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2014

Water Quality & Quantity MONITORING PROGRAM

Monitoring Report

WSB Project No. 1610-10

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2014 STORMWATER QUANTITY AND QUALITY MONITORING PROGRAM

FOR THE CITY OF SAINT PAUL, MINNESOTA

April 2015

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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.

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Executive Summary

Since 2006, the City of Saint Paul (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. The City has typically achieved this by constructing underground infiltration BMPs.

This report presents the results of the 2014 water quality and quantity data that was collected from April to December 2014. Historical data from 2011-2013 was also included and compared to the 2014 results. A trend analysis was completed to help determine changes in subwatershed water quality and quantity and BMP system performance. Based on the 2014 results and trend analysis, WSB has provided the following recommendations to optimize the City's BMP performance and monitoring program in 2015.

- **Beacon Bluff BMP Maintenance –** Since 2012, Beacon Bluff infiltration rates in the rain garden and BMP pipe have decreased every year (the BMP pipe infiltration rate increased slightly from 2013 to 2014) (**Section 3**). In 2014, infiltration rates for the rain garden and BMP pipe were 0.57 inches per hour (in/hr) and 0.64 in/hr respectively. These infiltration rates are less than the MSWM recommended infiltration rate for SP soils of 0.8 in/hr and the design infiltration rate of 2.5 in/hr. Sediment accumulation observed within the BMP is suspected to be the cause of the decline in infiltrations rates in the system. It is recommended that the City complete jet/vac maintenance on the Beacon Bluff BMP pipe in 2015.
- **Arundel BMP Maintenance –** Since 2012, infiltrations rates in the Arundel BMP have decreased from 8.0 in/hr to 1.64 in/hr (**Section 7**). These infiltration rates are above the MSWM recommended infiltration rate for SP soils of 0.8 in/hr, but below the design infiltration rate of 17.6 in/hr. In November 2014, 0.79 feet of sediment and debris was observed within the BMP and is suspected to be the cause of the decline in infiltration rates in the system. It is recommended that the City complete jet/vac maintenance on the Arundel BMP pipe in 2015.
- **Victoria Street Permeable Pavers Maintenance –** Since 2012, the average infiltration rate of the Victoria Street permeable pavers has decreased from 180.04 in/hr to 14.42 in/hr (**Section 12.1**). In one of five locations, the infiltration rate was observed to be zero. Sediment accumulation within the pavers has been observed at the site. It is recommended that the City complete maintenance of the pavers utilizing a vacuum air sweeper, and restore the aggregate fill between the pavers subsequent to vacuuming.
- **Hamline-Midway Library Pervious Pavement Maintenance –** Since 2013, the average infiltration rate at the Hamline-Midway Library decreased from 206.8 in/hr to 31.1 in/hr (**Section 12.2**). In 2014, seven of nine locations at Hamline-Midway Library were observed to have zero infiltration. Large amounts of sediment and debris was observed on the pavement. It is recommended that the City complete maintenance on the surface utilizing a vacuum air sweeper.

1 Introduction and Purpose

Ten BMPs were monitored in 2014 to quantify progress toward meeting the City's stormwater management goals and to refine current design and maintenance practices. Rainfall was also measured at seven locations. The 2014 monitoring sites are shown on **Figure 1-1** and the applicable monitoring parameters are listed in **Table 1-1**. This effort focused on evaluating five major parameters during the monitoring period which are included below:

- Infiltration rate
- Volume reduction
- Pollutant removal
- BMP maintenance
- Groundwater elevation

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. A discussion of those findings is included in this report.

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

Table 1-1: 2014 Stormwater Monitoring Locations

Site	Water Quality[1]	Flow	BMP Level	Groundwater
Beacon Bluff	Yes	Yes	Yes	Yes
Hillcrest Knoll Park	Yes	Yes	Yes	Yes
St. Alban's Street	No	Yes	Yes	No
AHUG	Yes[3]	Yes	Yes[3]	No
Arundel Street	No	No	Yes	No
Dale Street Facility [2]	Yes	Estimated	No	No
College Park	No	No	No	Yes
St. Catherine’s University	No	No	No	Yes
Hampden Park	No	Yes	Yes	Yes
Flandrau-Hoyt Pond	No	No	Yes	No
Case Pond	No	No	Yes	No
Victoria Street, Hamline-Midway Library, and 7th Street Fire Department	Pervious surface infiltration rate investigation			

1 Water Quality parameters and sampling frequency is outlined in Table 2.1
2 Dale Street includes conducting grab sampling for chlorides, nitrite plus nitrate, kjeldahl nitrogen, ortho-phosphorus, total phosphorus, total dissolved solids, total suspended solids, suspended sediment concentration, and volatile suspended solids.
3 Monitoring conducted by CRWD.

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 2014 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.

Data Collection

Water levels were monitored using Win-Situ Level Troll 500 level loggers. The loggers were configured at each site to log data at one minute intervals when the water level was three-inches-deep or greater above the transducer.

Enclosures for the level loggers were installed at Hillcrest Knoll Park, St. Albans Street, and Arundel Street. 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**).

Photo 2-1: Level Logger Enclosure

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:

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

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.

2.2 Volume Reduction

Stormwater runoff volume was measured at Beacon Bluff, Hillcrest Knoll, St. Albans Street, AHUG, and Hampden Park using continuous flow monitoring equipment to determine the total volume of water draining to and captured by each system. 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

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.

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, Hillcrest Knoll, St. Albans Street, and Dale Street sites. The following section provides a summary of the methods and procedures used to collect and test stormwater runoff samples and analyze the data.

Data Collection

ISCO 6712 automatic samplers were installed in the diversion structures at Beacon Bluff, Hillcrest Knoll, and St. Albans Street (**Photos 2-4** and **2-5**). Dale Street water quality was monitored by grab samples collected from upstream and downstream of the system.

Photo 2-4 : ISCO 6712 sample at Beacon Bluff

Photo 2-5 : 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.

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. 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 from Beacon Bluff, St. Albans, Hillcrest Knoll Park, and Dale Street sites 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.

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 (asCu)	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

These specific water quality parameters were selected to be monitored, because they are consistent with the target parameters of the Capitol Region Watershed District's stormwater monitoring program with a few exceptions. SSC was included in the suite of parameters, because recent studies have suggested that analytical methods for quantifying TSS concentrations in many cases yield differing results. Also, the SSC analysis typically represents a higher recovery of sand-size materials, because it measures the dry weight of all sediment from the entire sample as opposed to a subsample drawn from the original using a pipette. The SSC approach yields significantly higher concentrations of solid material in a given sample than the TSS approach.

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, and Arundel Street periodically during the monitoring period. Pretreatment structures were inspected for accumulated sediment depth and floatable debris. Underground chambers were observed from the access riser for accumulation of sediment and other debris that would require maintenance. 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 2-6: 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 Cos	$980,000
Storage Volume	159,350 cubic-feet
Volume Reduction Credit Received by the City of Saint Paul	116,435 cubic-feet
Volume Reduction Credit Received by Saint Paul Port Authority	42,925 cubic-feet

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**.

Infiltration rates are presented on **Charts A.3** and **A.4** of **Appendix A**. In 2014, average infiltration rates for the rain garden and BMP pipe were 0.70 and 0.64 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 the rain garden (IR-31) and BMP pipe (IR-32) are depicted on **Charts A.5** and **A.6** respectively. Since 2012, average adjusted infiltration rates in the rain garden have decreased from 2.9 in/hr to 0.7 in/hr. In 2014, the peak rain garden water elevation reached levels approximately 1.5 feet (ft) greater than levels in 2012 and 2013. The average adjusted infiltration rate for the BMP Pipe (IR-32) increased from 2013 (0.57 in/hr) to 2014 (0.64 in/hr), but was well below the 2012 rate of 2.6 in/hr.

Table 3-2: Beacon Bluff Infiltration Rates

Location	Range of Infiltration Rates (in/hr)			Average Infiltration Rate (in/hr)		
	2012	2013	2014	2012	2013	2014
Beacon Bluff Rain Garden (IR-31)	0.2 - 13.9	0.04 - 4.2	0.06 - 11.35	2.9	0.85	0.70
Beacon Bluff BMP Pipe (IR-32)	0.2 - 7.4	0.04 - 3.2	0 - 4.91	2.6	0.57	0.64

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**.

In 2014, total runoff for the Beacon Bluff systems was 2,532,633 cubic feet (cu-ft). Of that volume, 1,685,160 cu-ft was captured and infiltrated by the system, resulting in a volume reduction of 66.4 percent. These totals are presented in **Table 3-3** below. Storm specific runoff volumes are provided in the pollutant loading table discussed in the Pollutant Removal Monitoring Section. The total rainfall and runoff observed in 2014 was less than both 2013 and 2012 totals. Volume reduction at the site, for the past three years, has ranged from 62.2 percent in 2012 to 79.4 percent in 2013.

Table 3-3: Beacon Bluff Volume Reduction

Monitoring Period	03/29/12 to 11/08/12		04/24/13 to 11/16/13		05/27/14 to 10/23/14	
Total Rainfall	25.2	in.	31.6	in.	22.31	in.
Diversion Structure Water Balance						
Runoff Volume	3,504,574	cu-ft	2,819,296	cu-ft	2,383,462*	cu-ft
Bypassed Volume	1,413,451	cu-ft	636,127	cu-ft	850,829	cu-ft
Volume Diverted into BMP	2,091,123	cu-ft	2,183,169	cu-ft	1,532,633*	cu-ft
Volume Captured by Underground System						
Inflow Volume from Diversion Structure (SubWSHD A)	2,091,123	cu-ft	2,183,169	cu-ft	1,532,633	cu-ft
Inflow Volume from West Pond (SubWSHD B)	66,417	cu-ft	67,526	cu-ft	38,678	cu-ft
Inflow Volume from East Pond (SubWSHD C)	165,881	cu-ft	130,103	cu-ft	113,849	cu-ft
System Outlet						
Total Outflow Volume	0	cu-ft	0	cu-ft	0	cu-ft
Beacon Bluff System Performance						
Total Runoff Volume	3,736,872	cu-ft	3,016,926	cu-ft	2,535,989	cu-ft
Total Runoff Volume Captured	2,323,421	cu-ft	2,394,951	cu-ft	1,685,160	cu-ft
Percent of Total Runoff Volume Captured	62.2	%	79.4	%	66.4	%

*Due to erroneous flow data upstream of the diversion structure, runoff volume was modeled using the P8 program, which was calibrated using 2012 and 2013 monitoring flow data.

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 parameters defined in NPDES Permit issued to the city in addition to suspended sediment concentration. In 2014, pollutant load reductions ranged from 63.9 percent for total suspended solids (TSS) to 70.1 percent for chlorides. During the monitoring period 16,260 pounds of TSS and 53 pounds of total phosphorus (TP) were captured, and over the past three years of monitoring, a total of 40,976 pounds of TSS and 174.3 pounds of TP have been captured.

Table 3-4: Beacon Bluff Load/Capture Summary

Monitoring Period	04/25/12 – 7/18/12			04/24/13 – 11/16/13			05/27/14 to 10/23/14		
Total Rain	19.7			31.6			22.3		
Water Quality Parameter	**Total Pollutant Load (lbs.)**	**Load Captured (lbs.)**	**Percent Reduction**	**Total Pollutant Load (lbs.)**	**Load Captured (lbs.)**	**Percent Reduction**	**Total Pollutant Load (lbs.)**	**Load Captured (lbs.)**	**Percent Reduction**
Total Suspended Solids	24,318	13,618	56.0%	20,068	11,098	55.3%	25,446	16,260	63.9%
Volatile Suspended Solids	Not calc.	Not calc.	Not calc.	6,867	4,388	63.9%	8,116	5,267	64.9%
Suspended Sediment Concentration	91,578	52,107	56.9%	74,240	44,395	59.8%	85,162	57,570	67.6%
Total Phosphorus	120.9	78.7	65.1%	70.5	42.4	60.2%	81.8	53.2	65.0%
Chlorides	712.3	497	69.7%	591	394	66.7%	525	368	70.1%
Nitrate + nitrite as N	Not calc.	Not calc.	Not calc.	25.0	17.5	70.1%	29.5	20.3	68.9%
Total Kjeldahl nitrogen	Not calc.	Not calc.	Not calc.	72.1	54.7	75.9%	260	179	68.9%

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 ranged from 0.05 ft to 0.7 ft. Floatables (mostly garbage) were observed in the pretreatment structure on most visits. A thorough inspection of the BMP was completed at the conclusion of the monitoring season. Approximately 0.25 ft of sediment was observed through the central portion of the BMP pipe. The sediment accumulation had resulted in 2 ft of water remaining in the pipe as of November 6, 2014. Jet/vac maintenance is recommended for the Beacon Bluff BMP pipe. See **Appendix D** for **BMP Inspection Photographs.**

Table 3-5: Beacon Bluff Maintenance Inspections

Date	SAFL Baffle MH8			Observations
	Depth to Water (ft)	Depth to Sediment (ft)	Sediment Height (ft)	
05/16/2014	10.34	15.70	0.3	-
06/26/2014	10.3	14.2	0.7	Floatables (garbage) present in SAFL baffle
07/23/2014	10.45	10.85	0.05	Floatables (garbage) present in SAFL baffle
08/22/2014	10.38	15.48	0.52	Floatables (garbage) present in SAFL baffle
11/13/2014	10.30	15.80	0.20	Garbage in MH. Some items stuck in SB perforations.

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 Hayden Heights Recreation Center which is located one half mile to the east 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 cubic-feet
Volume Reduction Credit Received by the City of Saint Paul	85, 500 cubic-feet

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**.

2014 Infiltration rates and infiltration rate trends are presented on **Charts A.9** and **A.10** of **Appendix A,** respectively**.** In 2014, the average infiltration rate for the BMP pipe was 0.52 in/hr in comparison to 0.67 in/hr in 2013 (**Table 4-2**). This is below the MSWM recommended infiltration rate for SP soils of 0.8 in/hr and the design infiltration rate of 2 in/hr. In 2013 and 2014 groundwater interference contributed to reduced infiltration rates in the system.

Table 4-2: Hillcrest Knoll Infiltration Rates

Location	Range of Infiltration Rates (in/hr)		Average Infiltration Rate (in/hr)	
	2013	2014	2013	2014
Hillcrest Knoll BMP Pipe	0.0-15.29	0.0 - 13.24	0.67	0.52

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**.

In 2014, total runoff for the Hillcrest Knoll system was 901,278 cu-ft. Of that volume, 183,792 cu-ft was captured and infiltrated by the system, resulting in a volume reduction of 20.7 percent (**Table 4-3**). Storm specific runoff volumes are provided in the pollutant loading table discussed in the Pollutant Removal Monitoring Section. The total runoff volume was greater by 14,067 cu-ft in 2014 compared to 2013, but the captured volume was 30,089 cu-ft less. As mentioned in the previous section, groundwater interference in the system contributed to reduced volume reduction at the site. Since 2013, 394,720 cu-ft of runoff has been captured with an overall volume reduction percentage of 24 percent.

Table 4-3: Hillcrest Knoll Volume Reduction

Monitoring Period	05/17/13 - 10/14/13		05/27/2014 - 11/14/2014	
Total Rainfall	26.7	in.	23.1	in.
Hillcrest Knoll System Performance				
Total Runoff Volume	760,447	cu-ft	901,278	cu-ft
Total Runoff Volume Captured	213,881	cu-ft	180,839	cu-ft
Percent of Runoff Volume Captured	28.1	%	20.1	%
Maximum Percentage of Storage Volume Utilized	100	%	100	%

Pollutant Removal Monitoring

A water quality sampler was placed in the 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. Composite samples for each event were tested to provide EMC's for each event for each parameter analyzed. Grab samples were also collected during three runoff events. See **Charts C.3** and **C.4** of **Appendix C** for the complete water quality summary and pollutant loading calculations.

Table 4-4 below provides a load reduction summary for the parameters defined in NPDES Permit issued to the City in addition to suspended sediment concentration. Load reduction for the system ranged from 16.7 percent for suspended sediment concentration (SSC) to 22.9 percent for Total Kjeldahl Nitrogen (TKN). During the monitoring period, 1852.9 pounds of total suspended solids and 7.13 pounds of total phosphorus were captured.

Table 4-4: Hillcrest Knoll Load/Capture Summary

Monitoring Period	05/17/13 – 10/14/13			05/27/14 – 11/14/14		
Total Rain	26.7 in			23.1 in		
Water Quality Parameter	**Total Pollutant Load (lb.)**	**Load Captured (lb.)**	**Percent Reduction**	**Total Pollutant Load (lb.)**	**Load captured (lb.)**	**Percent Reduction**
Total Suspended Solids	7,732	1,949	25.2%	9,903	1,853	18.7%
Volatile Suspended Solids	2,242	601	26.8%	2,201	477.6	21.7%
Suspended Sediment Concentration	285,126	66,434	23.2%	194,515	32,484	16.7%
Total Phosphorus	66	14.1	21.3%	42	7.1	17.1%
Chlorides	192	51	26.6%	208	47	22.4%
Nitrate + nitrite as N	13.7	3.3	24.1%	11.7	2.3	19.7%
Total Kjeldahl nitrogen	69	18	26.1%	311	71	22.6%

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 4-5**, sediment depths in the pretreatment device ranged from 0.05 to 0.3 ft. Floatables (garbage) were observed in the pretreatment structure on most visits. A thorough inspection of the BMP was completed at the conclusion of the monitoring season. No significant sediment accumulation or maintenance needs were observed at that time. See **Appendix D** for **BMP Inspection Photographs.**

Table 4-5: Hillcrest Knoll Maintenance Inspections

Date	Pretreatment Chamber MH 1003			Observations
	Depth to Water (ft)	Depth to Sediment (ft)	Sediment Height (ft)	
06/26/2014	4.0	11.25	0.05	Floatables (leaves) present in pre-treatment
07/23/2014	5.25	11.20	0.10	Floatables (garbage) present in pre-treatment. Odor/sheen observed.
08/26/2014	4.95	11.03	0.27	Floatables (leaves) present in pre-treatment
11/13/2014	7.58	11.01	0.30	Floatables (leaves) present in pre-treatment

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 roof of Saint Paul Fire Department Engine House 18, located 0.1 miles to the north of the system.

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 cubic-feet
Volume Reduction Credit Received by the City of Saint Paul	31,189 cubic-feet

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

Infiltration Monitoring

BMP water level was monitored in the access manhole at the northwest corner of the system. 2014 water elevations and daily rainfall is provided on **Chart A.11** of **Appendix A**

Infiltration rates are presented on **Chart A.12** of **Appendix A**. In 2014, the average infiltration rate of the BMP pipe was 64.8 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**. The peak water level in the BMP, for all three years, was approximately four ft. From 2012 to 2013, the average adjusted infiltration rate decreased slightly from 38.5 to 35.7. From 2013 to 2014 the average infiltration rate nearly doubled.

Table 5-2: St. Albans Street Infiltration Rate

Location	Range of Infiltration Rates (in/hr)			Average Infiltration Rate (in/hr)		
	2012	2013	2014	2012	2013	2014
St. Albans Street BMP Pipe	0.2 - 190.9	0.0 - 129.2	0.09 - 326.6	38.5	35.7	64.8

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.3** of **Appendix B**.

In 2014, total runoff for the St. Albans Street system was 379,323 cu-ft. Of that volume, 376,200 cu-ft was captured and infiltrated by the system, resulting in a volume reduction of 98.37 percent (**Table 5-3**). Storm specific runoff volumes are provided in the pollutant loading table discussed in the Pollutant Removal Monitoring Section. Since 2012, 1,114,153 cu-ft of runoff has been captured with an overall volume reduction percentage of 93 percent.

Table 5-3: St. Albans Street Volume Reduction

Monitoring Period	03/29/12 - 11/6/12		05/17/2013 - 10/14/2013		05/26/14 - 10/23/14	
Total Rainfall	22.2	in.	26.7	in.	29.5	in.
Saint Albans Street System Performance						
Total Runoff Volume	456,395	cu-ft	360,787	cu-ft	379,323	cu-ft
Total Runoff Volume Captured	446,225	cu-ft	291,728	cu-ft	376,200	cu-ft
Percent of Runoff Volume Captured	97.8	%	80.9	%	98.37	%

Pollutant Removal Monitoring

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 2014 are provided in **Table C.5** and **C.6** of **Appendix C**.

Table 5-4 below provides a load reduction summary for the parameters defined in NPDES Permit issued to the City in addition to suspended sediment concentration. In 2014, load reductions ranged from 97.73 percent of TP to 98.88 percent of Nitrate + Nitrite as N. During the monitoring period, 3204.6 pounds of TSS and 16.8 pounds of TP were captured.

Table 5-4: Saint Albans Street Pollutant Load Reduction

	Monitoring Period	05/26/2014 – 10/23/2014	
	Total Rain	29.5	
Water Quality Parameter	**Total Pollutant Load (lb.)**	**Load Captured (lb.)**	**Percent Reduction**
Total Suspended Solids (TSS)	3,270	3,205	98.01%
Volatile Suspended Solids (VSS)	1,144	1,122	98.13%
Suspended Sediment Concentration (SSC)	20,701	20,296	98.04%
Total Phosphorus (TP)	17.2	16.8	97.73%
Chlorides	173	170	98.44%
Total Kjeldahl nitrogen	38.0	37.3	98.30%
Nitrate + nitrite as N	4.5	4.4	98.88%

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**, sediment depths in the pretreatment device ranged from 0 to 0.51 ft. Floatables (garbage) were observed in the pretreatment structure on most visits. A thorough inspection of the BMP was completed at the conclusion of the monitoring season. No significant sediment accumulation or maintenance needs were observed at that time. See **Appendix D** for **BMP Inspection Photographs.**

Table 5-5: St. Albans Maintenance Inspections

Date	Pretreatment Chamber MH 4001			Observations
	Depth to Water (ft)	Depth to Sediment (ft)	Sediment Height (ft)	
06/26/2014	10.90	14.55	0.20	Floatables (garbage) present in pretreatment device
07/23/2014	13.30	14.75	0.0	No sediment of water observed
08/26/2014	10.75	14.53	0.22	Floatables (garbage) observed in pretreatment and BMP Pipe
11/13/2014	10.78	14.24	0.51	No Comments

6 AHUG

This system, shown in **Figure 6-1**, is owned and operated by the Capitol Region Watershed District (CRWD) and funded in part by the City of Saint Paul. It has been monitored by the City since 2012. CRWD also conducted monitoring of the AHUG system during the 2014 season which included BMP level, flow data and water quality. A complete summary of those results can be found in CRWD Annual Monitoring Report. Water quality results and BMP maintenance are not discussed in this report.

The AHUG system consists of three parallel 283-foot long, 10-foot diameter perforated metal pipes placed underground to facilitate infiltration. A Vortechs storm water pretreatment system is located upstream of the infiltration chambers. Runoff is routed to the pretreatment system from a diversion structure in the main storm sewer in Arlington Avenue during low flow conditions. Runoff flows over a weir wall in the diversion structure during high flow conditions and continues through the storm sewer east to Como Lake.

The AHUG outlet structure has a weir wall that conveys stormwater when the system reaches its storage capacity. At the base of the weir wall is a six-inch orifice which allows the system to start discharging when it is about 25 percent full. The outlet structure discharges into the main storm sewer in Arlington Avenue one block east of the upstream diversion structure. Rainfall monitoring for this site is conducted on the roof of the Hubert H. Humphrey Job Corps Center.

Table 6-1: AHUG BMP Details

Total Drainage Area to BMP	55 acres
Year Constructed	2006
Total Construction Cost	$799,087
Storage Volume Below Normal Outlet	24,436 cubic-feet
Total Storage Volume	88,041 cubic-feet
Volume Reduction Credit Received by the City of Saint Paul	0 cubic-feet

Photo 6-1: Underground perforated CMP storage chambers

Photo 6-2: Accessing flow meters installed in the AHUG diversion structure.

Infiltration Rate Monitoring

Water levels were monitored by CRWD near the underground system outlet at "Manhole I" as identified on the monitoring equipment location map. Water elevations and daily rainfall are present on **Chart A.14** of **Appendix A.**

The BMP infiltration rates are presented on **Chart A.15** of **Appendix A**. In 2014, the average infiltration rate of the BMP pipe was 14.7 in/hr (**Table 6-2)**, which is above the MSWM recommended infiltration rate for SP soils of 0.8 in/hr. Infiltration rate trends are depicted on **Chart A.16.** Peak water level in the BMP pipe was approximately 3.5 ft in 2012 and 2014, and 4 ft in 2013. The average infiltration rate decreased slightly from 2012 (16.3 in/hr) to 2013 (12 in/hr) and increased in 2014.

Table 6-2: AHUG Infiltration Rates

Location	Range of Infiltration Rates (in/hr)			Average Infiltration Rate (in/hr)		
	2012	2013	2014	2012	2013	2014
AHUG BMP Pipe	0.8 - 19.9	0.25 - 62.0	0.31 – 24.7	16.3	12	14.7

Volume Reduction Monitoring

Flow meters were installed upstream and downstream of the inlet diversion structure located near the intersection of Arlington and Hamline 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. Flow rates and daily rainfall are depicted on **Chart B.4** of **Appendix B**.

In 2014, total runoff for the AHUG system was 844,425 cubic feet. Of that volume, 811,595 cu-ft was captured and infiltrated by the system, resulting in a volume reduction of 96.1 percent (**Table 6-3**). Since 2012, 2,837,914 cu-ft of runoff has been captured with an overall volume reduction percentage of 93.5 percent.

Table 6-3: AHUG Volume Reduction

Monitoring Period	04/1/2012 – 11/8/2012		05/17/13 - 10/14/13		05/19/2014 – 10/24/2014	
Total Rainfall	21.7		32.2	in.	24.0	in.
AHUG System Performance						
Total Runoff Volume	930,043	cu-ft	1,260,454	cu-ft	844,425	cu-ft
Total Runoff Volume Captured	902,657	cu-ft	1,123,662	cu-ft	811,595	cu-ft
Percent of Runoff Volume Captured	97.1	%	89.1	%	96.1	%

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 cubic-feet
Volume Reduction Credit Received by the City of Saint Paul	4,521 cubic-feet

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.17** of **Appendix A.**

The BMP pipe infiltration rates are presented on **Chart A.18** of **Appendix A**. In 2014, the average infiltration rate of the BMP pipe was 1.64 in/hr (**Table 7-2)**, which is greater than the MSWM recommended infiltration rate for SP soils of 0.8 in/hr, but less than the design infiltration rate of 17.6 in/hr. Infiltration rate trends are depicted on **Chart A.19.** Peak water level in the BMP pipe reached approximately four ft in 2012, 2013 and 2014. The average infiltration rate has decreased significantly every year since 2012, which is likely a result of sediment accumulation observed within the BMP.

Table 7-2: Infiltration Rates

Location	Range of Infiltration Rates (in/hr)			Average Infiltration Rate (in/hr)		
	2012	**2013**	**2014**	**2012**	**2013**	**2014**
Arundel BMP Pipe	0.1 - 80.4	0.0 - 44.46	0.01 - 46.20	8.0	2.43	1.64

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 ranged from 0.2 to 2.45 ft. Floatables (garbage) were observed in the pretreatment structure and in the BMP pipe on all visits. A thorough inspection of the BMP was completed at the conclusion of the monitoring season. Approximately 0.79 ft of sediment and garbage was observed within the BMP. Jet/vac maintenance of the Arundel BMP pipe is recommended. See **Appendix D** for **BMP Inspection Photographs.**

Table 7-3: Arundel Maintenance Inspections

Date	Pretreatment Chamber MH 5001			Observations
	Depth to Water (ft)	Depth to Sediment (ft)	Sediment Height (ft)	
06/26/2014	5.95	7.95	2.45	Floatables (garbage) present in pretreatment device. Observed odor and sheen.
07/23/2014	6.90	10.20	0.2	Floatables (garbage) present in pretreatment device. Observed odor.
08/26/2014	5.98	10.09	0.31	Floatables (garbage) present in pretreatment device. Observed odor.
11/13/2014	5.99	10.17	0.23	No water present in BMP pipe, but significant sediment and garbage observed.

8 Hampden Park

The Hampden Park infiltration gallery, shown in **Figure 8-1,** 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. 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 8-1: Hampden Park BMP Construction

Table 8-1 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
Volume Reduction Credit Received by the City of Saint Paul	15,904

Infiltration Monitoring

Water levels were monitored in the system and groundwater at the site. Due to the shortened, late-season monitoring period at Hampden Park in 2014 (September to December), inflow volumes were not sufficient enough to result in an increase in BMP water level at the observation location within the system. Water level and infiltration data and charts were not included for this reason.

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 Hampden and Raymond Avenues. The second meter was installed in the system bypass pipe. Flow rates and daily rainfall are depicted on **Chart B.5** of **Appendix B**.

In 2014, total runoff for the Hampden Park system was 20,516 cubic feet. Of that volume, 100% was captured and infiltrated by the system (**Table 8-2**).

Table 8-2: Hampden Park Volume Reduction

Monitoring Period	09/4/14 to 12/31/14	
Total Rainfall	3.2	in.
Hampden Park System Performance		
Total Runoff Volume	20,516	cu-ft
Total Runoff Volume Captured	20,516	cu-ft
Percent of Runoff Volume Captured	100	%

9 Dale Street

Vortechs system was constructed to collect sediment and debris from the Dale Street Facility, which is shown on **Figure 9-1**. Water quality monitoring has been conducted at the site since 2013.

Pollutant Removal Monitoring

Quarterly grab samples were collected at the Dale Street facility to determine pollutant concentrations at the site. Sampling events consisted of grab samples from the flow upstream and downstream of the Vortechs system. See **Chart C.7** of **Appendix C** for the complete water quality summary.

Rainfall totals for the three grab sampling events ranged from 0.19 inches to 2.21 inches and produced an estimated 13,490 cu-ft to 157,094 cu-ft of runoff. A summary of the average upstream and downstream concentrations observed from the three sampling events are included in **Table 9-1** below. TSS and TP concentrations at the site ranged from 57 µg/L to 65 µg/L and 0.157 µg/L and 0.162 µg/L, respectively.

Table 9-1: 2014 Dale Street Water Quality Summary

Water Quality Parameter	Average Upstream Concentration (µg/L)	Average Downstream Concentration (µg/L)
Total Suspended Solids	65	57
Volatile Suspended Solids	23.1	22.6
Suspended Sediment Concentration	74	73
Total Phosphorus	0.157	0.162
Chlorides	139	91.5
Total Kjeldahl nitrogen	1.03	1.23
Nitrate + Nitrite as N	0.41	0.27

10 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 10-1.**

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.20** of **Appendix A.** During the 2014 monitoring season (July – October), the maximum water elevation observed at Flandrau-Hoyt pond was 206.4 ft (Saint Paul City Datum) in comparison to the emergency overflow elevation of the pond which is 216.50 ft (Saint Paul City Datum).

Photo 10-1: Flandrau-Hoyt Pond outlet

11 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 11-1.**

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.21** of **Appendix A**. During the 2014 monitoring period, water levels reached the logger location one time following a 0.98 inch rain event on July 7, 2014.

Photo 11-1: Level logger configuration

Photo 11-2: Level logger in proximity to outlet

12 Pervious Surface Infiltration assessment

Infiltration rate monitoring was performed on August 28 and 29, 2014 at the Victoria Street and Hamline Midway Library pervious surface sites in accordance with the methods described in **Section 2.5**.

12.1 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 2014. As shown in **Table 12-1**, infiltration rates at all five locations have decreased every year since 2012. Additionally, the infiltration at was observed to be 0 in/hr in 2014. Overall the site average infiltration rate have been 185.04 (2012), 51.84 (2013), and 14.42 (2014). The test locations are presented in **Figure 12-1**

Table 12-1: Victoria Street Permeable Pavement Infiltration Rate

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

*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

Photo 12-1: Interlocking Pavers at Victoria Street

12.2 Hamline Midway Library

The Hamline Midway Library pervious surface consists of porous asphalt. The asphalt was installed in 2012 and infiltration rates were monitored in 2013 and 2014. As shown in **Table 12-2,** infiltration rates at nine locations on-site have decreased from 2013 to 2014. In 2014, seven of nine locations exhibited no infiltration. Overall, the site average infiltration rate in 2014 was 31.1 in/hr comparison to 206.8 in/hr in 2013. The test locations are presented in **Figure 12-2.**

Table 12-2: Hamline Midway Library Infiltration Rate Summary

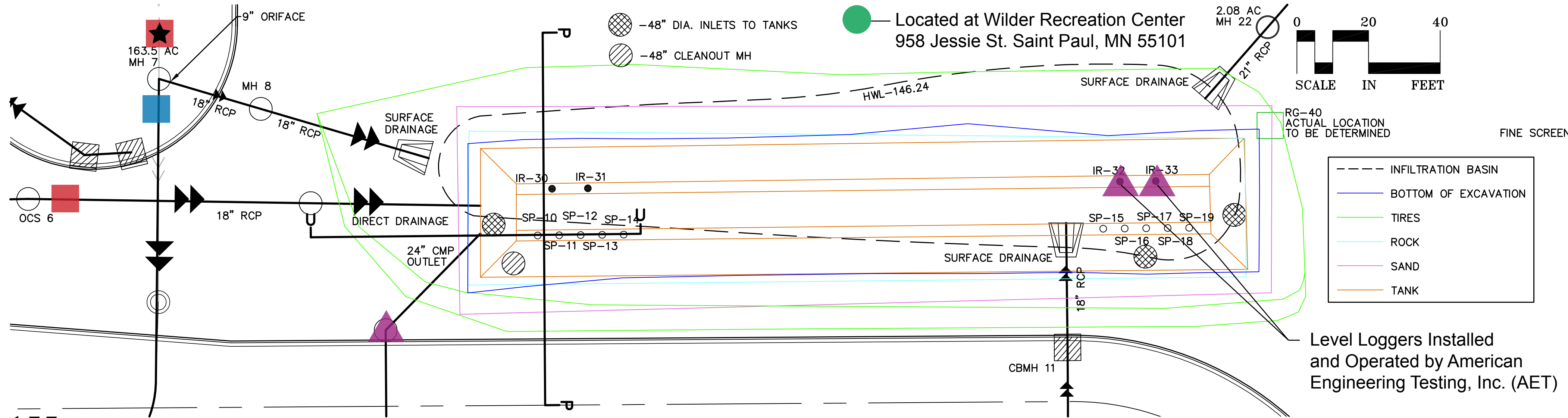
Infiltration Ring Location	2013 Infiltration Rate (in/hr)	2014 Infiltration Rate (in/hr)*
IR-1	102.4	0.0
IR-2	14.9	0.0
IR-3	11.4	0.0
IR-4	172.7	0.0
IR-5	0.0	0.0
IR-6	1125.3	206.7
IR-7	290.2	73.0
IR-8	28.4	0.0
IR-9	115.6	0.0
Average	**206.8**	**31.1**

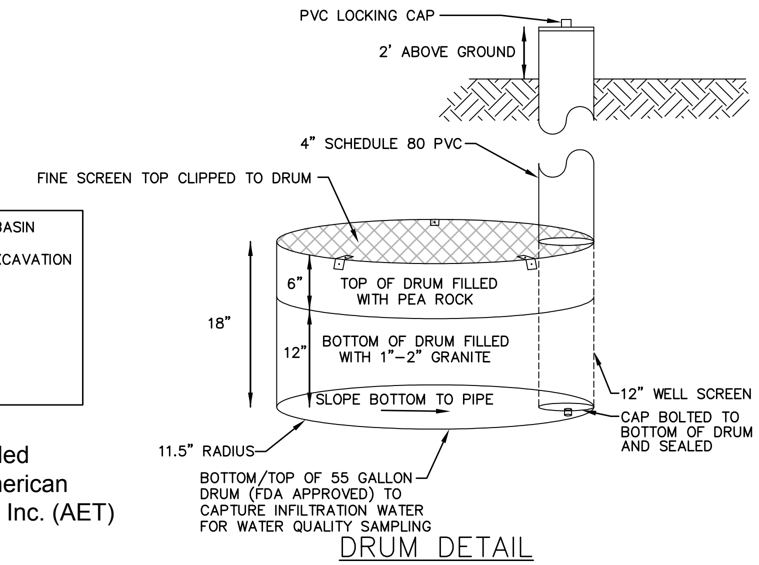
*Locations were monitored for a maximum of 25 minutes during the pre-wet test. If no infiltration was observed, no subsequent tests were completed and infiltrations rates were documented to be 0.0 in/hr.

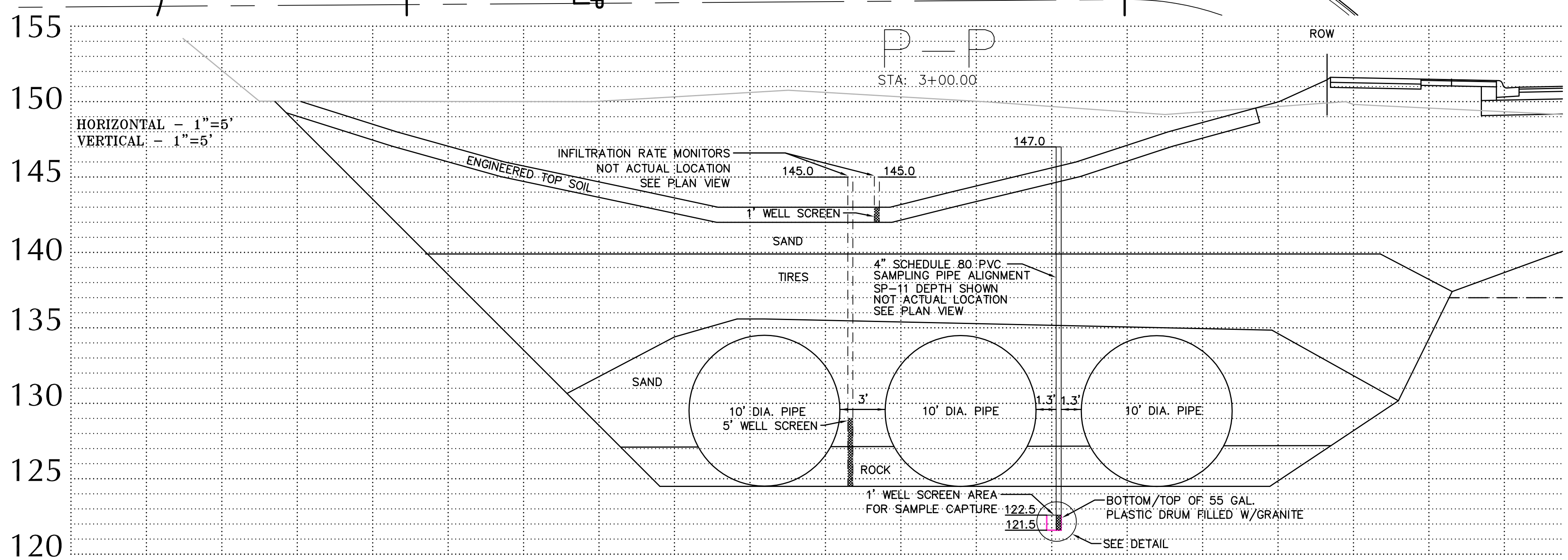
Photo 12-2: Sediment accumulation on pervious pavement

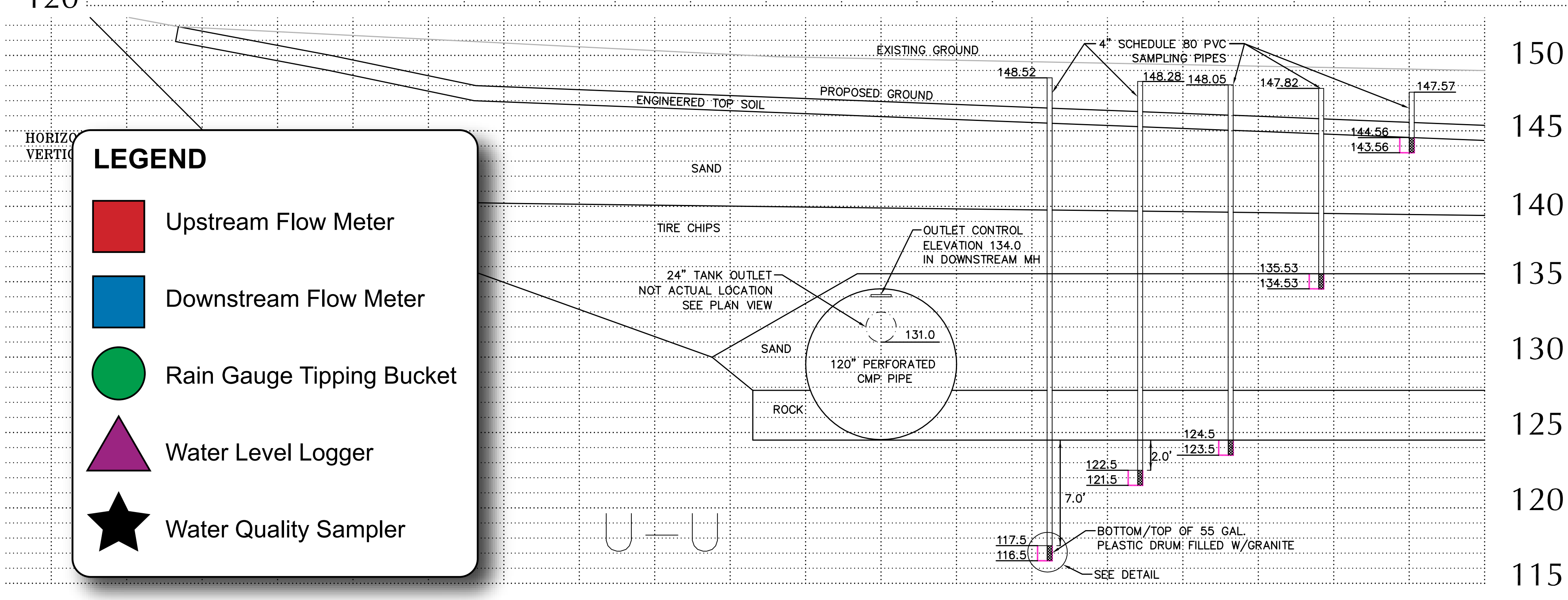
Photo 12-3: No infiltration observed

MONITORING EQUIPMENT LOCATION MAPS

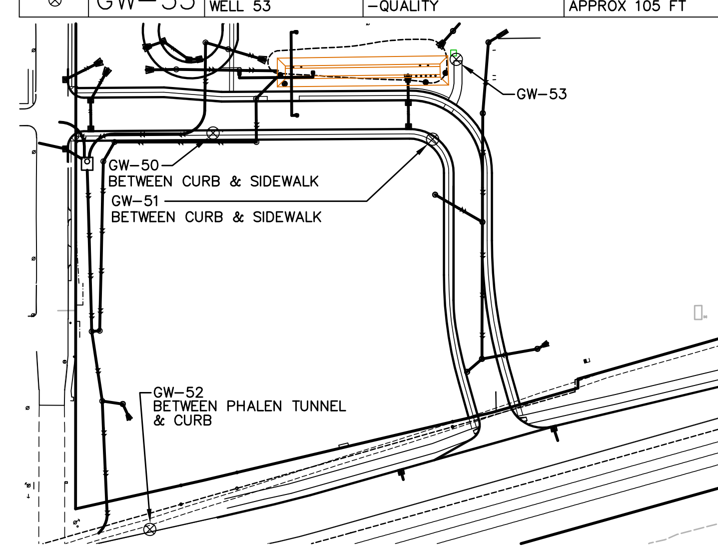








SYMBOL		DESCRIPTION	TYPE	LOCATION
	SW–1	SURFACE WATER IN BASIN	TREATMENT VARIES –WATER QUALITY	INFILTRATION BASIN 2
○	SP–10	SAMPLE PIPE 10	TREATED –WATER QUALITY	10' BELOW TIRE CHIPS
○	SP–11	SAMPLE PIPE 11	TREATED –WATER QUALITY	5' BELOW TIRE CHIPS
○	SP–12	SAMPLE PIPE 12	TREATED –WATER QUALITY	3' BELOW 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

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

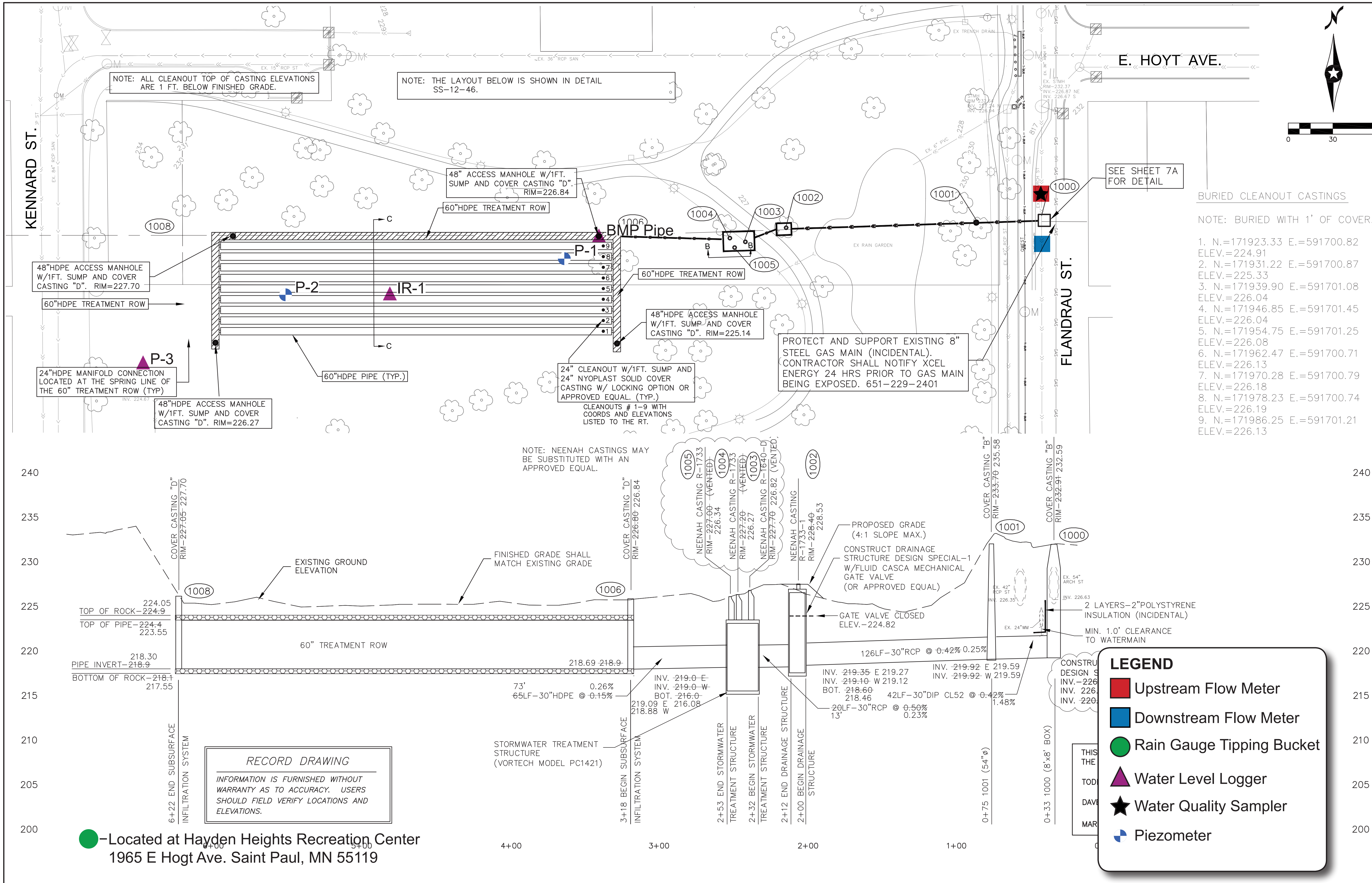
Project No.:

08244

Sheet No.:

C9-8

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



–Located at Hayden Heights Recreation Center
1965 E Hogt Ave. Saint Paul, MN 55119

2012 HILLCREST KNOLL PARK AND DALE STREET STORMWATER QUALITY IMPROVEMENTS

ST. PAUL, MINNESOTA

REVISION NO. DATE 8/20/12 EXPLANATION DESIGN REV.

SCALE: AS NOTED | PLAN BY: ECY | DESIGN BY: RWH | CHECKED BY: TAW | PROJECT NO: 01610-07

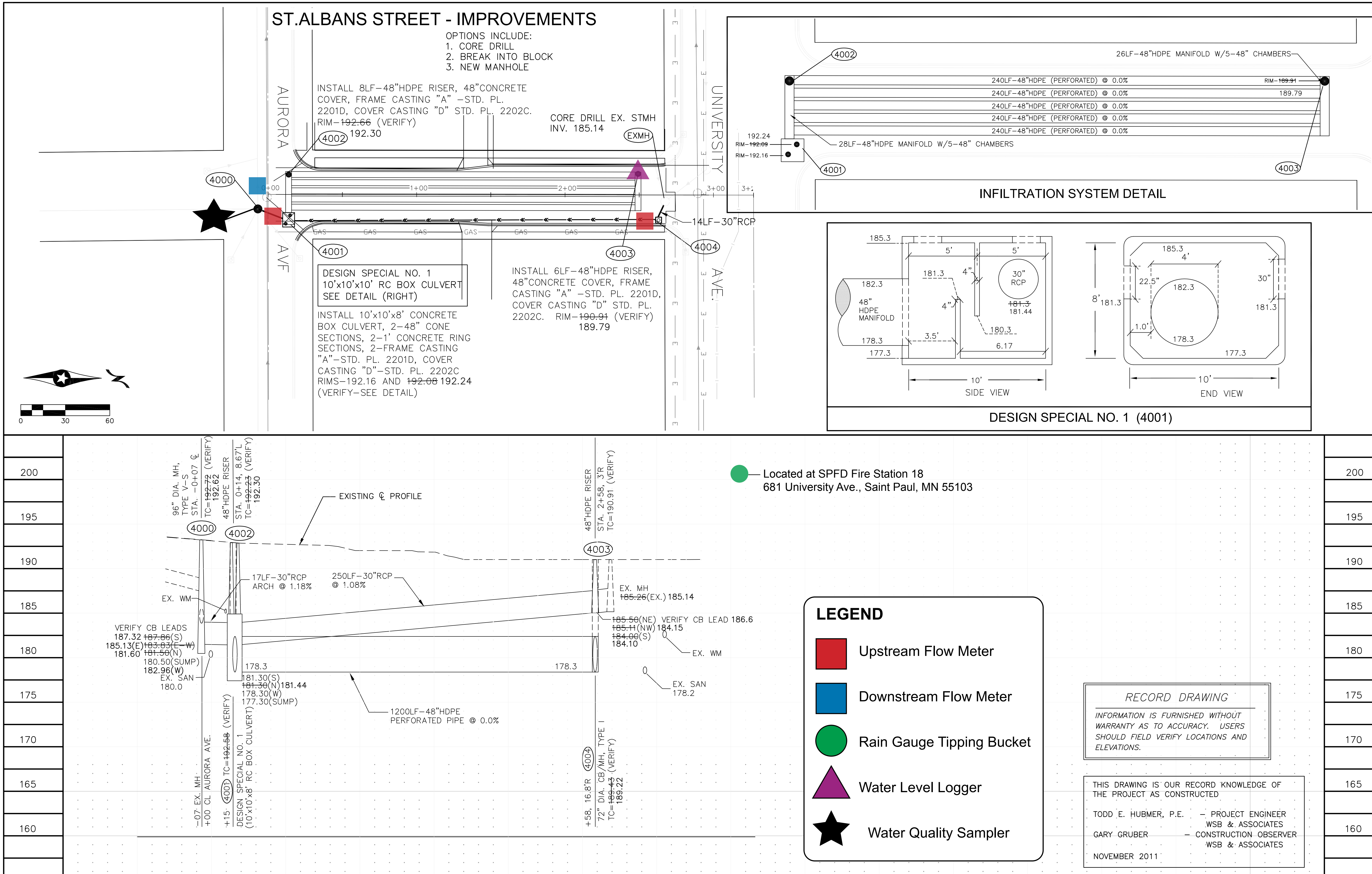
I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA

TODD E. HUBMER, P.E. LIC. NO. 24043 DATE: AUGUST 20, 2012

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

RECORD PLAN 2013 CONTRACTOR: EUREKA CONSTRUCTION INC.

DRAWER: DWG. NO. | CITY PROJECT NUMBER 12-S-2003 | PROPOSED IMPROVEMENTS | SHEET 7 OF 18 SHEETS



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

ST. PAUL, MINNESOTA

REVISED 4001 TO 10' BOX – 01/28/11
ADDED WM IN AURORA – 04/20/11

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

SCALE: AS NOTED; DESIGN BY: RH; PLAN BY: EY; PROJECT NO: 01610-03

WSB & Associates, Inc. 701 Xenia Avenue South, Suite 300 Minneapolis, MN 55416 www.wsbeng.com

CONTRACTOR: FOREST LAKE CONTRACTING, INC.

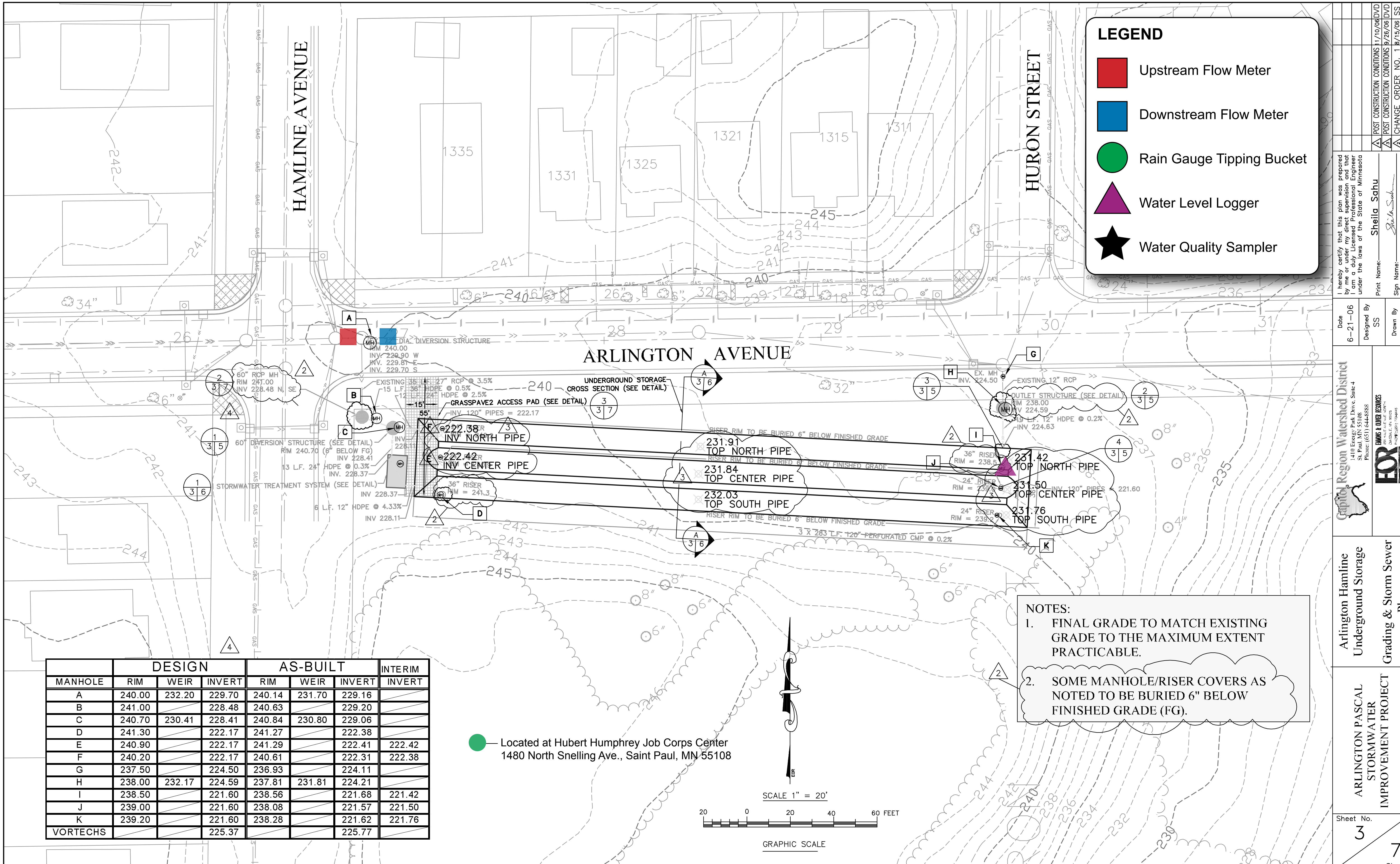
RECORD PLAN

DRAWER: DWG. NO.

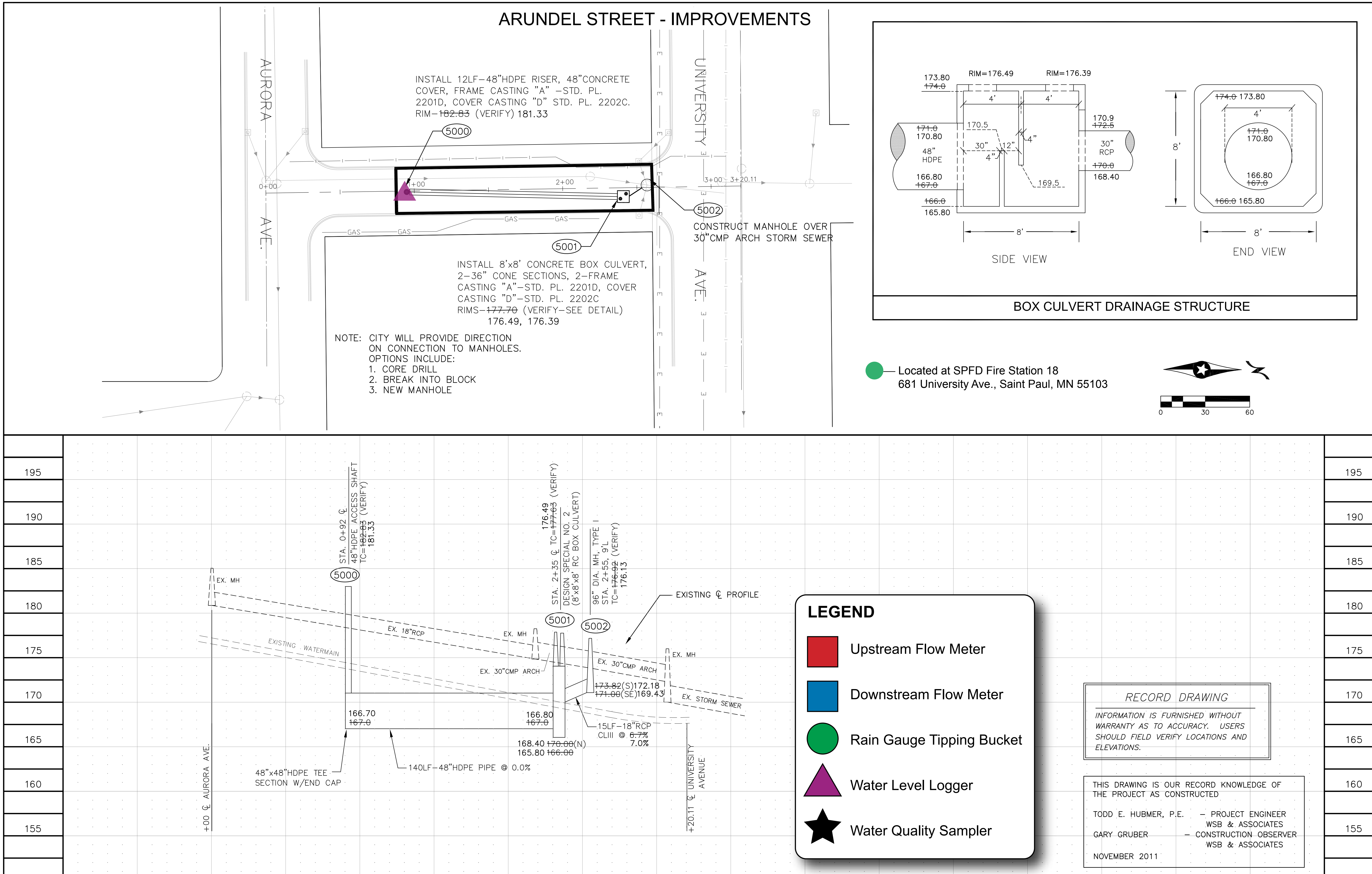
CITY PROJECT NUMBER 10–S–1983

2010 RSVP PROJECT PROPOSED IMPROVEMENTS

SHEET 7 OF 17 SHEETS



	DESIGN			AS-BUILT			INTERIM
MANHOLE	RIM	WEIR	INVERT	RIM	WEIR	INVERT	INVERT
A	240.00	232.20	229.70	240.14	231.70	229.16	
B	241.00		228.48	240.63		229.20	
C	240.70	230.41	228.41	240.84	230.80	229.06	
D	241.30		222.17	241.27		222.38	
E	240.90		222.17	241.29		222.41	222.42
F	240.20		222.17	240.61		222.31	222.38
G	237.50		224.50	236.93		224.11	
H	238.00	232.17	224.59	237.81	231.81	224.21	
I	238.50		221.60	238.56		221.68	221.42
J	239.00		221.60	238.08		221.57	221.50
K	239.20		221.60	238.28		221.62	221.76
VORTECHS			225.37			225.77	



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

ST. PAUL, MINNESOTA

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

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

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CONTRACTOR: FOREST LAKE CONTRACTING, INC.

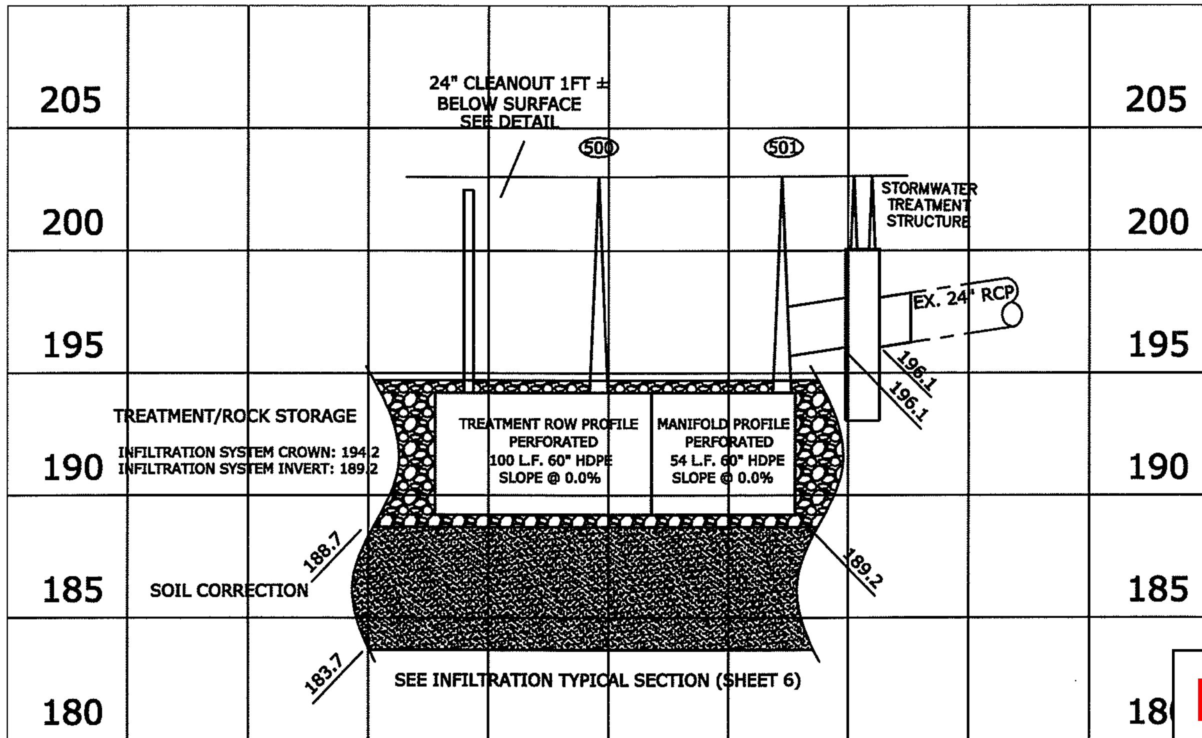
RECORD PLAN

DRAWER:
DWG. NO.

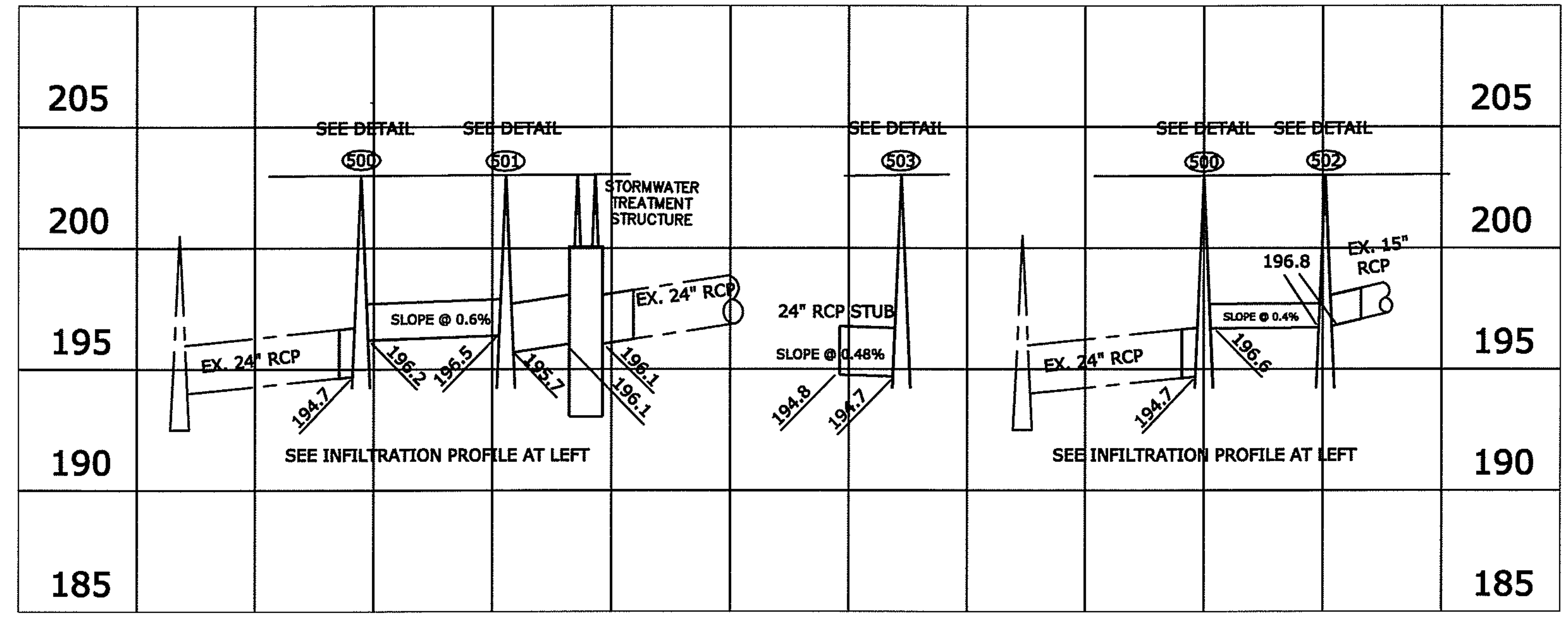
CITY PROJECT NUMBER 10-S-1983

2010 RSVP PROJECT PROPOSED IMPROVEMENTS

SHEET 8 OF 17 SHEETS

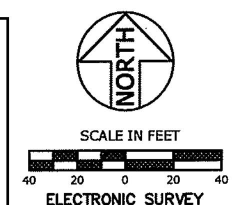


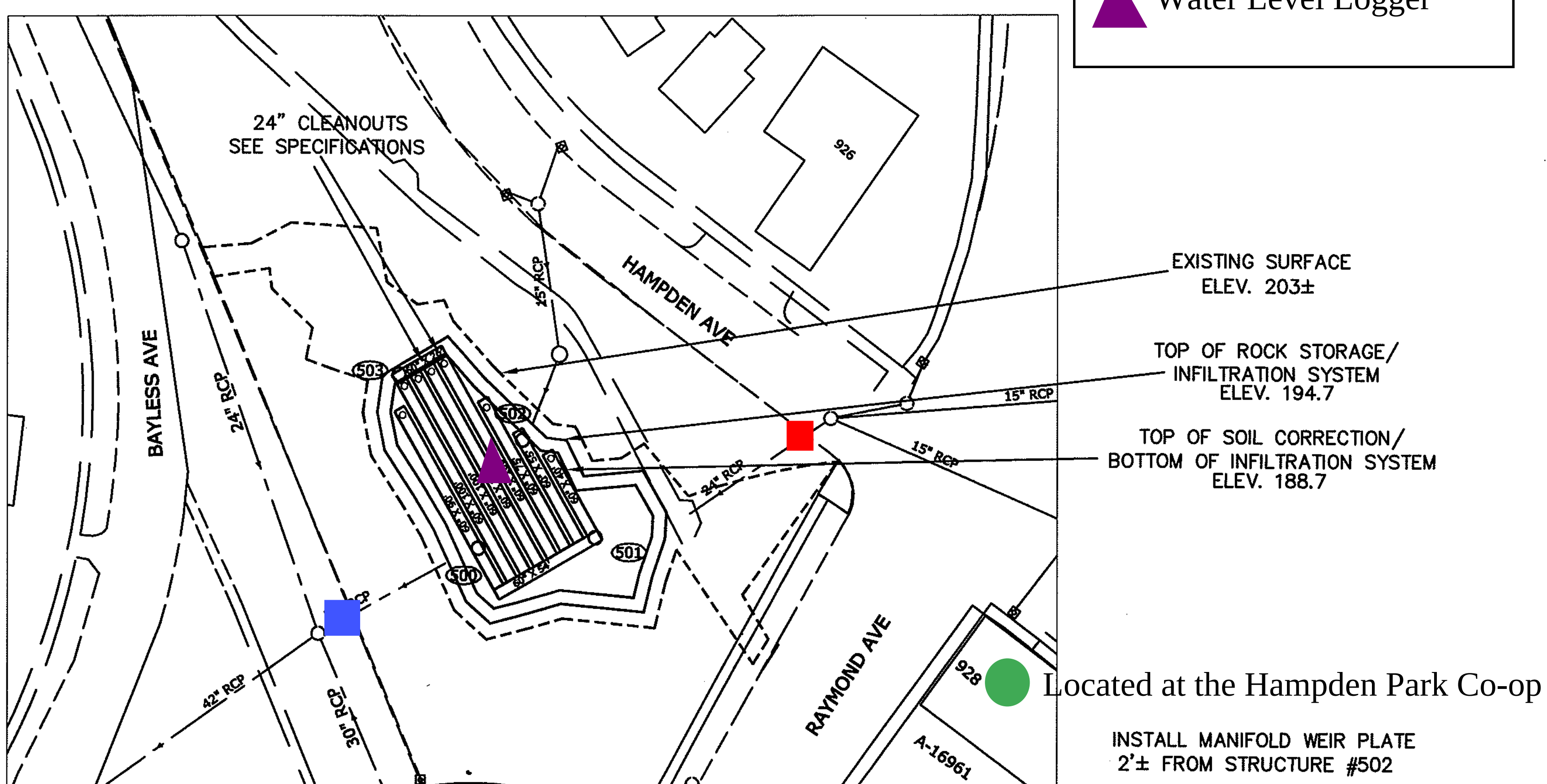
INFILTRATION SYSTEM CONSTRUCTION



SEWER CONSTRUCTION

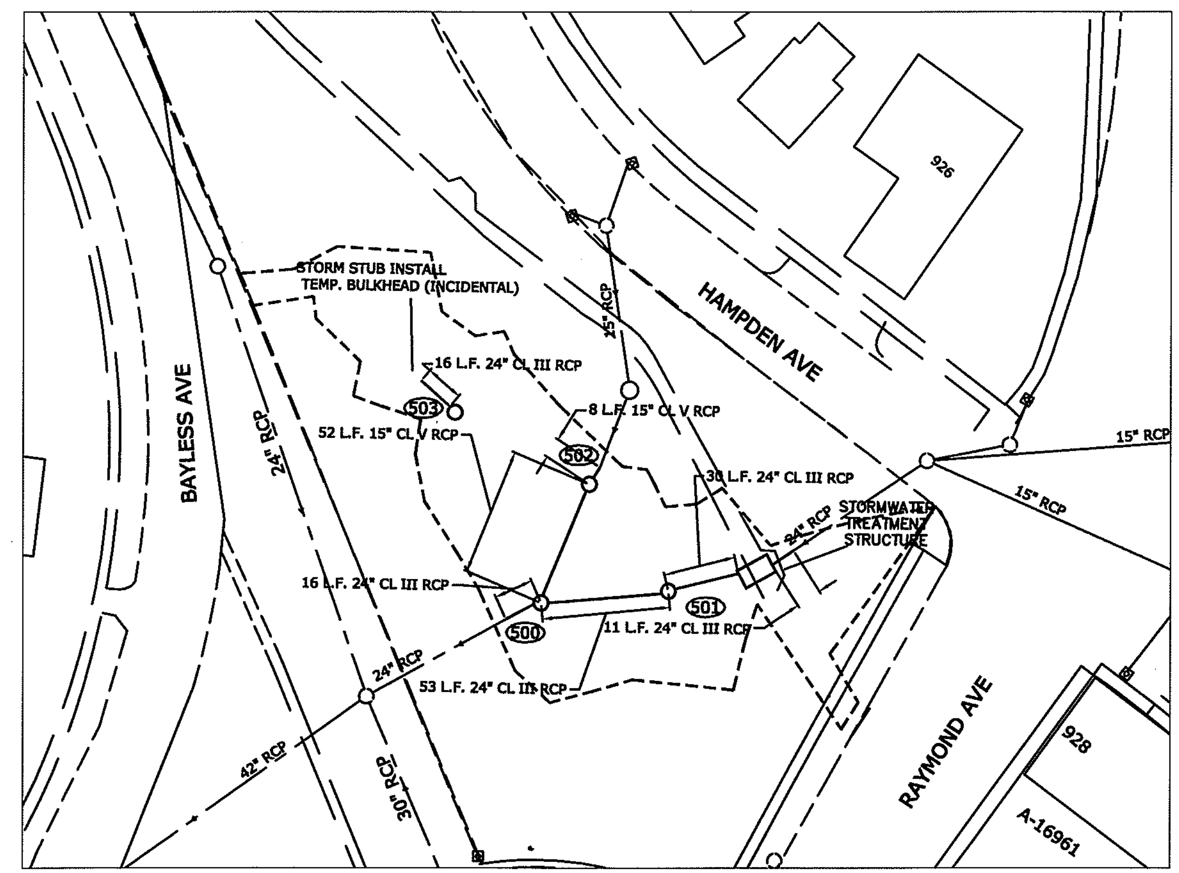
- Upstream Flow Meter (red square)
- Downstream Flow Meter (blue square)
- Rain Gauge (green circle)
- Water Level Logger (purple triangle)





INFILTRATION SYSTEM CONSTRUCTION

TYPICAL SECTION SHEET 6



SEWER CONSTRUCTION

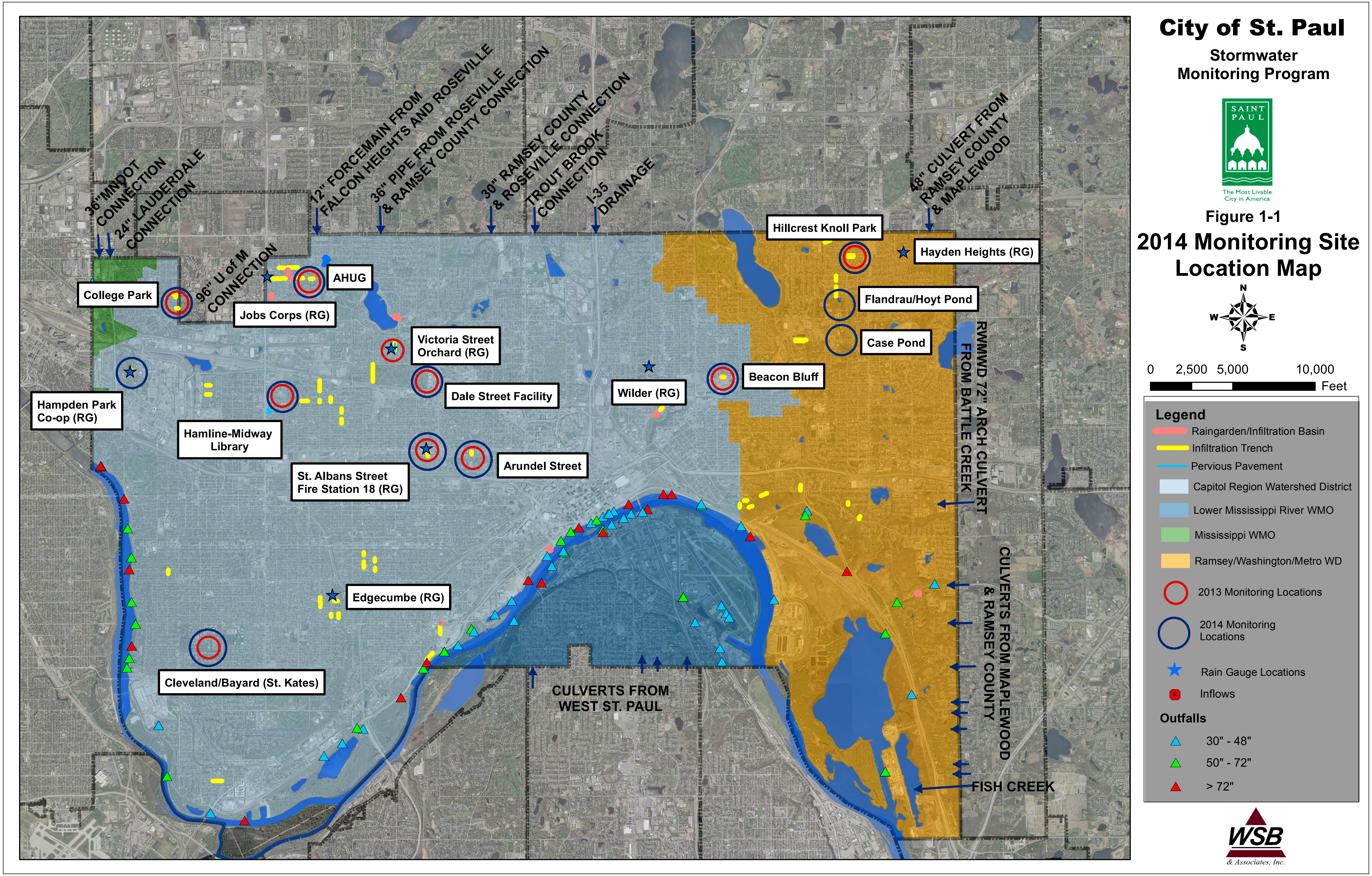
SAINT PAUL	DESIGNED	PGM	I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA	
	DRAWN	PGM	Signature: AARON D HASS	Date: 1/15/2014
	APPROVED	ADH		Lic. No. 26424

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	

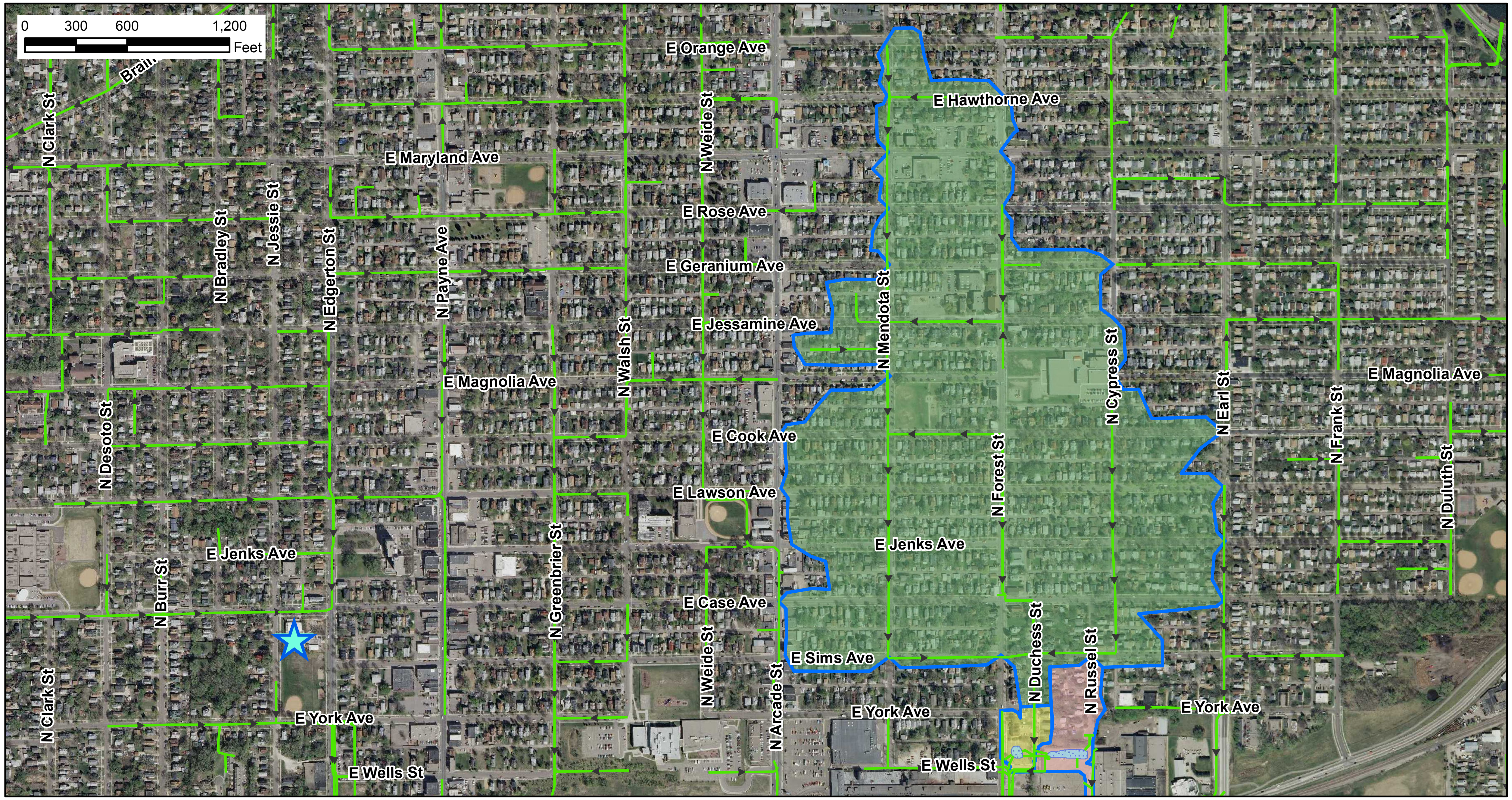
FIGURES

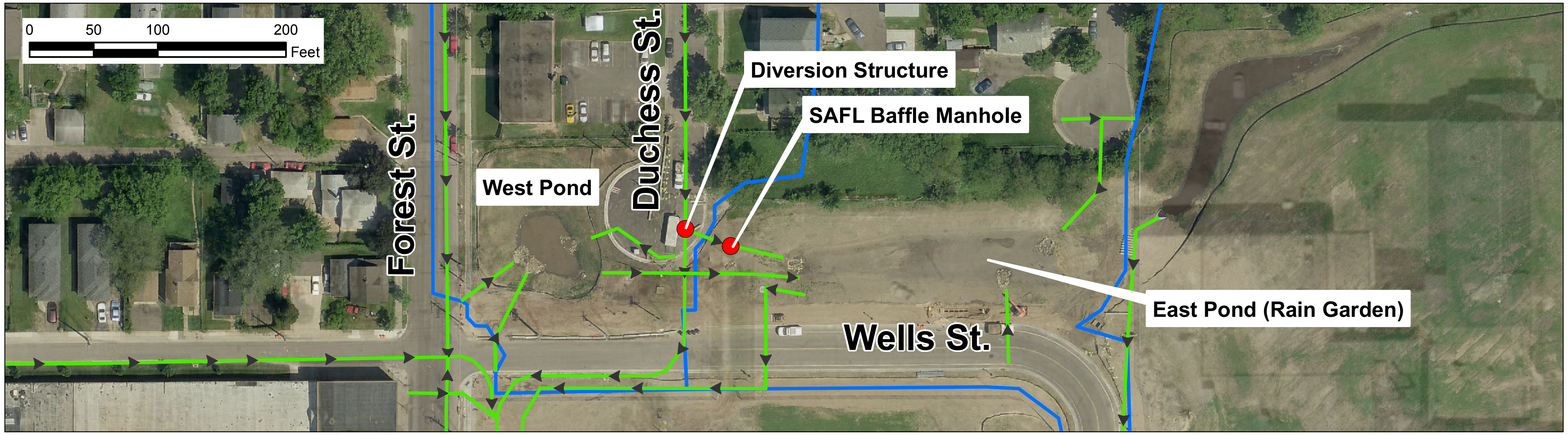

City of St. Paul
Stormwater Monitoring Program
SAINT PAUL
The Most Livable City in America
Figure 1-1
2014 Monitoring Site Location Map
N
W
E
S
0 2,500 5,000 10,000
Feet
Legend
Raingarden/Infiltration Basin
Infiltration Trench
Pervious Pavement
Capitol Region Watershed District
Lower Mississippi River WMO
Mississippi WMO
Ramsey/Washington/Metro WD
2013 Monitoring Locations
2014 Monitoring Locations
Rain Gauge Locations
Inflows
Outfalls
30" - 48"
50" - 72"
> 72"
WSB & Associates, Inc.
36"MNDOT CONNECTION
24" LAUDERDALE CONNECTION
96" U of M CONNECTION
12" FORCEMAIN FROM FALCON HEIGHTS AND ROSEVILLE
36" PIPE FROM ROSEVILLE & RAMSEY COUNTY CONNECTION
30" RAMSEY COUNTY & ROSEVILLE CONNECTION
TROUT BROOK CONNECTION
I-35 DRAINAGE
48" CULVERT FROM RAMSEY COUNTY & MAPLEWOOD
RWMWD 72" ARCH CULVERT FROM BATTLE CREEK
CULVERTS FROM MAPLEWOOD & RAMSEY COUNTY
FISH CREEK
CULVERTS FROM WEST ST. PAUL
College Park
AHUG
Jobs Corps (RG)
Victoria Street Orchard (RG)
Hampden Park Co-op (RG)
Hamline-Midway Library
Dale Street Facility
St. Albans Street Fire Station 18 (RG)
Arundel Street
Edgecumbe (RG)
Cleveland/Bayard (St. Kates)
Wilder (RG)
Beacon Bluff
Hillcrest Knoll Park
Hayden Heights (RG)
Flandrau/Hoyt Pond
Case Pond

City of St. Paul

2014 Water Quantity and Quality Monitoring Program

FIGURE 3-1
Beacon Bluff Infiltration BMP Drainage Areas



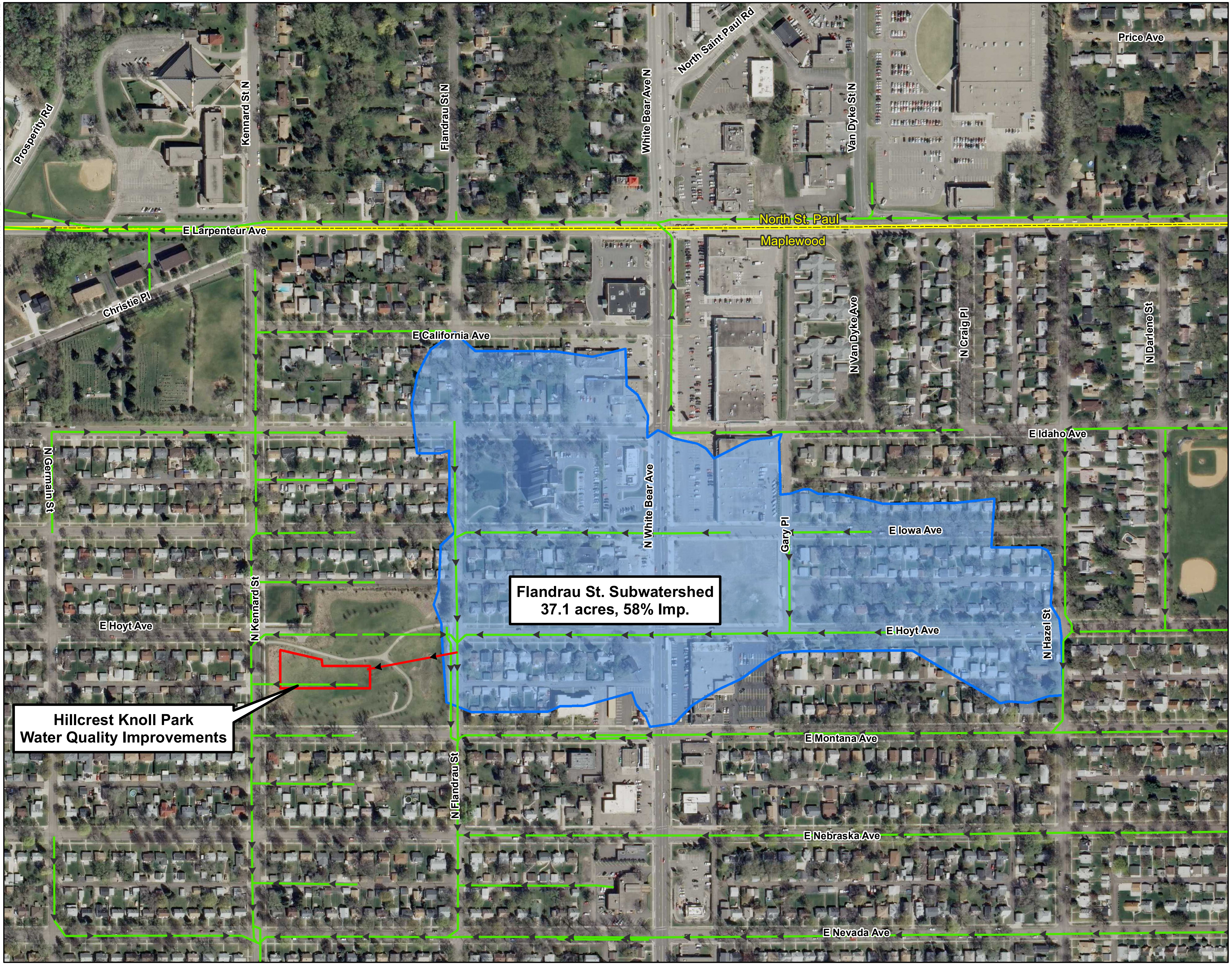


Legend

- 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)



City of St. Paul

2014 Water Quantity and Quality Monitoring Program

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FIGURE 4 - 1

Hillcrest Knoll Park Water Quality Improvements Drainage Area Map

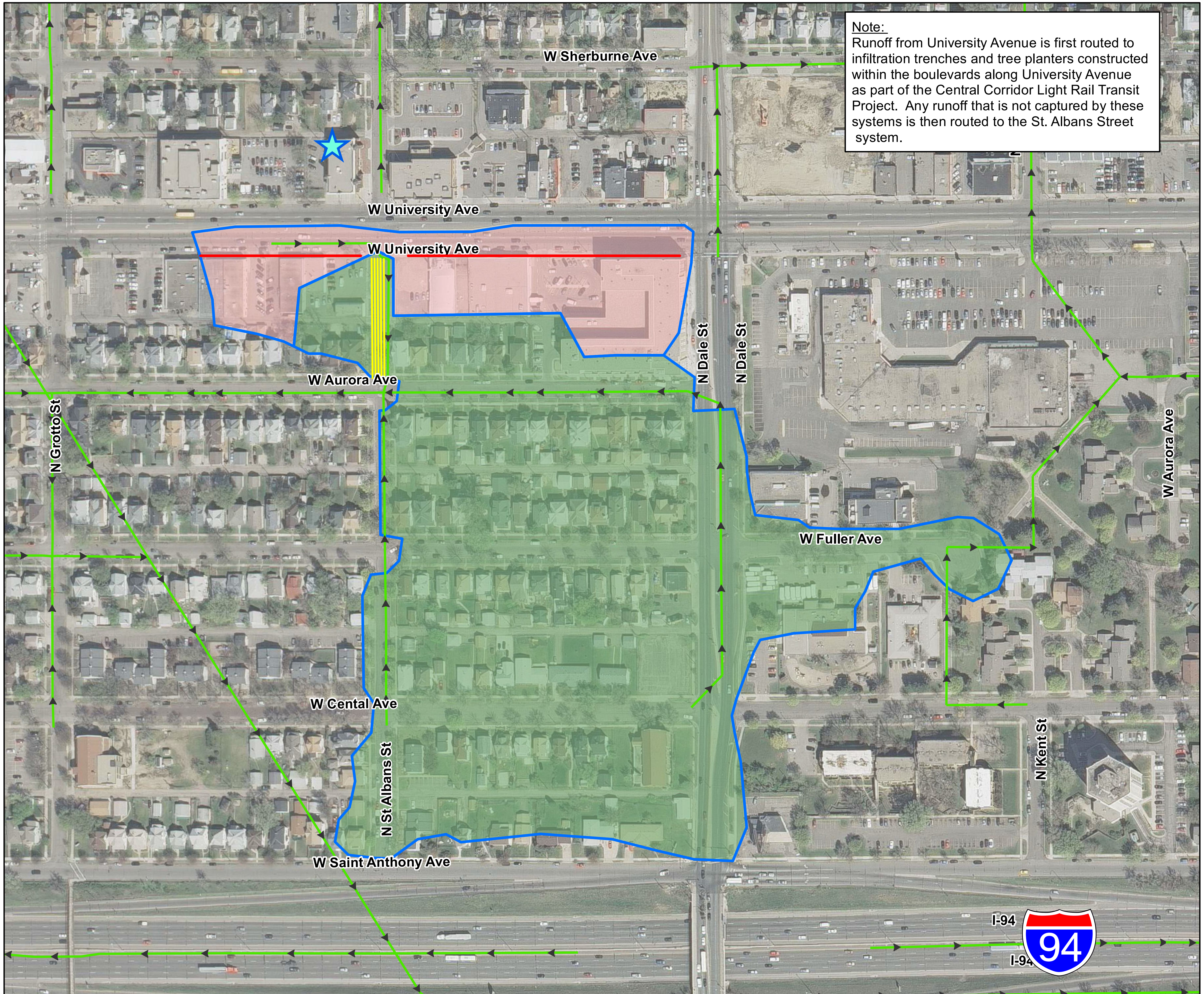
N W E S

0 150 300 600 Feet

Legend

- Ex. Storm Sewer
- City Boundaries
- Subwatershed
- Infiltration BMP

WSB & Associates, Inc.



City of St. Paul

2014 Water Quantity and Quality Monitoring Program

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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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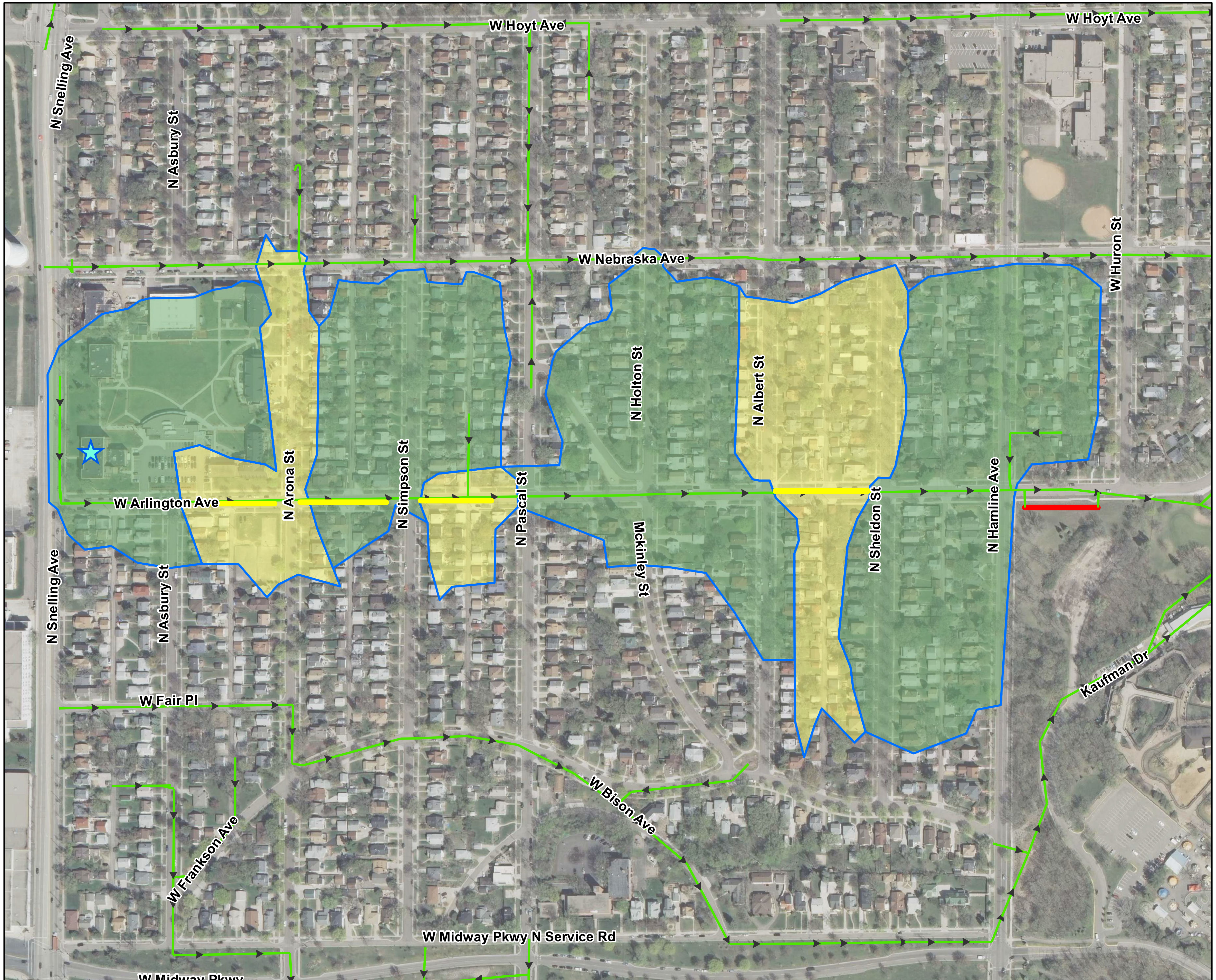

City of St. Paul

2014 Water Quantity and Quality Monitoring Program

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FIGURE 6-1
AHUG
Infiltration BMP
Drainage Areas

N
W E
S

0 150 300 600
Feet

Legend

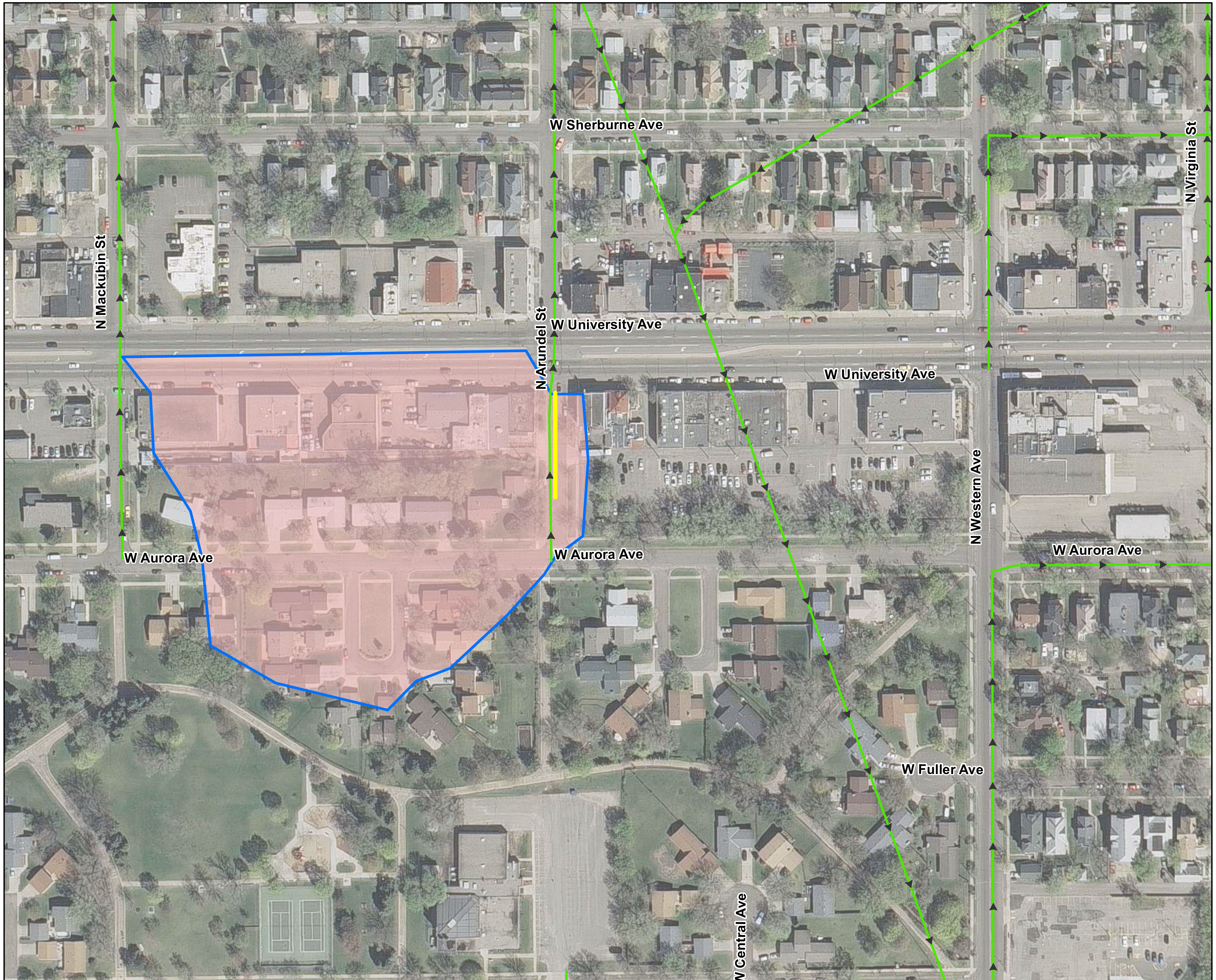
Infiltration BMPs

- AHUG
- Arlington Pascal RSVP Infiltration Trench
- Storm Pipe
- Rain Gauge Location

Drainage Areas

- Direct to AHUG
- Arlington Pascal RSVP Infiltration Trenches

WSB & Associates, Inc.



City of St. Paul

2014 Water Quantity and Quality Monitoring Program

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FIGURE 7-1

Arundel Street Infiltration BMP Drainage Areas

N
W E
S

0 75 150 300
Feet

Legend

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

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2014 Water Quantity and Quality Monitoring Program

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FIGURE 8-1
Hampden Park Infiltration BMP Drainage Areas

N W E S

0 60 120 240 360 480 Feet

Legend

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

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City of St. Paul

2014 Water Quantity and Quality Program

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Figure 9-1
Dale Street Facility Site Map

Legend

- Project Boundary
- Water Quality Manhole
- Sampling Location
- 10' Contour
- 2' Contour
- Storm Sewer Pipe
- Storm Sewer Catch Basin
- Storm Sewer Manhole
- Storm Sewer Flared End

N S E W

0 150 300 Feet

WSB

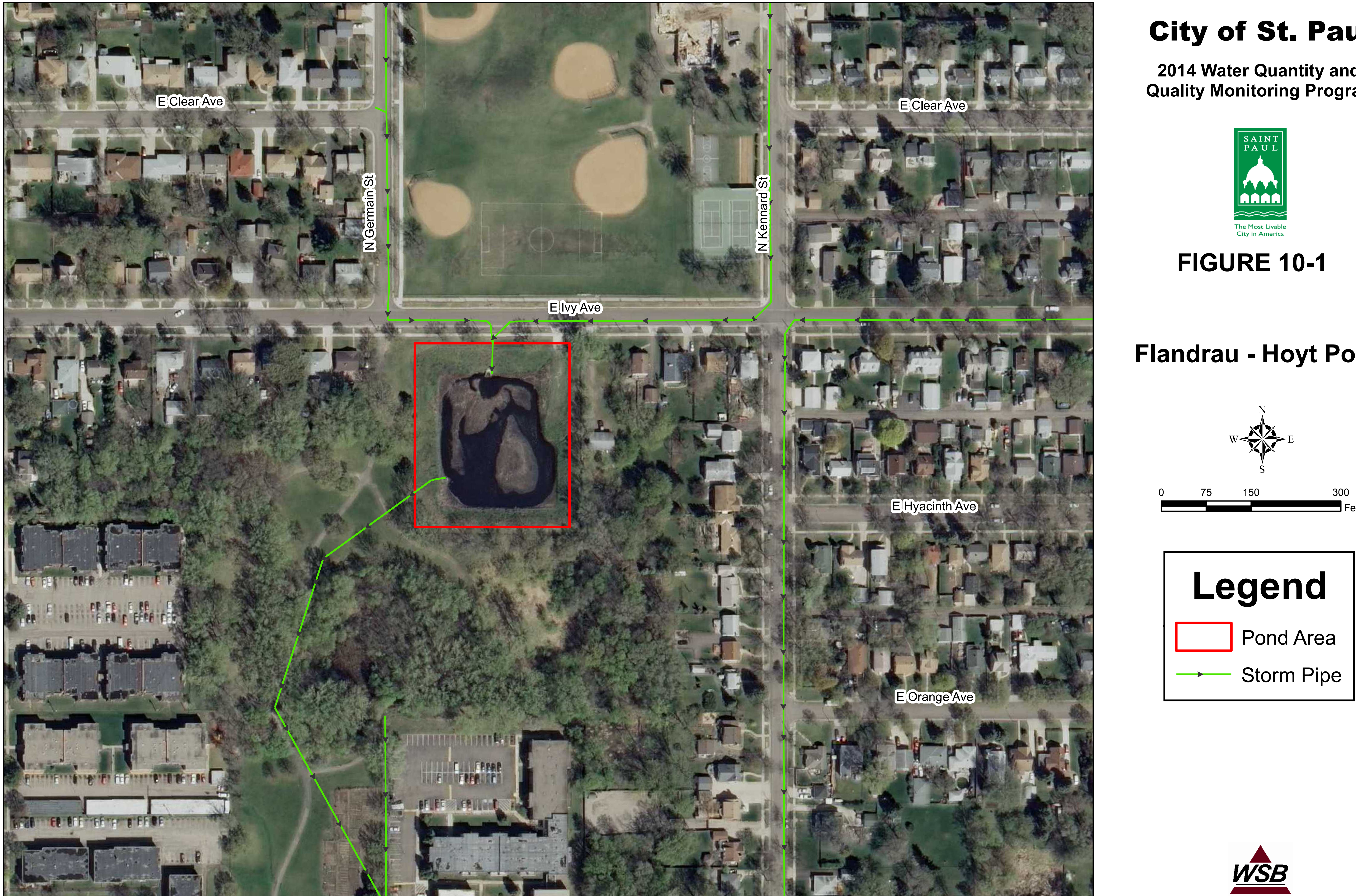
Path: K:\01610-100\GIS\Maps\Figures\2014\Figure 9-1 - Dale Stree Facility Sit

City of St. Paul

2014 Water Quantity and Quality Monitoring Program

FIGURE 10-1

Flandrau - Hoyt Pond



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2014 Water Quantity and Quality Monitoring Program

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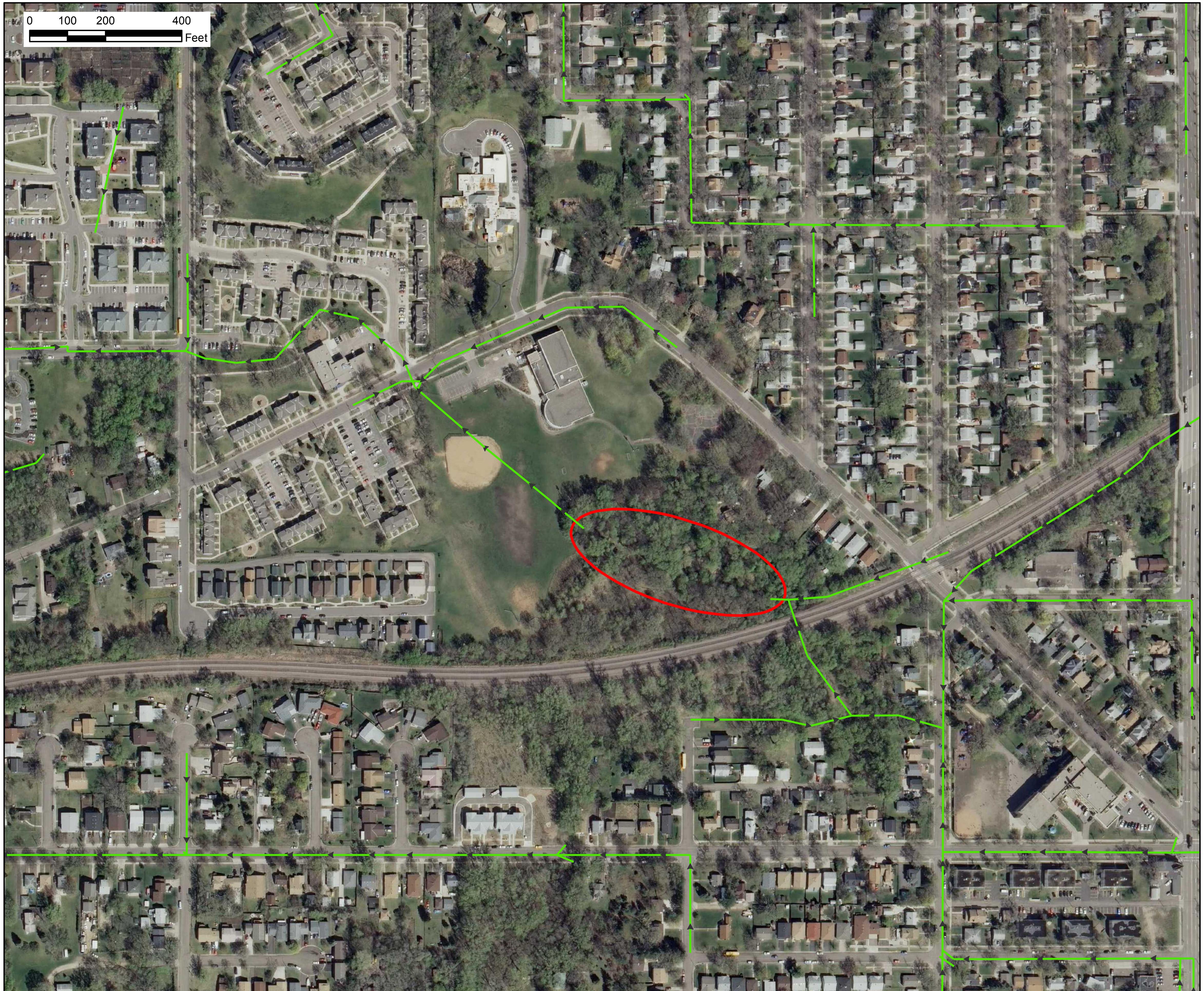
FIGURE 11-1

Flandrau - Case Pond



Legend

- Pond Area
- Storm Pipe

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2014 Water Quantity and Quality Monitoring Program

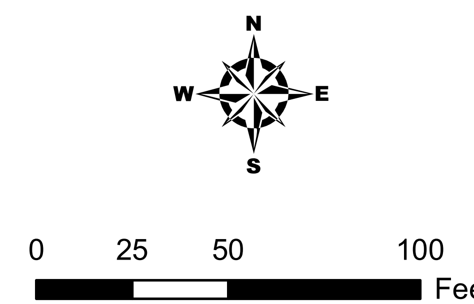

Figure 12-1

Victoria Street Pervious Pavement Testing

Legend

- storm_mh
- storm_cb
- Pervious Pavement Test Points
- storm_pipe
- Infiltration Trench
- Pervious Pavement
- Rain Gauge Location

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City of St. Paul

2014 Water Quantity and Quality Monitoring Program

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Figure 12-2

Hamline Midway Library Pervious Pavement Testing

N W E S

0 20 40 80 Feet

Legend

- storm_cb
- storm_mh
- Pervious Pavement Test Points
- storm_pipe
- Pervious Pavement

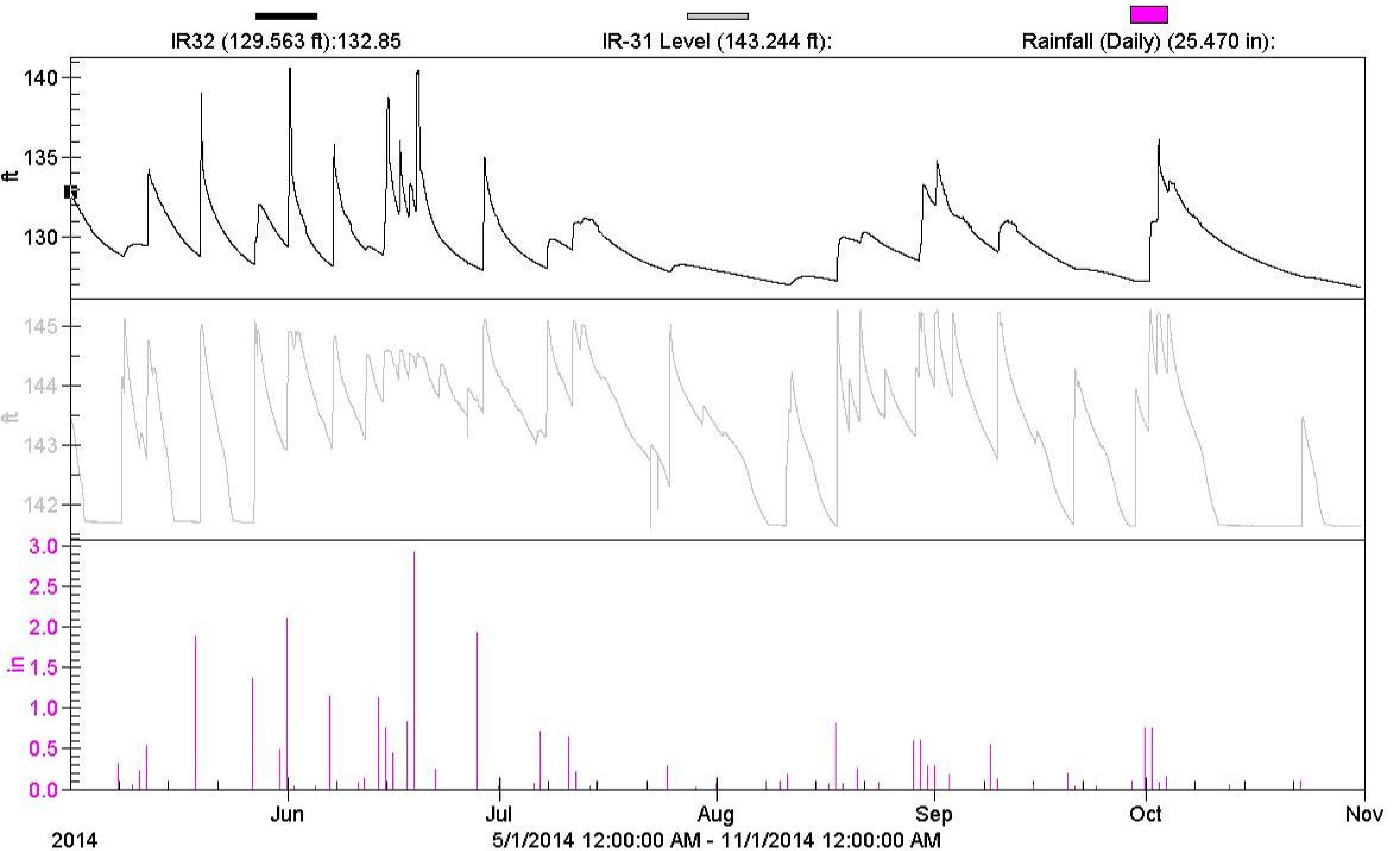
WSB & Associates, Inc.

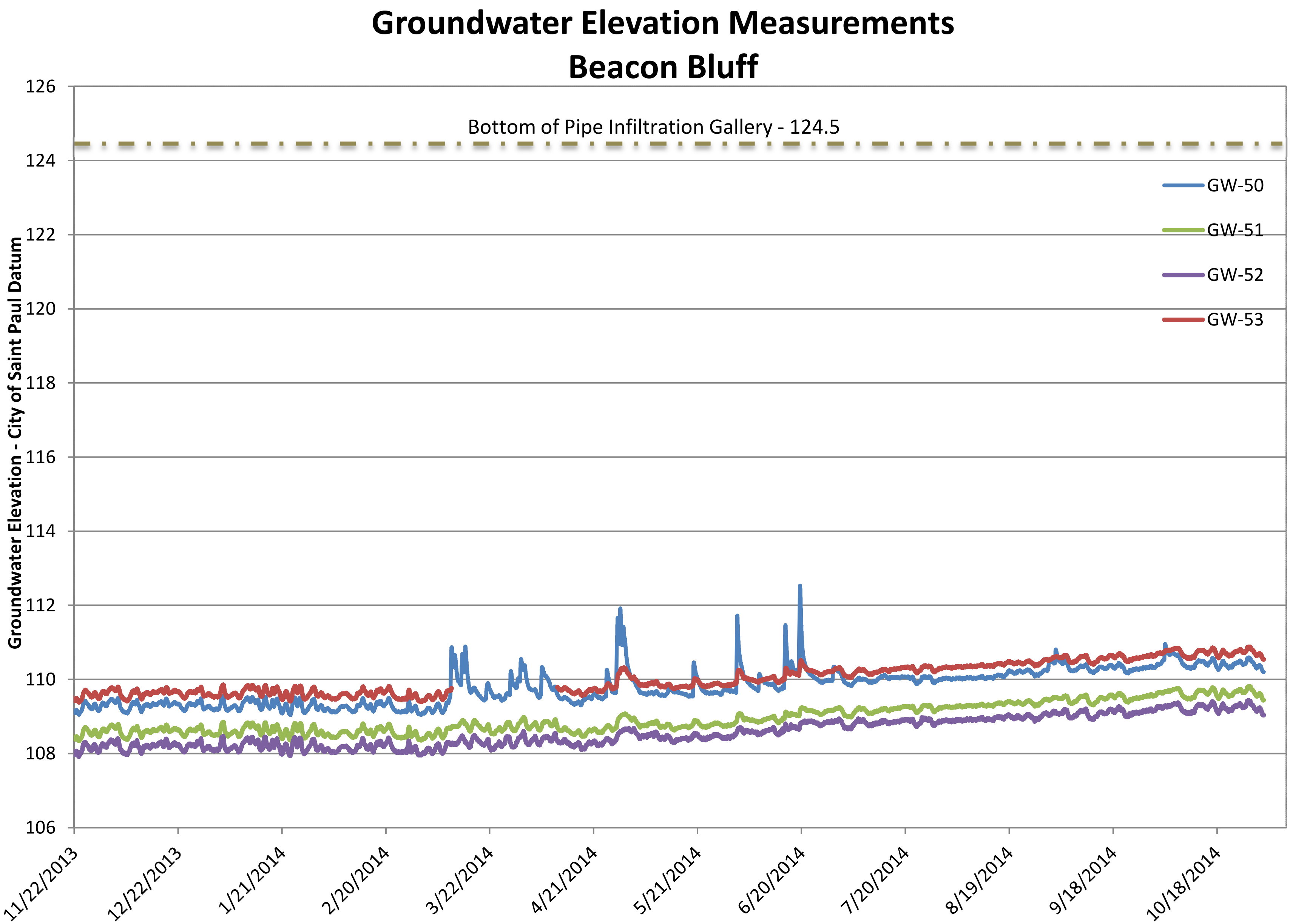
APPENDICES

5/1/2014 0:10, 132.846

Chart A.1 Beacon Bluff

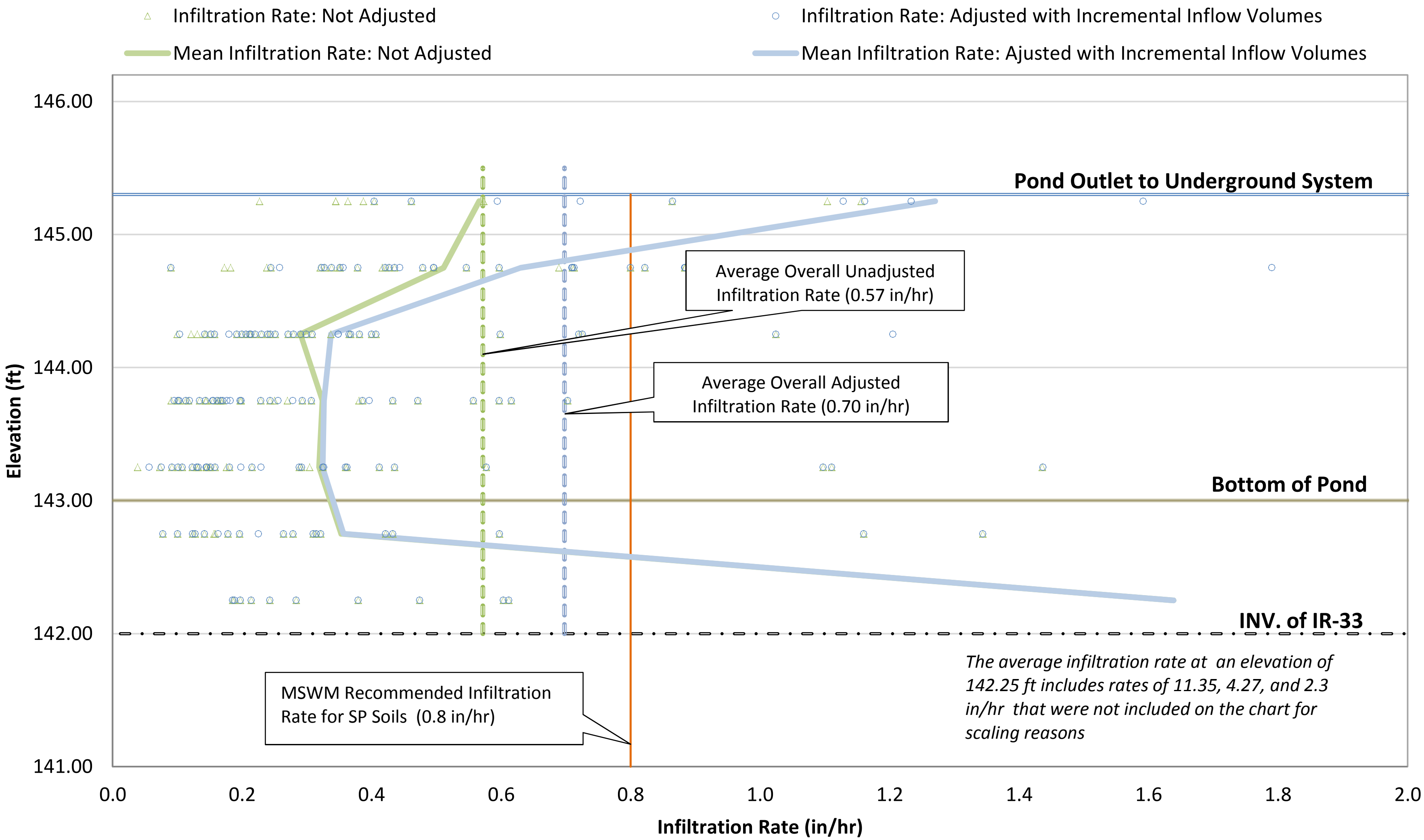
Water Level Elevation and Rainfall




Groundwater Elevation Measurements
Beacon Bluff
Bottom of Pipe Infiltration Gallery - 124.5
GW-50
GW-51
GW-52
GW-53
Groundwater Elevation - City of Saint Paul Datum
126
124
122
120
118
116
114
112
110
108
106
11/22/2013
12/22/2013
1/21/2014
2/20/2014
3/22/2014
4/21/2014
5/21/2014
6/20/2014
7/20/2014
8/19/2014
9/18/2014
10/18/2014

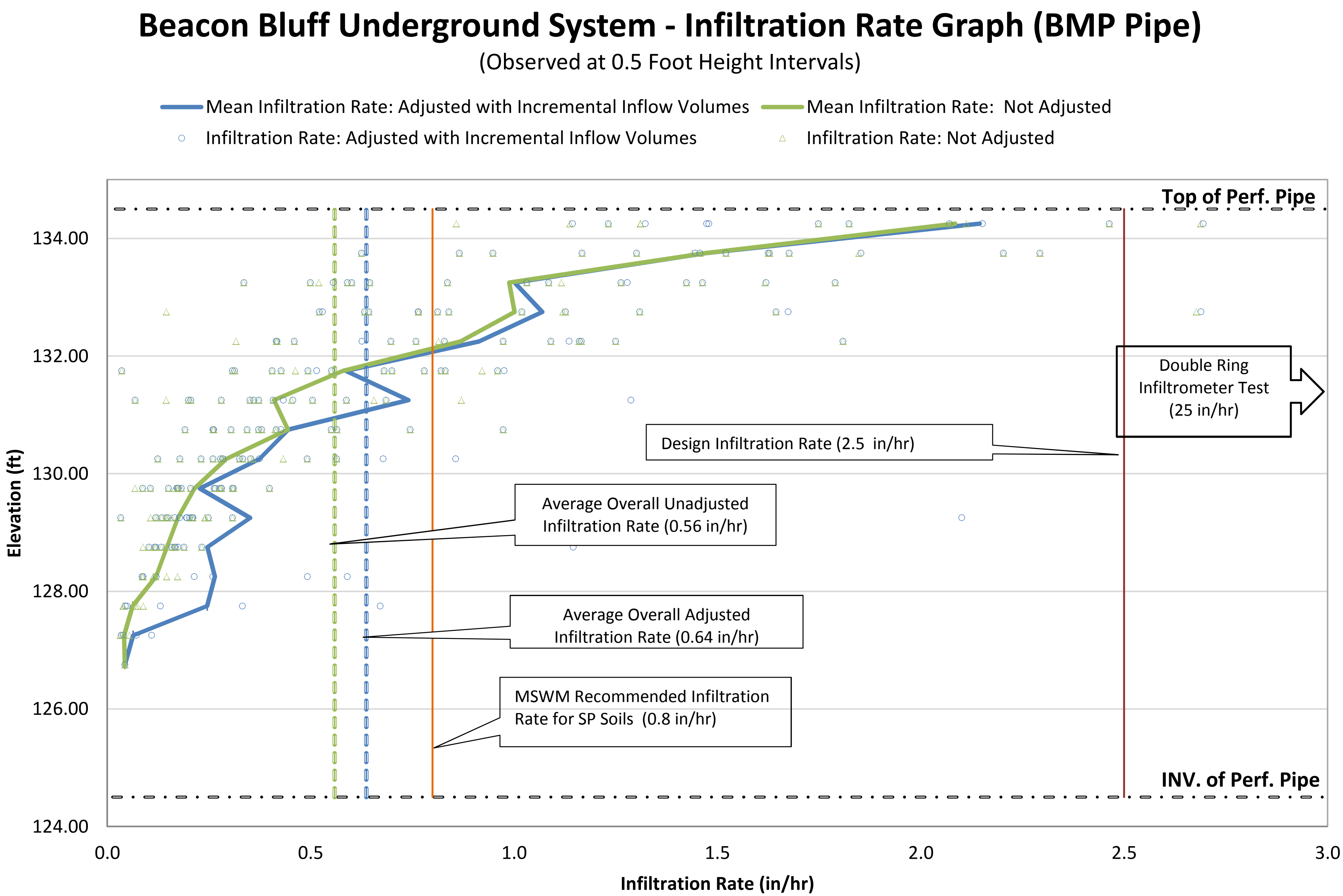
City of Saint Paul
2014 Water Quality and Quantity Monitoring
Chart A.3
WSB Project No.: 01610-100

Beacon Bluff Raingarden Soil - Infiltration Rate Graph (IR-31)
(Observed at 0.5 Foot Height Intervals)



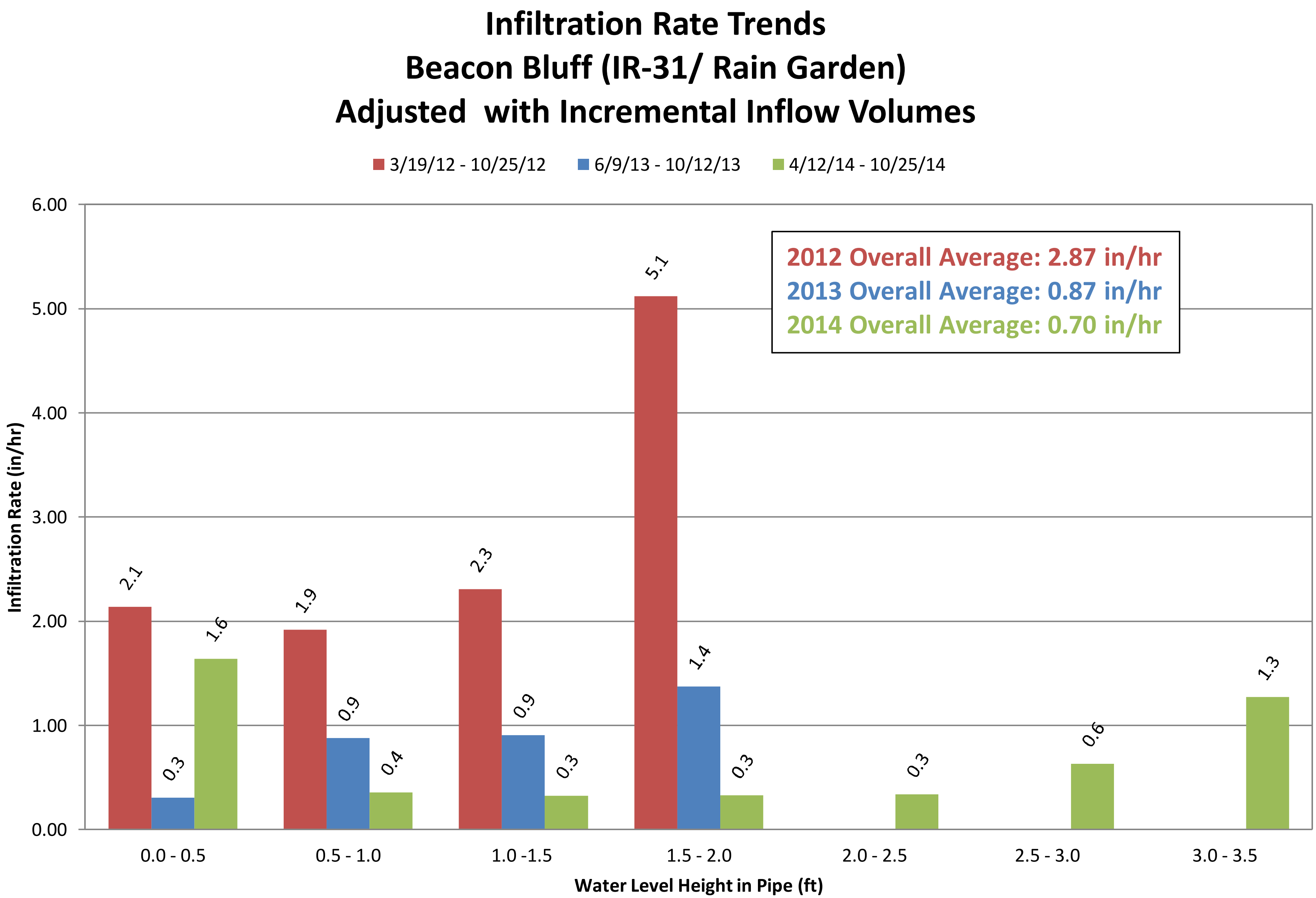
Note: Pipe Invert is 142.0'
Pipe perforated around circumference of pipe

City of Saint Paul
2014 Water Quality and Quantity Report
Chart A.4
WSB Project No.: 01610-100



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

City of Saint Paul
2014 Water Quality and Quantity Report
Chart A.5
WSB Job No.: 01610-100



City of Saint Paul
2014 Water Quality and Quantity Report
Chart A.6
WSB Job No.: 01610-100

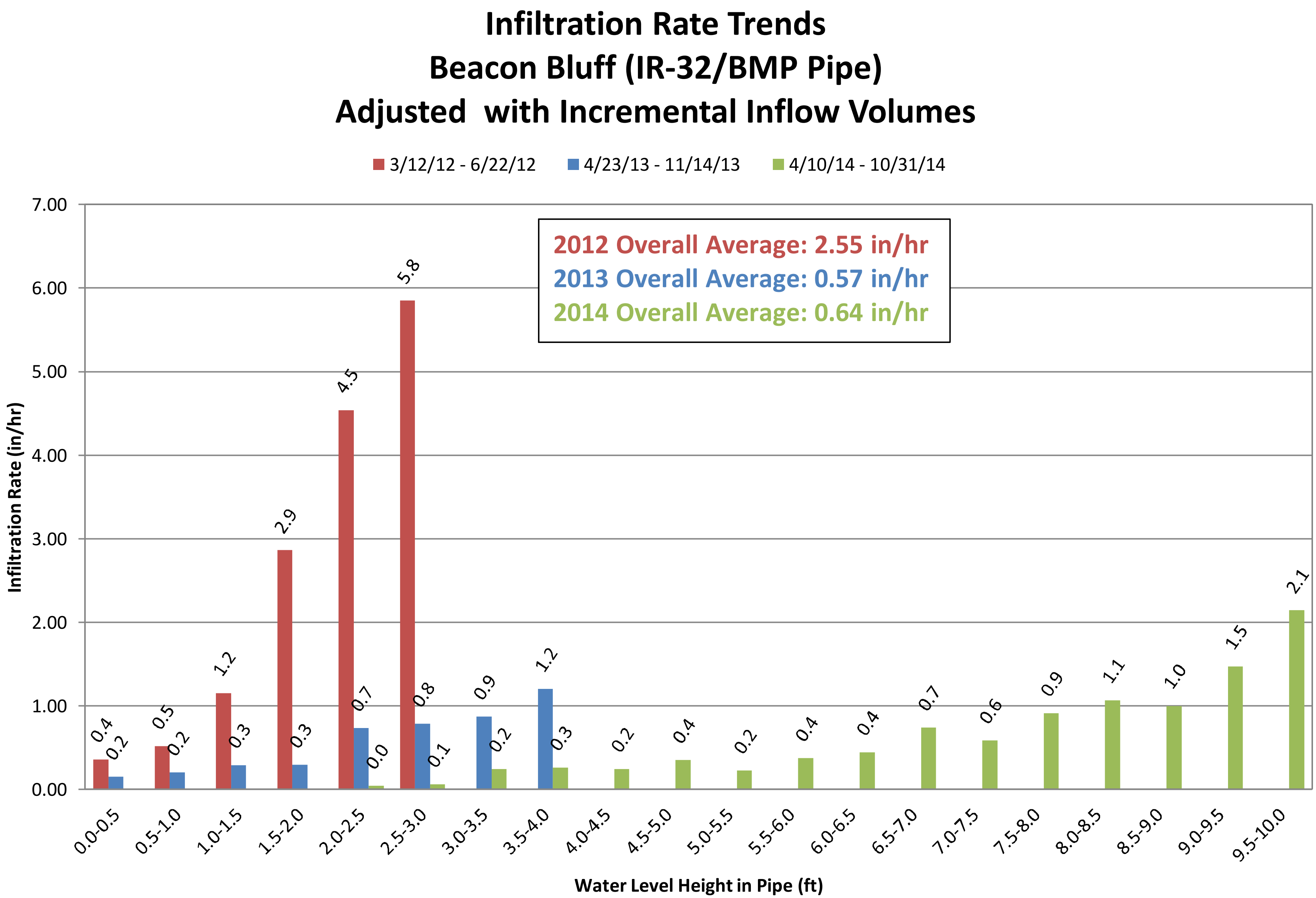
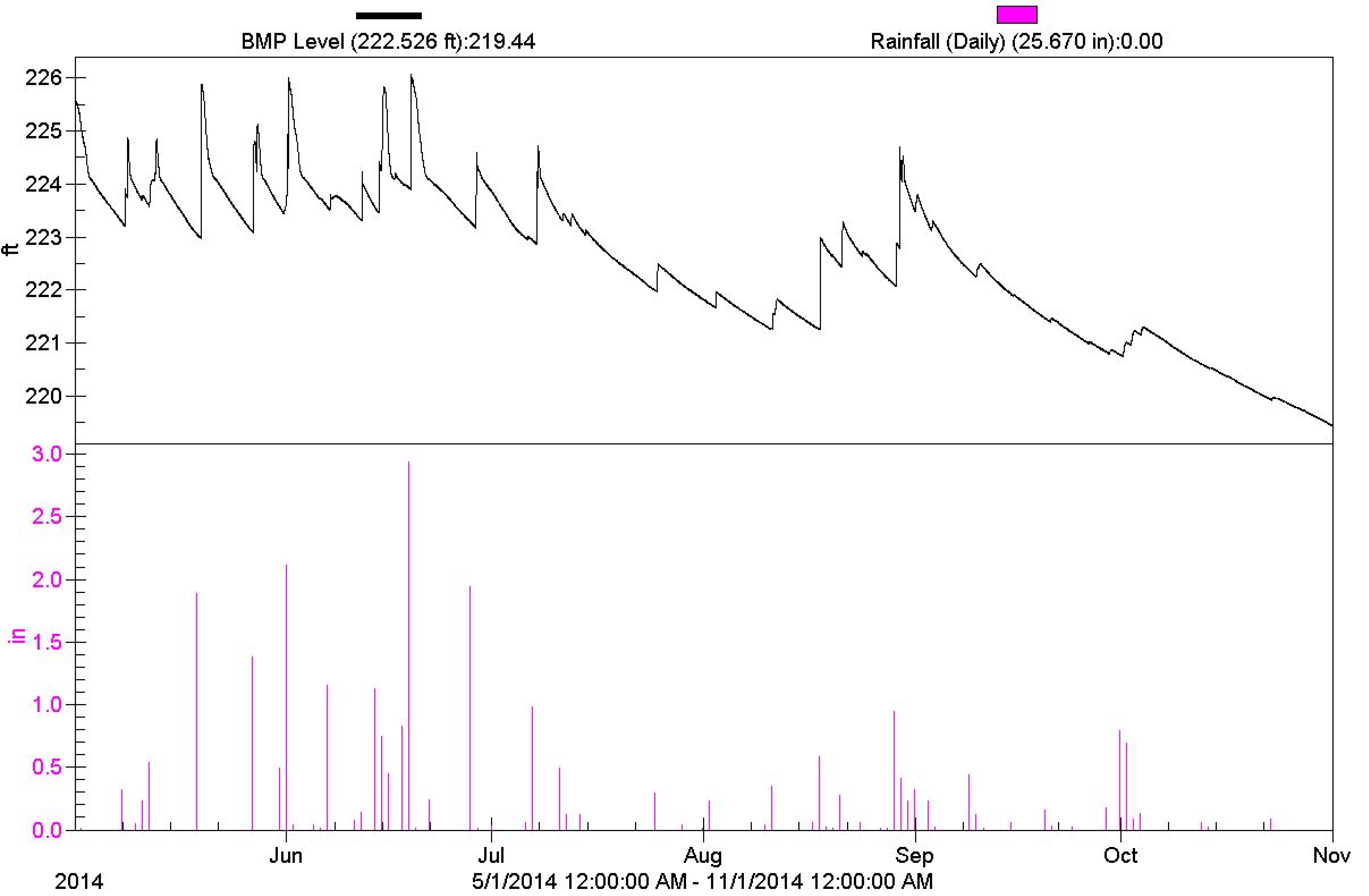
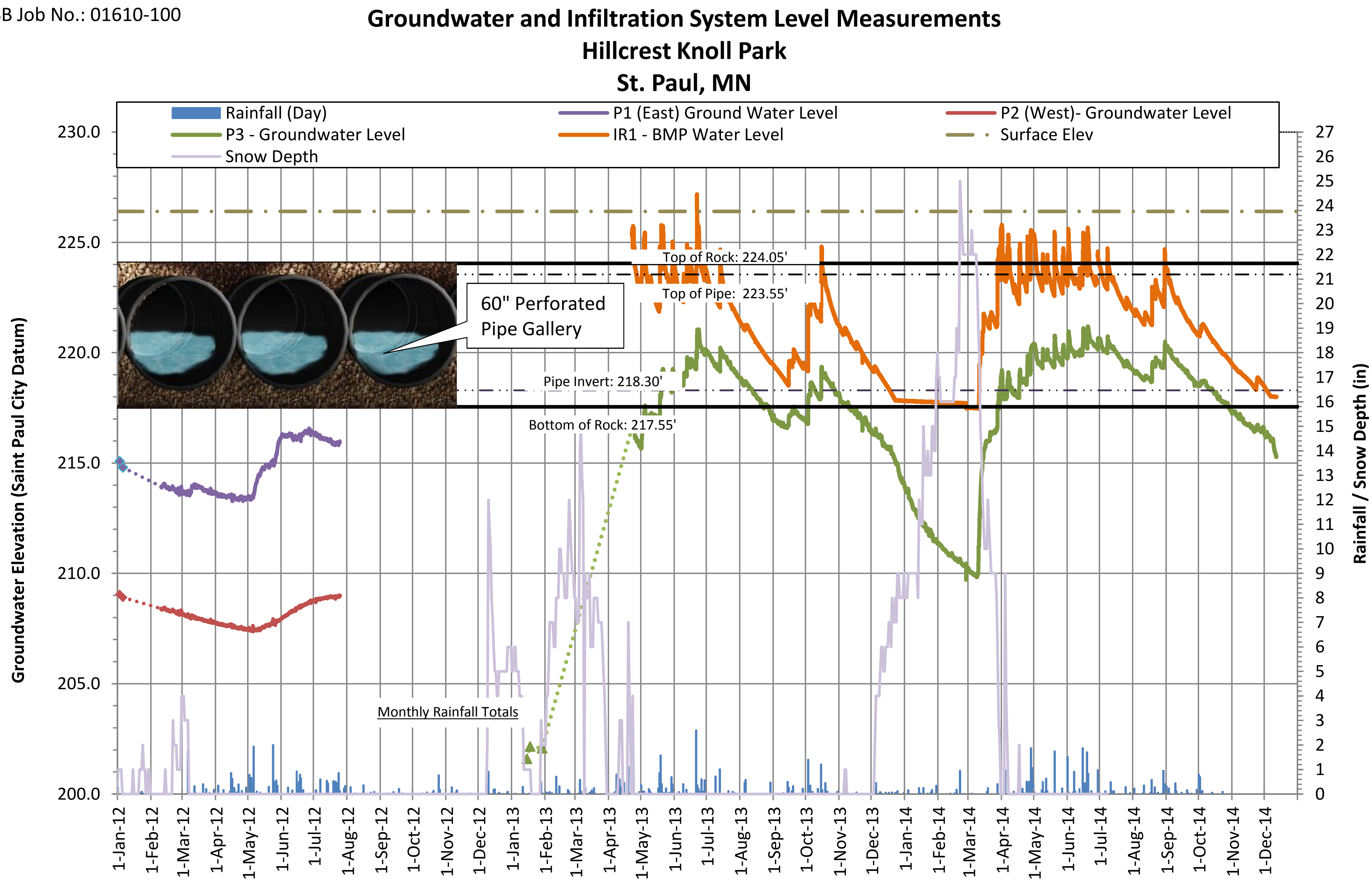


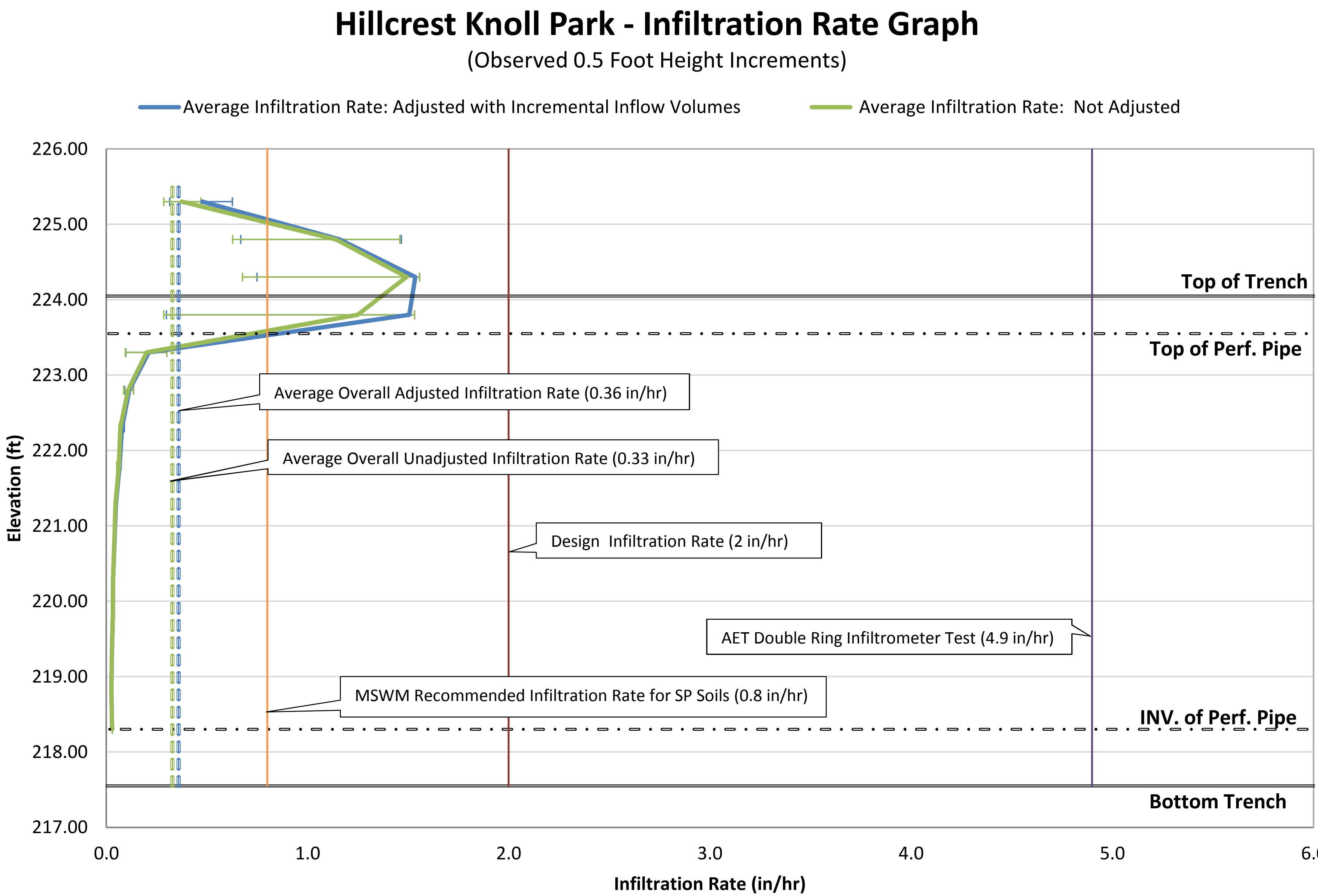
Chart A.7 Hillcrest Knoll

Water Level Elevation and Rainfall

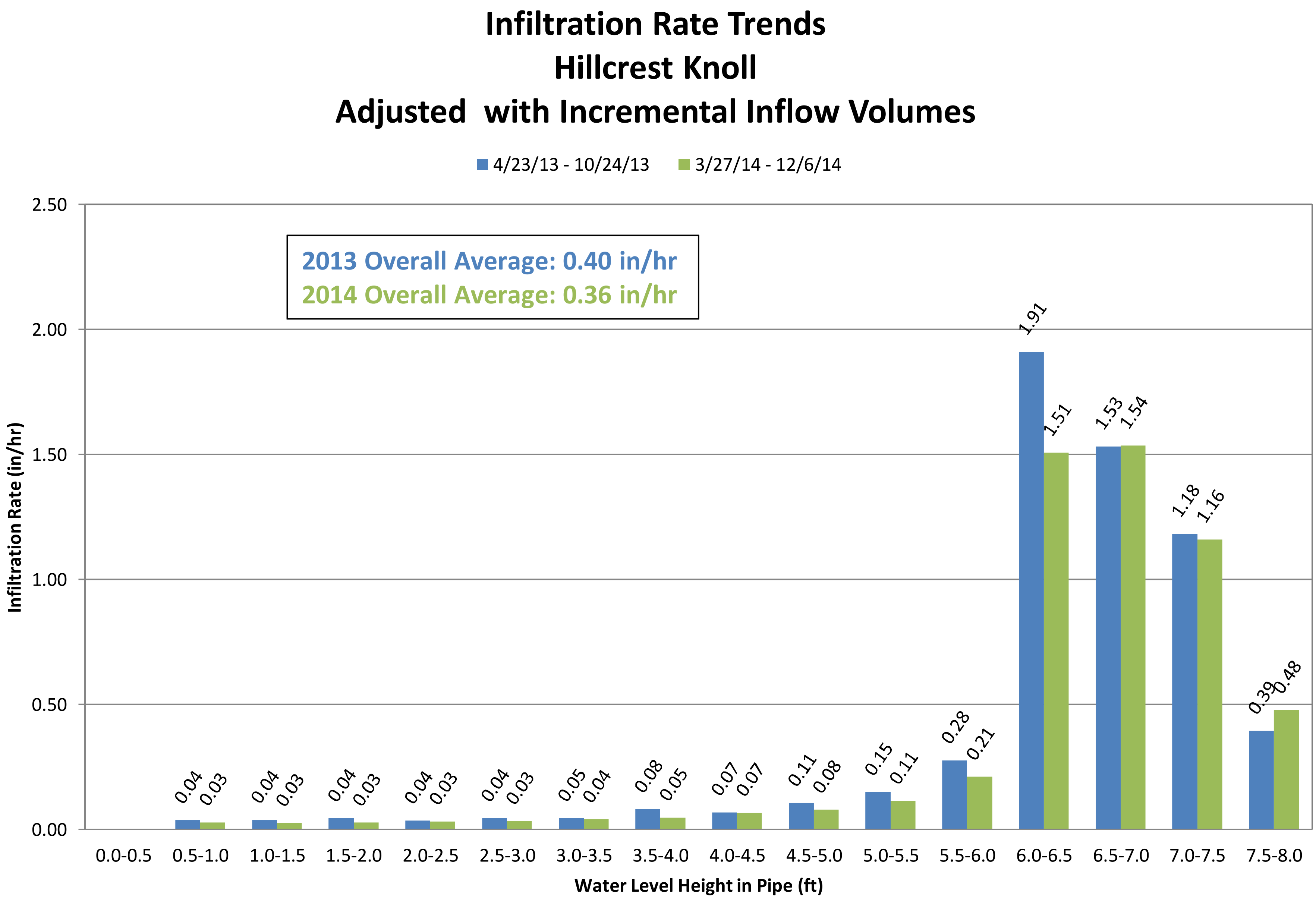


City of Saint Paul
2014 Water Quality and Quantity Report
Chart A.8
WSB Job No.: 01610-100





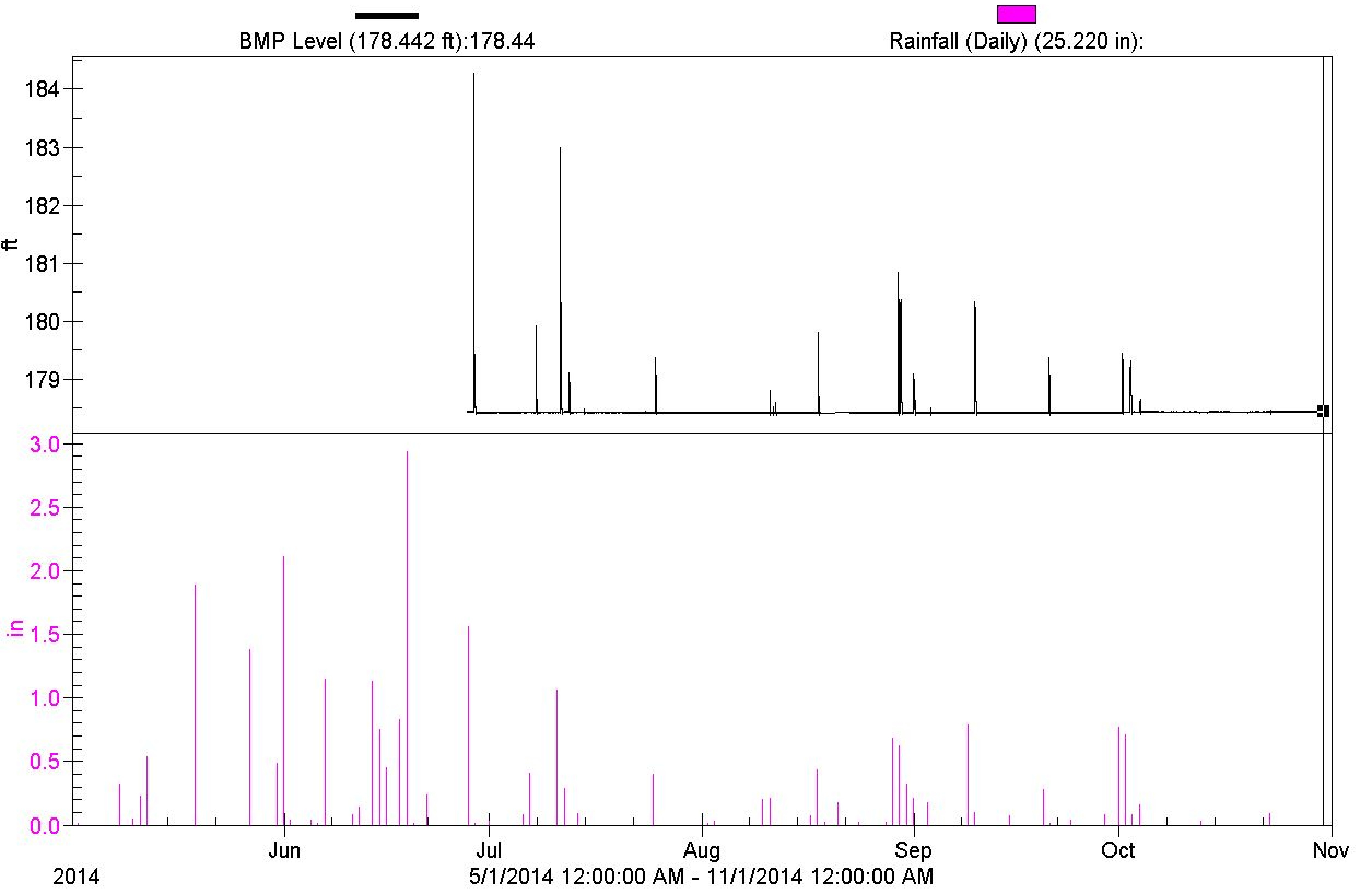
Note: Pipe Invert is 218.30'
Pipe perforated around circumference of pipe
Error Bars Represent 25th and 75th Percentiles


Infiltration Rate Trends
Hillcrest Knoll
Adjusted with Incremental Inflow Volumes
4/23/13 - 10/24/13
3/27/14 - 12/6/14
2013 Overall Average: 0.40 in/hr
2014 Overall Average: 0.36 in/hr
Infiltration Rate (in/hr)
Water Level Height in Pipe (ft)
2.50
2.00
1.50
1.00
0.50
0.00
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
0.04
0.03
0.05
0.04
0.08
0.05
0.07
0.07
0.11
0.08
0.15
0.11
0.28
0.21
1.91
1.51
1.53
1.54
1.18
1.16
0.39
0.48

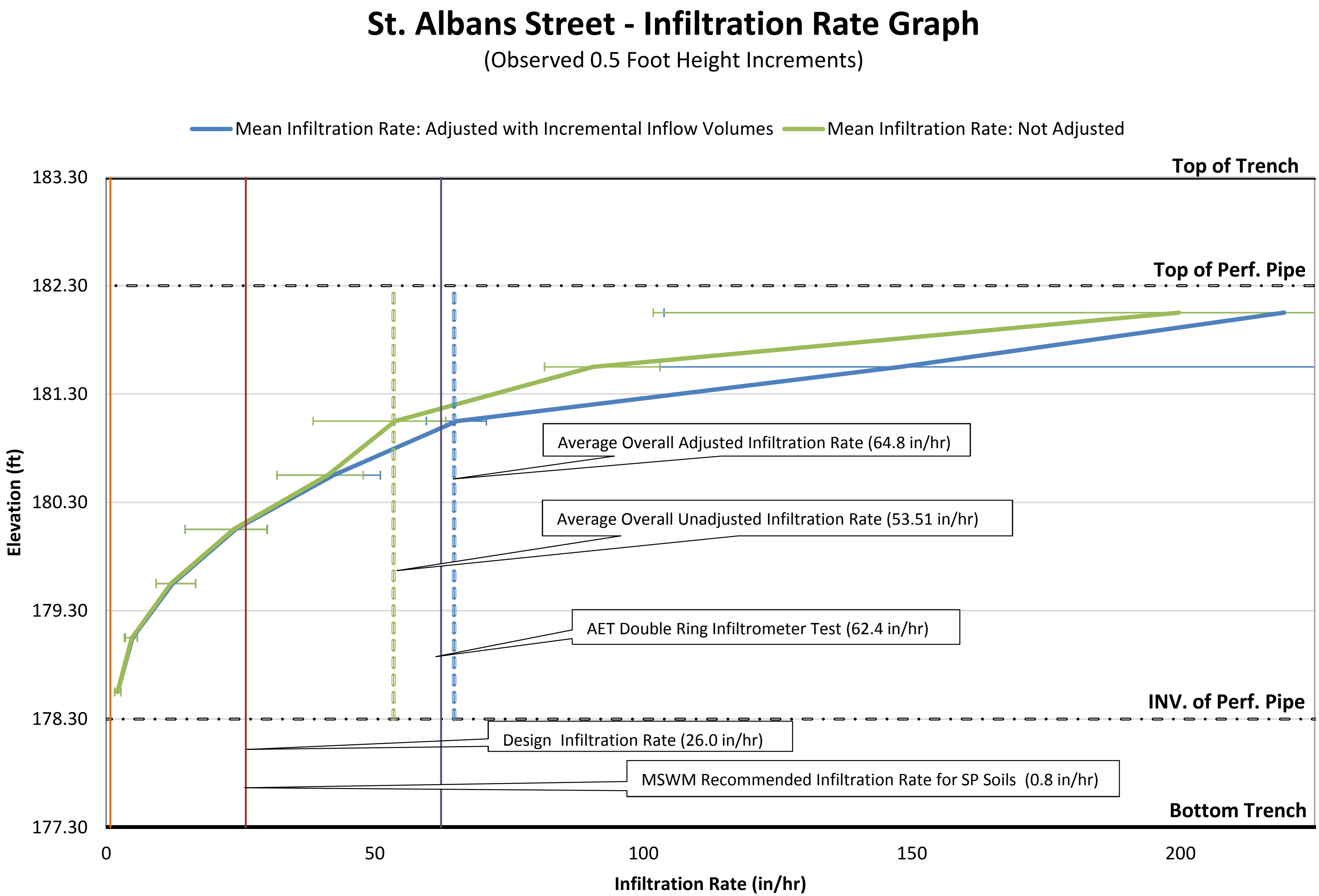
10/30/2014 17:26, 178.443

Chart A.11 St. Albans

Water Level Elevation and Rainfall



City of Saint Paul
2014 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'

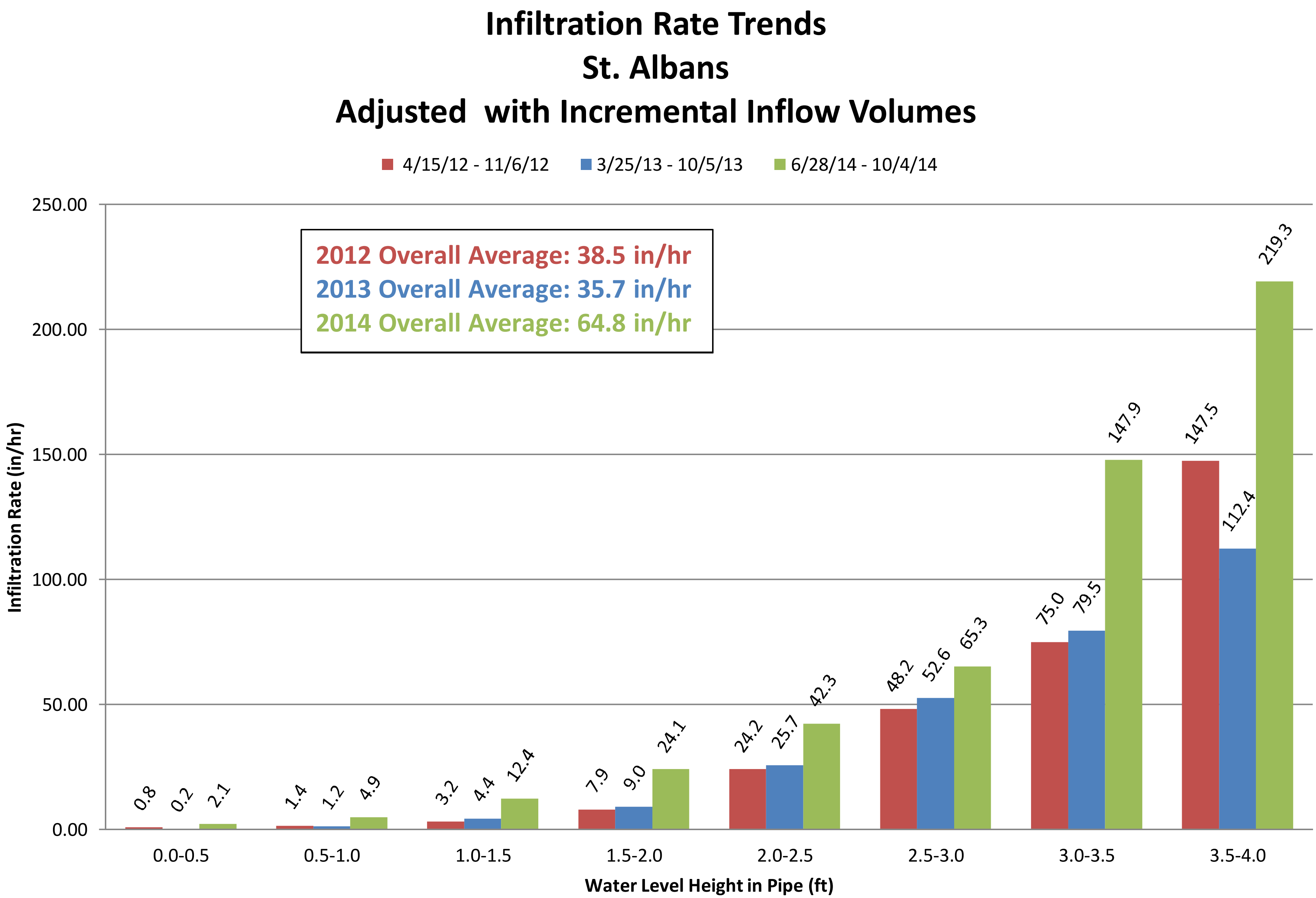
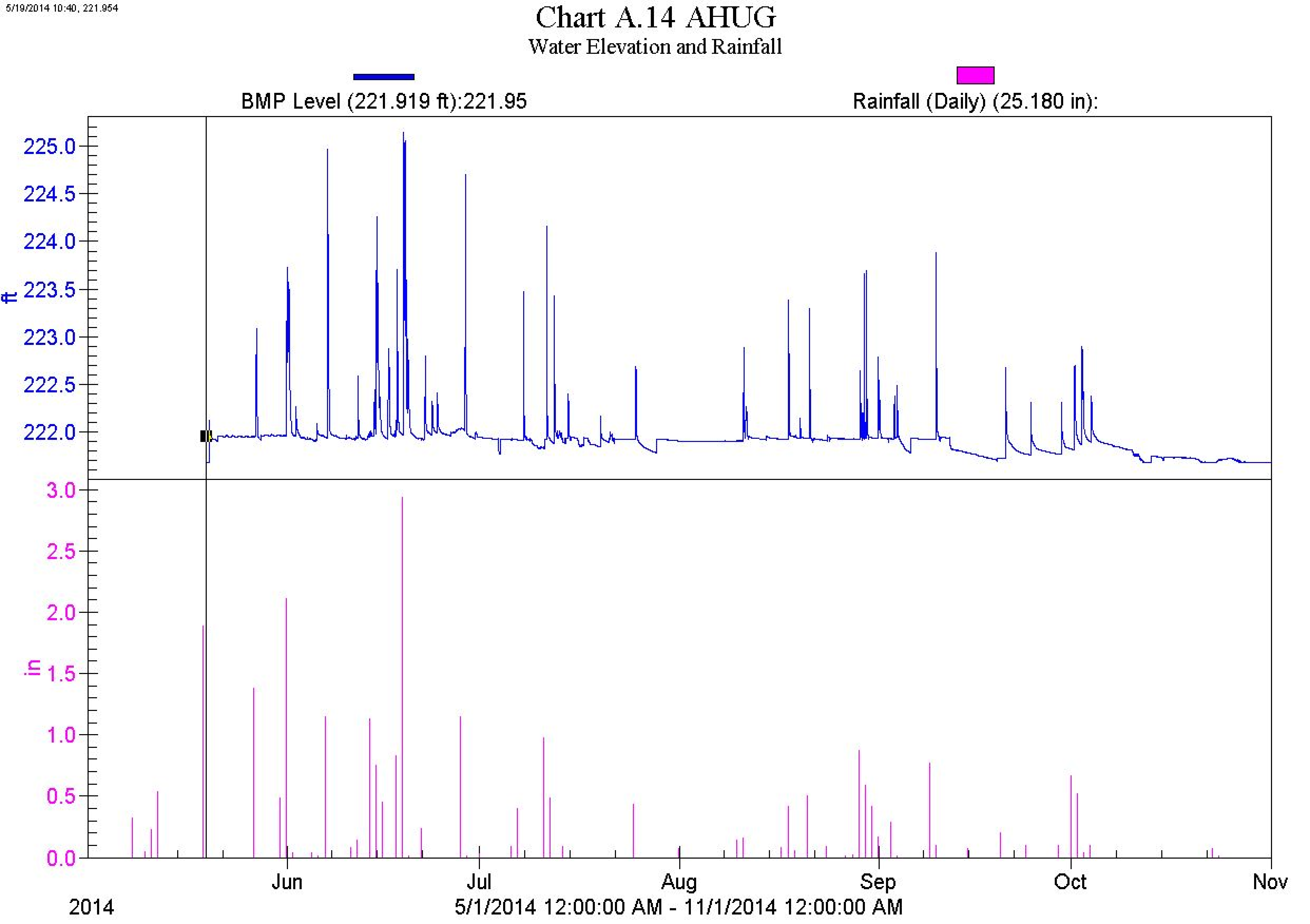
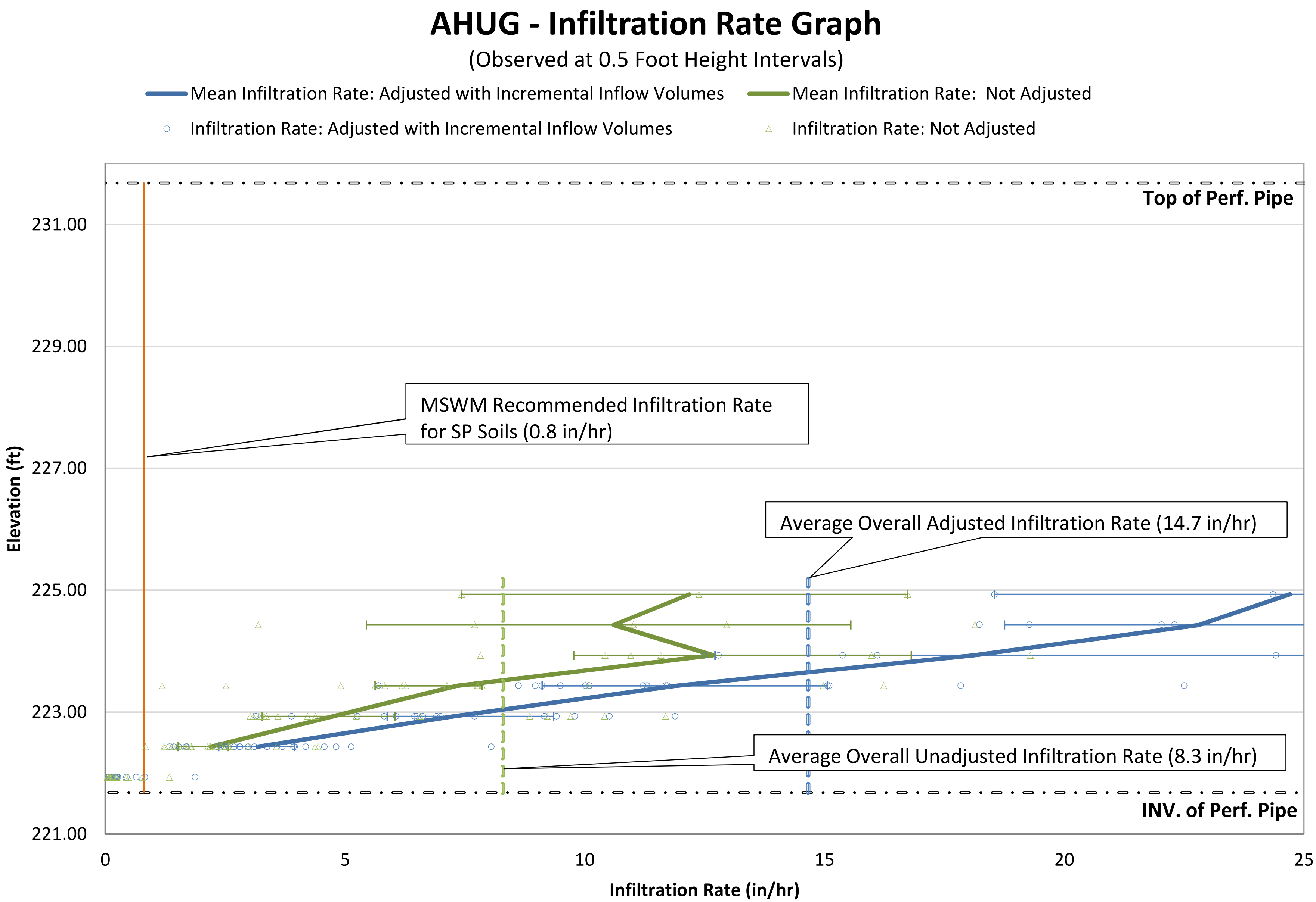

Infiltration Rate Trends
St. Albans
Adjusted with Incremental Inflow Volumes
4/15/12 - 11/6/12
3/25/13 - 10/5/13
6/28/14 - 10/4/14
2012 Overall Average: 38.5 in/hr
2013 Overall Average: 35.7 in/hr
2014 Overall Average: 64.8 in/hr
Infiltration Rate (in/hr)
250.00
200.00
150.00
100.00
50.00
0.00
0.8
0.2
2.1
1.4
1.2
4.9
3.2
4.4
12.4
7.9
9.0
24.1
24.2
25.7
42.3
48.2
52.6
65.3
75.0
79.5
147.9
147.5
112.4
219.3
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
3.5-4.0
Water Level Height in Pipe (ft)

Chart A.14 AHUG

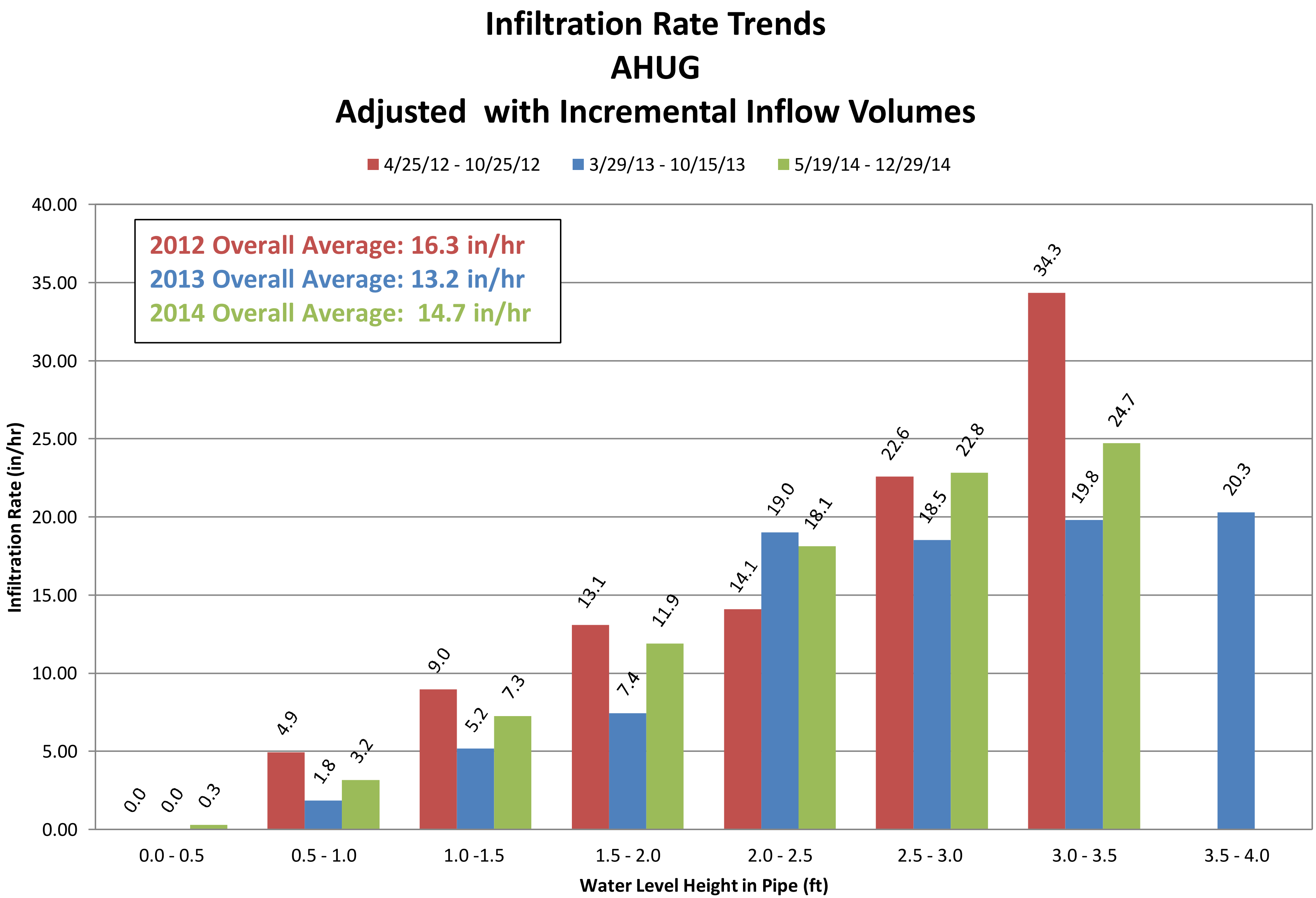
Water Elevation and Rainfall



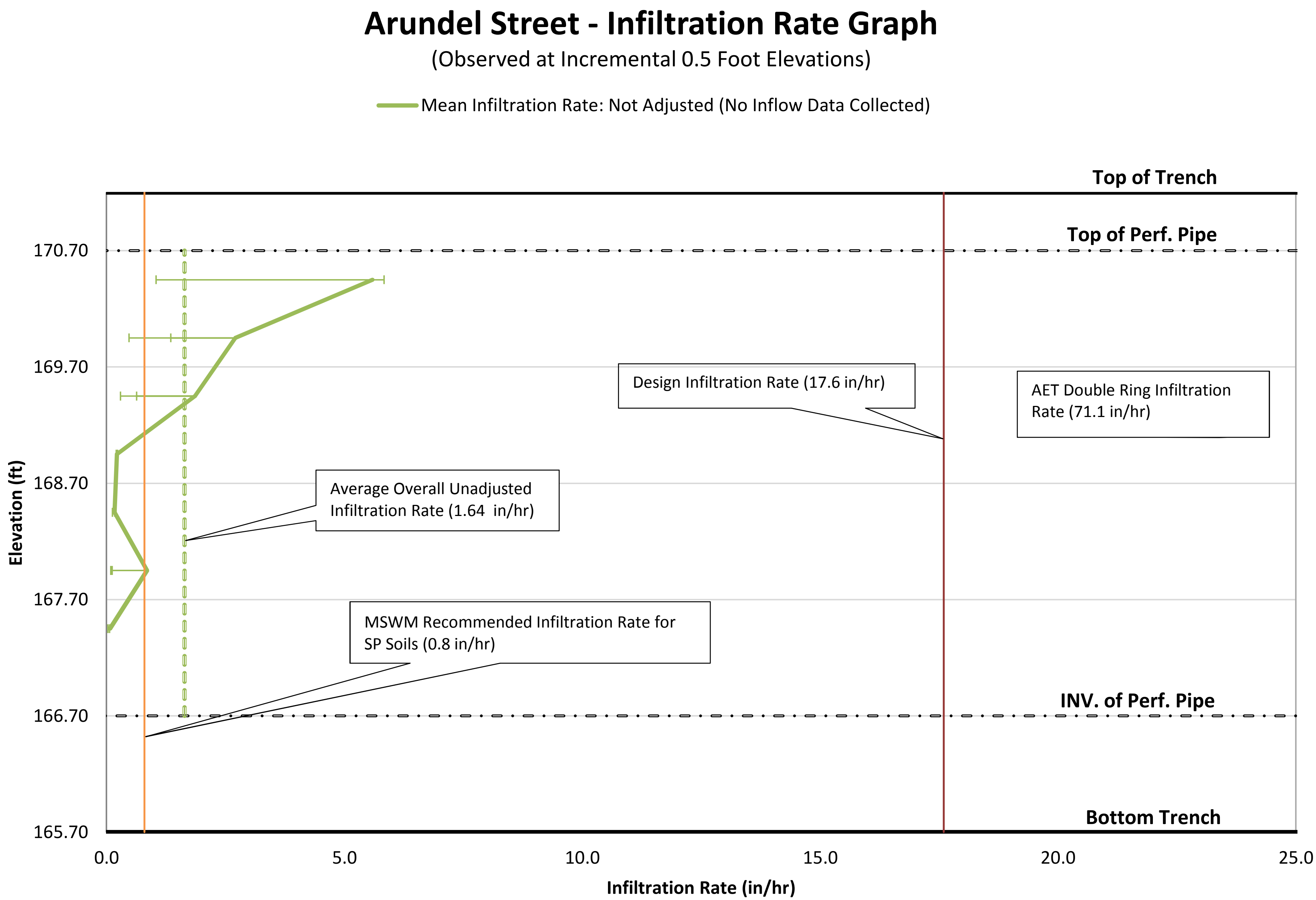
City of Saint Paul
2014 Water Quality and Quantity Report
Chart A.15
WSB Job No.: 01610-100



Note: Pipe Invert is 221.68'
Pipe perforated around circumference of pipe
Error Bars Represent 25th and 75th Percentiles


Infiltration Rate Trends
AHUG
Adjusted with Incremental Inflow Volumes
4/25/12 - 10/25/12
3/29/13 - 10/15/13
5/19/14 - 12/29/14
2012 Overall Average: 16.3 in/hr
2013 Overall Average: 13.2 in/hr
2014 Overall Average: 14.7 in/hr
Infiltration Rate (in/hr)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.0
0.0
0.3
4.9
1.8
3.2
9.0
5.2
7.3
13.1
7.4
11.9
14.1
19.0
18.1
22.6
18.5
22.8
34.3
19.8
24.7
20.3
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
3.5 - 4.0
Water Level Height in Pipe (ft)

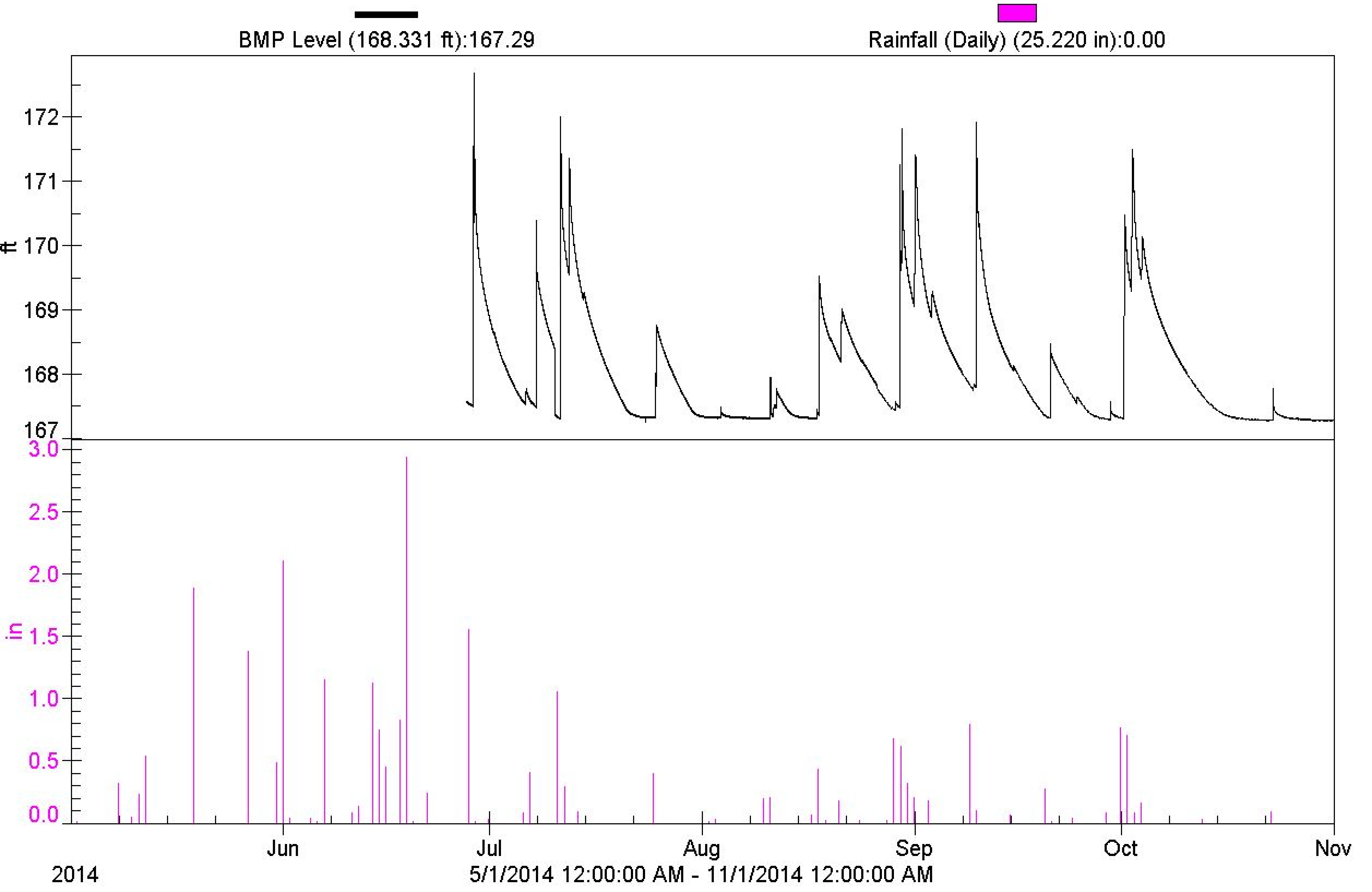
City of Saint Paul
2014 Water Quality and Quantity
Chart A.16
WSB Job No.: 01610-100



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'

Chart A.17 Arundel

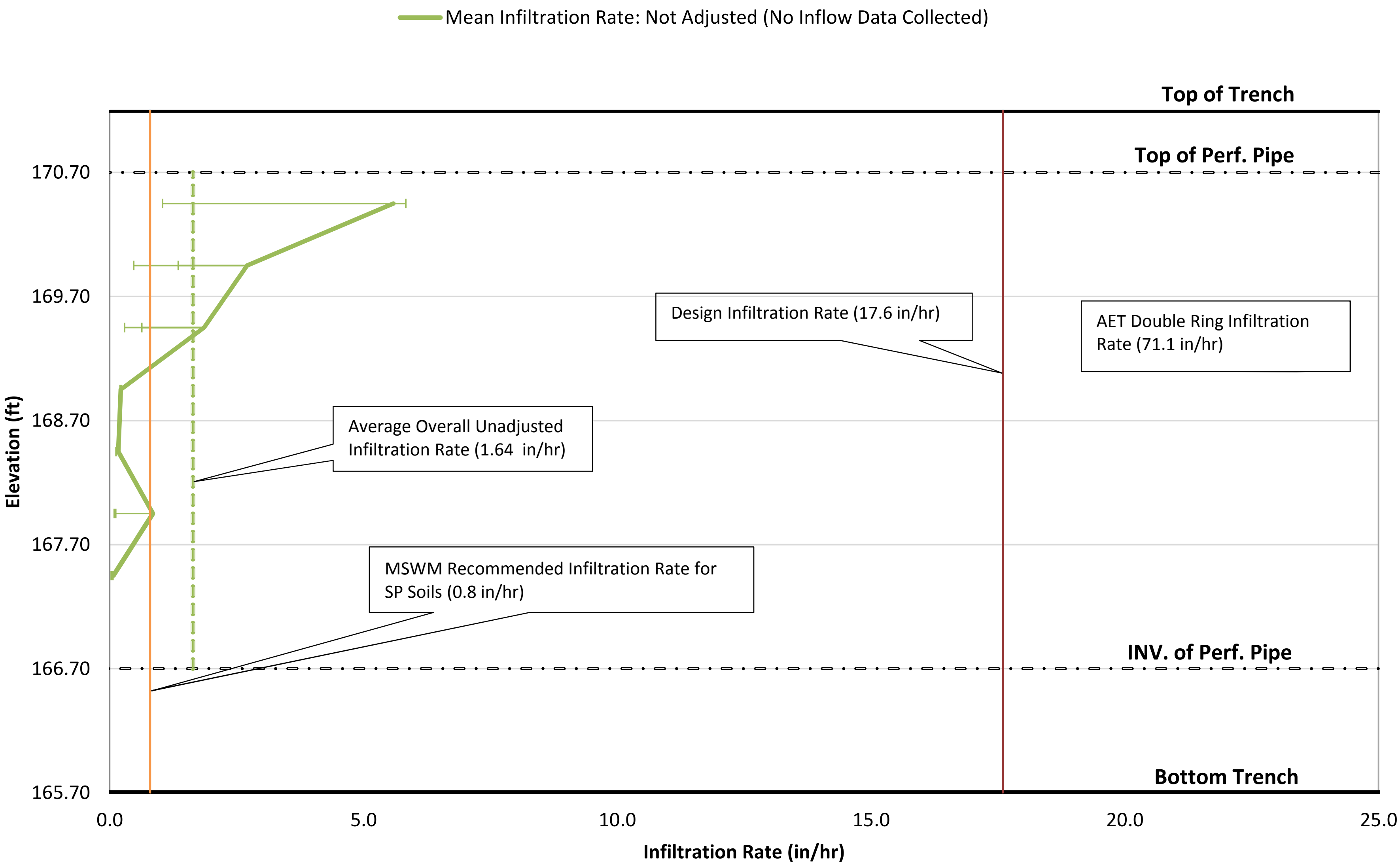
Water Level Elevation and Rainfall



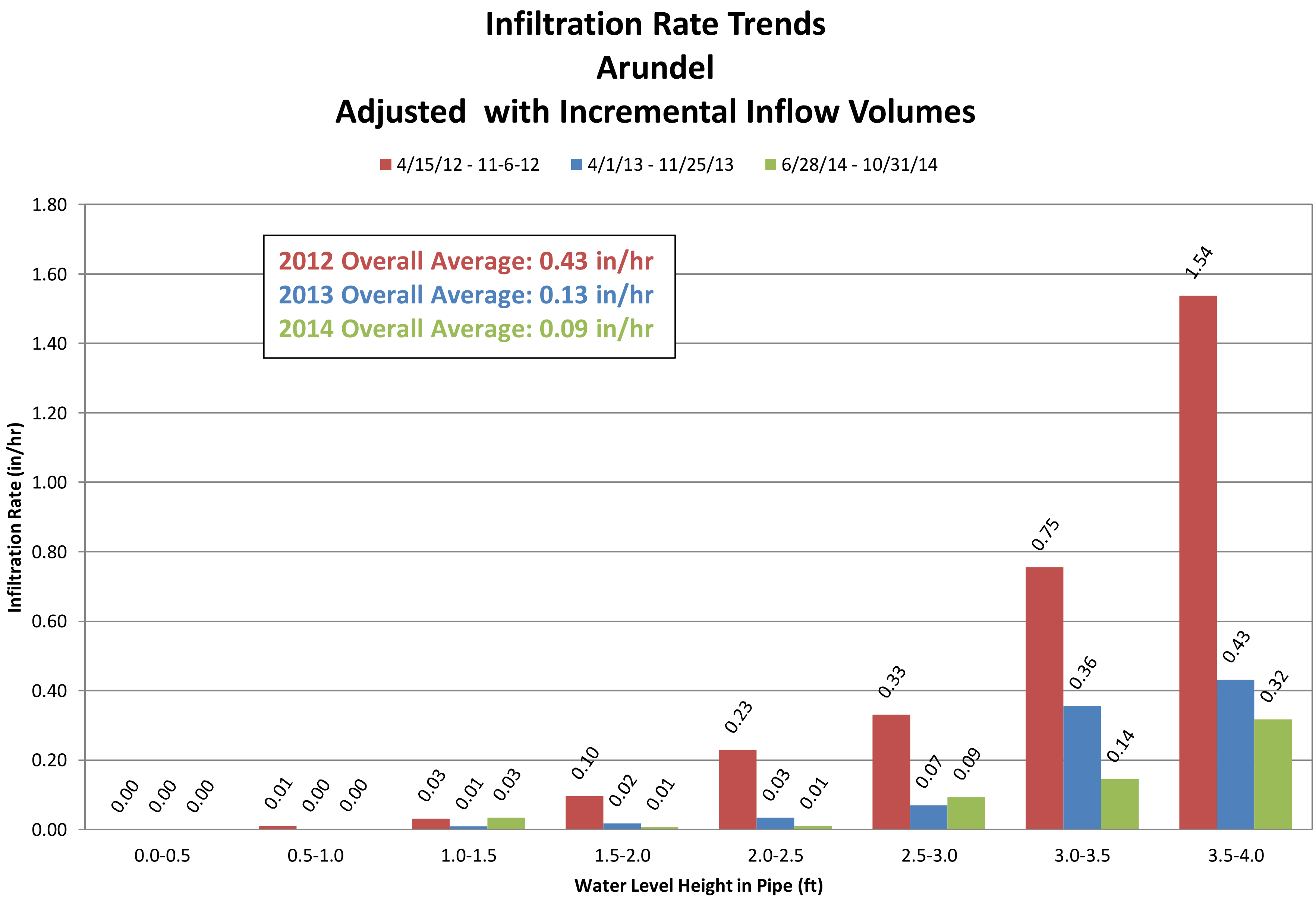
City of Saint Paul
2014 Water Quality and Quantity
Chart A.18
WSB Job No.: 01610-100

Arundel Street - Infiltration Rate Graph

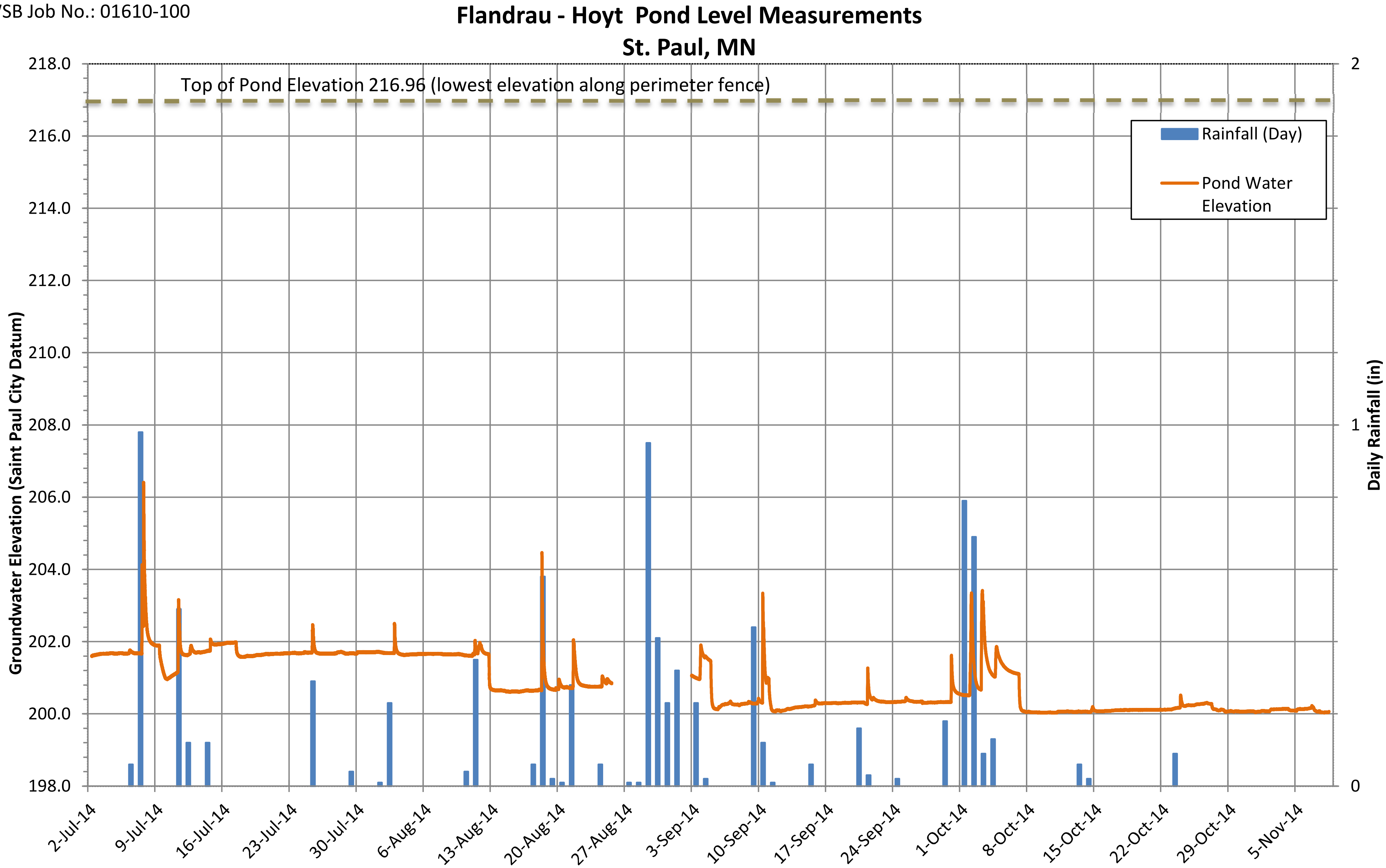
(Observed at Incremental 0.5 Foot Elevations)



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'


Infiltration Rate Trends
Arundel
Adjusted with Incremental Inflow Volumes
4/15/12 - 11-6-12
4/1/13 - 11/25/13
6/28/14 - 10/31/14
2012 Overall Average: 0.43 in/hr
2013 Overall Average: 0.13 in/hr
2014 Overall Average: 0.09 in/hr
Infiltration Rate (in/hr)
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00 0.00 0.00
0.01 0.00 0.00
0.03 0.01 0.03
0.10 0.02 0.01
0.23 0.03 0.01
0.33 0.07 0.09
0.75 0.36 0.14
1.54 0.43 0.32
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)

City of Saint Paul
2014 Water Quality and Quantity Report
Chart A.20
WSB Job No.: 01610-100



City of Saint Paul
2014 Water Quality and Quantity Report
Chart A.21
WSB Job No.: 01610-100

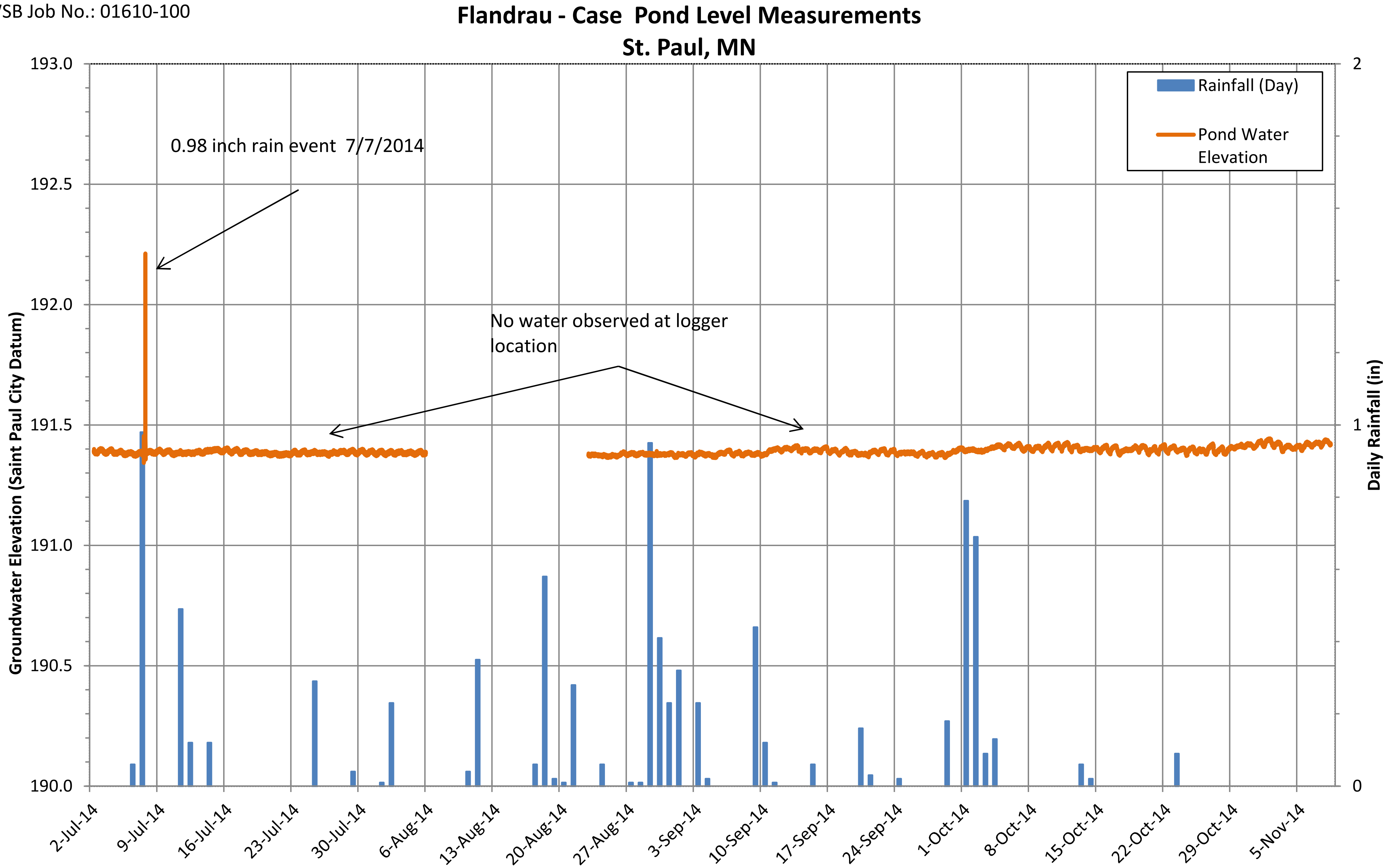
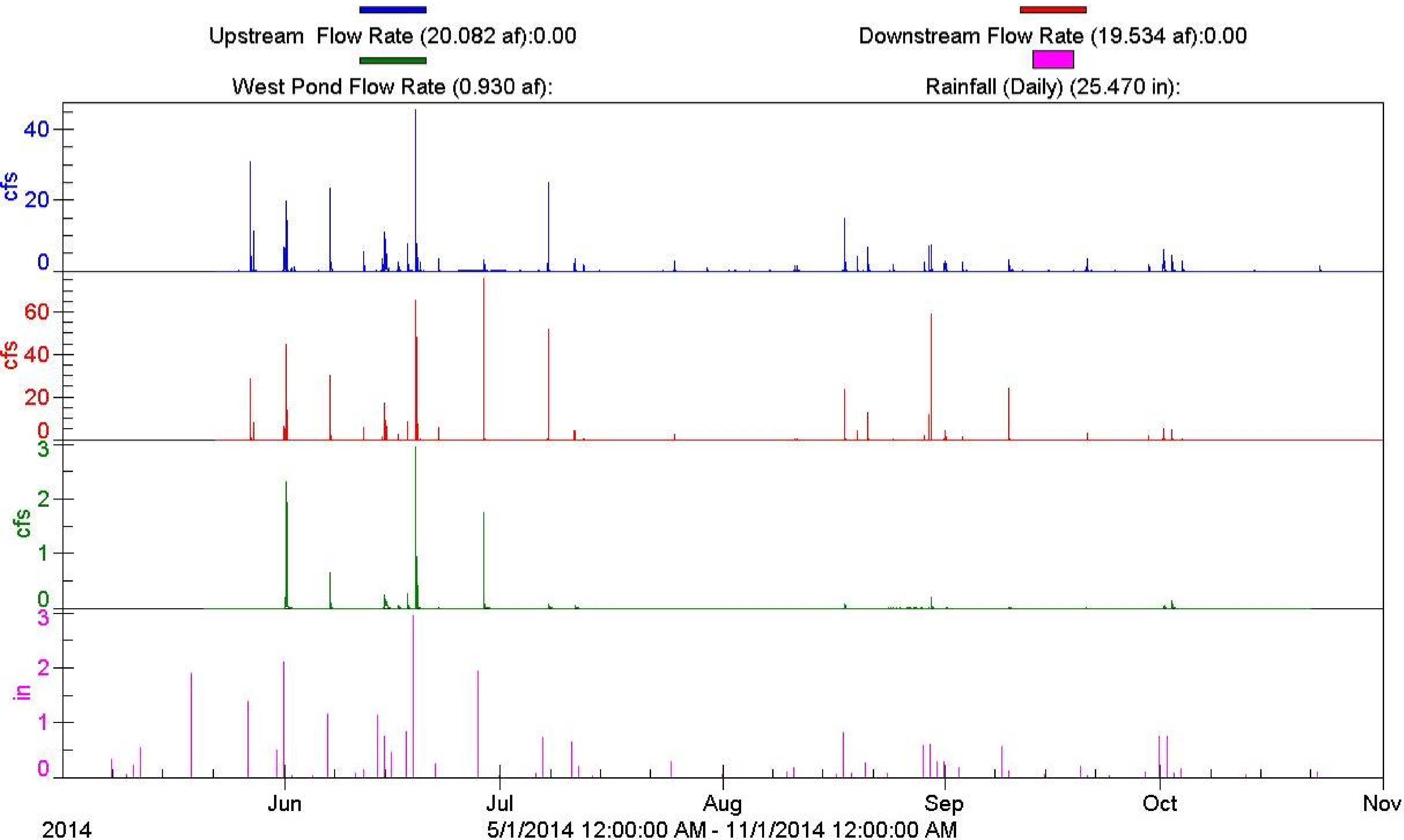


Chart B.1 Beacon Bluff

Flow Rates and Rainfall



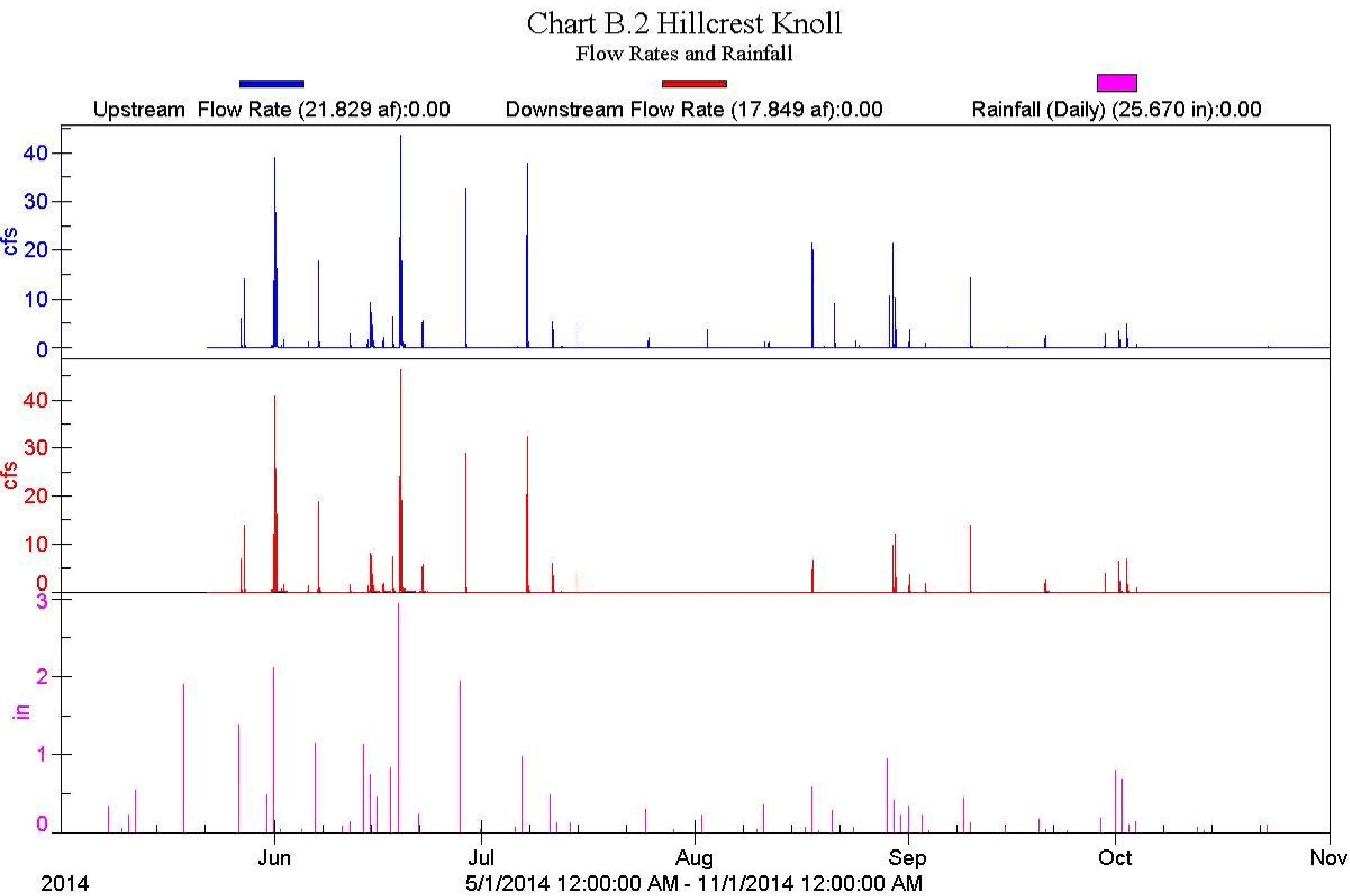


Chart B.2 Hillcrest Knoll
Flow Rates and Rainfall
Upstream Flow Rate (21.829 af):0.00
Downstream Flow Rate (17.849 af):0.00
Rainfall (Daily) (25.670 in):0.00
cfs
40
30
20
10
0
cfs
40
30
20
10
0
in
3
2
1
0
Jun
Jul
Aug
Sep
Oct
Nov
2014
5/1/2014 12:00:00 AM - 11/1/2014 12:00:00 AM

Chart B.3 St. Albans

Flow Rates and Rainfall

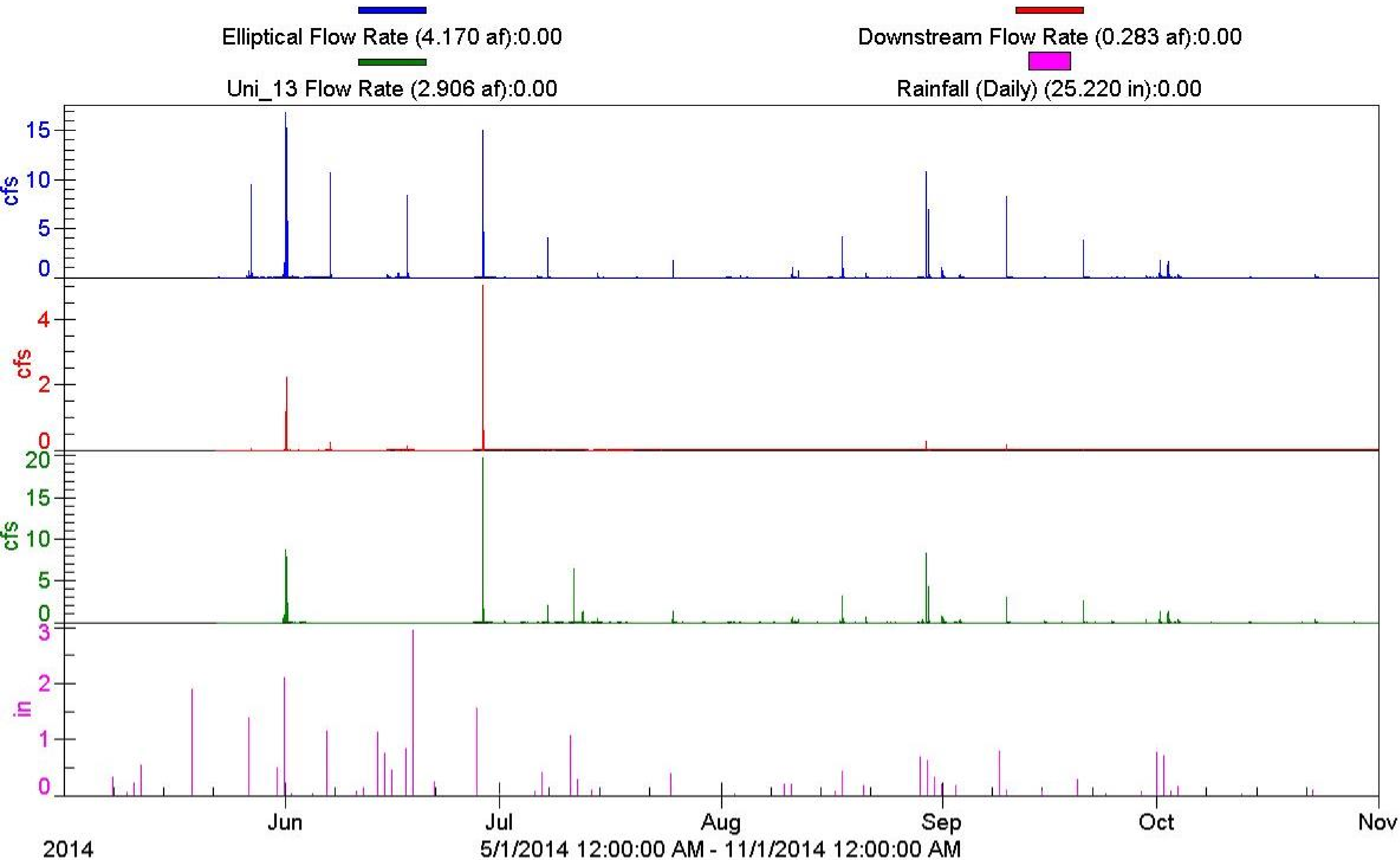
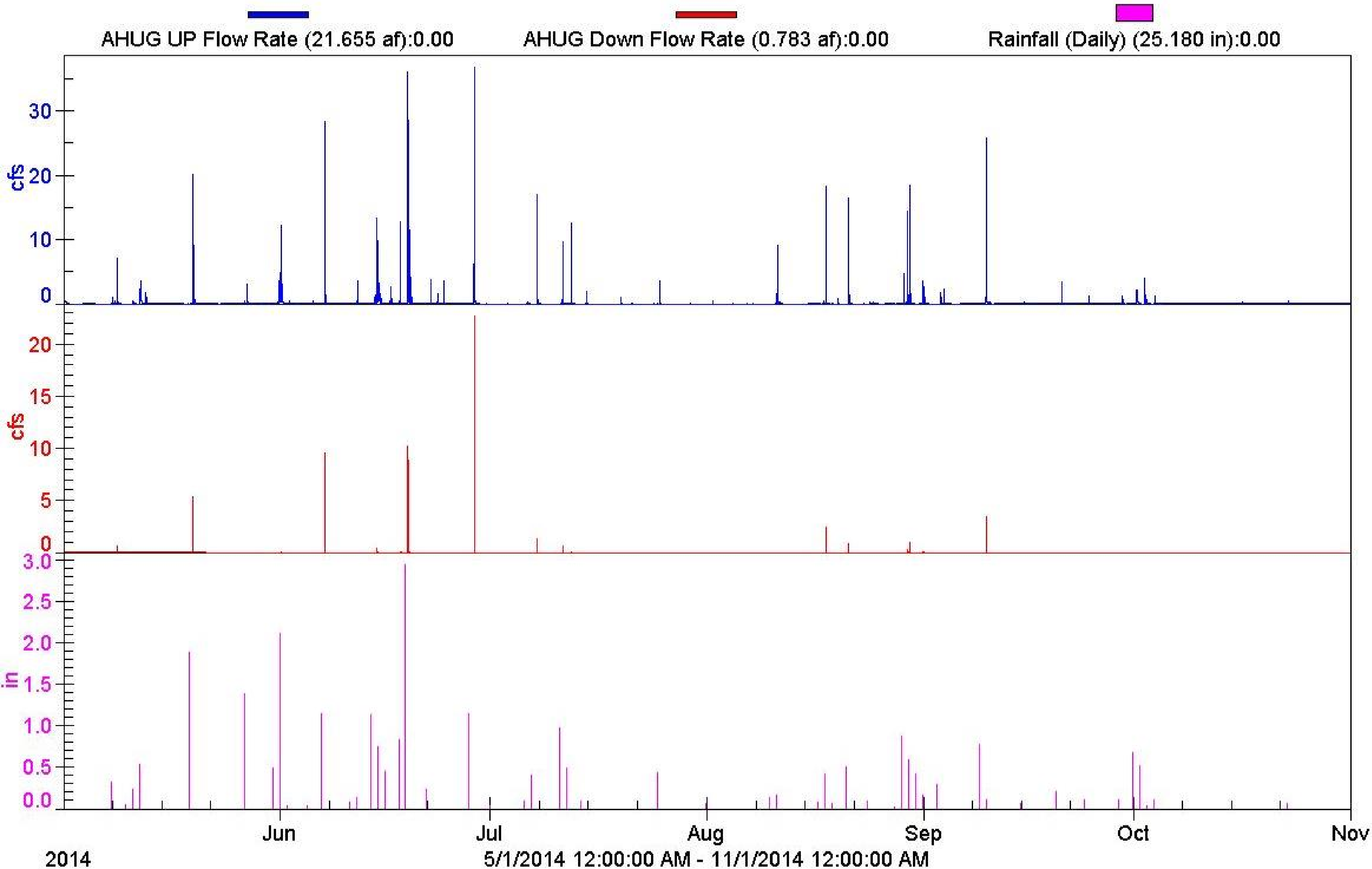


Chart B.4 AHUG

Flow Rates and Rainfall



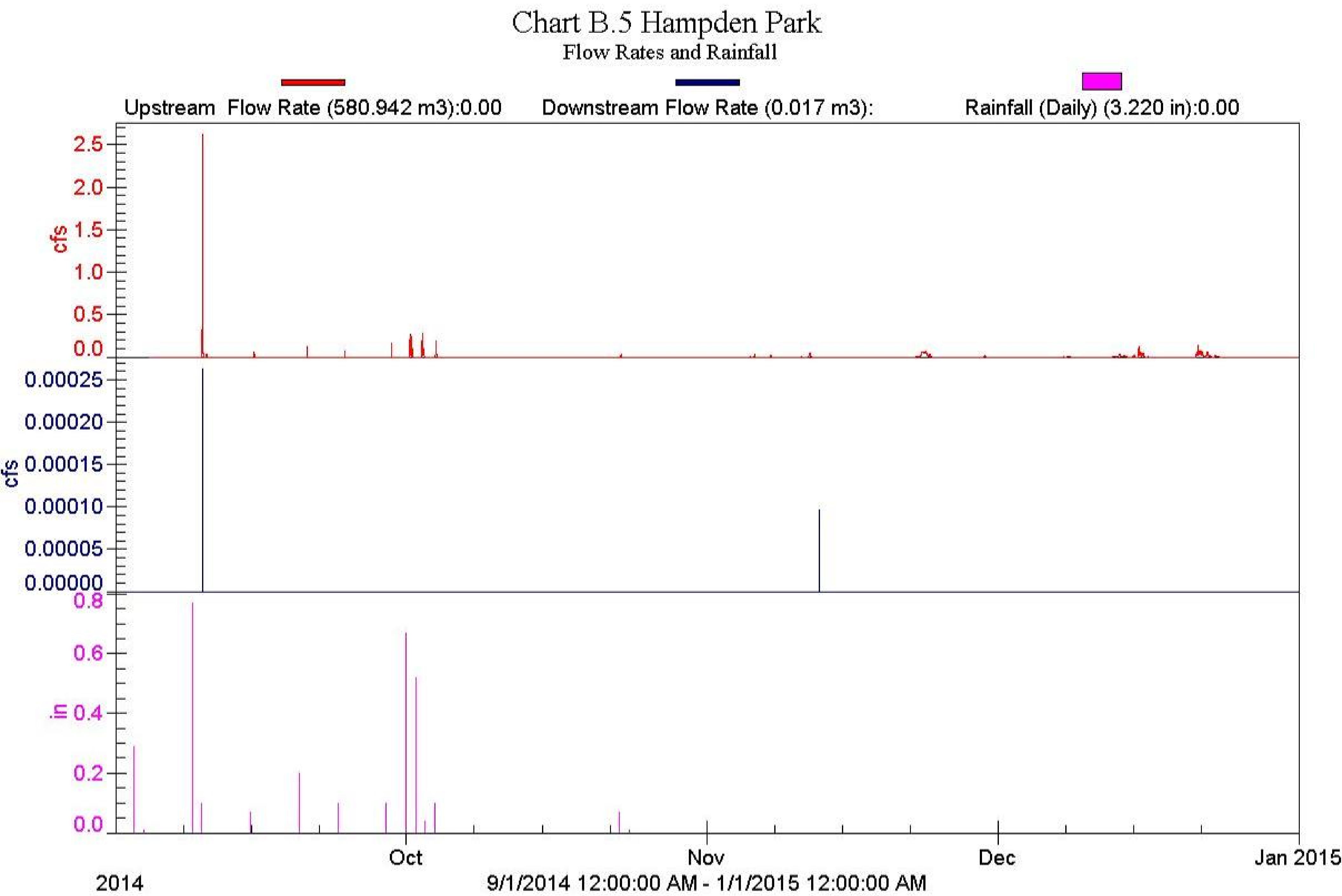


Chart B.5 Hampden Park
Flow Rates and Rainfall
Upstream Flow Rate (580.942 m3):0.00
Downstream Flow Rate (0.017 m3):
Rainfall (Daily) (3.220 in):0.00
cfs
2.5
2.0
1.5
1.0
0.5
0.0
cfs
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
in
0.8
0.6
0.4
0.2
0.0
Oct
Nov
Dec
Jan 2015
2014
9/1/2014 12:00:00 AM - 1/1/2015 12:00:00 AM

City of Saint Paul
2014 Beacon Bluff Water Quality Summary
Table C.1
WSB Project No.: 01610-100

Sample ID	# of Sample Bottles	# of 200 mL Samples	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-GR-042414 (1-5)				4/24/2014 9:00	87.0	46.0	39.0	100.0	77.0	25.0	0.28	0.085	6.3	0.61	1.60	0.32	36.0	17.0	20.0	88.0	2.8	7.78	6.40	5790.00
BB-AS-05/28/2014 (1-4 Composite)	4	16	5/27/2014 3:45	5/27/2014 9:16	340.0	36.0	100.0	380.0	29.0	350.0	0.77	0.051	2.1		3.10	0.32	66.0	38.0	56.0	210.0				
BB-AS-05/28/2014 (5-6 Composite)	2	9	5/27/2014 15:05	5/27/2014 19:01	200.0	44.0	71.0	320.0	49.0	270.0	0.57	0.068	4.7		2.40	0.14	48.0	36.0	39.0	170.0				
BB-AS-06/02/2014 (1-9 Composite)	9	40	5/31/2014 20:21	6/1/2014 0:02	200.0	54.0	60.0	440.0	24.0	420.0	0.50	0.089	2.1		2.20	0.17	42.0	26.0	38.0	120.0				
BB-AS-06/09/2014 (1-6 Composite)	6	22	6/7/2014 5:50	6/7/2014 14:00	180.0	80.0	67.0	290.0	24.0	260.0	0.66	0.130	3.2		2.60	0.19	37.0	24.0	36.0	130.0				
BB-AS-06/16/14 (1)	1	5	6/11/2014 23:34	6/12/2014 2:15	180.0	160.0	100.0				1.30 sd		17.0			0.02	65.0	51.0	30.0	220.0				
BB-AS-06/16/14 (2-11)	10	42	6/14/2014 11:18	6/15/2014 8:37	95.0	56.0	45.0	230.0	ND	230.0	0.37 sd	0.073 gg,	2.8		0.65	0.14	26.0	16.0	18.0	74.0				
BB-AS-06/17/14 (1-2)	2	9	6/16/2014 17:33	6/16/2014 22:34	38.0 sd	46.0	20.0	63.0	ND	58.0	0.28	0.073 gi	5.6		1.10	0.24	26.0	17.0	13.0	71.0				
BB-GS-6/19/2014				6/19/2014 8:15	25.0	36.0 J	8.7	27.0	22.0	ND	0.22	0..065 gi	1.7	0.14 qn	0.65	0.22	26.0	8.3 J	16.0	54.0	1.3	6.67	2.80 ts	10500.00
BB-AS-06/20/2014 (1-4)	4	7	6/18/2014 2:43	6/19/2014 4:19	110.0	ND	39.0	230.0	19.0	210.0	0.42	0.074 gg,	2.4		1.70	0.37	34.0	20.0	27.0	82.0				
BB-AS-06/20/2014 (4-17)	13	27	6/19/2014 4:20	6/19/2014 20:33	210.0	30.0 J	59.0	390.0	52.0	330.0	0.61	0.062 gi	1.9		2.00	0.22	47.0	24.0	55.0	120.0				
BB-AS-06/30/14 (1-3 Composite)	3	11	6/28/2014 16:00	6/28/2014 21:19	150.0	ND	39.0	1200.0	110.0	1100.0	0.68	0.130 ggl	3.6		0.54	0.16 qn								
BB-AS-06/26/14 (1)	1	2	6/22/2014 11:21	6/26/2014 12:54	190.0	ND	68.0				0.63		21.8			0.06								
BB-AS-07/09/14 (1-2)	2	6	7/7/2014 14:39	7/7/2014 20:25	240.0	ND	73.0				0.70 qn	0.120 qn	4.8		2.60	0.18								
BB-AS-07/11/14 (1-2 Composite)	2	5	7/11/2014 8:23	7/11/2014 11:40	69.0		36.0	2100.0	270.0	1900.0	0.33		4.9		0.54	0.17								
BB-AS-07/12/14 (1-1)	1	2	7/12/2014 14:05	7/12/2014 17:30	36.0 gk		18.0 J,g				0.25		8.2			0.28								
BB-AS-081814(1-2)	2	8	8/18/2014 0:16	8/18/2014 4:35	230.0	40.0	70.0				0.63	0.081	2.5		2.90	0.16					1.4	6.50	10.10	
BB-AS-082914(1)	1	3	08/29/2014 17:55	8/29/2014 19:40	189	32.0	37.0				0.28	0.10	3.9	0.41	2.6	0.16	40.7	28.8	48.7	153				
BB-AS-083014(1-2)	2	8	8/30/2014 0:19	8/29/2014 4:34	67.0	28.0	23.0				0.15	0.077	2.1	0.17	1.4	0.14	21.8	11.9	22.8	94.5				
BB-AS-083114(1-3)	3	12	8/31/2014 22:16		15.0	43.0	16.0				0.095	<0.020	4.0	0.14	1.2	0.084	19.8	<10.0	<10.0	26.2	<2.5	6.5	9.5	
BB-GS-090314			09/03/2014 09:15																					>200.5
BB-AS-090914(1)	1	4	09/09/2014 22:00	9/10/2014 1:19	23.0	44.0	<21.7				0.31	0.11	5.6	0.27	1.1	0.50	22.3	<10.0	<10.0	24.8				
BB-AS-092014 (1 of 1)	1	3	09/20/2014 18:25	9/20/2014 20:09	95.0	44.0	49.0				0.46	0.11	5.6		2.1	<0.020	38.8	22.0	24.0	124				
BB-AS-100114 (1-4)	4	16	10/01/2014 09:01	10/1/2014 16:19	50.0	37.0	26.0				0.49	0.16	4.7	0.055	1.3	0.044	29.2	<10.0	10.1	55.3				
BB-AS-100214 (1-3)	3	13	10/2/2014 13:05	10/2/2014 21:18	48.0	<10.0	27.0				0.22	0.064	3.2	0.13	1.2	0.24	22.8	10.7	<10.0	47.6				
BB-AS-100414 (1)	1	5	10/3/2014 23:49	10/4/2014 4:38	19.0	53.0	21.0				0.35	0.19	6.9	0.082	0.85	<0.020	24.1	<10.0	<10.0	32.8				
MINIMUM					**25.00**	**30.00**	**8.70**	**27.00**	**19.00**	**58.00**	**0.22**	**0.05**	**1.70**	**0.14**	**0.54**	**0.02**	**19.80**	**8.30**	**13.00**	**54.00**	**1.30**	**6.50**	**2.80**	**10500.00**
AVERAGE					**155.81**	**58.20**	**54.61**	**515.45**	**66.56**	**512.80**	**0.56**	**0.09**	**5.58**	**0.14**	**1.77**	**0.19**	**35.36**	**26.03**	**32.80**	**125.10**	**1.35**	**6.59**	**6.45**	**10500.00**
MAXIMUM					**340.00**	**160.00**	**100.00**	**2100.00**	**270.00**	**1900.00**	**1.30**	**0.13**	**21.80**	**0.14**	**3.10**	**0.37**	**66.00**	**51.00**	**56.00**	**220.00**	**1.40**	**6.67**	**10.10**	**10500.00**

NLR = No Lab Results as of Table Printing Date
Grab Samples
* The Lab received tha samplepast the method specified holding time or with insufficient time remaining to perform the analysis within the EPA recomemended holding time.
SSC analysis was not available for the later part of the season
Qualifiers and Abbreviations
ts - This analysis was performed by a subcontract laboratory.
qn - The spike recovery is outside of laboratory control limits for the matrix spike (MS) and/or the matrix spike duplicate (MSD).
J - Detected but below the Method Reporting Limit; therefore, result is an estimated concentration (CLP J-Flag).
gi - The sample was not filtered within 15 minutes of sample collection as required by the EPA.
gg1, H1 - Sample holding time exceeded
ND, <Value - Analyte NOT DETECTED above the MDL value

City of Saint Paul
2014 Beacon Bluff Pollutant Loading
Table C.2
WSB Job No.: 01610-100

BEACON BLUFF INFILTRATION SYSTEM POLLUTANT LOADING AND VOLUME REDUCTION TABLE

Sampling Data

Event Time Interval Start	Event Time Interval End	TSS (mg/L)	TDS (mg/L)	VSS (mg/L)	Suspended Sediment Conc. (SSC) (mg/L)	TP (mg/L)	Ortho-P (mg/L)	Chloride (mg/L)	Ammonia as N (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite as N (mg/L)
5/27/2014 3:46	5/27/2014 8:20	340	36	100	380	0.77	0.05	2.10	0.10	3.10	0.32
5/27/2014 15:05	5/27/2014 18:14	200	44	71	320	0.57	0.07	4.70	0.10	2.40	0.14
5/31/2014 20:22	6/1/2014 9:20	200	54	60	440	0.50	0.09	2.10	0.10	2.20	0.17
6/1/2014 22:37	6/1/2014 23:43	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
6/2/2014 7:10	6/2/2014 8:08	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
6/7/2014 5:51	6/7/2014 13:40	180	80	67	290	0.66	0.13	3.20	0.10	2.60	0.19
6/11/2014 23:33	6/12/2014 1:55	180	160	100	538	1.30	0.09	17.00	0.10	1.63	0.02
6/14/2014 11:17	6/15/2014 8:13	95	56	45	230	0.37	0.07	2.80	0.10	0.65	0.14
6/15/2014 10:04	6/15/2014 11:10	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
6/16/2014 17:34	6/16/2014 22:00	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
6/18/2014 2:43	6/19/2014 4:16	110	ND	39	230	0.42	0.07	2.40	0.10	1.70	0.37
6/19/2014 4:19	6/19/2014 21:37	210	30	59	390	0.61	0.06	1.90	0.10	2.00	0.22
6/22/2014 11:21	6/22/2014 12:30	190	ND	68	538	0.63	0.09	21.80	0.10	1.63	0.06
6/28/2014 16:00	6/28/2014 20:49	150	ND	39	1200	0.68	0.13	3.60	0.10	0.54	0.16
7/7/2014 14:39	7/7/2014 19:57	240	ND	73	538	0.70	0.12	4.80	0.10	2.60	0.18
7/11/2014 8:23	7/11/2014 11:15	69	35	36	2100	0.33	0.09	4.90	0.10	0.54	0.17
7/12/2014 14:05	7/12/2014 17:02	36	35	18	538	0.25	0.09	8.20	0.10	1.63	0.28
7/25/2014 5:31	7/25/2014 8:17	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
7/29/2014 20:59	7/29/2014 21:44	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
8/1/2014 19:55	8/1/2014 20:02	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
8/10/2014 20:02	8/10/2014 23:16	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
8/11/2014 2:19	8/11/2014 10:31	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
8/11/2014 9:41	8/11/2014 10:50	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
8/18/2014 0:16	8/18/2014 3:58	230	40	70	538	0.63	0.08	2.50	0.10	2.90	0.16
8/19/2014 18:30	8/19/2014 19:28	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
8/21/2014 6:28	8/21/2014 8:56	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
8/24/2014 6:14	8/24/2014 6:16	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
8/24/2014 17:48	8/24/2014 19:07	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
8/29/2014 3:38	8/29/2014 4:49	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
8/29/2014 17:16	8/29/2014 19:14	189	32	37	538	0.28	0.1	3.90	0.41	2.6	0.16
8/30/2014 0:18	8/30/2014 4:08	67	28	23	538	0.15	0.08	2.10	0.17	1.4	0.14
8/31/2014 22:16	9/1/2014 5:27	15	43	16	538	0.10	<0.020	4.00	0.14	1.2	0.08
9/3/2014 9:22	9/3/2014 12:44	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
9/9/2014 21:23	9/10/2014 1:19	23	44	<21.7	538	0.31	0.11	5.60	0.27	1.10	0.50
9/10/2014 6:51	9/10/2014 9:19	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
9/15/2014 7:42	9/15/2014 8:33	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
9/20/2014 18:01	9/20/2014 19:37	95	44	49	538	0.46	0.11	5.60	0.10	2.10	<0.020
9/21/2014 7:00	9/21/2014 7:18	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
9/24/2014 15:44	9/24/2014 15:45	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
9/29/2014 10:17	9/29/2014 11:40	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
10/1/2014 8:12	10/1/2014 15:39	50	37	26	538	0.49	0.16	4.70	0.06	1.30	0.04
10/2/2014 13:04	10/2/2014 20:37	48	<10.0	27	538	0.22	0.064	3.20	0.13	1.20	0.24
10/3/2014 23:48	10/4/2014 3:51	19	53	21	538	0.35	0.19	6.90	0.08	0.85	<0.020
10/23/2014 3:28	10/23/2014 5:35	160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
Sum											
Average		133	52	50	620	0.49	0.10	5.36	0.18	1.74	0.19
Weighted Ave		160	35	51	538	0.52	0.09	3.33	0.10	1.63	0.19
STDEV		88	31	25	391	0.26	0.03	4.89	0.08	0.77	0.11
Median		130	43	45	538	0.48	0.09	3.95	0.10	1.63	0.17
Min		15	28	16	230	0.10	0.05	1.90	0.06	0.54	0.02
Max		340	160	100	2100	1.30	0.19	21.80	0.41	3.10	0.50
Percent Capture of Total Runoff											

Event Loading and Volume Data[1]

Diversion Structure on Duchess Street: Runoff Volume Draining to Diversion Structure (Subwatershed A); Volume Directed from Diversion Structure into BMP (1)

Event Time Interval Start	Event Time Interval End	Interval Rain (In.)	Runoff Volume Draining to Diversion Structure (Subwatershed A) (cf)	Volume Directed from Diversion Structure into BMP (1) (cf)	Inflow Volume from West Pond (Subwatershed B) (2) (cf)	Inflow Volume from East Pond (Subwatershed C)[2] (3) (cf)	Underground System Discharged Volume (4) (cf)	Volume Captured by BMP (1+2+3)-4 (cf)	Captured TSS (lbs.)	Captured VSS (lbs.)	Captured SSC (lbs.)	Captured TP (lbs.)	Captured Chloride (lbs.)	Captured Total Kjeldahl Nitrogen (lbs.)	Captured Nitrate + Nitrite as N (lbs.)
5/27/2014 3:46	5/27/2014 8:20	1.20	123923	88154	0	5919	0	94073	1996.7	587.3	2231.7	4.52	12.3	18.21	1.88
5/27/2014 15:05	5/27/2014 18:14	0.17	18319	4660	0	875	0	5535	69.1	24.5	110.6	0.20	1.6	0.83	0.05
5/31/2014 20:22	6/1/2014 9:20	2.53	265086	140499	10366	12662	0	163528	2041.7	612.5	4491.8	5.10	21.4	22.46	1.74
6/1/2014 22:37	6/1/2014 23:43	0.07	4310	4310	1	206	0	4517	45.2	14.4	151.8	0.15	0.9	0.46	0.05
6/2/2014 7:10	6/2/2014 8:08	0.03	1078	1078	0	51	0	1129	11.3	3.6	38.0	0.04	0.2	0.12	0.01
6/7/2014 5:51	6/7/2014 13:40	1.15	122845	72823	1520	5868	0	80211	901.3	335.5	1452.1	3.30	16.0	13.02	0.95
6/11/2014 23:33	6/12/2014 1:55	0.22	20474	16782	0	978	0	17760	199.6	110.9	597.0	1.44	18.8	1.81	0.02
6/14/2014 11:17	6/15/2014 8:13	1.87	199354	126598	3290	9522	0	139410	826.8	391.6	2001.7	3.22	24.4	5.66	1.22
6/15/2014 10:04	6/15/2014 11:10	0.01	0	0	46	0	0	46	0.5	0.1	1.6	0.00	0.0	0.00	0.00
6/16/2014 17:34	6/16/2014 22:00	0.45	46336	36312	367	2213	0	38892	389.4	124.4	1307.3	1.26	8.1	3.96	0.45
6/18/2014 2:43	6/19/2014 4:16	1.33	109914	84733	742	5250	0	90726	623.0	220.9	1302.7	2.38	13.6	9.63	2.10
6/19/2014 4:19	6/19/2014 21:37	2.44	431951	211468	15375	20633	0	247476	3244.4	911.5	6025.3	9.42	29.4	30.90	3.40
6/22/2014 11:21	6/22/2014 12:30	0.23	23707	19566	0	1132	0	20699	245.5	87.9	695.8	0.81	28.2	2.11	0.08
6/28/2014 16:00	6/28/2014 20:49	1.95	204742	115274	3302	9780	0	128356	1201.9	312.5	9615.6	5.45	28.8	4.33	1.28
7/7/2014 14:39	7/7/2014 19:57	0.72	75431	40414	241	3603	0	44258	663.1	201.7	1487.7	1.93	13.3	7.18	0.50
7/11/2014 8:23	7/11/2014 11:15	0.64	66810	54003	288	3191	0	57483	247.6	129.2	7535.9	1.18	17.6	1.94	0.61
7/12/2014 14:05	7/12/2014 17:02	0.21	10776	10725	0	515	0	11240	25.3	12.6	377.8	0.18	5.8	1.15	0.20
7/25/2014 5:31	7/25/2014 8:17	0.29	29095	25243	0	1390	0	26632	266.6	85.2	895.2	0.86	5.5	2.71	0.31
7/29/2014 20:59	7/29/2014 21:44	0.02	0	0	0	0	0	0	0.0	0.0	0.0	0.00	0.0	0.00	0.00
8/1/2014 19:55	8/1/2014 20:02	0.06	4310	4310	0	206	0	4516	45.2	14.4	151.8	0.15	0.9	0.46	0.05
8/10/2014 20:02	8/10/2014 23:16	0.10	6466	6466	0	309	0	6774	67.8	21.7	227.7	0.22	1.4	0.69	0.08
8/11/2014 2:19	8/11/2014 10:31	0.12	10776	10724	0	515	0	11239	112.5	35.9	377.8	0.36	2.3	1.15	0.13
8/11/2014 9:41	8/11/2014 10:50	0.00	5388	5360	0	257	0	5617	56.2	18.0	188.8	0.18	1.2	0.57	0.07
8/18/2014 0:16	8/18/2014 3:58	0.80	86207	55666	430	4118	0	60214	864.6	263.1	2024.1	2.37	9.4	10.90	0.60
8/19/2014 18:30	8/19/2014 19:28	0.07	5388	3156	0	257	0	3413	34.2	10.9	114.7	0.11	0.7	0.35	0.04
8/21/2014 6:28	8/21/2014 8:56	0.26	24785	16977	0	1184	0	18161	181.8	58.1	610.5	0.59	3.8	1.85	0.21
8/24/2014 6:14	8/24/2014 6:16	0.02	0	0	0	0	0	0	0.0	0.0	0.0	0.00	0.0	0.00	0.00
8/24/2014 17:48	8/24/2014 19:07	0.06	6466	6404	0	309	0	6713	67.2	21.5	225.6	0.22	1.4	0.68	0.08
8/29/2014 3:38	8/29/2014 4:49	0.07	5388	3690	0	257	0	3947	39.5	12.6	132.7	0.13	0.8	0.40	0.05
8/29/2014 17:16	8/29/2014 19:14	0.52	53879	43777	0	2574	0	46351	546.9	107.1	1558.1	0.81	11.3	7.52	0.46
8/30/2014 0:18	8/30/2014 4:08	0.61	65733	37282	774	3140	0	41196	172.3	59.2	1384.8	0.39	5.4	3.60	0.36
8/31/2014 22:16	9/1/2014 5:27	0.56	58190	48114	8	2780	0	50902	47.7	50.8	1711.0	0.30	12.7	3.81	0.27
9/3/2014 9:22	9/3/2014 12:44	0.18	17241	16384	0	824	0	17208	172.3	55.0	578.4	0.56	3.6	1.75	0.20
9/9/2014 21:23	9/10/2014 1:19	0.58	59267	42392	146	2831	0	45369	65.1	ND	1525.0	0.88	15.9	3.12	1.42
9/10/2014 6:51	9/10/2014 9:19	0.09	7543	7543	0	360	0	7903	79.1	25.3	265.7	0.26	1.6	0.81	0.09
9/15/2014 7:42	9/15/2014 8:33	0.05	3233	3233	0	154	0	3387	33.9	10.8	113.9	0.11	0.7	0.35	0.04
9/20/2014 18:01	9/20/2014 19:37	0.20	14009	10699	0	669	0	11368	67.4	34.8	382.1	0.33	4.0	1.49	ND
9/21/2014 7:00	9/21/2014 7:18	0.03	3233	3233	0	154	0	3387	33.9	10.8	113.9	0.11	0.7	0.35	0.04
9/24/2014 15:44	9/24/2014 15:45	0.04	0	0	0	0	0	0	0.0	0.0	0.0	0.00	0.0	0.00	0.00
9/29/2014 10:17	9/29/2014 11:40	0.10	8621	7318	0	412	0	7730	77.4	24.7	259.8	0.25	1.6	0.79	0.09
10/1/2014 8:12	10/1/2014 15:39	0.76	76509	59407	319	3655	0	63380	197.8	102.9	2130.5	1.94	18.6	5.14	0.17
10/2/2014 13:04	10/2/2014 20:37	0.75	77586	59034	1463	3706	0	64202	192.4	108.2	2158.1	0.88	12.8	4.81	0.96
10/3/2014 23:48	10/4/2014 3:51	0.23	21552	21279	0	1029	0	22308	26.5	29.2	749.9	0.49	9.6	1.18	ND
10/23/2014 3:28	10/23/2014 5:35	0.09	7543	7543	0	360	0	7903	79.1	25.3	265.7	0.26	1.6	0.81	0.09
Sum		22.31	2,383,462	1,532,633	38,678	113,849	0	1,685,160	**16260.0**	**5266.8**	**57570.1**	**53.32**	**368.1**	**179.05**	**20.34**
Average		0.31	36,113	23,222	586	1,725	0	25,533	254.1	83.6	899.5	0.83	5.8	2.80	0.33
Weighted Ave															
STDEV			72863	40168	2317	3480	0		563.3	167.9	1769.9	1.65	8.3	5.59	0.64
Median			5388	4485	0	257	0	5026	45.2	14.4	170.3	0.18	1.3	0.63	0.05
Min			0	0	0	0	0	0	0	0.0	0.0	0.00	0.0	0.00	0.00
Max			431,951	211,468	15,375	20,633	0	247,476	3244	911.5	9615.6	9.42	29.4	30.90	3.40
Percent Capture of Total Runoff								66.4%	**63.9%**	**64.9%**	**67.6%**	**65.0%**	**70.1%**	**68.9%**	**68.9%**

Events with no sampling data (Weighted Average Concentration Used) (pink shading)
Sampling event (purple shading)

[1] See Figure 2 for Locations of Subwatersheds
[2] *Volume calculated based on ratio of Subwatershed C area to Subwatershed A area - (4.66 ac)/(136.77 ac)*(Upstream Volume)*
ND Not Detected: Sampline parameter below recording limit
ER Outlier removed from data Set

City of Saint Paul
2014 Hillcrest Knoll Water Quality Summary
Table C.3
WSB Project No.: 01610-100

Sample ID	# of Sample Bottles	# of 200 mL Samples	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)
HK-GR-042414 (1-5)				4/24/2014 9:30	60.0	44.0	27.0	60.0	43.0	17.0	0.150	0.056	6.1	0.69	1.3	0.34	31.0	11.0	3.6	71.0	2.4	7.6	4.3	308.0
HK-AS-05202014 (1-20 Composite)	20	100		5/20/2014 13:30	130.0	26.0	34.0	1300.0	88.0	1200.0	0.830	0.046			1.6	0.18	110.0	200.0	8.8	140.0				
HK-AS-05/28/2014 (1-2 Composite)	2	8	5/27/2014 2:30	5/27/2014 4:53	150.0	34.0	62.0	1000.0	61.0	960.0	0.360	0.019	7.7		3.1	0.36	53.0	75.0	8.6	180.0				
HK-AS-05/28/2014 (3-8 Composite)	6	17	5/27/2014 14:58	5/27/2014 18:11	150.0	28.0	40.0	500.0	39.0	460.0	0.340	0.027	2.8		1.2	0.14	59.0	20.0	5.5	110.0				
HK-AS-06/02/2014 (1-14, 23-24 Composite)	16	71	5/31/2014 20:25	6/1/2014 9:10	390.0	38.0	52.0	7900.0	46.0	7800.0	1.300	0.042	1.9		1.7	0.27	130.0	18.0	12.0	230.0				
HK-AS-06/09/2014 (1)	1	1	6/5/2014 21:59	6/5/2014 22:39	50.0	140.0	50.0				0.700	0.230	36.0			0.04	65.0	20.0	2.5	81.0				
HK-AS-06/09/2014 (2-9 Composite)	8	43	6/7/2014 6:08	6/7/2014 14:00	110.0	64.0	42.0	3300.0	20.0	3200.0	1.900	0.042	2.4		2.3	0.12	110.0	15.0	12.0	160.0				
HK-AS-06/16/14 (1)	1	3	6/11/2014 23:37	6/12/2014 1:34	80.0	130.0	61.0				0.460 s d		19.0			0.02 J	55.0	19.0	4.4 J	110.0				
HK-AS-06/16/14 (2-18)	17	74	6/14/2014 11:26	6/15/2014 11:46	47.0	62.0	24.0	390.0	ND	390.0	0.200 s d	0.025 gi	4.7		26.6	0.22	31.0	8.7 J	2.3 J	38.0				
HK-AS-06/17/2014 (1-3)	3	12	6/16/2014 17:26	6/16/2014 22:27	19.0 s d	44.0	14.0	41.0	ND	38.0	0.120	0.017 gi	7.2		0.6	0.27	34.0	6.2 J	2.1 J	40.0				
HK-GS-6/19/2014				6/19/2014 8:40	7.3	150.0	4.0 J	ND	ND	ND	0.300	0.210 gi	15.0	0.14	1.1	1.20	100.0	8.2 J	1.5 J	32.0	6.2	7.2 g h	3.2 t s	19900.0 t s
HK-AS-06/26/14 (1)	1	3	6/22/2014 11:24	6/26/2014 12:22	100.0	36.0 J	39.0				0.300		24.8			0.08								
HK-AS-06/30/14 (1-9 Composite)	9	42	6/28/2014 17:33	6/28/2014 21:12	97.0	ND	29.0	2100.0	85.0	2000.0	0.630	0.073 g gl	3.9		ND U	0.12								
HK-AS-07/09/14 (1-6)	6	29	7/7/2014 14:09	7/7/2014 20:03	180.0	ND	50.0	900.0	78.0	820.0	0.690	0.064	3.3		1.8	0.12								
HK-AS-081814 (1-2) *Should be (1-4)	4	16	8/18/2014 0:30	8/18/2014 1:58	179.0	13.0	46.0	1000.0	160.0	850.0	0.530	0.031	1.5	0.0044 J	2.0	0.16					ND U	6.5 H	ND U	
HK-AS-082914(1-2)	2	6	08/29/2014 03:44	8/29/2014 4:31	199	38.0	97.0				0.26	0.22	6.7	0.35	2.1	0.20	62.9	32.6	14.9	215				
HK-AS-082914(1-3)	3	12	08/29/2014 17:20	8/29/2014 18:57	113	32.0	40.0				0.19	0.064	3.8	0.32	1.4	0.24	35.9	16.3	<10.0	96.4				
HK-AS-083014(1-3)	3	13	08/30/2014 01:36	8/30/2014 4:23	36.0	26.0	14.0				0.14	0.044	2.8	0.17	<0.50	0.21	19.3	<10.0	<10.0	37.7	<2.5	6.7	7.9	
HK-AS-083114(1-2)	2	7	08/31/2014 22:35	9/1/2014 2:49	23.0	34.0	10.0				0.057	0.036	4.4	1.8	0.74	0.18	18.7	<10.0	<10.0	29.6				
HK-GS-090314				09/03/2014 09:30																				165.2
HK-AS-090914 (1-3)	3	10	09/09/2014 21:30	9/9/2014 23:50	111	60.0	46.0				0.52	0.13	5.4	0.40	2.2	0.38	38.7	16.7	<10.0	111				
HK-AS-092014 (1 of 1)	1	3	09/20/2014 18:06	9/20/2014 19:02	95.0	70.0	41.0				0.37	0.0055	17.5		3.0	<0.020	58.8	27.0	<10.0	245				
HK-AS-100214 (1-2)	2	9	10/02/2014 15:04	10/2/2014 18:41	18.0	<10.0	15.0				0.10	0.059	1.7	0.31	<0.50	0.33	18.5	<10.0	<10.0	28.5				
HK-AS-100414 (1)	1	2	10/04/2014 01:04	10/4/2014 2:53	10.0	<10.0	15.0				0.10	0.062	2.3	0.13	0.57	0.16	19.0	<10.0	<10.0	29.7				
MINIMUM					**7.30**	**13.00**	**4.00**	**41.00**	**20.00**	**17.00**	**0.12**	**0.02**	**1.50**	**0.00**	**0.64**	**0.02**	**18.50**	**6.20**	**1.50**	**32.00**	**2.40**	**6.50**	**3.20**	**308.00**
MEDIAN					**111.58**	**62.23**	**38.27**	**1681.00**	**68.89**	**1612.27**	**0.59**	**0.07**	**9.74**	**0.28**	**3.94**	**0.24**	**55.25**	**36.46**	**5.75**	**108.36**	**4.30**	**7.11**	**3.75**	**10104.00**
MAXIMUM					**390.00**	**150.00**	**62.00**	**7900.00**	**160.00**	**7800.00**	**1.90**	**0.23**	**36.00**	**0.69**	**26.60**	**1.20**	**130.00**	**200.00**	**12.00**	**230.00**	**6.20**	**7.64**	**4.30**	**19900.00**

Grab Samples
* The Lab received tha samplepast the method specified holding time or with insufficient time remaining to perform the analysis within the EPA recomemended holding time.
SSC analysis was not available for the later part of the season

Qualifiers and Abbreviations

ts - This analysis was performed by a subcontract laboratory.
qn - The spike recovery is outside of laboratory control limits for the matrix spike (MS) and/or the matrix spike duplicate (MSD).
J - Detected but below the Method Reporting Limit; therefore, result is an estimated concentration (CLP J-Flag).
gi - The sample was not filtered within 15 minutes of sample collection as required by the EPA.
gg1, H1 - Sample holding time exceeded
ND, <Value - Analyte NOT DETECTED above the MDL value

City of Saint Paul
2014 Hillcrest Knoll Pollutant Loading
Table C.4
WSB Job No.: 01610-100

HILLCREST KNOLL INFILTRATION SYSTEM POLLUTANT LOADING AND VOLUME REDUCTION TABLE

Event Time Interval		Sampling Data							Event Loading and Volume Data										
		TSS	VSS	Suspended Sediment Conc. (SSC)	TP	Chloride	Total Kjeldahl Nitrogen	Nitrate + Nitrite as N	Interval Rain	Runoff Volume (upstream pipe) (1)	Bypassed Volume (2)	Volume Captured by BMP (1-2)	Captured TSS	Captured VSS	Captured SSC	Captured TP	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	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5/27/2014 2:32	5/27/2014 8:54	150	62.0	1000	0.36	7.70	3.10	0.36	1.21	12499	6030	6469	60.58	25.04	403.84	0.15	3.11	1.25	0.15
5/27/2014 15:01	5/27/2014 18:11	150	40.0	500	0.34	2.80	1.20	0.14	0.17	34518	31972	2546	23.84	6.36	79.46	0.05	0.44	0.19	0.02
5/31/2014 14:00	6/1/2014 14:00	390	52.0	7900	1.30	1.90	1.70	0.27	2.53	161261	143781	17481	425.60	56.75	8621.06	1.42	2.07	1.86	0.29
6/1/2014 22:44	6/1/2014 23:35	176	39.1	3458	0.74	3.69	5.55	0.21	0.07	930	668	263	2.89	0.64	56.75	0.01	0.06	0.09	0.00
6/2/2014 7:14	6/2/2014 8:57	176	39.1	3458	0.74	3.69	5.55	0.21	0.04	2114	1631	483	5.30	1.18	104.20	0.02	0.11	0.17	0.01
6/5/2014 22:01	6/5/2014 22:39	50	50.0	3458	0.70	36.00	5.55	0.04	0.04	856	801	55	0.17	0.17	11.89	0.00	0.12	0.02	0.00
6/7/2014 6:10	6/7/2014 14:00	110	42.0	3300	1.90	2.40	2.30	0.12	1.15	49636	44758	4878	33.50	12.79	1004.87	0.58	0.73	0.70	0.04
6/11/2014 23:40	6/12/2014 1:34	80	61.0	3458	0.46	19.00	5.55	0.02	0.22	3658	610	3048	15.22	11.61	658.05	0.09	3.62	1.06	0.00
6/14/2014 11:29	6/15/2014 9:21	47	24.0	390	0.20	4.70	26.60	0.22	1.87	95231	72579	22653	66.47	33.94	551.52	0.28	6.65	37.62	0.31
6/15/2014 9:45	6/15/2014 11:46	176	39.1	3458	0.74	3.69	5.55	0.21	0.01	2490	1606	884	9.71	2.16	190.79	0.04	0.20	0.31	0.01
6/16/2014 17:29	6/16/2014 22:28	19 sd	14.0	41	0.12	7.20	0.64	0.27	0.45	17299	14400	2899	3.44	2.53	7.42	0.02	1.30	0.12	0.05
6/18/2014 2:32	6/18/2014 7:38	176	39.1	3458	0.74	3.69	5.55	0.21	0.83	15674	12509	3165	34.76	7.72	683.23	0.15	0.73	1.10	0.04
6/19/2014 3:43	6/19/2014 22:15	176	39.1	3458	0.74	3.69	5.55	0.21	2.94	220540	193746	26794	294.28	65.39	5784.27	1.24	6.17	9.28	0.35
6/22/2014 11:27	6/22/2014 12:22	100	39.0	3458	0.30	24.80	5.55	0.08	0.23	4848	3842	1006	6.28	2.45	217.15	0.02	1.56	0.35	0.00
6/28/2014 17:35	6/28/2014 21:12	97	29.0	2100	0.63	3.90	ND	0.12	1.95	54865	48539	6326	38.31	11.45	829.37	0.25	1.54	ND	0.05
7/6/2014 7:15	7/6/2014 7:30	176	39.1	3458	0.74	3.69	5.55	0.21	0.06	232	0	232	2.55	0.57	50.13	0.01	0.05	0.08	0.00
7/7/2014 14:11	7/7/2014 20:03	180	50.0	900	0.69	3.30	1.80	0.12	0.98	38255	29026	9229	103.70	28.81	518.51	0.40	1.90	1.04	0.07
7/11/2014 8:19	7/11/2014 11:00	176	39.1	3458	0.74	3.69	5.55	0.21	0.46	18719	17246	1473	16.18	3.59	317.98	0.07	0.34	0.51	0.02
7/12/2014 14:40	7/12/2014 16:30	176	39.1	3458	0.74	3.69	5.55	0.21	0.12	909	88	821	9.02	2.00	177.26	0.04	0.19	0.28	0.01
7/14/2014 16:20	7/14/2014 16:57	176	39.1	3458	0.74	3.69	5.55	0.21	0.12	2732	1678	1053	11.57	2.57	227.41	0.05	0.24	0.36	0.01
7/25/2014 5:33	7/25/2014 8:02	176	39.1	3458	0.74	3.69	5.55	0.21	0.29	7474	0	7474	82.08	18.238	1613.38	0.346	1.721	2.589	0.098
8/2/2014 17:51	8/2/2014 18:34	176	39.1	3458	0.74	3.69	5.55	0.21	0.22	3885	0	3885	42.67	9.481	838.72	0.180	0.895	1.346	0.051
8/11/2014 1:40	8/11/2014 2:29	176	39.1	3458	0.74	3.69	5.55	0.21	0.02	1558	0	1558	17.11	3.801	336.26	0.072	0.359	0.540	0.020
8/11/2014 14:05	8/11/2014 16:59	176	39.1	3458	0.74	3.69	5.55	0.21	0.08	1288	0	1288	14.15	3.144	278.14	0.060	0.297	0.446	0.017
8/18/2014 0:32	8/18/2014 1:58	179	46.0	1000	0.530	1.500	2.0	0.160	0.58	21148	2089	19059	212.98	54.733	1189.84	0.631	1.785	2.380	0.190
8/19/2014 18:40	8/19/2014 18:50	176	39.1	3458	0.74	3.69	5.55	0.21	0.02	197	0	197	2.16	0.481	42.52	0.009	0.045	0.068	0.003
8/21/2014 6:36	8/21/2014 8:19	176	39.1	3458	0.74	3.69	5.55	0.21	0.28	6546	0	6546	71.90	15.976	1413.22	0.303	1.508	2.267	0.086
8/24/2014 6:06	8/24/2014 6:31	176	39.1	3458	0.74	3.69	5.55	0.21	0.04	1096	0	1096	12.03	2.674	236.51	0.051	0.252	0.379	0.014
8/24/2014 18:15	8/24/2014 18:31	176	39.1	3458	0.74	3.69	5.55	0.21	0.02	494	0	494	5.42	1.204	106.54	0.023	0.114	0.171	0.006
8/29/2014 3:44	8/29/2014 4:30	199	97.0	3458	0.26	6.7	2.1	0.2	0.43	7971	0	7971	99.03	48.270	1720.84	0.129	3.334	1.045	0.100
8/29/2014 17:19	8/29/2014 18:56	113	40.0	3458	0.19	3.8	1.4	0.24	0.52	14746	8165	6581	46.42	16.433	1420.66	0.078	1.561	0.575	0.099
8/30/2014 0:45	8/30/2014 4:22	36	14.0	3458	0.14	2.8	ND	0.21	0.41	17356	16401	954	2.14	0.834	206.02	0.008	0.167	ND	0.013
8/31/2014 22:26	9/1/2014 2:48	23	10.0	3458	0.057	4.4	0.74	0.18	0.42	8291	7753	537	0.77	0.335	116.01	0.002	0.148	0.025	0.006
9/1/2014 3:15	9/1/2014 5:07	176	39.1	3458	0.74	3.69	5.55	0.21	0.13	1463	1419	44	0.48	0.107	9.49	0.002	0.010	0.015	0.001
9/3/2014 9:45	9/3/2014 11:51	176	39.1	3458	0.74	3.69	5.55	0.21	0.20	1363	1363	0	0.00	0.000	0.00	0.000	0.000	0.000	0.000
9/9/2014 21:30	9/9/2014 23:59	111	46.0	3458	0.52	5.4	2.2	0.38	0.44	13929	11615	2313	16.03	6.643	499.40	0.075	0.780	0.318	0.055
9/10/2014 0:00	9/10/2014 0:32	176	39.1	3458	0.74	3.69	5.55	0.21	0.04	566	472	94	1.03	0.229	20.25	0.004	0.022	0.032	0.001
9/20/2014 18:05	9/20/2014 19:01	95	41.0	3458	0.37	17.5	3	<0.020	0.16	3879	3048	831	4.93	2.127	179.36	0.019	0.908	0.156	ND
9/29/2014 7:51	9/29/2014 10:56	176	39.1	3458	0.74	3.69	5.55	0.21	0.18	2455	2078	377	4.14	0.919	81.31	0.017	0.087	0.130	0.005
10/1/2014 8:30	10/1/2014 15:09	176	39.1	3458	0.74	3.69	5.55	0.21	0.79	15948	15726	222	2.44	0.541	47.89	0.010	0.051	0.077	0.003
10/2/2014 13:15	10/2/2014 18:40	18	15.0	3458	0.1	1.7	<0.50	0.33	0.69	24655	22409	2246	2.52	2.103	484.77	0.014	0.238	ND	0.046
10/4/2014 0:00	10/4/2014 2:52	10	15.0	3458	0.1	2.3	0.57	0.16	0.21	3284	2388	896	0.56	0.839	193.51	0.006	0.129	0.032	0.009
10/23/2014 3:40	10/23/2014 3:58	176	39.1	3458	0.74	3.69	5.55	0.21	0.09	252	0	252	2.77	0.616	54.49	0.012	0.058	0.087	0.003
11/10/2014 17:00	11/10/2014 22:30	176	39.1	3458	0.74	3.69	5.55	0.21	0.27	2719	0	2719	29.86	6.635	586.95	0.126	0.626	0.942	0.036
11/11/2014 13:45	11/11/2014 15:00	176	39.1	3458	0.74	3.69	5.55	0.21	0.21	635	0	635	6.97	1.549	137.00	0.029	0.146	0.220	0.008
11/14/2014 13:30	11/14/2014 15:00	176	39.1	3458	0.74	3.69	5.55	0.21	0.00	814	0	814	8.94	1.986	175.72	0.038	0.187	0.282	0.011
Sum									23.06	901,278	720,438	180,839	1852.90	477.62	32483.93	7.13	46.57	70.49	2.33
Average		108	39.4	1903	0.463	7.990	3.660	0.190	0.34	13,254	10,595	2,659	27.25	7.02	477.70	0.10	0.68	1.08	0.03
Weighted Ave		176	39.1	3458	0.742	3.690	5.548	0.210											
STDEV		89	22.3	1837	0.448	9.124	5.970	0.107		35,265	30,931	5,323							
Median		99	40.5	3458	0.350	4.150	2.100	0.180		1,326	0	515							
Min		10	10.0	41	0.057	1.500	0.570	0.019		0	0	0							
Max		390	97.0	7900	1.900	36.000	26.600	0.380		220,540	193,746	26,794							
Percent Capture												20.1%	18.7%	21.7%	16.7%	17.1%	22.4%	22.6%	19.7%

Events with no sampling data (Weighted Average Concentration Used)
Sampling event
ND Not Detected: Sampling parameter below recording limit

City of Saint Paul
Saint Albans Water Quality Summary
Table C.5
WSB Project No.: 01610-100

Sample ID	# of Sample Bottles	# of 200 mL Samples	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-GR-042414 (1-5)				4/24/2014 11:30	78.0	78.0	27.0	160.0	68.0	88.0	0.16	0.0290	9.90	0.76	1.30	0.28	38.0	23.0	17.0	130.0	3.20	7.93	4.1	276
SA-AS-05/28/2014 (1)	1	1	5/26/2014 22:05	5/26/2014 22:36	130.0	460.0	72.0				1.00	0.0120	170.00			ND	100.0	80.0	25.0	320.0				
SA-AS-05/28/2014 (2-8 Composite)	7	31	5/27/2014 3:25	5/27/2014 9:24	140.0	ND	41.0	380.0	87.0	290.0	0.45	0.0280	1.60		1.80	0.22	57.0	34.0	46.0	170.0				
SA-AS-06/02/2014 (1-20 Composite)	20	77	5/31/2014 16:55	6/1/2014 8:02	160.0	24.0	52.0	560.0	23.0	540.0	0.56	0.0290	5.10		2.20	0.17	53.0	27.0	44.0	150.0				
SA-AS-06/09/2014 (1-6 Composite)	6	26	6/7/2014 7:58	6/7/2014 12:31	120.0	58.0	42.0	290.0	29.0	260.0	0.48	0.0630	5.90		2.10	0.22	42.0	26.0	42.0	170.0				
SA-AS-06/16/2014 (1)	1	5	6/11/2014 23:28	6/12/2014 1:24	130.0	150.0	64.0				0.40 sd		44.00			0.02	43.0	32.0	25.0	170.0				
SA-AS-06/16/14 (2-13)	12	47	6/14/2014 11:14	6/14/2014 18:07	89.0	68.0	38.0	350.0	17.0	330.0	0.48 sd	0.0180 gg	2.70		ND	0.19	26.0	14.0	26.0	110.0				
SA-AS-06/17/14 (1-3)	2	7	6/16/2014 17:18	6/16/2014 21:24	25.0 sd	18.0 J	17.0	28.0	ND	18.0	0.11	0.0210 gi	6.70		0.58	0.25	29.0	12.0	9.7 J	71.0				
SA-GS-6/19/2014				6/19/2014 9:15	400.0	30.0 J	100.0	110.0	29.0	78.0	0.90	0.0350 gi	1.00	0.19	ND	0.12	82.0	65.0	280.0	320.0	1.10	7.91 gh	3.5 ts	4610 ts
SA-AS-06/20/2014 (1-3)	3	14	6/18/2014 2:57	6/18/2014 4:10	160.0	44.0	50.0	890.0	69.0	820.0	0.28	0.0400 gg	10.00		1.60	0.32	37.0	19.0	39.0	110.0				
SA-AS-06/30/14 (1-2 Composite)	2	10	6/28/2014 15:53	6/28/2014 18:49	180.0	ND	60.0	1900.0	120.0	1800.0	1.80	0.0440 gg	10.20		0.69	0.05								
SA-AS-07/09/14 (1)	1	1	7/6/2014 6:28	7/6/2014 8:45	280.0	260.0	86.0				9.70		120.00			ND								
SA-AS-07/09/14 (2-3)	2	10	7/7/2014 18:19	7/7/2014 19:18	120.0	ND	47.0	240.0	84.0	150.0	0.38	0.0890	13.80		2.20	0.14								
SA-AS-07/11/14 (1-9 Composite)	9	41	7/11/2014 8:20	7/11/2014 10:39	78.0		26.0	440.0	15.0	420.0	0.42		3.40		1.20	0.10								
SA-AS-07/12/14 (1-2)	2	4	7/12/2014 13:36	7/12/2014 16:03	64.0 gk		36.0 gk				0.19		22.30			0.15								
SA-AS-081814 (1-4) *Should be 1-2	2	10	8/18/2014 0:13	8/18/2014 1:10	244.0	77.0	97.0	4900.0	440.0	4400.0	0.69	0.0620	8.50		2.70	0.39					3.00	6.60 H6	14.2	
SA-AS-082914(1-7)	7	31	8/29/2014 15:09	8/31/2014 16:11	205	40	70				1.8	0.081	3.7	0.27	2.2	0.24	85.3	52	57.3	258	<2.5	6.6	6.2	
SA-AS-083114(1-2)	2	8	8/31/2014 22:07	9/2/2014 2:03	18	46	13				0.12	0.057	7.8	0.19	0.87	0.24	17.4	10.1	<10.0	45.6				
SA-GS-090314			09/03/2014 09:35																					>200.5
SA-AS-090314(1)	1	5	09/03/2014 10:04	9/3/2014 11:33	194	136	50				0.4	0.084	12.7	0.37	3.3	0.59	60.3	42.5	48.8	225				
SA-AS-090914(1-3)	3	13	09/09/2014 21:24	9/9/2014 23:58	148	612	62				0.4	0.091	5.8	0.28	2.2	0.46	107.0	36.5	36.5	195				
SA-AS-092014 (1-2)	2	7	09/20/2014 18:03	9/20/2014 18:42	272	98	57				0.66	0.06	10.3		3.2	0.072	74.9	66.3	69.5	347				
SA-AS-100114 (1-2)	2	7	10/01/2014 10:13	10/1/2014 11:43	78	<10.0	25				0.26	0.056	3.9	0.089	0.84	<0.020	20.5	38.5	<10.0	89.6				
SA-AS-100214 (1-2)	2	10	10/02/2014 13:05	10/2/2014 17:12	54	16	35				0.14	0.021	7	0.11	0.9	0.25	27.9	14.4	<10.0	86.7				
SA-AS-100414 (1)	1	4	10/04/2014 00:33	10/4/2014 1:45	34	26	24				0.15	0.017	5.6	1.5	1	<0.020	23.6	13.9	<10.0	69.4				
MINIMUM					**18.0**	**16.0**	**13.0**	**28.0**	**15.0**	**18.0**	**0.11**	**0.012**	**1.0**	**0.09**	**0.58**	**0.020**	**17.4**	**10.1**	**9.7**	**45.6**	**1.1**	**6.6**	**3.5**	**276.0**
AVERAGE					**144.5**	**127.2**	**50.6**	**917.1**	**91.3**	**827.8**	**0.95**	**0.045**	**21.0**	**0.42**	**1.74**	**0.221**	**52.1**	**34.3**	**60.3**	**171.0**	**2.1**	**6.6**	**6.2**	**2443.0**
MAXIMUM					**400.0**	**612.0**	**100.0**	**4900.0**	**440.0**	**4400.0**	**9.70**	**0.091**	**170.0**	**1.50**	**3.30**	**0.590**	**107.0**	**80.0**	**280.0**	**347.0**	**3.0**	**7.9**	**14.2**	**4610.0**

NLR = No Lab Results as of Table Printing Date
Grab Samples
* The Lab received tha samplepast the method specified holding time or with insufficient time remaining to perform the analysis within the EPA recomemended holding time.
SSC analysis was not available for the later part of the season

Qualifiers and Abbreviations

ts - This analysis was performed by a subcontract laboratory.
qn - The spike recovery is outside of laboratory control limits for the matrix spike (MS) and/or the matrix spike duplicate (MSD).
J - Detected but below the Method Reporting Limit; therefore, result is an estimated concentration (CLP J-Flag).
gi - The sample was not filtered within 15 minutes of sample collection as required by the EPA.
gg1, H1 - Sample holding time exceeded
ND, <Value - Analyte NOT DETECTED above the MDL value

City of Saint Paul
2014 St. Albans Pollutant Loading
Table C.6
WSB Project No.: 01610-100

SAINT ALBANS INFILTRATION SYSTEM POLLUTANT LOADING AND VOLUME REDUCTION TABLE

Event Time Interval		Sampling Data							Event Loading and Volume Data											
		TSS	VSS	Suspended Sediment Conc. (SSC)	TP	Chloride	Total Kjeldahl Nitrogen	Nitrate + Nitrite as N	Interval Rain	Eliptical Volume Volume (1)	University Volume (2)	Bypass Volume (3)	Volume Captured by BMP (1+2-3)	Captured TSS	Captured VSS	Captured SSC	Captured TP	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.
5/26/14 11:46	5/26/14 11:49	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0	33.0	0	0	33.0	0.3	0.1	1.8	0.0	0.0	0.0	0.0
5/26/14 22:04	5/26/14 22:33	130	72	897.8	1	170	1.78	ND	0	379.8	0	0	379.8	3.1	1.7	21.3	0.0	4.0	0.0	ND
5/27/14 3:25	5/27/14 9:21	140	41	380	0.45	1.6	1.8	0.22	1.21	18404.8	0	0	18404.8	160.9	47.1	436.6	0.5	1.8	2.1	0.3
5/27/14 15:55	5/27/14 16:05	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.17	64.6	0	0	64.6	0.6	0.2	3.6	0.0	0.0	0.0	0.0
5/31/14 16:54	6/1/14 7:59	160	52	560	0.56	5.1	2.2	0.17	2.53	43186.2	24592.3	2006.7	65771.8	657.0	213.5	2299.4	2.3	20.9	9.0	0.7
6/1/14 22:52	6/1/14 23:12	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.07	232.1	51.0	0	283.1	2.6	0.9	15.9	0.0	0.1	0.0	0.0
6/7/14 7:58	6/7/14 10:57	120	42	290	0.48	5.9	2.1	0.22	1.11	15671.7	10592.4	0	26264.1	196.8	68.9	475.5	0.8	9.7	3.4	0.4
6/11/2014 23:28	6/12/2014 1:24	130	64	897.8	0.4	44	1.78	0.02	0.22	2198.0	1831.1	0	4029.1	32.7	16.1	225.8	0.1	11.1	0.4	0.0
6/14/2014 11:14	6/14/2014 18:07	89	38	350	0.48	2.7	ND	0.19	1.13	15974.5	10789.3	0	26763.8	148.7	63.5	584.8	0.8	4.5	ND	0.3
6/15/14 5:56	6/15/14 10:12	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.75	10221.7	7048.5	0	17270.2	160.2	54.5	968.0	0.8	7.7	1.9	0.2
6/16/14 17:17	6/16/14 21:21	25	17	28	0.11	6.7	0.58	0.25	0.45	4195.4	4095.2	0	8290.6	12.9	8.8	14.5	0.1	3.5	0.3	0.1
6/18/14 2:57	6/18/14 4:07	160	50	890	0.28	10	1.6	0.32	0.79	7210.6	7442.3	0	14652.8	146.4	45.7	814.1	0.3	9.1	1.5	0.3
6/28/14 15:53	6/28/14 18:46	180	60	1900	1.8	10.2	0.69	0.053	1.45	20070.3	15045.4	1116.3	33999.4	382.1	127.4	4032.8	3.8	21.6	1.5	0.1
6/28/14 19:11	6/28/14 20:28	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.12	1365.1	1075.4	0	2440.4	22.6	7.7	136.8	0.1	1.1	0.3	0.0
7/6/14 6:27	7/6/14 8:42	280	86	897.8	9.7	120	1.78	ND	0.08	905.9	359.0	0	1264.9	22.1	6.8	70.9	0.8	9.5	0.1	ND
7/7/14 18:18	7/7/14 19:15	120	47	240	0.38	13.8	2.2	0.14	0.41	5213.3	3237.0	0	8450.3	63.3	24.8	126.6	0.2	7.3	1.2	0.1
7/11/2014 8:20	7/11/2014 10:39	78	26	440	0.42	3.4	1.2	0.097	1.06	14914.7	10100.2	0	25014.9	121.8	40.6	687.1	0.7	5.3	1.9	0.2
7/12/2014 13:36	7/12/2014 16:03	64	36	897.8	0.19	22.3	1.78	0.15	0.29	3257.7	2520.2	0	5777.9	23.1	13.0	323.8	0.1	8.0	0.6	0.1
7/14/14 18:02	7/14/14 18:21	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.09	262.9	213.0	0	475.9	4.4	1.5	26.7	0.0	0.2	0.1	0.0
7/25/14 5:15	7/25/14 6:51	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.4	3389.9	3878.6	0	7268.5	67.4	23.0	407.4	0.4	3.2	0.8	0.1
8/3/14 16:10	8/3/14 16:19	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.03	48.9	139.4	0	188.3	1.7	0.6	10.6	0.0	0.1	0.0	0.0
8/10/14 22:01	8/10/14 22:54	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.2	968.0	746.8	0	1714.8	15.9	5.4	96.1	0.1	0.8	0.2	0.0
8/11/14 9:45	8/11/14 10:00	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.09	109.1	74.7	0	183.7	1.7	0.6	10.3	0.0	0.1	0.0	0.0
8/11/14 18:26	8/11/14 18:50	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.07	327.4	446.6	0	774.0	7.2	2.4	43.4	0.0	0.3	0.1	0.0
8/17/14 15:36	8/17/14 15:51	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.04	62.5	178.9	0	241.4	2.2	0.8	13.5	0.0	0.1	0.0	0.0
8/18/14 0:11	8/18/14 1:24	244.00	97.00	4900.0	0.69	8.50	2.70	0.39	0.44	5163.4	4843.3	0	10006.7	152.4	60.6	3061.0	0.4	5.3	1.7	0.2
8/21/14 6:25	8/21/14 8:04	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.18	650.1	1715.8	0	2366.0	21.9	7.5	132.6	0.1	1.1	0.3	0.0
8/29/14 17:22	8/30/14 3:23	205	70	897.8	1.8	3.7	2.2	0.24	1.24	16996.7	11135.2	0	28131.9	360.0	122.9	1576.8	3.2	6.5	3.9	0.4
8/31/14 22:05	9/1/14 4:13	18	13	897.8	0.12	7.8	0.87	0.24	0.53	4225.7	4978.6	0	9204.4	10.3	7.5	515.9	0.1	4.5	0.5	0.1
9/3/14 9:30	9/3/14 11:27	194	50	897.8	0.4	12.7	3.3	0.59	0.16	874.0	838.3	0	1712.3	20.7	5.3	96.0	0.0	1.4	0.4	0.1
9/3/14 11:59	9/3/14 12:01	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.02	66.3	14.9	0	81.2	0.8	0.3	4.5	0.0	0.0	0.0	0.0
9/9/14 21:17	9/9/14 23:30	148	62	897.8	0.4	5.8	2.2	0.46	0.79	8345.6	5852.0	0	14197.6	131.2	55.0	795.8	0.4	5.1	1.9	0.4
9/9/14 23:38	9/10/14 0:26	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.02	549.3	524.9	0	1074.2	10.0	3.4	60.2	0.1	0.5	0.1	0.0
9/20/14 18:00	9/20/14 18:55	272	57	897.8	0.66	10.3	3.2	0.072	0.28	2941.6	2684.2	0	5625.8	95.5	20.0	315.3	0.2	3.6	1.1	0.0
9/29/14 10:20	9/29/14 10:49	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.08	310.9	288.4	0	599.3	5.6	1.9	33.6	0.0	0.3	0.1	0.0
10/1/14 7:40	10/1/14 13:29	78	25	897.8	0.26	3.9	0.84	<0.020	0.77	7981.7	7138.8	0	15120.5	73.6	23.6	847.5	0.2	3.7	0.8	ND
10/2/14 12:57	10/2/14 19:43	54	35	897.8	0.14	7	0.9	0.25	0.71	7097.4	7347.5	0	14444.9	48.7	31.6	809.6	0.1	6.3	0.8	0.2
10/4/14 0:00	10/4/14 2:09	34	24	897.8	0.15	5.6	1	<0.020	0.16	956.6	1401.1	0	2357.7	5.0	3.5	132.1	0.0	0.8	0.1	ND
10/23/14 3:17	10/23/14 4:00	148.6	50.6	897.8	0.78	7.11	1.78	0.20	0.09	532.1	587.2	0	1119.2	10.4	3.5	62.7	0.1	0.5	0.1	0.0
Sum									29.54	225495	153828	3122.99	**376200**	**3204.6**	**1122.4**	**20295.6**	**16.8**	**169.8**	**37.3**	**4.4**
Average		132.9	48.4	997.8	0.95	21.9	1.74	0.23	0.39	3007	2079	42	5084	43.3	15.2	274.3	0.2	2.3	0.5	0.1
Weighted Ave		148.6	50.6	897.8	0.78	7.1	1.78	0.20												
STDEV		75.6	21.7	961.8	2.01	41.6	0.78	0.14		6791	4262	265	10708							
Min		18	13	28	0.11	1.6	0.58	0.02		0	0	0	0							
Max		280	97	4900	9.70	170.0	3.30	0.59		43186	24592	2007	65772							
Percent Capture													**98.37%**	**98.01%**	**98.13%**	**98.04%**	**97.72%**	**98.24%**	**98.30%**	**98.89%**

ND Not Detected: Sampling Parameter below recording limit

Events with no sampling data (Weighted Average Concentration Used) (shaded red)

Sampling event (shaded purple)

City of Saint Paul
Dale Street Water Quality Summary
Table C.7
WSB Project No.: 01610-100

Sample ID	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)
DSU-GR-042414	4/24/2014 10:30	150.00	240.00	43.00	130.00	120.00	17.00	0.230	0.020	130.00	0.68	1.80	0.28	65.00	23.00	12.00	150.00	6.90	7.58	4.60	108.00
DSD-GR-042414	4/24/2014 10:45	120.00	360.00	40.00	120.00	120.00	ND	0.180	0.023	200.00	0.62	1.50	0.29	55.00	22.00	12.00	140.00	6.90	7.50	4.60	96.00
DS-U-GS-6/19/2014	6/19/2014 8:30	12.00	290.00	7.30	18.00	14.00	ND	0.130	0.027 gi	150.00	0.22	ND	0.31	40.00	12.00	4.70 J	70.00	13.00	7.37 gh	4.00 ts	11200.00 ts
DS-D-GS-6/19/2014	6/19/2014 8:20	18.00	78.00	8.80	26.00	16.00	10.00	0.087	0.022 gi	37.00	0.18	0.60	0.21	27.00	7.80 J	4.00 J	67.00	3.70	7.17 gh	2.90 ts	2420.00 ts
DU-GS-090314	9/3/2014 8:50	35.0	306	19.0				0.11	0.023	138	0.27	1.3	0.63	39.50	12.1	ND	177	17.3	6.6	ND	>200.5
DD-GS-090314	9/3/2014 9:10	32.0	144	19.0				0.22	0.028	37.5	0.39	1.60	0.30	79.00	29.2	20.5	165	13.70	7.0	5.4	>200.5
MINIMUM		**12.00**	**78.00**	**7.30**	**18.00**	**14.00**	**10.00**	**0.09**	**0.02**	**37.00**	**0.18**	**0.60**	**0.21**	**27.00**	**7.80**	**4.00**	**67.00**	**3.70**	**7.17**	**2.90**	**96.00**
AVERAGE		**75.00**	**242.00**	**24.78**	**73.50**	**67.50**	**13.50**	**0.16**	**0.02**	**129.25**	**0.43**	**1.38**	**0.27**	**50.92**	**16.20**	**8.18**	**106.75**	**8.84**	**7.41**	**4.03**	**3456.00**
MAXIMUM		**150.00**	**360.00**	**43.00**	**130.00**	**120.00**	**17.00**	**0.23**	**0.03**	**200.00**	**0.68**	**1.80**	**0.31**	**79.00**	**23.00**	**12.00**	**150.00**	**13.70**	**7.58**	**4.60**	**11200.00**

Upstream Grab Sample
Downstream Grab Sample
SSC analysis was not available for the later part of the season

Qualifiers and Abbreviations

ts - This analysis was performed by a subcontract laboratory.
qn - The spike recovery is outside of laboratory control limits for the matrix spike (MS) and/or the matrix spike duplicate (MSD).
J - Detected but below the Method Reporting Limit; therefore, result is an estimated concentration (CLP J-Flag).
gi - The sample was not filtered within 15 minutes of sample collection as required by the EPA.

Beacon Bluff BMP Pipe

Hillcrest Knoll

St. Albans BMP Pipe

St. Albans Pretreatment MH 4001

Arundel Pretreatment MH 5001

Arundel BMP Pipe

STORMWATER MONITORING PROTOCOL

2014 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, e-coli, 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. Lightning safety is especially important due to the likelihood of thunderstorms during stormwater sampling events.
- 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:

Permits/Notifications:

- 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 Entering and Working in Confined Spaces, 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

<u>Required Safety Gear:</u>

- ☐ 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

<u>Gear Maintenance:</u>

- ☐ **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

<u>General Confined Space Entry Procedures:</u>

- ☐ 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:

1 - Tipping bucket rain gauge (Wilder Recreation Center)
3 – ISCO 2150 Area velocity sensors
2 – Rugged Troll 200 (by WSB)
2 –Level Troll 500 Level loggers (by AET) 1
1 – ISCO 6712 Portable water quality sampler
1—Grab sampling equipment

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:

1 –Tipping bucket rain gauge (Hayden Heights Recreation Center)
2 – ISCO 2150 Area velocity sensors
3 – Level Troll 500
1 – ISCO 6712 Portable water quality sampler
1—Grab sampling equipment

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:

1 - Tipping bucket rain gauge (SPFD Fire Station 18)
3 – ISCO 2150 Area velocity sensors
1 - Level Troll 500
1 – ISCO 6712 Portable water quality sampler

Monitoring Parameters:

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

III.4 College Park:

In September 2011, groundwater measurements were taken in four piezometers located in College Park in anticipation of construction of the proposed infiltration system beginning in the fall. These measurements indicated that groundwater had risen by nearly five feet since the last measurements were taken in February 2011 and by over six feet since measurements were taken in 2008. Upon identifying this unexpected rise in groundwater levels and based on the recommendations of WSB, the City decided to postpone construction of the proposed improvements in College Park. Since identifying the increase in groundwater levels in September 2011, on-going groundwater monitoring has been conducted at the site. Water levels will continue to be monitored at College Park and at one University of Minnesota well located on the state fairgrounds.

Equipment:

2 – ISCO 2150 Area velocity sensors
2 -- Level Troll 500Level loggers

Monitoring Parameters:

- Rainfall
- Groundwater elevation

III.5 Arlington-Hamline Underground System (AHUG):

This system is owned and operated by the Capitol Region Watershed District and funded in part by the City of St. Paul. It consists of three parallel 10-foot diameter perforated metal chambers placed underground to facilitate infiltration. A proprietary stormwater pretreatment system is located upstream of the infiltration chambers. Runoff is routed to the pretreatment system from the main storm sewer at a diversion structure. High flows bypass the diversion structure. If the system reaches its storage capacity, flow discharges at the north end of the infiltration system through a weir structure and storm sewer pipe that is connected into the main storm sewer a block north of the upstream diversion structure.

Equipment:

1 - Tipping bucket rain gauge (Hubert Humphrey Job Corps Center)
2 – ISCO 2150 Area velocity sensors
1 - Level Troll 500

Monitoring Parameters:

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

III.6 St. Catherine University (Monitored by AET):

In 2010, the Cleveland and Randolph Area Groundwater Study (CRGS) was conducted to assess routine high groundwater issues in the area. The results indicated an area of perched groundwater between Bayard Avenue and Eleanor Avenue, and Kenneth Street and Josephine Street. As a result of the high groundwater levels, the report proposed a no-infiltration buffer zone to mitigate water damage to susceptible properties in the area. Subsequent to the study findings, the City of Saint Paul installed five additional piezometers with continuous groundwater level loggers in the area to determine the continuous effect of precipitation on groundwater levels.

Equipment:

1 - Tipping bucket rain gauge (Edgecumbe Recreation Center)
5 - Level Troll 500 (AET)

Monitoring Parameters:

- Rainfall
- Groundwater elevation

III.7 Dale Street Facility:

A Vortechs system was constructed to collect sediment and debris from the Dale Street Facility. Quarterly grab samples will be collected upstream and downstream of the system and flow will be estimated based on the depth of water in the pipe.

Equipment:

1—Grab sampling equipment

Monitoring Parameters:

- Water Quality

III.8 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 - Tipping bucket rain gauge (SPFD Fire Station 18)
1 - Level Troll 500

Monitoring Parameters:

- Rainfall
- Water level/Infiltration rate

III.9 Victoria Street and Hamline-Midway Library Pervious Surfaces:

The Victoria Street paver parking area and Hamline-Midway Library porous concrete alley will serve as pilot projects to research the benefits, feasibility, and sustainability of permeable surface parking lanes and alley ways in the City of St. Paul.

Equipment:

1 - Infiltration measurement apparatus
1 - Water tank and feeder hose
1 - Digital camera
1 - Scale
1 - 12” PVC Pipe
1 - Plumbers putty

Monitoring Parameters:

- Infiltration rate
- BMP visual inspection

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

Frequency:

- Once per month

Visual Inspection:

- 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

Manual Data Collection:

- 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

Required Equipment:

- Measuring rod
- Digital camera

Required Forms:

- Infiltration BMP Inspection and Maintenance Form

V.2 Pervious Pavement Infiltration Tests

Frequency:

- Once per year

Visual Inspection:

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

Manual Data Collection:

- 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	Hillcrest Knoll
	Runoff Volume (cu-ft)	Runoff Volume (cu-ft)	Runoff Volume (cu-ft)
0.10-0.15”	450	4,500	1,035
0.25”	1,703	20,986	8,235
0.5”	5,112	63,000	24,724
1.0”	14,333	156,756	61,511
2.0”	48,834	373,550	142,157
3.0”	95,715	657,879	236,072

<u>Program Automated Sampling Parameters:</u>

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
  - Hillcrest Knoll: 1.5 inches

[3] [illegible] = [illegible]

- **Pacing:** Set sampler to collect samples at constant flow volume intervals
  - Victoria Street: minimum 450 cu-ft (0.003 Mgal)
  - Beacon Bluff: minimum 3,000 cu-ft (0.034 Mgal)
  - Hillcrest Knoll: 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, Hillcrest Knoll, St. Albans and Dale Street sites. 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 Hillcrest Knoll, St. Albans., and Beacon Bluff and the manholes both upstream and downstream of the Dale Street location.

<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). E. Coli., BOD5, pH, and sulfate will be tested quarterly.

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: VIC-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.

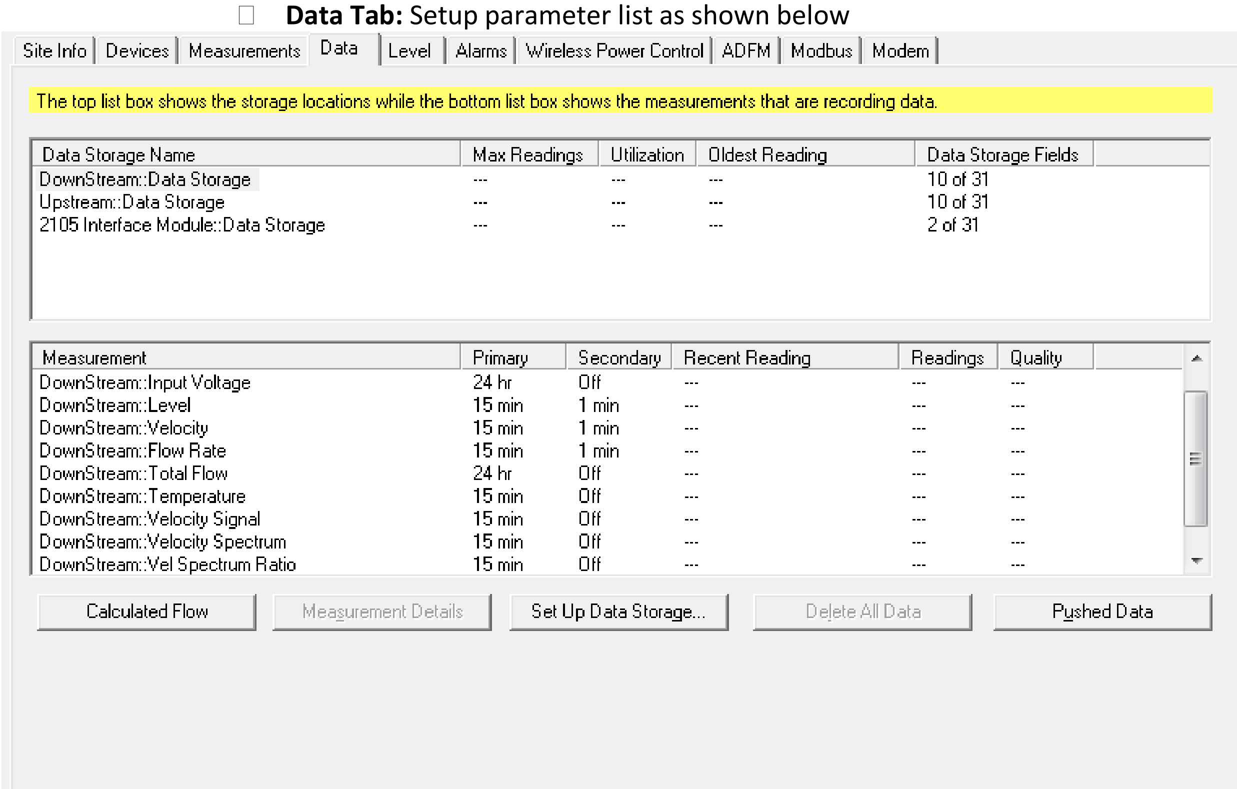
VI. Operation and Maintenance of Monitoring Equipment

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



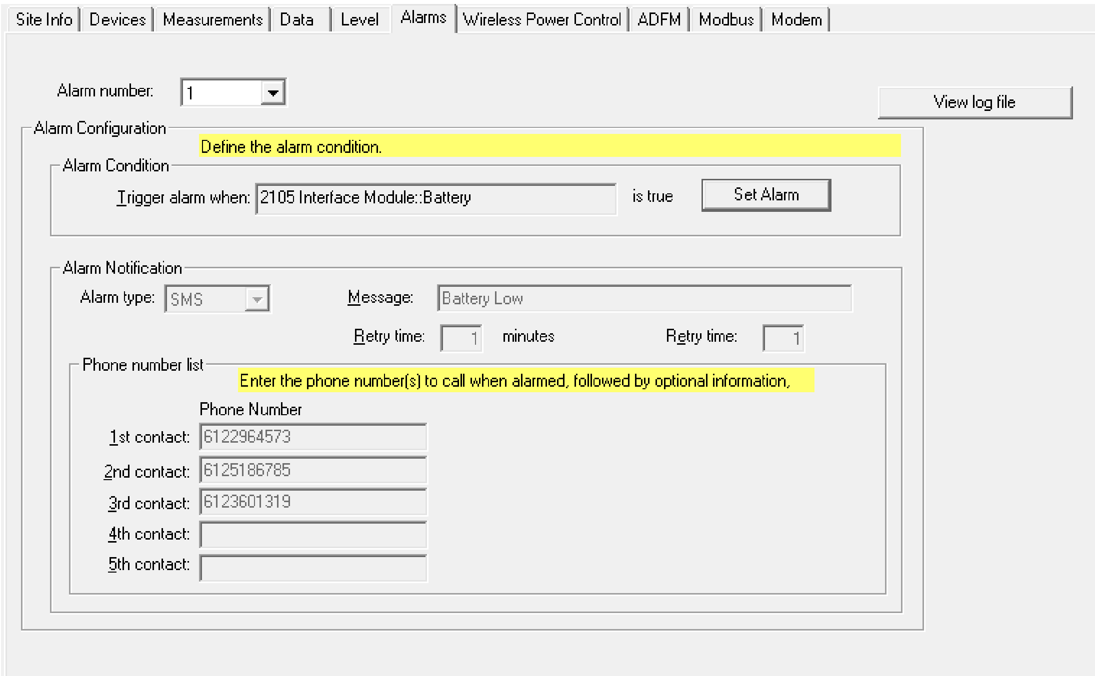
- **Measurement Details:** Set units for all measurements (in, cfs, or cf)

[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, Hillcrest Knoll)
  - (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.

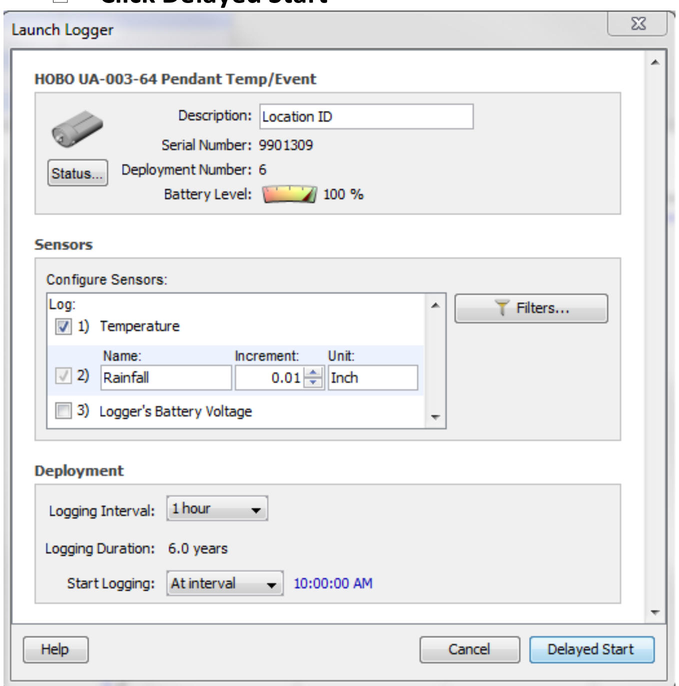
Routine Maintenance:

- **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_2013_ 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.

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.

Current edition approved Aug. 1, 2009. Published September 2009. DOI: 10.1520/C1701_C1701M-09.

[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

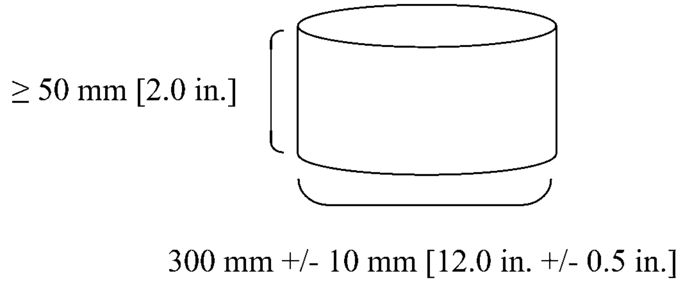

FIG. 1 Dimensions of Infiltration Ring

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 $(mm^3s)/(kgh)$ $[(in.^3s)/(lbh)]$ 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