SAINT PAUL

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2015 Water Quality & Quantity Monitoring Program

Monitoring Report

June 2016

Prepared for

City of Saint Paul

25 West 4th St. | 1500 City Hall Annex | Saint Paul, MN 55102

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WSB

2015 STORMWATER QUANTITY AND QUALITY MONITORING PROGRAM

FOR THE CITY OF SAINT PAUL, MINNESOTA

June 16, 2016

Prepared By:

WSB & Associates, Inc.
701 Xenia Avenue South, Suite 300
Minneapolis, MN 55416
(763) 541-4800
(763) 541-1700 (Fax)

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Todd E. Hubmer, PE

Date: June 16, 2016 Lic. No. 24043

Jesse Carlson, CPESC, CPSWQ

Date: June 16, 2016

Linnea Henkels

Date: June 16, 2016

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1 Introduction

The purpose of this report is to present the findings of the City of Saint Paul's (City) 2015 Stormwater Monitoring Program. The monitoring was conducted to fulfill requirements of the City's National Pollutant Discharge Elimination System (NPDES) MS4 Phase I Permit. Data collected and analyzed for the program is used to quantify stormwater volumes and loads from the MS4 and assist in the assessment of effectiveness of the City's Stormwater Management Program.

Since 2006, the City has been required by local watershed agencies to construct stormwater volume reduction Best Management Practices (BMPs) concurrent with City projects that generate or reconstruct impervious surfaces. The watershed requirements stipulate that these BMPs must provide volume reduction for the runoff from a one-inch rainfall event over the impervious surfaces of the project. In 2015 the watershed updated their standard to require that the BMP provide volume reduction for the runoff from a 1.1-inch rainfall event over the impervious surface of the project. The City has typically achieved this by constructing underground infiltration BMPs. The focus of the City's stormwater monitoring program has been to monitor the effectiveness and maintenance needs of these systems.

Twelve sites were monitored in 2015 to quantify progress toward meeting the City's stormwater management goals and to refine current design and maintenance practices. Rainfall was also measured at five locations. The 2015 monitoring sites are shown on **Figure 1-1** and listed in **Table 1-1**. This effort focused on evaluating four major parameters during the monitoring period which are included below:

- Water level / Infiltration rate
- Volume reduction
- Pollutant removal
- BMP maintenance

To evaluate these parameters, electronic monitoring equipment was used to continuously measure system water levels, inflow/outflow volumes, pollutant concentrations, groundwater elevation, and rainfall amounts. In addition, visual inspections and measurements of sediment accumulation were conducted periodically for each system to assess maintenance needs.

In addition to the BMP monitoring described above, a study was completed to assess pervious surface infiltration rates at two locations. The purpose of the study was to research the benefits, feasibility, and sustainability of pervious surface parking lanes and alley ways in the City of Saint Paul.

This report describes the procedures and methods used to collect water quality and quantity data, provides background information for each site monitored, and presents the results of the monitoring that was completed.

Table 1-1: 2015 City of Saint Paul Monitoring Site Summary

Site	Site Type	Monitored Parameters[1]	MS4 Monitoring Site
Beacon Bluff	Underground Infiltration Gallery & Rain Garden	WL, Q, WQ, GW	Yes
Hillcrest Knoll Park	Underground Infiltration Gallery	WL, Q, GW	Yes
St. Alban's Street	Underground Infiltration Gallery	WL, Q, WQ,	Yes
Hampden Park	Underground Infiltration Gallery	WL, Q, GW	Yes
Arundel Street	Underground Infiltration Gallery	WL	Yes
Flandrau – Hoyt Pond	Stormwater Pond	WL	No
Flandrau – Case Pond	Stormwater Pond	WL	No
Trout Brook Nature Sanctuary –Maryland Pond	Iron-Enhance Sand Filtration Pond	WL, Q, WQ	Yes
Trout Brook Nature Sanctuary –Magnolia Pond	Iron-Enhance Sand Filtration Pond	WL, Q, WQ	Yes
Trout Brook Nature Sanctuary –Jenks Pond	Iron-Enhance Sand Filtration Pond	WL, Q, WQ	Yes
Victoria Street Pervious Pavers	Pervious Pavers	Infiltration	Yes
Hamline-Midway Library Pervious Pavement	Pervious Asphalt	Infiltration	Yes
Wilder Recreation Center	Rainfall Monitoring Location	R	Yes
Fire Station 18	Rainfall Monitoring Location	R	Yes
Hampden Park Co-op	Rainfall Monitoring Location	R	Yes
Frost Elementary School	Rainfall Monitoring Location	R	Yes
Edgecumbe Recreation Center	Rainfall Monitoring Location	R	Yes

[1] **WL – Water Level, Q – Flow Rate, WQ – Water Quality, GW – Groundwater, R - Rainfall**

2 Procedures and Methodology

This section outlines the procedures and methods followed to perform monitoring and data analysis. For more detailed information related to equipment use monitoring protocols that were followed for this monitoring program, see the 2015 Stormwater Monitoring Protocols document located in **Appendix E**.

2.1 Infiltration Rate

The infiltration rate was measured at applicable locations by collecting water level data on a continual basis. The data was then analyzed to estimate the average infiltration rates observed during the monitoring period. The following provides a detailed description of how this was completed. Infiltration rates were not calculated for the Trout Brook Nature Sanctuary (TBNS) iron-enhanced sand filtration ponds (IESF), Flandrau-Hoyt Pond, and Flandrau-Case Pond as part of this assessment. The water level data collected at those sites was reviewed to determine level fluctuation over the monitoring period and to compare against normal and high water elevations.

<u>Data Collection</u>

Water levels were monitored using Win-Situ level loggers. The loggers were configured at each site to log data at a minimum of one reading per hour for groundwater and once every 15 minutes for BMPs. Groundwater was logged once every hour.

Enclosures for the infiltration gallery level loggers were installed at Beacon Bluff, Hillcrest Knoll Park, St. Albans Street, and Arundel Street Sites. These consisted of three-inch-diameter PVC pipes with four rows of half-inch-diameter holes drilled along the pipe achieving approximately twenty holes per foot. The enclosures were then wrapped with a highly permeable geotextile fabric and secured with zip ties to protect the instrument from fine sediment accumulation. Enclosures were secured to the system floor and to the access riser wall (**Photo 2-1**). Groundwater, in-rock (IR), and rain garden locations were monitored from permanent monitoring wells. (**Photo 2-2**).

Photo 2-1: Infiltration gallery level logger enclosure

Photo 2-2: Beacon Bluff rain garden level monitoring

Data Analysis

The data collected at each site reflected hydrograph-type curves resulting from the rise and fall of water within the systems during and after significant rainfall events. The data was analyzed in Microsoft Excel to develop stage/infiltration rate relationships for each system. Since the infiltration rates increase exponentially at higher depths in the systems, this relationship was developed by calculating the infiltration rate at each half foot height increment. These calculations also accounted for the volume of runoff entering the system at the same time that drawdown was occurring. Infiltration of water in the horizontal direction through the vertical surfaces of the trenches was not included in this analysis as the policies of the watershed districts only recognize infiltration through the bottom horizontal surface. The infiltration rates calculated at each increment were averaged and plotted on a graph.

The following equation was used to perform these calculations at each half foot increment:

$$\boldsymbol{Infiltration\ Rate\ \left(\frac{in}{hr}\right) = \frac{0.5\ ft + \frac{V_{in}}{WHSA}}{\Delta t}}$$

where:

V_{in} = Inflow Volume (cu-ft)
WHSA = Wetted Horizontal Surface Area (sq-ft)
Δt = Time it takes for water level to drop by 0.5 ft

The same analysis method was used to evaluate infiltration rates in the Arundel Street BMP. However, since no monitored inflow data was available, inflow volume was not accounted for.

The infiltration rate trends are also provided in this report to assess changes in infiltration performance overtime. This information can be used to develop maintenance procedures and schedules for these systems.

2.2 Volume Reduction

Stormwater runoff volume was measured at Beacon Bluff, Hillcrest Knoll, St. Albans Street, and Hampden Park using continuous flow monitoring equipment to determine the total volume of water draining to and captured by each system. The volume of treated water passing through the IESF ponds at the TBNS sites was also monitored to calculate load reductions. Collected data was analyzed using Flowlink software and Microsoft Excel to quantify the volumes measured during each discrete rainfall event recorded during the monitoring periods. The following section provides brief descriptions of the methods and procedures used to quantify volume reduction at each system.

Data Collection

Teledyne ISCO 2150 area velocity flow modules and sensors were used to monitor runoff volumes. These devices measure water level and flow velocity. Combining this information with a known conduit shape, the flow rate and flow volume through the conduit were calculated. Each of the monitored systems received stormwater runoff from a diversion structure located along the storm sewer system. The 2150 flow sensors were positioned at the upstream and downstream pipes in these structures to measure the total volume draining to each BMP and the total volume that bypassed each BMP. The following photos show the flow meters installed in the Beacon Bluff diversion structure:

Photo 2-2: Flow module in Beacon Bluff diversion structure (looking upstream)

Photo 2-3: Flow sensor in upstream pipe in Beacon Bluff diversion structure

Flow sensors at the TBNS IESF Pond sites were installed within the outlet control structure pipe of the ponds.

Photo 2-4: Flow sensor in outlet control structure Magnolia Pond

Photo 2-5 Flow sensor Magnolia Pond

The flow modules were configured at each site to log data at one minute intervals once the water level in the upstream pipe was greater than one-inch above the pipe invert to increase the resolution of the flow data.

Data Analysis

Flow data was regularly imported into Flowlink 5.1 for storage and analysis. Data was analyzed and validated using built-in velocity error checking parameters. The flow level and velocity data was converted to total flow volumes and exported to an Excel spreadsheet for further analysis. Each rainfall event and associated inflow and outflow volumes were tabulated. Turbulent flow at the Beacon Bluff site contributed to occasional erroneous level data at the upstream sensor location. Each flow event was evaluated individually and if the data was determined to be of poor quality (i.e. level drop out, significantly higher volumes recorded at the downstream location), the total event volume was modeled using

The runoff volume from about 6.8 acres of the total drainage area to the Beacon Bluff system was not measured during the entire monitoring period because it was not feasible to install expensive equipment in all of the four direct inlets to the system in addition to measuring sheet flow from the landscape surrounding the infiltration basin. Runoff volumes from these areas were estimated to be a proportion of the volume measured in the upstream pipe of the diversion structure based on the percentage of the total drainage area. All of the runoff generated by these areas was assumed to be captured by the system.

2.3 Water Quality

Water quality was monitored at the Beacon Bluff, St. Albans Street, and TBNS IESF Pond sites. The following section provides a summary of the methods and procedures used to collect and test water quality samples and analyze the data.

Data Collection

ISCO 6712 automatic samplers were installed in the diversion structures at Beacon Bluff and St. Albans Street (**Photos 2-6** and **2-7**).

Photo 2-6 : ISCO 6712 sampler at Beacon Bluff

Photo 2-7 : ISCO 6712 sampling carrousel (24 – 1,000 mL sample bottles)

The automatic samplers were configured to collect 200 mL samples at constant volume intervals. The flow pacing intervals were initially estimated for each site to provide a minimum of six samples during a quarter-inch storm but less than 120 samples for the three-inch storm. Flow pacing was refined during the monitoring period to achieve this objective.

The sampling configuration at each of the three TBNS IESF Ponds consisted of a job box containing two ISCO 6712 automated samplers, triggered by one - 2150 flow meter within the outlet control structure pipe (**Photos 2-8** and **2-9**). Tubing was routed from the first sampler through a buried conduit to a float within the pond basin. This location was established as the pre-treatment sample. Tubing was routed for the second sampler along with the 2150 area velocity meter to a position in the outlet pipe of the outlet control structure. This location was established as the post-treatment sample. The samplers were programmed to collect simultaneous flow weighted samples based on flow pacing monitored in the outlet control structure. The flow pacing at each pond was refined during the monitoring period to best capture the entire flow profile of a treatment event, while still meeting the 48 hour hold time for the ortho-phosphate laboratory method.

Photo 2-8: Maryland Pond sampler configuration

Photo 2-9: Magnolia Pond pretreatment sample float

Samples from sufficiently sized rainfall events were submitted to a certified laboratory for analysis. The samples were composited using a batch mixing technique to create one sample for the event. Beacon Bluff and St. Albans composite samples were analyzed for the parameters listed in the **Table 2-1** below, as volumes allowed, in accordance with the City's NPDES Permit. Grab samples were also collected during select storm events and analyzed for E. Coli. The most probable number (MPN) procedure was used to determine the concentration of E. Coli in the stormwater runoff. The TBNS IESF Pond samples were submitted for analysis of total phosphorus (TP), dissolved phosphorus (DP), and ortho-phosphate [soluble reactive phosphorus (SRP)]

Table 2-1: Water Quality Parameters

Monitoring Parameters			
Parameters	**Method**	**Sample Type**	**Frequency**
BOD, Carbonaceous 5-Day (20 Deg C)	SM 5210B	Composite or Grab	Quarterly
Chloride, Total	SM4500	Composite or Grab	For loading calculations
Copper, Total (as Cu)	EPA 200.7	Composite or Grab	Monthly
E. coli		Grab	Quarterly
Flow	NA	Measurement	NA
Hardness, Carbonate (as CaCo3)	SM 2340B	Composite or Grab	Monthly
Lead, Total (as Pb)	EPA 200.7	Composite or Grab	Monthly
Nitrite Plus Nitrate, Total (asN)	SM4500/NO3F	Composite	For loading calculations
Nitrogen, Ammonia, Un-ionized (as N)	EPA 350.1	Composite	Quarterly
Nitrogen, Kjeldahl, Total	EPA 351.2	Composite	For loading calculations
pH	EPA 9045D	Composite or Grab	Quarterly
Phosphate, total Dissolved or Ortho	EPA 365.1	Composite	Quarterly
Phosphorus, Total as P	EPA 365.1	Composite	For loading calculations
Precipitation	NA	Measurement	1 x Day
Solids, Total Dissolved (TDS)	SM2540 C-97	Composite	Quarterly
Solids, Total Suspended (TSS)	ASTM D3977-97	Composite	For loading calculations
Sulfate	EPA 9056A	Composite or Grab	2 x Year
Volatile Suspended Soilds (VSS)	EPA 160.4	Composite	For loading calculations
Zinc, Total (as Zn)	EPA 200.7	Composite or Grab	Monthly

Data Analysis

The event mean concentrations (EMCs) derived from sampling events were multiplied by the corresponding volume measurements taken at each site for every rainfall event sampled. For storm events with no sampling data, a flow weighted EMC concentration from that site's entire monitoring period was used. This information was tabulated and summed to determine the total amount of pollutants generated in the contributing drainage areas and the amount of pollutants captured by the BMP.

2.4 Maintenance Inspections

Inspections were conducted at Beacon Bluff, Hillcrest Knoll Park, St. Albans Street, Hampden Park, and Arundel Street Sites periodically during the monitoring period. Pre-treatment structures were inspected for accumulated sediment depth and floatable debris. Underground chambers were observed from the access riser for accumulation of sediment, debris, and standing water that would require maintenance. The TBNS IESF Ponds were inspected for muck accumulation and iron clumping within the sand filtration benches. Inspection photos are included as **Appendix D**.

2.5 Pervious Surface Infiltration Rate

The infiltration rate of the permeable surfaces was measured at Victoria Street and the Hamline-Midway Library following the protocols outlined in ASTM method C1701, which is included in **Appendix F**. The following section provides a brief summary of those methods.

Data Collection

Infiltration tests were conducted according to the modified ASTM C1701 methods for measuring infiltration rates. Five to nine tests were conducted at random locations over each of the permeable surfaces to develop an average infiltration rate measurement. Tests were taken at locations that remained consistent year to year and included a combination of high and low traffic areas. At each test location a pre-wet test was conducted, followed by two infiltration tests. The two infiltrations tests were averaged to generate the infiltration rate for each location. If after twenty five minutes of monitoring during a pre-wet test no infiltration was observed, the test was aborted and no subsequent tests were completed.

Photo 2-10: Permeable Pavement Infiltration Test

3 Beacon Bluff

This system, shown in **Figure 3-1**, is owned and operated by the City of Saint Paul. The Saint Paul Port Authority contributed financially to the project and oversaw its construction. Volume reduction credits were split between the City of Saint Paul and the Saint Paul Port Authority based on the respective financial contribution. Performance monitoring of the system has been conducted since 2012.

The system consists of three parallel 215 foot-long, ten-foot-diameter perforated metal underground chambers constructed beneath an infiltration basin. Stormwater is routed into the infiltration basin from a diversion structure in the storm sewer along Duchess Street and from two other storm sewer outfalls. Additionally, there is a small pond to the west of the underground infiltration system which drains directly into the underground chamber. An outlet structure, which is connected directly to the underground chamber, conveys stormwater back to the storm sewer when the system is full. Rainfall monitoring for the site is conducted on the roof of Wilder Recreation Center located 0.8 miles to the west of the system.

Table 3-1: Beacon Bluff BMP Details

Total Drainage Area to BMP	143.6 acres
Year Constructed	2011
Total Construction Cost	$980,000
Storage Volume	159,350 cu-ft
Volume Reduction Credit Received by the City of Saint Paul	116,435 cu-ft
Volume Reduction Credit Received by Saint Paul Port Authority	42,925 cu-ft

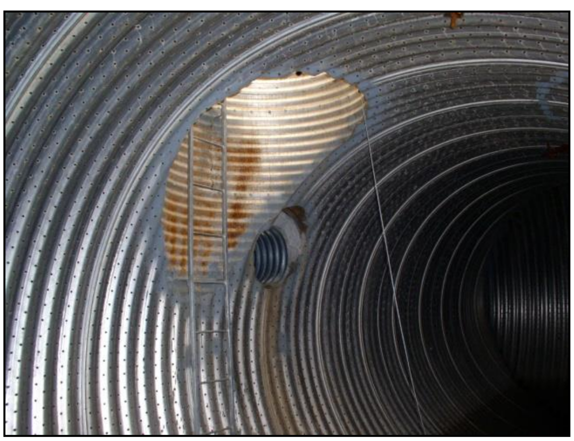


Photo 3-1: Underground perforated storage chambers and access port

Photo 3-2: Infiltration basin located above storage chambers

Water Level and Infiltration Rate Monitoring

Infiltration rates of the soil in the west infiltration basin (rain garden) and the underground system (BMP pipe) were measured by using continuous water level loggers placed in piezometers. Groundwater elevation was also measured in four locations at the site. Water level elevations, within the system and groundwater, and daily rainfall totals are presented on **Chart A.1** and **A.2** of **Appendix A**. Level monitoring in the infiltration gallery indicated a level range of 128.3-141.6 Saint Paul City Datum (SPCD) (bottom and top elevations of the infiltration gallery are 124.5 and 134.5 SPCD, respectively). This confirms that the system did not completely drain throughout the 2015 monitoring period. Monitoring in the outlet control structure of the system confirmed that system water levels exceeded the outlet control structure weir elevation five times during the monitoring season. On July 6th, July 13th, September 17th, November 11th, and November 17th a portion of volume from the underground system was conveyed back to the main stormsewer line. Groundwater elevations at the site were a minimum of thirteen ft below the bottom of the infiltration gallery for the 2015 season.

Infiltration rates are presented on **Charts A.3** and **A.4** of **Appendix A**. In 2015, average infiltration rates for the rain garden and BMP pipe were 0.29 and 0.30 inches per hour (in/hr) respectively, as shown in **Table 3-2**. These infiltration rates are below the MSWM recommended infiltration rate for SP soils of 0.8 in/hr and the design infiltration rate of 2.5 in/hr.

Infiltration rate trends for discrete 0.5 foot intervals for the rain garden (IR-33) and BMP pipe (IR-32) are depicted on **Charts A.5** and **A.6** respectively. Historical infiltration rates are also listed in **Table 3-2** below. Since 2012, average adjusted infiltration rates in the rain garden have decreased from 2.9 in/hr to 0.29 in/hr. Infiltration rates in the BMP pipe have also decreased from 2.6 in/hr to 0.30 in/hr. The decline in infiltration rates in both the rain garden and BMP are likely attributed to sediment accumulation. As mentioned above, standing water was observed in the infiltration gallery, and monitoring data indicated that BMP levels did not drop below five ft. A layer of 0.5 to 1.5 ft of sediment has been observed across the rain garden basin. In 2015, the rain garden was free of standing water for 24 out of 218 days monitored, primarily in early May and October.

Table 3-2: Beacon Bluff Infiltration Rates

Location	Average Infiltration Rate (in/hr)			
	2012	2013	2014	2015
Beacon Bluff Rain Garden (IR-33)	2.9	0.85	0.70	0.29
Beacon Bluff BMP Pipe (IR-32)	2.6	0.57	0.64	0.30

Volume Reduction Monitoring

Stormwater flowing into the BMP was measured in the Duchess Street diversion structure and at the west pond inlet. Volume that bypassed the system was measured with a flow meter downstream of the Duchess Street diversion structure. Inflow volume from the east pond was modeled using upstream flow data and the ratio of watershed areas. In addition, a level logger was placed in the outlet structure to measure the depth of any runoff that passed through the system outlet. Flow Rates for the three monitored locations and daily rainfall are depicted on **Chart B.1** of **Appendix B**. A volume reduction summary is provided with the pollutant loading data in Table **C.2** of **Appendix C**.

In 2015, total runoff to the Beacon Bluff system was 2,915,434 cubic feet (cu-ft). Of that volume, 1,265,473 cu-ft was captured and infiltrated by the system, resulting in a volume reduction of 43 percent. These totals are presented in **Table 3-3** below. Storm specific runoff volumes with rain are provided in the pollutant loading table discussed in the Pollutant Removal Monitoring Section.

Table 3-3: Beacon Bluff Volume Reduction

Monitoring Period	4/18/2015 – 11/12/2015		
Total Rainfall		30.11	in.
Diversion Structure Water Balance			
Runoff Volume:		2,778,394	cu-ft
Bypassed Volume:		1,649,961	cu-ft
Volume Diverted into BMP:		1,128,433	cu-ft
Beacon Bluff Rain Garden and Infiltration Gallery Inputs			
Inflow Volume from Diversion Structure:	SubWSHD A	1,128,433	cu-ft
Inflow Volume from West Pond:	SubWSHD B	71,429	cu-ft
Inflow Volume from East Pond :	SubWSHD C	65,611	cu-ft
Beacon Bluff System Performance			
Total Runoff Volume:		2,915,434	cu-ft
Total Runoff Volume Captured:		1,265,473	cu-ft
Percent of Total Runoff Volume Captured:		43	%
Maximum Percentage of Storage Volume Utilized:		100	%

Pollutant Removal Monitoring

A water quality sampler was placed in the Duchess Street diversion structure to collect samples during runoff events. The sampler was paced to collect samples at equal volume intervals to provide a representative sampling of each storm event. Samples for each event were tested as a composite to provide EMC during each event for each parameter analyzed. Grab samples were collected in the diversions structure near the automated sampler during three runoff events and tested for E Coli. See **Charts C.1** and **C.2** of **Appendix C** for the complete water quality summary and pollutant loading calculations.

Table 3-4 below provides a load reduction summary for the loading parameters defined in NPDES Permit issued to the city in addition to ortho-phosphate. In 2015, pollutant load reductions ranged from 35.7 percent for Nitrate + Nitrite as N to 52.7 percent for TP. During the monitoring period 8,581 pounds of TSS and 31.8 pounds of TP were captured, and over the past four years of monitoring, a total of 49,557 pounds of TSS and 206 pounds of TP have been captured at the Beacon Bluff Site.

Table 3-4: Beacon Bluff Load/Capture Summary

Monitoring Period		4/18/2015 – 11/12/2015		
Total Rain		30.11 in.		
Water Quality Parameter	**Flow Weighted Average (mg/L)**	**Total Pollutant Load (lbs.)**	**Load Captured (lbs.)**	**Percent Reduction %**
Total Suspended Solids	98.5	17,729	8,581	48.4
Volatile Suspended Solids	13	2,282	1052	46.1
Total Phosphorus	0.34	60.3	31.8	52.7
Ortho-phosphate	0.11	19	9.2	48.3
Chlorides	5.9	1,055	500	47.4
Total Kjeldahl nitrogen	1.96	351	175	49.8
Nitrate + Nitrite as N	0.2	36	13.5	37.5

Maintenance Inspection

Sediment depths in the pretreatment structure and in the underground infiltration system were measured during site visits to determine performance and maintenance needs. As shown in **Table 3-5**, sediment depths in the pretreatment device were approximately 0.1- 0.2 ft throughout the 2015 season. Floatables (mostly garbage) were observed in the pretreatment structure on most visits and within the rain garden. The western rain garden overflow structure was observed to have significant sediment and debris accumulation on the 6/25/2015 visit and was subsequently scraped clean. Sediment accumulation ranging from 0.5 ft to 1.5 ft in depth was observed across the entire rain garden basin in 2015.

Standing water was observed in the underground infiltration gallery on all visits with depths ranging from 5-8 ft. As noted in the **Water Level and Infiltration Rate Monitoring Section**, the underground infiltration gallery did not drain to empty at all during the 2015 season and system levels exceeded the outlet weir elevations five times. During the last visit in 2014 when the system was completely empty, 0.25 ft of sediment was observed within the grooves of the corrugated pipe. See **Appendix D** for the **Photolog.**

Table 3-5: Beacon Bluff Maintenance Inspections

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)[1]	Standing Water in Infiltration Gallery?	Observations
6/25/2015	0.1	NM	Y (7 ft)	Floatables present in Pre-treatment and rain garden. Sediment and debris covering rain garden overflow structure. 0.5 to 1.5 ft of sediment accumulation throughout the rain garden basin.
7/22/2015	0.1	NM	Y (5 ft)	Floatables present in Pre-treatment and rain garden. 0.5 to 1.5 ft of sediment accumulation throughout the rain garden basin.
9/11/2015	0.1	NM	Y (7.25 ft)	Floatables present in Pre-treatment and rain garden. 0.5 to 1.5 ft of sediment accumulation throughout the rain garden basin.
11/09/2015	0.2	NM	Y (8 ft)	Floatables present in Pre-treatment. Significant sediment accumulation in rain garden

1-Not Measured – A visual observation of sediment levels in the infiltration galley could not be completed due to the presence of standing water. The corrugated pipe bottom could not be accurately measured for sediment depth.

4 Hillcrest Knoll

This system, shown in **Figure 4-1**, is owned and operated by the City of Saint Paul. It was constructed in 2012 to help address local flooding issues and to contribute additional volume reduction credits to the City's general credit bank. Performance monitoring of the system has been conducted since 2013.

The system consists of an underground pipe gallery infiltration system containing nine parallel 275-foot-long, 60-inch-diameter perforated HDPE pipes. Stormwater runoff within the 37.1 acre subwatershed is directed to the system via a diversion structure in the trunk storm sewer system along Flandrau Street. When the system has reached its storage capacity, runoff continues to flow downstream through the storm sewer. Pretreatment for this design includes a Vortechs hydrodynamic separator and an isolator row within the storage gallery. Rainfall monitoring for this site is conducted at the Frost Lake Elementary School which is located approximately 0.4 miles west of the system.

Table 4-1: Hillcrest Knoll BMP Details

Total Drainage Area to BMP	37.1 acres
Year Constructed	2012
Total Construction Cost	$1,175,00
Total Storage Volume	85,500 cu-ft
Volume Reduction Credit Received by the City of Saint Paul	85,500 cu-ft

Photo 4-1: 60" Perforated HDPE pipes during system construction

Infiltration Rate Monitoring

Water elevation was monitored in the system at two locations and groundwater at one using continuous water level loggers placed in piezometers and pvc within the BMP. Water levels, within the BMP pipe and groundwater, and daily rainfall totals are presented on **Charts A.7** and **A.8** of **Appendix A**. In 2015, the float for the bypass gate valve was inadvertently stuck in the closed position, which diverted a majority of water directly downstream instead of allowing flow into the BMP pipe until August 11, 2015. Subsequent to maintenance of the float valve, levels in the infiltration gallery ranged from 218.5 to 228.8 SPCD (bottom and top pipe elevations are 218.3 and 223.55 SPCD, respectively). Following maintenance of the float, the infiltration gallery did not completely drain to empty for the remainder of the 2015 monitoring season. Groundwater levels were documented at elevations within infiltration gallery, consistent with previous years monitoring (See **Chart A.8**)

2015 infiltration rates and infiltration rate trends are presented on **Charts A.9** and **A.10** of **Appendix A,** respectively**.** In 2015, the average infiltration rate for the BMP pipe was 0.92 in/hr in comparison to 0.52 in/hr in 2014 and 0.67 in/hr in 2013 (**Table 4-2**). This is above the MSWM recommended infiltration rate for SP soils of 0.8 in/hr, but below the design infiltration rate of 2 in/hr. The calculated increase in infiltration rates may be a reflection of fewer flow events in which the infiltration rates were averaged over. As shown on **Chart A.10**, incremental infiltration rates for water depths of 2 – 7 ft are similar to infiltration rates calculated in 2013 and 2014. Water level within the BMP reached a depth of 7 – 8 ft during one flow event, which may have biased the infiltration rate for that interval and the overall average for 2015.

Table 4-2: Hillcrest Knoll Infiltration Rates

Location	Average Infiltration Rate (in/hr)		
	2013	2014	2015
Hillcrest Knoll BMP Pipe	0.67	0.52	0.92

Volume Reduction Monitoring

Flow meters were installed upstream and downstream of the diversion structure located on Flandrau Street to determine the volume bypassing the system. Flow rates and daily rainfall are depicted on **Chart B.2** of **Appendix B**. Flow event summary data is included on **Chart B.3** of **Appendix B**.

In 2015, total runoff for the Hillcrest Knoll system was 1,119,563 cu-ft. Of that volume, 257,283 cu-ft was captured and infiltrated by the system, resulting in an overall volume reduction of 23 percent (**Table 4-3**). The float for the bypass gate valve was found to be stuck in the closed position until August 11th, 2015. During that time the average volume reduction was 13 percent. Following maintenance of the float, the volume reduction percentage increased to 64 percent.

Table 4-3: Hillcrest Knoll Volume Reduction

Monitoring Period	5/6/2015 - 11/11/2015
Total Rainfall	28.3 in.
Diversion Structure Water Balance	
Runoff Volume:	1,119,563 cu-ft
Bypassed Volume:	862,318 cu-ft
Volume Diverted into BMP:	257,283 cu-ft
Hillcrest Knoll Park System Performance	
Total Runoff Volume	1,119,563 cu-ft
Total Runoff Volume Captured	257,283 cu-ft
Percent of Runoff Volume Captured:	23.0 %
Maximum Percentage of Storage Volume Utilized:	100 %

Maintenance Inspection

Sediment depths in the pretreatment structure and in the underground infiltration system were measured during site visits to determine performance and maintenance needs. As shown in **Table 4-5**, the sediment measured in the pretreatment device was 0.8 to 1.2 ft of soft material. Garbage was observed occasionally in the pretreatment structure, although none was observed in the infiltration gallery. Standing water was observed in the infiltration gallery during the September and November inspections.

On August 11, 2015 the float for the bypass gate valve was found to be stuck in the closed position. The float was manually forced down and water was observed flowing to the BMP. The float was found stuck again on November 10, 2015 and manually forced down during that visit. See **Appendix D** for the **Photolog.**

Table 4-5: Hillcrest Knoll Maintenance Inspections

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)[1]	Standing Water in Infiltration Gallery?	Observations
4/20/2015	NM	0	N	(Level logger installation) Infiltration gallery 2-3 inches of water, some leaves. No major sediment accumulation.
6/26/2015	0.8	0.1	Y (<1.0ft)	Small amount of standing water observed in BMP. Pre-treatment material was soft/mucky, no garbage or floatables observed.
7/23/2015	1.2	0.34	Y (<1.0 ft)	Small amount of standing water observed in the gallery, overall clear of debris with some sediment observed. Pre-treatment accumulation was very soft material/muck.
8/11/2015	NM	NM	NM	System bypass float value was found to be stuck. Manually forced float out of the stuck position to open the gate. Water observed flowing into the BMP.
9/15/2015	1.0	NM	Y (4.7 ft)	Standing water observed in the infiltration gallery, some leaves and grass. Pre-treatment material is soft/muck. Trace floatables observed.
11/10/2015	1.1	NM	Y (2.3 ft)	Standing water observed in the infiltration gallery, some leaves and grass. Pre-treatment material is soft/muck. Trace floatables observed. Float for bypass gate value was found stuck in the closed position and was manually forced down.

5 St. Albans Street

This system, shown in **Figure 5-1**, was constructed in 2010 to provide volume reduction along the Central Corridor light rail transit way. Volume and flow have been monitored at the site since 2012, with water quality being added in 2014.

A manhole structure positioned along the main storm sewer under Aurora Avenue diverts stormwater into the infiltration system via a 30-inch elliptical pipe. The system is also connected to the University Avenue storm sewer system. Any runoff that does not get treated by the infiltration trenches and tree planters along University Avenue is directed to this system. When the system reaches its storage capacity, water flows west through the existing storm sewer system. The system includes a pretreatment structure comprised of a grit chamber and baffled weir to provide settling for sediment and skimming. Rainfall monitoring for the site is conducted on the roof of Fire Station 18, located across the street from the BMP.

Table 5-1: St. Albans Street BMP Details

Total Drainage Area to BMP	22.2 acres
Year Constructed	2010
Total Construction Cost	$381,903
Storage Volume	31,189 cu-ft
Volume Reduction Credit Received by the City of Saint Paul	31,189 cu-ft

Photo 5-1: 48" perforated HDPE storage chambers at the time of construction

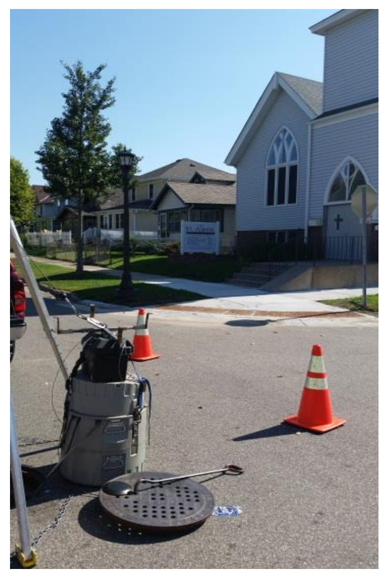


Photo 5-2: Saint Albans water quality sampler at the BMP diversion structure

Infiltration Monitoring

BMP water level was monitored in the access manhole at the northwest corner of the system. 2015 water elevations and daily rainfall is provided on **Chart A.11** of **Appendix A.** Water level monitoring indicated that the infiltration gallery reached full capacity during two occasions in 2015. Every flow event monitored in 2015 resulted in the infiltration gallery drawing down to empty in less than a 24 hour period.

Infiltration rates are presented on **Chart A.12** of **Appendix A**. In 2015, the average infiltration rate of the BMP pipe was 55.3 in/hr (**Table 5-2)**, which is above the MSWM recommended infiltration rate for SP soils of 0.8 in/hr and the design infiltration rate of 26.0 in/hr. Infiltration rate trends for the Saint Albans Street BMP pipe are depicted on **Chart A.13**. Infiltration rates have exceeded the design rate every year since monitoring was initiated at the Site in 2012.

Table 5-2: St. Albans Street Infiltration Rate

	Average Infiltration Rate (in/hr)			
Location	**2012**	**2013**	**2014**	**2015**
St. Albans Street BMP Pipe	38.5	35.7	64.8	55.3

Volume Reduction Monitoring

Two flow meters were installed in the diversion sump located in the intersection of St. Albans Street and Aurora Avenue. One was installed in the elliptical pipe to capture flows into the system from the south. The other was installed in the downstream storm sewer to measure flows bypassing the system to the west. An additional flow meter was installed in the 30-inch storm sewer near the corner of Saint Albans Street and University Avenue to capture flows into the system from the north. Flow rates and daily rainfall are depicted on **Chart B.4** of **Appendix B**.

In 2015, total runoff for the St. Albans Street system was 758,754 cu-ft. Of that volume, 753,516 cu-ft was captured and infiltrated by the system, resulting in a volume reduction of 99.3 percent (**Table 5-3**). Nearly equal volumes were conveyed to the BMP by the diversion and the University Avenue inlet pipe. Storm specific runoff volumes and pollutant loads are provided in **Table C.4** of **Appendix C**.

Table 5-3: St. Albans Street Volume Reduction

Monitoring Period	04/24/15 – 11/12/15	
Total Rainfall	26.8	in
Diversion Structure Water Balance		
Runoff Volume:	406,352	cu-ft
Bypassed Volume:	5,199	cu-ft
Volume Diverted into BMP:	401,153	cu-ft
St. Albans and University Volume	352,362	cu-ft
St. Albans Park System Performance		
Total Runoff Volume	758,754	cu-ft
Total Runoff Volume Captured	753,516	cu-ft
Percent of Runoff Volume Captured:	99.3	%

<u>Pollutant Removal Monitoring</u>

An automated water quality sampler was placed in the diversion structure at St. Albans Street and Aurora Avenue to collect samples during runoff events. The sampler was paced to collect samples at equal volume intervals to provide a representative sampling of each storm event. Composite samples for each event were analyzed to provide EMC's for each event for each parameter analyzed. Grab samples were also collected during three runoff events. The St. Albans Street water quality data and pollutant loading calculations for 2015 are provided in **Table C.3** and **C.4 of Appendix C**.

Table 5-4 below provides a load reduction summary for the loading parameters defined in NPDES Permit issued to the City in addition to ortho-phosphate. In 2015, load reductions for all loading parameters ranged from 98.6 to 99.7 percent. During the monitoring period, 4,251 pounds of TSS and 10.9 pounds of TP were captured.

Table 5-4: Saint Albans Street Pollutant Load Reduction

Monitoring Period		4/18/2015 – 11/12/2015		
Total Rain		30.11 in.		
Water Quality Parameter	**Flow Weighted Average (mg/L)**	**Total Pollutant Load (lbs.)**	**Load Captured (lbs.)**	**Percent Reduction %**
Total Suspended Solids	91.8	4,311	4,251	98.6
Volatile Suspended Solids	17.3	822	811	98.6
Total Phosphorus	0.20	11	10.9	98.8
Ortho-phosphate	0.074	3.4	3.4	98.6
Chlorides	5.7	276	272	98.7
Total Kjeldahl nitrogen	1.57	53.8	53.6	99.7
Nitrate + Nitrite as N	0.24	11.6	11.4	98.6

Maintenance Inspection

Sediment depths in the pretreatment structure and in the underground infiltration system were measured during site visits to determine performance and maintenance needs. As shown in **Table 5-5**, minimal sediment was observed in both the pretreatment device and infiltration gallery. A significant amount of garbage was observed in the pretreatment structure and to a lesser extent in the infiltration gallery during the July 29, 2015 visit, but on no other visit. Water level monitoring in the in the infiltration gallery confirms that the system is regularly drawing down to empty, which is consistent with no standing water observed during most BMP inspection visits. See **Appendix D** for the **Photolog.**

Table 5-5: St. Albans Maintenance Inspections

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)	Standing Water in Infiltration Gallery?	Observations
4/17/2015	0.1	0.1	N	(Level logger installation) No standing water in infiltration gallery, but some silt and debris observed. Minimal sediment in pre-treatment.
6/25/2015	0.2	0.1	N	Some trash observed in pre-treatment structure, none observed in infiltration gallery. Trace amounts of sediment in pre-treatment and infiltration gallery.
7/29/2015	0	0.16	Y (<0.5 ft)	Large amount of trash observed in pre-treatment and infiltration gallery. Minimal sediment observed in both. Small amount of standing water in infiltration gallery
9/11/2015	0.1	NM	N	No standing water observed, no trash and minimal sediment in infiltration gallery and pre-treatment structure
11/10/2015	0.1	0.1	N	No standing water observed, no trash and minimal sediment in infiltration gallery and pre-treatment structure

6 Hampden Park

The Hampden Park infiltration gallery, shown in **Figure 6-1,** was constructed in 2014. The system consists of eight parallel perforated pipes that are five ft in diameter and range in length from 40 to 100 ft. Runoff is routed to the pretreatment system via a 24" RCP from main storm sewer near Hampden and Raymond Avenues. From that location, stormwater enters a pretreatment structure which consists of a box culvert section and baffled weir to provide skimming and settling of runoff prior to entering the infiltration chamber. The infiltration gallery receives flow from a second inlet location along Raymond Avenue, farther to the north. When the system reaches full capacity, stormwater is routed back to the storm sewer via a 24" pipe from the southeast side of the system. Monitoring of the system began in September 2014.

Photo 6-1: Hampden Park BMP Construction

Table 6-1 Hampden Park BMP Details

Total Drainage Area to BMP	7.8 acres
Year Constructed	2014
Total Construction Cost	$687,132
Total Storage Volume	31,808 cu-ft
Volume Reduction Credit Received by the City of Saint Paul – Public Works	24,908 cu-ft
Volume Reduction Credit Received by the City of Saint Paul – Parks and Recreation	6,900 cu-ft

Infiltration Monitoring

Water levels were monitored in the system at the in-rock permanent monitoring location as well as three groundwater locations at the site. 2015 water levels and daily rainfall is provided on **Chart A.14 and A.15 of Appendix A.**

Levels monitored at the in-rock location recorded change in level two times during the monitoring season. On July 12 and November 3, 2015 BMP levels peaked at 2.25 and 2.0 ft of depth, respectively. The flow associated with those events was 27,800 cu-ft and 42,600 cu-ft. Flow monitoring at the site indicated bypass events occurring 11 times during the season which would require the pipes to be at full capacity (>5 ft). The data suggests that the in-rock monitoring location is not reflective of bmp pipe level and infiltration. An additional pipe monitoring location was installed in 2016. Groundwater monitoring data indicated a minimum separation of 10 ft from the bottom of the infiltration gallery.

Volume Reduction

Two flow meters were installed at Hampden Park. One meter was located in the 24" RCP diverting flow from the main storm to the BMP pipe from the intersection of Hampden and Raymond Avenues. The second meter was installed in the system outlet pipe to monitor flow diverted back to the main sewer line. Hampden Park flow rates and daily rainfall are depicted on **Chart B.5 of Appendix B**. The 2015 flow event summary is provided on **Chart B.6 of Appendix B**.

In 2015, total runoff for the Hampden Park system was 254,258 cu-ft. Of that volume, 93.1% was captured and infiltrated by the system (**Table 6-2**). During the monitoring season, 11 flow events resulted in BMP levels exceeding the bypass pipe elevation, diverting a portion of the flow back to the main storm sewer line. A total of 2,014 cu-ft was diverted back to the main sewer line. The largest flow event, recorded on November 3, 2015 totaling 42,600 cu-ft, did not correspond to a rainfall event.

Table 6-2: Hampden Park Volume Reduction

Monitoring Period	4/17/2015 – 11/09/2015	
Total Rainfall	20.8	in.
Hampden Park System Performance		
Total Runoff Volume	256,821	cu-ft
Total Runoff Volume Captured	239,499	cu-ft
Percent of Runoff Volume Captured	93.3	%

Maintenance Inspection

Sediment depths in the pretreatment structure and in the underground infiltration system were measured during site visits to determine performance and maintenance needs. As shown in **Table 6-3**, minimal sediment was observed in both the pretreatment device and infiltration gallery.

Table 6-3: Hampden Park BMP Maintenance Inspection

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)[1]	Standing water in Infiltration Gallery?	Observations
6/29/2015	0.1	0.0	N	Some garbage and organic debris in pretreatment. Minimal sediment observed in pretreatment, none in the infiltration gallery.
7/23/2015	0.2	0.0	N	Some garbage and organic debris in pretreatment. Minimal sediment observed in pretreatment, none in the infiltration gallery.
11/09/2015	0.1	0.0	N	Some garbage and organic debris in pretreatment. Minimal sediment observed in pretreatment, none in the infiltration gallery.

7 Arundel Street

This system, shown in **Figure 7-1**, was constructed in 2011 to provide volume reduction along the Central Corridor light rail transit way. A sump in the main storm sewer in Arundel Street diverts flow into the infiltration system via an 18-inch pipe. When the system reaches full capacity, water begins bypassing the diversion sump and continues downstream to the north. The system includes a pretreatment structure which consists of a box culvert section and baffled weir to provide skimming and settling of runoff prior to entering the infiltration chamber. Infiltration rates at the site have been monitored since 2012.

Table 7-1: Arundel Street BMP Details

Total Drainage Area to BMP	4.9 acres
Year Constructed	2011
Total Construction Cost	$76,300
Storage Volume	4,521 cu-ft
Volume Reduction Credit Received by the City of Saint Paul	4,521 cu-ft

Infiltration Monitoring

BMP pipe water level was monitored at the access manhole at the south end of the system. Water levels and daily rainfall are presented on **Chart A.16 of Appendix A.**

The BMP pipe infiltration rates are presented on **Chart A.17 of Appendix A**. In 2015, the average infiltration rate of the BMP pipe was 0.42 in/hr (**Table 7-2)**, which is less than the MSWM recommended infiltration rate for SP soils of 0.8 in/hr, and the design infiltration rate of 17.6 in/hr. Infiltration rate trends are depicted on **Chart A.18.** The average infiltration rate has decreased significantly every year since 2012, which is likely a result of sediment accumulation observed within the BMP. The City staff completed jet and vacuum maintenance on the BMP pipe on July 29, 2015. The average infiltration rate for treatment events following the BMP maintenance was 0.37 in/hr, indicating no direct increase in infiltration as a result of jetting and vacuuming. Additional details regarding the BMP maintenance are described in the following section.

Table 7-2: Infiltration Rates

Location	Average Infiltration Rate (in/hr)				
	2012	2013	2014	2015 (Annual)	2015 (Post Jet/vac)
Arundel BMP Pipe	8.0	2.43	1.64	0.42	0.37

Maintenance Inspection

Sediment depths in the pretreatment structure and in the underground infiltration system were measured during site visits to determine performance and maintenance needs. As shown in **Table 7-3**, sediment depths in the pretreatment device and infiltration gallery ranged from 0.1 to 2.0 ft and 0 to 1.25 ft. During the July 29, 2015 site visit, City staff was on-site completing jet and vacuum maintenance on the infiltration gallery. Prior to maintenance, floatables (garbage) covered the entire water surface and gallery bottom. During the site visit that was subsequent to maintenance, the infiltration gallery and pre-treatment were documented as free from silt and garbage. See **Appendix D** for the **Photolog.**

Table 7-3: Arundel Maintenance Inspections

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)[1]	Standing water in Infiltration Gallery?	Observations
4/23/2015	NM	1.0	N	(Level logger installation) Large amount of trash and silt/muck with in BMP.
6/26/2015	2.0	1.25	Y (2 ft)	Large amount of trash/sediment in the pre-treatment and infiltration gallery. 2 ft of standing water/muck.
7/29/2015	NA	NM	NA	City staff completing jet/vac maintenance of the infiltration gallery upon arrival.
9/10/2015	0.1	0.0	Y (3.5 ft)	Some leaves in bmp. No other trash/muck observed. Some standing water observed in infiltration gallery
11/10/2015	0.3	0.1	Y (3 ft)	No standing water observed, no trash and minimal sediment in infiltration gallery and pre-treatment structure

8 Flandrau-Hoyt Pond

Water elevations were monitored at Flandrau – Hoyt Pond to provide data that will help guide future improvements at that location. The pond location is provided as **Figure 8-1.**

Photo 8-1: Flandrau-Hoyt Pond outlet

Photo 8-2: Flandrau-Hoyt Pond inlet on 09/17/2015

Water Elevation Monitoring

A level logger was installed near the pond outlet and configured to record elevations once per hour. Pond water elevations and rainfall are presented on **Chart A.19 of Appendix A.** During the 2015 monitoring season, water levels in the pond ranged from 200.5 on July 20 to 214.89 on July 13, 2015. The July 13, 2015 rain event, totaling 2.11 inches resulted in a level bounce of 14 ft in the pond in two hours. The level in the pond decreased to pre-event levels within 24 hours. The emergency overflow elevation of the pond is 216.50 ft SPCD.

9 Flandrau-Case Pond

Water elevations were monitored at Flandrau – Case Pond to provide data that will help guide future improvements at that location. The pond location is provided as **Figure 9-1**. Stormwater flow through the site occurs through a preferential drainage channel through the site to the outlet control structure. When flow exceeds the capacity of the channel, it spills into an adjacent flood plain (See **Photos 9-1 and 9-2**).

Photo 9-1: Level logger configuration and outlet control structure

Photo 9-2: Rain event on September 17, 2015

Water Elevation Monitoring

A level logger was installed near the outlet control structure at Flandrau-Case Pond and configured to record elevations once per hour. Water elevations and rainfall are provided on **Chart A.20 of Appendix A.** The monitoring equipment was stolen mid-season, therefore the reported monitoring period is April 20 through July 23, 2015. During the monitoring season water levels reached at least one foot above the sensor on 12 occasions. Rainfall totals producing runoff volumes large enough to reach the senor location ranged from 0.22-2.16 inches. Maximum level observed at the site was 2.0 ft above the sensor on May 3, 2015 from a 0.38 inch rain event. Water levels during the July 6 and July 13, 2015 rain events (2.16 inch and 2.11 inches) increased to 1.0 and 1.2 ft, respectively.

10 Trout Brook Nature Sanctuary

The Trout Brook Nature Sanctuary (TBNS) (**Figure 10-1**) is a 42 acre site located between Norpac Road and Maryland Avenue, west of I-35E. The objective of the construction effort, which was finalized in 2015, was to create a nature preserve in the heart of a heavily urbanized area. The focal points of the plan included expanding the Trout Brook Regional Trail and daylighting the Trout Brook creek, which had previously been filled in and routed through underground sewer. The development of the sanctuary also included a series of stormwater management features including wetlands and ponds constructed with iron enhanced sand for additional water treatment. Volume reduction credits for the stormwater features were split between the City of Saint Paul Public Works and the City of Saint Paul Parks and Recreation departments based on the respective financial contribution.

Photo 10-1: Magnolia Pond Iron-Enhanced Sand Bench

Photo 10-2: Jenks Pond Iron-Enhanced Sand Bench

Stormwater monitoring at TBNS was a collaborative effort by the City of Saint Paul and Capitol Region Watershed District (CRWD) in 2015. The City completed performance monitoring at three iron enhanced ponds at the Site: Maryland Pond, Magnolia Pond, and Jenks Pond. Removal efficiency of the iron enhanced sand was determined by collecting samples simultaneously from the within the pond and the pond outlet control structure. A flow sensor was installed in the outlet control structure to provide treatment volume for load reductions. Rainfall monitoring for the site is conducted on the roof of Wilder Recreation Center. CRWD conducted monitoring of the water quality and volume reduction at the pond diversion structures as well as the site creek that had been day lighted. Preliminary data for those locations was available at the time this report was produced, although that data is not considered final.

At each of the three pond locations, stormwater is conveyed to the basin from individual diversion structures along the forty-two inch (42") main storm sewer line. Prior to the pond, the flow is routed through a Vortechs pre-treatment structure for particle settling. As the level in the pond rises, the water gravity flows through a sand filtration bench that has additional iron content. The iron-enhanced sand provides a mechanism to remove soluble reactive phosphorus (SRP), a dissolved bio-available form of phosphorus, which is not effectively removed by settling pre-treatment devices. Beneath the sand bench is eight inch (8") drain tile to convey the treated water to the outlet control structure of the pond.

Table 10-1: Trout Brook Nature Sanctuary Site Details.

Total Drainage Area to BMP	144.4 acres
Year Constructed	2015
Total Construction Cost	\$4 million ($1.53 million contributed by City of Saint Paul Public Works)
Storage Volume	155,571 cu-ft
Volume Reduction Credit Received by the City of Saint Paul Public Works	103,455 cu-ft
Volume Reduction Credit Received by the City of Saint Paul Parks and Recreation	5,445 cu-ft

Water Level Monitoring

Water level was monitored at Maryland, Magnolia and Jenks Ponds from within the outlet control structure of each pond. Water levels with daily rainfall are provided on **Charts A.21**, **A.22** and **A.23** of **Appendix A**. A summary of water elevations is presented in **Table 10-2** below. Water levels at Maryland and Magnolia Ponds were recorded at elevations near the weir overflow elevation. An overflow event likely occurred on September 17, 2015 at the Magnolia Pond site based on negative pollutant reduction observed for all three monitored parameters for that event. Minimum water elevations for Maryland and Magnolia were just below the normal water elevation for those sites. During the season, it was discovered that flow from the main sewer line was not being conveyed properly to Jenks Pond. The maximum water elevation recorded at Jenks Pond was 0.5 ft less than the normal water elevation.

Table 10-2: TBNS Water Level Summary (ft SPCD)

Pond Location	Minimum Water Elevation	Normal Water Level	Maximum Water Elevation	Weir overflow Elevation
Maryland	116.3	116.4	118.5	119
Magnolia	123.4	123.8	125.89	126.0
Jenks	93.14	95.5	95.02	98.0

Treatment Event and Pollutant Removal Monitoring

Water quality summary charts for Maryland, Magnolia, and Jenks Ponds are provided on **Tables C.5, C.7, and C.9 of Appendix C.** Water quality concentrations for SRP were near or below detection levels for many samples in 2015. Paired samples that show negative pollutant reduction can be attributed to both samples being at or near detection levels. Negative pollutant reductions for the September 17, 2015 flow event at Magnolia Pond are a result of the pond level exceeding the outlet control weir elevation.

Treatment flow rates and rainfall are provided on **Charts B.9**, **B.10**, and **B.11**of **Appendix B.** Event flow and pollutant loads are provided on **Charts C.6, C.8 and C.10 of Appendix C**. A summary of that information can be found in **Tables 10-3** and **10-4** below. Maryland Pond treated that greatest volume of stormwater, recording 754,516 cu-ft in the outlet control structure. In comparison, Magnolia and Jenks pond treated 200,393 cu-ft and 3,093 cu-ft respectively. As mentioned in the section above, minimal flow was diverted to the Jenks Pond, resulting in only four treatment events in 2015.

At Maryland Pond, 3.98 of TP and 1.84 pounds of SRP were removed by the iron-enhanced media (54 and 69 percent removal efficiency). The TP and SRP load reduction at Magnolia was 1.76 and 0.43 pounds, respectively (37 and 23 percent removal efficiency). This pollutant reduction is only reflective of the treatment that occurs from the pond water near the outlet control structure to the treatment system outlet. The overall total phosphorus load reduction is anticipated to be higher as a result of the Vortech's pre-treatment chamber as well as the settling occurring between the pond inlet and the pond sampling point. Preliminary laboratory data collect at the Maryland Pond diversion (provided by CRWD) indicates an overall removal efficiency for the Maryland Pond of 78% of TP and 90% of SRP (based on non-weighted averages in **Table 10-4**).

Table 10-3 TBNS Event and Load Reduction Summary

Pond Location	Treatment Summary		Total Phosphorus		Soluble Reactive Phosphorus	
	Total Flow (cu-ft)	Total Treatment Hours	Total Load Captured (lbs)	Load Reduction %	Total Load Captured (lbs)	Load Reduction %
Maryland	754,516	2,964	3.98	54	1.84	69
Magnolia	200,393	644	1.76	37	0.43	23
Jenks[1]	3,093	102	NA	NA	NA	NA

1- Pollutant load reduction calculations were not completed due to the limited data set at Jenks Pond.

Table 10-4 TBNS Water Quality Summary

Pond Location	Total Phosphorus (mg/L)			Soluble Reactive Phosphorus (mg/L)		
	Diversion[1] AVG	Pond AVG/FWA	OCS AVG/FWA	Diversion AVG	Pond AVG/FWA	OCS AVG/FWA
Maryland	0.33	0.21 / 0.164	0.07 / 0.076	0.121	0.044 / 0.059	0.012 / 0.018
Magnolia	NA	0.44 / 0.37	0.19 / 0.23	NA	0.10 / 0.15	0.11 / 0.059
Jenks[2]	NA	0.89 / NA	0.054 / NA	NA	0.32 / NA	0.0017 / NA

AVG – Mean concentration, FWA – Flow weighted average, OCS – Outlet Control Structure, NA – Not Available
1 – Value is mean concentration observed at the Maryland Pond diversion structure (Rose Street). Data provided by CRWD is preliminary and has not been validated or weighted by flow.
2- Only one grab sample was collected from Jenks Pond in 2015. Due to the limited sample size, load reduction and FWAs were not calculated.

11 Pervious Surface Infiltration Assessment

Infiltration rate monitoring was performed on November 24, 2015 at the Victoria Street and Hamline Midway Library pervious surface sites. This section presents the results of the 2015 infiltration testing, long term infiltration rates trends, and maintenance needs and objectives.

11.1 Victoria Street

The Victoria Street pervious surface consists of interlocking pavers separated by aggregate fill. The pavers were installed in 2011 and infiltration rates have been monitored annually from 2012 to 2015. In 2015, the exact test locations from 2014 could not be located, so new locations were established in the immediate area and identified as A-E. The test locations are presented in **Figure 11-1.** As shown in **Table 11-1**, infiltration rates at all five locations have decreased every year since 2012. In 2015, three of five locations recorded no infiltration. The Victoria site did not undergo any non-routine maintenance prior to infiltration testing in 2015.

Table 11-1. Victoria Street Permeable Pavement Infiltration Rate

Infiltration Ring Location	2012 Infiltration Rate (in/hr)	2013 Infiltration Rate (in/hr)	2014 Infiltration Rate (in/hr)	2015 Infiltration Rate (in/hr)	
IR-1	168.6	18.1	0	A	0
IR-2	266.6	75.7	13.0	B	0.9
IR-3	271.1	92.2	18.6	C	0
IR-4	69.1	24.0	9.7	D	0
IR-5	149.8	49.2	30.8	E	3.7
Average	**185.04**	**51.84**	**14.42**		**1.46**

Photo 11-1: Victoria Street pavers

Photo 11-2: Victoria Street infiltration testing

11.2 Hamline Midway Library

The Hamline Midway Library pervious surface consists of porous asphalt. The asphalt was installed in 2012 and infiltration rate monitoring has been conducted from 2013 through 2015. As shown in **Table 11-2**, infiltration rates from 2013 to 2014 severely diminished at the Site, with only two of nine locations exhibiting any infiltration. Photo documentation at the site has confirmed areas with significant sediment accumulation within the pore space of the asphalt. Prior to the 2015 infiltration testing, three different maintenance treatments were completed within areas of the Hamline Midway Library site. The objective was to determine if the pervious surface could be restored, and to identify the most effective treatment application. Maintenance consisted of a dry sweep in the area of test locations IR-1, IR-2, IR-3, IR-4 and IR-8. A wet vacuum sweep was conducted in the area of test location IR-7. The area near test locations IR-5 and IR-6 received a power wash and vacuum sweep. Following maintenance, infiltration testing was conducted at the Site. The test locations are presented in **Figure 11-2** and the test results are summarized in **Table 11-2.**

Table 11-2. Hamline Midway Library Infiltration Rate Summary

Infiltration Ring Location	2013 Infiltration Rate (in/hr)	2014 Infiltration Rate (in/hr)[1]	2015 Infiltration Rate (in/hr)[1]
IR-1	102.4	0.0	0
IR-2	14.9	0.0	0
IR-3	11.4	0.0	0
IR-4	172.7	0.0	0
IR-5	0.0	0.0	151.49
IR-6	1125.3	206.7	125.6
IR-7	290.2	73.0	0
IR-8	28.4	0.0	0
IR-9	115.6	0.0	0
Average	**206.8**	**31.1**	**12.95**

1 - Locations were monitored for a maximum of 25 minutes during the pre-wet test. If no infiltration was observed, no subsequent tests were completed and infiltrations rates were documented to be 0.0 in/hr.
BLUE – Dry sweep maintenance
RED – Wet sweep maintenance
GREEN – Power wash and vacuum sweep

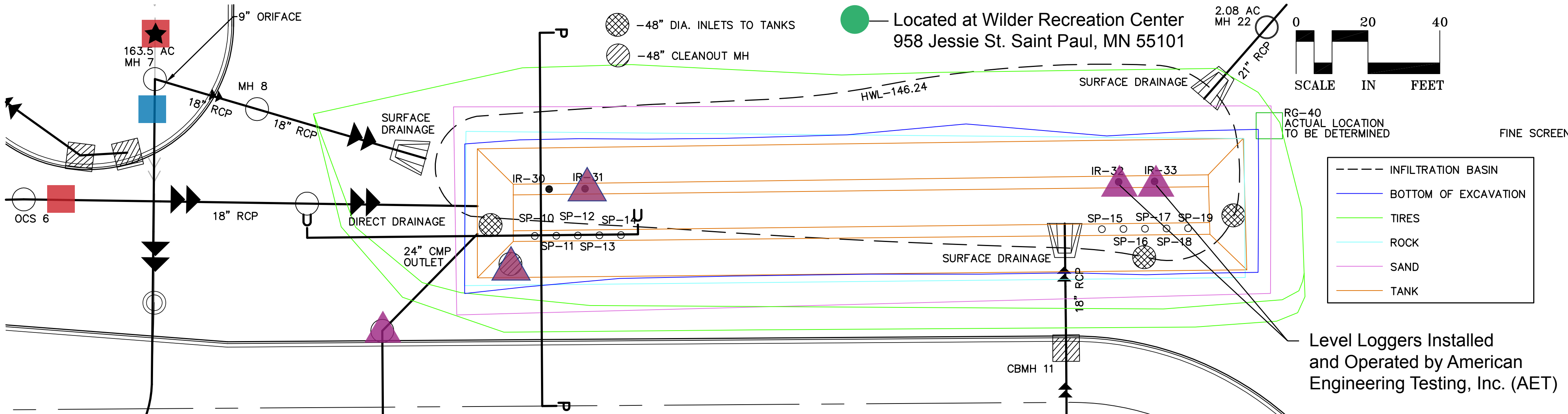
Photo 11-3: Recently Constructed Hamline Midway Library Porous Asphalt (2012)

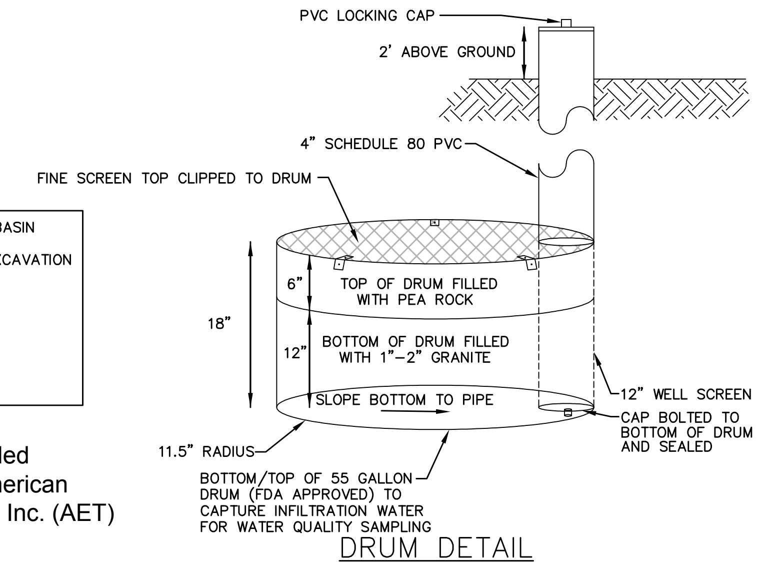

Photo 11-4: Silt accumulation on Hamline Midway Library asphalt (2015).

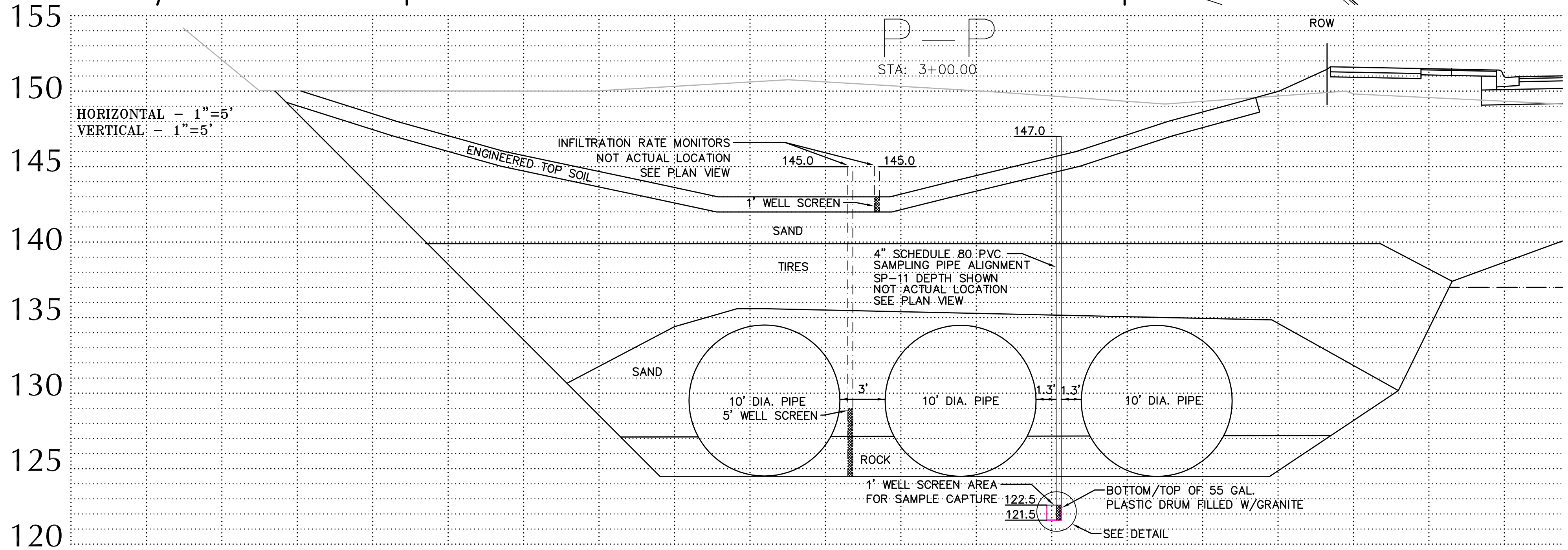
The section of pervious pavement that was power washed and vacuum swept (IR-5 and IR-6) responded the most favorably out of the three maintenance treatments. Infiltration rates in that area exceeded 125 in/hr, although the infiltration rate at IR-6 was less than rates measured in 2014. The areas that were maintained with a dry or wet vacuum sweep (IR-1, IR-2, IR-3, IR-4, IR-7, and IR-8) did not result in an increase in infiltration. No infiltration was observed at those sites following maintenance.

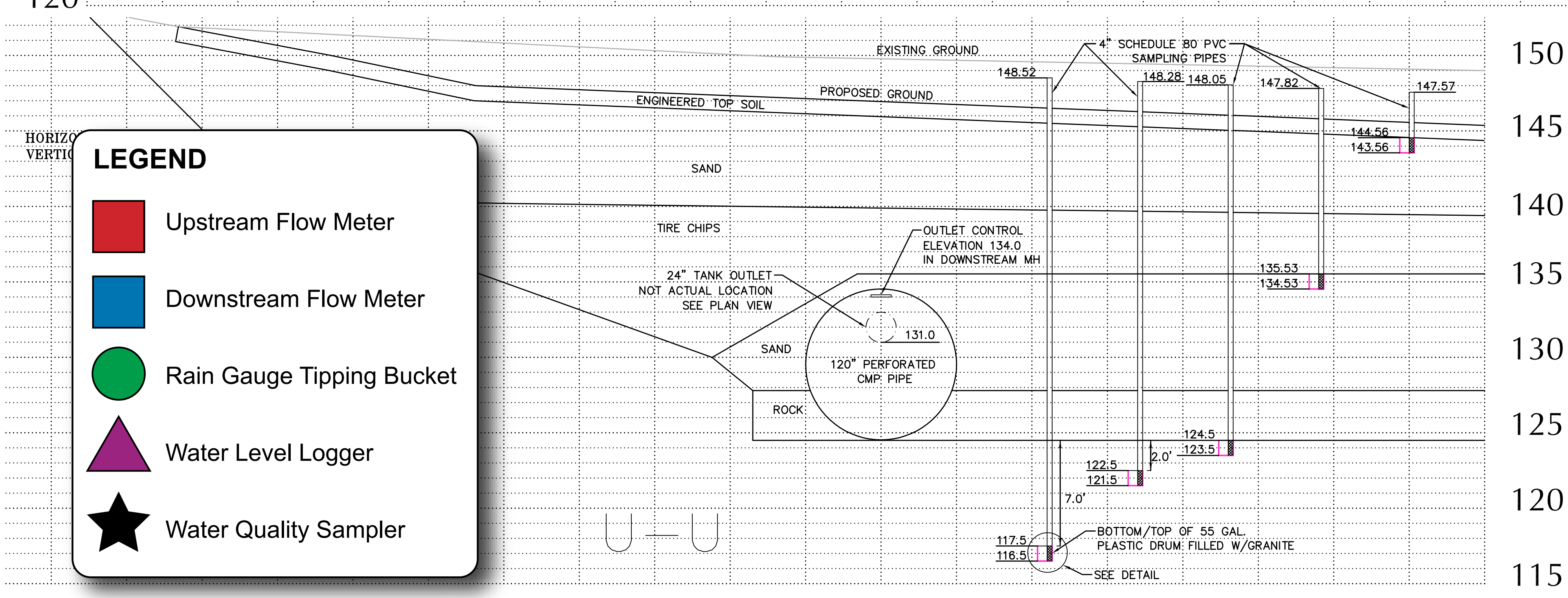
As a result of the 2015 infiltration test findings, maintenance in 2016 is anticipated to include power washing of the entire pervious asphalt surface at the Hamline Midway Library site. Following maintenance, infiltration rate testing will be completed in 2016 to observe the change in infiltration capability of the porous asphalt, subsequent to maintenance. The data will be used to guide future maintenance activities at the site and to provide cost/benefit data related to installation and long-term maintenance of porous pavement BMPs.

MONITORING EQUIPMENT LOCATION MAPS

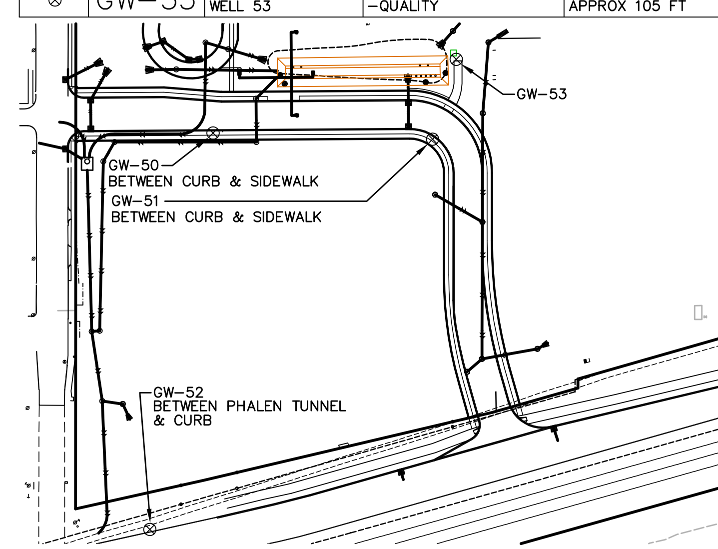








SYMBOL		DESCRIPTION	TYPE	LOCATION
	SW–1	SURFACE WATER IN BASIN	TREATMENT VARIES –WATER QUALITY	INFILTRATION BASIN 2
○	SP–10	SAMPLE PIPE 10	TREATED –WATER QUALITY	10' BELOW TIRE CHIPS
○	SP–11	SAMPLE PIPE 11	TREATED –WATER QUALITY	5' BELOW TIRE CHIPS
○	SP–12	SAMPLE PIPE 12	TREATED –WATER QUALITY	3' BELOW TIRE CHIPS
○	SP–13	SAMPLE PIPE 13	TREATED –WATER QUALITY	AT THE BOTTOM OF TIRE CHIPS
○	SP–14	SAMPLE PIPE 14	TREATED –WATER QUALITY	1' BELOW TOP OF TIRE CHIPS
○	SP–15	SAMPLE PIPE 15	TREATED –WATER QUALITY	1' BELOW TOP OF TIRE CHIPS
○	SP–16	SAMPLE PIPE 16	TREATED –WATER QUALITY	AT THE BOTTOM OF TIRE CHIPS
○	SP–17	SAMPLE PIPE 17	TREATED –WATER QUALITY	3' BELOW TIRE CHIPS
○	SP–18	SAMPLE PIPE 18	TREATED –WATER QUALITY	5' BELOW TIRE CHIPS
○	SP–19	SAMPLE PIPE 19	TREATED –WATER QUALITY	10' BELOW TIRE CHIPS
●	IR–30	INFILTRATION RATE PIPE 30	INFILTRATION RATE –MONITORING	5' SCREEN AT THE BOTTOM OF TIRE CHIPS
●	IR–31	INFILTRATION RATE PIPE 31	INFILTRATION RATE –MONITORING	2' SCREEN ABOVE THE TOP OF TIRE CHIPS
●	IR–32	INFILTRATION RATE PIPE 32	INFILTRATION RATE –MONITORING	5' SCREEN AT THE BOTTOM OF TIRE CHIPS
●	IR–33	INFILTRATION RATE PIPE 33	INFILTRATION RATE –MONITORING	2' SCREEN ABOVE THE TOP OF TIRE CHIPS
□	RG–40	AUTOMATIC RAIN GAUGE 40	RAIN RATE –MONITORING	
⊗	GW–50	GROUND MONITORING WELL 50	GROUNDWATER –QUALITY	GROUNDWATER DEPTH APPROX 105 FT
⊗	GW–51	GROUND MONITORING WELL 51	GROUNDWATER –QUALITY	GROUNDWATER DEPTH APPROX 105 FT
⊗	GW–52	GROUND MONITORING WELL 52	GROUNDWATER –QUALITY	GROUNDWATER DEPTH APPROX 105 FT
⊗	GW–53	GROUND MONITORING WELL 53	GROUNDWATER –QUALITY	GROUNDWATER DEPTH APPROX 105 FT



Project Name:
FOREST-PHALEN CONNECTION ROAD
AT RUSSELL & WELLS STREETS
City of St. Paul
Project No. A-28287-3

BEACON BLUFF
St. Paul, Minnesota

Owner/Developer Name:
ST. PAUL PORT AUTHORITY
Monte Hilleman
1900 Landmark Tower
345 Saint Peter Street
St. Paul, MN 55102
Phone: 651-224-5686

SAINT PAUL PORT AUTHORITY

Professional Services:
LOUCKS ASSOCIATES
Planning • Civil Engineering • Land Surveying
Landscape Architecture • Environmental
7200 Hemlock Lane • Suite 300
Minneapolis, Minnesota 55369
Telephone: (763)424-5505
www.LoucksAssociates.com

CADD Qualification:

Submittal:

Professional Signature:
I hereby certify that this plan, specification or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Eric Beazley - PE

License No. Date

Quality Control:
Project Lead: VMA Drawn By: TRG
Checked By: JAS/EWB Review Date:

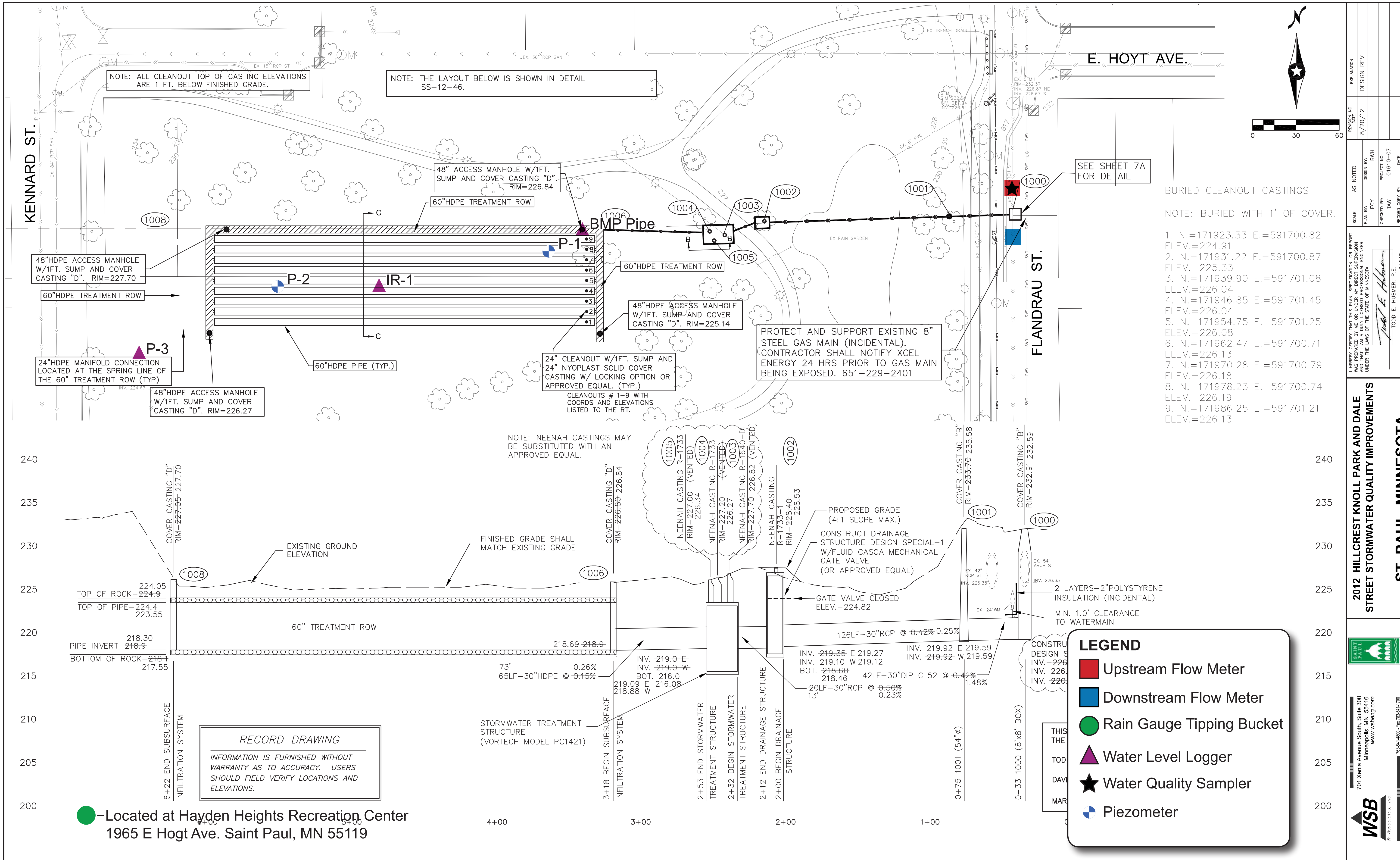
Sheet Index:

Sheet Title:
STORM TANK TESTING DETAILS

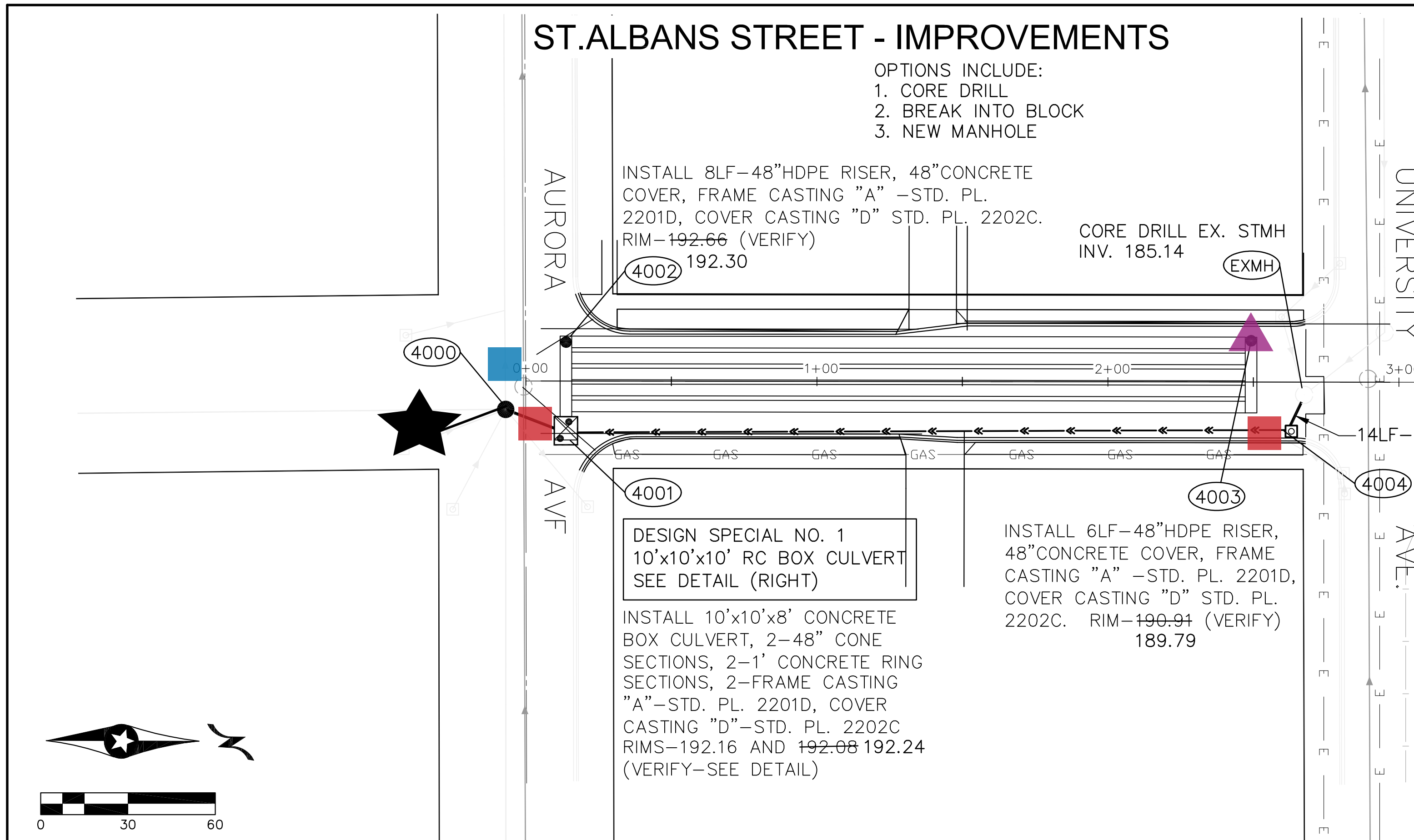
Project No.:
08244

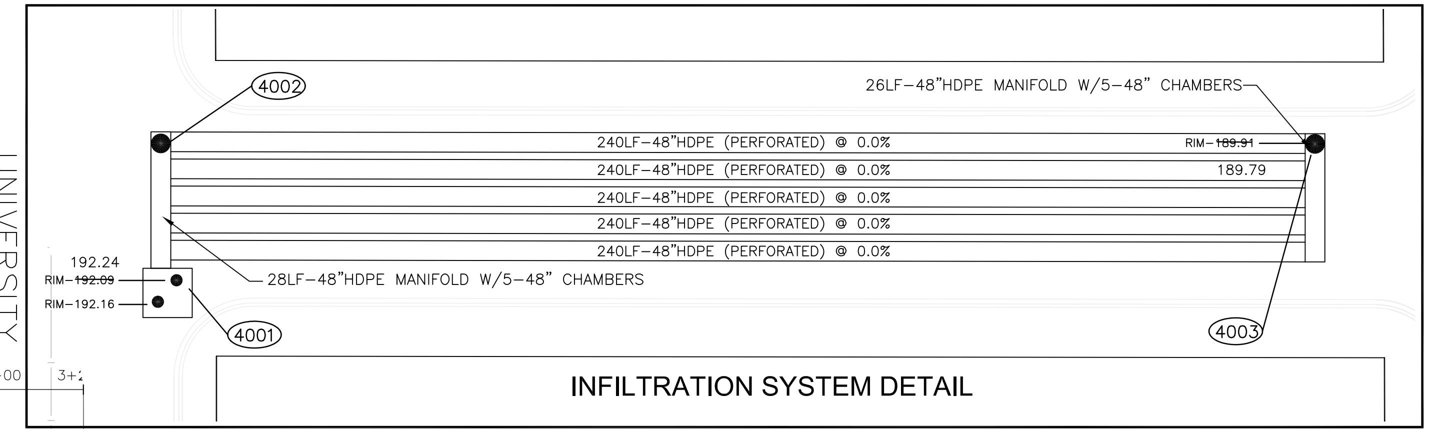
Sheet No.:
C9-8

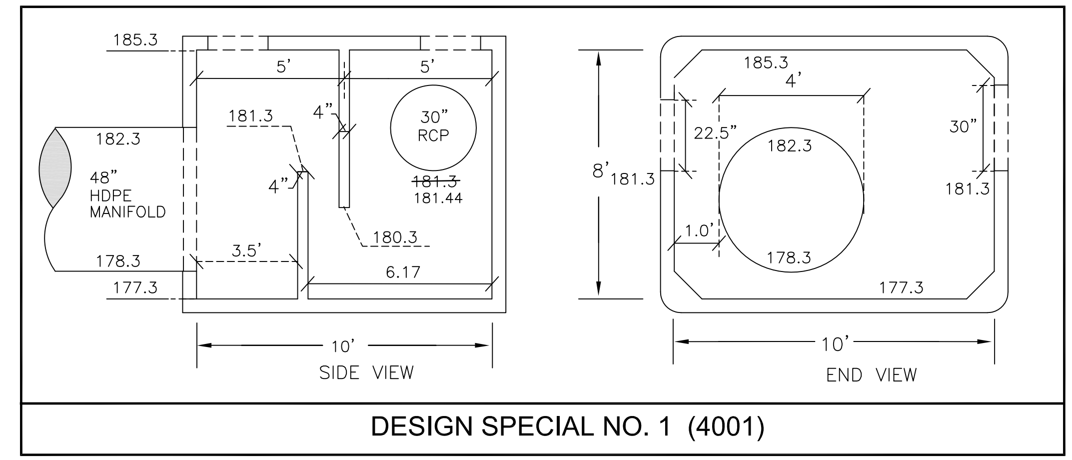
Plotted: 04 /21 / 2011 3:30 PM N:\08244\Parcel 5 Roadway\Dwg\Civil

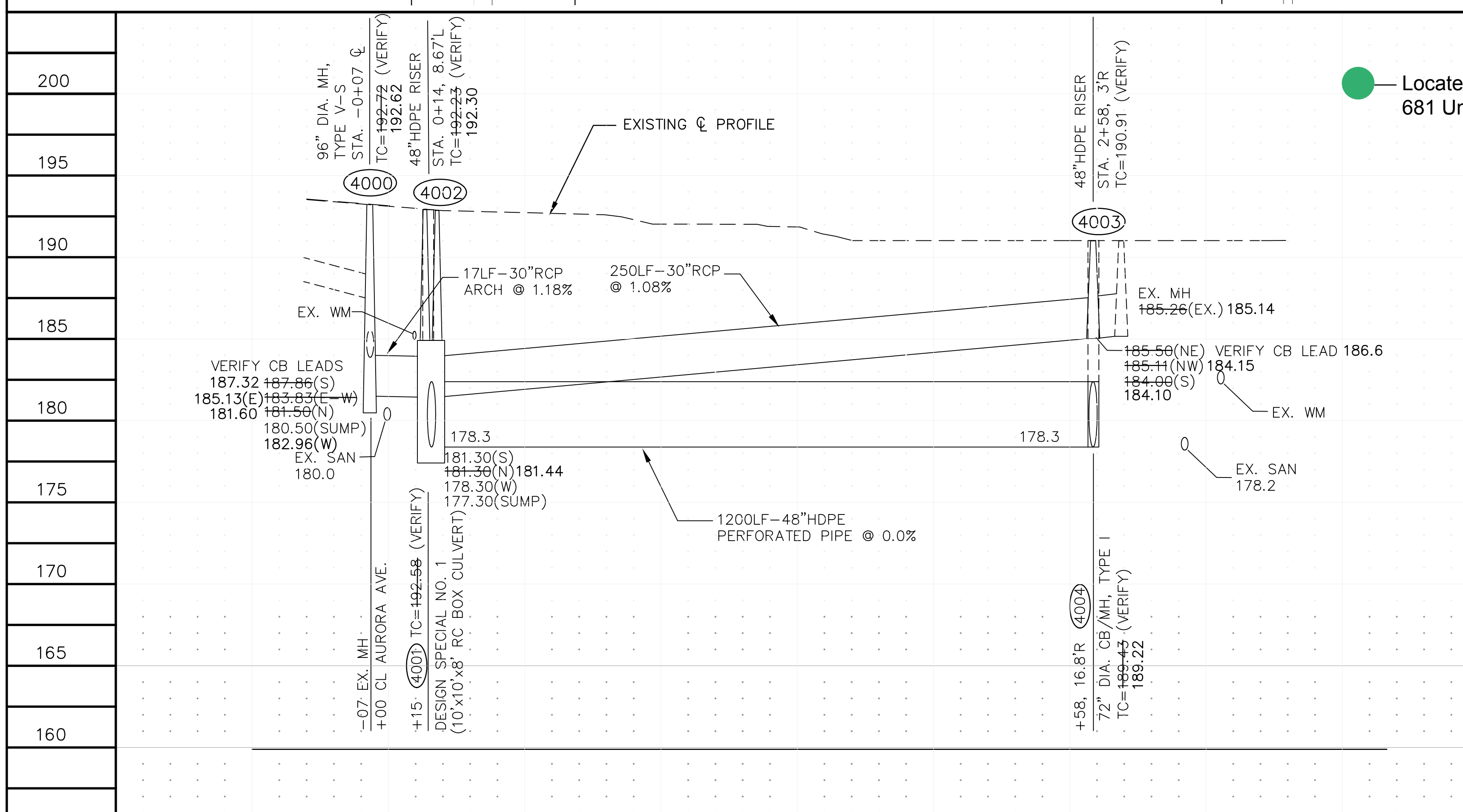


RECORD PLAN 2013 | CONTRACTOR: EUREKA CONSTRUCTION INC. | DRAWER: | DWG. NO. | CITY PROJECT NUMBER 12-S-2003 | PROPOSED IMPROVEMENTS | SHEET 7 OF 18 SHEETS









Located at SPFD Fire Station 18
681 University Ave., Saint Paul, MN 55103

LEGEND

- Upstream Flow Meter
- Downstream Flow Meter
- Rain Gauge Tipping Bucket
- Water Level Logger
- Water Quality Sampler

RECORD DRAWING

INFORMATION IS FURNISHED WITHOUT WARRANTY AS TO ACCURACY. USERS SHOULD FIELD VERIFY LOCATIONS AND ELEVATIONS.

THIS DRAWING IS OUR RECORD KNOWLEDGE OF THE PROJECT AS CONSTRUCTED

TODD E. HUBMER, P.E. – PROJECT ENGINEER WSB & ASSOCIATES

GARY GRUBER – CONSTRUCTION OBSERVER WSB & ASSOCIATES

NOVEMBER 2011

REVISION NO. DATE	EXPLANATION
01/28/11	REVISED 4001 TO 10' BOX
04/20/11	ADDED WM IN AURORA

SCALE: AS NOTED
PLAN BY: EY
DESIGN BY: RH
CHECKED BY: EY
PROJECT NO: 01610–03
RECORD COPY BY:
DATE:

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA

TODD E. HUBMER, P.E.
DATE: MAY 17, 2010 LIC. NO: 24043

2010 ST. ALBANS, ARUNDEL, LAKE PHALEN STORMWATER INFILTRATION IMPROVEMENTS

ST. PAUL, MINNESOTA

SAINT PAUL

WSB & Associates, Inc.
701 Xenia Avenue South, Suite 300
Minneapolis, MN 55416
www.wsbeng.com
763-541-4800 • Fax 763-541-1700
INFRASTRUCTURE | ENGINEERING | PLANNING | CONSTRUCTION

CONTRACTOR: FOREST LAKE CONTRACTING, INC.

RECORD PLAN

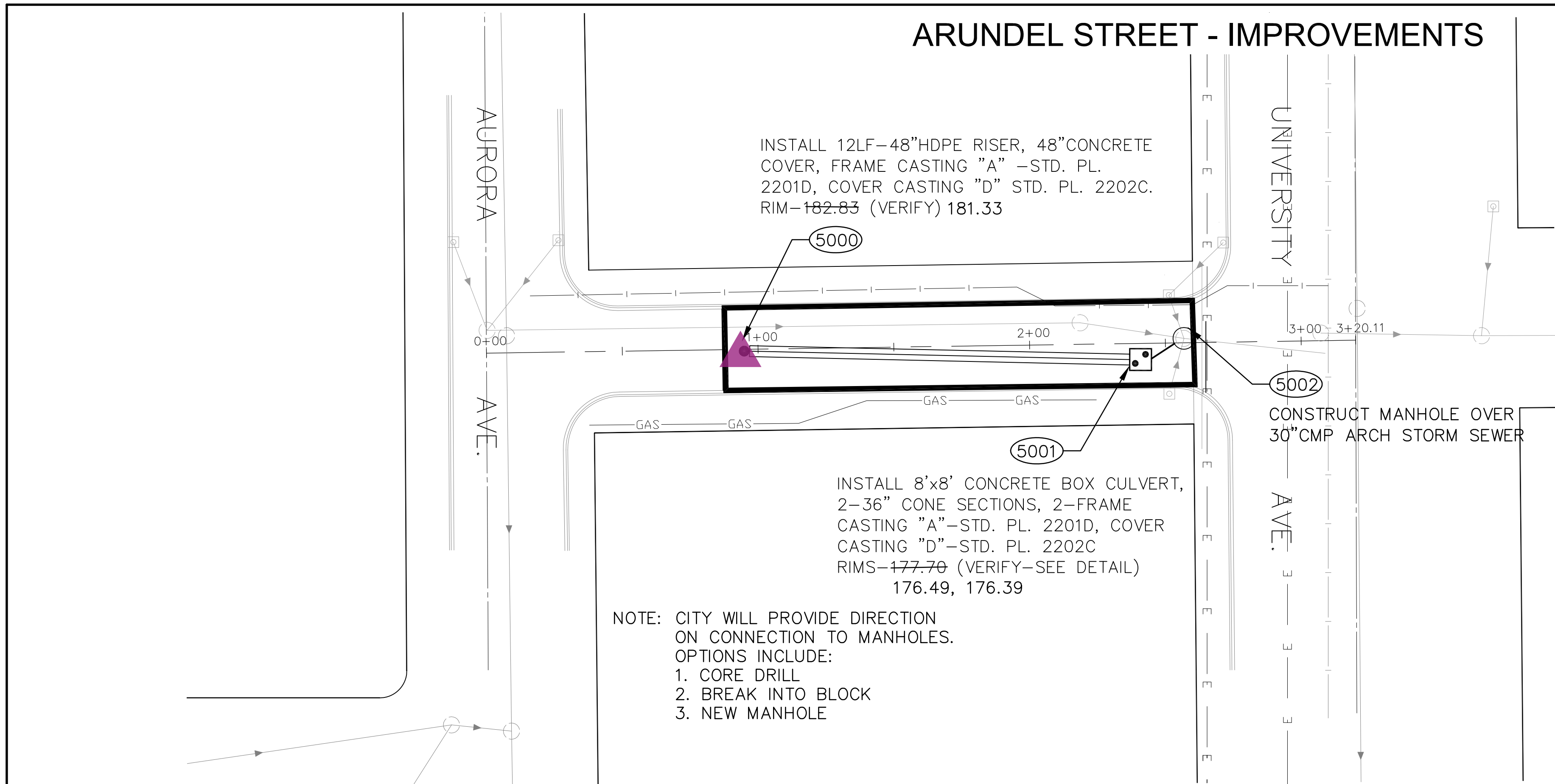
DRAWER:
DWG. NO.

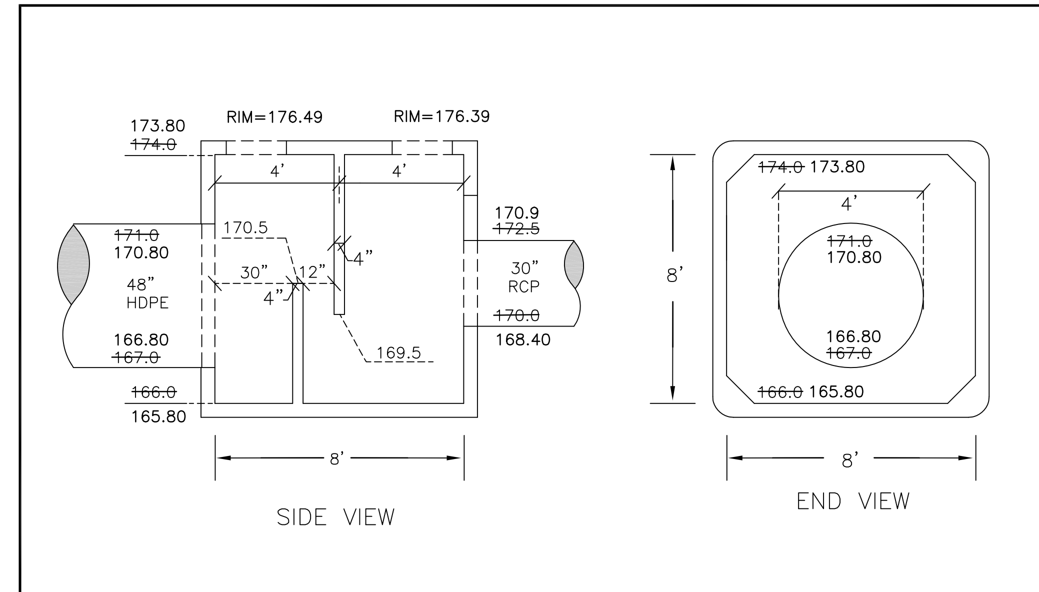
CITY PROJECT NUMBER 10–S–1983

2010 RSVP PROJECT
PROPOSED IMPROVEMENTS

SHEET 7 OF 17 SHEETS

ARUNDEL STREET - IMPROVEMENTS

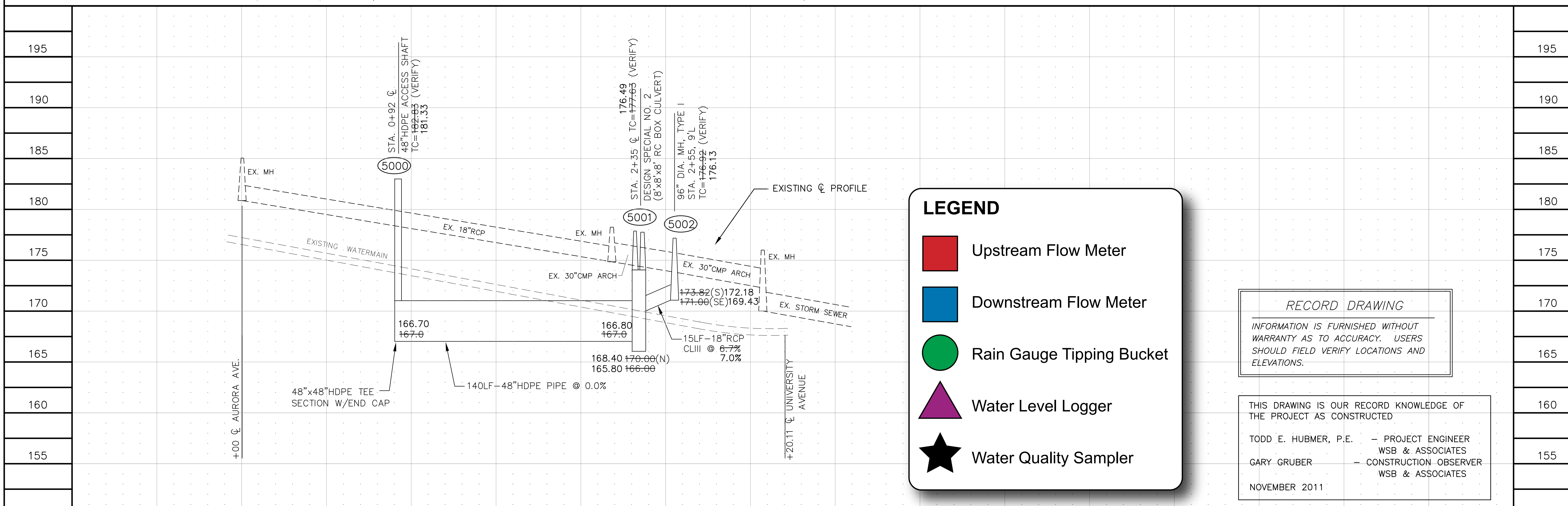




BOX CULVERT DRAINAGE STRUCTURE

Located at SPFD Fire Station 18
681 University Ave., Saint Paul, MN 55103

0 30 60



LEGEND

- Upstream Flow Meter
- Downstream Flow Meter
- Rain Gauge Tipping Bucket
- Water Level Logger
- Water Quality Sampler

RECORD DRAWING

INFORMATION IS FURNISHED WITHOUT WARRANTY AS TO ACCURACY. USERS SHOULD FIELD VERIFY LOCATIONS AND ELEVATIONS.

THIS DRAWING IS OUR RECORD KNOWLEDGE OF THE PROJECT AS CONSTRUCTED

TODD E. HUBMER, P.E. – PROJECT ENGINEER WSB & ASSOCIATES
GARY GRUBER – CONSTRUCTION OBSERVER WSB & ASSOCIATES
NOVEMBER 2011

2010 ST. ALBANS, ARUNDEL, LAKE PHALEN STORMWATER INFILTRATION IMPROVEMENTS

ST. PAUL, MINNESOTA

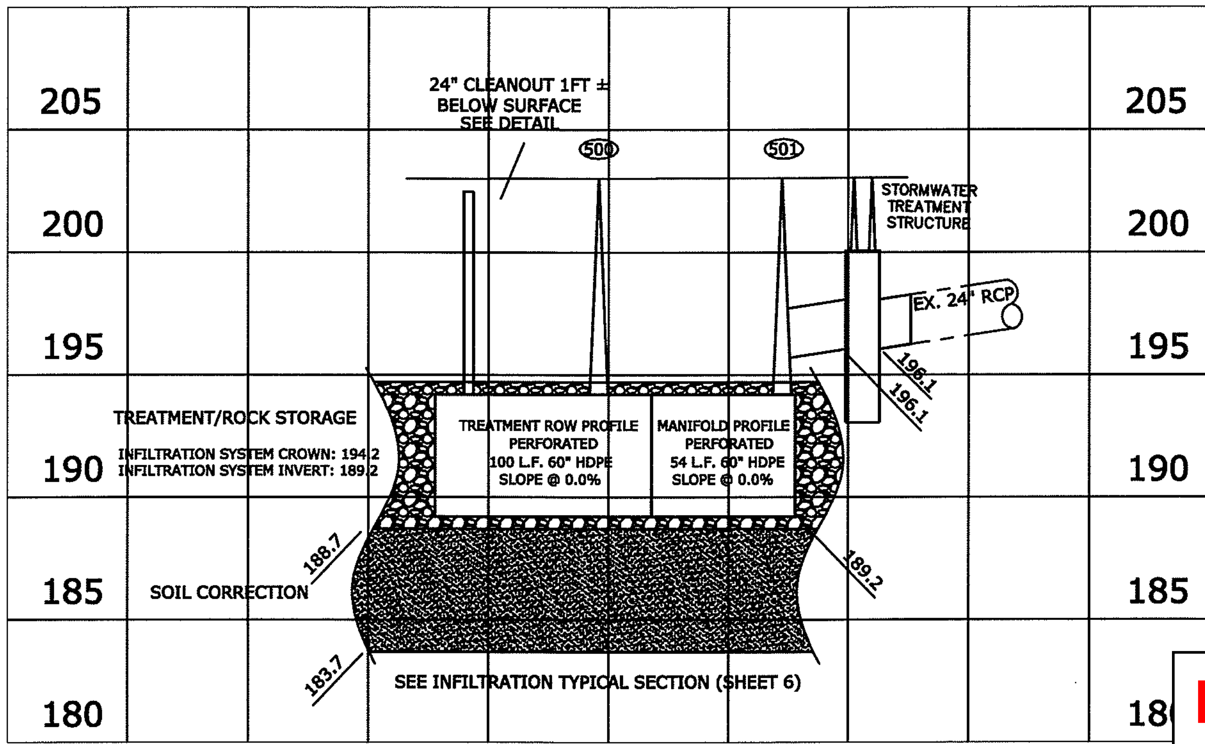
SCALE: AS NOTED | PLAN BY: EY | DESIGN BY: RH | CHECKED BY: | PROJECT NO: 01610-03 | RECORD COPY BY: | DATE:

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA

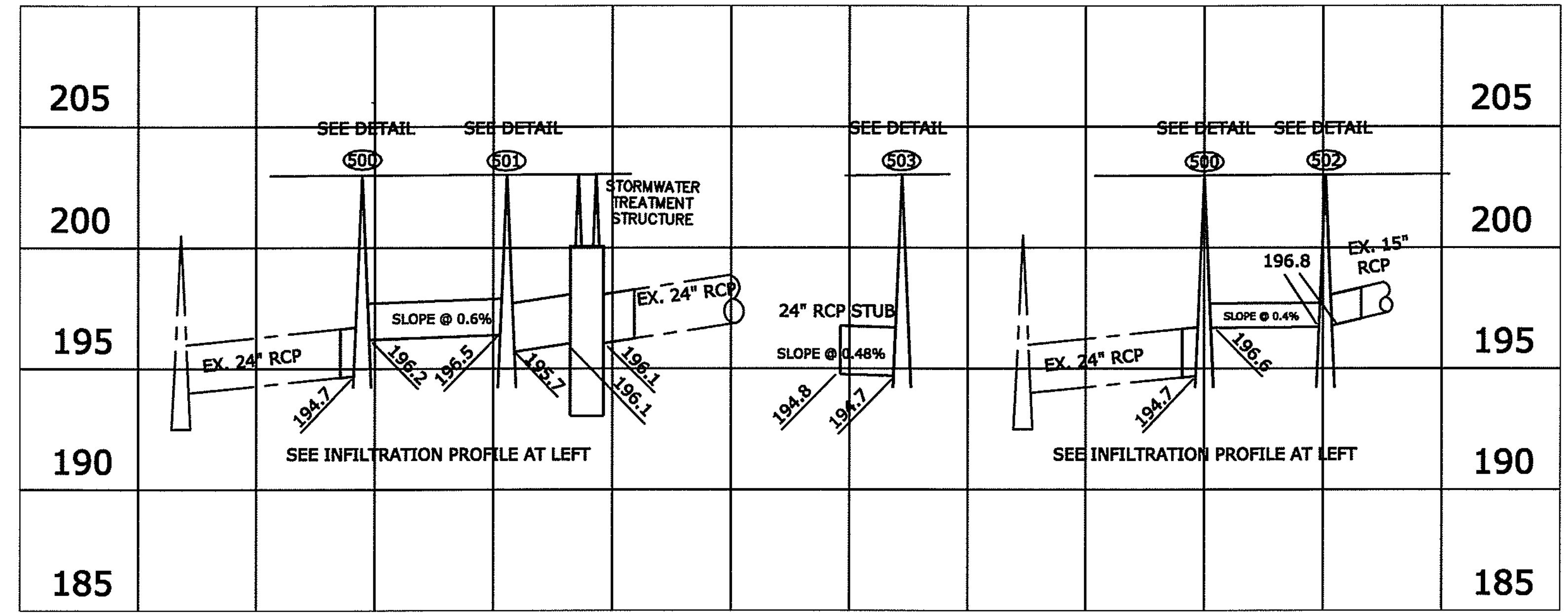
TODD E. HUBMER, P.E.
DATE: MAY 17, 2010 LIC. NO: 24043

WSB & Associates, Inc.
701 Xenia Avenue South, Suite 300
Minneapolis, MN 55416
www.wsbeng.com
763-541-4800 • Fax 763-541-1700
INFRASTRUCTURE | ENGINEERING | PLANNING | CONSTRUCTION

CONTRACTOR: FOREST LAKE CONTRACTING, INC. | RECORD PLAN | DRAWER: DWG. NO. | CITY PROJECT NUMBER 10-S-1983 | 2010 RSVP PROJECT PROPOSED IMPROVEMENTS | SHEET 8 OF 17 SHEETS



INFILTRATION SYSTEM CONSTRUCTION



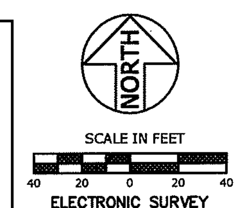
SEWER CONSTRUCTION

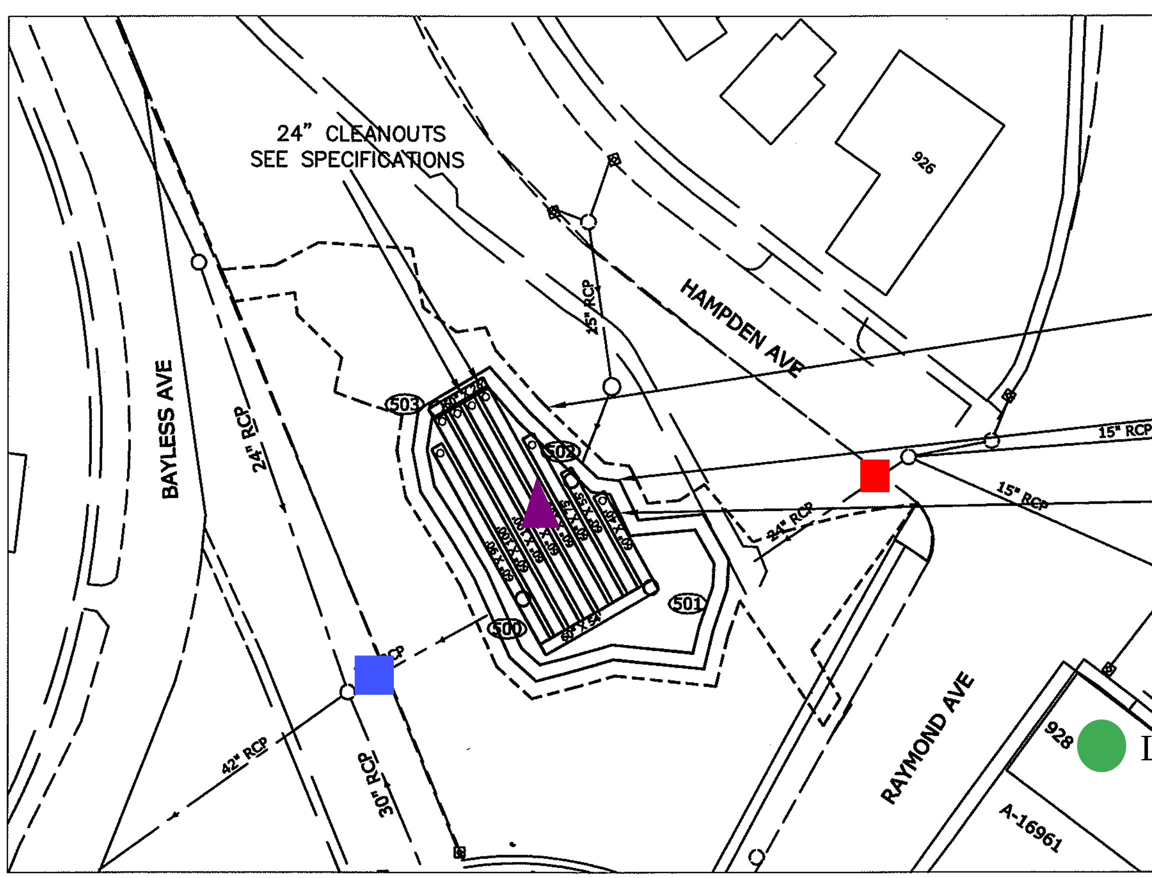
Upstream Flow Meter

Downstream Flow Meter

Rain Gauge

Water Level Logger





EXISTING SURFACE ELEV. 203±

TOP OF ROCK STORAGE/ INFILTRATION SYSTEM ELEV. 194.7

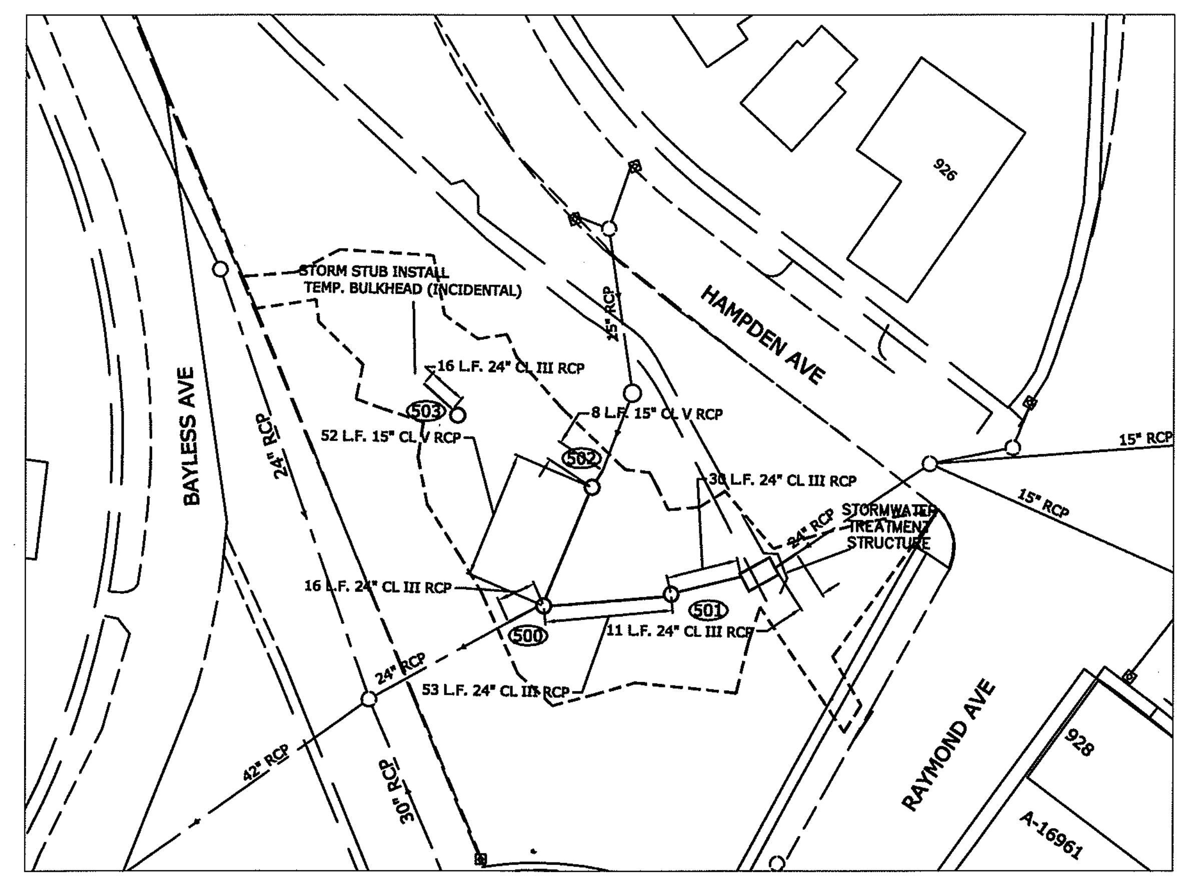
TOP OF SOIL CORRECTION/ BOTTOM OF INFILTRATION SYSTEM ELEV. 188.7

Located at the Hampden Park Co-op

INSTALL MANIFOLD WEIR PLATE 2'± FROM STRUCTURE #502

INFILTRATION SYSTEM CONSTRUCTION

TYPICAL SECTION SHEET 6



SEWER CONSTRUCTION

SAINT PAUL	DESIGNED	PGM	I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA
	DRAWN	PGM	Signature: AARON D HASS — Date: 1/15/2014
	APPROVED	ADH	Lic. No. 26424

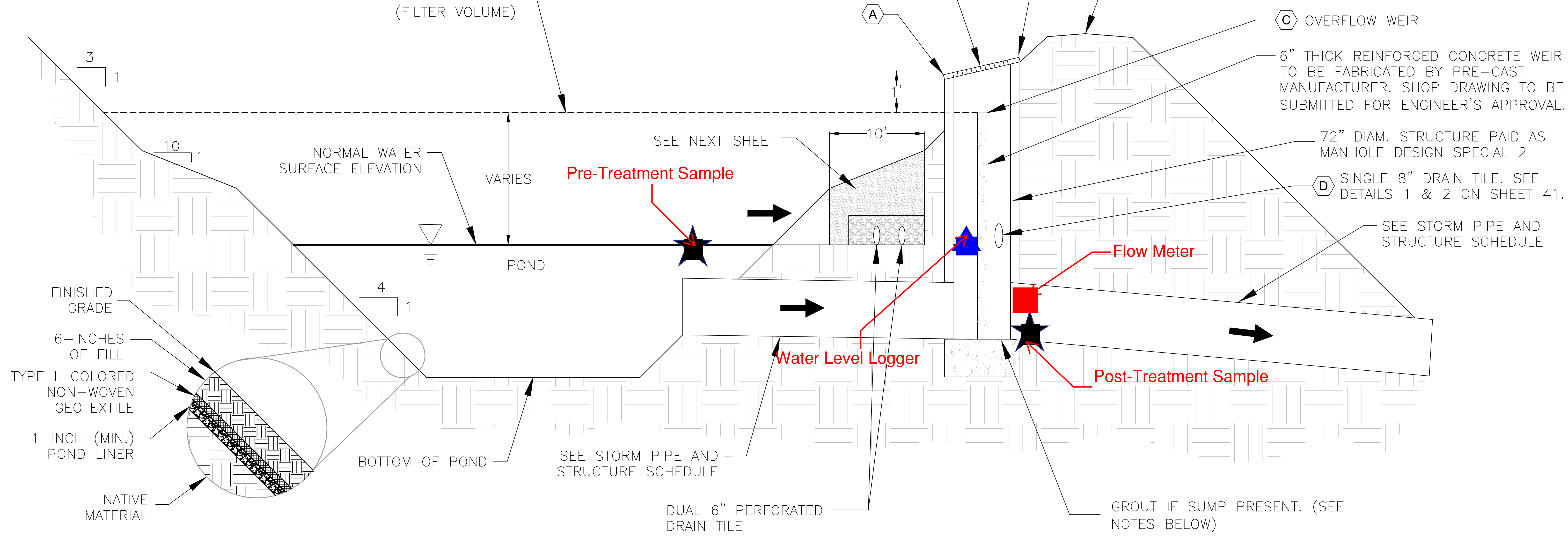
PREPARED BY SEWER ENGINEERING DIVISION FOR THE CITY OF ST. PAUL, DEPARTMENT OF PUBLIC WORKS

HAMPDEN PARK INFILTRATION

PROJECT:	13-S-2006		
DRAWER:	10	CAD NAME:	Z:\SEWERS\PROJECTS\2013\Hampden Park
DWG. NO.	5496	DATE:	10/3/13

SHEET NO. 4 OF 6 SHEETS

Trout Brook Nature Sanctuary Equipment Map



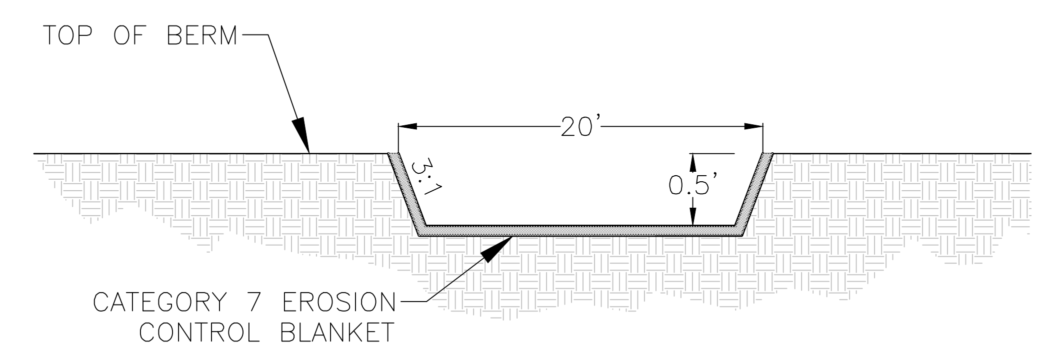
1 DRAIN TILE, OUTLET WEIR & PIPING POND SECTION DETAIL

SCALE: NONE, VERTICAL EXAGERATION 4X

LETTER	VALUE	JENKS POND	MAGNOLIA POND	MARYLAND POND
A	ELEVATION	99	127	120
B	ELEVATION	99.33	127.33	120.33
C	ELEVATION	98	126	119
D	DS INVERT	95.4	123.7	116.3

NOTES:

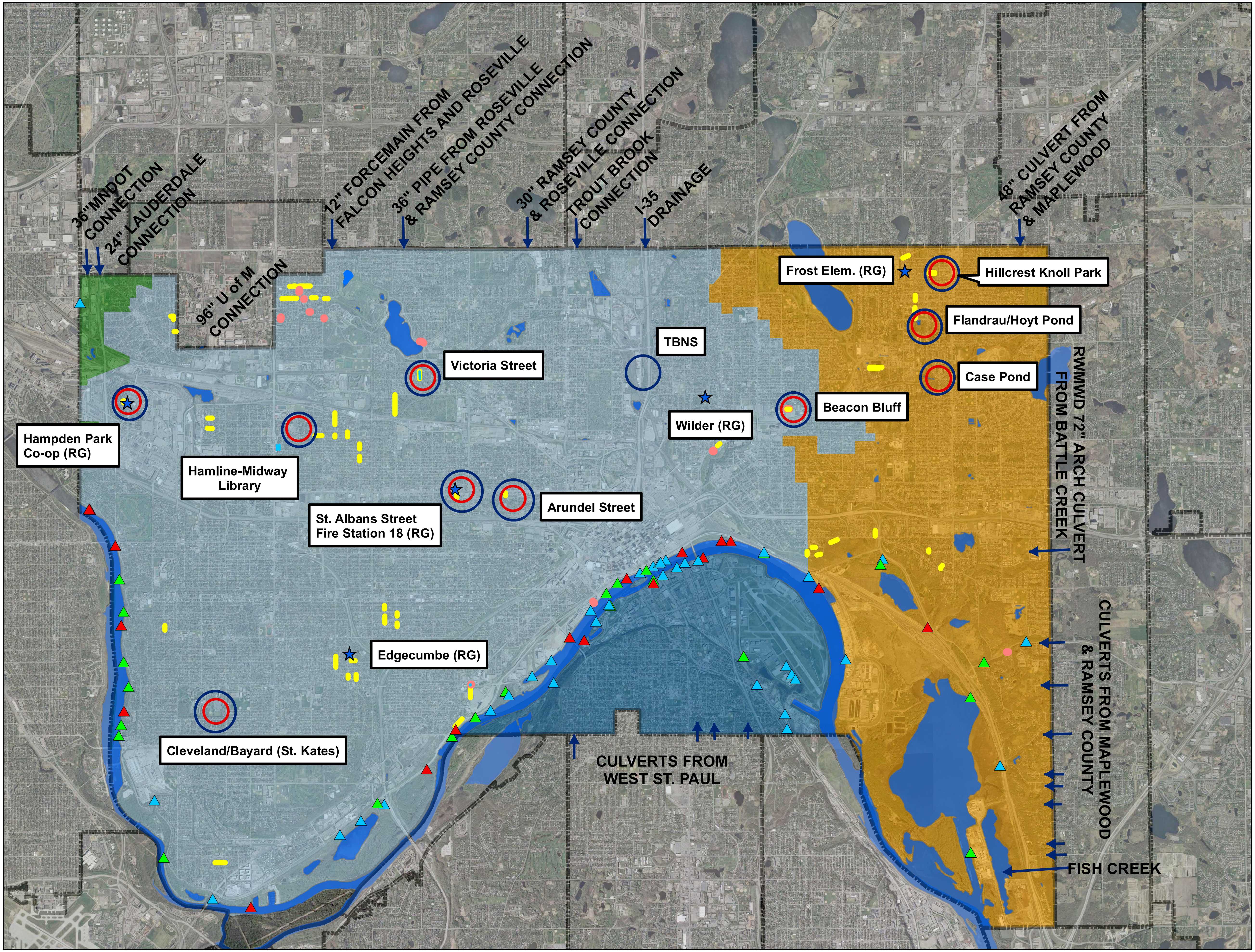
1. IF SUMP IS PRESENT BELOW OUTLET INVERT, CONTRACTOR TO FILL DOWNSTREAM PORTION OF OUTLET STRUCTURE WITH GROUT AND TROWEL FLUSH WITH INVERT ELEVATION. TIME AND MATERIAL CONSIDERED INCIDENTAL TO POND OUTLET INSTALLATION – MANHOLE DESIGN SPECIAL 2 STRUCTURES.



2 TYPICAL OF EMERGENCY OVERFLOW WEIR

SCALE: NONE, VERTICAL EXAGERATION 8X

FIGURES



City of St. Paul

2015 Water Quantity and Quality Monitoring Program

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The Most Livable City in America

Figure 1-1
Monitoring Site Location Map

N W E S

0 2,500 5,000 10,000 Feet

Legend

- Raingarden/Infiltration Basin
- Infiltration Trench
- Pervious Pavement
- Capitol Region Watershed District
- Lower Mississippi River WMO
- Mississippi WMO
- Ramsey/Washington/Metro WD
- 2014 Monitoring Locations
- 2015 Monitored Locations
- Rain Gauge Locations
- Inflows

Outfalls

- 30" - 48"
- 50" - 72"
- > 72"

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City of St. Paul

2015 Water Quantity and Quality Monitoring Program

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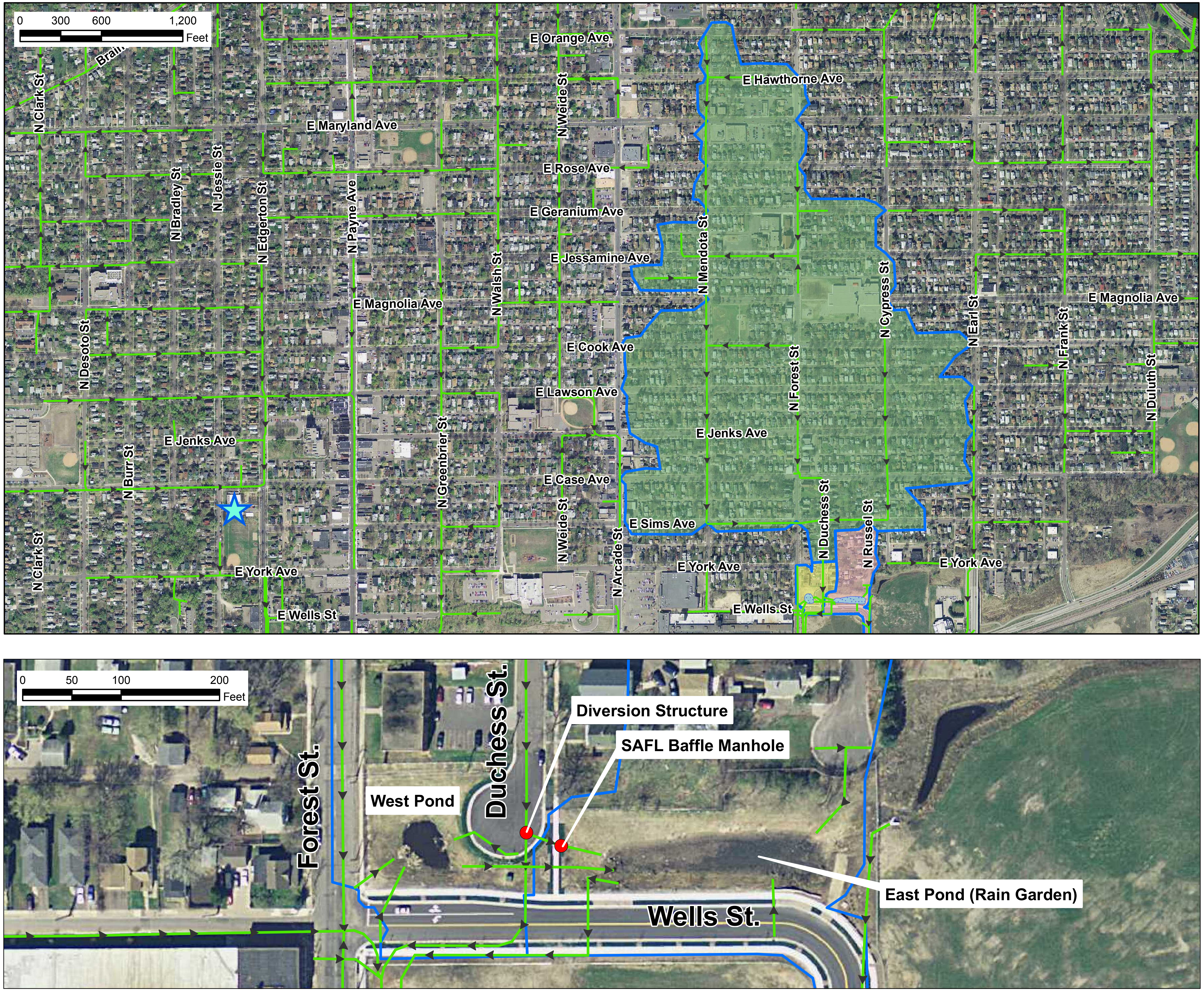
FIGURE 3-1
Beacon Bluff Infiltration BMP Drainage Areas



N
W E
S

Legend

- Underground Chamber
- Storm Pipe
- Rain Gauge Location

Drainage Areas

- Subwatershed A - Diversion Structure (136.8 ac)
- Suwatershed B - East Pond (4.7 ac)
- Subwatershed C - West Pond (2.1 ac)

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File: K:\01610-03\GIS\Maps\Volume Reduction\4.2 Storm Sewer.mxd, Feb 10, 2011 5:38:46 PM

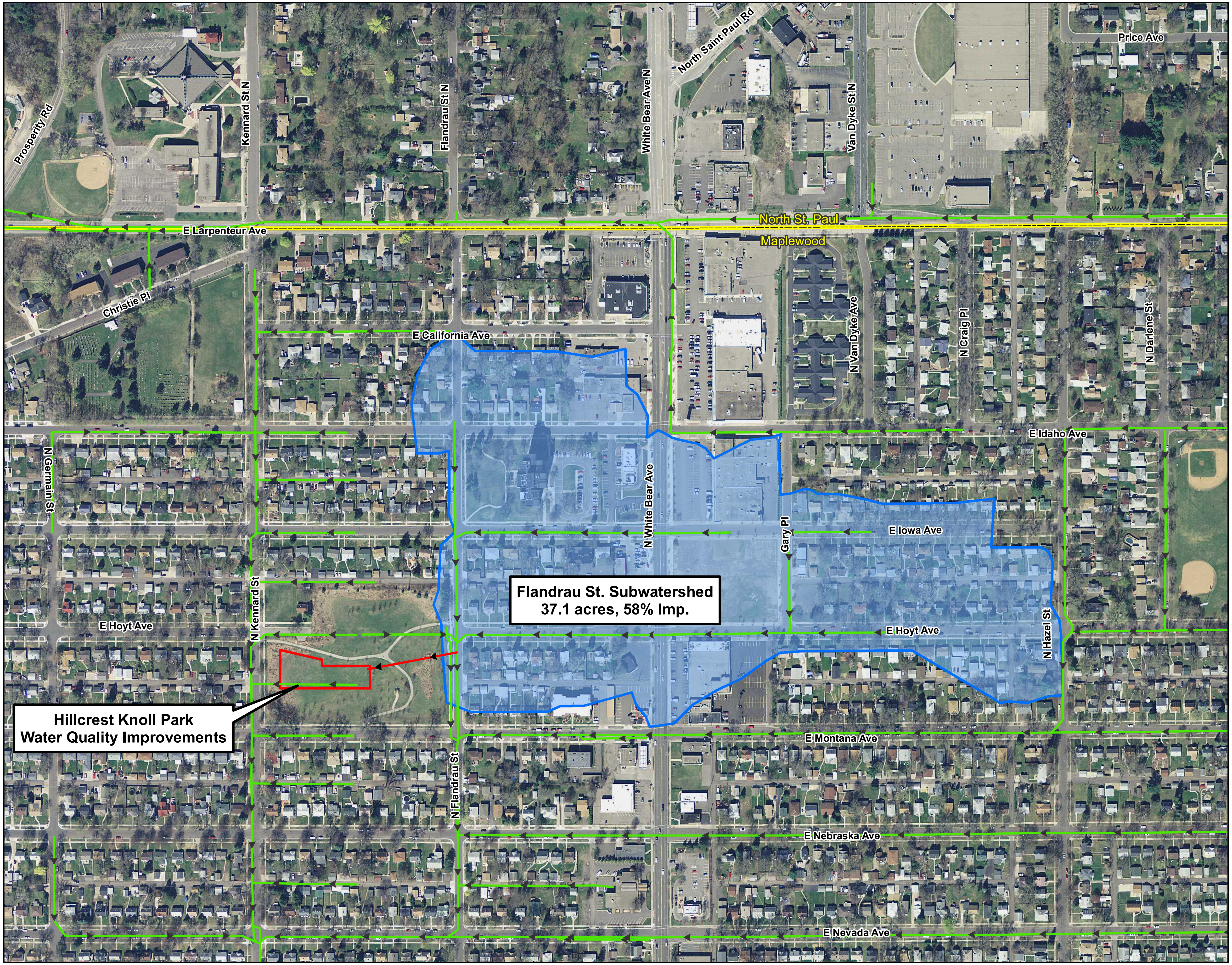

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FIGURE 4 - 1

Hillcrest Knoll Park Water Quality Improvements Drainage Area Map

N
W E
S

0 150 300 600
Feet

Legend

Ex. Storm Sewer
City Boundaries
Subwatershed
Infiltration BMP

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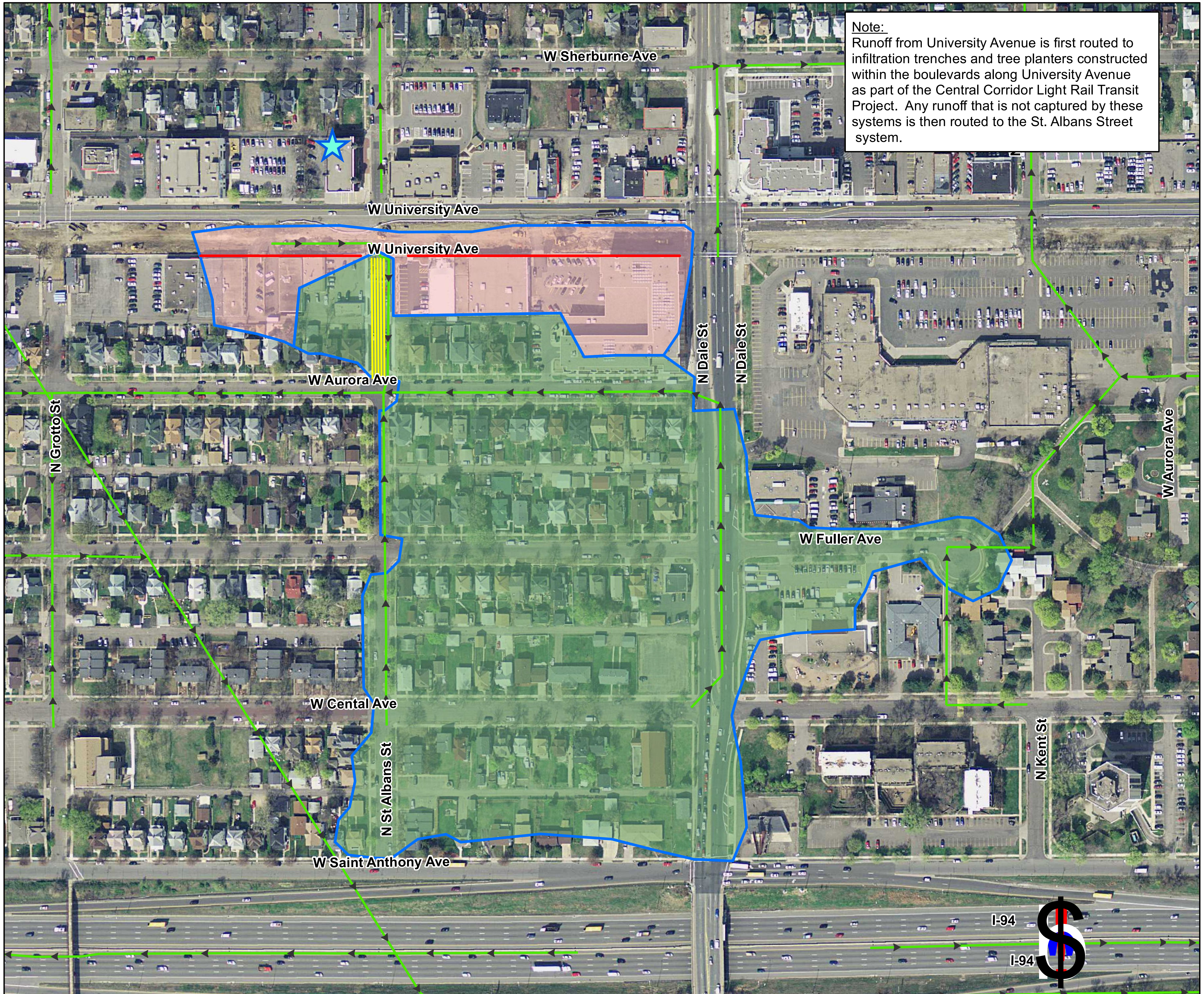

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FIGURE 5-1

St. Albans Street Infiltration BMP Drainage Areas

N W E S

0 100 200 400 Feet

Legend

- Infiltration Trench
- CCLRT Infiltration Trench (Not monitored)
- Storm Pipe
- Rain Gauge Location

Drainage Areas

- St. Albans Infiltration System (20.3 ac)
- CCLRT Infiltration Trenches (4.9 acres)

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FIGURE 6-1
Hampden Park Infiltration BMP Drainage Areas

N
W E
S

0 50 100 200 300 400
Feet

Legend

- Storm Pipe
- Rain Gauge Location
- Hampden Park BMP
- Hampden Park BMP Drainage Area

WSB

K:\01610-100\GIS\Maps\Figures\2015\Figure 6-1 - Hampden Park NEW.mxd

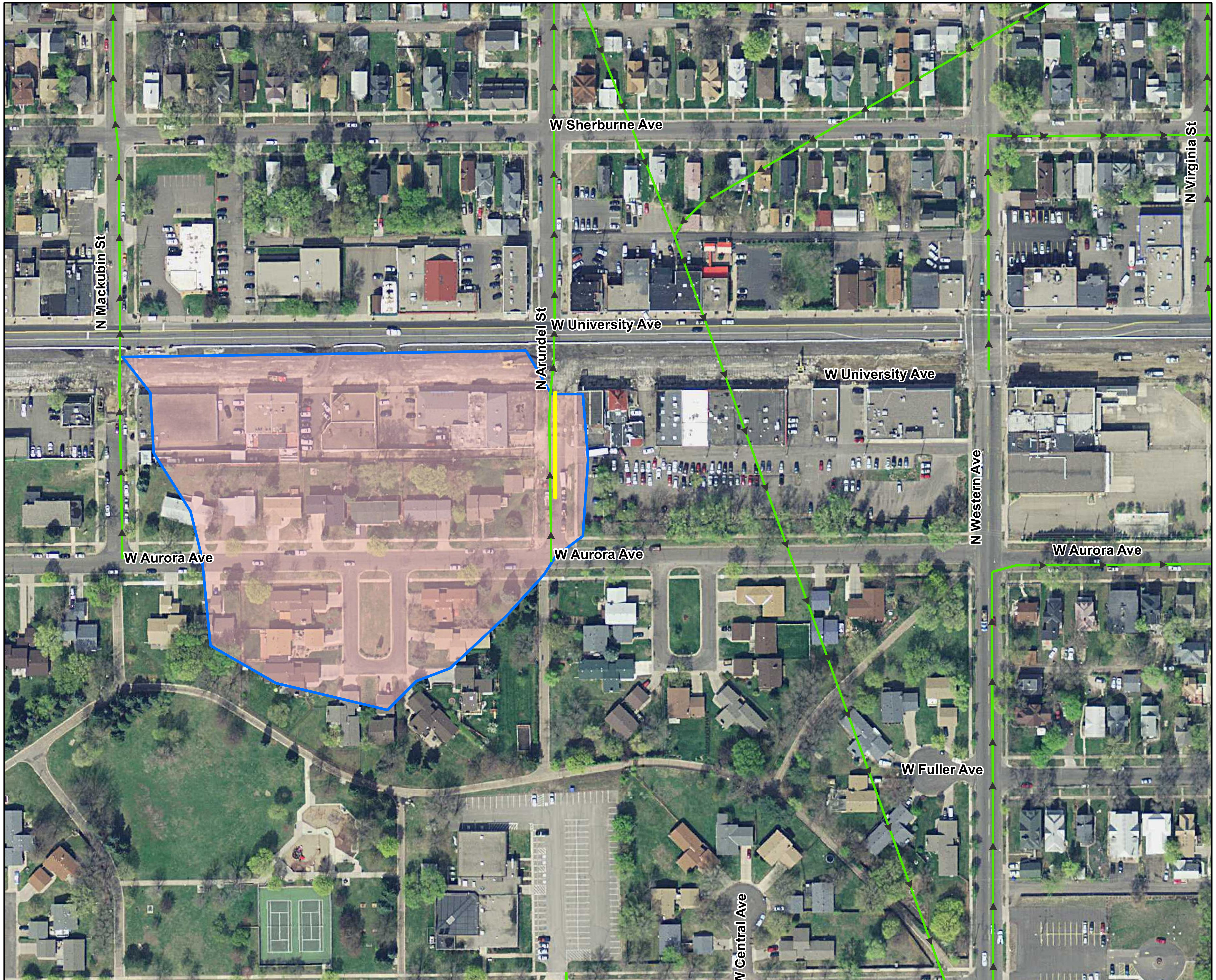

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FIGURE 7-1

Arundel Street Infiltration BMP Drainage Areas

Legend

- Infiltration Trench
- Storm Pipe
- Rain Gauge Location
- Arundel Street System (6.4 ac)

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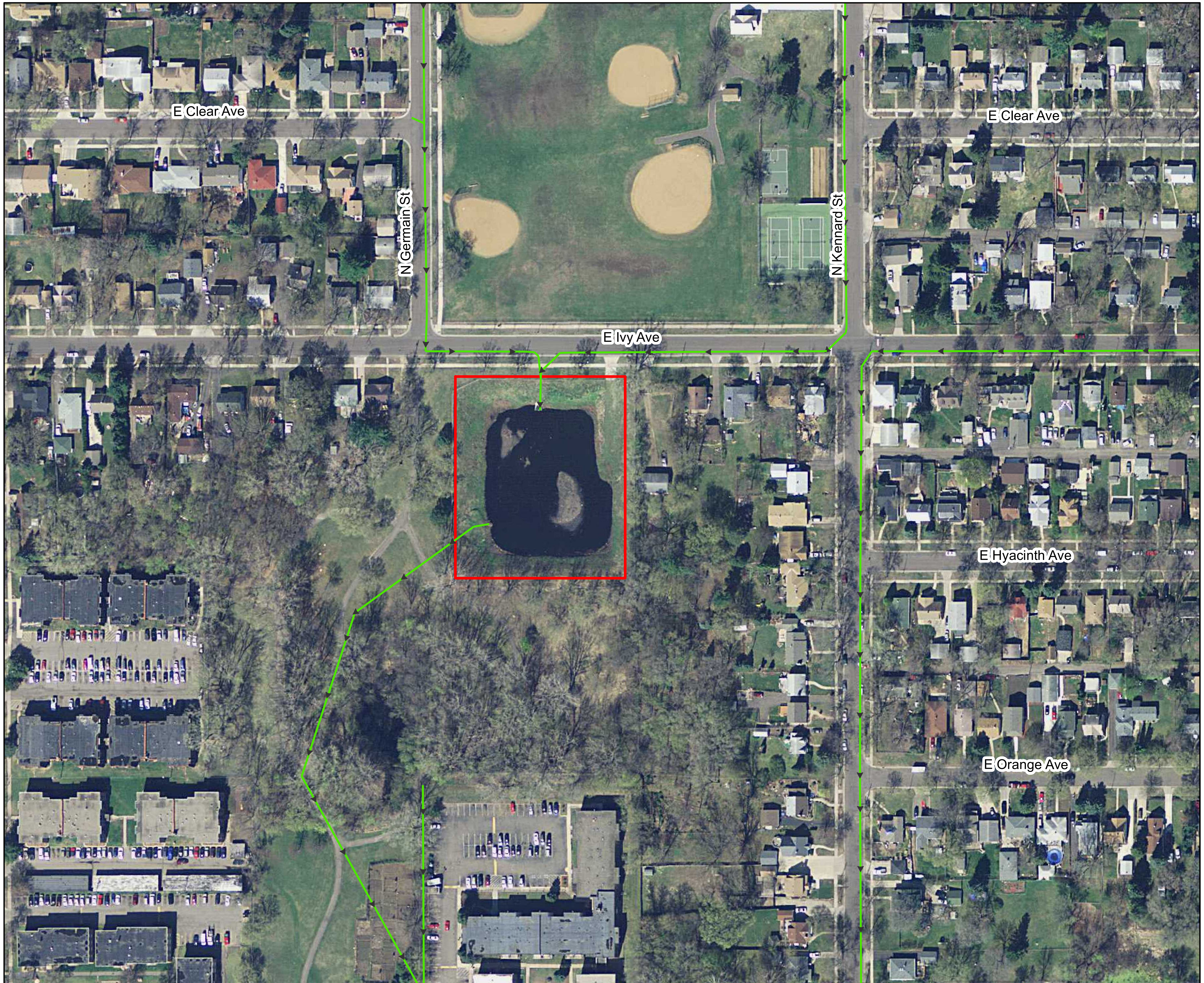
City of St. Paul

2015 Water Quantity and Quality Monitoring Program

FIGURE 8-1

Flandrau - Hoyt Pond



Legend

Pond Area

Storm Pipe

City of St. Paul

2015 Water Quantity and Quality Monitoring Program

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FIGURE 9-1

Flandrau - Case Pond

N
W
E
S

Legend

Pond Area

Storm Pipe

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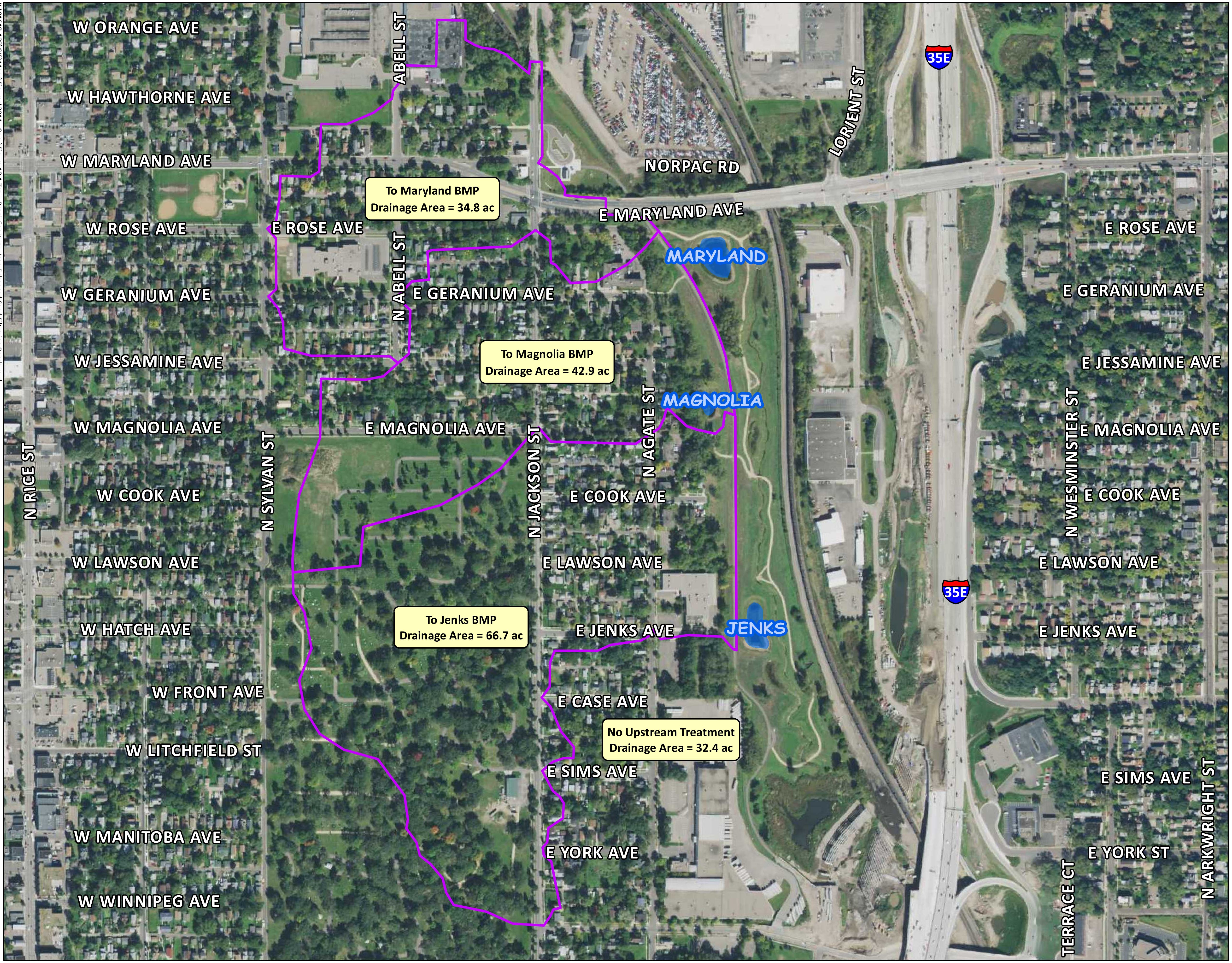

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2015 Water Quality & Quantity Program

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Figure 10-1 Trout Brook Sanctuary Iron Enhanced Sand Filtration Ponds

N W E S

0 200 400

Feet

LEGEND

Subwatershed to BMP

Iron Enhanced Sand Filtration Ponds

WSB

K:\01610-100\GIS\Maps\Figures\2014 - Copy\Figure 10-1 Trout Brook Sanctuary Iron Enhanced Sand Filtration Ponds.mxd

City of St. Paul

2015 Water Quantity and Quality Monitoring Program

Figure 11-1

Victoria Street Pervious Pavement Testing

N
W
E
S

0 25 50 100 Feet

Legend

- Storm Manhole
- Storm Catch Basin
- Pervious Pavement Test Points
- Storm Pipe
- Infiltration Trench
- Pervious Pavement
- Rain Gauge Location

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Figure 11-2

Hamline Midway Library Pervious Pavement Testing

N
W E
S

0 20 40 80
Feet

Legend

- Storm Catch Basin
- Storm Manhole
- Pervious Pavement Test Points
- Storm Pipe
- Pervious Pavement

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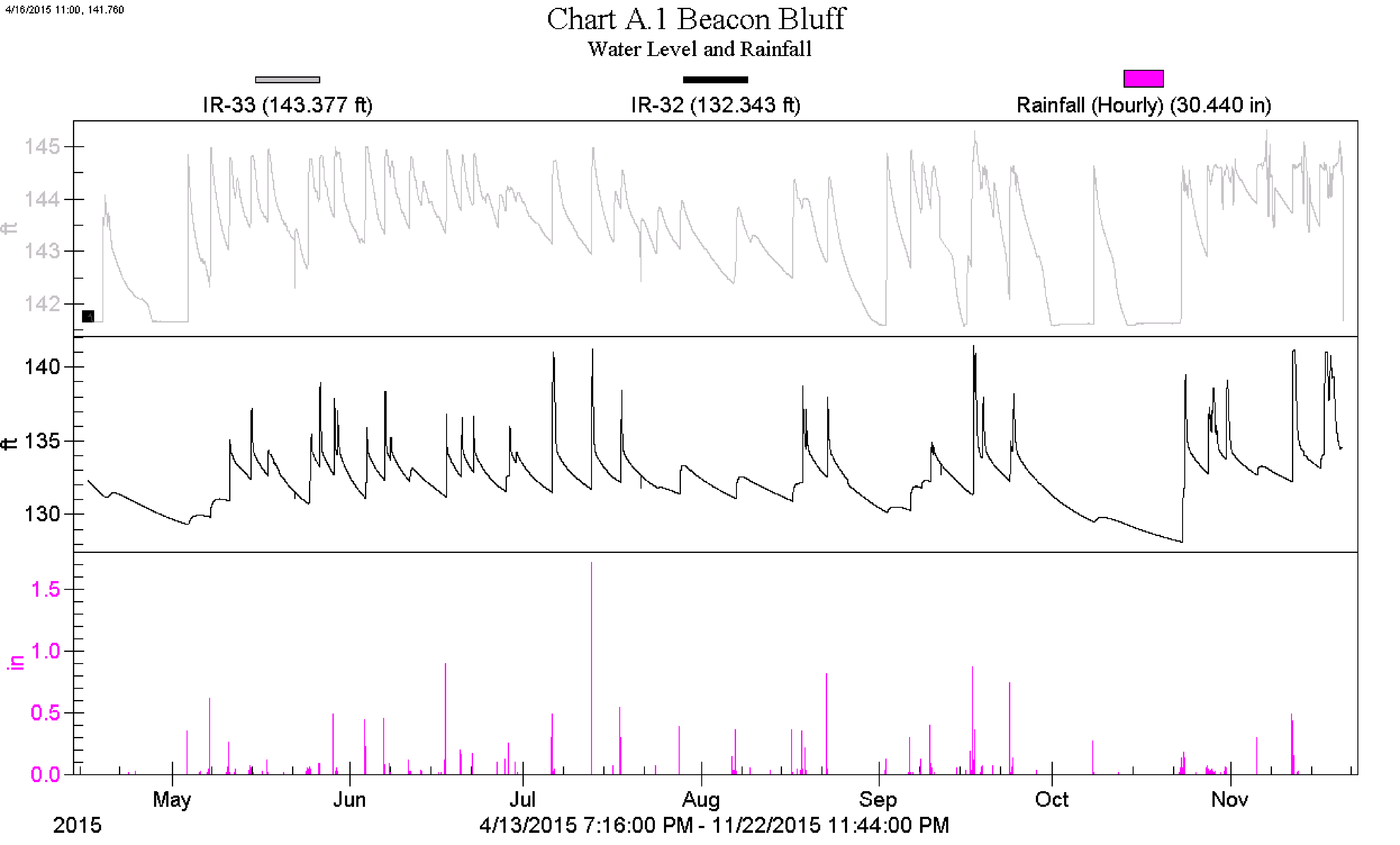
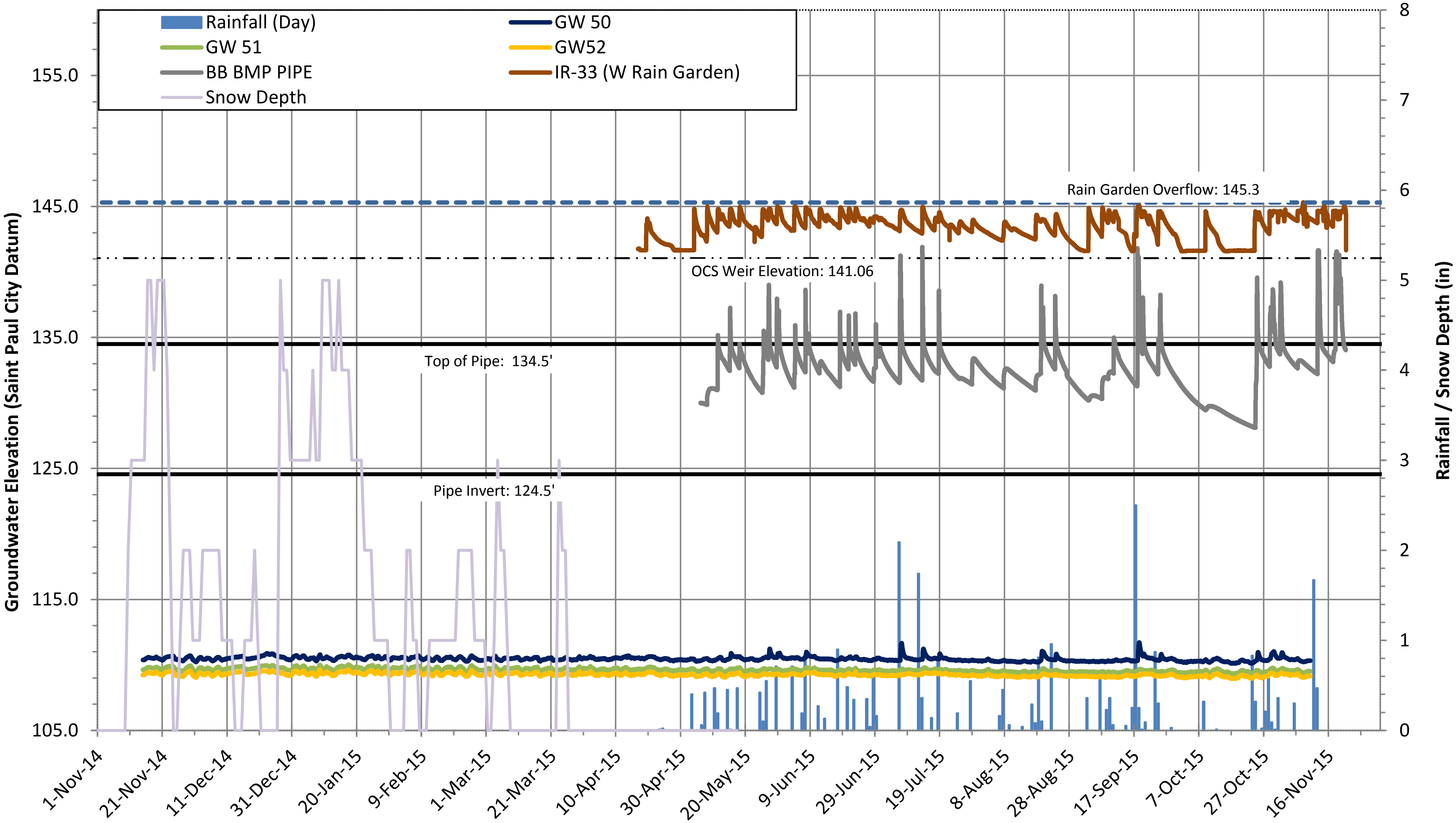
APPENDICES



4/16/2015 11:00, 141.760
Chart A.1 Beacon Bluff
Water Level and Rainfall
IR-33 (143.377 ft)
IR-32 (132.343 ft)
Rainfall (Hourly) (30.440 in)
ft
145
144
143
142
ft
140
135
130
in
1.5
1.0
0.5
0.0
May
Jun
Jul
Aug
Sep
Oct
Nov
2015
4/13/2015 7:16:00 PM - 11/22/2015 11:44:00 PM

City of Saint Paul
2015 Water Quality and Quantity Report
Chart A.2
WSB Job No.: 01610-100

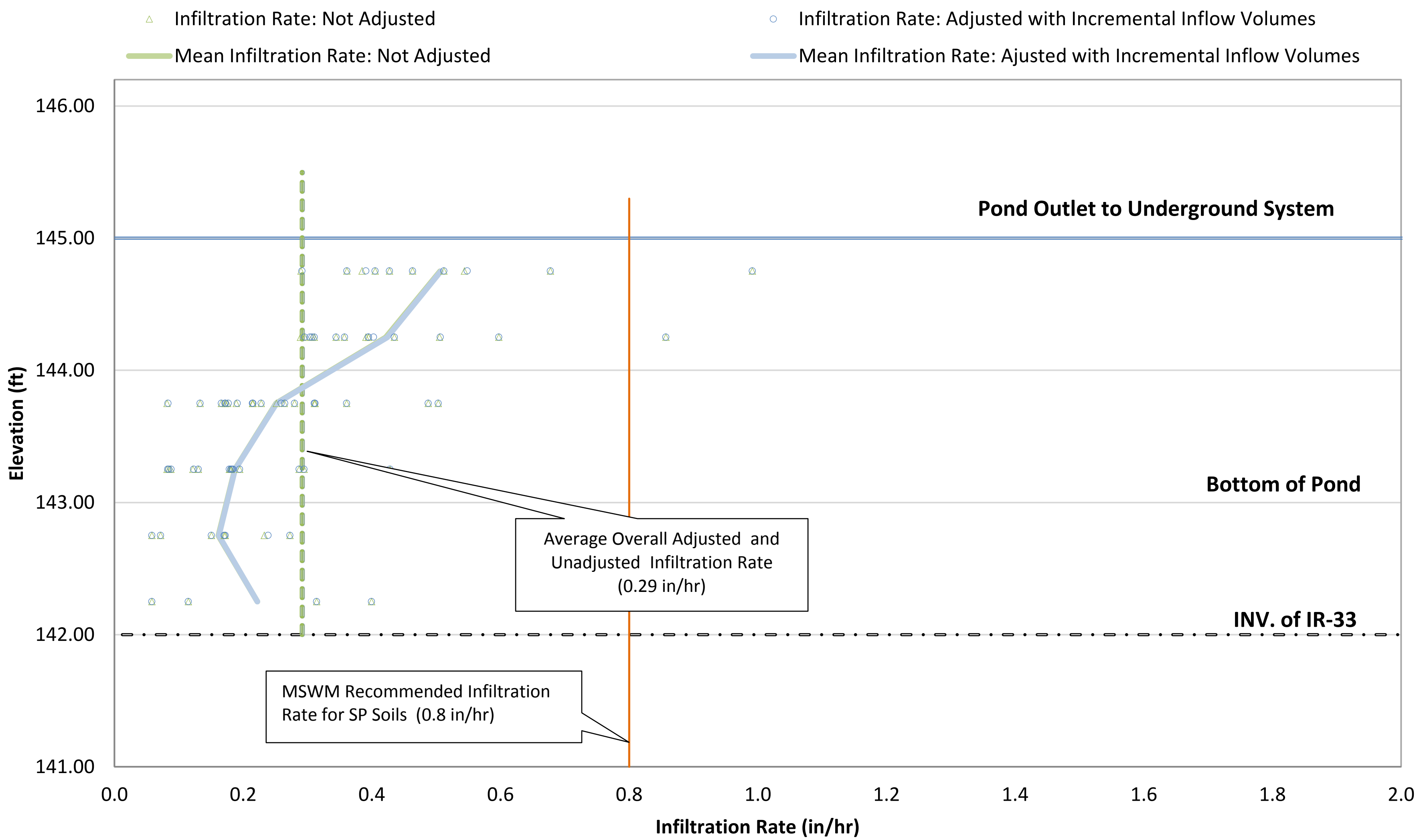
Groundwater and Infiltration System Level Measurements
Beacon Bluff
St. Paul, MN



City of Saint Paul
2015 Water Quality and Quantity Monitoring
Chart A.3
WSB Project No.: 01610-100

Beacon Bluff Raingarden Soil - Infiltration Rate Graph (IR-33)

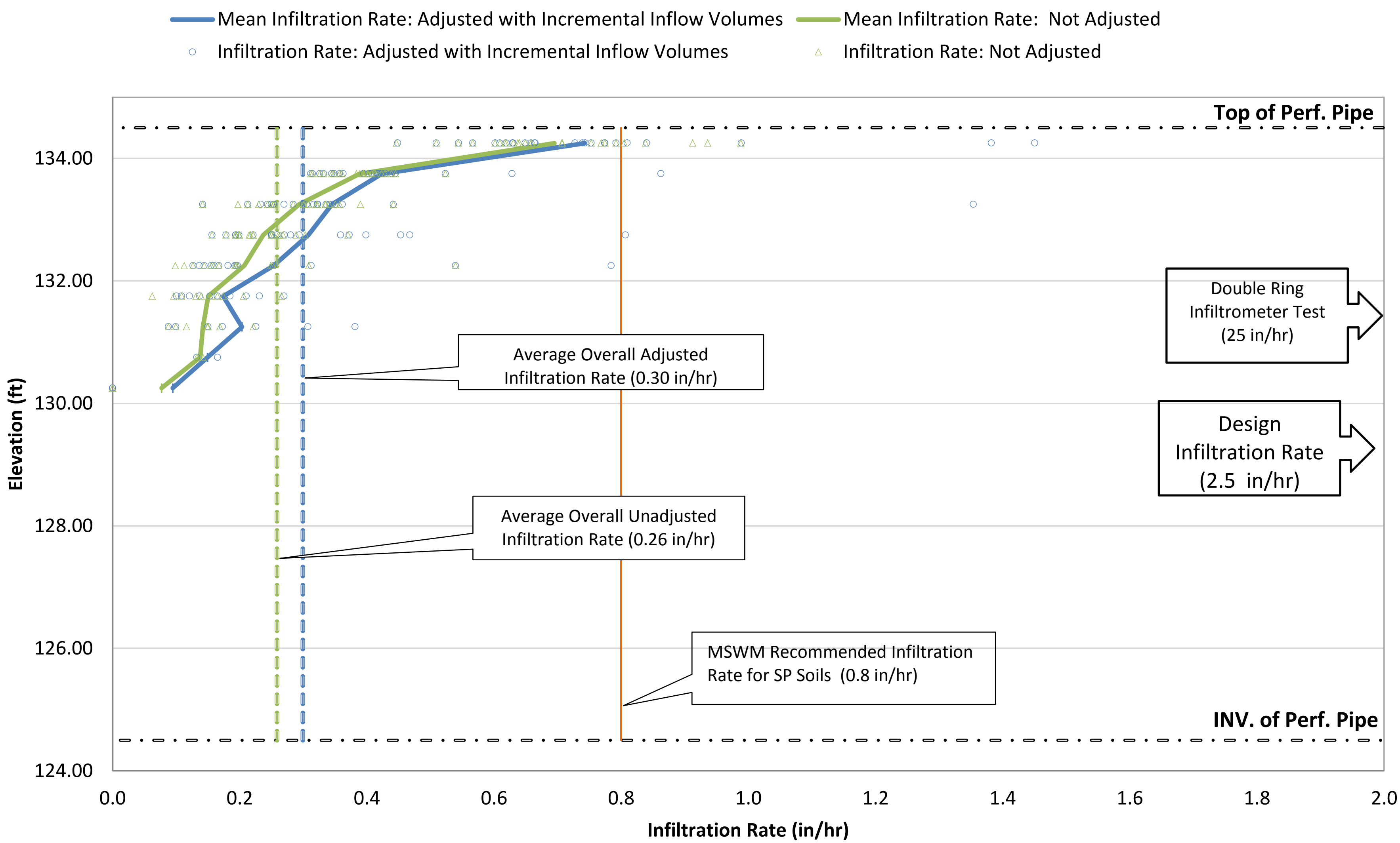
(Observed at 0.5 Foot Height Intervals)



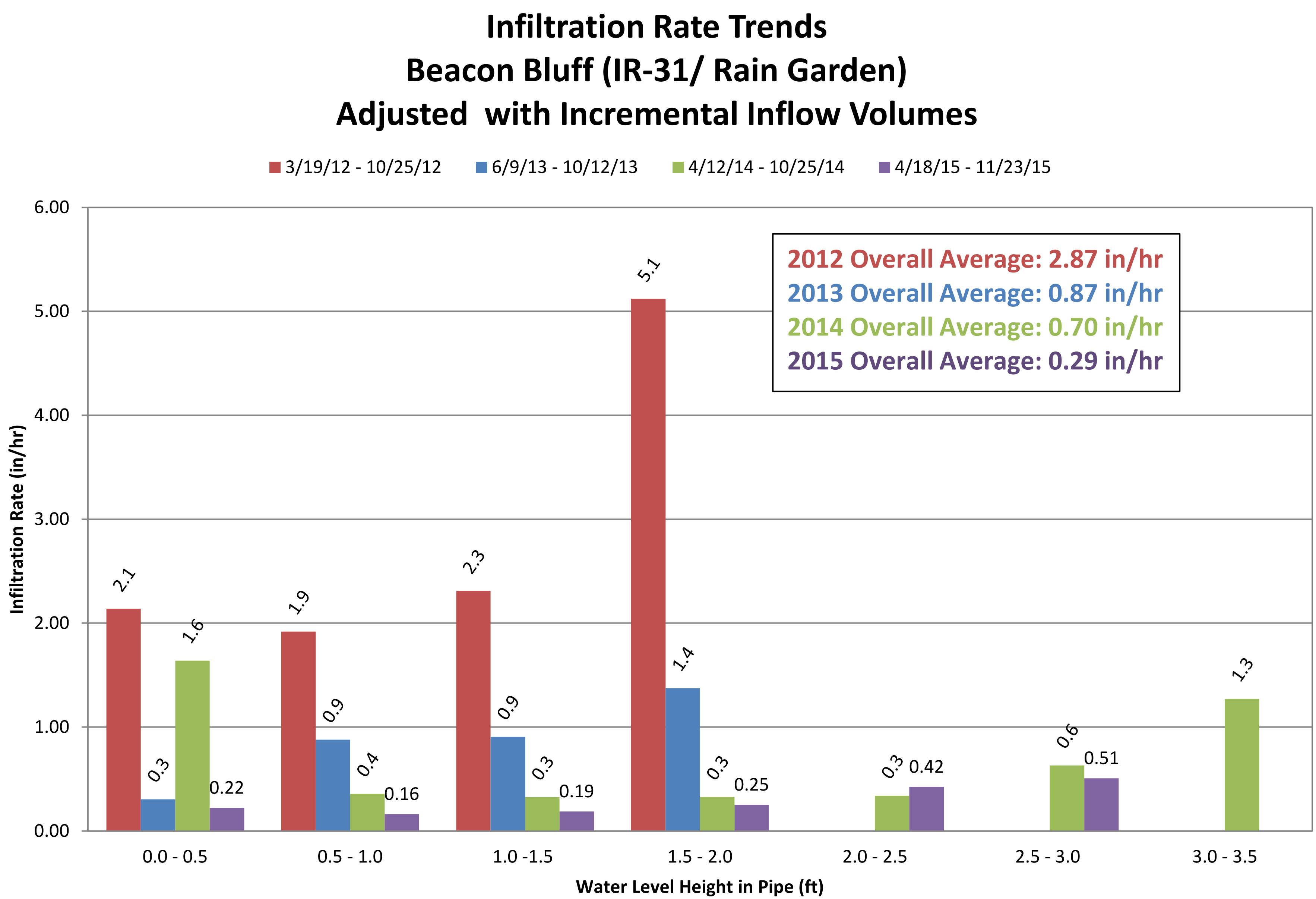
City of Saint Paul
2015 Water Quality and Quantity Report
Chart A.4
WSB Project No.: 01610-100

Beacon Bluff Underground System - Infiltration Rate Graph (BMP Pipe)

(Observed at 0.5 Foot Height Intervals)



Note: Pipe Invert is 124.5'
Pipe perforated around circumference of pipe


Infiltration Rate Trends
Beacon Bluff (IR-31/ Rain Garden)
Adjusted with Incremental Inflow Volumes
3/19/12 - 10/25/12
6/9/13 - 10/12/13
4/12/14 - 10/25/14
4/18/15 - 11/23/15
2012 Overall Average: 2.87 in/hr
2013 Overall Average: 0.87 in/hr
2014 Overall Average: 0.70 in/hr
2015 Overall Average: 0.29 in/hr
Infiltration Rate (in/hr)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2.1
0.3
1.6
0.22
1.9
0.9
0.4
0.16
2.3
0.9
0.3
0.19
5.1
1.4
0.3
0.25
0.3
0.42
0.6
0.51
1.3
0.0 - 0.5
0.5 - 1.0
1.0 -1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
3.0 - 3.5
Water Level Height in Pipe (ft)

City of Saint Paul
2015 Water Quality and Quantity Report
Chart A.6
WSB Job No.: 01610-100

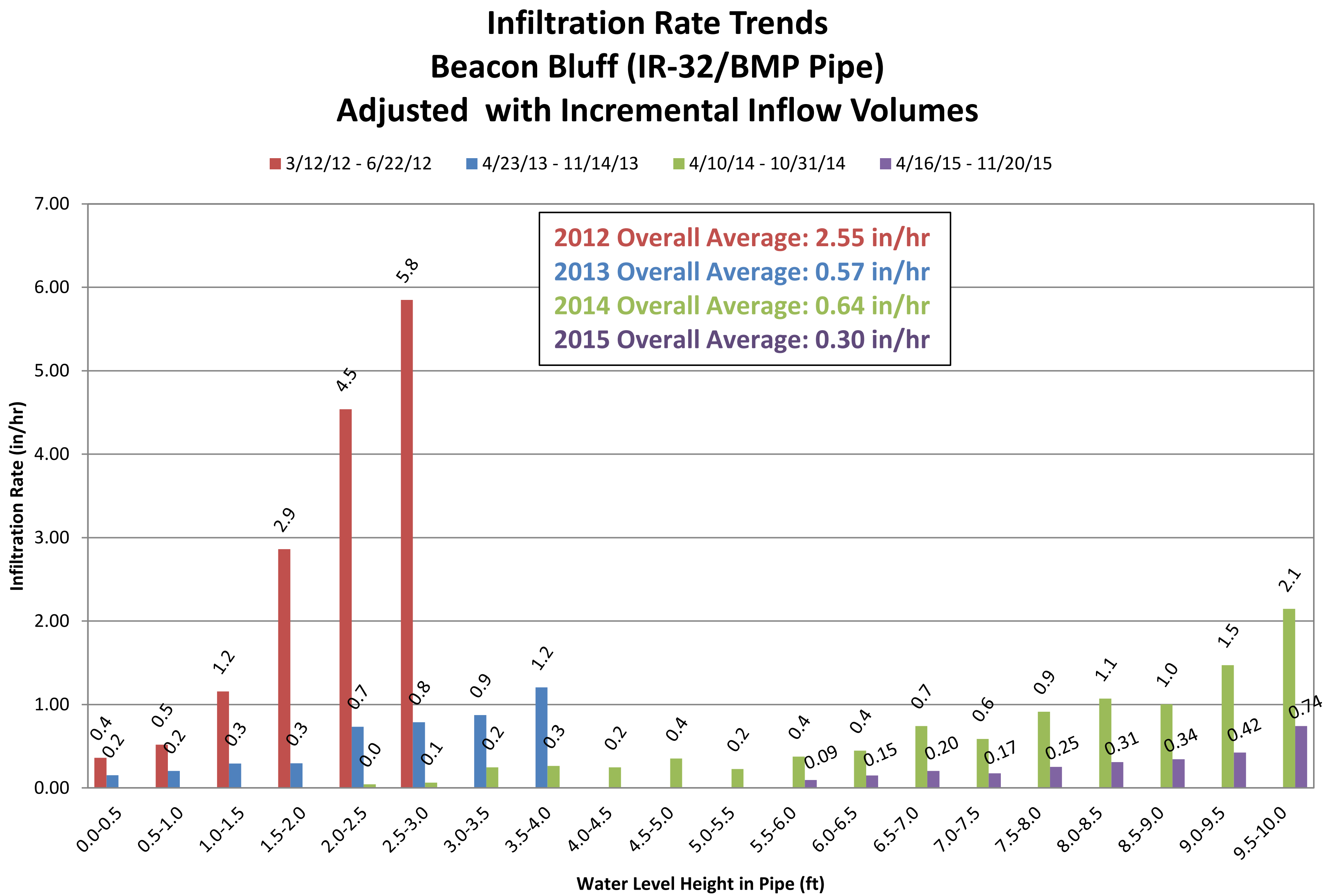
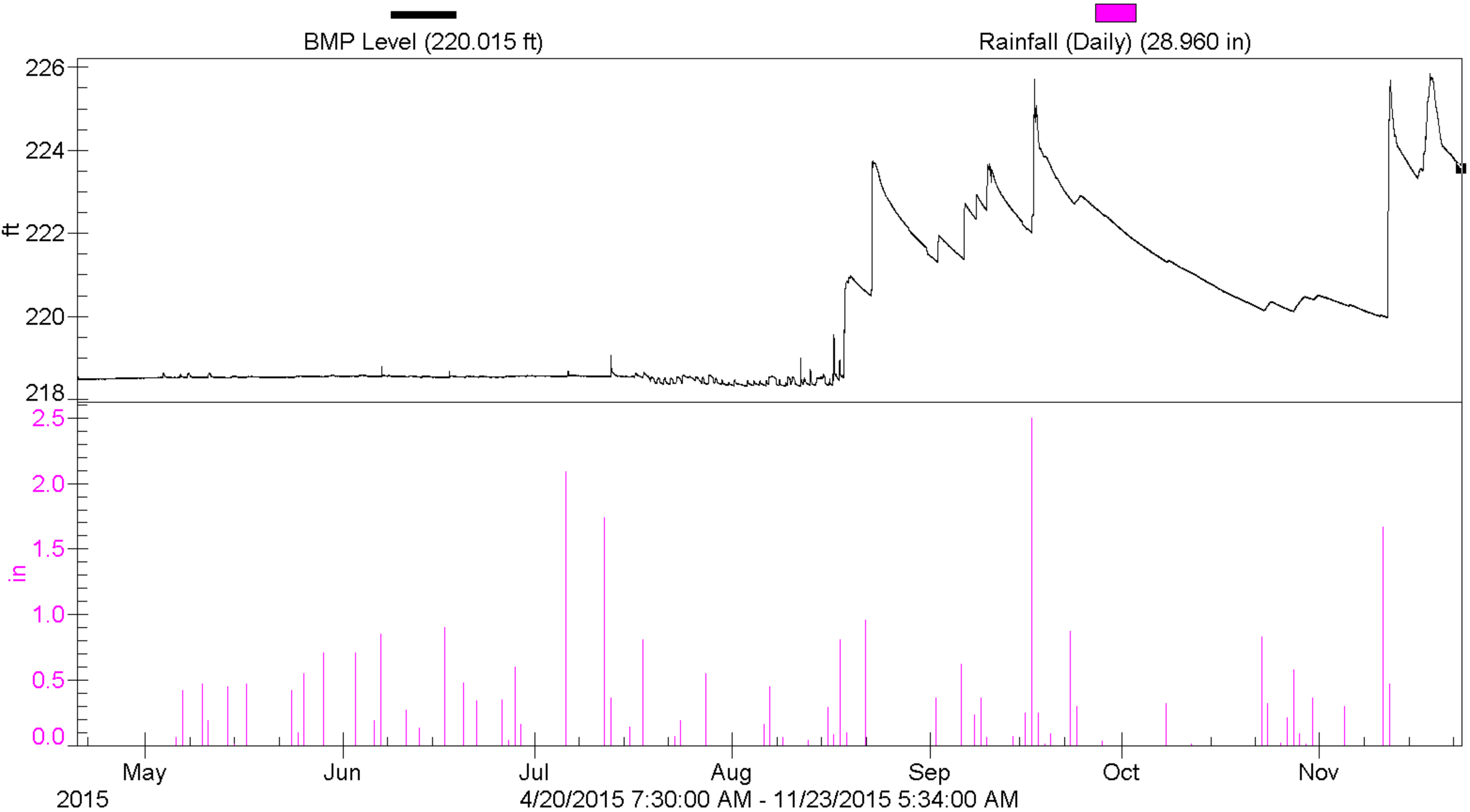


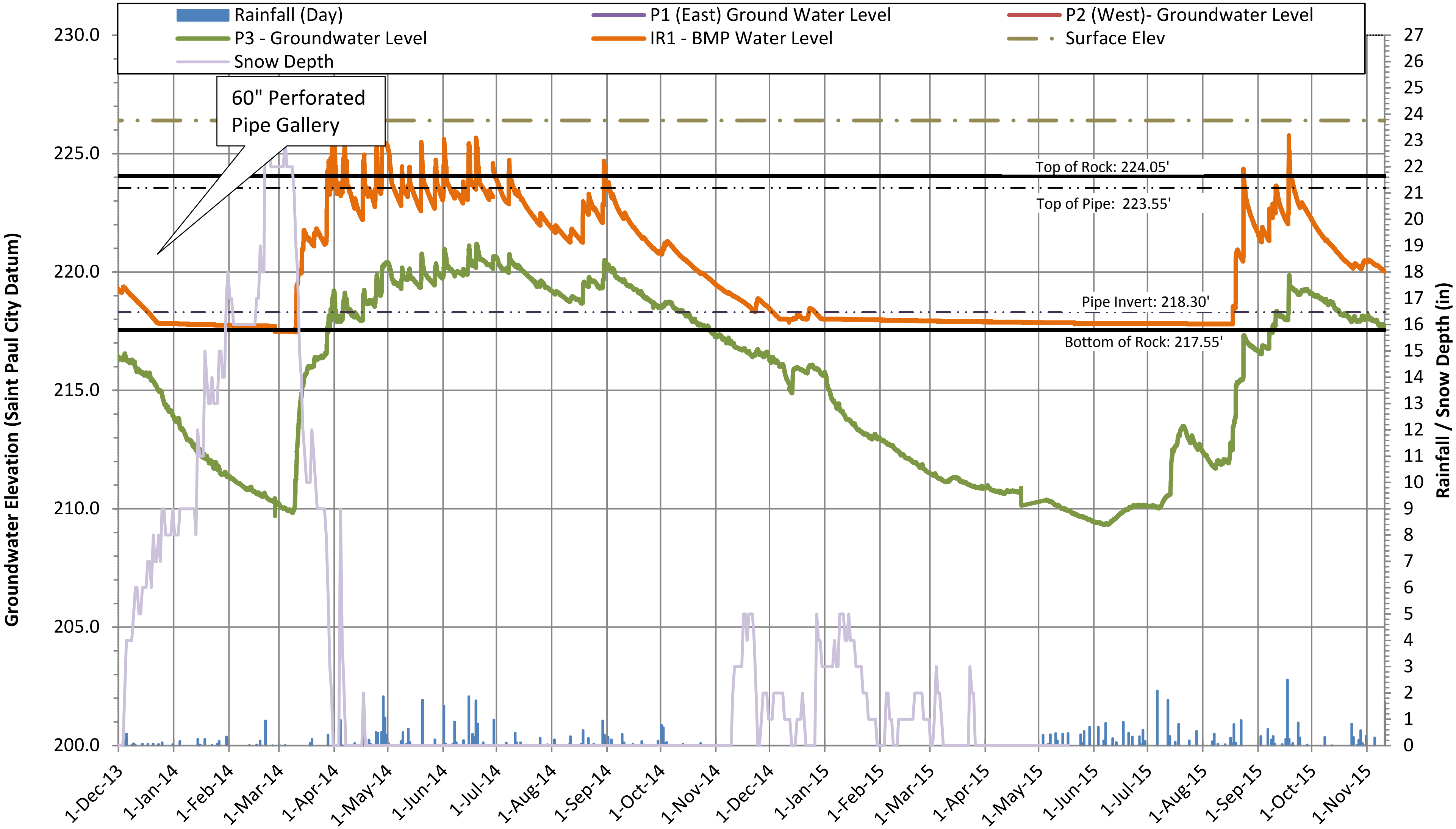
Chart A.7 Hillcrest Knoll

Water Level Elevation and Rainfall

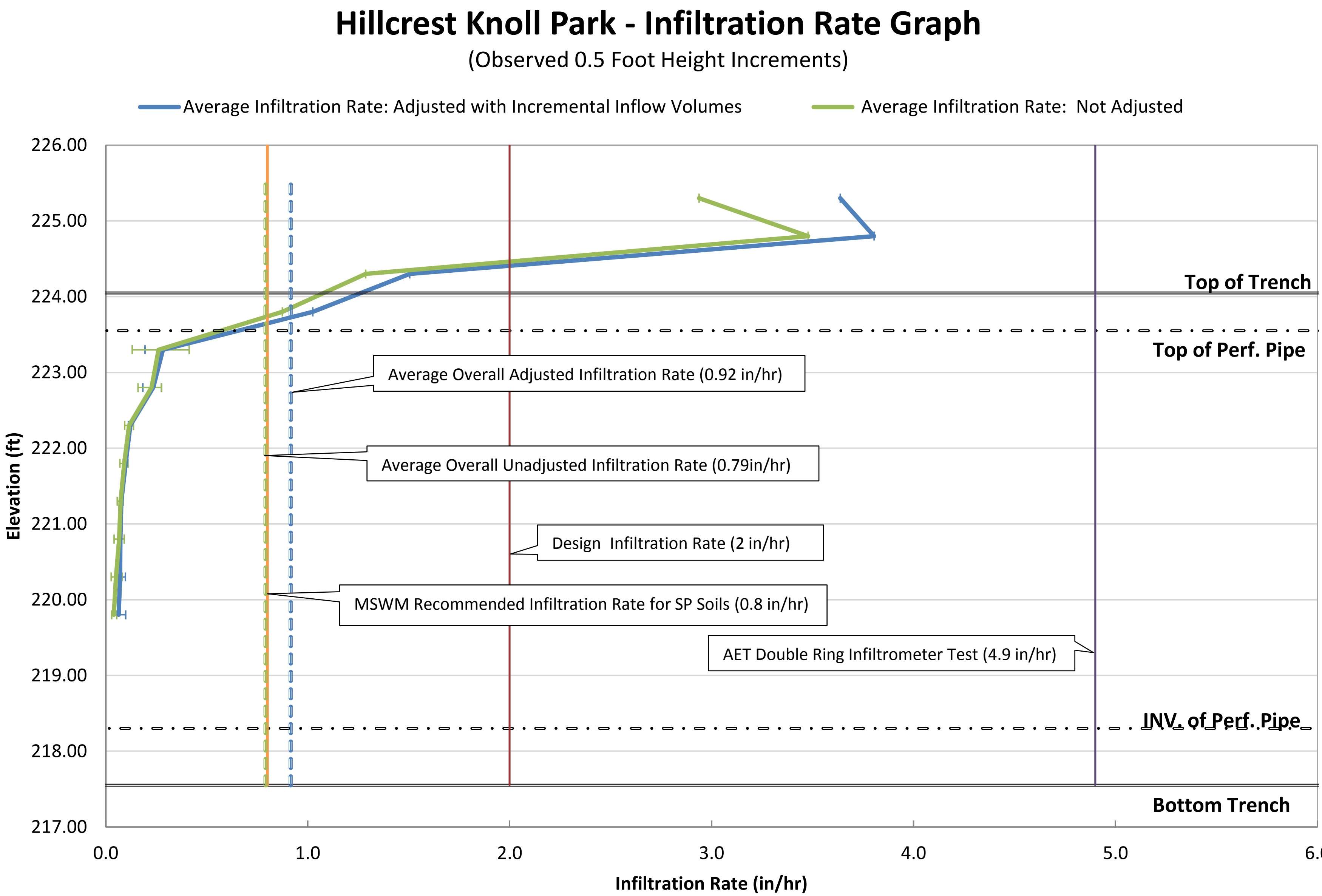


City of Saint Paul
2015 Water Quality and Quantity Report
Chart A.8
WSB Job No.: 01610-100

Groundwater and Infiltration System Level Measurements
Hillcrest Knoll Park
St. Paul, MN



City of Saint Paul
2015 Water Quality and Quantity Report
Chart A.9
WSB Job No.: 01610-100



Note: Pipe Invert is 218.30'
Pipe perforated around circumference of pipe
Error Bars Represent 25th and 75th Percentiles

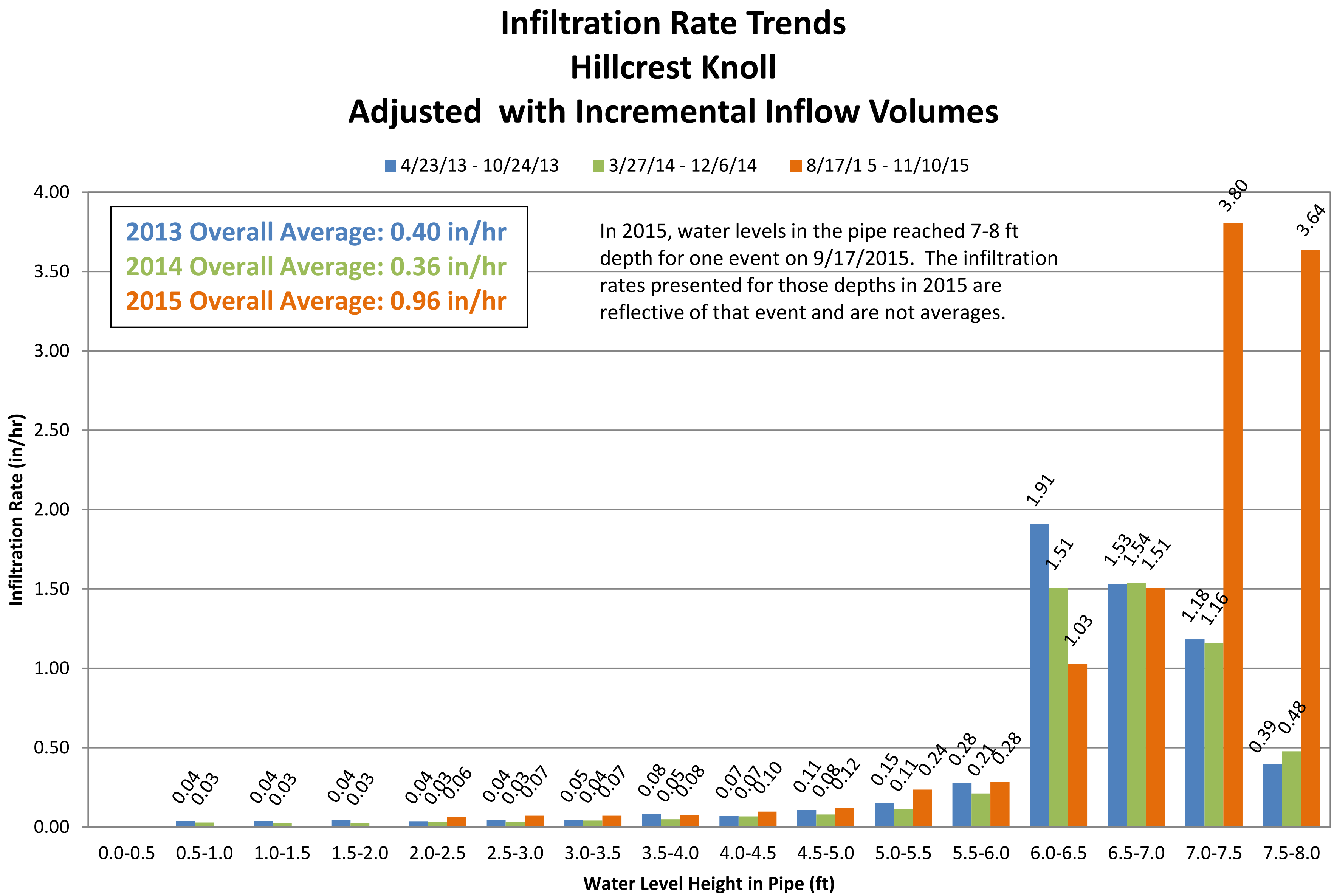
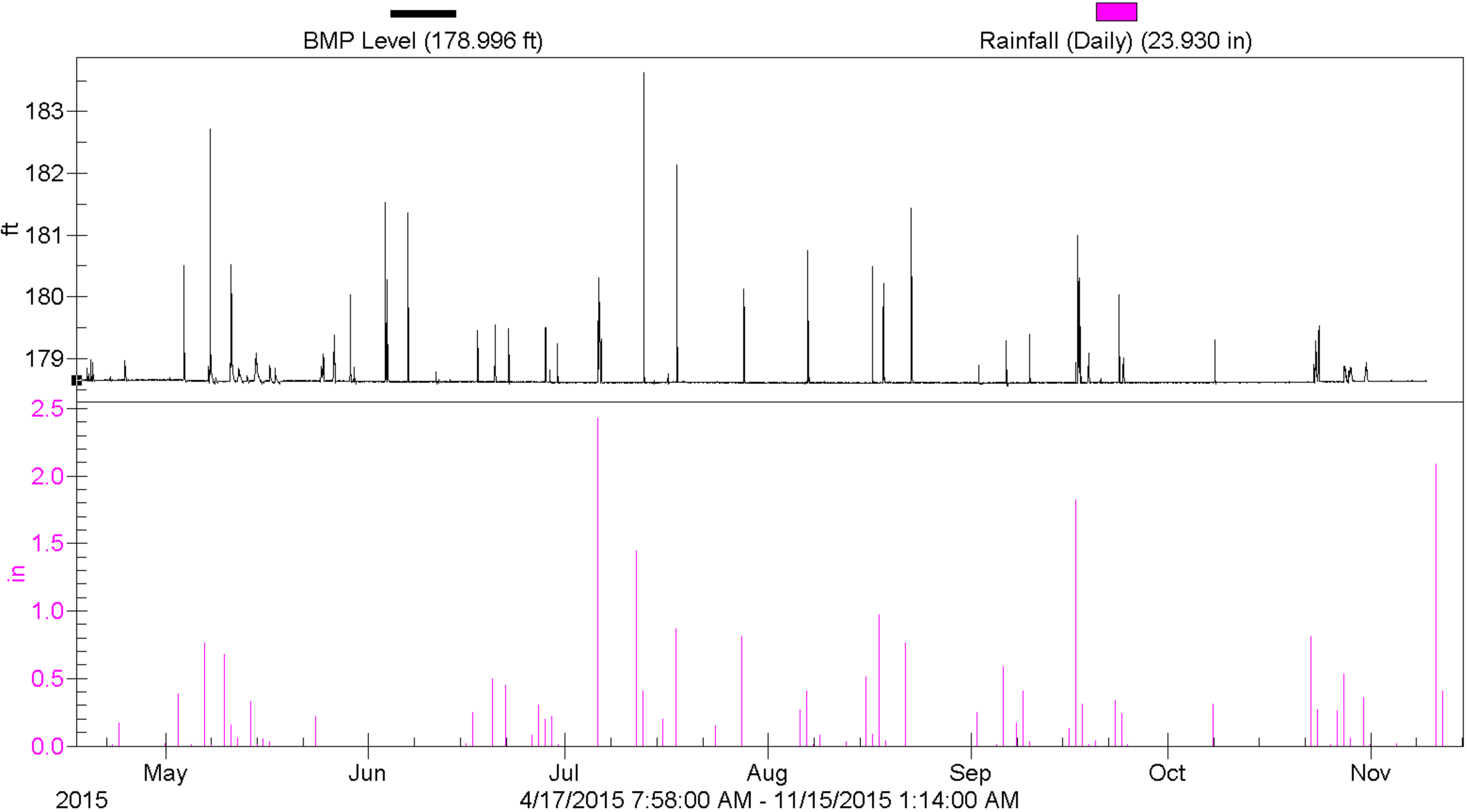
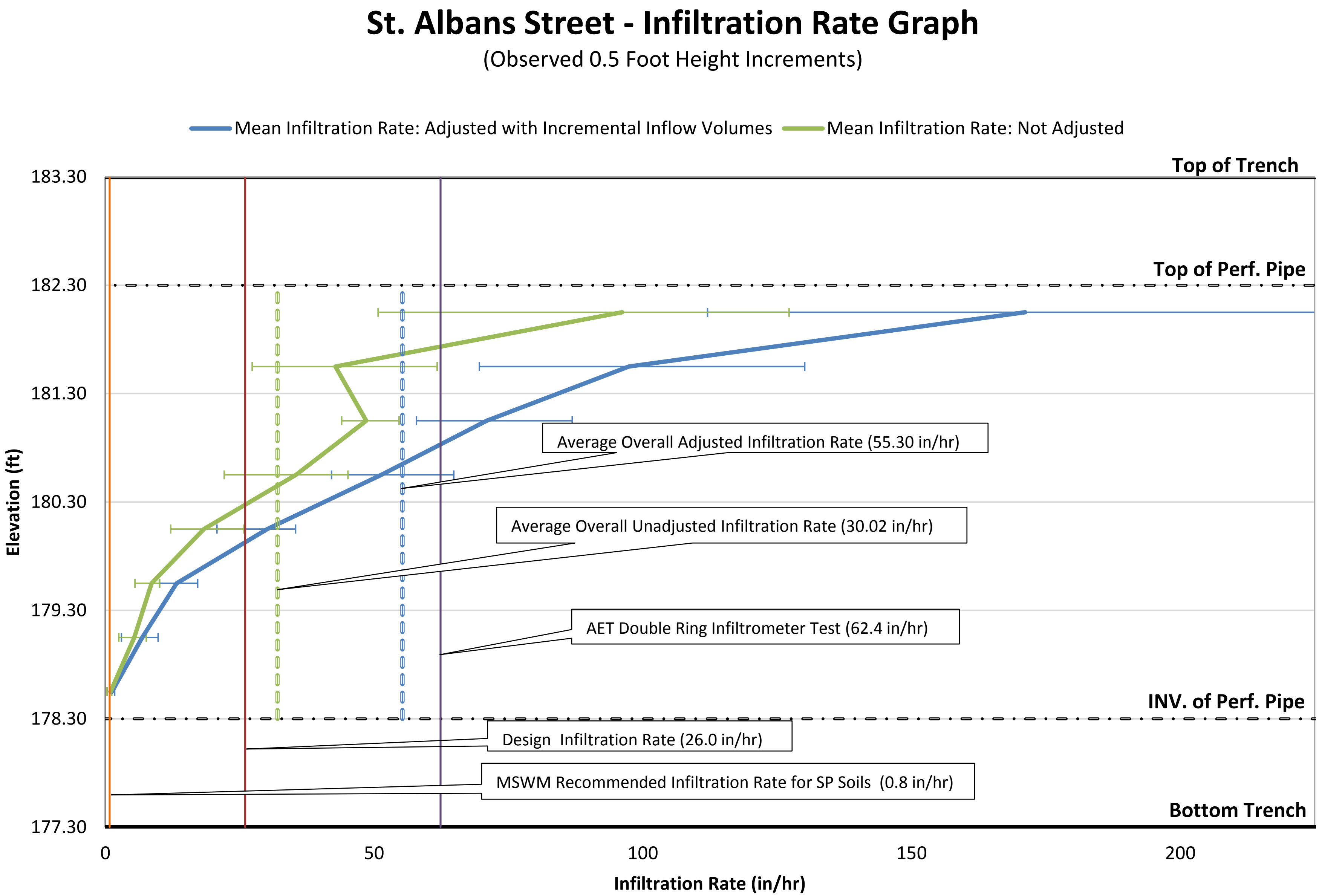

Infiltration Rate Trends
Hillcrest Knoll
Adjusted with Incremental Inflow Volumes
4/23/13 - 10/24/13
3/27/14 - 12/6/14
8/17/1 5 - 11/10/15
2013 Overall Average: 0.40 in/hr
2014 Overall Average: 0.36 in/hr
2015 Overall Average: 0.96 in/hr
In 2015, water levels in the pipe reached 7-8 ft depth for one event on 9/17/2015. The infiltration rates presented for those depths in 2015 are reflective of that event and are not averages.
Infiltration Rate (in/hr)
Water Level Height in Pipe (ft)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
0.0-0.5
0.5-1.0
1.0-1.5
1.5-2.0
2.0-2.5
2.5-3.0
3.0-3.5
3.5-4.0
4.0-4.5
4.5-5.0
5.0-5.5
5.5-6.0
6.0-6.5
6.5-7.0
7.0-7.5
7.5-8.0
0.04 0.03
0.04 0.03
0.04 0.03
0.04 0.03 0.06
0.04 0.03 0.07
0.05 0.04 0.07
0.08 0.05 0.08
0.07 0.07 0.10
0.11 0.08 0.12
0.15 0.11 0.24
0.28 0.21 0.28
1.91 1.51 1.03
1.53 1.54 1.51
1.18 1.16 3.80
0.39 0.48 3.64

Chart A.11 St. Albans

Water Level Elevation and Rainfall



City of Saint Paul
2015 Water Quality and Quantity Report
Chart A.12
WSB Job No.: 01610-100



Note: Pipe Invert is 178.3'
Error Bars Represent 25th and 75th Percentiles
Pipe perforated w/ 2 rows of holes at Elev: 178.9' and 179.2'

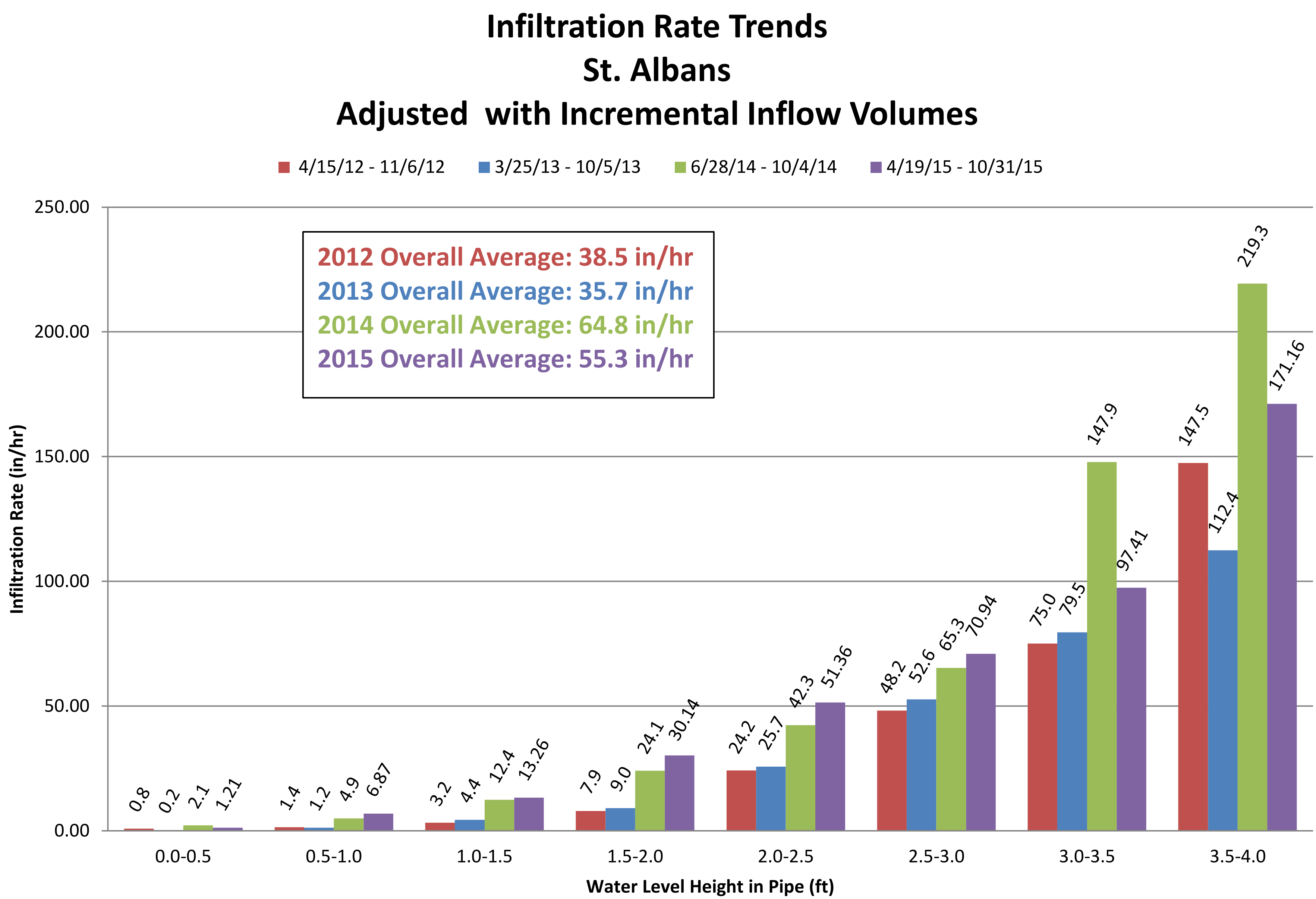
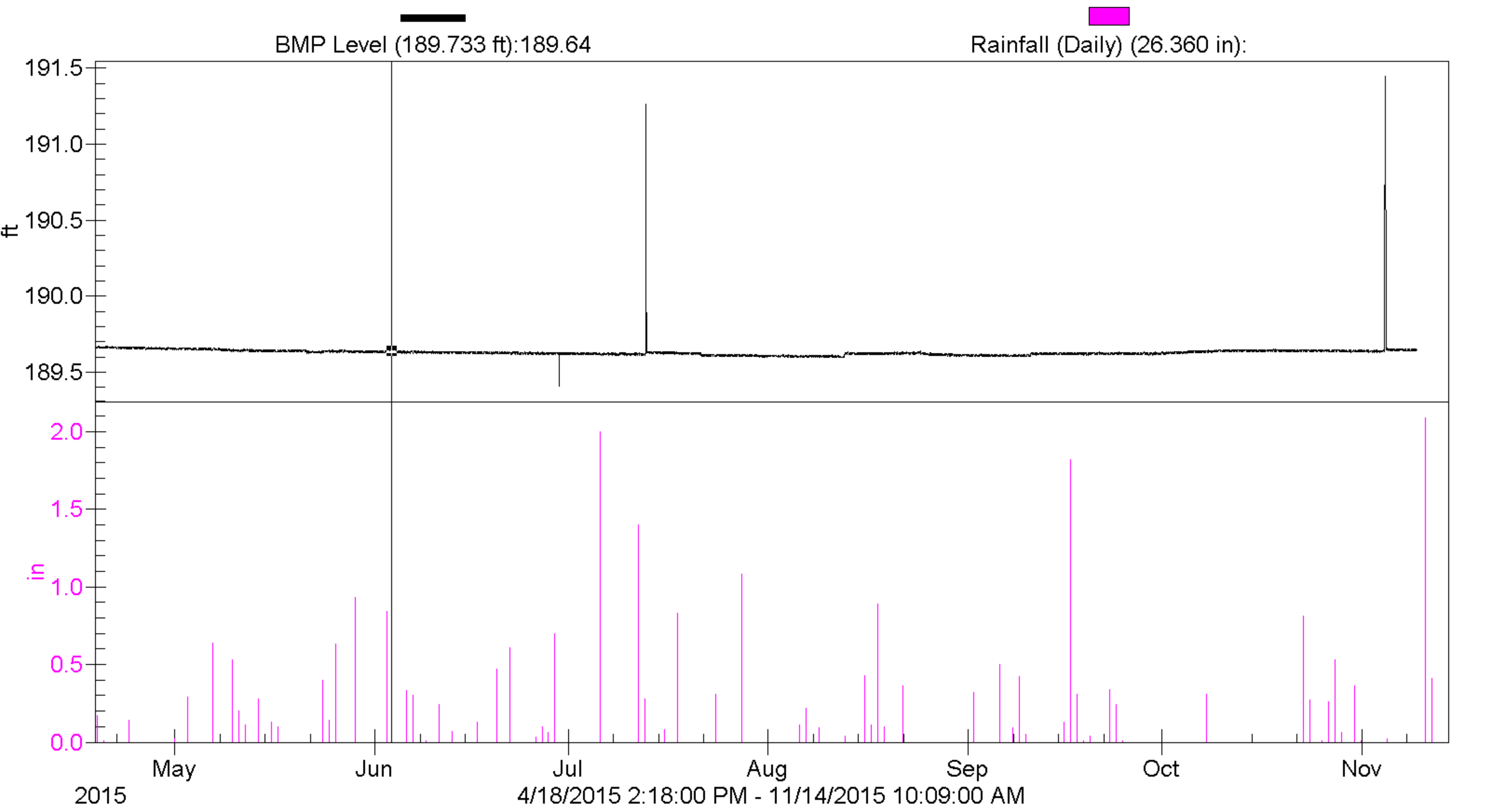

Infiltration Rate Trends
St. Albans
Adjusted with Incremental Inflow Volumes
4/15/12 - 11/6/12
3/25/13 - 10/5/13
6/28/14 - 10/4/14
4/19/15 - 10/31/15
2012 Overall Average: 38.5 in/hr
2013 Overall Average: 35.7 in/hr
2014 Overall Average: 64.8 in/hr
2015 Overall Average: 55.3 in/hr
Infiltration Rate (in/hr)
250.00
200.00
150.00
100.00
50.00
0.00
0.8
0.2
2.1
1.21
1.4
1.2
4.9
6.87
3.2
4.4
12.4
13.26
7.9
9.0
24.1
30.14
24.2
25.7
42.3
51.36
48.2
52.6
65.3
70.94
75.0
79.5
147.9
97.41
147.5
112.4
219.3
171.16
0.0-0.5
0.5-1.0
1.0-1.5
1.5-2.0
2.0-2.5
2.5-3.0
3.0-3.5
3.5-4.0
Water Level Height in Pipe (ft)

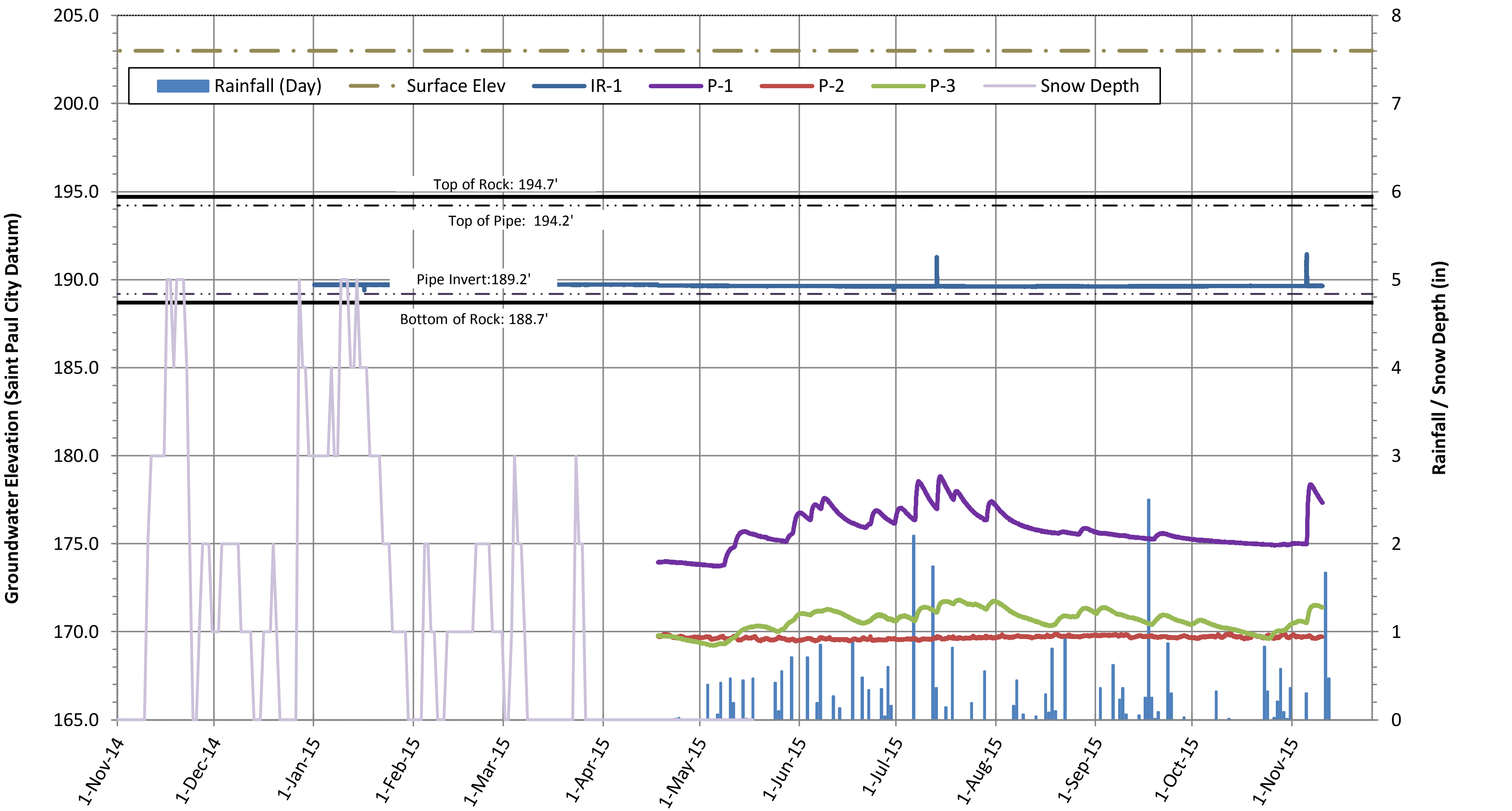
Chart A.14 Hampden Park

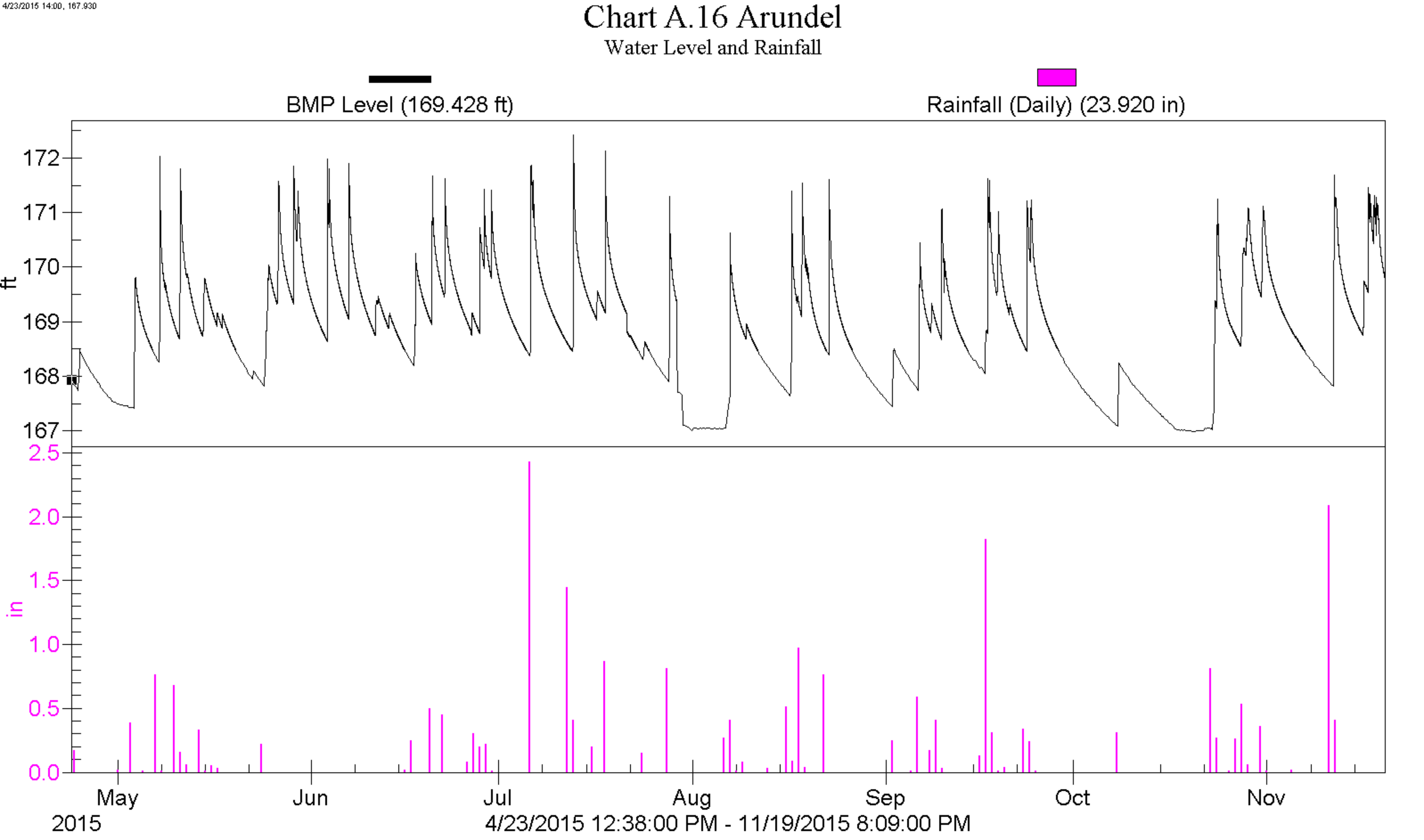
Water Level and Rainfall



City of Saint Paul
2015 Water Quality and Quantity Report
Chart A.15
WSB Job No.: 01610-100

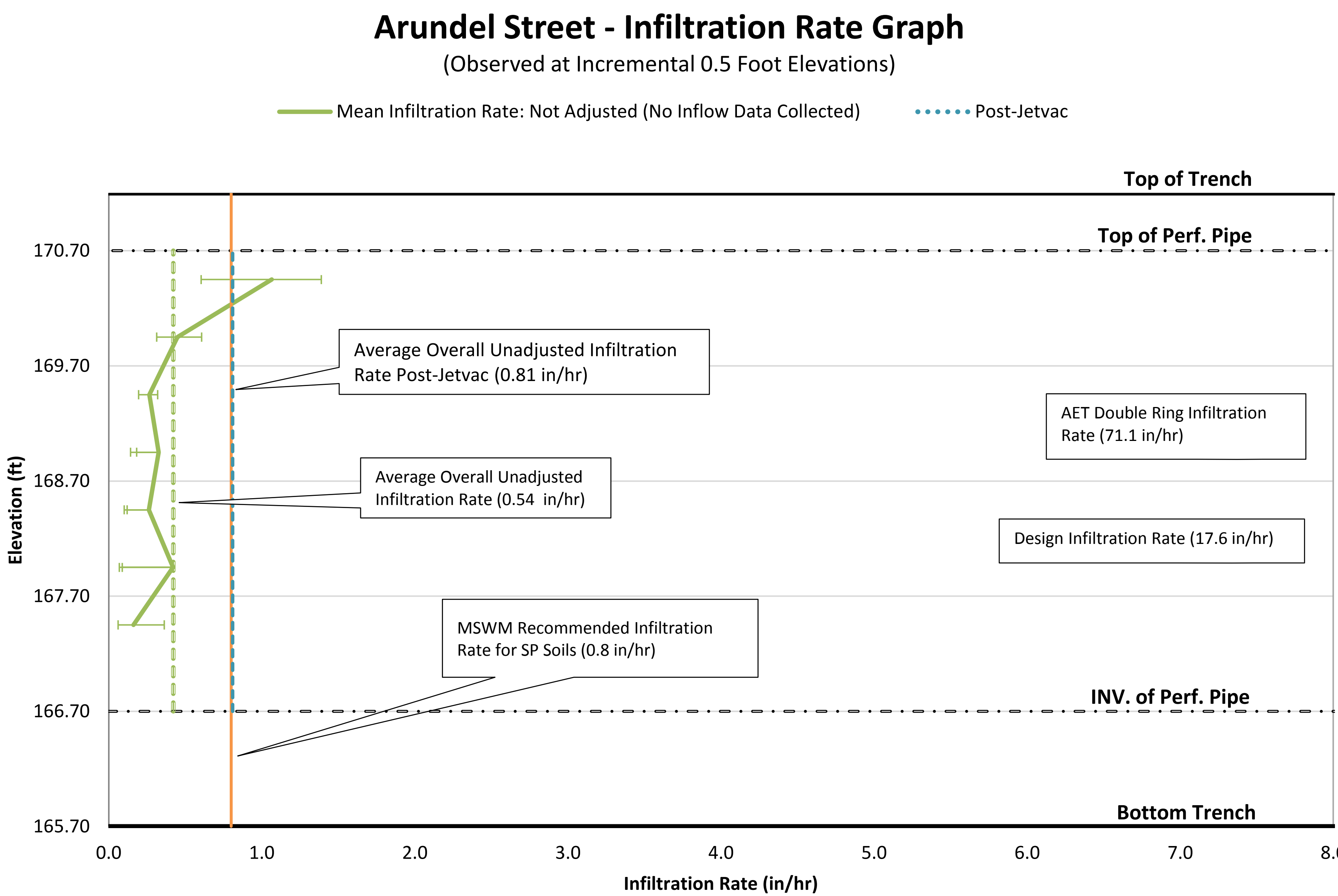
Groundwater and Infiltration System Level Measurements
Hampden Park
St. Paul, MN





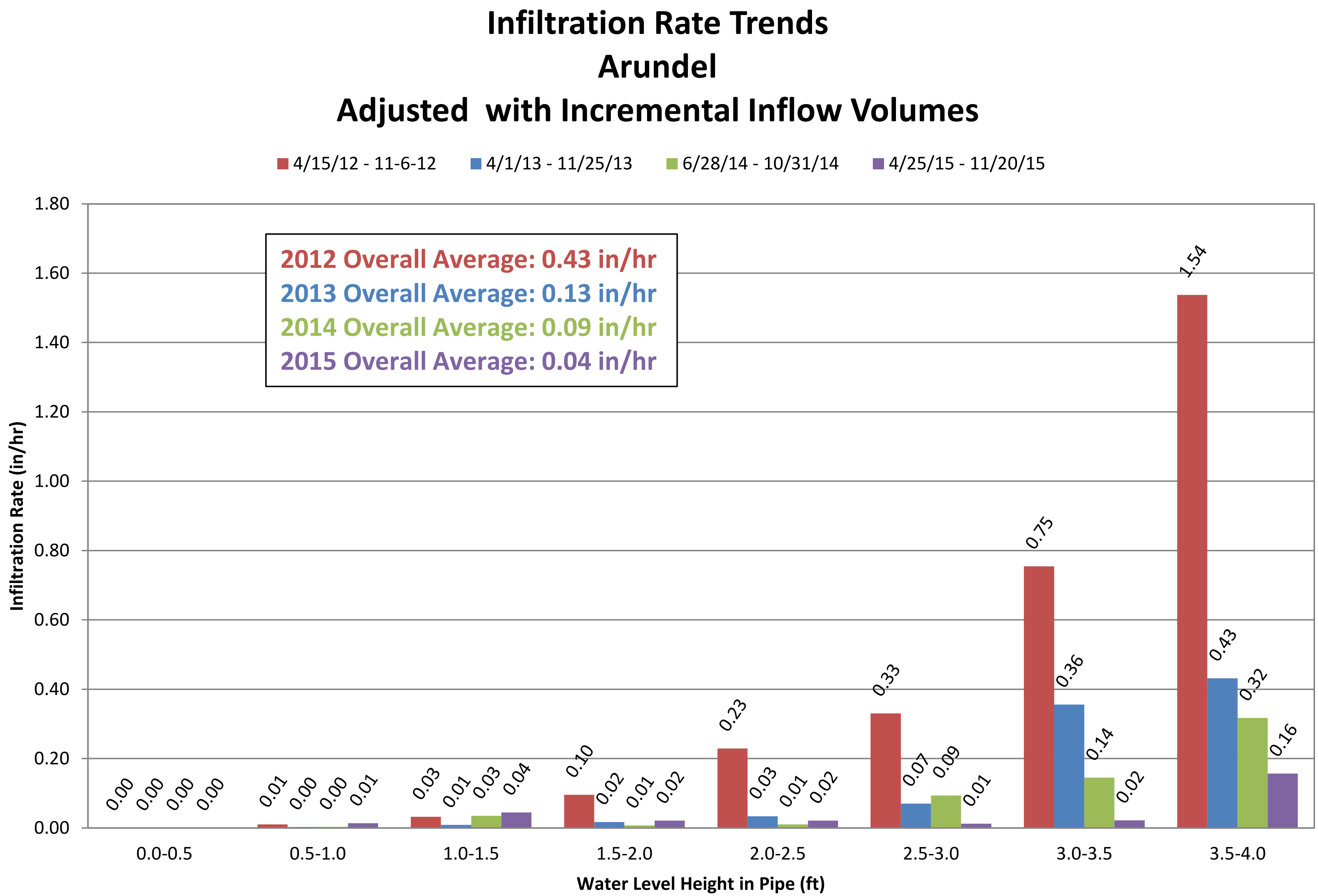
4/23/2015 14:00, 167.930
Chart A.16 Arundel
Water Level and Rainfall
BMP Level (169.428 ft)
Rainfall (Daily) (23.920 in)
ft
172
171
170
169
168
167
in
2.5
2.0
1.5
1.0
0.5
0.0
May
Jun
Jul
Aug
Sep
Oct
Nov
2015
4/23/2015 12:38:00 PM - 11/19/2015 8:09:00 PM

City of Saint Paul
2015 Water Quality and Quantity
Chart A.17
WSB Job No.: 01610-100



Note: Pipe Invert is 166.7'
Error Bars Represent 25th and 75th Percentiles
Pipe perforated w/ 2 rows of holes at Elev: 167.3' and 167.6'

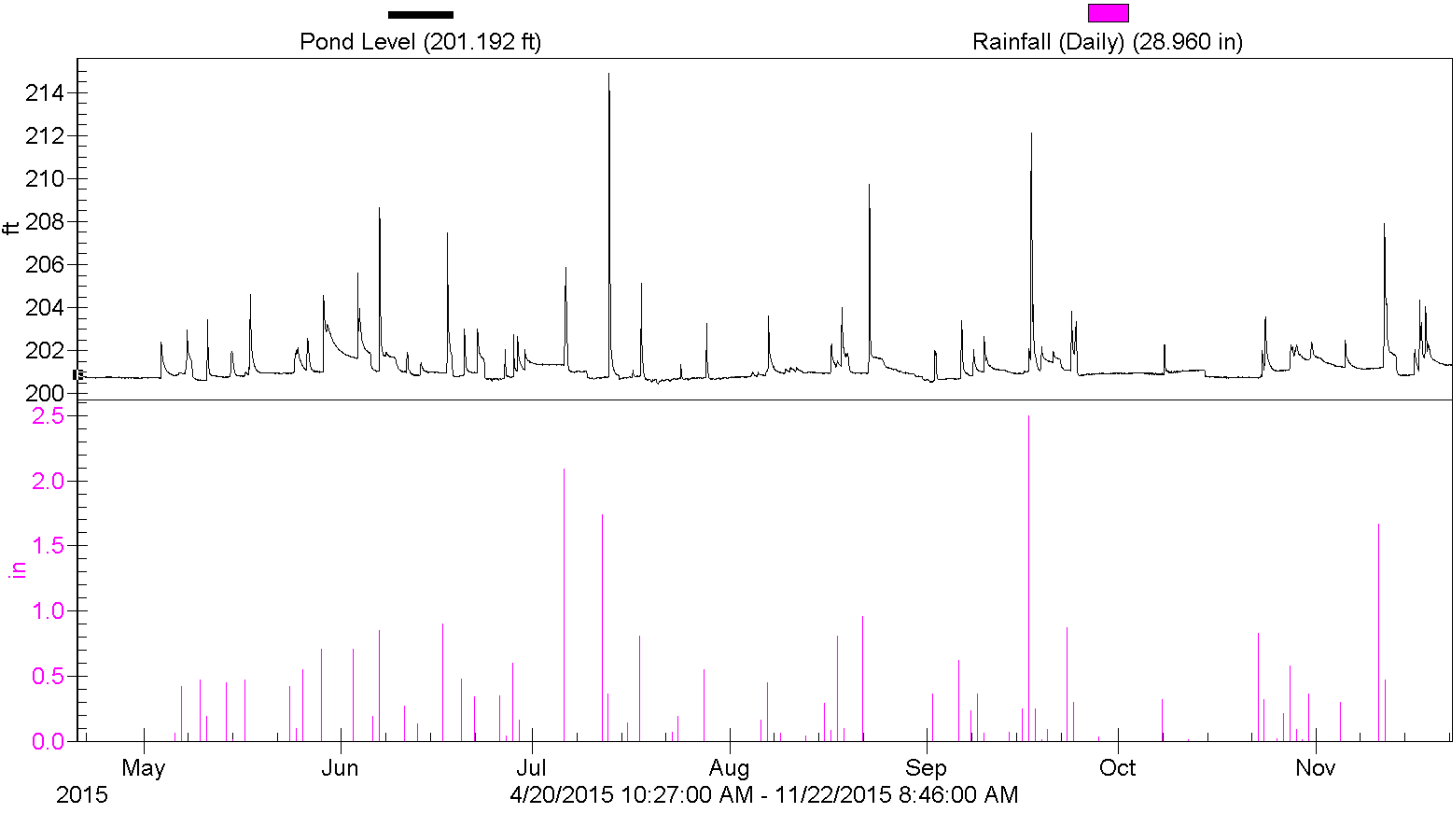
City of Saint Paul
2015 Water Quality and Quantity Report
Chart A.18
WSB Job No.: 01610-100



4/20/2015 16:00, 200.870

Chart A.19 Flandrau - Hoyt

Water Level and Rainfall



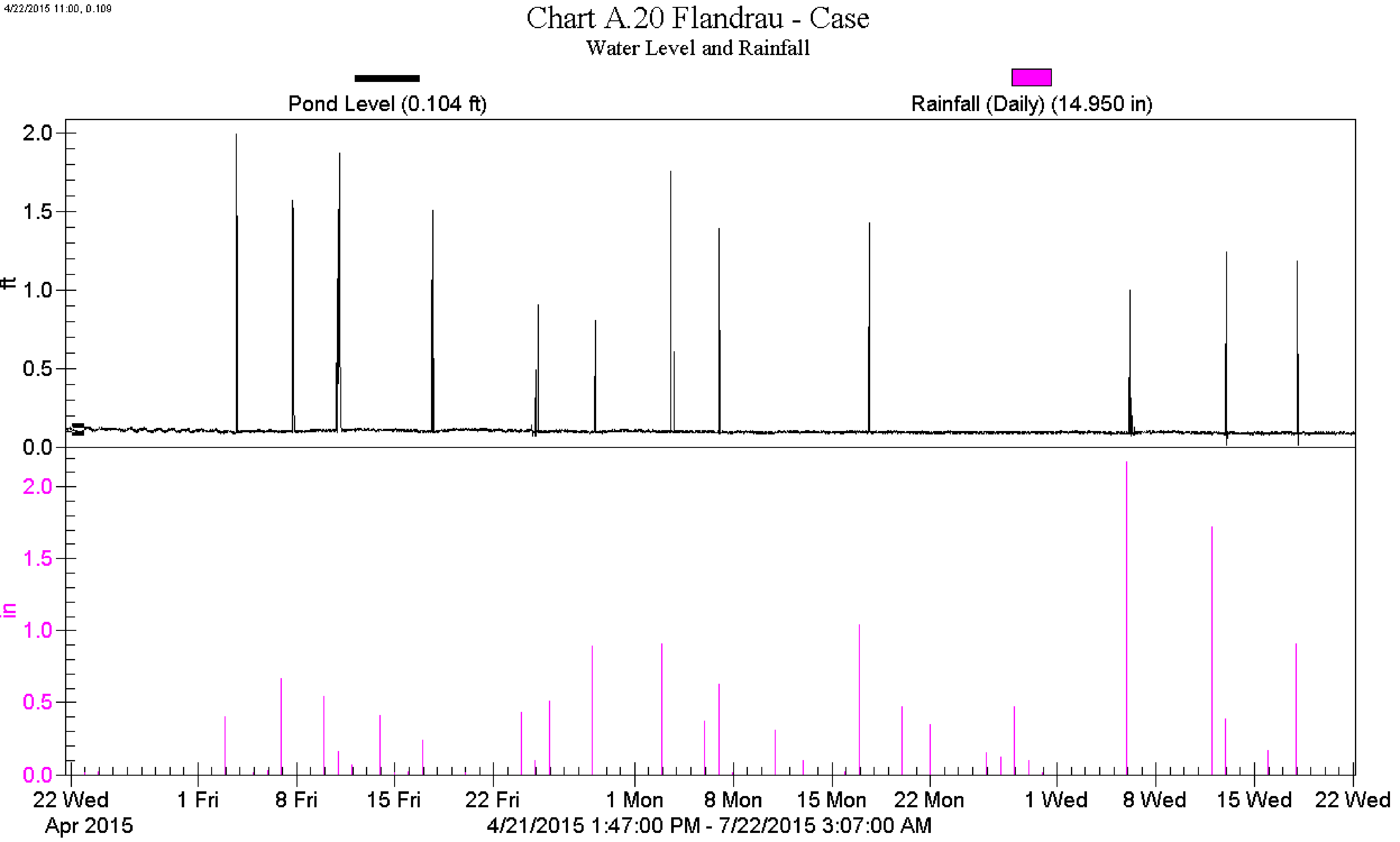
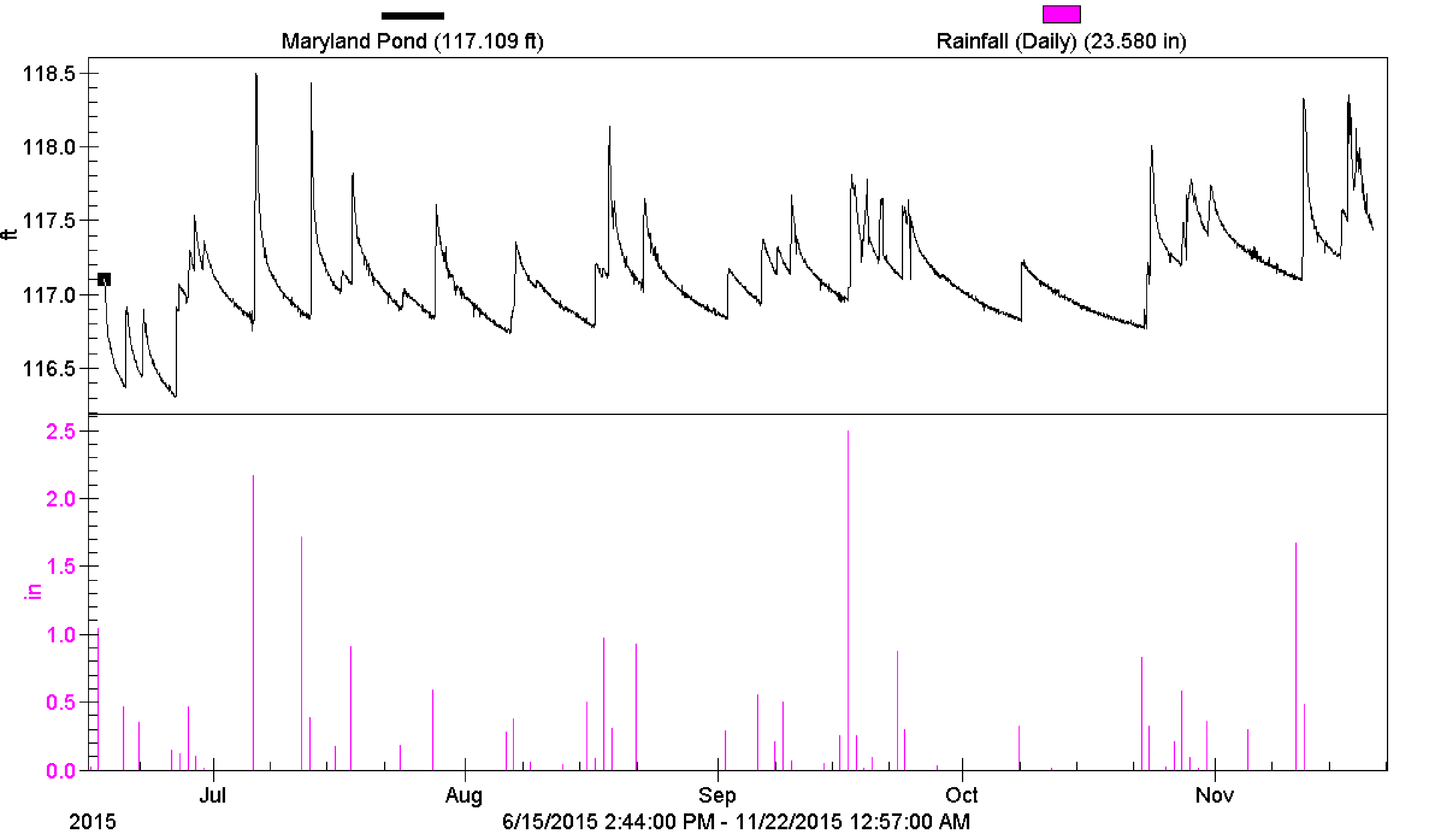
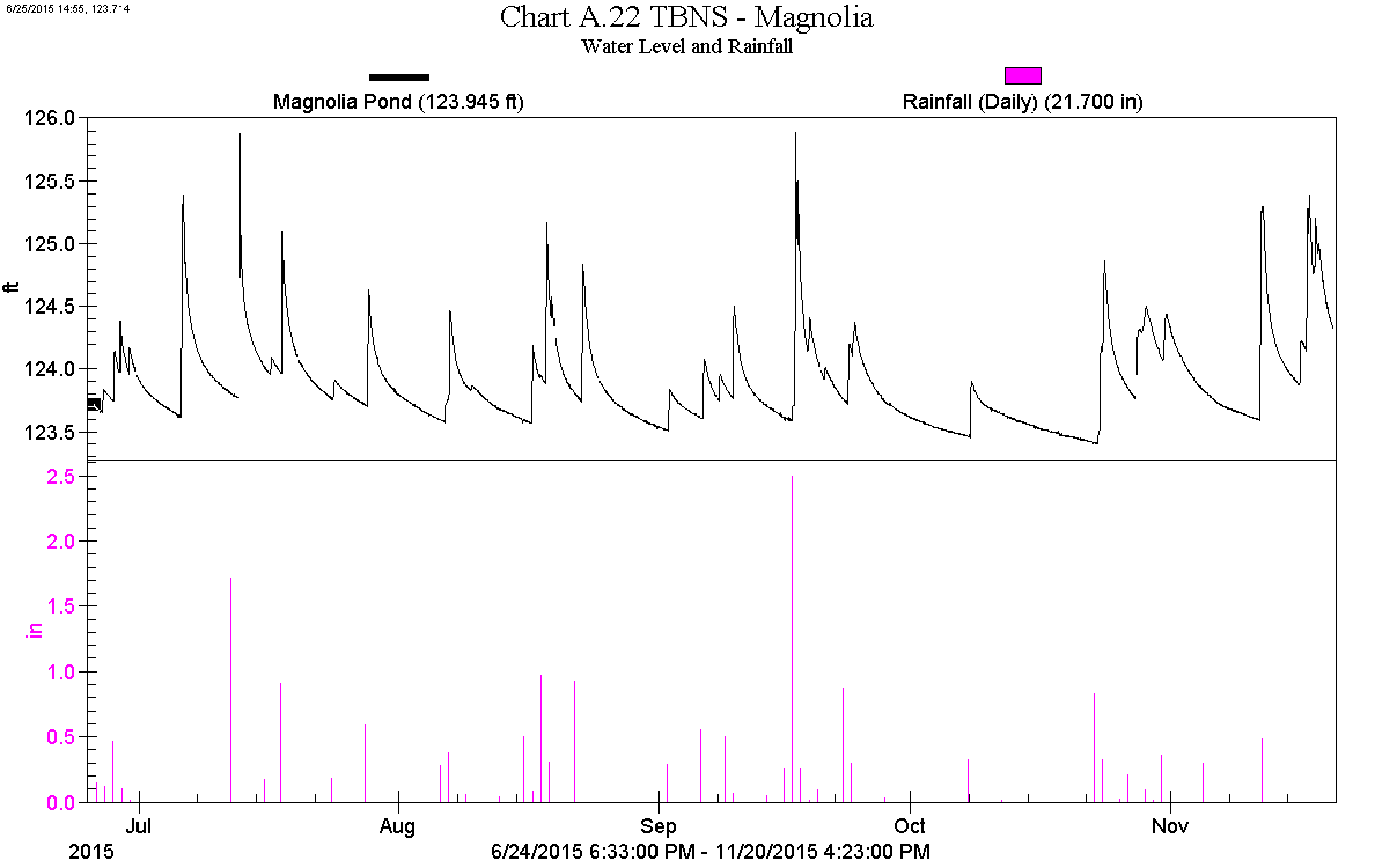


Chart A.20 Flandrau - Case
Water Level and Rainfall
Pond Level (0.104 ft)
Rainfall (Daily) (14.950 in)
ft
2.0
1.5
1.0
0.5
0.0
in
2.0
1.5
1.0
0.5
0.0
22 Wed
1 Fri
8 Fri
15 Fri
22 Fri
1 Mon
8 Mon
15 Mon
22 Mon
1 Wed
8 Wed
15 Wed
22 Wed
Apr 2015
4/21/2015 1:47:00 PM - 7/22/2015 3:07:00 AM

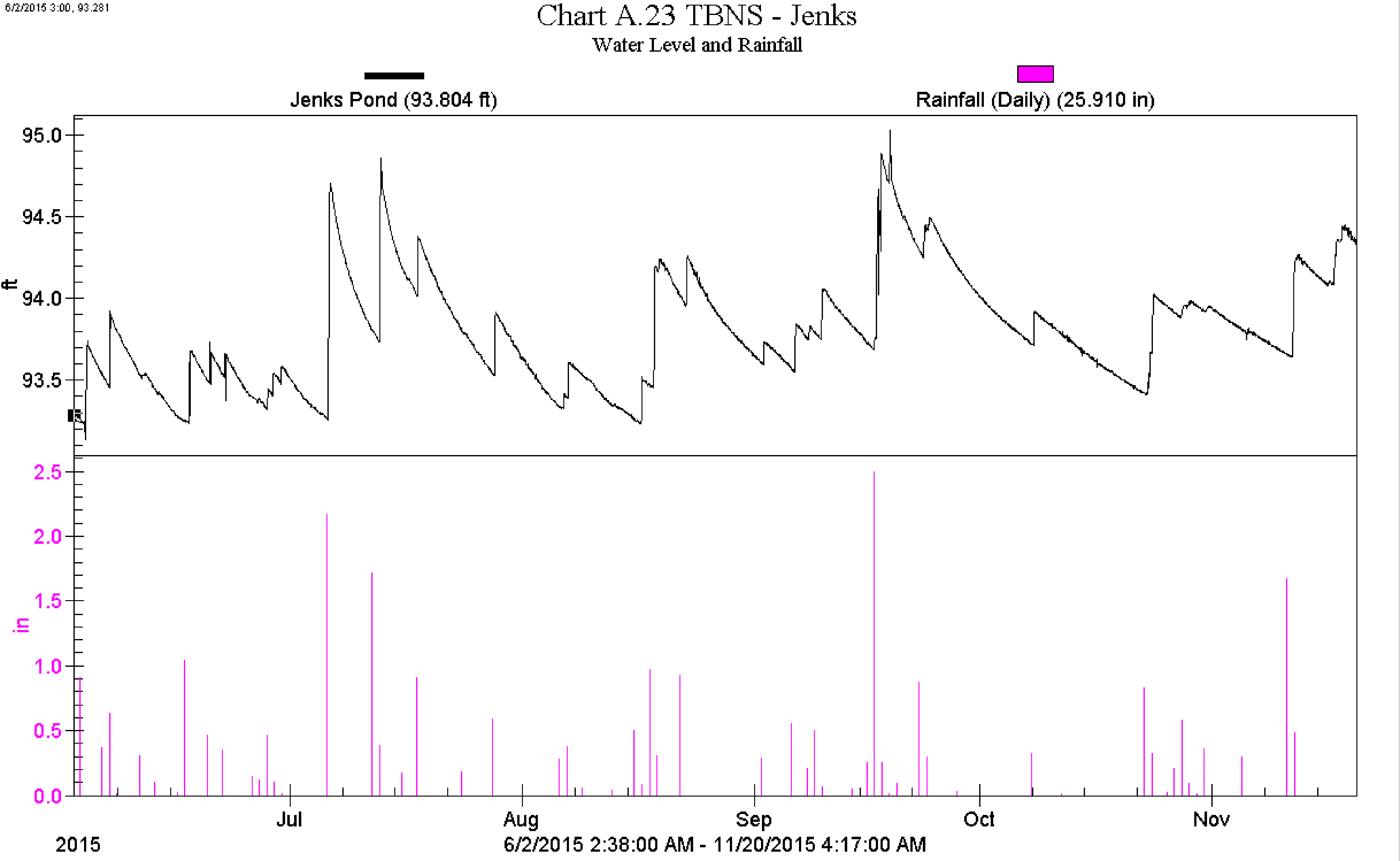
Chart A.21 TBNS - Maryland

Water Level and Rainfall

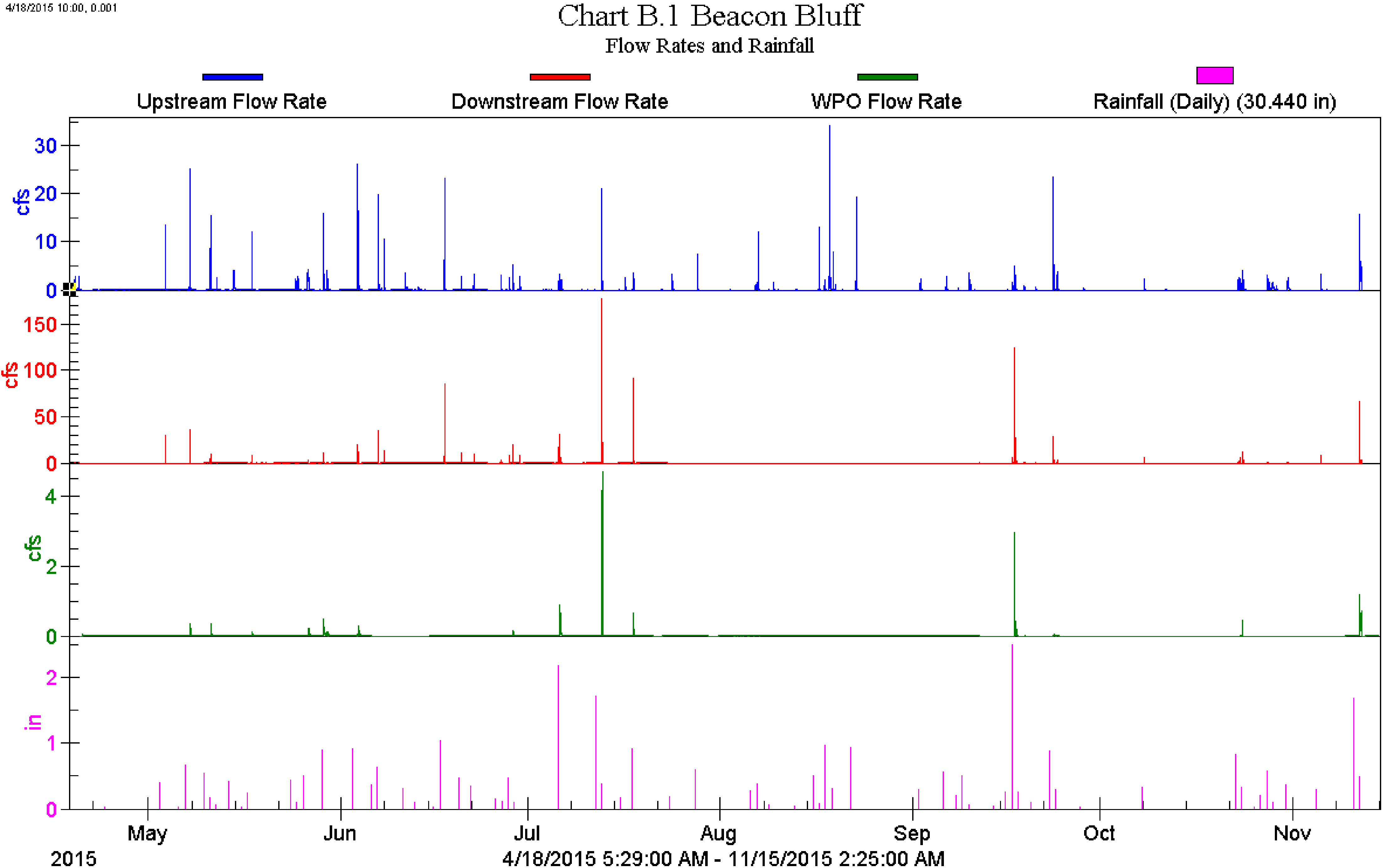


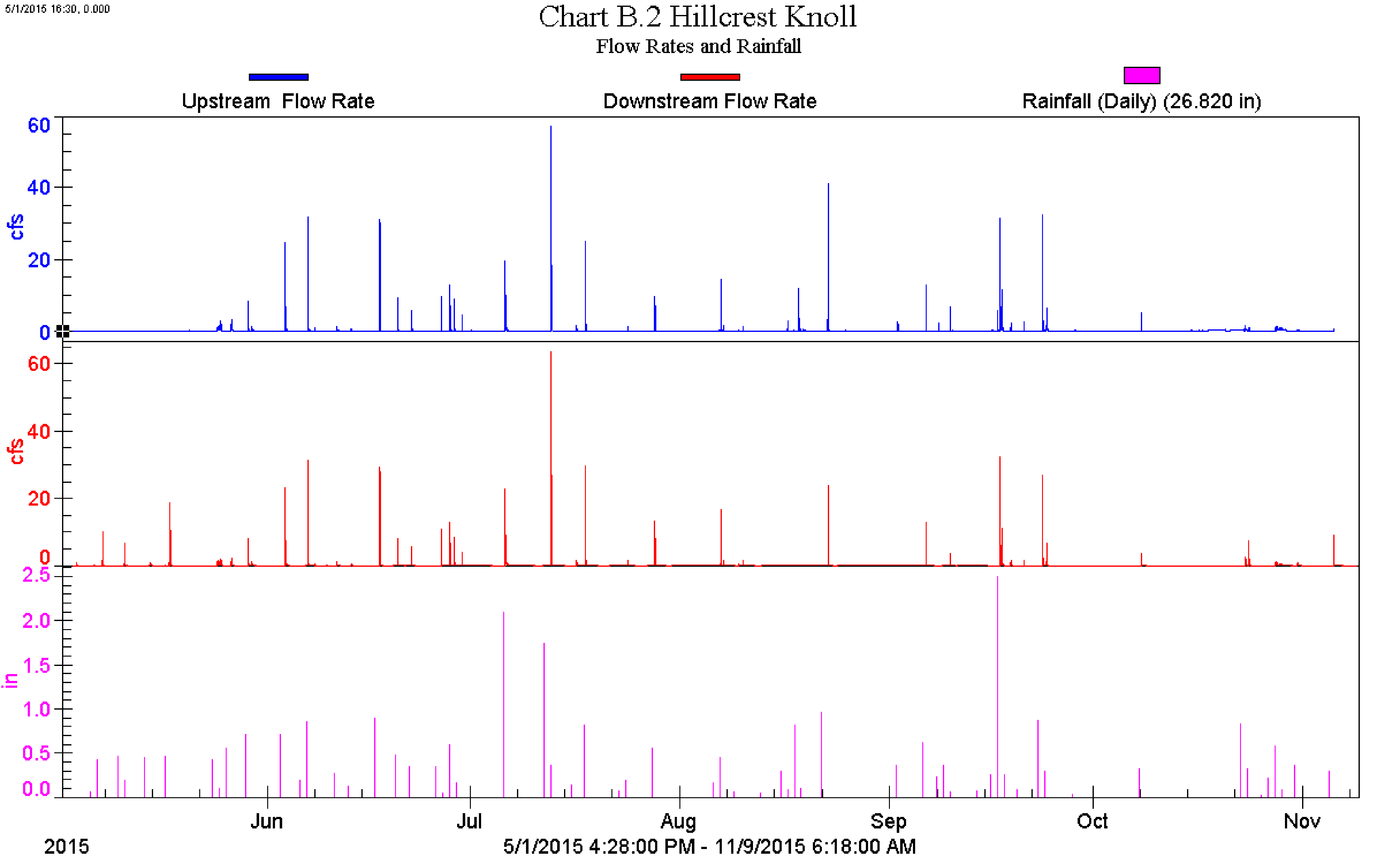


6/25/2015 14:55, 123.714
Chart A.22 TBNS - Magnolia
Water Level and Rainfall
Magnolia Pond (123.945 ft)
Rainfall (Daily) (21.700 in)
ft
126.0
125.5
125.0
124.5
124.0
123.5
in
2.5
2.0
1.5
1.0
0.5
0.0
Jul
Aug
Sep
Oct
Nov
2015
6/24/2015 6:33:00 PM - 11/20/2015 4:23:00 PM



6/2/2015 3:00, 93.281
Chart A.23 TBNS - Jenks
Water Level and Rainfall
Jenks Pond (93.804 ft)
Rainfall (Daily) (25.910 in)
ft
95.0
94.5
94.0
93.5
in
2.5
2.0
1.5
1.0
0.5
0.0
Jul
Aug
Sep
Oct
Nov
2015
6/2/2015 2:38:00 AM - 11/20/2015 4:17:00 AM


4/18/2015 10:00, 0.001
Chart B.1 Beacon Bluff
Flow Rates and Rainfall
Upstream Flow Rate
Downstream Flow Rate
WPO Flow Rate
Rainfall (Daily) (30.440 in)
cfs
in
May
Jun
Jul
Aug
Sep
Oct
Nov
2015
4/18/2015 5:29:00 AM - 11/15/2015 2:25:00 AM


5/1/2015 16:30, 0.000
Chart B.2 Hillcrest Knoll
Flow Rates and Rainfall
Upstream Flow Rate
Downstream Flow Rate
Rainfall (Daily) (26.820 in)
cfs
60
40
20
0
cfs
60
40
20
0
in
2.5
2.0
1.5
1.0
0.5
0.0
Jun
Jul
Aug
Sep
Oct
Nov
2015
5/1/2015 4:28:00 PM - 11/9/2015 6:18:00 AM

HILLCREST KNOLL PARK INFILTRATION SYSTEM VOLUME REDUCTION TABLE

Rain				Flow						
Start[1]	End	Duration (hr)	Amount (in)	Start	End	Duration (hr)	Volume Upstream (1) (cf)	Volume Downstream (2) (cf)	Total Inflow to BMP (1 -2) (cf)	Percent Captured (cf)
5/6/2015 0:11	5/6/2015 17:43	17.53	0.06	5/6/2015 10:45	5/6/2015 11:15	0.50	20.5	20.5	0.0	0.0%
5/7/2015 13:04	5/7/2015 21:46	8.70	0.41	5/7/2015 13:45	5/7/2015 20:00	6.25	12028.8	12028.8	0.0	0.0%
5/10/2015 19:55	5/11/2015 4:31	8.60	0.65	5/10/2015 20:30	5/11/2015 6:00	9.50	23335.8	23335.8	0.0	0.0%
5/14/2015 8:07	5/15/2015 1:22	17.25	0.46	5/14/2015 14:00	5/15/2015 2:00	12.00	10464.9	10464.9	0.0	0.0%
				5/16/2015 21:30	5/16/2015 23:00	1.50	326.0	326.0	0.0	0.0%
5/17/2015 14:33	5/17/2015 21:45	7.20	0.46	5/17/2015 10:30	5/17/2015 23:30	13.00	33918.4	33918.4	0.0	0.0%
5/24/2015 10:48	5/25/2015 3:54	17.10	0.51	5/24/2015 14:00	5/25/2015 17:45	27.75	23202.7	20641.4	2561.3	11.0%
5/26/2015 10:48	5/26/2015 22:07	11.32	0.55	5/26/2015 12:15	5/27/2015 2:15	14.00	23091.6	19757.3	3334.3	14.4%
5/29/2015 3:28	5/29/2015 22:24	18.93	0.71	5/29/2015 15:15	5/30/2015 2:40	11.42	4337.3	4092.0	245.2	5.7%
6/3/2015 12:38	6/3/2015 20:36	7.97	0.70	6/3/2015 13:00	6/4/2015 8:15	19.25	36466.6	34715.1	1751.5	4.8%
6/6/2015 23:52	6/7/2015 1:16	1.40	0.93	6/6/2015 23:45	6/8/2015 7:00	31.25	60428.2	57274.3	3153.9	5.2%
6/11/2015 5:09	6/11/2015 15:14	10.08	0.27	6/11/2015 5:45	6/11/2015 21:30	15.75	7231.1	5386.0	1845.0	25.5%
6/13/2015 8:25	6/13/2015 11:23	2.97	0.13	6/13/2015 8:45	6/13/2015 16:45	8.00	2524.7	1912.6	612.1	24.2%
6/17/2015 13:42	6/17/2015 15:40	1.97	0.90	6/17/2015 14:00	6/18/2015 2:00	12.00	45223.3	43105.9	2117.4	4.7%
6/20/2015 5:49	6/20/2015 12:58	7.15	0.47	6/20/2015 5:59	6/20/2015 15:45	9.77	23983.0	17883.4	6099.6	25.4%
6/22/2015 7:18	6/22/2015 9:05	1.78	0.34	6/22/2015 7:43	6/22/2015 12:45	5.03	16962.3	14047.0	2915.3	17.2%
6/26/2015 16:27	6/27/2015 4:18	11.85	0.34	6/26/2015 16:33	6/27/2015 1:00	8.45	10314.1	10258.2	56.0	0.5%
6/27/2015 23:42	6/28/2015 16:36	16.90	0.62	6/28/2015 0:15	6/28/2015 22:50	22.58	26535.0	25604.0	931.0	3.5%
6/29/2015 18:48	6/29/2015 19:31	0.72	0.15	6/29/2015 18:45	6/30/2015 2:00	7.25	5765.0	5578.3	186.7	3.2%
7/6/2015 1:01	7/6/2015 12:27	11.43	2.06	7/6/2015 1:10	7/6/2015 16:45	15.58	110810.9	108931.8	1879.0	1.7%
7/12/2015 22:53	7/13/2015 1:18	2.42	2.07	7/12/2015 23:08	7/13/2015 9:45	10.62	120898.9	118119.1	2779.8	2.3%
7/16/2015 15:55	7/16/2015 20:09	4.23	0.14	7/16/2015 17:15	7/16/2015 21:45	4.50	1861.5	1817.9	43.6	2.3%
7/18/2015 0:55	7/18/2015 2:54	1.98	0.82	7/18/2015 1:00	7/18/2015 5:45	4.75	31019.4	29778.3	1241.1	4.0%
7/24/2015 3:24	7/24/2015 10:02	6.63	0.19	7/24/2015 3:45	7/24/2015 9:00	5.25	3050.9	926.0	2124.9	69.6%
7/28/2015 6:34	7/28/2015 11:15	4.68	0.55	7/28/2015 6:58	7/28/2015 11:15	4.28	19846.6	15323.8	4522.8	22.8%
8/6/2015 12:13	8/7/2015 4:19	16.10	0.60	8/6/2015 23:15	8/7/2015 10:45	11.50	14891.1	12116.9	2774.2	18.6%
8/9/2015 13:42	8/9/2015 14:48	1.10	0.06	8/9/2015 14:30	8/9/2015 16:15	1.75	396.9	364.8	32.1	8.1%
				8/10/2015 8:00	8/10/2015 10:00	2.00	566.7	566.7	0.0	0.0%
8/13/2015 3:40	8/13/2015 4:46	1.10	0.04					0.0	0.0	
8/16/2015 17:58	8/16/2015 22:11	4.22	0.29	8/16/2015 18:00	8/17/2015 0:15	6.25	24259.9	38.9	24221.0	99.8%
8/17/2015 17:17	8/17/2015 19:15	1.97	0.08	8/17/2015 17:45	8/18/2015 15:30	21.75	23794.6	70.9	23723.7	99.7%
8/18/2015 7:51	8/19/2015 11:30	27.65	0.91	8/18/2015 15:45	8/19/2015 13:00	21.25	3187.1	116.0	3071.1	96.4%
8/22/2015 18:32	8/22/2015 23:16	4.73	0.95	8/22/2015 18:40	8/23/2015 0:45	6.08	52817.3	17181.5	35635.8	67.5%
				8/25/2015 12:00	8/25/2015 12:15	0.25	55.9	2.8	53.1	95.0%
9/2/2015 2:17	9/2/2015 7:16	4.98	0.36	9/2/2015 3:00	9/2/2015 9:00	6.00	6169.6	30.4	6139.2	99.5%
9/6/2015 5:15	9/6/2015 11:40	6.42	0.60	9/6/2015 6:15	9/6/2015 13:00	6.75	20316.2	7221.1	13095.1	64.5%
9/8/2015 3:58	9/8/2015 5:56	1.97	0.23	9/8/2015 4:45	9/8/2015 8:15	3.50	5339.3	0.0	5339.3	100.0%
9/9/2015 12:29	9/10/2015 6:11	17.70	0.42	9/9/2015 21:23	9/10/2015 7:45	10.37	7651.8	1276.5	6375.3	83.3%
9/16/2015 3:26	9/16/2015 3:45	0.32	0.03	9/16/2015 3:30	9/16/2015 8:30	5.00	1075.5	0.0	1075.5	100.0%
9/16/2015 18:12	9/17/2015 7:29	13.28	2.03	9/16/2015 21:00	9/17/2015 13:00	16.00	120154.0	91621.2	28532.8	23.7%
9/17/2015 9:10	9/17/2015 17:21	8.18	0.66	9/17/2015 13:15	9/17/2015 22:00	8.75	27022.2	20930.2	6092.0	22.5%
9/18/2015 16:50	9/18/2015 22:47	5.95	0.25	9/18/2015 18:00	9/19/2015 9:45	15.75	13249.1	7500.7	5748.3	43.4%
9/20/2015 17:53	9/20/2015 18:26	0.55	0.09	9/20/2015 18:11	9/21/2015 1:15	7.07	4069.1	2217.3	1851.8	45.5%
9/23/2015 14:06	9/24/2015 7:06	17.00	1.16	9/23/2015 14:23	9/25/2015 11:00	44.62	44219.2	36021.3	8197.9	18.5%
				9/28/2015 10:30	9/28/2015 13:00	2.50	372.7	0.0	372.7	100.0%
10/8/2015 3:45	10/8/2015 6:10	2.42	0.30	10/8/2015 4:00	10/8/2015 9:45	5.75	14185.5	5230.1	8955.4	63.1%
10/23/2015 4:45	10/24/2015 3:58	23.22	1.14	10/23/2015 8:00	10/24/2015 8:50	24.83	16251.5	13117.5	3133.9	19.3%
10/27/2015 19:08	10/29/2015 1:14	30.10	0.82	10/27/2015 20:45	10/29/2015 22:50	50.08	52888.5	27910.2	24978.4	47.2%
10/31/2015 1:34	10/31/2015 10:39	9.08	0.36	10/31/2015 1:40	10/31/2015 23:45	22.08	3414.3	2771.8	642.5	18.8%
11/5/2015 14:37	11/5/2015 14:53	0.27	0.28	11/5/2015 14:45	11/5/2015 17:19	2.57	796.2	763.9	32.2	4.0%
11/11/2015 16:55	11/12/2015 19:00	26.08	2.14	11/11/2015 17:00	11/11/2015 17:33	0.55	8771.2	0.0	8771.2	100.0%
Subtotals:			**28.3**				**1,119,563**	862,318	**257,245**	**23.0%**

Flow with no rain

Rain with no flow

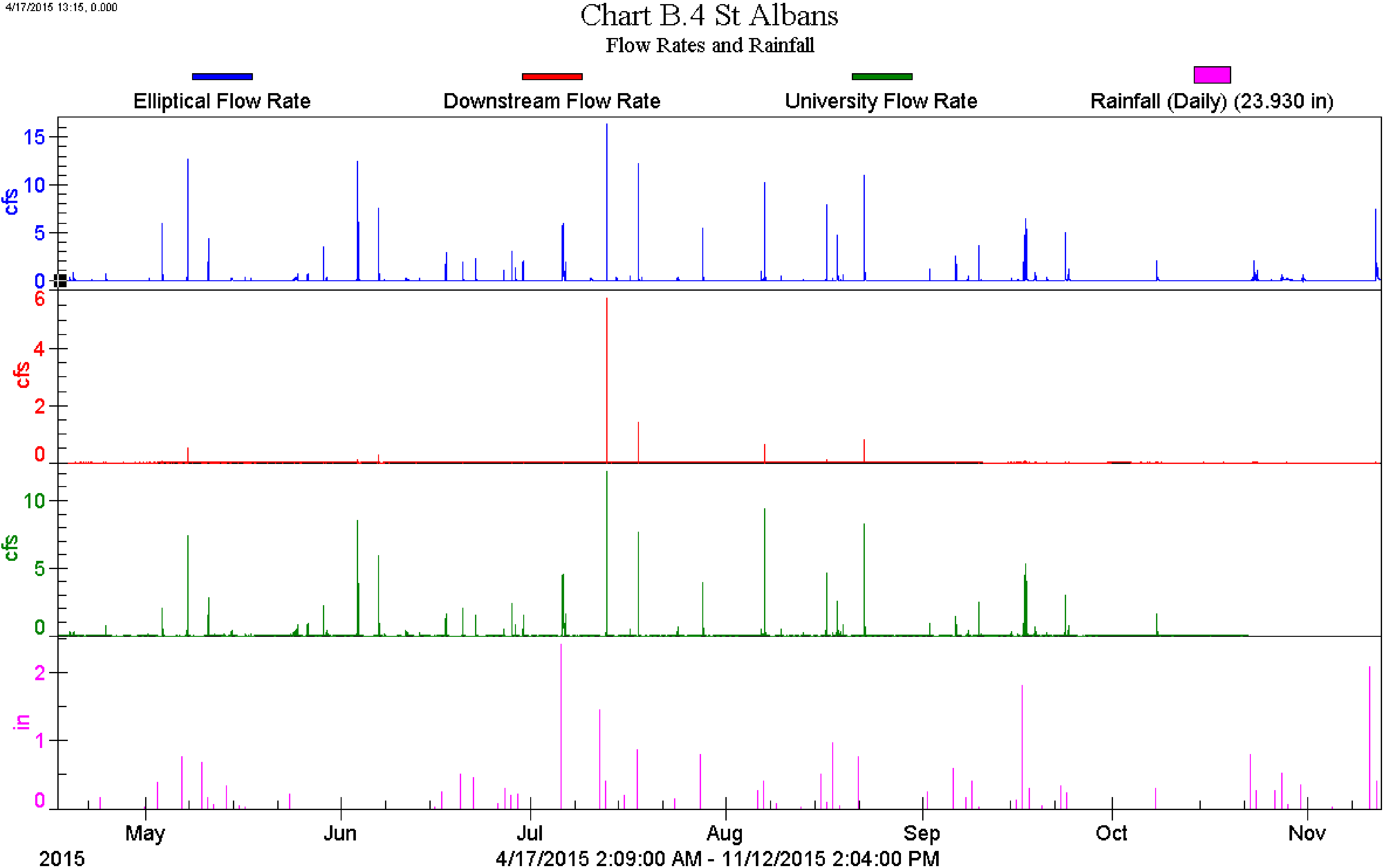
The float for the gate value was found stuck in the closed position on August 11th and November 10th and subsequently fixed.

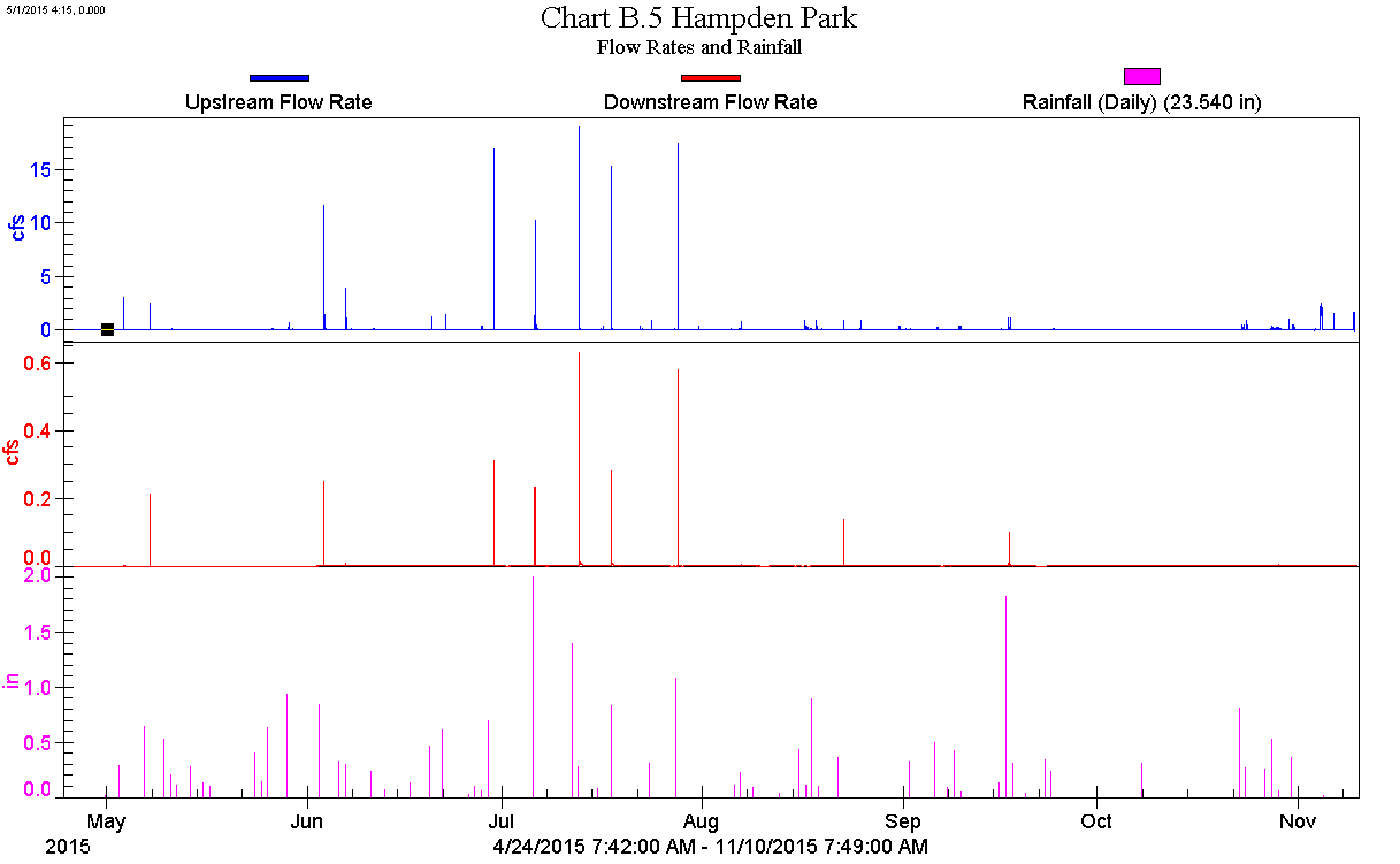
1 The upstream sensor was damaged with no data recorded from 5/6 through 5/17. With the majority of of flow bypassed prior to the float maintenance in August, the upstream volume was assumed to be equal to the downstream for that time frame.

1 Power to the flow meter was lost during the 11/11 flow event, flow volumes are not representative of the entire event.

Chart B.4 St Albans

Flow Rates and Rainfall





5/1/2015 4:15, 0.000
Chart B.5 Hampden Park
Flow Rates and Rainfall
Upstream Flow Rate
Downstream Flow Rate
Rainfall (Daily) (23.540 in)
cfs
15
10
5
0
cfs
0.6
0.4
0.2
0.0
in
2.0
1.5
1.0
0.5
0.0
May
Jun
Jul
Aug
Sep
Oct
Nov
2015
4/24/2015 7:42:00 AM - 11/10/2015 7:49:00 AM

HAMPDEN PARK INFILTRATION SYSTEM VOLUME REDUCTION TABLE

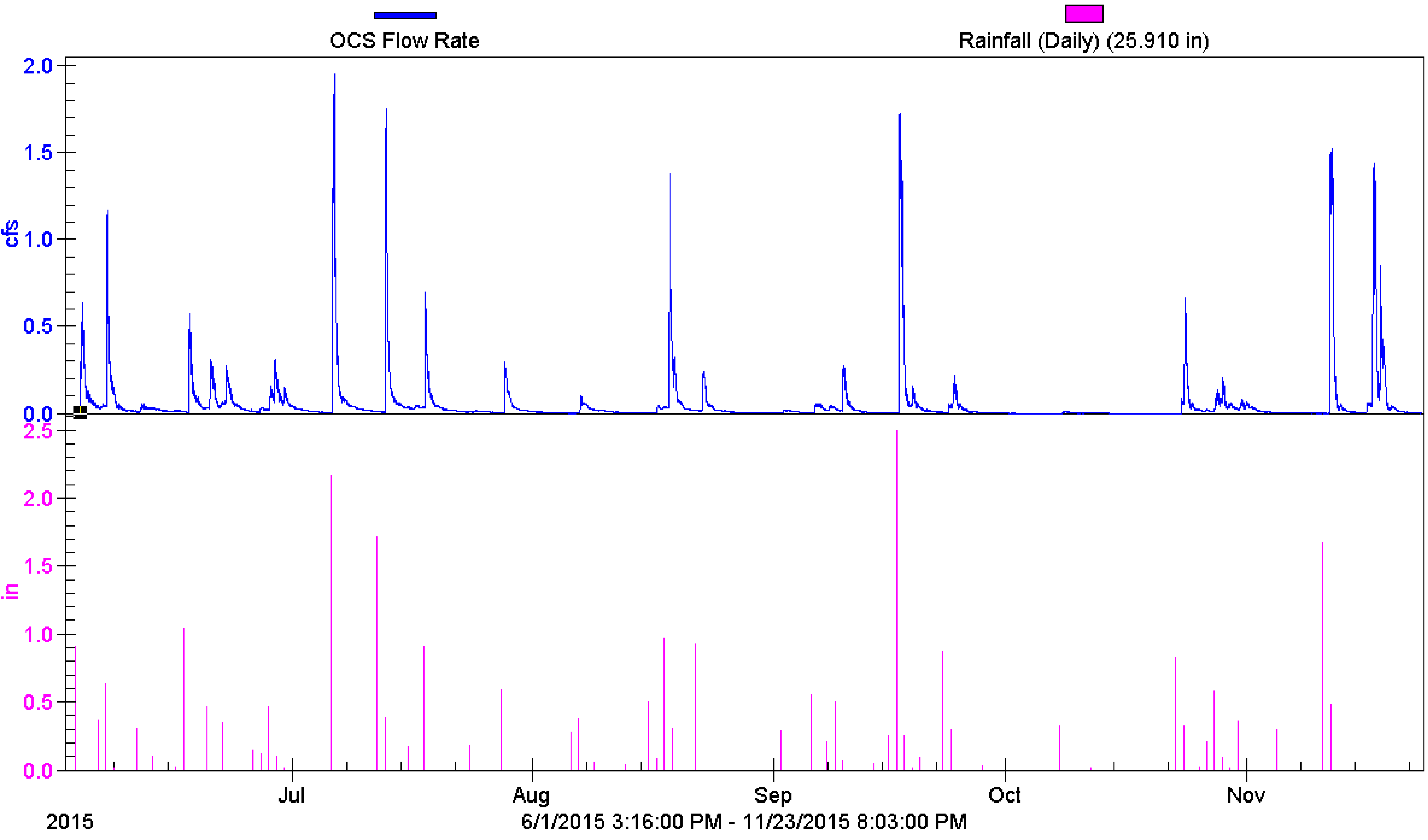
Rain				Flow						
Start	End	Duration (hr)	Amount (in)	Start	End	Duration (hr)	Volume Upstream (1) (cf)	Volume Bypass (2) (cf)	Total Inflow to BMP (1 -2) (cf)	Percent Captured (cf)
4/18/2015 22:43	4/19/2015 0:21	1.63	0.08	4/18/2015 23:15	4/19/2015 0:45	1.50	125.1	0.0	125.1	100.0%
4/19/2015 4:57	4/19/2015 7:11	2.23	0.06	4/19/2015 5:45	4/19/2015 7:45	2.00	65.5	0.0	65.5	100.0%
4/19/2015 18:46	4/19/2015 20:13	1.45	0.09	4/19/2015 19:30	4/19/2015 20:45	1.25	93.5	0.0	93.5	100.0%
4/24/2015 17:11	4/24/2015 20:32	3.35	0.14	4/24/2015 18:28	4/24/2015 19:45	1.28	99.9	0.0	99.9	100.0%
5/3/2015 17:23	5/3/2015 18:57	1.57	0.29	5/3/2015 17:30	5/3/2015 19:30	2.00	852.4	0.0	852.3	100.0%
5/7/2015 12:53	5/7/2015 17:49	4.93	0.61	5/7/2015 13:30	5/7/2015 19:00	5.50	2021.7	100.4	1921.3	95.0%
5/10/2015 19:39	5/11/2015 1:48	6.15	0.70	5/10/2015 20:15	5/11/2015 2:30	6.25	672.3	0.0	672.3	100.0%
5/11/2015 23:39	5/12/2015 3:41	4.03	0.12	5/12/2015 0:15	5/12/2015 4:00	3.75	95.2	0.0	95.2	100.0%
5/14/2015 10:17	5/14/2015 22:34	12.28	0.28	5/14/2015 15:05	5/14/2015 22:00	6.92	307.7	0.0	307.7	100.0%
5/16/2015 20:57	5/16/2015 21:25	0.47	0.12			0.00	0.0	0.0	0.0	0.0%
5/17/2015 9:55	5/17/2015 11:01	1.10	0.10			0.00	0.0	0.0	0.0	0.0%
5/24/2015 9:26	5/25/2015 3:15	17.82	0.53	5/24/2015 11:00	5/25/2015 4:00	17.00	1067.8	0.0	1067.8	100.0%
5/26/2015 10:31	5/26/2015 19:24	8.88	0.63	5/26/2015 11:00	5/26/2015 20:30	9.50	1710.9	0.0	1710.9	100.0%
5/29/2015 3:14	5/29/2015 4:31	1.28	0.57	5/29/2015 3:22	5/29/2015 5:30	2.13	1280.8	0.0	1280.8	100.0%
5/29/2015 14:39	5/29/2015 22:07	7.47	0.33	5/29/2015 15:00	5/29/2015 22:45	7.75	583.8	0.0	583.8	100.0%
6/3/2015 8:37	6/3/2015 20:00	11.38	0.82	6/3/2015 8:45	6/3/2015 23:30	14.75	7513.9	211.9	7302.0	97.2%
6/6/2015 23:36	6/7/2015 1:02	1.43	0.54	6/6/2015 23:55	6/7/2015 4:15	4.33	3672.9	0.0	3672.9	100.0%
6/7/2015 18:23	6/7/2015 18:27	0.07	0.05	6/7/2015 18:30	6/7/2015 21:30	3.00	367.0	0.0	367.0	100.0%
				6/9/2015 18:45	6/9/2015 22:15	3.50	174.7	0.0	174.7	100.0%
6/11/2015 5:03	6/11/2015 15:07	10.07	0.24	6/11/2015 5:30	6/11/2015 18:00	12.50	1889.9	0.0	1889.9	100.0%
6/13/2015 8:14	6/13/2015 10:50	2.60	0.07	6/13/2015 8:30	6/13/2015 13:00	4.50	536.1	0.0	536.1	100.0%
6/17/2015 13:49	6/17/2015 13:55	0.10	0.12	6/17/2015 13:45	6/17/2015 18:15	4.50	349.2	0.0	349.2	100.0%
6/20/2015 5:42	6/20/2015 8:12	2.50	0.44	6/20/2015 5:49	6/20/2015 10:30	4.68	1899.9	0.0	1899.9	100.0%
6/22/2015 7:04	6/22/2015 8:57	1.88	0.59	6/22/2015 7:30	6/22/2015 11:30	4.00	2409.8	0.0	2409.8	100.0%
6/26/2015 17:11	6/26/2015 17:17	0.10	0.03	6/26/2015 17:28	6/26/2015 19:15	1.78	181.4	0.0	181.4	100.0%
6/27/2015 23:20	6/28/2015 1:42	2.37	0.14	6/27/2015 23:23	6/28/2015 3:45	4.37	797.6	0.0	797.6	100.0%
6/28/2015 16:18	6/28/2015 16:24	0.10	0.02	6/28/2015 16:30	6/28/2015 18:15	1.75	137.1	0.0	137.1	100.0%
6/29/2015 19:17	6/29/2015 19:37	0.33	0.60	6/29/2015 19:25	6/29/2015 21:30	2.08	11721.3	140.9	11580.4	98.8%
7/6/2015 0:43	7/6/2015 13:20	12.62	1.94	7/6/2015 0:51	7/6/2015 15:00	14.15	14363.7	257.6	14106.1	98.2%
7/12/2015 23:01	7/13/2015 0:50	1.82	1.18	7/12/2015 22:30	7/13/2015 2:00	3.50	27795.8	663.9	27131.9	97.6%
7/16/2015 16:43	7/16/2015 21:52	5.15	0.08	7/16/2015 17:30	7/17/2015 1:45	8.25	1256.4	0.0	1256.4	100.0%
7/18/2015 0:44	7/18/2015 4:30	3.77	0.66	7/18/2015 0:45	7/18/2015 5:00	4.25	13551.9	220.9	13331.0	98.4%
				7/22/2015 9:15	7/22/2015 12:45	3.50	1722.4	0.0	1722.4	100.0%
7/24/2015 3:13	7/24/2015 9:04	5.85	0.31	7/24/2015 3:30	7/24/2015 7:30	4.00	1118.6	0.0	1118.6	100.0%
7/28/2015 6:18	7/28/2015 7:52	1.57	1.08	7/28/2015 6:30	7/28/2015 9:15	2.75	16902.9	22.3	16880.6	99.9%
				7/31/2015 8:30	7/31/2015 14:15	5.75	419.3	0.0	419.3	100.0%
8/6/2015 15:36	8/7/2015 4:29	12.88	0.33	8/6/2015 15:45	8/7/2015 10:15	18.50	3299.1	0.0	3299.1	100.0%
8/9/2015 13:37	8/9/2015 14:32	0.92	0.09	8/9/2015 14:00	8/9/2015 16:15	2.25	301.9	0.0	301.9	100.0%
8/13/2015 3:41	8/13/2015 6:31	2.83	0.04	8/13/2015 4:00	8/13/2015 5:45	1.75	78.9	0.0	78.9	100.0%
8/16/2015 17:29	8/16/2015 21:03	3.57	0.43	8/16/2015 17:30	8/17/2015 11:15	17.75	6079.3	0.0	6079.3	100.0%
8/17/2015 17:02	8/17/2015 19:31	2.48	0.11	8/17/2015 18:20	8/17/2015 22:30	4.17	543.6	0.0	543.6	100.0%
8/18/2015 10:28	8/18/2015 19:20	8.87	0.89	8/18/2015 10:30	8/19/2015 0:00	13.50	7082.0	0.0	7082.0	100.0%
8/19/2015 3:43	8/19/2015 18:02	14.32	0.10	8/19/2015 9:15	8/19/2015 17:30	8.25	680.3	0.0	680.3	100.0%
8/22/2015 18:09	8/22/2015 22:42	4.55	0.36	8/22/2015 18:15	8/23/2015 2:15	8.00	1190.5	88.2	1102.3	92.6%
				8/24/2015 11:30	8/24/2015 13:15	1.75	240.4	0.0	240.4	100.0%
				8/25/2015 7:45	8/25/2015 13:45	6.00	3537.9	0.0	3537.9	100.0%
				8/31/2015 7:30	8/31/2015 14:45	7.25	3959.9	0.0	3959.9	100.0%
				9/1/2015 8:51	9/1/2015 9:45	0.90	69.8	0.0	69.8	100.0%
9/2/2015 2:04	9/2/2015 6:02	3.97	0.32	9/2/2015 2:15	9/2/2015 11:45	9.50	751.5	0.0	751.5	100.0%
9/6/2015 4:19	9/6/2015 11:25	7.10	0.49	9/6/2015 4:26	9/6/2015 16:30	12.07	2399.2	0.0	2399.2	100.0%
9/8/2015 3:44	9/8/2015 5:31	1.78	0.09	9/8/2015 4:00	9/8/2015 9:30	5.50	564.2	0.0	564.2	100.0%
9/9/2015 12:26	9/10/2015 6:42	18.27	0.47	9/9/2015 12:30	9/10/2015 8:22	19.87	4298.5	0.0	4298.5	100.0%
9/16/2015 3:02	9/16/2015 3:41	0.65	0.03	9/16/2015 3:15	9/16/2015 9:15	6.00	917.5	0.0	917.5	100.0%
9/16/2015 21:48	9/17/2015 17:34	19.77	1.92	9/16/2015 23:45	9/17/2015 18:45	19.00	5621.4	157.3	5464.0	97.2%
10/8/2015 3:50	10/8/2015 5:31	1.68	0.31	10/8/2015 3:30	10/8/2015 17:45	14.25	155.3	0.0	155.3	100.0%
10/23/2015 3:06	10/23/2015 7:35	4.48	0.13	10/23/2015 5:00	10/24/2015 6:10	25.17	11410.1	0.0	11410.1	100.0%
10/26/2015 4:00	10/26/2015 4:15	0.25	0.01	10/26/2015 4:28	10/26/2015 16:15	11.78	148.8	0.0	148.8	100.0%
10/27/2015 18:39	10/29/2015 1:28	30.82	0.82	10/27/2015 19:00	10/29/2015 16:00	45.00	19053.9	140.0	18913.8	99.3%
10/31/2015 0:44	10/31/2015 11:28	10.73	0.36	10/31/2015 1:15	10/31/2015 14:32	13.28	8757.3	10.5	8746.8	99.9%
				11/3/2015 20:15	11/4/2015 17:36	21.35	42613.5	0.0	42613.5	100.0%
				11/6/2015 11:16	11/6/2015 11:30	0.23	633.9	0.0	633.9	100.0%
				11/9/2015 12:30	11/9/2015 16:04	3.57	14673.3	0.0	14673.3	100.0%
Subtotals:			**20.9**				**256,821**	2,014	**239,499**	**93.3%**

Flows with no rainfall
Rain with no flow

6/3/2015 12:20, 0.000

Chart B.7 TBNS - Maryland

Flow Rates and Rainfall



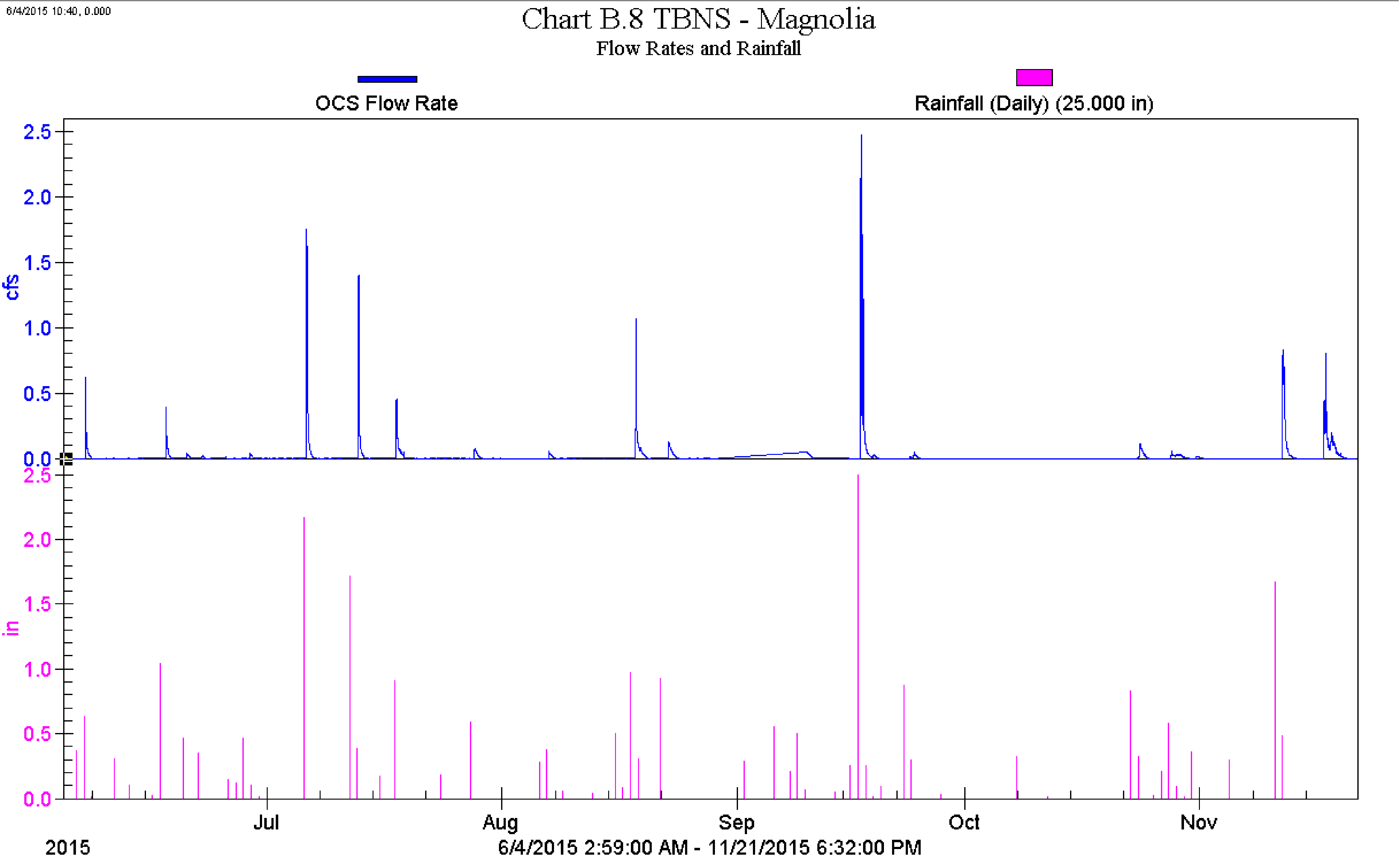
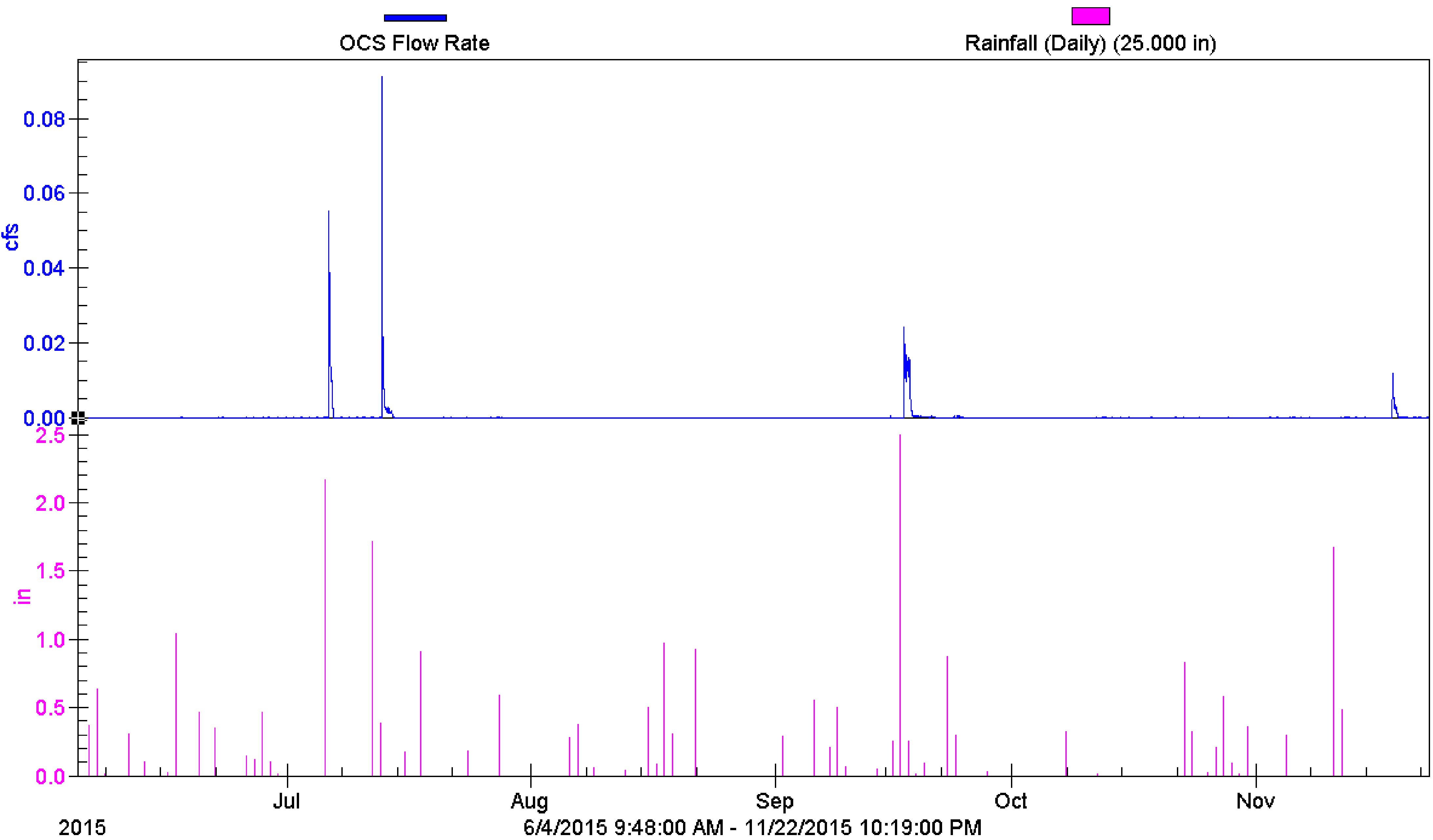

6/4/2015 10:40 , 0.000
Chart B.8 TBNS - Magnolia
Flow Rates and Rainfall
OCS Flow Rate
Rainfall (Daily) (25.000 in)
cfs
in
2.5
2.0
1.5
1.0
0.5
0.0
Jul
Aug
Sep
Oct
Nov
2015
6/4/2015 2:59:00 AM - 11/21/2015 6:32:00 PM

Chart B.9 TBNS - Jenks

Flow Rates and Rainfall



City of Saint Paul
2015 Water Quality and Quantity Report
Table C.1
WSB Project Number: 01610-100

BEACON BLUFF WATER QUALITY SUMMARY

Sample ID	Date Composite Sampling Started	Date Composite Sampling Ended	TSS (mg/L)	TDS (mg/L)	VSS (mg/L)	Suspended Sediment Conc. (SSC) (mg/L)	Fine Fraction Sediment (mg/L)	Coarse Fraction Sediment (mg/L)	TP (mg/L)	Ortho-P (mg/L)	Chlorides (mg/L)	Ammonia as N (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite as N (mg/L)	Hardness as CaCO3 (mg/L)	Copper (ug/L)	Lead (ug/L)	Zinc (ug/L)	Sulfate (mg/L)	pH	CBOD (mg/L)	E. Coli (MPN/ 100 mL)
BB-AS-041815	4/18/2015 23:17	4/19/2015 2:19	115.0						0.33													
BB-AS-041915	4/19/2015 5:47	4/19/2015 8:41	112.0						0.14													
BB-AS-041915	4/19/2015 19:20	4/19/2015 23:22	96.0						0.20													
BB-AS-051015	5/10/2015 20:16	5/11/2015 3:34	92.0	56.0	15.2	1400.0	11.5	1390.0	0.42	0.079		0.15	2.40	0.32					2.5 <	6.50	14.0	
BB-AS-051415	5/14/2015 13:17	5/15/2015 1:13	72.0	120.0	9.6	32.4	10.0 <	24.4	0.41	0.120	12.6	0.19	1.80	0.32	22300	14.9	11.8	77.6		6.30		
BB-AS-051715	5/17/2015 14:42	5/17/2015 19:18	298.0	88.0	19.8				0.93	0.088	15.1	0.06	4.90	0.11	64400	45.4	59.2	220.0	2.5 <	6.70		
BB-AS-052415	5/24/2015 13:53	5/25/2015 6:19	84.0		8.6				0.66	0.170		0.09	2.70	0.05					2.5 <	6.90	27.8	
BB-AS-052615	5/26/2015 18:06	5/26/2015 22:25	97.0		17.6	130.0	63.5	66.7	0.41	0.044		0.09	2.50	0.14					2.5 <	7.20	17.1	
BB-AS-052915	5/29/2015 3:53	5/29/2015 7:58	208.0		25.6				0.67			0.25	3.70	0.18					2.5 <	6.20	16.5	
BB-GS-063115		6/3/2015 15:48																	2.5 <	6.80	13.9	2419.60 >
1 BB-AS-060315(1-2)	6/3/2015 12:48	6/3/2015 15:48	329.0		20.2	628.0	201.0	427.0	0.67	0.089	5.5	0.13	4.50	0.26	54000	34.2	65.3					
2 BB-AS-060315 (1-2)	6/3/2015 19:20	6/3/2015 22:29	158.0		14.0				0.41	0.060	6.0	0.40	2.30	0.37	34300	20.3	33.8	105.0				
BB-AS-060615	6/6/2015 23:57	6/7/2015 3:22	294.0		17.6					0.560	4.9			0.08	38300	23.7	53.7	109.0				
BB-AS-060715	6/7/2015 23:36	6/8/2015 1:27	226.0		18.9 <						7.5			0.46	52000	34.2	61.5	166.0				
BB-GS-061115		6/11/2015 11:20																	2.5 <	7.10	16.3	2419.60 >
BB-AS-062215	6/22/2015 7:30	6/22/2015 10:40	48.0		9.6				0.27	0.039	7.4		1.60	0.37								
BB-AS-070515	7/6/2015 1:13	7/6/2015 13:28	128.0		11.6				0.29		6.0		3.60	0.05								
BB-AS-081615	8/16/2015 20:05	8/16/2015 23:28	29.0		8.2				0.20		2.8		1.10	0.29								
BB-GS-081815		8/18/2015 12:00																	2.5 <	7.80	5.6	2180.00 >
BB-AS-081815	8/18/2015 11:17	8/19/2015 6:05	88.0		7.8				0.18		3.2		0.92	0.14								
Beacon-Bluff-AS-091715	9/17/2015 1:11	9/17/2015 14:05	40.0		9.0				0.11	0.005 <	4.8		1.10	0.38								
BB-GS-091715		9/17/2015 12:30																				1000.00
BB-AS-092415	9/23/2015 14:08	9/24/2015 8:18	77.0		18.0				0.26	0.089	3.6		1.50	0.39								
BB-AS-102815	10/27/2015 20:55	10/28/2015 7:21	44.0		7.9 <				0.62		6.5		1.20	0.02 <								
BB-AS-102915	10/28/2015 14:28	10/29/2015 2:55	64.0		15.2 <				0.71		7.8		2.00	0.02 <								
BB-AS-111115	11/11/2015 17:16	11/12/2015 6:09	34.0		14.2	72.8	12.6	60.2				0.06	0.83	0.12							9.7	
MINIMUM			**29.0**	**56.0**	**7.8**	**32.4**	**10.0**	**24.4**	**0.11**	**0.005**	**2.8**	**0.06**	**0.83**	**0.02**	**22300**	**14.9**	**11.8**	**77.6**	**3**	**6.20**	**5.6**	**1000.0**
AVERAGE			**124.2**	**88.0**	**14.1**	**452.6**	**59.7**	**393.7**	**0.42**	**0.122**	**6.7**	**0.16**	**2.27**	**0.21**	**44217**	**28.8**	**47.6**	**135.5**	**3**	**6.83**	**15.1**	**2004.8**
MAXIMUM			**329.0**	**120.0**	**25.6**	**1400.0**	**201.0**	**1390.0**	**0.93**	**0.560**	**15.1**	**0.40**	**4.90**	**0.46**	**64400**	**45.4**	**65.3**	**220.0**	**3**	**7.80**	**27.8**	**2419.6 >**

< - Sample was not detected above the method detection limit (value reported)
Grab Sample
SSC analysis was not available for the later part of the season

City of Saint Paul
2015 Water Quality and Quantity Report
Table C.2
WSB Job No.: 01610-100

BEACON BLUFF INFILTRATION SYSTEM VOLUME REDUCTION AND POLLUTANT LOADING

Event Time Interval		Sampling Data							Event Loading and Volume Data														
										Diversion Structure on Duchess Street													
		TSS	VSS	TP	Ortho-P	Chloride	Total Kjeldahl Nitrogen	Nitrate + Nitrite as N	Interval Rain	Runoff Volume[1] Draining to Diversion Structure (Subwatershed A)	Volume Directed from Diversion Structure to Downstream Storm Sewer (Bypassed Volume)	Volume Directed from Diversion Structure into BMP (1)	Inflow Volume from West Pond (Subwatershed B) (2)	Inflow Volume from East Pond (Subwatershed C)[2] (3)	Volume Captured by BMP (1+2+3)	% of Total Inflow to BMP from Diversion Structure	Captured TSS	Captured VSS	Captured TP	Captured Ortho-P	Captured Chloride	Captured Total Kjeldahl Nitrogen	Captured Nitrate + Nitrite as N
Start	**End**	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	In.	cf	cf	cf	(cf)	(cf)	(cf)		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4/18/2015 23:16	4/19/2015 2:16	**115**	12.7	**0.33**	0.11	5.89	1.96	0.20	0.09	7564	0	7563	165	362	8090	100.0%	58.1	6.4	0.17	0.05	3.0	0.99	0.10
4/19/2015 5:45	4/19/2015 23:19	**104**	12.7	**0.17**	0.11	5.89	1.96	0.20	0.14	20027	23	20003	150	329	20482	99.9%	133.0	16.3	0.22	0.14	7.5	2.50	0.26
5/3/2015 17:30	5/3/2015 23:30	**98**	12.7	0.34	0.11	5.89	1.96	0.20	0.39	17473	14328	3145	474	836	4455	18.0%	27.4	3.5	0.09	0.03	1.6	0.54	0.06
5/5/2015 23:45	5/6/2015 13:45	98	12.7	0.34	0.11	5.89	1.96	0.20	0.03	1217	0	1217	1027	58	2302	100.0%	14.2	1.8	0.05	0.02	0.8	0.28	0.03
5/7/2015 13:37	5/8/2015 2:15	98	12.7	0.34	0.11	5.89	1.96	0.20	0.66	33284	29606	3677	2724	1592	7993	11.0%	49.1	6.3	0.17	0.05	2.9	0.98	0.10
5/10/2015 19:30	5/11/2015 3:41	**92**	**15.2**	**0.42**	**0.08**	5.89	**2.40**	**0.32**	0.66	68087	28779	39308	2409	3257	44975	57.7%	258.3	42.7	1.18	0.22	16.5	6.74	0.90
5/12/2015 1:00	5/12/2015 6:30	98	12.7	0.34	0.11	5.89	1.96	0.20	0.08	7539	13	7526	277	361	8164	99.8%	50.2	6.5	0.17	0.05	3.0	1.00	0.10
5/14/2015 13:00	5/15/2015 1:45	**72**	**9.6**	**0.41**	**0.12**	**12.60**	**1.80**	**0.32**	0.41	63809	2822	60987	695	3052	64735	95.6%	291.0	38.8	1.66	0.48	50.9	7.27	1.29
5/17/2015 14:40	5/17/2015 21:00	**298**	**19.8**	**0.93**	**0.09**	**15.10**	**4.90**	**0.11**	0.22	32200	15908	16292	942	1540	18774	50.6%	349.3	23.2	1.09	0.10	17.7	5.74	0.13
5/24/2015 11:00	5/25/2015 6:45	**84**	**8.6**	**0.66**	**0.17**	5.89	**2.70**	**0.05**	0.52	51543	308	51235	806	2466	54506	99.4%	285.8	29.3	2.25	0.58	20.1	9.19	0.17
5/26/2015 12:46	5/26/2015 23:30	**97**	**17.6**	**0.41**	**0.04**	5.89	**2.50**	**0.14**	0.51	67226	4747	62480	3289	3216	68984	92.9%	417.7	75.8	1.77	0.19	25.4	10.77	0.60
5/29/2015 3:50	5/30/2015 2:30	**208**	**25.6**	**0.67**	0.11	5.89	**3.70**	**0.18**	0.89	73888	25494	48393	5174	3534	57102	65.5%	741.5	91.3	2.39	0.38	21.0	13.19	0.64
6/3/2015 12:45	6/3/2015 23:29	**244**	**17.1**	**0.50**	**0.10**	**5.80**	**3.40**	**0.30**	0.91	61948	26044	35904	2452	2963	41320	58.0%	628.1	44.1	1.29	0.26	15.0	8.77	0.77
6/6/2015 23:55	6/7/2015 13:30	**294**	**17.6**	0.34	**0.56**	**4.90**	1.96	**0.08**	0.89	95905	59339	36566	755	1658	38978	38.1%	715.4	42.8	0.82	1.36	11.9	4.77	0.19
6/7/2015 23:32	6/8/2015 1:45	**226**	**18.9** <	0.34	0.11	**7.50**	1.96	**0.46**	0.09	10031	10668	-637	218	480	62	-6.3%	0.9	0.1	0.00	0.00	0.0	0.01	0.00
6/11/2015 5:57	6/11/2015 18:00	98	12.7	0.34	0.11	5.89	1.96	0.20	0.31	21712	1294	20418	473	1039	21930	94.0%	134.8	17.4	0.46	0.15	8.1	2.68	0.28
6/13/2015 8:45	6/13/2015 14:45	98	12.7	0.34	0.11	5.89	1.96	0.20	0.10	4792	28	4764	104	229	5097	99.4%	31.3	4.0	0.11	0.03	1.9	0.62	0.06
6/17/2015 13:59	6/17/2015 18:00	98	12.7	0.34	0.11	5.89	1.96	0.20	1.03	109913	74734	35179	495	1088	36762	32.0%	226.0	29.2	0.77	0.24	13.5	4.50	0.46
6/20/2015 5:54	6/20/2015 11:30	98	12.7	0.34	0.11	5.89	1.96	0.20	0.47	33260	26608	6652	270	593	7515	20.0%	46.2	6.0	0.16	0.05	2.8	0.92	0.09
6/22/2015 7:29	6/22/2015 12:15	**48**	**9.6**	**0.27**	**0.04**	**7.40**	**1.60**	**0.37**	0.35	48491	23735	24756	400	878	26034	51.1%	78.0	15.6	0.44	0.06	12.0	2.60	0.60
6/26/2015 16:46	6/26/2015 19:15	98	12.7	0.34	0.11	5.89	1.96	0.20	0.15	6011	1971	4039	36	288	4363	67.2%	26.8	3.5	0.09	0.03	1.6	0.53	0.05
6/27/2015 23:51	6/28/2015 3:45	98	12.7	0.34	0.11	5.89	1.96	0.20	0.29	11251	6472	4779	103	538	5420	42.5%	33.3	4.3	0.11	0.04	2.0	0.66	0.07
6/28/2015 15:55	6/28/2015 18:30	98	12.7	0.34	0.11	5.89	1.96	0.20	0.30	29094	17270	11824	746	493	13063	40.6%	80.3	10.4	0.27	0.09	4.8	1.60	0.16
6/29/2015 19:16	6/29/2015 21:30	98	12.7	0.34	0.11	5.89	1.96	0.20	0.10	8620	6442	2178	28	239	2445	25.3%	15.0	1.9	0.05	0.02	0.9	0.30	0.03
7/6/2015 1:03	7/6/2015 14:45	**128**	**11.6**	**0.29**	0.11	**6.00**	**3.60**	**0.05**	2.16	231681	111856	119825	8421	1604	129851	51.7%	1037.6	94.0	2.35	0.86	48.6	29.18	0.41
7/12/2015 23:09	7/13/2015 2:31	98	12.7	0.34	0.11	5.89	1.96	0.20	2.11	225215	206983	18232	8491	1109	27832	8.1%	171.1	22.1	0.58	0.18	10.2	3.40	0.35
7/16/2015 17:00	7/16/2015 20:45	98	12.7	0.34	0.11	5.89	1.96	0.20	0.16	8501	99	8402	24	407	8832	98.8%	54.3	7.0	0.19	0.06	3.2	1.08	0.11
7/18/2015 0:55	7/18/2015 5:00	98	12.7	0.34	0.11	5.89	1.96	0.20	0.91	95905	66303	29602	2252	537	32391	30.9%	199.1	25.7	0.68	0.21	11.9	3.96	0.41
7/24/2015 3:30	7/24/2015 9:45	98	12.7	0.34	0.11	5.89	1.96	0.20	0.18	15784	0	15784	41	755	16579	100.0%	101.9	13.2	0.35	0.11	6.1	2.03	0.21
7/28/2015 6:45	7/28/2015 11:00	98	12.7	0.34	0.11	5.89	1.96	0.20	0.59	61422	31984	29438	131	665	30234	47.9%	185.9	24.0	0.64	0.20	11.1	3.70	0.38
8/6/2015 12:30	8/7/2015 3:30	98	12.7	0.34	0.11	5.89	1.96	0.20	0.63	68965	35922	33043	1175	927	35145	47.9%	216.1	27.9	0.74	0.23	12.9	4.30	0.44
8/9/2015 14:44	8/9/2015 16:30	98	12.7	0.34	0.11	5.89	1.96	0.20	0.06	2688	0	2688	59	129	2875	100.0%	17.7	2.3	0.06	0.02	1.1	0.35	0.04
8/13/2015 4:30	8/13/2015 7:15	98	12.7	0.34	0.11	5.89	1.96	0.20	0.04	252	0	252	5	12	270	100.0%	1.7	0.2	0.01	0.00	0.1	0.03	0.00
8/16/2015 18:30	8/17/2015 0:15	**29**	**8.2**	**0.20**	0.11	**2.80**	**1.10**	**0.29**	0.50	26074	23125	2949	568	1247	4764	11.3%	8.6	2.4	0.06	0.03	0.8	0.33	0.09
8/17/2015 17:27	8/17/2015 21:45	98	12.7	0.34	0.11	5.89	1.96	0.20	0.08	5872	0	5872	128	281	6281	100.0%	38.6	5.0	0.13	0.04	2.3	0.77	0.08
8/18/2015 11:05	8/18/2015 22:30	**88**	**7.8**	**0.18**	0.11	**3.20**	**0.92**	**0.14**	0.97	96838	69391	27447	2109	4632	34188	28.3%	187.8	16.6	0.38	0.23	6.8	1.96	0.30
8/19/2015 3:30	8/19/2015 7:30	98	12.7	0.34	0.11	5.89	1.96	0.20	0.28	17025	1469	15556	371	814	16742	91.4%	102.9	13.3	0.35	0.11	6.2	2.05	0.21
8/19/2015 10:58	8/19/2015 13:30	98	12.7	0.34	0.11	5.89	1.96	0.20	0.03	2594	0	2594	56	124	2775	100.0%	17.1	2.2	0.06	0.02	1.0	0.34	0.03
8/22/2015 18:34	8/23/2015 0:15	98	12.7	0.34	0.11	5.89	1.96	0.20	0.93	98060	65453	32607	219	480	33305	33.3%	204.7	26.4	0.70	0.22	12.3	4.07	0.42
9/2/2015 3:30	9/2/2015 8:45	98	12.7	0.34	0.11	5.89	1.96	0.20	0.28	11864	1469	10395	258	568	11221	87.6%	69.0	8.9	0.24	0.07	4.1	1.37	0.14
9/6/2015 6:59	9/6/2015 11:15	98	12.7	0.34	0.11	5.89	1.96	0.20	0.52	56034	25094	30940	99	218	31258	55.2%	192.2	24.8	0.66	0.21	11.5	3.82	0.39
9/8/2015 4:52	9/8/2015 7:22	98	12.7	0.34	0.11	5.89	1.96	0.20	0.21	1852	0	1852	40	89	1981	100.0%	12.2	1.6	0.04	0.01	0.7	0.24	0.02
9/9/2015 21:21	9/10/2015 0:30	98	12.7	0.34	0.11	5.89	1.96	0.20	0.50	6599	0	6599	144	316	7058	100.0%	43.4	5.6	0.15	0.05	2.6	0.86	0.09
9/10/2015 5:45	9/10/2015 7:30	98	12.7	0.34	0.11	5.89	1.96	0.20	0.06	2514	0	2514	55	120	2688	100.0%	16.5	2.1	0.06	0.02	1.0	0.33	0.03
9/16/2015 3:30	9/16/2015 5:00	98	12.7	0.34	0.11	5.89	1.96	0.20	0.03	344	0	344	7	16	368	100.0%	2.3	0.3	0.01	0.00	0.1	0.04	0.00
9/16/2015 22:05	9/17/2015 16:00	**40**	**9.0**	**0.11**	**0.01** <	**4.80**	**1.10**	**0.38**	2.66	361636	361636	0	7424	605	8028	0.0%	20.0	4.5	0.06	0.00	2.4	0.55	0.19
9/18/2015 18:45	9/19/2015 0:15	98	12.7	0.34	0.11	5.89	1.96	0.20	0.29	4234	7	4227	1	203	4430	99.8%	27.2	3.5	0.09	0.03	1.6	0.54	0.06
9/20/2015 18:15	9/20/2015 20:00	98	12.7	0.34	0.11	5.89	1.96	0.20	0.09	991	0	991	0	47	1038	100.0%	6.4	0.8	0.02	0.01	0.4	0.13	0.01
9/23/2015 14:00	9/24/2015 8:45	**77**	**18.0**	**0.26**	**0.09**	**3.60**	**1.50**	**0.39**	1.16	52032	24615	27417	179	2489	30086	52.7%	144.6	33.8	0.49	0.17	6.8	2.82	0.73
9/28/2015 11:00	9/28/2015 13:30	98	12.7	0.34	0.11	5.89	1.96	0.20	0.03	438	0	438	0	21	459	100.0%	2.8	0.4	0.01	0.00	0.2	0.06	0.01
10/8/2015 4:11	10/8/2015 6:45	98	12.7	0.34	0.11	5.89	1.96	0.20	0.29	32327	8976	23351	0	213	23564	72.2%	144.9	18.7	0.49	0.16	8.7	2.88	0.30
10/23/2015 5:00	10/24/2015 7:15	98	12.7	0.34	0.11	5.89	1.96	0.20	1.14	58689	34076	24614	1960	2807	29381	41.9%	180.6	23.3	0.62	0.19	10.8	3.59	0.37
10/27/2015 20:45	10/29/2015 14:30	**44**	**7.9** <	**0.62**	0.11	**6.50**	**1.20**	**0.02** <	0.87	76918	1376	75542	0	3679	79221	98.2%	217.6	39.1	3.07	0.52	32.1	5.93	0.10
10/31/2015 2:28	10/31/2015 14:00	**64**	**15.2** <	**0.71**	0.11	**7.80**	**2.00**	**0.02** <	0.36	38093	854	37239	0	1822	39061	97.8%	156.1	37.1	1.73	0.26	19.0	4.88	0.05
11/5/2015 14:42	11/5/2015 17:15	98	12.7	0.34	0.11	5.89	1.96	0.20	0.28	5777	5387	390	0	276	667	6.8%	4.1	0.5	0.01	0.00	0.2	0.08	0.01
11/11/2015 17:13	11/12/2015 8:15	**34**	**14.2**	0.34	0.11	5.89	**0.83**	**0.12**	2.12	226293	197253	29040	12999	7311	49350	12.8%	104.7	43.7	1.04	0.33	18.2	2.56	0.37
Sum									30.11	2,778,394	1,649,961	1,128,433	71,429	65,611	1,265,473		**8581.4**	**1052.3**	**31.82**	**9.19**	**500.3**	**175.40**	**13.53**
Average		119	14	0.42	0.13	7.01	2.20	0.21	0.57	49,614	29,464	20,151	1,276	1,172	22,598		153.2	18.8	0.57	0.16	8.9	3.13	0.24
Weighted Ave		98.5	13	0.34	0.11	5.89	1.96	0.20															
STDEV		84	5	0.23	0.16	3.57	1.19	0.14									205.3	21.4	0.71	0.23	10.8	4.59	0.26
Median		90	14	0.41	0.09	6.00	1.90	0.16							14821		79.2	11.8	0.26	0.08	5.5	1.78	0.14
Min		29	8	0.11	0.01	2.80	0.83	0.02							62		1	0.1	0.00	0.00	0.0	0.01	0.00
Max		298	26	0.93	0.56	15.10	4.90	0.46							129,851		1038	94.0	3.07	1.36	50.9	29.18	1.29
Percent Capture of Total Runoff															**43.4%**		**48.4%**	**46.1%**	**52.7%**	**48.3%**	**47.4%**	**49.8%**	**37.5%**

< Sample was not detected above the method detection limit (value reported)

GREY FONT Events with no sample data (weighted average concentration used)

BOLD Sampled events

1 Erroneous level data was encountered in the upstream sensor location during numerous flow events. Those events are highlighted and flows are estimated using the P8 Modeling Program.

Erroneous level data in the flow sensor did not produce quality flow data. Downstream recorded flow data was substantially great than P8 model for total event flow. The upstream volume is reported as equivalent to the downstream assumsing majority of flow was bypassed

2 Flow from the East Pond is calcuated using monitored flow and the ratio of drainage areas

City of Saint Paul
2015 Water Quality and Quantity Report
Table C.3
WSB Project Number: 01610-100

SAINT ALBANS WATER QUALITY SUMMARY

Sample ID	Date Composite Sampling Started	Date Composite Sampling Ended	TSS (mg/L)	TDS (mg/L)	VSS (mg/L)	Suspended Sediment Conc. (SSC) (mg/L)	Fine Fraction Sediment (mg/L)	Coarse Fraction Sediment (mg/L)	TP (mg/L)	Ortho-P (mg/L)	Chlorides (mg/L)	Ammonia as N (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite as N (mg/L)	Hardness as CaCO3 (mg/L)	Copper (ug/L)	Lead (ug/L)	Zinc (ug/L)	Sulfate (mg/L)	pH	CBOD (mg/L)	E. Coli (MPN/ 100 mL)
SA-AS-050315	5/3/2015 17:36	5/3/2015 18:20	302.0		41.6				0.71				4.90	0.12								
SA-AS-050715	5/7/2015 17:33	5/7/2015 19:24	366.0		37.0				0.50	0.051		0.42	2.40	0.22					2.5 <	7.4	7.6	
SA-AS-051015	5/10/2015 22:05	5/11/2015 1:14	96.0	33.0	10.0 <	1040.0	76.1	965.0	0.25	0.036		0.32	1.30	0.24					2.5 <	6.7	5.2	
SA-AS-051415	5/14/2015 16:20	5/14/2015 19:12	130.0	130.0	10.0 <				0.34	0.081	22.1	0.37	3.70	0.43	39600	32.7	18.8	180.0		6.7		
SA-AS-052415	5/24/2015 14:08	5/25/2015 3:07	62.0		19.2				0.40	0.017		0.09	3.40	0.14					2.5 <	7.0	20.0 <	
SA-AS-052615	5/26/2015 14:30	5/26/2015 17:30	95.0		20.4				0.18	0.022		0.11	1.30	0.23					2.5 <	7.1	9.7	
SA-AS-052915	5/29/2015 3:52	5/29/2015 19:17	124.0		11.2	885.0	38.3	847.0	0.41			0.24	2.00	0.30					2.5 <	6.2	7.1	
1 SA-AS-060315	6/3/2015 12:53	6/3/2015 14:23	250.0		12.4	525.0	127.0	398.0	0.53	0.0050 <	12.2	0.28	3.90	0.082	61500	35.8	59.8	216.0				
SA-GS-060315		6/3/2015 15:15																	2.5 <	6.8	6.0 nd	2419.60 >
2 SA-AS-060315	6/3/2015 19:06	6/3/2015 20:18	57.0		10.0 <				0.14	0.033	3.8	0.51	2.00	0.28	19900	10.9	14.8	59.5				
SA-AS-060715	6/7/2015 0:18	6/7/2015 1:16	45.0								5.8			0.27	17600	10.0 <	12.7	45.4				
SA-GS-061115		6/11/2015 11:41																	2.5 <	7.0	13.4	2419.60 >
SA-AS-062015	6/20/2015 6:09	6/20/2015 8:46	39.0		7.8				0.14		8.0		1.30	0.44								
SA-AS-062215	6/22/2015 8:00	6/22/2015 9:29	43.0		11.0				0.13	0.022	6.1		0.78	0.34								
SA-AS-062915	6/29/2015 19:38	6/29/2015 20:21	82.0		19.8				0.27	0.0050 <	8.0	0.27	2.00 <	0.43	31800	21.6	29.2	105.0				
SA-AS-070515	7/6/2015 0:58	7/6/2015 12:24	45.0		18.6	85.0	10.0 <	78.4	0.15		3.6		2.00	0.16								
SA-AS-071815	7/18/2015 0:55	7/18/2015 15:19	41.0		14.4	60.4	27.0	33.4	0.13		8.7		0.82	0.37								
SA-AS-072815	7/28/2015 7:00	7/28/2015 8:32	78.0		9.2				0.20		6.0		1.00	0.19								
SA-AS-080716	8/7/2015 1:20	8/7/2015 2:21	98.0		9.6				0.20		2.6		0.93	0.55								
SA-AS-081615	8/16/2015 20:01	8/16/2015 22:28	75.0		10.2				0.30		2.1		0.84	0.46								
SA-GS-081815		8/18/2015 15:00																	2.5 <	7.8	3.0	7500.00
SA-AS-081815	8/18/2015 12:10	8/18/15: 16:04	74.0		12.0				0.17		2.9		0.50 <	0.12								
SA-AS-082215	8/22/2015 20:41	8/23/2015 0:30	66.0		9.4				0.12		2.9		0.60	0.20								
SA-AS-090615	9/6/2015 7:01	9/6/2015 9:47	62.0		22.4				0.23		3.1		1.40	0.42								
SA-AS-090915	9/9/2015 22:19	9/9/2015 23:16	39.0		15.4				0.16		3.1		0.95	0.26								
SA-AS-100815	10/8/2015 4:11	10/8/2015 6:03				137.0	57.4	79.7														
SA-AS-102315	10/23/2015 7:42	10/23/2015 18:33	90.0		22.0				0.50		12.1		2.30	0.020 <								
SA-AS-111115	11/11/2015 16:10	11/12/2015 8:02	63.6		22.6	1350.0	29.1	1320.0				0.25	1.00	0.22		12.0	12.7	63.6	2.5 <			
MINIMUM			**39**	**33.0**	**7.8**	**60.4**	**10.0**	**33.4**	**0.12**	**0.005**	**2.1**	**0.09**	**0.50**	**0.02**	**17600**	**10.0**	**12.7**	**45.4**	**2.5 <**	**6.2**	**3.0**	**2420 >**
AVERAGE			**99**	**66.2**	**16.6**	**675.3**	**49.3**	**633.9**	**0.28**	**0.030**	**6.4**	**0.29**	**1.76**	**0.27**	**31633**	**19.3**	**23.0**	**104.7**	**2.5 <**	**7.0**	**9.0**	**4113**
MAXIMUM			**366**	**130.0**	**41.6**	**1350.0**	**127.0**	**1350.0**	**0.71**	**0.081**	**22.1**	**0.51**	**4.90**	**0.55**	**61500**	**35.8**	**59.8**	**216.0**	**2.5 <**	**7.8**	**20.0**	**7500**

< - Sample was not detected above the method detection limit (value reported)
Grab Sample
SSC analysis was not available for the later part of the season

City of Saint Paul
2015 St. Albans Volume Reduction Pollutant Loading
Table C.4
WSB Project No.: 01610-100

SAINT ALBANS INFILTRATION SYSTEM VOLUME REDUCTION AND POLLUTANT LOADING

Event Time Interval [1]		Sampling Data							Event Loading and Volume Data											
		TSS	VSS	TP	Ortho-P	Chloride	Total Kjeldahl Nitrogen	Nitrate + Nitrite as N	Interval Rain	Eliptical Volume (1)	University [2] Volume (2)	Bypass Volume (3)	Volume Captured by BMP (1+2-3)	Captured TSS	Captured VSS	Captured TP	Captured Ortho-P	Captured Chloride	Captured Total Kjeldahl Nitrogen	Captured Nitrate + Nitrite as N
Start	End	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	In.	cu-ft	cu-ft	cu-ft	cu-ft	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4/18/15 23:00	4/21/15 4:15	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.16	2572.1	3299	0	5871.4	33.7	6.4	0.07	0.027	2.1	0.1	0.1
4/24/15 13:00	4/25/15 17:45	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.17	1290.0	2416	0	3706.4	21.2	4.0	0.05	0.017	1.3	0.1	0.1
5/1/15 12:30	5/2/15 22:15	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.01	233.2	268	0	500.8	2.9	0.5	0.01	0.002	0.2	0.0	0.0
5/3/15 17:34	5/3/15 23:15	**302**	**41.6**	**0.71**	0.074	5.7	**4.90**	0.24	0.2	4105.9	3100	0	7206.2	135.9	18.7	0.32	0.033	2.6	2.2	0.1
5/7/15 13:04	5/7/15 21:45	**366**	**37.0**	**0.50**	**0.051**	5.7	**2.40**	0.24	0.68	14849.8	8649	0	23499.1	536.9	54.3	0.73	0.075	8.4	3.5	0.4
5/10/15 20:00	5/11/15 11:00	**96**	**10.0** <	**0.25**	**0.036**	5.7	**1.30**	0.24	0.74	11308.4	11164	0	22472.4	134.7	14.0	0.35	0.051	8.0	1.8	0.3
5/11/15 21:45	5/12/15 9:15	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.1	26.7	915	0	941.4	5.4	1.0	0.01	0.004	0.3	0.0	0.0
5/14/15 11:00	5/15/15 3:45	**130**	**10.0** <	**0.34**	**0.081**	**22.1**	**3.70**	0.24	0.28	1520.0	4497	0	6016.9	48.8	3.8	0.13	0.030	8.3	1.4	0.1
5/16/15 21:08	5/17/15 19:00	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.05	356.9	616	0	973.1	5.6	1.1	0.01	0.005	0.3	0.0	0.0
5/24/15 0:45	5/25/15 14:30	**62**	**19.2**	**0.40**	**0.017**	5.7	**3.40**	**0.14**	0.56	5082.9	9106	0	14188.6	54.9	17.0	0.35	0.015	5.1	3.0	0.1
5/26/15 11:15	5/27/15 10:30	**95**	**20.4**	**0.18**	**0.022**	5.7	**1.30**	**0.23**	0.49	5426.4	7419	0	12845.8	76.2	16.4	0.14	0.018	4.6	1.0	0.2
5/29/15 0:45	5/30/15 3:15	**124**	**11.2**	**0.41**	0.074	5.7	**2.00**	**0.3**	0.87	11181.2	9623	0	20804.1	161.0	14.5	0.53	0.096	7.4	2.6	0.4
6/3/15 8:46	6/4/15 6:30	**153.5**	**6.2**	**0.33**	**0.162**	**8.0**	**2.95**	**0.181**	0.91	20351.0	13054	0	33404.9	320.1	12.9	0.69	0.338	16.7	6.2	0.4
6/6/15 23:47	6/8/15 2:30	**45**	17.3	0.20	0.074	**5.8**	0.29	**0.27**	0.66	6816.9	10413	0	17229.6	48.4	18.7	0.22	0.080	6.2	0.3	0.3
6/11/15 5:00	6/12/15 2:00	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.3	1534.1	3159	0	4693.4	26.9	5.1	0.06	0.022	1.7	0.1	0.1
6/13/15 8:15	6/13/15 19:45	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.13	666.5	1392	0	2058.2	11.8	2.2	0.03	0.010	0.7	0.0	0.0
6/17/15 13:51	6/17/15 21:45	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.66	3602.9	3282	0	6884.8	39.5	7.5	0.09	0.032	2.5	0.1	0.1
6/20/15 5:51	6/20/15 16:30	**39**	**7.8**	**0.14**	0.074	**8.0**	**1.30**	**0.44**	0.4	5048.7	5604	0	10653.1	25.9	5.2	0.09	0.049	5.3	0.9	0.3
6/22/15 7:13	6/22/15 17:45	**43**	**11.0**	**0.13**	**0.02**	**6.1**	**0.78**	**0.34**	0.61	5064.9	4765	0	9830.2	26.4	6.8	0.08	0.014	3.7	0.5	0.2
6/27/15 23:28	6/28/15 19:00	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.09	5977.7	5070	0	11047.9	63.3	12.0	0.14	0.051	3.9	0.2	0.2
6/29/15 19:15	6/30/15 0:15	**82**	**19.8**	**0.27**	**0.0050** <	**8.0**	**1.00**	**0.43**	0.39	2734.6	2156	0	4890.7	25.0	6.0	0.08	0.002	2.4	0.3	0.1
7/6/15 0:55	7/6/15 15:15	**45**	**18.6**	**0.15**	0.074	**3.6**	**2.00**	**0.16**	2.13	36623.9	34667	0	71290.8	200.3	82.8	0.67	0.330	16.0	8.9	0.7
7/12/15 23:11	7/13/15 4:30	91.8	17.3	0.20	0.074	5.7	0.29	0.24	1.63	32795.4	21439	5199	49035.1	281.1	53.1	0.62	0.227	17.5	0.9	0.7
7/16/15 14:15	7/17/15 3:30	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.19	1173.6	2095	0	3269.1	18.7	3.5	0.04	0.015	1.2	0.1	0.0
7/18/15 0:50	7/18/15 16:45	**41**	**14.4**	**0.13**	0.074	**8.7**	**0.82**	**0.37**	0.83	14715.6	12730	0	27445.2	70.2	24.7	0.22	0.127	14.9	1.4	0.6
7/24/15 3:45	7/24/15 12:45	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.12	530.6	1895	0	2425.4	13.9	2.6	0.03	0.011	0.9	0.0	0.0
7/28/15 6:38	7/28/15 11:00	**78**	**9.2**	**0.20**	0.074	**6.0**	**1.00**	**0.19**	0.74	9481.2	8467	0	17948.4	87.4	10.3	0.22	0.083	6.7	1.1	0.2
8/6/15 12:00	8/6/15 12:44	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.25	947.4	539	0	1486.1	8.5	1.6	0.02	0.007	0.5	0.0	0.0
8/7/15 1:00	8/7/15 6:00	**98**	**9.6**	**0.20**	0.074	**2.6**	**0.93**	**0.55**	0.37	8146.3	5175	0	13321.7	81.5	8.0	0.17	0.062	2.2	0.8	0.5
8/9/15 13:45	8/9/15 19:00	91.83	17.34	0.20	0.074	5.7	0.29	0.24	0.03	528.9	942	0	1471.3	8.4	1.6	0.02	0.007	0.5	0.0	0.0
8/16/15 21:07	8/17/15 0:00	**75**	**10.2**	**0.30**	0.074	**2.1**	**0.84**	**0.46**	0.5	10648.3	6128	0	16776.4	78.5	10.7	0.31	0.078	2.2	0.9	0.5
8/18/15 10:15	8/19/15 0:00	91.8	17.3	0.20	0.074	5.7	0.29	0.24	1.05	14599.4	11804	0	26403.5	151.4	28.6	0.33	0.122	9.4	0.5	0.4
8/19/15 3:00	8/19/15 13:00	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.04	473.3	1839	0	2312.1	13.3	2.5	0.03	0.011	0.8	0.0	0.0
8/22/15 18:30	8/23/15 3:30	**66**	**9.40**	**0.12**	0.074	**2.9**	**0.60**	**0.20**	0.76	13062.7	13599	0	26661.7	109.9	15.6	0.20	0.123	4.8	1.0	0.3
9/2/15 2:09	9/2/15 9:00	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.25	2467.2	2578	0	5045.6	28.9	5.5	0.06	0.023	1.8	0.1	0.1
9/6/15 4:45	9/6/15 15:00	**62**	**22.4**	**0.23**	0.074	**3.1**	**1.4**	**0.42**	0.58	5390.8	4574	0	9965.0	38.6	13.9	0.14	0.046	1.9	0.9	0.3
9/8/15 4:00	9/8/15 9:00	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.17	1149.7	1370	0	2519.6	14.4	2.7	0.03	0.012	0.9	0.0	0.0
9/9/15 21:15	9/10/15 7:00	**39**	**15.4**	**0.16**	0.074	**3.1**	**0.95**	**0.26**	0.44	5737.5	4823	0	10560.6	25.7	10.2	0.11	0.049	2.0	0.6	0.2
9/16/15 3:02	9/17/15 0:00	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.14	1587.1	1629	0	3215.8	18.4	3.5	0.04	0.015	1.1	0.1	0.0
9/17/15 4:45	9/17/15 19:45	91.8	17.3	0.20	0.074	5.7	0.29	0.24	1.79	28566.2	21777	0	50342.8	288.6	54.5	0.63	0.233	17.9	0.9	0.8
9/18/15 17:00	9/19/15 3:30	**74**	**12.00**	**0.17**	0.074	**2.9**	**0.50**	**0.12**	0.31	3947.4	3084	0	7031.8	32.5	5.3	0.07	0.033	1.3	0.2	0.1
9/20/15 13:15	9/21/15 5:00	91.8	17.34	0.20	0.074	5.7	0.29	0.24	0.04	754.3	721	0	1474.8	8.5	1.6	0.02	0.007	0.5	0.0	0.0
9/23/15 13:59	9/24/15 2:00	91.8	17.34	0.20	0.074	5.7	0.29	0.24	0.19	6678.3	3601	0	10279.1	58.9	11.1	0.13	0.048	3.7	0.2	0.2
9/24/15 2:22	9/24/15 8:00	91.8	17.34	0.20	0.074	5.7	0.29	0.24	0.09	3969.7	2782	0	6751.6	38.7	7.3	0.08	0.031	2.4	0.1	0.1
10/8/15 3:57	10/8/15 14:45	91.8	17.34	0.20	0.074	5.7	0.29	0.24	0.3	3690.7	3255	0	6945.2	39.8	7.5	0.09	0.032	2.5	0.1	0.1
10/23/15 5:00	10/24/15 5:15	**90**	**22.00**	**0.50**	0.074	**12.1**	**2.30**	**0.02**	1.08	12407.0	*10311*	0	22717.9	127.6	31.2	0.71	0.105	17.2	3.3	0.0
10/27/15 19:00	10/29/15 4:00	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.85	12798.8	*10606*	0	23405.1	134.2	25.3	0.29	0.108	8.3	0.4	0.4
10/31/15 2:09	10/31/15 13:45	91.8	17.3	0.20	0.074	5.7	0.29	0.24	0.36	4763.6	*4548*	0	9311.3	53.4	10.1	0.12	0.043	3.3	0.2	0.1
11/11/15 16:00	11/12/15 9:36	**63.6**	**22.60**	0.20	0.074	5.7	**1.00**	**0.22**	2.44	58966.9	*45417*	0	104384.0	414.4	147.3	1.31	0.483	37.2	6.5	1.4
Sum									26.13	406352.6	352362.8	5199.4	**753516.1**	**4250.5**	**810.6**	**10.9**	**3.4**	**271.6**	**53.6**	**11.4**
Average		98.7	16.4	0.28	0.056	6.6	1.70	0.28	0.53	8292.9	7191.1	106.1	15377.9	86.7	16.5	0.22	0.1	5.5	1.1	0.2
Weighted Avg		91.8	17.3	0.20	0.074	5.7	1.57	0.24												
STDEV		90.8	9.1	0.15	0.051	5.0	1.15	0.14					19252							
Min		39.0	6.2	0.12	0.01	2.1	0.50	0.02					501							
Max		366.0	41.6	0.71	0.16	22.1	4.90	0.55					104384							
Percent Capture													**98.64%**	**98.62%**	**98.63%**	**98.82%**	**98.62%**	**98.65%**	**99.65%**	**98.63%**

< Sample was not detected above the method detection limit (value reported)
GREY FONT Events with no sampling data (weighted average concentration used)
BOLD Sampling event
1 6/3/2016 flow event is an average of two samples
2 University Volumes after 10/23 are estimated flow based on the relationship between the elipital and unvisity volumes for previous flow events

City of Saint Paul
2015 Water Quality and Quantity Report
Table C.5
WSB Project number 01610-100 Ph.04

Maryland Pond Iron-Enhanced Sand Filtration Water Quality Summary

Pre-Treatment[1]	Post-Treatment[2]	Treatment Event Start	Soluble Reactive Phosphorus (mg/L)			Total Phosphorus (mg/L)			Dissolved Phosphorus (mg/L)		
Sample ID [3,4,5]	Sample ID		Pre-Treament	Post-Treatment	% Reduction	Pre-Treament	Post-Treatment	% Reduction	Pre-Treament	Post-Treatment	% Reduction
MAR-P-AS-060515-1	MAR-O-AS-060515-1	06/04/2015 13:53	0.081	0.011	86	0.30	0.10	68	0.180	0.045 J	75
MAR-P-AS-060515-2	MAR-O-AS-060515-2	06/04/2015 17:53	0.048	0.007	86	0.36	0.08	79	0.190	0.045 J	76
MAR-P-AS-060515-3	MAR-O-AS-060515-3	06/04/2015 21:53	0.036	0.005	85	0.67	0.07	90	0.180	0.027 J	85
MAR-P-AS-060515-4	MAR-O-AS-060515-4	6/5/2015 1:53	0.045	0.005	89	0.29	0.06	81	0.160	0.029 J	82
MAR-P-AS-060515-5	MAR-O-AS-060515-5	06/05/2015 05:53	0.078	0.014	82	0.37	0.05	87	0.220	*0.025* <	89
MAR-P-AS-060515-6	MAR-O-AS-060515-6	06/05/2015 09:53	0.082	0.014	83	0.31	0.05	84	0.200	0.057	72
MAR-P-AS-060515-7	MAR-O-AS-060515-7	06/05/2015 11:53	0.079	0.006	92	0.31	0.04	87	0.190	*0.025* <	87
MARPON-AS-071215	MAROCS-AS-071215	07/13/2015 12:34	0.008	0.009	-9	0.19	0.10	47	*0.025* <	0.032 J	-28
MARPON-AS-071815	MAROC-AS-071815	07/18/2015 12:14	0.005 J	0.012	-150	0.16	0.07	55	*0.025* <	*0.025* <	0
MARPON-AS-072815	MARCOS-AS-072815	07/28/2015 15:59	0.008	0.006	33	0.20	0.09	55	0.250	0.079	68
MARPON-081015	MAROCS-081015	08/10/2015 14:05	0.006	0.010	-64	0.12	0.03	78	*0.025* <	*0.025* <	0
MARPON-081615	MAROCS-081615	08/17/2015 08:28	*0.002* <	*0.002* <	0	0.10	0.06	42	NA*	*0.025* <	NA
MARPON-AS-081815	MAROCS-AS-081816	08/19/2015 05:25	0.011	0.011 J	0	0.16	0.10	39	0.042 J	0.044 J	-5
Maryland-Pond-AS-081915 (1-4)	Maryland-OSC-AS-081915 (1-4)	08/20/2015 08:30	0.007	0.005 J	33	0.09	0.03	66	0.039 J	*0.025* <	36
MARYLAND-POND-AS-082215	MARYLAND-OCS-AS-082215	08/24/2015 05:04	*0.002* <	*0.002* <	0	0.08	0.03	60	*0.025* <	0.054 J	-116
MARYLAND-POND-090615	MARYLAND-OCS-090615	09/07/2015 10:14	*0.002* <	*0.003 J*	-47	0.11	0.04	63	*0.025* <	*0.025* <	0
MARYLAND-POND-090915	MARYLAND-OCS-090915	09/11/2015 13:04	*0.002* <	*0.002* <	0	0.12	0.06	48	*0.025* <	*0.025* <	0
MARYLAND-POND-AS-091715	MARYLAND-OCS-AS-091715	09/17/2015 13:17	0.005 J	*0.002* <	62	0.06	0.04	36	*0.025* <	*0.025* <	0
MARYLAND-POND-AS-092415	MARYLAND-OCS-AS-092415	09/24/2015 23:39	*0.002* <	*0.003* <	-53	0.08	0.03	62	*0.097*	0.046 J	53
MARYLAND-POND-102415	MARYLAND-OCS-102415	10/24/2015 11:00	0.087	0.017	80	0.18	0.05	72	0.100	0.032 J	68
MARYLAND-POND-102915	MARYLAND-OCS-102915	10/29/2015 09:00	0.086	0.019	78	0.14	0.02	84	*NA**	*0.025* <	NA
MARYLAND-PON-AS-110115	MARYLAND-OCS-AS-110115	11/01/2015 07:36	0.085	0.020	76	0.18	0.16	11	0.073	0.027 J	63
MARYLAND-POND-G-111215	MARYLAND-OCS-G-111215	11/12/2015 09:40	0.130	0.042	68	0.22	0.09	60	0.130	0.060	54
MARYLAND-POND-AS-111115	MARYLAND-OSC-AS-111115	11/12/2015 14:50	0.120	0.054	55	0.26	0.14	46	0.110	0.044 J	60
Maryland-Pond-AS-111715	Maryland-OCS-AS-111715	11/18/2015 10:28	0.059	0.034	42	0.18	0.09	51	0.079	0.060	24
MINIMUM			0.002 <	0.002 <	-150.0	0.06	0.02	11	0.025	0.025	-116
AVERAGE			0.044	0.012	32.4	0.21	0.07	62	0.105	0.037	37
MAXIMUM			0.130	0.054	91.9	0.67	0.16	90	0.25	0.079	89

1 - Pre-treatment samples were collected from the pond near the outlet control structure (OCS) 1 foot below the water surface

2 - Post-treatment samples were collected from the oulet pipe within the OCS

3 - Pre-treatment and post-treatment automated samplers were programmed to collect simultaneously at consistant flow intervals recorded by the flow meter within the OCS

4 - Seven (7) samples were collected for the treatment event on 06/05/2015 to observe changes in treatment effectivness over the duration of a flow event.

5 - Sample MAR-P-AS-060515-4 was mislabeld on laboratory documentation as occuring on 06/04/2015. Acutal collection date is 06/05/2015

Grab Sample

< Sample was not detected above the method detection limit (value reported)

J - Result reported as estimated between the MDL and RL

MARYLAND POND POLLUTANT REDUCTION SUMMARY

Flow Event Start	Treatment Event Duration (hours)	Flow Volume (cubic feet)	Total Rainfall Depth (inches)	TP Load In (grams)	TP Load Out (grams)	TP Load Captured (grams)	SRP Load In (grams)	SRP Load Out (grams)	SRP Load Captured (grams)
3-Jun	82.3	33716	0.91	277	93	184.3	43.0	10.5	32.5
6-Jun	41.0	31868	0.91	148	68	79.6	53.1	16.3	36.8
11-Jun	19.0	2018	0.31	9	4	5.0	3.4	1.0	2.3
17-Jun	45.3	22419	1.04	104	48	56.0	37.4	11.5	25.9
20-Jun	33.8	16038	0.47	74	34	40.1	26.7	8.2	18.5
22-Jun	52.2	16832	0.35	78	36	42.1	28.1	8.6	19.4
26-Jun	7.2	582	0.15	3	1	1.5	1.0	0.3	0.7
27-Jun	15.5	5359	0.29	25	11	13.4	8.9	2.7	6.2
28-Jun	26.8	12869	0.3	60	28	32.2	21.5	6.6	14.9
29-Jun	61.0	10579	0.11	49	23	26.4	17.6	5.4	12.2
6-Jul	104.5	72974	2.17	339	156	182.4	121.7	37.4	84.3
12-Jul	88.3	51453	2.11	277	146	131.2	276.9	12.4	264.6
16-Jul	31.5	4167	0.17	19	9	10.4	6.9	2.1	4.8
18-Jul	80.3	27267	0.91	127	58	68.1	3.7	9.3	-5.6
24-Jul	98.3	2858	0.18	13	6	7.1	4.8	1.5	3.3
28-Jul	199.0	18440	0.59	104	47	57.5	4.3	2.9	1.4
6-Aug	243.8	11362	0.66	39	8	30.3	1.9	3.1	-1.2
16-Aug	40.5	4170	0.5	12	7	5.0	0.2	0.2	0.0
18-Aug	103.2	45670	1.25	115	39	76.3	8.9	6.0	3.0
22-Aug	190.5	15500	0.93	35	14	21.1	0.7	0.7	0.0
2-Sep	96.5	3187	0.29	15	7	8.0	5.3	1.6	3.7
6-Sep	87.0	8924	0.54	28	10	17.4	0.4	0.6	-0.2
9-Sep	7.3	4713	0.5	16	8	7.6	0.2	0.2	0.0
10-Sep	161.0	10494	0.07	49	22	26.2	17.5	5.4	12.1
16-Sep	41.0	64827	2.7	112	72	40.4	8.3	3.1	5.1
18-Sep	117.2	10362	0.26	48	22	25.9	17.3	5.3	12.0
23-Sep	187.0	13038	1.17	30	11	18.8	0.6	1.0	-0.3
23-Oct	100.8	24748	1.15	126	36	90.4	61.0	11.9	49.1
27-Oct	77.3	16917	0.88	67	11	56.6	41.2	9.1	32.1
31-Oct	224.3	10195	0.36	52	46	5.8	24.5	5.8	18.8
11-Nov	114.5	62633	2.12	461	248	212.9	212.9	95.8	117.1
16-Nov	186.8	86755	1.85	442	216	226.1	145.0	83.6	61.4
Totals	2964.3	722931	24.35	3354	1548	1806.1	1205.1	370.1	835.0
Average	179.7	22592							

No Sample collected, Annual FWA used

TP	
FWA In (mg/L)	0.164
FWA Out (mg/L	0.076
Total Load Captured (g)	1806
Percent Reduction %	54

SRP	
FWA In (mg/L)	0.059
FWA Out (mg/L	0.018
Total Load Captured (g)	835
Percent Reduction %	69

City of Saint Paul
2015 Water Quality and Quantity Report
Table C.7
WSB Project Number 01610-100

Magnolia Pond Iron Enhanced Sand Filtration Water Quality Summary

Pre-treatment[1]	Post-treatment[2]	Treatment Event Start	Soluble Reactive Phosphorus (mg/L)			Total Phosphorus (mg/L)			Dissolved Phosphorus (mg/L)		
Sample ID[3]	Sample ID		Pre-Treament	Post Treatment	% Reduction	Pre-Treament	Post Treatment	% Reduction	Pre-Treament	Post Treatment	% Reduction
MAGPON-AS-062915	MAGOCS-AS-062915	06/29/2015 08:19	0.002 J	0.003 J	-35	0.31	0.21	32	0.048 J	*0.025* <	48
MAGPON-AS-071215	MAGOCS-AS-071215	07/13/2015 13:39	0.003 J	0.006	-71	0.34	0.14	59	*0.025* <	*0.025* <	0
MAGPON-AS-071815	MAGOCS-AS-071815	07/19/2015 02:35	0.072	0.031	57	0.27	0.12	56	0.075	0.037 J	51
MAGPON-080715	MAGOCS-080715	08/07/2015 18:00	0.055	*0.002* <	97	0.41	0.068	83	0.098	*0.025* <	74
MAGPON-081715	MAGOCS-081715	08/17/2015 07:30	0.007	0.002 J	70	1.1	0.18	84	0.037 J	*0.025* <	32
MAGPON-AS-081817	MAGOCS-AS-081818	08/18/2015 16:05	0.046	0.006	87	0.38	0.051	87	0.130	0.069	47
Magnolia Pond-AS-081915 (1-7)	Magnolia OCS-AS-081915 (1-7)	08/20/2015 04:56	0.030	0.030	0	0.34	0.14	59	*0.025* <	0.078	-212
MAGNOLIA-POND-AS-082215	MAGNOLIA-OCS-AS-082215	08/23/2015 12:18	0.044	0.032	27	0.21	0.12	43	0.029 J	0.079	-172
MAGNOLIA-POND-091015	MAGNOLIA-OCS-091015	09/10/2015 22:55	0.003 J	0.005	-83	0.47	0.2	57	*0.025* <	*0.025* <	0
MAGNOLIA-POND-AS-091715	MAGNOLIA-OCS-AS-091715	09/17/2015 13:00	0.046	0.074	-61	0.15	0.17	-13	0.043 J	0.100	-133
MAGNOLIA-POND-AS-092415	MAGNOLIA-OLS-AS-092415	09/24/2015 21:43	0.093	0.011	88	0.35	0.13	63	0.340	0.140	59
MAGNOLIA-POND-102415	MAGNOLIA-OCS-102415	10/24/2015 10:48	0.190	0.100	47	0.61	0.47	23	0.110	0.048 J	56
MAGNOLIA-POND-102915	MAGNOLIA-OCS-102915	10/29/2015 07:57	0.290	0.094	68	0.55	0.25	55	0.450	0.096	79
MAGNOLIA-POND-G-111215	MAGNOLIA-OCS-G-111215	11/12/2015 09:50	0.450	0.330	27	0.7	0.45	36	0.460	0.300	35
MAGNOLIA-POND-AS-11715	MAGNOLIA-OCS-AS-11715	11/19/2015 09:30	0.190	0.160	16	0.39	0.26	33	0.240	0.190	21
MININUM			0.002	0.002 <	-82.8	0.1500	0.0510	-13.3	0.0250	0.0250	-212.0
AVERAGE			0.101	0.059	22.3	0.4387	0.1973	50.4	0.1423	0.0841	-1.0
MAXIMUM			0.450	0.330	96.9	1.1000	0.4700	86.6	0.4600	0.3000	78.7

1 - Pre-treatment samples were collected from the pond near the outlet control structure (OCS) 1 foot below the water surface

2 - Post-treatment samples were collected from the oulet pipe within the OCS

3 - Pre-treatment and post-treatment automated samplers were programmed to collect simultaneously at consistant flow intervals recorded by the flow meter within the OCS

Grab Samples

ND, < Value - Analyte NOT DETECTED above the Method Detection Limit

J - Result reported as estimated between the MDL and Reporting Limit (RL)

MAGNOLIA POND POLLUTANT REDUCTION SUMMARY

Treatment Event Start	Treatment Event Duration (hours)	Flow Volume (cubic feet)	Total Rainfall Depth (inches)	TP Load In (grams)	TP Load Out (grams)	Total Phosphorus Load Captured	SRP Load In (grams)	SRP Load Out (grams)	Load Captured
4-Jun	4.00	89	0.91	0.9	0.6	0.3	0.4	0.3	0.1
7-Jun	20.25	7386	1.01	76.6	48.0	28.6	30.9	23.8	7.1
17-Jun	17.75	4980	1.04	51.6	32.4	19.3	20.8	16.0	4.8
20-Jun	14.25	972	0.47	10.1	6.3	3.8	4.1	3.1	0.9
22-Jun	10.50	419	0.35	4.3	2.7	1.6	1.8	1.4	0.4
28-Jun	17.75	940	0.3	8.3	5.6	2.7	0.1	0.1	0.0
29-Jun	9.75	129	0.1	1.3	0.8	0.5	0.5	0.4	0.1
6-Jul	33.50	26299	2.17	272.8	170.9	101.9	110.0	84.7	25.3
12-Jul	34.25	16590	2.11	159.8	65.8	94.0	1.6	2.7	-1.1
18-Jul	32.25	8308	0.91	63.5	28.2	35.3	16.9	0.0	16.9
28-Jul	21.25	2341	0.59	24.3	15.2	9.1	9.8	7.5	2.2
7-Aug	21.50	1733	0.5	20.1	3.3	16.8	2.7	0.1	2.6
17-Aug	7.75	130	0.58	4.1	0.7	3.4	0.0	0.0	0.0
18-Aug	39.75	14168	1.28	144.5	38.3	106.2	18.5	2.4	16.1
22-Aug	32.50	5428	0.93	32.3	18.5	13.8	6.8	4.9	1.8
10-Sep	18.25	1486	0.56	19.8	8.4	11.4	0.1	0.2	-0.1
17-Sep	56.25	44640	2.52	189.7	215.0	-25.3	58.2	93.6	-35.4
23-Sep	31.25	1528	1.17	15.1	5.6	9.5	4.0	0.5	3.5
23-Oct	33.00	4211	1.14	72.8	56.1	16.7	22.7	11.9	10.7
28-Oct	53.05	3401	0.88	53.0	24.1	28.9	27.9	9.1	18.9
31-Oct	22.00	676	0.36	7.0	4.4	2.6	2.8	2.2	0.6
11-Nov	41.25	27688	2.12	549.1	353.0	196.1	353.0	258.8	94.1
17-Nov	72.25	26851	1.85	296.7	197.8	98.9	144.5	121.7	22.8
Totals:	644.30	200393	23.85	2077.6	1301.6	**801**	838.1	645.5	**192.5**
Averages:	28.01	8712.72							

No Sample Collected, FWA used

TP	
FWA In (mg/L)	0.37
FWA Out (mg/L)	0.23
Total Load Captured (g)	801
Percent Reduction %	37.4

SRP	
FWA In (mg/L)	0.15
FWA Out (mg/L)	0.11
Total Load Captured (g)	193
Percent Reduction %	23.0

Jenks Pond Iron-Enhanced Sand Filtration Water Quality Summary

Pre-treatment[1]	Post-treatment[2]	Treatment Event Start	Soluble Reactive Phosphorus (mg/L)			Total Phosphorus (mg/L)			Dissolved Phosphorus (mg/L)		
Sample ID[3]	Sample ID		Influent	Effluent	% Reduction	Influent	Effluent	% Reduction	Influent	Effluent	% Reduction
JENKS-POND-AS-091715	JENKS-OCS-AS-091715	9/17/2015 7:00	0.32	*0.0017* <	99	0.89	0.054	94	0.30 J	*0.025* <	92

1 - Pre-treatment samples were collected from the pond near the outlet control structure (OCS) 1 foot below the water surface
2 - Post-treatment samples were collected from the oulet pipe within the OCS
3 - Sample collected on 06/29/2015 was collected as a grab sample.
< - Sample was not detected above the method detection limit (value reported)
J - Result reported as estimated between the MDL and Reporting Limit (RL)
* Sample labels were inadvertently switched on the JENKS-POND-AS-091715 sample event. Values in the table reflect the necessary revision.

JENKS POND TREATMENT EVENT SUMMARY

Flow Event Start	Treatment Event Duration (hours)	Flow Volume (cubic feet)	Total Rainfall Depth (inches)
6-Jul	16.8	822	2.17
13-Jul	37.7	861	2.11
17-Sep	28.0	1110	2.46
18-Nov	19.5	237	1.85
Totals:	102.0	3029	8.59
Averages:	26	757	

* Only one pair of grab samples was collected at Jenks Pond in 2015 therefore, loading calculations were not completed do to insufficent data

Arundel 6/26/15

Arundel BMP Pipe

Arundel - pretreatment

20150504_141306

Beacon Bluff 5/4/15

20150504_151413

20150504_151418

20150505_172410

20150505_172428

20150508_112847

20150508_112939

Beacon Bluff BMP 6/25/15

BB BMP Pipe 6-25-15

BB Pre treatment 6-25-15

BB OCS 6-25-15

Beacon Bluff 7/23/15

DS pipe and bmp IMG_1226

Beacon Bluff 8/11/15

US sensor install IMG_1225

DS sensor install IMG_1224

Beacon Bluff
9/17/15 Rain Event

20150918_111729

20150918_111535

20150917_122024

20150918_111755

20150917_121749

20150917_121825

20150917_121953

20150917_122015

Beacon Bluff 11/9/15

20151109_112244

20151109_114425

20151109_112256

20151215_103133

12/15/15
Beacon Bluff

20151215_104946

20151215_103307

20151215_103455

20151215_103611

20151215_103415

20151215_103437

Case Logger Installation 4-20-15

20150420_163001

20150420_163009

20150420_160807

20150420_160819

20150420_160848

20150420_160857

Case 6/26/15

Case 7/23/15

Case 9/10/15

Case Rain Event 9/17/15

1387_ 9-18 0957 (2)

1387_ 9-18 0957

20150917_105200

20150917_105257

20150917_105310

20150917_105544

20150917_105538

20150917_104904

20150917_104956

Case 11/12/15

20151112_115221

20151112_115242

20151112_115227

Case 11/16/15

Sackett Playground
Level Logger Install 1-7-16

Hampden Park Pretreatment 6/29/15

Hampden Bypass Manhole 6/30/15

Hampden Park 7/23/15

Hampden 2 IMG_1651

Hampden IMG_1650

Hampden Park 12/15/15

20151215_142647_001

20151215_143020

20151215_143034

Hillcrest Knoll 6/26/15 Pretreatment and BMP Pipe

Pre-treatment

bmp Pipe

Hillcrest Knoll 7/23/15

Hillcrest IMG_1644

Hillcrest Logger IMG_1646

Hillcrest Pre IMG_1645

Hoyt Pond Installation 4/20/15

20150420_151956

20150420_152013

20150420_154050

20150420_154217

20150420_154227

20150420_154702

20150420_154806

20150420_154821

Hoyt Pond
6/22/15

IMG_1075

IMG_1076

IMG_1071

IMG_1072

IMG_1073

IMG_1074

Hoyt Pond 6/26/15

Hoyt Pond 9/10/15

Hoyt Pond 9/17/15 Rain Event

1386

1388

20150917_110737

20150917_110742

20150917_110856

20150917_110903

20150917_111259

20150917_111350

20150917_111404

Hoyt Pond Logger Re-Route 9/18/15

20150918_120523

20150918_120524

20150918_120534

20150918_120548

SP Rain Gauges

Frost1_20150504_105642 (1)

Frost2_20150504_105642 (2)

HP COOP 20150417_104944

St. Albans 6/25/15

St. Alban's Pre treatment 6-25-15

St. Alban's level logger location 6-25-15

St. Albans 7/29/15

st.albans MH4001South IMG_1190

st.albans MH4001North IMG_1191

St. Albans Winterization 12/15/15

20151215_133410

20151215_134441_001

20151215_133423

20151215_134635

20151215_134433

Jenks Pond 6/3/15

20150603_111206

20150603_161312

20150603_161915

20150603_161920

20150603_162142

20150603_162804

20150604_144145

Jenks Pond OCS 6/30/15

Jenks 6-30-15

Jenks 6-30-15 (2)

Magnolia Pond 6/3/15

20150603_161211

20150603_161229

20150603_161230

20150603_161255

20150603_161301

20150603_161303

20150604_104353

20150604_104358

20150604_104409

Magnolia OCS 6/30/16

Magnolia 6-30-15 (2)

Magnolia 6-30-15

Maryland Pond 6/3/15

20150603_152959

20150603_152949

20150603_101427

20150603_101433

20150603_101440

20150603_101454

Maryland Pond 6/30/15

Maryland OCS 2 6-30-15

Maryland OCS 6-30-15

Maryland Pond Rain Event 7/6/15

Maryland Pond 7/28/15

20150728_101034

20150728_101041

STORMWATER MONITORING PROTOCOL

2015 WATER QUANTITY AND QUALITY MONITORING PROGRAM

FOR THE CITY OF ST. PAUL, MINNESOTA

WSB PROJECT NO. 01610-100

SAINT PAUL

The Most Livable City in America

WSB

& Associates, Inc.

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I. Objectives

This section provides a summary of objectives for this monitoring effort. These objectives are presented in question form anticipating that the answers will be obtained through analysis of the data collected as part of this monitoring program.

a) How do team members maintain a safe work environment?

b) How much stormwater runoff volume reduction is achieved by each BMP on an event and annual basis?

c) What is the average measured infiltration rate of each BMP?

d) How often does each BMP require maintenance?

e) How many volume reduction credits are available at each BMP? Do they perform in accordance with or exceed watershed district rules?

f) What is the cost per cubic-foot of volume reduction actually being achieved by each BMP?

g) What is the mass of pollutants (TP, TSS, chlorides, etc.) removed from the stormwater system by each BMP on an average annual basis?

II. Safety Overview

The following safety guidelines have been developed to ensure that all WSB team members are providing and maintaining a safe work environment. Proper planning and situational awareness can help team members identify and eliminate potentially dangerous situations. Every team member has stop work authority if they feel endangered by unsafe working conditions. All team members are encouraged to report unsafe acts or unsafe working conditions to their supervisor as soon as possible. The following sections describe potentially hazardous working conditions and hazard mitigation procedures.

II.1 Adverse Weather Conditions:

Field team members will likely encounter a wide range of weather conditions during field duties. Field staff should be aware of the weather conditions and take proper measures to protect themselves from the elements.

- During excessive heat and sun conditions, field staff should stay hydrated, don skin protective clothing, and apply sunscreen .
- During excessive cold conditions, field staff should dress in layers and avoid perspiration.
- During lightning producing conditions, field staff must seek shelter in a work vehicle or other safe location if a lightning strike or thunder is observed. The field staff should wait at least 30 minutes from the last lightning strike before resuming outdoor activities. <u>Lightning safety is especially important due to the likelihood of thunderstorms during stormwater sampling events.</u>
- Field staff should be aware of the signs of heat exhaustion, heat stroke, hypothermia, and frostbite, and have an understanding of basic first aid procedures.

II.2 Working in the street:

At times, it will be necessary for team members to access manholes in roadways.

- While working in roadways, field staff should be visible to traffic, don reflective vests and hardhats, and utilize vehicle hazard lights.
- Field staff should park close to the manhole and encompass work area with safety cones.
- Field staff should be aware of any unauthorized entry into the work area by untrained personnel or the public.

II.3 Confined Space Entry[1]

Only WSB staff with Confined Space Entry training can complete a confined space entry. When entry to confined spaces is required for monitoring activities, the following checklist must be reviewed and adhered to:

<u>Permits/Notifications:</u>

- Execute a confined space entry permit form and follow appropriate protocols. See WSB's safety office, Pete Helder, for a copy of the form.
- Obtain a no fee lane use right-of-way permit if work is to be done in the street:
    - St. Paul ROW: 651-266-6151

[1] Review <u>Entering and Working in Confined Spaces</u>, Confined Space Entry Program for WSB & Associates, Inc. for WSB's confined space entry protocols prior to entering a confined space.

- ☐ Notify City staff
    - St. Paul Sewer Maintenance: 651-266-9836
- ☐ Notify local fire department of planned confined space entry

Required Safety Gear:

- ☐ Hard hat
- ☐ Sturdy boots
- ☐ Reflective safety vest
- ☐ 4-Gas Monitor
- ☐ Tripod
- ☐ 3-way lifeline winch
- ☐ Body harness
- ☐ Air ventilation blower and generator
- ☐ 28" reflective traffic cones and vehicle hazard lighting

Gear Maintenance:

- ☐ **Calibrate 4-gas monitor every 180 days:** The 4-gas monitor will indicate when calibration is needed. Viking Safety Products will calibrate the device free of charge. Call Viking for more information: 651-646-6374.
- ☐ **Inspect the tripod for wear and damage annually:** Viking Safety Products will inspect the equipment and provide a formal certificate of inspection free of charge. Call Viking for more information: 651-646-6374

General Confined Space Entry Procedures:

- ☐ Never complete a confined space entry during a rain event. Check the weather forecast and ensure clear conditions for the duration of the entry.
- ☐ Prior to leaving the office, confirm all equipment is functioning and that monitoring equipment is in compliance with the calibration schedule.
- ☐ Secure the area from untrained personnel and pedestrians.
- ☐ Ensure team members are knowledgeable of the roles and responsibilities of the confined space entrant, attendant, and supervisor.
- ☐ Complete air monitoring prior to, and for the duration of the confined space entry. Ensure team members are knowledgeable of the 4-gas monitor alarms and unsafe gas levels that prompt an evacuation of the confined space.
- ☐ Utilize a rope and bucket to deliver equipment to the entrant.
- ☐ Ensure there is a reliable method of communication between all team members completing the confined space entry.

III. Monitoring Sites

Below is a summary of sites which are included in this monitoring effort. Equipment and methods used and monitoring parameters analyzed for each site are provided for quick reference. (See Figures for site locations and monitoring configuration.)

III.1 Beacon Bluff:

This site consists of an infiltration basin situated over the top of an underground infiltration pipe gallery system. Stormwater flows into the infiltration basin from three storm sewer outfalls and into the underground chambers from a single storm sewer pipe. An outlet pipe connected directly to the underground chambers conveys overflow back to the storm sewer when the system reaches capacity.

Equipment:

3 – ISCO 2150 Area velocity sensors (Upstream, Downstream, WPO)
6 – System Level Loggers
- BMP Pipe
- OCS
- IR-31(Rain Garden - west)
- IR-32 (In-rock east)
- IR-33 (Rain Garden - east)
- BaroTroll (atmospheric logger)

4 – Groundwater Level Loggers
1 – ISCO 6712 Portable water quality sampler

Monitoring Parameters:

- Rainfall
- Flow rate/Volume
- Water level/Infiltration rate
- Water Quality

III.2 Hillcrest Knoll Park:

Flow is diverted from the main storm sewer into the Hillcrest Knoll Park infiltration BMP. When the system has reached its storage capacity, a float gate valve closes the inlet and water continues through the storm sewer downstream. The system includes a Vortechs pretreatment device to provide skimming and settling of runoff prior to entering the infiltration chamber.

Equipment:

2 – ISCO 2150 Area velocity sensors (Upstream, Downstream)
3 – Level Troll 500
- BMP Pipe
- IR-1
- HK-GW

Monitoring Parameters:

- Rainfall
- Flow rate/Volume
- Water level/Infiltration rate
- Water Quality

III.3 St. Albans:

The St. Albans Street infiltration system was constructed in 2010 to provide volume reduction along the Central Corridor. The system was constructed in an offline configuration. When the system reaches its storage capacity, water stops flowing into the system and continues through the storm sewer. The system includes a pretreatment structure which consists of box culvert sections and baffled weirs to provide skimming and settling of runoff prior to entering the infiltration chamber.

Equipment:

3 – ISCO 2150 Area velocity sensors (Upstream, Downstream, SA-University)
1 - Level Troll 500
BMP Pipe
1 – ISCO 6712 Portable water quality sampler

Monitoring Parameters:

- Rainfall
- Flow rate/Volume
- Water level/Infiltration rate
- Water Quality

III.4 Arundel Street:

The Arundel Street infiltration system was constructed in 2011 to provide volume reduction along the Central Corridor. The system was constructed in an offline configuration. When the system reaches its storage capacity, water stops flowing into the system and continues through the storm sewer. The system includes a pretreatment structure which consists of box culvert sections and baffled weirs to provide skimming and settling of runoff prior to entering the infiltration chamber.

Equipment:

1 - Level Troll 500
BMP Pipe

Monitoring Parameters:

- Rainfall
- Water level/Infiltration rate

III.5 Hampden Park

The Hampden Park infiltration gallery was constructed in 2014. The system consists of eight parallel perforated pipes that are five feet in diameter and range in length from 40 to 100 feet. Runoff is routed to the pretreatment system via a 24" RCP from main storm sewer near Hampden and Raymond Avenues. From that location, stormwater enters a pretreatment structure which consists of a box culvert section and baffled weir to provide skimming and settling of runoff prior to entering the infiltration chamber. The infiltration gallery receives flow from a second inlet location along Raymond Avenue, farther to the north. When the system reaches full capacity, stormwater is routed back to the storm sewer via a 24" pipe from the southeast side of the system.

Equipment:

2 – ISCO 2150 Area velocity sensors (Upstream, Downstream- **No modem, direct connect download**)

4 – Level Troll 500
- IR-1 (system)
- P-1
- P-2
- P-3

Monitoring Parameters:
- Rainfall
- Water level/Infiltration rate
- Flow Rate

III.6 Trout Brook Nature Sanctuary

The Trout Brook Nature Sanctuary (TBNS) is a 42 acre site located between Norpac Road and Maryland Avenue, west of I-35E. The objective of the construction effort, which was finalized in 2015, was to create a nature preserve in the heart of a heavily urbanized area. The focal points of the plan included expanding the Trout Brook Regional Trail and daylighting the Trout Brook creek, which had previously been filled in and routed through underground sewer. The development of the sanctuary also included a series of stormwater management features including wetlands and ponds constructed with iron enhanced sand for additional water treatment.

Stormwater is conveyed to the iron-enhanced ponds from individual diversion structures along the 42” main stormsewer line. Prior to the pond, the flow is routed through a Vortech’s pre-treatment structure for particle settling. As the level in the pond rises, the water gravity flows through a sand filtration bench that has additional iron content. The iron-enhanced sand provides a mechanism to remove soluble reactive phosphorus, a dissolved bio-available form of phosphorus, which is not effectively removed by settling pre-treatment devices. Beneath the sand bench is 8” drain tile to convey the treated water to the outlet control structure of the pond.

The City completed performance monitoring at three iron enhanced ponds at the Site: Maryland Pond, Magnolia Pond, and Jenks Pond. Removal efficiency of the iron enhanced material was determined by collecting samples simultaneously from the within the pond and the pond outlet control structure. A flow sensor was installed in the outlet control structure to provide treatment volume for load reductions.

<u>Equipment (Complete set at each of the three ponds) :</u>

1 – ISCO 2150 Area velocity sensors (outlet control structure)
2 – ISCO 6712 portable water quality sampler (pond, outlet control structure)
1 – Level Troll 500
Pond

<u>Monitoring Parameters:</u>

- Rainfall
- Water level
- Flow Rate
- Water Quality

IV. Preparation and Logistics

Preparedness is crucial to successful implementation of this monitoring program. Anticipation of target storm events, readiness with field equipment, and understanding of confined space entry procedures play a role in this process. This section provides essential information related to these items.

IV.1 Storm Selection Criteria for Water Quality Sampling

The activities below should be completed at least weekly to determine the potential need to prepare sampling equipment and mobilize crews to undertake water quality samplings:

- Track storms using local ALERT systems and by accessing National Weather Service forecasts: www.nws.noaa.gov
- Determine Quantity of Precipitation Forecast (QPF) for an impending storm.
- If QPF is greater than 0.1-inches initiate sample collection preparation procedures (see **Section 6**).

IV.2 Portable Sampler (ISCO 6712) Preparation

This is to be done after all sampling events and or when receive a low battery alarm.

- Change out samples bottles in automated sampler with clean bottles.
- Reset automated sampler for a new event. Update the sample flow volume interval if more or less samples need to be collected based on lab requirements, storm event size, or modification to protocols.
- Ensure that batteries are adequately charged and positioned.
- Make sure clean grab sample bottles are on hand.

V. Visual Inspection and Manual Data Collection

Routine BMP inspections conducted on a visual basis will provide information related to specific maintenance needs and provide information that may be pertinent to any anomalies in the water quality sampling results. Additionally, the pervious pavement infiltration studies will consist of manual data collection in accordance with ASTM method C1701. The following section provides field guidance for those tasks.

V.1 Infiltration Trenches

<u>Frequency:</u>

- Once per month

<u>Visual Inspection:</u>

- Identify significant obstructions present in the source pipes
- Indicate whether there is standing water in the infiltration system
- Indicate whether there is evidence of illicit discharges
- Identify any structural issues in the system
- Describe other observations
- Sketch inspection observations as appropriate

<u>Manual Data Collection:</u>

- Take digital photos of all visual inspection parameters
- Quantify the amount of sediment present in the system's:
  - Sump manhole
  - Pretreatment device
  - Stormwater storage area
- Quantify the amount of floatables present in the system's:
  - Sump manhole
  - Pretreatment device
  - Stormwater storage area

<u>Required Equipment:</u>

- Measuring rod
- Digital camera

<u>Required Forms:</u>

- Infiltration BMP Inspection and Maintenance Form

V.2 Pervious Pavement Infiltration Tests

<u>Frequency:</u>

- Once per year

<u>Visual Inspection:</u>

- Identify number and location of missing pavers (if present)
- Identify significant cracking, chips, or other damage
- Identify location and approximate depth of deflection

<u>Manual Data Collection:</u>

- Take digital photos of all visual inspection parameters
- Record depth of aggregate at six (6) locations (if pavers)
- Measure infiltration rate in six (6) locations
    - Follow the modified ASTM method C1701
    - Locations should be marked by a drill hole or a nail so that the same locations can be tested each time
    - 3 locations should be within 1 foot of the concrete strip separating the permeable surface from the roadway.

Equipment:

- Infiltration measurement apparatus
- Water tank and feeder hose
- Digital camera
- Scale
- 12” PVC Pipe
- Plumbers putty

Required Forms:

- Permeable paver inspection form

Monitoring Parameters:

- Infiltration rate
- BMP visual inspection

Sample Collection, Preservation, and Laboratory Analysis

The following procedures must be followed to maintain a consistent approach for obtaining composite water quality samples and to reduce the risk of cross contamination when retrieving and transporting samples to the laboratories:

V.3 Composite Sampling Using Automated Sampler:

Estimating pollutant loads as part of this monitoring program will include determination of the event mean concentration (EMC) for the target storm events using composite samples. To obtain composite samples that are representative of the storm events analyzed, the following minimum number of aliquots and percent capture values should be met:

Total Event Precipitation (in.)	Minimum Acceptable Number of Aliquots	Percent Capture Requirement[3]
0 – 0.25	6	85
0.25 – 0.50	8	80
0.50 – 1.0	10	80
> 1.0	12	75

To meet these requirements the automatic samplers should be programmed to collect samples at flow-paced intervals. Determination of the flow volume between sampling events should be based on the following information:

Total Event Precipitation (in.)	Saint Albans	Beacon Bluff
	Runoff Volume (cu-ft)	Runoff Volume (cu-ft)
0.10-0.15”	450	4,500
0.25”	1,703	20,986
0.5”	5,112	63,000
1.0”	14,333	156,756
2.0”	48,834	373,550
3.0”	95,715	657,879

Program Automated Sampling Parameters:

Based on the information above and other considerations, the following provides the parameters that should be used for programming the automated samplers:

- **Start Time:** Begin sampling at specific water level depths
    - St. Albans 1.5-inches
    - Beacon Bluff: 1.5-inches

[3] $Percent\ storm\ capture = \frac{flow\ volume\ that\ passed\ during\ sample\ collection}{total\ flow\ that\ passed\ during\ the\ entire\ monitoring\ event}$

- **Pacing:** Set sampler to collect samples at constant flow volume intervals
  - Beacon Bluff: minimum 3,000 cu-ft (0.034 Mgal)
  - Saint Albans: 1,300 cu-ft (0.010 Mgal)
- **Distribution:** Multiple samples per bottle - sample aliquot volume should be no less than 200 mL.
- Minimum of 1 liter is required for suspended sediment concentration (SSC).

Multiple bottles will be collected for each event. The testing laboratory should be directed to develop a composite sample with the collection of bottles by either batch mixing or by combining equal fractions of each bottle into a single bottle or container.

V.4 Grab Sample Collection

Grab samples will be collected for E coli analysis from the Beacon Bluff and St. Albans. Samples will be collected from the influent stormwater stream prior to entering the systems. At the Dale Street location, both the influent and the effluent streams will be sampled for E coli, and additional parameters described in **Section III.8**. The purpose of E. coli analysis is to ensure that human effluent is not contaminating the water. The following provides the process for obtaining the grab samples:

<u>Sampling Locations:</u>

- Man holes up stream of the automatic samplers at St. Albans. and Beacon Bluff

<u>Procedures:</u>

- Collect 3 samples (one every 10 minutes for composite testing) while it is raining.
- Use sterile sample bottles with an unbroken seal when testing for e-coli.
- Place sample bottle directly below or in outfall water stream to collect the sample.

<u>Required Equipment:</u>

- Personal rain gear
- Powder-free nitrile gloves
- 1-Liter plastic sample bottles and lids
- Sterile bacteria sample bottles and lids from laboratory
- Bottle labels and water proof pen
- Chain of custody forms for laboratory
- Manhole pick
- Cooler with ice
- Grab sample collection rod

V.5 Analytical Parameters:

The following table provides a list of parameters and the sampling frequency as established by Permit No. MN0061263. Samples collected from the automated samplers will be analyzed for all water quality parameters in Table 1 of the City of St. Paul's MS4 permit for every sampling event (when volumes allow) except for E. Coli., BOD5, pH, and Sulfate (These parameters do not apply to the TBNS or the Dale Street Facility)

Monitoring Parameters		
Parameters	**Sample Type**	**Frequency**
BOD, Carbonaceous 5-Day (20 Deg C)	Composite or Grab	Quarterly
Chloride, Total	Composite or Grab	As noted for loading calculations (Par V.C7.f)
Copper, Total (asCu)	Composite or Grab	Monthly
E. coli	Grab	Quarterly
Flow	Measurement	
Hardness, Carbonate (as CaCo3)	Composite or Grab	Monthly
Lead, Total (as Pb)	Composite or Grab	Monthly
Nitrite Plus Nitrate, Total (asN)	Composite	As noted for loading calculations (Par V.C7.f)
Nitrogen, Ammonia, Un-ionized (as N)	Composite	Quarterly
Nitrogen, Kjeldahl, Total	Composite	As noted for loading calculations (Par V.C7.f)
pH	Composite or Grab	Quarterly
Phosphorus, total Dissolved or Ortho	Composite	Quarterly
Phosphorus, Total as P	Composite	As noted for loading calculations (Par V.C7.f)
Precipitation	Measurement	1 x Day
Solids, Total Dissolved (TDS)	Composite	Quarterly
Solids, Total Suspended (TSS)	Composite	As noted for loading calculations (Par V.C7.f)
Sulfate	Composite or Grab	2 x Year
Volatile Suspended Solids (VSS)	Composite	As noted for loading calculations (Par V.C7.f)
Zinc, Total (as Zn)	Composite or Grab	Monthly

V.6 Sample Preservation

- Collect samples from automated sampler within 24 hours
- Place lids on all sample bottles to be submitted to the laboratory
- Fill out sample labels using a consistent naming convention:
  - Site (abbreviation)-Method (abbreviation, i.e. AS=automated sampler, GS=grab sample)-Date (mmddyy)-Sample # of Total # of samples
  - Example: BB-AS-040112 (2 of 4)
  - Date/Time for the sample label should be recorded as the date and time of sample fill as indicated on the automated sampler, not the date of sample pick up.
- Place all samples to be analyzed in a cooler with ice
  - Target holding temperature for samples is 4˚C
- Deliver samples to lab or request pick up services

V.7 Cleaning of Sample Equipment and Bottles

- **Clean sample bottles after every use:** wash them with a brush and soapy water or use a dishwasher.
- **Clean the suction line, strainer, and pump tubes twice per year:** Place the end of the suction line in a cleaning solution and pump it through the system. Rinse with clean water.

V.8 Quality Assurance/Quality Control:

- Before samples are collected, make sure that all sampling equipment and bottles are cleaned using the appropriate cleaning procedures.
- Wear powder-free nitrile gloves when handling bottles, lids, tubing, or strainers.
- Never touch the inside surface or exposed end of a sample bottle or lid, even with a gloved hand.
- Never let any material other than sample water touch the inside surface or exposed end of sample bottle.
- Avoid allowing rain water to drip from rain gear or other surfaces into sample bottles.

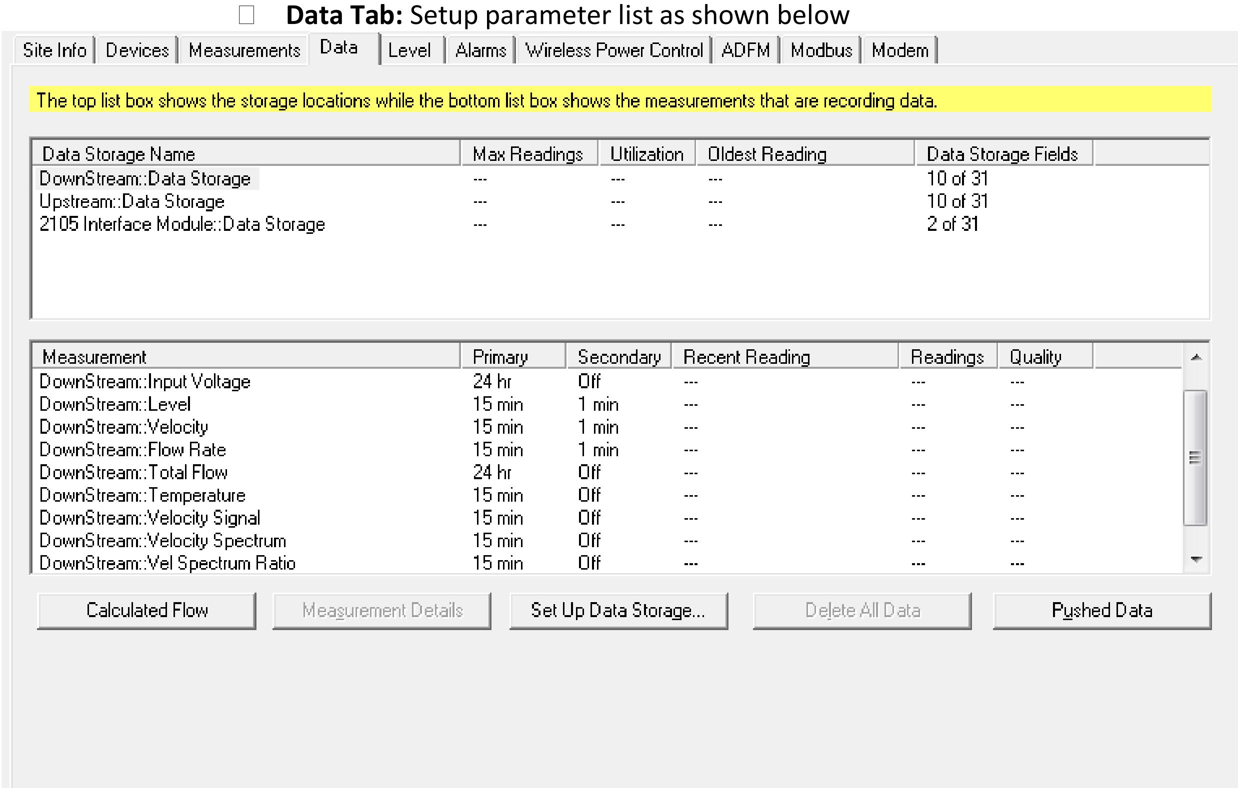
VI. Operation and Maintenance of Monitoring Equipment

The following provides a summary of procedures to follow for operating and maintaining monitoring equipment for collection of flow, rainfall, water level, and sampling data. These procedures should be followed when the devices are initially setup and during routine data dumps and maintenance activities.

VI.1 Flow Meters (ISCO 2150)[4] and Interface Modules (ISCO 2105/2103)[5]:

Setup/Initialization:

- **Software Required:** Flowlink
- **Quick Connect:** Connect the device to a laptop using the communication cable. Start Flowlink and select Quick Connect Icon in the tool bar. Use “Direct” Type Connection and check “Create New Site” for new instillation. Click on the large *2100 Instruments* button to connect.
- **Site Info Tab:** Add applicable information and “Synchronize Site’s Time to Computer’s”.
- **Devices Tab:** Change Module Names for Area Velocity Meters to reflect location.
- **Data Tab:** Setup parameter list as shown below



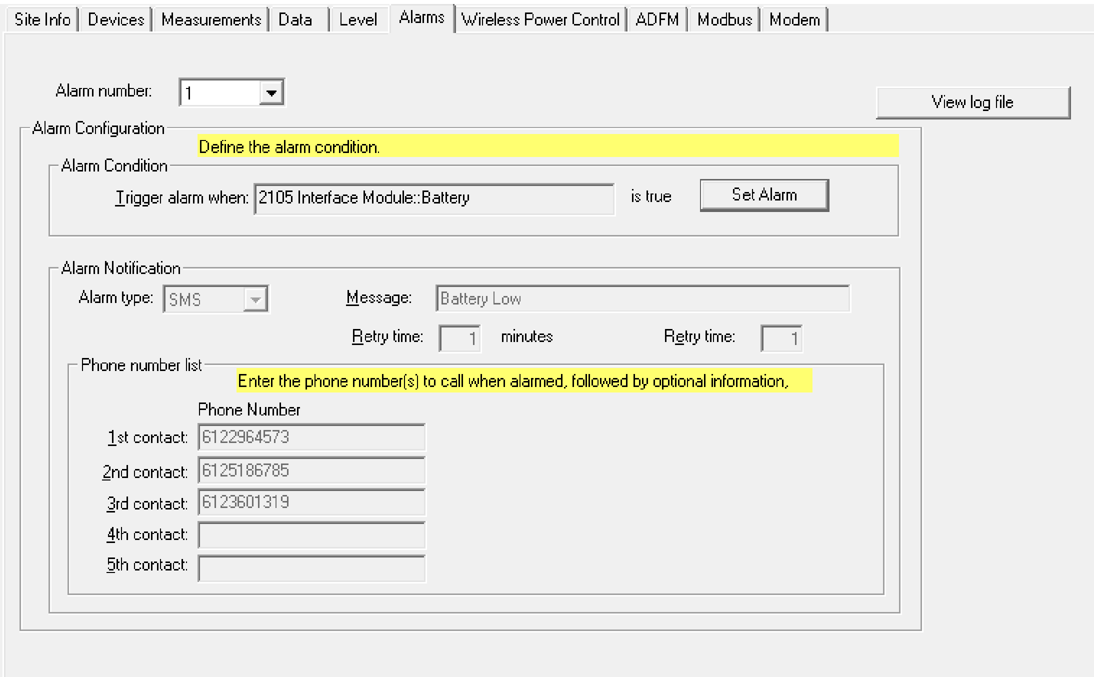
- **Measurement Details:** Set units for all measurements (in, cfs, or cf)

[4] See 2150 Area Velocity Flow Module and Sensor – Installation and Operation Guide, Teledyne ISCO, Rev. March 9, 2011.

[5] See 2105 Interface Module – Installation and Operation Guide, Teledyne ISCO, Rev. July 8, 2010.

- **Level:** If flow is present, measure the water depth from the water surface to the channel bottom. Enter the value on the *Level* measurement tab in FLowlink. If no flow is present, enter a value of zero. (Level measurements may drift over time, so it is important to do this routinely.)
- **Velocity Measure Tab:**
  - **No Velocity Data:** Uncheck the *"Set flow rate to zero if no velocity data"* checkbox on the *Velocity* measurement tab in Flowlink. Data can be post processed to remove low level velocity noise.
  - **Synchronize Velocity Measurements:** Check the Prevent *interference box* on the *Velocity* measurement tab in Flowlink to prevent velocity signal interference at sites with multiple modules.
- **Flow Rate Tab:** Input pipe shape and diameter.

- **Data Storage Rates:** Click on *Set Up Data Storage…* button on a measurement tab in Flowlink to set storage rate.
  - <u>Level</u>, <u>Velocity</u>, <u>Flow Rate</u>, <u>Total flow</u>,: Primary = *15 min*, Secondary = *1 min* (Flow Depth > 1in)
  - <u>Temperature</u>, <u>Velocity Signal</u>, <u>Velocity Spectrum</u>, <u>Velocity Spectrum Ratio</u>: Primary = 15 min
  - <u>Input Voltage</u>, <u>Wireless Signal</u>: Primary = *24 hours*
    Note: In "Condition Builder" set Hysteresis to 0.5" and Duration to 5 min for all Sampler Level Triggers.
- **Pushed Data Capability:** Click the Pushed Data button to set up a schedule for the data to be pushed.
  - **Set IP address:** 207.173.231.99, Port 1700
  - Use Primary Data Transmission interval of *4 hours*
- **Alarms Tab:**
  - **Alarm Condition:** Define alarm condition using Equation Builder.
    - Low Battery: When Modem Input voltage drops below 10V.



- **Sampler Interface:**
  - **Set Up Data Storage:** Select "Enable Logging"
  - **Sampler enable:** Enable on Trigger - using equation builder to specify level threshold to enable sampler.

    Note: In "Condition Builder" set Hysteresis to 0.5" and Duration to 5 min for all Sampler Level Triggers
  - **Sampler Pacing:** input desired flow pulsing interval in cubic feet.

<u>Routine Data Retrieval and Re-initialization:</u>

- **Frequency:** Once per month
- **Quick Connect:** Connect the device to a laptop using the communication cable. Start Flowlink and click on the large *2100 Instruments* button to connect.
- Download data and transfer to WSB server folder K:\01610-100\WR\Flow Data
- Set water level to zero. (Make sure to annotate date and time of level reset)

<u>Routine Maintenance:</u>

The following maintenance activities must be completed routinely and during every field visit:

- **Check desiccant cartridges:** When entire length of the cartridge turns pink or green, the desiccant needs to be replaced.
- **Check battery voltage:** Replace both batteries when voltage is below 10.
- **Check hydrophobic filter:** Rinse and dry if the filter is plugged.
- **Check connector O-rings:** Replace or lubricate as needed.
- **Check flow sensor:** Remove debris and clean sensor as needed.
- **Check sensor cable for damage:** Replace if needed. Loose cable should be fastened to the structure.

VI.2 Portable Sampler (ISCO 6712)[6]:

Setup/Initialization:

- **Software Required:** Flowlink
- **Measure length of suction hose:** Length will be a required input during Program setup. Cut hose to whole ft. Increments if required. Hose should generally slope downward toward the sampling probe.
- **Use Standard Program:** Follow Steps in Table 4-2 of the operation guide for flow pacing. Make the corresponding deviations listed below. Standard Programing Flow Charts can also be found in Appendix A in the operation guide (Figures A-2 & A-3).
    - (3)Set appropriate Site Description (i.e. St. Albans, Beacon Bluff)
    - (8) Select 1 pulse between sample events
    - (9) Samples/Bottle
    - (11) 5 Samples/Bottle (200 mL each)
    - (12) No Delay to Start
- **Automatically index to next bottle when sampler is enabled:** This will allow each storm event to be composited separately, but may decrease the overall available sampling volume during multiple events.
    - From home screen, enter 6712.9 and hit enter
    - Enter Code: 1199 and hit enter (Sampler should report Code Accepted)
- **Calibration:** The Sampler delivers accurate sample volumes without calibration. If you find that sample volumes vary significantly from the programmed values, first check the suction line for proper installation. Be sure it slopes continuously downhill to the liquid source and drains completely after each sampling cycle. Refer to Section 4.12 of the operation guide for additional calibration notes.
    - Note: If sampler does not disable when the program is set to run, check all cable connections and then make sure the 2105 is configured correctly. If the water level is below the trigger threshold, the 2105 should be indicating that the Sampler is disabled. If the sampler is still not disabling, the cable or the sampler may be malfunctioning. The cable can be diagnosed by removing the sampler cable and using a paper clip to short pins “B” and “F” on the back of the sampler control head.

Routine Data Retrieval and Re-initialization:

- **Frequency:** Once per month
- **Interrupt Program:** Press the Stop button once to pause the program. Scroll down to “VIEW DATA” and check for errors with sampling. See page 4-19 in the operators guide for more information. When complete, select “RESUME PROGRAM”.

[6] See 6712 Portable Samplers – Installation and Operation Guide, Teledyne ISCO, Rev. April 11, 2011.

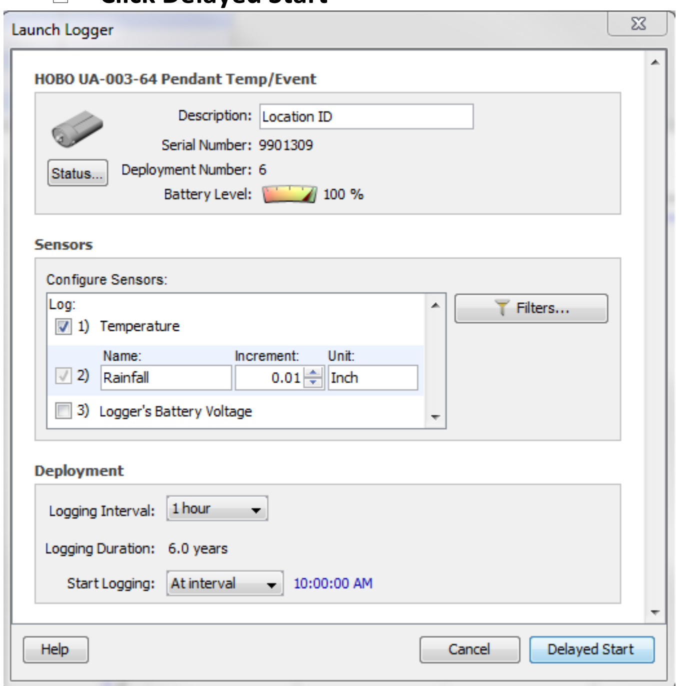
Routine Maintenance:

- ☐ **Check the pump tube for wear:** Replace if necessary.
- ☐ **Check the pump tubing housing:** Clean if necessary.
- ☐ **Check the suction line:** Change if necessary.
- ☐ **Check the humidity indicator:** Desiccant should be replaced when all indicator areas turn light pink or white.
- ☐ **Check the controller's internal battery status:** Replace the battery every five years.
- ☐ **Check the keypad label:** If it has bubbles under it, the air inside the controller has expanded, and pressure can be released by unscrewing the flow meter cable or connector cap on the back of the controller.

VI.3 Data Logging Rain Gauge:

Setup/Initialization:

- **Software Required:** Onset HOBOware.
- **Connect Rain Gauge:** Open HOBOware and select Launch Device.
- **Configure Sensors:**
  - Log 1) Temperature
  - Log 2) Rainfall
    - Name: Rainfall
    - Increment: 0 .01
    - Unit: Inch
- **Deployment**
  - Logging Interval: 1 hour
  - Start Logging: At Interval
- **Click Delayed Start**



Routine Data Retrieval and Re-initialization:

- **Frequency:** Once per month
- **Connect to device using HOBOware:**
- Download data using readout device and transfer to WSB server folder K:\01610-100\WR\Exported Data. (Do not stop logging before reading out the logger until the end of the season)

Routine Maintenance:

- **Check the filter screen, funnel, and tipping mechanism for debris** (dirt, bugs, bird droppings, etc.): Clean with mild soap and water.
- **Check the needle bearings and apply light oil annually.**

VI.4 Water Level Logger (Level Troll 500)[7]:

Setup/Initialization:

- **Software Required:** Win-Situ 5
- **Piezometer Specifications:** 3” PVC Pipe should be used as a Piezometer for underground stormwater structures. Drill ½” holes on four sides of the pipe so that there are approximately 20 holes per foot of length in the pipe. Holes do not need to be drilled above top of BMP structure. Wrap section expected to be submerged in highly permeable geotextile fabric, and secure with zip ties. Secure the pipe to the floor, the manhole, and the overhead casting wall.
- Hang the Logger from the eye bolt installed inside of PVC pipe piezometer. This will allow a more accurate set up of the reference elevation.
- **Stabilization Time:** Allow the Level TROLL to stabilize to the water conditions for *about an hour* before logging data. A generous stabilization time is always desirable, especially in long-term deployments. Even though the cable is shielded, temperature stabilization, stretching, and unkinking can cause apparent changes in the probe reading. If you expect to monitor water levels to the accuracy of the probe, it’s worth allowing the extra time for the probe to stabilize to its environment.
- **Connection:** With the Troll Com plugged into a USB port, launch Win-Situ Software.
- **Win-Situ Launches:** the screen shows the “My Data Tab”.
    - On first connection, be sure to select the correct COM port for a USB connection.
    - Then connect to the device.
- When Connected, the focus shifts to the Home tab. Readings are shown in “meter” view. Values in gray are not being updated in real time.
- **Set up a site**: Click the Site Button, select the Default Site or Click the New button to set up a custom site. The site name can have up to 32 characters. Location coordinates are optional.
- **Set up a data log:** follow the steps in the logging setup wizard.
    - **Log Name:** Site_2015_ Monitoring Season
    - **Log Parameters:** Pressure (PSI), Temperature (F), Elevation (ft.)
    - **Choose Logging Method:** Long-Term Monitoring – Event
    - **Choose Event Parameter:**
        - Check event parameter every 1 min
        - Log all parameters when the event is greater than 0.25 ft. above BMP invert, or normal water level elevation.
        - Default record data every 60 measurements.
    - **Schedule Start time:** on Next Hour
    - **Output:** Ground Water Elevation
    - **Set Level Reference to Depth of Water:** Select new reference.
        - Calculate the reference elevation as either the casting invert (known elevation) minus the distance to the water surface, or to the bottom of the sensor probe if the Piezometer is dry.

[7] See Level TROLL – Operator’s Manual, In-Situ Inc., March 2010.

        - Be sure to note the casting invert reference elevation used, and the calculated elevation of the bottom of the sensor probe in the Notes option in the Site Data Folder for future reference.
    - **Specific Gravity Value**: Custom 0.999
- **Finished Programing:** Disconnect the Troll Com and reattach the desiccant.

Routine Data Retrieval and Re-initialization:

- **Frequency:** Once per month
- **Connect to device using Win-Situ 5:**
- Download data and transfer to WSB server folder K:\01610-100\WR\Exported Data. (Do not stop logging until the end of the season)
- Re-reference water level elevation.
    - Select “Sensor Tab” then click on calibrate sensor.
    - **Adjust Level Reference:** input the New Reference if required.

Routine Maintenance:

- **Check desiccant cartridge:** When entire length of the cartridge changes color, the desiccant needs to be replaced.
- **Check minimum cable bend radius:** Half the cable diameter = Approx. 0.54”.
- **Check the holes in the nose cone:** If they are plugged, swish the Level TROLL in a bucket of water, rinse under a tap, or soak in a mild acidic solution such as vinegar overnight.
    - DON’T dig or scrape in the pressure sensor openings!
    - DON’T touch the pressure sensor diaphragm when the nose cone is removed!
- **Check twist-lock connectors**: Keep pins on all connectors free of dirt and moisture.
- **Field Recalibration:** Sensor should be factory recalibrated every 12-18 months. The following procedure may be used, **with caution,** to “zero” the offset of a vented pressure sensor to correct for electronic drift. The drifted offset is visible when the sensor is in air and reading other than zero. It is recommended you **do not** zero the offset if it is outside the specified accuracy of your pressure sensor (30 PSI Sensor: ±0.03 PSI). If the reading in air deviates from zero by more than this amount, you may want to consider a factory recalibration.

Designation: C1701/C1701M – 09

Standard Test Method for Infiltration Rate of In Place Pervious Concrete[1]

This standard is issued under the fixed designation C1701/C1701M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the field water infiltration rate of in place pervious concrete.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes that provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C920 Specification for Elastomeric Joint Sealants

2.2 *Other Standards*

Federal Specification A-A-3110 (TT-P-1536A) Plumbing Fixture Setting Compound[3]

3. Terminology

3.1 *Definitions:*

3.1.1 The terms used in this test method are defined in Terminology C125.

4. Summary of Test Method

4.1 An infiltration ring is temporarily sealed to the surface of a pervious pavement. After prewetting the test location, a given mass of water is introduced into the ring and the time for the water to infiltrate the pavement is recorded. The infiltration rate is calculated in accordance with 9.1.

5. Significance and Use

5.1 Tests performed at the same location across a span of years may be used to detect a reduction of infiltration rate of the pervious concrete, thereby identifying the need for remediation.

5.2 The infiltration rate obtained by this method is valid only for the localized area of the pavement where the test is conducted. To determine the infiltration rate of the entire pervious pavement multiple locations must be tested and the results averaged.

5.3 The field infiltration rate is typically established by the design engineer of record and is a function of the design precipitation event.

5.4 This test method does not measure the influence on in-place infiltration rate due to sealing of voids near the bottom of the pervious concrete slab. Visual inspection of concrete cores is the best approach for determining sealing of voids near the bottom of the pervious concrete slab.

6. Apparatus

6.1 *Infiltration Ring*—A cylindrical ring, open at both ends (See Fig. 1). The ring shall be watertight, sufficiently rigid to retain its form when filled with water, and shall have a diameter of 300 ± 10 mm [12.0 ± 0.5 in.] with a minimum height of 50 mm [2.0 in.]. The bottom edge of the ring shall be even. The inner surface of the ring shall be marked or scored with two lines at a distance of 10 and 15 mm [0.40 and 0.60 in.] from the bottom of the ring. Measure and record the inner diameter of the ring to the nearest 1 mm [0.05 in.].

NOTE 1—Ring materials that have been found to be suitable include steel, aluminum, rigid plastic, and PVC.

6.2 *Balance*—A balance or scale accurate to 10 g [0.02 lb].

6.3 *Container*—A cylindrical container typically made of plastic having a volume of at least 20 L [5 gal], and from which water may be easily poured at a controlled rate into the infiltration ring.

6.4 *Stop Watch*—Accurate to 0.1 s.

6.5 *Plumbers Putty (Non-Hardening)*—Meeting Specification C920 or Federal Specification A-A-3110.

6.6 *Water*—Potable water.

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[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.49 on Pervious Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] http://www.everyspec.com

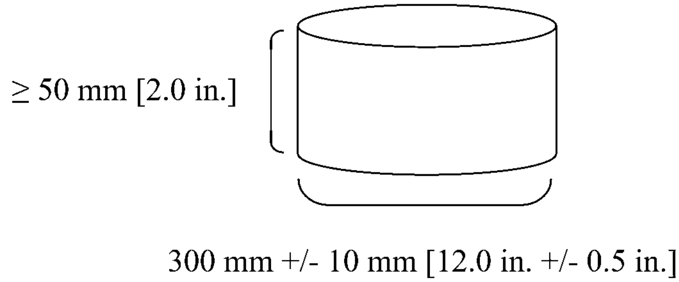

FIG. 1 Dimensions of Infiltration Ring

7. Test Locations

7.1 Perform tests at multiple locations at a site as requested by the purchaser of testing services. Unless otherwise specified, use the following to determine the number of tests to perform:

7.1.1 Three test locations for areas up to 2,500 m^2 [25,000 ft^2].

7.1.2 Add one test location for each additional 1,000 m^2 [10,000 ft^2] or fraction thereof.

7.2 Provide at least 1 m [3 ft] clear distance between test locations, unless at least 24 h have elapsed between tests.

7.3 Do not test if there is standing water on top of the pervious concrete. Do not test within 24 h of the last precipitation.

8. Procedure

8.1 *Infiltration Ring Installation*—Clean the pavement surface by only brooming off trash, debris, and other non-seated material. Apply plumbers putty around the bottom edge of the ring and place the ring onto the pervious concrete surface being tested. Press the putty into the surface and around the bottom edge of the ring to create a watertight seal. Place additional putty as needed

NOTE 2—In a hot environment where the surface temperature is over 38 °C [100 °F] plumbers putty may not adhere to the concrete surface easily. Therefore it is advisable to perform this test during cooler temperature.

8.2 *Prewetting*—Pour water into the ring at a rate sufficient to maintain a head between the two marked lines. Use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Begin timing as soon as the water impacts the pervious concrete surface. Stop timing when free water is no longer present on the pervious surface. Record the amount of elapsed time to the nearest 0.1 s.

8.3 *Test*—The test shall be started within 2 min after the completion of the prewetting. If the elapsed time in the prewetting stage is less than 30 s, then use a total of 18.00 ± 0.05 kg [40.00 ± 0.1 lb] of water. If the elapsed time in the prewetting stage is greater than or equal to 30 s, then use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Record the weight of water to the nearest 10 g [0.02 lb] (M). Pour the water into the ring at a rate sufficient to maintain a head between the two marked lines and until the measured amount of water has been used. Begin timing as soon as the water impacts the pervious concrete surface. Stop timing when free water is no longer present on the pervious surface. Record the testing duration (t) to the nearest 0.1 s.

NOTE 3—If a sloped pavement is being measured, maintain head between the two marked lines at the lowest point of the slope.

8.4 If a test is repeated at the same location, the repeat test does not require pre-wetting if conducted within 5 min after completion of the first test. If more than one test is conducted at a location on a given day, the infiltration rate at that location on that day shall be calculated as the average of the two tests. Do not repeat this test more than twice at the same location on a given day.

9. Calculation

9.1 Calculate the infiltration rate (I) using consistent units as follows:

$$I = \frac{KM}{(D^2 * t)}$$

where:

I = Infiltration rate, mm/h [in./h],
M = Mass of infiltrated water, kg [lb],
D = Inside diameter of infiltration ring, mm [in.],
t = time required for measured amount of water to infiltrate the concrete, s, and
K = 4 583 666 000 in SI units or 126 870 in [inch-pound] units.

NOTE 4—The factor K has units of $(mm^3 s)/(kgh)$ [$(in.^3 s)/(lbh)$] and is needed to convert the recorded data (W, D, and t) to the infiltration rate I in mm/h [in./h].

10. Report

10.1 Report the following information:

10.1.1 Identification number,

10.1.2 Location,

10.1.3 Date of test,

10.1.4 Age and thickness of concrete (label Unknown if not known),

10.1.5 Time elapsed during prewetting, s,

10.1.6 Amount of rain during last event, if known, mm [in.],

10.1.7 Weight of infiltrated water, kg [lb],

10.1.8 Inside diameter of infiltration ring, mm [in.],

10.1.9 Time elapsed during infiltration test, s,

10.1.10 Infiltration rate, mm/h [in./h], and

10.1.11 Number of tests performed at each location, if applicable.

11. Precision and Bias

11.1 Repeatability testing was performed by a single laboratory by making 2 replicate measurements at three locations on a newly placed pervious concrete pavement. The replicate measurements were repeated daily from day 1 to day 10. The single-operator coefficient of variation of the infiltration rate at one test location was found to be 4.7 %.

11.2 The multi-operator variability data has not been developed. The reproducibility of this test method is being determined and will be available on or before October 1, 2014.

11.3 This test method has no bias because the infiltration rate of in-place pervious concrete is defined only in terms of this test method.

12. Keywords

12.1 concrete; infiltration; pervious; water