



Prepared for:
City of Mequon
Engineering Department
11333 N. Cedarburg Road
Mequon, WI 53092

Prepared by:
AECOM
1555 N RiverCenter Dr. Suite 214
Milwaukee, WI 53212
60189482
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Final Report

City of Mequon, Wisconsin Pilot Private Property Infiltration and Inflow Reduction Program Study



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1.0 Introduction

1.1 Introduction

The Milwaukee Metropolitan Sewerage District (MMSD) in an effort to reduce infiltration and inflow (I/I) into sewer systems from tributary municipal systems has initiated a program to reduce I/I from private property sources. The program is funded annually by the MMSD by allocating funds that are made available to each municipality based on the current municipal tax value. The program is currently anticipated to be funded for 10 years with a City of Mequon projected funding total of \$2.855 million. Funding currently allocated to the City of Mequon through 2013 is \$1.151 million.

Infiltration is water that enters a sewer system through such sources as defective pipes, pipe joints, connections, or manhole walls. Inflow is water that enters a sewer system through connections such as area or foundation drains, connected downspouts, and catch basins. During significant rain events, I/I dramatically increases flow in sanitary sewer systems, which can lead to overflows from the sewer system into area waterways and can cause property damage from basement backups.

Approximately fifty percent of a municipal sanitary sewer system is made up of public sewers and fifty percent is private sewers, primarily sewer laterals. Many municipalities in the MMSD sewer service area have addressed public I/I, including Mequon. The city routinely televises the sanitary sewer and inspects sanitary sewer manholes, developing a rehabilitation approach for each component annually. Additionally, projects such as sanitary sewer mainline replacement during roadway reconstruction efforts or special projects such as the flood grouting demonstration project conducted in the area tributary to Lift Station C are implemented to target and reduce infiltration. While the elimination of public sewer I/I is an ongoing process, private property I/I has not been previously addressed. The MMSD has determined that it may perform or fund work on private property to reduce I/I and thereby reduce operating costs, capital program expenditures, and reduce the risks of overflows and basement backups.

The City of Mequon has experienced inflow and infiltration (I/I) into its sanitary sewer system from a variety of sources. Based on a study of the sanitary sewer system (City of Mequon Sanitary Sewer System Evaluation (SSSE), AECOM, January 2011) and other resources and experience, many of these sources are from private property. The SSSE included flow monitoring, system modeling, manhole and sewer inspections in critical areas of the sanitary sewer system, evaluation of alternatives and recommended actions to improve the system's performance. Much of this work was completed in the Lift Station G (LS G) service area.

To provide a higher level of service in the area (lowering the ratio between the existing peak sewage flow and sewer capacity by reducing the peak flow), a recommendation of the SSSE was to evaluate ways to reduce I/I in the LS G service area.

Data collected as part of the SSSE within the LS G service area was merged with the City's Geographic Information System (GIS) to guide this Private Property Infiltration/Inflow (PPII) pilot program. During the SSSE investigation in 2009, visual inspection of laterals at the mainline sewer connection point found 63 active (flowing) laterals in the LS G service area out of 341 laterals investigated. While some of the active laterals may have been from normal home use, many appeared to be from I/I related sources due to the visual observations of the flow.

Based on the preliminary SSSE analysis in 2009, it was recommended and approved by Resolution no. 3041 to proceed with a PPII study in the LS G service area. The purpose of this study is to: 1) identify portions the LS G service area as a pilot project to further investigate sources of PPII; 2) conduct field investigations (through lateral and home inspections); 3) develop recommendations to mitigate sources of PPII; and 4) develop a program/policy for implementing the District's PPII program throughout the City Mequon in a systematic and cost effective manner.

The following sections document the development approach taken in investigating the Pilot Study area, findings, and recommendations to move towards a city-wide PPII program.

2.0 Project Initiation

The City of Mequon and AECOM initiated the Pilot PPII program with the following items:

- Kickoff meeting for program development
- Selection of pilot study areas tributary to LS G
- Review and evaluation of flow meter locations
- Initial discussion on program inspection resident notification details
- Development of general pilot program description for future resident involvement
- Meetings with City of Mequon Common Council and Utility Committee

The LS G service area was recommended for this pilot study because there was previous flow monitoring and CCTV from previous investigations, was recommended in the SSSE for further I/I reduction efforts, and could benefit from further investigation. Historically, basement backups have occurred in the LS G service area because of flows in excess of what the lift station pumping capacity. In recent years, the City has had a plan in place during wet weather events to mitigate this problem by supplementing the fixed pumps at LS G with portable pumps and bypassing flows directly from the LS to adjacent waterway to avoid surcharging and basement backups. These sanitary sewer overflows (SSOs) are in violation of the City's WPDES permit.

In 2009, flow monitoring of the mainline sanitary sewers tributary to LS G returned instantaneous peaking factors (ratio of peak wet weather flow to dry weather base flow) of 30.9:1 and 13.7:1 and 24-hour peaking factors of 11.7:1 and 7.4:1, with the 30.9:1 peaking factor being the highest of all peaking factors in the study. Additionally, sanitary sewer televising during the SSSE in this area captured evidence of I/I from private laterals.

Implementing recommendations of the SSSE included upgrading the pumps and forcemain at LS G to approximately a 5-year wastewater recurrence interval capacity. Reductions in I/I would benefit the area by providing a higher level of service and also reduce total flows to other sensitive and problematic portions of the East Trunk Sewer System. The area tributary to LS G showed a high occurrence of I/I in 2009 that was considered problematic for this small service area and provided an opportunity to focus on a relatively localized area with varying conditions for this pilot study. It is also important to note that the LS G service area ultimately flows through the City's Lift Station E and East Trunk Sewer which is also experiencing surcharging and high peaking factors during wet weather events.

The LS G service area contains a variety of sewer/lateral materials and various home ages. One of the purposes of this effort was to try and determine if age, pipe material, or other conditions contributed to the amount of I/I in the system. Based on previous municipal experience in targeted study areas such as this, approximately 60% of homeowners have participated in the program throughout the Milwaukee Metro area with actual participation varying significantly on an area by area basis. The work plan developed for this pilot study identified a desire to investigate approximately 50 homes. This represents a reasonable sample size for the funding allocated. Assuming a 60% participation rate would require contacting 80-100 property owners to solicit participation.

There are a total of 341 properties tributary to LS G. As part of this pilot study, 92 properties (or 27% of the total number tributary to LS G) within 3 distinct areas were selected for contact to participate primarily based on the 2009 closed circuit televising (CCTV) results (as part of the SSSE) in the area tributary to LS G but also with input from City staff. The request to homeowners included permission to conduct lateral televising with dye water injection and external building inspections of each property in the study area. Homeowners could opt out of the dye water injection component or this element would not be completed if private wells were within 50 feet of dye injection locations. Homeowners could also opt out of the external home inspection component. Only external building inspections (as opposed to internal and external) were completed to potentially increase homeowner participation and limit disruption to the homeowner.

Letters describing the activities, as well as waivers allowing access to the property and lateral, were mailed to the study area residents. Direction provided by the Mequon City Council included conditions such that homeowner participation was completely voluntary, there was no requirement established to implement any rehabilitation actions regardless of the pilot study findings, and there was no promise at this time by the City to provide any funding for future rehabilitation efforts.

A public information meeting was held at City Hall for those selected for potential participation but was lightly attended. As follow-up for properties where no response was received to the initial mailing, project team members researched participant phone numbers and attempted to call and solicit participation. Additionally, AECOM field crews knocked on doors in an effort to contact homeowners to describe the program and solicit participation. If there was no response at the property the crew left door hanger information describing the program.

The 3 pilot program areas tributary to LS G for lateral CCTV and building inspections are as follows:

- Area 1: Meadow Circle
 - West of River Road and south of Highland Road
 - Containing 13 selected properties
 - Mainline pipe material: PVC
 - Lateral Material: PVC
 - Year mainline sewer was installed: 1988
 - Number of properties participating: 6
- Area 2: Sherbrooke Drive and Marseilles Drive
 - East of River Road
 - Containing 49 selected properties
 - Mainline pipe material: PVC
 - Lateral pipe material: PVC
 - Year mainline sewer was installed: 1978
 - Number of properties participating: 21
- Area 3: West Shoreland Drive
 - North of Highland Road and Highland Road, east of West Shoreland Drive
 - Containing 30 selected properties.
 - Mainline pipe material: Concrete

- Lateral pipe material: Concrete and Vitrified Clay
- Year mainline sewer was installed: 1970
- Number of properties participating: 12

Specific properties selected for contact are listed in Section 3.0 of this report and are shown in their respective areas on the attached maps (Figures 1 through 3).

The process of flow monitoring helps to understand overall I/I impacts and prioritize areas that have the greatest impact on improving the level of service by reducing I/I. Sanitary sewer flow monitoring was conducted in key locations within the pilot study area in 2012 and 2013 as well as other areas of the City in anticipation of future need to document and characterize I/I flows. Flow meters were installed, maintained, and downloaded by MMSD staff at no direct cost to the City of Mequon. AECOM staff evaluated the flow monitoring data for this study. Details on this effort are also further described in Section 3.0 of this report.

3.0 Field Investigations

Of the 92 properties selected for the investigation, 74 property owners responded to the information presented at the public meetings, via regular mail, personal contact by the inspections crew, or via follow-up response to the door hangers. Of the 74 responses, 27 residents refused to participate, 39 (42% of the 92 properties selected and 53% of property owners contacted) residents signed waivers and participated in one form or another. Another 8 property owners responded positively indicating they were likely to participate, but did not ultimately sign and return a waiver form. This rate of participation is slightly lower than seen in some other focused project areas of a similar nature, but could be attributed to the fact that the City of Mequon does have a plan that is executed in wet weather events and is providing relief to the sanitary sewer system in this area and keeping sewerage out of residents' basements. Therefore, the situation that exists does not directly manifest itself as a problem to residents directly.

All 39 property owners authorized televising of their lateral and 37 of the same owners authorized an exterior inspection of their property. The lateral inspections consisted of CCTV of the lateral with dye water injections in the area of the trench above the lateral (for those properties that gave permission and were not near private water wells) to aid in determining I/I sources.

Table 1
I/I Investigation Property Summary

Area	# Properties Selected	# Properties Participated	% Participation
1	13	6	46%
2	49	21	43%
3	30	12	40%
TOTAL	92	39	43%

Each of these three focus areas and individual property participation are further described in the following three tables. Properties highlighted in green in each table participated in the program. Properties not highlighted did not participate in the program. Figures 1 through 3 graphically show the areas and participating properties.

Table 2
Properties for I/I Investigation
Area 1

Count	Property Address	Count	Property Address
1	4527 W Marseilles Ct	8	12718 N Meadow Cir East
2	4405 W Marseilles Dr	9	12630 N Meadow Cir West
3	4411 W Marseilles Dr	10	12633 N Meadow Cir West
4	4414 W Marseilles Dr	11	12711 N Meadow Cir West
5	4417 W Marseilles Dr	12	12714 N Meadow Cir West
6	4420 W Marseilles Dr	13	4502 W Meadow Cir West
7	12623 N Meadow Cir East		

Table 3
Properties for I/I Investigation
Area 2

Count	Property Address	Count	Property Address
1	3503 W Marseilles Dr	26	3915 W Marseilles Dr
2	3506 W Marseilles Dr	27	3634 W Sherbrooke Dr
3	3512 W Marseilles Dr	28	3637 W Sherbrooke Dr
4	3607 W Marseilles Dr	29	3700 W Sherbrooke Dr
5	3608 W Marseilles Dr	30	3701 W Sherbrooke Dr
6	3619 W Marseilles Dr	31	3705 W Sherbrooke Dr
7	3626 W Marseilles Dr	32	3712 W Sherbrooke Dr
8	3704 W Marseilles Dr	33	3717 W Sherbrooke Dr
9	3705 W Marseilles Dr	34	3720 W Sherbrooke Dr
10	3710 W Marseilles Dr	35	3723 W Sherbrooke Dr
11	3711 W Marseilles Dr	36	3728 W Sherbrooke Dr
12	3715 W Marseilles Dr	37	3736 W Sherbrooke Dr
13	3718 W Marseilles Dr	38	3802 W Sherbrooke Dr
14	3722 W Marseilles Dr	39	3809 W Sherbrooke Dr
15	3800 W Marseilles Dr	40	3810 W Sherbrooke Dr
16	3801 W Marseilles Dr	41	3815 W Sherbrooke Dr
17	3805 W Marseilles Dr	42	3819 W Sherbrooke Dr
18	3808 W Marseilles Dr	43	3822 W Sherbrooke Dr
19	3816 W Marseilles Dr	44	3906 W Sherbrooke Dr
20	3817 W Marseilles Dr	45	3907 W Sherbrooke Dr
21	3902 W Marseilles Dr	46	3918 W Sherbrooke Dr
22	3903 W Marseilles Dr	47	3921 W Sherbrooke Dr
23	3908 W Marseilles Dr	48	3924 W Sherbrooke Dr
24	3909 W Marseilles Dr	49	3925 W Sherbrooke Dr
25	3914 W Marseilles Dr		

Table 4
Properties for I/I Investigation
Area 3

Count	Property Address	Count	Property Address
1	2604 W Highland Rd	16	12929 N West Shoreland Dr
2	2620 W Highland Rd	17	12932 N West Shoreland Dr
3	2636 W Highland Rd	18	12936 N West Shoreland Dr
4	2700 W Highland Rd	19	12942 N West Shoreland Dr
5	12825 N West Shoreland Dr	20	12945 N West Shoreland Dr
6	12828 N West Shoreland Dr	21	12952 N West Shoreland Dr
7	12831 N West Shoreland Dr	22	12953 N West Shoreland Dr
8	12832 N West Shoreland Dr	23	12960 N West Shoreland Dr
9	12845 N West Shoreland Dr	24	13019 N West Shoreland Dr
10	12852 N West Shoreland Dr	25	13022 N West Shoreland Dr
11	12853 N West Shoreland Dr	26	13035 N West Shoreland Dr
12	12862 N West Shoreland Dr	27	13040 N West Shoreland Dr
13	12908 N West Shoreland Dr	28	13050 N West Shoreland Dr
14	12915 N West Shoreland Dr	29	13100 N West Shoreland Dr
15	12916 N West Shoreland Dr	30	13106 N West Shoreland Dr

3.1 Lateral Televising

Sanitary sewer lateral testing was completed by National Power Rodding (NPR) between November 5, 2012 and November 14, 2012. Lateral televising involved using a launch camera from the mainline sewer into each lateral. During the lateral televising, dyed water was injected over the top of each lateral at three locations along the length of the lateral at the same time that each lateral was televised. Typically, dyed water is injected over the lateral at the following three locations: the property line, half way to the house, and close to the house or else the furthest extent that the lateral televising could go. Dye injections have been completed for many of the MMSD tributary municipality and the effort, with exceptions, has been effective in identifying leaking laterals. Although 15 of the laterals selected for lateral CCTV were identified with clear water flow in 2009, only 4 laterals had dye present during this effort. While not observed leaking during the 2012 lateral CCTV, the property at 3816 Marseilles Drive had a broken section of pipe that was most likely the cause of the observed flow in the 2009. This lateral was also observed by City of Mequon field crew as flowing in the 2013 mainline sewer televising as discussed in the next paragraph. The potential reasons for the limited success of the 2012 lateral CCTV include: 2012 being a very dry year with groundwater elevations below the lateral; injections being completed at 3 locations along the lateral, limiting the available locations for dyed water to enter the lateral; as the lateral launch camera is capable of a maximum distance of 120 feet from the mainline sewer, laterals longer than this could not be televised without access to the inside cleanout; soil type may limit the flow path of the injections and potentially divert the flow away from any lateral defects

On April 22, 2013, City crews televised the sanitary sewers in areas that were televised in 2012. This was completed due to the limited findings during the 2012 lateral televising and because the ground water was high in April, 2013, particularly following the rain events of April 17th and 18th. They did identify flow in a number of laterals, most likely due to high ground water that was not identified during the 2012 lateral televising effort. Table 5 shows the findings of the city televising on April 22, 2013 and compares the results from the 2012 and 2013 lateral televising.

Table 5
2013 City Televising Results

Area	Address	Street	Mequon CCTV April 22, 2013	2012 Lateral CCTV Findings	2013 Lateral CCTV Findings
1	4527	Marseilles Ct	Heavy	No leaks observed	Leak at MH wall
	12633	Meadow Circle W	Heavy	No leaks observed	Leak at MH wall
1	4420	Marseilles	Medium	No leaks observed	No leaks observed
2	3902	Marseilles	Medium	No leaks observed	No leaks observed
	3908	Marseilles	Medium	No leaks observed	No leaks observed
	3808	Marseilles	Light	No leaks observed	No leaks observed
	3816	Marseilles	Heavy	Broken pipe, but no leaks observed	No leaks observed
	3817	Marseilles	Medium	No leaks observed	No leaks observed
3	13040	Shoreland	Medium	Leaks throughout lateral	No leaks observed
	13035	Shoreland	Light	No leaks observed	No leaks observed
	13100	Shoreland	Light	No leaks observed	No leaks observed
3	12916	Shoreland	Medium	No leaks observed	Did not televise
	12825	Shoreland	Medium	No leaks observed	Did not televise
	12862	Shoreland	Medium	No leaks observed	Did not televise
	12932	Shoreland	Medium	No leaks observed	Did not televise
	12852	Shoreland	Medium	Leaks throughout lateral	Did not televise

Following the City CCTV effort on April 22, 2013, NPR was mobilized to provide lateral televising during conditions of high groundwater. On April 30, 2013 NPR televised 11 of the laterals shown in Table 5. Two occurrences of I/I were observed during the second NPR lateral televising, highlighted in blue in Table 5. The two properties at 4527 Marseilles Court and 12633 Meadow Circle West were observed with clear water entering the manhole from the lateral connection to the manhole. However, except for those two laterals with leaks at the lateral connection to the manhole, the next nine laterals were dry (highlighted in brown in Table 5), due to the ground water having dropped since the rain event ending on April 18, 2013. The 5 remaining laterals in the table are all in Area 3 on N. West Shoreland Avenue were not televised as indications were that no additional I/I would be identified by re-televising.

Based on the City CCTV effort in 2009 and April of 2013, it would appear that to identify the specific sources of I/I in each lateral, a prompt response to a significant storm event would be required so that the laterals could be televised while ground water is high.

In 2009, 35 properties were identified with clear water flow in the pilot program study area. 15 of the properties participated in the program and of those 15 properties, 9 were identified with I/I issues.

Results by area are summarized as follows:

- For Area 1, the area west of River Road including Marseilles Drive and Meadow Circle, 5 properties were identified with clear water flow in 2009 of which 3 participated in this program. Of the 3 participating properties in Area 1, 2 were identified with I/I during the 2013 follow-up CCTV.
- For Area 2, the area between River Road and Fleur de Lis Drive including Marseilles Drive and Sherbrooke Drive, 10 properties were identified with clear water flow in 2009 of which 3 participated in the program. None of the properties showed infiltration during the dye injection process; although one lateral had a broken section of pipe which was most likely the cause of the I/I in 2009.
- For Area 3, the area north of LS G including Highland Road and N. West Shoreland Drive, 20 properties were identified with clear water flow in the lateral in 2009 of which 9 participated in the program. Of the 9 properties that participated in the program, 4 were identified with leaking laterals, one additional property had a significant root blockage 5 feet from the mainline lateral and could therefore not be televised, and one additional property had roots and deposits, indicating the past occurrence of leakage, but did not authorize the injection of dyed water over the lateral. The root problems have since been addressed by City personnel.

3.1.1 Properties with Lateral Maintenance Issues

Defects on 4 laterals are considered maintenance issues: 2 properties had sags and 2 properties had roots in the lateral. The sags did not appear to be significant (< 40% of lateral diameter) and in all likelihood, have little effect on lateral flow. These laterals should be watched for future problems. The property at 12916 N. West Shoreland Drive had a complete root blockage 5 feet upstream from the mainline sewer. The lateral camera could not pass the roots. Moderate to severe roots were observed in the lateral at 12862 N. West Shoreland Drive. However, dye water injections were not completed during the lateral televising at this property, because the owner did not sign the consent to dye test waiver. The roots in both laterals have since been cut. Table 6 lists laterals identified with maintenance issues as discussed above and laterals with light roots or deposits. While no direct I/I was observed during our inspection for the properties with root issues or deposits, the existence of roots and deposits is an indication of past and/or future potential I/I sources. For the properties with roots, the 2009 and 2013 City CCTV effort showed clear water running in the lateral at the time of televising.

Table 6
Properties with Lateral Maintenance Issues and Potential I/I Sources

Area	Address	Estimated Lateral Length	Length Televised	Type of Rehab or Condition
1	12714 Meadow Circle West	95	97	Sag from mainline sewer to 11 feet. Structural Cond. = 1 Leak Condition = 0 Deposit Condition = 0 Root Condition = 0
	12630 Meadow Circle West	82	85	Sag from 10 feet to 27 feet from mainline sewer. Structural Cond. = 1 Leak Condition = 0 Deposit Condition = 0 Root Condition = 0
2	3815 W Sherbrooke Dr	100	94	Structural Cond. = 1 Leak Condition = 0 Deposit Condition = 0 Root Condition = 1
3	12916 N. West Shoreland Drive	135	5	100% root plug 5 feet from mainline sewer. (Roots have since been removed by city personnel.) Structural Cond. = NA Leak Condition = NA Deposit Condition = NA Root Condition = NA
	12862 N. West Shoreland Drive	125	69	Medium to severe roots throughout. (Roots have since been removed by city personnel.) Structural Cond. = 2 Leak Condition = NA Deposit Condition = 3 Root Condition = 2
	13040N W Shoreland Dr	150	120	Structural Cond. = 3 Leak Condition = 3 Deposit Condition = 1 Root Condition = 1
	13100N W Shoreland Dr	140	120	Structural Cond. = 2 Leak Condition = 0 Deposit Condition = 2 Root Condition = 0
	2620W Highland Rd	135	103	Structural Cond. = 2 Leak Condition = 0 Deposit Condition = 3 Root Condition = 1

Note: Scale
 Scale Structural Condition: Scale 1 (Good) TO 5 (Critical Failure)
 Leak Condition / Deposit Condition / Root Condition: Scale 0 (None) TO 5 (Severe)
 NA = Not Applicable

3.1.2 Properties with Lateral I/I

The lateral televising identified 5 laterals with leaks or other more significant defects during the 2012 lateral televising and 2 lateral/manhole connections with leaks during the follow-up televising in 2013, presented in Table 7.

Table 7
Properties with Lateral I/I

Area	Address	Estimated Lateral Length	Length Televised	Rehabilitation Recommendation	Type of Rehabilitation
1	4527 Marseilles Court	175	90	Grout	Grout around lateral/manhole connection
	12633 Meadow Circle West	95	95	Grout	Grout around lateral/manhole connection
2	3816 Marseilles Drive	120	115	Spot Repair	Broken pipe at 32.5 feet from mainline sewer
3	13040 N. West Shoreland Drive	150	120	Line Lateral	16 feet-runner/gusher, 38 feet-weeper, 50 feet- weeper/runner
	12960 N. West Shoreland Drive	130	120	Line Lateral	16 feet to 23 feet wet deposits - no injections
	12852 N. West Shoreland Drive	135	120	Line Lateral	26 feet - runner, 36 feet - gusher, 46 feet - gusher, 97 feet - runner & weeper
	2620 W. Highland Rd	135	103	Spot Repair	33 feet - weeper

CCTV data from the 2009 televising conducted by City of Mequon personnel (part of SSSE Report) was compared to the 2012 lateral televising effort (NPR) to identify discrepancies between the separate CCTV operations. In a number of instances, flow was observed in the laterals during the 2009 CCTV, but no leakage was identified during the 2012 lateral CCTV, although dye water was injected over the top of the lateral during the lateral televising. It appears that the primary reason for these discrepancies was due to very dry conditions during 2012. In all likelihood, ground water was considerably lower in 2012 than in 2009 or in early 2013. Although dyed water was injected over the lateral, it was typically only injected in 3 locations. Therefore, if the injected dyed water did not disperse over the entire lateral, a leaking joint could have been missed.

The lateral launch camera has a maximum televising distance of 120 feet from the mainline sewer in ideal conditions. In 14 instances, the entire lateral could not be televised because the lateral was longer than 120 feet. An additional 7 laterals did not have the full length televised due to roots or friction on the camera cable as a result of bends in the lateral. The 2009 televising was conducted following significant rainfall and in all likelihood, groundwater was considerably higher. Dry weather during 2012 could contribute to the discrepancies between 2009 and 2012. A good example of this is

the broken pipe at 32.5 feet at 3816 Marseilles Drive. This lateral had significant flow during the 2009 and 2013 mainline CCTV effort, most likely infiltration, but during the lateral televising in 2012, no leaks were observed. Appendix A shows a property-by-property comparison between the 2009 mainline televising and the 2012 lateral televising.

3.2 Building Inspections

An external inspection of houses was completed to identify downspout discharge locations and to review drainage around the house for 37 properties. No specific problems were identified during the external building inspections, although 12 properties had downspouts entering the ground in which an exact discharge location could not be determined. The field investigation team did make an extra effort to identify the location of the unknown discharge point for downspouts by walking the property and talking with the property owner (if they were available). The 12 properties in which downspout locations could not be identified are presented in Table 8. There is a potential that these could be a source on unidentified I/I. A follow-up effort or request to identify the discharge locations with the property owner may be appropriate.

Table 8
Properties with Unknown Downspout Discharge Locations

Area	Address	Downspouts with Unknown Discharge Location
1	4420 W. Marseilles Drive	4
	12630 Meadow Circle West	5
	12715 Meadow Circle West	3
2	3718 W. Marseilles Drive	2
	3808 W. Marseilles Drive	5
	3908 W. Marseilles Drive	3
	3701 W. Sherbrooke Drive	5
	3717 W. Sherbrooke Drive	2
	3723 W. Sherbrooke Drive	5
	3906 W. Sherbrooke Drive	1
3	12828 N West Shoreland Drive	4
	12845 N West Shoreland Drive	1

3.3 Flow Monitoring

Flow monitoring was conducted at three sites in the LS G area to determine the impact of rainfall on the sanitary sewer system prior to lateral rehabilitation. An additional 3 meters were installed in areas downstream of LS G to determine if these sites would be candidates for future PPII investigations. There were a total of 6 meters installed in Mequon beginning on May 5, 2012 and running at a minimum through June 3, 2013. The MMSD installed and maintained the meters, and supplied flow and rainfall data to AECOM for analysis. The six meter sites are shown in Table 9. A summary of the

flow monitoring analysis is shown below and on the following pages. Details of the flow monitoring are included in Appendix B with flow graphs for 2012 and 2013 in Appendix C and Appendix D respectively.

**Table 9
Flow Monitoring Sites**

Meter Site Name	Metering Manhole	Location	Pipe Size	Comments
ME3080	113-080	Yvonne Dr & Fleur de Lis Dr	8	Tributary to LS G
ME3081	113-081	N. Fieldwood DR & W Highland R	8	Tributary to LS G
ME 3028	113-028	Fleur de Lis & Marseilles	8	Tributary to LS G
ME503E	625-003E	Scenic Dr & River Rd	8	Tributary to LS C
ME503S	625-003S	Scenic Dr & River Rd	8	Tributary to LS C
ME 3031	623-031	5006 N. Parkview Dr	8	Tributary to LS B

Rain data was taken from MMSD rain gauge WS1214, located on W. Pioneer Road at the Milwaukee River in Cedarburg, which is the MMSD rain gauge closest to the Mequon flow metering locations. For the full analysis, 4 rain events were used for determination of I/I components as shown in Appendix B.

For the 2012 data, rainfall on October 13th and 14th totaling 2.28 inches of rain was used for the analysis. For the 2013 data, three rain events caused significant peaks in that sanitary sewer system. On December 20, 2012, 2.39 inches of rain fell in 24 hours, from April 8 to April 11, 2013 a total of 4.04 inches fell over 4 days and on April 17 and 18, 2013, a total of 1.64 inches of rain fell over a 2 day period when the ground was already saturated from the earlier April rainfall. Table 10 shows rainfall events used during the flow monitoring analysis.

**Table 10
Rainfall for Flow Monitoring Analysis**

Rain Event	Date	24-hour Rainfall	Peak 30-min Intensity	Total Event Rainfall
1	10/13/2012	1.09	0.21	2.28
	10/14/2012	1.19	0.22	
2	12/20/2012	2.39	0.13	2.39
3	4/8/2013	0.74	0.19	4.04
	4/9/2013	0.87	0.22	
	4/10/2013	1.42	0.23	
	4/11/2013	1.01	0.09	
4	4/17/2013	0.56	0.16	1.64
	4/18/2013	1.08	0.11	

The rain event of April 8 through April 11, 2013 caused the greatest peaking factors and RDII at three of the meter sites: 113-081, 625-003E, and 625-003E, the rain event of December 12, 2013 caused the greatest peaking factor and RDII at two of the meter sites: 113-028 and 623-031. The April 17 and April 18, 2013 rain events cause the greatest peaking factor and RDII at meter site 113-080. However, all three rain events caused a significant reaction in the sanitary sewer. Graphs for the 2013 data showing flow rate, velocity, flow depth, and rainfall are included in Appendix D.

For the 2012 analysis, rainfall that fell on October 13 and 14, 2012 was the only event that caused a reaction in the sanitary sewers tributary to each meter. Graphs for the 2012 data showing flow rate, velocity, flow depth, and rainfall are presented in Appendix C.

For a direct comparison of flow data, the rain events from April 8 through April 11, 2013 are shown in Table 11.

3.3.1 Flow Monitoring Data Analysis

Analysis for the six flow meters was completed as two data series. The first series of analysis was completed on flow and rainfall data collected between May 5, 2012 and November 1, 2012. This is referred to as the 2012 analysis or data. The second series of analysis was completed between November 1, 2012 and June 3, 2013. Although the second series of analysis included November and December of 2012, this analysis is referred to as the 2013 analysis or data in the text that follows. The second data set which included the December, 2012 event and data through June 3, 2013 was significantly wetter than the period in 2012.

For the 2012 analysis, the sanitary sewers upstream of each meter reacted to a single rain event that occurred on October 13 and October 14, 2012. This event was the basis for the original I/I evaluation. For the 2013 analysis, up to 10 rain events caused a reaction in the sanitary sewers upstream of the 6 meters. Three significant rain events on December 20, 2012, April 10, 2013 and April 18, 2013 all caused the greatest peak flows in the sanitary sewer and were used for the analysis described in Appendix B.

The flow analysis for both series involved examining the collected flow data and establishing dry weather flow (base flow), instantaneous, 1-hour, and 24-hour peak flows and peaking factors, and 24-hour Rainfall Dependent Inflow and Infiltration (RDII). 24-hour RDII is the amount of clear water that enters the sanitary sewer over a single day.

Dry weather flow, or base flow, was determined by examining a week of dry weather flow for each meter site. Determination of the base flow component was made by averaging three consecutive daily flows following a 5-day period of little or no rain. Although this flow contains some base infiltration, it represents the maximum flow in low infiltration conditions. The reaction of the sanitary sewer to the rainfall presented in Tables 10 was the basis for the I/I analysis. Two locations tributary to LS G (sites 113-080 and 113-082) were also metered in 2009. A comparison of these two sites is included in the analysis. Analysis by meter site is presented in Appendix B.

3.3.2 Flow Monitoring Summary

For all meter sites during the April 8th to April 11th storm event, the instantaneous, 1-hour, and 24-hour peaking factors exceed 6:1 (peak flow to base flow), which is indicative of high I/I that should at least be partially removed from the system. While some of the high I/I enters from public sources, some enters from private property sources as documented findings discussed previously in this report.

Table 11 shows a comparison of each site for the series of rain events that occurred over 4 days beginning on April 8th and ending on April 11th with peak flows occurring on April 10, 2013.

Table 11
Flow Data Comparison
April 10, 2013

Flow Meter (Manhole) Location	Base Flow (cfs)	Instantaneous Peak Flow (cfs)	Instantaneous Peaking Factor	1-hr Peak Flow (cfs)	1-hr Peaking Factor	24-hr Peak Flow (cfs)	24-hr Peaking Factor	24-hr RDII (cfs)	24-hr RDII (gpd)
113-080	0.091	1.028	11.3	0.926	10.2	0.638	7.0	0.547	353,526
113-081	0.016	0.444	27.8	0.423	26.4	0.293	18.3	0.277	179,025
113-028	0.067	0.705	10.5	0.645	9.6	0.507	7.6	0.440	284,372
623-031	0.027	0.715	26.5	0.434	16.1	0.337	12.5	0.310	200,353
625-003E	0.018	0.838	46.6	0.363	20.2	0.263	14.6	0.245	158,344
625-003S	0.010	0.417	41.7	0.359	35.9	0.256	25.6	0.246	158,990

The greatest peaking factors occur at the two meters tributary to LS-C (625-003E and 625-003S). However, 24-hour RDII is lowest at these 2 meters. This would tend to indicate a greater likelihood of inflow versus infiltration upstream of these meters. The meter site that picks up flow from north of LS-G (113-081), as well as the meter at 623-031 also have very high peaking factors. The greatest 24-hour RDII, a good indicator of the total volume of I/I entering an area upstream of a meter, occurs at 113-028 and 623-031. The 24-hour RDII at 113-080 includes flow from 113-028. As can be seen from the table, the areas tributary to LS-G contribute a high amount of I/I to the sanitary sewer system.

The manhole at 113-080 surcharged to 1.2 feet above the crown of the pipe on April 18, 2013 with minor surcharging, less than 0.2 feet above the crown of the pipe, on April 20, 2013 and May 5, 2013. Manhole 623-031 surcharged to 1.8 feet above the crown of the pipe on December 20, 2012; 3.5 feet on April 10, 2013; and 2.7 feet on April 18, 2013. Surcharging is an indication of excessive I/I and should be high on the priority list for I/I removal.

3.4 Pilot Project Results

Area 1 and Area 2 consist primarily of PVC pipe for the mainline sewer and laterals. Area 2 is approximately 10 years older than Area 1. Area 3 consists of concrete mainline sewer with concrete and vitrified clay pipe material for the laterals and is approximately 10 years older than Area 2. A summary of the findings per area are as follows:

Area 1:

- Mainline pipe material: PVC
- Lateral Material: PVC
- Year mainline sewer was installed: 1988
- Properties in the Area: 33
- Number of properties selected: 13
- Number of properties participating: 6
- Flow meters 113-028 and 113-080 (includes Area 2)

Results: During the 2009 mainline televising, 5 of the 13 properties were identified with infiltration. Of the 5 properties identified with I/I in 2009, 3 participated in the program and 2 refused. The 2012 lateral televising did not identify any properties with I/I in this area. Two sags were identified, but do not appear to cause a flow problem. The three properties identified with I/I were again televised by the city in April, 2013 during a period of high groundwater and again observed with flow. The NPR CCTV crew did identify leakage on 2 of the properties around the lateral/manhole connection on April 30, 2013, even though groundwater was down.

Area 2:

- Mainline pipe material: PVC
- Lateral pipe material: PVC
- Year mainline sewer was installed: 1978
- Properties in the Area: 102
- Number of properties selected: 49
- Number of properties participating: 21
- Flow meters 113-028 and 113-080

Results: During the 2009 mainline televising, 10 of the 21 properties were identified with infiltration. Of the 10 properties identified with I/I in 2009, 3 participated in the program, 6 refused and 1 property did not respond. The 2012 lateral televising identified 1 property with broken pipe matching the identified I/I from the 2009 mainline televising. The broken pipe was not leaking during the lateral televising even though dye water was injected over the lateral. However, as this property showed significant flow in 2009 and 2013 it is assumed that the broken pipe was the source of the infiltration in 2009. The 2009 televising was completed during a wet period. In 2012, the year was very dry and most likely the surrounding ground absorbed the dye water injection. During April, 2013, the city again televised the mainline sewer during a period of high groundwater and identified 5 properties with running water in the lateral ranging from light to heavy clear water flow. NPR televised each of these laterals on April 30, 2013, but none were observed leaking. It appears that by the time that NPR was mobilized for the lateral launch CCTV, the groundwater had receded to an elevation lower than the invert of the laterals.

Area 3:

- Mainline pipe material: Concrete
- Lateral pipe material: Concrete and Vitrified Clay
- Year mainline sewer was installed: 1970
- Properties in the Area: 36
- Number of properties selected: 30
- Number of properties participating: 12
- Flow meter 113-081

Results: During the 2009 mainline televising, 20 of the 30 properties were identified with infiltration. Of the 20 properties identified with I/I in 2009, 9 participated in the program, 6 refused and 5 did not respond. 4 of the 9 properties that participated in the lateral televising were identified with leaks or potential leaks in the lateral. In addition, 2 of the properties were identified with roots, indicating a potential source of infiltration. The lateral at 12916 N West Shoreland Drive had a root plug 5 feet off of the mainline sewer and therefore, the lateral could not be televised beyond this point. The property at 12960 N West Shoreland Drive had wet deposits, but did not authorize the use of injections. The deposits indicate the previous occurrence of infiltration. Eight properties were identified with flow during the City's 2013 mainline televising as shown in Table 5. However, the lateral televising by NPR on April 30th did not identify I/I in three of the properties and so the additional lateral televising operation by NPR was shut down.

Based on the results for each of the three areas, it appears that age of pipe as well as concrete and vitrified clay materials are significant I/I contributing factors. As the City program moves forward, addressing those areas with older concrete and vitrified clay pipe should be a priority for identifying and removing I/I from laterals within the City of Mequon sanitary sewer system as discussed in more detail in the following chapter.

4.0 Recommendations

4.1 Pilot Area Recommendations

Based on the 2012 and 2013 findings, there are 9 laterals with significant I/I contributions that should be repaired and/or replaced as part of the MMSD PPII Reduction Program. Table 12 shows the estimated costs for removal of I/I. Costs for rehabilitation would fall within the MMSD funding program, whereby rehabilitation costs by the City can be recovered as part of the MMSD PPII Program. Additional funding options are discussed further in the report.

Prior to the completion of any design for addressing these concerns, the entire lateral should be televised to identify any additional lateral issues or features (clean outs, bends, or defects) within the remaining lateral not previously televised. Table 12 also shows the length televised for each lateral. Maximum length for televising with a launch camera is 120 feet from the mainline sewer. In addition, debris, roots, or friction on the cable due to bends in the lateral, limited the length that a lateral can be televised. To completely televise each lateral may require access to the cleanout inside the house.

In addition, 9 properties were identified with clear water flow by City crews during the 2013 follow-up mainline televising. While the specific source of I/I within the lateral was not identified, follow-up lateral televising during periods of high ground water may identify the specific source of I/I within each lateral. Identifying the specific source of I/I for these laterals would allow for a more accurate assessment of the most cost-effective means of rehabilitation. Table 13 shows those properties with clear water flow identified during the 2013 mainline televising, that did not show leaks during the 2012 lateral televising effort. Again, this is most likely due to 2012 being a dry year.

Several locations within the pilot area had roof downspouts that went into the ground but the exit point could not be found with the brief property walk conducted by field staff. It is recommended that the discharge locations be identified and confirmed that they are not connected to the sanitary sewer system as sources of inflow.

Table 12
Cost Estimate for Properties with Lateral I/I

Area	Address	Estimated Lateral Length	Lateral Length Televised	Lateral Material	Rehabilitation Recommendation	Estimated Unit Cost	Cost/Property
1	4527 Marseilles Court	175	89	PVC	Grout Pipe/Manhole Connection	\$1,400 Lump Sum	\$1,400
	12633 Meadow Circle West	95	96	PVC	Grout Pipe/Manhole Connection	\$1,400 Lump Sum	\$1,400
2	3816 Marseilles Drive	120	115	PVC	Spot Repair (3LF)	\$800/LF	\$2,400
3	13040 N. West Shoreland Drive	150	120	Concrete and Clay	Line Lateral	\$100/LF	\$15,000
	12960 N. West Shoreland Drive	130	120	Concrete and Clay	Line Lateral	\$100/LF	\$13,000
	12852 N. West Shoreland Drive	135	120	Concrete and Clay	Line Lateral	\$100/LF	\$13,500
3	2620 W. Highland Rd	135	103	Concrete and Clay	Spot Repair (3 LF)	\$800/LF	\$2,400
	12862 N. West Shoreland Drive ¹	125	69	Concrete and Clay	Line Lateral	\$100/LF	\$12,500
	12916 N. West Shoreland Drive ¹	125	5	Concrete	Line Lateral	\$100/LF	\$12,500
TOTAL							\$74,100

1. These properties were identified with roots during the 2012 lateral CCTV and clear water running in the lateral during the 2009 and 2013 CCTV.

**Table 13
Lateral Clear Water Flow
City CCTV April 22, 2013**

Area	Address	From Manhole	To Manhole	Mequon CCTV April 22, 2013	Estimated Lateral Length	Length Televised in 2012
1	4420 W. Marseilles Drive	O114-014	O114-012	Medium	120	120
2	3902 W. Marseilles Drive	O113-006	O113-005	Medium	95	89
	3908 W. Marseilles Drive	O113-006	O113-005	Medium	80	78
	3808 W. Marseilles Drive	O113-007	O113-006	Light	125	120
	3817 W. Marseilles Drive	O113-007	O113-006	Medium	90	88
3	13035 N. West Shoreland Drive	O112-002	O112-001	Light	140	114
	13100 N. West Shoreland Drive	O112-002	O112-001	Light	140	120
	12825 N. West Shoreland Drive	O112-008	O112-008	Medium	200	120
	12932 N. West Shoreland Drive	O112-006	O112-005	Medium	150	109

4.2 City-Wide Program Recommendation

Based on the results of the Pilot Private Property I/I Program, it appears that laterals constructed with vitrified clay and concrete pipe are more susceptible to I/I than is plastic pipe. Typically, clay and concrete pipe are also older than plastic pipe. Moving forward, the City may want to target specific areas in which concrete or clay pipe is the predominant pipe material or perhaps open the program to the entire city with an emphasis on clay and concrete pipe. The map on the following page shows pipe material for the entire city.

Fewer defects were identified from the lateral televising than was expected based on the 2009 Sanitary Sewer System Evaluation efforts which noted many laterals active in the three pilot areas. As noted previously, this may be partially due to the very dry year we had in 2012, laterals that were longer than the televising crew could reach, conditions under the foundation of the house, or other factors. In addition to lateral televising, the City may want to increase the identification of potential I/I from inside the house, such as sump pumps directly connected to the sanitary sewer or foundation drains connected to floor drains. This could be accomplished by conducting internal building inspection including internal CCTV evaluation.

The City does not have any current sanitary basins that are out of compliance with the MMSD's performance standards, but there are areas where higher levels of I/I exists, areas of sensitive infrastructure or other areas of concern such as those subject to potential basement backups. Therefore, a program that identifies and removes clear water from the private property system and supplements efforts by the City on the public system can make an impact in reducing I/I. Moving

forward, the City generally has multiple directions it may want to consider when implementing a City-wide PPII program.

From a presentation by the MMSD at a Water Environment Federation (WEF) Collection System Conference in March of 2013, 22 Municipalities have participated in the program in some way. Participation ranges from planning and policy development to investigative efforts (such as this study) through construction of repairs to laterals, disconnection of foundation drains, and other rehabilitation methods.

Municipal programs have ranged from targeted municipal led investigation and rehabilitation at no cost to the resident, to targeted municipal led investigation of problem areas with a cost-share by the resident the depends on the type of repair, to programs that are open to residents to participate at their initiative with investigation performed by the municipality but rehabilitation (eg obtaining quotes for work and contracting for repairs) at the direction and effort of the owner with set municipal funding reimbursement limits.

One alternative available to the City of Mequon is to make the PPII program available to all residents who may want to participate in the program. This approach is a more open policy and may be perceived as 'fairer' but does not focus efforts on any specific area of interest. Additionally, a broader approach where resources and improvements are more scattered around the City may make it more difficult to see positive impacts of the program.

A second alternative would be to target specific areas and introduce this program to those areas as a preference to opening it to the entire City. This could be done in stages or in a single offering that might identify target areas based on one or more factors such as:

- areas where concrete or clay pipe is the predominant pipe material;
- areas tributary to critical infrastructure;
- areas of known high I/I;
- areas of known SSO or basement backup potential; or
- areas where the City is planning to do public system rehabilitation.

Regardless of the direction chosen, the City would need to develop a policy statement for the PPII program that establishes what the city expects to accomplish with the program, develops guidelines for who may participate, what the residential cost share (if any) and reimbursement limits would be, how would inspection and reimbursement take place, and other general guiding factors to the program.

Appendix A

Comparison: 2009 Mainline CCTV and 2012 Lateral CCTV

MEQUON CCTV COMPARISON 2009 TO 2012

AREA 1

4527 Marseilles Court - service enters manhole 0114.013, and in 2009 was found to be leaking moderately from around the pipe at the manhole wall. No flow was observed from the service itself. During the 2012 lateral inspection, no leaks were observed in the service itself and the leaks from around the pipe at the manhole wall were nonexistent.

12633 Meadow Circle West - service enters manhole 0114.010, and in 2009 was found to be leaking moderately from around the pipe at the manhole wall. No flow was observed from the service itself. During the 2012 lateral inspection, no leaks were observed in the service itself and the leaks from around the pipe at the manhole wall were nonexistent.

12714 Meadow Circle West - in 2009, no flow was observed from the service into the main sewer. During the 2012 lateral televising, no leaks were observed in this service. The lateral is PVC and moderately sagged from the main sewer to eleven feet upstream.

12630 Meadow Circle West – in 2009, no flow was observed from the service into the main sewer. During the 2012 lateral televising, no leaks were observed in this service. The lateral is PVC and moderately sagged from ten to twenty-seven feet upstream of the main sewer.

4420 Marseilles Drive – in 2009, greater than a moderate amount of clear flow was observed entering the main sewer from this service. During the 2012 lateral televising, no leaks were observed in this service. The lateral length was estimated to be 120 feet from the main sewer to the corresponding side of the house. The entire 120 feet was televised.

4411 Marseilles Drive – in 2009, no flow was observed entering the main sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

AREA 2

3902 Marseilles Drive – in 2009, a minor amount of flow was observed entering the main sewer from this service and well could have been the result of usage rather than infiltration. During the 2012 lateral televising, no leaks were observed in this service.

3908 Marseilles Drive – in 2009, no flow was observed entering the main sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

3808 Marseilles Drive – in 2009, no flow was observed entering the main sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

3816 Marseilles Drive – in 2009, extremely heavy clear flow was observed entering the main from this service. During the 2012 lateral televising, no leaks were observed in this service. It is suspected that the 2009 flow was groundwater entering a break in the lateral 32.5 feet upstream of the main sewer. The 2009 mainline televising was performed under rather wet conditions. Considerably dryer conditions existed for the 2012 lateral televising, and groundwater levels were likely lower as well.

3817 Marseilles Drive – in 2009, with a bit of standing water in this service, it did not appear that any flow was entering the main sewer. During the 2012 lateral televising, no leaks were observed in this service.

3722 Marseilles Drive – in 2009, no flow was observed entering the main sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

3715 Marseilles Drive – in 2009, no flow was observed entering the main sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

3718 Marseilles Drive – in 2009, confirmation of flow entering/not entering the main sewer could not be made given the low elevation of the service in relation to the main. During the 2012 lateral televising, no leaks were observed in this service.

3701 Sherbrooke Drive – problems with the DVD prevented a review of the 2009 mainline televising video. During the 2012 lateral televising, no leaks were observed in this service.

3717 Sherbrooke Drive – problems with the DVD prevented a review of the 2009 mainline televising video. During the 2012 lateral televising, no leaks were observed in this service.

3720 Sherbrooke Drive – problems with the DVD prevented a review of the 2009 mainline televising video. During the 2012 lateral televising, no leaks were observed in this service.

3723 Sherbrooke Drive – problems with the DVD prevented a review of the 2009 mainline televising video. During the 2012 lateral televising, no leaks were observed in this service.

3728 Sherbrooke Drive – in 2009, no flow was observed entering the main sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

3809 Sherbrooke Drive – in 2009, no flow was observed entering the main sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

3736 Sherbrooke Drive – problems with the DVD prevented a review of the 2009 mainline televising video. During the 2012 lateral televising, no leaks were observed in this service.

3819 Sherbrooke Drive – in 2009, no flow was observed entering the main sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

3906 Sherbrooke Drive – in 2009, multiple drips were observed entering the main sewer from this service. It's likely the service was in use. During the 2012 lateral televising, no leaks were observed in this service.

3921 Sherbrooke Drive – in 2009, no flow was observed entering the mainline sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

3924 Sherbrooke Drive – in 2009, no flow was observed entering the mainline sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

3815 Sherbrooke Drive – in 2009, no flow was observed entering the mainline sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

3634 Sherbrooke Drive – problems with the DVD prevented a review of the 2009 mainline televising video. During the 2012 lateral televising, no leaks were observed in this service.

AREA 3

13040 W. Shoreland Drive – in 2009, no flow was observed entering the mainline sewer from this service. Deposits indicating infiltration were present. During the 2012 lateral televising, joints in this service were found to be leaking at 16, 38, and 50 feet upstream of the main

13035 W. Shoreland Drive – in 2009, no flow was observed entering the mainline sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

13100 W. Shoreland Drive – in 2009, minor clear flow was observed entering the mainline sewer from this service. Deposits indicating infiltration were also present. During the 2012 lateral televising, no leaks were observed in this service.

12960 W. Shoreland Drive - in 2009, very minor flow was observed entering the mainline sewer from this service. During the 2012 lateral televising, wet deposits indicating infiltration and possibly cracks were found from 16 to 23 feet upstream of the main. No injections were performed during the lateral televising. Property owner did not consent.

12916 W. Shoreland Drive – in 2009, minor to moderate clear flow was observed entering the mainline sewer from this service. During the 2012 lateral televising, a 95% root plug was encountered five feet upstream of the main. Televising further upstream was not possible.

12825 W. Shoreland Drive – service enters manhole 0112.008, and in 2009 was found to be leaking from what appeared to be around the pipe at the manhole wall. During the 2012 lateral televising, no leaks were observed in this service itself and the leaks from around the pipe at the manhole wall were nonexistent. 120 feet of an estimated 200 foot PVC lateral was televised.

12862 W. Shoreland Drive – in 2009, moderate clear flow was observed entering the mainline sewer from this service. During the 2012 lateral televising, no leaks were observed in this service. Intermittent deposits indicating infiltration were noted throughout at joints and on pipe walls. Medium to severe roots were noted as well. 69 feet of an estimated 125 foot lateral was televised. Clear water injections were performed, no dye was used.

12845 W. Shoreland Drive – in 2009, this service began to flow while viewing the connection to the mainline sewer. It is assumed that flow was the result of usage. During the 2012 lateral televising, no leaks were observed in this service.

12932 W. Shoreland Drive – in 2009, no flow was observed entering the mainline sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

12828 W. Shoreland Drive – in 2009, no flow was observed entering the mainline sewer from this service. During the 2012 lateral televising, no leaks were observed in this service.

12852 W. Shoreland Drive – in 2009, moderate clear flow was observed entering the mainline sewer from this service. During the 2012 lateral televising, joints in this section were found to be leaking at 26, 36, 46, and 97 feet upstream of the main.

2620 W. Highland Road – a video recording of this mainline sewer was not found. During the 2012 lateral televising, a single joint leak was observed 33 feet upstream of the main.

Appendix B

Flow Monitoring Analysis

**City of Mequon
Flow Meter Data Analysis**

113-080

Date	Base Flow (cfs)	Instantaneous Peak Flow (cfs)	Instantaneous Peaking Factor	1-hr Peak Flow (cfs)	1-hr Peaking Factor	24-hr Peak Flow (cfs)	24-hr Peaking Factor	Flow 6-hr after event (cfs)	Maximum Infiltration (cfs)	Maximum Inflow (cfs)	24-hr RDII (cfs)	24-hr RDII (gpd)	
4/26/2009	0.095	1.299	13.7	1.217	12.8	0.707	7.4	0.412	0.317	0.887	0.612	395,536	From West
10/14/2012	0.095	0.527	5.5	0.432	4.5	0.313	3.3	0.177	0.082	0.350	0.218	140,893	From West
12/20/2012	0.091	1.064	11.7	0.977	10.7	0.617	6.8	0.264	0.173	0.800	0.526	339,954	From West
4/10/2013	0.091	1.028	11.3	0.926	10.2	0.638	7.0	0.496	0.405	0.532	0.547	353,526	From West
4/18/2013	0.091	1.542	16.9	1.045	11.5	0.715	7.9	0.301	0.210	1.242	0.624	403,291	From West

113-081

Date	Base Flow (cfs)	Instantaneous Peak Flow (cfs)	Instantaneous Peaking Factor	1-hr Peak Flow (cfs)	1-hr Peaking Factor	24-hr Peak Flow (cfs)	24-hr Peaking Factor	Flow 6-hr after event (cfs)	Maximum Infiltration (cfs)	Maximum Inflow (cfs)	24-hr RDII (cfs)	24-hr RDII (gpd)	
6/19/2009	0.010	0.309	30.9	0.260	26.0	0.117	11.7	0.060	0.050	0.249	0.107	69,154	From Highland
10/14/2012	0.014	0.153	10.9	0.106	7.6	0.079	5.6	0.054	0.040	0.099	0.065	42,010	From Highland
12/20/2012	0.016	0.349	21.8	0.328	20.5	0.200	12.5	0.097	0.081	0.252	0.184	118,919	From Highland
4/10/2013	0.016	0.444	27.8	0.423	26.4	0.293	18.3	0.105	0.089	0.339	0.277	179,025	From Highland
4/18/2013	0.016	0.403	25.2	0.387	24.2	0.281	17.6	0.142	0.126	0.261	0.265	171,270	From Highland

**City of Mequon
Flow Meter Data Analysis**

113-028

Date	Base Flow (cfs)	Instantaneous Peak Flow (cfs)	Instantaneous Peaking Factor	1-hr Peak Flow (cfs)	1-hr Peaking Factor	24-hr Peak Flow (cfs)	24-hr Peaking Factor	Flow 6-hr after event (cfs)	Maximum Infiltration (cfs)	Maximum Inflow (cfs)	24-hr RDII (cfs)	24-hr RDII (gpd)	
10/14/2012	0.036	0.595	16.5	0.504	14.0	0.341	9.5	0.205	0.169	0.390	0.305	197,122	From West
12/20/2012	0.067	1.019	15.2	0.968	14.4	0.594	8.9	0.290	0.223	0.729	0.527	340,600	From West
4/10/2013	0.067	0.705	10.5	0.645	9.6	0.507	7.6	0.252	0.185	0.453	0.440	284,372	From West
4/18/2013	0.067	0.630	9.4	0.573	8.6	0.477	7.1	0.241	0.174	0.389	0.410	264,983	From West

623-031

Date	Base Flow (cfs)	Instantaneous Peak Flow (cfs)	Instantaneous Peaking Factor	1-hr Peak Flow (cfs)	1-hr Peaking Factor	24-hr Peak Flow (cfs)	24-hr Peaking Factor	Flow 6-hr after event (cfs)	Maximum Infiltration (cfs)	Maximum Inflow (cfs)	24-hr RDII (cfs)	24-hr RDII (gpd)
10/23/2012	0.010	0.197	19.7	0.160	16.0	0.108	10.8	0.063	0.053	0.134	0.098	63,337
12/20/2012	0.027	1.023	37.9	0.777	28.8	0.292	10.8	0.203	0.176	0.820	0.265	171,270
4/10/2013	0.027	0.715	26.5	0.434	16.1	0.337	12.5	0.102	0.075	0.613	0.310	200,353
4/18/2013	0.027	1.014	37.6	0.554	20.5	0.341	12.6	0.113	0.086	0.901	0.314	202,938

**City of Mequon
Flow Meter Data Analysis**

625-003E

Date	Base Flow (cfs)	Instantaneous Peak Flow (cfs)	Instantaneous Peaking Factor	1-hr Peak Flow (cfs)	1-hr Peaking Factor	24-hr Peak Flow (cfs)	24-hr Peaking Factor	Flow 6-hr after event (cfs)	Maximum Infiltration (cfs)	Maximum Inflow (cfs)	24-hr RDII (cfs)	24-hr RDII (gpd)
10/23/2012	0.015	0.193	12.9	0.179	11.9	0.113	7.5	0.087	0.072	0.106	0.098	63,337
12/20/2012	0.018	0.337	18.7	0.320	17.8	0.207	11.5	0.020	0.002	0.317	0.189	122,151
4/10/2013	0.018	0.838	46.6	0.363	20.2	0.263	14.6	0.085	0.067	0.753	0.245	158,344
4/18/2013	0.018	0.384	21.3	0.363	20.2	0.271	15.1	0.088	0.070	0.296	0.253	163,514

625-003S

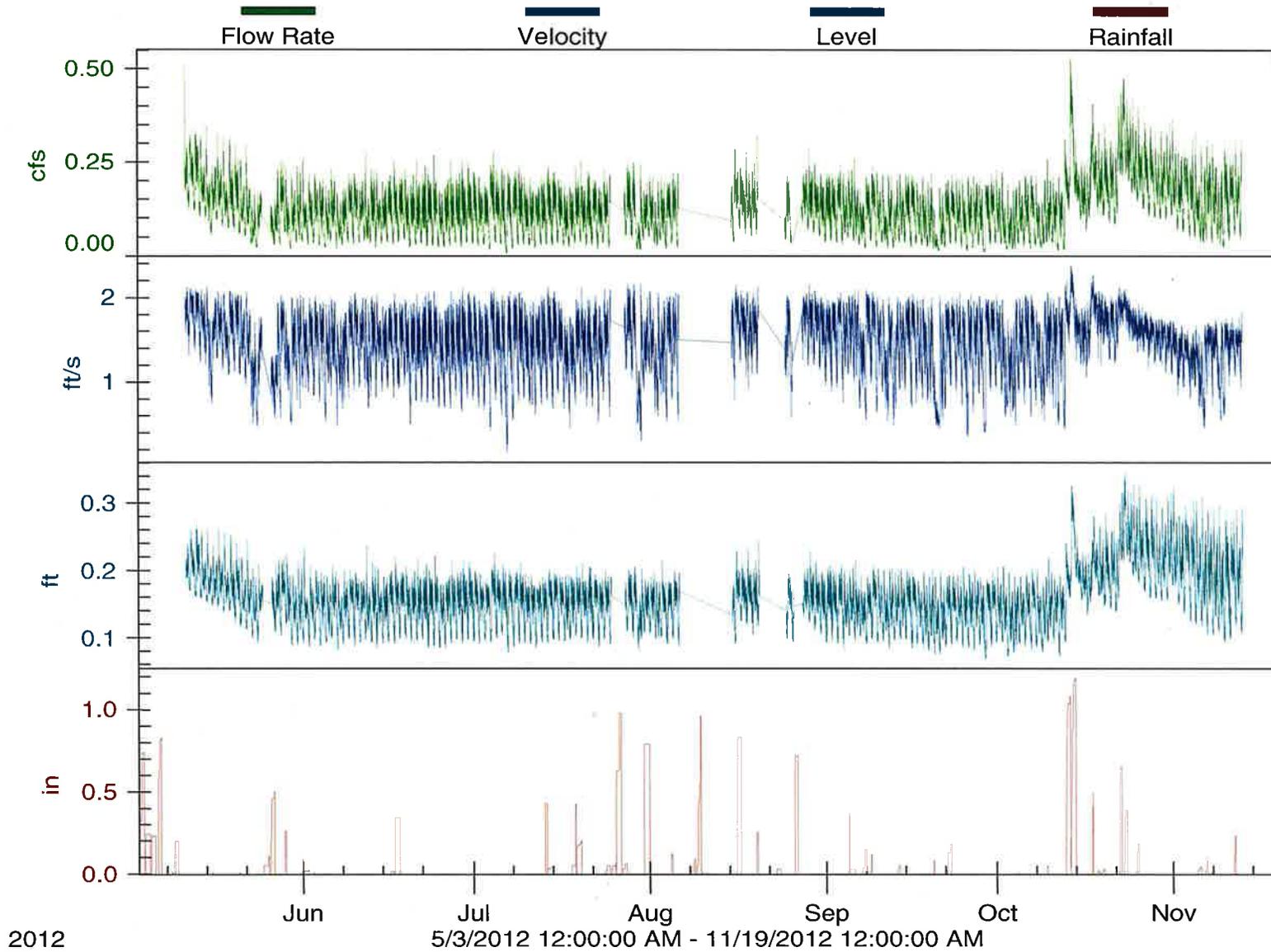
Date	Base Flow (cfs)	Instantaneous Peak Flow (cfs)	Instantaneous Peaking Factor	1-hr Peak Flow (cfs)	1-hr Peaking Factor	24-hr Peak Flow (cfs)	24-hr Peaking Factor	Flow 6-hr after event (cfs)	Maximum Infiltration (cfs)	Maximum Inflow (cfs)	24-hr RDII (cfs)	24-hr RDII (gpd)
10/23/2012	0.010	0.151	15.1	0.117	11.7	0.057	5.7	0.035	0.025	0.116	0.047	30,376
12/20/2012	0.010	0.384	38.4	0.349	34.9	0.213	21.3	0.109	0.099	0.275	0.203	131,199
4/10/2013	0.010	0.417	41.7	0.359	35.9	0.256	25.6	0.110	0.100	0.307	0.246	158,990
4/18/2013	0.010	0.365	36.5	0.339	33.9	0.244	24.4	0.126	0.116	0.239	0.234	151,234

Appendix C

Flow Graphs for 2012 Data

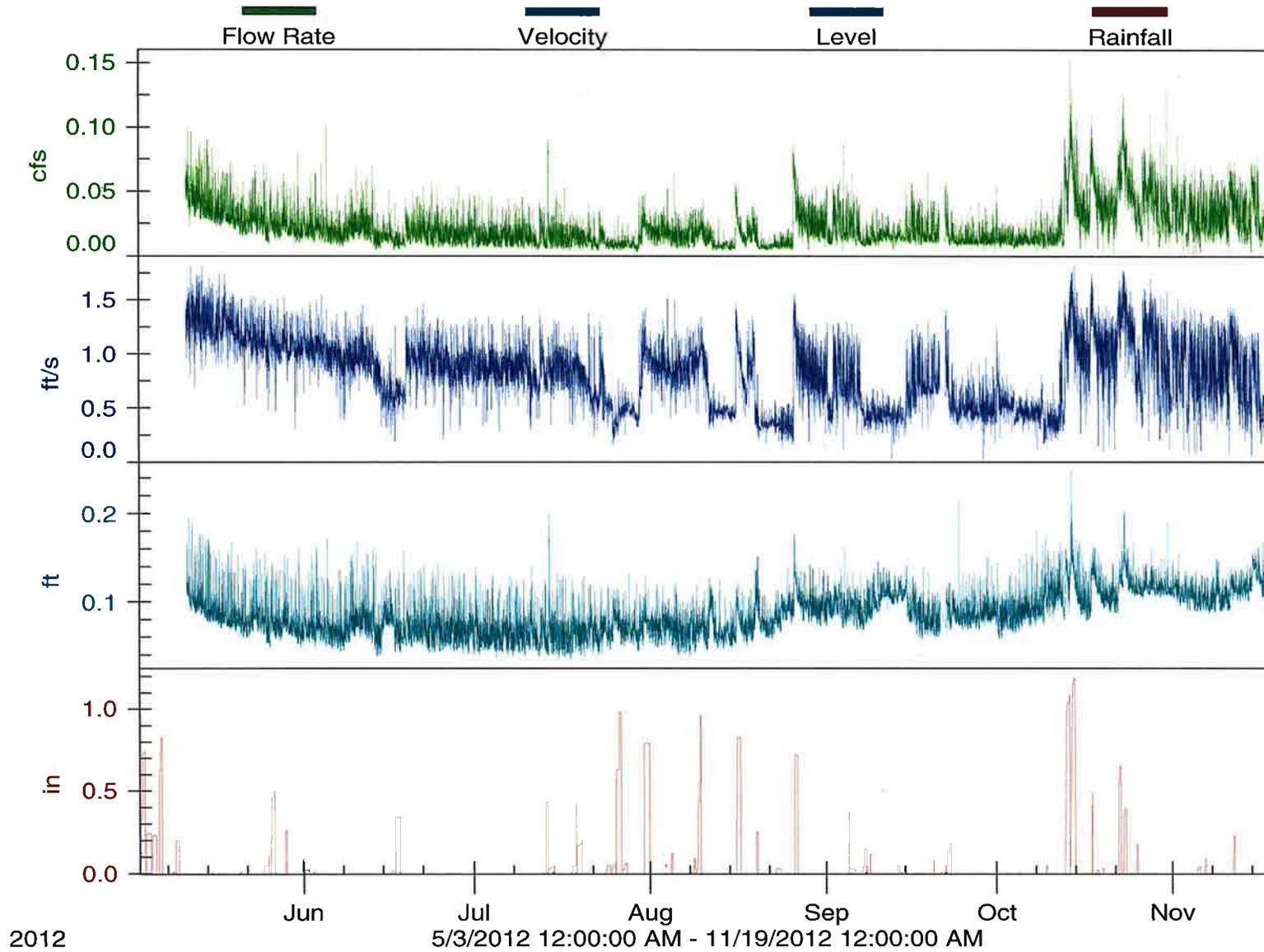
ME3080 Yvonne Dr and Fluerdelis

Flowlink 4 for Windows



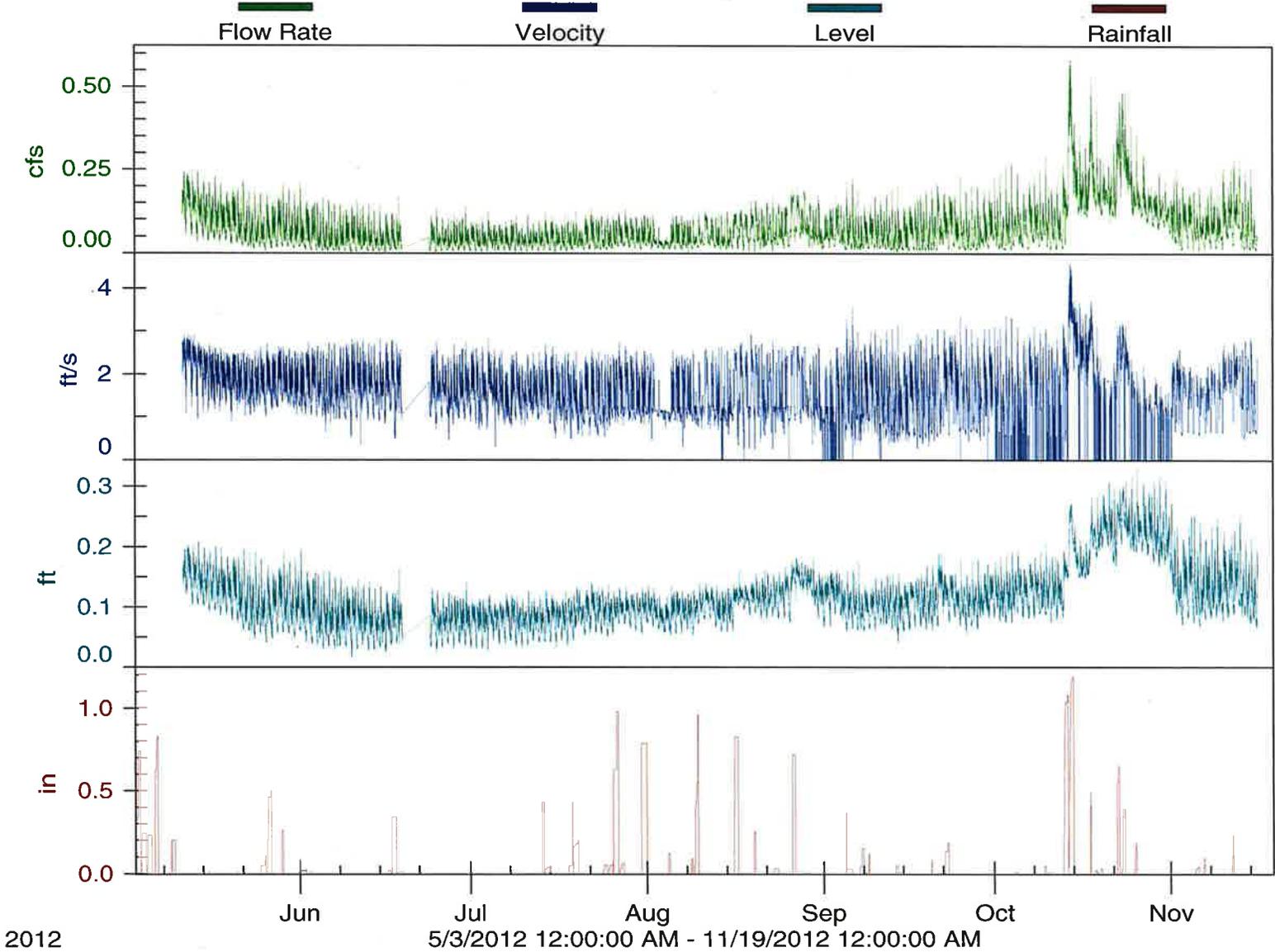
ME3081 N Fieldwood Dr

Flowlink 4 for Windows



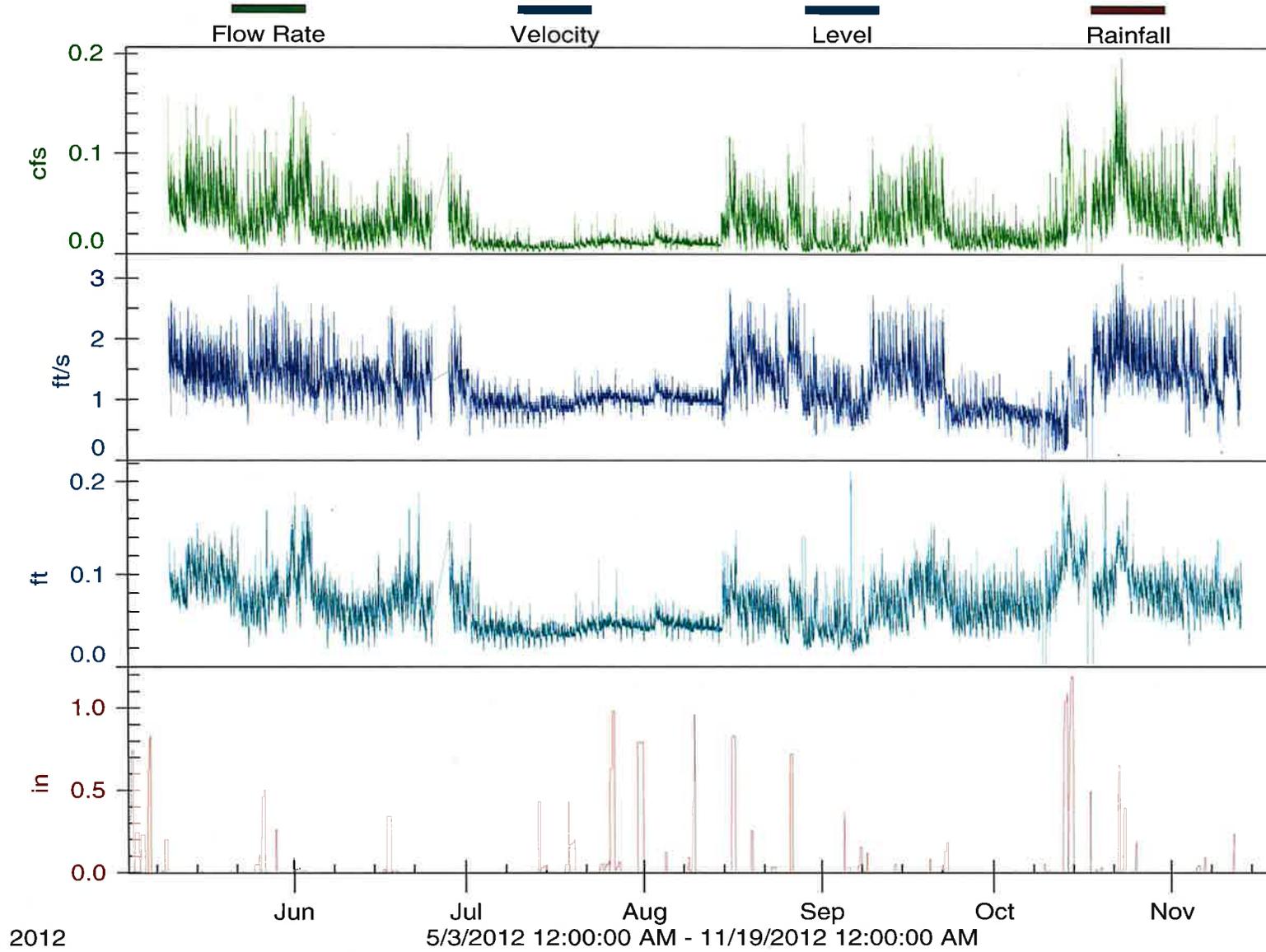
ME3028 Fluerdelis and Marseilles

Flowlink 4 for Windows



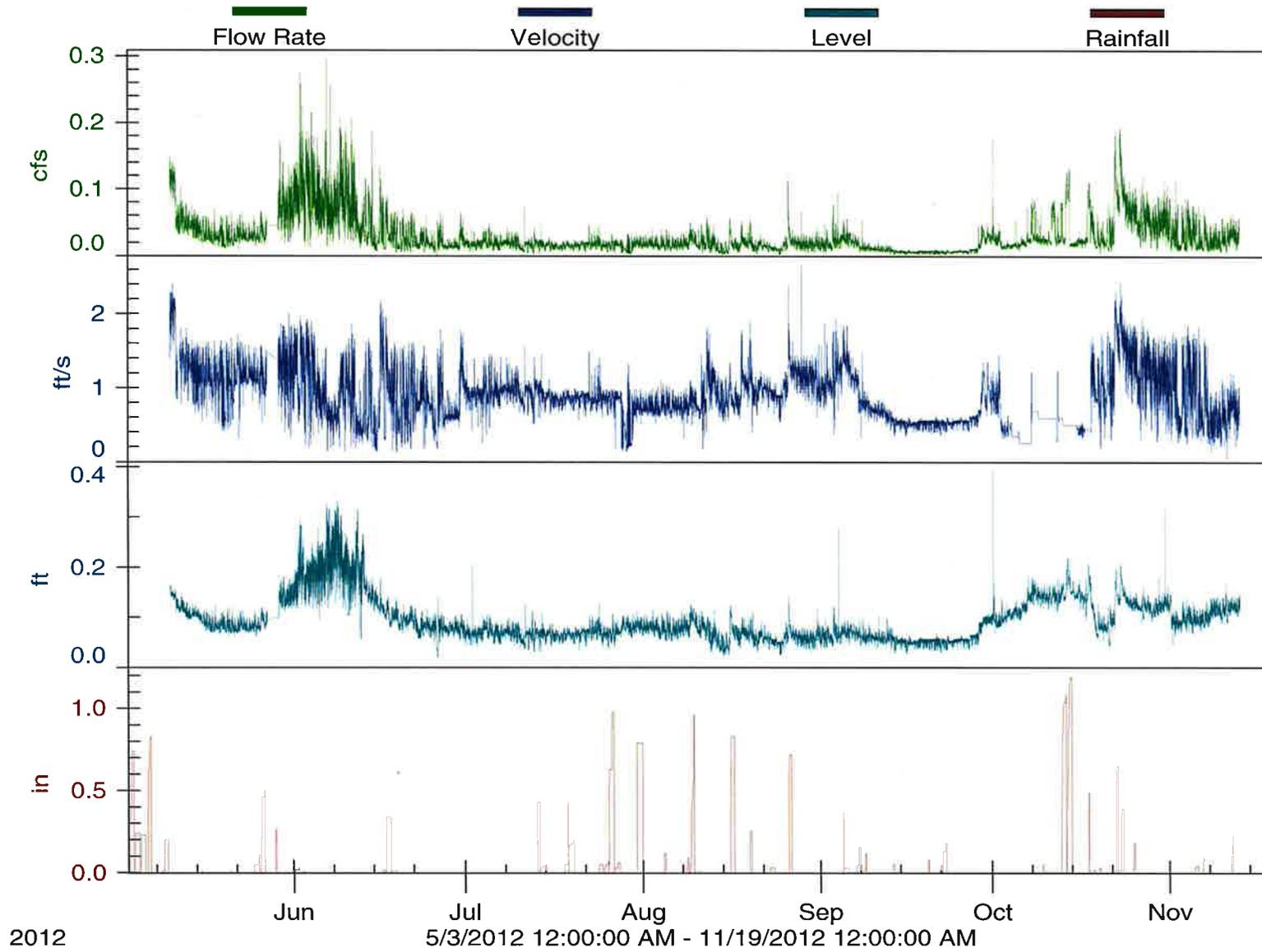
ME3031 5006 N Parkview Dr

Flowlink 4 for Windows



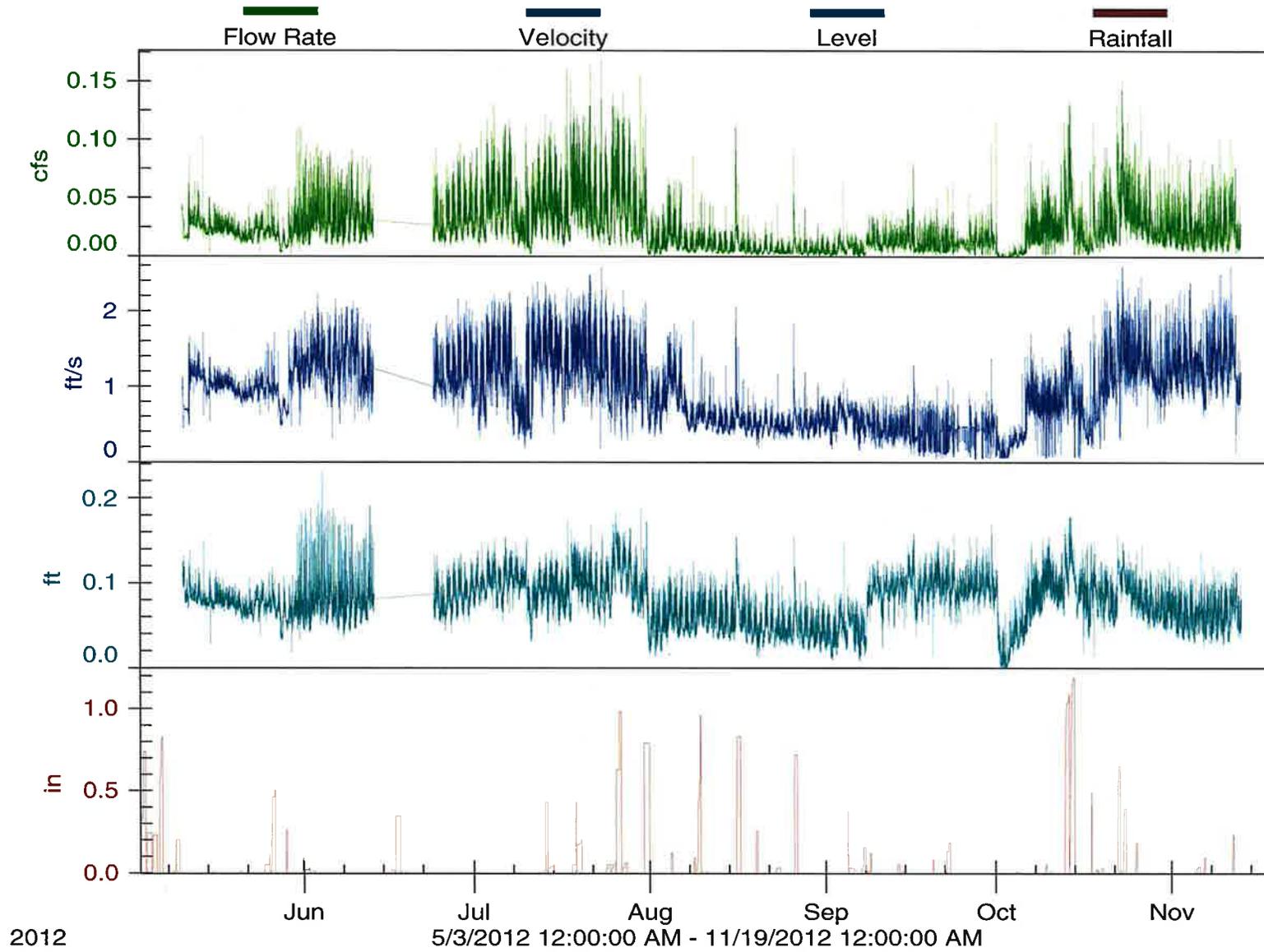
ME503E Scenic Dr and River Rd

Flowlink 4 for Windows



ME503S River Road and Scenic Dr

Flowlink 4 for Windows

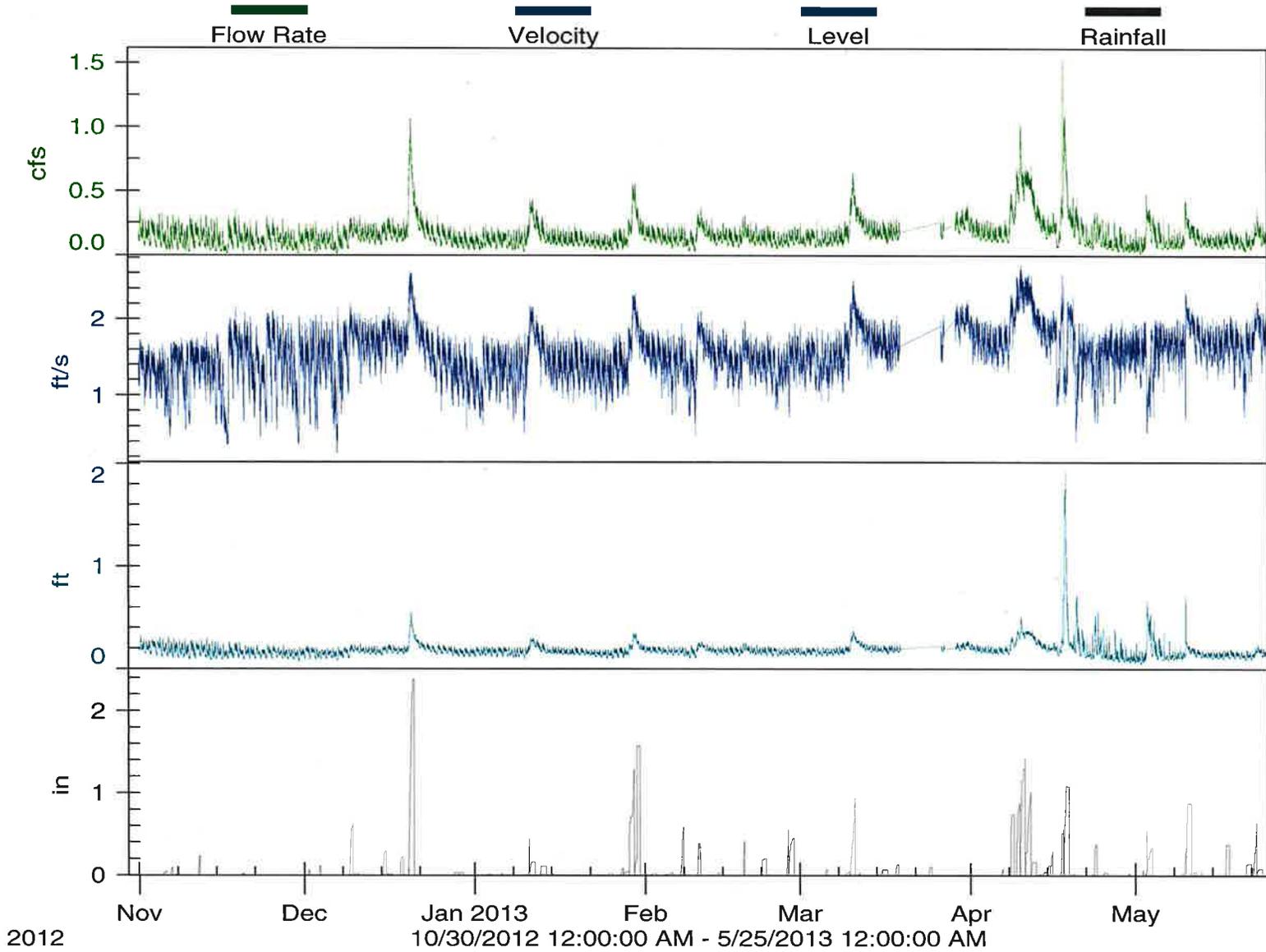


Appendix D

Flow Graphs for 2013 Data

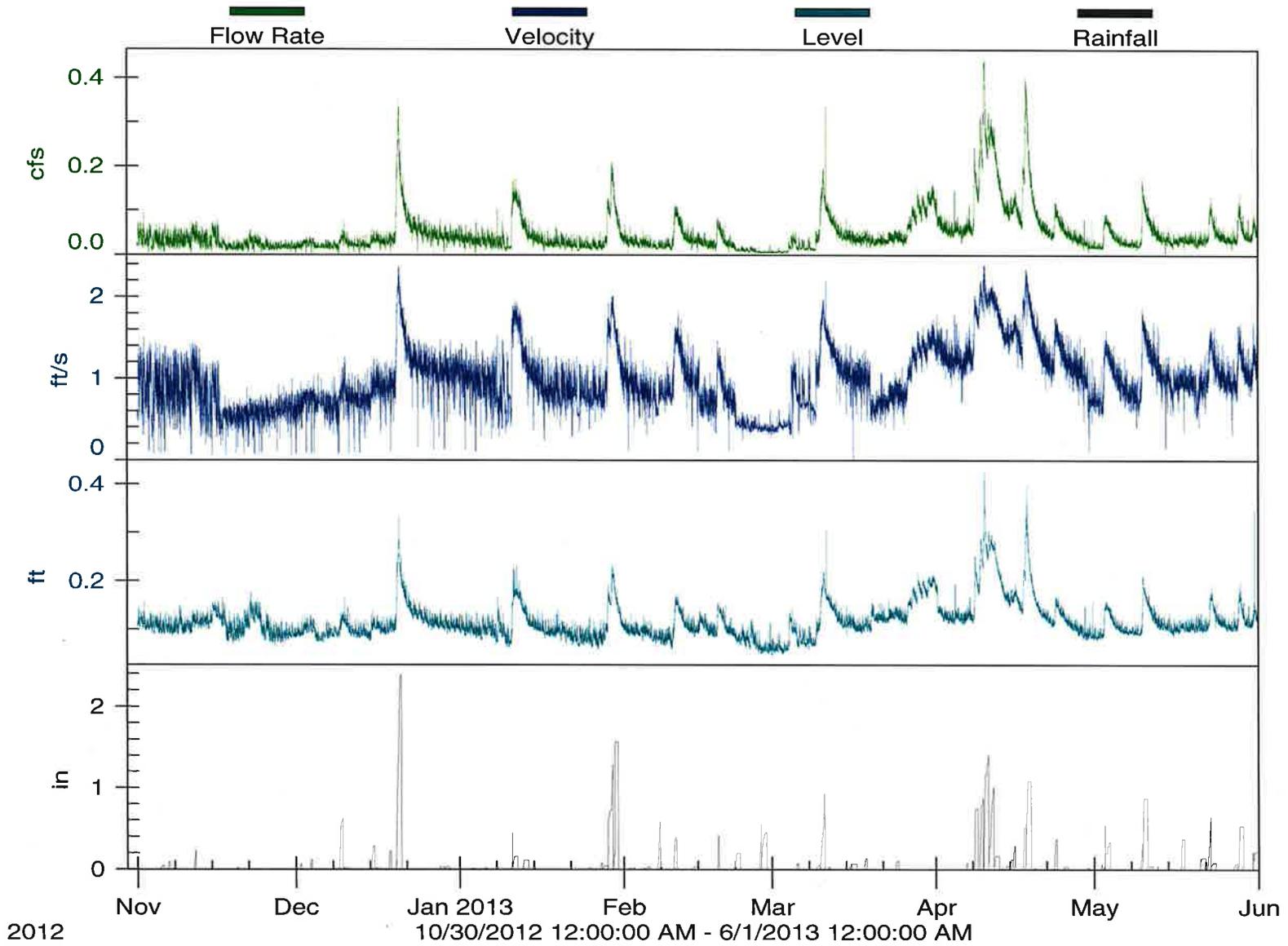
ME3080 11-1-12 to 6-3-13

Flowlink 4 for Windows



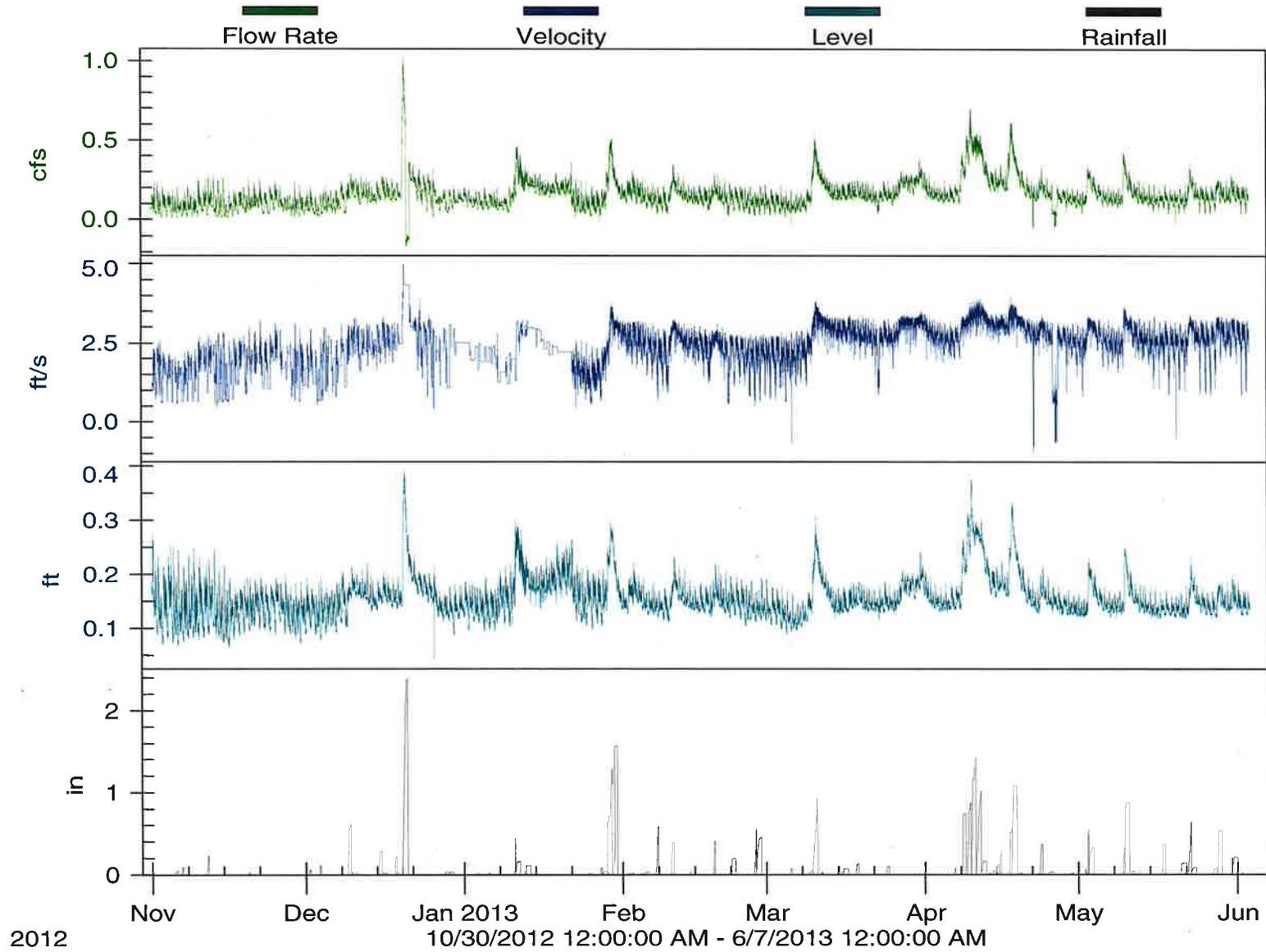
ME3081 11-1-12 to 6-3-13 B

Flowlink 4 for Windows



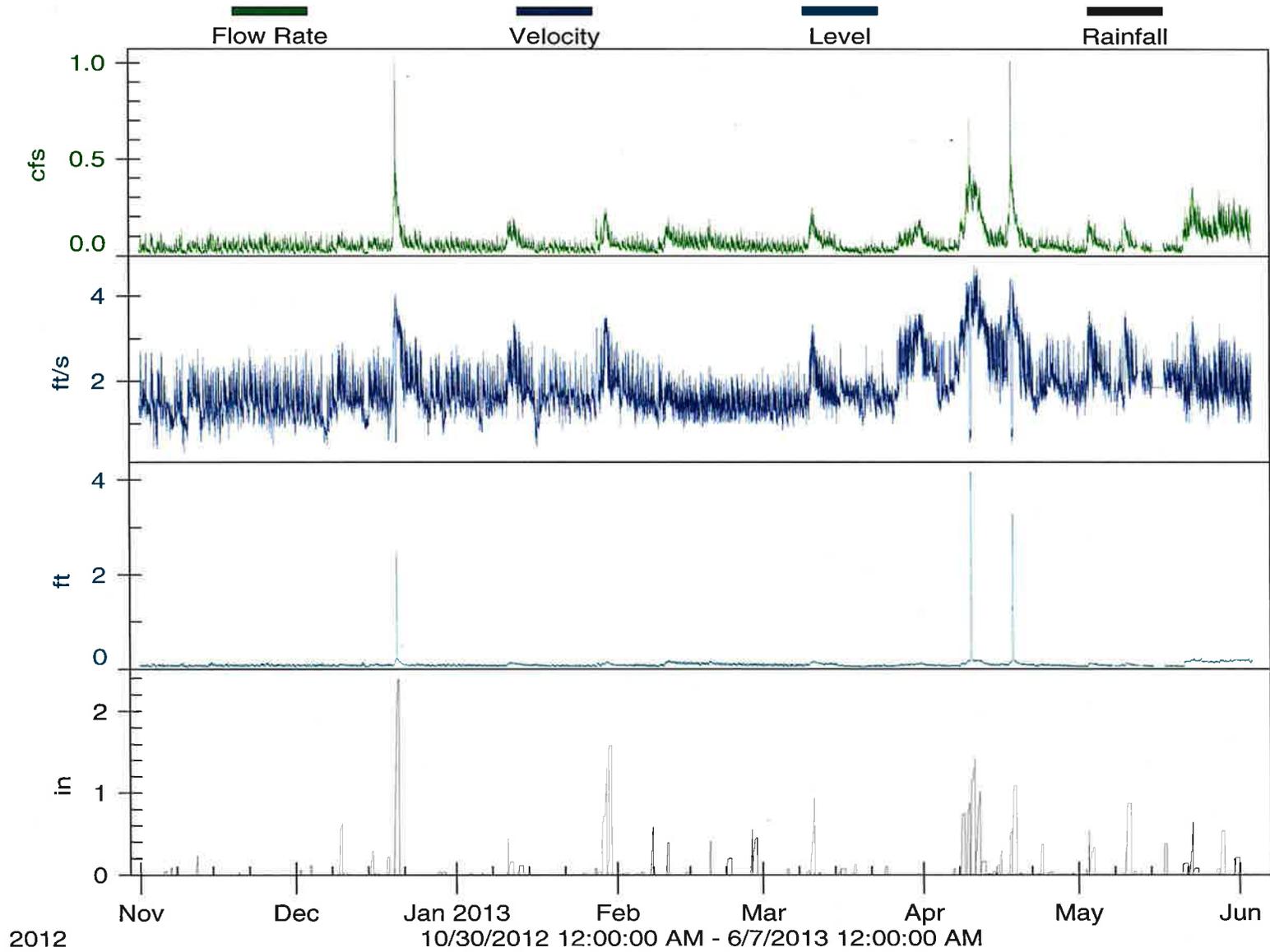
ME3028 11-1-12 to 6-3-13

Flowlink 4 for Windows



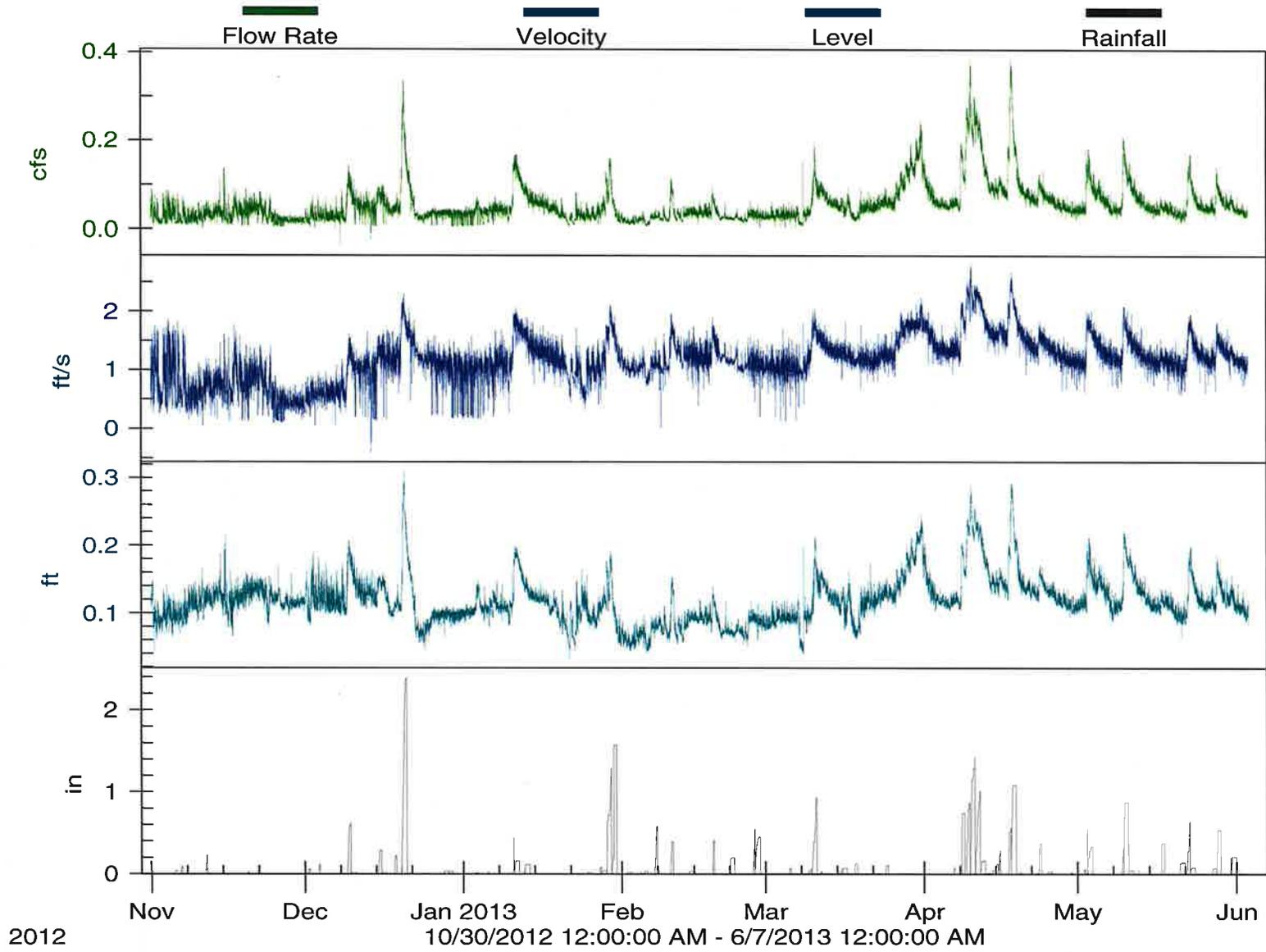
ME3031 11-1-12 to 6-3-13

Flowlink 4 for Windows



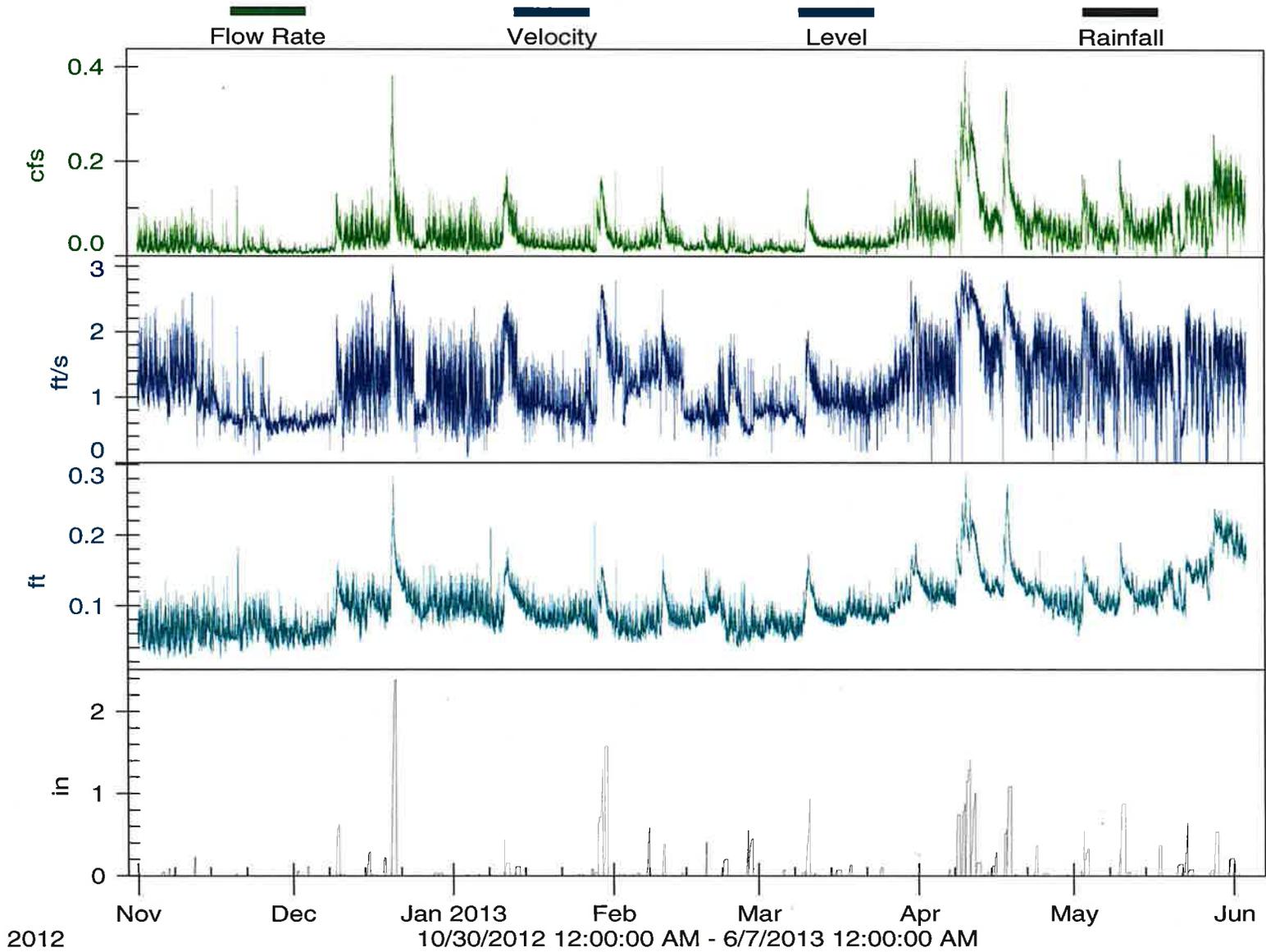
ME503E 11-1-13 to 6-3-13 B

Flowlink 4 for Windows



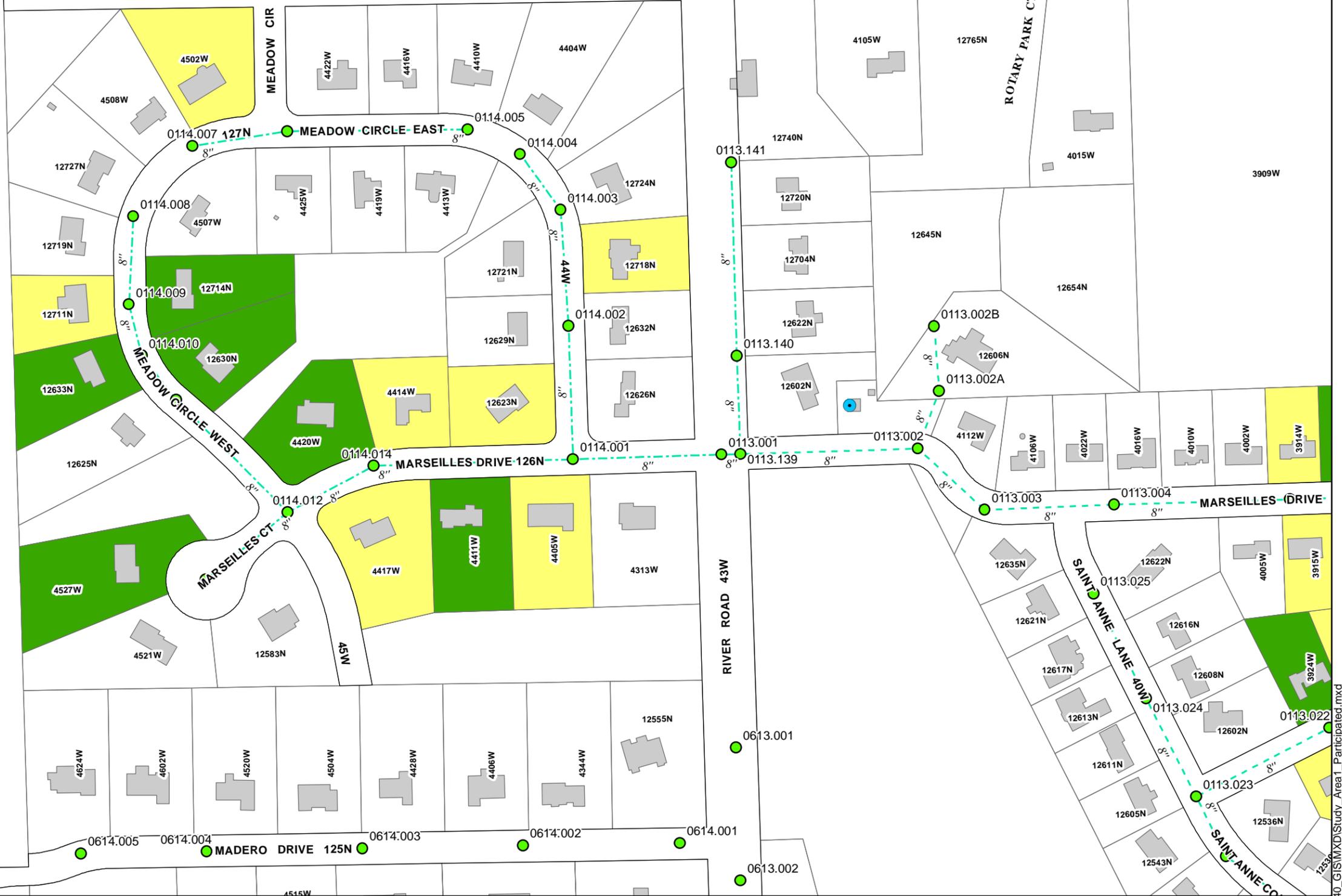
ME503S 11-1-12 to 6-3-13 B

Flowlink 4 for Windows



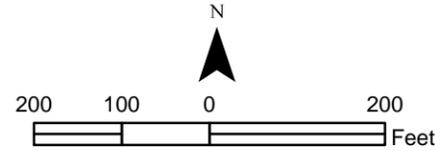
Appendix E

Figures

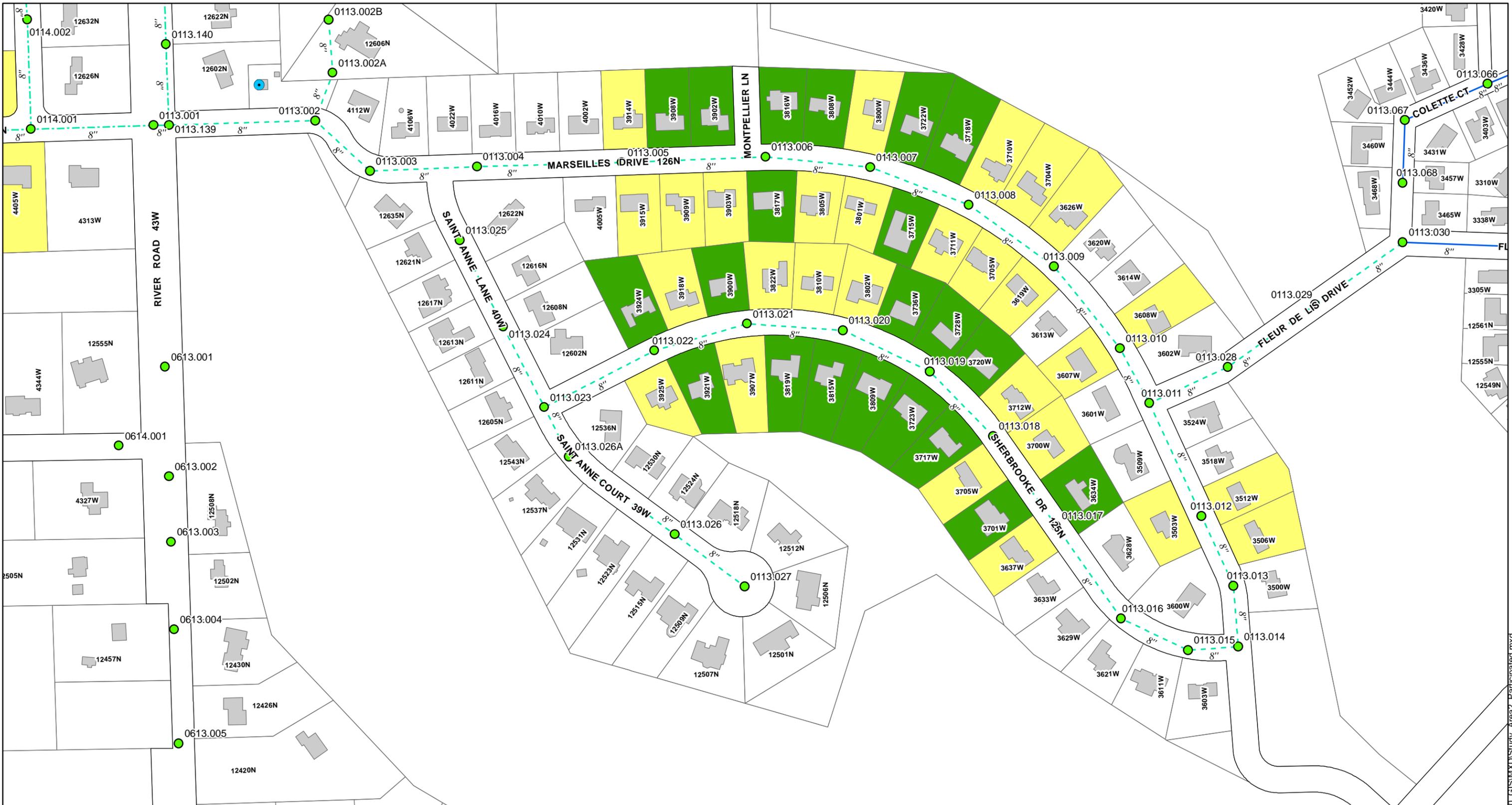


City of Mequon PP I/I Project

Study Area 1

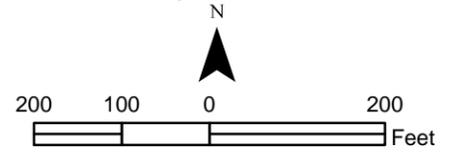


- | | | |
|----------------|----------------|----------------------|
| Well Sites | Concrete, 1970 | Participated |
| Manholes | PVC, 1972 | Did Not Participate |
| Unknown | PVC, 1978 | Structures |
| Concrete, 1963 | PVC, 1988 | Parcels Not Selected |
| Concrete, 1969 | PVC, 2000 | |



City of Mequon PP I/I Project

Study Area 2

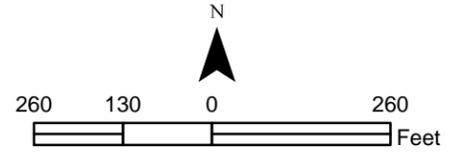


- | | | |
|----------------|----------------|----------------------|
| Well Sites | Concrete, 1970 | Participated |
| Manholes | PVC, 1972 | Did Not Participate |
| Unknown | PVC, 1978 | Structures |
| Concrete, 1963 | PVC, 1988 | Parcels Not Selected |
| Concrete, 1969 | PVC, 2000 | |



City of Mequon PP I/I Project

Study Area 3



- | | | |
|----------------|----------------|----------------------|
| Well Sites | Concrete, 1970 | Participated |
| Manholes | PVC, 1972 | Did Not Participate |
| Unknown | PVC, 1978 | Structures |
| Concrete, 1963 | PVC, 1988 | Parcels Not Selected |
| Concrete, 1969 | PVC, 2000 | |