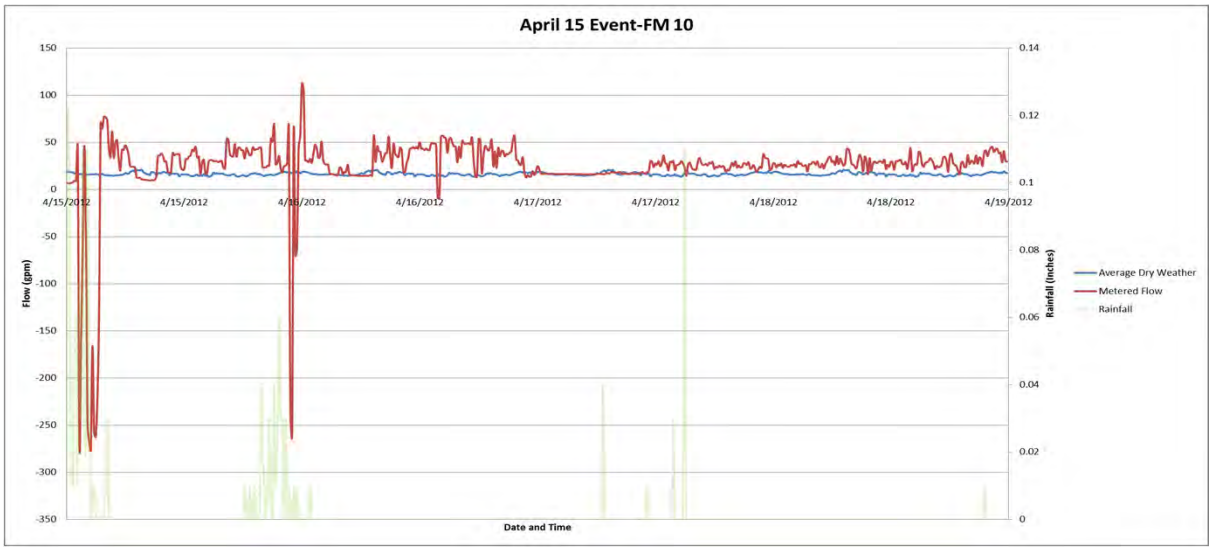

May 26 Event-FM 08
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012

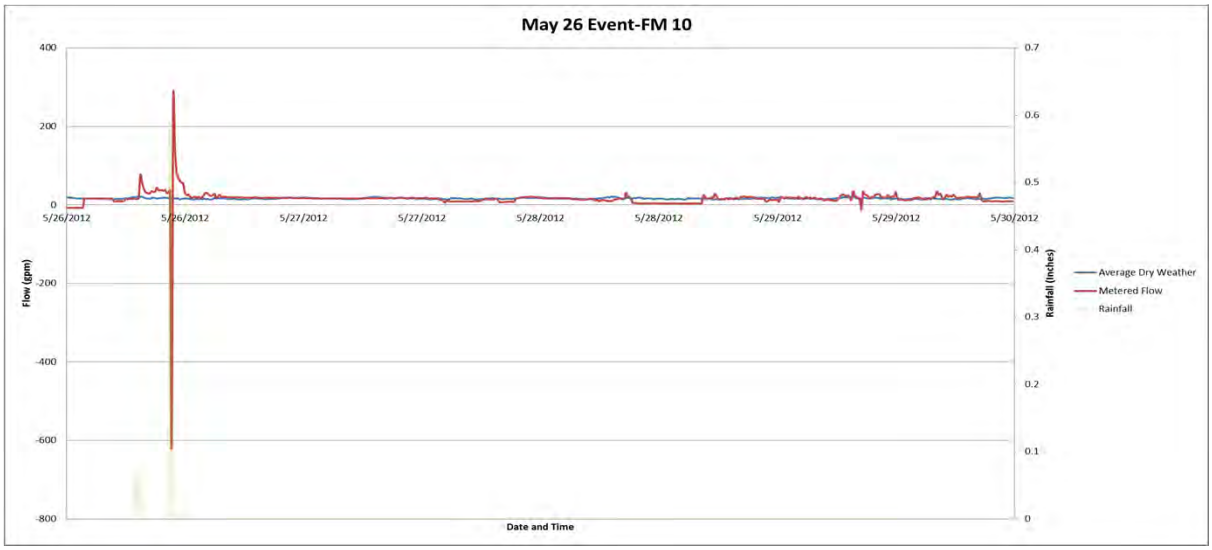

May 31 Event-FM 08
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012

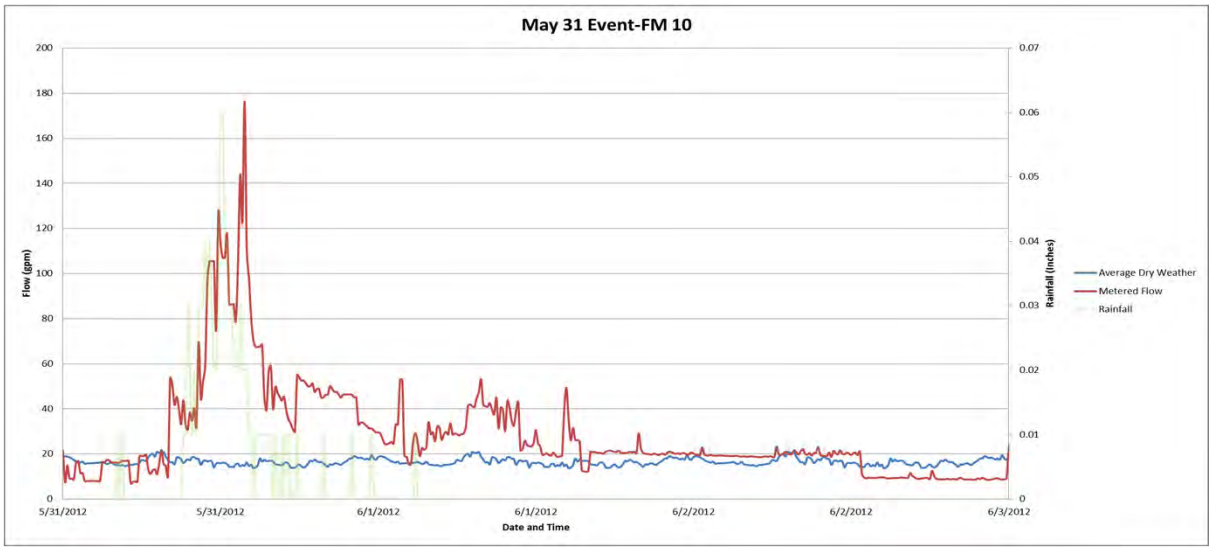

April 15 Event-FM 09
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012

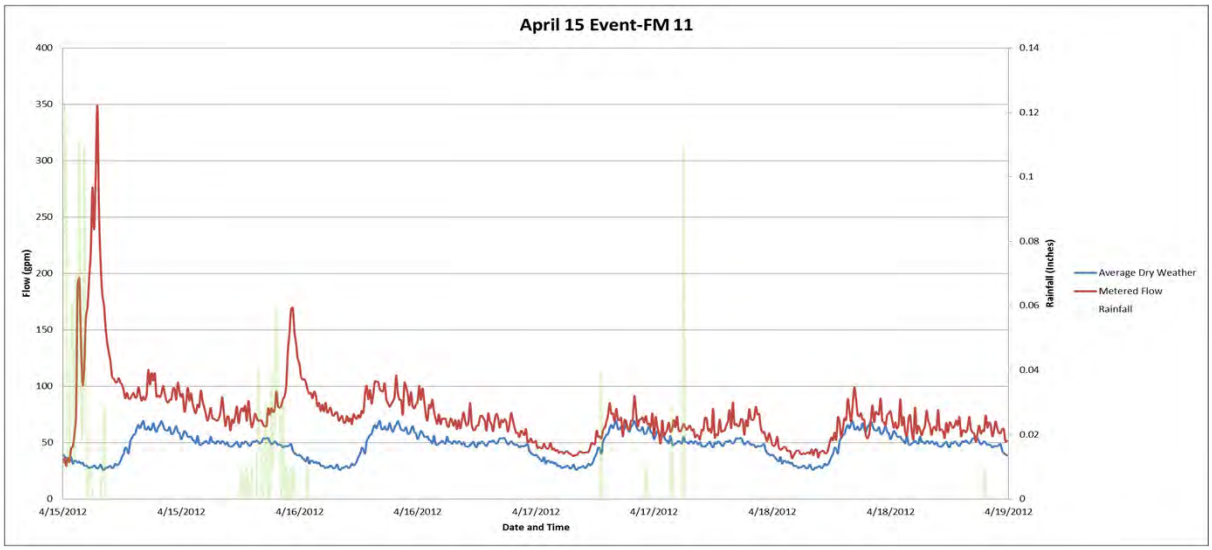

May 26 Event-FM 09
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012

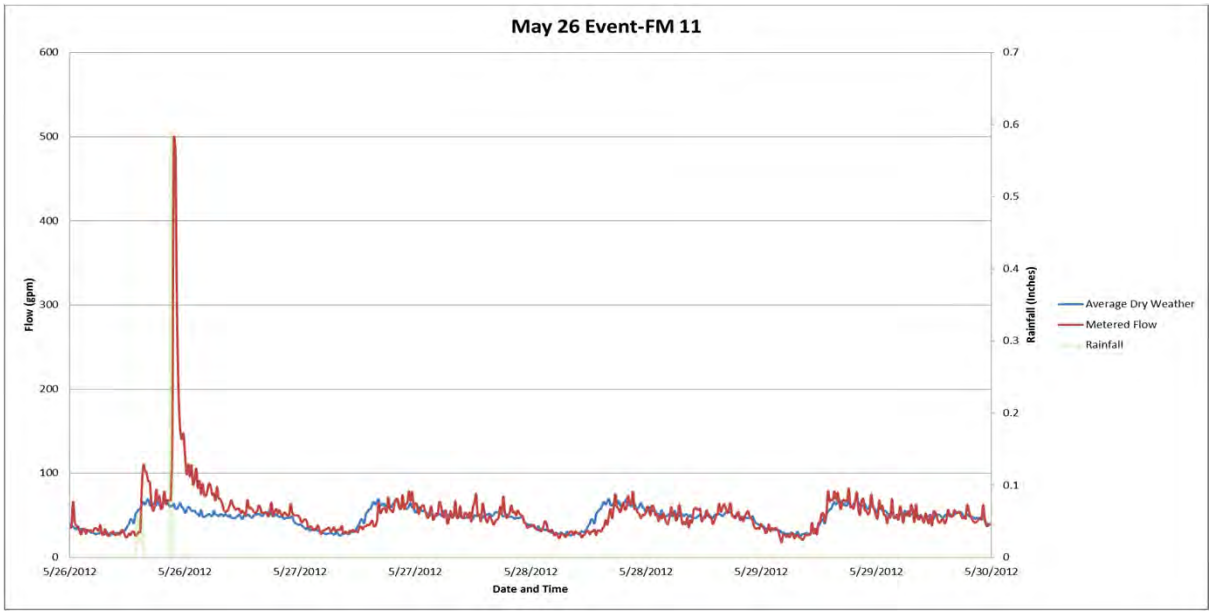

May 31 Event-FM 09
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012

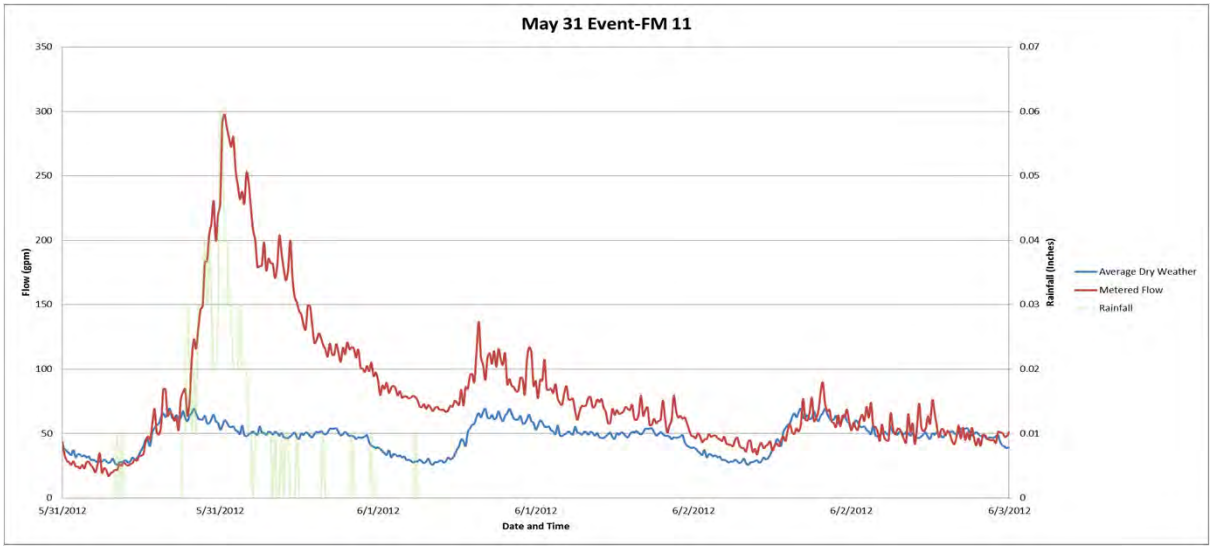

April 15 Event-FM 10
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall

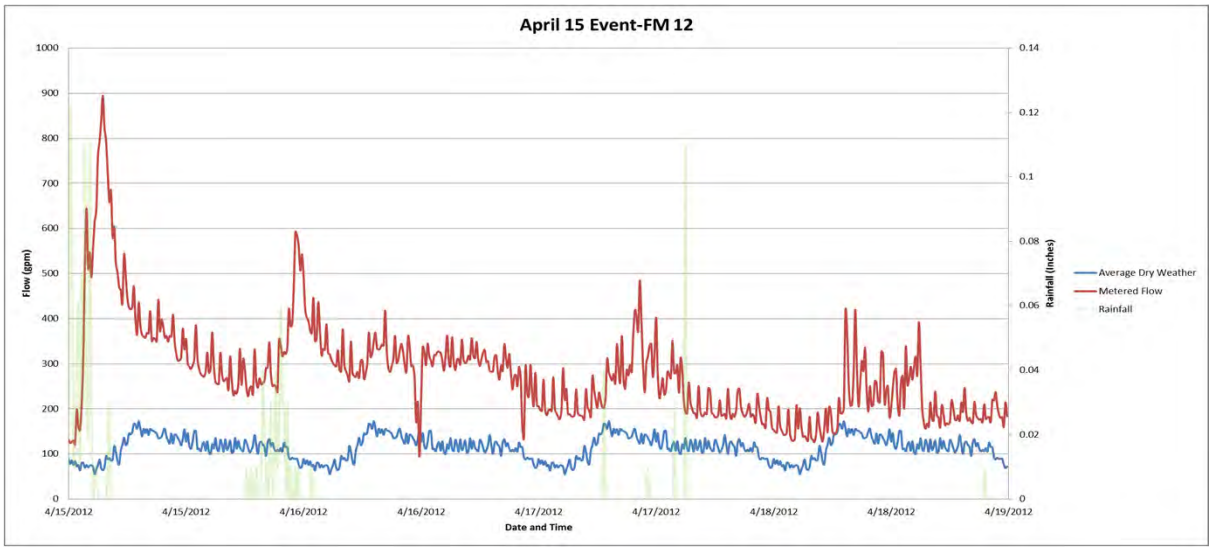

May 26 Event-FM 10
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall

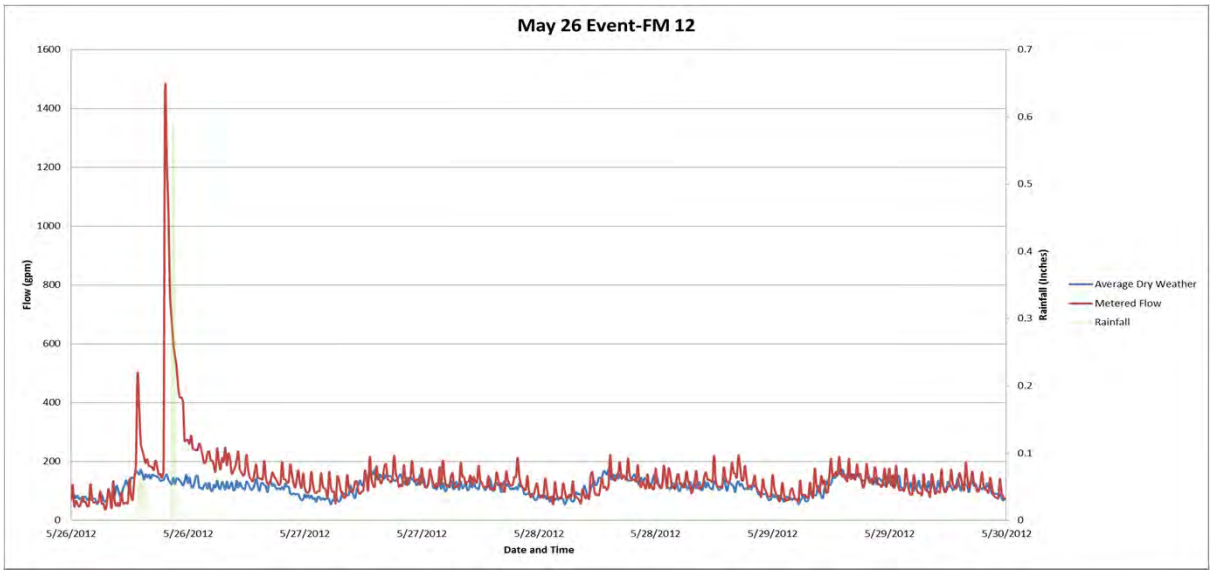

May 31 Event-FM 10
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall

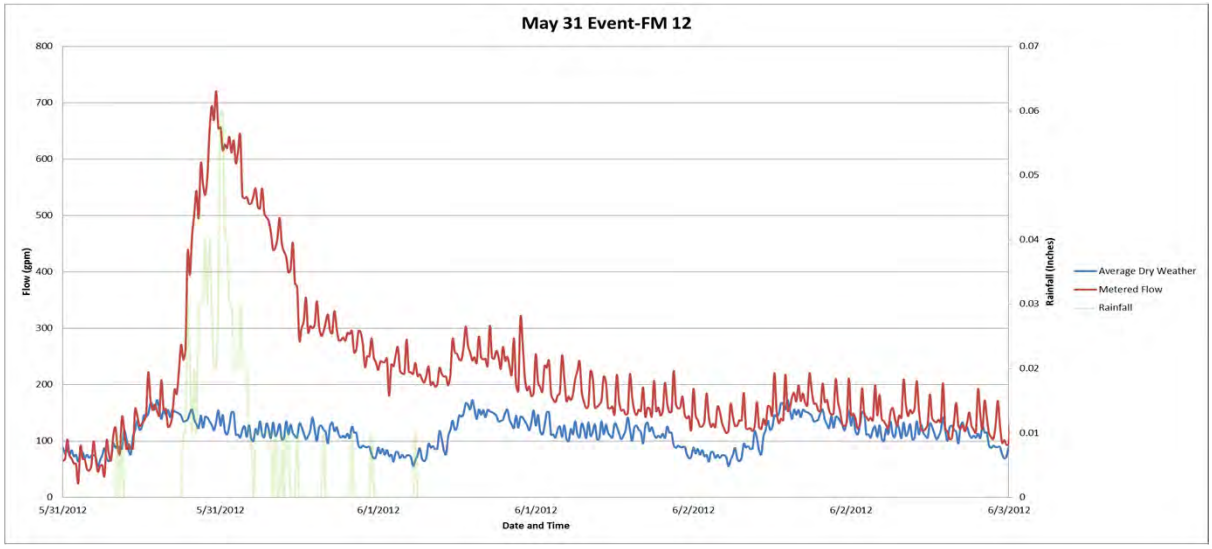

April 15 Event-FM 11
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
400
350
300
250
200
150
100
50
0
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012

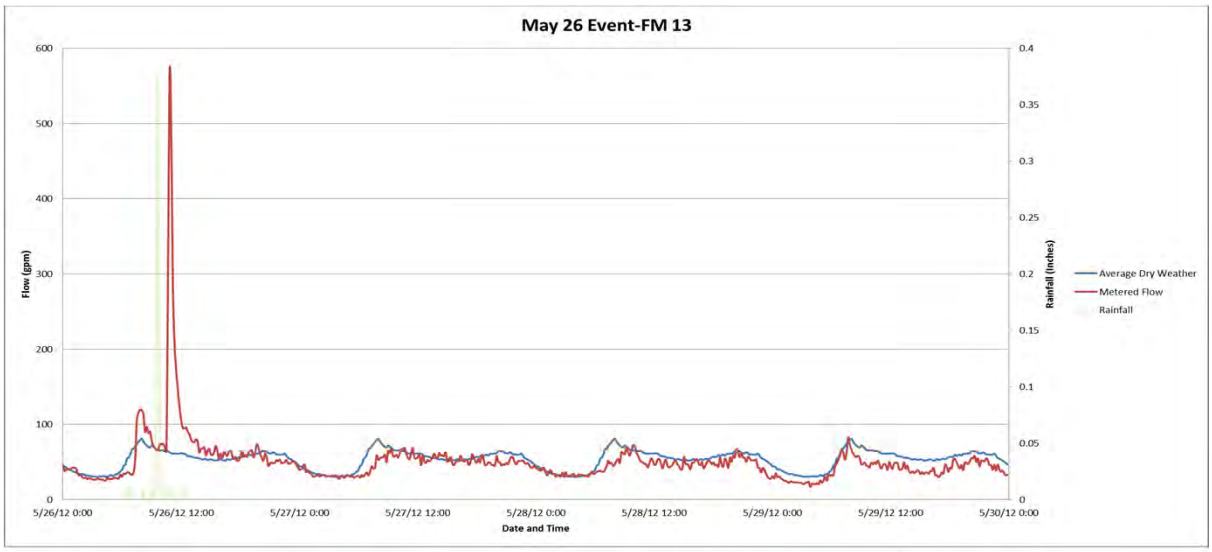

May 26 Event-FM 11
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
600
500
400
300
200
100
0
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012

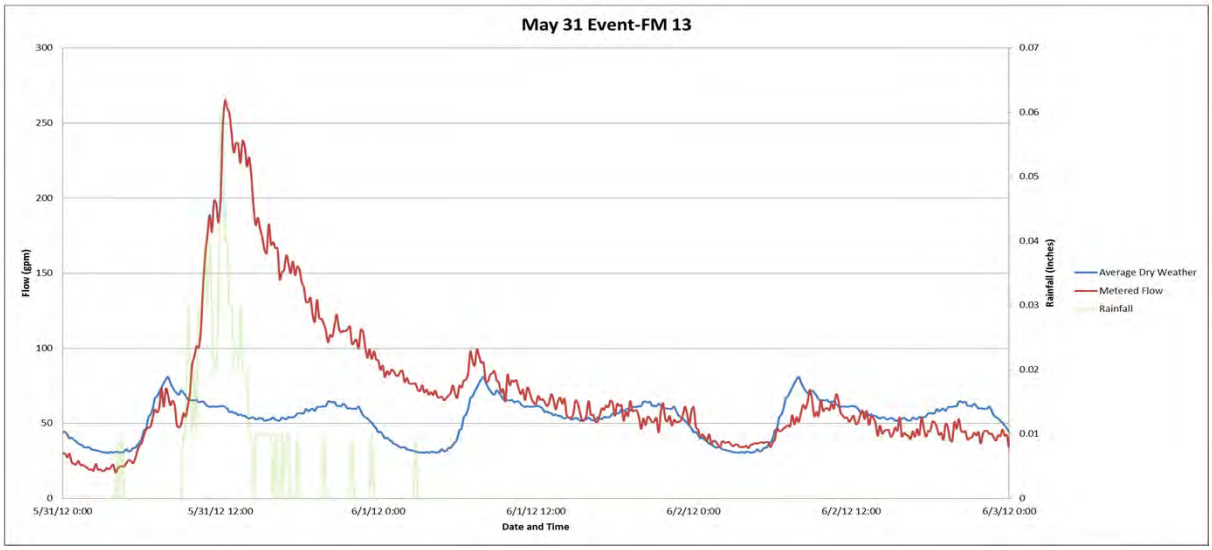

May 31 Event-FM 11
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
350
300
250
200
150
100
50
0
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012

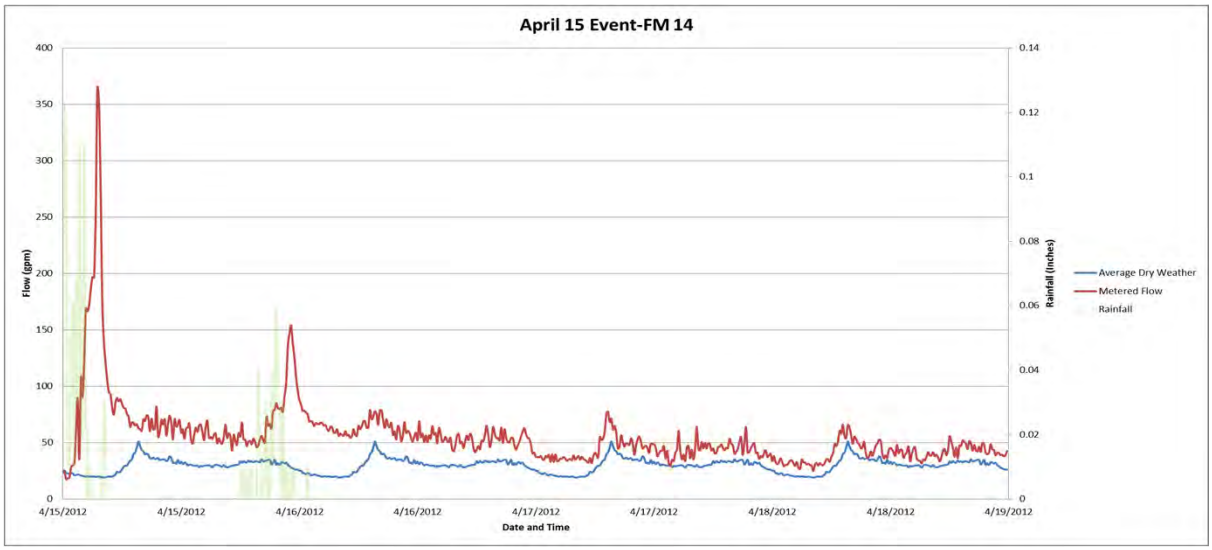

April 15 Event-FM 12
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012

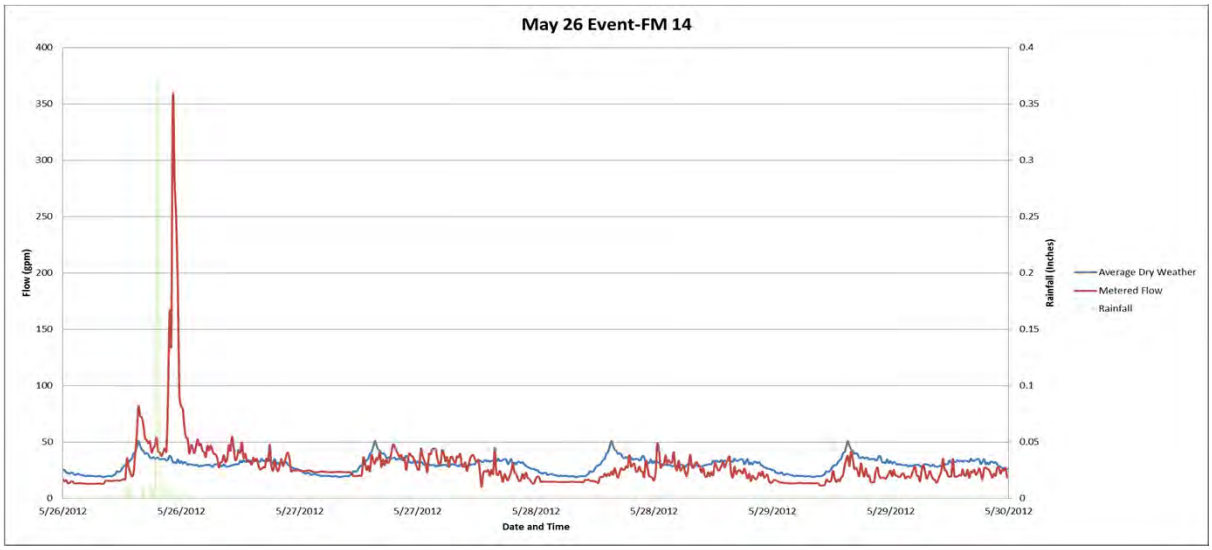

May 26 Event-FM 12
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012

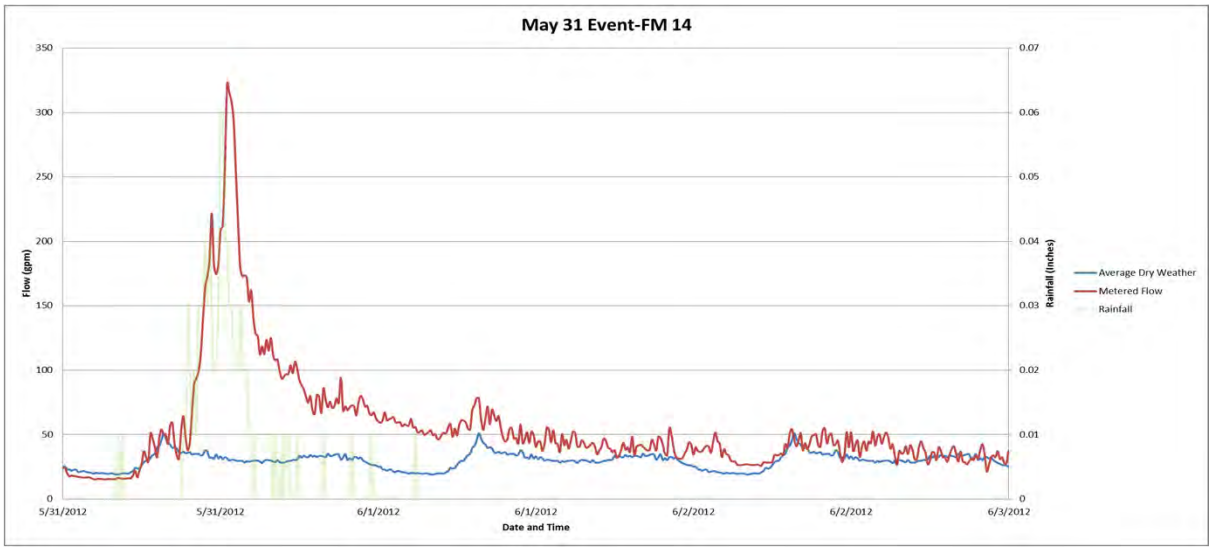

May 31 Event-FM 12
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012

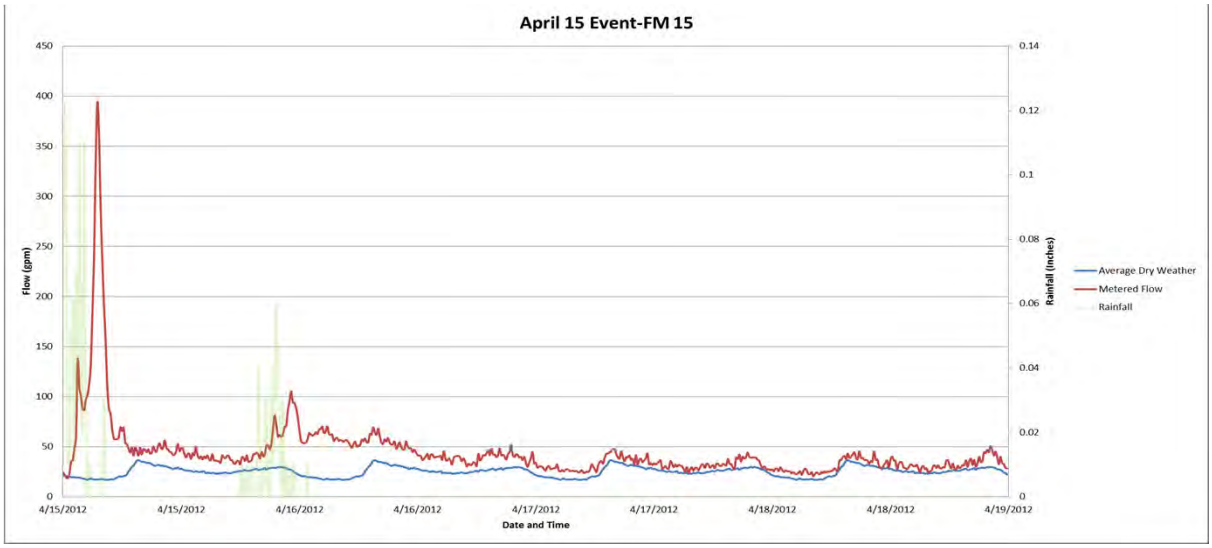

May 26 Event-FM 13
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
0
100
200
300
400
500
600
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
5/26/12 0:00
5/26/12 12:00
5/27/12 0:00
5/27/12 12:00
5/28/12 0:00
5/28/12 12:00
5/29/12 0:00
5/29/12 12:00
5/30/12 0:00

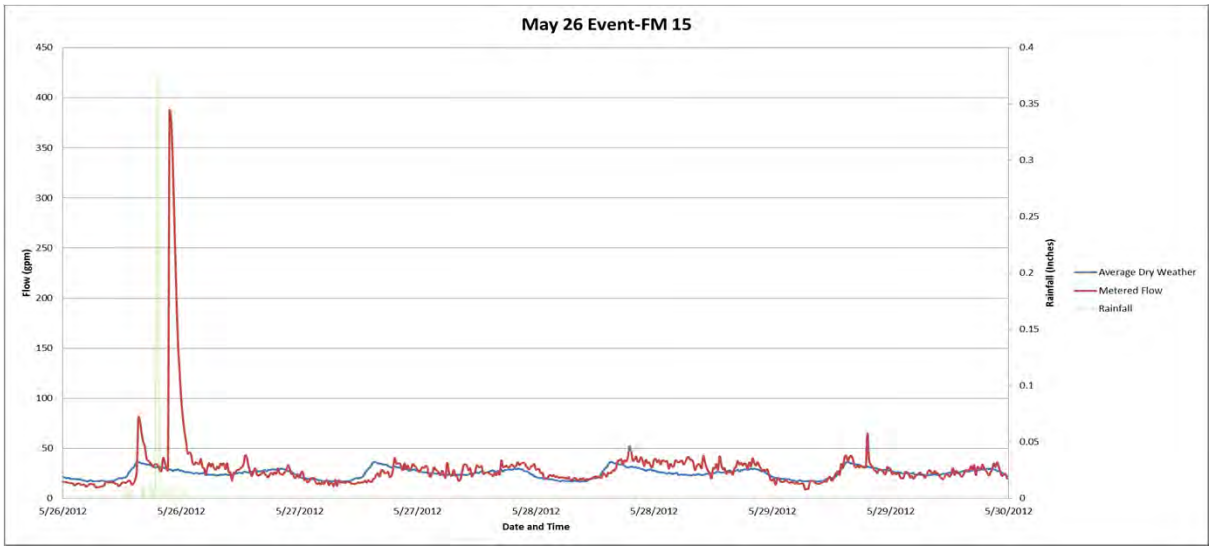

May 31 Event-FM 13
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
0
50
100
150
200
250
300
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
5/31/12 0:00
5/31/12 12:00
6/1/12 0:00
6/1/12 12:00
6/2/12 0:00
6/2/12 12:00
6/3/12 0:00

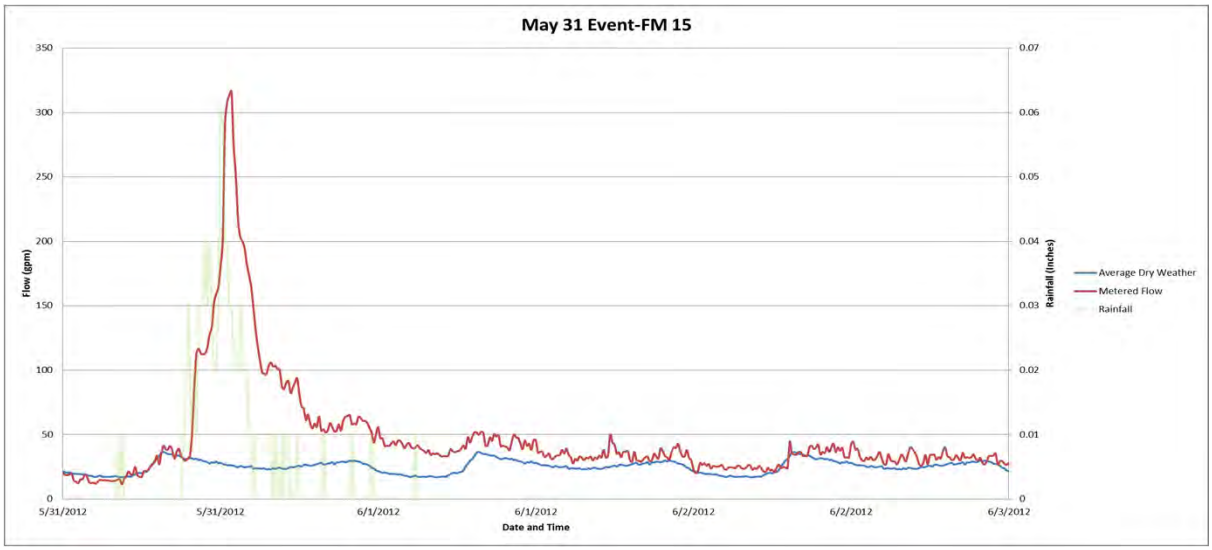

April 15 Event-FM 14
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
400
350
300
250
200
150
100
50
0
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012

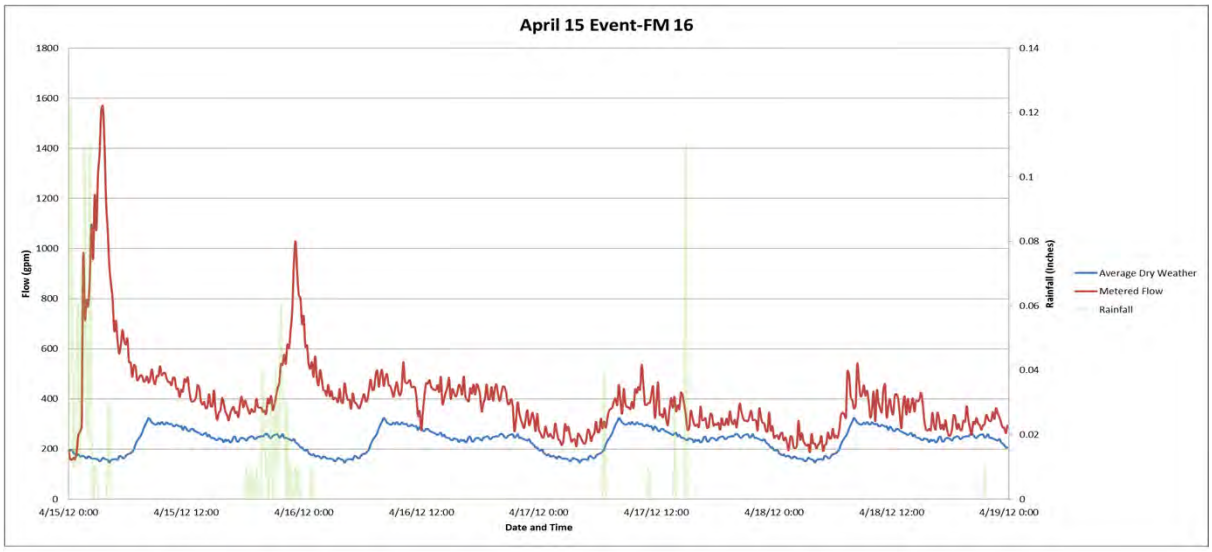

May 26 Event-FM 14
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
400
350
300
250
200
150
100
50
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012


May 31 Event-FM 14
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
350
300
250
200
150
100
50
0
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012


April 15 Event-FM 15
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012


May 26 Event-FM 15
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012


May 31 Event-FM 15
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012


April 15 Event-FM 16
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/12 0:00
4/15/12 12:00
4/16/12 0:00
4/16/12 12:00
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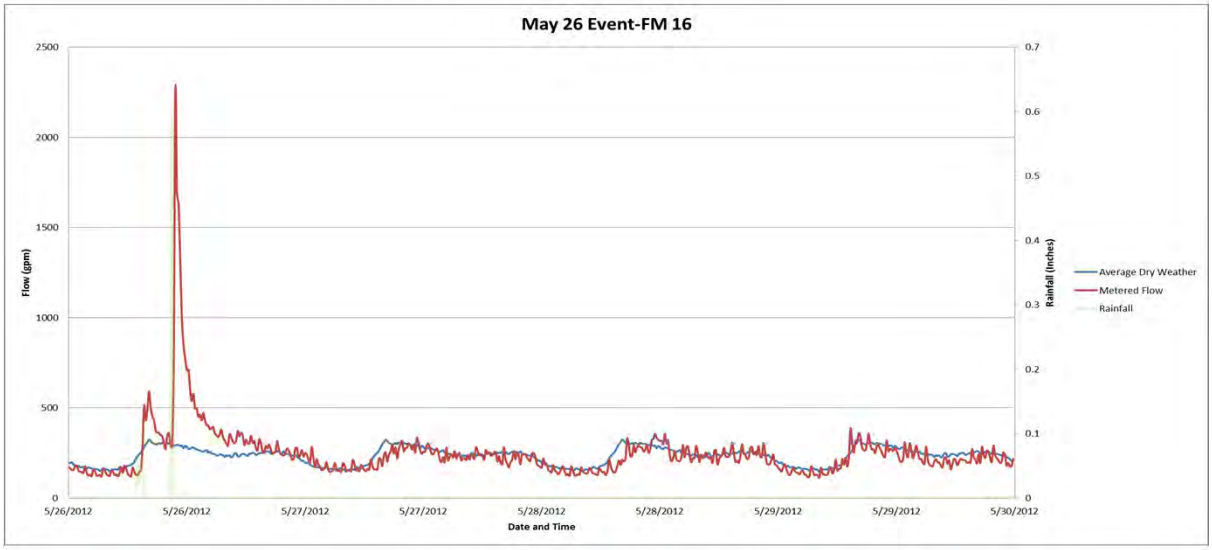
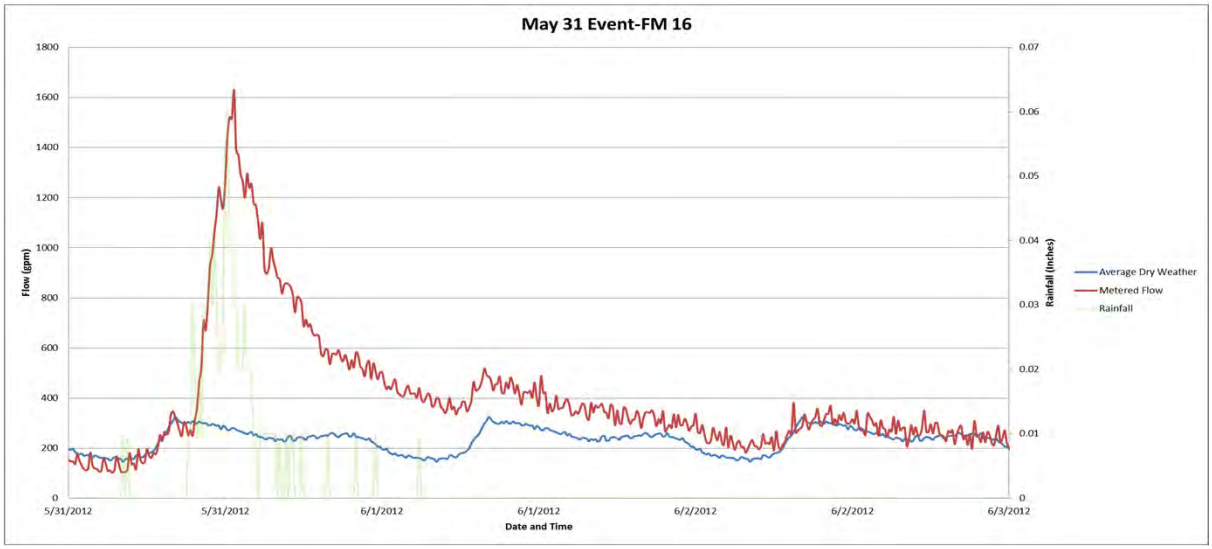
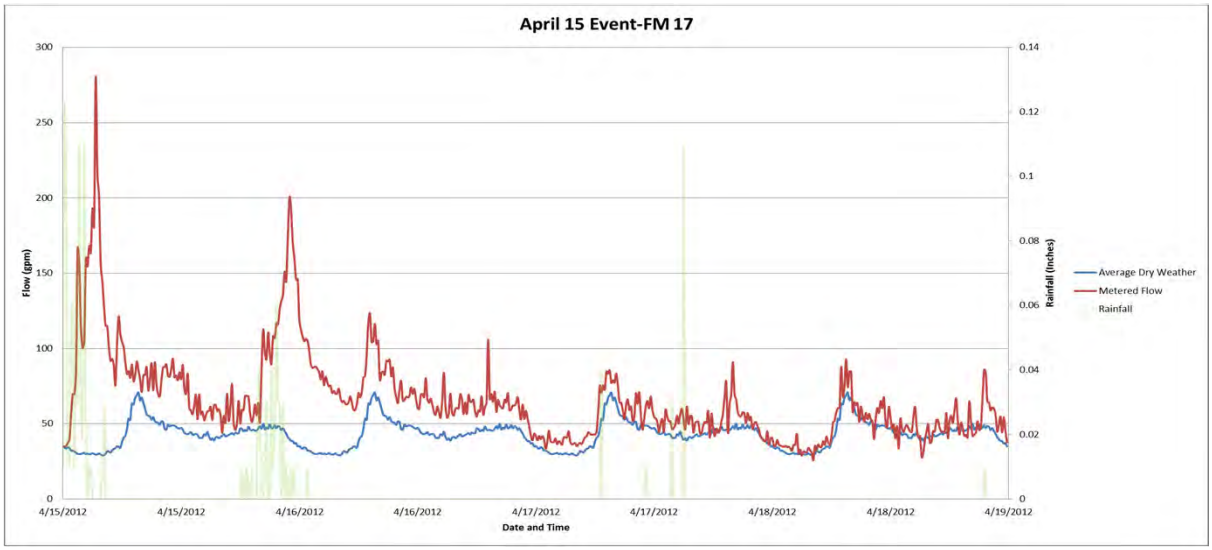
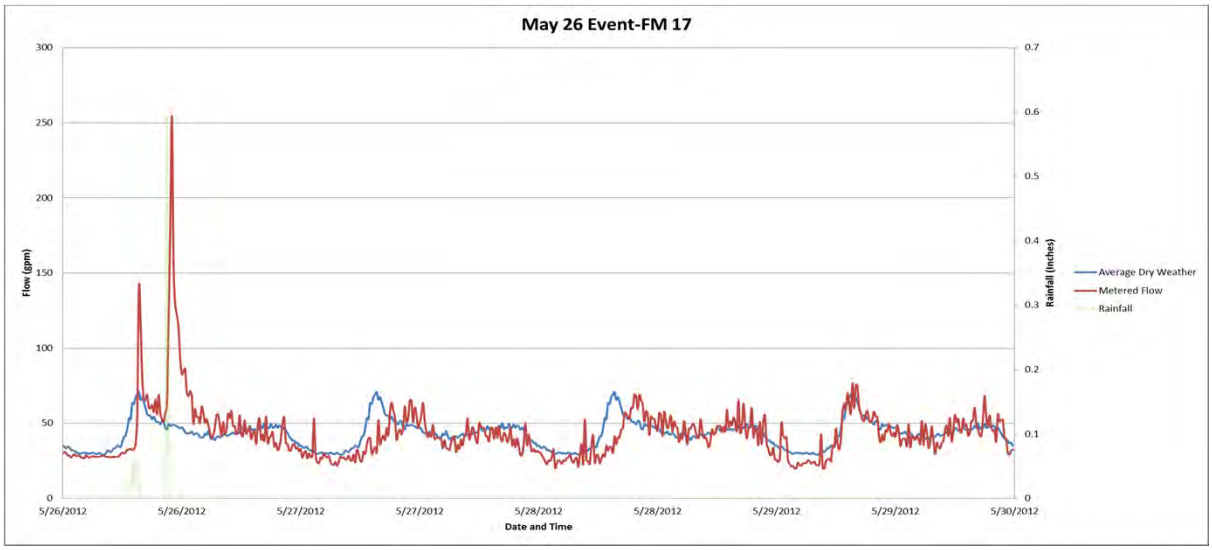
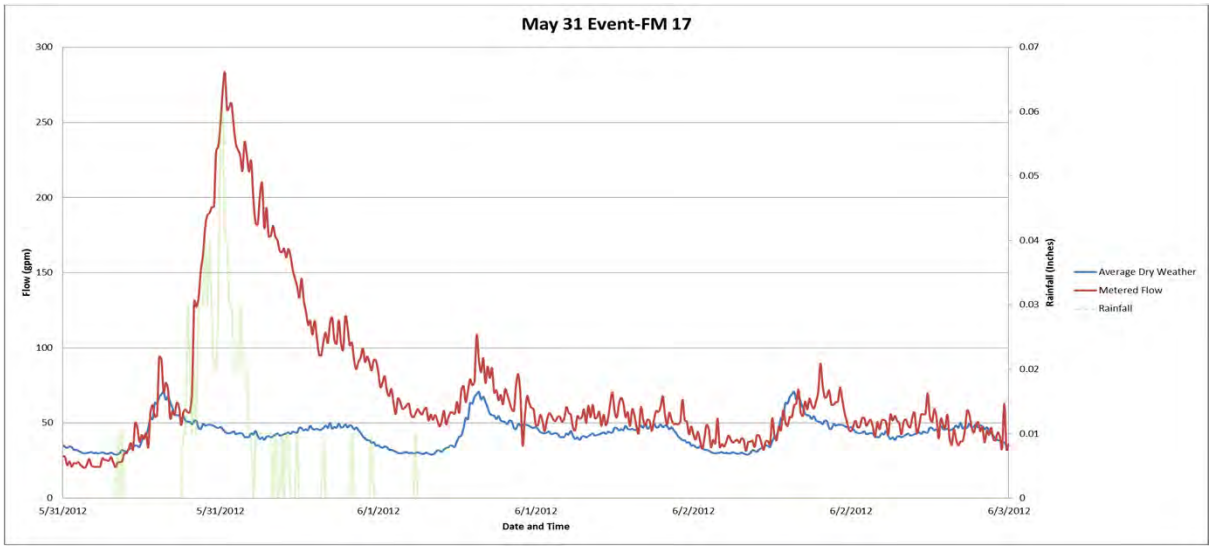
4/18/12 12:00
4/19/12 0:00

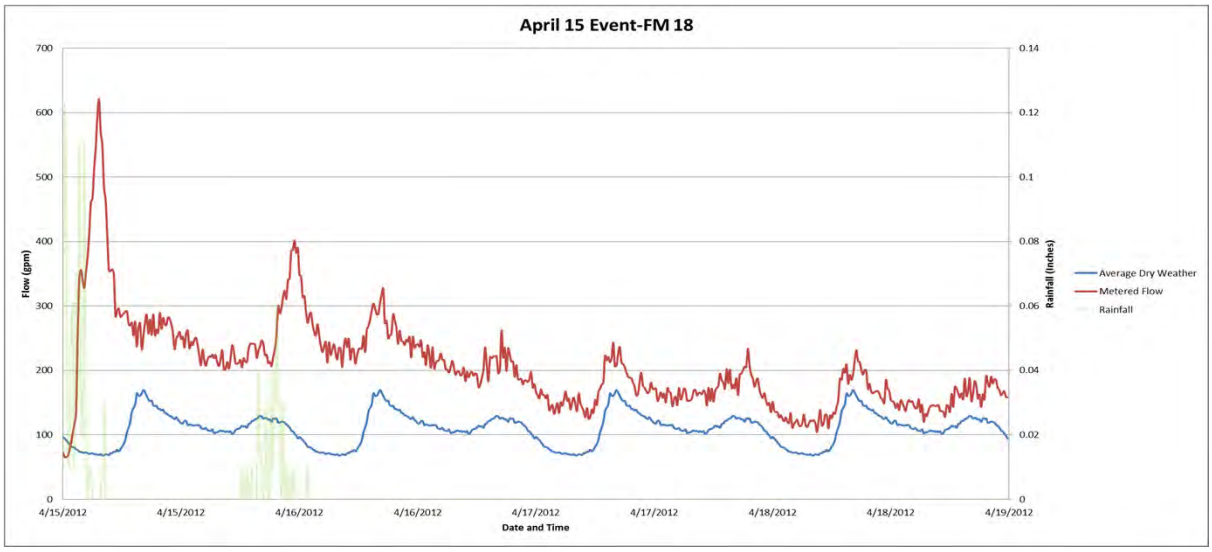

May 26 Event-FM 16
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012

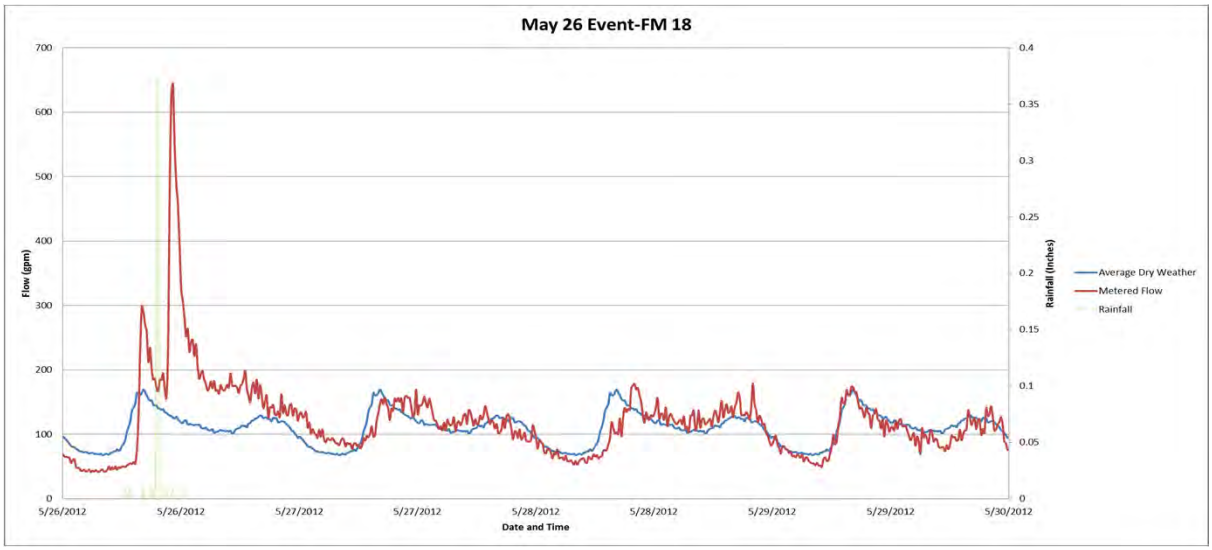

May 31 Event-FM 16
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012


April 15 Event-FM 17
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012


May 26 Event-FM 17
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012


May 31 Event-FM 17
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012


April 15 Event-FM 18
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012


May 26 Event-FM 18
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
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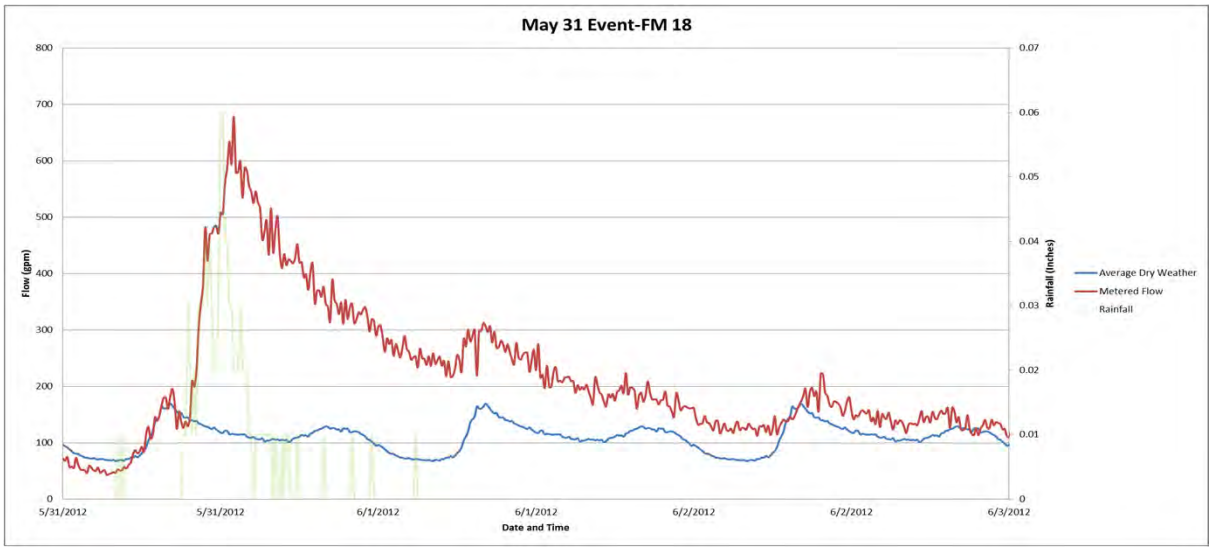
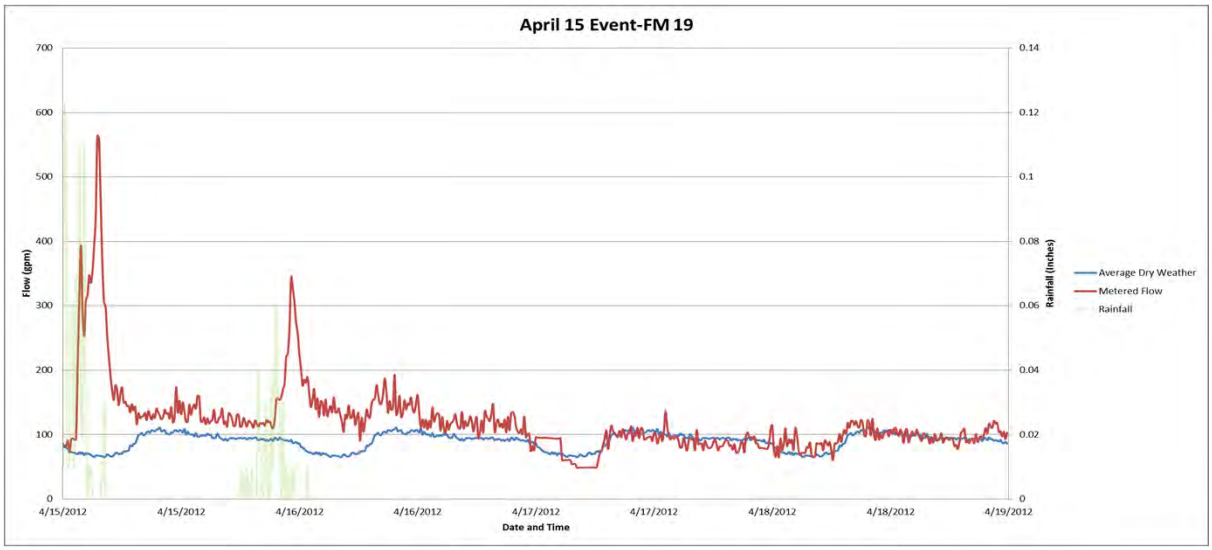
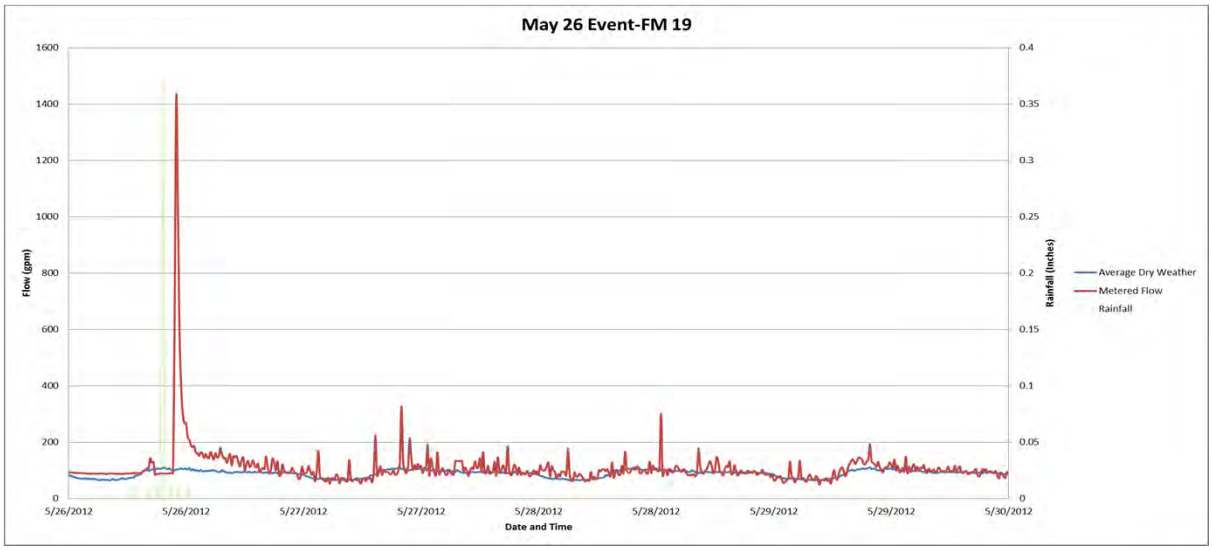
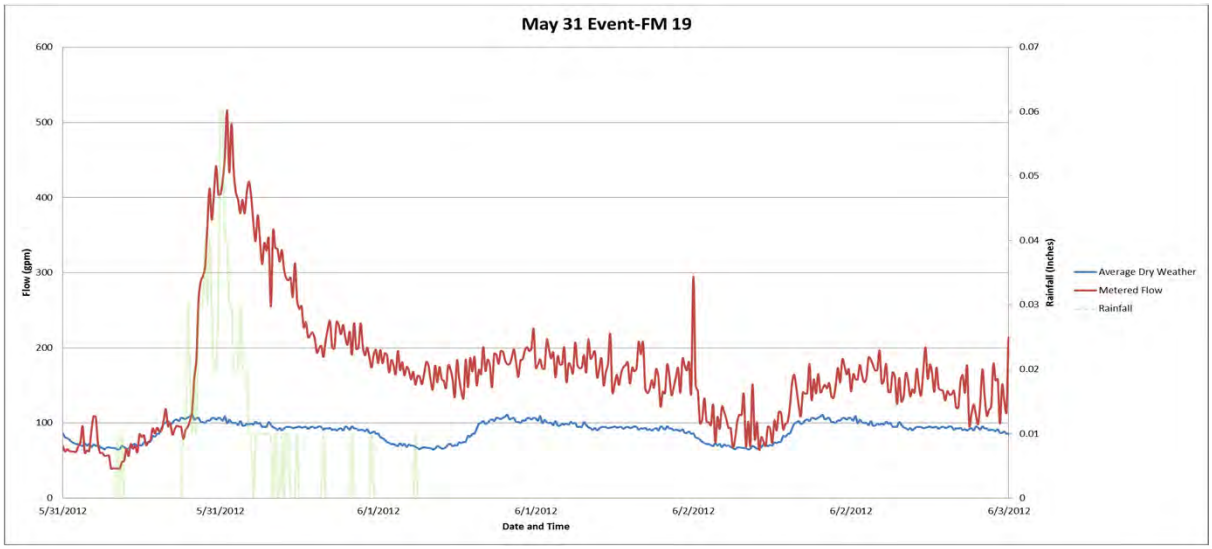
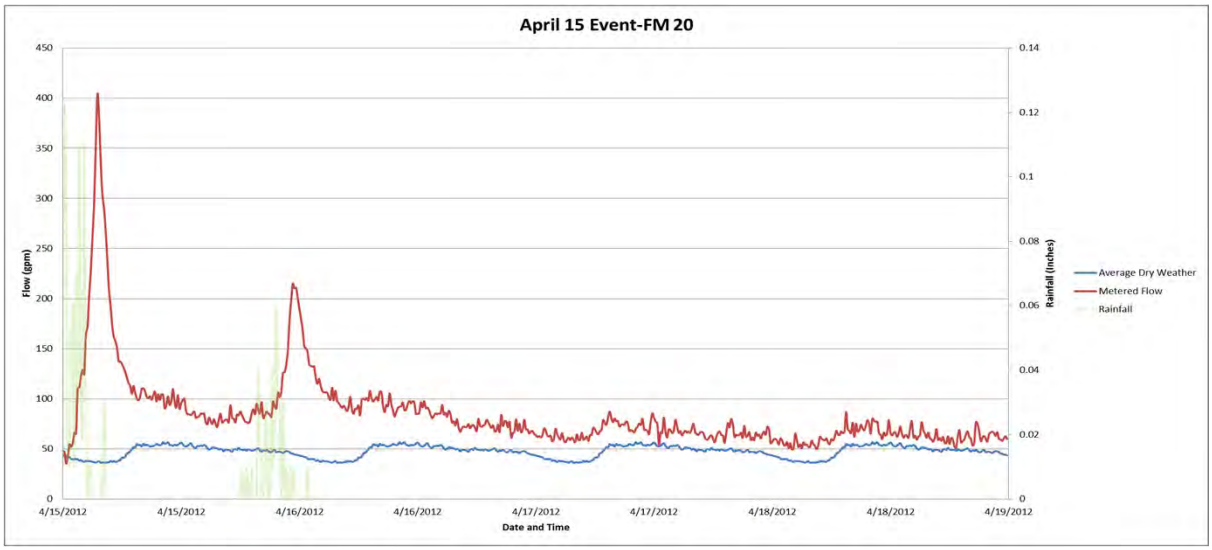
5/29/2012
5/29/2012
5/30/2012

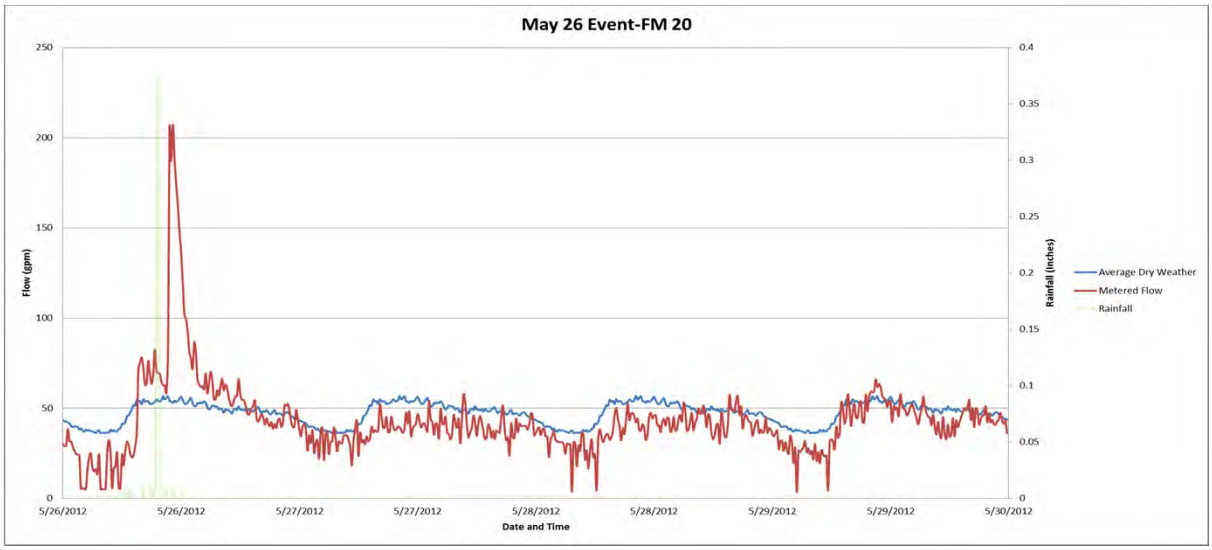

May 31 Event-FM 18
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012

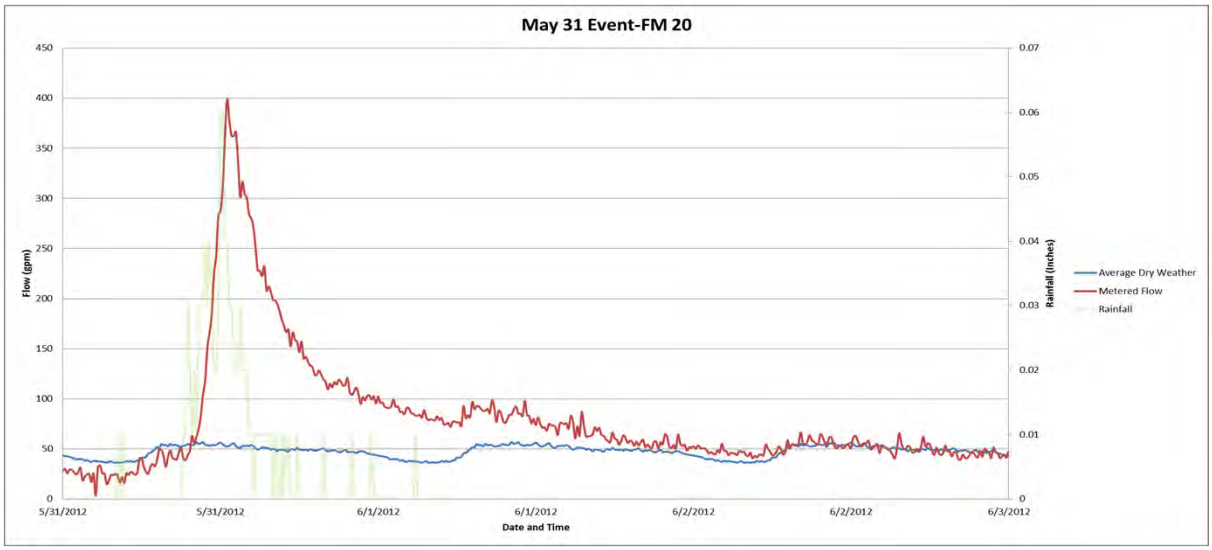

April 15 Event-FM 19
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012

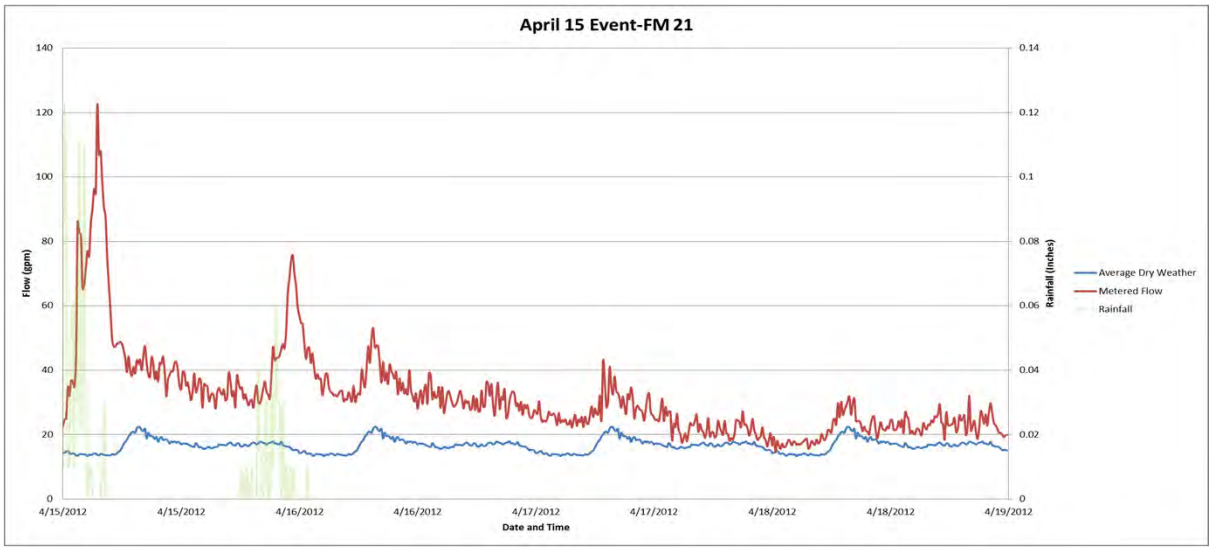

May 26 Event-FM 19
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012

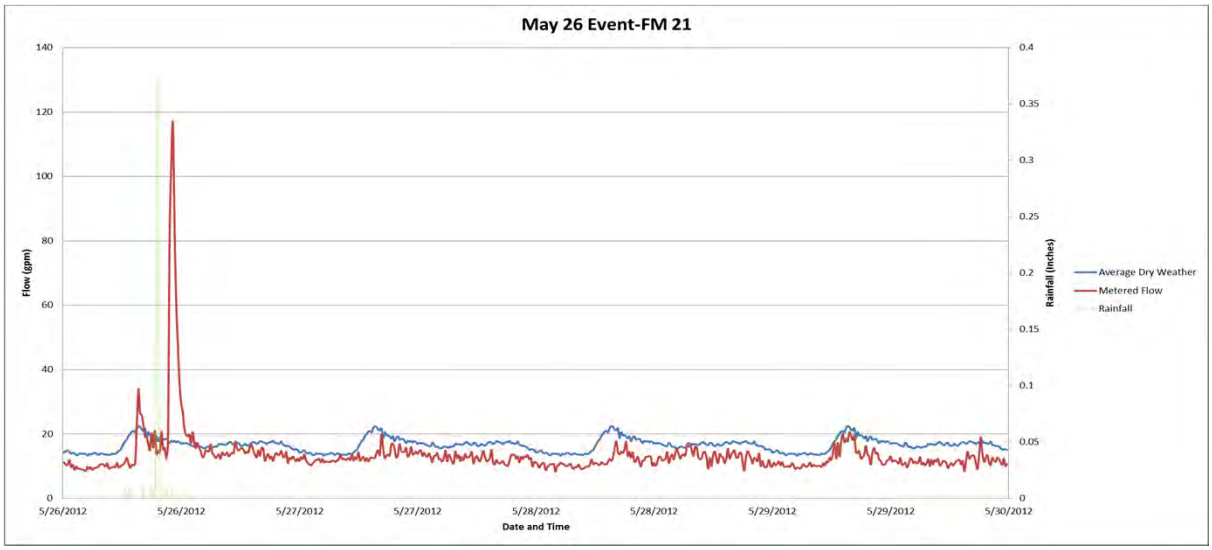

May 31 Event-FM 19
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012

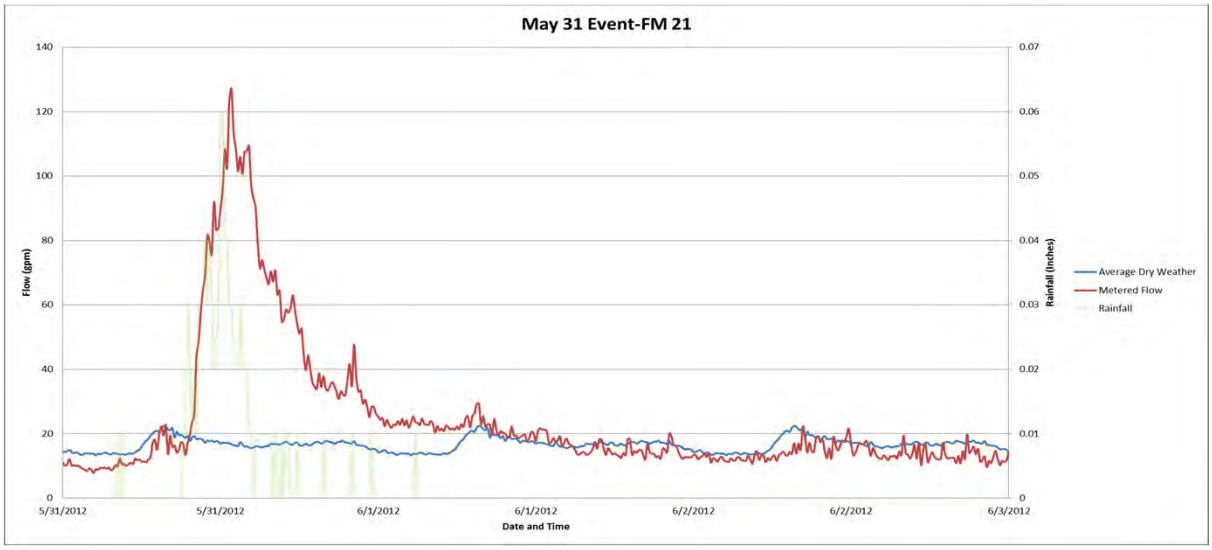

April 15 Event-FM 20
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012

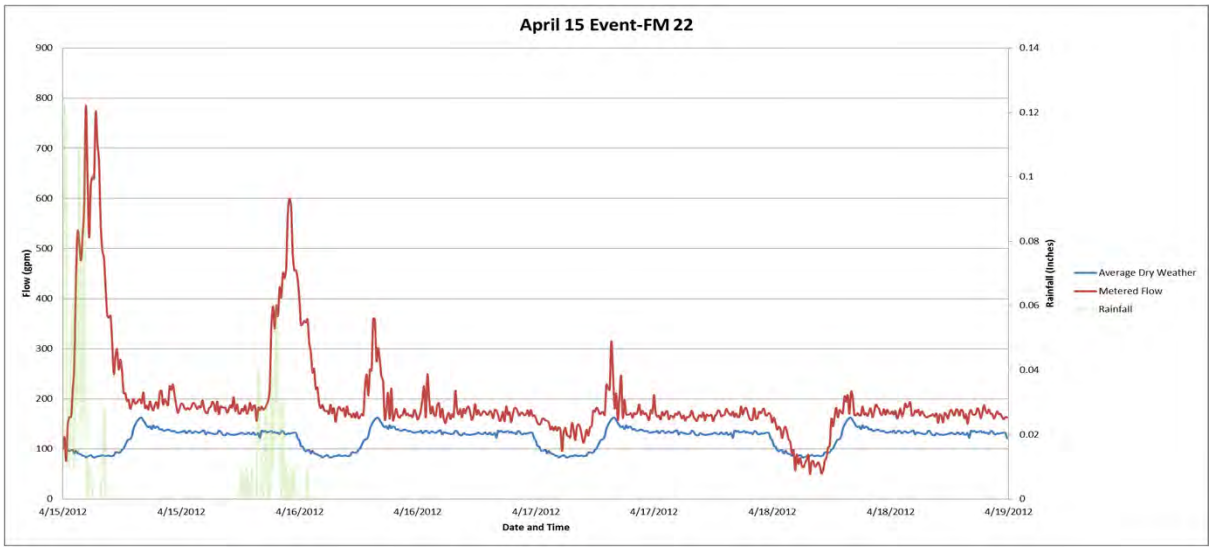

May 26 Event-FM 20
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012

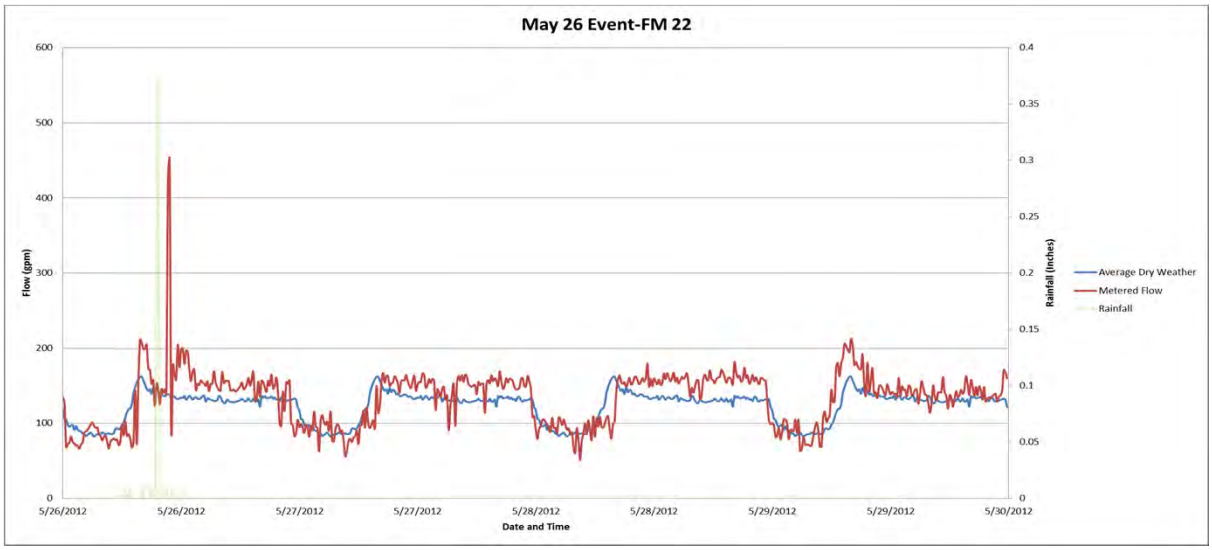

May 31 Event-FM 20
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012

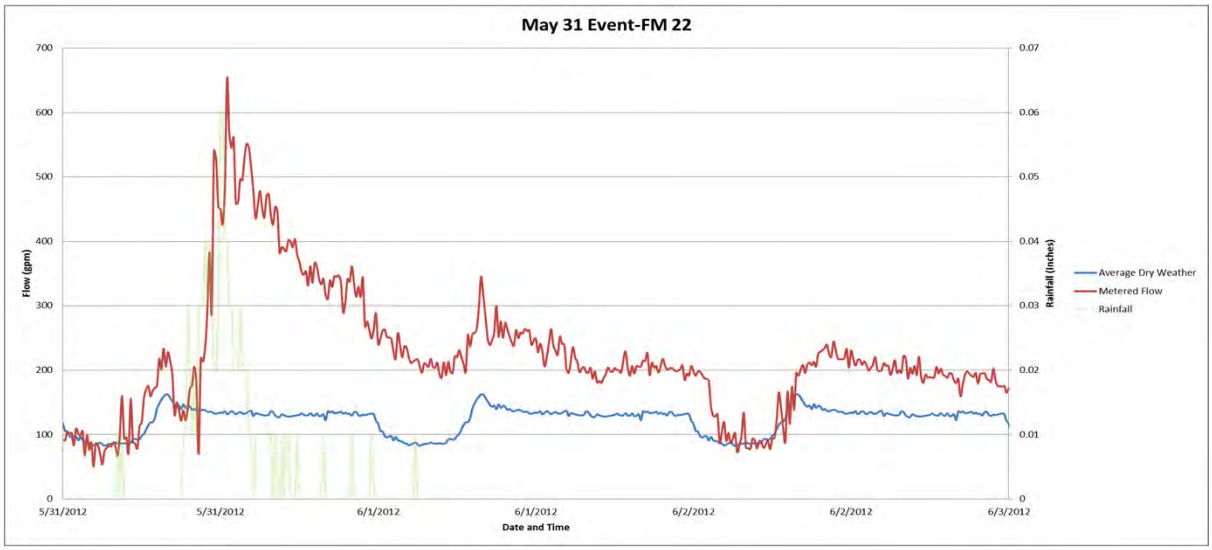

April 15 Event-FM 21
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
140
120
100
80
60
40
20
0
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012

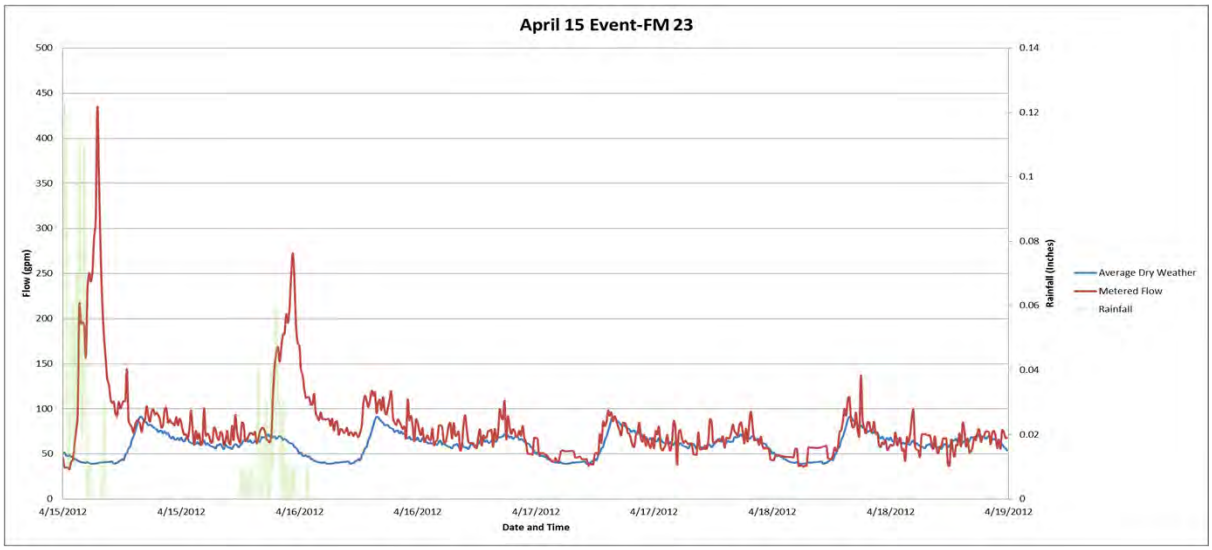

May 26 Event-FM 21
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
140
120
100
80
60
40
20
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012

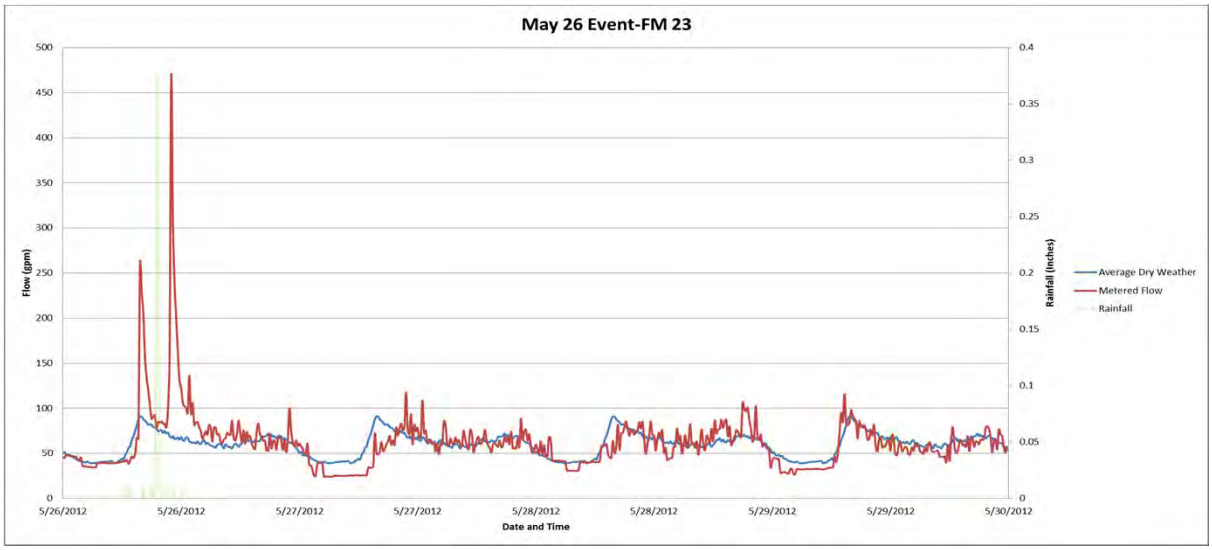

May 31 Event-FM 21
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
140
120
100
80
60
40
20
0
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012

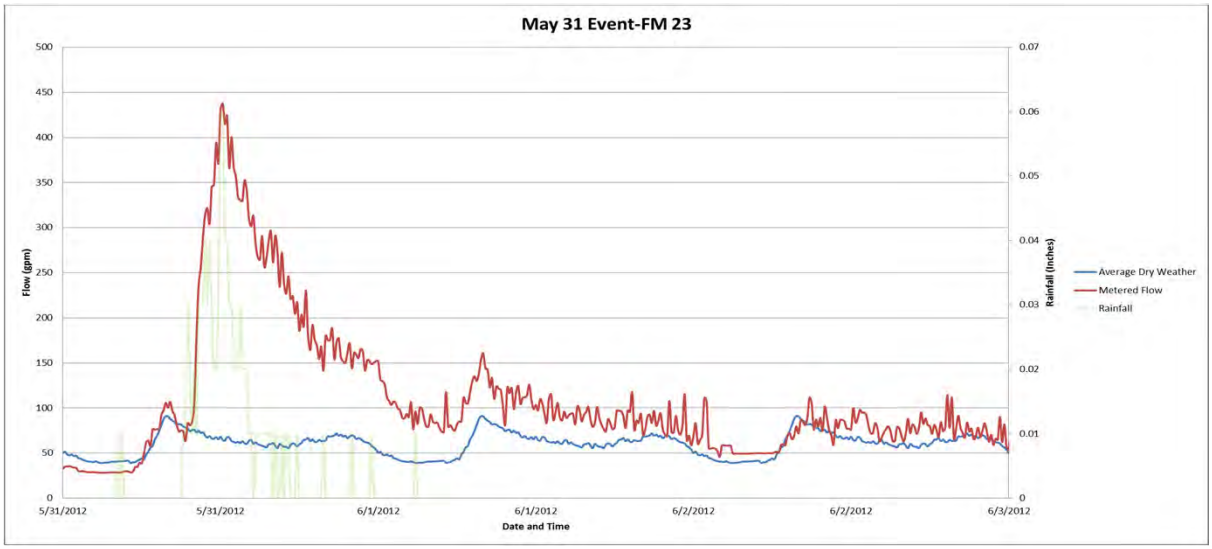

April 15 Event-FM 22
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall

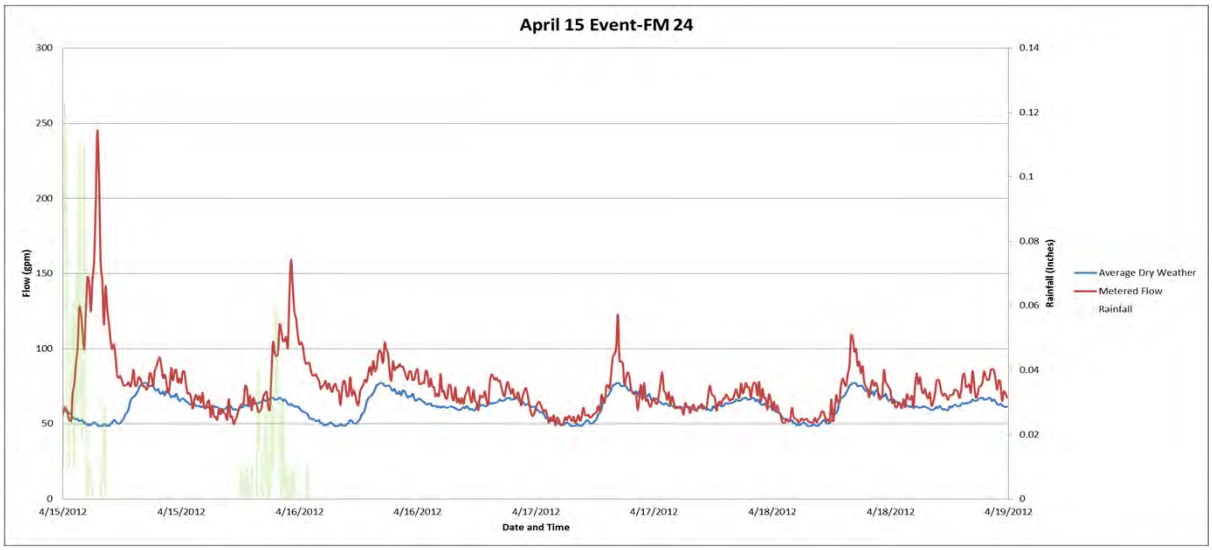

May 26 Event-FM 22
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall

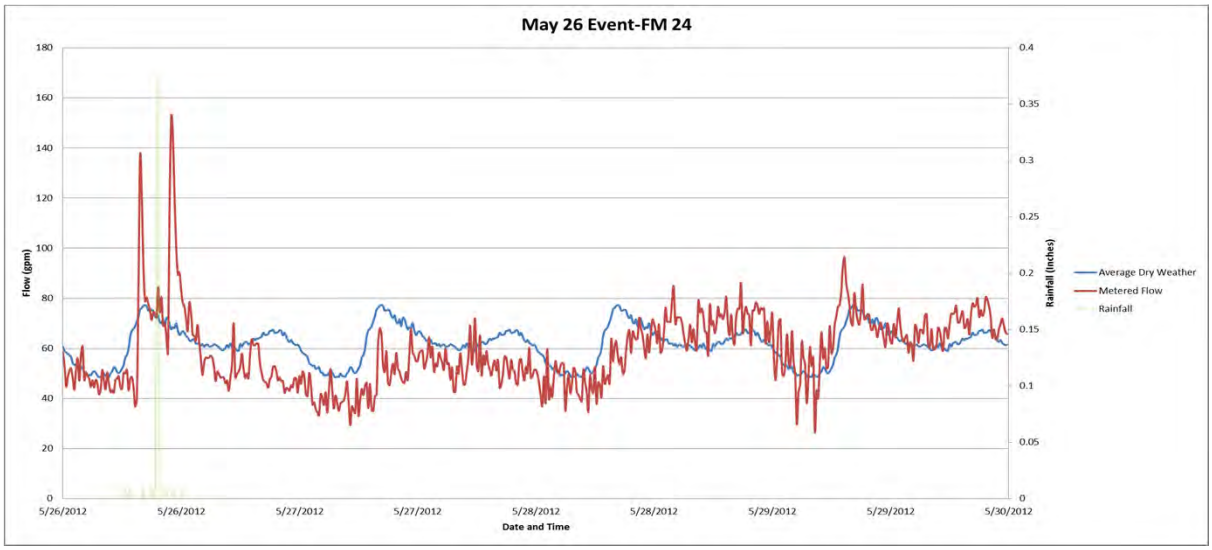

May 31 Event-FM 22
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall

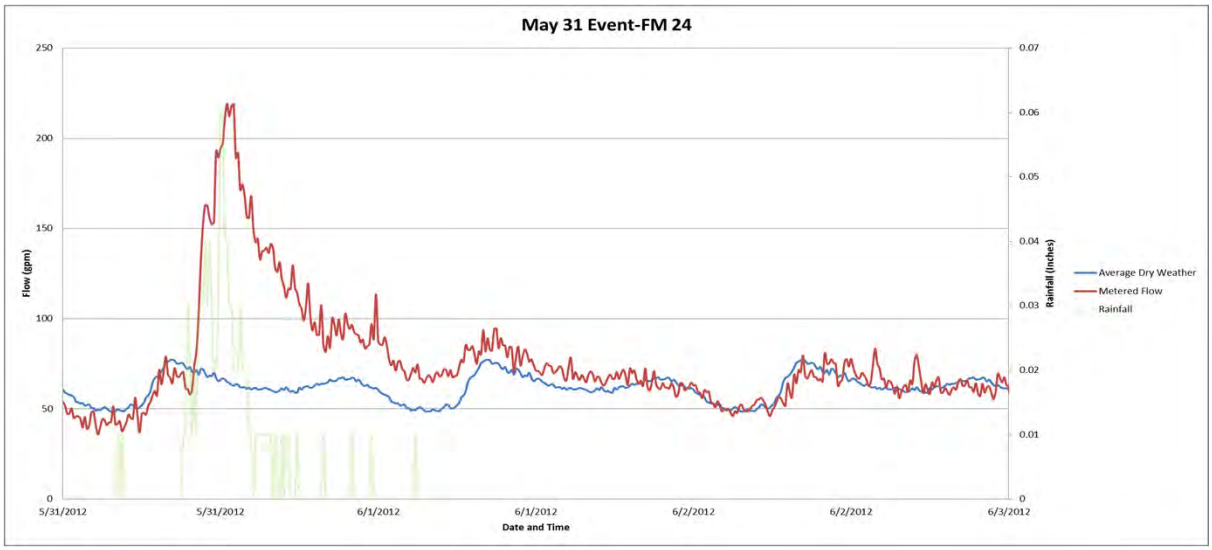

April 15 Event-FM 23
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012

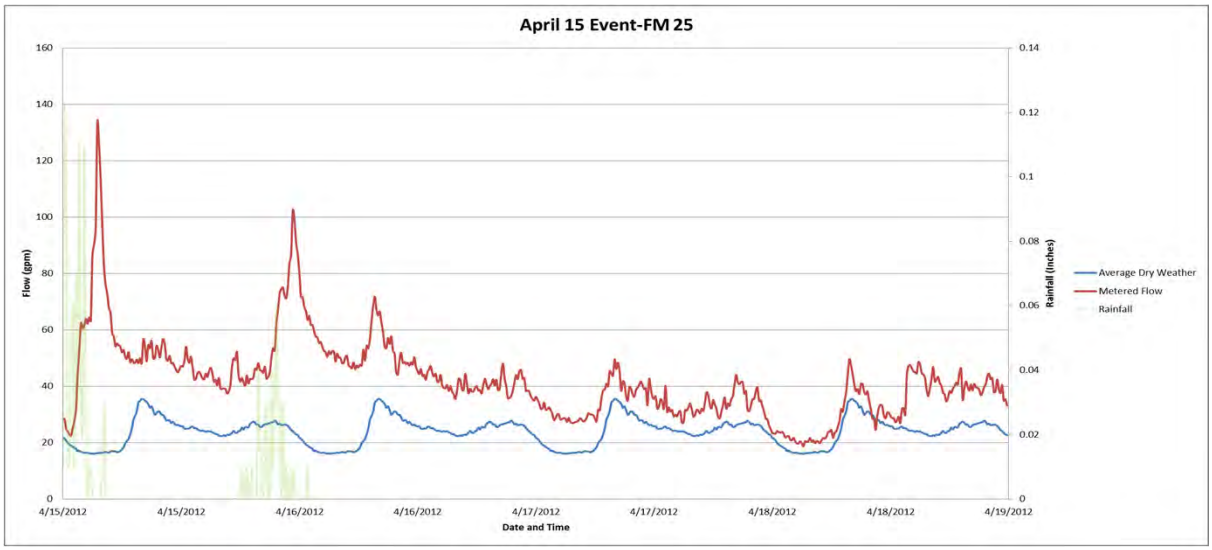

May 26 Event-FM 23
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012

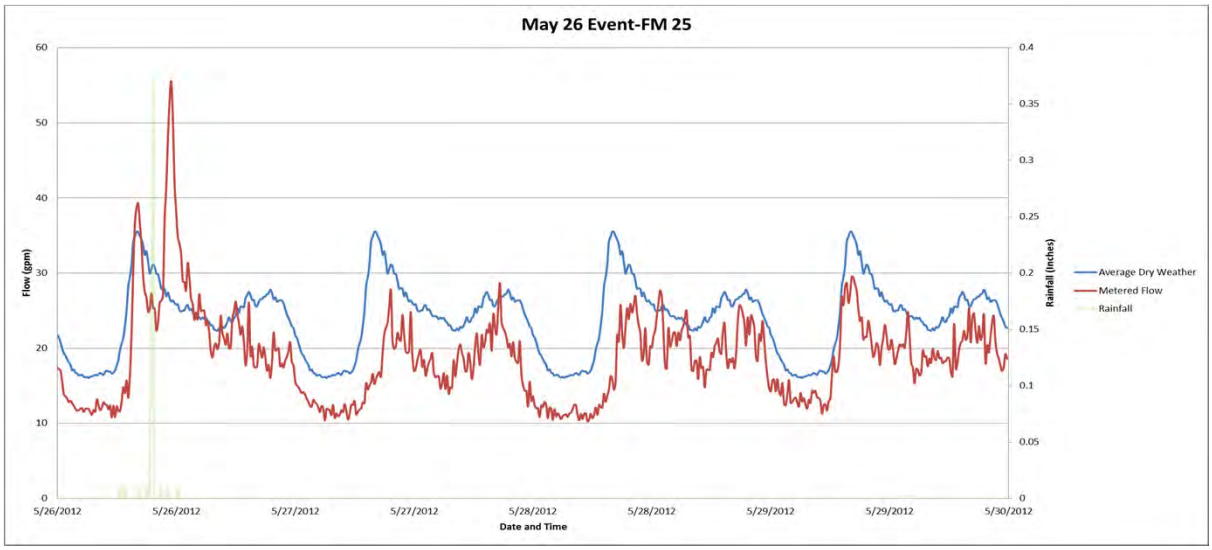

May 31 Event-FM 23
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012

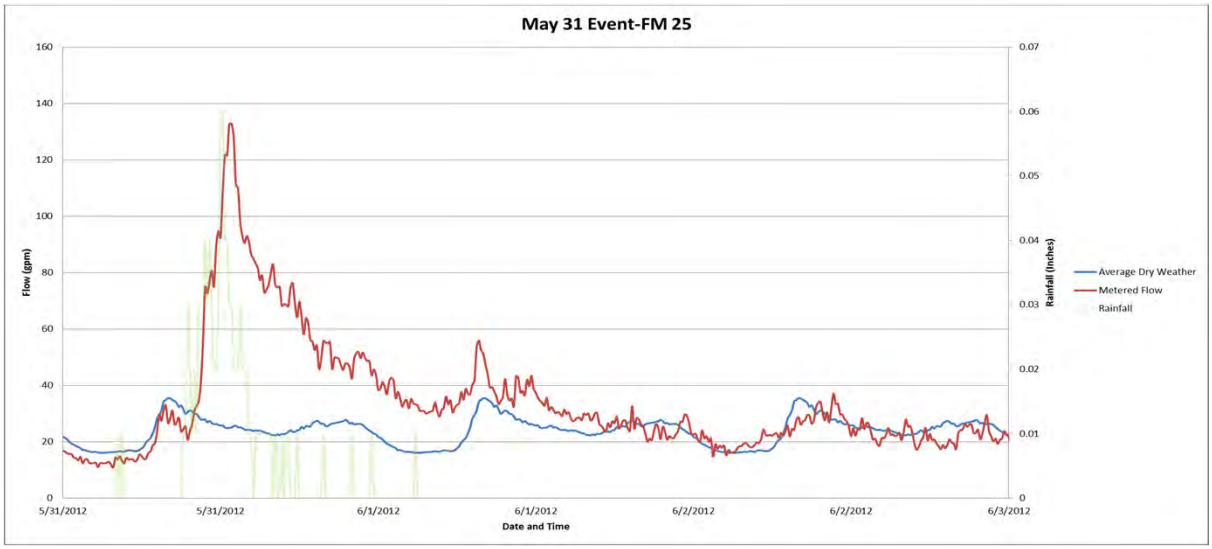

April 15 Event-FM 24
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
300
250
200
150
100
50
0
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012

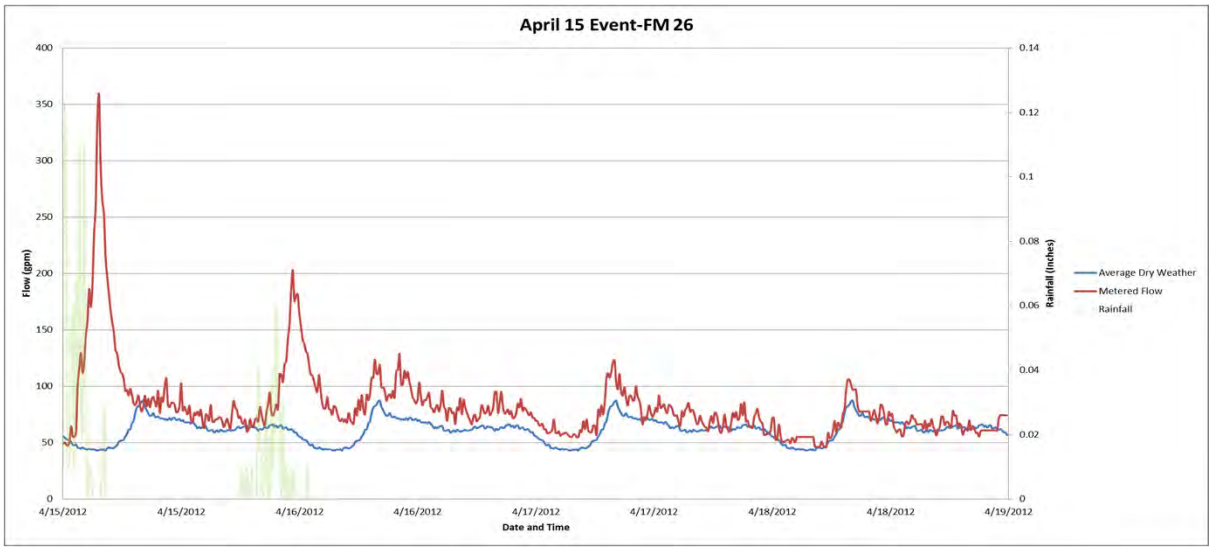

May 26 Event-FM 24
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
180
160
140
120
100
80
60
40
20
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012

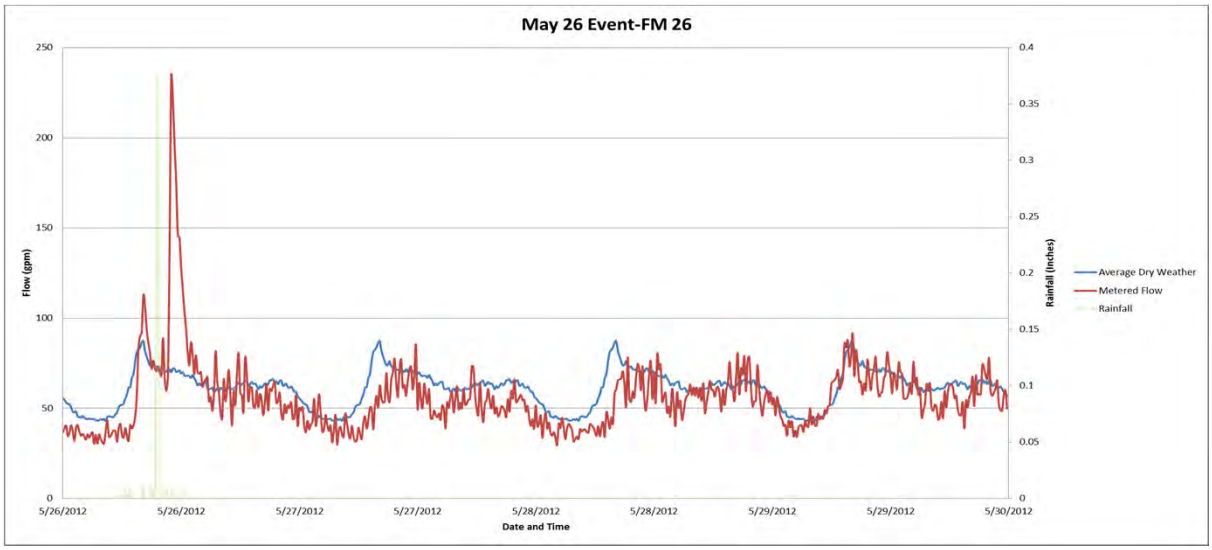

May 31 Event-FM 24
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
250
200
150
100
50
0
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012

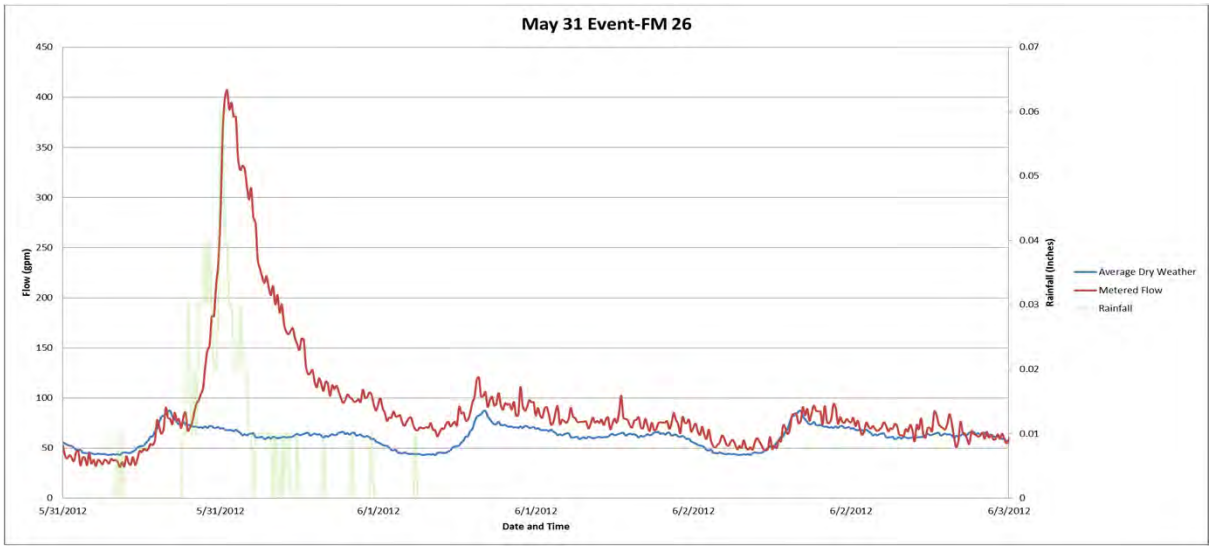

April 15 Event-FM 25
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012

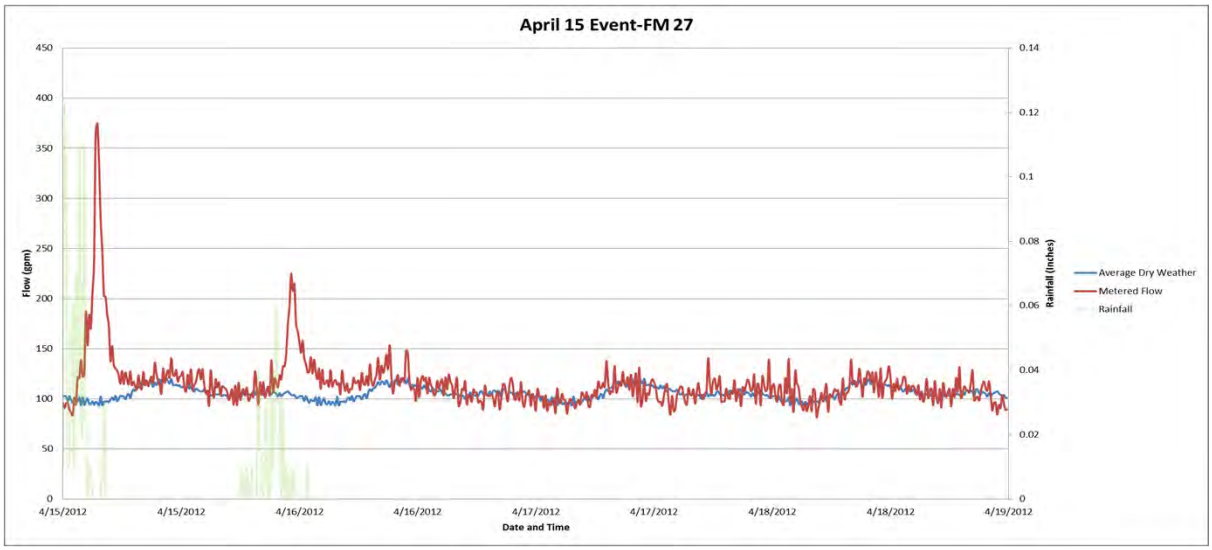

May 26 Event-FM 25
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012

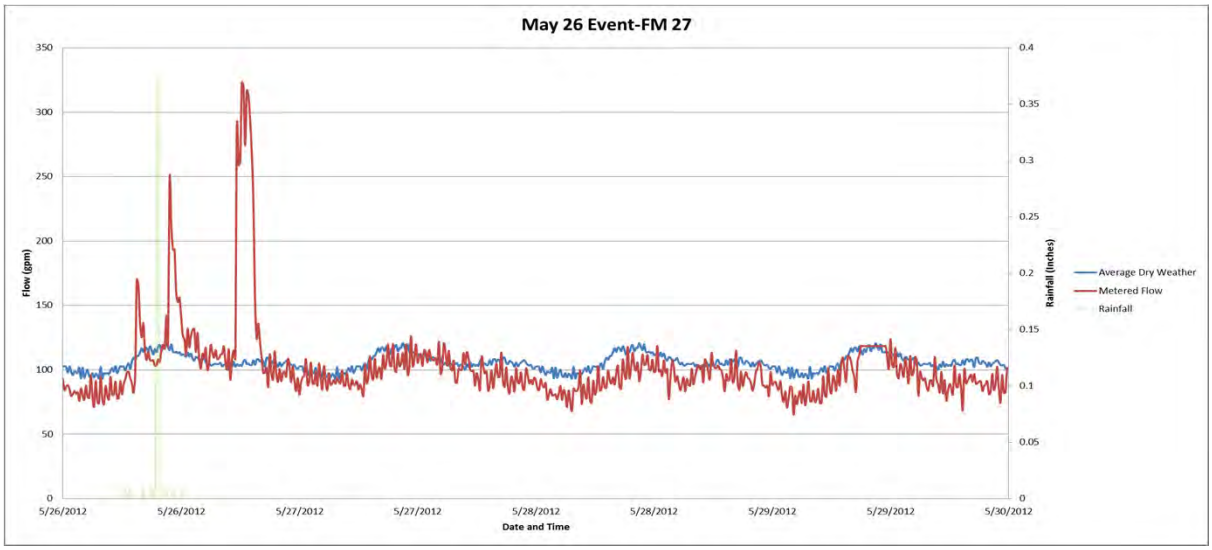

May 31 Event-FM 25
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012


April 15 Event-FM 26
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
400
350
300
250
200
150
100
50
0
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012


May 26 Event-FM 26
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
250
200
150
100
50
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012


May 31 Event-FM 26
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
450
400
350
300
250
200
150
100
50
0
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012


April 15 Event-FM 27
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012


May 26 Event-FM 27
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
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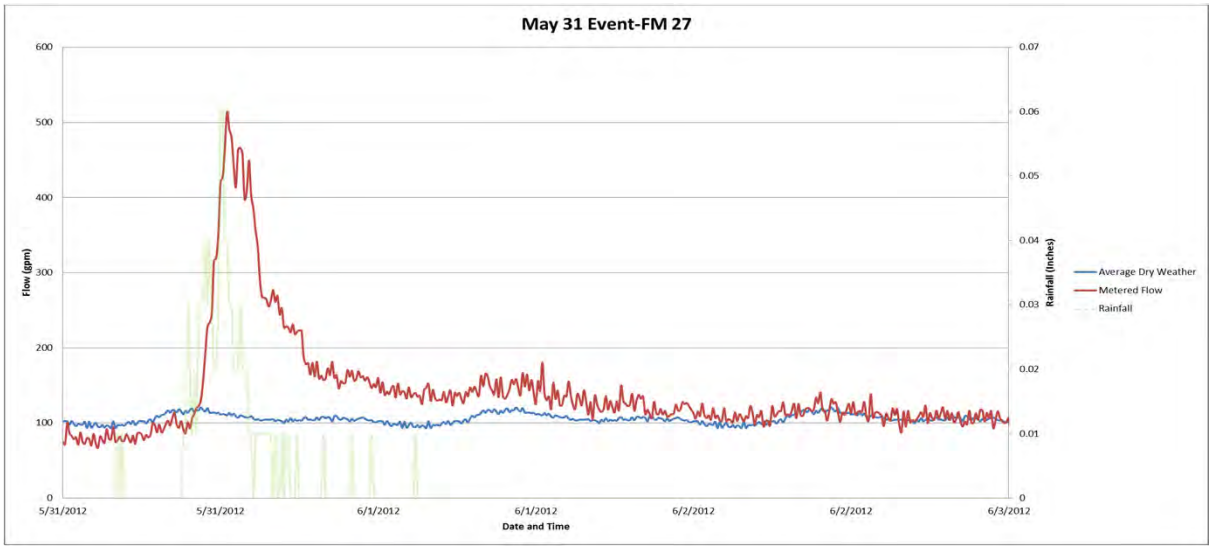
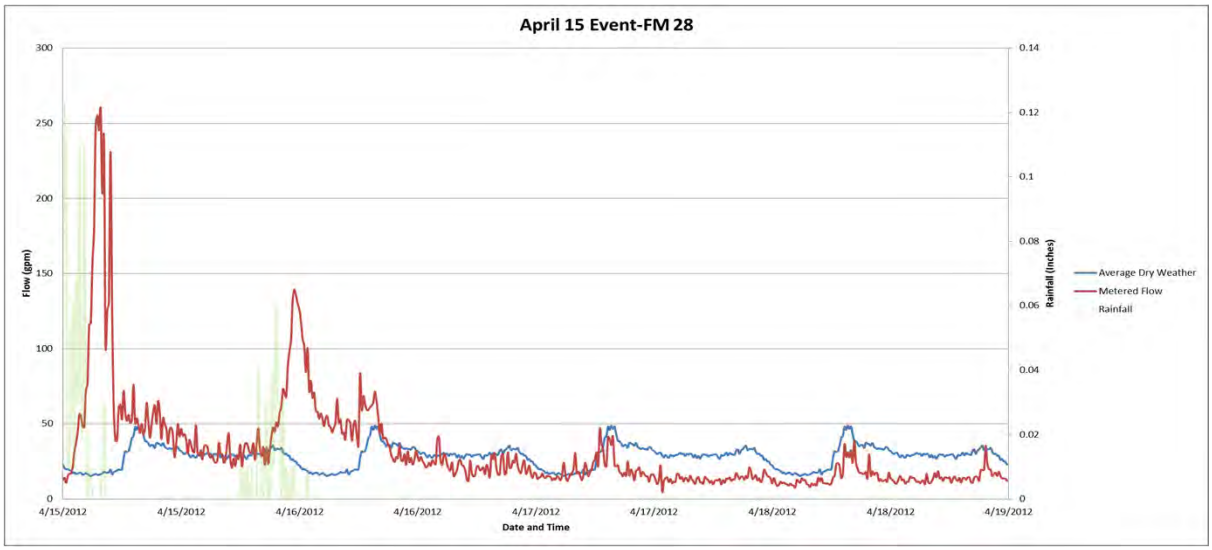
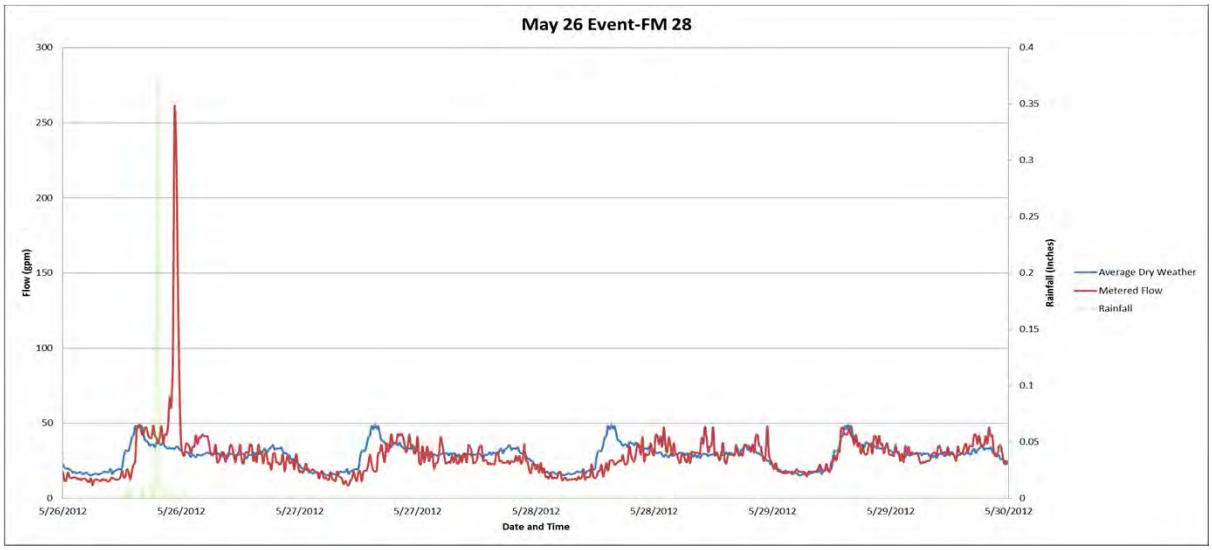
5/29/2012
5/29/2012
5/30/2012


May 31 Event-FM 27
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012


April 15 Event-FM 28
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012


May 26 Event-FM 28
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
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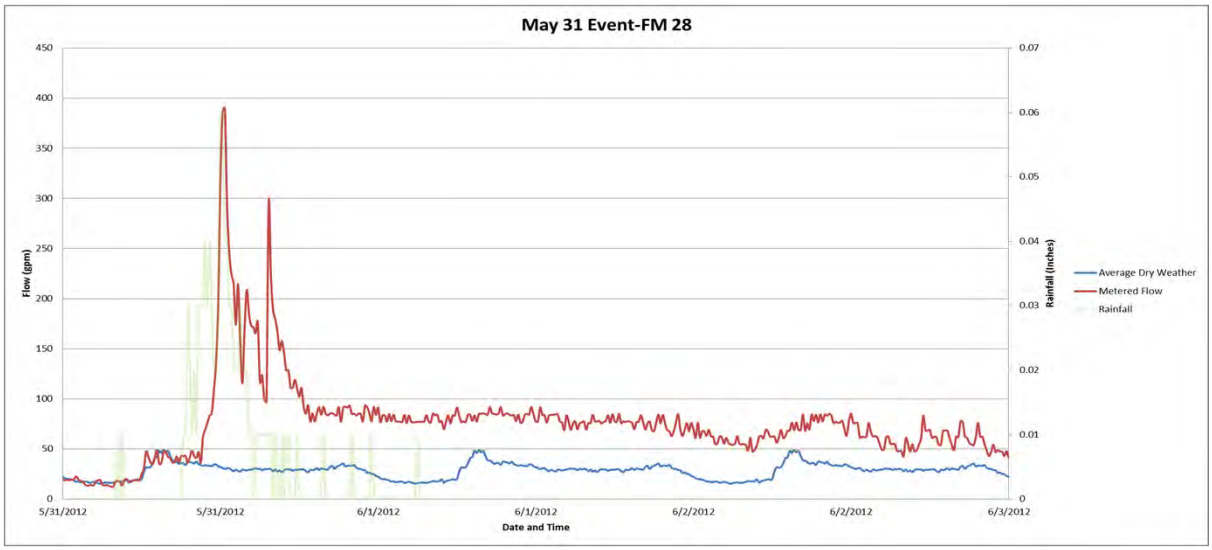
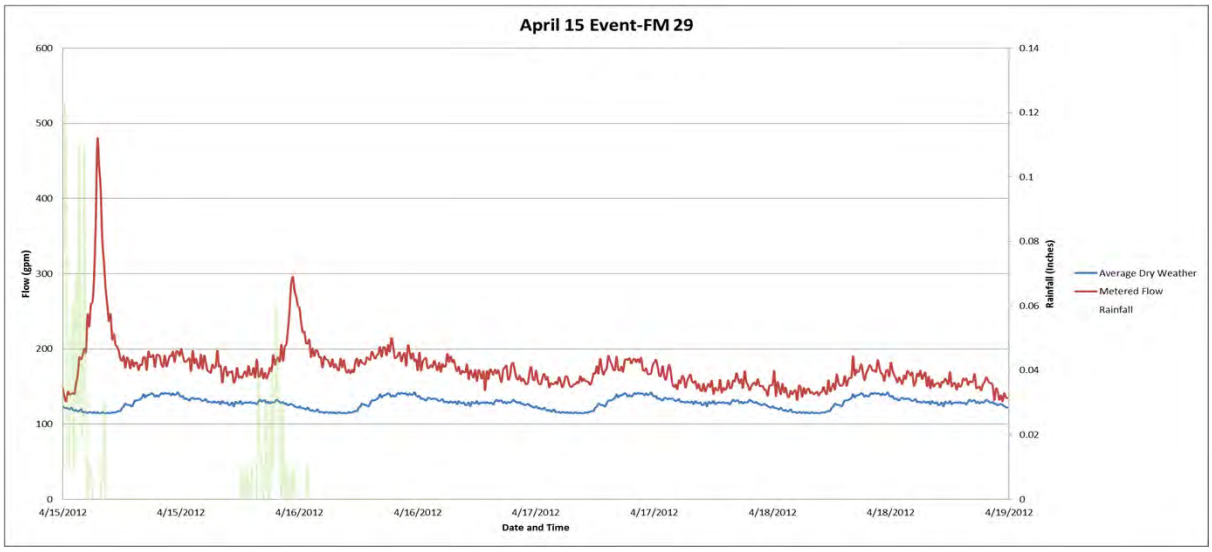
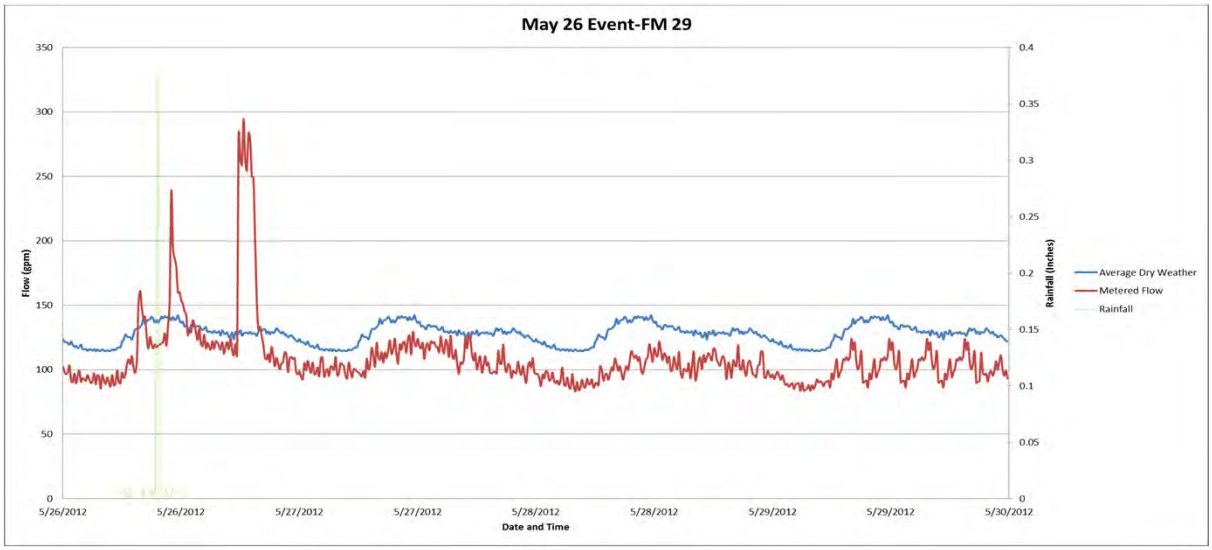
5/29/2012
5/30/2012


May 31 Event-FM 28
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012


April 15 Event-FM 29
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012


May 26 Event-FM 29
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
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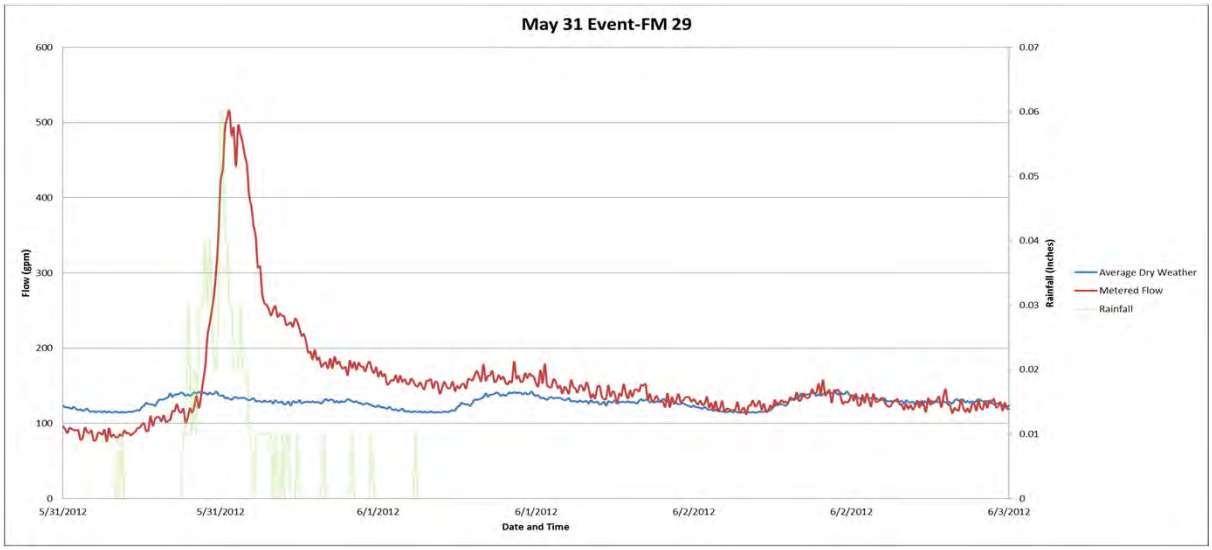
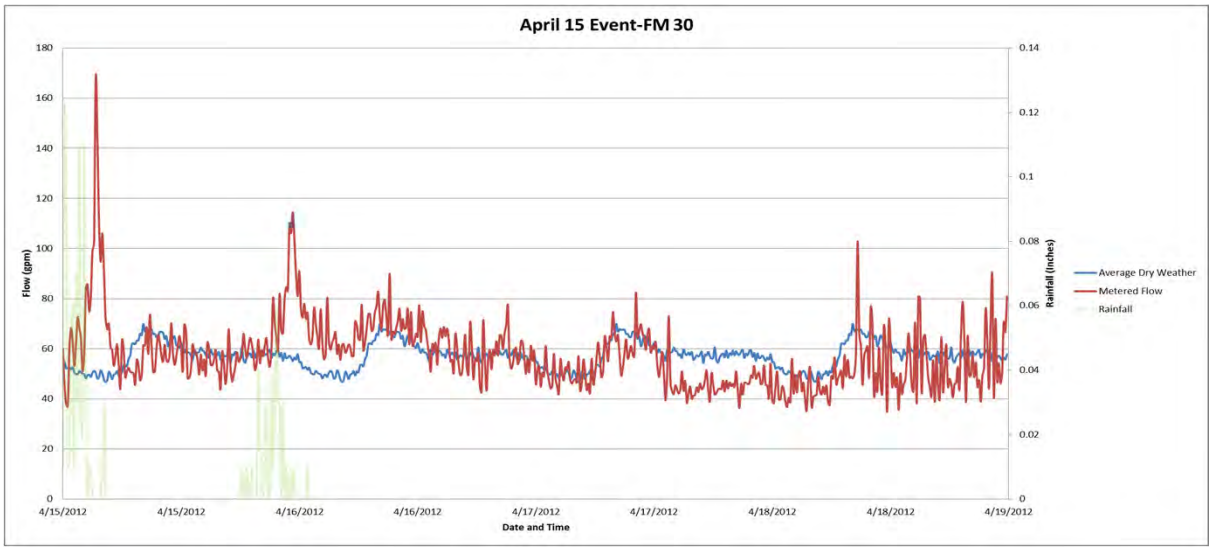
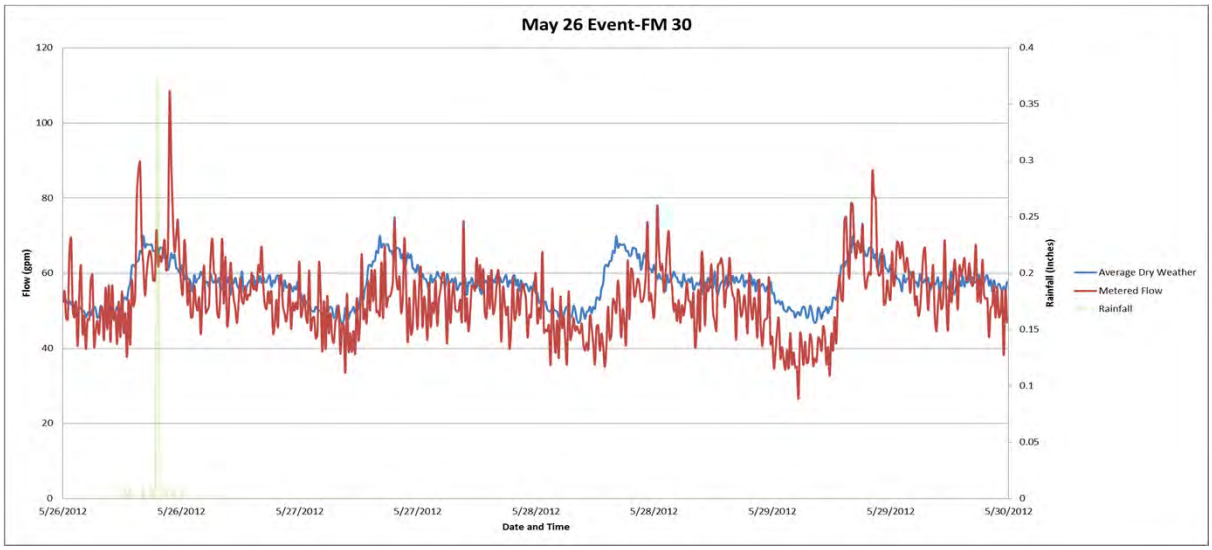
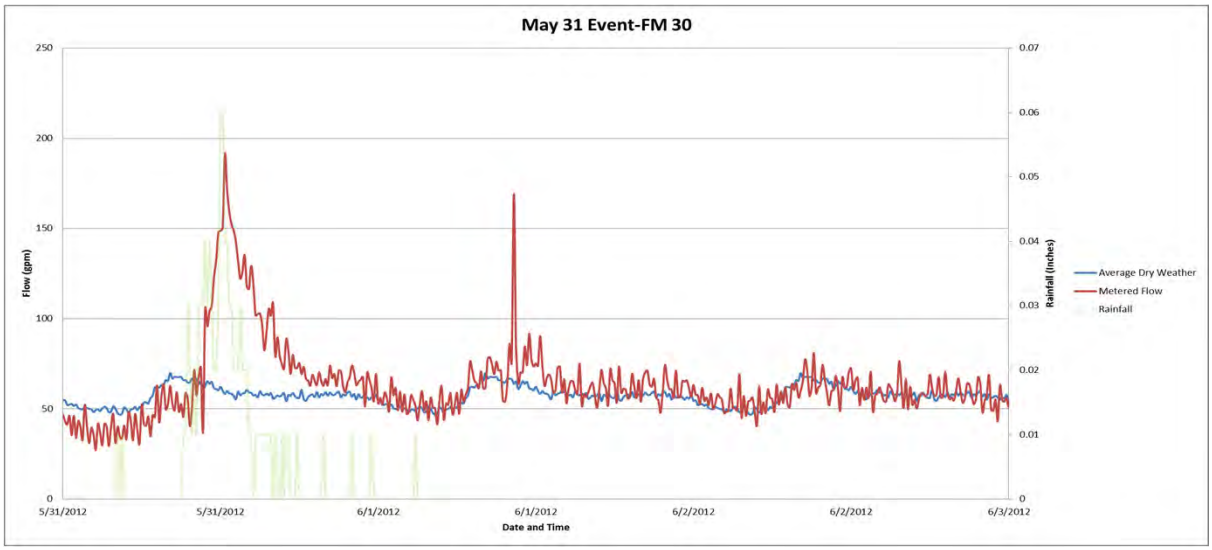
5/29/2012
5/29/2012
5/30/2012


May 31 Event-FM 29
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
6/1/2012
6/1/2012
6/2/2012
6/2/2012
6/3/2012


April 15 Event-FM 30
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
4/15/2012
4/15/2012
4/16/2012
4/16/2012
4/17/2012
4/17/2012
4/18/2012
4/18/2012
4/19/2012


May 26 Event-FM 30
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/26/2012
5/26/2012
5/27/2012
5/27/2012
5/28/2012
5/28/2012
5/29/2012
5/29/2012
5/30/2012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Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall
5/31/2012
5/31/2012
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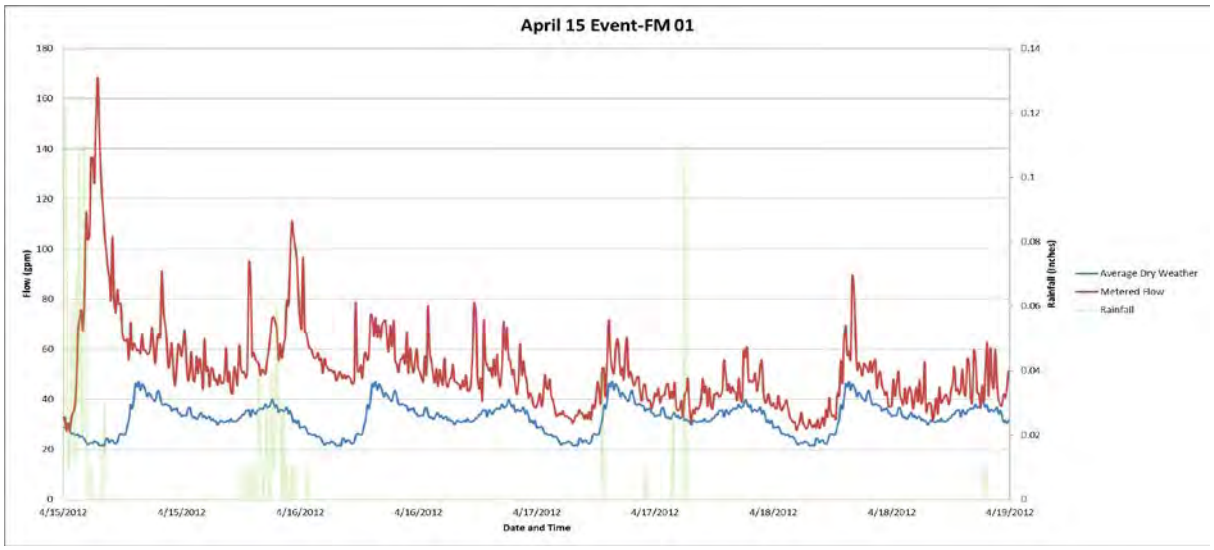
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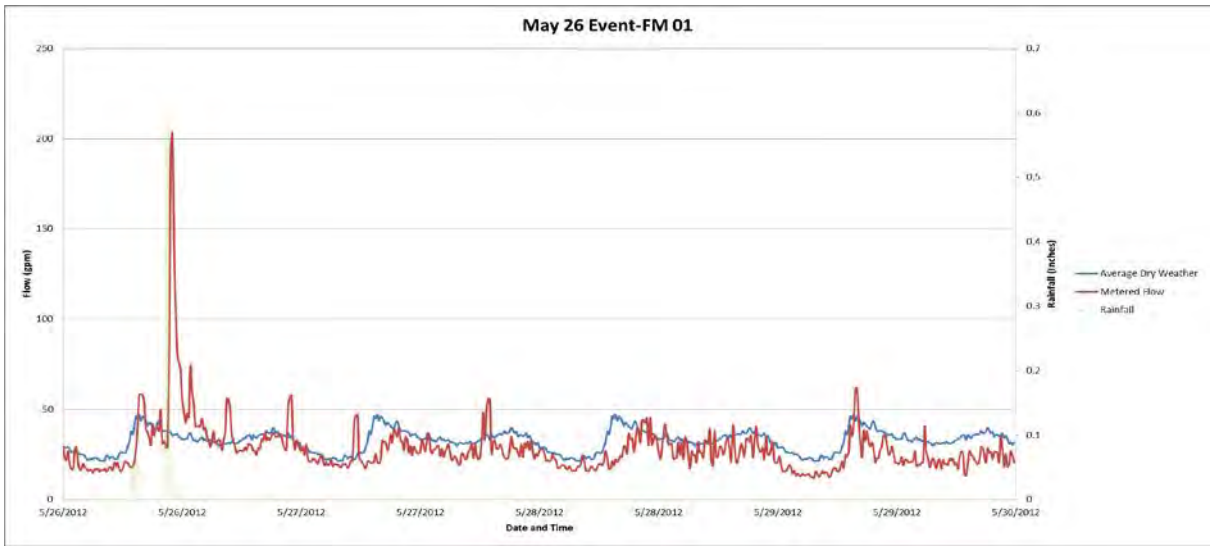
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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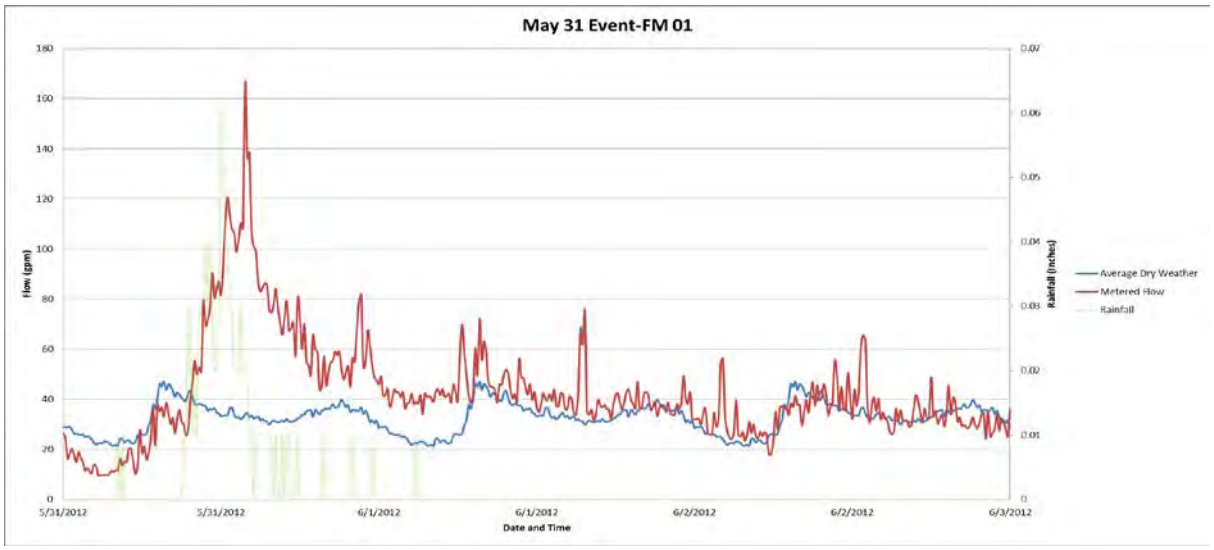
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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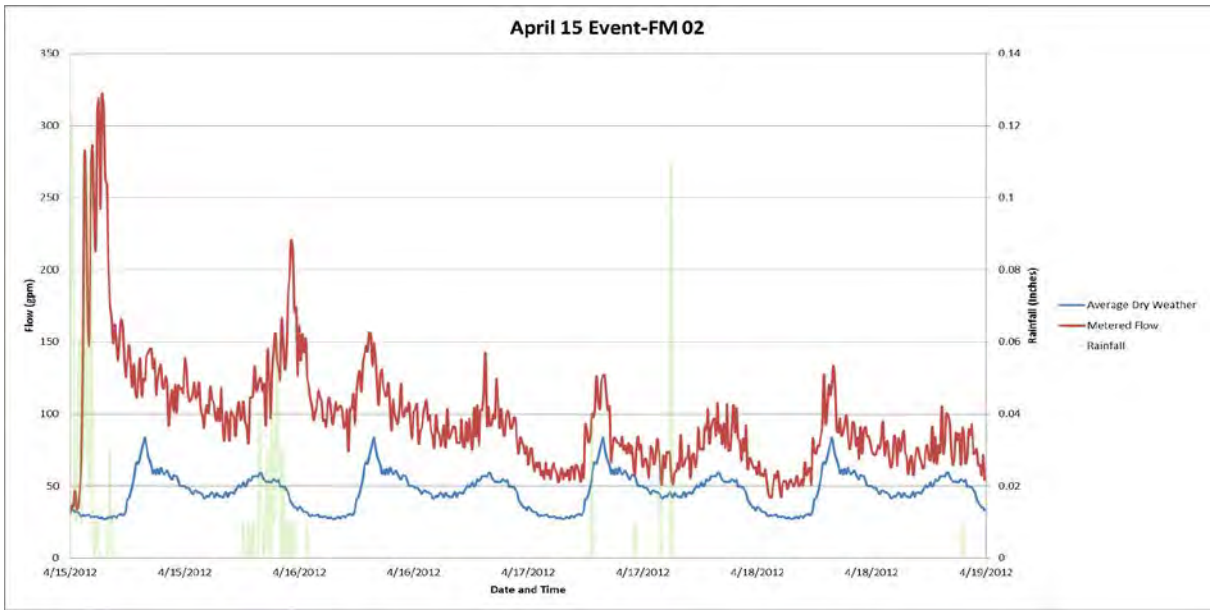
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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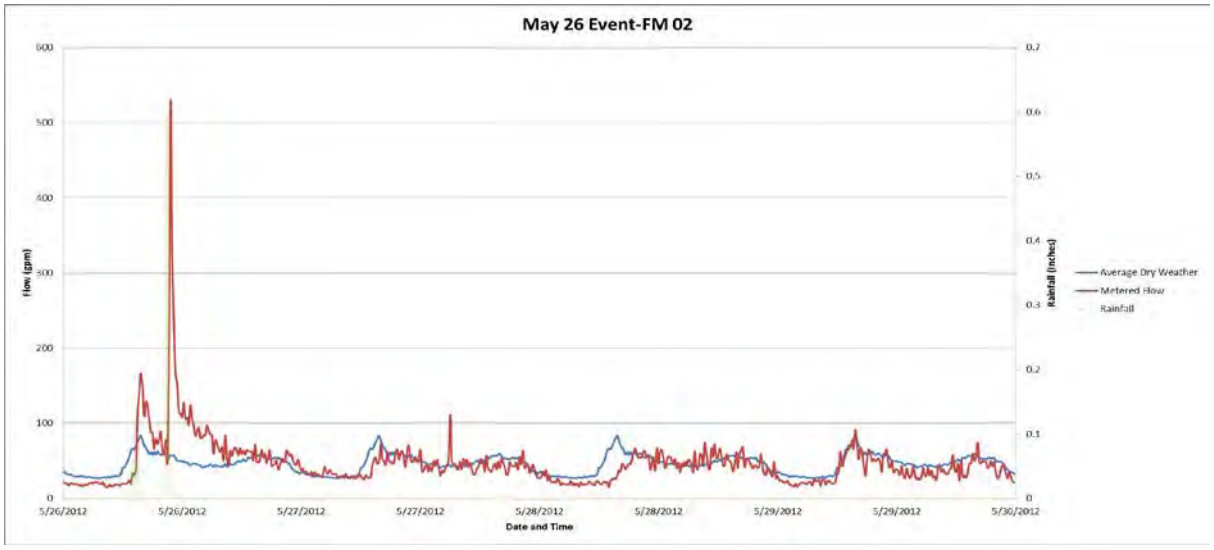
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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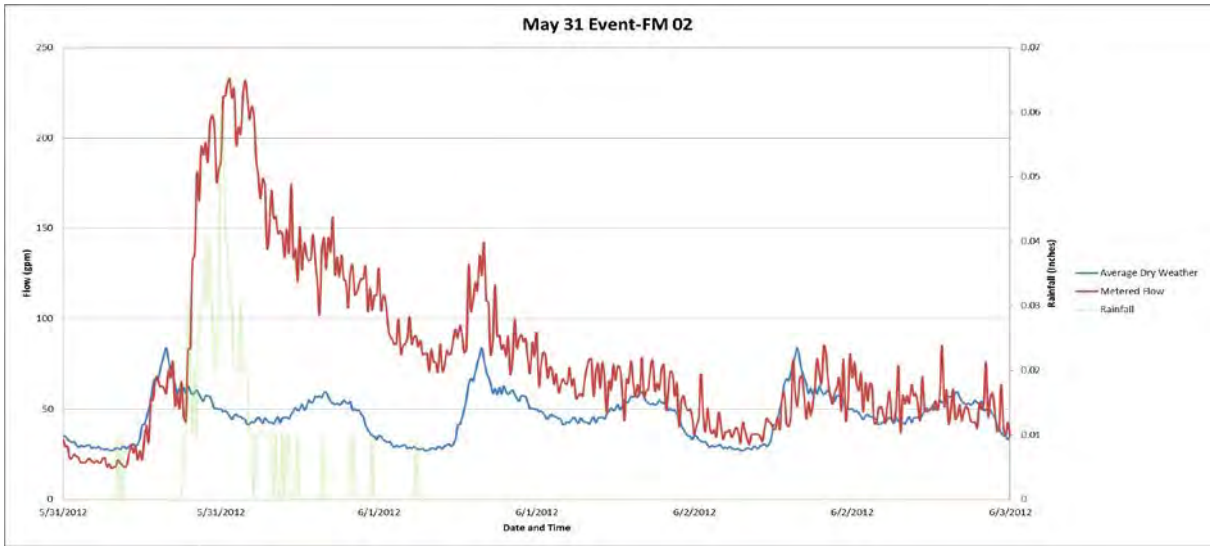
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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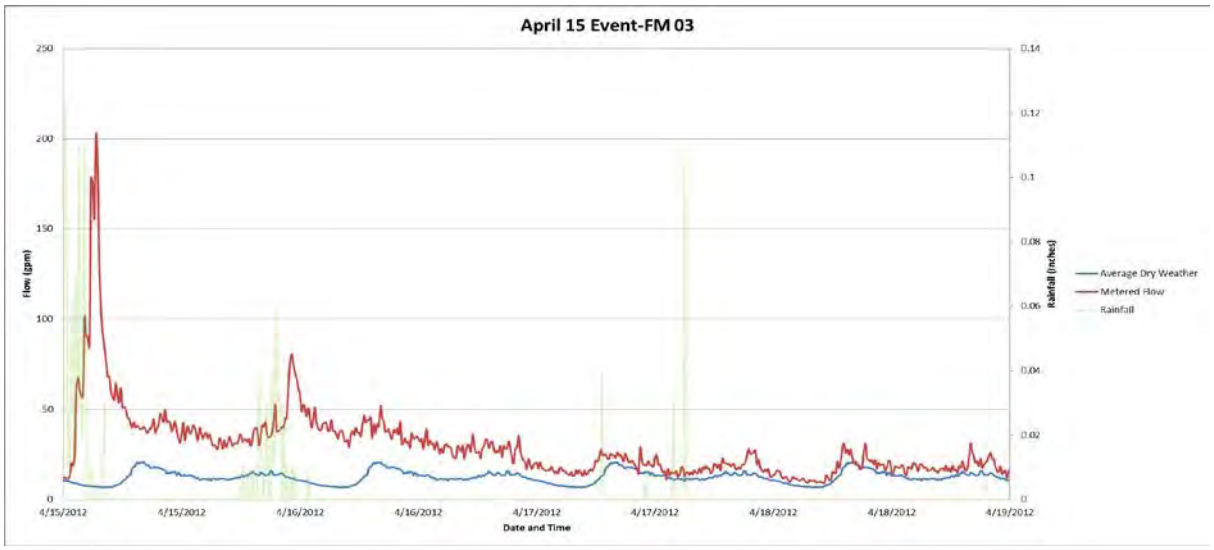
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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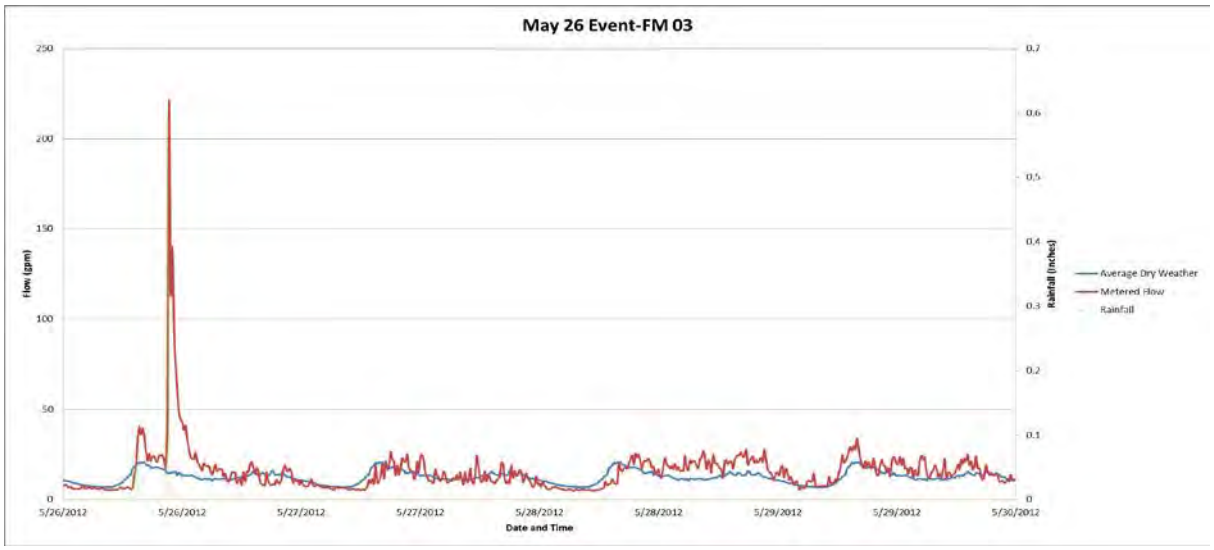
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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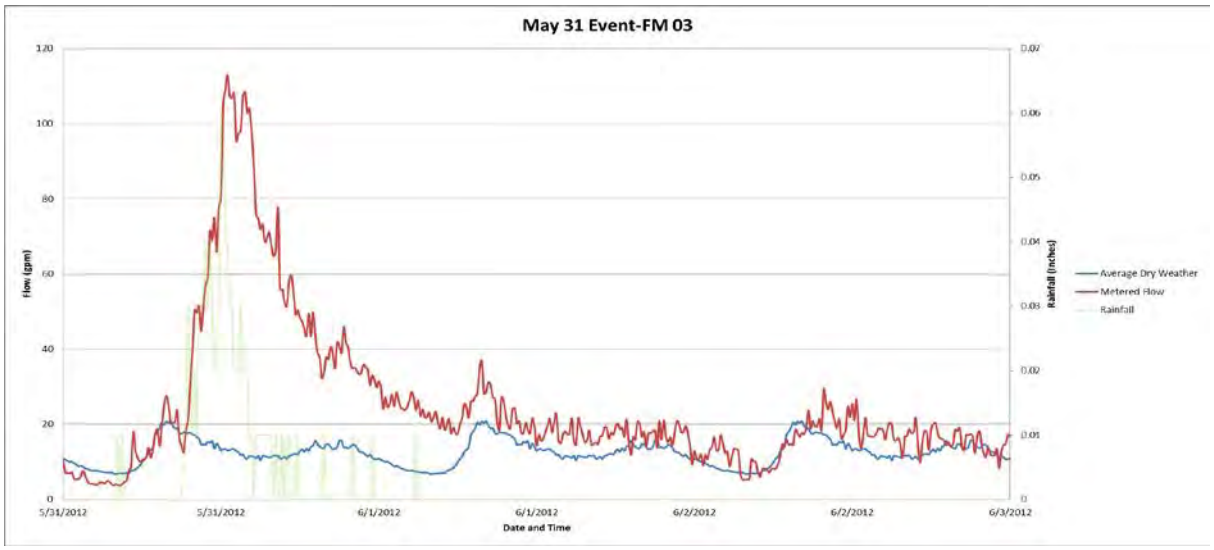
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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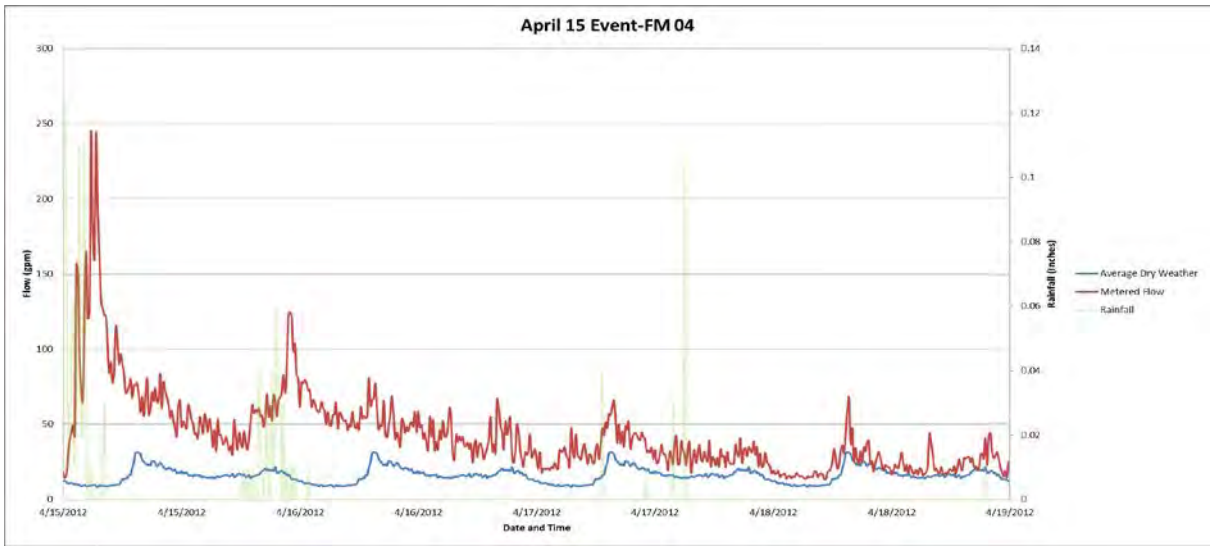
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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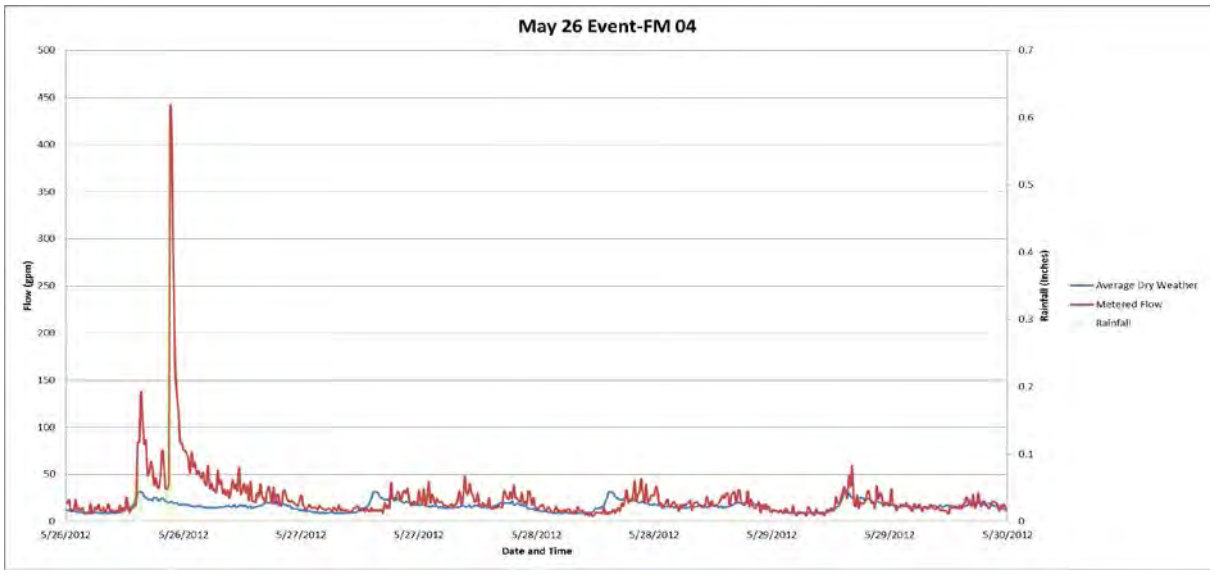
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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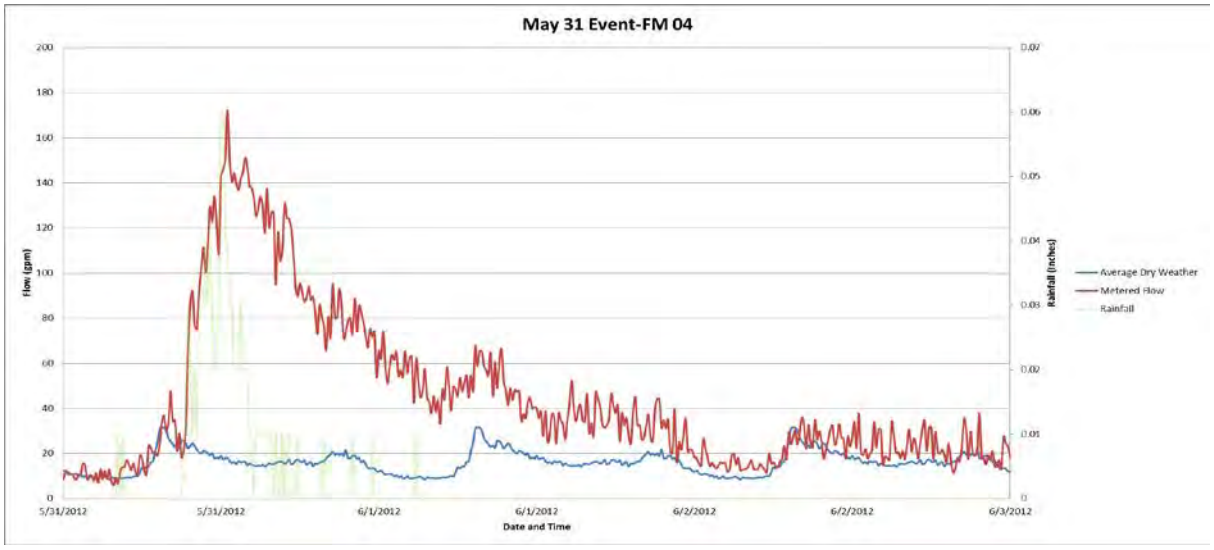
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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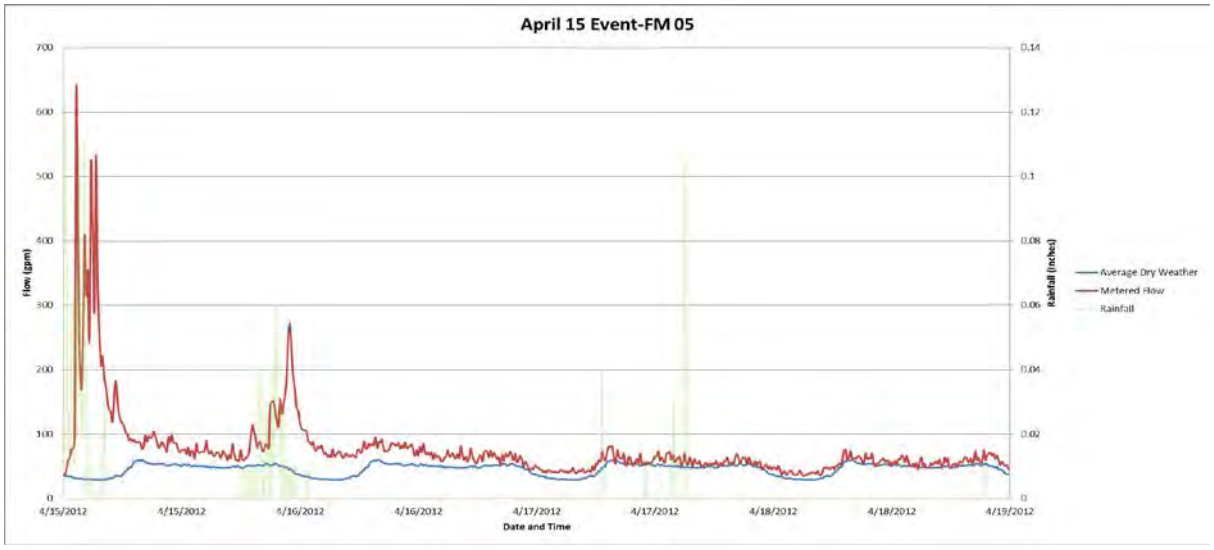
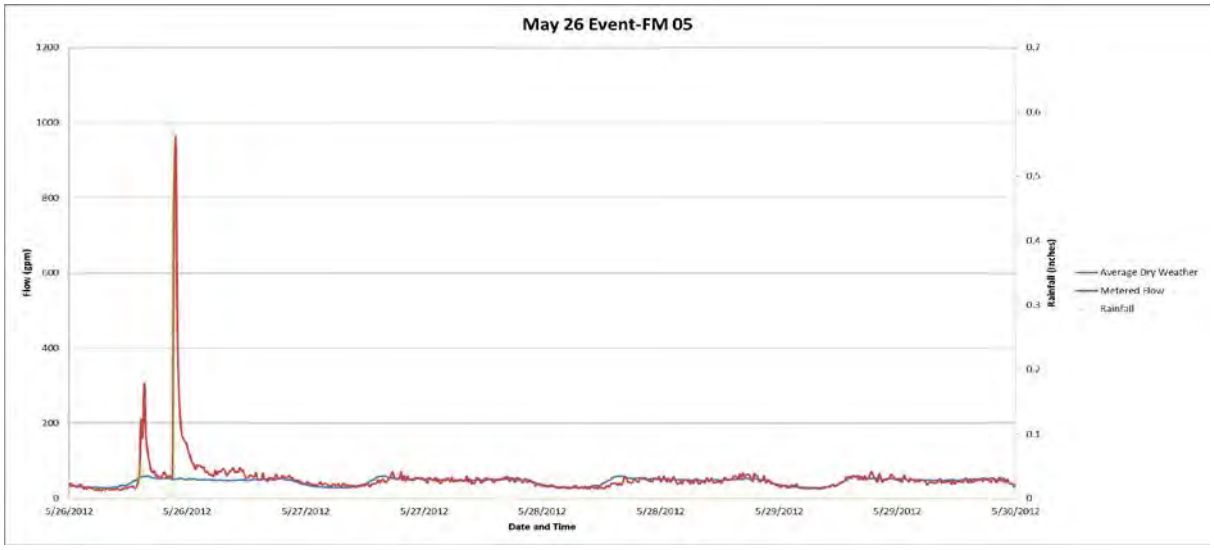
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall


April 15 Event-FM 05
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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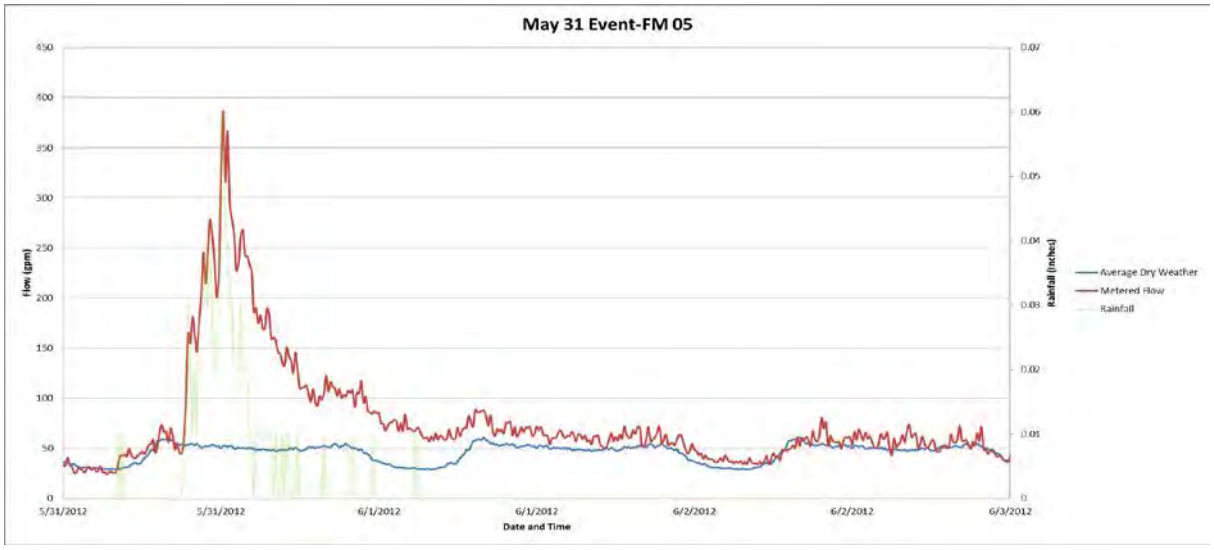
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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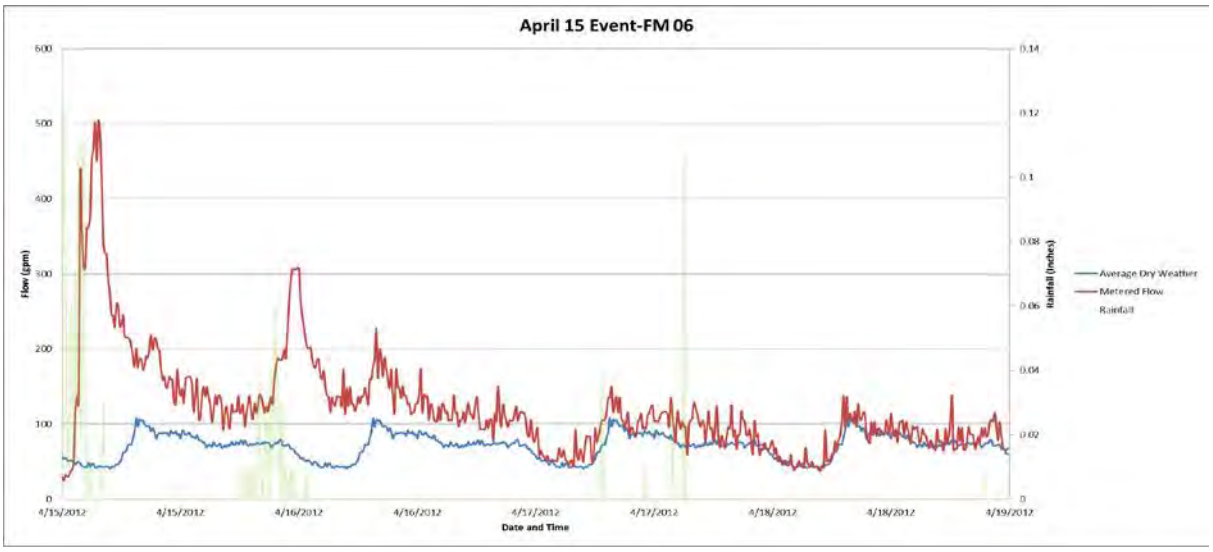
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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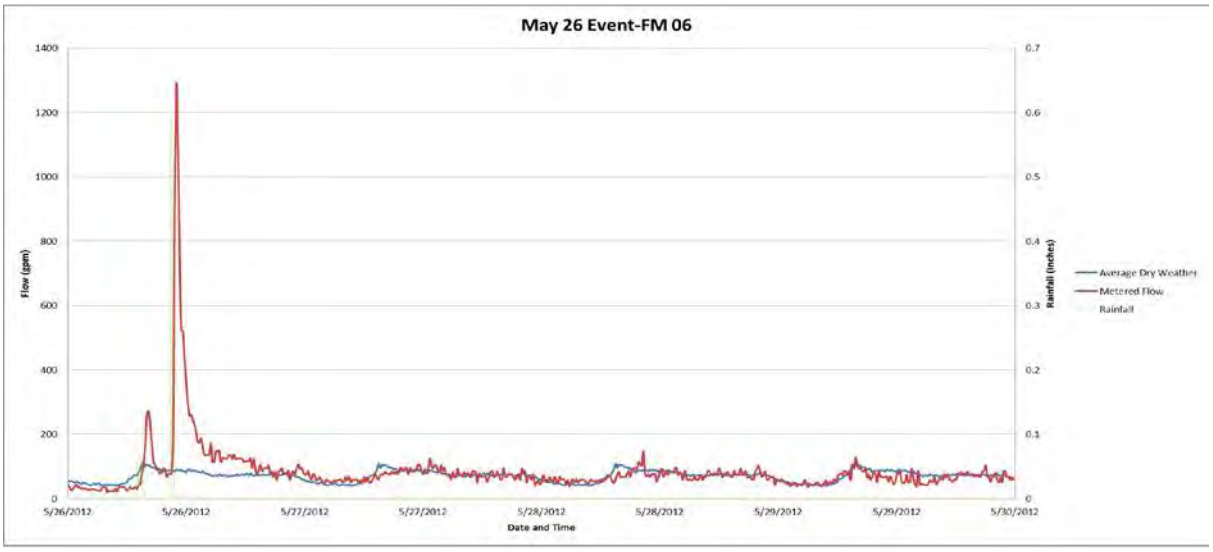
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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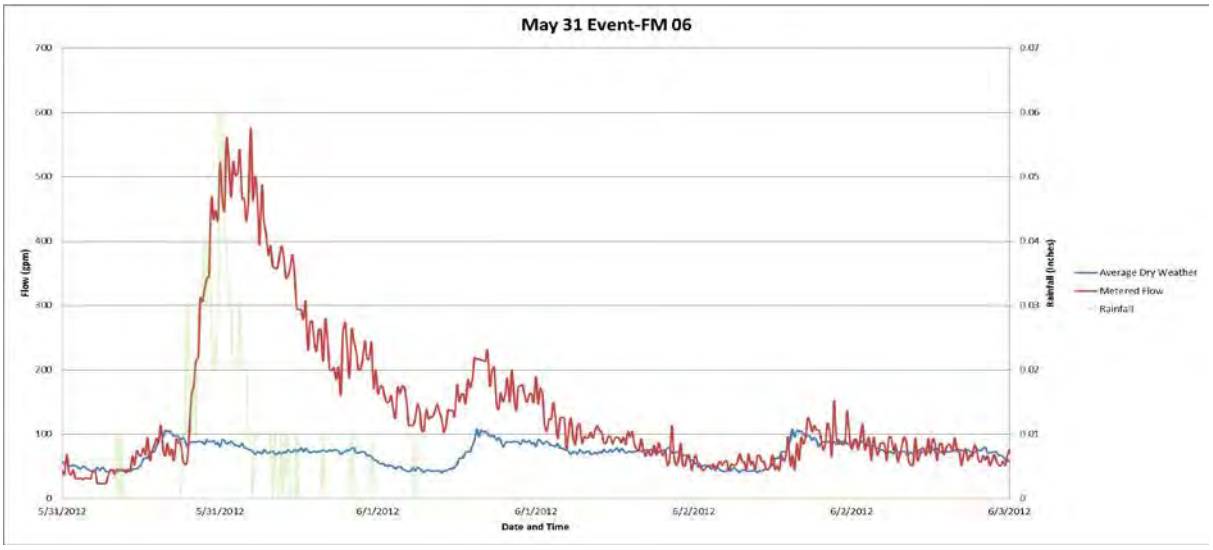
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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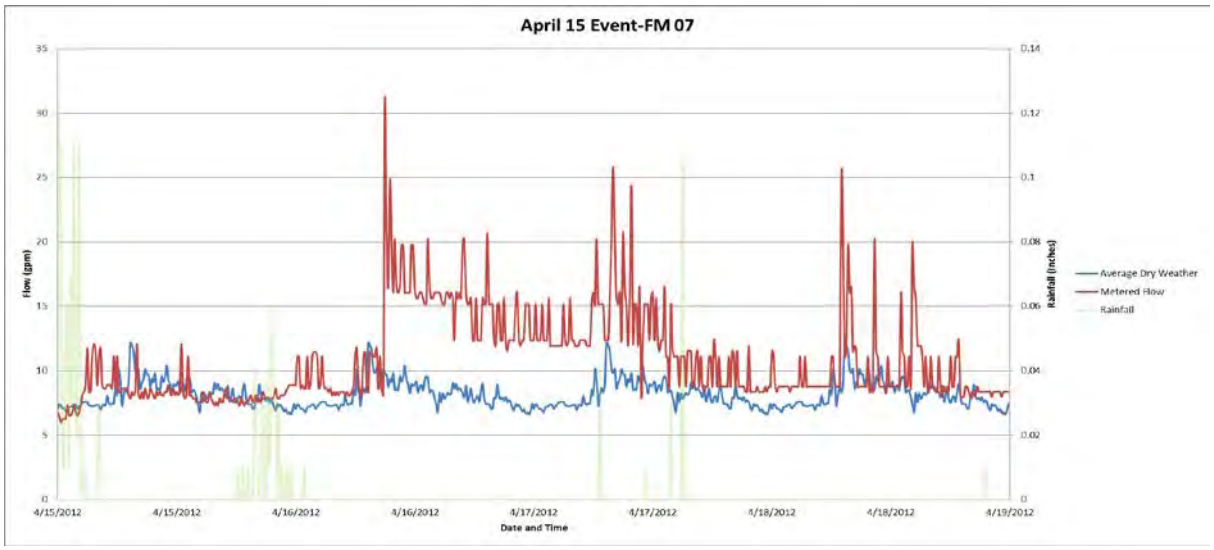
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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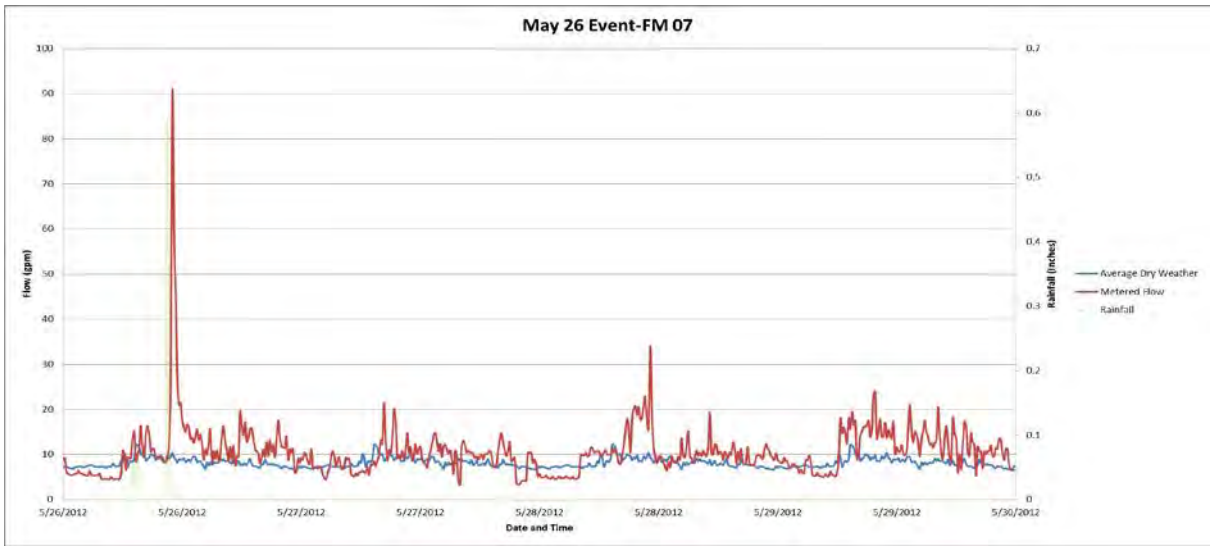
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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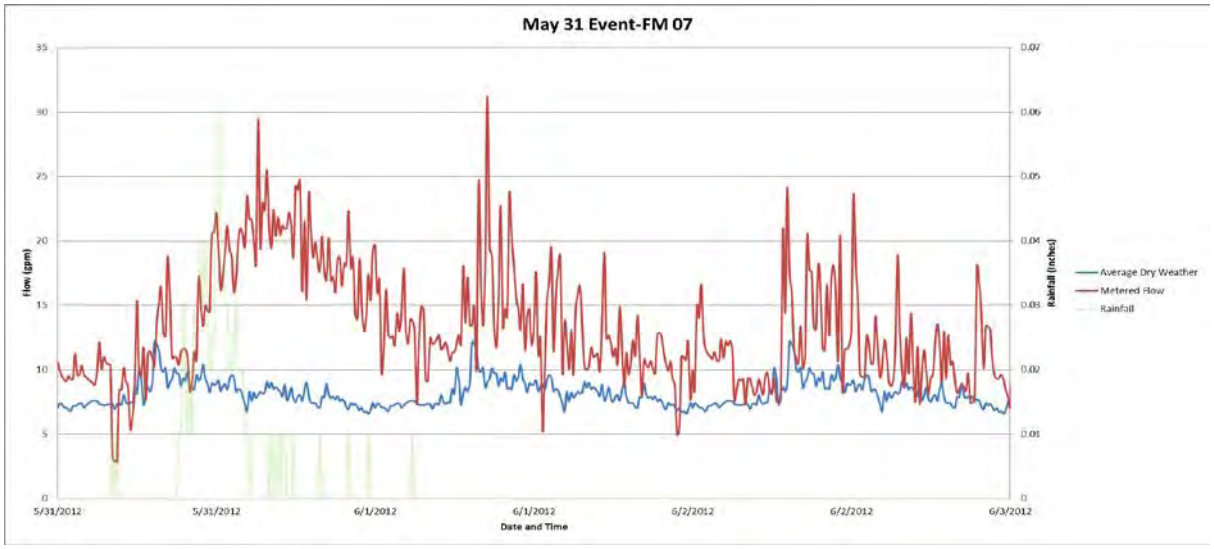
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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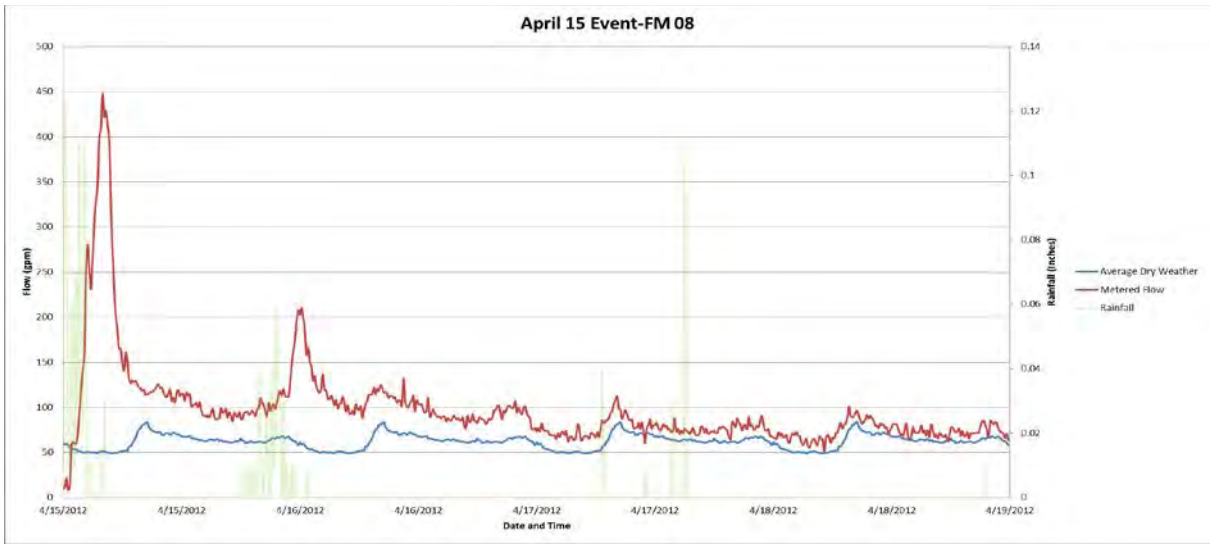
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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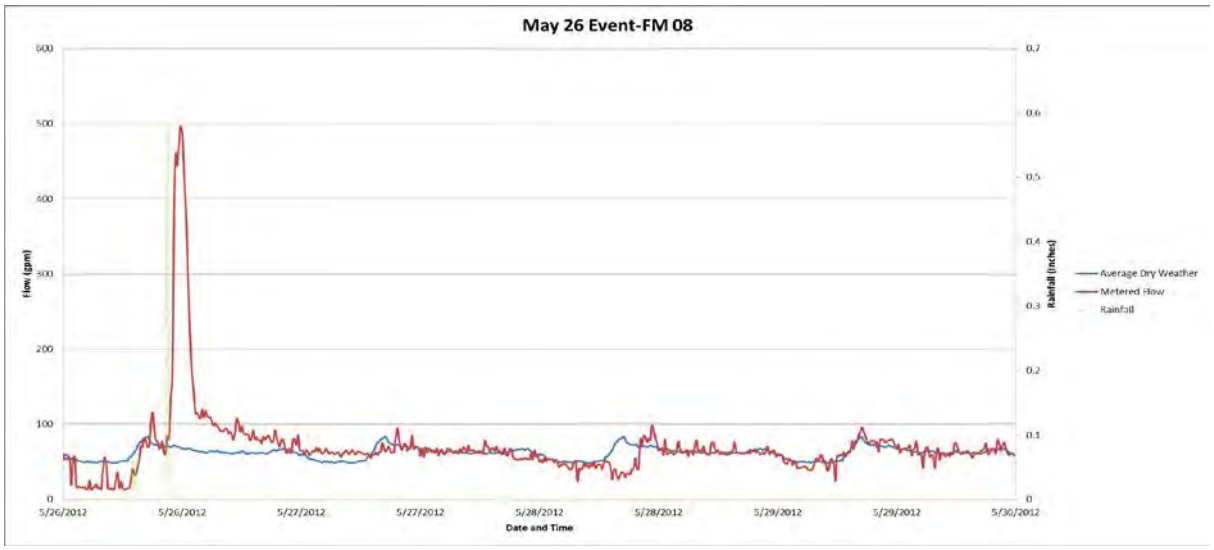
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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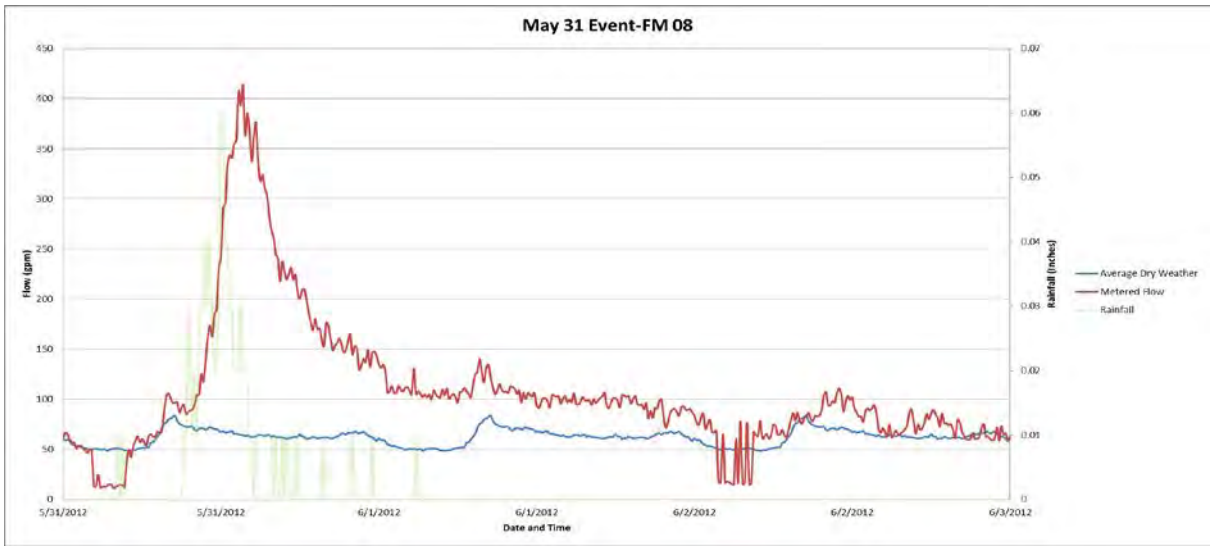
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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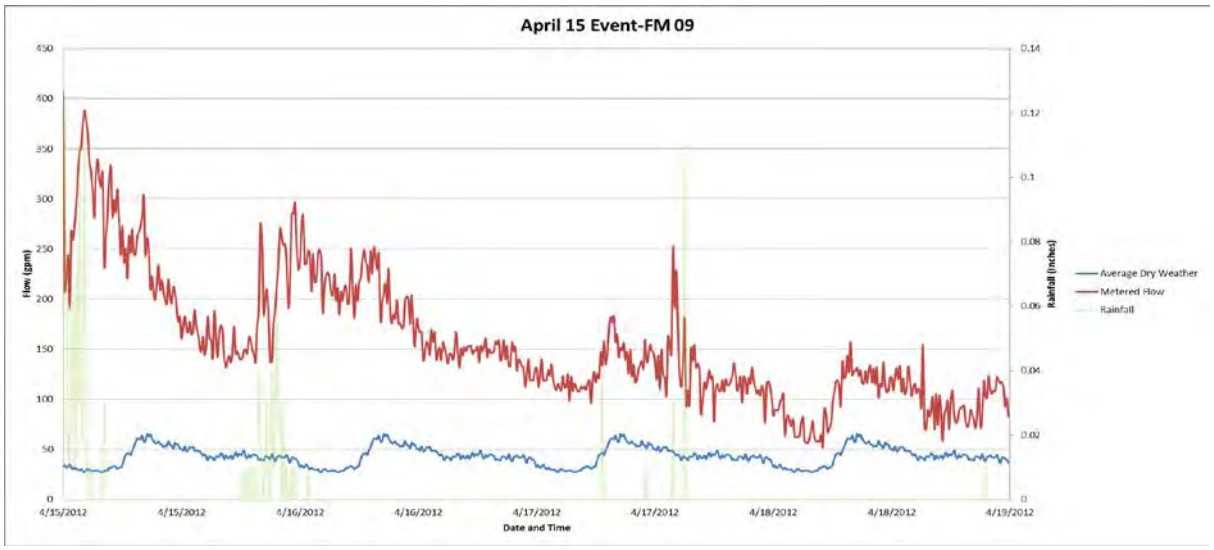
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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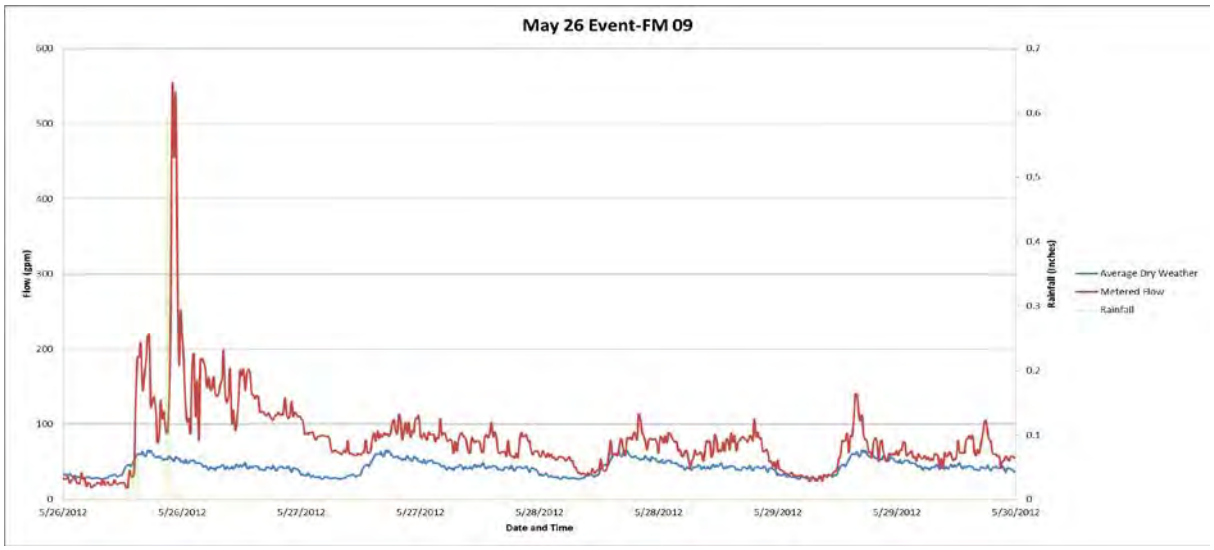
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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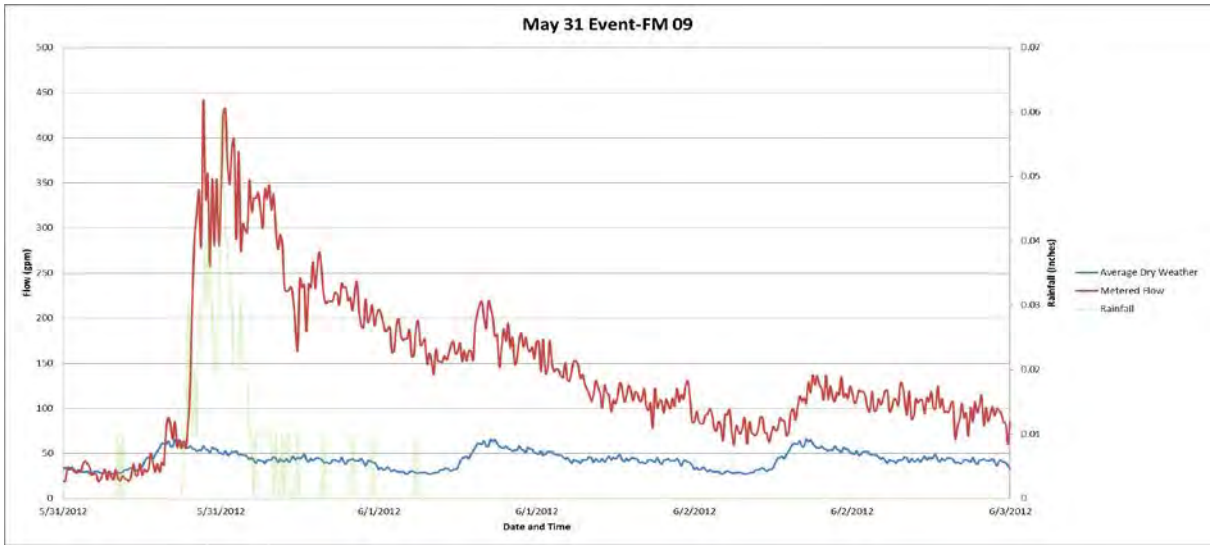
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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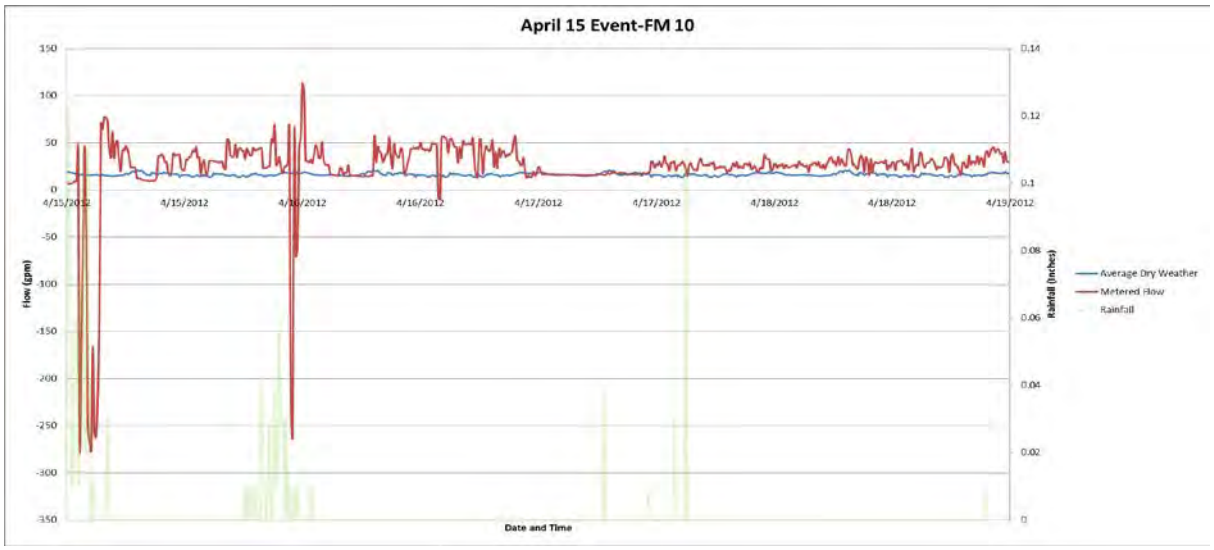
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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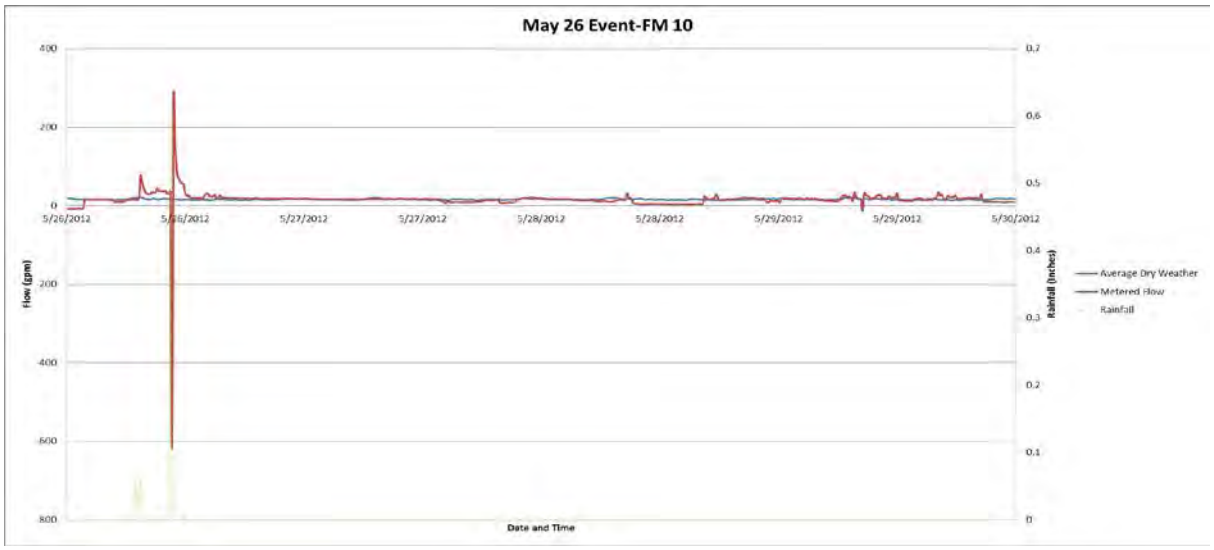
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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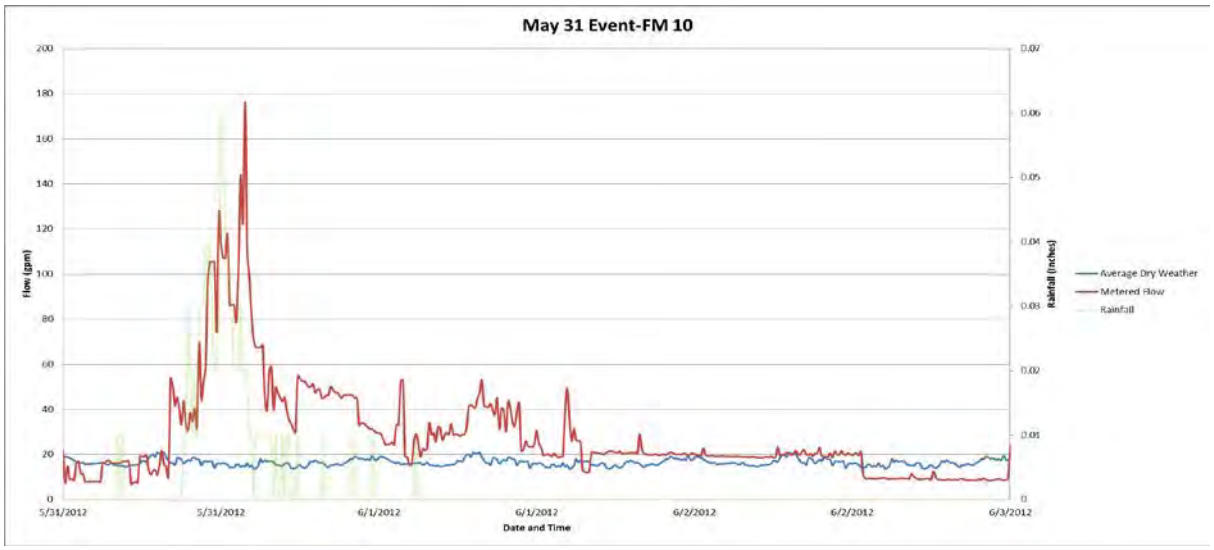
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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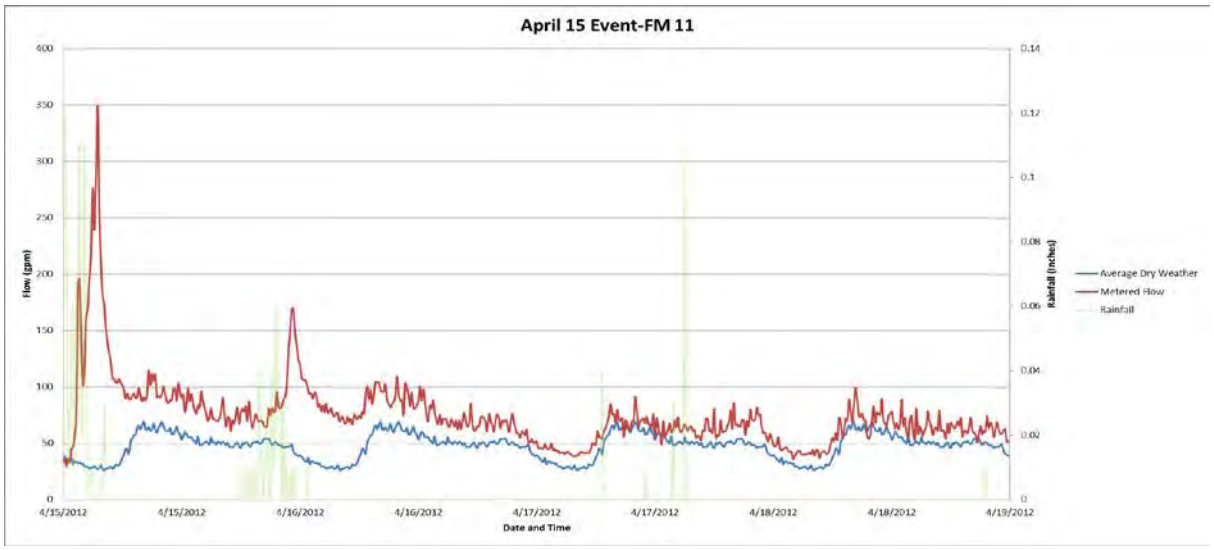
Flow (gpm)
Rainfall (Inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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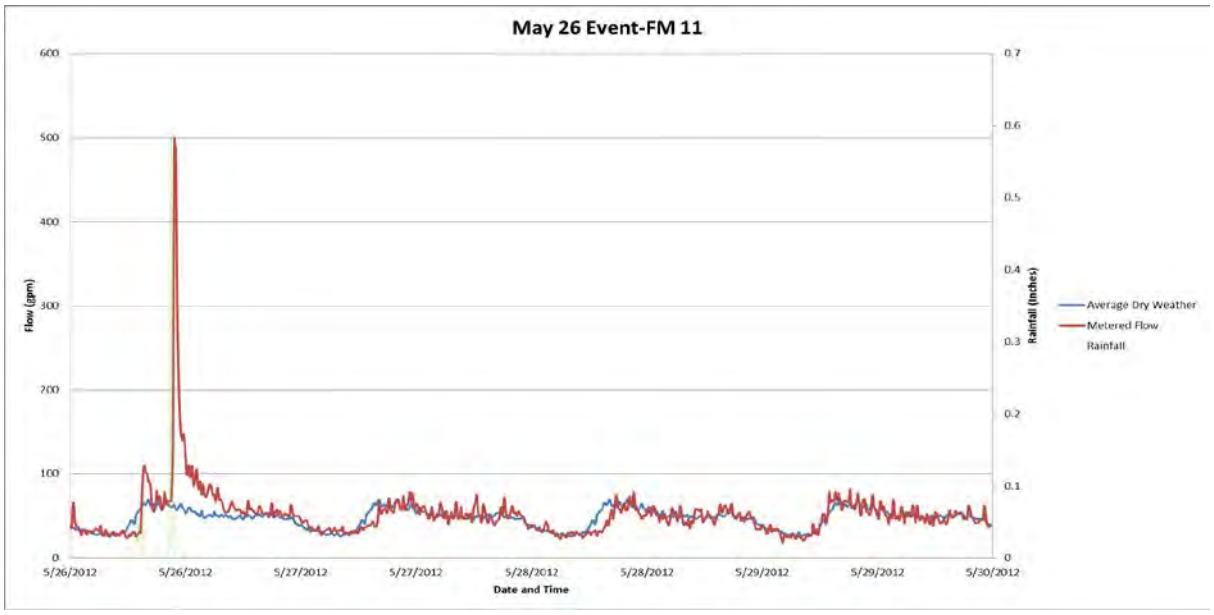
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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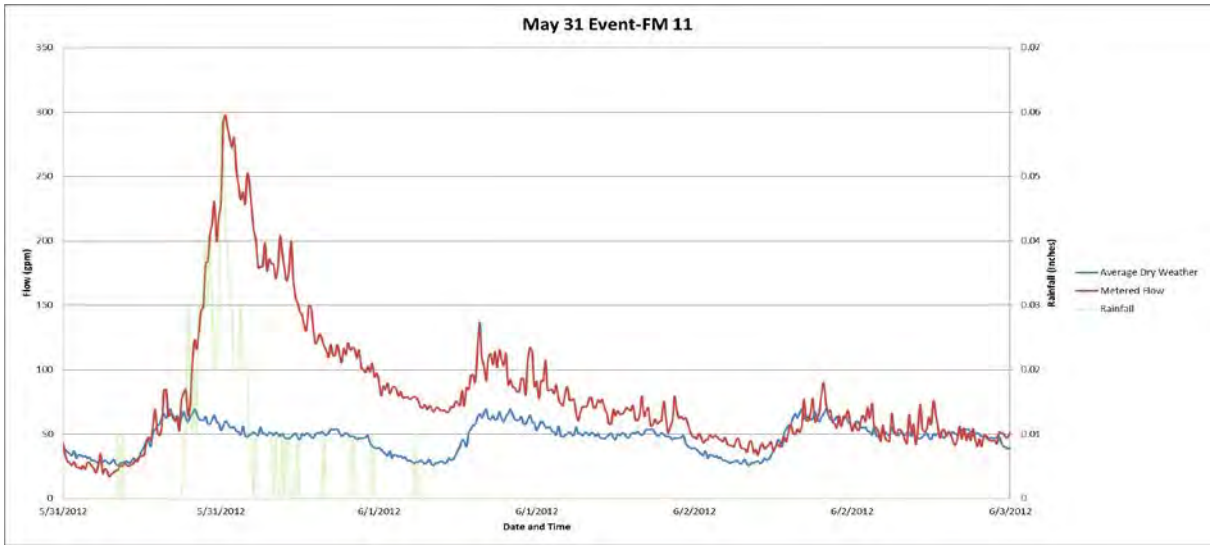
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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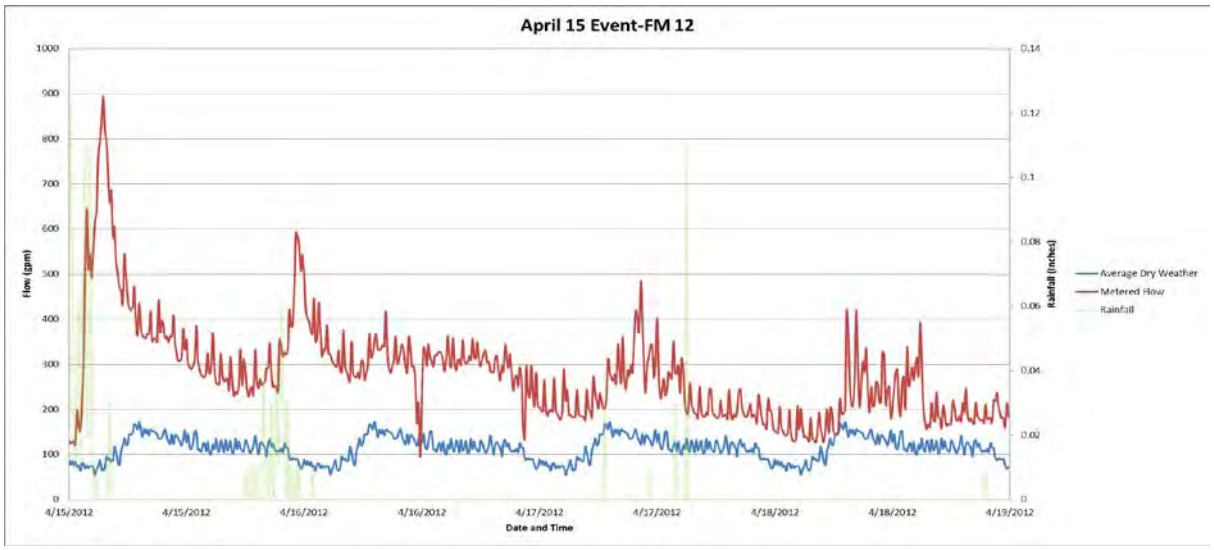
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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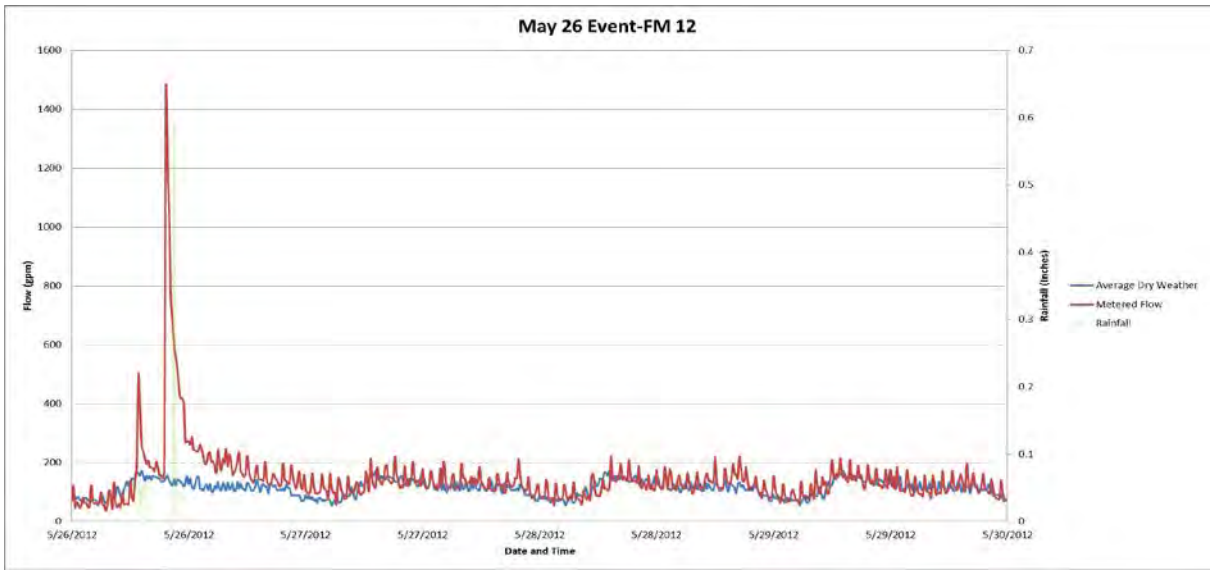
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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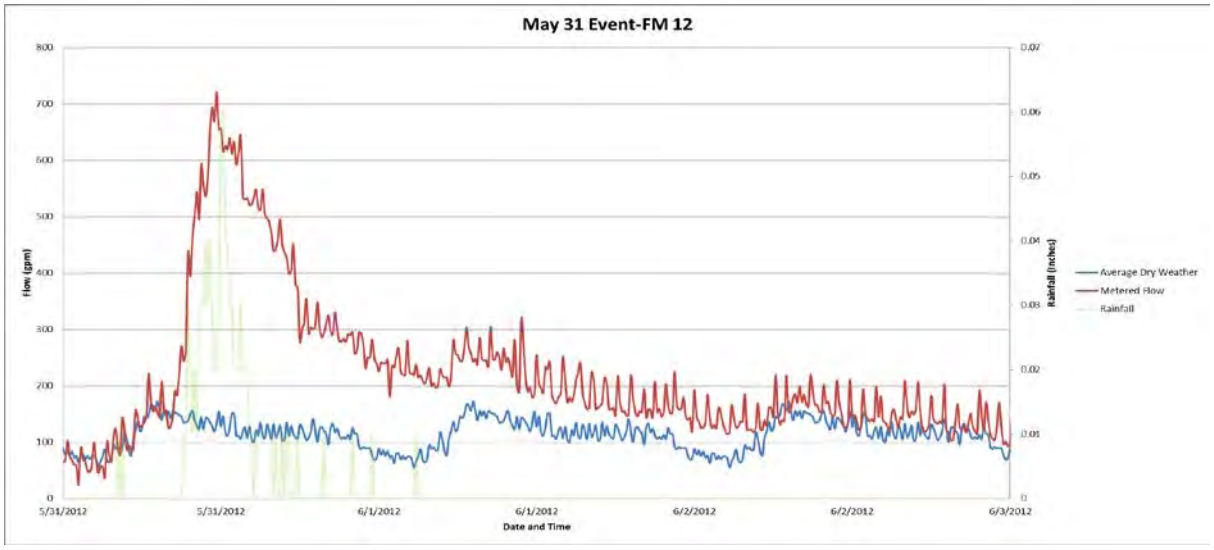
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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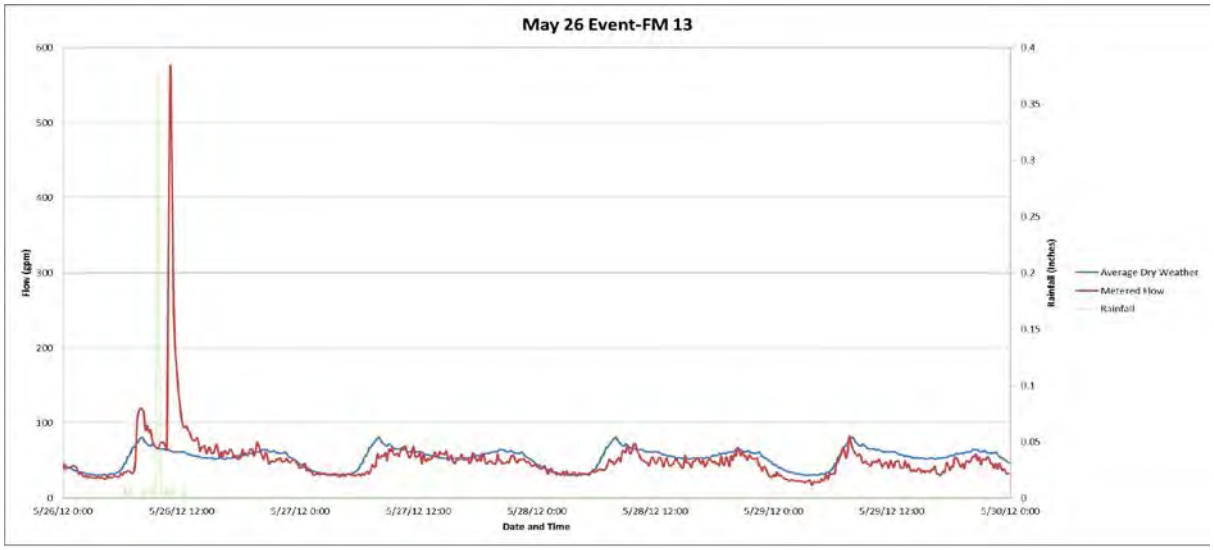
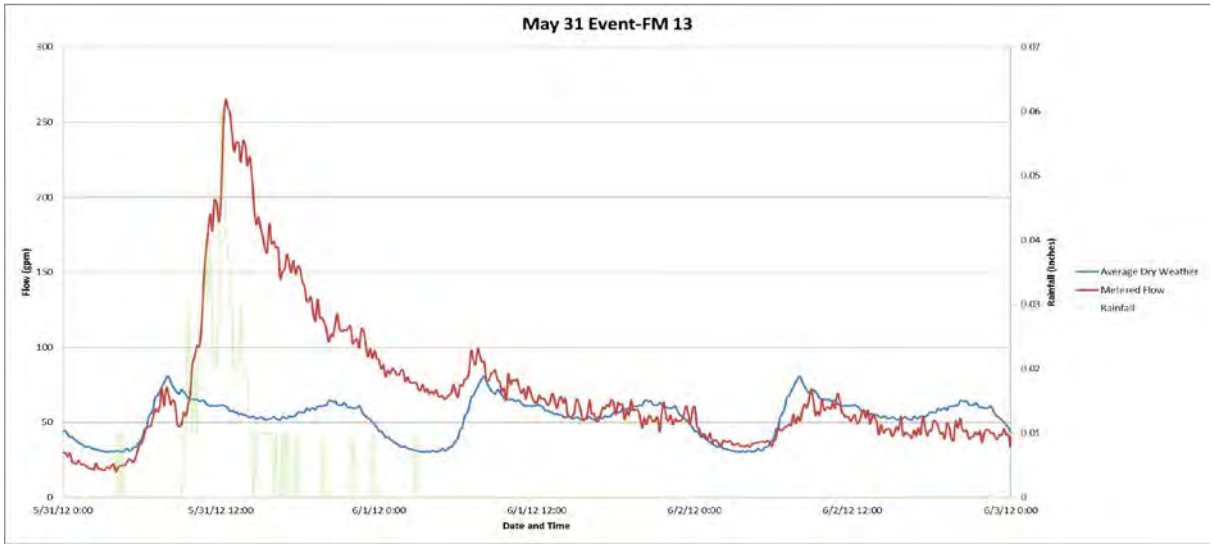
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall


May 26 Event-FM 13
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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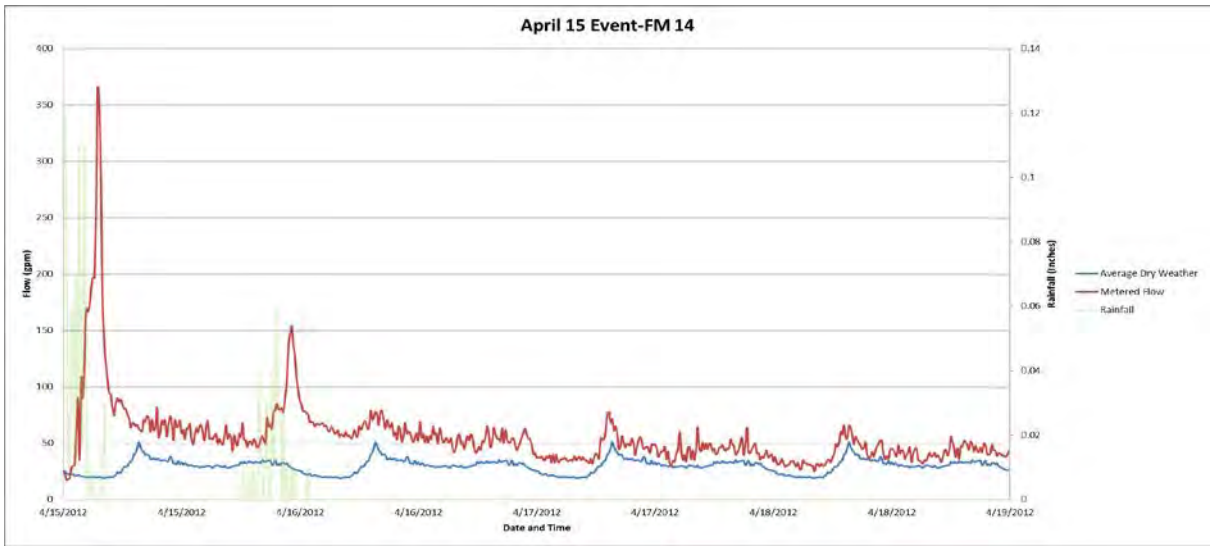
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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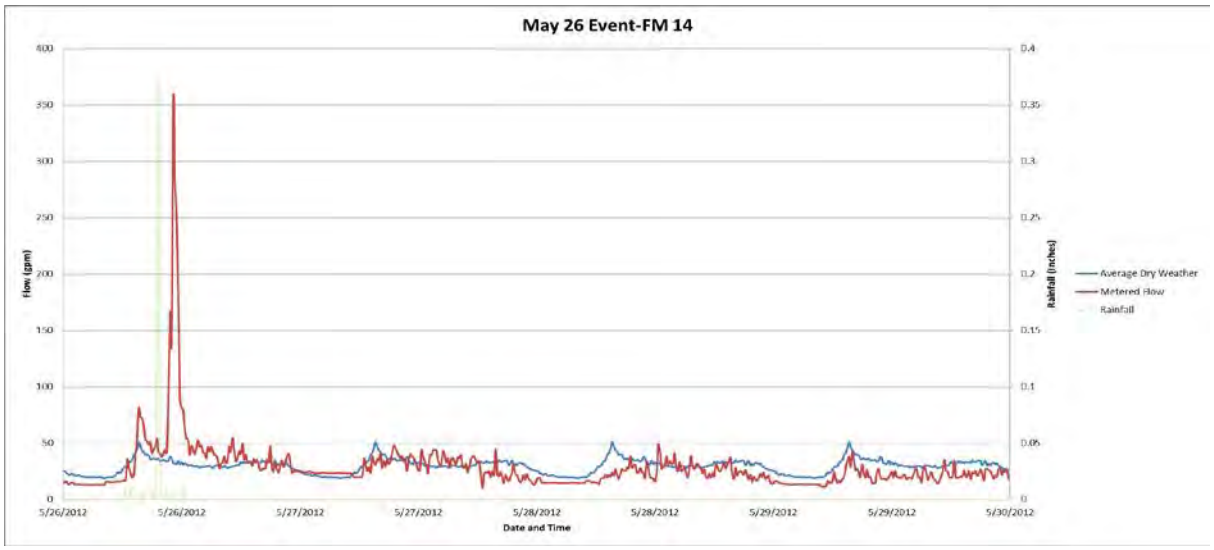
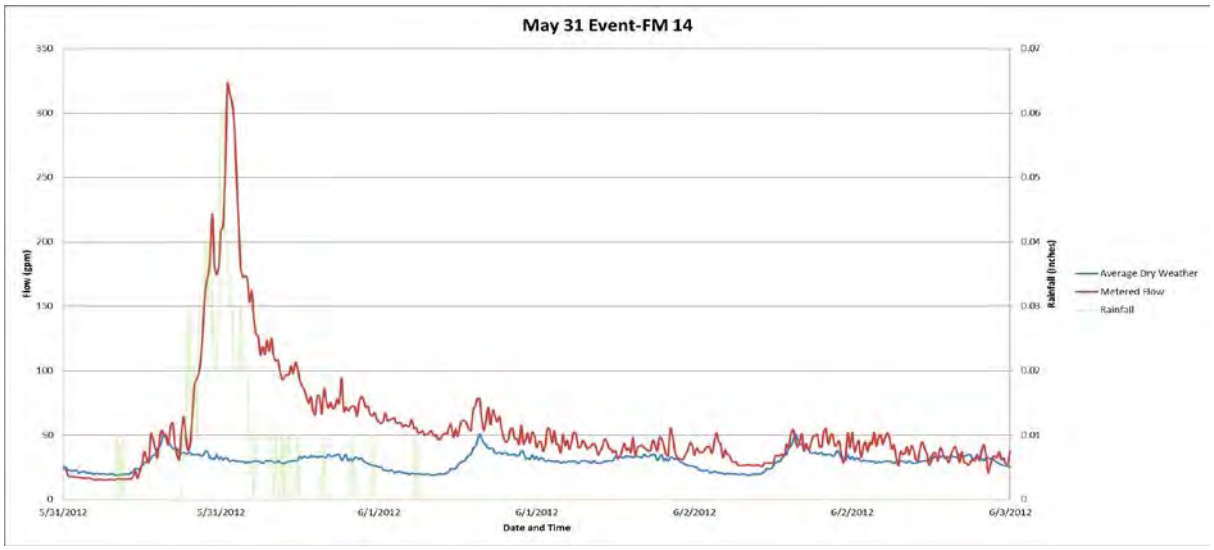
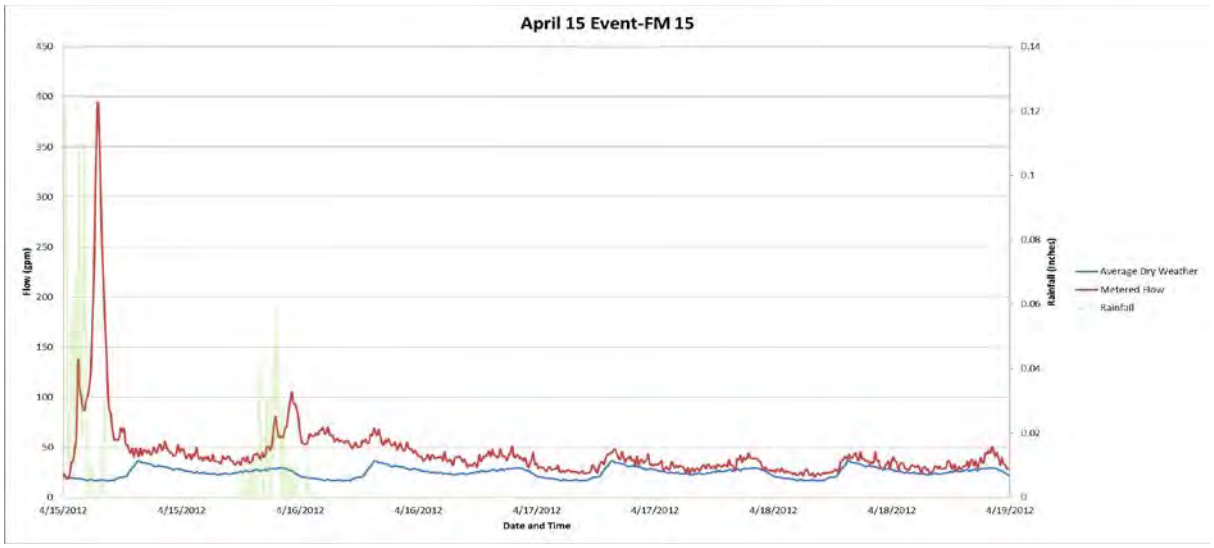
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall


May 26 Event-FM 14
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall


May 31 Event-FM 14
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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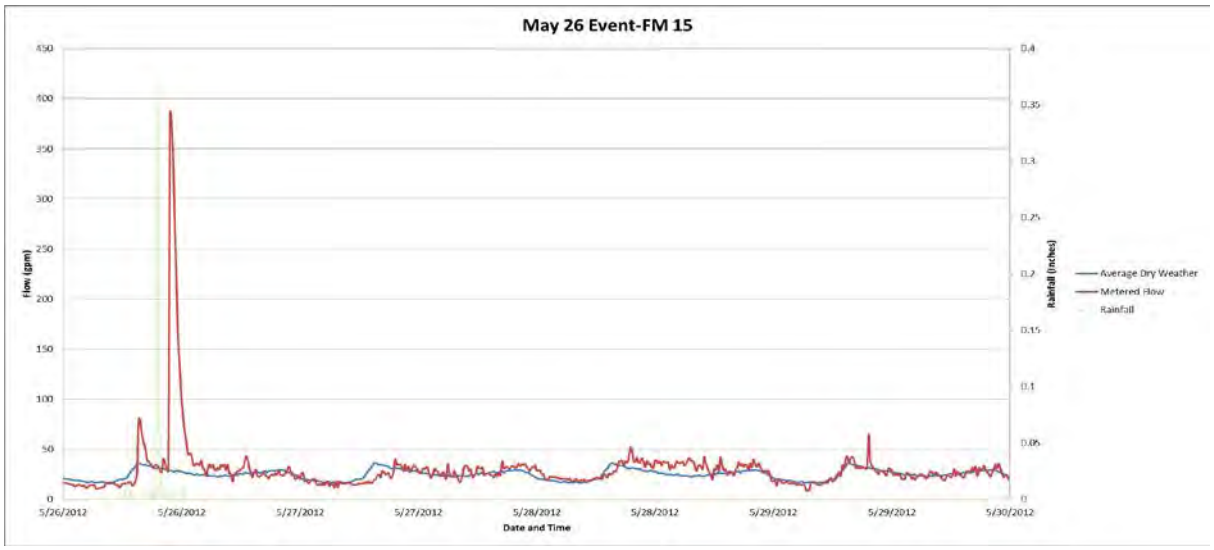
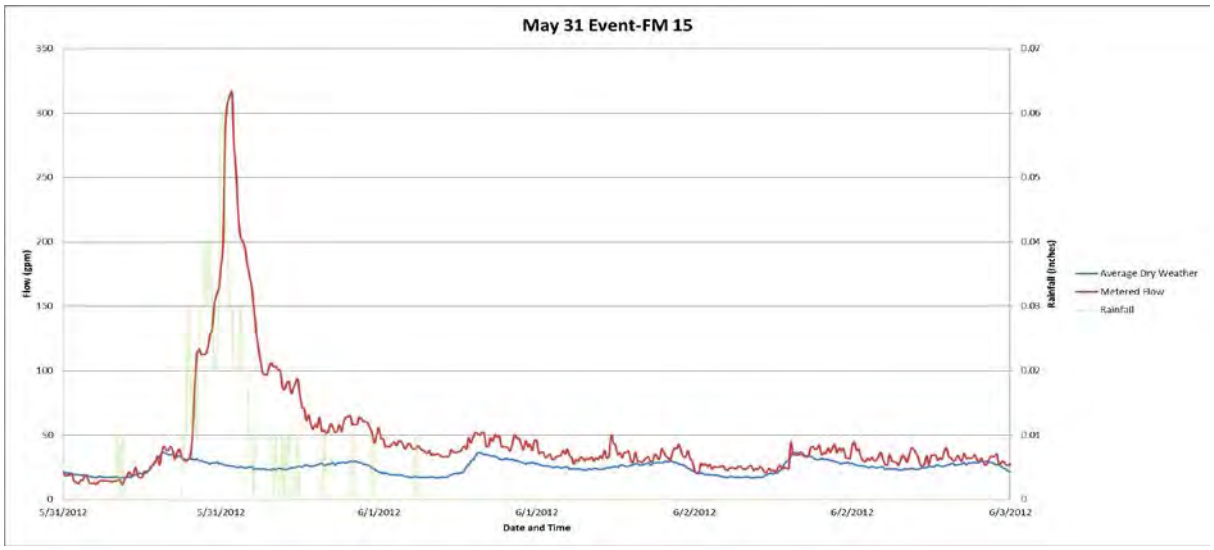
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall


May 26 Event-FM 15
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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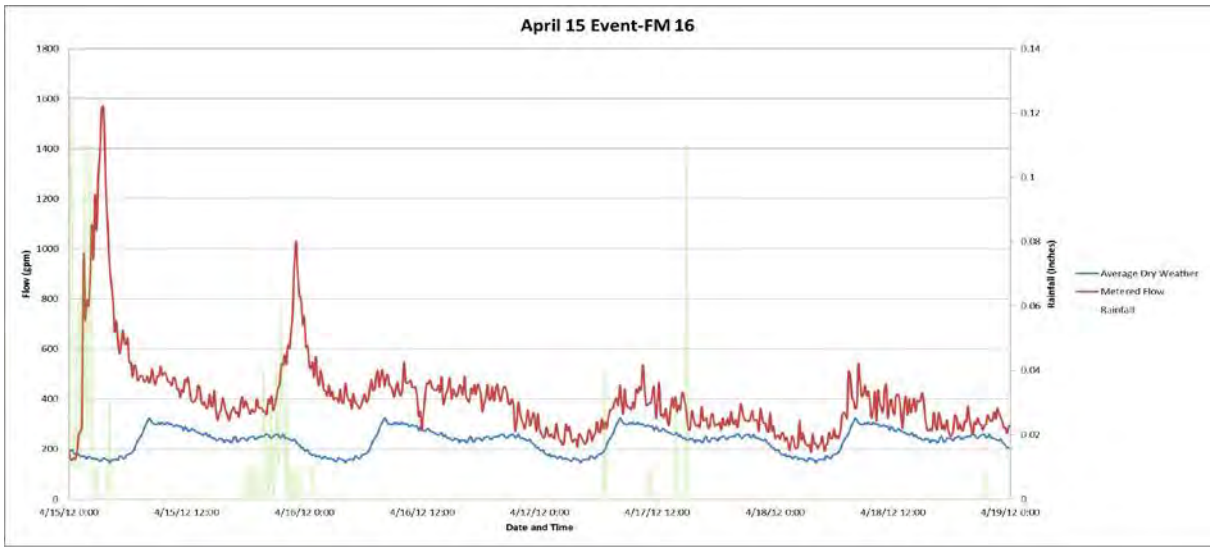
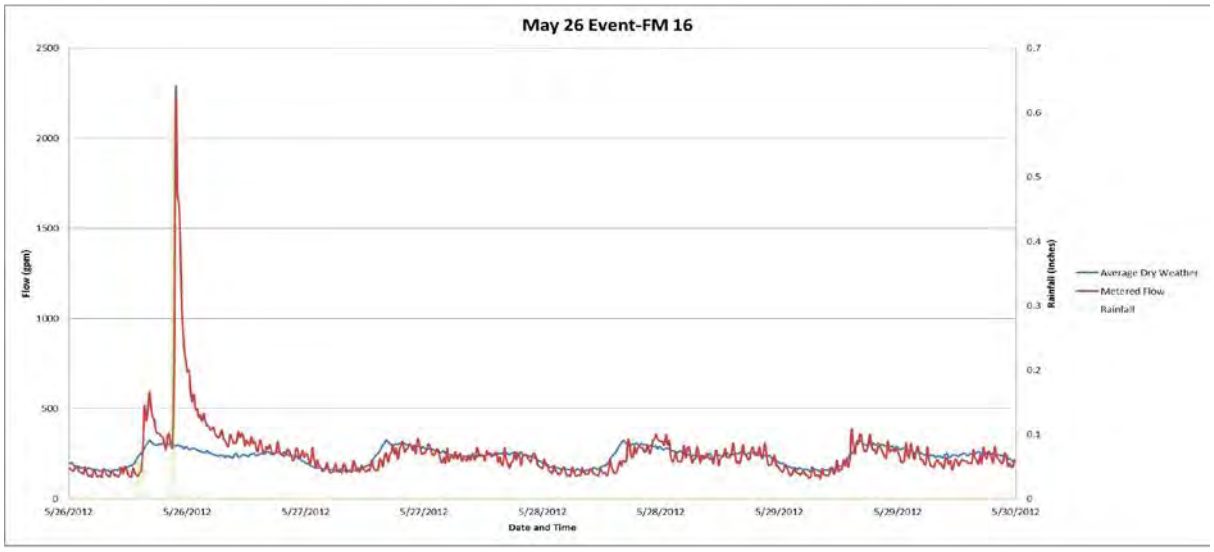
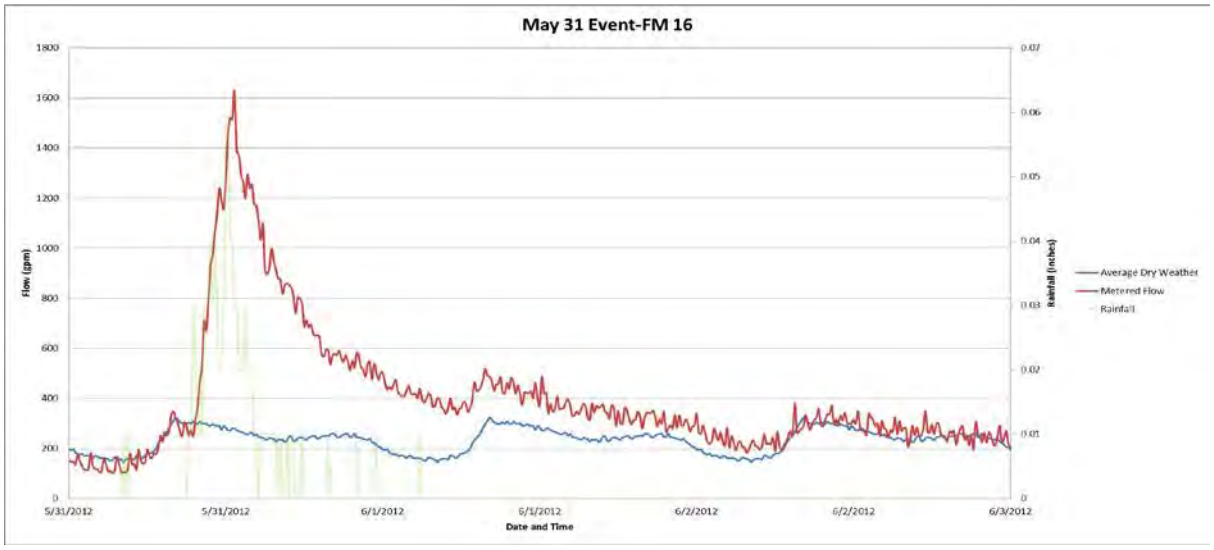
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall


April 15 Event-FM 16
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall


May 26 Event-FM 16
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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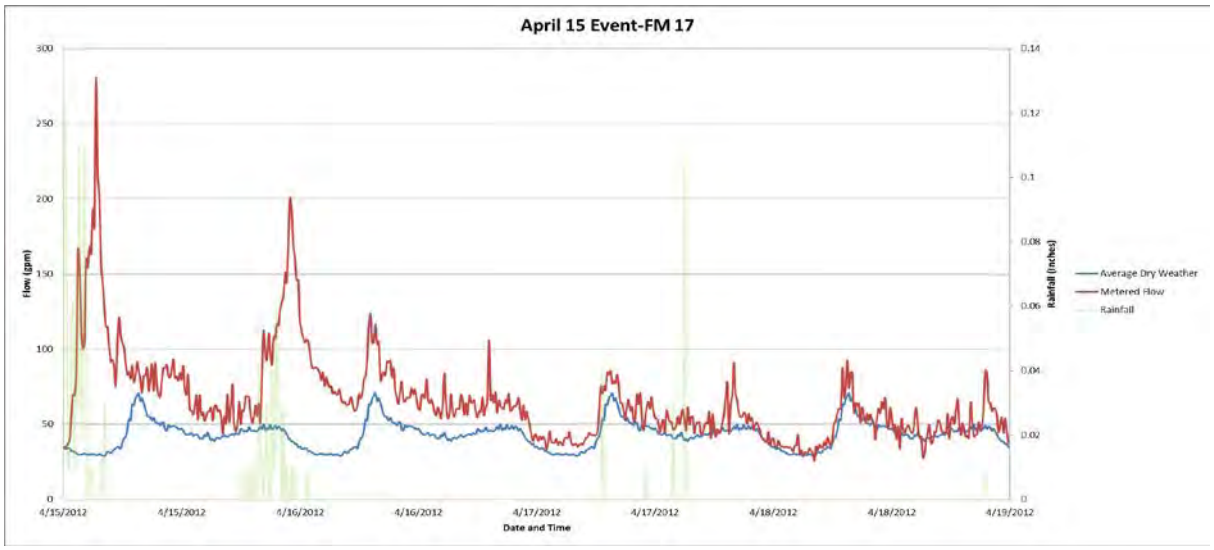
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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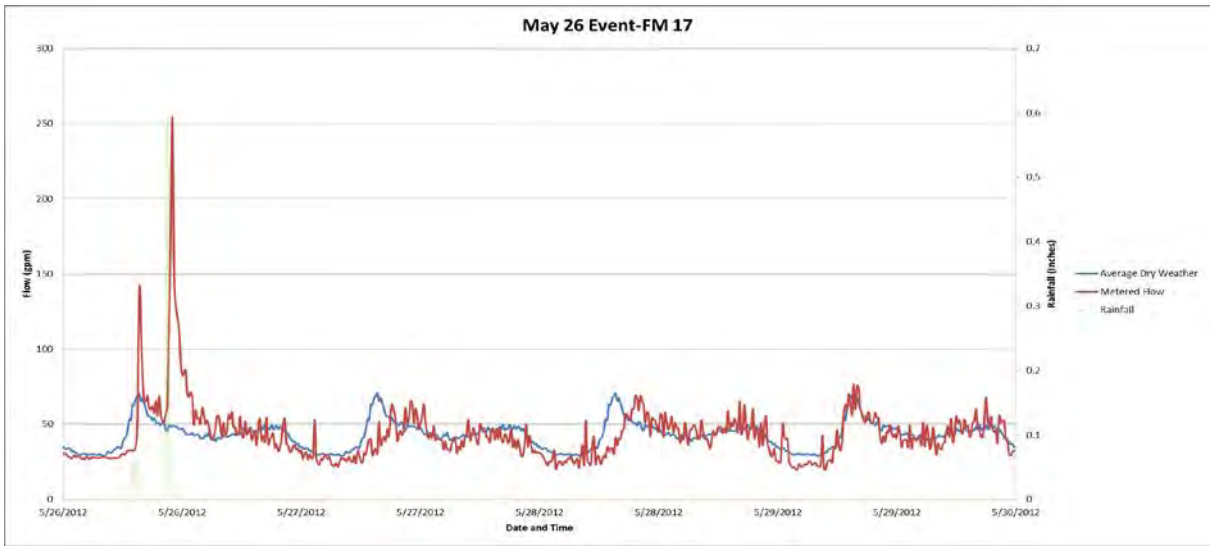
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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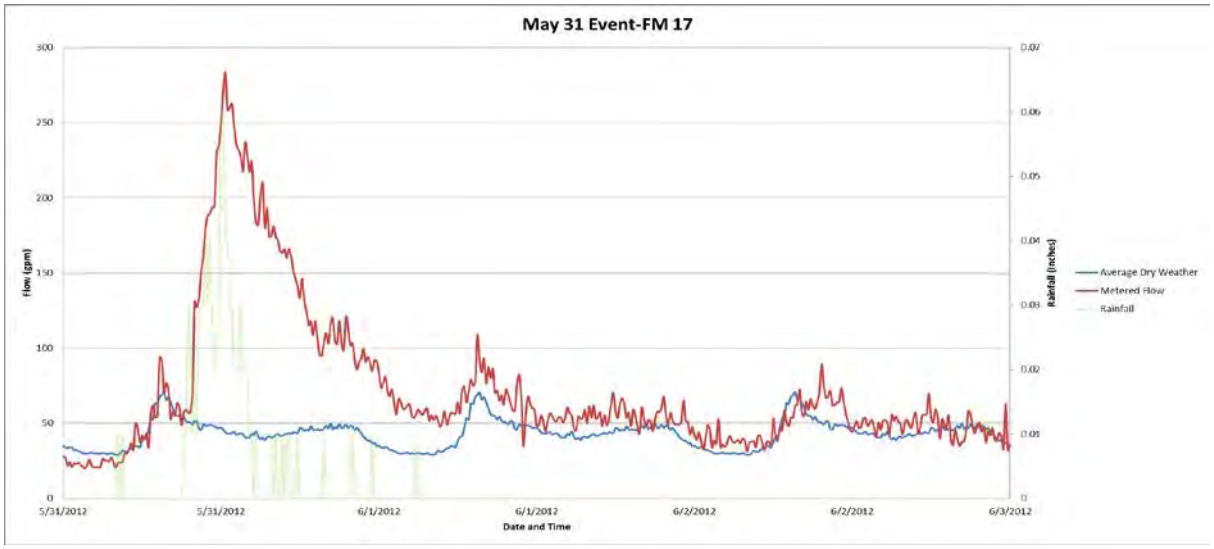
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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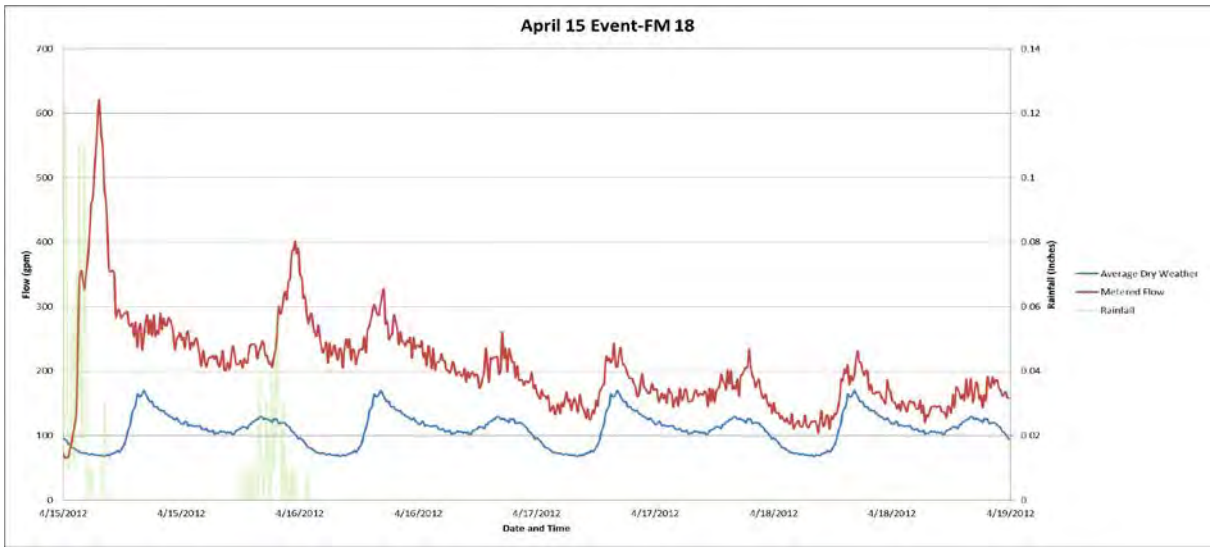
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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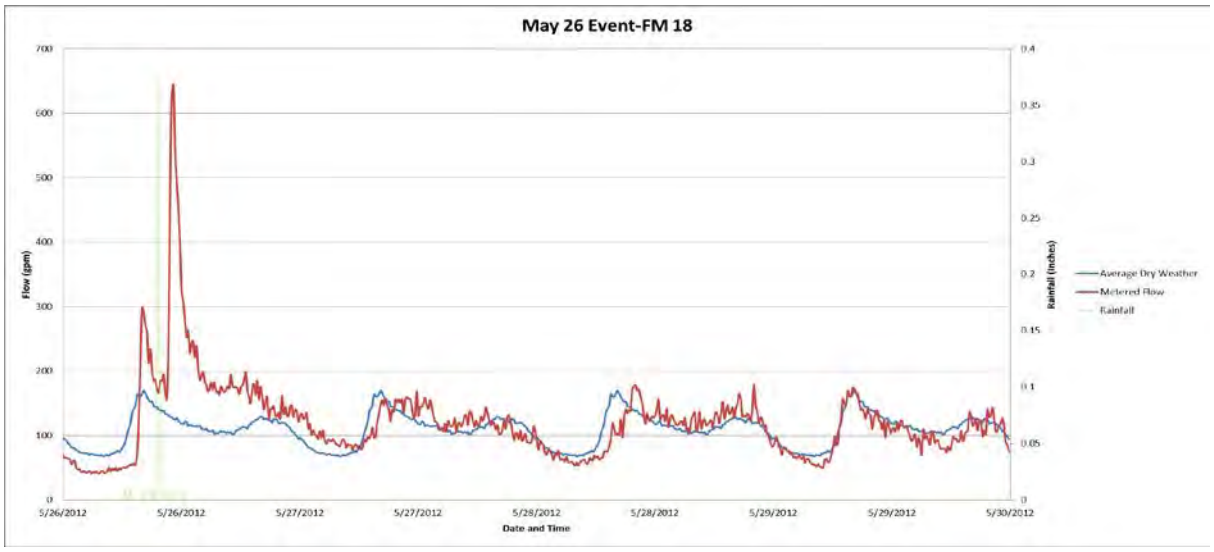
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall

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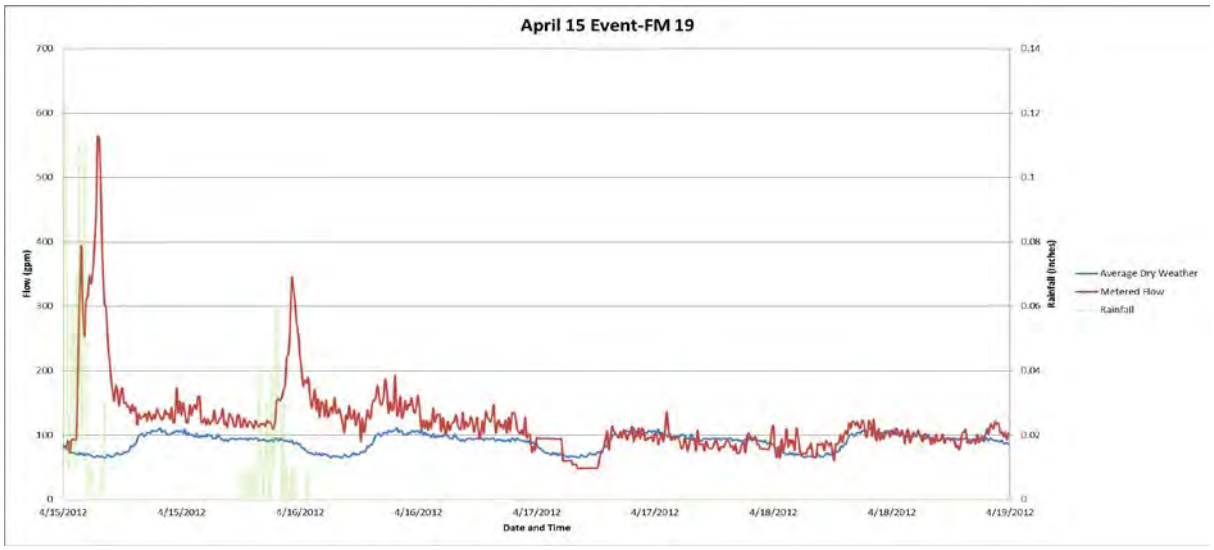
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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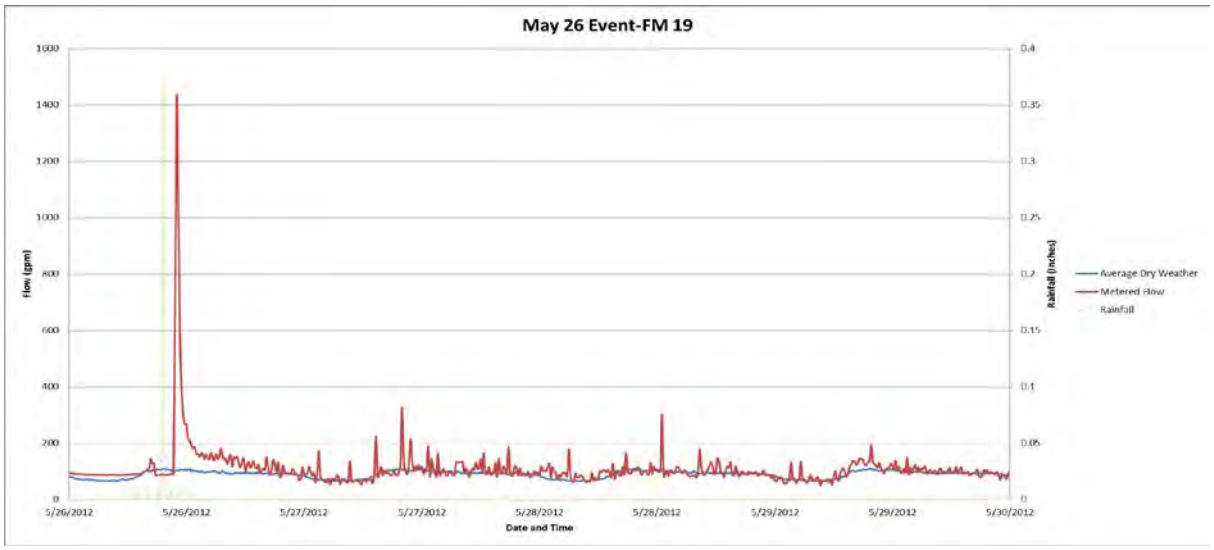
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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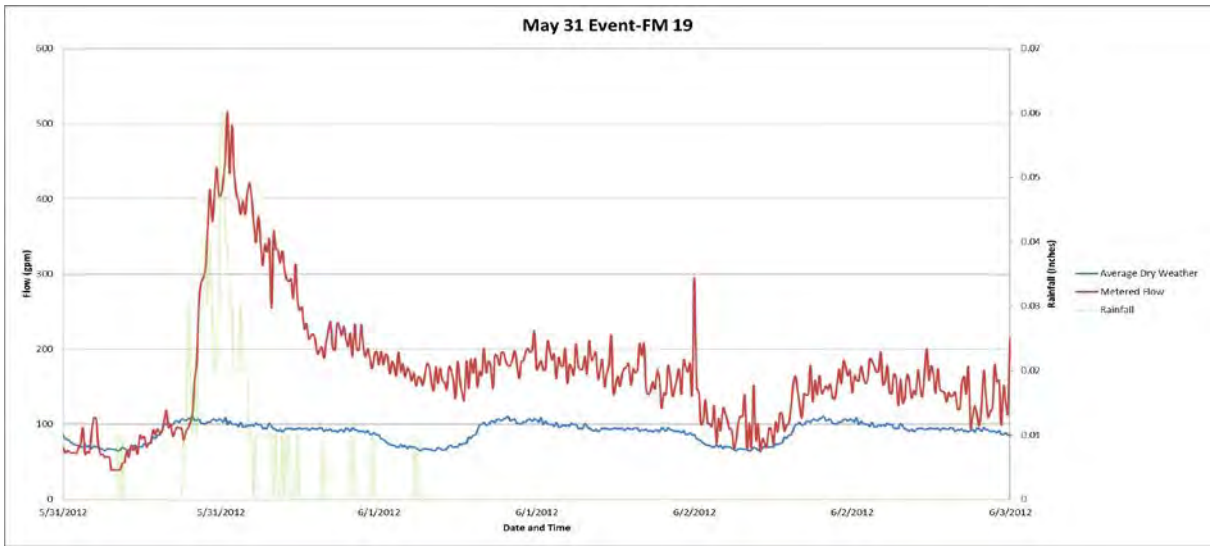
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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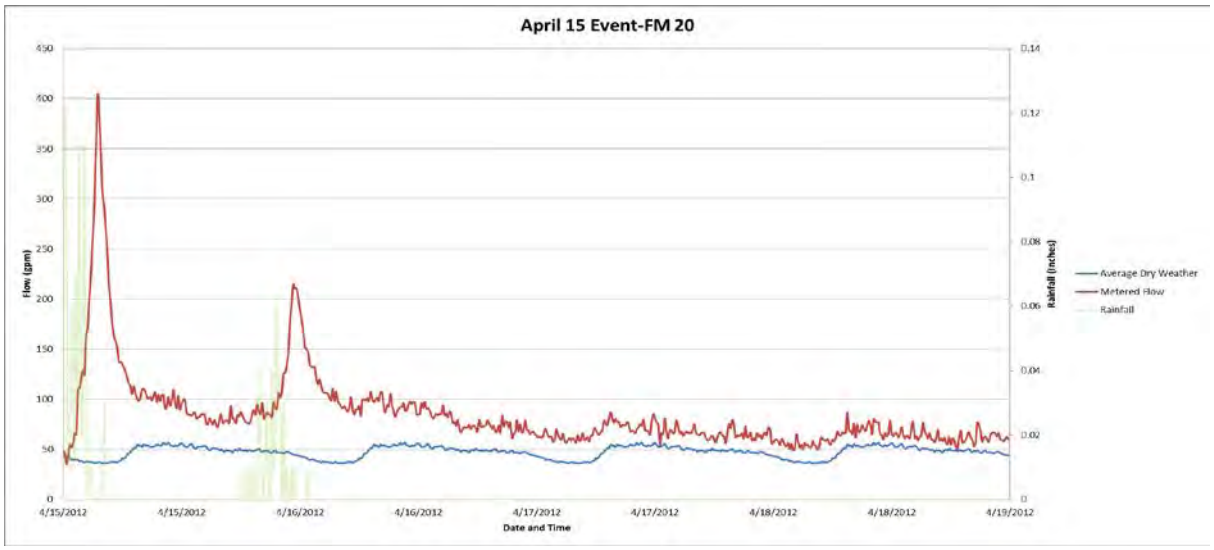
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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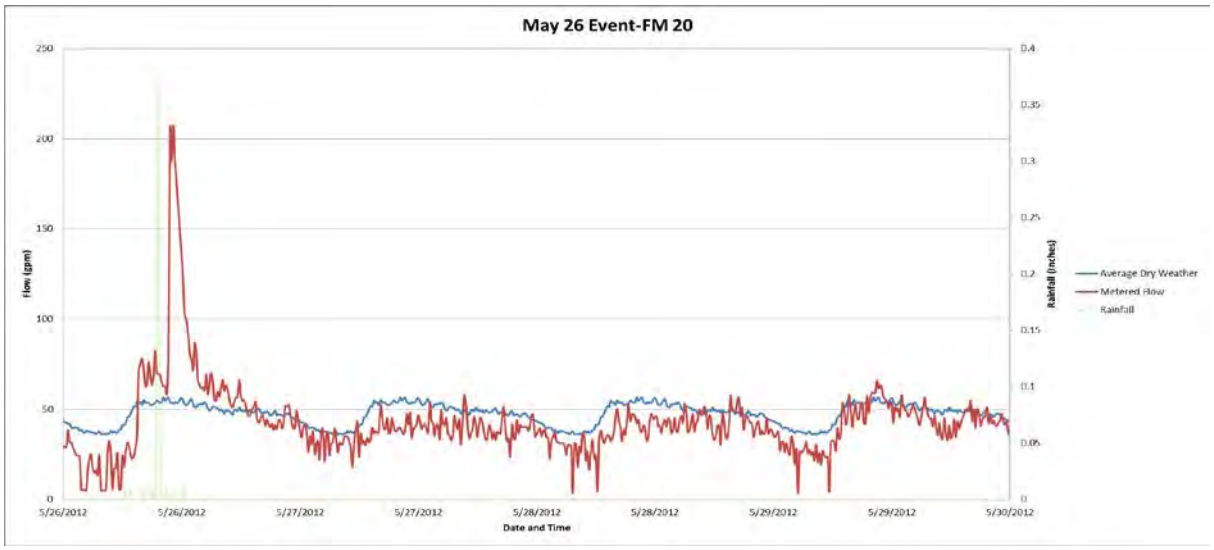
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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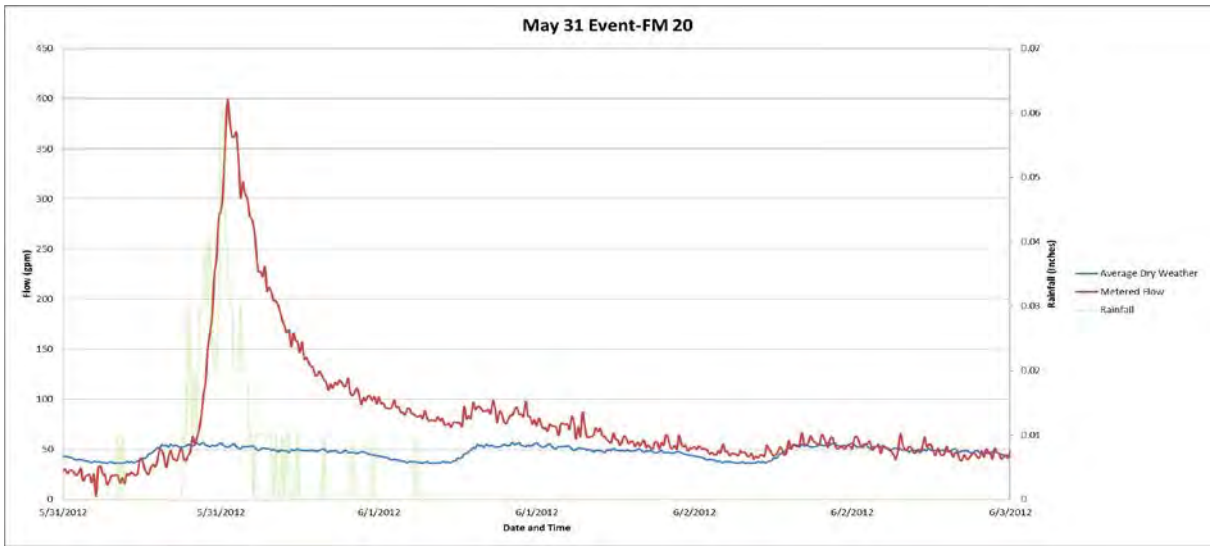
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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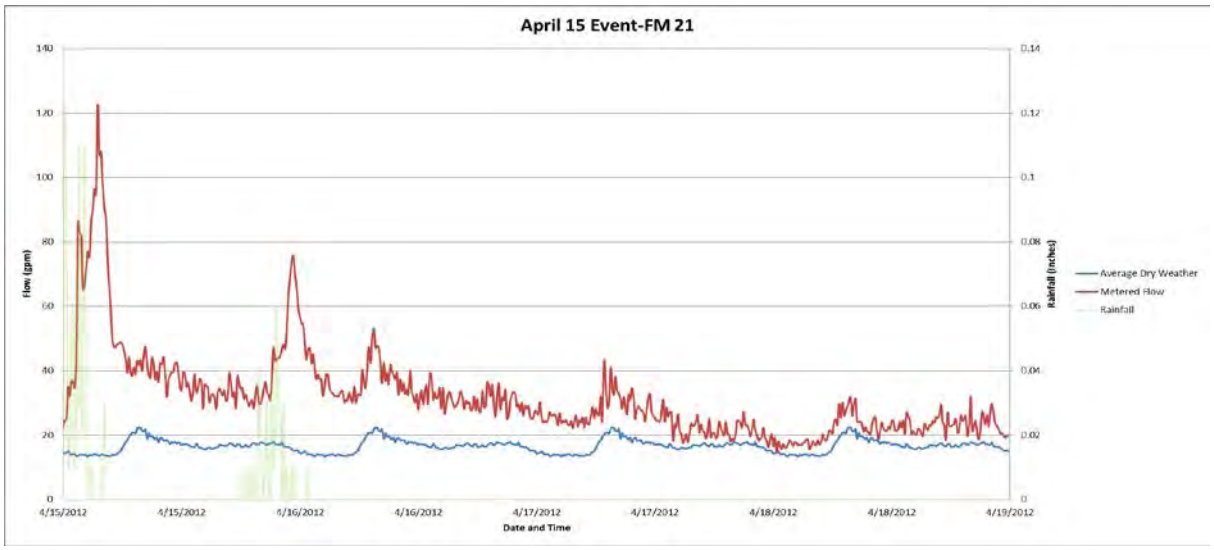
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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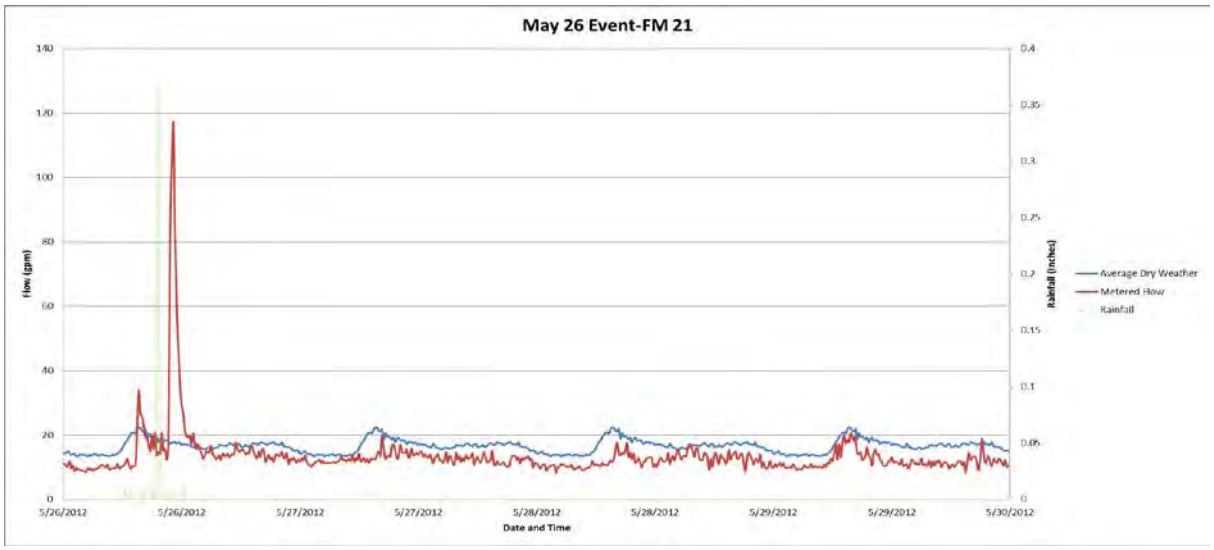
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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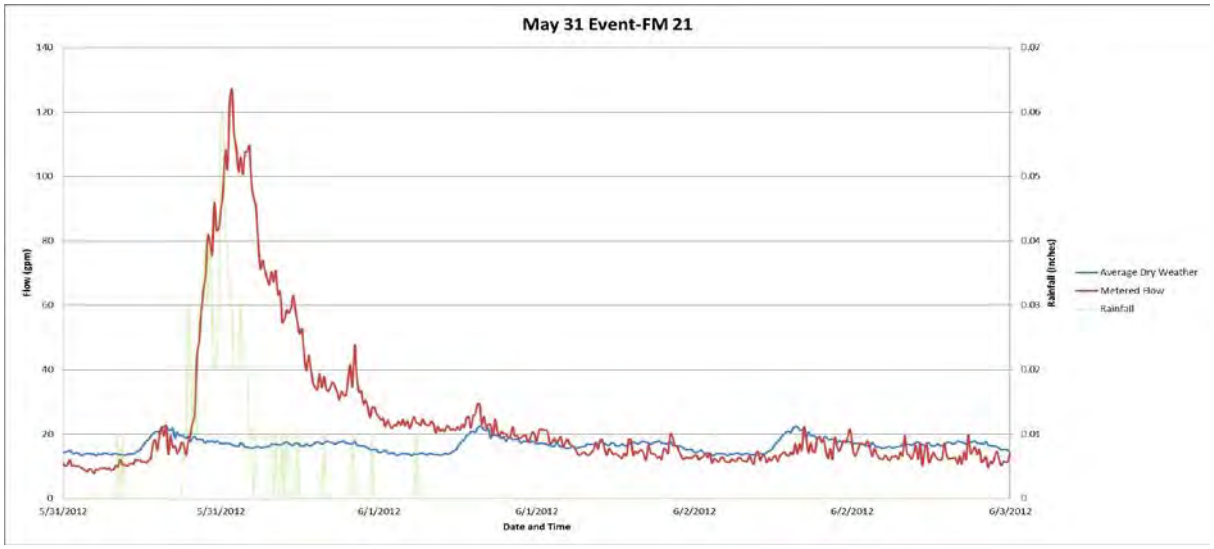
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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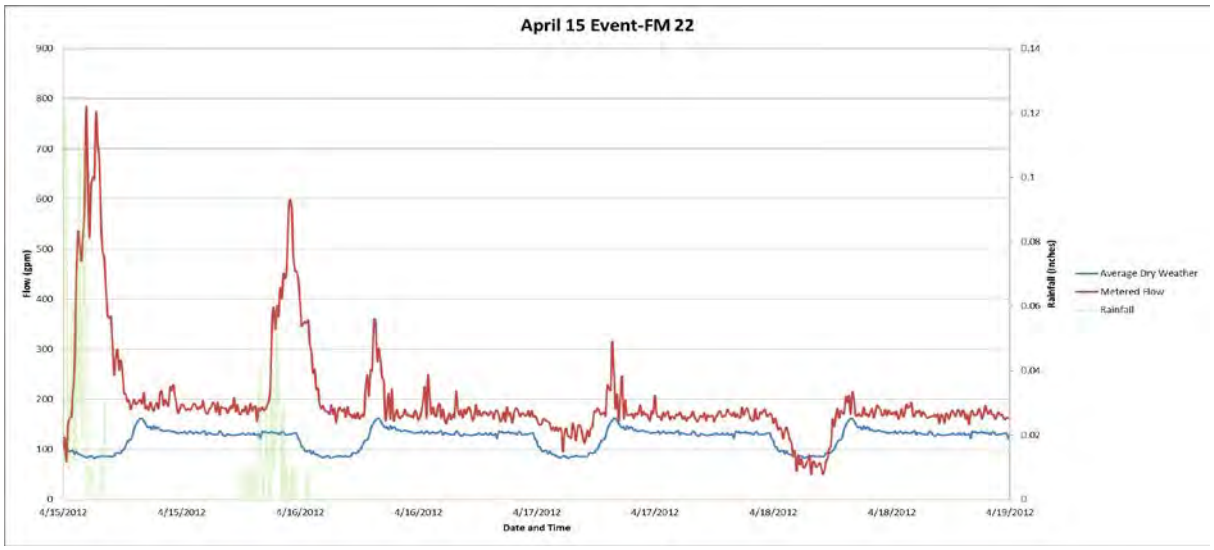
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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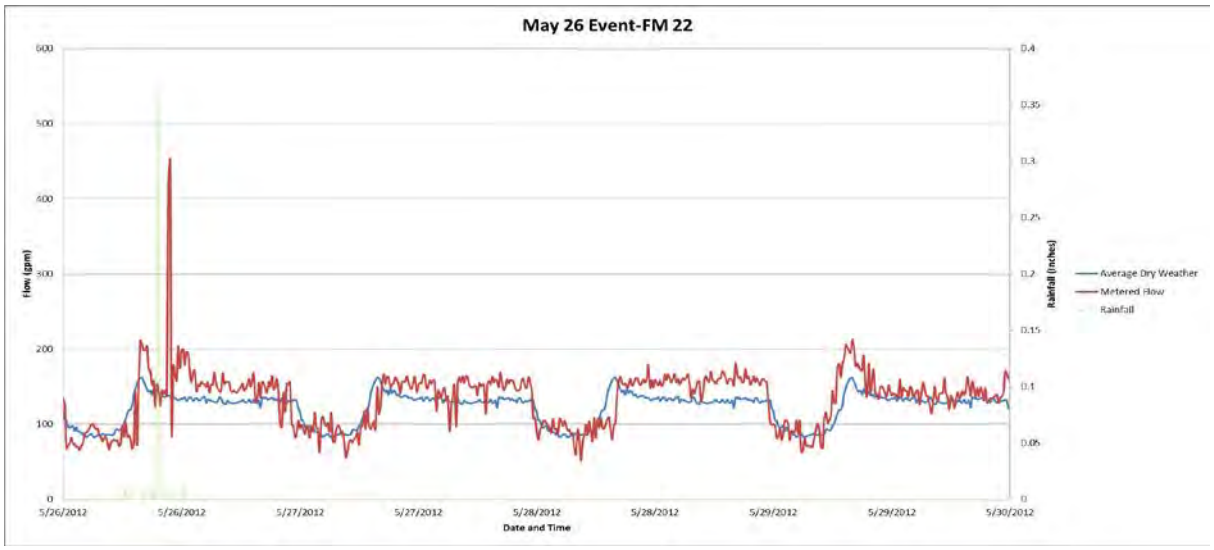
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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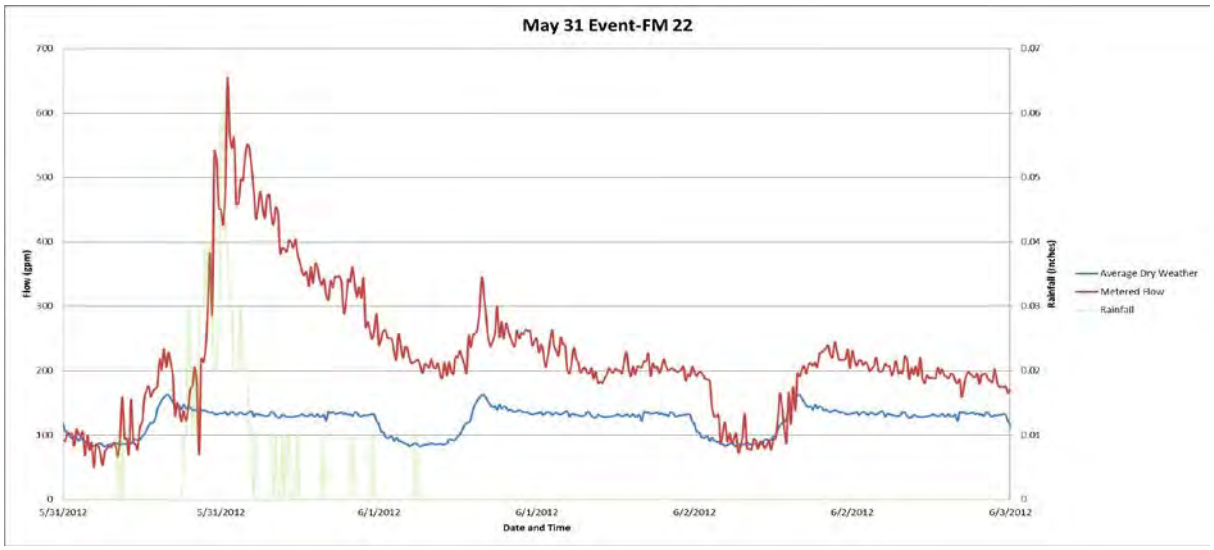
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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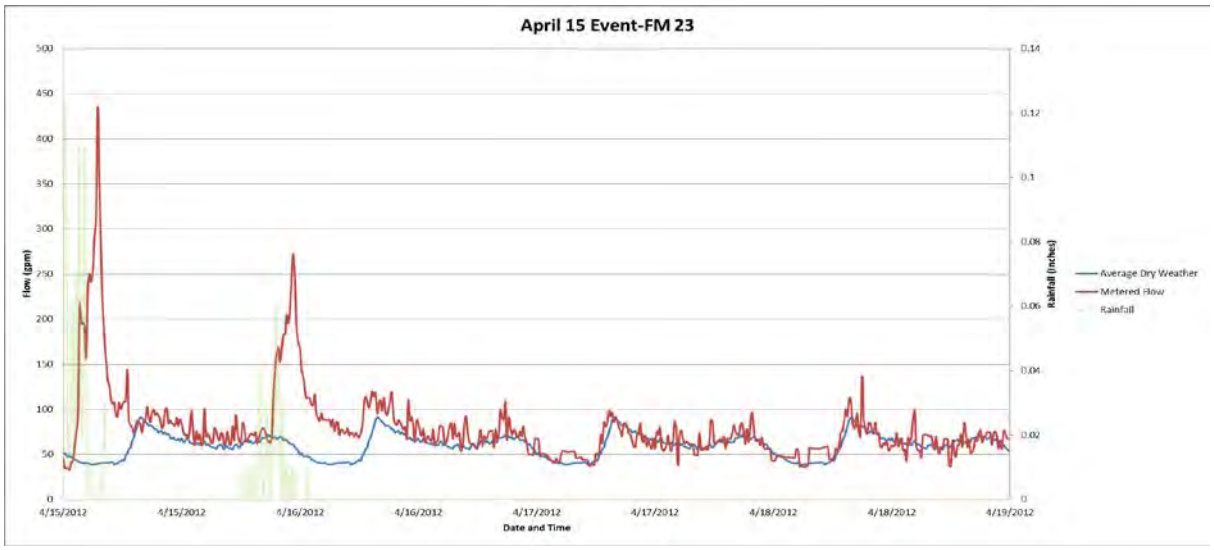
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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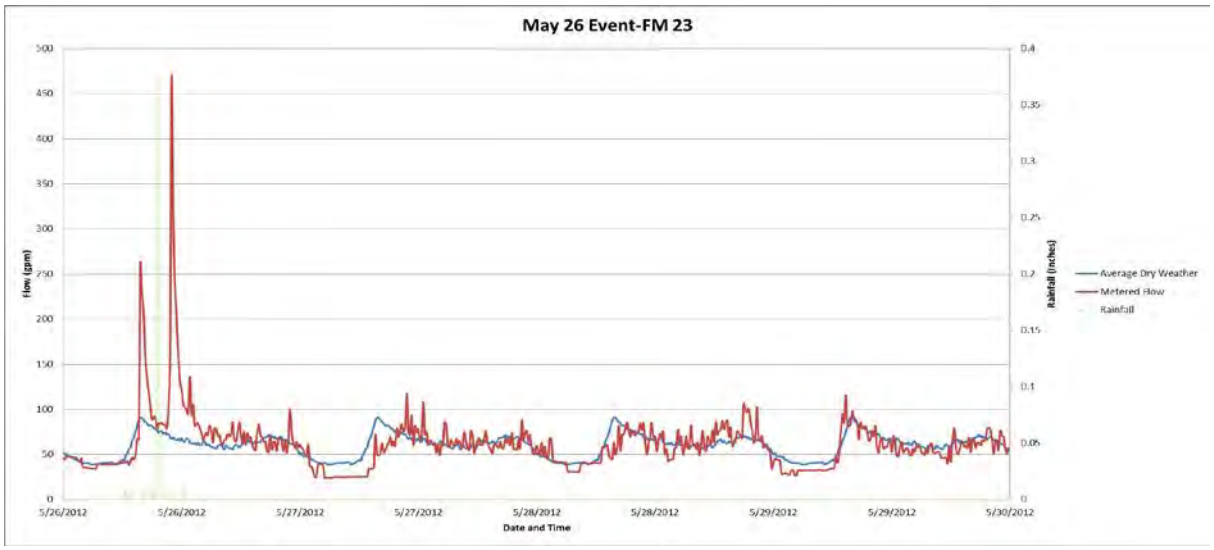
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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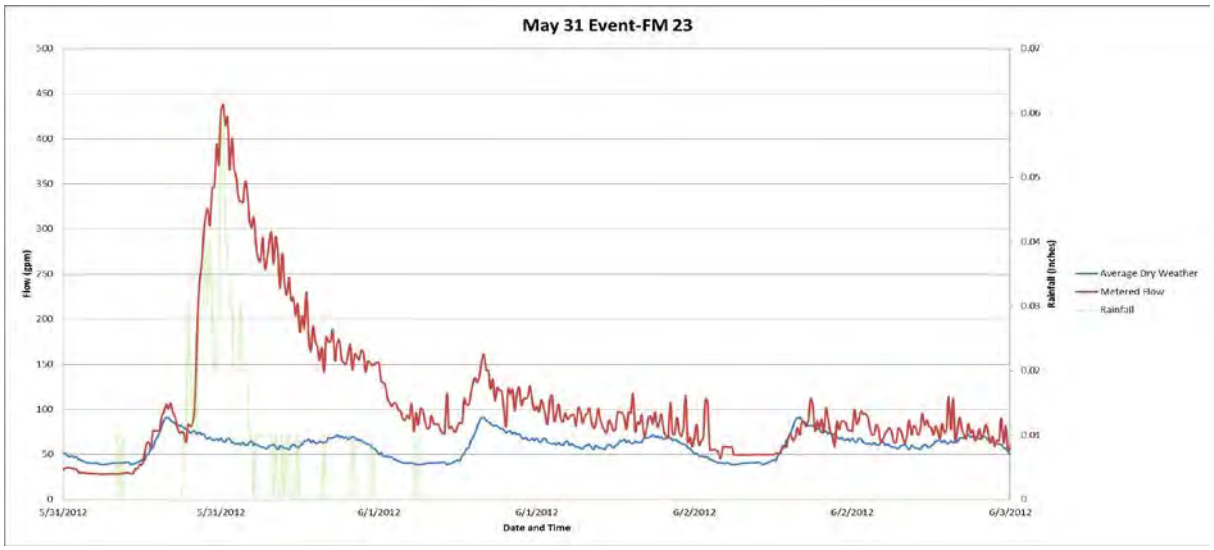
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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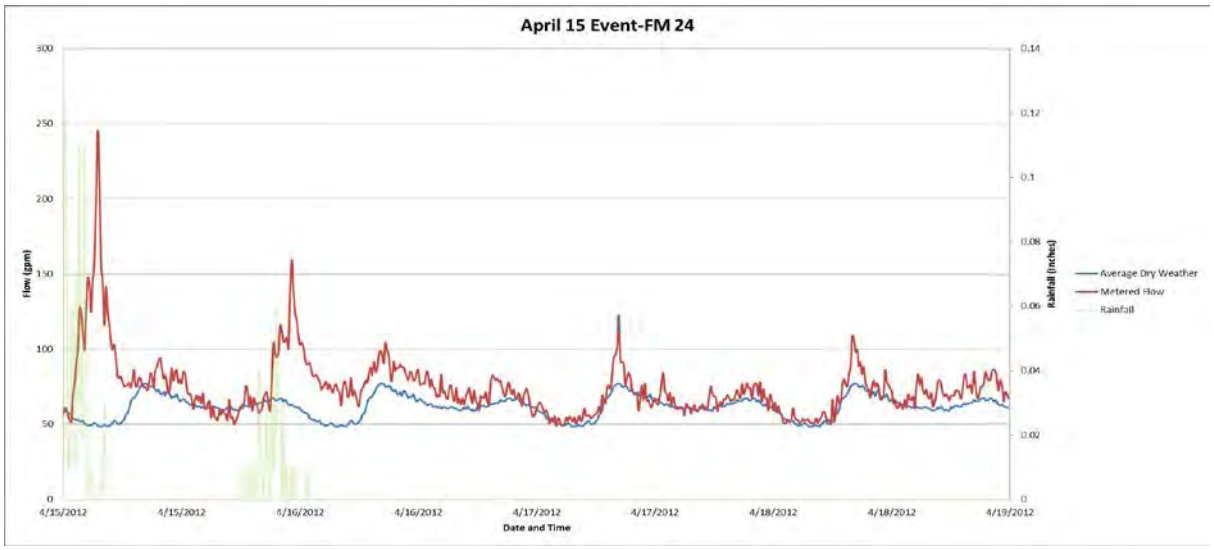
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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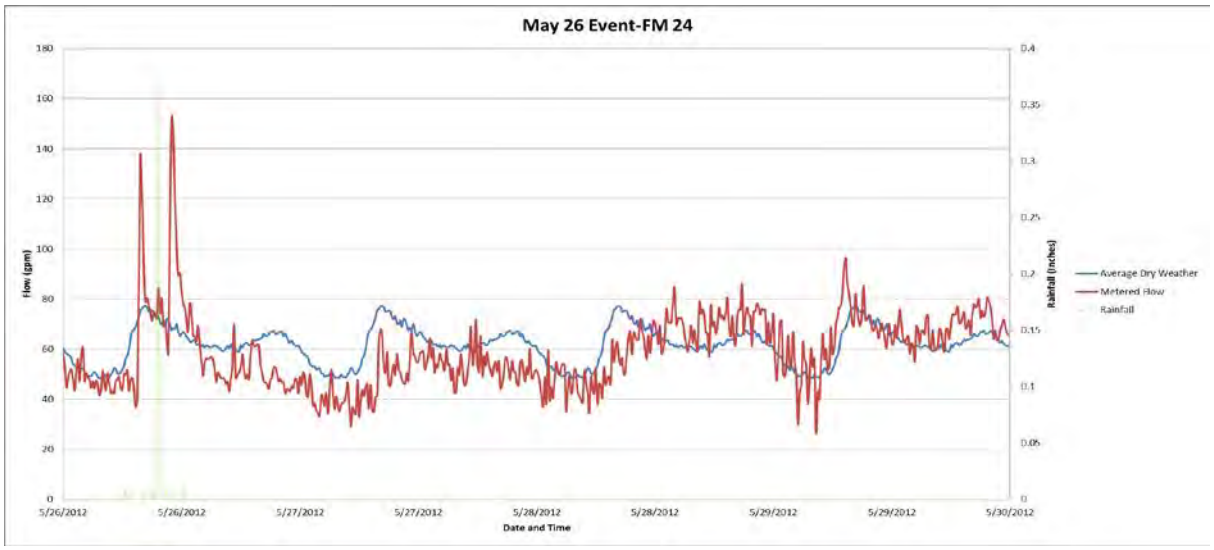
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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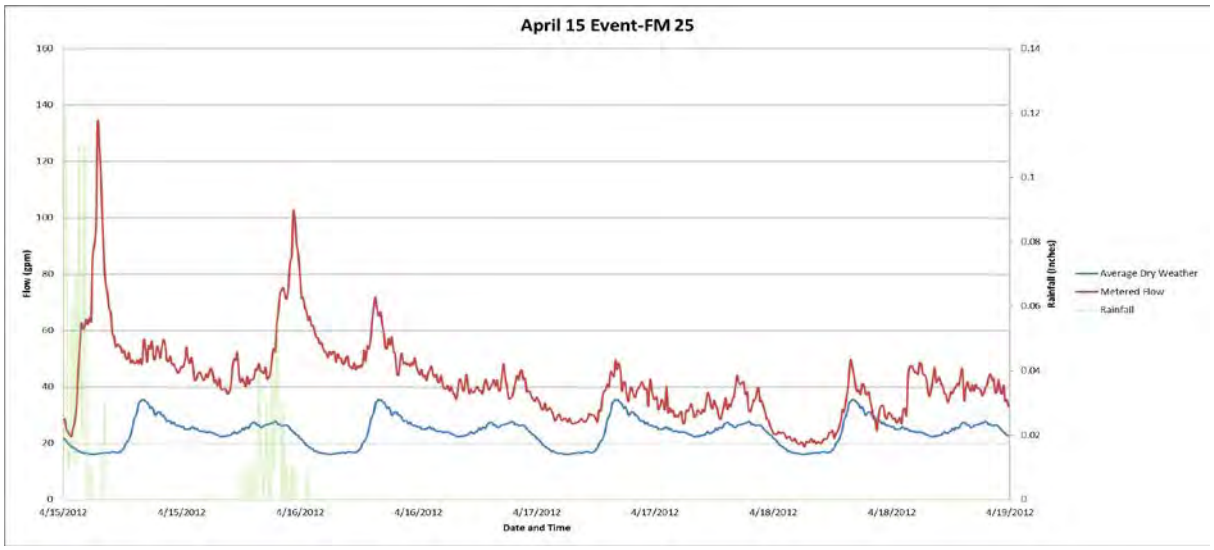
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall

May 31 Event-FM 24
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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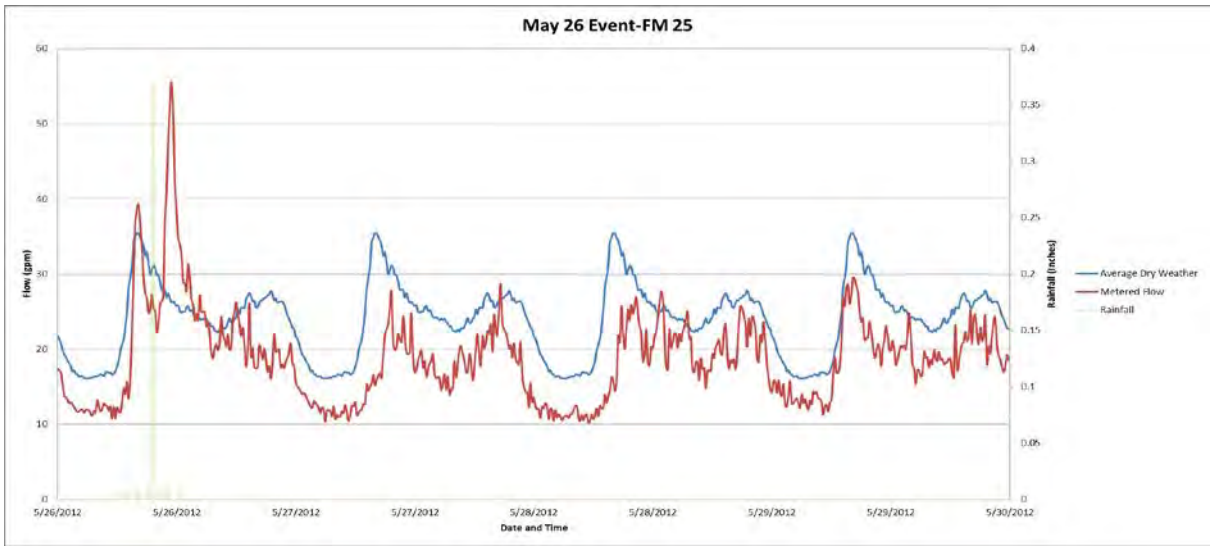
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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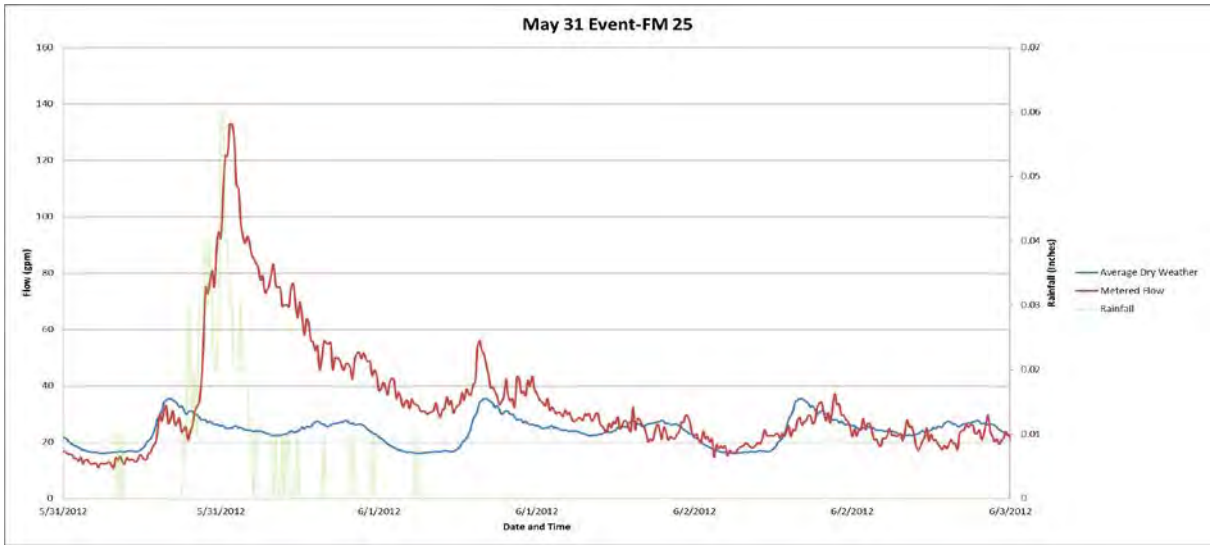
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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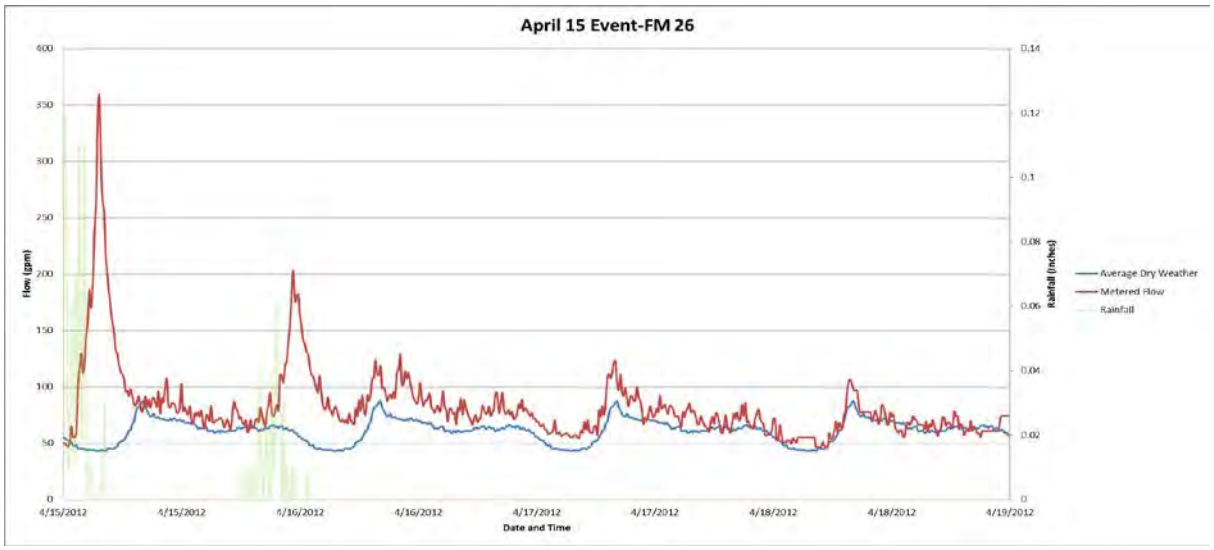
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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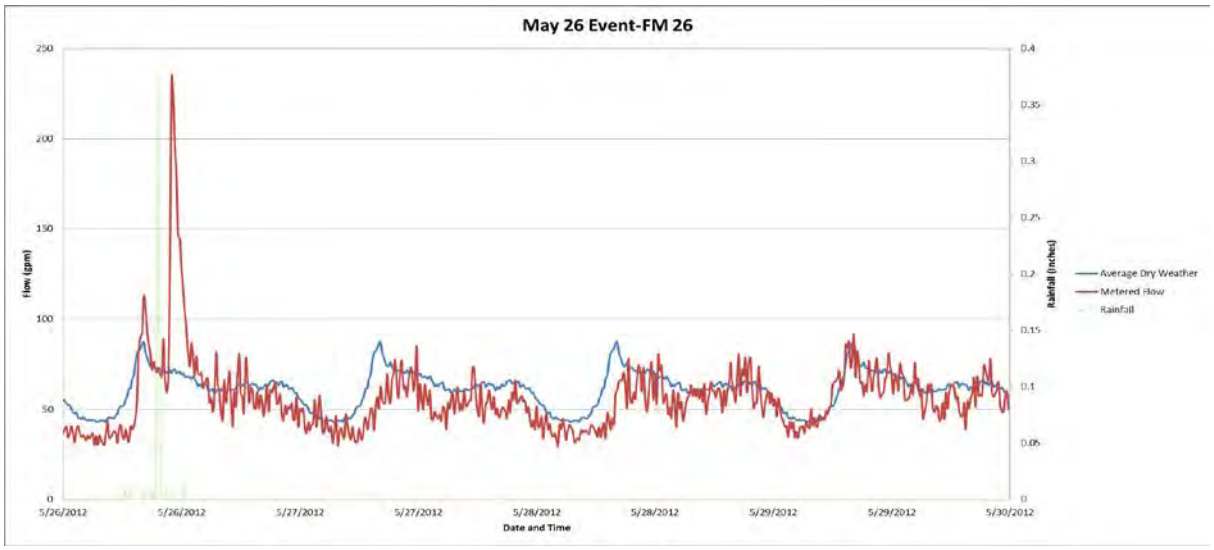
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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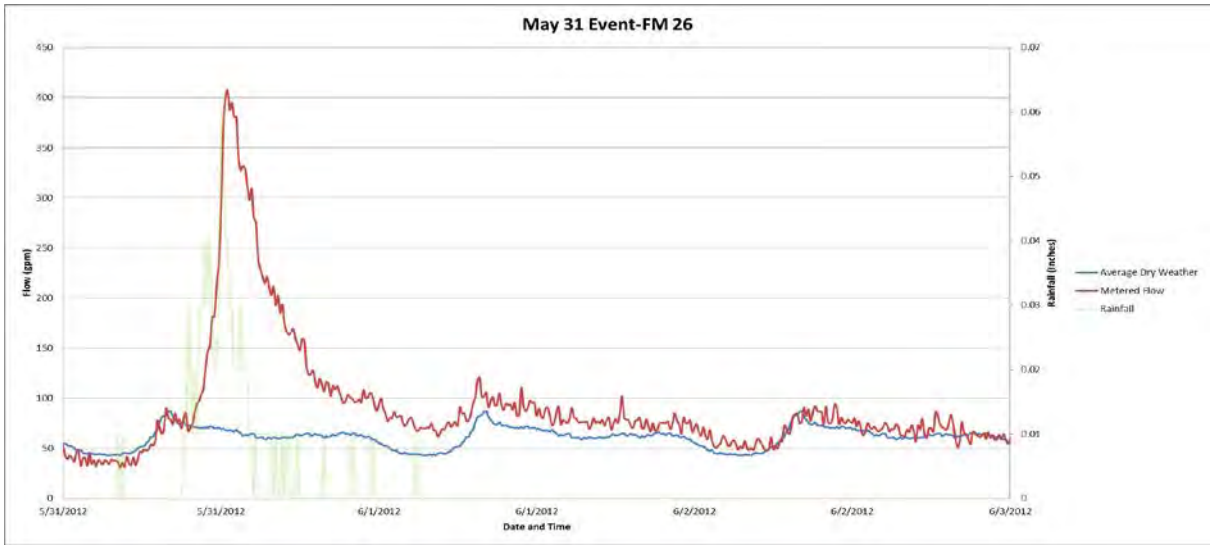
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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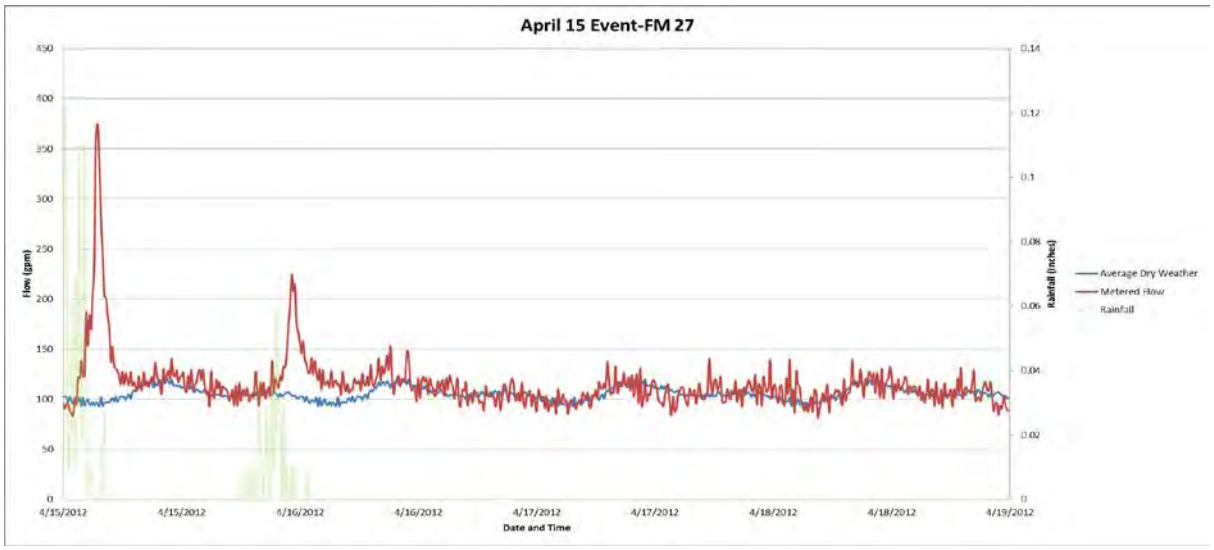
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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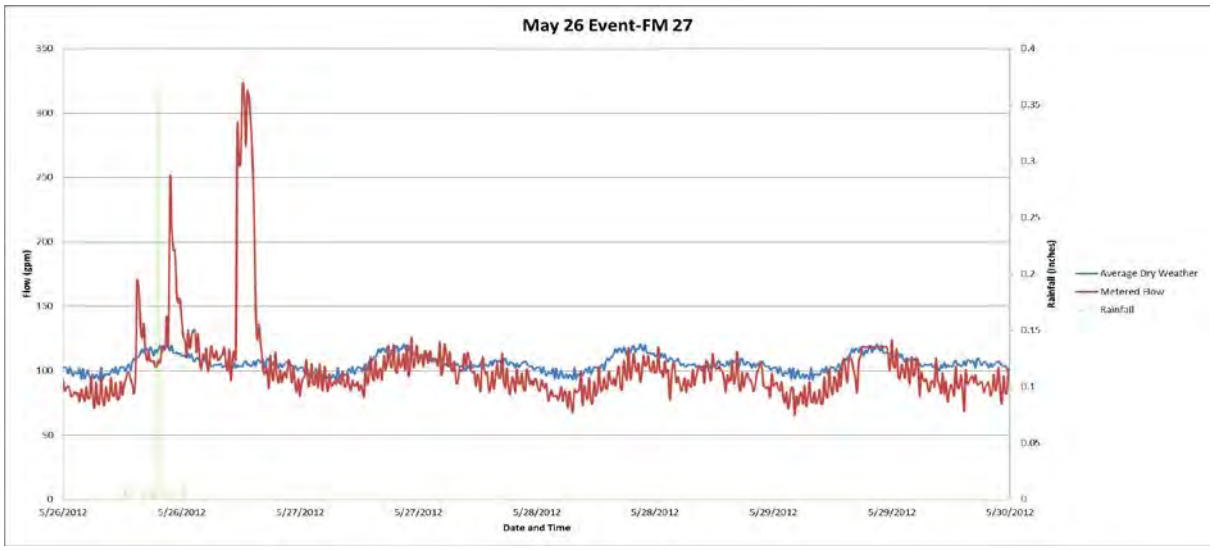
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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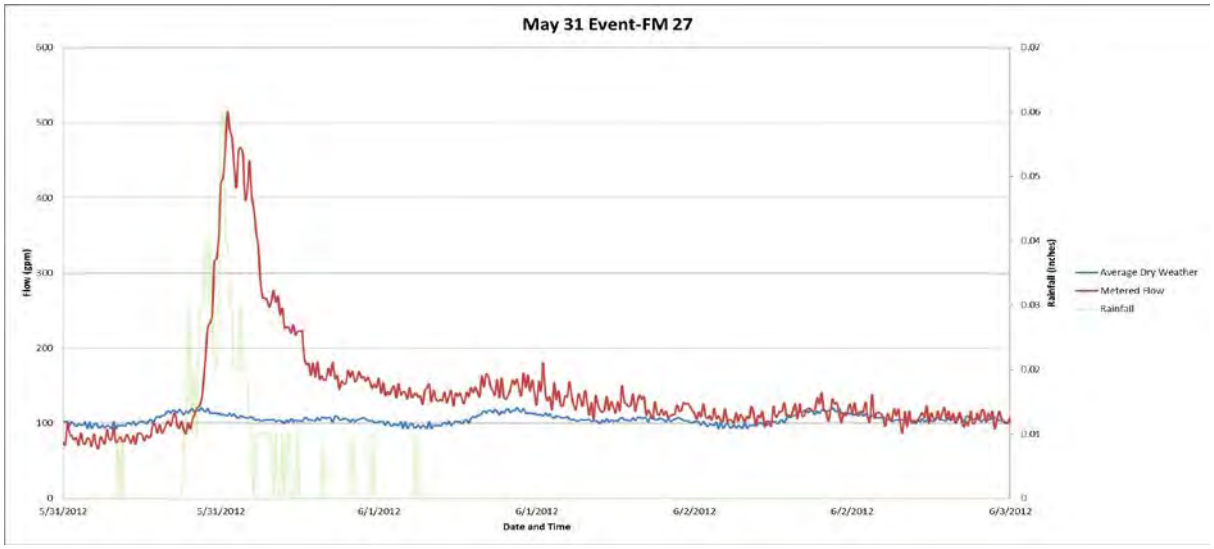
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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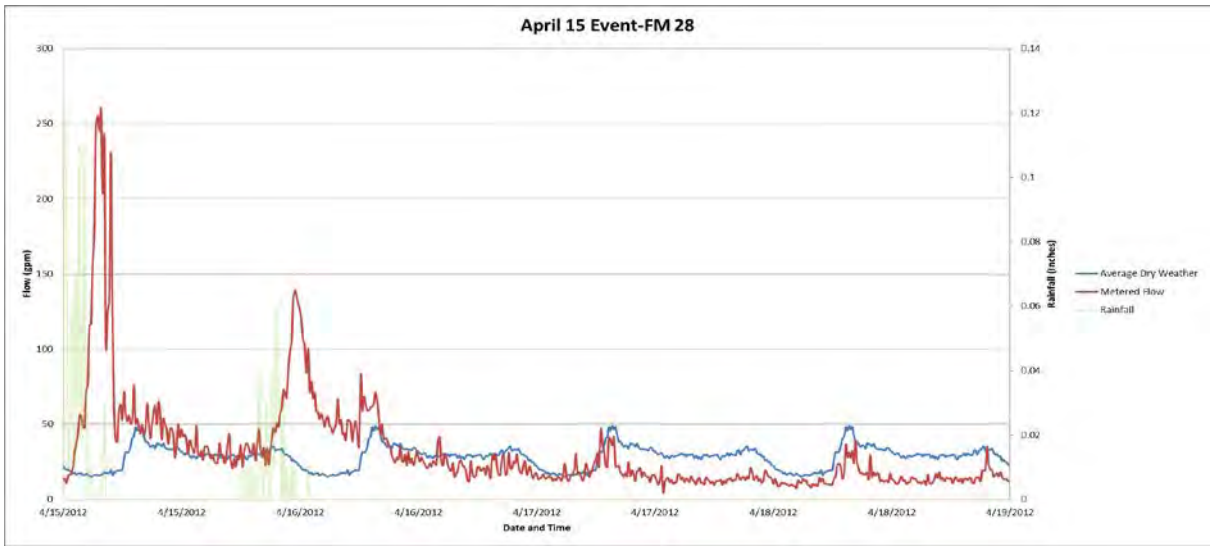
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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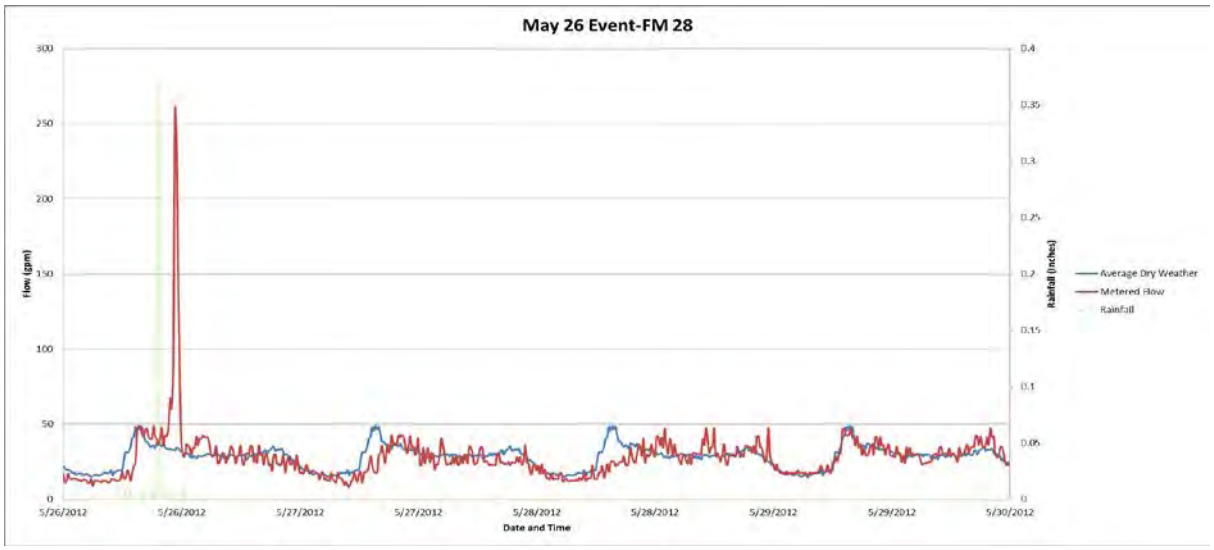
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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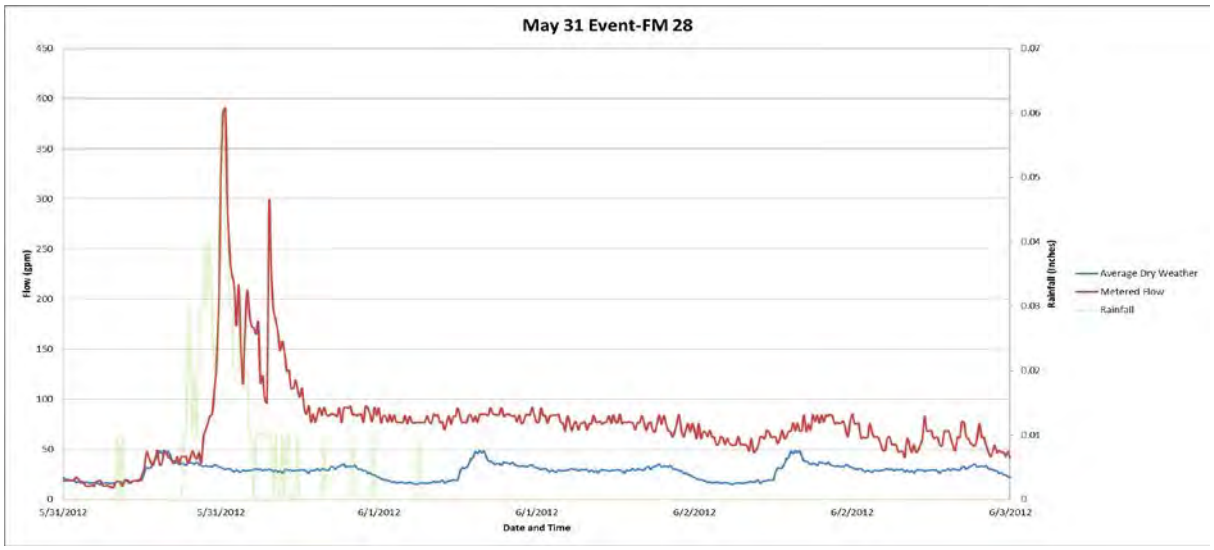
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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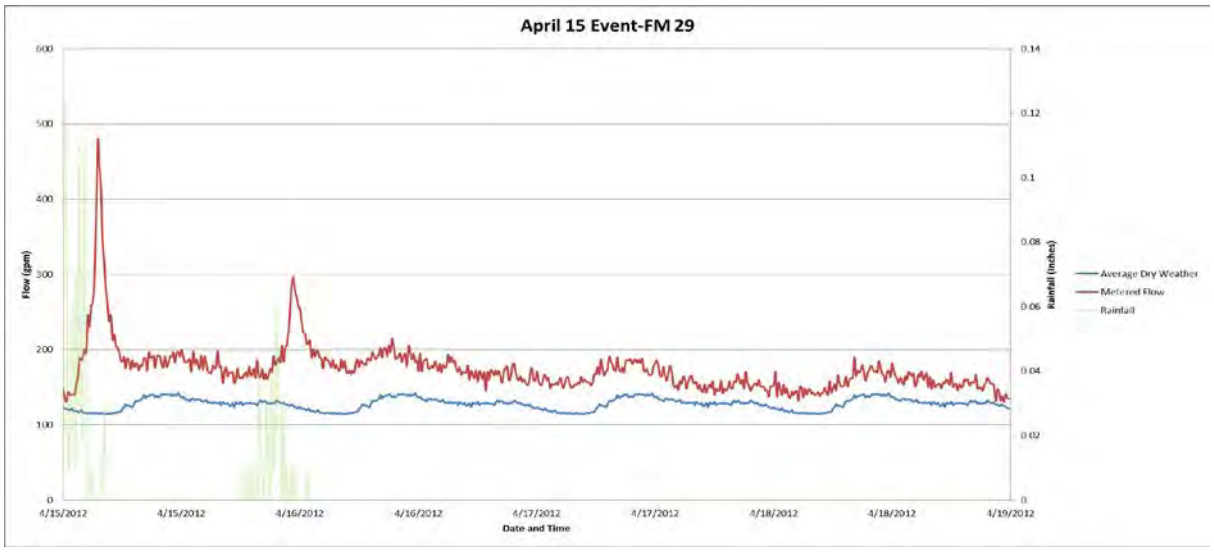
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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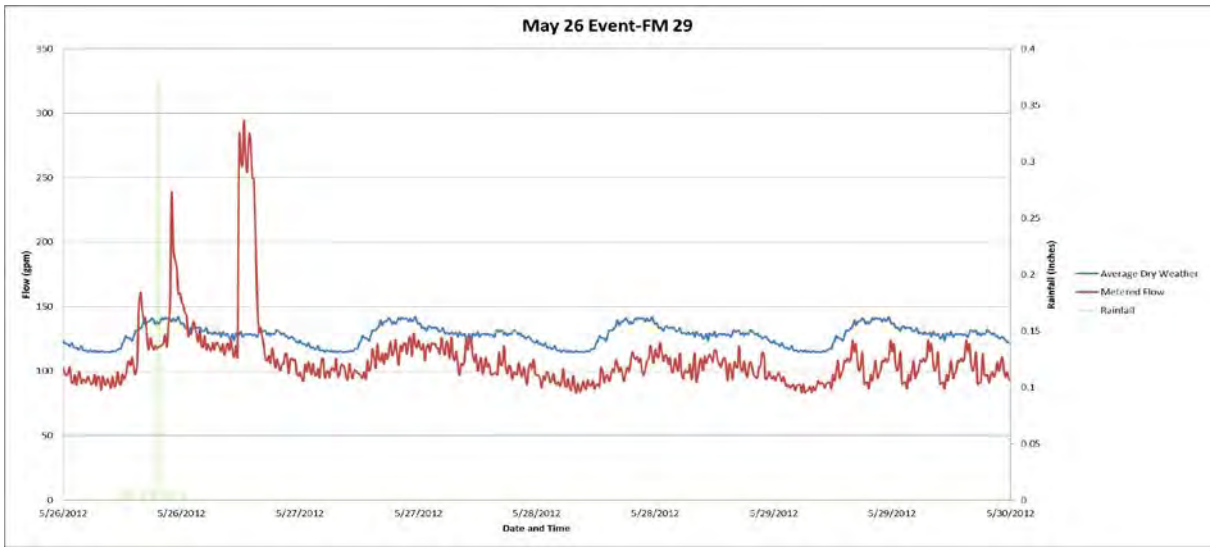
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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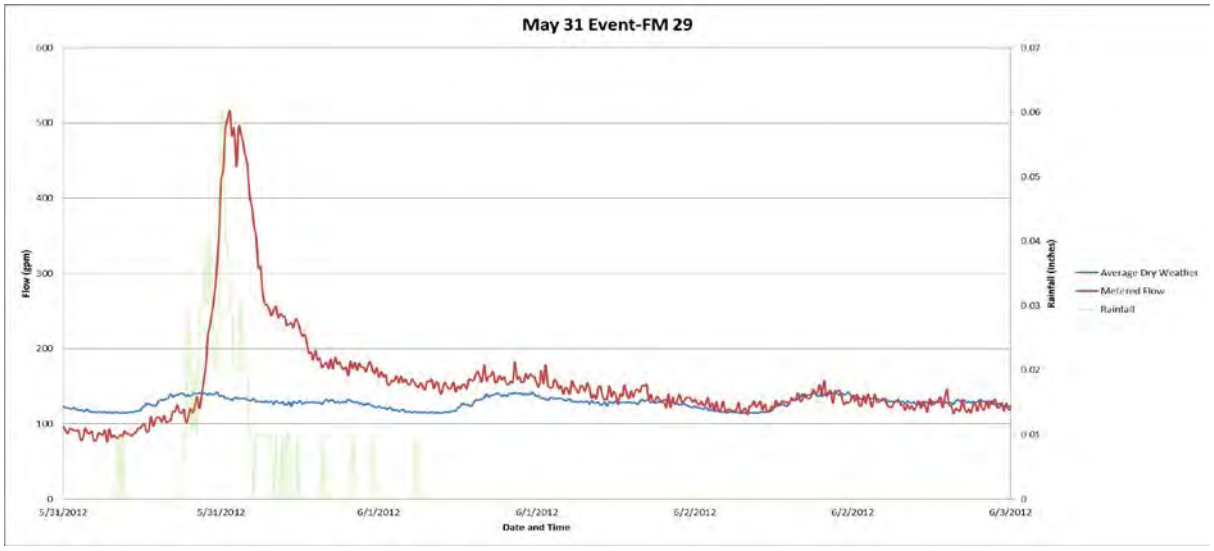
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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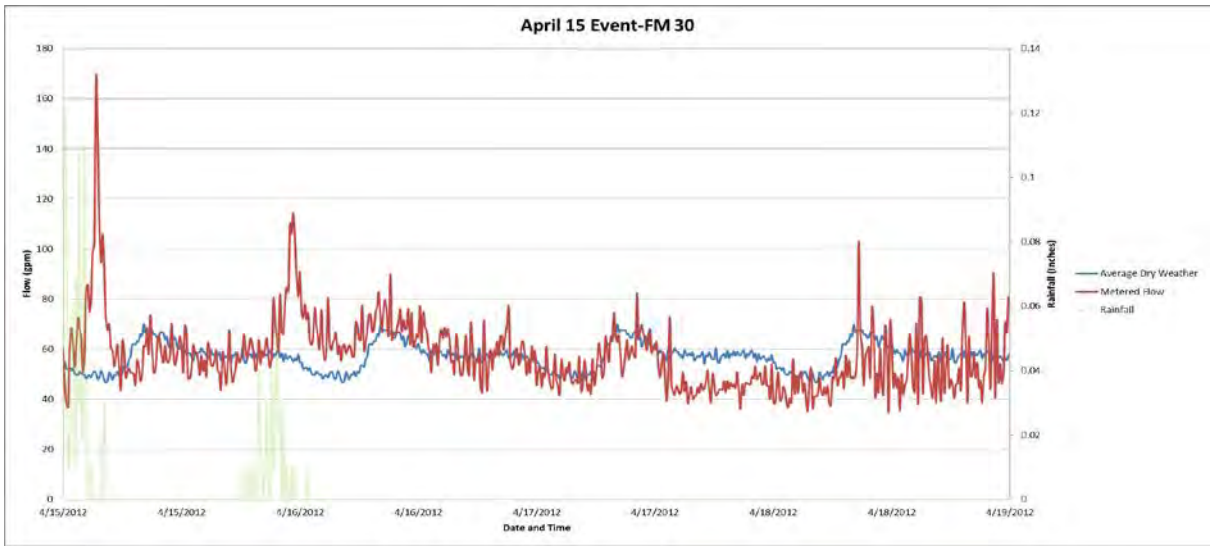
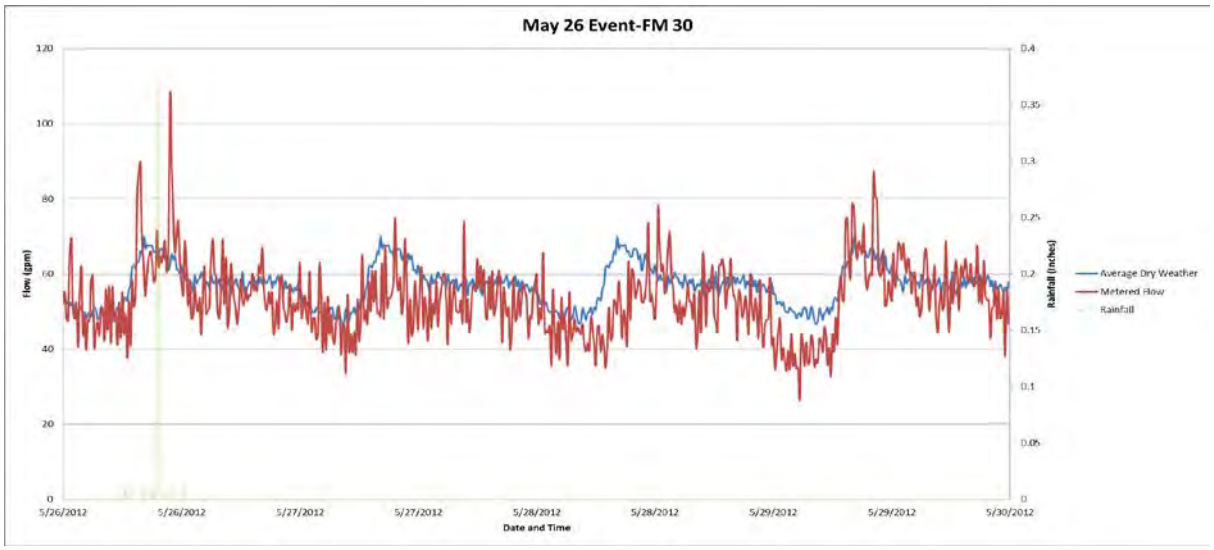
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall


April 15 Event-FM 30
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall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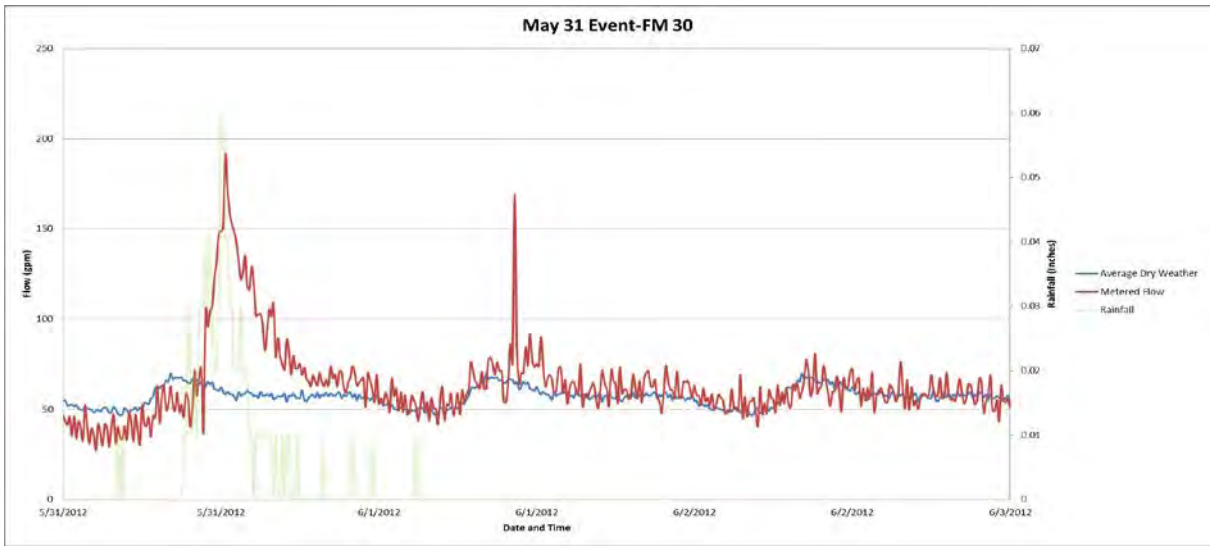
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall


May 31 Event-FM 30
Flow (gpm)
Rainfall (inches)
Date and Time
Average Dry Weather
Metered Flow
Rainfall

APPENDIX C
MANHOLE ASSESSMENT FIELD SHEETS

1 MH Inspection Form

Manhole_ID_(12): start

Manhole ID Selector

Update Next Manhole =>

Add New MH

System_Owner_(2):

Drainage_Area_(4):

Location_Code_(38): C = Light Highway

Curb_Material: C = Concrete (Non-Reinforced)

Surveyor_Name_(1):

Date_Inspected_(8):

Time_Inspected_(9):

Weather_(37):

Manhole_Surface_Type_(40): Concrete Pavemen

Manhole_Surface_Condition

Rim_to_Invert_(ft)_(13):

Rim_to_Grade_(ft)_(15):

PreCleaning_(36): Z = Not Known

Date_Cleaned_(36a):

Additional_Information_(39):

Access_Point_Type_(42): Manhole (AMH)

Inspection_Status_(48): Surface Inspection (SI)

Potential_for_Runoff_(41):

Close_To_Curb:

Evidence_Of_Surcharge_(49):

Use_of_Sewer_(20): SS = Sanitary

Purpose_of_Survey_(34): D = Pre Rehabilitation Survey

<= Back to 4 MH Defects

Save

Forward to MH Component Observations =>

2 MH Component Observations

Manhole_ID_(12):	start
Cover_Shape:	C = Circular
Cover_Material:	CAS = Cast Iron
Cover_Type:	Solid
Number_Vent_Holes:	
Vent_Hole_Diameter:	
Cover_Frame_Fit:	Good (G)
Cover_Condition:	Sound
Gasket_Condition:	
Adjusting_Ring_Type:	
Adjusting_Ring_Condition:	
Adjustment_Ring_Height_(ft):	
Frame Material:	CAS = Cast Iron
Frame_Condition	Sound
Frame Seal Condition:	
Frame_Offset_Distance_(ft)	
Chimney_Material_1:	
Int_Chim_Coating_Liner:	None (NC)
Ext_Chim_Coating_Liner:	

Cone_Type:	
Cone_Material:	
Int_Cone_Coating_Liner:	None (NC)
Ext_Cone_Coating_Liner	
MH_Diameter_1_(ft):	
MH_Diameter_2_(ft):	
Wall_Material_1:	
Wall_Material_2:	
Int_Wall_Coating_Liner:	
Ext_Wall_Coating_Liner:	
Bench_Present:	Yes (Y)
Bench_Coating_Liner:	None (NC)
Bench_Material:	C = Concrete (Non-Reinf
Channel_Installed:	Yes
Channel_Material:	C = Concrete (Non-Reinforc
Channel_Type:	
Channel_Exposure:	Fully Open (F)
Number_Steps:	
Step_Material:	
Step_Condition:	

<= Backward to 1 MH Inspection | Save | Forward to 3 Pipe Connections =>

3PipeConnections

Manhole_ID_(12): start

Cxn1_Compass_Dir:		Cxn5_Compass_Dir:	
Cxn1_Direction:		Cxn5_Direction:	
Cxn1_Special_Condn:		Cxn5_Special_Condn:	
Cxn2_Compass_Dir:		Cxn6_Compass_Dir:	
Cxn2_Direction:		Cxn6_Direction:	
Cxn2_Special_Condn:		Cxn6_Special_Condn:	
Cxn3_Compass_Dir:		Cxn7_Compass_Dir:	
Cxn3_Direction:		Cxn7_Direction:	
Cxn3_Special_Condn:		Cxn7_Special_Condn:	
Cxn4_Compass_Dir:		Cxn8_Compass_Dir:	
Cxn4_Direction:		Cxn8_Direction:	
Cxn4_Special_Condn:		Cxn8_Special_Condn:	

<= Back to 2 MH Component Observations | Save | Forward to 4 MH Defects =>

Manhole_ID_(12): 65-14

Cxn1_Compass_Dir:	S	Cxn5_Compass_Dir:	
Cxn1_Direction:	Out	Cxn5_Direction:	
Cxn1_Special_Condn:		Cxn5_Special_Condn:	
Cxn2_Compass_Dir:	N	Cxn6_Compass_Dir:	
Cxn2_Direction:	In	Cxn6_Direction:	
Cxn2_Special_Condn:		Cxn6_Special_Condn:	

4MHDefects

Manhole_ID_(12): start

Overall_Condition:

Rehab Method 1:

Rehab Method 2:

Rehab Method 3:

Rehab Method 4:

D1_Location:

D1_Code:

D1_Rating:

D1_II:

D1_Comments:

D2_Location:

D2_Code:

D2_Rating:

D2_II:

D2_Comments:

D3_Location:

D3_Code:

D3_Rating:

D3_II:

D3_Comments:

D4_Location:

D4_Code:

D4_Rating:

D4_II:

D4_Comments:

D5_Location:

D5_Code:

D5_Rating:

D5_II:

D5_Comments:

D6_Location:

D6_Code:

D6_Rating:

D6_II:

D6_Comments:

APPENDIX D
OPINION OF PROBABLE COSTS OF FURTHER INVESTIGATIONS

FURTHER SSES INVESTIGATIONS OPINION OF PROBABLE COSTS BY BASIN

Basin	Number of Manholes	Length of Sewer (ft)	Opinion of Cost of SSES Investigations	Opinion of Cost of Televising
14	8	1,413	$2,900	$1,100
15	32	5,391	$6,200	$3,900
5	23	5,899	$5,100	$4,300
6	49	14,240	$9,100	$10,400
13	25	8,050	$5,800	$5,800
18	39	11,571	$7,200	$8,400
21	10	2,437	$2,300	$1,800
4	16	2,594	$4,000	$1,900
12	103	18,261	$17,800	$13,200
20	25	4,514	$5,100	$3,300
Priority Unmetered Areas	48	8,083	$7,700	$5,900
Basin 23 Flood Cluster	16	3,213	$4,700	$2,300
Basin 25 Flood Cluster	35	7,526	$7,700	$5,500
Basin 24 Flood Cluster	12	2,545	$3,100	$1,800
Basin 26 Flood Cluster	20	3,417	$5,600	$2,500
Basin 16 Flood Cluster	19	4,266	$4,800	$3,100
Basin 17 Flood Cluster	15	3,204	$3,900	$2,300
Non-Priority Unmetered Areas	202	41,575	$26,700	$29,900
3	19	5,819	$4,900	$4,200
2	26	4,768	$6,600	$3,500
1	25	5,440	$5,800	$3,900
28	28	7,017	$6,700	$5,100
10	20	5,207	$5,000	$3,800
19	47	5,308	$9,700	$3,800
Remaining 26	34	6,730	$4,900	$4,900
Remaining 23	14	1,423	$3,200	$1,000
Remaining 24	33	4,047	$6,900	$2,900
Remaining 25	29	6,142	$5,300	$4,500
11	34	7,023	$7,000	$5,100
8	23	4,708	$5,000	$3,400
Remaining 17	14	2,857	$3,300	$2,100
Remaining 16	26	4,228	$4,500	$3,100
22	45	11,152	$11,000	$8,100
7	43	10,881	$8,100	$7,900
29	29	1,604	$3,900	$1,200
27	4	710	$2,900	$500
30	9	1,563	$3,600	$1,100

For more location information please visit www.strand.com

Office Locations

Cincinnati, Ohio | 513.861.5600

Columbus, Indiana | 812.372.9911

Columbus, Ohio | 614.835.0460

Indianapolis, Indiana | 317.423.0935

Joliet, Illinois | 815.744.4200

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