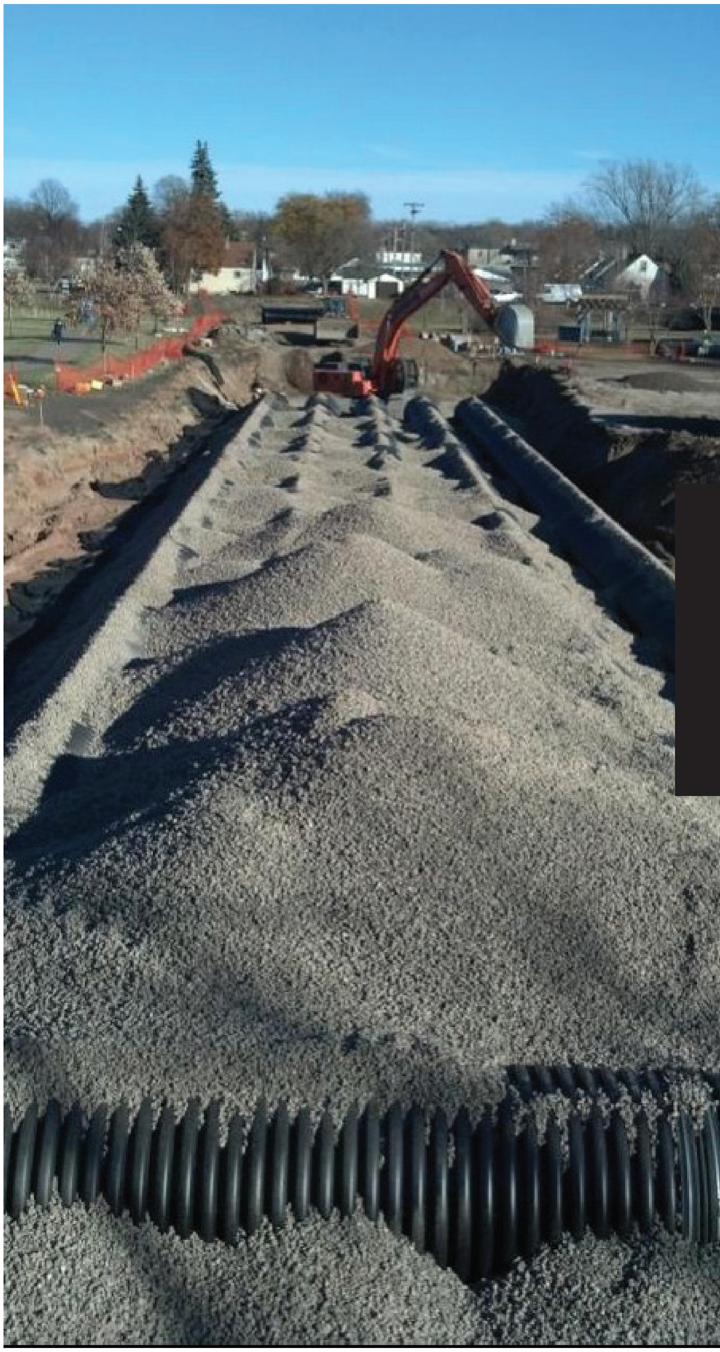

SAINT PAUL

The Most Livable City in America

# 2017 Water Quality & Quantity Program

## Monitoring Report

April 2018

Prepared for

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

Project No. 01610-10

WSB

# THE CITY OF ST. PAUL

# 2017 STORMWATER QUALITY AND QUANTITY MONITORING PROGRAM

APRIL 2018

**PREPARED BY:**

WSB

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**APPENDICES**

**LIST OF ABBREVIATIONS**

| | |
|---|---|
| BMP | Best Management Practices |
| CCB | Capital City Bikeway |
| CRWD | Capitol Region Watershed District |
| Cu-ft | Cubic feet |
| DP | Dissolved phosphorus |
| EMC | Event mean concentration |
| ft | Feet |
| FWA | Flow-weighted average |
| HDPE | High-density polyethylene |
| IESF | Iron-enhanced sand filtration ponds |
| In/hr | Inches per hour |
| IR | In-rock |
| lbs | Pounds |
| mg/L | Milligrams per liter |
| MS4 | Municipal Separate Storm Sewer System |
| MSWM | Minnesota Stormwater Manual |
| MPN | Most probable number |
| MnDOT | Minnesota Department of Transportation |
| NPDES | National Pollutant Discharge Elimination System |
| OCS | Outlet control structure |
| SP | Poorly graded sand |
| SPCD | Saint Paul City Datum |
| SRP | Soluble reactive phosphorus |
| TBNS | Trout Brook Nature Sanctuary |
| TP | Total phosphorus |
| TSS | Total suspended solids |

# 1. INTRODUCTION

The purpose of this report is to present the findings of the City of Saint Paul's (City) 2017 Stormwater Monitoring Program. The monitoring was conducted to fulfill requirements of the City's National Pollutant Discharge Elimination System (NPDES) MS4 Phase I Permit. Data collected and analyzed is used to quantify stormwater volumes and loads from the Municipal Separate Storm Sewer System (MS4) and assist in the assessment of effectiveness of the City's Stormwater Management Program.

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

The focus of the City's stormwater monitoring program has been to monitor the effectiveness and maintenance needs of stormwater BMPs. Outfall monitoring data, collected by Capitol Region Watershed District (CRWD), is used to evaluate pollutant loading from major sub-watersheds and to estimate City-wide pollutant loading from the MS4. That information is provided in the annual MS4 Report submitted to the MPCA and is not further evaluated in this report.

Fifteen BMPs were monitored in 2017 to quantify progress toward meeting the City's stormwater management goals and to refine current design and maintenance practices. Rainfall was also measured at five locations in the City. The 2017 monitoring sites are shown on **Figure 1-1** and listed in **Table 1-1**. This effort focused on evaluating four major parameters during the monitoring period:

- Water level/infiltration rate
- Volume reduction
- Pollutant capture
- BMP maintenance

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

Three of the monitored BMPs are pervious pavement sites, evaluated for infiltration performance. Long-term monitoring at these sites is completed to research the benefits, feasibility, and sustainability of pervious surface parking lanes, alleyways, and bike trails in the City.

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

**Table 1-1: 2017 City of Saint Paul Monitoring Site Summary**

| BMP Site Name | BMP Type | Monitored Parameters[1] |
|---|---|---|
| Beacon Bluff | Underground Infiltration Gallery & Rain Garden | WL, Q, WQ, GW |
| Hillcrest Knoll Park | Underground Infiltration Gallery | WL, Q, GW |
| St. Alban's Street | Underground Infiltration Gallery | WL, Q |
| Hampden Park | Underground Infiltration Gallery | WL, Q, WQ, GW |
| Arundel Street | Underground Infiltration Gallery | WL |
| Wordsworth | Infiltration Trench | WL |
| Montreal | Infiltration Trench | WL |
| Flandrau – Hoyt Pond | Stormwater Pond | WL |
| Sackett Park Pond | Stormwater Pond | WL |
| Trout Brook Nature Sanctuary – Maryland Pond | Iron-Enhance Sand Filtration Pond | WL, Q, WQ |
| Trout Brook Nature Sanctuary – Magnolia Pond | Iron-Enhance Sand Filtration Pond | WL, Q, WQ |
| Trout Brook Nature Sanctuary – Jenks Pond | Iron-Enhance Sand Filtration Pond | WL, Q, WQ |
| Victoria Street Pervious Pavers | Pervious Pavers | Infiltration |
| Hamline-Midway Library Pervious Pavement | Pervious Asphalt | Infiltration |
| Jackson Street Pervious Bike Path | Pervious Asphalt | Infiltration |
| | | |
| Wilder Recreation Center | Rainfall Monitoring Location | R |
| Fire Station 18 | Rainfall Monitoring Location | R |
| Hampden Park Co-op | Rainfall Monitoring Location | R |
| Frost Elementary School | Rainfall Monitoring Location | R |
| Edgecumbe Recreation Center | Rainfall Monitoring Location | R |

**. - Water Level, Q – Flow Rate, WQ – Water Quality, GW – Groundwater, R – Rainfall**

# 2. PROCEDURES AND METHODOLOGY

This section outlines the procedures and methods followed to perform monitoring and data analysis. For more detailed information related to equipment use monitoring protocols that were followed for this monitoring program, see the 2017 Stormwater Monitoring Protocols document located in **Appendix F**.

## 2.1. Infiltration Rate

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

**Data Collection**

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

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

**Photo 2-1: Infiltration gallery level monitoring enclosure**

**Photo 2-2: Beacon Bluff Rain Garden and in-rock permanent monitoring wells**

**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 while drawdown was occurring. Infiltration of water in the horizontal direction through the vertical surfaces of the trenches was not included in this analysis as the policies of the watershed districts only recognize infiltration through the bottom horizontal surface. The infiltration rates calculated at each increment were averaged and plotted on a graph.

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

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

where:

$V_{in}$ = Inflow Volume (cu-ft)
WHSA = Wetted Horizontal Surface Area (sq-ft)
$\Delta t$ = 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, Montreal Avenue and Wordsworth Avenue BMPs, however, since no monitored inflow data was available, inflow volume was not accounted for.

Monitored Infiltration rates were evaluated against design infiltration rates as described in the Minnesota Stormwater Manual (MPCA, 2008) and infiltration rates observed during pre-construction field testing.

## 2.2. Volume Reduction

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

**Data Collection**

Teledyne ISCO 2150 area velocity flow modules and sensors were used to monitor runoff volumes. These devices measure water level and flow velocity. Combining this information with a known conduit shape, the flow rate and flow volume through the conduit were calculated. Each of the monitored systems received stormwater runoff from a diversion structure located along the storm sewer system. The 2150 flow sensors were positioned at the upstream and downstream pipes in these structures to measure the total volume draining to each BMP and the total volume that bypassed each BMP. **Photos 2-3** and **2-4** show the flow meters installed in the 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.

**Photo 2-3: Flow monitoring module**

**Photo 2-4: Flow sensor in upstream pipe in Beacon Bluff diversion structure**

Water treated by the IESF ponds at the TBNS is conveyed to the outlet control structure by eight-inch drain tile beneath the sand benches (**Photo 2-5**). Flow sensors at the TBNS IESF Pond sites were installed within the drain tile discharge point to the outlet control structure of the ponds (**Photo 2-6**). Additional details regarding the TBNS IESF pond monitoring configurations are described in **Section 2.3** and **Section 11.**

**Photo 2-6: Jenks Pond 8" drain tile and outlet pipe within the outlet control structure**

**Photo 2-5: Sensor and sampler intake location in 8" drain tile in Magnolia Pond outlet control structure**

**<u>Data Analysis</u>**

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 were converted to total flow volumes and exported to a Microsoft Excel spreadsheet for further analysis. Each rainfall event and associated inflow and outflow volumes were tabulated.

For the Beacon Bluff and Hampden Park BMPs, runoff volume was estimated for un-monitored system inlets by taking the monitored flow data and multiplying by the ratio the respective drainage areas.

## 2.3. Water Quality

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

**Data Collection**

ISCO 6712 automatic samplers were installed in the diversion structures at Beacon Bluff and Hampden Park (**Photos 2-7** and **2-8**).


**Photo 2-7: ISCO 6712 Sampler at Beacor Bluff**

**Photo 2-8: ISCO Bottle Configuration**

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

The sampling configuration at each of the three TBNS IESF Ponds consisted of a job box containing two ISCO 6712 automated samplers, triggered by a 2150 flow meter. Tubing was routed from the first sampler through a buried conduit to a float within the pond basin (**Photo 2-9**). This location was established as the pre-treatment sample. Tubing was routed for the second sampler along with the 2150 flow meter to a position in the eight-inch drain tile outlet into the outlet control structure. This location was established as the post-treatment sample. The samplers (**Photo 2-10**) were programmed to collect simultaneous flow weighted samples based on flow pacing monitored in the outlet control structure. The flow pacing at each pond was refined during the monitoring period to best capture the entire flow profile of a treatment event, while still meeting the 48-hour hold time for the ortho-phosphate laboratory method.

**Photo 2-10: Magnolia Pond pretreatment sample float**

**Photo 2-9: Maryland Pond sampler configuration**

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

**Table 2-1: Water Quality Parameters**

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

**Data Analysis**

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

## 2.4. Maintenance Inspections

BMP inspections were conducted at Beacon Bluff, Hillcrest Knoll Park, St. Albans Street, Hampden Park, and Arundel Street sites periodically during the monitoring period. Pre-treatment structures were inspected for accumulated sediment depth and floatable debris. Underground chambers were inspected from the level monitoring location for accumulation of sediment, debris, and standing water. The TBNS IESF Ponds were inspected for muck accumulation and iron clumping within the sand filtration benches. Inspection photos are included in the photo log (**Appendix E**)

## 2.5. Pervious Surface Infiltration Rate

The infiltration rate of the permeable surfaces was measured at the Victoria Street, Hamline-Midway Library, and Jackson Street pervious pavement sites following the protocols outlined in ASTM method C1701 (**Appendix G**). The following section provides a summary of those methods.

**Data Collection**

Infiltration tests were conducted according to the modified ASTM C1701 methods for measuring infiltration rates (**Photo 2-11).** Five to 11 tests were conducted at each of the permeable surface sites to develop an average infiltration rate measurement. Seven additional test locations (18 test locations total) were added to the Jackson Street Site in November 2017 upon the completion of additional sections of the BMP. 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 15 minutes of monitoring during a pre-wet test no infiltration was observed, the test was concluded and no subsequent tests were completed.

**Photo 2-11: Permeable Pavement Infiltration Test**

# 3. PRECIPITATION SUMMARY

As part of the City's stormwater monitoring program, seasonal precipitation monitoring is conducted at the following locations: Hampden Park Co-op, Saint Paul Fire Station 18, Wilder Recreation Center, Frost Elementary School, and the Edgcumbe Recreation Center (**Figure 1-1**). Precipitation data collected at these locations provides localized rainfall totals which are utilized for calculating rainfall intensity and runoff yield at monitored BMP sites. Each station is equipped with an automated tipping bucket that records continuously throughout the season.

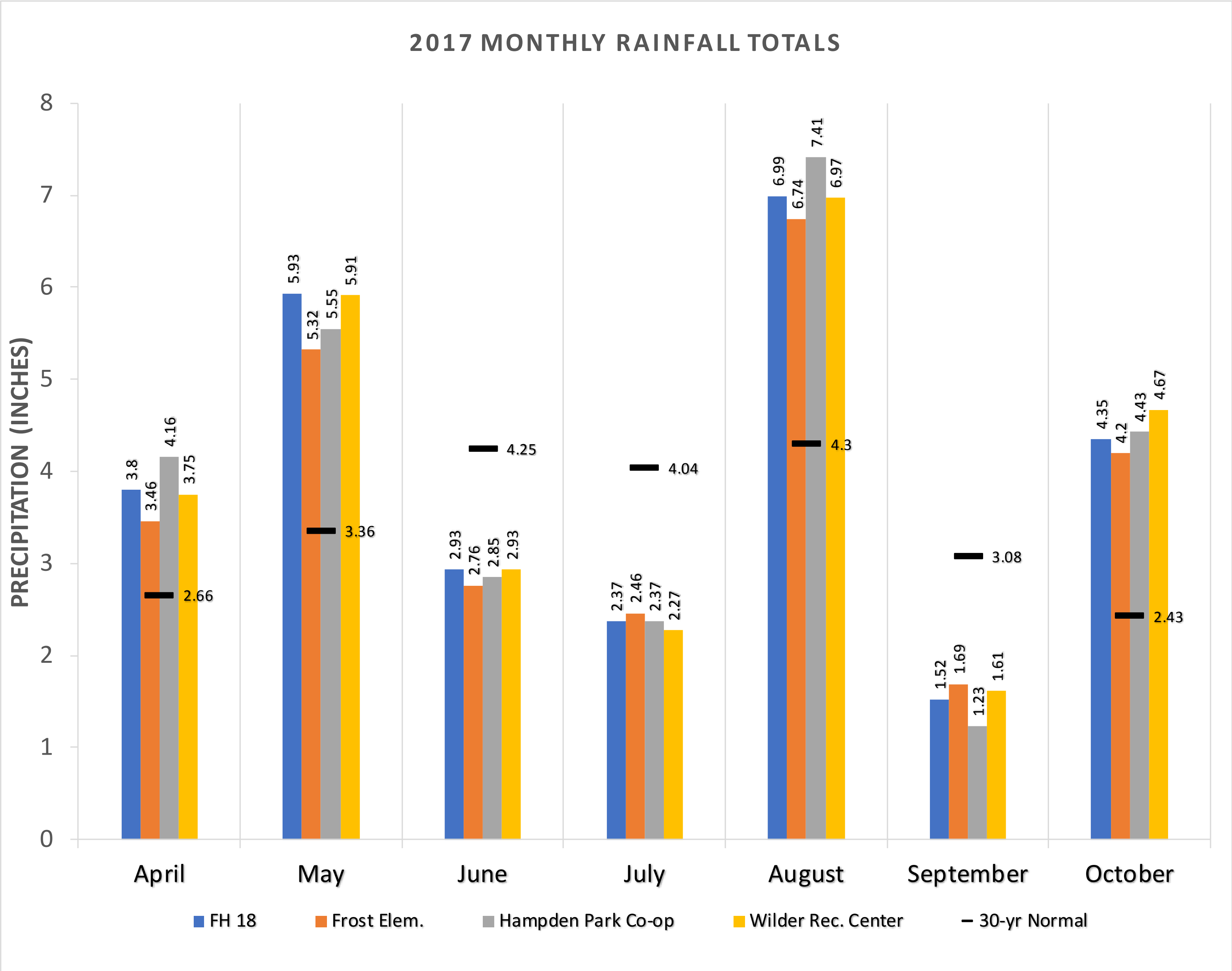
Precipitation data collected by MCES, Minnesota Climatology Working Group (MCWG), and the National Weather Service (NWS) is used to supplement the City's data as needed. This includes any data gaps in seasonally monitored stations as well parameters such as snowfall and snow pack depth, which exceed the limitations of the City's monitoring equipment. These stations also provide a longer period of record which is valuable for analyzing rainfall trends. Data collected by MCWG and NWS is accessible through the Midwest Regional Climate Center online database (MCWG, 2017).

**Table 3-1** and **Chart 3-1** show 2017 monthly precipitation totals for seasonally monitored sites compared to the 30-year normals. The 30-year normals reflect data collected from 1981-2010 and are updated every ten years, with the most recent update being in 2010. The Edgcumbe Recreation Center rainfall data was not evaluated due to equipment malfunctions that persisted throughout the monitoring season.

April through October rainfall ranged from 26.63 inches at Frost Elementary to 28.11 inches at Wilder Recreation Center. The city-wide average for those months was 27.66 inches which is 3.54 inches greater than the 30-year normal. The greatest variability between stations was observed during the month of April with 0.7 inches more rainfall recorded at the Hampden Co-op than Frost Elementary. The month of August saw the greatest departure from the 30-year normal (+2.73 inches).

**Table 3-1: 2017 Seasonal Precipitation Summary**

| Month | FH 18 | Frost Elem. | Hampden Park Co-op | Wilder Rec. Center | City-Wide Average | 30-yr Normal[1] | Departure from 30-yr Normal |
|---|---|---|---|---|---|---|---|
| **April** | 3.8 | 3.46 | 4.16 | 3.75 | 3.79 | 2.66 | 1.13 |
| **May** | 5.93 | 5.32 | 5.55 | 5.91 | 5.68 | 3.36 | 2.32 |
| **June** | 2.93 | 2.76 | 2.85 | 2.93 | 2.87 | 4.25 | -1.38 |
| **July** | 2.37 | 2.46 | 2.37 | 2.27 | 2.37 | 4.04 | -1.67 |
| **August** | 6.99 | 6.74 | 7.41 | 6.97 | 7.03 | 4.3 | 2.73 |
| **September** | 1.52 | 1.69 | 1.23 | 1.61 | 1.51 | 3.08 | -1.57 |
| **October** | 4.35 | 4.2 | 4.43 | 4.67 | 4.41 | 2.43 | 1.98 |
| **Seasonal Total** | **27.89** | **26.63** | **28.00** | **28.11** | **27.66** | **24.12** | **3.54** |


2017 MONTHLY RAINFALL TOTALS
PRECIPITATION (INCHES)
0
1
2
3
4
5
6
7
8
April
May
June
July
August
September
October
3.8
3.46
4.16
3.75
2.66
5.93
5.32
5.55
5.91
3.36
2.93
2.76
2.85
2.93
4.25
2.37
2.46
2.37
2.27
4.04
6.99
6.74
7.41
6.97
4.3
1.52
1.69
1.23
1.61
3.08
4.35
4.2
4.43
4.67
2.43
FH 18
Frost Elem.
Hampden Park Co-op
Wilder Rec. Center
30-yr Normal

Major rainfall events in 2017 are provided in **Table 3-2** below:

**Table 3-2: 2017 Significant Rainfall Events**

| Date | Rainfall Total (in)[1] | Duration (hr) | Intensity (in/hr) |
|---|---|---|---|
| May 17-18, 2017 | 1.97 | 22.1 | 0.09 |
| May 20, 2017 | 1.32 | 8.6 | 0.15 |
| July 17, 2017 | 1.24 | 2.6 | 0.49 |
| August 6, 2017 | 0.8 | 1.1 | 0.76 |
| August 13, 2017 | 1.44 | 1 | 1.44 |
| August 16, 2017 | 1.39 | 5 | 0.29 |
| September 25, 2017 | 0.92 | 3.5 | 0.26 |
| October 2- 3, 2017 | 1.89 | 8.1 | 0.23 |

1 - Rainfall event totals may not reflect total daily rainfall

**Table 3-3** below provides a five-year monthly precipitation summary as recorded at the University of Minnesota Saint Paul Campus. Annual precipitation has exceeded the 30-year normal every year since 2013. Total precipitation in 2017 was 34.06 inches, 3.45 inches above normal. The largest departure from normal occurred in 2016, which exceeded the 30-year by 11.06 inches. August 2016 recorded 9.90 inches of rain, exceeding the 30-year normal maximum for that month (9.20 inches – 2007).

**Table 3-3: 5-year Precipitation Summary (UMN – Saint Paul Campus)**

| Month | 2013 | 2014 | 2015 | 2016 | 2017 | 30-yr Normal |
|---|---|---|---|---|---|---|
| **January** | 0.76 | 1.51 | 0.26 | 0.28 | 0.93 | 0.90 |
| **February** | 1.31 | 1.19 | 0.22 | 0.79 | 0.70 | 0.77 |
| **March** | 2.01 | 0.78 | 0.71 | 2.15 | 0.58 | 1.89 |
| **April** | 5.10 | 6.94 | 2.07 | 3.66 | 3.68 | 2.66 |
| **May** | 7.21 | 3.54 | 4.94 | 2.05 | 6.54 | 3.36 |
| **June** | 7.31 | 9.20 | 3.31 | 3.65 | 3.16 | 4.25 |
| **July** | 3.18 | 2.73 | 6.19 | 5.97 | 2.45 | 4.04 |
| **August** | 1.48 | 3.12 | 2.79 | 9.90 | 8.89 | 4.30 |
| **September** | 1.30 | 2.19 | 3.82 | 5.19 | 1.25 | 3.08 |
| **October** | 4.35 | 1.44 | 2.87 | 3.32 | 4.84 | 2.43 |
| **November** | 0.48 | 0.95 | 4.58 | 2.70 | 0.42 | 1.77 |
| **December** | 1.39 | 0.99 | 2.13 | 2.01 | 0.62 | 1.16 |
| **Total** | **35.88** | **34.58** | **33.89** | **41.67** | **34.06** | **30.61** |
| **Departure from 30-yr Normal** | **+5.27** | **+3.97** | **+3.28** | **+11.06** | **+3.45** | **N/A** |

# 4. BEACON BLUFF

This system, shown in **Figure 4-1**, is owned and operated by the City. The Saint Paul Port Authority contributed financially to the project and oversaw its construction. Volume reduction credits were split between the City and the Saint Paul Port Authority based on the respective financial contribution. Performance monitoring of the system has been conducted since 2012 and rainfall monitoring for the site is conducted at the Wilder Recreation Center, located 0.8 miles to the west. The BMP system details are provided in **Table 4-1**.

The system is comprised of three connected stormwater treatment structures, which include a stormwater pond west of the Duchess Street cul-de-sac (west pond), an infiltration basin east of the cul-de-sac (rain garden) (**Photo 4-1**), and an underground infiltration chamber (**Photo 4-2**) constructed directly beneath the rain garden. The underground chamber consists of three, parallel, 215-foot-long, ten-foot-diameter perforated metal pipes for infiltration.

The Beacon Bluff system has a total drainage area of 143.6 acres, which consists of three subwatersheds. Stormwater from a 136.8-acre drainage area is routed to a diversion structure in the storm sewer along Duchess Street (MH7). The diverted stormwater passes through a manhole equipped with a SAFL Baffle pre-treatment system for particle settling, and then discharges to the rain garden. Two inlets on the eastern side of the rain garden discharge stormwater from a 4.7-acre drainage area immediately surrounding the BMP. Stormwater from a 2.1-acre drainage area discharges to the west pond, which outlets directly to the underground chamber.

Overflow grates within the rain garden allow stormwater to spill from the rain garden, directly into the underground chamber. When the underground chamber reaches capacity, stormwater discharges from the underground system, through an outlet control structure, back to the main storm sewer line.

**Table 4-1: Beacon Bluff BMP Details**

| | |
|---|---|
| Total Drainage Area to BMP | 143.6 acres |
| *Sub-watershed to Diversion Structure (discharge to rain garden)* | *136.8 acres* |
| *Sub-watershed to Eastern Inlet Pipes (discharge to rain garden)* | *4.7 acres* |
| *Sub-watershed to West Pond (discharge from west pond to underground chamber)* | *2.1 acres* |
| Year Constructed | 2011 |
| Total Construction Cost | $980,000 |
| Storage Volume[1] | 159,350 cu-ft |
| Volume Reduction Credit Received by the City of Saint Paul | 116,435 cu-ft |
| Volume Reduction Credit Received by Saint Paul Port Authority | 42,925 cu-ft |

**Photo 4-1: Underground infiltration chamber (Facing west)**

**Photo 4-2: Rain garden located above infiltration chambers (Facing east)**

## 4.1. Water Level and Infiltration Rate Monitoring

Water level in the rain garden (IR-31) and the underground system (IR-32) were measured using continuous water level loggers installed within piezometers. An additional logger was installed within the outlet control structure of the system to confirm when flow was being conveyed back to the storm sewer from the underground chamber. Groundwater elevation was also measured in two 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**.

**Photo 4-3: IR-31 (Rain garden) and IR-32 (underground system) monitoring piezometers (yellow caps), and open grate overflow structure to underground chamber**

Water level in the rain garden ranged from 0.0 feet (ft) to 3.5 ft of depth in 2017. Overflow from the rain garden to the underground system, through open grate structures (**Photo 4-3**), occurred during most treatment events. The 2017 rain garden infiltration rate and infiltration rate trends are provided on **Charts A.5** and **A.6** of **Appendix A**, respectively. The 2017 average infiltration rate for the rain garden was 0.50 inches per hour (in/hr), which is less than the Minnesota Stormwater Manual (MSWM) recommended infiltration rate for SP (poorly graded sand) soils of 0.8 in/hr. This is slightly greater than the rates observed in 2016 (0.43 in/hr) and 2015 (0.29 in/hr) (**Table 4-2**). Sediment accumulation has been observed ranging from 0.5 ft to 1.5 ft of depth, across the basin. The 141.5-acre drainage area discharging directly to the pond conveys a significant amount of sediment and debris, which has accumulated primarily around the diversion inlet pipe.

**Table 4-2: Beacon Bluff Infiltration Rates**

| Location | Average Infiltration Rate (in/hr) | | | | | |
|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Beacon Bluff Rain Garden (IR-31) | 2.9 | 0.85 | 0.70 | 0.29 | 0.43 | 0.50 |
| Beacon Bluff Underground System (IR-32) | 2.6 | 0.57 | 0.64 | 0.30 | 0.15 | 0.11 |

Water level in the underground system ranged from 6.3 ft to 19.5 ft deep. Depths greater than 10 feet indicate the water is rising into the substrate above the 10-ft diameter corrugated metal infiltration pipes. The data indicates that the system did not drain to empty during the 2017 monitoring period, including over the winter months. The underground system discharged back to the storm sewer (system outflow) during ten storm events in 2017. This is an increase from discharge events occurring in 2012-2014 (zero), 2015 (five) and 2016 (nine). The increased frequency of system discharge events is a result of the standing water in the underground system and the capacity it utilizes. Groundwater elevations at the site were a minimum of 12 ft below the bottom of the underground chamber, which suggests that groundwater mounding is not the cause of standing water in the system.

The 2017 underground chamber infiltration rate and infiltration rate trends are provided on **Charts A.3** and **A.4** of **Appendix A**, respectively. The 2017 average infiltration rate for the was 0.11 in/hr, which is less than MSWM recommended infiltration rate for SP soils of 0.8 in/hr. From 2012 to 2017, the infiltration rate has decreased from 2.6 in/hr to 0.11 in/hr, with the largest decline following the first year of monitoring in 2012. As mentioned above, standing water in the underground system has resulted in a decrease in infiltration rates each year.

## 4.2. Volume Reduction Monitoring

Stormwater flowing into the BMP was measured in the Duchess Street diversion structure and at the outlet of the west pond, which discharges directly to the underground chamber. Volume that bypassed the system was measured with a flow meter downstream of the Duchess Street diversion structure. Inflow volume from the inlets discharging into the eastern side of the rain garden was modeled using the Duchess upstream flow data and the ratio of drainage areas. Level logger data from within outlet control structure was used to identify when the underground system was at capacity, and estimate the volume being conveyed back to the storm sewer system from the BMP. Flow rates and daily rainfall are depicted on **Chart B.1** of **Appendix B**. An event-based volume reduction summary is provided with the pollutant loading data in **Table C.2** of **Appendix C**. A summary of the 2017 Beacon Bluff Volume Reduction is included in **Table 4-3** below.

In 2017, total runoff to the Beacon Bluff system was 4,158,836 cubic feet (cu-ft). Of that volume, 3,239,891 cu-ft was captured by the system, resulting in a 72% volume reduction. The total flow conveyed back to the storm sewer from the underground system was 193,840 cu-ft, which is 6% of the volume that was diverted to the BMP. For the 136.8-acre drainage area to the diversion structure, the total water yield was 30,401 cu-ft/acre which is equivalent to 8.38 inches of runoff as a result of 24.06

inches of rain. The greatest volume captured by the BMP was 214,673 cu-ft on October 2, 2017. This volume represents 135% of the total storage capacity of the system.

**Table 4-3: Beacon Bluff Volume Reduction**

| | | | |
|---|---|---|---|
| **Monitoring Period** | 4/19/2017 - 11/21/2017 | | |
| **Total Rainfall** | | 24.06 | in. |
| **Diversion Structure Water Balance** | | | |
| Runoff Volume: | | 4,158,836 | cu-ft |
| Bypassed Volume: | | 822,816 | cu-ft |
| Volume Diverted into BMP: | | 3,075,989 | cu-ft |
| **Beacon Bluff Rain Garden and Infiltration Gallery Inputs** | | | |
| Inflow Volume from Diversion Structure: | SubWSHD A | 3,075,989 | cu-ft |
| Inflow Volume from West Pond: | SubWSHD B | 171,540 | cu-ft |
| Inflow Volume from Eastern Inlets | SubWSHD C | 186,201 | cu-ft |
| System Discharge (conveyed back to storm sewer from OCS) | | 193,840 | cu-ft |
| **Beacon Bluff System Performance** | | | |
| Total Runoff Volume: | | 4,516,578 | cu-ft |
| Total Runoff Volume Captured: | | 3,239,891 | cu-ft |
| Percent of Total Runoff Volume Captured: | | 72 | % |
| Maximum Percentage of Storage Volume Utilized [1] | | 135 | % |

1- This is the maximum volume infiltrated by the BMP for a treatment event as a percentage of the total storage volume. The system exceeded 100% capacity on several occasions, but only a portion of the total capacity was available for infiltration due to standing water in the BMP.

## 4.3. 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 quarterly 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 4-4** below provides a load reduction summary for the loading parameters defined in NPDES Permit issued to the city in addition to ortho-phosphate. During the monitoring period, 26,747 pounds of TSS and 80.9 pounds of TP were captured by the system. Over the past five years of monitoring, 85,016 pounds of TSS and 320 pounds of TP have been captured at the Beacon Bluff Site.

**Table 4-4: Beacon Bluff Load/Capture Summary**

| **Monitoring Period** | | 4/25/2017 – 10/21/2017 | | |
|---|---|---|---|---|
| **Total Rain** | | 24.1 in. | | |
| **Water Quality Parameter** | **Flow Weighted Average (mg/L)** | **Total Pollutant Load (lbs)** | **Load Captured (lbs)** | **Percent Reduction %** |
| Total Suspended Solids | April – June: 196.0<br>July – November: 99.9 | 35,806 | 26,747 | 74.7 |
| Volatile Suspended Solids | 47 | 12,251 | 9,384 | 76.6 |
| Total Phosphorus | 0.4 | 110.4 | 80.9 | 73.3 |
| Ortho-phosphate | 0.17 | 45.1 | 34.3 | 76.2 |
| Chloride | 3.34 | 880.3 | 690.2 | 78.4 |
| Total Kjeldahl nitrogen | 1.97 | 555.4 | 407.1 | 77.3 |
| Nitrate + Nitrite as N | 0.17 | 43.9 | 33.2 | 75.7 |

## 4.4. Maintenance Inspection

Visual inspections of the pretreatment structure, rain garden, and underground system were completed during site visits to determine performance and maintenance needs. As shown in **Table 4-5**, sediment depths in the pretreatment device were approximately 0.2 ft to 0.8 ft throughout the 2017 season. Floatables were observed in the pretreatment structure on most visits and within the rain garden. Sediment accumulation ranging from 0.5 ft to 1.5 ft in depth was observed across the entire rain garden in 2017. It is recommended that the rain garden undergo dredge maintenance.

Standing water was observed in the underground system on all visits, as discussed in **Section 4.1**. The last chamber inspection was completed in November 2014 when the system was mostly empty. At that time, roughly 0.25 ft of sediment was observed within the grooves of the corrugated pipe, along the bottom. It's recommended that the underground chamber be pumped down and inspected. See **Appendix E** for photos of the BMP inspections.

**Table 4-5: Beacon Bluff Maintenance Inspections**

| Date | Sediment Depth in Pre-treatment (ft) | Sediment Depth in Infiltration Gallery (ft)[1] | Standing Water in Infiltration Gallery? | Observations |
|---|---|---|---|---|
| May 11, 2017 | 0.2 | NM | Y | Some trash in pre-treatment and rain garden. No trash observed in infiltration gallery. Minimal sediment in pre-treatment. |
| June 26, 2017 | 0.2 | NM | Y | Some trash in pre-treatment and rain garden. No trash observed in infiltration gallery. Minimal sediment in pre-treatment. |
| July 17, 2017 | 0.8 | NM | Y | Some trash in pre-treatment and rain garden. No trash observed in infiltration gallery. Pre-treatment accumulation is soft sediment. |
| October 20, 2017 | 0.8 | NM | Y | Bolt head on OSC grate broke off, needs replacement. Trash in pre-treatment. Pre-treatment accumulation is soft sediment. |

1-Not Measured – Sediment levels could not be evaluated in the infiltration galley due to the significant depth of standing water and the total depth of the system.

# 5. HILLCREST KNOLL

This system, shown in **Figure 5-1**, is owned and operated by the City. It was constructed in 2012 to help address local flooding issues near Hillcrest Knoll Park (**Photo 5-1**) 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 high-density polyethylene (HDPE) pipes (**Photo 5-2**). 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, a float forces down a gate valve that restricts flow to the BMP, and the runoff continues to flow downstream through the storm sewer. Pre-treatment for this design includes a Vortechs hydrodynamic separator and an isolator row within the storage gallery. Rainfall monitoring for this site is conducted at the Frost Lake Elementary School which is located approximately 0.4 miles west of the system. The BMP details are provided in **Table 5-1**.

**Table 5-1: Hillcrest Knoll BMP Details**

| | |
|---|---|
| Total Drainage Area to BMP | 37.1 acres |
| Year Constructed | 2012 |
| Total Construction Cost | $1,175,00 |
| Total Storage Volume | 86,606 cu-ft |
| Volume Reduction Credit Received by the City of Saint Paul | 86,606 cu-ft |


**Photo 5-1: Hillcrest Knoll Park Entrance**

**Photo 5-2: 60" Perforated HDPE pipes during system constructio**n

## 5.1. Water Level and Infiltration Rate Monitoring

Water elevation was monitored in the system at two locations and groundwater at one location using continuous water level loggers placed in piezometers and PVC within the BMP pipe gallery. Water levels within the BMP pipe and groundwater and daily rainfall totals are presented on **Charts A.7** and **A.8** of **Appendix A**. Water Levels in the infiltration gallery ranged from 2.2 ft to 6.9 ft. The 2017 minimum BMP water level of 2.2 ft was observed on October 1, 2017. There is no indication that the system drained to empty over the 2016-2017 winter. Water level monitoring during the 2013-2014 and 2014-2015 winter seasons showed that the system was draining to empty. Groundwater levels were documented at elevations within the infiltration gallery from January 2017 through December 2017, indicating that standing water within the BMP is primarily due to perched groundwater at the site. Groundwater interference has been observed during every season monitored to-date.

2017 infiltration rates and infiltration rate trends are presented on **Charts A.9** and **A.10** of **Appendix A,** respectively**.** In 2017, the average infiltration rate within the BMP pipe was 0.52 in/hr (**Table 5-2**). This is below the MSWM recommended infiltration rate of 0.8 in/hr for SP soils and the design infiltration rate of 2.0 in/hr. The 2017 infiltration rate is slightly less than the infiltration rate observed in 2016, but greater than rates observed in 2013 and 2014. Overall, the limiting factor for infiltration within the system is groundwater intrusion.

**Table 5-2: Hillcrest Knoll Infiltration Rate**

| Location | Average Infiltration Rate (in/hr) | | | | |
|---|---|---|---|---|---|
| | 2013[1] | 2014[1] | 2015 | 2016 | 2017 |
| Hillcrest Knoll BMP Pipe | 0.40 | 0.36 | 0.92 | 0.58 | 0.52 |

1- In the 2015 Water Quality and Quantity Monitoring Report, the 2013 and 2014 infiltration rates were inadvertently reported to be 0.67 and 0.52 in/hr, respectively.

## 5.2. Volume Reduction Monitoring

Flow meters were installed upstream and downstream of the diversion structure located on Flandrau Street. The difference in the upstream and downstream volume recorded for a runoff event is volume that has been conveyed to, and infiltrated by, the BMP. Flow rates and daily rainfall are depicted on **Chart B.2** of **Appendix B**.

In 2017, the total runoff for the Hillcrest Knoll System was 1,270,727 cu-ft. Of that volume, 580,775 cu-ft was conveyed to the underground infiltration gallery resulting in an overall volume reduction of 46% (**Table 5-3**). This is an increase from the 36% captured in 2016. The total water yield for the 37.1-acre drainage area is 34,251 cu-ft/acre which is equivalent to 9.4 inches of runoff resulting from 25.6 inches of rain. The greatest volume received by the BMP was 38,578 cu-ft from a 1.32-inch rain event on May 20, 2017, which is 45% of the total storage capacity of the system. Storm-specific rainfall and volume reduction data is provided on **Chart B.3** of **Appendix B.**

**Table 5-3: Hillcrest Knoll Volume Reduction**

| | | |
|---|---|---|
| **Monitoring Period** | 4/3/2017 - 10/29/2017 | |
| **Total Rainfall** | 25.6 | in. |
| **Diversion Structure Water Balance** | | |
| Runoff Volume: | 1,270,727 | cu-ft |
| Bypassed Volume: | 689,952 | cu-ft |
| Volume Diverted into BMP: | 580,775 | cu-ft |
| **Hillcrest Knoll Park System Performance** | | |
| Percent of Runoff Volume Captured: | 46 | % |
| Maximum Percentage of Storage Volume Utilized[1]: | 45 | % |

1- This is the maximum volume infiltrated by the BMP for a treatment event as a percentage of the total storage volume

## 5.3. Maintenance Inspection

The pretreatment device and the underground infiltration system were inspected during site visits to evaluate maintenance needs. The results of those visits are shown in **Table 5-4**. Garbage was observed occasionally in the pretreatment structure, although none was observed in the infiltration gallery. Standing water was observed in the infiltration gallery during all maintenance visits in 2017.

The float mechanism for the system gate valve was inspected regularly in 2017 (**Photo 5-3**). The float was exercised during multiple maintenance visits in 2017 to ensure that it was not stuck in the closed position, which would prevent flow from entering the infiltration system. Photos from the inspection visits are included in the photo log (**Appendix E**).

**Photo 5-3: System gate valve and float**

**Table 5-4: Hillcrest Knoll System Maintenance Inspections**

| Date | Sediment Depth in Pre-treatment (ft) | Sediment Depth in Infiltration Gallery (ft)[1] | Standing Water in Infiltration Gallery? | Observations |
|---|---|---|---|---|
| May 12, 2017 | 0.5 | 0.2 | Y | Soft bottom felt in infiltration gallery ~0.2 ft sediment accumulation. Float was stuck in closed position, exercised. Trash observed in pre-treatment, none infiltration gallery. |
| June 26, 2017 | 0.2 | 0.2 | Y | Soft bottom felt in infiltration gallery ~0.2 ft sediment accumulation. Float was stuck in closed position, exercised. No backed-up water observed. |
| July 17, 2017 | 0.7 | 0.2 | Y | Soft bottom felt in infiltration gallery ~0.2 ft sediment accumulation. Float was in open position, exercised |
| October 20, 2017 | 0.7 | 0.2 | Y | Soft bottom felt in infiltration gallery ~0.2 ft sediment accumulation. Float was in open position, exercised. |

# 6. ST. ALBANS STREET

This system, shown in **Figure 6-1**, 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 monitored in 2014 and 2015.

A manhole structure positioned along the main storm sewer under Aurora Avenue diverts stormwater into the underground infiltration system (**Photo 6-1**) 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 infiltration trenches and tree planters along University Avenue is directed to this system (**Photo 6-2**). When the system reaches its storage capacity, water flows west through the existing storm sewer system. The system includes a pretreatment structure comprised of a grit chamber and baffled weir to provide settling for sediment and skimming. Rainfall monitoring for the site is conducted on the roof of Fire Station 18, located across the street from the BMP. The BMP system details are provided in **Table 6-1.**

**Table 6-1: St. Albans Street BMP Details**

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

**Photo 6-1: St. Albans 48" perforated HDPE installation**

**Photo 6-2: St. Albans flow meter installation at the University BMP inlet**

## 6.1. Water Level and Infiltration Rate Monitoring

BMP water level was monitored in the access manhole at the northwest corner of the system. The 2017 water elevations and daily rainfall is provided on **Chart A.11** of **Appendix A.** Water level monitoring indicated that the infiltration gallery reached 100% capacity four times in 2017. Every treatment event monitored in 2017 resulted in the infiltration gallery drawing down to empty in less than a 24-hour period.

Infiltration rates are presented on **Chart A.12** of **Appendix A**. In 2016, the average infiltration rate of the BMP pipe was 20.6 in/hr (**Table 6-2**), which is above the MSWM recommended infiltration rate for SP soils of 0.8 in/hr but below the design infiltration rate of 26.0 in/hr. Infiltration rate trends for the St. Albans Street BMP pipe are depicted on **Chart A.13**.

**Table 6-2: St. Albans Infiltration Rate**

| Location | Average Infiltration Rate (in/hr) | | | | | |
|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| St. Albans Street BMP Pipe | 38.5 | 35.7 | 64.8 | 55.3 | 36.2 | 20.6 |

## 6.2. Volume Reduction Monitoring

Two flow meters were installed in the storm sewer diversion manhole located in the intersection of St. Albans Street and Aurora Avenue. One meter was installed in the elliptical pipe to capture flows into the system from the south and the other was installed in the downstream pipe to measure flows bypassing the system to the west. The difference in volume recorded by the two meters is assumed to be diverted into, and infiltrated by, the BMP. An additional flow meter was installed in the 30-inch pipe at the corner of St. Albans Street and University Avenue to capture flows into the system from along University Avenue. Flow rates and daily rainfall are depicted on **Chart B.4** of **Appendix B**.

In 2017, total runoff for the St. Albans Street system was 799,170 cu-ft. Of that volume, 776,623 cu-ft was captured and infiltrated by the system, resulting in a volume reduction of 97% (**Table 6-3**). Of the volume diverted to the BMP, 58% was conveyed from the Aurora Avenue diversion and 42% from the University Avenue inlet pipe. The total water yield for the 22.2-acre drainage area is 35,999 cu-ft/acre which is equivalent to 9.9 inches of runoff resulting from 25.4 inches of rain. The greatest volume received by the BMP was 84,722 cu-ft resulting from a 2.02-inch rain event on October 2, 2017. This volume represents 272% of the total storage capacity of the system. Storm-specific rainfall and volume reduction data is provided on **Chart B.5** of **Appendix B.**

**Table 6-3: St. Albans Street Volume Reduction**

| | | |
|---|---|---|
| **Monitoring Period** | 03/25/17 – 11/1/17 | |
| **Total Rainfall** | 25.4 | in |
| **System Water Balance** | | |
| Aurora Runoff Volume: | 464,100 | cu-ft |
| Aurora Bypassed Volume: | 19,129 | cu-ft |
| St. Albans and University Volume | 312,523 | cu-ft |
| **St. Albans System Performance** | | |
| Total Runoff Volume | 799,170 | cu-ft |
| Total Runoff Volume Captured | 776,623 | cu-ft |
| Percent of Runoff Volume Captured: | 97 | % |
| Maximum Volume Discharge to BMP | 84,722 | cu-ft |
| Maximum Percentage of Storage Volume Utilized[1] | 272 | % |

1- This is the maximum volume infiltrated by the BMP for a treatment event as a percentage of the total storage volume

## 6.3. Maintenance Inspection

The pretreatment device and the underground infiltration system were inspected during site visits to evaluate maintenance needs of the BMP. As shown in **Table 6-4**, minimal sediment was observed in both the pretreatment device and the infiltration gallery. Garbage was observed in the pretreatment structure during several visits. Water level monitoring in the in the infiltration gallery confirms that the system is regularly drawing down to empty, which is consistent with no standing water observed during most BMP inspection visits. See **Appendix E** for the **Photolog.**

**Table 6-4: St. Albans Maintenance Inspections**

| Date | Sediment Depth in Pre-treatment (ft) | Sediment Depth in Infiltration Gallery (ft) | Standing Water in Infiltration Gallery? | Observations |
|---|---|---|---|---|
| May 11, 2017 | 0.2 | 0 | N | Some sediment in pre-treatment |
| June 26, 2017 | 0.1 | 0 | N | Trash and minimal sediment in pre-treatment. Minimal trash in BMP |
| July 27, 2017 | 0.1 | 0 | N | Trash and minimal sediment in pre-treatment. Trace amounts of sediment in BMP. |
| October 10, 2017 | 0.3 | 0 | N | Trash and minimal sediment in pre-treatment. Trace amounts of sediment in BMP. |

# 7. HAMPDEN PARK

The Hampden Park infiltration gallery, shown in **Figure 7-1,** was constructed in 2014. The system consists of eight parallel perforated pipes that are five ft in diameter, and range in length from 40 to 100 ft. Runoff is routed to the system via a 24-inch RCP from the storm sewer line near Hampden and Raymond Avenues. Prior to entering the infiltration gallery, stormwater passes through a Vortechs pre-treatment chamber for particle settling. The infiltration gallery receives flow from a second inlet location along Hampden Avenue, farther to the north. When the system reaches full capacity, stormwater is routed back to the storm sewer via a 24-inch pipe from the southeast side of the system. Rainfall monitoring is conducted on top of the Hampden Park Co-Op across the street from the park. Monitoring has been conducted at the site since 2014. The BMP system details are provided in **Table 7-1** below.

**Photo 6-1: Hampden Park BMP Construction**

**Table 7-1 Hampden Park BMP Details**

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

## 7.1. Water Level and Infiltration Rate Monitoring

Water levels were monitored within the underground infiltration system and groundwater (P2), using electronic water level loggers. Water levels and daily rainfall for 2017 are provided on **Chart A.14** and **A.15** of **Appendix A.** Water level within the BMP ranged from 0 to 1.8 ft. The BMP water level must exceed 6.5 ft for the system to reach capacity and for water to be conveyed back to the sewer system. Based on the 2017 level data, no flow discharged back to the sewer system. Groundwater monitoring data showed that groundwater elevation fluctuated by 1.1 ft in 2017 with a minimum separation of 16.3 ft from the bottom of the BMP.

The 2017 infiltration rates are presented on **Chart A.16** of **Appendix A**. The average infiltration rate for the BMP was 8.30 in/hr which is greater than the MSWM recommended infiltration rate for SP soils of 0.8 in/hr and the design infiltration rate of 1.8 in/hr. Infiltration rates at the base of site during construction were calculated to be, on average, 60 in/hr using a Double Ring Infiltrometer (DRI). Infiltration rate trends are depicted on **Chart A17.** The average and half foot incremental infiltration rates were lower in 2017 compared to 2016, although the overall water levels within the BMP were lower in 2017 compared to 2016. Water level data shows that all 2017 events were infiltrated within 48 hours of a treatment event.

**Table 7-2: Hampden Park Infiltration Rate**

| Location | Average Infiltration Rate (in/hr) | |
|---|---|---|
| | **2016** | **2017** |
| Hampden Park BMP | 14.38 | 8.30 |

## 7.2. Volume Reduction

One flow meter was used to measure the inflow volume to the Hampden Park BMP. This meter was located in the 24-inch RCP diverting flow from the main storm to the BMP pipe from the intersection of Hampden and Raymond Avenues. The metered drainage area consists of 6.7 acres of the total 7.8-acre drainage area to the BMP. The 2017 flow rates and daily rainfall are depicted on **Chart B.6** of **Appendix B**. No discharge was observed at the system outlet therefore that data is not plotted.

In 2017, the total runoff monitored at the Hampden and Raymond Avenues system inlet was 274,013 cu-ft. The inflow from the second system inlet along Hampden Avenue was estimated to be 45,212 cu-ft based on the ratio of the drainage areas. Since no discharge was observed, 100% of the runoff was infiltrated by the system which totaled 319,225 cu-ft (**Table 7-3**). The total water yield for the 7.8-acre drainage area is 40,926 cu-ft/acre which is equivalent to 11.3 inches of runoff as a result of 27.25 inches of rain. The greatest volume received by the BMP was 37,825 cu-ft as a result of a 2.11-inch rain event on August 16-18, 2017. This volume represents 119% of the total storage capacity of the system. Storm-specific rainfall and volume reduction data is provided on **Chart B.6** of **Appendix B.**

**Table 7-3: Hampden Park Volume Reduction**

| **Monitoring Period** | 3/29/2017 – 11/1/2017 | |
|---|---|---|
| **Total Rainfall** | 27.25 | in |
| **Hampden Park Water Balance** | | |
| Raymond/Hampden Runoff Volume: | 274,013 | cu-ft |
| Hampden (2nd inlet) Runoff Volume[1] | 45,212 | cu-ft |
| System Bypass Volume | 0 | cu-ft |
| **Hampden Park System Performance** | | |
| Total Runoff Volume | 319,225 | cu-ft |
| Total Runoff Volume Captured | 319,225 | cu-ft |
| Percent of Runoff Volume Captured: | 100 | % |
| Maximum Event Volume Captured by BMP | 37,825 | cu-ft |
| Maximum Percentage of Storage Volume Utilized[2] | 119 | % |

1 – The second system inlet along Hampden Avenue is not monitored, and the volume discharged to the system from that location is estimated based on monitored data at Hampden/Raymond and the ratio of the drainage areas
2- This is the maximum volume infiltrated by the BMP for a treatment event as a percentage of the total storage volume

## 7.3. Pollutant Removal Monitoring

A water quality sampler was placed in the Hampden and Raymond Avenues system inlet 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 for select runoff events and tested for E Coli. See **Charts C.3** and **C.4** of **Appendix C** for the complete water quality summary and pollutant loading calculations.

**Table 7-4** below provides a load reduction summary for the loading parameters defined in NPDES Permit issued to the City in addition to ortho-phosphate. During the monitoring period, 864 pounds of TSS and 2.3 pounds of TP were captured by the system.

**Table 7-4: Hampden Park Load/Capture Summary**

| Monitoring Period | | 3/29/2017 – 11/1/2017 | | |
|---|---|---|---|---|
| **Total Rain** | | 27.25 in. | | |
| **Water Quality Parameter** | **Flow Weighted Average (mg/L)** | **Total Pollutant Load (lbs)** | **Load Captured (lbs)** | **Percent Reduction %** |
| Total Suspended Solids | 26.3 | 864 | 864 | 100 |
| Volatile Suspended Solids | 17.4 | 506 | 506 | 100 |
| Total Phosphorus | 0.114 | 2.3 | 2.3 | 100 |
| Ortho-phosphate | 0.023 | 0.46 | 0.46 | 100 |
| Chloride | 3.9 | 77.6 | 77.6 | 100 |
| Total Kjeldahl nitrogen | 0.87 | 17.4 | 17.4 | 100 |
| Nitrate + Nitrite as N | 0.25 | 5.1 | 5.1 | 100 |

## 7.4. 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 7-5** minimal sediment was observed in both the pretreatment device and infiltration gallery.

**Table 7-5: Hampden Park BMP Maintenance Inspection**

| Date | Sediment Depth in Pre-treatment (ft) | Sediment Depth in Infiltration Gallery (ft)[1] | Standing water in Infiltration Gallery? | Observations |
|---|---|---|---|---|
| May 12, 2017 | 0.2 | 0.0 | N | Muck in pre-treatment. |
| June 26, 2017 | 0.2 | 0.2 | N | Some areas of BMP pipe had 4" of mucky sediment, but other areas had very little. |
| July 17, 2017 | 0.2 | 0.2 | N | No trash noted in pre-treatment, conditions in BMP similar to previous inspection. |
| October 20, 2017 | 0.2 | 0.2 | N | No trash noted in pre-treatment, conditions in BMP similar to previous inspection. |

# 8. ARUNDEL STREET

This system, shown in **Figure 8-1**, 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 pre-treatment 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 8-1: Arundel Street BMP Details**

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

**Photo 8-1: Arundel infiltration system access manhole and BMP level monitoring location**

## 8.1. Water Level and Infiltration Rate 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.18 of Appendix A.** Water Levels in the infiltration gallery ranged from 1.0 ft to 7.3 ft. Level data shows that the system did not drain to empty during the 2017 season. The system exceeded 100% capacity during 33 runoff events in 2017.

The BMP pipe infiltration rates are presented on **Chart A.19 of Appendix A**. In 2017, the average infiltration rate of the BMP pipe was 0.09 in/hr (**Table 8-2)**, which is less than the MSWM recommended infiltration rate for SP soils of 0.8 in/hr, and the design infiltration rate of 17.6 in/hr. Infiltration rate trends are depicted on **Chart A.20.** The average infiltration rate has decreased every year since 2012, which is likely a result of sediment accumulation observed within the BMP.

**Table 8-2: Arundel Infiltration Rate**

| Location | Average Infiltration Rate (in/hr) | | | | | |
|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Arundel BMP Pipe | 8.0 | 2.43 | 1.64 | 0.42 | 0.16 | 0.09 |

## 8.2. Maintenance Inspection

Sediment depths in the pre-treatment structure and in the underground infiltration system were measured during site visits to determine performance and maintenance needs. As shown in **Table 8-3**, sediment depths in the infiltration gallery ranged from 0.1 to 0.2 ft. In contrast, prior to 2015 maintenance, sediment depth in the BMP pipe was observed to be 2.0 ft. Standing water was routinely observed in the BMP pipe, as mentioned in the previous section. See **Appendix E** for the **Photolog.**

**Table 8-3: Arundel Maintenance Inspections**

| Date | Sediment Depth in Pre-treatment (ft) | Sediment Depth in Infiltration Gallery (ft) | Standing water in Infiltration Gallery? | Observations |
|---|---|---|---|---|
| May 12, 2017 | 0.5 | 0.1 | Y | Trash and some sediment accumulation observed in BMP. |
| June 26, 2017 | 0.75 | 0.1 | Y | Trash and some sediment accumulation observed in BMP |
| July 17, 2017 | 1.0 | 0.1 | Y | Trash and some sediment accumulation observed in BMP |
| October 20, 2017 | 0.7 | 0.1 | Y | Sediment depositing directly around pipe entering pre-treatment structure, very little sediment on downstream side of weir structure in MH. |

# 9. FLANDRAU-HOYT POND

The Flandrau-Hoyt Pond was constructed to provide stormwater runoff storage for the neighborhood surrounding Prosperity Heights Park. The pond is located near the intersection of Ivy Avenue E and Germain Street in St. Paul. Water elevations were monitored at Flandrau-Hoyt Pond to evaluate water level fluctuation in the basin, and to provide hydrology data for future improvements. The pond location is provided as **Figure 9-1.**

**Photo 9-1: Flandrau-Hoyt Pond outlet control structure**

**Photo 9-2: Flandrau-Hoyt Pond inlet**

## 9.1. Water Level Monitoring

A level logger was installed near the pond outlet and configured to record elevations once per hour. Water elevation and rainfall are presented on **Chart A.21** of **Appendix A.** A summary of select runoff events from 2017 is presented in **Table 9-1** below. The elevation of the top of the outlet control structure and the top of the emergency spillway are 205 ft SPCD and 218 ft SPCD, respectively.

**Table 9-1: Flandrau-Hoyt Pond Water Level Summary**

| Date | Rainfall (in) | Rainfall Intensity (in/hr) | Level Increase (ft) | Peak Water Elevation (ft SPCD) | Time to Return to NWL (hrs) |
|---|---|---|---|---|---|
| May 1, 2017 | 0.81 | 0.16 | 3.64 | 206.66 | 10 |
| May 18, 2017 | 1.44 | 0.08 | 3.46 | 206.45 | 10 |
| July 18, 2017 | 1.25 | 0.31 | 5.58 | 207.62 | 20 |
| August 14, 2017 | 1.28 | 0.32 | 7.22 | 209.31 | 12 |
| October 2, 2017 | 1.64 | 0.12 | 7.53 | 209.60 | 12 |

During the 2017 monitoring season, water levels in the pond ranged from 201.95 ft SPCD to 209.60 ft SPCD. The largest level fluctuation and maximum water level occurred during a 1.64-inch rain event on October 2, 2017. The pond water level increased by 7.53 ft. During all events monitored in 2017, water level in the pond decreased back to pre-event levels in less than 20 hours, and levels never exceeded the emergency spillway elevation.

# 10. SACKETT PARK POND

The Sackett Park Pond is situated in a wooded area between the Boys and Girls Club and the Chicago Northwestern Railroad on St. Paul's East Side. The basin receives runoff from the east via a storm sewer inlet pipe. The runoff flows northwest through a shallow channel, until it reaches an outlet control structure that conveys water away from the site though a 42-inch RCP pipe (**Photo 10-1**). When runoff exceeds the banks of the channel, it spills into the surrounding flood plain (**Photo 10-2**). Water elevations were monitored within the Sackett Park Pond to evaluate water level fluctuation in the basin, and to provide hydrology data for future improvements at that location. The pond location is provided as **Figure 10-1.**

**Photo 10-1: Level logger configuration and outlet control structure**

## 10.1. Water Level Monitoring

A level logger was installed near the pond outlet control structure and configured to record water elevations once every 15 minutes. Water elevations and rainfall are presented on **Chart A.22** of **Appendix A.** A summary of select runoff events from 2017 is presented in **Table 10-1** below. The elevation of the top of the outlet control structure is 194 ft SPCD. Groundwater monitoring was conducted during the 2015 monitoring season and those results indicated that a continuous artesian condition was present at the site. Groundwater was not monitored in 2017.

**Table 10-1: Sackett Park Pond Water Level Summary (Select Flow Events)**

| Date | Rainfall (in) | Rainfall Intensity (in/hr) | Level Increase (ft) | Peak Water Elevation (ft SPCD) | Depth above OCS (ft) |
|---|---|---|---|---|---|
| May 18, 2017 | 1.44 | 0.08 | 2.31 | 194.99 | 0.99 |
| June 11, 2017 | 0.65 | 0.22 | 2.29 | 195.05 | 1.05 |
| August 14, 2017 | 1.28 | 0.32 | 0.18 | 191.99 | -2.01 |
| August 17 – 17, 2017 | 1.76 | 0.18 | 3.30 | 195.1 | 1.1 |
| October 2, 2017 | 1.64 | 0.12 | 0.11 | 191.88 | -2.12 |

In 2017, water levels ranged from 191.6 ft SPCD on September 28, 2017 to 195.1 ft SPCD on August 16, 2017. The maximum level occurred as a result of 1.76 inches of rain on August 16-17th, 2017, which increased the level by 3.3 ft. In 2017, 20 rain events ranging from 0.18 inches to 1.76 inches resulted in water level elevations that exceeded the top of the outlet control structure. Following those events, the level decreased to below the top of the outlet control structure within 6 hours. Rain events totaling 1.28 inches and 1.64 inches occurred on August 14, 2017 and October 2, 2017, respectively. Although these were among the largest rainfall events in 2017, there was no major rainfall six days prior, and therefore there was no appreciable change in water level.

**Photo 10-2: Sackett Park Pond outlet control structure – runoff exceeds channel bank and enters flood plain (4/19/2017).**

# 11. TROUTBROOK NATURE SANCTUARY – IRON-ENHANCED SAND FILTRATION PONDS

The Trout Brook Nature Sanctuary (TBNS) (**Figure 11-1**) is a 42-acre site located between Norpac Road and Maryland Avenue, west of I-35E. The objective of the construction effort, which was finalized in 2015, was to create a nature preserve in the heart of a heavily urbanized area. The plan featured expanding the Trout Brook Regional Trail and daylighting the Trout Brook Creek, which had previously been filled in and routed through underground sewer. Three iron-enhanced sand filtration (IESF) ponds were constructed in the TBNS to provide additional phosphorus treatment. Volume reduction credits for the stormwater features were split between the City Public Works and Parks and Recreation departments based on the respective financial contribution. Monitoring at TBNS has been conducted since 2015. The BMP system details are provided in **Table 11-1**.

**Photo 11-1: Magnolia Pond**

**Photo 11-2: Jenks Pond**

**Table 11-1: Trout Brook Nature Sanctuary Site Details.**

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

The IESF technology was produced by the University of Minneapolis Saint Anthony Falls Laboratory in 2005 (Erickson et al. 2012). The research findings indicated that sand media mixed with iron filings (recommended mixture of 5% by weight) can provide a mechanism to remove SRP, a dissolved bio-available form of phosphorus, which is not effectively removed by traditional stormwater BMPs such as stormwater ponds. As stormwater passes through IESF media, the oxidized iron filings remove SRP through surface sorption.

At each of the three IESF pond locations, stormwater is conveyed to the basin from individual diversion structures along the 42-inch main storm sewer line that runs along the western side of the site. After flow is diverted from the sewer line, it passes through a Vortechs pre-treatment structure for particle settling, then discharges to the pond. As the level in the pond rises, the water gravity flows through a sand filtration bench that was mixed to have iron fillings at approximately five percent by weight. Beneath the sand bench is six-inch perforated drain tile that conveys the treated water to the outlet control structure of the pond. From the pond, the treated stormwater flows through a wetland, then connects with the constructed creek.

The monitoring completed by the City includes performance monitoring of three IESF ponds at the site: Maryland Pond (**Photo 11-3**), Magnolia Pond (**Photo 11-1** and **11-4**), and Jenks Pond (**Photo 11-2**). The effectiveness of the IESF ponds was determined by collecting samples from the within the pond and the pond outlet control structure during treatment events. The samplers were programmed to collect simultaneous flow weighted samples based on flow pacing monitored in the outlet control structure. Additional information regarding equipment and monitoring procedures for the TBNS monitoring effort is described in **Section 2.3**.

**Photo 11-3: Maryland Pond sensor/intake inspection**

**Photo 11-4 Magnolia Pond treatment**

## 11.1. Water Level Monitoring

Water level was monitored at Maryland, Magnolia and Jenks Ponds from within the outlet control structure of each pond. Water levels with daily rainfall are provided on **Charts A.23**, **A.24,** and **A.25** of **Appendix A**. A summary of water elevations is presented in **Table 11-2** below.

**Table 11-2: TBNS Water Level Summary**

| Pond Location | Minimum Water Elevation (ft SPCD) | Normal Water Elevation (ft SPCD) | Maximum Water Elevation (ft SPCD) | Observed Treatment Elevation (ft SPCD) | Weir Overflow Elevation (ft SPCD) |
|---|---|---|---|---|---|
| Maryland | 116.7 | 116.4 | 119.0 | 116.8 | 119.0 |
| Magnolia | 123.1 | 123.8 | 126.2 | 124.1 | 126.0 |
| Jenks | 94.4 | 95.5 | 97.1 | 95.5 | 98.0 |

The results of the level monitoring data are summarized below:

- Maryland Pond
  - Flow through the IESF benches was observed when water levels exceeded 116.8 ft SPCD
  - The minimum water level was 0.3 ft greater than the normal water level (recorded on June 10, 2017). The periods from June 9 to June 11, 2017 and July 16 through July 17, 2017 were the only time that flow through the IESF system was not occurring
  - Water levels exceeded the weir overflow elevation one time on October 2, 2017
- Magnolia Pond
  - Flow through the IESF benches was observed when water levels exceed 124.1 ft

  - The minimum water level was 0.7 ft less than the normal water level (Recorded on June 10, 2017)
  - Water levels exceeded the weir overflow elevation one time on October 2, 2017
- Jenks Pond
  - Flow through the IESF benches was observed when water levels exceed 95.5 ft
  - The minimum water level was 0.1 ft less than the normal water level (recorded on June 10, 2017)
  - The maximum water level was 1.6 ft above the normal water level (recorded on May 20, 2017)
  - A modification was made to the diversion structure to Jenks Pond, resulting in greater flow conveyed to the basin and an increase in pond level and treatment volume in 2017 compared to previous years.

## 11.2. Treatment Volume Monitoring

The treatment volume was monitored at each of the sites using a 2150 flow meter installed within the 8-inch drain tile discharge point to the outlet control structure. This is a modification from 2016 equipment configuration which had the flow meter placed within the outlet pipe of the outlet control structure. Flow over the drain tile metering location was less turbulent and produced better quality data compared to flows observed in prior years at the outlet control pipe monitoring location. Flow rates and daily rainfall for the three sites are provided on **Charts B.7** through **B.9** of **Appendix B**. A summary of that data is provided in **Table 11-3** below.

**Table 11-3 TBNS IESF Pond Flow Summary**

| Pond Location | Monitoring Period | Total Treated Flow | Average Event Flow |
|---|---|---|---|
| Maryland | 4/19 – 11/21 | 533,000 | 18,697 |
| Magnolia | 4/19 – 11/21 | 144,832 | 5,773 |
| Jenks | 4/20 – 11/21 | 131,458 | 7,535 |

Maryland Pond treated the greatest volume of water of the three sites, recording 533,000 cu-ft in 2017. Continuous flow was observed through the drain tile during the entire 2017 monitoring period, except for two days in June and July following extended periods with minimal rain. 2017 treatment volumes at Maryland were significantly less than 2016 treatment volumes. This is likely due to the change in the flow monitoring location which produced better quality flow data in 2017.

Magnolia and Jenks Ponds treated 144,832 cu-ft and 131,458 cu-ft of stormwater, respectively. As mentioned in **Section 11.1**, a modification to the Jenks Pond diversion structure resulted in significantly more volume diverted to and treated by Jenks Pond in 2017.

## 11.3. Pollutant Reduction Monitoring

Water Quality was monitored by collecting flow-paced samples from within the pond (pre-treatment) and the drain tile outlet (post-treatment). Samples were collected simultaneously using automated samplers programmed to collect samples based on the outlet flow pacing. The sample collected from the stormwater pond was collected approximately one foot below the water surface. All samples in 2017 at the Jenks Pond location were collected as grabs due to programing related issues with the water quality samplers. At the other two ponds, grab samples were collected periodically for comparison to flow paced sample concentrations. Water quality samples were analyzed for total phosphorus, dissolved phosphorus, and soluble reactive phosphorus (ortho-phosphate). New analytical parameters in 2017 included TSS, hardness, and total iron.

In 2017, 17 treatment events were sampled at Maryland Pond. The analytical data and individual event treatment summary are provided on **Tables C.5** and **C.6** of **Appendix C**. The percent of mass TP and SRP retained during the monitored events was 37% and 10%, respectively. Of the 17 treatment events, seven events had a negative SRP load reduction. The influent SRP concentrations were relatively low for negative load reduction events, ranging from 6 µg/L to 18 µg/L. Overall, SRP load reductions ranged from -138% to 84%

The median removal efficiencies for TP and SRP from 2015 to 2017 are presented in **Table 11-4** below. The median SRP removal efficiencies have varied between 0% in 2016 to 55% in 2015. In 2016, median pre-treatment (pond) concentrations for both TP and SRP were significantly less than concentrations observed in 2015 and 2017. This resulted in a median negative reduction for TP and no reduction for SRP. Continuous flow through the IESF median has been observed every year at Maryland Pond and may be affecting the performance of the media. For proper sorption of phosphate to iron oxides, the IESF media must dry out between treatment events to ensure continued rusting of the iron particles (Erickson et al. 2012). The results of iron sampling conducted at Maryland is discussed later in this section.

**Table 11-4: TBNS Maryland Median TP, SRP, and Removal Efficiencies**

| Year | TP Pre (mg/L) | TP Post (mg/L) | % Reduction[1] | SRP Pre (mg/L) | SRP Post (mg/L) | % Reduction[1] |
|---|---|---|---|---|---|---|
| 2015 | 0.180 | 0.058 | 62 | 0.036 | 0.009 | 55 |
| 2016 | 0.075 | 0.100 | -48 | 0.009 | 0.010 | 0 |
| 2017 | 0.183 | 0.114 | 34 | 0.017 | 0.019 | 5 |

1 – The % reduction reflects the median reduction of monitored treatment events.

At Magnolia Pond, 14 treatment events were sampled in 2017. The analytical data and treatment event summary are provided on **Tables C.7** and **C.8** of **Appendix C**. The percent mass of TP and SRP retained in 2017 was 38% and 13%, respectively. Of the 14 treatment events, five events had a negative SRP load reduction.

The median TP concentrations, SRP concentrations, and removal efficiencies from 2015 to 2017 are presented in **Table 11-5** below. Median pre-treatment SRP concentration have been similar over the past three years of monitoring ranging from 0.038 mg/L to 0.046 mg/L. The post-treatment SRP median in 2017 was over 50% greater than 2015 and 2016. This resulted in an overall lower percent reduction in 2017 compared to previous years. Of the three IESF ponds, Magnolia Pond consistently sees the greatest pre-treatment and post-treatment concentrations of TP and SRP.

**Table 11-5: TBNS Magnolia Median TP, SRP, and Removal Efficiencies**

| Year | TP Pre (mg/L) | TP Post (mg/L) | % Reduction[1] | SRP Pre (mg/L) | SRP Post (mg/L) | % Reduction[1] |
|---|---|---|---|---|---|---|
| 2015 | 0.380 | 0.170 | 56 | 0.046 | 0.030 | 27 |
| 2016 | 0.190 | 0.116 | 33 | 0.039 | 0.029 | 21 |
| 2017 | 0.284 | 0.173 | 33 | 0.038 | 0.050 | 5 |

1 – The % reduction reflects the median reduction of monitored treatment events.

At Jenks Pond, nine treatment events were sampled in 2017. Due to programming issues with the Jenks Pond samplers, all samples were collected as grab samples. The analytical data and treatment event summary are provided on **Tables C.9** and **C.10** of **Appendix C**. The percent mass of TP and SRP retained in 2017 was 51% and 19%, respectively. Of the nine treatment events, four events had a negative SRP load reduction. All pre-treatment SRP samples during negative reduction events were detected at low levels (8 µg/L to 9 µg/L). A majority of the SRP load reduction occurred as a result of the second largest treatment event on May 20, 2017, which had an SRP reduction of 40%.

Median TP, SRP, and removal efficiencies from 2015 to 2017 are presented in **Table 11-6** below. In 2015 and 2016 data sets were limited due to minimal flow being diverted to the basin, resulting in few treatment events. 2017 TP and SRP concentrations at Jenks Pond were the lowest of the three sites. Overall, SRP median reduction rates have ranged from -12% to 99%.

**Table 11-6: TBNS Jenks Median TP, SRP, and Removal Efficiencies**

| Year[1] | TP Pre (mg/L) | TP Post (mg/L) | % Reduction[2] | SRP Pre (mg/L) | SRP Post (mg/L) | % Reduction[2] |
|---|---|---|---|---|---|---|
| 2015 | 0.890 | 0.054 | 94 | 0.320 | 0.002 | 99 |
| 2016 | 0.106 | 0.104 | 2 | 0.020 | 0.021 | -12 |
| 2017 | 0.144 | 0.083 | 38 | 0.009 | 0.013 | 13 |

1 – Only one event was monitoring in 2015
2 – The % reduction reflects the median reduction of monitored treatment events.

Additional parameters collected in 2017 included TSS, hardness, and total iron. The median reduction in concentrations of TSS and total iron through the IESF Ponds is provided in **Table 11-7** below. All three ponds exhibited a decrease in TSS as a result of the IESF treatment, with the greatest reduction occurring at Magnolia Pond. This is a result of higher TSS and other pollutant concentrations observed in pre-treatment samples at that site. The primary means of TSS treatment is particle settling provided by Votechs pre-treatment system and settling that occurs within the pond prior to the IESF benches. Overall, median post-treatment effluent TSS concentration were 8 mg/L at Maryland, 9 mg/L at Magnolia Pond, and 2 mg/L at Jenks Pond.

**Table 11-7: 2017 Median Reduction in TSS and Total Iron**

| Site | % Reduction TSS | % Reduction Total Iron |
|---|---|---|
| Maryland | 20 | -29 |
| Magnolia | 73 | 45 |
| Jenks | 60 | 61 |

Total iron in the effluent at Magnolia and Jenks Ponds decreased by 45% and 61%, respectively. Iron in stormwater is often particulate-bound, therefor a reduction in suspended solids by filtration will also result in capture of the particulate-bound metals. In comparison, total iron in the effluent at Maryland Pond increased by a median of 29%. The increase in iron is suspected to be related to continuous flow through the IESF media. Additionally, iron precipitate was also observed accumulating at the drain tile outlet (**Photo 11-5**). Based on the analytical data and observed precipitate, it is suspected that continuous flow may be creating anaerobic conditions, which have contributed to the export of iron from the media beds. Additionally, with anaerobic conditions present, iron-bound phosphorus (captured SRP) can become mobile. It is important to note that this may be occurring at only a small portion of the media bed, while other areas of the IESF bench are adequately aeriated and functional. It is recommended that the source of the continuous flow be further evaluated in 2018.

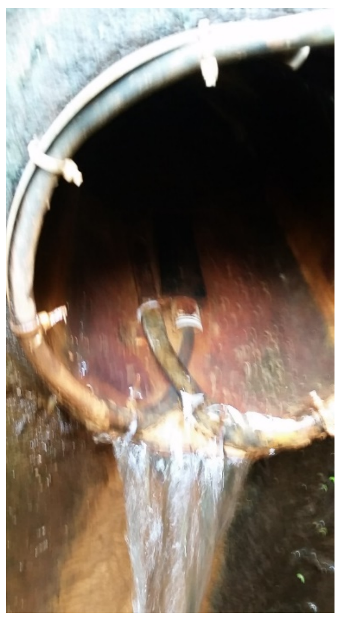


**Photo 11-5: Iron Precipitate at drain tile outlet to OCS**

Overall, the mass SRP reductions at Maryland Pond (10%), Magnolia Pond (13%), and Jenks Pond (19%) were less than reduction rates observed during similar studies which have identified removal efficiencies from 26% SRP (Erickson et al. 2015) to 75% SRP (Erickson 2012). The cited studies have also identified that many small events with low SRP loads resulted in negative removals, similar to the results described here. Overall, low SRP concentrations have been observed at TBNS, with 2017 median concentrations ranging from 13 µg/L at Jenks Pond to 38 µg/L at Magnolia Pond.

# 12. MONTREAL INFILTRATION TRENCH

This system, shown in **Figure 12-1** and **Photo 12-1**, consists of an infiltration trench situated beneath Montreal Avenue that was constructed to treat runoff from 1.38 acres of local right-of-way. Stormwater runoff is conveyed to the system from the east by a 15-inch RCP near Snelling Avenue into two 12-inch perforated pipes that total 225 ft in length. Stormwater drains through the pipe perforations into a six-foot-deep trench filled with aggregate for increased infiltration capability. Water levels were monitored within the trench beginning in 2016 to evaluate infiltration rates at the site. The BMP system details are provided in **Table 12-1**.

**Table 12-1 Montreal BMP Details**

| | |
|---|---|
| Total Drainage Area to BMP | 1.38 acres |
| Year Constructed | 2014 |
| Trench Storage Volume | 8,069 cu-ft |

**Photo 12-1: Infiltration Trench Monitoring Location (Montreal & Snelling Avenues)**

## 12.1. Water Level and Infiltration Rate Monitoring

The trench water level was monitored at the access manhole at the mid-point of the system. Water levels and daily rainfall are presented on **Chart A.26** of **Appendix A.** Water Levels in the trench ranged from 279.4 ft SPCD to 282.2 ft SPCD (bottom and top trench elevations are 278 ft SPCD and 284 ft SPCD, respectively). Level data shows that the trench drained to empty within 48 hours for every event in 2017. The trench infiltration rates are presented on **Chart A.27** of **Appendix A**. In 2017, the average infiltration rate was 11.67 in/hr **(Table 12-2)**, which is greater than the design infiltration rate of 0.6 in/hr. Infiltration rate trends are depicted on **Chart A.28.**

**Table 12-2: Montreal Infiltration Rate**

| Location | Average Infiltration Rate (in/hr) | |
|---|---|---|
| | 2016 | 2017 |
| Montreal Trench | 7.51 | 11.67 |

# 13. WORDSWORTH INFILTRATION TRENCH

This system, shown in **Figure 13-1**, consists of an infiltration trench situated beneath a bioretention system, along Wordsworth Avenue. Stormwater is conveyed from Sue Street from the west and Edgecumbe Road from the east into two 12-inch perforated pipes (**Photos 13-1** and **13-2**) that total 559 ft in length. Stormwater drains through the pipe perforations into a six-foot-deep trench filled with aggregate for increased infiltration capability. Water levels were monitored within the trench beginning in 2016 to evaluate infiltration rates at the site. The BMP system details are provided in **Table 13-1** below.

**Table 13-1: Wordsworth BMP Details**

| | |
|---|---|
| Total Drainage Area to BMP | 4.5 acres |
| Year Constructed | 2013 |
| Trench Storage Volume | 6,278 cu-ft |
| Total Storage Volume (Trench, Soil Area, & Bioretention) | 8,805 cu-ft |

**Photo 13-1: Discharge location from Sue Avenue to the 2- 12" infiltration trench pipes**

**Photo 13-2: Infiltration Trench Monitoring Location (Wordsworth Avenue)**

## 13.1. Water Level and Infiltration Rate Monitoring

The trench water level was monitored at the access manhole at the midpoint of the system. Water levels and daily rainfall are presented on **Chart A.29** of **Appendix A.** Water levels in the trench ranged from 0 to 5.0 feet. Level data shows that the trench drained to empty within 48 hours for every event through April 2017. From May through October, approximately 2.5 feet of standing water was observed within the trench, although infiltration occurred at depths exceeding 2.5 feet. Beginning in mid-October, water levels gradually decreased until the equipment was pulled on November 22, 2017. At that time 0.3 ft of water was observed. This is similar to what was observed in 2016.

The trench infiltration rate and infiltration rate trends are presented on **Charts A.30** and **A.31** of **Appendix A**. In 2017, the average infiltration rate was 5.76 in/hr **(Table 13-2)**, which is greater than the design infiltration rate of 0.6 in/hr, and slightly greater than the 2016 infiltration rate of 4.35 in/hr.

**Table 13-2: Wordsworth Infiltration Rate**

| Location | Average Infiltration Rate (in/hr) | |
|---|---|---|
| | 2016 | 2017 |
| Wordsworth Trench | 4.35 | 5.76 |

# 14. PERVIOUS SURFACE INFILTRATION ASSESSMENT

The City has been monitoring the performance of pervious pavement BMPs constructed in the City since 2012. Pervious pavement is constructed with substantial void space to allow for infiltration or filtration of stormwater through the pavement surface as a means of stormwater management. Pervious pavement BMPs monitored in the city include porous asphalt and permeable interlocking concrete pavers. The purpose of the infiltration testing is to monitor the change in site conditions and infiltration capability of the BMPs overtime. Pavement maintenance is also monitored to study the effect of routine and rehabilitative maintenance on these BMPs.

Infiltration testing was completed at the Jackson Street Pervious Bike Path BMP in July and November 2017. Testing was also completed at the Victoria Street and Hamline Midway Library pervious pavement BMPs in November. This section presents the results of the 2017 infiltration testing. The Infiltration testing methodologies are described in **Section 2.5.** A photolog of infiltration testing is provided in **Appendix E.**

## 14.1. Victoria Street

The Victoria Street pervious surface consists of a parking area completed with permeable concrete pavers designed to receive stormwater runoff from Victoria Street and the properties adjacent to it. The pavers themselves are non-permeable and they are separated with aggregate fill (**Photo 14-1** and **14-2**). The spaces between the pavers allow stormwater runoff to infiltrate into the parking surface instead of running off and being collected by the storm sewer system. The pavers were installed in 2011 and infiltration rates have been monitored annually since 2012. The site and the infiltration test locations are provided on **Figure 14-1.**

**Photo 14-1: Victoria Street pavers**

**Photo 14-2: Victoria Street infiltration testing**

**<u>Infiltration Test Results and Observations</u>**

Five locations were tested for infiltration at the Victoria Street site. In 2015, the exact test locations from 2014 could not be located, so new locations were established in the immediate area and identified as A-E (these locations were used in 2016 and 2017). Those locations are depicted on **Figure 14-1** and the results of the testing are presented in **Table 14-1** and **Chart D.1** in **Appendix D**.

**Table 14-1: Victoria Street Infiltration Rate Summary**

| Infiltration Ring Location | 2012 Infiltration Rate (in/hr) | 2013 Infiltration Rate (in/hr) | 2014 Infiltration Rate (in/hr) | 2015 Infiltration Rate (in/hr) | | 2016 Infiltration Rate (in/hr) | | 2017 Infiltration Rate (in/hr) | |
|---|---|---|---|---|---|---|---|---|---|
| IR-1 | 168.6 | 18.1 | 0 | E | 3.7 | E | 4.4 | E | 0.85 |
| IR-2 | 266.6 | 75.7 | 13.0 | A | 0 | A | 4.8 | A | 0.94 |
| IR-3 | 271.1 | 92.2 | 18.6 | B | 0.9 | B | 5.7 | B | 2.51 |
| IR-4 | 69.1 | 24.0 | 9.7 | C | 0 | C | 1.6 | C | 1.6 |
| IR-5 | 149.8 | 49.2 | 30.8 | D | 0 | D | 0 | D | 0 |
| **Average** | **185.04** | **51.84** | **14.42** | **0.92** | | **3.33** | | **1.19** | |

A summary of the 2017 infiltration test results is provided below:

- The overall site infiltration rate decreased from 3.33 in/hr in 2016 to 1.19 in/hr in 2017
- No infiltration was observed at Location D, which is consistent with 2015 and 2016 testing
- Infiltration rates at Locations A, B, and E (**Photo 14-3** and **14-4**) decreased from 2016 to 2017, while Location C remained the same

**Photo 14-3: Location E Pre-test**

**Photo 14-4: Location E Infiltration Test**

## 14.2. Hamline Midway Library

The Hamline Midway Library pervious surface consists of 920 square yards of porous asphalt within the two alleyways adjacent to the Hamline Midway Library and the center alleyway connecting the sections (**Photos 14-5** and **14-6).** The asphalt content of the mix is 6.3% and the specific voids ratio is 18%. The asphalt was installed in 2012 and infiltration rate monitoring has been completed annually since 2013. The site and the infiltration test locations are provided on **Figure 14-2**.


**Photo 14-5: Hamline Midway Library porous asphalt (post-construction)**

**Photo-14-6: Hamline Midway Library porous asphalt**

**<u>Infiltration Test Results and Observations</u>**

Nine locations were tested for infiltration at the Hamline Midway Library Site in November 2017. The results are presented in **Table 14-2** below and graphically on **Chart D.2** in **Appendix D**. Prior to construction in 2012, the sub-surface soil infiltration rate was determined to be 29.0 inches per hour (in/hr) and 59.1 in/hr using a double ring infiltrometer.

**Table 14-2: Hamline Midway Library Infiltration Rate Summary**

| Infiltration Test Location | July 2013 Infiltration Rate (in/hr) | August 2014 Infiltration Rate (in/hr) | November 2015 Infiltration Rate (in/hr) | July 2016 Infiltration Rate (in/hr) | November 2017 Infiltration Rate (in/hr) |
|---|---|---|---|---|---|
| IR-1 | 102.4 | 0 | 0 | 0 | 0 |
| IR-2 | 14.9 | 0 | 0 | 0 | 0 |
| IR-3 | 11.4 | 0 | 0 | 0 | 0 |
| IR-4 | 172.7 | 0 | 0 | 0 | 0 |
| IR-5 | 0 | 0 | 151.5 | 16.0 | 3.3 |
| IR-6 | 1125.3 | 206.7 | 125.6 | 15.0 | 20.0 |
| IR-7 | 290.2 | 73.0 | 0 | 0 | 0 |
| IR-8 | 28.4 | 0 | 0 | 0 | 0 |
| IR-9 | 115.6 | 0 | 0 | 0 | 0 |
| **Site Average** | **206.8** | **31.1** | **30.8** | **3.4** | **2.6** |

A summary of the 2017 infiltration test results is provided below:

- The overall site infiltration rate decreased from 3.4 in/hr in 2016 to 2.6 in/hr in 2017
- No infiltration was observed at IR-1, IR-2, IR-3, IR-4 (**Photo 14-7**), IR-7, IR-8, and IR-9, which is consistent with testing completed in 2015 and 2016
- The 2017 infiltration rate is 1% of the post-construction rate monitored in 2013.
- Visual observations at the site indicate significant sediment accumulation and asphalt compaction, although locations IR-5 and IR-6 (**Photo 14-8**) were noticeably less affected

- Rehabilitative maintenance completed at the site prior to the 2016 infiltration testing, did not result in an increase in infiltration rates across the site (City of Saint Paul, 2017). That maintenance was completed in accordance with recommended rehabilitative practices by the Minnesota Department of Transportation (MnDOT) (MnDOT, 2015).

**Photo 14-7: Near IR-4, compaction & heavy silt accumulation**

**Photo 14-8: IR-6, less compaction & silt**

## 14.3. Jackson Street

The Jackson Street BMP (**Photo 14-9** and **14-10**) is a designated bike path constructed of pervious asphalt. It is a section of the Capital City Bikeway (CCB), a system of off-street bicycle trails in downtown Saint Paul. The BMP is eight blocks long, stretching from Kellogg Street to 11$^{th}$ Street, and consists of 2,750 square yards of pervious asphalt. Stormwater runoff filters through the asphalt and underlying media and is then conveyed to the storm sewer system via drain tile.

Monitoring locations JS-1 through JS-11 were established In November 2016 upon completion of the four-block stretch from Kellogg Boulevard to 7$^{th}$ Place East. Monitoring locations JS-12 through JS-18 were established in November 2017 upon completion of the four-block stretch from 7$^{th}$ Place East to 11$^{th}$ street. The monitoring locations were carefully selected to evaluate sediment loading and asphalt compaction from varying levels of pedestrian and vehicular traffic. Each site was characterized into one of three groups, identified in **Table 14-3**, based on their location and surroundings. The site and infiltration test locations are depicted on **Figure 14-3**. Site photos are provided in **Appendix E.**

**Table 14-3: Monitoring Site Traffic Characterization**

| Site Traffic Characterization |
|---|
| **Low:** No driving and minimal foot traffic area. Adjacent to planter or minimal impervious surface. |
| **Medium:** Pedestrian cross walks or adjacent to large areas of impervious surface. |
| **High:** Driveways for parking or businesses, heavy vehicular traffic. |


**Photo 14-9: Capital City Bikeway (CCB) – Jackson Street/Kellogg Avenue**

**Photo 14-10: Jackson Street Infiltration Test**

**<u>Infiltration Test Results and Observations</u>**

The site was tested for infiltration in June 2017 and November 2017. The infiltration test results from the 18 locations are summarized in **Table 14-4** and **Chart D.3** in **Appendix D**, which includes all infiltration test results completed to-date. **Table 14-4** is color coded to identify the site traffic characterizations described above. The infiltration tests results are also summarized in **Table 14-5**, which presents an average infiltration rate based on the monitoring location traffic characterization. The infiltration test locations are depicted on **Figure 14-3**.

**Table 14-4: Jackson Street Infiltration Rate Summary**

| Infiltration Ring Location | Test Location Description | Nov 2016 Infiltration Rate (in/hr) | June 2017 Infiltration Rate (in/hr) | Nov 2017 Infiltration Rate (in/hr) |
|---|---|---|---|---|
| JS-1 | Northern half of Securian ramp entrance. Non-painted surface east of path center line. | 143.2 | 2.3 | 0.7 |
| JS-2 | Midline of Securian ramp entrance. Non-painted surface east of path center line. | 187.6 | 1.6 | 0 |
| JS-3 | Jackson Street pedestrian cross south of 6th Street. Near midline of bike path. | 320.5 | 267.3 | 90.0 |
| JS-4 | Midblock between 6th & 5th Street. North of skyway. Near midline of bike path. | 530.6 | 380.0 | 155.6 |
| JS-5 | 345 parking ramp entrance. Non-painted surface just north of the midline of the entrance. Midline of bike path. | 96.5 | 1.1 | 0 |
| JS-6 | 345 parking ramp entrance. Green painted stripe farthest south. West side of bike path. | 29.7 | 3.0 | 0 |
| JS-7 | Jackson Street pedestrian cross north of 4th Street. Near midline of bike path. | 133.4 | 88.5 | 20.6 |
| JS-8 | Midblock between 4th & Kellogg. Western edge of bike path (adjacent to concrete). | 44.4 | 68.8 | 10.3 |
| JS-9 | Midblock between 4th & Kellogg. Eastern side of bike path. | 69.5 | 14.0 | 0.3 |
| JS-10 | In line with the southern wall of the US Courthouse (facing Kellogg). Western edge of bike path adjacent to concrete. | 139.5 | 31.4 | 0.2 |
| JS-11 | In line with the southern wall of the US Courthouse (facing Kellogg). Eastern side of the bike path. | 117.9 | 31.4 | 4.0 |
| JS-12 | N of Credit Union Driveway between 11$^{th}$ St. and 10$^{th}$ St Midline of bike path, next to a planter. | NM | NM | 95.6 |
| JS-13 | In front of Child Care Center between 11$^{th}$ St. and 10$^{th}$ St. Western edge of bike path, next to a planter. | NM | NM | 141.8 |
| JS-14 | S of 10$^{th}$ St. Adjacent to planter (2$^{nd}$ weir). Between Western edge and bike path midline. | NM | NM | 52.7 |
| JS-15 | Firestone driveway, N of 2$^{nd}$ stripe from the S. | NM | NM | 11.3 |
| JS-16 | Pedestrian cross, SW intersection of Jackson and 9$^{th}$ | NM | NM | 125.2 |
| JS-17 | Mid-block of 9$^{th}$ St. and 7$^{th}$ St. Adjacent to planter (southern-most tree). Just W of bike path midline. | NM | NM | 189.4 |
| JS-18 | Pedestrian cross, NW intersection of Jackson and 7$^{th}$ Pl. Adjacent to large concrete area. | NM | NM | 75.4 |
| | **Site Average:** | **164.8** | **80.9** | **64.9** |
| | *Average of Locations JS-1 through JS-11 (Estab. Nov 2016)* | | | **35.2** |
| | *Average of Locations JS-12 through JS-18 (Estab. Nov 2017)* | | | **98.8** |

NM – Not Measured

**Table 14-5: Jackson Street Infiltration Summary by Site Traffic Characterization**

| Site Traffic Characterization | Nov 2016 Infiltration Rate (in/hr) | June 2017 Infiltration Rate (in/hr) | Nov 2017 Infiltration Rate (in/hr)[1] |
|---|---|---|---|
| **Low:** No driving and minimal foot traffic area. Adjacent to planter or minimal impervious surface. | 530.6 | 380.0 | 127.0 |
| **Medium:** Pedestrian cross walks or adjacent to large areas of impervious surface. | 137.5 | 83.6 | 40.8 |
| **High:** Driveways for parking or businesses, heavy vehicular traffic. | 114.2 | 2.0 | 6.0[2] |

1 – Includes new monitoring locations established in November 2017

2 - The increase in the site average for high traffic areas from June 2017 to November 2017 is a result of a new location added in November 2017

A summary of the 2017 infiltration testing completed at the Jackson Street Pervious Pavement Site is provided below:

- The overall site infiltration rate in November 2017 was 64.9 in/hr
  - Sites JS-1 through JS-11, established in November 2016, had an average infiltration rate of 35.2 in/hr (79% reduction since November 2016)
  - Sites JS-12 through JS-18, established in November 2017, had an average infiltration rate of 98.8 in/hr
- Low traffic areas were observed to have a significantly greater infiltration rates on average (127.0 in/hr) than medium traffic (40.8 in/hr) and high traffic (6.0 in/hr) areas (**Photo 14-11**)
- During the November 2017 infiltration testing, three of four high traffic areas (locations established in November 2016) were observed to have 0.0 in/hr infiltration
- Two sets of paired monitoring locations (JS-8/JS-9 and JS-10/JS-11) were established to evaluate infiltration rates immediately adjacent to impervious surface in comparison to infiltration along the center of the bike path
  - During the first round of testing in November 2016, Locations JS-9 and JS-10, which are immediately adjacent to the concrete sidewalk, had greater infiltration rates than their paired locations along the center of the bike path, JS-8 and JS-11, respectively
  - In November 2017, locations JS-9 and JS-10, had an infiltration rate of 0.2 and 0.3 in/hr in comparison to 4.0 in/hr (JS-8) and 10.3 in/hr (JS-11)
  - The November 2017 infiltration rates along the center of the bike were an order of magnitude greater than the paired locations adjacent to the side walk, suggesting reduced infiltration from sediment loading immediately adjacent to impervious surfaces

**Photo 14-11: Test Locations JS-1 and JS-2 (high traffic)**

# 15. 2017 SUMMARY

Fifteen stormwater BMPs were evaluated for performance in 2017 to help the City meet its Phase I MS4 Permit monitoring requirements. The BMP systems that were monitored include underground infiltration systems, a rain garden, stormwater ponds, IESF ponds, and pervious pavement. The systems were monitored to determine infiltration rates, volume reduction, and pollutant removal efficiencies. Long-term monitoring data has shown how the effectiveness of these systems change over time.

## 15.1. Underground Infiltration Systems

Four underground infiltration BMPs (Beacon Bluff, Hillcrest Knoll Park, St. Albans, and Hampden Park) were monitored for flow and level to evaluate infiltration and volume reduction, in addition to water quality at the Beacon Bluff and Hampden Park sites. The runoff data for each site was normalized over equal monitoring periods to compare runoff from the drainage areas. A summary of runoff from the BMP drainage areas is provided in **Table 15-1** below.

**Table 15-1: Underground Infiltration System Runoff Summary**

| BMP Site | Drainage Area (acres)[1] | Total Monitored Runoff (cf) | % Runoff Captured | Water Yield (in/acre)[1] | Water Yield (cu-ft/acre)[1] | 2017 Rainfall to Runoff Ratio[1] |
|---|---|---|---|---|---|---|
| Beacon Bluff | 136.8 | 4,158,836 | 72 | 8.4 | 30,401 | 0.35 |
| Hillcrest Knoll Park | 37.1 | 1,270,727 | 46 | 9.4 | 38,578 | 0.37 |
| St. Albans | 22.2 | 799,170 | 97 | 9.9 | 35,999 | 0.39 |
| Hampden Park | 7.8 | 319,225 | 100 | 11.3 | 40,926 | 0.41 |

1-For the Beacon Bluff and Hampden Park Sites, the drainage area and total runoff presented in the table includes the total for the BMP system. The water yield calculations were generated from the monitored runoff volume and the corresponding drainage area.

Of the four sites, the Hampden Park BMP received the greatest amount of runoff per drainage acre, resulting in a rainfall to runoff coefficient of 0.41. Beacon Bluff received the least amount of runoff per drainage acre, with a rainfall to runoff coefficient of 0.35. Rainfall to runoff rations were higher in 2017 compared to 2016, with the exception of Hampden Park.

TSS and TP loads captured by the four-flow monitored BMPs are summarized in **Table 15-2.** TSS and TP loads for Hillcrest Knoll Park and St. Albans were generated using 2017 flow data and flow-weighted averages from the last year of water quality monitoring at each site, which was 2014 and 2015, respectively. The total TSS load and TP load captured by the four systems was 38,441 pounds and 119.8 pounds, respectively.

**Table 15-2: Underground Infiltration System Pollutant Capture Summary**

| BMP Site | TSS Captured (pounds) | TP Captured (pounds) |
|---|---|---|
| Beacon Bluff | 26,747 | 80.9 |
| Hillcrest Knoll Park | 6,380 | 26.9 |

| | | |
|---|---|---|
| St. Albans | 4,450 | 9.7 |
| Hampden Park | 864 | 2.3 |
| **Total** | **38,388** | **119.5** |

A summary of the 2017 infiltration rates for the underground infiltration systems is provided below. In addition to the flow monitored BMPs described above, infiltration rates were calculated for the Arundel, Montreal and Wordsworth BMPs:

- The infiltration rate for the Beacon Bluff underground system was 0.11 in/hr, which is 4% of the post-construction infiltration rate. The underground system no longer drains to empty and groundwater mounding does not appear to be the cause of standing water, based on groundwater elevation data. This suggests that clogging of the construction material within the trench is restricting flow. Even with the standing water observed in the BMP and an increase in system discharge events, the BMP infiltrated 72% of the total volume monitored.
- Groundwater intrusion into the Hillcrest Knoll BMP has been observed every year since 2013. The mounding that occurs at the site is a limiting factor for infiltration. The 2017 infiltration rate of 0.52 in/hr is greater than the observed post-construction rate, although all infiltration rates calculated for the Site have been below the design and MSWM infiltration rates. The system infiltrated 46% of the volume monitored.
- The 2017 St. Albans infiltration rate of 20.6 in/hr is greater than the MSWM infiltration rate, but slightly less than design rate of 26.0 in/hr. The St. Albans BMP system consistently infiltrates greater than 95% of the volume monitored to the system, with the 2017 volume reduction totaling 97%.
- The infiltration rate for the Hampden Park BMP was 8.3 in/hr, which exceeded the design rate of 1.8 in/hr. This is slightly less than the rate observed in 2016, although 100% of monitored volume was infiltrated by the system.
- The infiltration rate for the Arundel BMP was 0.01 in/hr, which is less than 1% of the post-construction infiltration rate. The system never fully drained to empty in 2017, although only 0.5 ft of water was observed at the conclusion of the monitoring season.
- The Montreal Trench had a monitored infiltration rate of 11.7 in/hr in 2017, which exceeds the design rate of 0.6 in/hr and the 2016 infiltration rate of 7.5 in/hr
- The Wordsworth Trench had a monitored infiltration rate of 5.8 in/hr in 2017, which exceeds the design rate of 0.6 in/hr and the 2016 infiltration rate of 4.4 in/hr.

## 15.2. Rain Garden & Stormwater Ponds

In 2017, the Beacon Bluff rain garden and the Flandrau-Hoyt and Sackett Park stormwater ponds were monitored for water level. Infiltration within the Beacon Bluff rain garden has decreased from 2.9 in/hr to 0.52 in/hr since 2012, primarily due to sediment accumulation within the basin. Water that does not infiltrate within the rain garden will spill into the underground infiltration gallery through open grates on the surface.

Level data collected at Flandrau-Hoyt and Sackett Park Ponds is primarily used for evaluating future improvements at those locations. The maximum level increase at Flandrau-Hoyt Pond was 7.53 ft, which is half of the maximum level increase observed in 2016. During all events monitored in 2017, water level in the pond decreased back to pre-event levels in less than 20 hours, and levels never exceeded the emergency spillway elevation. Water levels at Sackett Park Pond exceeded the outlet control structure on 20 occasions in 2017, and it took less than six hours for water levels to drop back below that elevation.

## 15.3. Iron-Enhanced Sand Filtration Ponds

Overall, the mass SRP reductions at Maryland Pond (10%), Magnolia Pond (13%), and Jenks Pond (19%) were less than reduction rates observed during similar studies which have identified removal efficiencies from 26% SRP (Erickson et al. 2016) to 75% SRP (Erickson 2012). The cited studies have also identified that many small events with low SRP loads resulted in negative removals, similar to the results described here. Overall, low SRP concentrations have been observed at TBNS, with 2017 median concentrations ranging from 13 µg/L at Jenks Pond to 38 µg/L at Magnolia Pond.

Continuous flow through the Maryland IESF Pond media may be creating anaerobic conditions, which have contributed to the export of iron from the media beds. Additionally, anaerobic conditions can mobilize SRP by breaking the bonds created during the sorption of SRP to iron oxide. It is recommended that the source of the continuous flow be further evaluated in 2018.

## 15.4. Pervious Pavement

Infiltration testing was conducted at the Victoria Street permeable pavers, and the Hamline-Midway Library and Jackson Street pervious asphalt sites in 2017. The Victoria and Hamline Midway Library 2017 infiltration rates are both 1% of post-construction monitored infiltration rates (1.2 in/hr and 2.6 in/hr, respectively). Rehabilitative maintenance efforts at Hamline-Midway Library did not result in an increase in infiltration at the site. Major sediment loading from adjacent properties has been observed at the site.

The November 2017 infiltration rate at the Jackson Street Site was 64.9 in/hr, which is 36% of the infiltration rate observed during the first year of monitoring (2016). Low traffic areas were observed to have a significantly greater infiltration rates on average (127.0 in/hr) than medium traffic (40.8 in/hr) and high traffic (6.0 in/hr) areas.

## 15.5. 2018 Recommendations

The recommendations for the 2018 Monitoring Program include:

- Evaluate export of iron from TBNS Maryland Pond
- Continue to perform inspections and regular maintenance on BMP pre-treatment systems and infiltration galleries as needed.
- Continue to notify of potential illicit discharges observed at flow monitoring locations
- Complete additional infiltration testing at Jackson Street Pervious Bike Path to further evaluate changes in pervious surface performance with respect to path traffic.
- On-going review of composite sampling methodologies and flow pacing

# 16. REFERENCES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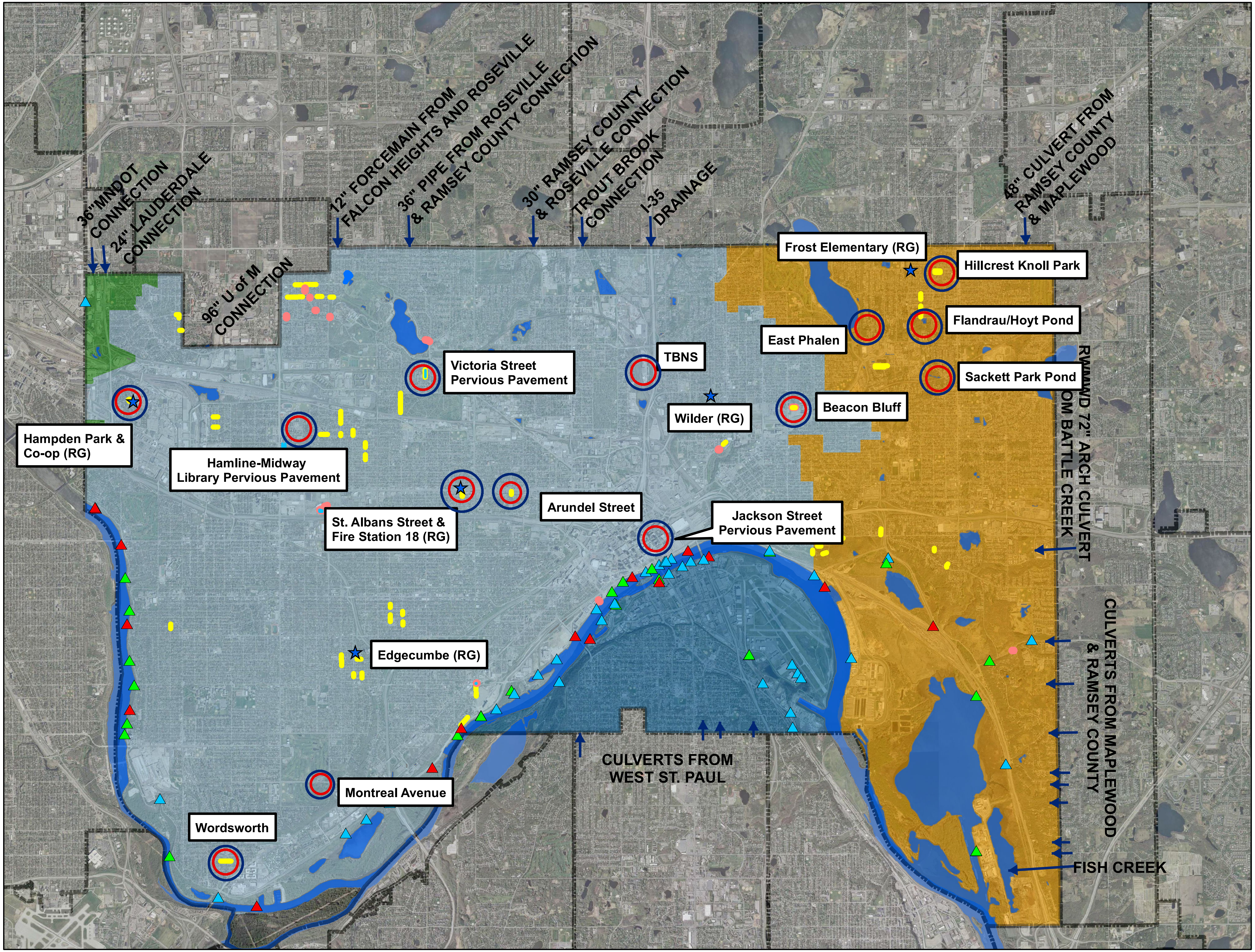
***Figures***

# City of St. Paul
## 2017 Water Quantity & Quality Monitoring Program

Figure 1-1
## 2017 Monitoring Site Locations

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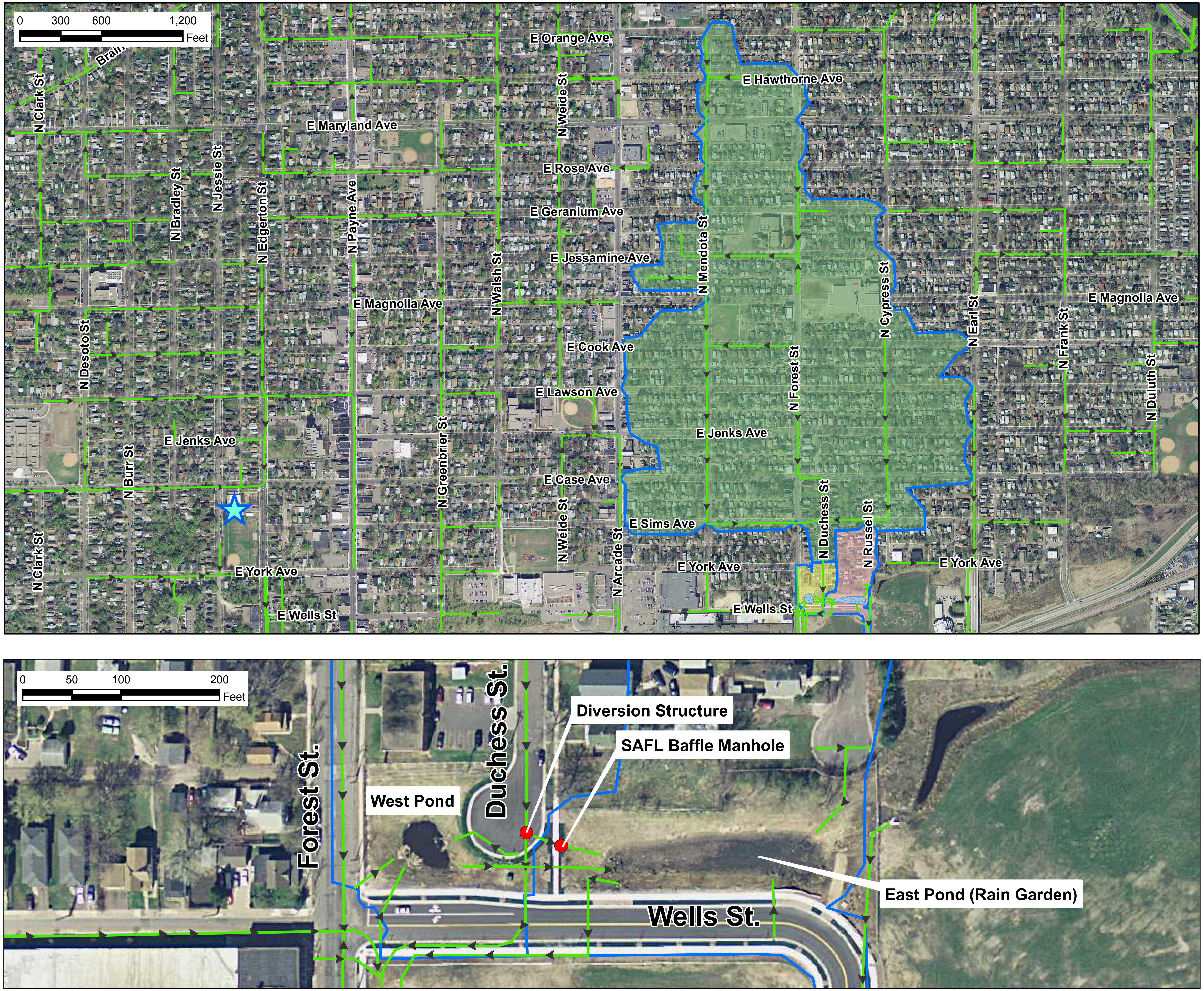
N W E S

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
- 2016 Monitoring Locations
- 2017 Monitoring Locations
- Rain Gauge Locations

**Outfalls**
- 30" - 48"
- 50" - 72"
- > 72"




# City of St. Paul

2017 Water Quantity and Quality Monitoring Program

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## FIGURE 4-1

## Beacon Bluff Infiltration BMP Drainage Areas

N
W E
S

### Legend

- Underground Chamber
- Storm Pipe
- Rain Gauge Location

**Drainage Areas**

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

WSB

# City of St. Paul

**2017 Water Quantity and Quality Monitoring Program**

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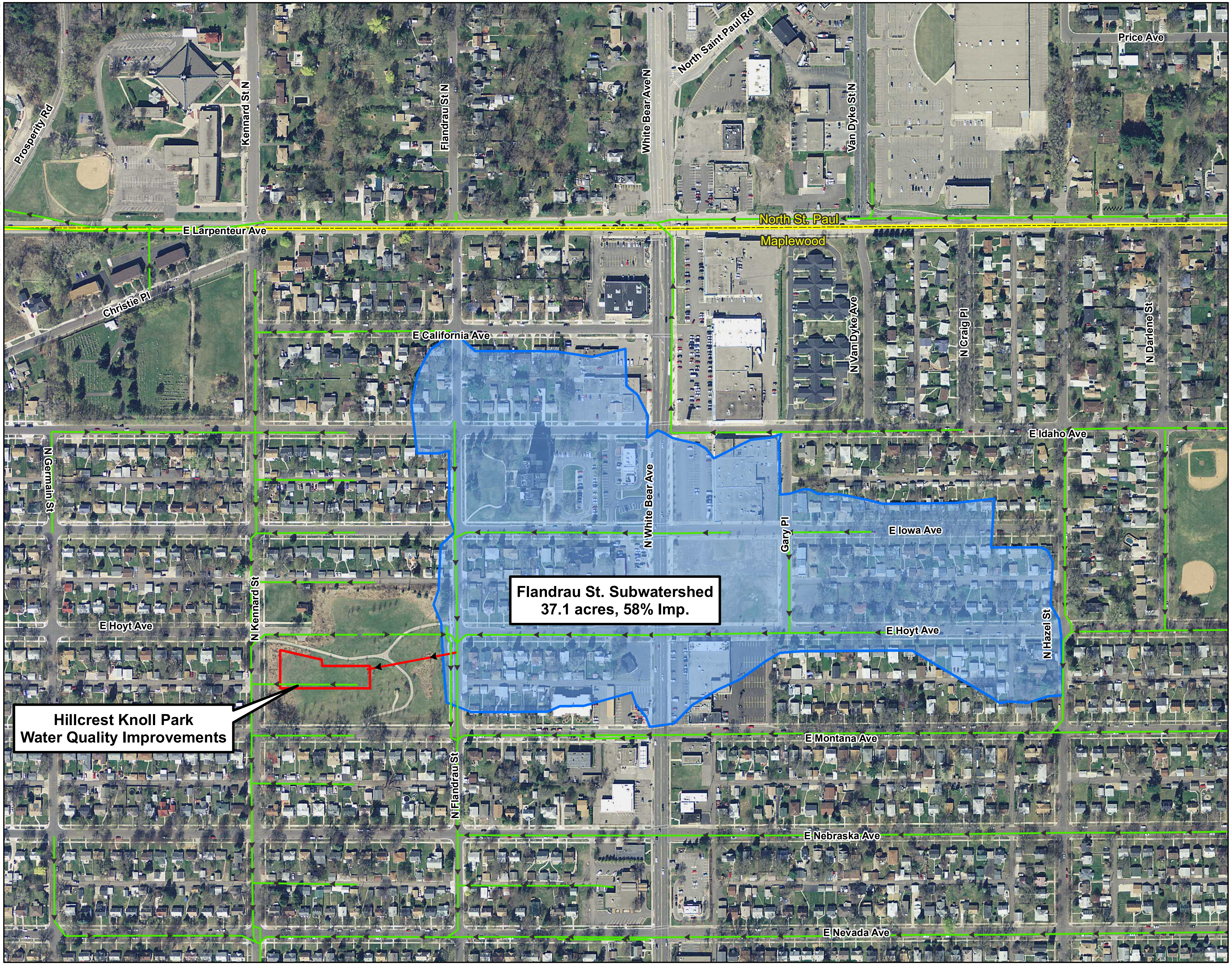
## FIGURE 5 - 1

## Hillcrest Knoll Park Infiltration BMP Drainage Area



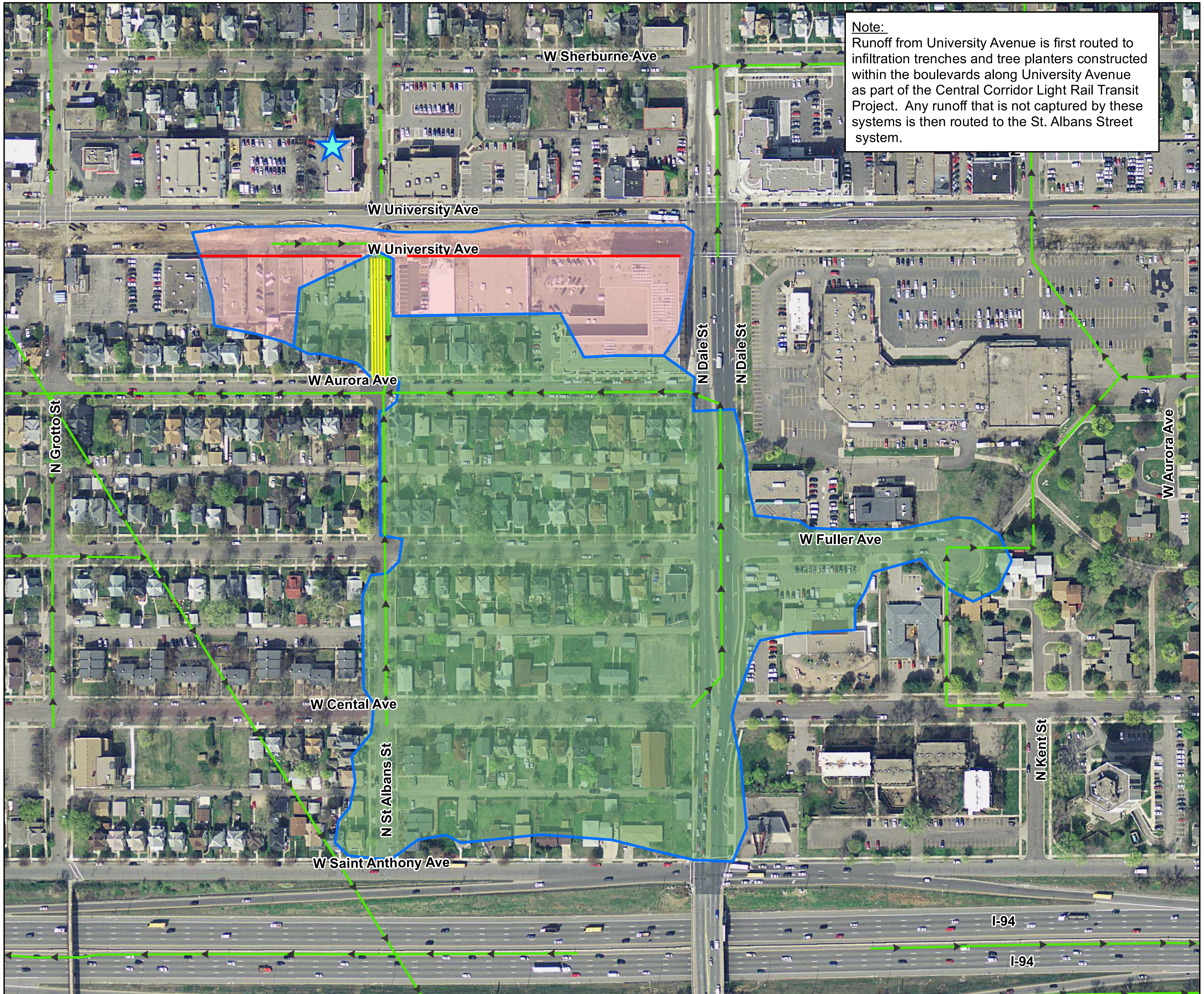

N
W E
S

0 150 300 600 Feet

## Legend

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

WSB




# City of St. Paul

## 2017 Water Quantity and Quality Monitoring Program

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## FIGURE 6-1

## 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)

WSB


# City of St. Paul

**2017 Water Quantity and Quality Monitoring Program**

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## FIGURE 7-1
## Hampden Park Infiltration BMP Drainage Area

N
W E
S

0 50 100 200 300 400
Feet

**Legend**

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

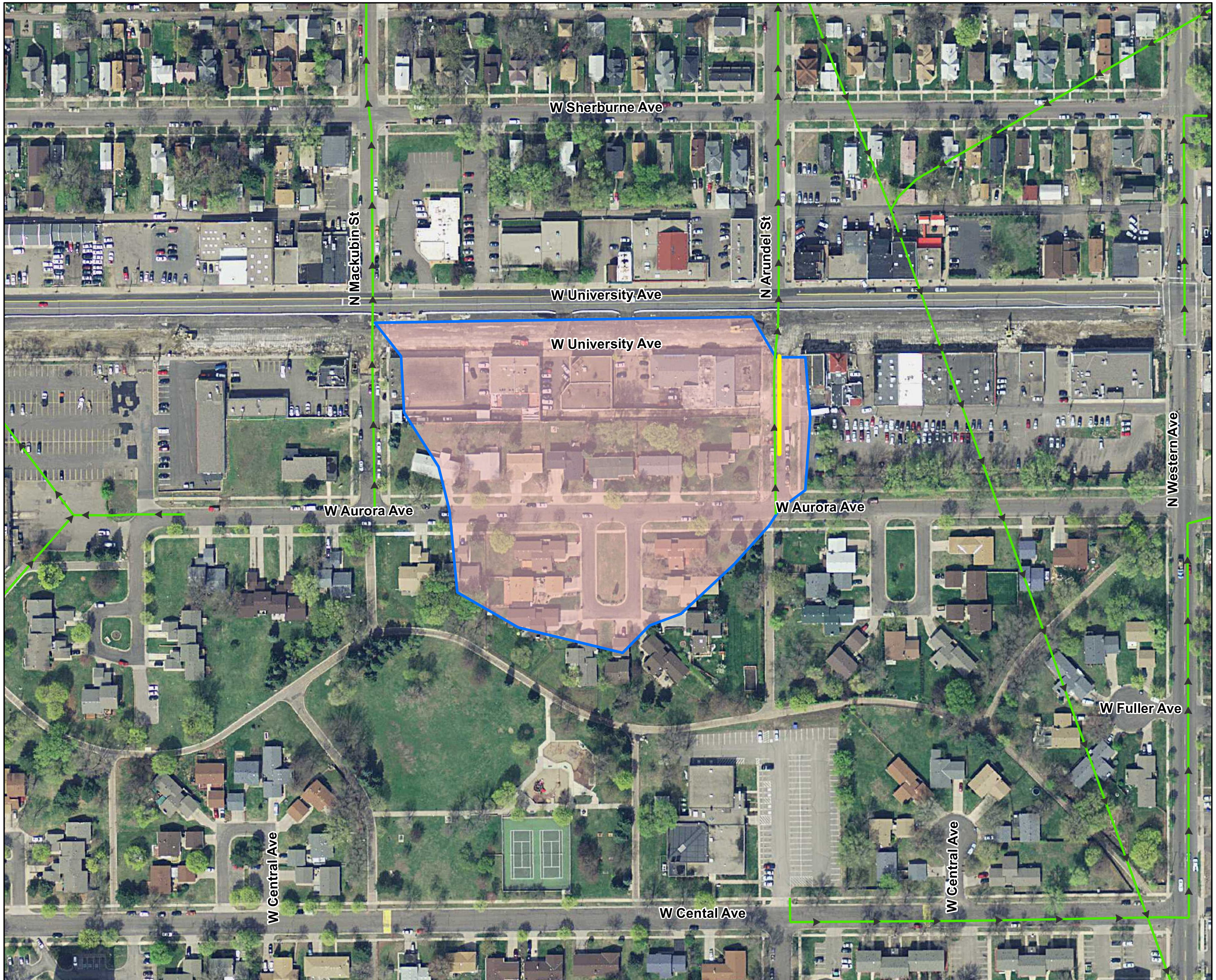
WSB

# City of St. Paul

2017 Water Quantity and Quality Monitoring Program

## FIGURE 8-1

## Arundel Street Infiltration BMP Drainage Area

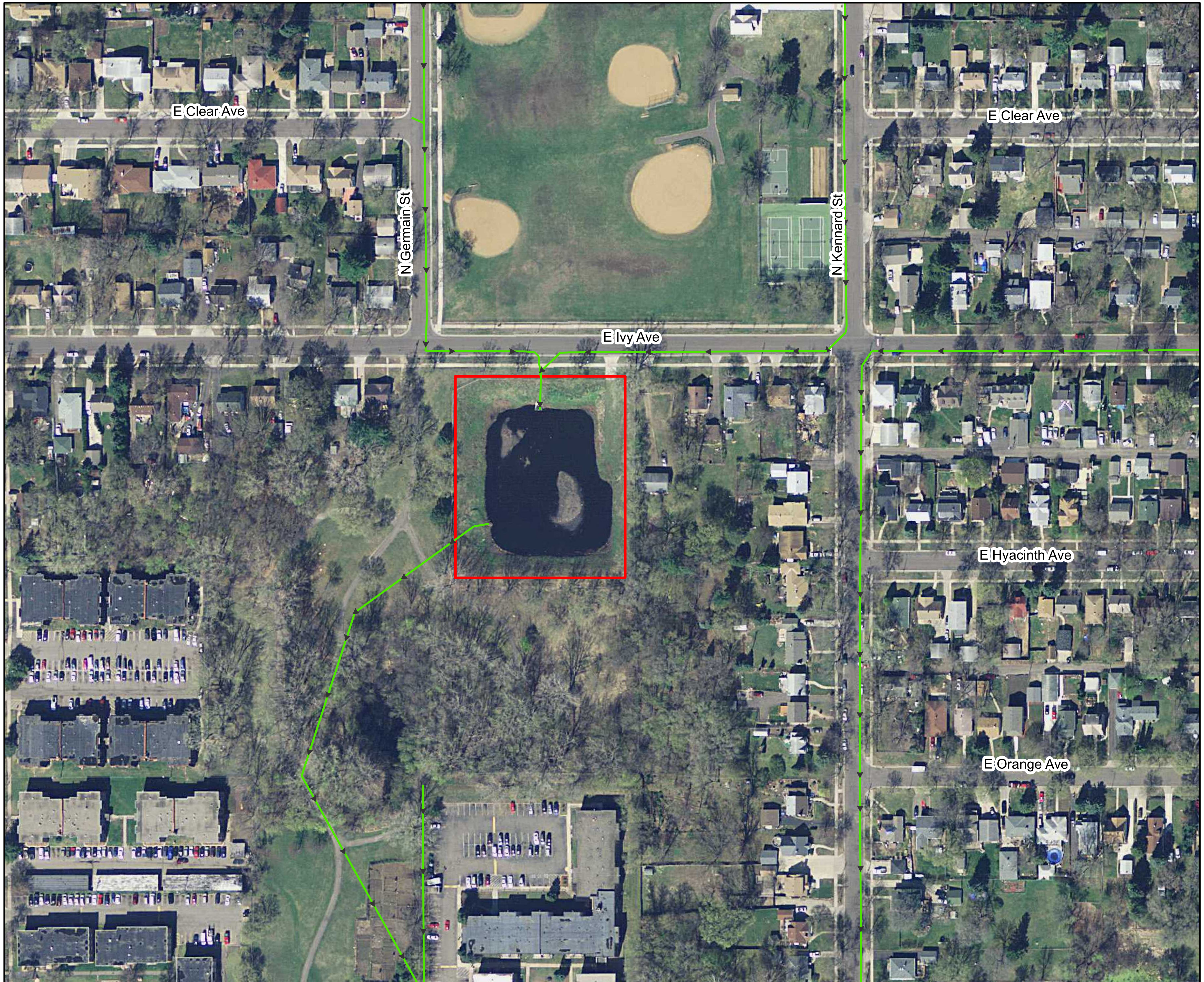





**Legend**

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

WSB




# City of St. Paul

**2017 Water Quantity and Quality Monitoring Program**

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## FIGURE 9-1

## Flandrau - Hoyt Pond Site Location

N
W E
S

0 100 200 400 Feet

**Legend**

Pond Area

Storm Pipe

WSB

# City of St. Paul

**2017 Water Quantity and Quality Monitoring Program**

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## FIGURE 10-1

## Sackett Park Pond Site Location



WSB


K:\01610-100\GIS\Maps\Figures\2017\Figure 11-1 Trout Brook Sanctuary Iron Enhanced Sand Filtration Ponds.mxd

# City of St. Paul

## 2017 Water Quality & Quantity Program

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## Figure 11-1
## Trout Brook Nature Sanctuary Iron-Enhanced Sand Filtration Ponds Drainage Areas

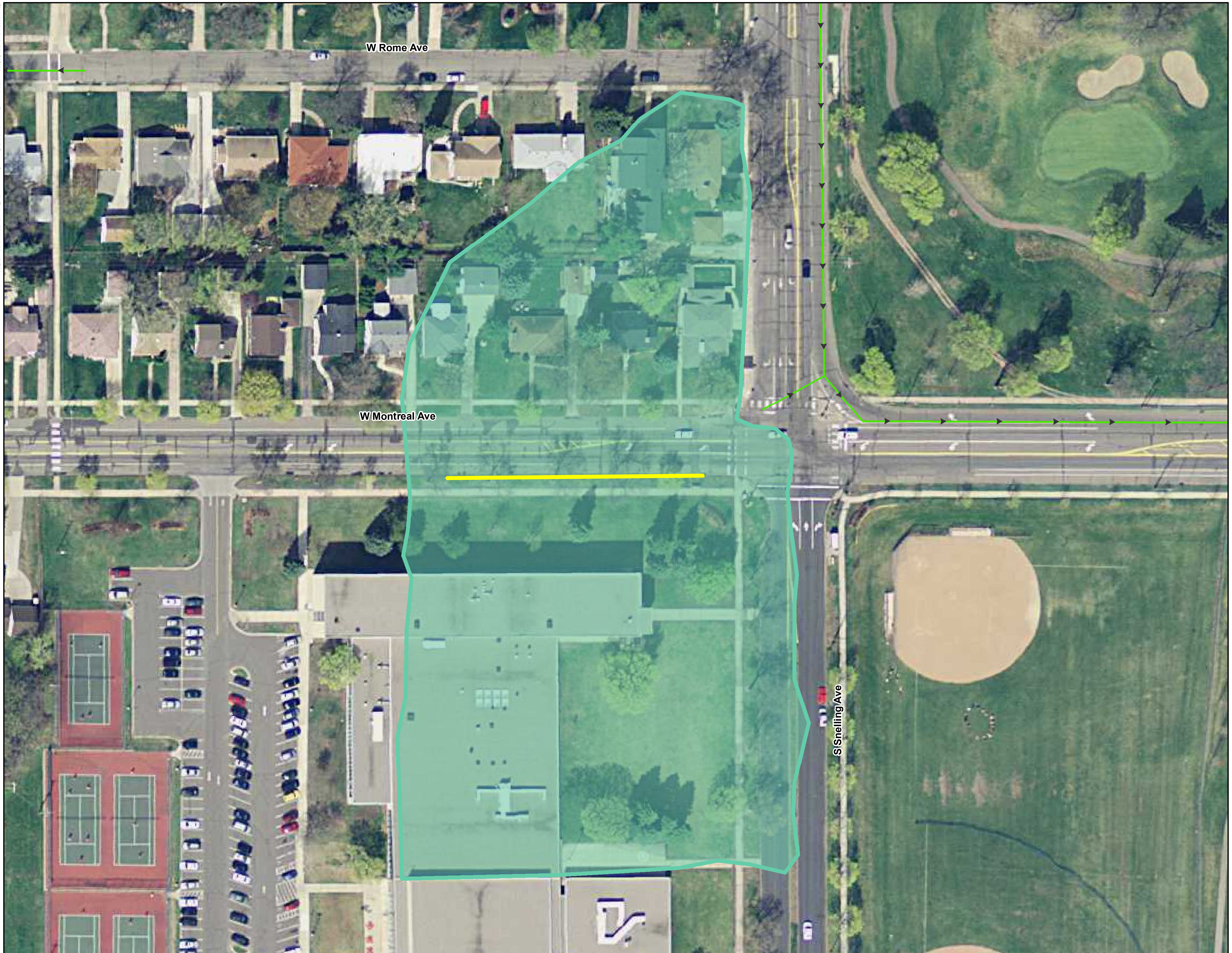
N W E S

0 200 400 800 Feet

### LEGEND

- Storm Pipe
- Subwatershed to BMP
- Iron Enhanced Sand Filtration Ponds

WSB




# City of St. Paul

**2017 Water Quantity and Quality Monitoring Program**

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## FIGURE 12 - 1

## Montreal Infiltration BMP Drainage Area

N
W E
S

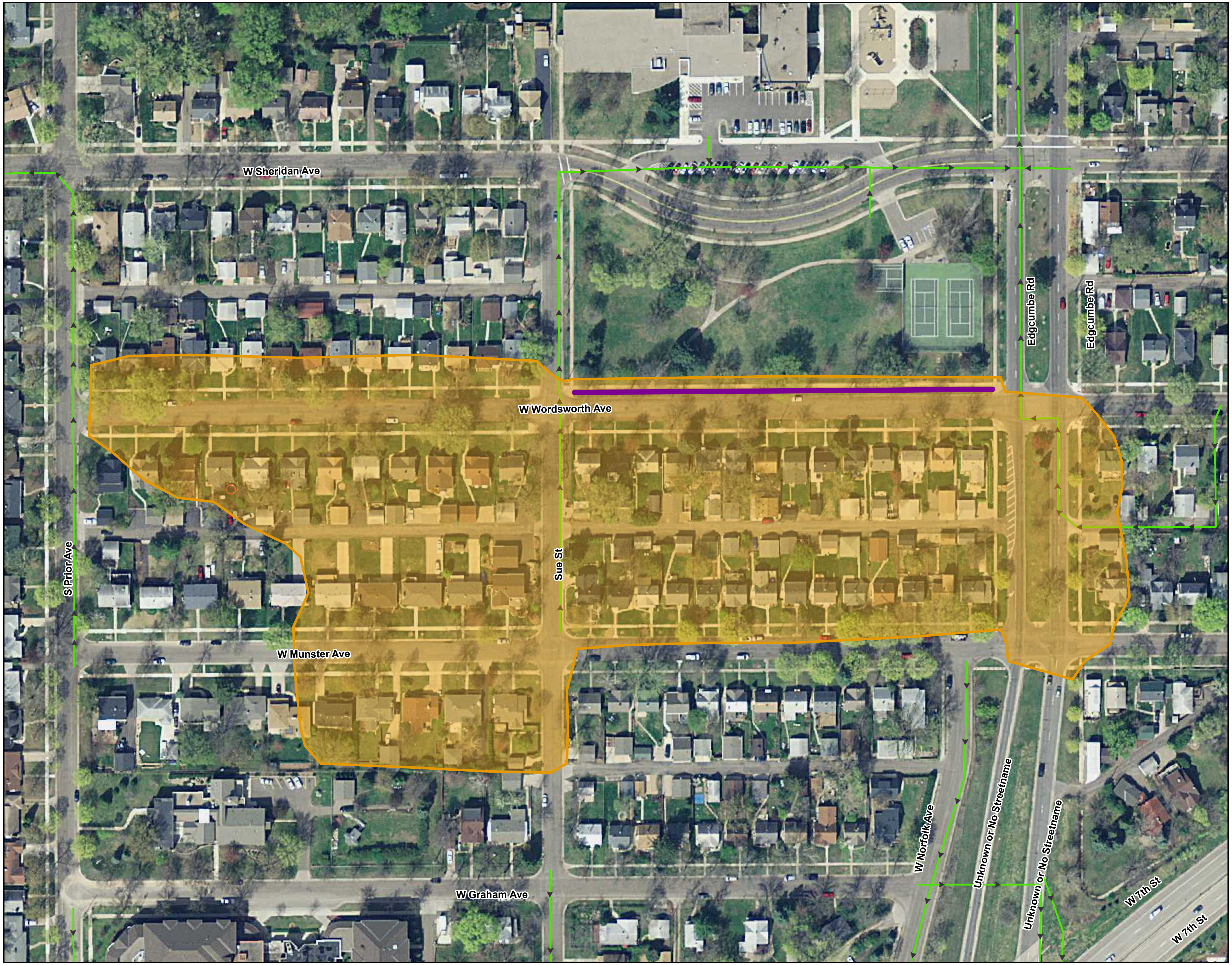
0 80 160 Feet

**Legend**

- Infiltration Trench
- Drainage Area
- Ex. Storm Sewer
- City Boundaries

WSB

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




# City of St. Paul

2017 Water Quantity and Quality Monitoring Program

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## FIGURE 13 - 1

## Wordsworth Infiltration BMP Drainage Area

N
W E
S

0 125 250 Feet

### Legend

- Infiltration Trench
- Drainage Area
- Ex. Storm Sewer
- City Boundaries

WSB

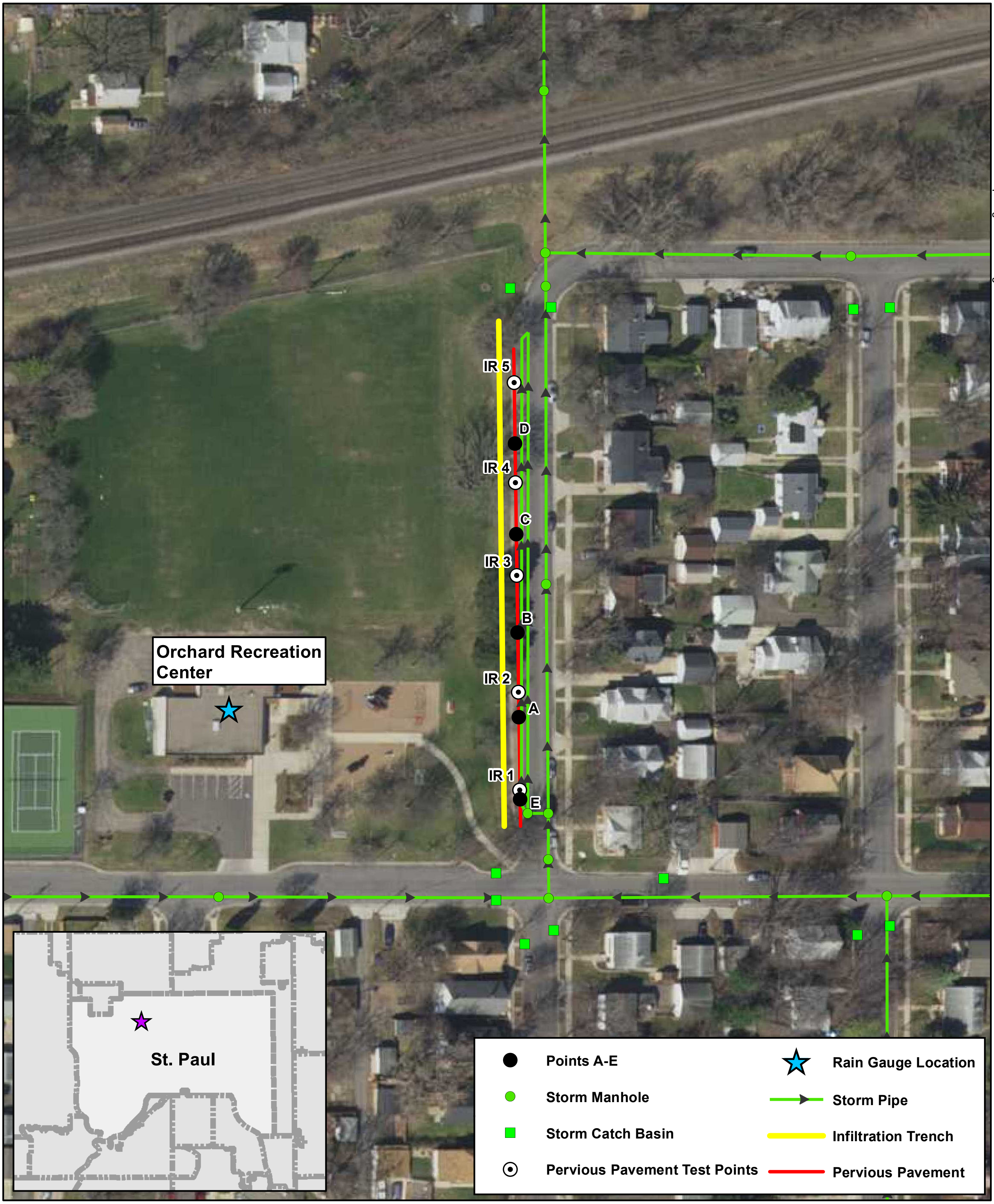


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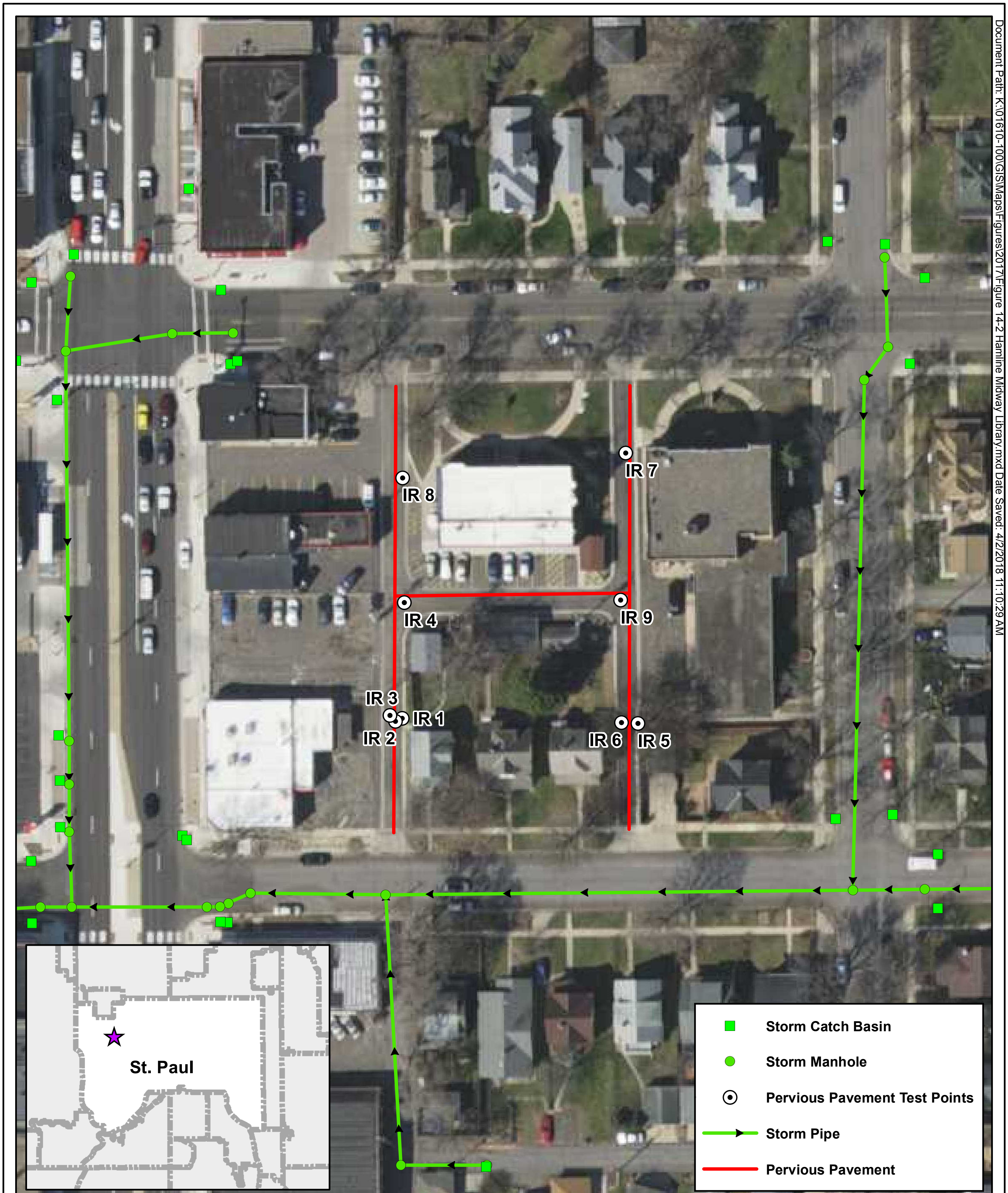
**Figure 14-1 - Victoria Street**
**Pervious Pavement Test Locations**

2017 Water Quantity and Quality Monitoring Program
City of St Paul, MN

N
0 30 60 120 Feet

WSB

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# Figure 14-2 - Hamline Midway Library Pervious Pavement Test Locations

2017 Water Quantity and Quality Monitoring Program
City of St Paul, MN

WSB


**Figure 14-3 Jackson Street**
**Pervious Pavement Test Locations**
2017 Water Quantity and Quality Monitoring Program
City of St. Paul, MN

Document Path: K:\01610-100\GIS\Maps\Figures\2017\Figure 14-3 JacksonStPerviousPavement.mxd Date Saved: 4/2/2018 11:13:56 AM

***Appendix A – Infiltration/Water Level Charts***

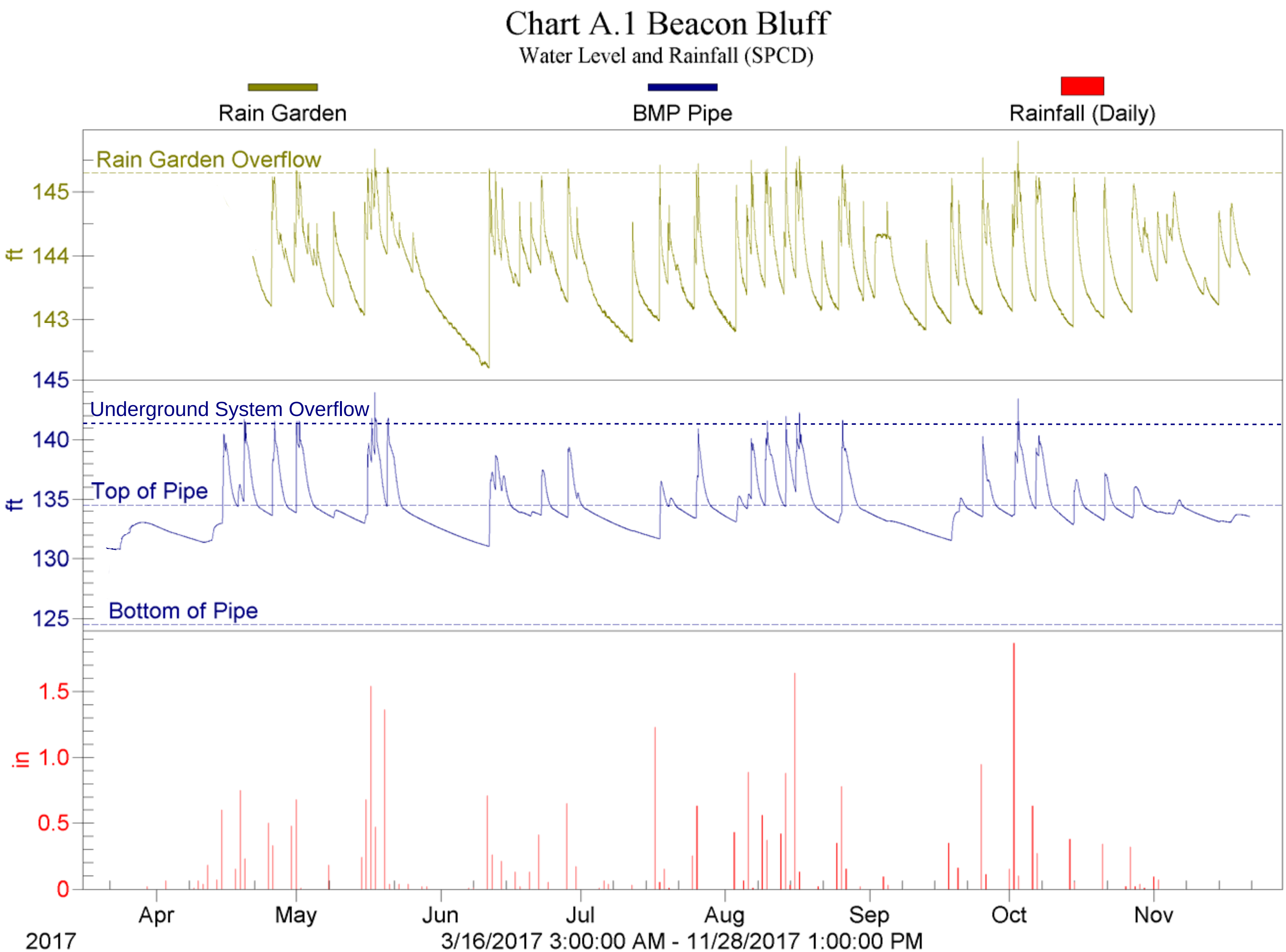
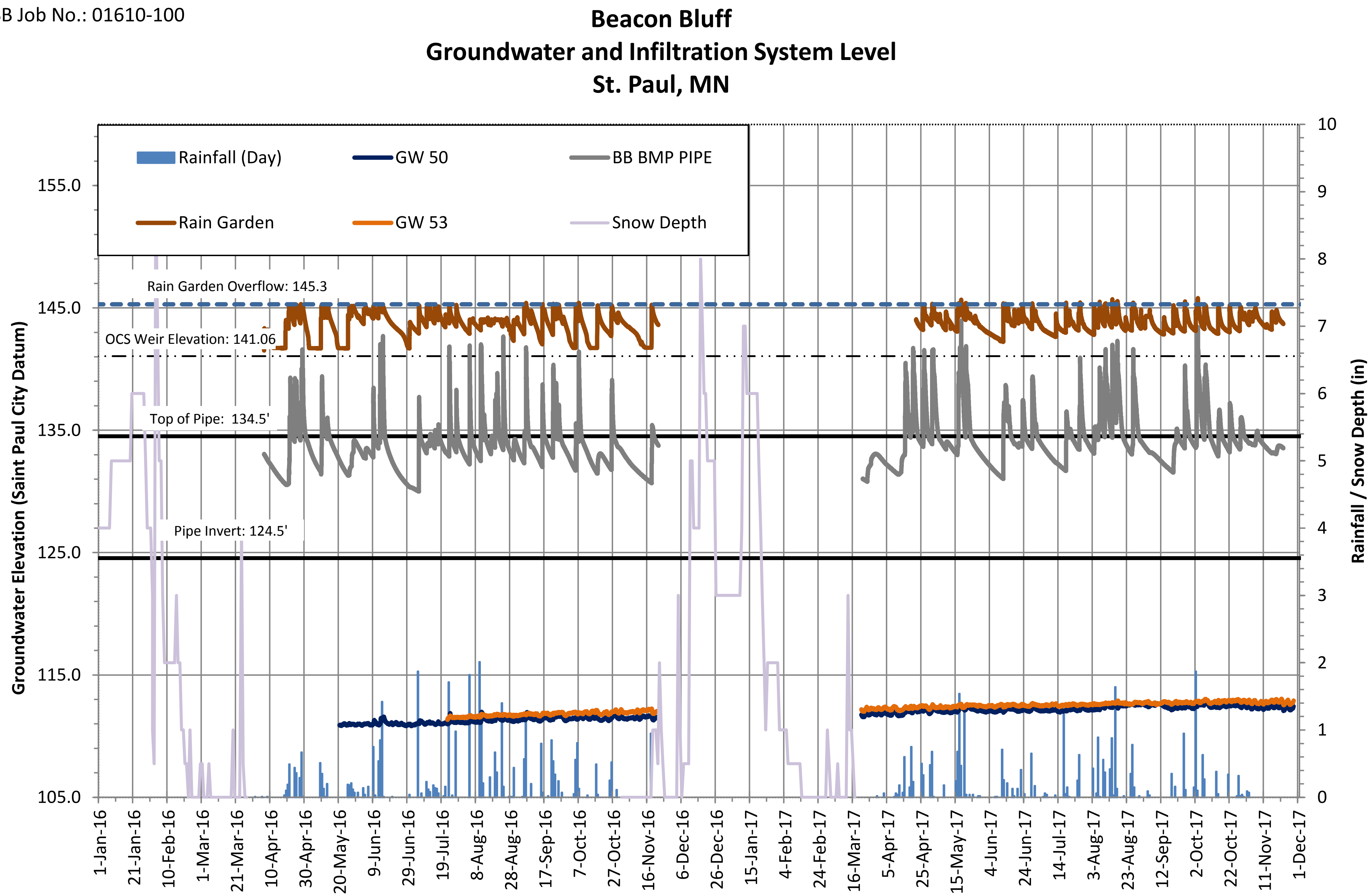
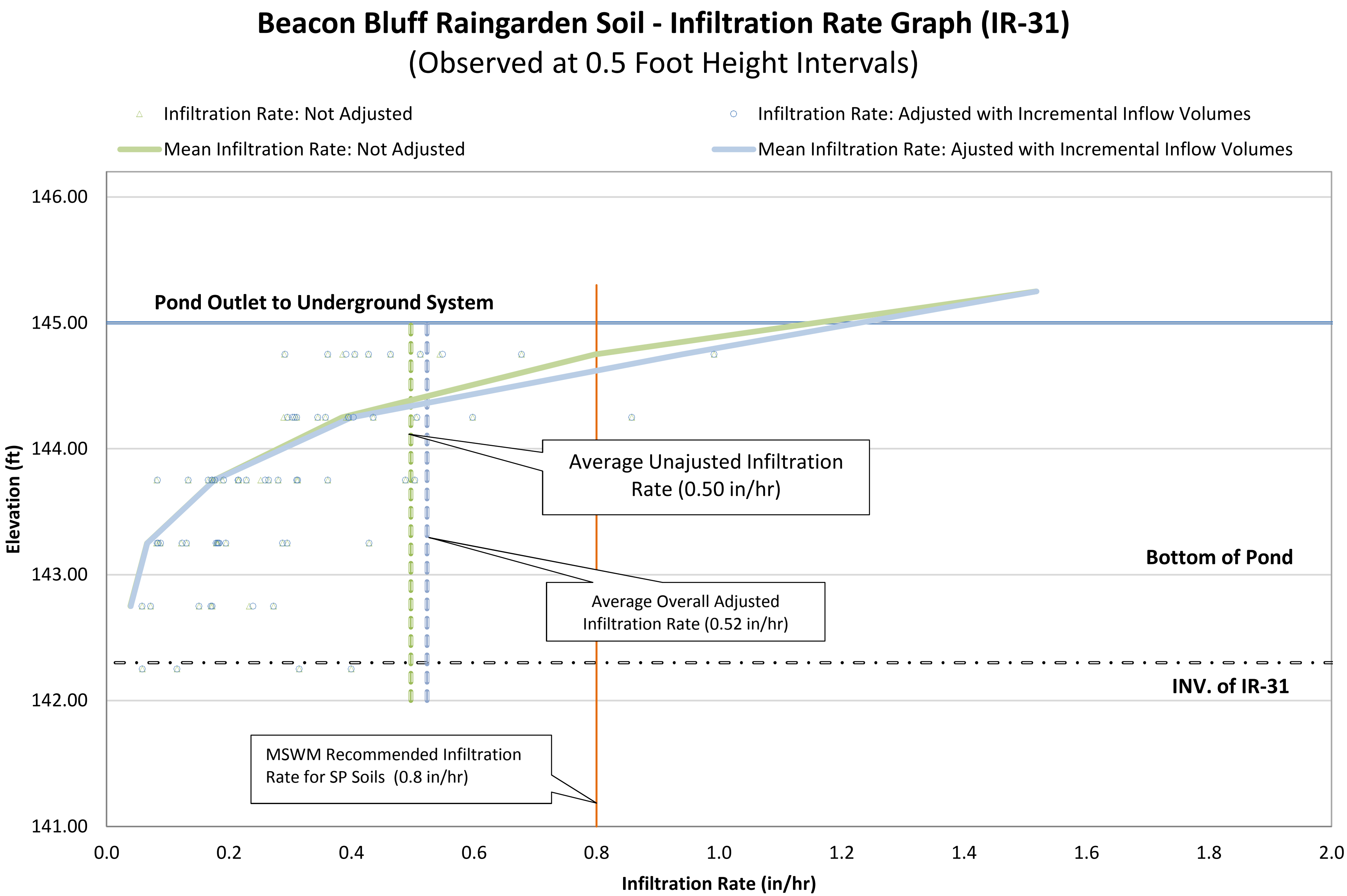


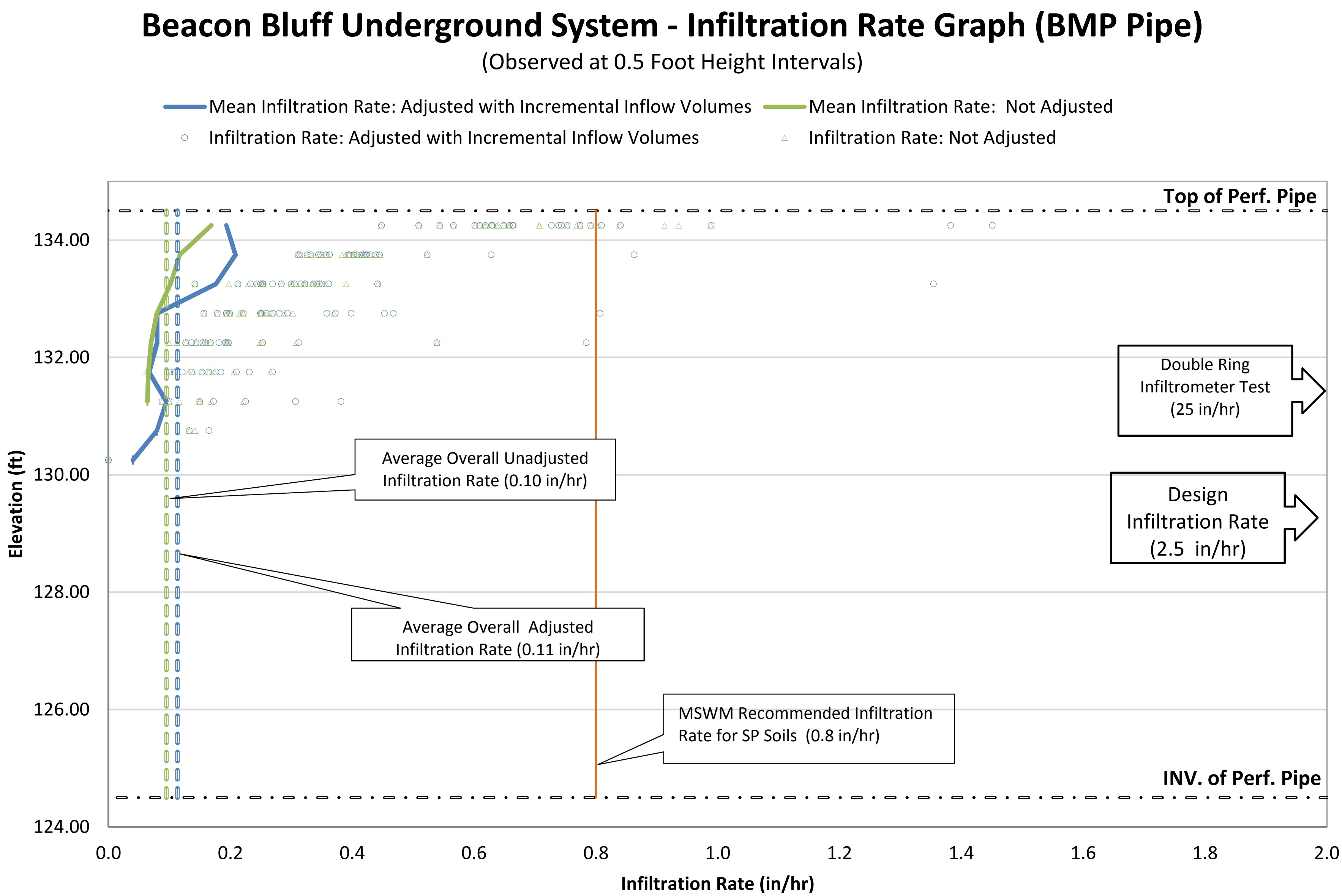
Chart A.1 Beacon Bluff
Water Level and Rainfall (SPCD)
Rain Garden
BMP Pipe
Rainfall (Daily)
Rain Garden Overflow
145
144
143
ft
145
Underground System Overflow
140
Top of Pipe
135
130
Bottom of Pipe
125
ft
1.5
1.0
0.5
0
in
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
2017
3/16/2017 3:00:00 AM - 11/28/2017 1:00:00 PM

City of Saint Paul
2017 Beacon Bluff Groundwater and System Level
Chart A.2
WSB Job No.: 01610-100



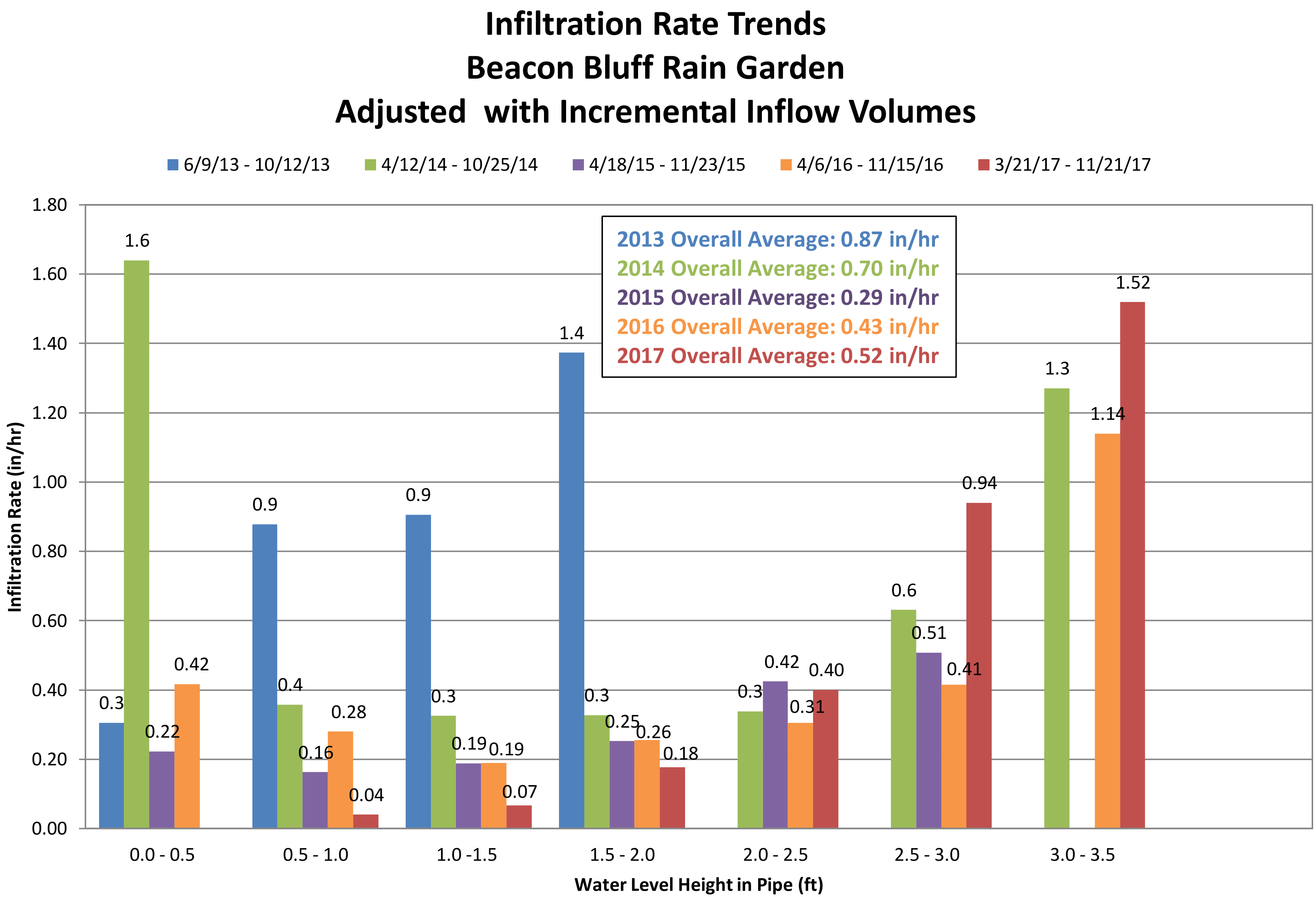

Beacon Bluff Raingarden Soil - Infiltration Rate Graph (IR-31)
(Observed at 0.5 Foot Height Intervals)
Infiltration Rate: Not Adjusted
Infiltration Rate: Adjusted with Incremental Inflow Volumes
Mean Infiltration Rate: Not Adjusted
Mean Infiltration Rate: Ajusted with Incremental Inflow Volumes
146.00
145.00
144.00
143.00
142.00
141.00
Elevation (ft)
Pond Outlet to Underground System
Average Unajusted Infiltration Rate (0.50 in/hr)
Average Overall Adjusted Infiltration Rate (0.52 in/hr)
Bottom of Pond
INV. of IR-31
MSWM Recommended Infiltration Rate for SP Soils (0.8 in/hr)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Infiltration Rate (in/hr)

City of Saint Paul
2017 Water Quality and Quantity Report
Chart A.4
WSB Project No.: 01610-100

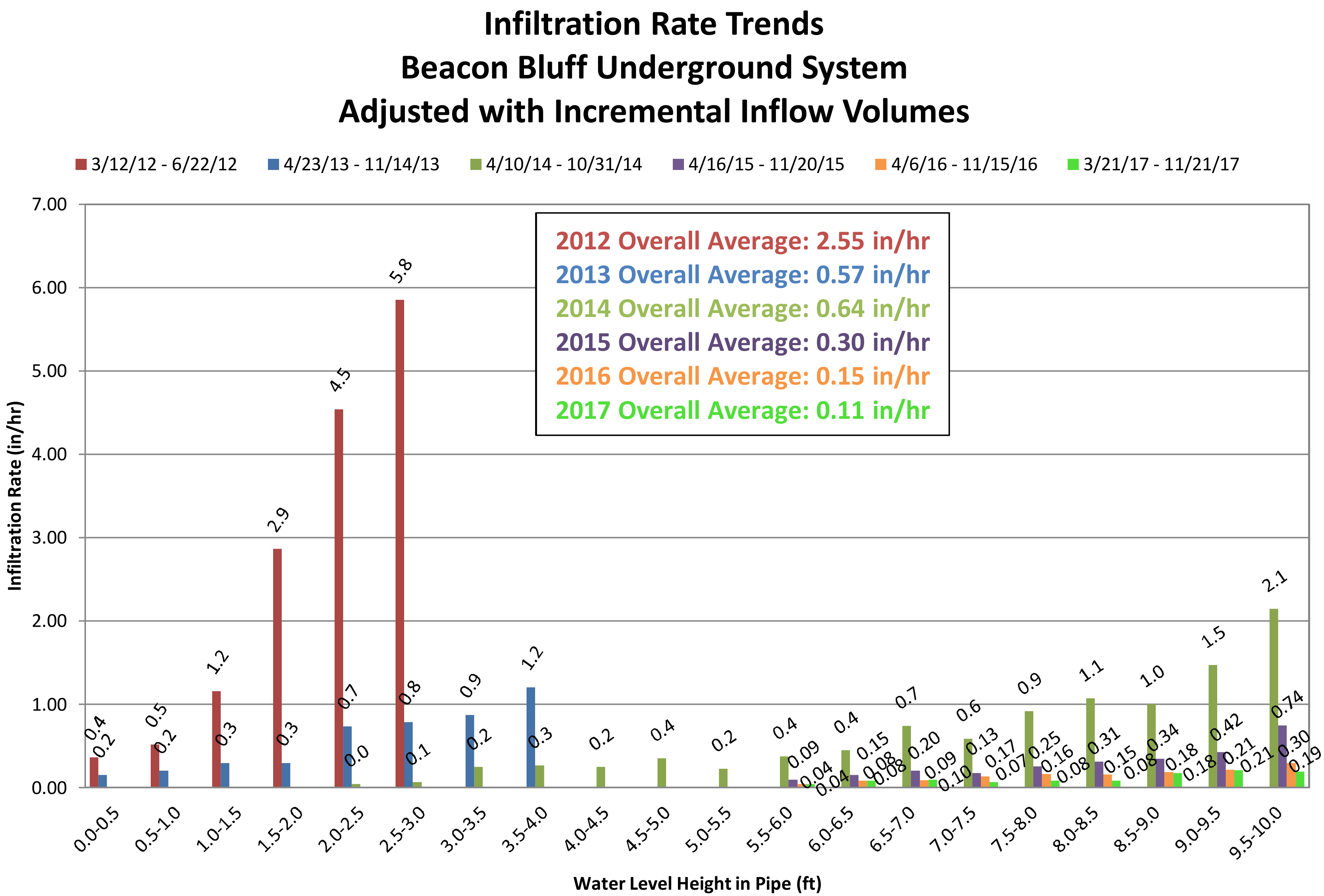



Note: Pipe Invert is 124.5'
Pipe perforated around circumference of pipe

City of Saint Paul
2017 Water Quality and Quantity Report
Chart A.5
WSB Job No.: 01610-100
*2017 data is from IR-31, previous years is from IR-33

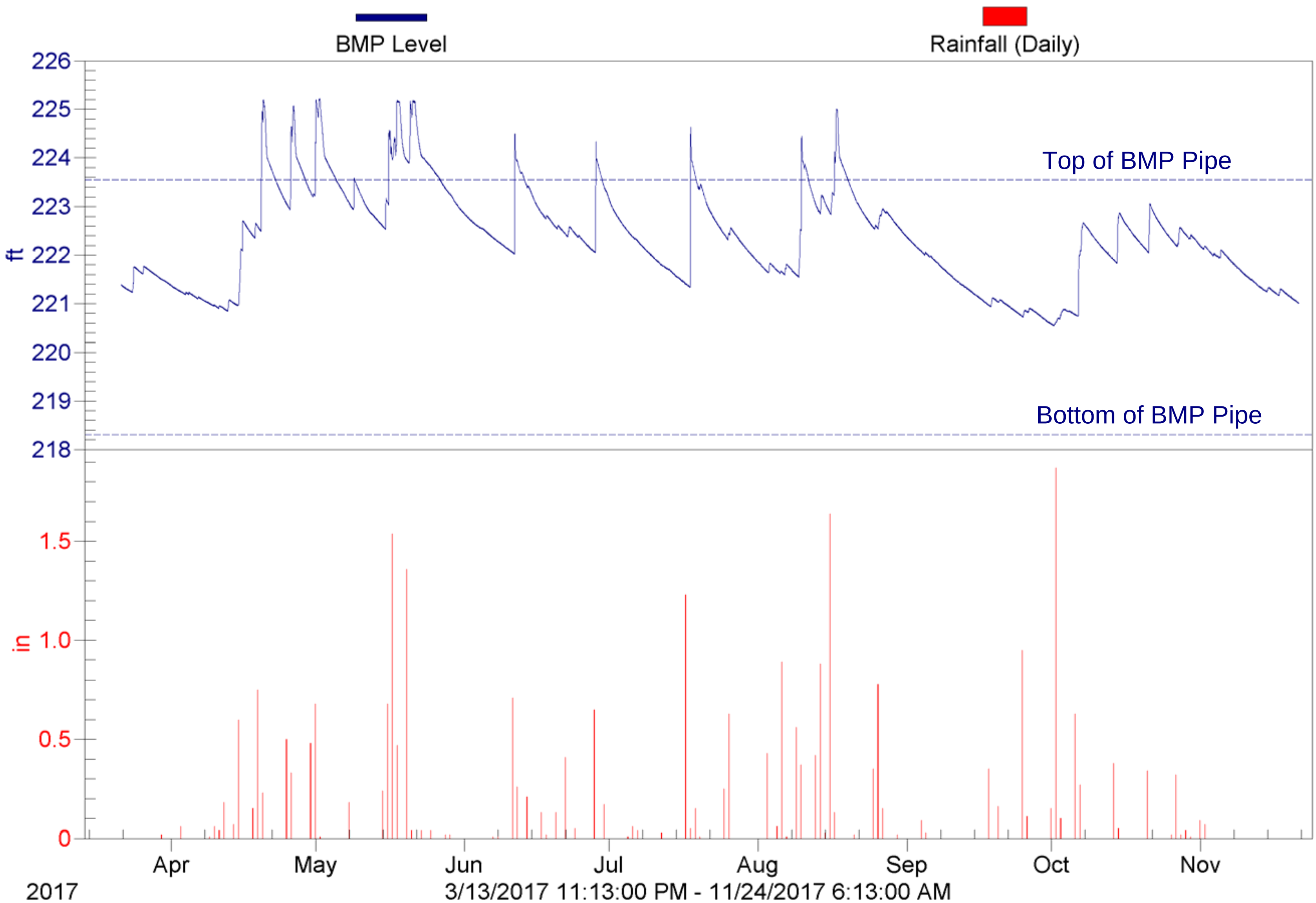


City of Saint Paul
2017 Water Quality and Quantity Report
Chart A.6
WSB Job No.: 01610-100

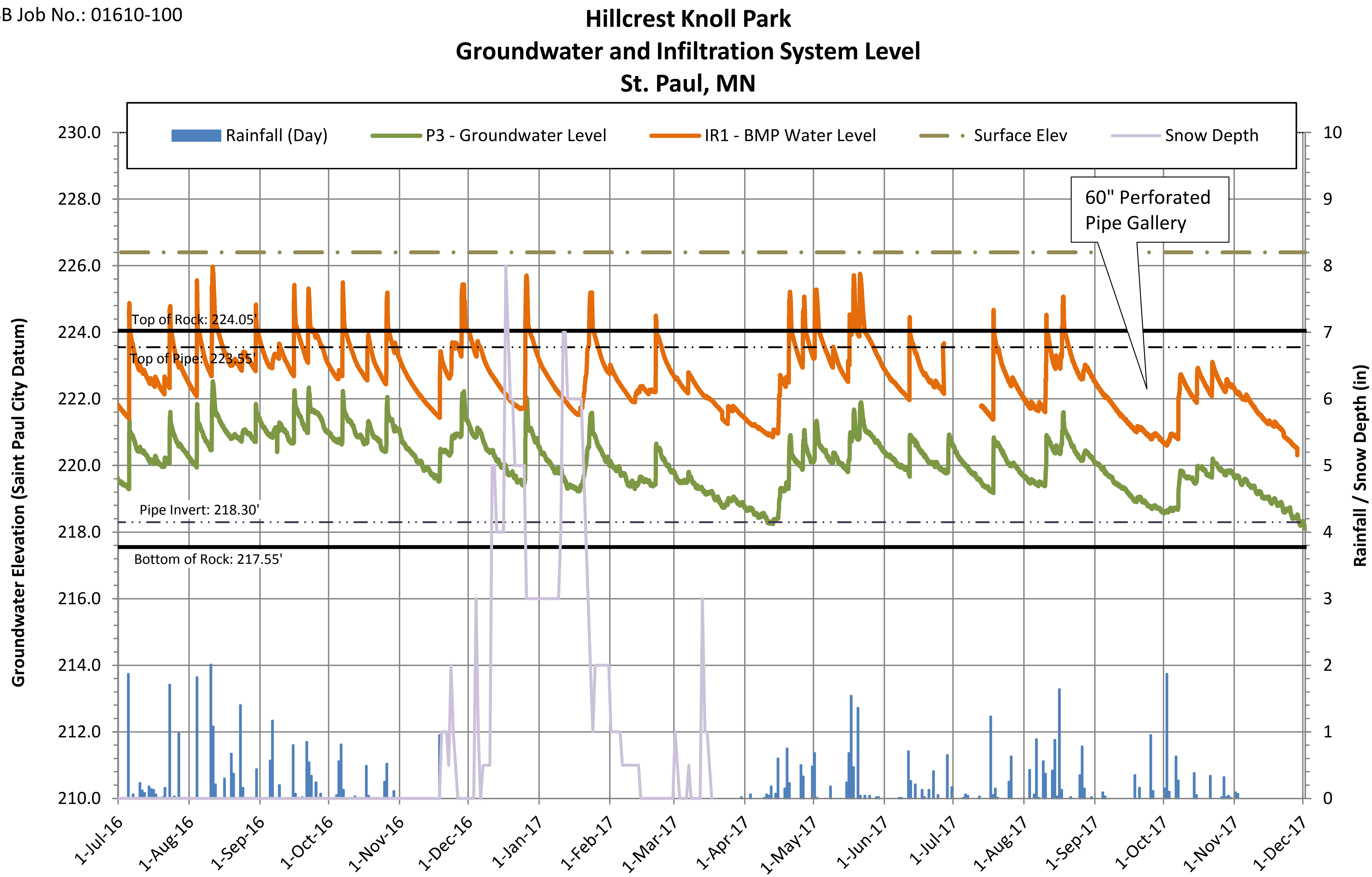


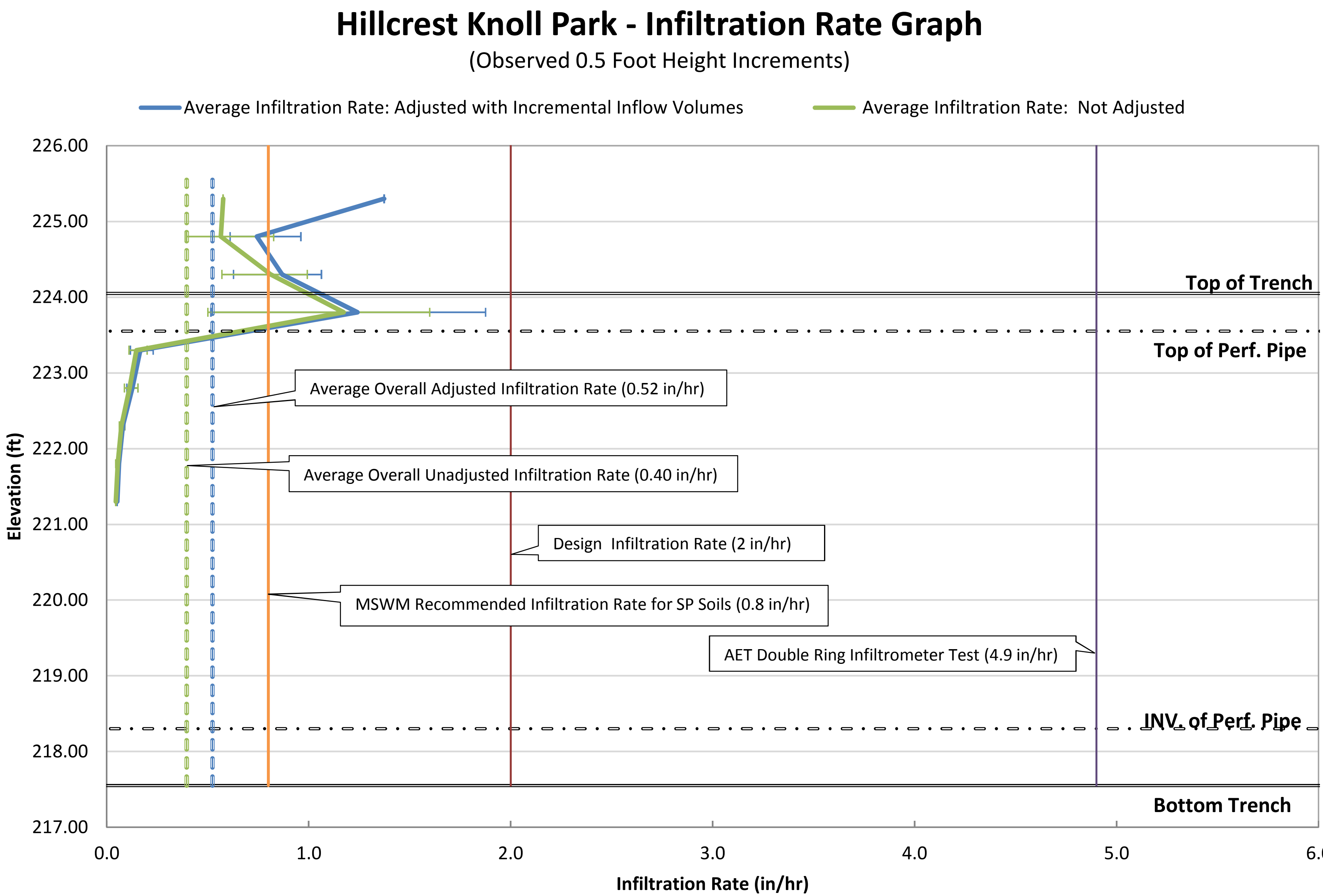
# Chart A.7 Hillcrest Knoll Park

Water Level and Rainfall (SPCD)

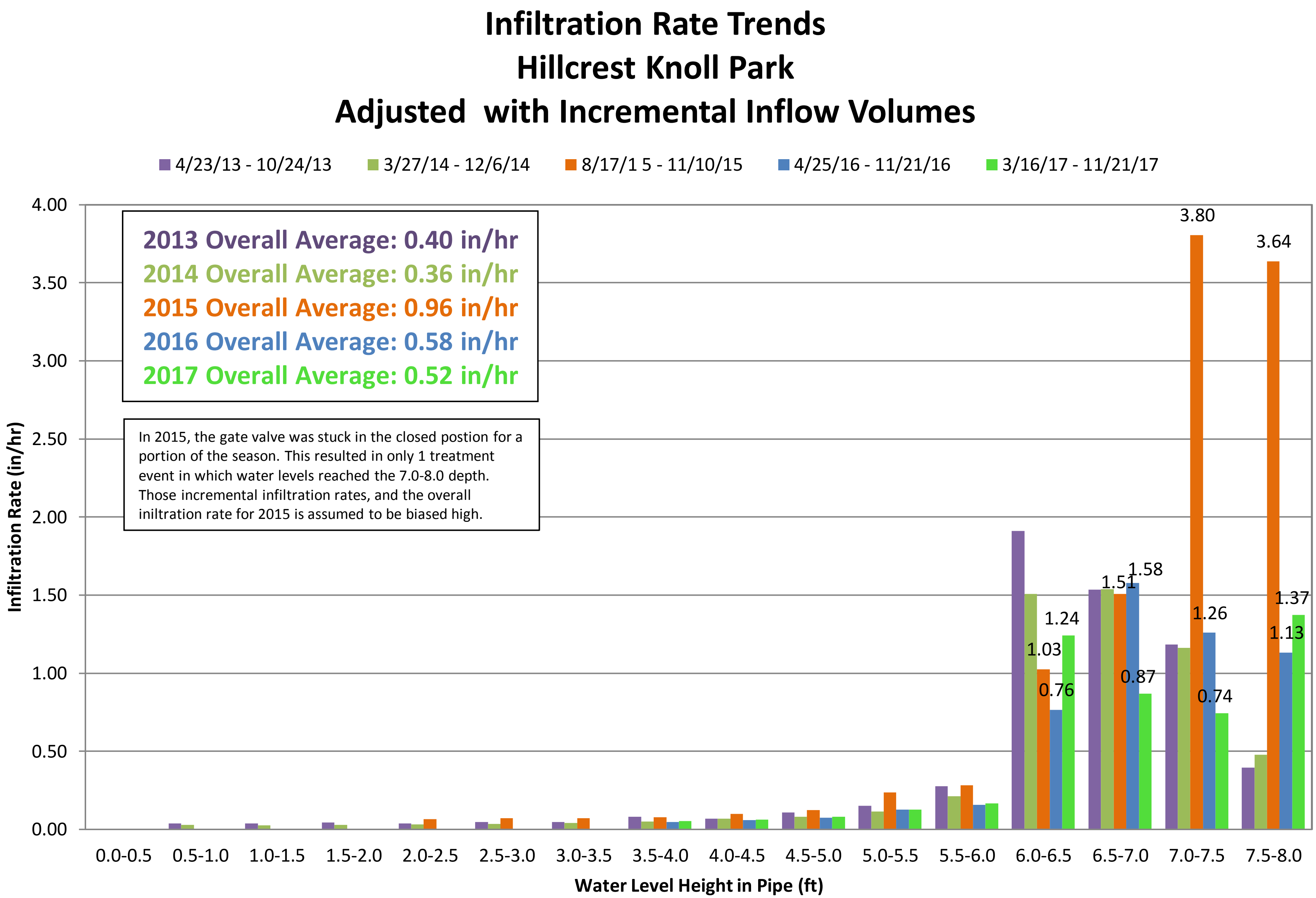


City of Saint Paul
2017 Water Quality and Quantity Report
Chart A.8
WSB Job No.: 01610-100



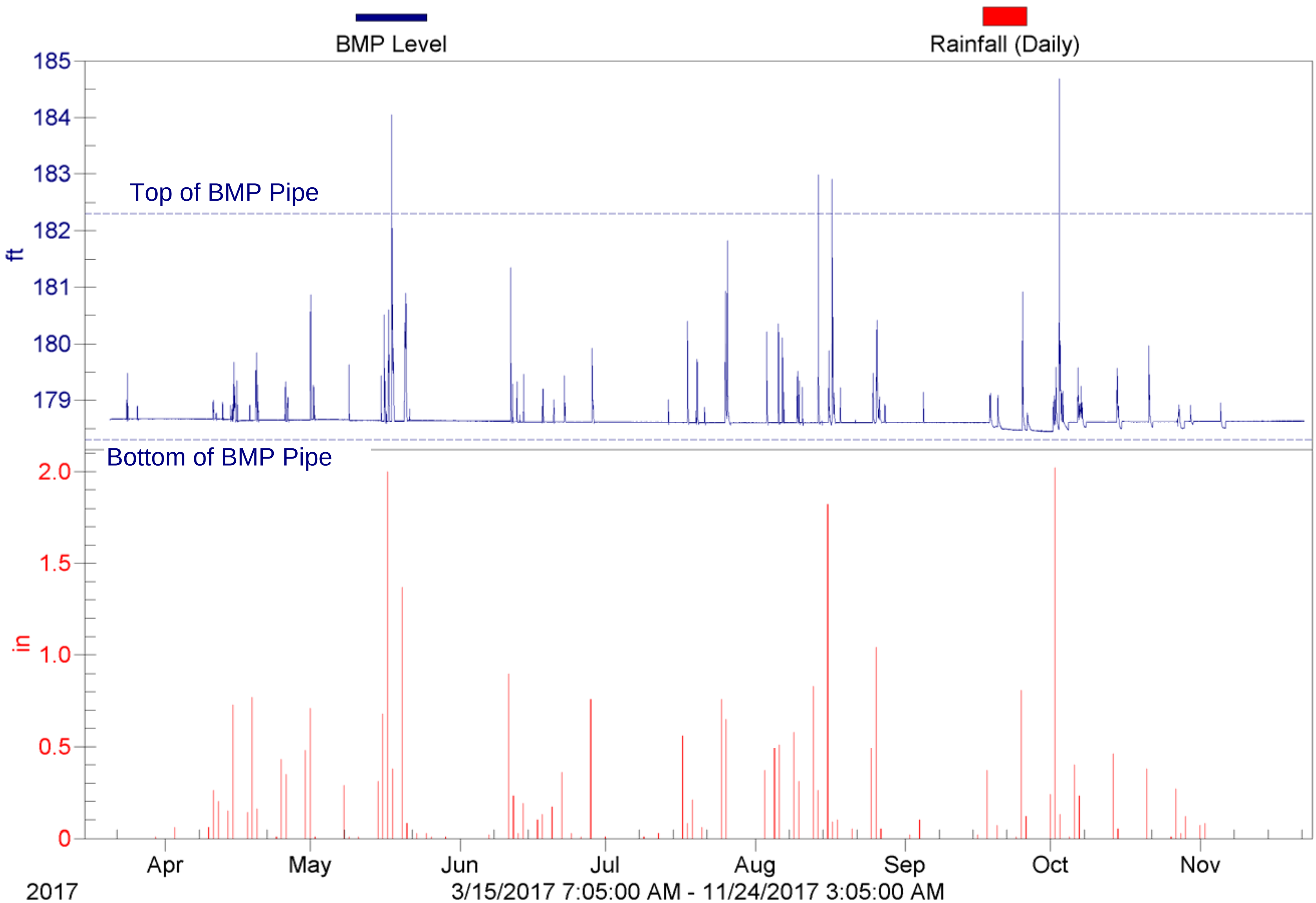



Note: Pipe Invert is 218.30'
Pipe perforated around circumference of pipe
Error Bars Represent 25th and 75th Percentiles

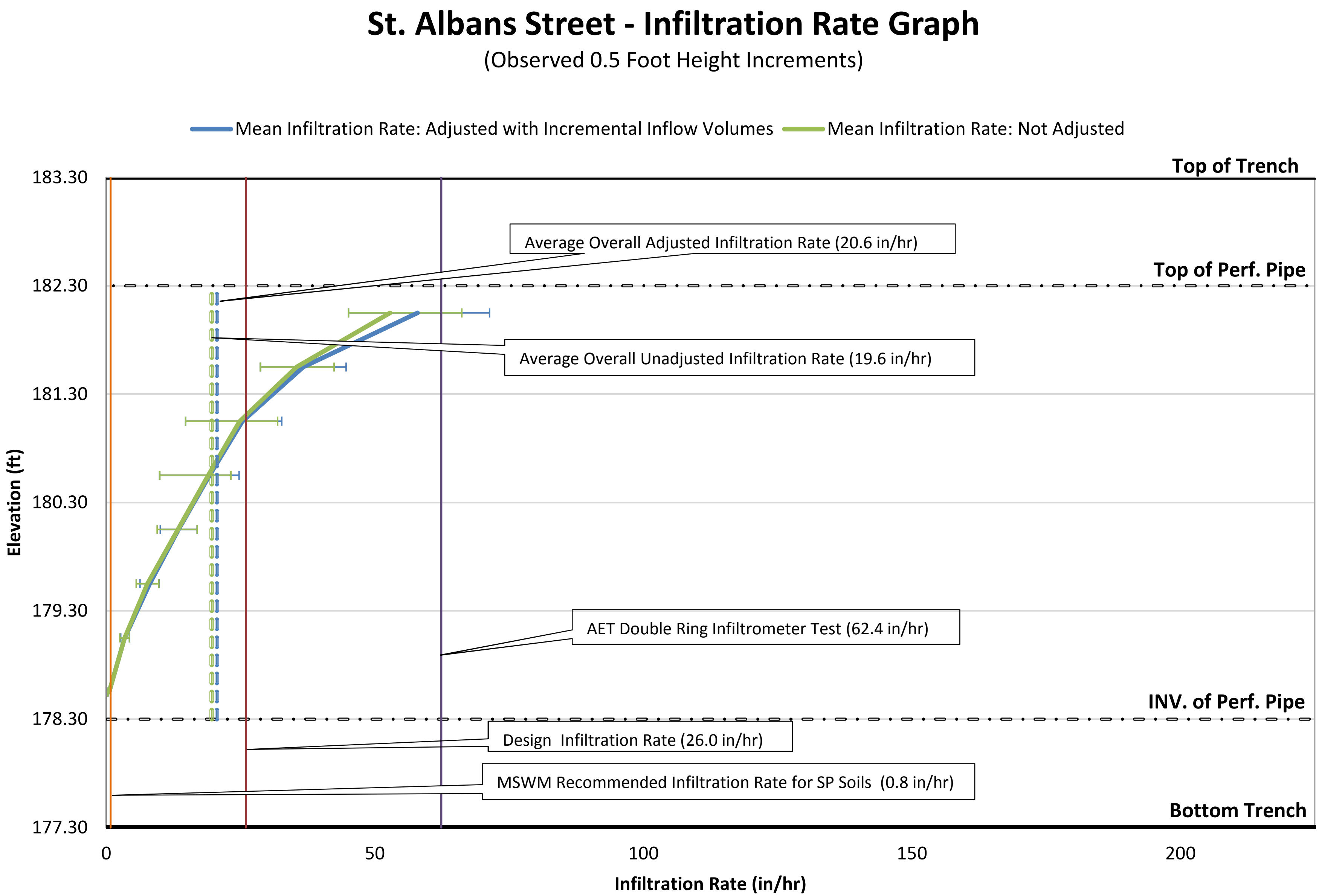

Infiltration Rate Trends
Hillcrest Knoll Park
Adjusted with Incremental Inflow Volumes
4/23/13 - 10/24/13
3/27/14 - 12/6/14
8/17/1 5 - 11/10/15
4/25/16 - 11/21/16
3/16/17 - 11/21/17
2013 Overall Average: 0.40 in/hr
2014 Overall Average: 0.36 in/hr
2015 Overall Average: 0.96 in/hr
2016 Overall Average: 0.58 in/hr
2017 Overall Average: 0.52 in/hr
In 2015, the gate valve was stuck in the closed postion for a portion of the season. This resulted in only 1 treatment event in which water levels reached the 7.0-8.0 depth. Those incremental infiltration rates, and the overall iniltration rate for 2015 is assumed to be biased high.
Infiltration Rate (in/hr)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
3.80
3.64
1.58
1.51
1.37
1.24
1.26
1.13
1.03
0.87
0.76
0.74
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
Water Level Height in Pipe (ft)

# Chart A.11 St. Albans

Water Level and Rainfall (SPCD)

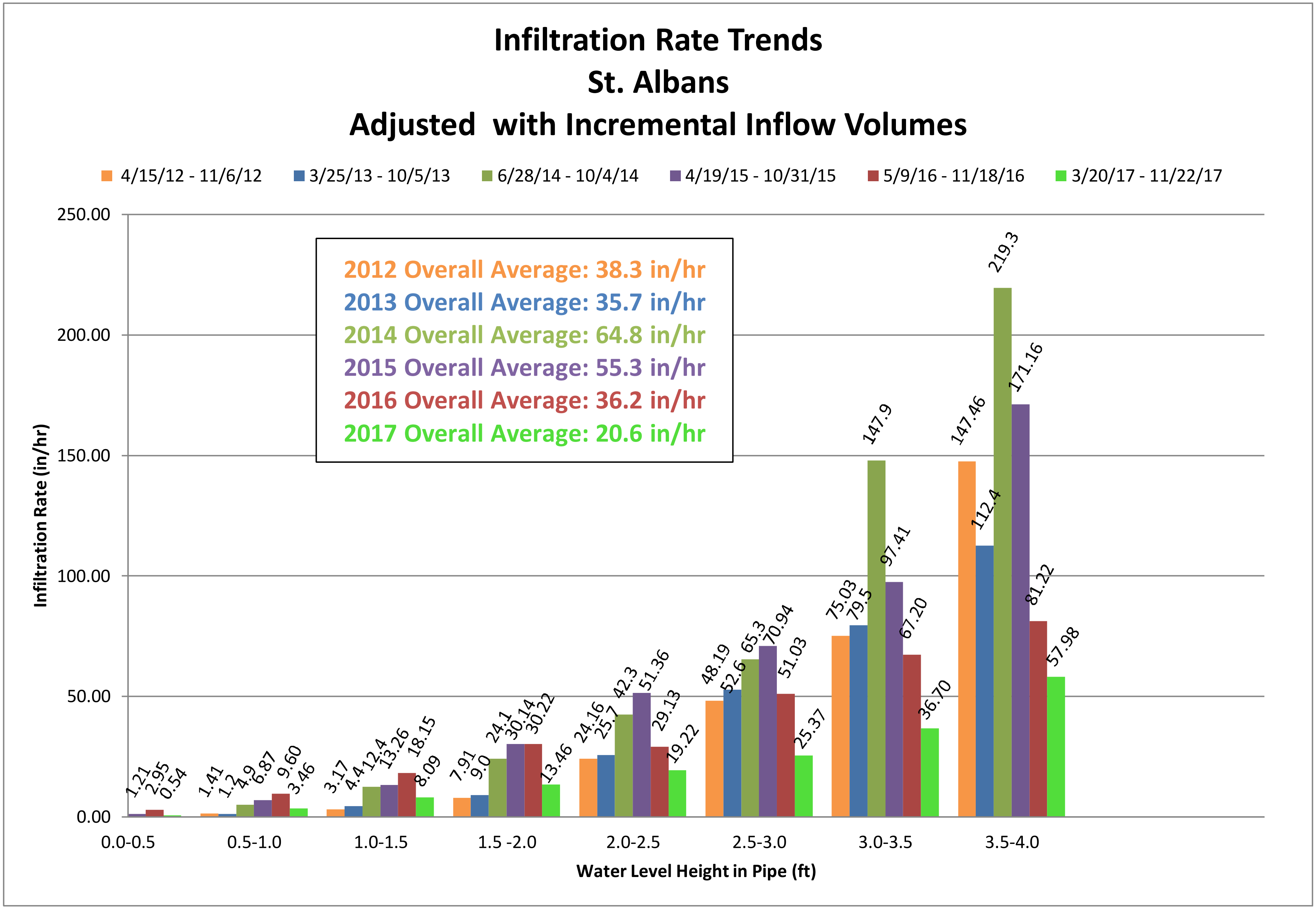


City of Saint Paul
2017 Water Quality and Quantity Report
Chart A.12
WSB Job No.: 01610-100



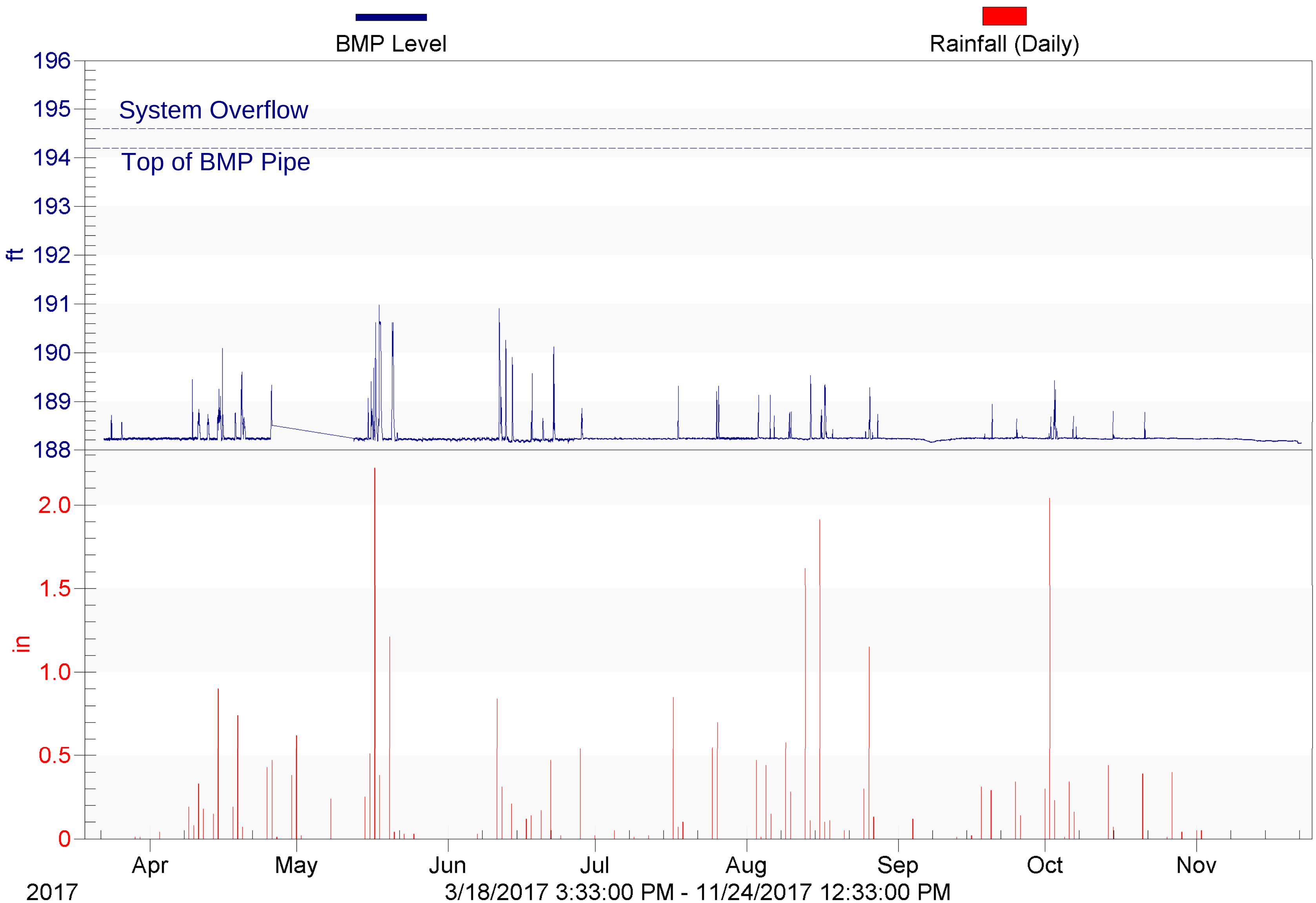

Note: Pipe Invert is 178.3'
Error Bars Represent 25th and 75th Percentiles
Pipe perforated w/ 2 rows of holes at Elev: 178.9' and 179.2'

City of Saint Paul
2017 Water Quality and Quantity Report
Chart A.13
WSB Project No.: 01610-100

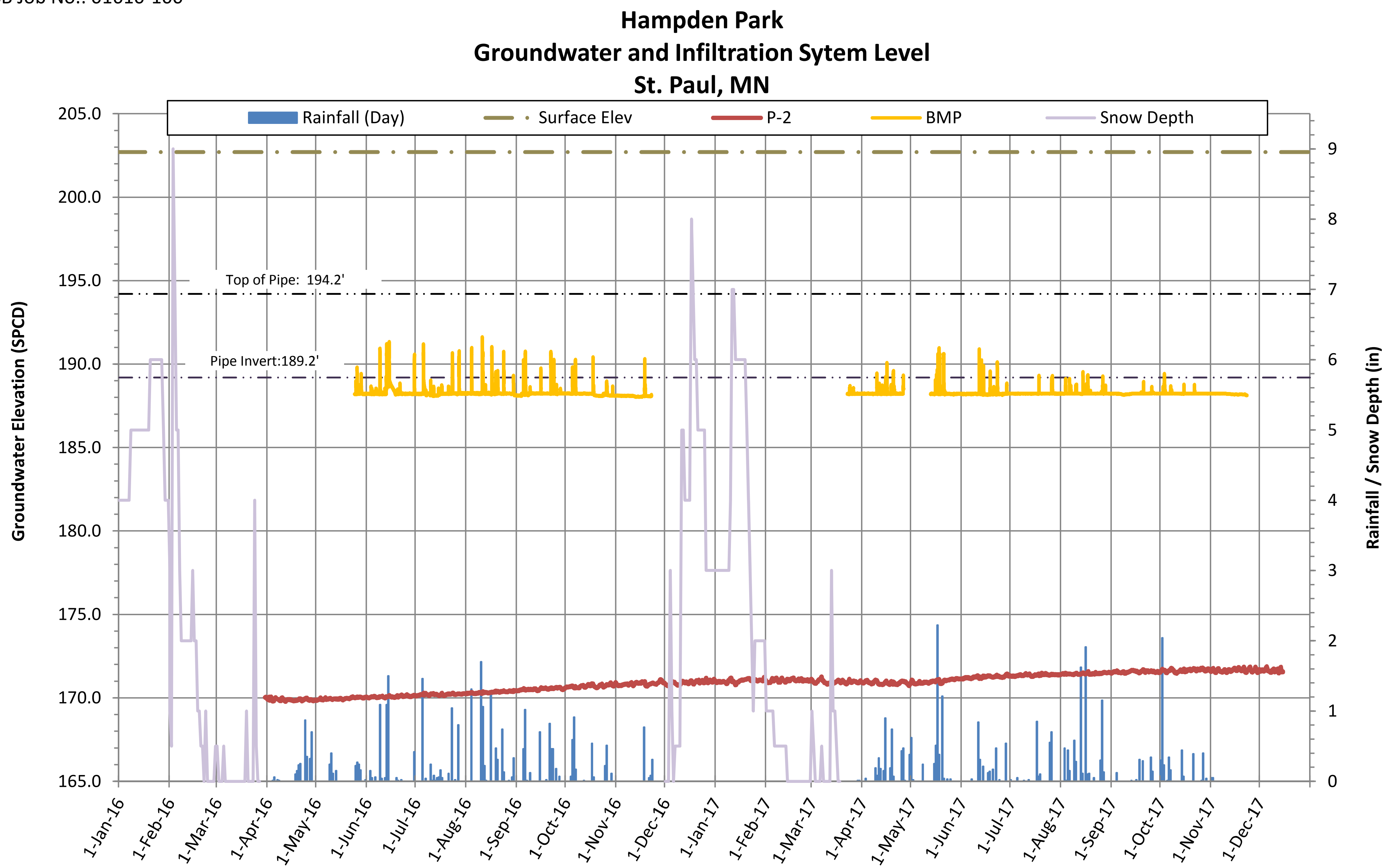


# Chart A.14 Hampden Park

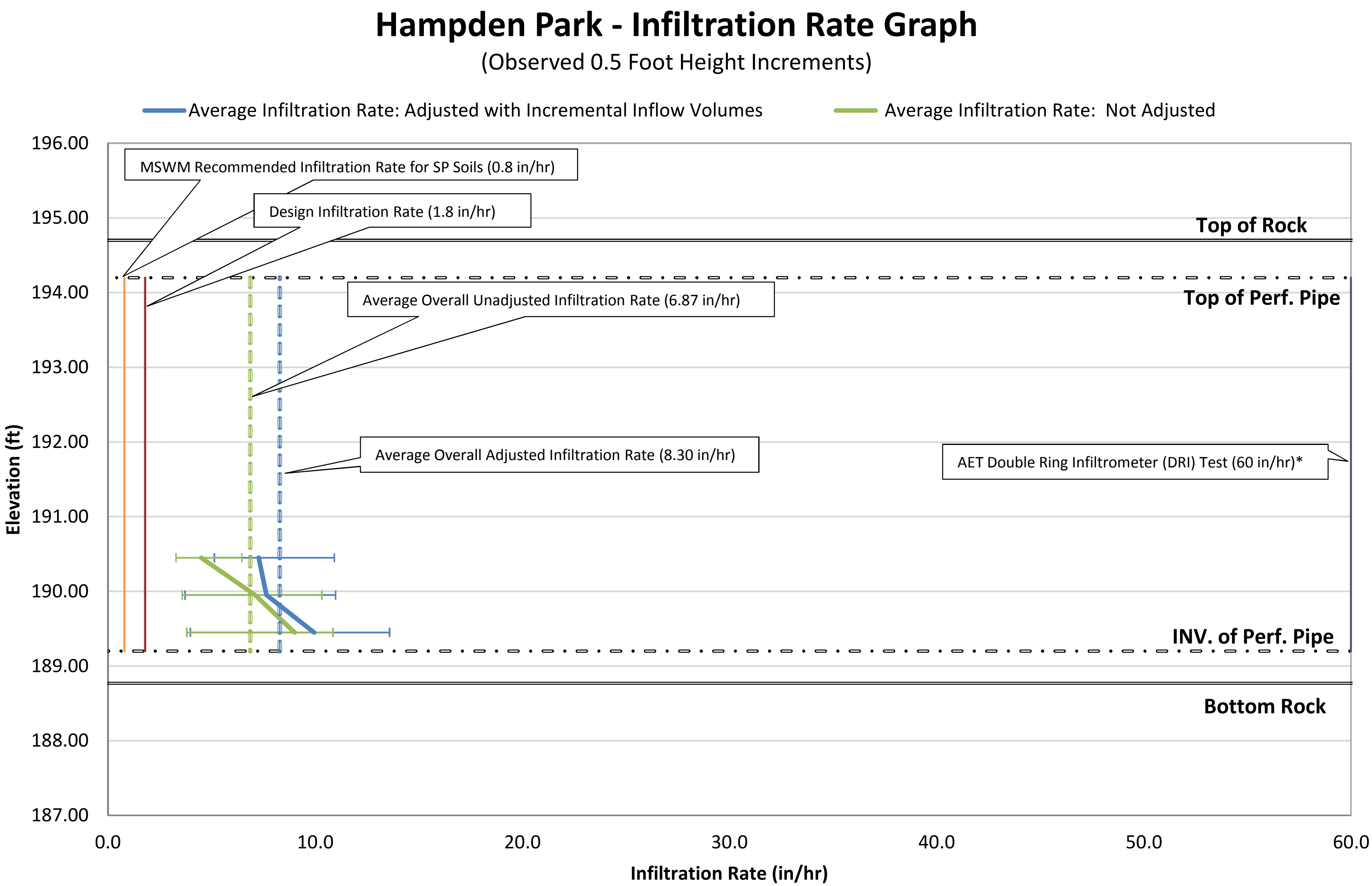
BMP Water Level and Rainfall



City of Saint Paul
2017 Water Quality and Quantity Report
Chart A.15
WSB Job No.: 01610-100



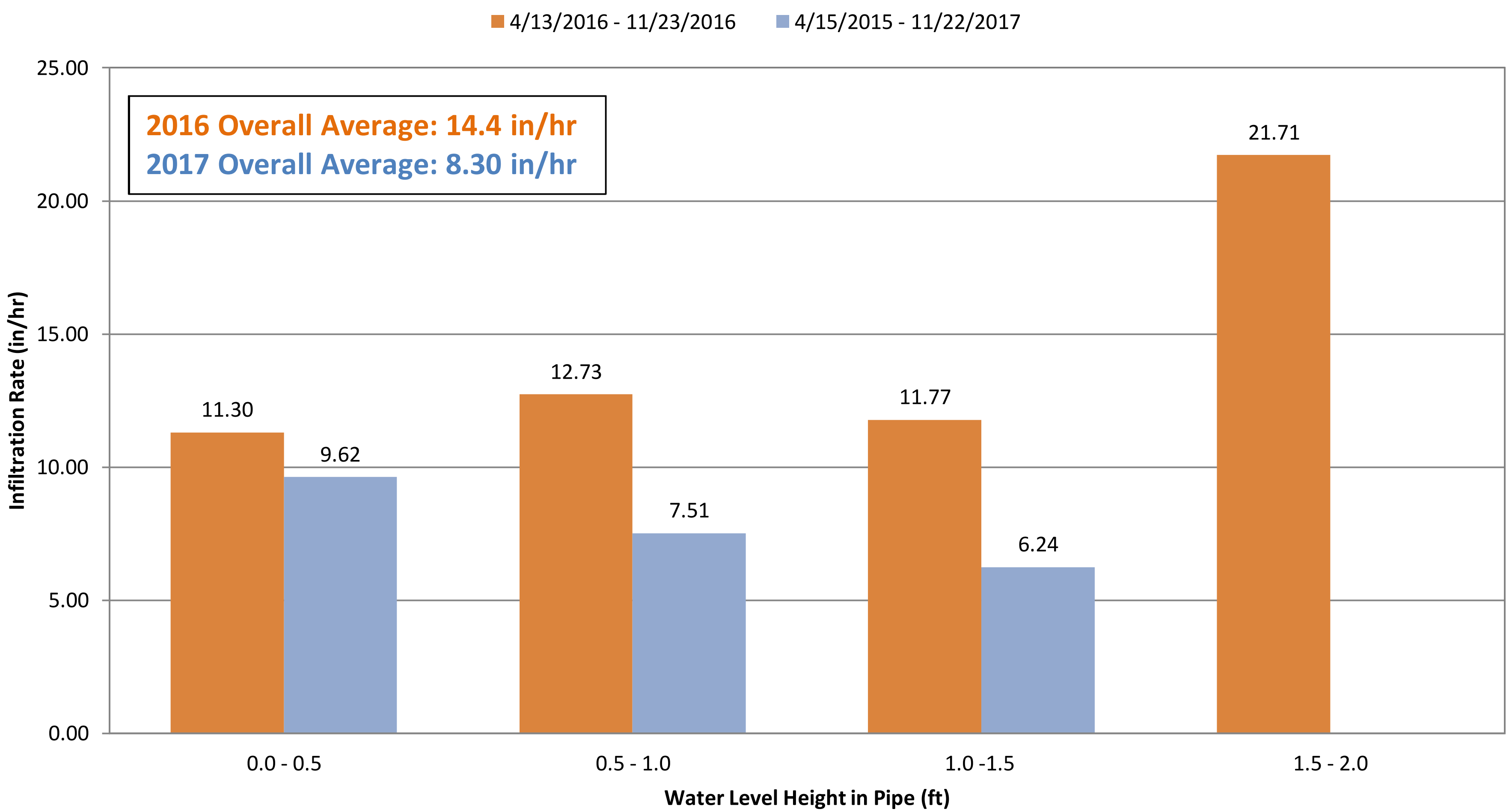
City of Saint Paul
2017 Water Quality and Quantity Monitoring
Chart A.16
WSB Job No.: 01610-100




Note: Pipe Invert is 189.2'
Error Bars Represent 25th and 75th Percentiles
* The DRI testing was completed on top of a 5 ft layer of fine filter aggregate that was constructed above the native soils, per the design.

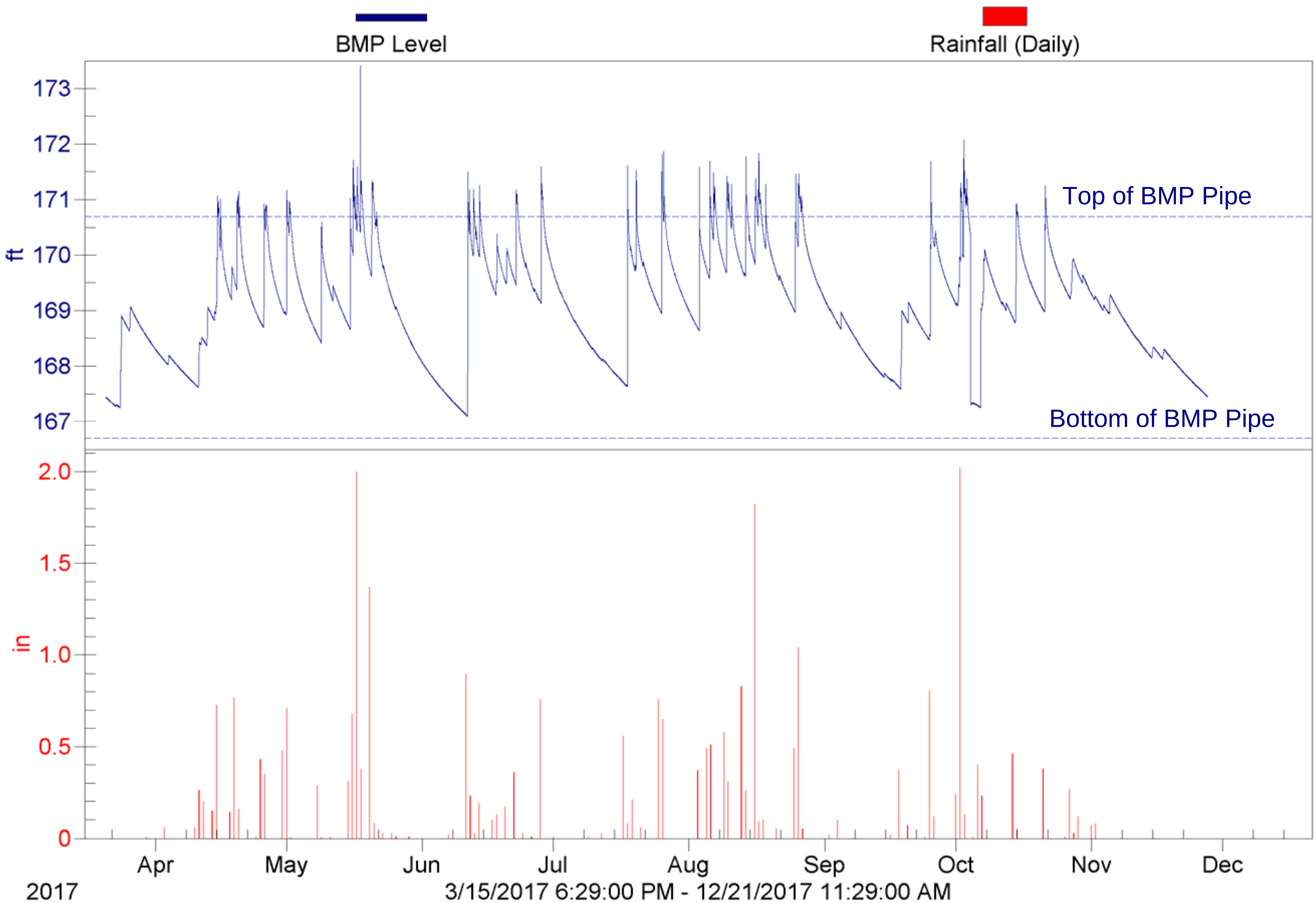
City of Saint Paul
2017 Water Quality and Quantity Report
Chart A.17
WSB Job No.: 01610-100

# Infiltration Rate Trends
# Hampden Park
# Adjusted with Incremental Inflow Volumes

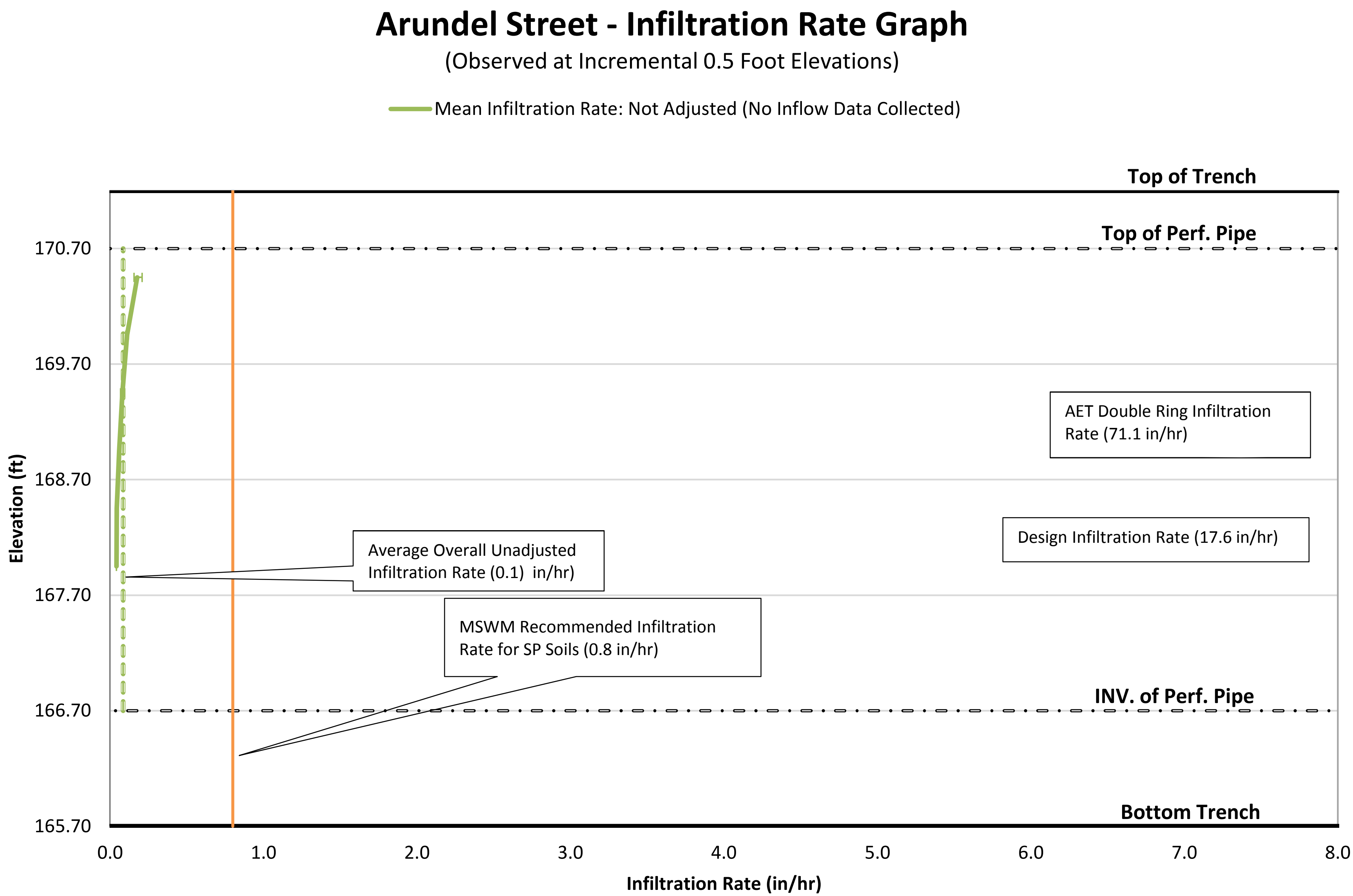


## Chart A. 18 Arundel

Water Level and Rainfall (SPCD)

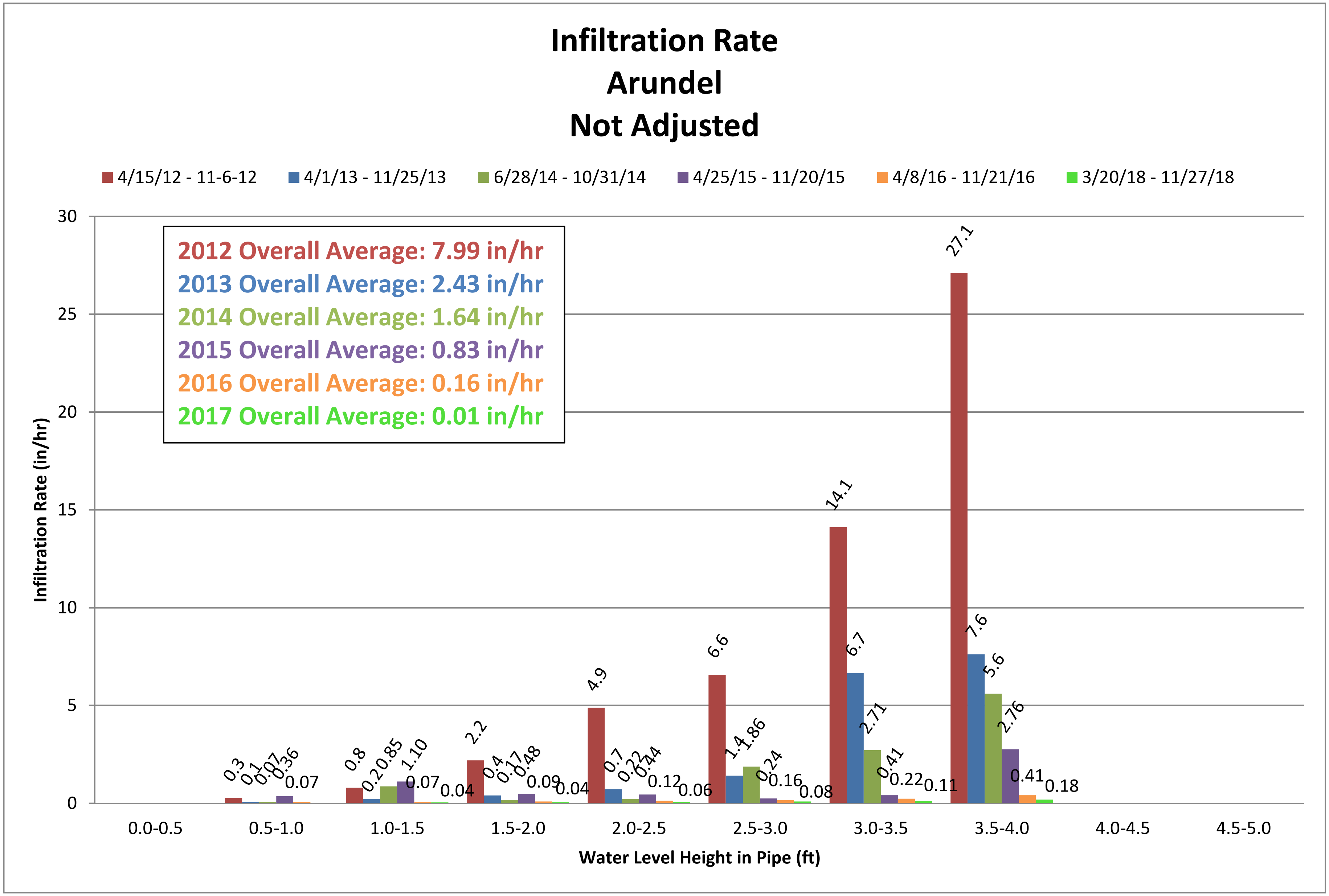


City of Saint Paul
2017 Water Quality and Quantity
Chart A.19
WSB Job No.: 01610-100



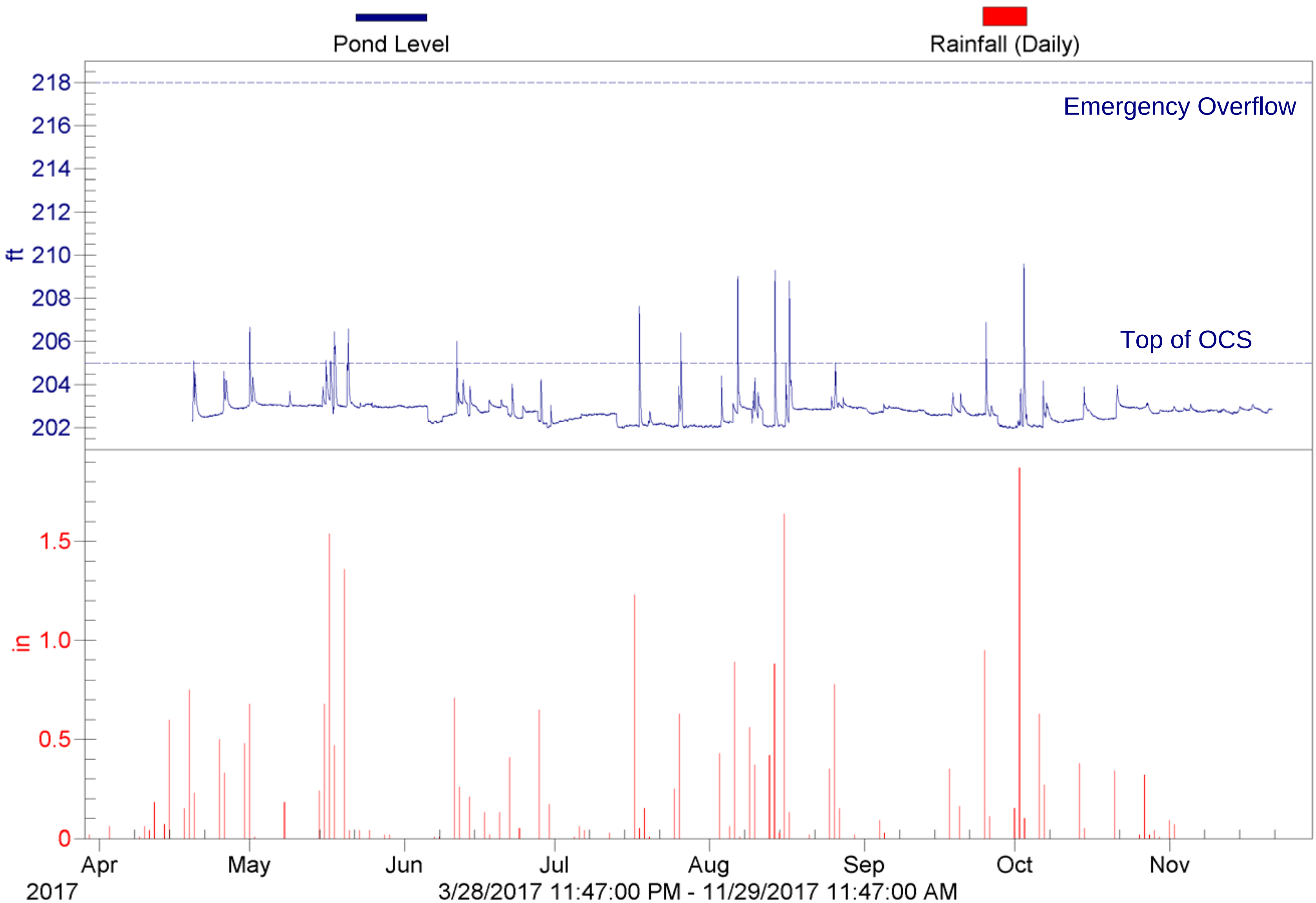

Note: Pipe Invert is 166.7'
Error Bars Represent 25th and 75th Percentiles
Pipe perforated w/ 2 rows of holes at Elev: 167.3' and 167.6'

City of Saint Paul
2017 Water Quality and Quantity Report
Chart A.20
WSB Job NO.: 01610-100



# Chart A.21 Flandrau-Hoyt

Pond Level and Rainfall (SPCD)



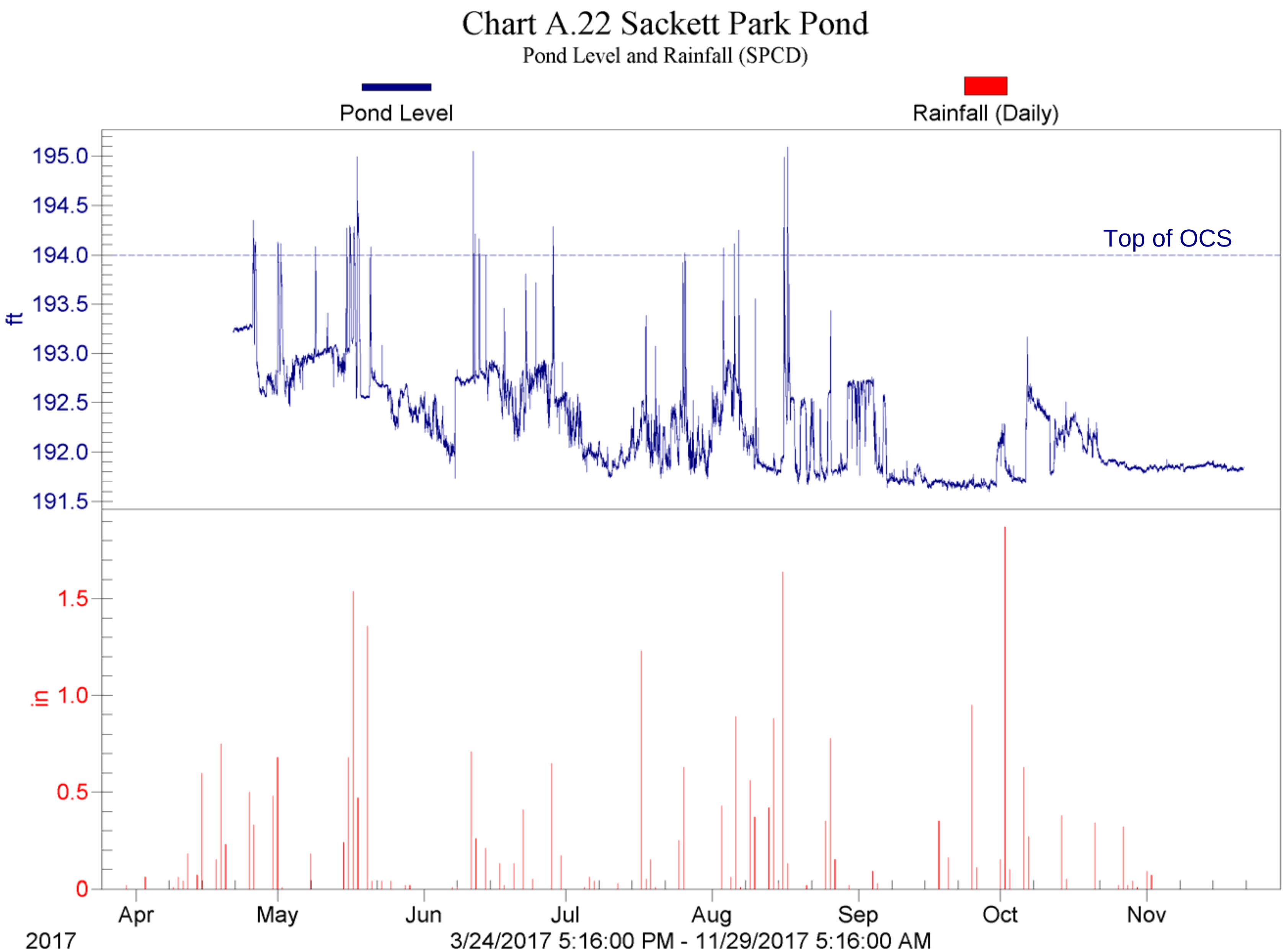


Chart A.22 Sackett Park Pond
Pond Level and Rainfall (SPCD)
Pond Level
Rainfall (Daily)
Top of OCS
ft
195.0
194.5
194.0
193.5
193.0
192.5
192.0
191.5
in
1.5
1.0
0.5
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
2017
3/24/2017 5:16:00 PM - 11/29/2017 5:16:00 AM

# Chart A.23 TBNS - Maryland Pond

Pond Level and Rainfall (SPCD)

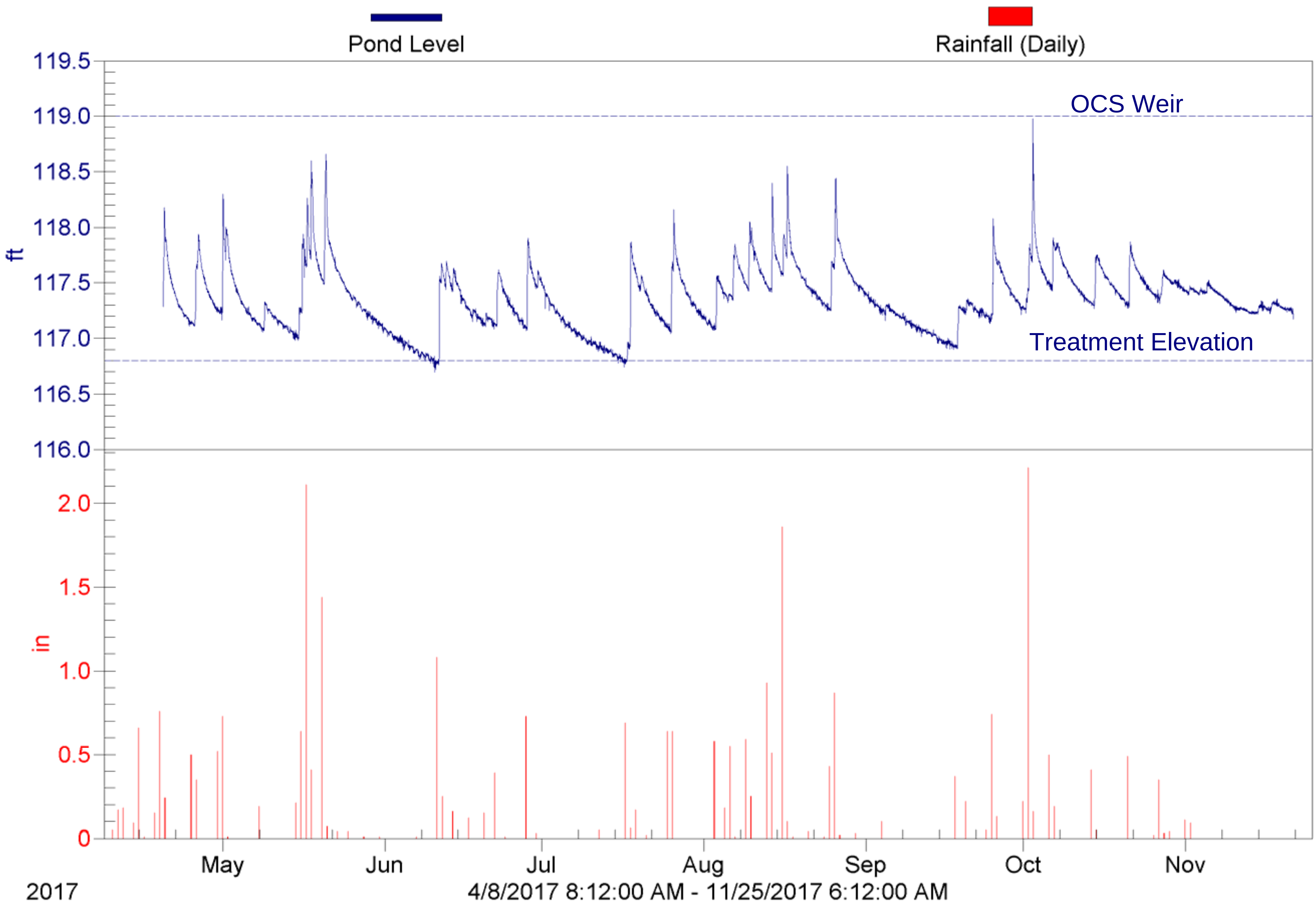
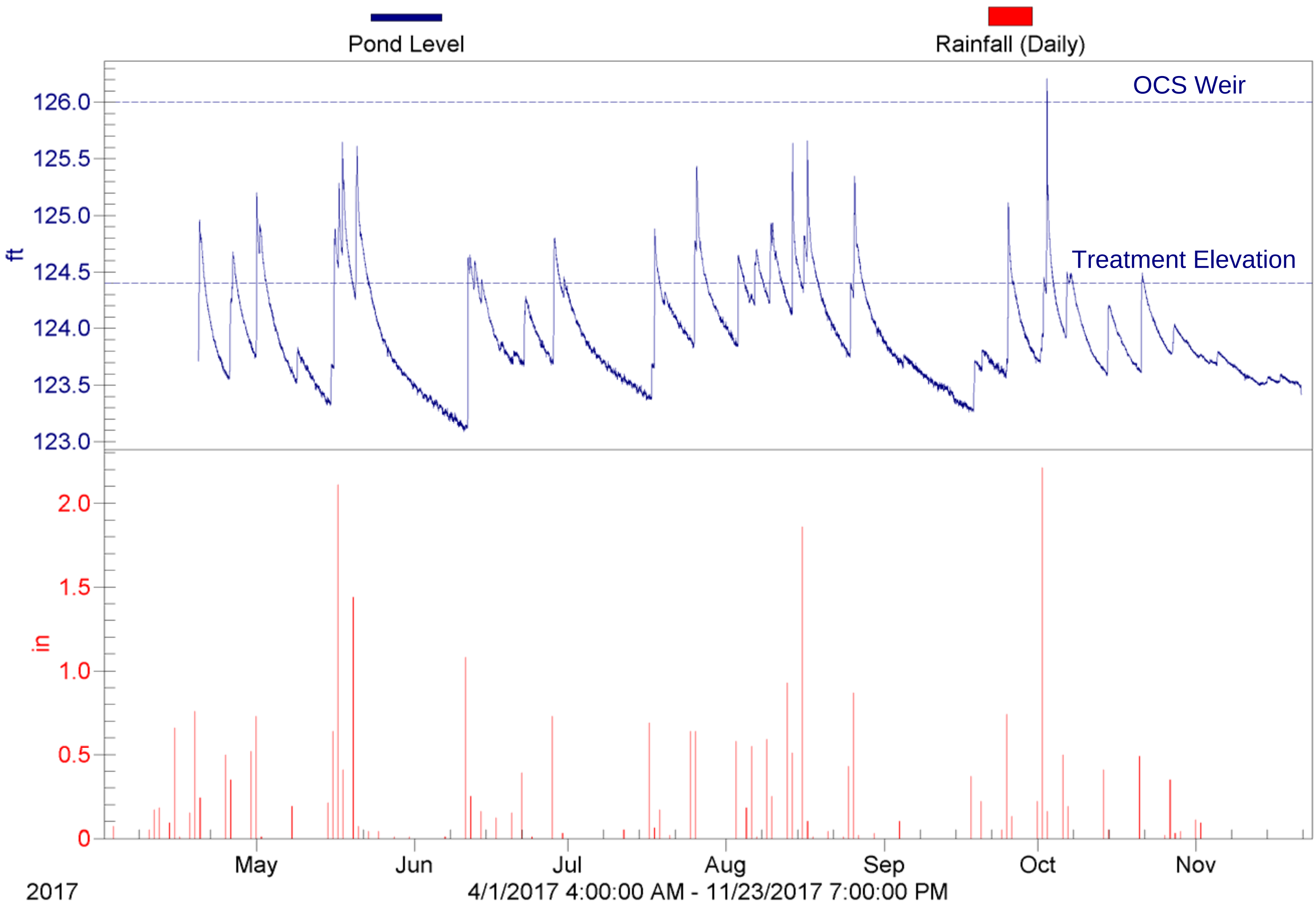


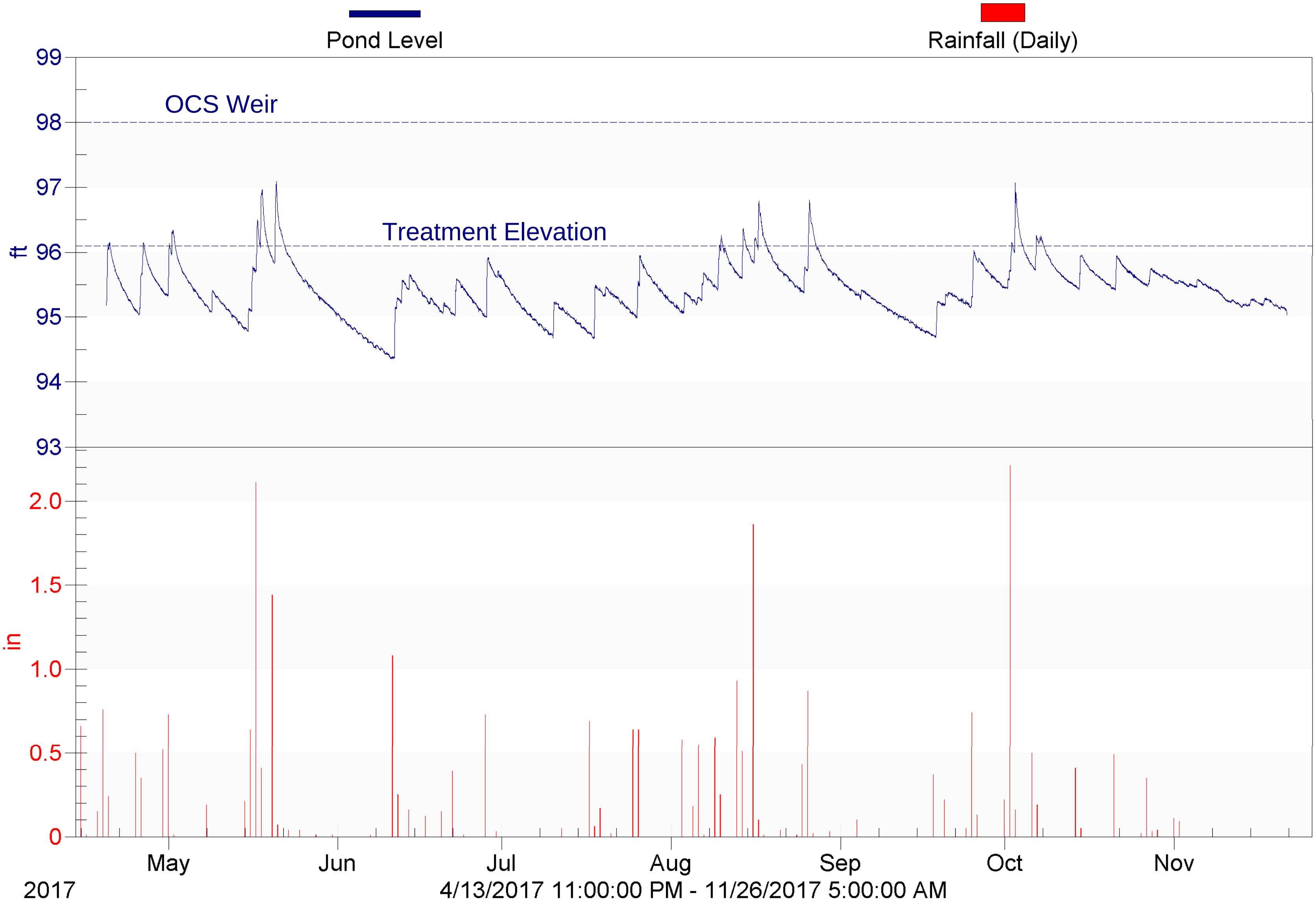
Chart A.24 TBNS - Magnolia

Pond Level and Rainfall (SPCD)



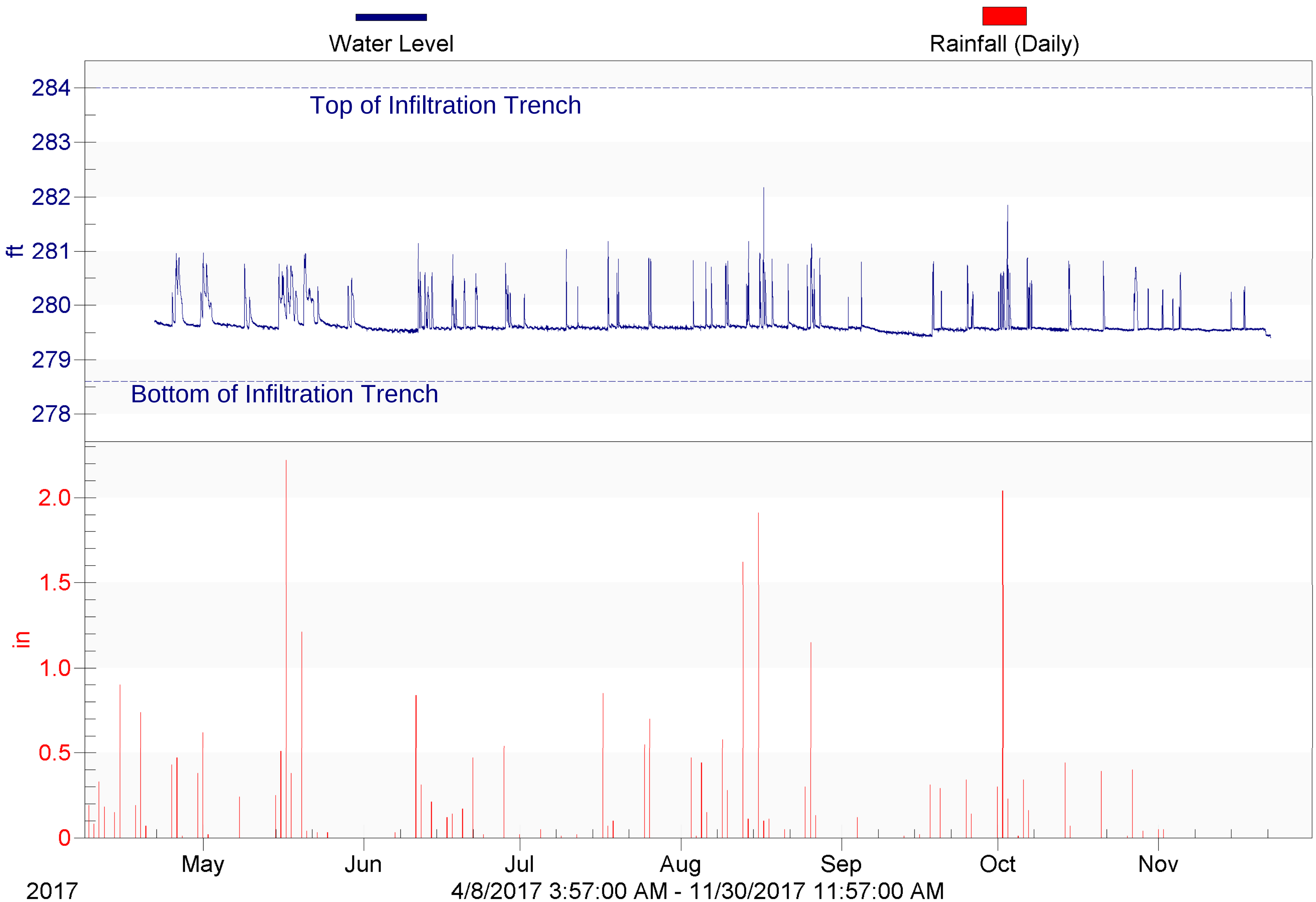
# Chart A.25 TBNS - Jenks

Pond Level and Rainfall (SPCD)



# Chart A.26 Montreal Trench

Flowlink 5

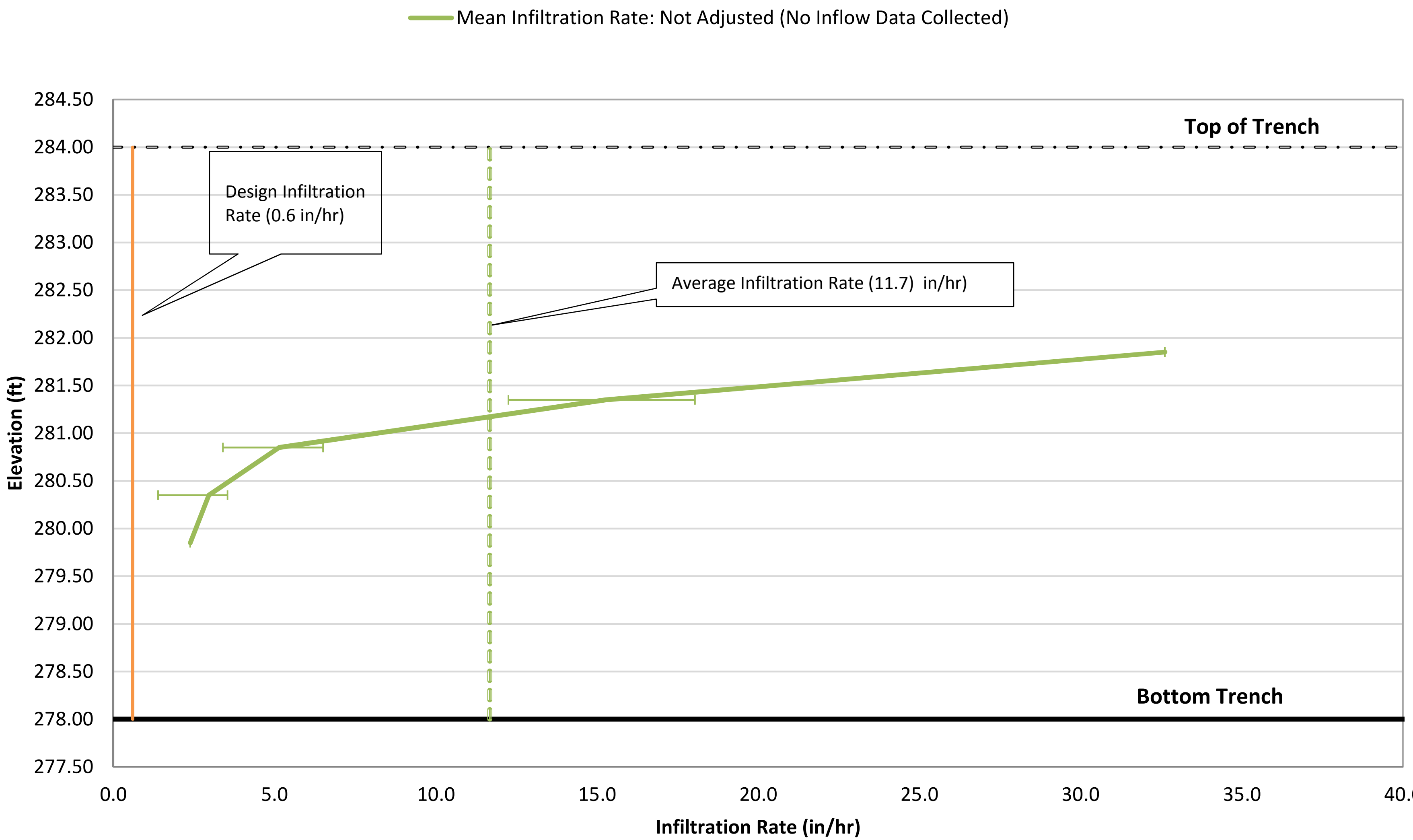



*The bottom of the monitoring piezometer is 0.7 ft above the bottom of the trench, therefore the infiltration rate within that area is not calculated.

City of Saint Paul
2017 Water Quality and Quantity
Chart A.27
WSB Job No.: 01610-100

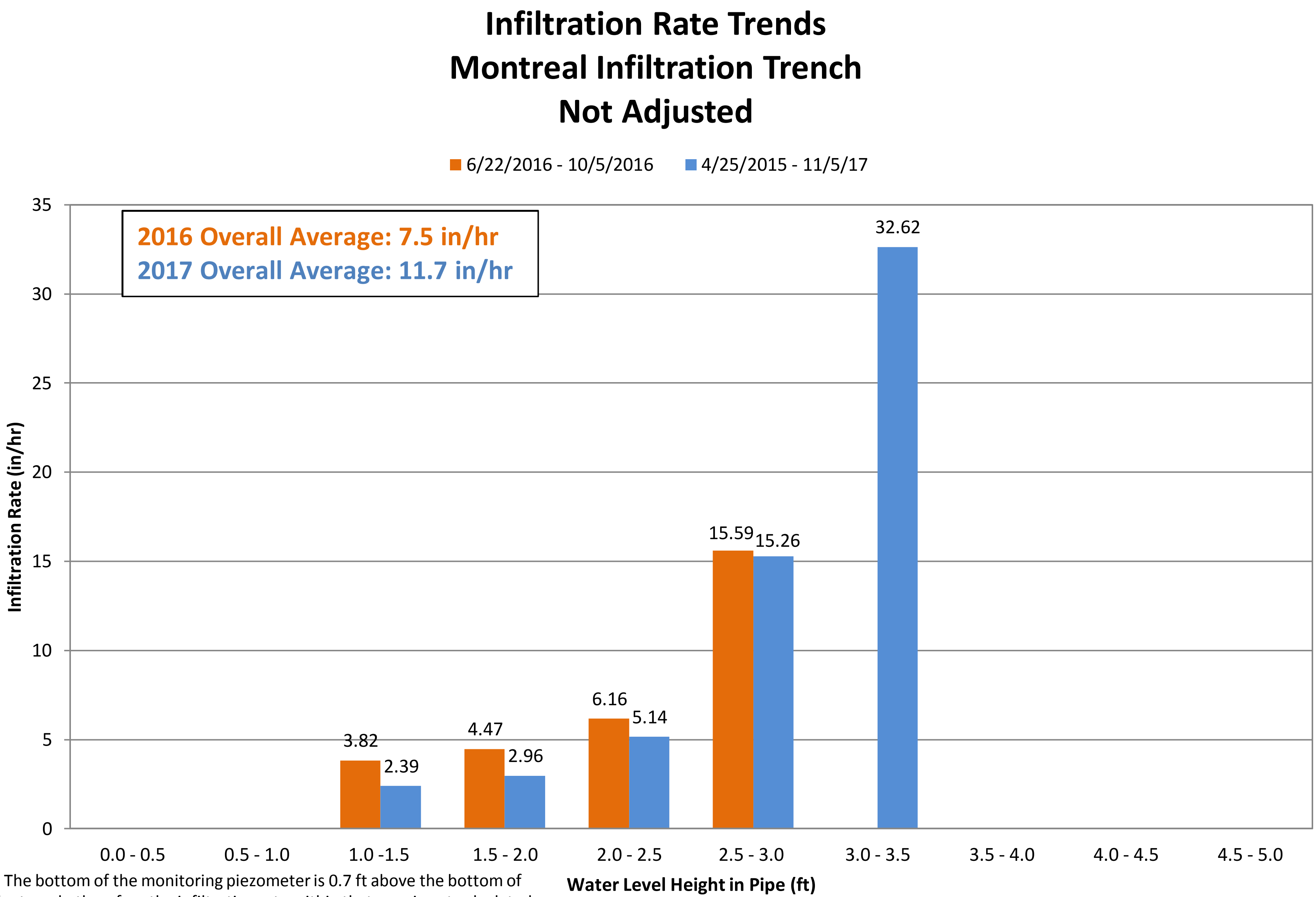
# Montreal Trench - Infiltration Rate Graph

(Observed at Incremental 0.5 Foot Elevations)




Error Bars Represent 25th and 75th Percentiles

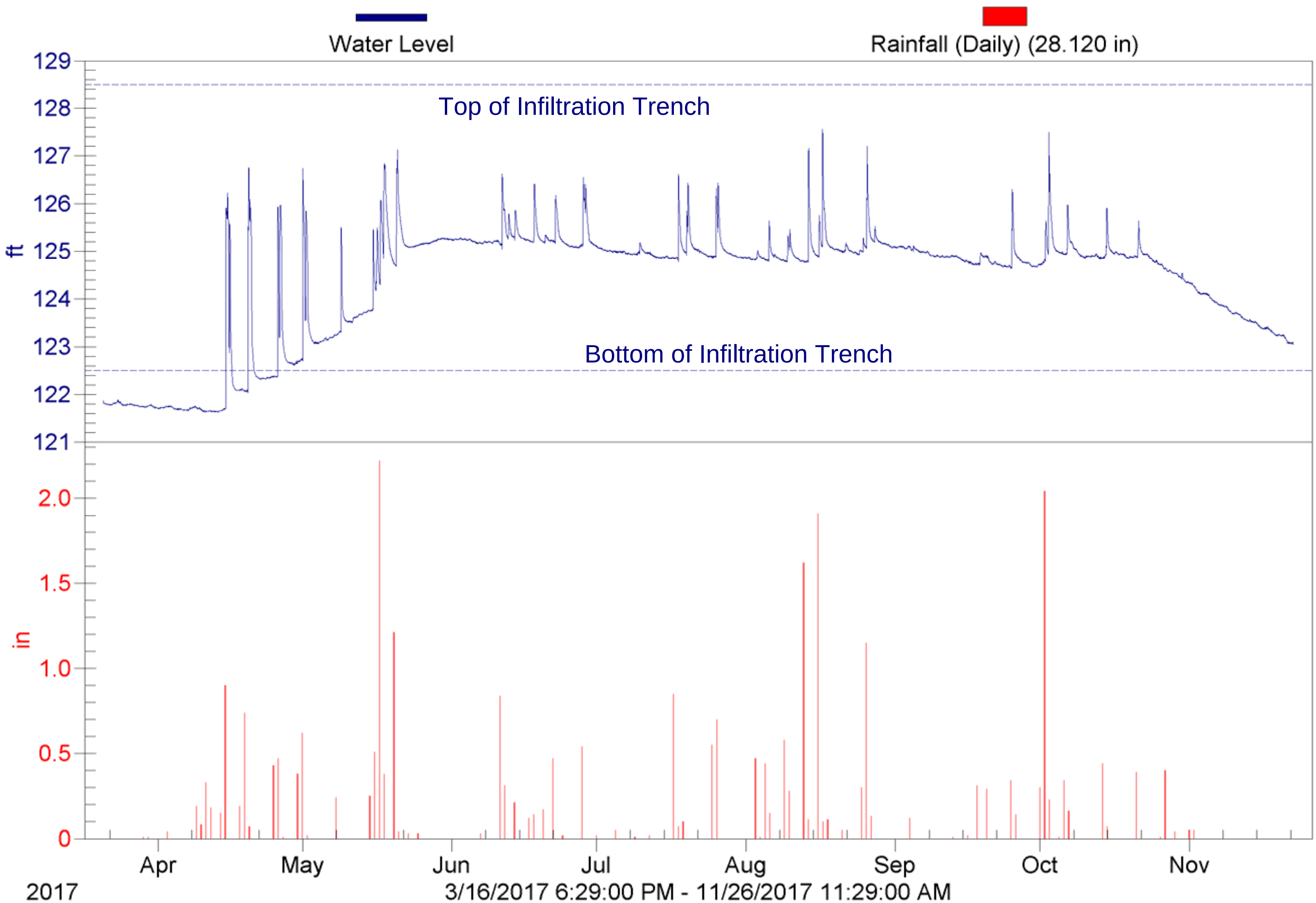
City of Saint Paul
2017 Water Quality and Quantity Report
Chart A.28
WSB Job No.: 01610-100




* The bottom of the monitoring piezometer is 0.7 ft above the bottom of the trench, therefore the infiltration rate within that area is not calculated.

# Chart A.29 Wordsworth Trench

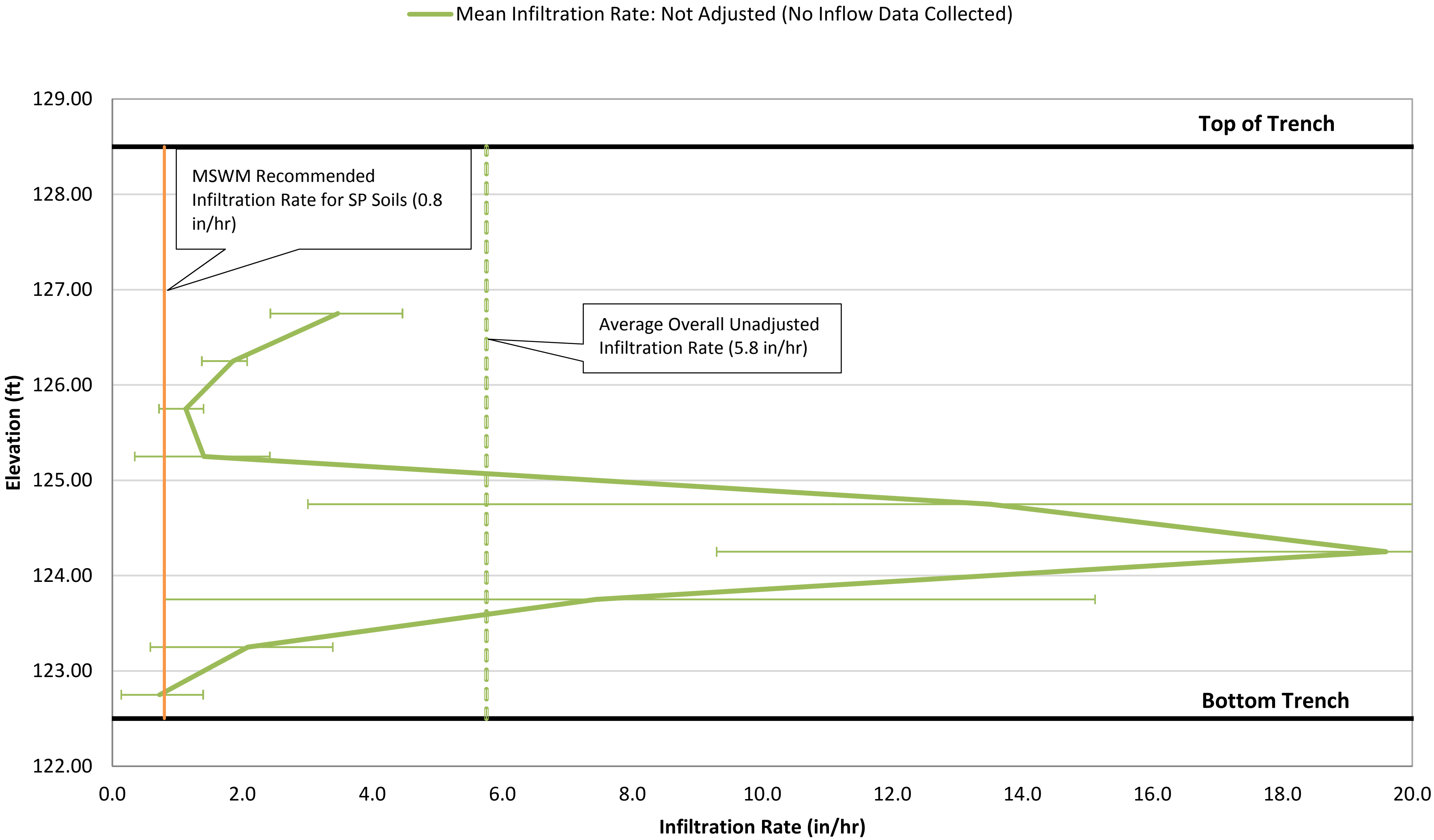
Trench Water Level and Rainfall (SPCD)



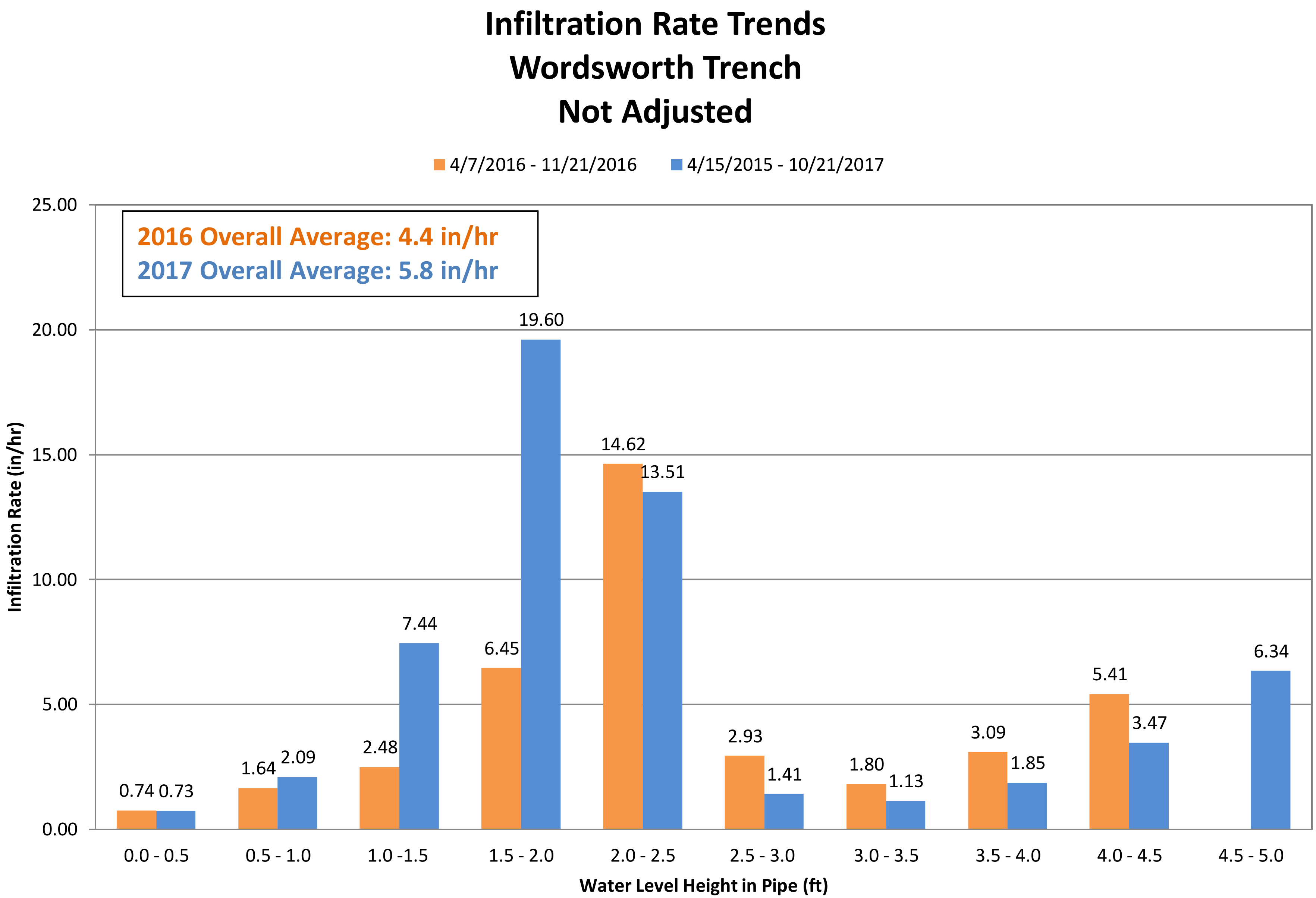
City of Saint Paul
2017 Water Quality and Quantity
Chart A.30
WSB Job No.: 01610-100

# Wordsworth Trench - Infiltration Rate Graph

(Observed at Incremental 0.5 Foot Elevations)



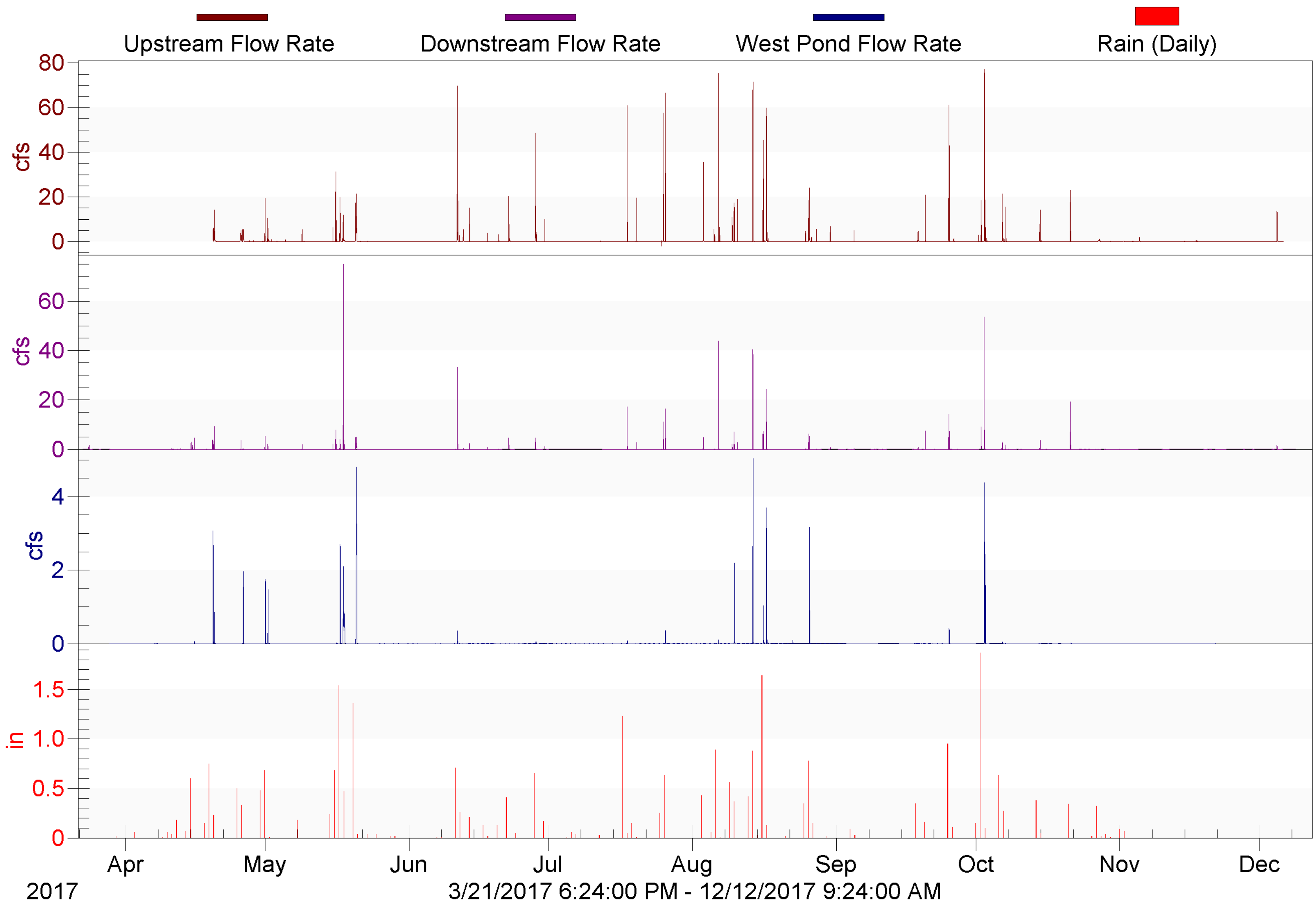

Note:
Error Bars Represent 25th and 75th Percentiles


Infiltration Rate Trends
Wordsworth Trench
Not Adjusted
4/7/2016 - 11/21/2016
4/15/2015 - 10/21/2017
2016 Overall Average: 4.4 in/hr
2017 Overall Average: 5.8 in/hr
Infiltration Rate (in/hr)
25.00
20.00
15.00
10.00
5.00
0.00
0.74 0.73
1.64 2.09
2.48 7.44
6.45 19.60
14.62 13.51
2.93 1.41
1.80 1.13
3.09 1.85
5.41 3.47
6.34
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
Water Level Height in Pipe (ft)

## *Appendix B – Flow Rate Charts*

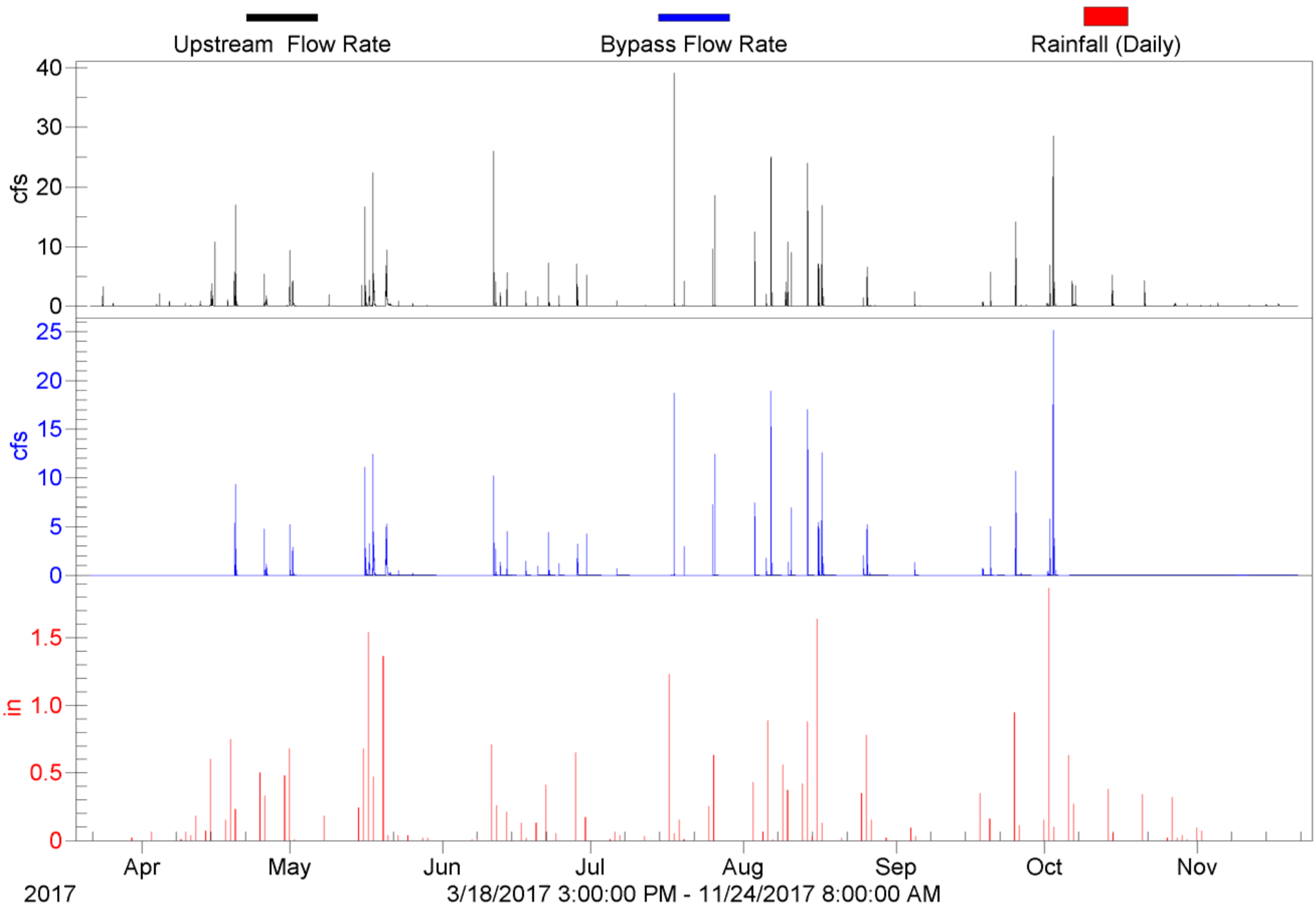
# Chart B.1 Beacon Bluff

Flow Rates and Rainfall



# Chart B.2 Hillcrest Knoll Park

Flow Rates and Rainfall



# HILLCREST KNOLL PARK INFILTRATION SYSTEM FLOW EVENT SUMMARY

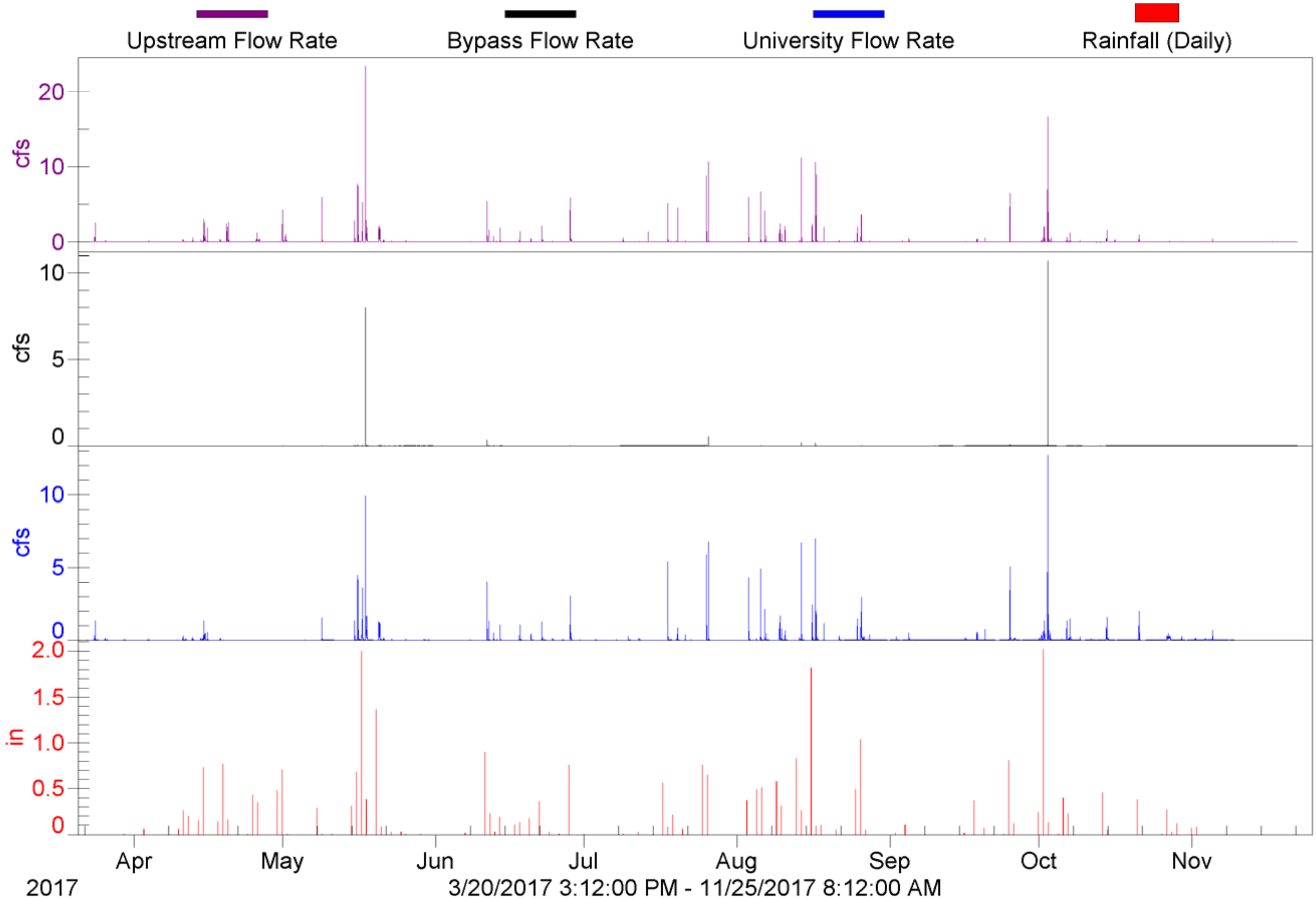
| Rain | | | | Flow | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Start | End | Duration | Amount | Start | End | Duration | Flandrau St. Runoff Volume (Upstream of Diversion) (1) | Flandrau St. Bypass Volume (Downstream of Diversion) (2) | Total Inflow to BMP (1 -2) | Percent Captured |
| | | (hr) | (in) | | | (hr) | (cf) | (cf) | (cf) | (%) |
| 4/3/2017 19:53 | 4/3/2017 23:13 | 3.33 | 0.06 | 4/3/2017 20:30 | 4/4/2017 5:15 | 8.75 | 2304.7 | 0.0 | 2304.7 | 100.0% |
| | | | | 4/4/2017 14:45 | 4/4/2017 17:38 | 2.88 | 993.4 | 0.0 | 993.4 | 100.0% |
| | | | | 4/6/2017 13:13 | 4/6/2017 18:15 | 5.03 | 1279.6 | 0.0 | 1279.6 | 100.0% |
| 4/9/2017 19:44 | 4/9/2017 19:45 | 0.02 | 0.01 | 4/9/2017 19:45 | 4/9/2017 20:45 | 1.00 | 571.5 | 0.0 | 571.5 | 100.0% |
| 4/10/2017 18:53 | 4/10/2017 21:26 | 2.55 | 0.06 | 4/10/2017 20:00 | 4/11/2017 2:00 | 6.00 | 1332.8 | 0.0 | 1332.8 | 100.0% |
| 4/11/2017 8:06 | 4/11/2017 8:54 | 0.80 | 0.04 | 4/11/2017 9:30 | 4/11/2017 13:30 | 4.00 | 174.3 | 0.0 | 174.3 | 100.0% |
| 4/12/2017 17:00 | 4/12/2017 23:40 | 6.67 | 0.18 | 4/11/2017 17:30 | 4/12/2017 5:30 | 12.00 | 87.5 | 0.0 | 87.5 | 100.0% |
| 4/14/2017 18:37 | 4/15/2017 10:16 | 15.65 | 0.52 | 4/14/2017 19:15 | 4/15/2017 13:45 | 18.50 | 24546.3 | 0.0 | 24546.3 | 100.0% |
| 4/15/2017 19:21 | 4/15/2017 19:40 | 0.32 | 0.14 | 4/15/2017 19:30 | 4/15/2017 22:45 | 3.25 | 8184.4 | 0.0 | 8184.4 | 100.0% |
| 4/18/2017 8:29 | 4/18/2017 11:02 | 2.55 | 0.15 | 4/18/2017 8:58 | 4/18/2017 12:45 | 3.78 | 4291.8 | 0.0 | 4291.8 | 100.0% |
| 4/19/2017 14:58 | 4/19/2017 20:51 | 5.88 | 0.75 | 4/19/2017 15:45 | 4/19/2017 22:15 | 6.50 | 37867.0 | 16301.2 | 21565.8 | 57.0% |
| 4/20/2017 1:10 | 4/20/2017 1:23 | 0.22 | 0.14 | 4/20/2017 1:14 | 4/20/2017 10:32 | 9.30 | 17903.7 | 8669.5 | 9234.2 | 51.6% |
| 4/25/2017 14:45 | 4/25/2017 21:36 | 6.85 | 0.49 | 4/25/2017 16:30 | 4/25/2017 23:45 | 7.25 | 21828.7 | 7493.8 | 14334.8 | 65.7% |
| 4/26/2017 1:59 | 4/26/2017 9:26 | 7.45 | 0.33 | 4/26/2017 3:00 | 4/26/2017 13:30 | 10.50 | 16815.1 | 8304.7 | 8510.4 | 50.6% |
| 4/30/2017 10:20 | 4/30/2017 13:18 | 2.97 | 0.05 | 4/30/2017 10:15 | 4/30/2017 14:15 | 4.00 | 733.6 | 0.0 | 733.6 | 100.0% |
| 4/30/2017 21:01 | 5/1/2017 2:17 | 5.27 | 0.81 | 4/30/2017 21:08 | 5/1/2017 9:15 | 12.12 | 49341.9 | 23424.0 | 25917.9 | 52.5% |
| 5/1/2017 12:44 | 5/1/2017 15:13 | 2.48 | 0.22 | 5/1/2017 11:15 | 5/1/2017 23:00 | 11.75 | 21919.4 | 9110.7 | 12808.8 | 58.4% |
| 5/8/2017 21:52 | 5/8/2017 23:31 | 1.65 | 0.18 | 5/8/2017 22:00 | 5/9/2017 4:45 | 6.75 | 5119.6 | 0.0 | 5119.6 | 100.0% |
| 5/15/2017 13:26 | 5/15/2017 14:37 | 1.18 | 0.24 | 5/15/2017 13:36 | 5/15/2017 16:30 | 2.90 | 7453.5 | 0.0 | 7453.5 | 100.0% |
| 5/16/2017 2:04 | 5/16/2017 10:02 | 7.97 | 0.61 | 5/16/2017 4:45 | 5/16/2017 11:15 | 6.50 | 23389.8 | 13622.7 | 9767.0 | 41.8% |
| 5/16/2017 15:46 | 5/16/2017 15:51 | 0.08 | 0.05 | 5/16/2017 15:59 | 5/16/2017 17:15 | 1.27 | 922.6 | 594.6 | 328.0 | 35.5% |
| 5/17/2017 0:48 | 5/17/2017 5:43 | 4.92 | 0.53 | 5/17/2017 1:26 | 5/17/2017 11:15 | 9.82 | 28601.4 | 19502.0 | 9099.4 | 31.8% |
| 5/17/2017 15:48 | 5/18/2017 8:56 | 17.13 | 1.44 | 5/17/2017 16:00 | 5/18/2017 11:00 | 19.00 | 105020.5 | 70289.1 | 34731.5 | 33.1% |
| 5/20/2017 9:13 | 5/20/2017 17:51 | 8.63 | 1.32 | 5/20/2017 9:45 | 5/21/2017 0:20 | 14.58 | 112654.2 | 74076.3 | 38577.9 | 34.2% |
| 5/21/2017 7:45 | 5/21/2017 8:54 | 1.15 | 0.03 | 5/21/2017 8:00 | 5/21/2017 14:45 | 6.75 | 4970.2 | 2275.5 | 2694.7 | 54.2% |
| 5/23/2017 1:18 | 5/23/2017 2:01 | 0.72 | 0.04 | 5/23/2017 1:30 | 5/23/2017 11:45 | 10.25 | 2733.5 | 1235.7 | 1497.8 | 54.8% |
| 5/25/2017 22:12 | 5/25/2017 22:45 | 0.55 | 0.04 | 5/25/2017 22:39 | 5/26/2017 2:45 | 4.10 | 1488.9 | 695.9 | 793.0 | 53.3% |
| 6/11/2017 8:56 | 6/11/2017 11:07 | 2.18 | 0.65 | 6/11/2017 9:00 | 6/11/2017 12:15 | 3.25 | 29162.9 | 8772.1 | 20390.8 | 69.9% |
| 6/11/2017 18:14 | 6/11/2017 18:30 | 0.27 | 0.06 | 6/11/2017 18:31 | 6/11/2017 20:00 | 1.48 | 3973.6 | 2352.4 | 1621.2 | 40.8% |
| 6/12/2017 14:49 | 6/12/2017 17:21 | 2.53 | 0.26 | 6/12/2017 15:00 | 6/12/2017 21:15 | 6.25 | 13822.9 | 7505.0 | 6318.0 | 45.7% |
| 6/14/2017 0:51 | 6/14/2017 2:37 | 1.77 | 0.20 | 6/14/2017 0:59 | 6/14/2017 4:30 | 3.52 | 9245.6 | 5786.7 | 3458.9 | 37.4% |
| 6/17/2017 20:58 | 6/18/2017 2:24 | 5.43 | 0.15 | 6/17/2017 21:24 | 6/18/2017 5:15 | 7.85 | 3674.1 | 1671.3 | 2002.7 | 54.5% |
| 6/20/2017 5:05 | 6/20/2017 7:52 | 2.78 | 0.13 | 6/20/2017 6:08 | 6/20/2017 11:15 | 5.12 | 2872.7 | 1194.1 | 1678.5 | 58.4% |
| 6/22/2017 7:17 | 6/22/2017 16:35 | 9.30 | 0.40 | 6/22/2017 11:00 | 6/22/2017 19:00 | 8.00 | 15475.9 | 8799.4 | 6676.5 | 43.1% |
| 6/24/2017 14:47 | 6/24/2017 14:57 | 0.17 | 0.05 | 6/24/2017 14:58 | 6/24/2017 17:30 | 2.53 | 1342.2 | 627.4 | 714.7 | 53.3% |
| 6/28/2017 4:29 | 6/28/2017 10:32 | 6.05 | 0.62 | 6/28/2017 4:45 | 6/28/2017 14:45 | 10.00 | 27791.1 | 7141.5 | 20649.6 | 74.3% |
| 6/30/2017 4:52 | 6/30/2017 5:33 | 0.68 | 0.17 | 6/30/2017 5:00 | 6/30/2017 7:30 | 2.50 | 5197.1 | 3766.5 | 1430.7 | 27.5% |
| 7/6/2017 8:00 | 7/6/2017 8:06 | 0.10 | 0.06 | 7/6/2017 8:13 | 7/6/2017 10:45 | 2.53 | 976.3 | 563.7 | 412.6 | 42.3% |
| 7/17/2017 21:49 | 7/18/2017 0:22 | 2.55 | 1.24 | 7/17/2017 21:53 | 7/18/2017 1:45 | 3.87 | 53463.6 | 16881.0 | 36582.6 | 68.4% |
| 7/19/2017 15:48 | 7/20/2017 0:10 | 8.37 | 0.16 | 7/19/2017 22:58 | 7/20/2017 3:15 | 4.28 | 3632.7 | 1581.2 | 2051.5 | 56.5% |
| 7/25/2017 18:14 | 7/25/2017 19:55 | 1.68 | 0.25 | 7/25/2017 18:30 | 7/25/2017 22:45 | 4.25 | 12151.7 | 8621.3 | 3530.5 | 29.1% |
| 7/26/2017 4:17 | 7/26/2017 5:20 | 1.05 | 0.60 | 7/26/2017 4:22 | 7/26/2017 7:30 | 3.13 | 30922.4 | 20295.0 | 10627.5 | 34.4% |
| 8/3/2017 6:16 | 8/3/2017 8:43 | 2.45 | 0.40 | 8/3/2017 6:30 | 8/3/2017 11:00 | 4.50 | 20768.5 | 15481.4 | 5287.0 | 25.5% |
| 8/5/2017 15:30 | 8/5/2017 15:35 | 0.08 | 0.06 | 8/5/2017 15:39 | 8/5/2017 18:00 | 2.35 | 1990.8 | 1292.0 | 698.9 | 35.1% |
| 8/6/2017 13:43 | 8/6/2017 14:46 | 1.05 | 0.80 | 8/6/2017 13:48 | 8/6/2017 16:15 | 2.45 | 41045.3 | 26332.7 | 14712.6 | 35.8% |
| 8/6/2017 19:36 | 8/6/2017 20:49 | 1.22 | 0.09 | 8/6/2017 20:05 | 8/6/2017 21:45 | 1.67 | 3585.4 | 1834.9 | 1750.5 | 48.8% |
| 8/9/2017 12:23 | 8/9/2017 18:15 | 5.87 | 0.49 | 8/9/2017 12:36 | 8/9/2017 20:15 | 7.65 | 15672.4 | 0.0 | 15672.4 | 100.0% |
| 8/9/2017 23:15 | 8/10/2017 1:48 | 2.55 | 0.27 | 8/9/2017 23:18 | 8/10/2017 3:38 | 4.33 | 15488.6 | 1546.9 | 13941.7 | 90.0% |
| 8/10/2017 15:52 | 8/10/2017 16:06 | 0.23 | 0.15 | 8/10/2017 15:58 | 8/10/2017 17:45 | 1.78 | 8252.0 | 6001.9 | 2250.1 | 27.3% |
| 8/13/2017 23:03 | 8/14/2017 1:27 | 2.40 | 1.26 | 8/13/2017 23:37 | 8/14/2017 3:30 | 3.88 | 68892.7 | 55931.3 | 12961.4 | 18.8% |
| 8/16/2017 3:20 | 8/16/2017 7:38 | 4.30 | 0.61 | 8/16/2017 3:33 | 8/16/2017 5:30 | 1.95 | 21296.0 | 14419.6 | 6876.4 | 32.3% |
| 8/16/2017 19:36 | 8/17/2017 6:19 | 10.72 | 1.11 | 8/16/2017 7:36 | 8/17/2017 9:30 | 25.90 | 78902.9 | 54829.0 | 24073.9 | 30.5% |
| 8/25/2017 6:39 | 8/25/2017 8:30 | 1.85 | 0.20 | 8/25/2017 7:03 | 8/25/2017 11:30 | 4.45 | 4669.8 | 4412.3 | 257.5 | 5.5% |
| 8/25/2017 23:12 | 8/26/2017 10:31 | 11.32 | 0.85 | 8/25/2017 23:30 | 8/26/2017 11:30 | 12.00 | 40109.5 | 33327.8 | 6781.7 | 16.9% |
| 8/26/2017 14:54 | 8/26/2017 21:38 | 6.73 | 0.08 | 8/26/2017 15:30 | 8/27/2017 0:30 | 9.00 | 1253.3 | 467.9 | 785.4 | 62.7% |
| 8/27/2017 15:21 | 8/27/2017 15:27 | 0.10 | 0.15 | 8/27/2017 15:30 | 8/27/2017 17:30 | 2.00 | 416.9 | 14.9 | 402.0 | 96.4% |
| 9/4/2017 17:26 | 9/4/2017 17:59 | 0.55 | 0.09 | 9/4/2017 17:47 | 9/4/2017 19:45 | 1.97 | 2156.6 | 1157.4 | 999.2 | 46.3% |
| 9/18/2017 9:57 | 9/18/2017 15:17 | 5.33 | 0.35 | 9/18/2017 10:30 | 9/18/2017 18:45 | 8.25 | 5204.7 | 3899.3 | 1305.3 | 25.1% |
| 9/20/2017 3:16 | 9/20/2017 3:30 | 0.23 | 0.16 | 9/20/2017 3:25 | 9/20/2017 5:15 | 1.83 | 4920.9 | 3548.3 | 1372.6 | 27.9% |
| 9/25/2017 3:05 | 9/25/2017 6:35 | 3.50 | 0.92 | 9/25/2017 3:27 | 9/25/2017 8:30 | 5.05 | 41764.9 | 31281.4 | 10483.5 | 25.1% |
| 9/26/2017 1:54 | 9/26/2017 7:35 | 5.68 | 0.11 | 9/26/2017 2:45 | 9/26/2017 10:00 | 7.25 | 948.9 | 389.1 | 559.8 | 59.0% |
| 10/1/2017 12:28 | 10/1/2017 14:03 | 1.58 | 0.08 | 10/1/2017 13:30 | 10/1/2017 15:30 | 2.00 | 1576.1 | 374.3 | 1201.9 | 76.3% |
| 10/1/2017 19:23 | 10/1/2017 20:33 | 1.17 | 0.06 | 10/1/2017 20:00 | 10/1/2017 21:23 | 1.38 | 749.8 | 626.1 | 123.8 | 16.5% |
| 10/2/2017 2:07 | 10/2/2017 4:48 | 2.68 | 0.31 | 10/2/2017 2:21 | 10/2/2017 7:15 | 4.90 | 17330.3 | 14394.3 | 2936.0 | 16.9% |
| 10/2/2017 17:38 | 10/2/2017 20:47 | 3.15 | 1.44 | 10/2/2017 17:45 | 10/2/2017 21:47 | 4.03 | 69211.9 | 59091.5 | 10120.4 | 14.6% |
| 10/2/2017 23:08 | 10/3/2017 1:24 | 2.27 | 0.14 | 10/2/2017 23:38 | 10/3/2017 2:30 | 2.87 | 7943.5 | 7422.6 | 520.9 | 6.6% |
| 10/3/2017 5:58 | 10/3/2017 8:08 | 2.17 | 0.04 | 10/3/2017 7:30 | 10/3/2017 10:15 | 2.75 | 769.4 | 674.9 | 94.4 | 12.3% |
| 10/6/2017 14:21 | 10/6/2017 17:00 | 2.65 | 0.58 | 10/6/2017 14:36 | 10/6/2017 19:00 | 4.40 | 23512.5 | 5.7 | 23506.8 | 100.0% |
| 10/6/2017 20:45 | 10/7/2017 12:35 | 15.83 | 0.30 | 10/6/2017 21:00 | 10/7/2017 15:15 | 18.25 | 13279.3 | 24.7 | 13254.6 | 99.8% |
| 10/14/2017 14:41 | 10/15/2017 4:22 | 13.68 | 0.43 | 10/14/2017 15:15 | 10/15/2017 5:00 | 13.75 | 19709.2 | 16.4 | 19692.7 | 99.9% |
| 10/21/2017 7:08 | 10/21/2017 10:54 | 3.77 | 0.34 | 10/21/2017 7:15 | 10/21/2017 14:00 | 6.75 | 13734.1 | 4.2 | 13729.9 | 100.0% |
| 10/27/2017 2:39 | 10/27/2017 20:11 | 17.53 | 0.31 | 10/27/2017 4:15 | 10/27/2017 22:45 | 18.50 | 8159.0 | 10.0 | 8149.0 | 99.9% |
| 10/29/2017 21:58 | 10/29/2017 22:51 | 0.88 | 0.04 | 10/29/2017 23:00 | 10/30/2017 1:30 | 2.50 | 1251.8 | 1.3 | 1250.5 | 99.9% |
| **Subtotals:** | | | **25.6** | | | | **1270802** | **689968** | **580833** | **46%** |

Flow to the BMP is monitored at a flow diversion structure along Flandrau St.

(shaded) Flow, No Rain

# Chart B.4 St. Albans

Flow Rates and Rainfall



City of Saint Paul
2017 Water Quality and Quantity Report
Chart B.5
WSB Project Number 01610-100

## SAINT ALBANS INFILTRATION SYSTEM FLOW EVENT SUMMARY

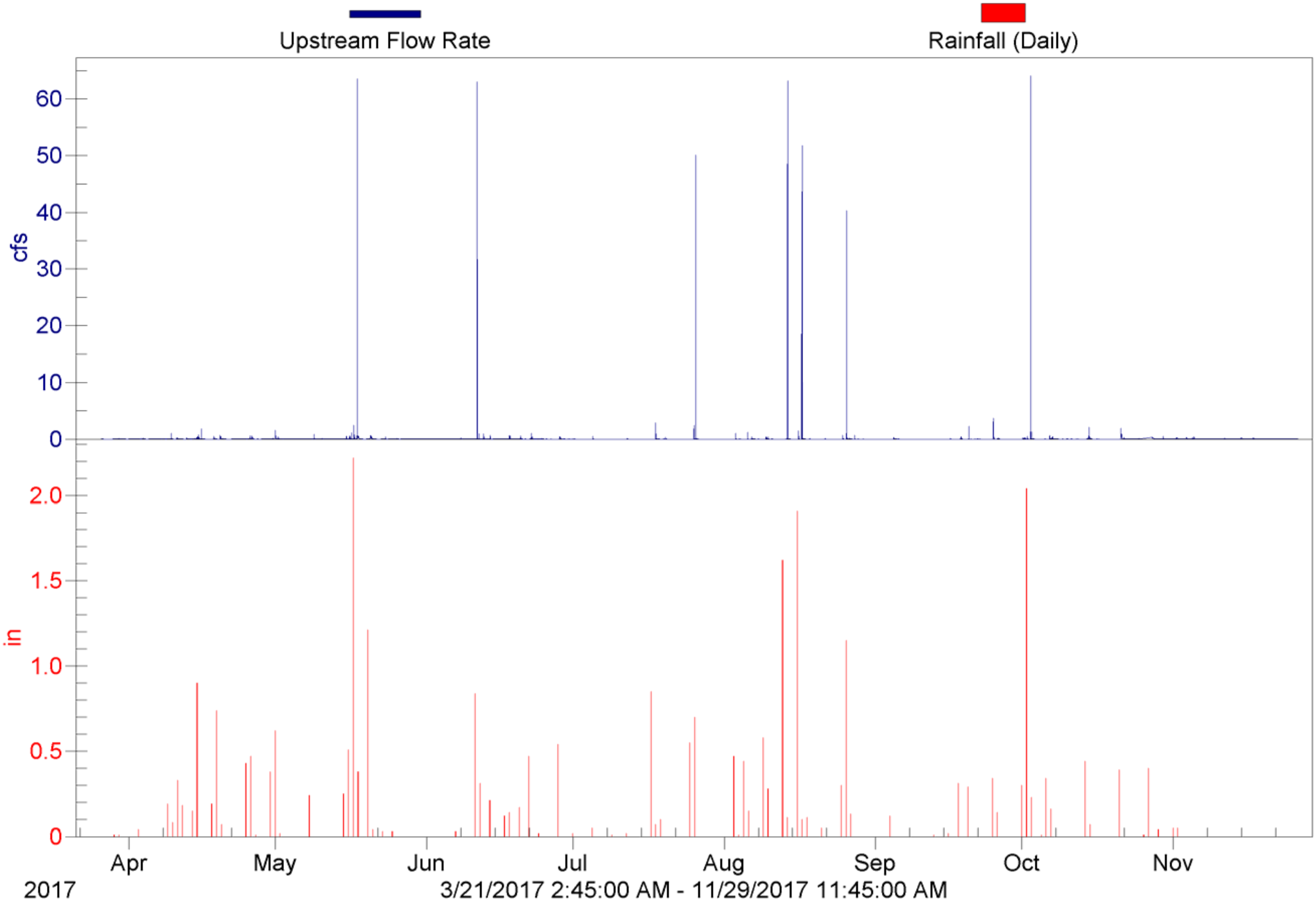
| Rain | | | | Flow | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start | End | Duration | Amount | Start | End | Duration | Aurora Avenue Runoff Volume (Upstream of Diversion) (1) | University Avenue Runoff Volume (2) | Aurora Avenue Bypass Volume (Downstream of Diversion) (3) | Total BMP Drainage Area Runoff (1+2) | Total Inflow to BMP (1 + 2 - 3) | Percent Captured |
| | | (hr) | (in) | | | (hr) | (cf) | (cf) | (cf) | (cf) | (cf) | (%) |
| | | | | 3/23/2017 21:00 | 3/24/2017 11:00 | 14.00 | 5599.2 | 2738.8 | 0.0 | 8338.02 | 8338.0 | 100.0% |
| | | | | 3/25/2017 23:00 | 3/26/2017 15:45 | 16.75 | 1746.8 | 737.4 | 0.0 | 2484.19 | 2484.2 | 100.0% |
| 4/3/2017 20:07 | 4/3/2017 23:15 | 3.13 | 0.06 | 4/3/2017 15:15 | 4/4/2017 3:15 | 12.00 | 906.0 | 379.5 | 0.0 | 1285.43 | 1285.4 | 100.0% |
| 4/10/2017 18:57 | 4/10/2017 20:18 | 1.35 | 0.06 | 4/10/2017 18:00 | 4/11/2017 1:45 | 7.75 | 2381.2 | 1112.4 | 0.0 | 3493.65 | 3493.6 | 100.0% |
| 4/11/2017 10:51 | 4/11/2017 11:38 | 0.78 | 0.25 | 4/11/2017 7:15 | 4/11/2017 14:00 | 6.75 | 629.9 | 772.4 | 0.0 | 1402.30 | 1402.3 | 100.0% |
| 4/12/2017 16:53 | 4/12/2017 23:30 | 6.62 | 0.20 | 4/12/2017 16:15 | 4/13/2017 2:30 | 10.25 | 2290.1 | 1167.6 | 0.0 | 3457.65 | 3457.7 | 100.0% |
| 4/14/2017 10:38 | 4/15/2017 10:07 | 23.48 | 0.69 | 4/14/2017 9:30 | 4/15/2017 13:15 | 27.75 | 14258.8 | 7807.1 | 0.0 | 22065.91 | 22065.9 | 100.0% |
| 4/15/2017 19:02 | 4/15/2017 19:31 | 0.48 | 0.15 | 4/15/2017 18:15 | 4/16/2017 0:00 | 5.75 | 2441.6 | 1103.7 | 0.0 | 3545.28 | 3545.3 | 100.0% |
| 4/18/2017 8:23 | 4/18/2017 10:57 | 2.57 | 0.14 | 4/18/2017 7:30 | 4/18/2017 15:00 | 7.50 | 2192.6 | 740.5 | 0.0 | 2933.13 | 2933.1 | 100.0% |
| 4/19/2017 14:51 | 4/19/2017 20:32 | 5.68 | 0.77 | 4/19/2017 15:00 | 4/19/2017 22:45 | 7.75 | 14144.8 | 0.0 | 0.0 | 14144.76 | 14144.8 | 100.0% |
| 4/20/2017 1:02 | 4/20/2017 3:41 | 2.65 | 0.13 | 4/20/2017 1:06 | 4/20/2017 9:00 | 7.90 | 3302.3 | 0.0 | 0.0 | 3302.28 | 3302.3 | 100.0% |
| 4/25/2017 15:27 | 4/25/2017 22:14 | 6.78 | 0.43 | 4/25/2017 15:45 | 4/26/2017 0:30 | 8.75 | 7646.7 | 0.0 | 0.0 | 7646.67 | 7646.7 | 100.0% |
| 4/26/2017 2:55 | 4/26/2017 9:23 | 6.47 | 0.35 | 4/26/2017 3:00 | 4/26/2017 12:15 | 9.25 | 5475.9 | 0.0 | 0.0 | 5475.94 | 5475.9 | 100.0% |
| 4/30/2017 21:10 | 5/1/2017 18:51 | 21.68 | 1.15 | 4/30/2017 20:45 | 5/2/2017 0:00 | 27.25 | 26537.3 | 0.0 | 0.0 | 26537.38 | 26537.3 | 100.0% |
| 5/8/2017 21:51 | 5/8/2017 23:15 | 1.40 | 0.28 | 5/8/2017 21:15 | 5/9/2017 3:00 | 5.75 | 10623.9 | 3705.4 | 0.0 | 14329.75 | 14329.3 | 100.0% |
| 5/15/2017 13:20 | 5/15/2017 14:34 | 1.23 | 0.30 | 5/15/2017 13:23 | 5/15/2017 17:30 | 4.12 | 5649.6 | 3314.7 | 0.0 | 8964.59 | 8964.3 | 100.0% |
| 5/16/2017 4:25 | 5/16/2017 5:32 | 1.12 | 0.52 | 5/16/2017 4:15 | 5/16/2017 11:45 | 7.50 | 11965.5 | 6898.1 | 0.0 | 18898.35 | 18863.6 | 99.8% |
| 5/16/2017 8:16 | 5/16/2017 9:32 | 1.27 | 0.12 | 5/16/2017 15:30 | 5/16/2017 17:30 | 2.00 | 183.2 | 288.3 | 0.0 | 471.50 | 471.5 | 100.0% |
| 5/17/2017 0:41 | 5/17/2017 6:05 | 5.40 | 0.81 | 5/17/2017 0:45 | 5/17/2017 7:15 | 6.50 | 11493.4 | 9024.2 | 0.0 | 20522.25 | 20517.5 | 100.0% |
| 5/17/2017 19:31 | 5/18/2017 3:22 | 7.85 | 1.52 | 5/17/2017 19:32 | 5/18/2017 5:00 | 9.47 | 35208.1 | 25327.7 | 7196.2 | 67771.85 | 60535.7 | 89.3% |
| 5/20/2017 8:29 | 5/20/2017 18:58 | 10.48 | 1.35 | 5/20/2017 7:45 | 5/21/2017 0:15 | 16.50 | 26054.0 | 17796.8 | 0.0 | 43853.76 | 43850.9 | 100.0% |
| 5/21/2017 7:36 | 5/21/2017 11:55 | 4.32 | 0.07 | 5/21/2017 7:30 | 5/21/2017 16:45 | 9.25 | 1654.1 | 883.5 | 0.0 | 2537.66 | 2537.6 | 100.0% |
| 5/23/2017 1:01 | 5/23/2017 1:27 | 0.43 | 0.03 | 5/23/2017 1:15 | 5/23/2017 9:15 | 8.00 | 494.0 | 194.1 | 0.0 | 688.18 | 688.2 | 100.0% |
| 5/25/2017 22:03 | 5/26/2017 0:01 | 1.97 | 0.04 | 5/25/2017 22:15 | 5/26/2017 16:00 | 17.75 | 1466.3 | 198.9 | 0.0 | 1668.14 | 1665.3 | 99.8% |
| 6/11/2017 8:51 | 6/11/2017 11:11 | 2.33 | 0.80 | 6/11/2017 8:45 | 6/11/2017 14:00 | 5.25 | 10541.6 | 9112.5 | 0.0 | 19977.00 | 19654.1 | 98.4% |
| 6/11/2017 18:07 | 6/11/2017 18:26 | 0.32 | 0.08 | 6/11/2017 18:00 | 6/11/2017 20:00 | 2.00 | 1169.6 | 1012.3 | 0.0 | 2182.13 | 2181.9 | 100.0% |
| 6/12/2017 15:07 | 6/12/2017 17:19 | 2.20 | 0.23 | 6/12/2017 15:30 | 6/12/2017 20:45 | 5.25 | 2618.8 | 1774.1 | 0.0 | 4393.31 | 4392.9 | 100.0% |
| 6/13/2017 6:26 | 6/13/2017 6:29 | 0.05 | 0.03 | 6/13/2017 6:30 | 6/13/2017 9:45 | 3.25 | 256.8 | 92.5 | 0.0 | 349.31 | 349.3 | 100.0% |
| 6/14/2017 0:45 | 6/14/2017 1:21 | 0.60 | 0.16 | 6/14/2017 0:45 | 6/14/2017 4:45 | 4.00 | 2518.0 | 1290.3 | 0.0 | 3808.74 | 3808.3 | 100.0% |
| 6/17/2017 20:46 | 6/18/2017 1:54 | 5.13 | 0.23 | 6/17/2017 20:45 | 6/18/2017 4:30 | 7.75 | 2352.9 | 2702.1 | 0.0 | 5055.07 | 5055.1 | 100.0% |
| 6/20/2017 3:57 | 6/20/2017 7:53 | 3.93 | 0.17 | 6/20/2017 4:00 | 6/20/2017 10:00 | 6.00 | 1374.2 | 1755.8 | 0.0 | 3129.97 | 3130.0 | 100.0% |
| 6/22/2017 9:43 | 6/22/2017 16:33 | 6.83 | 0.36 | 6/22/2017 8:15 | 6/22/2017 18:15 | 10.00 | 4860.7 | 3609.8 | 0.0 | 8470.42 | 8470.4 | 100.0% |
| 6/24/2017 14:41 | 6/24/2017 14:48 | 0.12 | 0.03 | 6/24/2017 14:45 | 6/24/2017 18:45 | 4.00 | 192.4 | 310.6 | 0.0 | 503.05 | 503.0 | 100.0% |
| 6/28/2017 3:51 | 6/28/2017 10:24 | 6.55 | 0.74 | 6/28/2017 3:56 | 6/28/2017 12:00 | 8.07 | 13484.0 | 9316.9 | 0.0 | 22802.06 | 22801.0 | 100.0% |
| | | | | 7/8/2017 22:30 | 7/8/2017 23:30 | 1.00 | 367.8 | 0.0 | 0.0 | 368.25 | 367.8 | 99.9% |
| 7/12/2017 2:10 | 7/12/2017 2:39 | 0.48 | 0.03 | 7/12/2017 2:15 | 7/12/2017 3:45 | 1.50 | 115.9 | 180.8 | 0.0 | 299.19 | 296.7 | 99.2% |
| | | | | 7/14/2017 0:02 | 7/14/2017 0:45 | 0.72 | 1578.7 | 0.0 | 0.0 | 1580.37 | 1578.7 | 99.9% |
| 7/17/2017 22:19 | 7/18/2017 0:51 | 2.53 | 0.60 | 7/17/2017 22:27 | 7/18/2017 3:30 | 5.05 | 7968.5 | 6226.7 | 0.0 | 14229.97 | 14195.2 | 99.8% |
| 7/19/2017 15:47 | 7/19/2017 16:14 | 0.45 | 0.04 | 7/19/2017 16:00 | 7/19/2017 17:45 | 1.75 | 436.0 | 206.4 | 0.0 | 646.81 | 642.4 | 99.3% |
| 7/19/2017 22:32 | 7/19/2017 22:39 | 0.12 | 0.14 | 7/19/2017 22:33 | 7/20/2017 0:30 | 1.95 | 2565.2 | 1187.9 | 0.0 | 3762.22 | 3753.1 | 99.8% |
| 7/21/2017 10:55 | 7/21/2017 11:04 | 0.15 | 0.06 | 7/21/2017 11:00 | 7/21/2017 13:00 | 2.00 | 324.9 | 423.0 | 0.0 | 753.28 | 747.9 | 99.3% |
| 7/25/2017 17:54 | 7/25/2017 20:19 | 2.42 | 0.74 | 7/25/2017 18:00 | 7/25/2017 22:15 | 4.25 | 12743.4 | 8478.1 | 0.0 | 21265.72 | 21221.5 | 99.8% |
| 7/26/2017 4:08 | 7/26/2017 5:10 | 1.03 | 0.63 | 7/26/2017 4:09 | 7/26/2017 6:15 | 2.10 | 12761.5 | 11176.6 | 0.0 | 24455.09 | 23938.1 | 97.9% |
| 8/3/2017 6:24 | 8/3/2017 8:38 | 2.23 | 0.35 | 8/3/2017 7:45 | 8/3/2017 10:15 | 2.50 | 5293.9 | 4216.7 | 0.0 | 9510.64 | 9510.6 | 100.0% |
| 8/5/2017 15:20 | 8/5/2017 18:53 | 3.55 | 0.47 | 8/5/2017 15:30 | 8/5/2017 22:15 | 6.75 | 7804.4 | 8463.5 | 0.0 | 16268.38 | 16267.9 | 100.0% |
| 8/6/2017 13:13 | 8/6/2017 14:22 | 1.15 | 0.37 | 8/6/2017 13:30 | 8/6/2017 16:45 | 3.25 | 6254.0 | 3897.5 | 0.0 | 10151.49 | 10151.5 | 100.0% |
| 8/6/2017 19:23 | 8/6/2017 20:37 | 1.23 | 0.13 | 8/6/2017 19:45 | 8/6/2017 22:15 | 2.50 | 1705.1 | 1322.6 | 0.0 | 3027.62 | 3027.6 | 100.0% |
| 8/9/2017 12:11 | 8/9/2017 17:43 | 5.53 | 0.58 | 8/9/2017 12:00 | 8/9/2017 19:45 | 7.75 | 8620.9 | 6856.9 | 0.0 | 15477.79 | 15477.8 | 100.0% |
| 8/10/2017 0:00 | 8/10/2017 1:03 | 1.05 | 0.19 | 8/10/2017 0:13 | 8/10/2017 3:15 | 3.03 | 2803.5 | 2400.0 | 0.0 | 5203.46 | 5203.5 | 100.0% |
| 8/10/2017 15:58 | 8/10/2017 16:07 | 0.15 | 0.11 | 8/10/2017 16:00 | 8/10/2017 18:00 | 2.00 | 1319.9 | 880.4 | 0.0 | 2200.29 | 2200.3 | 100.0% |
| 8/13/2017 14:09 | 8/13/2017 14:22 | 0.22 | 0.03 | 8/13/2017 14:29 | 8/13/2017 15:30 | 1.02 | 295.4 | 264.9 | 0.0 | 560.38 | 560.4 | 100.0% |
| 8/13/2017 19:33 | 8/14/2017 1:08 | 5.58 | 1.01 | 8/13/2017 20:00 | 8/14/2017 2:30 | 6.50 | 24880.4 | 11207.8 | 0.0 | 36257.06 | 36088.2 | 99.5% |
| 8/16/2017 3:10 | 8/16/2017 4:42 | 1.53 | 0.38 | 8/16/2017 3:15 | 8/16/2017 10:45 | 7.50 | 6688.6 | 5763.7 | 0.0 | 12452.25 | 12452.3 | 100.0% |
| 8/16/2017 19:30 | 8/16/2017 23:24 | 3.90 | 1.38 | 8/16/2017 19:30 | 8/17/2017 1:00 | 5.50 | 28407.8 | 15241.2 | 23.7 | 43814.61 | 43648.9 | 99.6% |
| 8/17/2017 4:25 | 8/17/2017 5:35 | 1.17 | 0.07 | 8/17/2017 4:30 | 8/17/2017 7:30 | 3.00 | 1008.0 | 934.0 | 0.0 | 1942.02 | 1942.0 | 100.0% |
| 8/18/2017 12:51 | 8/18/2017 13:05 | 0.23 | 0.10 | 8/18/2017 12:53 | 8/18/2017 14:15 | 1.37 | 1331.1 | 1582.2 | 0.0 | 2913.27 | 2913.3 | 100.0% |
| 8/21/2017 14:33 | 8/21/2017 15:13 | 0.67 | 0.05 | 8/21/2017 14:45 | 8/21/2017 19:15 | 4.50 | 297.1 | 1008.4 | 0.0 | 1305.45 | 1305.4 | 100.0% |
| 8/25/2017 5:49 | 8/25/2017 8:11 | 2.37 | 0.32 | 8/25/2017 5:45 | 8/25/2017 10:00 | 4.25 | 4278.5 | 4845.8 | 0.0 | 9124.27 | 9124.3 | 100.0% |
| 8/25/2017 22:27 | 8/26/2017 1:44 | 3.28 | 0.50 | 8/25/2017 23:00 | 8/26/2017 1:45 | 2.75 | 5266.9 | 6488.7 | 0.0 | 11755.61 | 11755.6 | 100.0% |
| 8/26/2017 2:21 | 8/26/2017 5:39 | 3.30 | 0.57 | 8/26/2017 2:27 | 8/26/2017 10:50 | 8.38 | 8537.1 | 9935.8 | 0.0 | 18474.26 | 18472.9 | 100.0% |
| 8/26/2017 14:33 | 8/26/2017 15:54 | 1.35 | 0.08 | 8/26/2017 14:30 | 8/26/2017 18:30 | 4.00 | 482.9 | 1601.7 | 0.0 | 2084.65 | 2084.7 | 100.0% |
| 8/27/2017 18:06 | 8/27/2017 18:15 | 0.15 | 0.05 | 8/27/2017 18:15 | 8/27/2017 20:00 | 1.75 | 135.4 | 689.2 | 0.0 | 824.62 | 824.6 | 100.0% |
| 9/2/2017 4:10 | 9/2/2017 4:17 | 0.12 | 0.02 | 9/2/2017 4:15 | 9/2/2017 7:30 | 3.25 | 62.1 | 628.1 | 0.0 | 690.19 | 690.2 | 100.0% |
| 9/4/2017 16:52 | 9/4/2017 17:48 | 0.93 | 0.10 | 9/4/2017 17:00 | 9/4/2017 22:30 | 5.50 | 970.6 | 1198.0 | 0.0 | 2168.53 | 2168.5 | 100.0% |
| 9/16/2017 2:07 | 9/16/2017 7:35 | 5.47 | 0.02 | 9/16/2017 2:30 | 9/16/2017 9:15 | 6.75 | 178.9 | 767.2 | 0.0 | 946.39 | 946.0 | 100.0% |
| 9/18/2017 9:43 | 9/18/2017 15:08 | 5.42 | 0.37 | 9/18/2017 9:45 | 9/18/2017 16:30 | 6.75 | 2744.5 | 4694.6 | 0.0 | 7457.83 | 7439.1 | 99.7% |
| 9/20/2017 3:08 | 9/20/2017 3:19 | 0.18 | 0.07 | 9/20/2017 3:15 | 9/20/2017 5:15 | 2.00 | 341.1 | 1097.9 | 0.0 | 1451.44 | 1439.0 | 99.1% |
| 9/25/2017 2:55 | 9/25/2017 6:17 | 3.37 | 0.77 | 9/25/2017 3:00 | 9/25/2017 4:45 | 1.75 | 3669.4 | 5199.4 | 0.0 | 8918.60 | 8868.8 | 99.4% |
| 9/25/2017 21:24 | 9/26/2017 4:42 | 7.30 | 0.09 | 9/25/2017 5:30 | 9/26/2017 7:30 | 26.00 | 7352.8 | 7776.6 | 0.0 | 15423.70 | 15129.4 | 98.1% |
| 10/1/2017 3:48 | 10/1/2017 4:13 | 0.42 | 0.02 | 10/1/2017 4:00 | 10/1/2017 7:00 | 3.00 | 60.9 | 379.1 | 0.0 | 464.03 | 440.0 | 94.8% |
| 10/1/2017 12:05 | 10/1/2017 13:56 | 1.85 | 0.13 | 10/1/2017 12:30 | 10/1/2017 16:00 | 3.50 | 1054.9 | 1704.3 | 0.0 | 2788.28 | 2759.2 | 99.0% |
| 10/1/2017 17:13 | 10/1/2017 20:20 | 3.12 | 0.08 | 10/1/2017 19:30 | 10/1/2017 22:30 | 3.00 | 551.9 | 1023.5 | 0.0 | 1614.34 | 1575.4 | 97.6% |
| 10/2/2017 1:51 | 10/2/2017 4:45 | 2.90 | 0.35 | 10/2/2017 2:00 | 10/2/2017 6:15 | 4.25 | 4056.8 | 4376.0 | 0.0 | 8516.75 | 8432.7 | 99.0% |
| 10/2/2017 17:33 | 10/2/2017 20:08 | 2.58 | 1.46 | 10/2/2017 17:45 | 10/2/2017 21:45 | 4.00 | 43249.4 | 17956.4 | 11909.2 | 74304.45 | 61205.7 | 82.4% |
| 10/2/2017 23:11 | 10/3/2017 1:16 | 2.08 | 0.24 | 10/2/2017 23:15 | 10/3/2017 1:45 | 2.50 | 3941.0 | 3788.3 | 0.0 | 7823.75 | 7729.3 | 98.8% |
| 10/3/2017 6:47 | 10/3/2017 7:52 | 1.08 | 0.06 | 10/3/2017 7:00 | 10/3/2017 8:30 | 1.50 | 590.6 | 1095.8 | 0.0 | 1720.25 | 1686.4 | 98.0% |
| 10/6/2017 14:29 | 10/6/2017 16:52 | 2.38 | 0.34 | 10/6/2017 14:45 | 10/6/2017 19:00 | 4.25 | 2302.5 | 5628.8 | 0.0 | 7936.99 | 7931.3 | 99.9% |
| 10/6/2017 22:15 | 10/6/2017 23:07 | 0.87 | 0.05 | 10/6/2017 22:15 | 10/7/2017 1:00 | 2.75 | 319.2 | 337.3 | 0.0 | 657.61 | 656.5 | 99.8% |
| 10/7/2017 2:43 | 10/7/2017 7:44 | 5.02 | 0.19 | 10/7/2017 2:45 | 10/7/2017 16:45 | 14.00 | 2195.3 | 3893.3 | 0.0 | 6097.22 | 6088.7 | 99.9% |
| | | | | 10/9/2017 8:15 | 10/9/2017 10:45 | 2.50 | 91.4 | 231.3 | 0.0 | 323.94 | 322.6 | 99.6% |
| 10/14/2017 14:28 | 10/14/2017 20:11 | 5.72 | 0.44 | 10/14/2017 14:30 | 10/15/2017 7:00 | 16.50 | 5312.9 | 7796.3 | 0.0 | 13117.84 | 13109.2 | 99.9% |
| | | | | 10/16/2017 8:31 | 10/16/2017 12:30 | 3.98 | 233.6 | 6.5 | 0.0 | 242.39 | 240.1 | 99.1% |
| 10/21/2017 7:02 | 10/21/2017 10:29 | 3.45 | 0.38 | 10/21/2017 7:10 | 10/21/2017 14:15 | 7.08 | 1730.0 | 4316.4 | 0.0 | 6066.13 | 6046.4 | 99.7% |
| 10/26/2017 22:11 | 10/27/2017 8:42 | 10.52 | 0.15 | 10/26/2017 23:15 | 10/27/2017 12:15 | 13.00 | 592.4 | 6953.9 | 0.0 | 7562.67 | 7546.3 | 99.8% |
| 10/27/2017 14:32 | 10/27/2017 19:48 | 5.27 | 0.13 | 10/27/2017 14:45 | 10/28/2017 0:00 | 9.25 | 329.4 | 1303.9 | 0.0 | 1646.88 | 1633.3 | 99.2% |
| 10/29/2017 11:36 | 10/29/2017 22:34 | 10.97 | 0.12 | 10/29/2017 11:30 | 10/30/2017 8:45 | 21.25 | 280.6 | 1050.1 | 0.0 | 1336.62 | 1330.7 | 99.6% |
| 11/1/2017 16:03 | 11/1/2017 19:15 | 3.20 | 0.07 | 11/1/2017 12:00 | 11/1/2017 19:45 | 7.75 | 63.5 | 1117.6 | 0.0 | 1183.50 | 1181.1 | 99.8% |
| **Subtotals** | | | **26.9** | | | | **470263** | **314969** | **19129** | **807659** | **747077** | **92%** |

Flow to the BMP is monitored at a flow diversion structure located at the intersection of Aurora Ave. and St. Albans st., and another inlet near University Ave.

Flow, No Rain

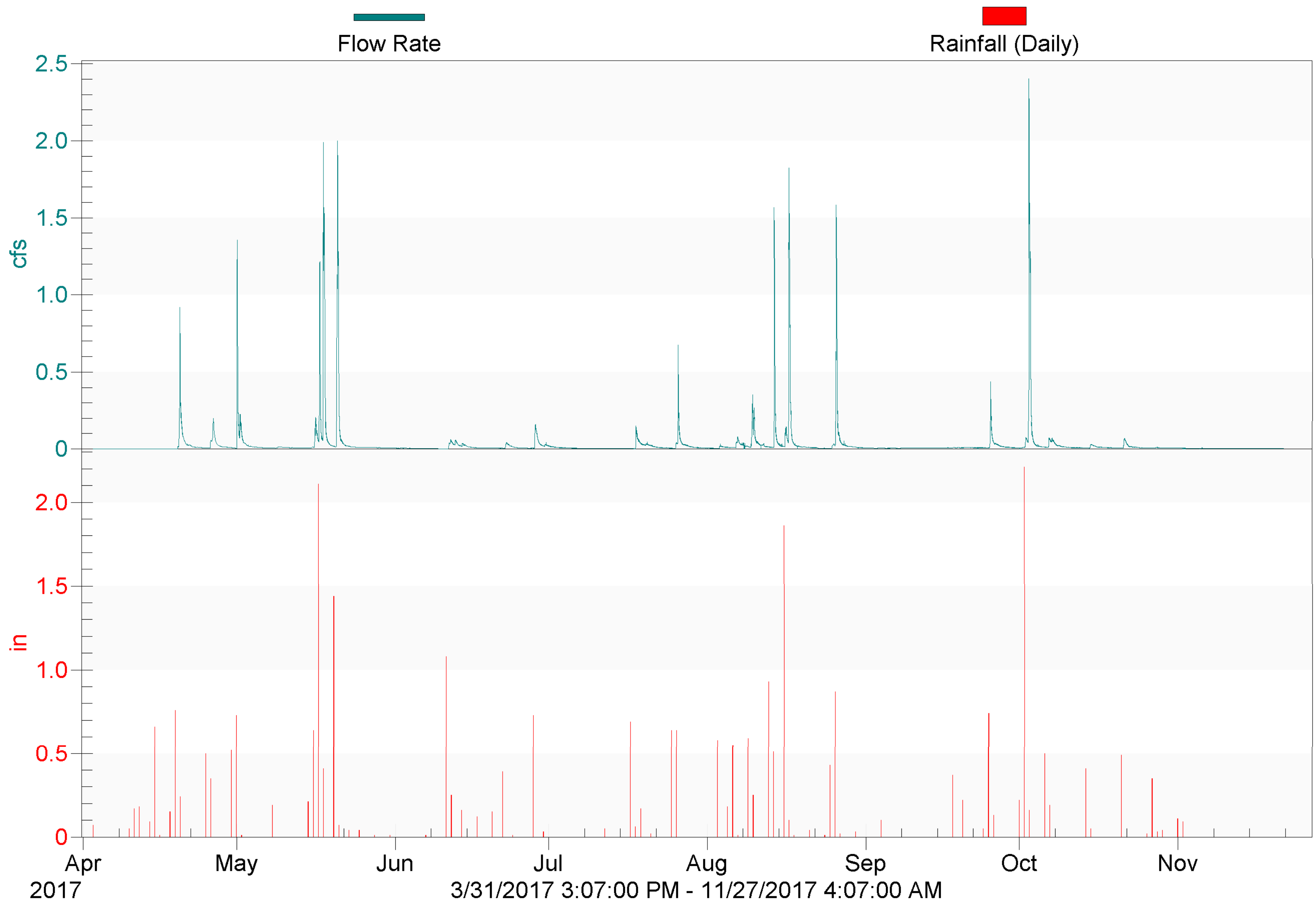
# Chart B.6 Hampden Park

Flow Rates and Rainfall



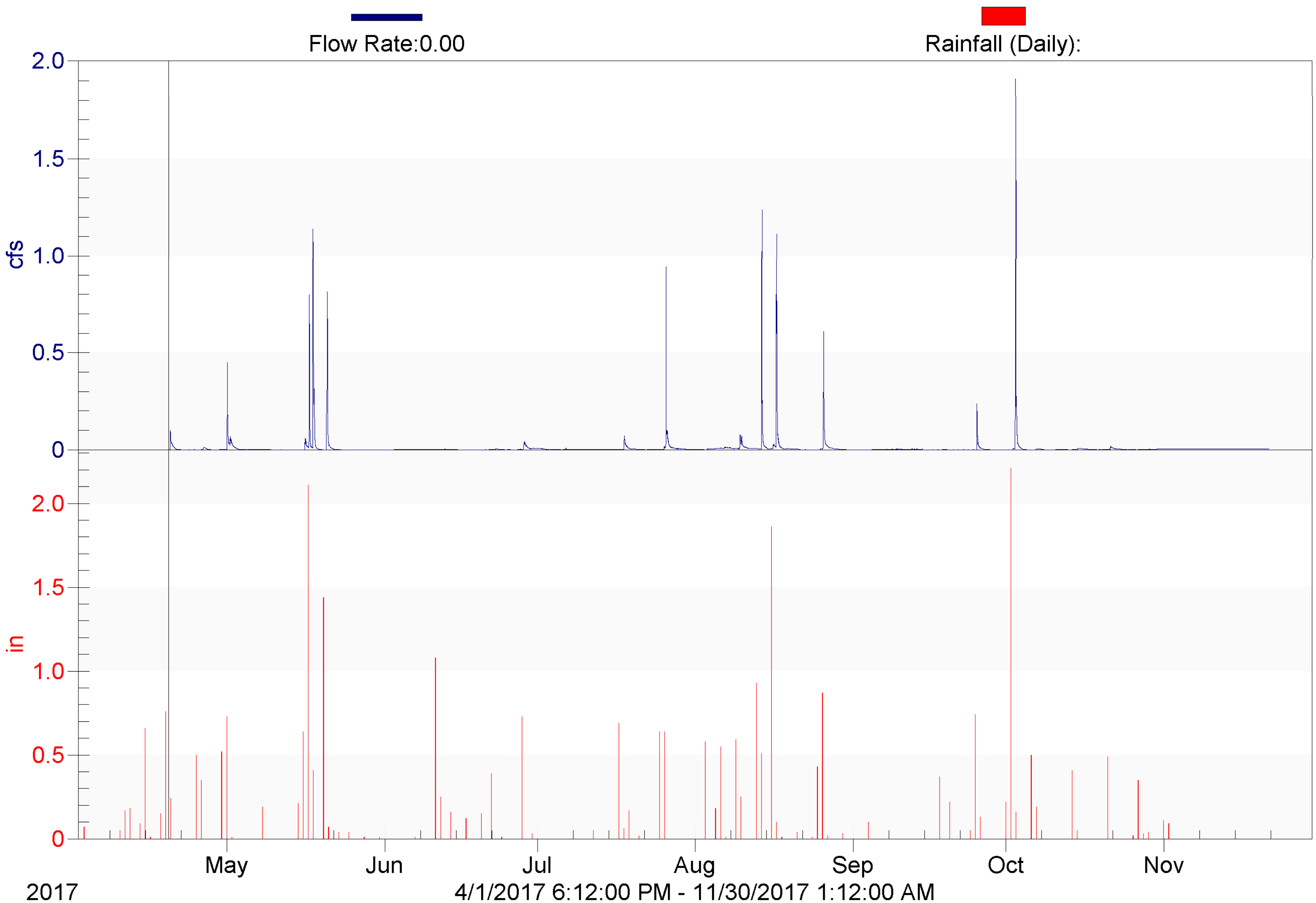
# Chart B.7 TBNS - Maryland Pond

Flow Rates and Rainfall



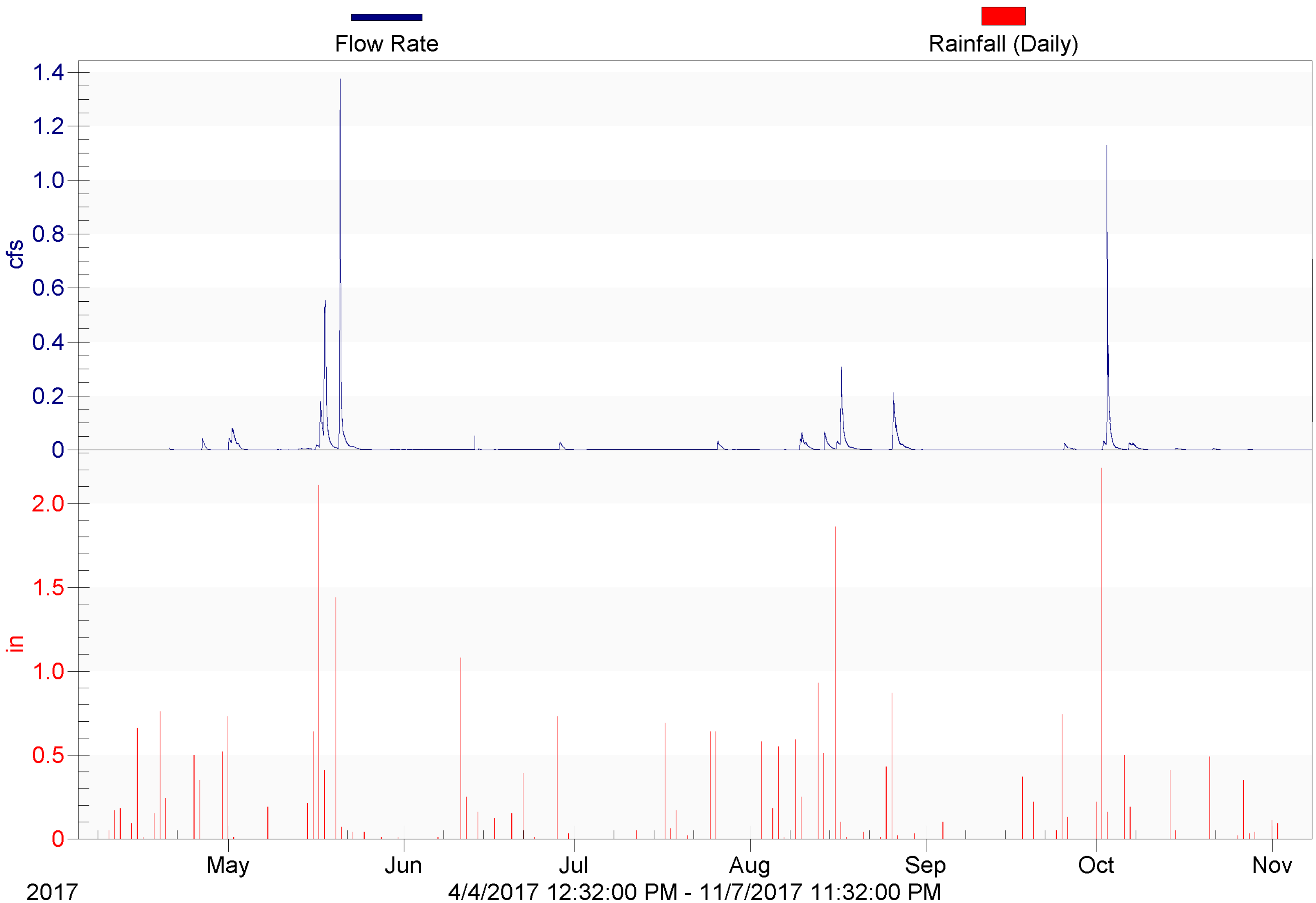
# Chart B.8 TBNS - Magnolia Pond

Flow Rates and Rainfall



# Chart B.9 TBNS - Jenks

Flow Rates and Rainfall



***Appendix C – Water Quality Summary and Pollutant Load Calculations***

City of Saint Paul
2017 Water Quality and Quantity Report
Table C.1
WSB Project Number: 01610-100

# BEACON BLUFF WATER QUALITY SUMMARY

| LAB ID | Date Composite Sampling Started | Date Composite Sampling Ended | TSS (mg/L) | TDS (mg/L) | VSS (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) | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2555044 | 2/13/2017 12:00 | 2/13/2017 12:00 | 21.0 | 524.0 | 13.0 | 0.74 | 0.400 | 236.5 | 0.76 | 3.90 | 0.260 | 52 | 0.0163 | 0.0071 | 0.04100 | 8.78 | 7.40 | 17.0 | 1140 |
| 2571921 | 4/26/2017 9:00 | 4/26/2017 9:00 | 25.0 | 51.0 | 12.0 | 0.17 | 0.075 | 3.9 | 0.34 | 1.10 | 0.200 < | 12 | 0.0068 | 0.0083 | 0.04020 | 2.16 | 7.00 | 8.4 > | 2420 |
| 2573222 | 5/1/2017 9:14 | 5/1/2017 9:14 | 9.0 | 84.0 | 5.0 J | 0.10 | 0.029 | 12.9 | 0.02 J | 0.67 | 0.270 | 32 | 0.0072 | 0.0038 | 0.03460 | 4.48 | 7.30 | 4.9 | |
| 2576999 | 5/15/2017 13:49 | 5/15/2017 15:16 | 1560.0 | | 234.0 | 1.64 | | 26.4 | | 9.80 | 0.080 < | | | | | | | | |
| 2577000 | 5/16/2017 4:49 | 5/16/2017 6:40 | 598.0 | 77.0 | 182.0 | 1.08 | 0.218 | 4.9 | 0.74 | 6.80 | 0.420 | 108 | 0.0496 | 0.0910 | 0.26900 | | 6.80 | 26.0 > | |
| 2577660 | 5/16/2017 8:48 | 5/16/2017 10:19 | 306.0 | | 106.0 | 0.65 | | 5.8 | | 3.60 | 0.320 | | | | | | | | |
| 2577661 | 5/17/2017 1:19 | 5/17/2017 6:42 | 96.0 | | 38.0 | 0.26 | | 3.7 | | 1.50 | 0.350 | | | | | | | | |
| 2578169 | 5/17/2017 19:14 | 5/18/2017 3:50 | 376.0 | | 74.0 | 0.42 | | 2.3 | | 2.10 | 0.160 < | | | | | | | | |
| 2578979 | 5/20/2017 10:19 | 5/20/2017 14:50 | 48.0 | | 20.0 | 0.16 | | 2.0 < | | 0.92 | 0.130 < | | | | | | | | |
| 2584326 | 6/11/2017 9:04 | 6/11/2017 9:47 | 378.0 | 101.0 | 152.0 | 1.43 | 0.357 | 7.5 | 0.05 J | 6.40 | 0.080 < | 40 | 0.0278 | 0.0362 | 0.13900 | 3.86 | 6.10 | 22.0 > | |
| 2584966 | 6/12/2017 15:34 | 6/12/2017 18:20 | 22.0 | | 18.0 | 0.43 | | 6.6 | | 1.80 | 0.090 < | | | | | | | | |
| 2584967 | 6/14/2017 1:04 | 6/14/2017 3:35 | 87.0 | | 44.0 | 0.40 | | 5.8 | | 2.20 | 0.500 | | | | | | | | |
| 2586065 | 6/17/2017 21:19 | 6/17/2017 22:50 | 50.0 | | 32.0 | 0.84 | | 13.1 | | 3.90 | 0.520 | | | | | | | | |
| 2587372 | 6/22/2017 10:16 | 6/22/2017 18:20 | 39.0 | | 26.0 | 0.28 | | 4.8 | | 1.60 | 0.140 < | | | | | | | | |
| 2588805 | 6/28/2017 4:50 | 6/28/2017 6:38 | 79.0 | | 42.0 | 0.29 | | 3.4 | | 1.60 | 0.110 < | | | | | | | | |
| 2588807 | 6/28/2017 11:00 | 6/28/2017 11:00 | | | | | | | | | | | | | | | | | 12100 |
| 2594424 | 7/17/2017 22:20 | 7/17/2017 23:52 | 104.0 | | 56.0 | 0.43 | 0.006 J | 2.9 | | 2.90 | 0.080 < | 15 J | 0.0115 | 0.0099 | 0.04830 | | | | |
| 2595190 | 7/19/2017 16:20 | 7/20/2017 0:05 | 103.0 | | 54.0 | 0.31 | | 5.3 | | 2.40 | 0.080 < | | | | | | | | |
| 2597243 | 7/26/2017 4:35 | 7/26/2017 4:58 | 58.0 | | 20.0 | 0.07 | | 2.0 < | | 0.36 | 0.270 < | | | | | | | | |
| 2599951 | 8/3/2017 7:30 | 8/3/2017 9:07 | 110.0 | | 48.0 | 0.46 | | 5.1 | | 2.40 | 0.080 < | 28 | 0.0189 | 0.0152 | 0.08130 | | | | |
| 2600534 | 8/6/2017 14:24 | 8/6/2017 16:05 | 84.0 | 24.0 | 22.0 | 0.23 | | 2.1 | 0.15 | 1.40 | 0.280 < | | | | | | 6.30 | 4.4 | |
| 2601232 | 8/9/2017 12:40 | 8/9/2017 12:40 | | | | | | | | | | | | | | | | | 1986 |
| 2601542 | 8/9/2017 12:35 | 8/9/2017 18:21 | 66.0 | | 22.0 | 0.13 | | 2.0 < | | 1.10 | 0.320 < | | | | | | | | |
| 2601543 | 8/9/2017 23:20 | 8/10/2017 3:27 | 49.0 | | 20.0 | 0.17 | | 2.4 | | 1.50 | 0.130 < | | | | | | | | |
| 2602380 | 8/13/2017 23:30 | 8/14/2017 0:39 | 118.0 | | 32.0 | 0.28 | | 2.0 < | | 1.60 | 0.140 < | | | | | | | | |
| 2604585 | 8/16/2017 3:35 | 8/16/2017 10:20 | 84.0 | | 21.0 | 0.20 | | 3.2 | | 0.91 | 0.140 | | | | | | | | |
| 2604586 | 8/16/2017 20:00 | 8/16/2017 21:23 | 140.0 | | 33.0 | 0.28 | | 2.0 < | | 1.20 | 0.170 | | | | | | | | |
| 2606820 | 8/25/2017 7:00 | 8/25/2017 9:05 | 65.0 | | 36.0 | 0.28 | | 8.6 | | 2.20 | 0.100 < | | | | | | | | |
| 2613056 | 9/20/2017 3:25 | 9/20/2017 6:25 | 201.0 | | 66.0 | 0.53 | 0.085 | 4.3 | | 2.40 | 0.190 < | 15 J | 0.0212 | 0.0199 | 0.11400 | | | | |
| 2614544 | 9/25/2017 3:25 | 9/25/2017 7:20 | 68.0 | | 26.0 | 0.35 | | 2.5 | | 1.10 | 0.160 < | | | | | | | | |
| 2620364 | 10/14/2017 16:10 | 10/15/2017 1:05 | 24.0 | | 20.0 | 0.64 | 0.353 | 5.9 | | 1.70 | 0.080 < | 29 | 0.0110 | 0.0027 | 0.04800 | | | | |
| 2622452 | 10/21/2017 7:15 | 10/21/2017 11:20 | 161.0 | | 86.0 | 1.09 | | 7.8 | | 2.80 | 0.080 < | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| **MINIMUM** | | | **9.0** | **24.0** | **5.0** | **0.07** | **0.006** | **2.0** | **0.02** | **0.36** | **0.08** | **12** | **0.0** | **0.0** | **0.0** | **2.2** | **6.10** | **4.4** | **1986** |
| **AVERAGE** | | | **120.7** | **67.4** | **57.2** | **0.46** | **0.137** | **5.8** | **0.26** | **2.62** | **0.22** | **39** | **0.0** | **0.0** | **0.1** | **3.5** | **6.70** | **13.1** | **5502** |
| **MEDIAN** | | | **85.5** | **77.0** | **35.0** | **0.30** | **0.075** | **4.4** | **0.15** | **1.70** | **0.15** | **30** | **0.0** | **0.0** | **0.1** | **3.9** | **6.8** | **8.4** | **2420** |
| **MAXIMUM** | | | **1560.0** | **101.0** | **234.0** | **1.64** | **0.357** | **26.4** | **0.74** | **9.80** | **0.52** | **108** | **0.0** | **0.1** | **0.3** | **4.5** | **7.30** | **26.0** | **12100 >** |

Laboratory analysis was completed by Metroplian Council Environmental Services (The sample collected on 3/7/2016 was analyzed by Pace Analytical

Grab Sample

< - Analyte not detected above the Method Detection Limit (MDL), MDL value reported

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

# City of Saint Paul
# 2017 Water Quality and Quantity Report
# Table C.2
# WSB Job No.: 01610-100

## *BEACON BLUFF VOLUME AND POLLUTANT REDUCTION SUMMARY*

### Sampling Data

| Event Time Interval: Start | Event Time Interval: End | TSS | TDS | VSS | TP | Ortho-P | Chloride | Ammonia as N | Total Kjeldahl Nitrogen | Nitrate + Nitrite as N |
|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L |
| 4/19/2017 15:45 | 4/20/2017 14:54 | 196 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 4/25/2017 14:45 | 4/26/2017 12:24 | **25** | **51** | **12** | **0.17** | **0.08** | **3.9** | **0.34** | **1.10** | **0.20** < |
| 4/30/2017 21:30 | 5/1/2017 3:16 | 196 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 5/1/2017 6:15 | 5/1/2017 8:45 | **9** | **84** | **5** | **0.10** | **0.03** | **12.9** | **0.02** J | **0.67** J | **0.27** |
| 5/2/2017 10:45 | 5/2/2017 11:15 | 196 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 5/5/2017 8:45 | 5/5/2017 12:15 | 196 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 5/8/2017 22:15 | 5/9/2017 0:45 | 196 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 5/15/2017 13:45 | 5/15/2017 16:15 | **9** | **84** | **5** | **1.64** | 0.17 | **26.4** | 0.21 | **9.80** | **0.08** < |
| 5/16/2017 4:45 | 5/16/2017 8:30 | **598** | **77** | **182** | **1.08** | **0.22** | **4.9** | **0.74** | **6.80** | **0.42** |
| 5/16/2017 8:45 | 5/16/2017 12:45 | **306** | 67 | **106** | **0.65** | 0.17 | **5.8** | 0.21 | **3.60** | **0.32** |
| 5/17/2017 1:00 | 5/17/2017 6:22 | **96** | 67 | **38** | **0.26** | 0.17 | **3.7** | 0.21 | **1.50** | **0.35** |
| 5/17/2017 16:00 | 5/17/2017 17:00 | 196 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 5/17/2017 19:30 | 5/18/2017 4:00 | **376** | 67 | **74** | **0.42** | 0.17 | **2.3** | 0.21 | **2.10** | **0.16** < |
| 5/20/2017 9:45 | 5/20/2017 19:15 | **48** | 67 | **20** | **0.16** | 0.17 | **2.0** < | 0.21 | **0.92** | **0.13** < |
| 6/11/2017 9:00 | 6/11/2017 11:41 | **378** | **101** | **152** | **1.43** | **0.36** | **7.5** | **0.05** J | **6.40** | **0.08** < |
| 6/11/2017 18:30 | 6/11/2017 20:00 | 196 | 67 | 47 | 0.40 | 0.17 | **3.4** | 0.21 | 1.97 | 0.17 |
| 6/12/2017 15:00 | 6/12/2017 19:30 | **22** | 67 | **18** | **0.43** | 0.17 | **6.6** | 0.21 | **1.80** | **0.09** < |
| 6/14/2017 1:00 | 6/14/2017 3:30 | 196 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 6/17/2017 21:15 | 6/18/2017 4:00 | **50** | 67 | **32** | **0.84** | 0.17 | **13.1** | 0.21 | **3.90** | **0.52** |
| 6/20/2017 5:15 | 6/20/2017 10:00 | 196 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 6/22/2017 10:00 | 6/22/2017 20:30 | **39** | 67 | **26** | **0.28** | 0.17 | **4.8** | 0.21 | **1.60** | **0.14** < |
| 6/28/2017 4:45 | 6/28/2017 12:00 | **79** | 67 | **42** | **0.29** | 0.17 | 3.3 | 0.21 | **1.60** | **0.11** < |
| 6/30/2017 5:00 | 6/30/2017 6:41 | 196 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 7/12/2017 2:06 | 7/12/2017 5:32 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 7/17/2017 21:56 | 7/18/2017 1:42 | **104** | 67 | **56** | **0.43** | **0.01** J | **2.9** | 0.21 | **2.90** | **0.08** < |
| 7/19/2017 16:15 | 7/19/2017 17:56 | **103** | 67 | **54** | **0.31** | 0.17 | **5.3** | 0.21 | **2.40** | 0.17 < |
| 7/19/2017 22:45 | 7/20/2017 1:06 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 7/25/2017 18:21 | 7/25/2017 21:00 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 7/26/2017 4:21 | 7/26/2017 6:17 | **58** | 67 | **20** | **0.07** | 0.17 | **2.0** < | 0.21 | **0.36** | **0.27** < |
| 8/3/2017 7:26 | 8/3/2017 9:50 | **110** | 67 | **48** | **0.46** | 0.17 | **5.1** | 0.21 | **2.40** | **0.08** < |
| 8/5/2017 18:20 | 8/5/2017 20:01 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 8/6/2017 14:06 | 8/6/2017 15:30 | **84** | **24** | **22** | **0.23** | 0.17 | **2.1** | **0.15** | **1.40** | **0.28** < |
| 8/6/2017 20:00 | 8/6/2017 21:40 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 8/9/2017 12:30 | 8/9/2017 19:18 | **66** | 67 | **22** | **0.13** | 0.17 | **2.0** < | 0.21 | **1.10** | **0.32** < |
| 8/9/2017 23:15 | 8/10/2017 2:30 | **49** | 67 | **20** | **0.17** | 0.17 | **2.4** | 0.21 | **1.50** | **0.13** < |
| 8/10/2017 16:06 | 8/10/2017 17:20 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 8/13/2017 23:26 | 8/14/2017 2:22 | **118** | 67 | **32** | **0.28** | 0.17 | **2.0** < | 0.21 | **1.60** | **0.14** < |
| 8/16/2017 3:30 | 8/16/2017 6:11 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 8/16/2017 7:32 | 8/16/2017 10:21 | **84** | 67 | **21** | **0.20** | 0.17 | **3.2** | 0.21 | **0.91** | **0.14** |
| 8/16/2017 19:56 | 8/17/2017 1:04 | **140** | 67 | **33** | **0.28** | 0.17 | **2.0** < | 0.21 | **1.20** | **0.17** |
| 8/17/2017 4:45 | 8/17/2017 6:44 | 100 | 67 | 47 | 0.40 | 0.17 | **3.4** | 0.21 | 1.97 | 0.17 |
| 8/25/2017 6:56 | 8/25/2017 9:17 | **65** | 67 | **36** | **0.28** | 0.17 | **8.6** | 0.21 | **2.20** | **0.10** < |
| 8/25/2017 23:26 | 8/26/2017 7:26 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 8/26/2017 15:06 | 8/26/2017 17:31 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 8/27/2017 15:30 | 8/27/2017 17:10 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 8/30/2017 15:30 | 8/30/2017 16:35 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 9/4/2017 17:45 | 9/4/2017 19:01 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 9/18/2017 10:26 | 9/18/2017 17:15 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 9/20/2017 3:21 | 9/20/2017 6:25 | **201** | 67 | **66** | **0.53** | **0.09** | **4.3** | 0.21 | **2.40** | **0.19** < |
| 9/25/2017 3:21 | 9/25/2017 9:26 | **68** | 67 | **26** | **0.35** | 0.17 | **2.5** | 0.21 | **1.10** | **0.16** < |
| 9/25/2017 22:30 | 9/26/2017 9:54 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/1/2017 12:56 | 10/1/2017 15:35 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/1/2017 20:30 | 10/1/2017 22:13 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/2/2017 2:15 | 10/2/2017 6:40 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/2/2017 17:45 | 10/2/2017 22:27 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/2/2017 23:22 | 10/3/2017 2:55 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/6/2017 14:36 | 10/6/2017 19:00 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/7/2017 3:15 | 10/7/2017 9:34 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/7/2017 11:26 | 10/7/2017 14:30 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/14/2017 15:30 | 10/14/2017 18:48 | **24** | 67 | **20** | **0.64** | **0.35** | **5.9** | 0.21 | **1.70** | **0.08** < |
| 10/14/2017 19:25 | 10/14/2017 22:24 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/14/2017 23:30 | 10/15/2017 4:23 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/21/2017 7:11 | 10/21/2017 8:57 | **161** | 67 | **86** | **1.09** | 0.17 | **7.8** | 0.21 | **2.80** | **0.08** < |
| 10/21/2017 9:31 | 10/21/2017 12:13 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 10/27/2017 4:45 | 10/27/2017 21:41 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| 11/1/2017 16:59 | 11/1/2017 21:46 | 100 | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.17 |
| **Sum** | | | | | | | | | | |
| **Average** | | 124 | 70 | 46 | 0.47 | 0.16 | 5.5 | 0.26 | 2.42 | 0.19 |
| **Weighted Ave** | | 196 / 100* | 67 | 47 | 0.40 | 0.17 | 3.3 | 0.21 | 1.97 | 0.16 |
| **STDEV** | | 135 | 28 | 42 | 0.40 | 0.15 | 5.1 | 0.30 | 2.09 | 0.11 |
| **Median** | | 82 | 81 | 32 | 0.30 | 0.09 | 4.1 | 0.15 | 1.65 | 0.15 |
| **Min** | | 9 | 24 | 5 | 0.07 | 0.01 | 2.0 | 0.02 | 0.36 | 0.08 |
| **Max** | | 598 | 101 | 182 | 1.64 | 0.36 | 26.4 | 0.74 | 9.80 | 0.52 |
| **Percent Capture of Total Runoff** | | | | | | | | | | |

### Event Loading and Volume Data[1]

| Start | End | Interval Rain | Runoff Volume Draining to Diversion Structure (Subwatershed A) [Diversion Structure on Duchess Street] | Volume Directed from Diversion Structure to Downstream Storm Sewer (Bypassed Volume) [Diversion Structure on Duchess Street] | Volume Directed from Diversion Structure into Surface Basin (1) [Diversion Structure on Duchess Street] | Inflow Volume from West Pond (Subwatershed B - Discharges to Underground System) (2) | Inflow Volume from Eastern Inlet (Subwatershed C - Discharges to Surface Basin)[2] (3) | Underground System Discharged Volume (4) | Volume Captured by BMP (1+2+3)-4 | % of Total Inflow to BMP from Diversion Structure | Overall Volume reduction | Captured TSS | Captured VSS | Captured TP | Captured Ortho-P | Captured Chloride | Captured Total Kjeldahl Nitrogen | Captured Nitrate + Nitrite as N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | In. | cf | cf | cf | cf | cf | cf | cf | | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 4/19/2017 15:45 | 4/20/2017 14:54 | 0.98 | 83802 | 28931 | 54871 | 14087 | 4003 | 6340 | 66621 | 69.3% | 65.4% | 815.2 | 193.4 | 1.66 | 0.71 | 13.9 | 8.19 | 0.69 |
| 4/25/2017 14:45 | 4/26/2017 12:24 | 0.83 | 128917 | 11029 | 117887 | 8779 | 6158 | 2318 | 130506 | 88.0% | 90.7% | 203.7 | 97.8 | 1.39 | 0.61 | 31.8 | 8.96 | 1.63 |
| 4/30/2017 21:30 | 5/1/2017 3:16 | 0.81 | 86104 | 24678 | 61426 | 7739 | 4113 | 0 | 73278 | 81.9% | 74.8% | 896.6 | 212.7 | 1.83 | 0.78 | 15.3 | 9.01 | 0.75 |
| 5/1/2017 6:15 | 5/1/2017 8:45 | 0.02 | 525 | 0 | 525 | 1 | 25 | 0 | 551 | 95.3% | 100.0% | 0.3 | 0.2 | 0.00 | 0.00 | 0.4 | 0.02 | 0.01 |
| 5/2/2017 10:45 | 5/2/2017 11:15 | 0.00 | 1070 | 0 | 1070 | 0 | 51 | 0 | 1121 | 95.4% | 100.0% | 13.7 | 3.3 | 0.03 | 0.01 | 0.2 | 0.14 | 0.01 |
| 5/5/2017 8:45 | 5/5/2017 12:15 | 0.00 | 1168 | 0 | 1168 | 0 | 56 | 0 | 1224 | 95.4% | 100.0% | 15.0 | 3.6 | 0.03 | 0.01 | 0.3 | 0.15 | 0.01 |
| 5/8/2017 22:15 | 5/9/2017 0:45 | 0.18 | 13703 | 2937 | 10766 | 0 | 655 | 0 | 11420 | 94.3% | 79.5% | 139.7 | 33.2 | 0.29 | 0.12 | 2.4 | 1.40 | 0.12 |
| 5/15/2017 13:45 | 5/15/2017 16:15 | 0.24 | 12278 | 2295 | 9983 | 0 | 586 | 0 | 10570 | 94.5% | 82.2% | 5.9 | 3.3 | 1.08 | 0.11 | 17.4 | 6.47 | 0.05 |
| 5/16/2017 4:45 | 5/16/2017 8:30 | 0.47 | 40023 | 15106 | 24917 | 0 | 1912 | 0 | 26829 | 92.9% | 64.0% | 1001.6 | 304.8 | 1.81 | 0.37 | 8.2 | 11.39 | 0.70 |
| 5/16/2017 8:45 | 5/16/2017 12:45 | 0.11 | 15414 | 2277 | 13137 | 128 | 736 | 0 | 14002 | 93.8% | 86.0% | 267.5 | 92.7 | 0.56 | 0.15 | 5.1 | 3.15 | 0.28 |
| 5/17/2017 1:00 | 5/17/2017 6:22 | 0.53 | 65928 | 11901 | 54027 | 11428 | 3149 | 7702 | 60902 | 74.5% | 75.7% | 365.0 | 144.5 | 0.98 | 0.65 | 14.1 | 5.70 | 1.33 |
| 5/17/2017 16:00 | 5/17/2017 17:00 | 0.03 | 2216 | 0 | 2216 | 0 | 106 | 0 | 2321 | 95.4% | 100.0% | 28.4 | 6.7 | 0.06 | 0.02 | 0.5 | 0.29 | 0.02 |
| 5/17/2017 19:30 | 5/18/2017 4:00 | 1.41 | 230000 | 55277 | 174723 | 18149 | 10986 | 30629 | 173229 | 84.3% | 66.8% | 4066.2 | 800.3 | 4.57 | 1.84 | 24.9 | 22.71 | 1.73 |
| 5/20/2017 9:45 | 5/20/2017 19:15 | 1.32 | 235954 | 53776 | 182178 | 55682 | 11271 | 37034 | 212097 | 65.4% | 70.0% | 635.6 | 264.8 | 2.09 | 2.25 | 26.5 | 12.18 | 1.72 |
| 6/11/2017 9:00 | 6/11/2017 11:41 | 0.65 | 183913 | 27399 | 156515 | 670 | 8785 | 0 | 165970 | 94.3% | 85.8% | 3916.5 | 1574.9 | 14.82 | 3.70 | 77.7 | 66.31 | 0.83 |
| 6/11/2017 18:30 | 6/11/2017 20:00 | 0.06 | 26991 | 2380 | 24611 | 3 | 1289 | 0 | 25903 | 95.0% | 91.6% | 316.9 | 75.2 | 0.65 | 0.27 | 5.5 | 3.19 | 0.27 |
| 6/12/2017 15:00 | 6/12/2017 19:30 | 0.26 | 25711 | 764 | 24947 | 0 | 1228 | 0 | 26175 | 95.3% | 97.2% | 35.9 | 29.4 | 0.70 | 0.28 | 10.8 | 2.94 | 0.15 |
| 6/14/2017 1:00 | 6/14/2017 3:30 | 0.20 | 31114 | 3622 | 27492 | 0 | 1486 | 0 | 28978 | 94.9% | 88.9% | 354.6 | 84.1 | 0.72 | 0.31 | 6.0 | 3.56 | 0.30 |
| 6/17/2017 21:15 | 6/18/2017 4:00 | 0.15 | 7374 | 494 | 6879 | 0 | 352 | 0 | 7232 | 95.1% | 93.6% | 22.6 | 14.4 | 0.38 | 0.08 | 5.9 | 1.76 | 0.23 |
| 6/20/2017 5:15 | 6/20/2017 10:00 | 0.12 | 6315 | 150 | 6165 | 0 | 302 | 0 | 6467 | 95.3% | 97.7% | 79.1 | 18.8 | 0.16 | 0.07 | 1.3 | 0.80 | 0.07 |
| 6/22/2017 10:00 | 6/22/2017 20:30 | 0.39 | 41630 | 10013 | 31617 | 0 | 1989 | 0 | 33606 | 94.1% | 77.0% | 81.8 | 54.5 | 0.58 | 0.36 | 10.1 | 3.36 | 0.29 |
| 6/28/2017 4:45 | 6/28/2017 12:00 | 0.61 | 124884 | 18306 | 106578 | 453 | 5965 | 0 | 112997 | 94.3% | 86.1% | 557.3 | 296.3 | 2.03 | 1.20 | 23.6 | 11.29 | 0.78 |
| 6/30/2017 5:00 | 6/30/2017 6:41 | 0.00 | 13916 | 1179 | 12738 | 0 | 665 | 0 | 13403 | 95.0% | 91.9% | 164.0 | 38.9 | 0.33 | 0.14 | 2.8 | 1.65 | 0.14 |
| 7/12/2017 2:06 | 7/12/2017 5:32 | 0.03 | 2070 | 342 | 1728 | 0 | 99 | 0 | 1827 | 94.6% | 84.2% | 11.4 | 5.3 | 0.05 | 0.02 | 0.4 | 0.22 | 0.02 |
| 7/17/2017 21:56 | 7/18/2017 1:42 | 1.22 | 157846 | 30873 | 126973 | 0 | 7540 | 0 | 134513 | 94.4% | 81.3% | 873.3 | 470.3 | 3.59 | 0.05 | 24.4 | 24.35 | 0.67 |
| 7/19/2017 16:15 | 7/19/2017 17:56 | 0.04 | 634 | 0 | 634 | 0 | 30 | 0 | 665 | 95.4% | 100.0% | 4.3 | 2.2 | 0.01 | 0.01 | 0.2 | 0.10 | 0.01 |
| 7/19/2017 22:45 | 7/20/2017 1:06 | 0.10 | 25805 | 3541 | 22264 | 0 | 1233 | 0 | 23497 | 94.8% | 86.9% | 146.5 | 68.2 | 0.59 | 0.25 | 4.9 | 2.89 | 0.24 |
| 7/25/2017 18:21 | 7/25/2017 21:00 | 0.25 | 98325 | 16828 | 81497 | 1143 | 4697 | 0 | 87337 | 93.2% | 83.8% | 544.7 | 253.5 | 2.18 | 0.93 | 18.2 | 10.74 | 0.90 |
| 7/26/2017 4:21 | 7/26/2017 6:17 | 0.60 | 102109 | 25161 | 76948 | 1 | 4877 | 0 | 81826 | 94.0% | 76.5% | 296.3 | 102.2 | 0.38 | 0.87 | 10.2 | 1.84 | 1.38 |
| 8/3/2017 7:26 | 8/3/2017 9:50 | 0.40 | 57573 | 7474 | 50099 | 0 | 2750 | 0 | 52850 | 94.8% | 87.6% | 362.9 | 158.4 | 1.53 | 0.56 | 16.8 | 7.92 | 0.26 |
| 8/5/2017 18:20 | 8/5/2017 20:01 | 0.00 | 5920 | 26 | 5895 | 171 | 283 | 0 | 6348 | 92.7% | 99.6% | 39.6 | 18.4 | 0.16 | 0.07 | 1.3 | 0.78 | 0.07 |
| 8/6/2017 14:06 | 8/6/2017 15:30 | 0.80 | 112344 | 49199 | 63144 | 1 | 5366 | 0 | 68511 | 92.2% | 58.2% | 359.3 | 94.1 | 0.97 | 0.73 | 9.0 | 5.99 | 1.20 |
| 8/6/2017 20:00 | 8/6/2017 21:40 | 0.09 | 13665 | 52 | 13613 | 0 | 653 | 0 | 14266 | 95.4% | 99.6% | 89.0 | 41.4 | 0.36 | 0.15 | 3.0 | 1.75 | 0.15 |
| 8/9/2017 12:30 | 8/9/2017 19:18 | 0.23 | 72526 | 8473 | 64053 | 7480 | 3464 | 0 | 74998 | 83.8% | 89.8% | 309.0 | 103.0 | 0.62 | 0.80 | 9.4 | 5.15 | 1.50 |
| 8/9/2017 23:15 | 8/10/2017 2:30 | 0.20 | 59244 | 9083 | 50161 | 2 | 2830 | 0 | 52993 | 94.7% | 85.4% | 162.1 | 66.2 | 0.56 | 0.56 | 7.9 | 4.96 | 0.43 |
| 8/10/2017 16:06 | 8/10/2017 17:20 | 0.16 | 21066 | 3340 | 17727 | 1 | 1006 | 3332 | 15402 | 94.6% | 69.8% | 96.1 | 44.7 | 0.38 | 0.16 | 3.2 | 1.89 | 0.16 |
| 8/13/2017 23:26 | 8/14/2017 2:22 | 1.26 | 240867 | 91077 | 149790 | 2 | 11505 | 15801 | 145497 | 92.9% | 57.7% | 1071.8 | 290.7 | 2.51 | 1.54 | 18.2 | 14.53 | 1.27 |
| 8/16/2017 3:30 | 8/16/2017 6:11 | 0.38 | 62866 | 16985 | 45881 | 1387 | 3003 | 0 | 50271 | 91.0% | 74.7% | 313.5 | 145.9 | 1.26 | 0.53 | 10.5 | 6.18 | 0.52 |
| 8/16/2017 7:32 | 8/16/2017 10:21 | 0.23 | 42714 | 7750 | 34964 | 9898 | 2040 | 0 | 46903 | 67.7% | 85.8% | 246.0 | 61.5 | 0.59 | 0.50 | 9.4 | 2.66 | 0.41 |
| 8/16/2017 19:56 | 8/17/2017 1:04 | 1.00 | 253893 | 63230 | 190663 | 234 | 12128 | 36788 | 166237 | 93.9% | 62.4% | 1452.9 | 342.5 | 2.91 | 1.76 | 20.8 | 12.45 | 1.76 |
| 8/17/2017 4:45 | 8/17/2017 6:44 | 0.09 | 10771 | 71 | 10700 | 2 | 514 | 0 | 11216 | 95.4% | 99.4% | 70.0 | 32.6 | 0.28 | 0.12 | 2.4 | 1.38 | 0.12 |
| 8/25/2017 6:56 | 8/25/2017 9:17 | 0.20 | 21305 | 417 | 20888 | 130 | 1018 | 0 | 22035 | 94.8% | 98.1% | 89.4 | 49.5 | 0.39 | 0.23 | 11.8 | 3.03 | 0.14 |
| 8/25/2017 23:26 | 8/26/2017 7:26 | 0.82 | 155932 | 35015 | 120917 | 148 | 7448 | 8261 | 120252 | 94.1% | 73.5% | 750.0 | 349.1 | 3.00 | 1.28 | 25.1 | 14.79 | 1.24 |
| 8/26/2017 15:06 | 8/26/2017 17:31 | 0.06 | 7312 | 0 | 7312 | 2 | 349 | 0 | 7664 | 95.4% | 100.0% | 47.8 | 22.2 | 0.19 | 0.08 | 1.6 | 0.94 | 0.08 |
| 8/27/2017 15:30 | 8/27/2017 17:10 | 0.15 | 4486 | 141 | 4344 | 2 | 214 | 0 | 4561 | 95.3% | 97.0% | 28.4 | 13.2 | 0.11 | 0.05 | 1.0 | 0.56 | 0.05 |
| 8/30/2017 15:30 | 8/30/2017 16:35 | 0.02 | 9048 | 856 | 8192 | 2 | 432 | 0 | 8626 | 95.0% | 91.0% | 53.8 | 25.0 | 0.22 | 0.09 | 1.8 | 1.06 | 0.09 |
| 9/4/2017 17:45 | 9/4/2017 19:01 | 0.09 | 6072 | 424 | 5648 | 0 | 290 | 0 | 5938 | 95.1% | 93.3% | 37.0 | 17.2 | 0.15 | 0.06 | 1.2 | 0.73 | 0.06 |
| 9/18/2017 10:26 | 9/18/2017 17:15 | 0.35 | 35770 | 2231 | 33538 | 2 | 1709 | 0 | 35249 | 95.1% | 94.0% | 219.8 | 102.3 | 0.88 | 0.37 | 7.3 | 4.33 | 0.36 |
| 9/20/2017 3:21 | 9/20/2017 6:25 | 0.16 | 23906 | 3328 | 20578 | 0 | 1142 | 0 | 21720 | 94.7% | 86.7% | 272.5 | 89.5 | 0.72 | 0.12 | 5.8 | 3.25 | 0.26 |
| 9/25/2017 3:21 | 9/25/2017 9:26 | 0.92 | 159066 | 32427 | 126639 | 0 | 7598 | 0 | 134237 | 94.3% | 80.5% | 569.8 | 217.9 | 2.92 | 1.42 | 21.0 | 9.22 | 1.34 |
| 9/25/2017 22:30 | 9/26/2017 9:54 | 0.13 | 9521 | 0 | 9521 | 0 | 455 | 0 | 9975 | 95.4% | 100.0% | 62.2 | 29.0 | 0.25 | 0.11 | 2.1 | 1.23 | 0.10 |
| 10/1/2017 12:56 | 10/1/2017 15:35 | 0.08 | 9016 | 0 | 9016 | 4 | 431 | 0 | 9451 | 95.4% | 100.0% | 58.9 | 27.4 | 0.24 | 0.10 | 2.0 | 1.16 | 0.10 |
| 10/1/2017 20:30 | 10/1/2017 22:13 | 0.06 | 5035 | 2 | 5033 | 2 | 241 | 0 | 5275 | 95.4% | 100.0% | 32.9 | 15.3 | 0.13 | 0.06 | 1.1 | 0.65 | 0.05 |
| 10/2/2017 2:15 | 10/2/2017 6:40 | 0.30 | 66496 | 13190 | 53306 | 27409 | 3176 | 0 | 83891 | 45.8% | 86.4% | 523.2 | 243.5 | 2.09 | 0.89 | 17.5 | 10.32 | 0.86 |
| 10/2/2017 17:45 | 10/2/2017 22:27 | 1.43 | 324120 | 87527 | 236593 | 327 | 15482 | 37729 | 214673 | 93.7% | 63.2% | 1338.8 | 623.2 | 5.36 | 2.28 | 44.8 | 26.40 | 2.21 |
| 10/2/2017 23:22 | 10/3/2017 2:55 | 0.14 | 43797 | 124 | 43672 | 0 | 2092 | 1546 | 44218 | 95.4% | 96.4% | 275.8 | 128.4 | 1.10 | 0.47 | 9.2 | 5.44 | 0.46 |
| 10/6/2017 14:36 | 10/6/2017 19:00 | 0.58 | 92847 | 12195 | 80651 | 0 | 4435 | 0 | 85086 | 94.8% | 87.5% | 530.6 | 247.0 | 2.12 | 0.90 | 17.7 | 10.46 | 0.88 |
| 10/7/2017 3:15 | 10/7/2017 9:34 | 0.21 | 28484 | 2658 | 25826 | 0 | 1361 | 0 | 27186 | 95.0% | 91.1% | 169.5 | 78.9 | 0.68 | 0.29 | 5.7 | 3.34 | 0.28 |
| 10/7/2017 11:26 | 10/7/2017 14:30 | 0.04 | 5783 | 0 | 5783 | 0 | 276 | 0 | 6059 | 95.4% | 100.0% | 37.8 | 17.6 | 0.15 | 0.06 | 1.3 | 0.75 | 0.06 |
| 10/14/2017 15:30 | 10/14/2017 18:48 | 0.16 | 17583 | 425 | 17159 | 1 | 840 | 0 | 17999 | 95.3% | 97.7% | 27.0 | 22.5 | 0.72 | 0.40 | 6.6 | 1.91 | 0.09 |
| 10/14/2017 19:25 | 10/14/2017 22:24 | 0.19 | 31285 | 5131 | 26153 | 3 | 1494 | 0 | 27651 | 94.6% | 84.3% | 172.4 | 80.3 | 0.69 | 0.29 | 5.8 | 3.40 | 0.28 |
| 10/14/2017 23:30 | 10/15/2017 4:23 | 0.06 | 2329 | 0 | 2329 | 7 | 111 | 0 | 2447 | 95.2% | 100.0% | 15.3 | 7.1 | 0.06 | 0.03 | 0.5 | 0.30 | 0.03 |
| 10/21/2017 7:11 | 10/21/2017 8:57 | 0.18 | 20314 | 11489 | 8825 | 0 | 970 | 0 | 9795 | 90.1% | 46.0% | 98.5 | 52.6 | 0.67 | 0.10 | 4.8 | 1.71 | 0.05 |
| 10/21/2017 9:31 | 10/21/2017 12:13 | 0.15 | 8982 | 1594 | 7388 | 0 | 429 | 0 | 7817 | 94.5% | 83.1% | 48.8 | 22.7 | 0.20 | 0.08 | 1.6 | 0.96 | 0.08 |
| 10/27/2017 4:45 | 10/27/2017 21:41 | 0.29 | 16794 | 0 | 16793 | 0 | 802 | 0 | 17596 | 95.4% | 100.0% | 109.7 | 51.1 | 0.44 | 0.19 | 3.7 | 2.16 | 0.18 |
| 11/1/2017 16:59 | 11/1/2017 21:46 | 0.09 | 2801 | 0 | 2801 | 0 | 134 | 0 | 2935 | 95.4% | 100.0% | 18.3 | 8.5 | 0.07 | 0.03 | 0.6 | 0.36 | 0.03 |
| **Sum** | | 24.06 | 4,156,841 | 822,186 | 3,075,989 | 171,540 | 186,201 | 193,840 | **3,239,891** | | | **26,747** | **9,384** | **80.9** | **34.3** | **690.2** | **407.1** | **33.2** |
| **Average** | | 0.26 | 1,846 | 9,035 | 33,802 | 1,885 | 88 | 1,965 | 35,603 | | | 293.9 | 103.1 | 0.89 | 0.38 | 3.8 | 2.4 | 0.4 |
| **Weighted Ave** | | | | | | | | | | | | | | | | | | |
| **STDEV** | | | | | | | | | | | | | | | | | | |
| **Median** | | | | | | | | | | | | | | | | | | |
| **Min** | | | | | | | | | | | | | | | | | | |
| **Max** | | | | | | | | | | | | | | | | | | |
| **Percent Capture of Total Runoff** | | | | | | | | | **71.8%** | | | **74.7%** | **76.6%** | **77.3%** | **76.2%** | **78.4%** | **77.3%** | **75.7%** |

< Sample Was not detected above the method detection limit (MDL) - MDL is reported
J Result reported as estimated between the MDL and the Reporting Limit (RL)
**BOLD** Sampled Event
GREY Events with no sampling data (weighted average used)
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)
* The weighted average for TSS was calucated seperately for April-June and July-November

City of Saint Paul
2017 Water Quality and Quantity Report
Table C.3
WSB Project Number: 01610-100

# HAMPDEN PARK WATER QUALITY SUMMARY

| LAB ID | Date Composite Sampling Started | Date Composite Sampling Ended | TSS (mg/L) | TDS (mg/L) | VSS (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) | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2555046 | 2/13/2017 12:30 | 2/13/2017 12:30 | 425.0 | 3390.0 | 135.0 J | 0.99 | 0.205 | 3961 | 4.66 | 12.00 | 0.270 | 232 | 0.0507 | 0.0276 | 0.335 | 41.00 | 7.30 | 48.0 | 17000 |
| 2570776 | 4/19/2017 15:19 | 4/19/2017 21:24 | 14.0 | | 6.0 | 0.09 | 0.025 | 5.10 | | 0.51 | 0.200 < | 10 < | 0.0032 | 0.0018 | 0.025 | | | | |
| 2571923 | 4/26/2017 9:30 | 4/26/2017 9:30 | 22.0 | 29.0 | 8.0 | 0.07 | 0.025 | 2.90 | 0.31 | 0.71 | 0.110 < | 10 < | 0.0045 | 0.0024 | 0.041 | 1.57 | 7.10 | 3.2 | 25 |
| 2572293 | 4/25/2017 16:39 | 4/25/2017 22:59 | 14.0 | | 10.0 | 0.13 | | 11.10 | | 1.30 | 0.250 | | | | | | | | |
| 2572294 | 4/26/2017 3:14 | 4/26/2017 10:10 | 8.0 | | 4.0 | 0.05 J | 0.023 | 2.70 | | 0.72 | 0.320 < | 10 < | 0.0021 | 0.0013 | 0.018 | | | | |
| 2573224 | 4/30/2017 22:00 | 5/1/2017 3:17 | 36.0 | | 11.0 | 0.07 | | 2.00 < | | 0.44 | 0.080 < | | | | | | | | |
| 2575261 | 5/8/2017 22:40 | 5/9/2017 0:14 | | | | 0.14 | | 3.00 | | 1.70 | 0.460 < | | | | | | | | |
| 2577662 | 5/17/2017 1:25 | 5/17/2017 7:27 | 34.0 | | 10.0 | 0.06 | | 2.10 | | 1.00 | 0.360 < | | | | | | | | |
| 2578170 | 5/17/2017 19:55 | 5/18/2017 4:45 | 28.0 | | 10.0 | 0.11 | | 2.20 | | 0.72 | 0.290 < | | | | | | | | |
| 2578980 | 5/20/2017 9:35 | 5/20/2017 18:41 | 21700.0 | | 210.0 J | 0.04 J | | 3.60 | | 0.39 | 0.160 < | 12 | 0.0037 | 0.0051 | 0.023 | | | | |
| 2584328 | 6/11/2017 9:10 | 6/11/2017 11:54 | 24.0 | 57.0 | 13.0 | 0.21 | 0.070 | 4.20 | 0.04 J | 1.50 | 0.320 | 20 | 0.0085 | 0.0049 | 0.046 | 2.78 | 6.80 | 8.3 > | |
| 2584968 | 6/12/2017 15:15 | 6/12/2017 17:47 | 23.0 | | 13.0 | 0.16 | | 3.80 | | 1.00 | 0.450 | | | | | | | | |
| 2584969 | 6/14/2017 1:10 | 6/14/2017 3:05 | | | | 0.16 | | 2.20 | | 0.98 | 0.410 < | | | | | | | | |
| 2586066 | 6/17/2017 21:15 | 6/18/2017 2:12 | 19.0 | | 15.0 | 0.10 | | 2.20 | | 0.72 | 0.260 < | | | | | | | | |
| 2588806 | 6/28/2017 4:35 | 6/28/2017 5:36 | 773.0 | | 177.0 | 0.46 | | 2.00 < | | 2.80 | 0.190 < | | | | | | | | |
| 2594426 | 7/17/2017 22:15 | 7/18/2017 1:23 | 235.0 | | 29.0 J | 0.17 | 0.006 J | 2.00 < | | 1.20 | 0.400 < | 17 J | 0.0078 | 0.0041 | 0.083 | | | | |
| 2597244 | 7/25/2017 18:00 | 7/25/2017 20:33 | 48.0 | | 14.0 | 0.12 | | 5.70 | | 1.50 | 0.390 < | | | | | | | | |
| 2597245 | 7/26/2017 4:10 | 7/26/2017 5:51 | 31.0 | | 10.0 | 0.10 | | 2.00 < | | 0.67 | 0.230 < | | | | | | | | |
| 2601233 | 8/9/2017 13:05 | 8/9/2017 13:05 | | | | | | | | | | | | | | | | | 931 |
| 2601540 | 8/9/2017 12:15 | 8/10/2017 18:18 | 16.0 | 41.0 | 9.0 | 0.04 J | 0.005 < | 2.80 | 0.10 | 0.63 | 0.270 | 22 J | 0.0059 | 0.0020 | 0.032 | | 7.40 | 4.8 | |
| 2601544 | 8/10/2017 0:15 | 8/10/2017 2:00 | 10.0 | | 5.0 J | 0.02 < | | 2.00 < | | 0.48 | 0.320 < | | | | | | | | |
| 2602382 | 8/13/2017 19:35 | 8/13/2017 23:16 | 46.0 | | 20.0 | 0.31 | | 15.20 | | 1.40 | 0.160 < | | | | | | | | |
| 2612759 | 9/18/2017 10:10 | 9/18/2017 16:34 | 83.0 | | 60.0 | 0.183 | 0.016 | 6.20 | | 1.50 | 0.130 < | 20 J | 0.0155 | 0.0024 | 0.073 | | | | |
| 2613058 | 9/20/2017 3:20 | 9/20/2017 3:45 | 10.0 | | 5.0 | 0.093 | | 2.00 < | | 1.00 | 0.470 < | | | | | | | | |
| 2614545 | 9/25/2017 3:21 | 9/25/2017 6:51 | 20.0 | | 12.0 | 0.096 | | 4.20 | | 0.84 | 0.330 < | | | | | | | | |
| 2617106 | 10/2/2017 2:23 | 10/2/2017 19:55 | 51.0 | | 17.0 | 0.103 | | 2.00 < | | 0.68 | 0.220 < | | | | | | | | |
| 2618754 | 10/6/2017 14:56 | 10/7/2017 0:28 | 4.0 | | 3.0 | 0.035 J | | 9.30 | | 0.52 | 0.490 | | | | | | | | |
| 2620366 | 10/14/2017 15:10 | 10/15/2017 4:42 | 11.0 | | 8.0 | 0.062 | 0.005 < | 4.50 | | 0.68 | 0.120 < | 27 | 0.0062 | 0.0009 | 0.037 | | | | |
| 2622453 | 10/21/2017 7:21 | 10/21/2017 11:48 | 8.0 | | 6.0 | 0.069 | 0.005 < | 3.60 | | 0.65 | 0.150 < | 21 J | 0.0048 | 0.0007 | 0.025 | | | | |
| **MINIMUM** | | | **4** | **29.0** | **3.0** | **0.020** | **0.005** | **2.0** | **0.04** | **0.39** | **0.08** | **10** | **0.0** | **0.0** | **0.0** | **0.00** | **6.8** | **3.2** | **25** |
| **AVERAGE** | | | **931** | **42.3** | **27.4** | **0.120** | **0.020** | **4.1** | **0.10** | **0.97** | **0.28** | **17** | **0.0** | **0.0** | **0.0** | **2.18** | **7.1** | **5.4** | **478** |
| **MEDIAN** | | | **23** | **41** | **10.0** | **0.096** | **0.016** | **2.9** | **0.10** | **0.72** | **0.27** | **19** | **0.0** | **0.0** | **0** | **2.18** | **7.1** | **4.8** | **478** |
| **MAXIMUM** | | | **21700** | **57.0** | **210.0** | **0.463** | **0.070** | **15.2** | **0.31** | **2.80** | **0.49** | **27** | **0.0** | **0.0** | **0** | **2.78** | **7.4** | **8.3** | **931** |

Laboratory analysis was completed by Metroplian Council Environmental Services (The sample collected on 3/7/2016 was analyzed by Pace Analytical
Grab Sample
< - Analyte not detected above the Method Detection Limit (MDL), MDL value reported
J - Result reported as estimated between the MDL and Reporting Limit (RL)

City of Saint Paul
2017 Water Quality and Quantity Report
Table C.4
WSB Project No.: 01610-100

# HAMPDEN PARK VOLUME AND POLLUTANT REDUCTION SUMMARY

| Event Time Interval | | Sampling Data | | | | | | | | | Event Loading and Volume Data | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TSS | TDS | VSS | TP | Ortho-P | Chloride | Ammonia as N | Total Kjeldahl Nitrogen | Nitrate + Nitrite as N | Interval Rain | Hampden/Raymond Inflow Volume (1) | Eastern Hampden Modeled Inflow Volume[1] (2) | Bypass Volume2 (3) | Volume Captured by BMP (1+2-3) | Percent Captured | Captured TSS | Captured VSS | Captured TP | Captured Ortho-P | Captured Chloride | Captured Total Nitrogen[4] | 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 | mg/L | mg/L | In. | cu-ft | cu-ft | cu-ft | cu-ft | | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 3/29/17 21:00 | 3/30/17 11:40 | 26 | 44 | 17 | 0.114 | 0.02 | 3.9 | 0.14 | 0.87 | 0.25 | 0.16 | 1688.5 | 279 | 0 | 1967.1 | 100% | 3.2 | 2.1 | 0.01 | 0.003 | 0.48 | 0.14 | 0.11 | 0.03 |
| 4/3/17 20:50 | 4/4/17 6:20 | 26 | 44 | 17 | 0.114 | 0.02 | 3.9 | 0.14 | 0.87 | 0.25 | 0.04 | 827.2 | 136 | 0 | 963.7 | 100% | 1.6 | 1.0 | 0.01 | 0.001 | 0.23 | 0.07 | 0.05 | 0.02 |
| 4/9/17 16:25 | 4/10/17 0:20 | 26 | 44 | 17 | 0.114 | 0.02 | 3.9 | 0.14 | 0.87 | 0.25 | 0.17 | 779.5 | 129 | 0 | 908.2 | 100% | 1.5 | 1.0 | 0.01 | 0.001 | 0.22 | 0.06 | 0.05 | 0.01 |
| 4/10/17 16:45 | 4/11/17 15:35 | 26 | 44 | 17 | 0.114 | 0.02 | 3.9 | 0.14 | 0.87 | 0.25 | 0.41 | 3800.5 | 627 | 0 | 4427.6 | 100% | 7.3 | 4.8 | 0.03 | 0.006 | 1.08 | 0.31 | 0.24 | 0.07 |
| 4/12/17 17:05 | 4/13/17 2:30 | 26 | 44 | 17 | 0.114 | 0.02 | 3.9 | 0.14 | 0.87 | 0.25 | 0.14 | 2382.1 | 393 | 0 | 2775.2 | 100% | 4.6 | 3.0 | 0.02 | 0.004 | 0.67 | 0.19 | 0.15 | 0.04 |
| 4/14/17 18:45 | 4/15/17 22:00 | 26 | 44 | 17 | 0.114 | 0.02 | 3.9 | 0.14 | 0.87 | 0.25 | 1.02 | 10153.0 | 1675 | 0 | 11828.3 | 100% | 19.4 | 12.8 | 0.08 | 0.017 | 2.88 | 0.83 | 0.64 | 0.19 |
| 4/18/17 8:25 | 4/18/17 16:20 | 26 | 44 | 17 | 0.114 | 0.02 | 3.9 | 0.14 | 0.87 | 0.25 | 0.19 | 2460.4 | 406 | 0 | 2866.3 | 100% | 4.7 | 3.1 | 0.02 | 0.004 | 0.70 | 0.20 | 0.16 | 0.05 |
| 4/19/17 15:05 | 4/20/17 11:00 | **14** | 44 | **6** | **0.090** | **0.025** | **5.1** | 0.14 | **0.51** | **0.20** < | 0.81 | 7832.2 | 1292 | 0 | 9124.5 | 100% | 8.0 | 3.4 | 0.05 | 0.014 | 2.91 | 0.40 | 0.29 | 0.11 |
| 4/25/17 16:10 | 4/26/17 0:00 | **14** | 44 | **10** | 0.114 | 0.023 | **11.1** | 0.14 | **1.30** | **0.25** | 0.43 | 4358.2 | 719 | 0 | 5077.3 | 100% | 4.4 | 3.2 | 0.04 | 0.007 | 3.52 | 0.49 | 0.41 | 0.08 |
| 4/26/17 2:55 | 4/26/17 11:30 | **8** | **29** | **4** | **0.050** | **0.023** | **2.7** | **0.31** | **0.72** | **0.32** < | 0.5 | 5941.5 | 980 | 0 | 6921.9 | 100% | 3.5 | 1.7 | 0.02 | 0.010 | 1.17 | 0.45 | 0.31 | 0.14 |
| 4/30/17 10:55 | 5/1/17 20:30 | **36** | 44 | **11** | **0.070** | 0.023 | **2.0** < | 0.14 | **0.44** | **0.08** < | 0.98 | 13919.8 | 2297 | 0 | 16216.5 | 100% | 36.4 | 11.1 | 0.07 | 0.023 | 2.02 | 0.53 | 0.45 | 0.08 |
| 5/8/17 22:15 | 5/9/17 1:35 | 26 | 44 | 17 | **0.140** | 0.023 | **3.0** | 0.14 | **1.70** | **0.46** < | 0.24 | 1953.5 | 322 | 0 | 2275.9 | 100% | 3.7 | 2.5 | 0.02 | 0.003 | 0.43 | 0.31 | 0.24 | 0.07 |
| 5/10/17 13:20 | 5/10/17 15:55 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | - | 239.3 | 39 | 0 | 278.8 | 100% | 0.5 | 0.3 | 0.00 | 0.000 | 0.07 | 0.02 | 0.02 | 0.00 |
| 5/15/17 13:25 | 5/15/17 16:10 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.25 | 1857.4 | 306 | 0 | 2163.9 | 100% | 3.5 | 2.3 | 0.02 | 0.003 | 0.53 | 0.15 | 0.12 | 0.03 |
| 5/16/17 3:25 | 5/16/17 18:05 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.51 | 4084.6 | 674 | 0 | 4758.6 | 100% | 7.8 | 5.2 | 0.03 | 0.007 | 1.16 | 0.33 | 0.26 | 0.08 |
| 5/17/17 1:05 | 5/17/17 7:40 | **34** | 44 | **10** | **0.060** | 0.023 | **2.1** | 0.14 | **1.00** | **0.36** < | 0.96 | 8638.6 | 1425 | 0 | 10063.9 | 100% | 21.4 | 6.3 | 0.04 | 0.014 | 1.32 | 0.85 | 0.63 | 0.23 |
| 5/17/17 15:55 | 5/18/17 5:00 | **28** | 44 | **10** | **0.110** | 0.023 | **2.2** | 0.14 | **0.72** | **0.29** < | 1.61 | 20811.3 | 3434 | 0 | 24245.2 | 100% | 42.4 | 15.1 | 0.17 | 0.035 | 3.33 | 1.53 | 1.09 | 0.44 |
| 5/20/17 9:15 | 5/21/17 14:30 | 26 | 44 | **210** | **0.040** | 0.023 | **3.6** | 0.14 | **0.39** | **0.16** < | 1.25 | 11403.8 | 1882 | 0 | 13285.5 | 100% | 21.8 | 174.2 | 0.03 | 0.019 | 2.99 | 0.46 | 0.32 | 0.13 |
| 5/23/17 13:50 | 5/23/17 17:10 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.03 | 397.7 | 66 | 0 | 463.3 | 100% | 0.8 | 0.5 | 0.00 | 0.001 | 0.11 | 0.03 | 0.03 | 0.01 |
| 5/25/17 22:05 | 5/26/17 3:30 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.02 | 417.0 | 69 | 0 | 485.8 | 100% | 0.8 | 0.5 | 0.00 | 0.001 | 0.12 | 0.03 | 0.03 | 0.01 |
| 6/7/17 23:45 | 6/8/17 3:05 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.03 | 257.0 | 42 | 0 | 299.4 | 100% | 0.5 | 0.3 | 0.00 | 0.000 | 0.07 | 0.02 | 0.02 | 0.00 |
| 6/11/17 8:50 | 6/11/17 11:50 | **24** | **57** | **13** | **0.210** | **0.070** | **4.2** | **0.04** | **1.50** | **0.32** | 0.76 | 8141.2 | 1343 | 0 | 9484.5 | 100% | 14.2 | 7.7 | 0.12 | 0.041 | 2.49 | 1.08 | 0.89 | 0.19 |
| 6/11/17 16:25 | 6/11/17 21:05 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.07 | 1079.4 | 178 | 0 | 1257.5 | 100% | 2.1 | 1.4 | 0.01 | 0.002 | 0.31 | 0.09 | 0.07 | 0.02 |
| 6/12/17 15:00 | 6/12/17 19:50 | **23** | 44 | **13** | **0.160** | 0.023 | **3.8** | 0.14 | **1.00** | **0.45** | 0.30 | 3521.1 | 581 | 0 | 4102.1 | 100% | 5.9 | 3.3 | 0.04 | 0.006 | 0.97 | 0.37 | 0.26 | 0.12 |
| 6/14/17 0:45 | 6/14/17 4:55 | 26 | 44 | 17 | **0.160** | 0.023 | **2.2** | 0.14 | **0.98** | **0.41** < | 0.19 | 1256.8 | 207 | 0 | 1464.2 | 100% | 2.4 | 1.6 | 0.01 | 0.002 | 0.20 | 0.13 | 0.09 | 0.04 |
| 6/17/17 20:50 | 6/18/17 6:35 | **19** | 44 | **15** | **0.100** | 0.023 | **2.2** | 0.14 | **0.72** | **0.26** < | 0.26 | 2223.4 | 367 | 0 | 2590.2 | 100% | 3.1 | 2.4 | 0.02 | 0.004 | 0.36 | 0.16 | 0.12 | 0.04 |
| 6/20/17 4:30 | 6/20/17 12:00 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.17 | 1920.8 | 317 | 0 | 2237.7 | 100% | 3.7 | 2.4 | 0.02 | 0.003 | 0.54 | 0.16 | 0.12 | 0.04 |
| 6/22/17 6:50 | 6/22/17 18:05 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.47 | 4467.0 | 737 | 0 | 5204.1 | 100% | 8.5 | 5.6 | 0.04 | 0.007 | 1.27 | 0.37 | 0.28 | 0.08 |
| 6/24/17 14:55 | 6/24/17 16:30 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.02 | 260.8 | 43 | 0 | 303.8 | 100% | 0.5 | 0.3 | 0.00 | 0.000 | 0.07 | 0.02 | 0.02 | 0.00 |
| 6/28/17 4:15 | 6/28/17 14:45 | **773** | 44 | **177** | **0.460** | 0.023 | **2.0** < | 0.14 | **2.80** | **0.19** < | 0.54 | 4969.9 | 820 | 0 | 5790.0 | 100% | 279.4 | 64.0 | 0.17 | 0.008 | 0.72 | 1.08 | 1.01 | 0.07 |
| 7/1/17 1:15 | 7/1/17 2:45 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.02 | 155.0 | 26 | 0 | 180.5 | 100% | 0.3 | 0.2 | 0.00 | 0.000 | 0.04 | 0.01 | 0.01 | 0.00 |
| 7/5/17 1:30 | 7/5/17 4:00 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.05 | 413.3 | 68 | 0 | 481.4 | 100% | 0.8 | 0.5 | 0.00 | 0.001 | 0.12 | 0.03 | 0.03 | 0.01 |
| 7/12/17 2:41 | 7/12/17 4:15 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.02 | 193.0 | 32 | 0 | 224.9 | 100% | 0.4 | 0.2 | 0.00 | 0.000 | 0.05 | 0.02 | 0.01 | 0.00 |
| 7/17/17 22:11 | 7/18/17 3:15 | **235** | 44 | **29** | **0.170** | **0.006** | **2.0** < | 0.14 | **1.20** | **0.40** < | 0.90 | 4627.4 | 764 | 0 | 5390.9 | 100% | 79.1 | 9.8 | 0.06 | 0.002 | 0.67 | 0.54 | 0.40 | 0.13 |
| 7/19/17 16:00 | 7/20/17 1:15 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.1 | 722.1 | 119 | 0 | 841.2 | 100% | 1.4 | 0.9 | 0.01 | 0.001 | 0.20 | 0.06 | 0.05 | 0.01 |
| 7/25/17 17:56 | 7/25/17 21:30 | **48** | 44 | **14** | **0.120** | 0.023 | 3.9 | 0.14 | **1.50** | **0.39** < | 0.54 | 3198.9 | 528 | 0 | 3726.7 | 100% | 11.2 | 3.3 | 0.03 | 0.005 | 0.91 | 0.44 | 0.35 | 0.09 |
| 7/26/17 4:06 | 7/26/17 6:15 | **31** | 44 | **10** | **0.100** | 0.023 | **2.0** < | 0.14 | **0.67** | **0.23** < | 0.69 | 14261.2 | 2353 | 0 | 16614.3 | 100% | 32.2 | 10.4 | 0.10 | 0.024 | 2.07 | 0.93 | 0.69 | 0.24 |
| 8/3/17 7:06 | 8/3/17 13:30 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.47 | 1674.5 | 276 | 0 | 1950.8 | 100% | 3.2 | 2.1 | 0.01 | 0.003 | 0.47 | 0.14 | 0.11 | 0.03 |
| 8/5/17 18:06 | 8/5/17 21:15 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.44 | 1510.3 | 249 | 0 | 1759.5 | 100% | 2.9 | 1.9 | 0.01 | 0.003 | 0.43 | 0.12 | 0.10 | 0.03 |
| 8/6/17 13:45 | 8/6/17 16:00 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.11 | 634.5 | 105 | 0 | 739.2 | 100% | 1.2 | 0.8 | 0.01 | 0.001 | 0.18 | 0.05 | 0.04 | 0.01 |
| 8/6/17 19:45 | 8/6/17 22:15 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.04 | 460.3 | 76 | 0 | 536.3 | 100% | 0.9 | 0.6 | 0.00 | 0.001 | 0.13 | 0.04 | 0.03 | 0.01 |
| 8/9/17 12:11 | 8/9/17 20:15 | **16** | **41** | **9** | **0.040** | **0.005** < | **2.8** | **0.10** | **0.63** | **0.27** | 0.57 | 2820.4 | 465 | 0 | 3285.8 | 100% | 3.3 | 1.8 | 0.01 | 0.001 | 0.57 | 0.18 | 0.13 | 0.06 |
| 8/10/17 0:11 | 8/10/17 18:45 | **10** | 44 | **5** | **0.020** < | 0.023 | **2.0** < | 0.14 | **0.48** | **0.32** < | 0.29 | 1175.9 | 194 | 0 | 1369.9 | 100% | 0.9 | 0.4 | 0.00 | 0.002 | 0.17 | 0.07 | 0.04 | 0.03 |
| 8/13/17 22:45 | 8/14/17 7:00 | **46** | 44 | **20** | **0.310** | 0.023 | **15.2** | 0.14 | **1.40** | **0.16** < | 1.68 | 6175.7 | 1019 | 0 | 7194.7 | 100% | 20.7 | 9.0 | 0.14 | 0.010 | 6.83 | 0.70 | 0.63 | 0.07 |
| 8/16/17 3:26 | 8/18/17 13:45 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 2.11 | 32467.6 | 5357 | 0 | 37824.8 | 100% | 62.0 | 41.0 | 0.27 | 0.054 | 9.20 | 2.66 | 2.06 | 0.60 |
| 8/21/17 14:36 | 8/21/17 18:15 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.05 | 566.6 | 93 | 0 | 660.1 | 100% | 1.1 | 0.7 | 0.00 | 0.001 | 0.16 | 0.05 | 0.04 | 0.01 |
| 8/25/17 6:21 | 8/27/17 19:15 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 1.55 | 11600.6 | 1914 | 0 | 13514.7 | 100% | 22.2 | 14.7 | 0.10 | 0.019 | 3.29 | 0.95 | 0.74 | 0.21 |
| 9/4/17 16:56 | 9/4/17 20:15 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.11 | 828.9 | 137 | 0 | 965.7 | 100% | 1.6 | 1.0 | 0.01 | 0.001 | 0.23 | 0.07 | 0.05 | 0.02 |
| 9/16/17 7:41 | 9/16/17 9:30 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.02 | 229.9 | 38 | 0 | 267.8 | 100% | 0.4 | 0.3 | 0.00 | 0.000 | 0.07 | 0.02 | 0.01 | 0.00 |
| 9/18/17 10:00 | 9/18/17 18:30 | **83** | 44 | **60** | **0.183** | **0.016** | **6.2** | 0.14 | **1.50** | **0.13** < | 0.31 | 3041.2 | 502 | 0 | 3542.9 | 100% | 18.4 | 13.3 | 0.04 | 0.004 | 1.37 | 0.36 | 0.33 | 0.03 |
| 9/20/17 3:00 | 9/20/17 4:15 | **10** | 44 | **5** | **0.093** | 0.023 | **2.0** < | 0.14 | **1.00** | **0.47** < | 0.28 | 1372.7 | 226 | 0 | 1599.2 | 100% | 1.0 | 0.5 | 0.01 | 0.002 | 0.20 | 0.15 | 0.10 | 0.05 |
| 9/25/17 3:11 | 9/25/17 8:15 | **20** | 44 | **12** | **0.096** | 0.023 | **4.2** | 0.14 | **0.84** | **0.33** < | 0.30 | 3771.2 | 622 | 0 | 4393.4 | 100% | 5.5 | 3.3 | 0.03 | 0.006 | 1.15 | 0.32 | 0.23 | 0.09 |
| 9/25/17 21:30 | 9/26/17 9:00 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.16 | 1415.9 | 234 | 0 | 1649.5 | 100% | 2.7 | 1.8 | 0.01 | 0.002 | 0.40 | 0.12 | 0.09 | 0.03 |
| 10/1/17 3:46 | 10/2/17 6:00 | **51** | 44 | **17** | **0.103** | 0.023 | **2.0** < | 0.14 | **0.68** | **0.22** < | 0.76 | 4241.4 | 700 | 0 | 4941.3 | 100% | 15.7 | 5.2 | 0.03 | 0.007 | 0.62 | 0.28 | 0.21 | 0.07 |
| 10/2/17 16:15 | 10/3/17 11:30 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 1.77 | 22957.9 | 3788 | 0 | 26746.0 | 100% | 43.9 | 29.0 | 0.19 | 0.038 | 6.50 | 1.88 | 1.46 | 0.42 |
| 10/6/17 14:30 | 10/7/17 13:16 | **4** | 44 | **3** | **0.035** | 0.023 | **9.3** | 0.14 | **0.52** | **0.49** | 0.49 | 6389.2 | 1054 | 0 | 7443.4 | 100% | 1.9 | 1.4 | 0.02 | 0.011 | 4.32 | 0.47 | 0.24 | 0.23 |
| 10/14/17 14:41 | 10/15/17 5:22 | **11** | 44 | **8** | **0.062** | **0.005** < | **4.5** | 0.14 | **0.68** | **0.12** < | 0.51 | 5534.4 | 913 | 0 | 6447.6 | 100% | 4.4 | 3.2 | 0.02 | 0.002 | 1.81 | 0.32 | 0.27 | 0.05 |
| 10/21/17 7:11 | 10/22/17 0:34 | **8** | 44 | **6** | **0.069** | **0.005** < | **3.6** | 0.14 | **0.65** | **0.15** < | 0.39 | 8169.1 | 1348 | 0 | 9516.9 | 100% | 4.8 | 3.6 | 0.04 | 0.003 | 2.14 | 0.48 | 0.39 | 0.09 |
| 10/29/17 22:15 | 10/30/17 4:26 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.04 | 565.2 | 93 | 0 | 658.4 | 100% | 1.1 | 0.7 | 0.00 | 0.001 | 0.16 | 0.05 | 0.04 | 0.01 |
| 11/1/17 15:12 | 11/2/17 0:00 | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | 0.05 | 794.7 | 131 | 0 | 925.8 | 100% | 1.5 | 1.0 | 0.01 | 0.001 | 0.23 | 0.07 | 0.05 | 0.01 |
| **Sum** | | | | | | | | | | | 27.35 | 274013 | 45212 | 0 | 319225 | 100% | 863.7 | 506.1 | 2.28 | 0.46 | 77.6 | 22.4 | 17.4 | 5.1 |
| **Average** | | 26 | 42 | 20 | 0.122 | 0.019 | 4.1 | 0.15 | 0.98 | 0.29 | | | | | | | | | | | | | | |
| **Weighted Avg** | | 26 | 44 | 17 | 0.114 | 0.023 | 3.9 | 0.14 | 0.87 | 0.25 | | | | | | | | | | | | | | |
| **STDEV** | | 19 | 14 | 52 | 0.096 | 0.022 | 3.2 | 0.14 | 0.53 | 0.05 | | | | | | | | | | | | | | |
| **Min** | | 4 | 29 | 3 | 0.020 | 0.005 | 2.0 | 0.04 | 0.39 | 0.19 | | | | | | | | | | | | | | |
| **Max** | | 83 | 57 | 210 | 0.460 | 0.070 | 15.2 | 0.31 | 2.80 | 0.40 | | | | | | | | | | | | | | |
| **Percent Capture** | | | | | | | | | | | | | | | | | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |

< Sample was not detected above the method detection limit (value reported)
GREY FONT Events with no sampling data (weighted average concentration used)
**BOLD** Sampling event
1 - Additional stormwater is conveyed to the system from the east via a pipe along Hampden Avenue. This flow is modeled using the monitored flow from the Hampden/Raymond location and the ratio of drainage areas.
2 - Water Levels in the BMP did not exceed the system outlet elevation
*Samples identified as outliers have been omitted from annual flow weighted averages

## MARYLAND POND WATER QUALITY SUMMARY

| Date Composite Sampling Start | Date Composite Sampling End/ Grab Sample | Soluble Reactive Phosphorus (mg/L) | | | Total Phosphorus (mg/L) | | | Dissolved Phosphorus (mg/L) | | | Total Iron (mg/L) | | | Hardness (mg/L) | | | TSS (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction |
| | 4/26/2017 10:10 | 0.008 J | 0.019 | -138 | 0.125 | 0.073 | 42 | 0.021 J | 0.027 J | -29 | 0.67 J | 0.61 J | 9 | 44 | 64 | -45 | 13 | 2 J | 85 |
| 5/1/2017 0:07 | 5/1/2017 11:04 | 0.022 | 0.023 | -5 | 0.105 | 0.069 | 34 | 0.027 J | 0.031 J | -15 | 0.79 J | 0.81 J | -3 | 40 | 56 | -40 | 47 | 5 | 89 |
| | 5/12/2017 10:19 | 0.011 | 0.020 | -82 | 0.087 | 0.040 J | 54 | 0.022 J | 0.031 J | -41 | 0.66 J | 0.53 J | 20 | 40 | 92 | -130 | 6 | 1 J | 83 |
| 5/17/2017 0:55 | 5/17/2017 15:11 | 0.007 J | 0.007 J | 0 | 0.161 | 0.109 | 32 | 0.023 J | 0.022 J | 4 | 0.79 J | 0.83 J | -5 | 40 | 60 | -50 | 26 | 8 | 69 |
| 5/20/2017 11:31 | 5/21/2017 3:46 | 0.015 | 0.020 | -33 | 0.114 | 0.058 | 49 | 0.038 J | 0.040 J | -5 | 0.70 J | 0.39 J | 44 | 24 | 44 | -83 | 10 | 2 J | 80 |
| | 6/9/2017 12:33 | 0.021 | 0.014 | 33 | 0.102 | 0.077 | 25 | 0.046 J | 0.024 J | 48 | 0.70 J | 1.50 | -114 | 32 | 116 | -263 | 10 | 3 | 70 |
| 6/11/2017 14:36 | 6/12/2017 4:51 | 0.012 | NA | NA | 0.259 | 0.118 | 54 | 0.100 | 0.031 J | 69 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | 6/28/2017 10:01 | 0.087 | 0.019 | 78 | 0.226 | 0.152 | 33 | 0.129 | 0.037 J | 71 | 2.80 | 3.60 | -29 | 40 | 64 | -60 | 8 | 7 | 13 |
| 6/28/2017 5:19 | 6/29/2017 2:49 | 0.085 | 0.014 | 84 | 0.265 | 0.167 | 37 | 0.133 | 0.031 J | 77 | 2.50 | 4.20 | -68 | 40 | 68 | -70 | 5 | 9 | -80 |
| | 7/17/2017 15:05 | 0.074 | 0.005 < | 93 | 0.220 | 0.032 J | 85 | 0.144 | 0.020 < | 86 | 3.30 | 1.80 | 45 | 28 | 117 | -318 | 7 | 4 | 43 |
| 7/17/2017 23:19 | 7/18/2017 20:29 | 0.034 | 0.011 | 68 | 0.298 | 0.151 | 49 | 0.146 | 0.052 | 64 | 2.40 | 2.90 | -21 | 30 | 66 | -120 | 8 | 8 | 0 |
| 7/25/2017 19:39 | 7/26/2017 15:15 | 0.017 | 0.038 | -124 | 0.187 | 0.308 | -65 | 0.043 J | 0.058 | -35 | 3.20 | 2.60 | 19 | 53 | 29 | 45 | 9 | 19 | -111 |
| 8/3/2017 9:19 | 8/4/2017 10:54 | NA | NA | NA | 0.464 | 0.306 | 34 | NA | NA | NA | 3.60 | 15.90 | -342 | 32 | 103 | -222 | 39 | 39 | 0 |
| 8/6/2017 14:14 | 8/7/2017 9:49 | 0.048 | 0.039 | 19 | 0.312 | 0.330 | -6 | 0.070 | 0.039 J | 44 | 2.30 | 14.90 | -548 | 30 | 71 | -137 | 20 | 41 | -105 |
| 8/9/2017 17:49 | 8/10/2017 10:19 | 0.006 J | 0.011 | -83 | 0.267 | 0.280 | -5 | 0.031 J | 0.024 J | 23 | 1.60 | 2.50 | -56 | 29 | 45 | -55 | 21 | 7 | 67 |
| 8/13/2017 23:54 | 8/14/2017 13:09 | 0.030 | 0.021 | 30 | 0.193 | 0.133 | 31 | 0.046 J | 0.040 J | 13 | 2.00 | 2.80 | -40 | 16 J | 33 | -106 | 20 | 11 | 45 |
| 8/16/2017 7:18 | 8/16/2017 16:37 | 0.008 J | 0.007 J | 13 | 0.110 | 0.072 | 35 | 0.031 J | 0.022 J | 29 | 0.97 J | 2.50 | -158 | 14 J | 35 | -150 | 4 | 6 | -50 |
| 8/16/2017 18:29 | 8/17/2017 16:37 | 0.018 | 0.020 | -11 | 0.118 | 0.054 | 54 | 0.028 J | 0.030 J | -7 | 1.20 | 1.00 | 17 | 13 J | 34 | -162 | 14 | 4 | 71 |
| 9/25/2017 6:29 | 9/25/2017 13:53 | 0.030 | 0.018 | 40 | 0.173 | 0.141 | 18 | 0.071 | 0.041 J | 42 | 2.50 | 3.90 | -56 | 27 | 49 | -81 | 13 | 31 | -138 |
| 10/2/2017 3:29 | 10/2/2017 22:21 | 0.010 | 0.009 J | 10 | 0.215 | 0.066 | 69 | 0.020 < | 0.021 J | -5 | 1.70 | 1.70 | 0 | 20 J | 40 | -100 | 60 | 9 | 85 |
| 10/6/2017 18:34 | 10/8/2017 2:19 | 0.007 J | 0.008 J | -14 | 0.088 | 0.066 | 25 | 0.020 < | 0.020 < | 0 | 0.59 J | 1.10 | -86 | 20 J | 57 | -185 | 5 | 4 | 20 |
| **MINIMUM** | | 0.006 | 0.007 | -138 | 0.088 | 0.054 | -65 | 0.020 | 0.020 | -35 | 0.59 | 0.39 | -548 | 13 | 29 | -222 | 4 | 2 | -138 |
| **AVERAGE** | | 0.026 | 0.018 | -4 | 0.204 | 0.147 | 29 | 0.057 | 0.033 | 20 | 1.78 | 3.66 | -78 | 30 | 54 | -95 | 19 | 12 | 8 |
| **MEDIAN** | | 0.017 | 0.019 | 5 | 0.190 | 0.126 | 34 | 0.038 | 0.031 | 13 | 1.70 | 2.50 | -29 | 30 | 56 | -83 | 13 | 8 | 20 |
| **MAXIMUM** | | 0.087 | 0.039 | 84 | 0.464 | 0.330 | 69 | 0.146 | 0.058 | 77 | 3.60 | 15.90 | 44 | 53 | 103 | 45 | 60 | 41 | 89 |

Laboratory analysis was completed by Metropolian Council Environmental Services

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

Post-treatment samples were collected from the drain tile outlet to the OCS

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

Grab Sample

Baseflow Sample

< - Analyte not detected above the Method Detection Limit (MDL), MDL value reported

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

NA - Not Analyzed

## MARYLAND POND TREATMENT SUMMARY

| Flow Event Start | Treatment Event Duration (hours) | Flow Volume (cubic feet)[1] | Rainfall (inches) | TP Pre-Treatment (mg/L) | TP Post-Treatment (mg/L) | Removal Efficieny | TP Load Captured (grams) | SRP Pre-Treatment (mg/L) | SRP Post-Treatment (mg/L) | Removal Efficieny | SRP Load Captured (grams) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 19-Apr | 66.0 | 23686 | 0.76 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 25-Apr | 64.5 | 10710 | 0.85 | **0.125** | **0.073** | **42%** | **15.8** | **0.008** | **0.019** | **-138%** | **-3.3** |
| 30-Apr | 78.5 | 30125 | 1.25 | **0.105** | **0.069** | **34%** | **30.7** | **0.022** | **0.023** | **-5%** | **-0.9** |
| 8-May | 29.0 | 1059 | 0.19 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 16-May | 57.9 | 79058 | 3.35 | **0.161** | **0.109** | **32%** | **116.4** | **0.007** | **0.007** | **0%** | **0.0** |
| 20-May | 38.0 | 49412 | 1.43 | **0.114** | **0.058** | **49%** | **78.4** | **0.015** | **0.020** | **-33%** | **-7.0** |
| 11-Jun | 151.5 | 11229 | 1.39 | **0.259** | **0.118** | **54%** | **44.8** | *NA* | *NA* | *NA* | *NA* |
| 22-Jun | 62.5 | 3751 | 0.39 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 28-Jun | 79.7 | 11228 | 0.73 | **0.265** | **0.167** | **37%** | **31.2** | **0.085** | **0.014** | **84%** | **22.6** |
| 17-Jul | 73.2 | 10591 | 0.72 | **0.298** | **0.151** | **49%** | **44.1** | **0.034** | **0.011** | **68%** | **6.9** |
| 25-Jul | 53.9 | 14578 | 0.63 | **0.187** | **0.308** | **-65%** | **-49.9** | **0.017** | **0.038** | **-124%** | **-8.7** |
| 3-Aug | 26.3 | 1265 | 0.57 | **0.464** | **0.306** | **34%** | **5.7** | *NA* | *NA* | *NA* | *NA* |
| 6-Aug | 32.4 | 4612 | 0.55 | **0.312** | **0.330** | **-6%** | **-2.4** | **0.048** | **0.039** | **19%** | **1.2** |
| 9-Aug | 37.0 | 13424 | 0.84 | **0.267** | **0.280** | **-5%** | **-4.9** | **0.006** | **0.011** | **-83%** | **-1.9** |
| 13-Aug | 52.3 | 24919 | 1.39 | **0.193** | **0.133** | **31%** | **42.3** | **0.030** | **0.021** | **30%** | **6.4** |
| 16-Aug | 14.3 | 4610 | 0.62 | **0.110** | **0.072** | **35%** | **5.0** | **0.008** | **0.007** | **13%** | **0.1** |
| 16-Aug | 50.3 | 39592 | 1.22 | **0.118** | **0.054** | **54%** | **71.7** | **0.018** | **0.020** | **-11%** | **-2.2** |
| 25-Aug | 90.5 | 37084 | 1.30 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 25-Sep | 56.0 | 12269 | 0.77 | **0.173** | **0.141** | **18%** | **11.1** | **0.030** | **0.018** | **40%** | **4.2** |
| 1-Oct | 26.8 | 3124 | 0.18 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 2-Oct | 61.3 | 59790 | 2.36 | **0.215** | **0.066** | **69%** | **252.3** | **0.010** | **0.009** | **10%** | **1.7** |
| 6-Oct | 46.0 | 6944 | 0.48 | **0.088** | **0.066** | **25%** | **4.3** | **0.007** | **0.008** | **-14%** | **-0.2** |
| 14-Oct | 78.2 | 3826 | 0.46 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 21-Oct | 51.8 | 4655 | 0.49 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 27-Oct | 64.2 | 1350 | 0.37 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| Total | 1442.2 | 462891 | 23.29 | | | | 696.5 | | | | 18.8 |

1 - Due to continous flow observed through the Maryland Pond IESF system, the treatment event volumes summarized in column E do not reflect the total volume monitored at the site. The total volume observed in 2017 was 533,000 cubic feet.

*NA - Not Analyzed*
**Bold -** Sampled Event
Negative Load Reduction
TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus

| | |
|---|---|
| Mass TP in | 1863.6 |
| Mass TP out | 1167.2 |
| Mass TP Retained | 696.5 |
| % P Retained | 37% |

| | |
|---|---|
| Mass SRP in | 181.8 |
| Mass SRP out | 163.0 |
| Mass SRP Retained | 18.8 |
| % SRP Retained | 10% |

## MAGNOLIA POND WATER QUALITY SUMMARY

| Date Composite Sampling Start | Date Composite Sampling End/ Grab Sample | Soluble Reactive Phosphorus (mg/L) | | | Total Phosphorus (mg/L) | | | Dissolved Phosphorus (mg/L) | | | Iron (mg/L) | | | Hardness (mg/L) | | | TSS (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction |
| | 4/26/2017 10:25 | 0.015 | 0.074 | -393 | 0.170 | 0.135 | 21 | 0.034 J | 0.080 | -135 | 0.60 J | 0.16 J | 73 | 28 | 48 | -71 | 18 | 4 | 78 |
| 5/1/2017 0:39 | 5/1/2017 11:28 | 0.096 | 0.094 | 2 | 0.221 | 0.137 | 38 | 0.108 | 0.097 | 10 | 1.20 | 0.33 J | 73 | 36 | 40 | -11 | 47 | 8 | 83 |
| 5/17/2017 0:35 | 5/17/2017 14:44 | 0.054 | 0.050 | 7 | 0.280 | 0.201 | 28 | 0.085 | 0.095 | -12 | 0.99 J | 0.54 J | 45 | 32 | 52 | -63 | 35 | 12 | 66 |
| 5/17/2017 19:59 | 5/18/2017 9:14 | 0.064 | 0.049 | 23 | 0.311 | 0.162 | 48 | 0.088 | 0.070 | 20 | 1.50 | 0.50 J | 67 | 40 | 40 | 0 | 56 | 11 | 80 |
| 5/20/2017 1:34 | 5/20/2017 19:34 | 0.084 | 0.061 | 27 | 0.171 | 0.107 | 37 | 0.108 | 0.077 | 29 | 0.30 J | 0.22 J | 27 | 16 | 40 | -150 | 4 | 2 J | 50 |
| 6/12/2017 1:56 | 6/12/2017 12:49 | 0.031 | 0.097 | -213 | 0.838 | 0.694 | 17 | 0.104 | 0.216 | -108 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 6/28/2017 6:14 | 6/29/2017 9:19 | 0.013 | 0.028 | -115 | 0.441 | 0.331 | 25 | 0.060 | 0.067 | -12 | 1.30 | 0.96 J | 26 | 44 | 76 | -73 | 43 | 12 | 72 |
| 8/6/2017 17:29 | 8/7/2017 12:14 | 0.023 | 0.021 | 9 | 0.590 | 0.268 | 55 | 0.081 | 0.064 | 21 | 1.70 | 2.40 | -41 | 45 | 60 | -33 | 53 | 12 J | 77 |
| 8/9/2017 17:54 | 8/10/2017 11:04 | 0.019 | 0.010 | 47 | 0.180 | 0.361 | -101 | 0.036 J | 0.045 J | -25 | 1.10 | 0.83 J | 25 | 57 | 33 | 42 | 7 | 24 | -243 |
| 8/13/2017 23:54 | 8/14/2017 2:54 | 0.016 | 0.026 | -63 | 0.287 | 0.167 | 42 | 0.032 J | 0.053 | -66 | 1.40 | 0.73 J | 48 | 12 J | 25 J | -108 | 30 | 9 | 70 |
| 8/16/2017 4:54 | 8/16/2017 16:24 | 0.006 J | 0.024 | -300 | 0.142 | 0.132 | 7 | 0.033 J | 0.043 J | -30 | 0.430 J | 1.30 | -202 | 18 J | 44 | -144 | 8 | 6 | 25 |
| 8/16/2017 18:19 | 8/17/2017 1:31 | 0.045 | 0.039 | 13 | 0.185 | 0.099 | 46 | 0.046 J | 0.048 J | -4 | 1.200 | 0.33 J | 73 | 8 < | 16 J | -100 | 46 | 6 | 87 |
| 9/25/2017 12:54 | 9/25/2017 12:55 | 0.122 | 0.119 | 2 | 0.332 | 0.273 | 18 | 0.235 | 0.178 | 24 | 2.100 | 2.10 | 0 | 25 J | 55 | -120 | 15 | 4 J | 73 |
| 10/2/2017 18:17 | 10/2/2017 21:23 | 0.111 | 0.090 | 19 | 0.311 | 0.178 | 43 | 0.130 | 0.100 | 23 | 2.900 | 0.88 J | 70 | 42 | 30 | 29 | 129 | 11 | 91 |
| **MININUM** | | 0.006 | 0.010 | -393 | 0.142 | 0.099 | -101 | 0.032 | 0.043 | -135 | 0.30 | 0.16 | -202 | 8 | 16 | -150 | 4 | 2 | -243 |
| **AVERAGE** | | 0.050 | 0.056 | -67 | 0.319 | 0.232 | 23 | 0.084 | 0.088 | -19 | 1.29 | 0.87 | 22 | 31 | 43 | -62 | 38 | 9 | 47 |
| **MEDIAN** | | 0.038 | 0.050 | 5 | 0.284 | 0.173 | 33 | 0.083 | 0.074 | -8 | 1.20 | 0.73 | 45 | 32 | 40 | -71 | 35 | 9 | 73 |
| **MAXIMUM** | | 0.122 | 0.119 | 47 | 0.838 | 0.694 | 55 | 0.235 | 0.216 | 29 | 2.90 | 2.40 | 73 | 57 | 76 | 42 | 129 | 24 | 91 |

Laboratory analysis was completed by Metropolian Council Environmental Services

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

2 - Post-treatment samples were collected from the drain tile outlet to the OCS

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

Grab Sample

< - Analyte not detected above the Method Detection Limit (MDL), MDL value reported

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

NA - Not Analyzed

City of Saint Paul
2017 Water Quality and Quantity Summary
Table C.8
WSB Project Number 01610-100

## MAGNOLIA POND TREATMENT SUMMARY

| Treatment Event Start | Treatment Event Duration (hours) | Treatment Volume (cubic feet) | Rainfall (inches) | TP Pre-Treatment (mg/L) | TP Post-Treatment (mg/L) | Removal Efficieny | TP Load Captured (grams) | SRP Pre-Treatment (mg/L) | SRP Post-Treatment (mg/L) | Removal Efficieny | SRP Load Captured (grams) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 19-Apr | 51.0 | 2635 | 1.00 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 25-Apr | 46.0 | 617 | 0.85 | **0.170** | **0.135** | 21% | 0.6 | **0.015** | **0.074** | -393% | **-1.0** |
| 1-May | 73.5 | 7897 | 1.25 | **0.221** | **0.137** | 38% | 18.8 | **0.096** | **0.094** | 2% | **0.4** |
| 16-May | 36.0 | 7721 | 1.41 | **0.280** | **0.201** | 28% | 17.3 | **0.054** | **0.050** | 7% | **0.9** |
| 17-May | 33.5 | 17569 | 1.96 | **0.311** | **0.162** | 48% | 74.1 | **0.064** | **0.049** | 23% | **7.5** |
| 20-May | 43.0 | 11445 | 1.43 | **0.171** | **0.107** | 37% | 20.7 | **0.084** | **0.061** | 27% | **7.5** |
| 12-Jun | 68.5 | 424 | 1.08 | **0.838** | **0.694** | 17% | 1.7 | **0.031** | **0.097** | -213% | **-0.8** |
| 22-Jun | 43.0 | 302 | 0.39 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 28-Jun | 121.5 | 3652 | 0.73 | **0.441** | **0.331** | 25% | 11.4 | **0.013** | **0.028** | -115% | **-1.6** |
| 17-Jul | 80.3 | 2646 | 0.89 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 25-Jul | 68.6 | 7309 | 1.26 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 3-Aug | 128.8 | 3027 | 0.58 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 5-Aug | 93.4 | 2642 | 0.18 | **0.590** | **0.268** | 55% | 24.1 | **0.023** | **0.021** | 9% | **0.1** |
| 9-Aug | 36.0 | 3273 | 0.55 | **0.180** | **0.361** | -101% | -16.8 | **0.019** | **0.010** | 47% | **0.8** |
| 14-Aug | 26.5 | 9974 | 1.41 | **0.287** | **0.167** | 42% | 33.9 | **0.016** | **0.026** | -63% | **-2.8** |
| 16-Aug | 15.8 | 1041 | 0.62 | **0.142** | **0.132** | 7% | 0.3 | **0.006** | **0.024** | -300% | **-0.5** |
| 16-Aug | 27.3 | 14811 | 1.31 | **0.185** | **0.099** | 46% | 36.1 | **0.045** | **0.039** | 13% | **2.5** |
| 25-Aug | 53.8 | 8915 | 1.17 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 18-Sep | 19.0 | 21 | 0.37 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 25-Sep | 62.0 | 3146 | 0.77 | **0.332** | **0.273** | 18% | 5.3 | **0.122** | **0.119** | 2% | **0.3** |
| 2-Oct | 54.5 | 21181 | 2.53 | **0.311** | **0.178** | 43% | 79.8 | **0.111** | **0.090** | 19% | **12.6** |
| 6-Oct | 40.5 | 340 | 0.69 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 14-Oct | 72.0 | 786 | 0.46 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 21-Oct | 81.5 | 1363 | 0.49 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| Totals: | 1375.9 | 144833 | 23.4 | | | | 307.2 | | | | 25.9 |

*NA - Not Analyzed*
**Bold -** Sampled Event
Negative Load Reduction
TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus

| | |
|---|---|
| Mass TP in | 819.2 |
| Mass TP out | 511.9 |
| Mass TP Retained | 307.2 |
| % P Retained | 38% |

| | |
|---|---|
| Mass SRP in | 198.8 |
| Mass SRP out | 172.9 |
| Mass SRP Retained | 25.9 |
| % SRP Retained | 13% |

City of Saint Paul
2017 Water Quality and Quantity Report
Table C.9
WSB Project number 01610-100

## JENKS POND WATER QUALITY SUMMARY

| Date Composite Sampling Start | Date Composite Sampling End/ Grab Sample | Soluble Reactive Phosphorus (mg/L) | | | Total Phosphorus (mg/L) | | | Dissolved Phosphorus (mg/L) | | | Iron (mg/L) | | | Hardness (mg/L) | | | TSS (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction | Pre | Post | % Reduction |
| 4/26/2017 10:40 | 4/26/2017 10:40 | 0.009 J | 0.013 | -44 | 0.144 | 0.092 | 36 | 0.028 J | 0.035 J | -25 | 0.51 J | 0.45 J | 12 | 24 | 48 | -100 | 7 | 7 | 0 |
| 5/17/2017 15:44 | 5/17/2017 15:44 | 0.009 J | 0.011 | -22 | 0.126 | 0.087 | 31 | 0.043 J | 0.048 J | -12 | 0.37 J | 0.37 J | 0 | 20 | 56 | -180 | 5 | 2 J | 60 |
| 5/22/2017 10:23 | 5/22/2017 10:23 | 0.025 | 0.015 | 40 | 0.054 | 0.033 J | 39 | 0.038 J | 0.032 J | 16 | 0.35 J | 0.08 J | 77 | 12 | 56 | -367 | 1 J | 1 < | 0 |
| 6/28/2017 9:54 | 6/28/2017 9:54 | 0.047 | 0.033 | 30 | 0.091 | 0.056 | 38 | 0.085 | 0.033 J | 61 | 0.54 J | 0.57 J | -6 | 12 | 40 | -233 | 8 | 4 J | 50 |
| 7/26/2017 10:50 | 7/26/2017 10:50 | 0.029 | 0.020 | 31 | 0.123 | 0.083 | 33 | 0.050 | 0.040 J | 20 | 1.50 | 0.45 J | 70 | 29 | 67 | -131 | 29 | 3 J | 90 |
| 8/10/2017 13:30 | 8/10/2017 13:30 | 0.007 J | 0.010 | -43 | 0.172 | 0.086 | 50 | 0.020 J | 0.025 J | -25 | 1.50 | 0.59 J | 61 | 11 J | 76 | -591 | 9 | 2 J | 78 |
| 8/14/2017 13:05 | 8/14/2017 13:05 | 0.008 J | 0.010 | -25 | 0.216 | 0.063 | 71 | 0.025 J | 0.020 < | 20 | 2.00 | 0.45 J | 78 | 15 J | 48 | -220 | 12 | 2 J | 83 |
| 8/16/2017 16:21 | 8/16/2017 16:21 | 0.008 J | 0.007 J | 13 | 0.198 | 0.028 J | 86 | 0.034 J | 0.020 < | 41 | 1.80 | 0.20 J | 89 | 23 J | 47 | -104 | 13 | 1 J | 92 |
| 9/25/2017 12:11 | 9/25/2017 12:11 | 0.075 | 0.059 | 21 | 0.189 | 0.129 | 32 | 0.108 | 0.079 | 27 | 1.80 | 1.20 | 33 | 23 J | 68 | -196 | 4 J | 3 | 25 |
| **MININUM** | | 0.007 | 0.007 | -44 | 0.054 | 0.028 | 31 | 0.020 | 0.020 | -25 | 0.350 | 0.080 | -6 | 11 | 40 | -591 | 1 | 1 | 0 |
| **AVERAGE** | | 0.024 | 0.020 | 0 | 0.146 | 0.073 | 46 | 0.048 | 0.037 | 14 | 1.152 | 0.484 | 46 | 19 | 56 | -236 | 10 | 3 | 53 |
| **MEDIAN** | | 0.009 | 0.013 | 13 | 0.144 | 0.083 | 38 | 0.038 | 0.033 | 20 | 1.500 | 0.450 | 61 | 20 | 56 | -196 | 8 | 2 | 60 |
| **MAXIMUM** | | 0.075 | 0.059 | 40 | 0.216 | 0.129 | 86 | 0.108 | 0.079 | 61 | 2.000 | 1.200 | 89 | 29 | 76 | -100 | 29 | 7 | 92 |

Laboratory analysis was completed by Metropolian Council Environmental Services

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

Post-treatment samples were collected from the drain tile outlet to the OCS

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

Grab Sample

< - Analyte not detected above the Method Detection Limit (MDL), MDL value reported

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

NA - Not Analyzed

City of Saint Paul
2017 Water Quality and Quantity Summary
Table C.10
WSB Project Number 01610-100

## JENKS POND TREATMENT SUMMARY

| Treatment Event Start | Treatment Event Duration (hours) | Treatment Volume (cubic feet) | Rainfall (inches) | TP Pre-Treatment (mg/L) | TP Post-Treatment (mg/L) | Removal Efficieny | TP Load Captured (grams) | SRP Pre-Treatment (mg/L) | SRP Post-Treatment (mg/L) | Removal Efficieny | SRP Load Captured (grams) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 26-Apr | 39.0 | 1617 | 0.85 | **0.144** | **0.092** | 36% | 2.38 | **0.009** | **0.013** | -44% | -0.18 |
| 1-May | 79.5 | 6810 | 1.25 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 16-May | 92.0 | 30269 | 3.16 | **0.126** | **0.087** | 31% | 33.43 | **0.009** | **0.011** | -22% | -1.71 |
| 20-May | 88.5 | 27593 | 1.43 | **0.054** | **0.033** | 39% | 16.41 | **0.025** | **0.015** | 40% | 7.81 |
| 28-Jun | 61.0 | 1432 | 0.73 | **0.091** | **0.056** | 38% | 1.42 | **0.047** | **0.033** | 30% | 0.57 |
| 26-Jul | 46.0 | 1535 | 1.26 | **0.123** | **0.083** | 33% | 1.74 | **0.029** | **0.020** | 31% | 0.39 |
| 9-Aug | 86.5 | 4525 | 0.84 | **0.172** | **0.086** | 50% | 11.02 | **0.007** | **0.010** | -43% | -0.38 |
| 14-Aug | 48.0 | 3596 | 1.41 | **0.216** | **0.063** | 71% | 15.58 | **0.008** | **0.010** | -25% | -0.20 |
| 16-Aug | 75.0 | 13098 | 1.93 | **0.198** | **0.028** | 86% | 63.05 | **0.008** | **0.007** | 13% | 0.37 |
| 25-Aug | 102.0 | 11911 | 1.17 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 25-Sep | 53.5 | 1471 | 0.90 | **0.189** | **0.129** | 32% | 2.50 | **0.075** | **0.059** | 21% | 0.67 |
| 2-Oct | 63.5 | 20696 | 2.53 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 6-Oct | 81.5 | 2774 | 0.69 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 14-Oct | 44.0 | 363 | 0.46 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 21-Oct | 33.0 | 231 | 0.49 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| 27-Oct | 19.5 | 110 | 0.40 | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* | *NA* |
| Totals: | 1012.5 | 128032 | 19.5 | | | | 147.5 | | | | 7.3 |

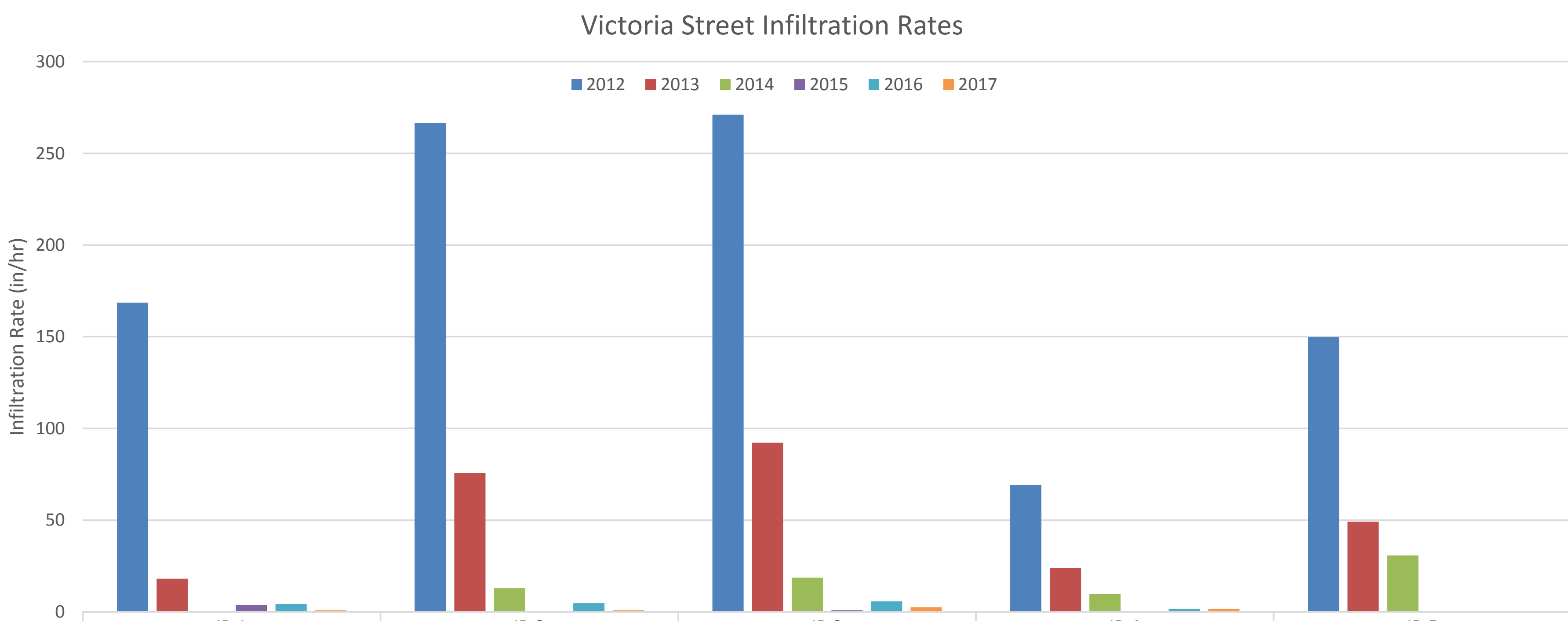
*NA - Not Analyzed*
**Bold -** Sampled Event
Negative Load Reduction
TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus

| | |
|---|---|
| Mass TP in | 291.2 |
| Mass TP out | 143.6 |
| Mass TP Retained | 147.5 |
| % P Retained | 51% |

| | |
|---|---|
| Mass SRP in | 38.6 |
| Mass SRP out | 31.3 |
| Mass SRP Retaine | 7.3 |
| % SRP Retained | 19% |

***Appendix D – Pervious Pavement Infiltration Charts***

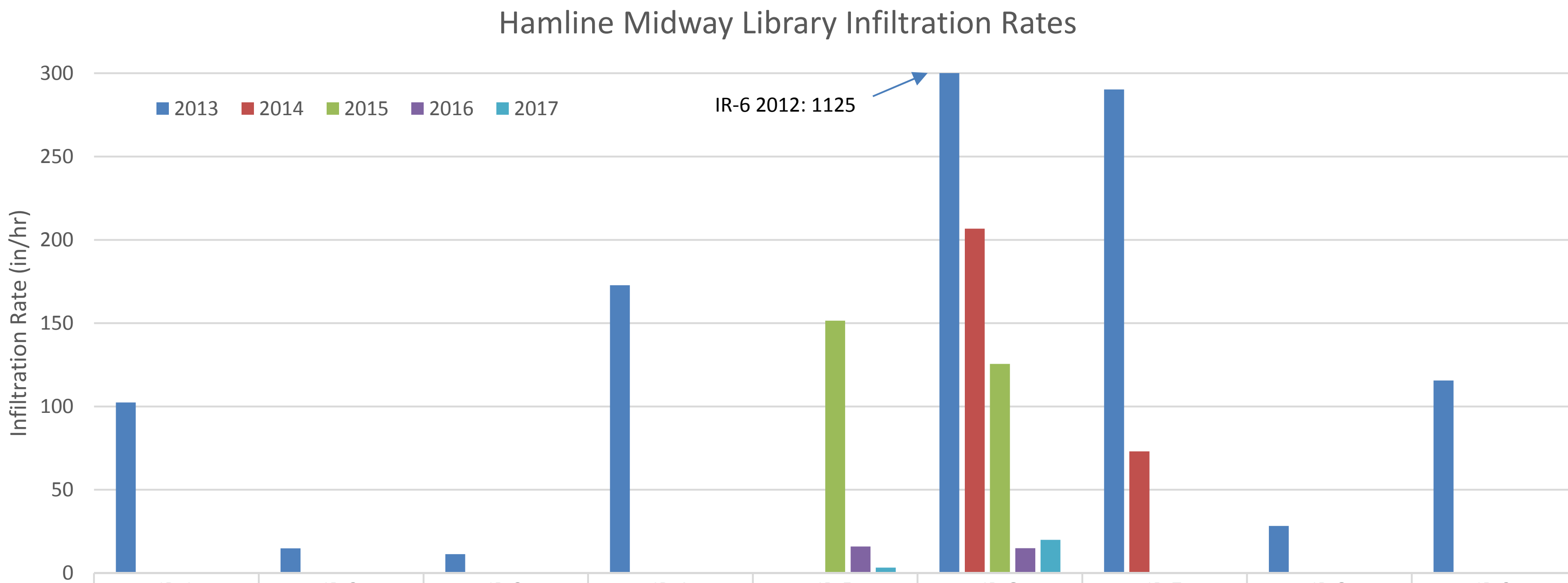
City of Saint Paul
2017 Water Quality and Quantity Report
Chart D.1
WSB Project Number: 01610-100




| | IR-1 | IR-2 | IR-3 | IR-4 | IR-5 |
|---|---|---|---|---|---|
| 2012 | 168.6 | 266.6 | 271.1 | 69.1 | 149.8 |
| 2013 | 18.1 | 75.7 | 92.2 | 24 | 49.2 |
| 2014 | 0 | 13 | 18.6 | 9.7 | 30.8 |
| 2015 | 3.7 | 0 | 0.9 | 0 | 0 |
| 2016 | 4.4 | 4.8 | 5.7 | 1.6 | 0 |
| 2017 | 0.85 | 0.94 | 2.51 | 1.6 | 0 |

Monitoring Location

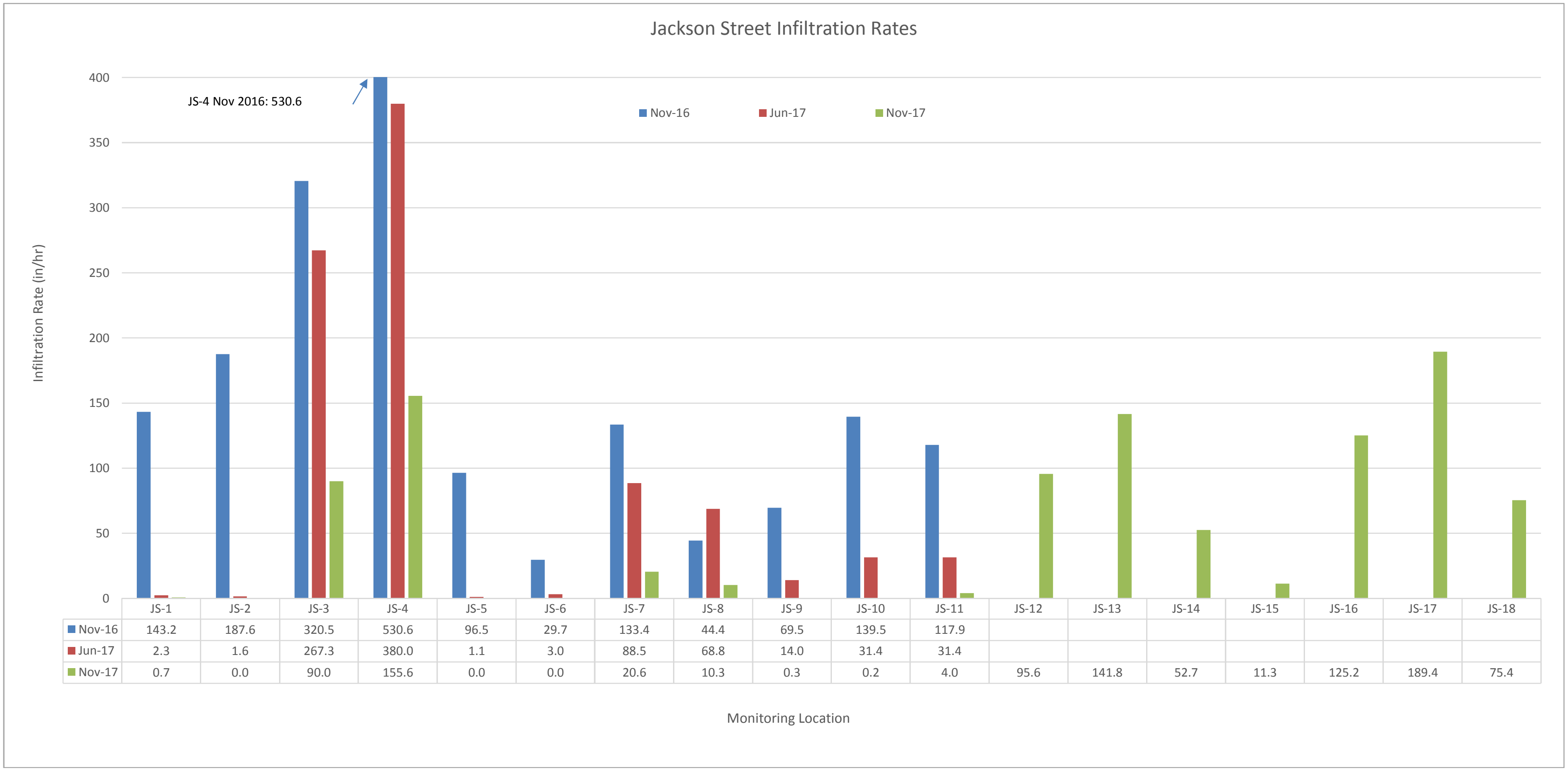
City of Saint Paul
2017 Water Quality and Quantity Report
Chart D.2
WSB Project Number: 01610-100




| | IR-1 | IR-2 | IR-3 | IR-4 | IR-5 | IR-6 | IR-7 | IR-8 | IR-9 |
|---|---|---|---|---|---|---|---|---|---|
| 2013 | 102.4 | 14.9 | 11.4 | 172.7 | 0 | 1125.3 | 290.2 | 28.4 | 115.6 |
| 2014 | 0 | 0 | 0 | 0 | 0 | 206.7 | 73 | 0 | 0 |
| 2015 | 0 | 0 | 0 | 0 | 151.5 | 125.6 | 0 | 0 | 0 |
| 2016 | 0 | 0 | 0 | 0 | 16 | 15 | 0 | 0 | 0 |
| 2017 | 0 | 0 | 0 | 0 | 3.3 | 20 | 0 | 0 | 0 |

Monitoring Location

City of Saint Paul
2017 Water Quality and Quantity Report
Chart D.3
WSB Project Number: 01610-100




| | JS-1 | JS-2 | JS-3 | JS-4 | JS-5 | JS-6 | JS-7 | JS-8 | JS-9 | JS-10 | JS-11 | JS-12 | JS-13 | JS-14 | JS-15 | JS-16 | JS-17 | JS-18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nov-16 | 143.2 | 187.6 | 320.5 | 530.6 | 96.5 | 29.7 | 133.4 | 44.4 | 69.5 | 139.5 | 117.9 | | | | | | | |
| Jun-17 | 2.3 | 1.6 | 267.3 | 380.0 | 1.1 | 3.0 | 88.5 | 68.8 | 14.0 | 31.4 | 31.4 | | | | | | | |
| Nov-17 | 0.7 | 0.0 | 90.0 | 155.6 | 0.0 | 0.0 | 20.6 | 10.3 | 0.3 | 0.2 | 4.0 | 95.6 | 141.8 | 52.7 | 11.3 | 125.2 | 189.4 | 75.4 |

***Appendix E – Photolog***

# 2017 Saint Paul Water Quality and Quantity Report

# Photo Log

# Arundel 2017

5/11/17

Installation 3/20/17

# Beacon Bluff OCS Weir Elevation Survey

2/14/17

Beacon Bluff Rain Garden
3/20/17

# Beacon Bluff MH7 Installation
3/28/17

West Pond Outlet Installation
3/28/17

# Beacon Bluff - 4/19/17 Rain Event




Beacon Bluff Pre-treatment
5/11/17

Beacon Bluff Post-Rain Event 5/16/17

Photos indicating water levels and damage after at 1.54” rain even on 5/17/17

Beacon Bluff





Photos of equipment – Beacon Bluff
6/14/17

Beacon Bluff Pre-treatment and BMP 7/17/17

Beacon Bluff Rain Garden
8/21/17

Beacon Bluff 10/20/17

Case Logger Install – 4/21/17

Sackett Playground Floodplain – 4/19/17 Rain Event

Sackett Playground – 6/7/17

Sackett Playground – 10/6/17

Hillcrest Knoll – 3/22/17

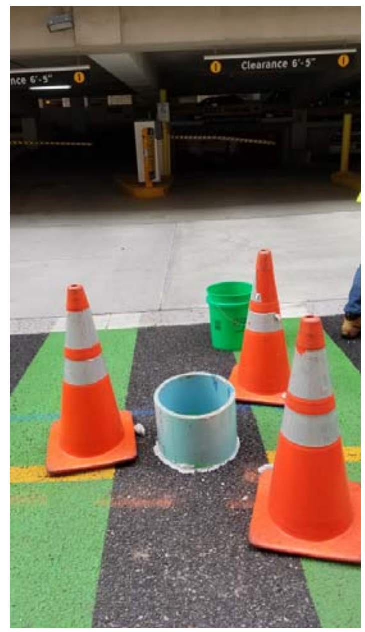


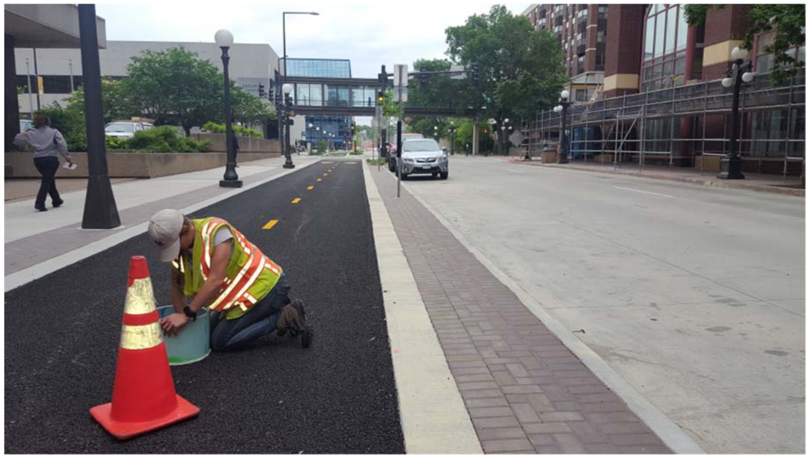

Hillcrest Knoll – 6/5/17

Hillcrest Knoll 7/17/7

Hillcrest Knoll 10/20/17

# Jackson Street Pervious Pavement Testing 7/17




CCB

Jackson Street Pervious Pavement Testing 11/7



PIONEER
PRESS

# Pervious Pavement Testing – Hamline Library 11/8/17







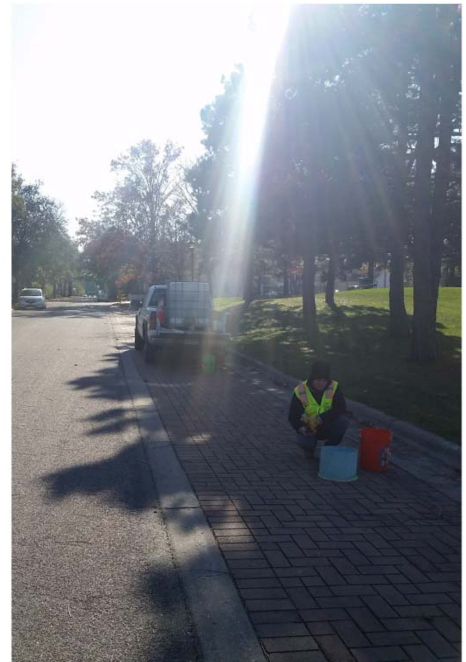


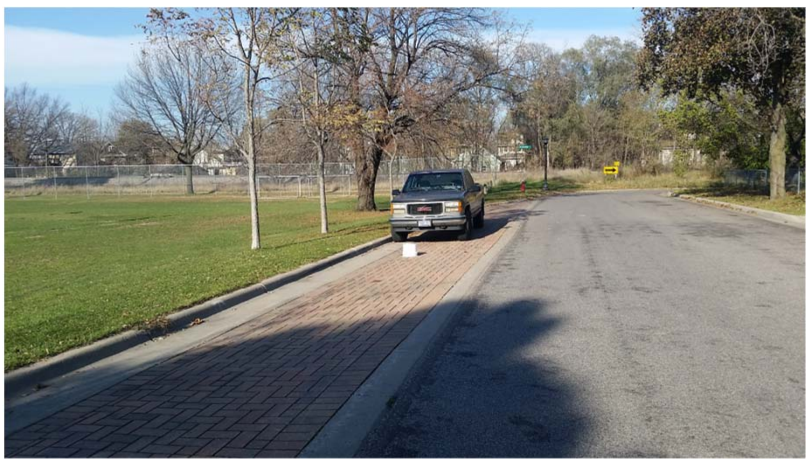

Pervious Pavement Testing – Victoria 11/8/17











Hoyt Pond – 4/19/17

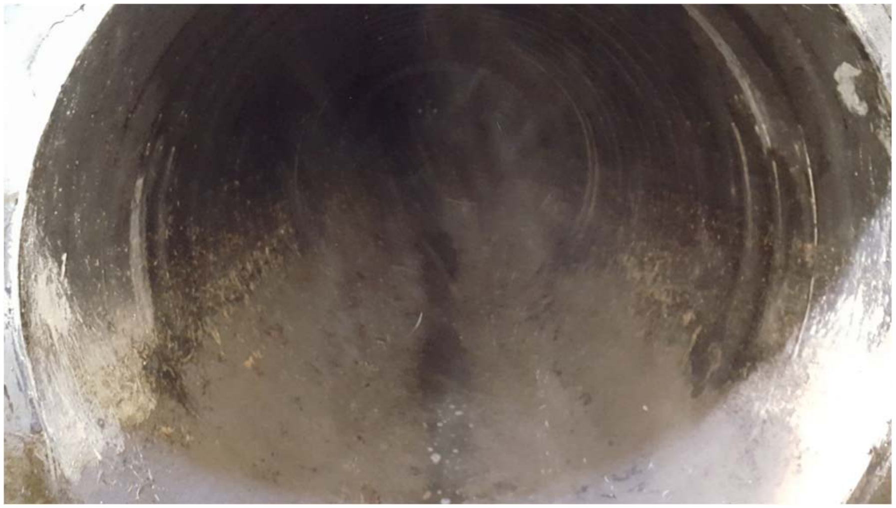
Hoyt Pond – 10/6/17

Hampden Park Installs – 3/22/17


NOT A
TRUCK
ROUTE

Hampden Park – 4/18/17


# Hampden Park 5/12/17



# Hampden Park - 7/17/17

Hampden Park 10/20/17

Wordsworth RSVP Trench 3/16/17

## Montreal RSVP Trench – 3/16/17

Montreal RSVP Trench – 3/19/17

# Saint Albans Install/Maintenance – 3/22/17

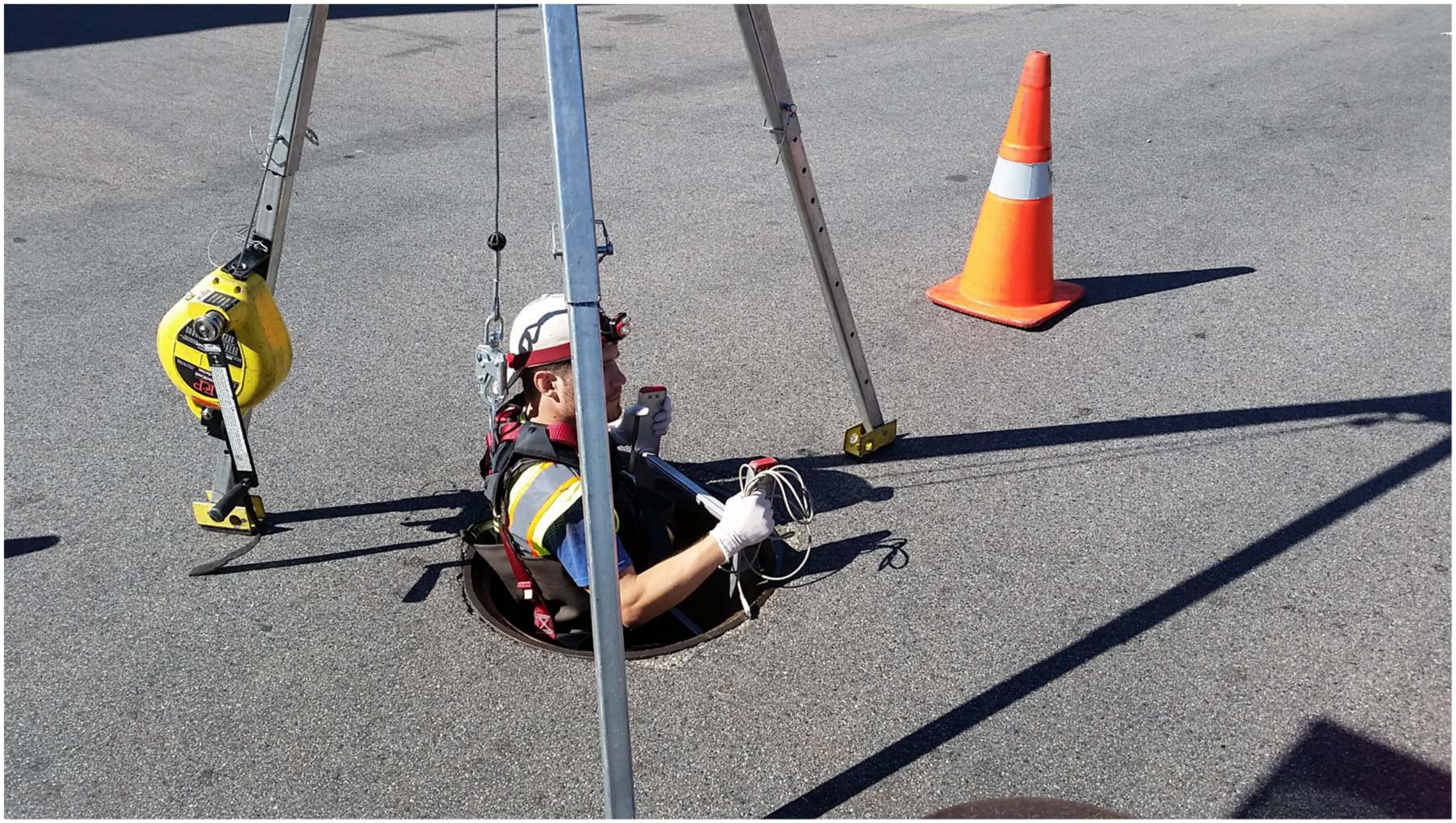
Saint Albans and University Install –
3/22/17


Saint Albans - 5/22/17

# Saint Albans – 7/17/17




Saint Albans 8/22/17



Saint Albans 10/20/17

# Saint Kates Logger Installs 7/14/17

# TBNS Installs – 4/19/17



TBNS – 4/19/17 Rain Event

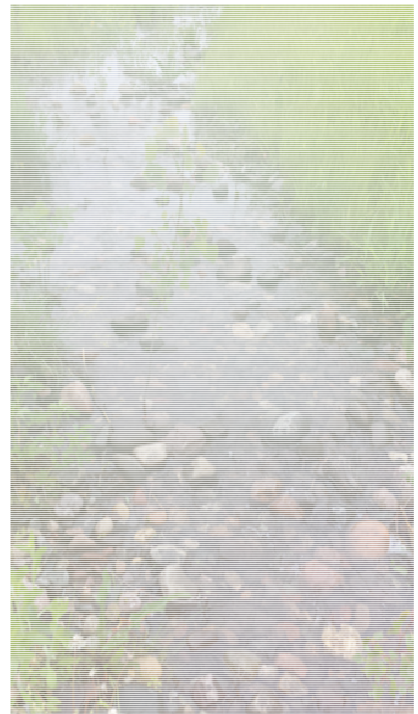






# TBNS – 5/18/17 Rain Event






TBNS – 6/17/17


6712
6712


WSB

Jenks Pond – 7/26/17 Rain Event

# Magnolia Pond – 7/19/17




TBNS BMP Inspection – 8/22/17


SEWER UTILITY







TBNS – 10/4/17

***Appendix F – 2017 Monitoring Protocols***

# STORMWATER MONITORING PROTOCOL

**2017 WATER QUANTITY AND QUALITY MONITORING PROGRAM**

**FOR THE CITY OF ST. PAUL, MINNESOTA**

**WSB PROJECT NO. 01610-100**

The Most Livable City in America

& Associates, Inc.

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**TITLE PAGE**

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Attachments:

WSB Confined Space Entry Permit

Metropolitan Council Environmental Services Laboratory Chain-of-Custody (BMP Infiltration Sites)

Metropolitan Council Environmental Services Laboratory Chain-of-Custody (TBNS Infiltration Sites)

# I. Objectives

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

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

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

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

d) How often does each BMP require maintenance?

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

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

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

## II. Safety Overview

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

### II.1 Adverse Weather Conditions:

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

- During excessive heat and sun conditions, field staff should stay hydrated, don skin protective clothing, and apply sunscreen .During excessive cold conditions, field staff should dress in layers and avoid perspiration
- During lightning producing conditions, field staff must seek shelter in a work vehicle or other safe location if a lightning strike or thunder is observed. The field staff should wait at least 30 minutes from the last lightning strike before resuming outdoor activities. 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 (**Confined Space Entry Permit Attached**). See WSB's safety office, Trent Noeker, 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

Required Safety Gear:

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

Gear Maintenance:

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

General Confined Space Entry Procedures:

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

# III. Monitoring Sites

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

## III.1 Beacon Bluff:

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

Equipment:

- 3 – ISCO 2150 Area velocity sensors (Upstream, Downstream, WPO)
- 5 – System Level Loggers
  - BMP Pipe
  - OCS
  - IR-31(Rain Garden - west)
  - IR-32 (In-rock east)
  - BaroTroll (atmospheric logger)
- 2 – Rugged Troll 100
  - GW-50
  - GW-53
- 1 – ISCO 6712 Portable water quality sampler

Monitoring Parameters:

- Rainfall
- Flow Rate/Volume
- Water Level/Infiltration rate
- Water Quality **(NPDES Permit Required Parameters)**

## III.2 Hillcrest Knoll Park:

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

Equipment:

2 – ISCO 2150 Area velocity sensors (Upstream, Downstream)
2 – Level Troll 500
BMP Pipe
HK-GW
1 – Rugged Troll 100
IR-1

Monitoring Parameters:

- Rainfall
- Flow Rate/Volume
- Water Level/Infiltration rate

### III.3 St. Albans:

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

Equipment:

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

Monitoring Parameters:

- Rainfall
- Flow Rate/Volume
- Water Level/Infiltration rate

### III.4 Arundel Street:

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

Equipment:

1 - Level Troll 500
BMP Pipe

Monitoring Parameters:

- Rainfall

- Water Level/Infiltration rate

## III.5 Hampden Park

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

Equipment:

1 – ISCO 6712 Portable water quality sampler
1 – ISCO 2150 Area velocity sensor (Upstream)
1 – Level Troll 500
P-2
1 – Rugged Troll 100
BMP

Monitoring Parameters:

- Rainfall
- Water level/Infiltration rate
- Flow Rate
- Water Quality **(NPDES Permint Required Parameters)**

## III.6 Trout Brook Nature Sanctuary

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

Stormwater is conveyed to the iron-enhanced ponds from individual diversion structures along the 42” main stormsewer line. Prior to the pond, the flow is routed through a

Vortech's pre-treatment structure for particle settling. As the level in the pond rises, the water gravity flows through a sand filtration bench that has additional iron content. The iron-enhanced sand provides a mechanism to remove soluble reactive phosphorus, a dissolved bio-available form of phosphorus, which is not effectively removed by settling pre-treatment devices. Beneath the sand bench is 8" drain tile to convey the treated water to the outlet control structure of the pond.

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

Equipment (Complete set at each of the three ponds) :

1 – ISCO 2150 Area velocity sensors (8" drain tiel)
2 – ISCO 6712 portable water quality sampler (pond, 8" drain tile)
1 – Rugged Troll 100

Monitoring Parameters:

- Rainfall
- Water Level
- Flow Rate
- Water Quality **(Total Phosphorus, Dissolved Phosphorus, Soluble Reactive Phospohrus, Total Iron, Total Suspended Solids, Hardness)**

### III.7 Level Logger Only Sites

The following Sites are evaluated for level/infiltration only. The sites include:

Level Only sites:

- Montreal Trench
- Wordsworth Trench
- Sackett Park Pond
- Flandrau-Hoyt Pond
- East Phalen (groundwater)
- St. Kate's (5 groundwater piezometers)

Each site consists of 1 – In-Situ electronic level logger

## 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.

Infiltration SystemsFrequency:

- 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.1 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

## VI. 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:

### VI.1 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[2] |
|---|---|---|
| 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.) | Hampden Park | Beacon Bluff |
|---|---|---|
| | Runoff Volume (cu-ft) | Runoff Volume (cu-ft) |
| 0.10-0.15" | 2,430 | 4,500 |
| 0.25" | 3,869 | 20,986 |
| 0.5" | 5,516 | 63,000 |
| 1.0" | 10,539 | 156,756 |
| 2.0" | 48,834 | 373,550 |
| 3.0" | 138,105 | 657,879 |

Program Automated Sampling Parameters:

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

- **Start Time:** Begin sampling at specific water level depths
  - Hampden Park 1.0-inches
  - Beacon Bluff: 1.0-inches

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

- **Pacing:** Set sampler to collect samples at constant flow volume intervals
  - Beacon Bluff: minimum 1,750 cu-ft (0.034 Mgal)
  - Hampden Park:  405 cu-ft (0.010 Mgal)
- **Distribution:** Multiple samples per bottle - sample aliquot volume should be no less than 200 mL

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.

**VI.2 Grab Sample Collection**

Grab samples will be collected for E coli analysis from the Beacon Bluff and Hampden Park. Samples will be collected from the influent stormwater stream prior to entering the systems. 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:

Sampling Locations:

- Man holes up stream of the automatic samplers at Hampden Park and Beacon Bluff

Procedures:

- 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

Required Equipment:

- 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

**VI.3 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 the water quality parameters in Table 1 of the City of St. Paul's MS4 permit (when volumes allow). These parameters do not apply to the TBNS Sites.

| 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 |

Samples Collected at the TBNS shall be analyzed for Total Phosphorus, Dissolved Phosphorus, Soluble Reactive Phosphorus, Total Suspended Solids, Total Iron, and Hardness.

### VI.4 Sample Preservation

- Collect samples from automated sampler within 24 hours
- Composite individual sample containers from the autosampler into one, clean, 4-liter jug, provided by MCES Lab
  - If the storm event produced volume in exceess of 4 liters, the sample volume shall be composited in the churn sampler splitter.
  - Fill the churn will all samples collected from the event. One staff shall provide constant mixing using the paddle, while the other staff shall open the spickot, gradually filling the lab container with the mixed sample
  - The churn sampler splitter shall be cleaned between uses
- The sample containers shall be labeled with the relevant Site and sample information which shall include:
  - Site Name [**See attached Chain of Custody (CoC)** examples for Site IDs].
  - The composite start and end time, as indicated on the autosampler
  - Name of staff collecting the sample
- The sampler shall complete a CoC form to submit with the sampler or communicate sample information to the Project Manager to complete the form electronically, and submit to the lab
- Place all samples to be analyzed in a cooler with ice
  - Target holding temperature for samples is 4˚C
- Deliver samples to lab

### VI.5 Cleaning of Sample Equipment and Bottles

- **Clean sample bottles and churn splitter 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

### VI.6 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

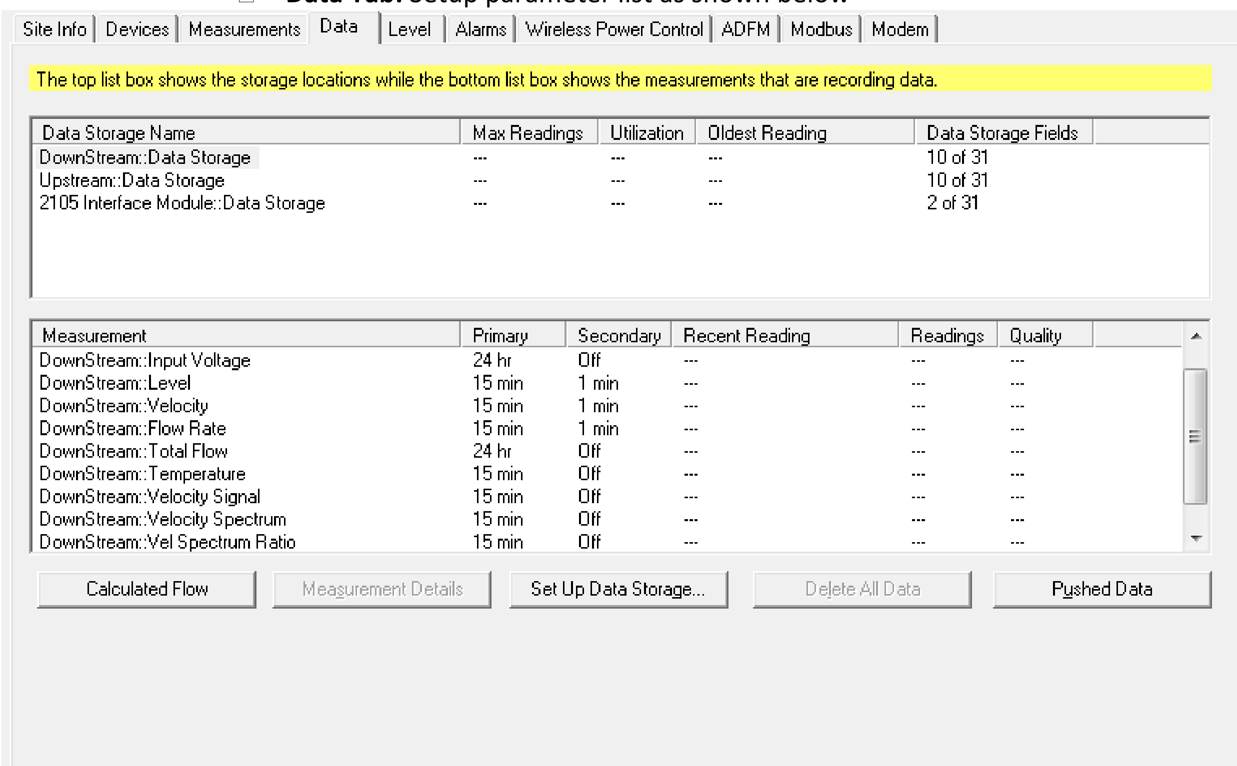
# VII. Operation and Maintenance of Monitoring Equipment

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.

### VII.1 Flow Meters (ISCO 2150)[3] and Interface Modules (ISCO 2105/2103)[4]:

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)
  - **Level:** If flow is present, measure the water depth from the water surface to the channel bottom. Enter the value on the *Level*

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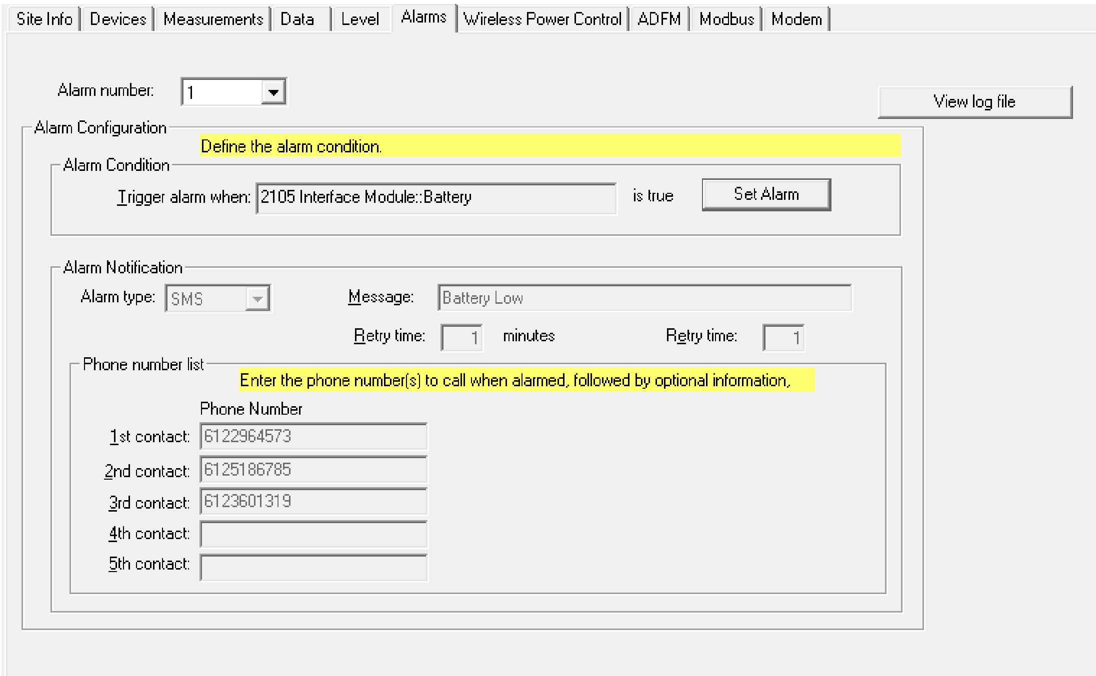
[3] See 2150 Area Velocity Flow Module and Sensor – Installation and Operation Guide, Teledyne ISCO, Rev. March 9, 2011.

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

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

Routine Data Retrieval and Re-initialization:

- **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)

Routine Maintenance:

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

## VII.2 Portable Sampler (ISCO 6712)[5]:

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. Hampden Park, Beacon Bluff)
    - (8) Select 1 pulse between sample events
    - (9) Samples/Bottle
    - (11) 5 Samples/Bottle (200 mL each)
    - (12) No Delay to Start
- **Automatically index to next bottle when sampler is enabled:** This will allow each storm event to be composited separately, but may decrease the overall available sampling volume during multiple events
    - From home screen, enter 6712.9 and hit enter
    - Enter Code: 1199 and hit enter (Sampler should report Code Accepted)
- **Calibration:** The Sampler delivers accurate sample volumes without calibration. If you find that sample volumes vary significantly from the programmed values, first check the suction line for proper installation. Be sure it slopes continuously downhill to the liquid source and drains completely after each sampling cycle. Refer to Section 4.12 of the operation guide for additional calibration notes
    - Note: If sampler does not disable when the program is set to run, check all cable connections and then make sure the 2105 is configured correctly. If the water level is below the trigger threshold, the 2105 should be indicating that the Sampler is disabled. If the sampler is still not disabling, the cable or the sampler may be malfunctioning. The cable can be diagnosed by removing the sampler cable and using a paper clip to short pins “B” and “F” on the back of the sampler control head

Routine Data Retrieval and Re-initialization:

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

Routine Maintenance:

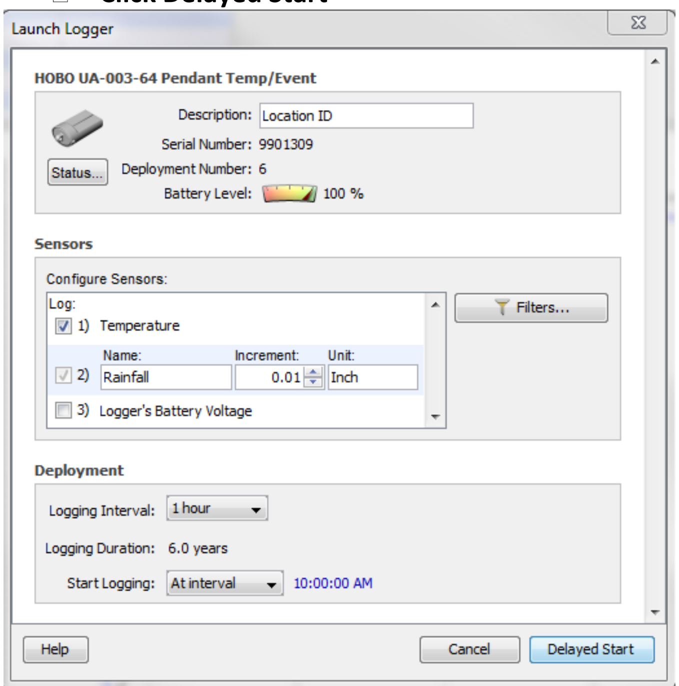
[5] See 6712 Portable Samplers – Installation and Operation Guide, Teledyne ISCO, Rev. April 11, 2011.

- ☐ **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

## VII.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**

## VII.4 Water Level Logger (Level Troll 500)[6]:

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_2017
    - **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 (sites with standing water in the BMP should utilize a threshold that will prevent the "event" setting from being continuously triggered)
        - Default record data every 60 measurements
    - **Schedule Start time:** on Next Hour
    - **Output:** Depth (BMP Sites) Depth to water (Groundwater Sites)

[6] 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

## Attachments

WSB Confined Space Entry Permit

Metropolitan Council Environmental Services Laboratory Chain-of-Custody (BMP Infiltration Sites)

Metropolitan Council Environmental Services Laboratory Chain-of-Custody (TBNS Infiltration Sites)

***Appendix G – ASTM C1701 Procedures***

Designation: C1701/C1701M – 09

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

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

## 1. Scope

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

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

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

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

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C920 Specification for Elastomeric Joint Sealants

2.2 *Other Standards*

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

## 3. Terminology

3.1 *Definitions:*

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

## 4. Summary of Test Method

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

## 5. Significance and Use

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

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

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

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

## 6. Apparatus

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

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

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

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

6.4 *Stop Watch*—Accurate to 0.1 s.

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

6.6 *Water*—Potable water.

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

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

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

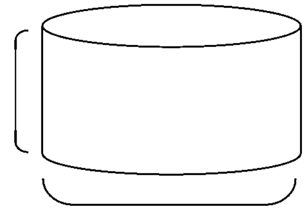


**FIG. 1 Dimensions of Infiltration Ring**

## 7. Test Locations

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

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

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

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

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

## 8. Procedure

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

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

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

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

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

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

## 9. Calculation

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

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

where:

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

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

## 10. Report

10.1 Report the following information:

10.1.1 Identification number,

10.1.2 Location,

10.1.3 Date of test,

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

10.1.5 Time elapsed during prewetting, s,

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

10.1.7 Weight of infiltrated water, kg [lb],

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

10.1.9 Time elapsed during infiltration test, s,

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

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

## 11. Precision and Bias

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

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

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

## 12. Keywords

12.1 concrete; infiltration; pervious; water