Ottawa. ON
Paris. ON
Gatineau. QC
Montréal. QC
Québec. QC

JFSA
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS

KANATA GOLF & COUNTRY CLUB 2019 MONITORING & HYDROLOGIC MODEL CALIBRATION REPORT

July 2020

Prepared For:
David Schaeffer Engineering Ltd
120 Iber Rd
Stittsville, ON
K2S 1E9

Prepared By:
J.F. Sabourin and Associates Inc.
52 Springbrook Drive,
Ottawa, ON K2S 1B9
T 613-836-3884 F 613-836-0332

jfsa.com

Ottawa. ON
Paris. ON
Gatineau. QC
Montréal. QC
Québec. QC

KANATA GOLF & COUNTRY CLUB 2019 MONITORING & HYDROLOGIC MODEL CALIBRATION REPORT

July 2020

Prepared For:
David Schaeffer Engineering Ltd
120 Iber Rd
Stittsville, ON
K2S 1E9

Prepared by:

Tamarra Lewis, EIT, Water Resources Engineer in Training,
Jonathon Burnett, P. Eng, Water Resources Engineer

Approved by:

J.F. Sabourin, M.Eng., P.Eng.,
President and Director of Water Resources Projects
J.F. Sabourin and Associates Inc.

TABLE OF CONTENTS:

FIGURES:

TABLES:

APPENDICES:

1 PROJECT OVERVIEW

1.1 Introduction

The Kanata Golf and Country Club is located at 7000 Campeau Drive in Kanata, Ontario. The existing Golf and Country Club is located north of Campeau Drive, west of Teron Road, south of Walden Drive and east of Kanata Avenue. The area includes an 18-hole golf course surrounded by existing residential development. The Golf and Country Club and surrounding area drain to the existing Beaver Pond just off Walden Drive, which discharges to the Kizell Drain and then to Watts Creek before ultimately discharging to the Ottawa River. J.F. Sabourin and Associates Inc (JFSA) were commissioned to complete surface water, storm sewer, and rainfall monitoring around the study area in 2018 and 2019, with the intention to develop a better understanding of the existing hydrologic and hydraulic characteristics of the area. The following report outlines the data obtained from the 2019 monitoring program and explains how this data was used to produce a more realistic and dependable hydrologic model of the area. Where possible, the calibrated model was then compared with field data obtained by AECOM from the same study area in 2013.

1.1.1 2018 - Rainfall, Surface Runoff Monitoring and Infiltration Testing

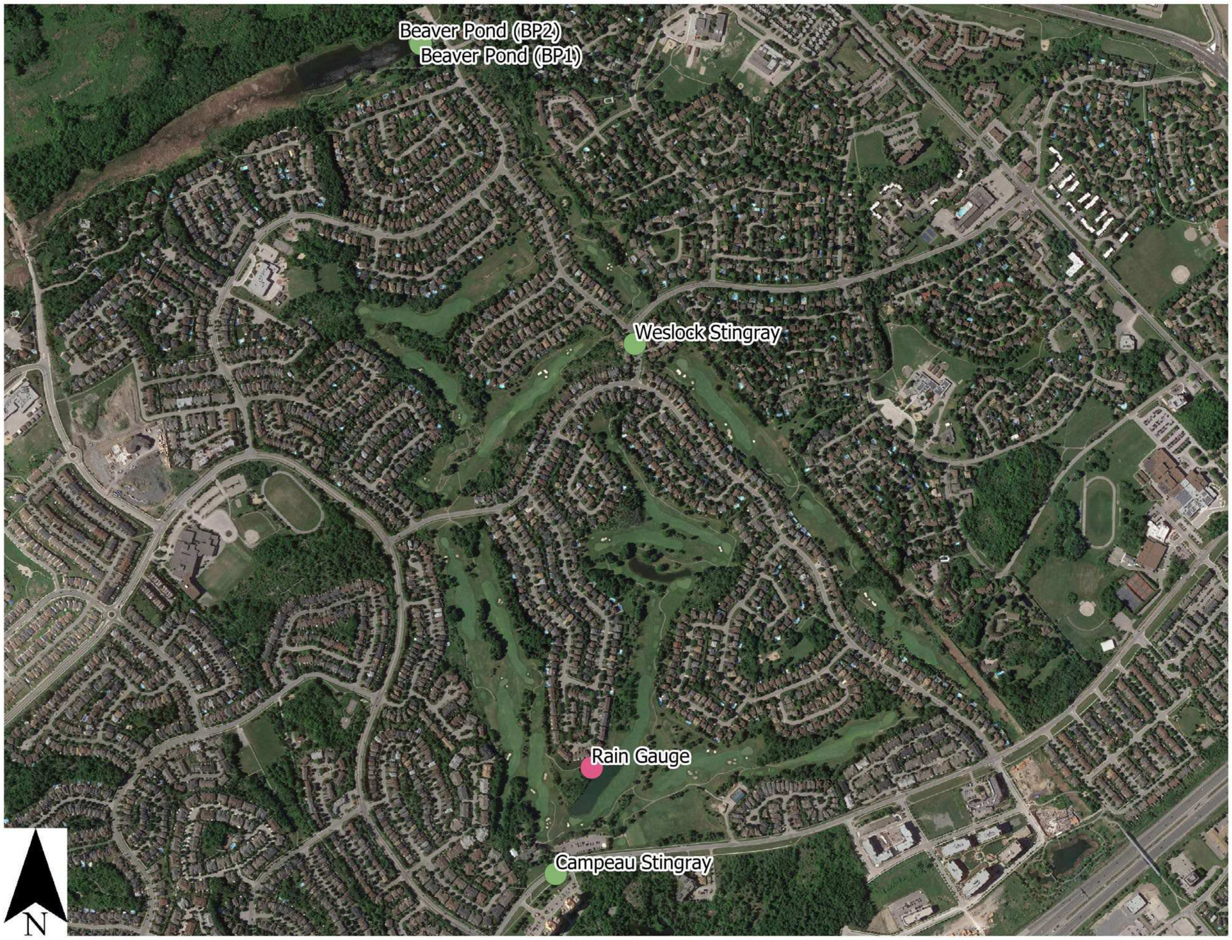
As discussed above, JFSA also completed a monitoring program in 2018, this program consisted of three-level loggers, one barometric logger, one Stingray Level-Velocity Logger and one rain gauge, all of which were located within the Kanata Golf and Country Club Property. Full details of the 2018 field program have been presented in JFSA's "*Kanata Golf & Country Club – 2018 Surface Water and Rainfall Monitoring Program*" Memo, dated February 6, 2019, which has been included in Appendix A of this report. Infiltration and percolation tests were also completed at four locations within the site and have been documented in JFSA's February 2019 memo titled "Kanata Golf & Country Club – 2018 Surface Infiltration testing", which has been included in Appendix B of this report.

1.1.2 2019 - Rainfall, Storm Sewer and SWM Facility Monitoring

The 2019 Monitoring Program consisted of one rain gauge on the Kanata Golf and Country Club site, two Stingray Level-Velocity Loggers (Stingray) within the existing storm sewer system, two level-loggers and one barometric logger located at the Beaver Pond. The two Stingray loggers were installed at strategic locations within the storm sewer system that discharges to the Beaver Pond. One stingray was placed on Campeau Drive (in a 1350 mm storm sewer pipe) to capture the runoff from a portion of the subwatershed that is comprised mostly of residential units, that are typical for the area. The second logger was located on Weslock Way (in a 2250 mm storm sewer pipe) to capture the largest possible drainage area that could be safely monitored, while not being affected by the backwater from the Beaver Pond. The Weslock site captures runoff from both the existing golf course and residential areas.

The rain gauge was re-installed at the same location as in 2018; on top of the pump house located within the golf course. The level-loggers were installed at the Beaver Pond to measure the pond water level and temperature throughout the year. Refer to Figure 1 for all and monitoring locations from 2019.

Figure 1: 2019 General Site Location, Testing and Monitoring Locations



During the 2019 monitoring period, JFSA conducted 18 site visits to; install equipment, inspect the operation of the field equipment, download recorded data and measure instantaneous water levels and velocities. Table 1 summarizes all dates JFSA staff were onsite and provides a brief description of the task(s) completed on that date. All field instruments were installed between late April – early June of 2019 and uninstalled in October 2019.

Table 1: 2019 Site Visit Summary

Date	Description
April 30, 2019	**Rain gauge installation**
May 15, 2019	Rain gauge download, **Beaver Pond level logger and barometric logger Installation**
May 23, 2019	Download level loggers
May 30, 2019	Download level loggers
June 3, 2019	Maintenance hole reconnaissance for Stingray level logger location
June 5, 2019	**Campeau Drive Stingray installation**
June 6, 2019	**Weslock Way Stingray installation**
June 11, 2019	Stingray, level logger, and rain gauge download
June 17, 2019	Stingray download
June 21, 2019	Stingray, level logger, and rain gauge download
June 27, 2019	Move rain gauge logger to avoid working at heights during download
July 8, 2019	Stingray, level logger, and rain gauge download
July 16, 2019	Stingray, level logger, and rain gauge download
July 29, 2019	Stingray, level logger, and rain gauge download
August 6, 2019	Level logger download, GPS points, and velocity measurement downstream of the Beaver Pond
August 20, 2019	Stingray, level logger rain gauge download and velocity measurement downstream of the Beaver Pond
August 29, 2019	Stingray, level logger rain gauge download and velocity measurement downstream of the Beaver Pond
September 9, 2019	Stingray, level logger rain gauge download and velocity measurement downstream of the Beaver Pond
October 9, 2019	Stingray, level logger rain gauge download and velocity measurement downstream of the Beaver Pond
October 18, 2019	**Remove Campeau Drive stingray and Weslock Way stingray loggers**
October 23, 2019	**Remove rain gauge and Beaver Pond level loggers**

2 RAINFALL

A TE525-series tipping bucket rain gauge was installed on-site on April 30th, 2019 and was located on the roof of the pumphouse on the Kanata Golf and Country Club property. The gauge was installed on the roof to avoid any interruption to precipitation due to nearby vegetation or trees. The rain gauge was mounted on a device enabling a level placement and that would withstand large rainstorms and wind without shifting the rain gauge. The gauge was calibrated before it was initiated and the lip of the funnel was horizontal, and at least 30 cm above the ground. To avoid climbing on the roof during each download, the logger was placed in a waterproof box at ground level for easy access and locked with a padlock to ensure no interference. See Figure 2 below for a photo of the rain gauge setup.

Figure 2: 2019 Rain Gauge Setup

The rain gauge was active from April 30 to October 23, 2019, and as such, provided 177 days of rainfall data. The rainfall data collected at the Kanata Golf & Country Club was compared with the rainfall collected by the City of Ottawa at their St. Gabriel School rain gauge, on 400 Keyrock Dr, Kanata, located approximately 1.6 km northwest of the site's rain gauge. Figure 3 on the following pages compares the cumulative volume recorded by JFSA's gauge against the City of Ottawa gauge at St Michael's. From this figure, it is seen that the response of the two gauges is similar with only slight differences for particular events which are resulting in the difference in total rainfall volume over this window.

The comparison of total rainfall for monthly and annual rainfall (mm) for these two gauges has been provided in Table 2 below. Plots comparing the two rain gauges every month can be found in Appendix C. These plots show a similar response for the respective rainfall events, with only slight differences in intensity, total volume and timing due to the differences in the variance in rainfall over a given area. Overall, the Kanata Golf and Country Club rain gauge (KGCC) was deemed reliable, as the response and total rainfall collected over this period compared reasonably well to the City of Ottawa rainfall data at St Gabriel's School.

Table 2: Kanata Golf & Country Club Rain Gauge Rainfall Comparison with City of Ottawa St Gabriel's Rain Gauge - 2019

Rainfall (mm)

Month	Total Rainfall (mm)	
	KGCC	St. G
April-May	103.27	109.60
June	139.15	145.80
July	50.48	63.00
August	64.86	71.00
September	75.67	76.20
October	71.19	74.80
Total	**504.62**	**540.40**

2.1 Significant Rainfall Events

The following section outlines the "Significant Rainfall Events" that occurred during this monitoring period. For this study, a 'Significant Rainfall Event' was defined as a single event if the total rainfall volume was greater than 5 mm and was followed by at least 12 hours without any additional rainfall. A total of 34 significant rainfall events were observed and measured between April 30th to October 23rd, 2019. See Table 3 for a full breakdown of these events.

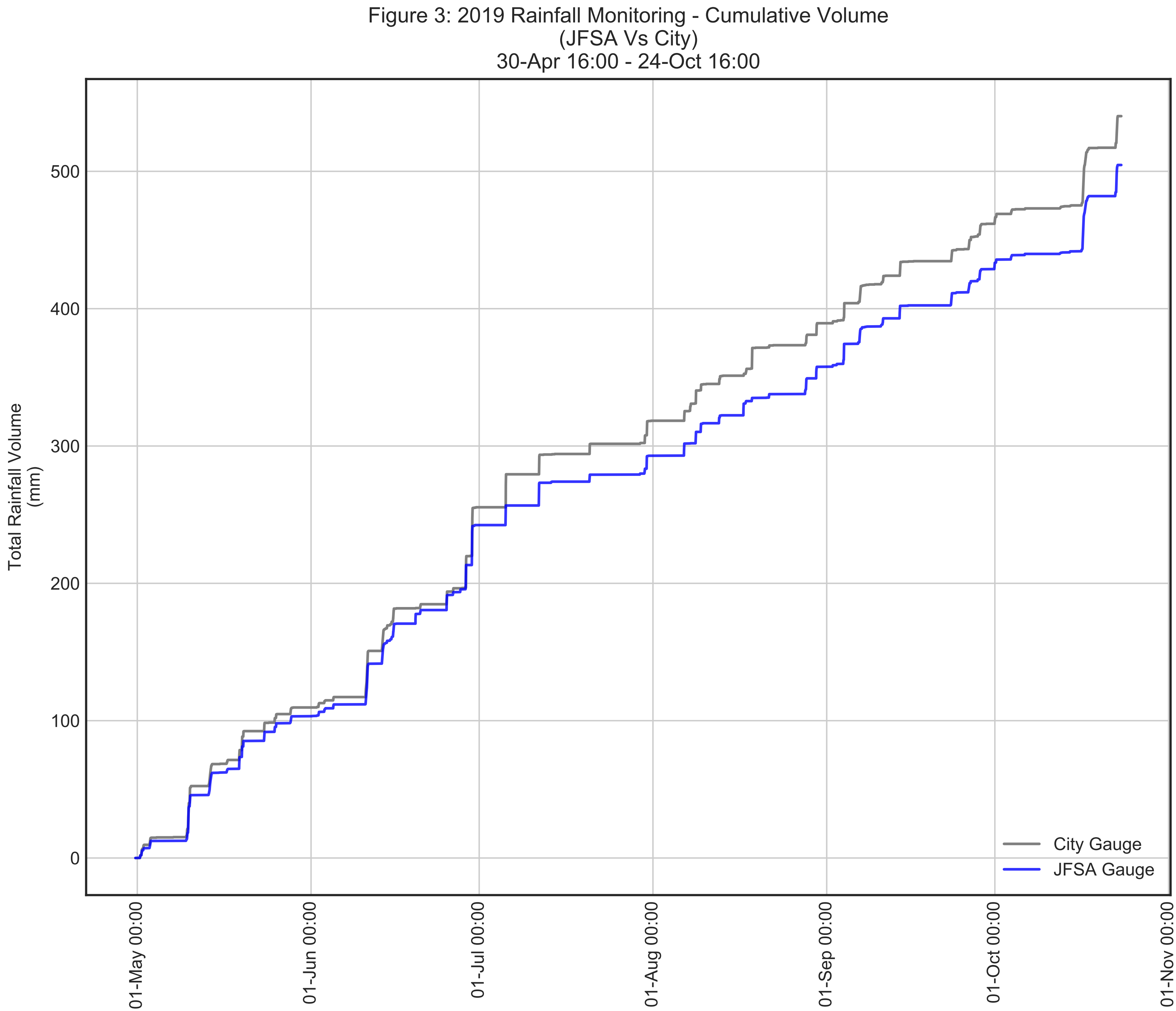


Figure 3: 2019 Rainfall Monitoring - Cumulative Volume
(JFSA Vs City)
30-Apr 16:00 - 24-Oct 16:00
Total Rainfall Volume
(mm)
0
100
200
300
400
500
01-May 00:00
01-Jun 00:00
01-Jul 00:00
01-Aug 00:00
01-Sep 00:00
01-Oct 00:00
01-Nov 00:00
City Gauge
JFSA Gauge

Table 3: 2019 - Total Significant Rainfall Events
(events with more than 5 mm and separated by at least 12 hours of no rain)

Event	Start Date/Time	Finish Date/Time	Duration (day:hr:min)	Total Rainfall (mm)
1	01-May 11:15	02-May 4:35	0:17:20	7.13
2	03-May 4:00	03-May 8:40	0:04:40	5.29
3	09-May 16:35	10-May 13:30	0:20:55	33.24
4	13-May 16:55	14-May 14:00	0:21:05	16.22
5	19-May 3:55	20-May 4:50	1:00:55	20.47
6	23-May 14:40	23-May 17:15	0:02:35	6.56
7	25-May 11:30	25-May 20:25	0:08:55	6.33
8	28-May 5:55	28-May 13:25	0:07:30	5.06
9	10-Jun 16:25	11-May 5:45	0:13:20	29.56
10	13-Jun 15:05	16-Jun 4:30	2:13:25	29.21
11	19-Jun 15:10	19-Jun 15:25	0:00:15	7.02
12	25-Jun 4:20	25-Jun 7:40	0:03:20	10.93
13	28-Jun 13:30	28-Jun 15:25	0:01:55	17.60
14	29-Jun 16:25	30-Jun 4:45	0:12:20	29.10
15	05-Jul 16:40	05-Jul 17:25	0:00:45	14.26
16	11-Jul 15:15	11-Jul 17:05	0:01:50	16.56
17	20-Jul 15:45	20-Jul 16:25	0:00:40	5.06
18	30-Jul 10:50	31-Jul 4:30	0:17:40	13.00
19	06-Aug 12:35	06-Aug 13:50	0:01:15	8.86
20	08-Aug 14:30	08-Aug 15:25	0:00:55	8.28
21	09-Aug 12:20	09-Aug 21:25	0:09:05	6.33
22	12-Aug 18:35	13-Aug 4:40	0:10:05	5.75
23	17-Aug 3:15	17-Aug 14:20	0:11:05	10.35
24	28-Aug 3:00	28-Aug 10:15	0:07:15	11.50
25	30-Aug 2:55	30-Aug 6:00	0:03:05	8.51
26	03-Sep 22:40	04-Sep 2:45	0:04:05	14.61
27	06-Sep 14:10	08-Sep 3:25	1:13:15	12.54
28	14-Sep 00:00	14-Sep 01:30	0:01:30	9.09
29	23-Sep 1:50	24-Sep 7:30	0:05:40	8.86
30	26-Sep 5:55	26-Sep 16:00	0:10:05	8.05
31	27-Sep 5:05	28-Sep 14:20	1:09:15	8.86
32	30-Sep 21:30	01-Sep 5:10	0:07:40	6.90
33	16-Oct 10:05	17-Oct 17:45	1:07:40	40.25
34	22-Oct 11:20	22-Oct 21:40	0:10:20	22.66

2.2 2019 Intensity-Duration-Frequency Analysis

The Rainfall-Duration Max Intensity summary for the 2019 collected rainfall is shown in Table 4 for this analysis. The IDF curves from the Ottawa International Airport, based on data from 1967-2003 was used to evaluate the return period of the measured intensities for the specified events. Appendix C contains the full hyetographs and their comparison against the Intensity-Duration-Frequency (IDF) curves. As indicated in Table 4 below, all the significant events from April 30th to October 23rd, 2019 were less than a 2-year return period.

Table 4: Kanata Golf and Country Club – 2019 Rainfall Duration/Max Intensity Summary

Duration	Maximum Measured Rainfall Intensity (mm/hr)	Return Periods Based on Ottawa Airport IDF (Years)
5 Minute	71.76	<2
10 Minute	51.06	<2
15 Minute	42.78	<2
30 Minute	28.98	<2
60 Minute	17.37	<2
2 Hour	13.57	<2
6 Hour	4.75	<2
12 Hour	2.47	<2
24 Hour	1.59	<2

AECOM Completed a similar IDF analysis based on the 2013 rainfall data that they acquired near the study area. From their analysis, it was determined that there were 4 events recorded during 2013 that had return periods greater than the 2-Year event, with one event having a 10-year return period. An excerpt from AECOM's 2015 documenting the IDF from the 2013 data has been provided in Appendix D.

3 BEAVER POND WATER LEVEL MONITORING

Two level loggers and one barometric logger were installed at the Beaver Pond in May 2019. The purpose of these loggers was to identify the fluctuations in water levels in the pond as well as determine the outflow of the pond. A barometric logger was placed near the site to account for the changes in air pressure, recorded by all level loggers. With the atmospheric pressure accounted for in the recorded data, these values were then converted to depths, as both the temperature of the water and the total hydrostatic pressure were known. Manual depth measurements obtained in the field were used to correct the depths recorded by the loggers. A GPS survey of the site was completed during the August 6th field visit, which allowed for the conversion of the recorded depths into geodetic elevations. Table 5 is a summary of the water surface elevations physically measured in the Beaver Pond during site visits. Table 6 is a summary of the minimum, maximum, and average elevations recorded during this monitoring period. Appendix E contains plots of the Beaver Pond water levels from May – October 2019, on monthly windows.

Note that the invert of the Beaver Pond outlet (a 600 mm circular orifice) is at an elevation of 90.42 m. From the results presented in Table 6, the maximum recorded pond level was 90.989 m (depth of 569 mm), therefore the 600 mm orifice was never completely submerged during this monitoring period. Additionally, the minimum water surface elevation obtained was 90.414 m, which is only 6 mm below the orifice invert. For the full monitoring window (3866 hours) there was a total of 13 hours (0.33%) where there was no flow through the Beaver Pond outlet.

Table 5: Summary of Manual Water Elevation Measurements of Beaver Pond - 2019

Date	Manual Measurements (m)
15 May	90.83
23 May	90.75
30 May	90.64
11 June	90.79
21 June	90.58
8 July	90.73
16 July	90.48
29 July	90.43
6 Aug	90.42
20 Aug	90.49
29 Aug	90.47
9 Sept	90.48
8 Oct	90.45
23 Oct	90.69

Table 6: Summary of Logger Water Elevations Measured in Beaver Pond - 2019

Parameter	Beaver Pond	
	Water Level Elevation (m)	Date and Time
Minimum	90.414	8 June 2019 12:35
Maximum	90.989	30 June 2019 3:50
Average	90.546	-

Below are photos taken from the field of the Beaver Pond throughout the monitoring period to validate the fluctuation of water levels.

Figure 4: April 30, 2019

Figure 5: June 11, 2019

Figure 6: July 16, 2019

Figure 7: August 29, 2019

4 FLOW MONITORING

Two Stingray water level, velocity, and temperature loggers were installed at two key locations within the Beaver Pond subwatershed trunk sewer. JFSA sub-contracted LCTEC, who specializes in implementing flow monitoring systems within storm sewers, to set up and implement the two stingray units. The first logger was installed on June 5 in a storm sewer maintenance hole at 7300 Campeau Drive (Campeau). This location was chosen as it only captures flow from the 22.6 ha existing residential development near Campeau Drive and Kanata Avenue. This site was also a convenient and safe place to access, as it was located slightly off Campeau Drive in a large swale on the south side of the road. Note that a read/write error occurred for this logger in early September which resulted in new data not being recorded by the logger, as such the data at this location ended on September 9. There was some slight noise recorded by the logger from approximately June 16, to August 10, and again from August 22 to September 1; although this noise was only present when there were small quantities of flows in the culvert and did not affect the results obtained during this window for the high flow events.

The second logger was installed in a storm sewer maintenance hole at 6 Weslock Way (Weslock). This spot was chosen as it was the further downstream location, that can capture the mix of residential and golf course lands draining to the Beaver Pond (173.7 ha), without being impacted by the backwater of the pond. This logger was operational from June 6 to October 10. There was some noise recorded by the logger from approximately July 1, to July 10, and again from July 15 to July 29; although this noise was only present when there were small quantities of flows in the storm sewer and did not affect the results obtained during this window for the high flow events.

As the stingray units simultaneously record the velocity and depth of flow in a pipe, it is possible to use this data to calculate the total flow in the pipe at any given time if the pipe diameter is known. Table 7 summarizes the Minimum, Maximum, and Average flows observed from June to September/October 2019 from each stingray unit. The flow data derived from the data collected by the stingray units at each site were used to calibrate the SWMHMYO model.

Table 7: Summary of Stingray Flows Measured at Campeau and Weslock

Value	Campeau Drive (1350 mm pipe with approximate Q cap= 2.5 m^3/s) Flow (m3/s)	Weslock Way (2250 mm pipe with approximate Q cap= 8.5 m^3/s) Flow (m3/s)
Minimum	0.000	0.000
Maximum	0.602	1.508
Average	0.002	0.018

5 HYDROLOGIC MODEL REVIEW & CALIBRATION

The SWMHYMO model used by the Mississippi Valley Conservation Authority (MVCA) in their "Watts Creek / Kizell Drain Flood Plain Mapping Study (Final November 2017)" was used as the basis for the modelling work completed as a part of this flow monitoring and model calibration study. The MVCA model, built on work originally completed by AECOM in 2015, which used field data collected in 2013 and 2014, for the City of Ottawa as part of the "Shirley's Brook and Watts Creek Phase 2 Stormwater Management Study". MVCA indicate in their report that the AECOM, SWMHYMO model was thoroughly calibrated and verified. Therefore, as part of this analysis, the model's catchment delineation was not reviewed, although the model catchment parameters were further investigated.

The model calibration process completed by AECOM in their 2015 study was based solely on water levels measured in the Beaver Pond, and no consideration was given to the operation of storm sewer upstream of the Beaver Pond. The field data obtained in 2019 outlined in this study has been used to further calibrate AECOM's/MVCA's model. The following section outlines the process and results of this updated calibration.

5.1 Updated Model Parameters

In undertaking the model calibration process using the new 2019 rainfall and flow data, MVCA's single event model was transformed into a continuous model. The conversion to a continuous model allows for the various subcatchment parameters to change during the simulation based on conditions that may have been present prior to a rainfall event. Furthermore, by using a continuous model, the need to undertake a baseflow separation exercise is eliminated from the analytical process. The original model used IDs to identify each of the various model components (which are limited to 10 individual IDs). Given the complexity and level of detail within this model, the model was updated to use NHYD's instead of ID's, which are not bound by such individual ID limitations. The Beaver Pond storage volume curve was updated based on IBI's latest detailed topographic survey of the area, see Appendix D for full curve details. Outflows from the Beaver Pond were updated based on a theoretical partially full orifice equation, which provides a better representation of flows through the orifice when it is not surcharged[1].

The model's simulated flows were compared against those obtained in the field at Campeau Drive, Weslock Way and the Beaver Pond outlet, and several of the SWMHYMO model parameters iteratively adjusted to improve the model's conformance with the field data. There are two categories of subcatchment model parameters that can be adjusted:

- those that affect the computed runoff volumes.
- those that affect the shape of the simulated hydrographs.

Depression storage or initial abstraction (IA), total imperviousness (TIMP), directly connected imperviousness (XIMP), Curve Numbers (CN), Horton's infiltration parameters (Fo, Fc, DCAY), and groundwater/baseflow parameters (InitGWResVol, GSResk, VHydCond), all affect the total simulated runoff volume. Surface slopes (SLPI and SLPP), surface lengths (LGP and LGI), surface Manning's values (MNI and MNP), Time to Peak (TP), and the number of linear reservoirs (N), all affect the shape of the hydrograph. Table 8 below provides a list of the parameters that were adjusted through a calibration process using the monitoring data of 2019.

[1] "Flow through Partially Submerged Orifice" James C. Y. Guo and Ryan P. Stitt (2018)

Table 8: Updated Hydrologic Parameters – 2019 Data – Calibration

SWMHYMO Parameters	MVCA Model	JFSA Model
NASHYD		
N	1.1	2
TP	Variable	Unchanged
CN	Variable	CN values converted to CN*
SK	0.03	0.01 ²
STANDHYD		
TIMP	Variable based on catchment	Unchanged
XIMP	Variable	Set to 0.25 for existing residential developments
Infiltration Loss Method	SCS Procedure	Horton's equation with Fo=125 mm/hr, Fc=25 mm/hr, DCAY=2.0 (see Note 1)
Manning's Impervious	0.025	0.013 as per City default value
Manning's Pervious	0.25	Unchanged
Depression Storage (IAimp /IAper	1.57 mm for Impervious and 4.67 mm for Pervious	1.57 mm for Impervious and 4.67 mm for Pervious, as per City default values
Slopes (SLPI /SLPP)	0.2% for Impervious and 2% for Pervious	0.75% for Impervious and 2% for Pervious
Flow Length (LGI / LGP)	Variable value for impervious with some set to 225 m per ha, and 40 m for Pervious	Value for Impervious based on LGI=(A/1.5)^.5, and 40 m for Pervious
CONTINUOUS PARAMETERS		
APII and APIK	N/A	40 mm and 0.8
IARECimp and IARECper	N/A	1.5 hours and 6 hours
BASEFLOW PARAMETERS		
InitGWResVol	N/A	175 mm
GWResK	N/A	0.962 mm/day/mm ²
VHydCond	N/A	.02 mm/hr ²

Note 1: these infiltration rates are similar to the values obtain from the 2018 infiltration tests documented in "*Rainfall. Surface Runoff and Infiltration at Kanata Golf and Country Club, Summary Report – 2018 Monitoring Program*", by JFSA and Geofirma, February 2019.
Note 2: Values obtained from the model calibration for Watts Creek completed by C. Brennan et al September 2017, "*Continuous prediction of clay‐bed stream erosion in response to climate model output for a small urban watershed*".

5.2 Calibrated Model Results

With the updated set of hydrologic parameters provided in Table 8, it was found that simulated and measured Beaver Pond conditions were much improved over previous calibration efforts. As such, the two representative underground storage routing (one for the Kizell Wetland and another for the Beaver Pond) that were previously deemed necessary to better replicate the observed operation of the Beaver Pond, were no longer necessary and subsequently removed from the model. As a part of the model validation, the updated model was re-run using the 2013 data obtained by AECOM as a part of their study, which showed a reasonable correlation of flows out of the Beaver Pond with the field data. A comparison of the measured versus simulated Beaver Pond outflows, for both 2019 and 2013, have been provided in Appendix F.

Table 9 provides a statistical comparison of the peak flow and total volumes out of the Beaver Pond based on the model simulation and 2019 field observed data. Based on the model calibration of the 2019 data for the flows out of the Beaver Pond, the SWMHMYO model slightly underestimated the peak flow (-0.08 m³/s), with the total simulated and observed outflow volumes matching up very well (total simulated volume 1% larger than the observed). The model against this data had a coefficient of determination (R^2) of 0.72 and a Nash-Sutcliffe model efficiency coefficient of 0.62. Note that the closer both the coefficient of determination (R^2) and Nash-Sutcliffe model efficiency coefficient are to 1.0, the better the fit.

Table 9: Beaver Pond Outflow - 2019 Data – Calibration

Parameter	Value
Total Rainfall Volume (mm)	442.4
Measured Peak Flow (m³/s)	0.38
Simulated Peak Flow (m³/s)	0.30
Peak Flow Difference (m³/s)	-0.08
Peak Flow Ratio (Sim/Meas)	0.79
Measured Volume (m³)	587772
Simulated Volume (m³)	594326
Volume Difference (m³)	6554
Volume Ratio (Sim/Meas)	1.01
R^2	0.72
Nash-Sutcliffe	0.62

After validating the model based on the 2019 outflow data from the Beaver Pond, the model was re-stimulated using the 2013 rainfall data and compared against the Beaver Pond outflows obtained by AECOM. Table 10 below provides a full statistical summary for this analysis. From this analysis, it was found that the model overestimated the peak flow out of the pond by 0.22 m³/s, although the total simulated and observed outflow volume for this window was still quite similar (model total volumes only 10% less than the observed). The model had a coefficient of determination (R^2) of 0.55 and a Nash-Sutcliffe model efficiency coefficient of 0.51. It is expected that the verification data does not correspond as well to the field data as the calibration data set (2019), but irrespective of this the results obtained for this validation seems reasonable, especially in light of the fact that the total outflow volumes are so similar.

Table 10: Beaver Pond Outflow - 2013 Data -Validation

Parameter	Value
Total Rainfall Volume (mm)	586.2
Measured Peak Flow (m³/s)	0.24
Simulated Peak Flow (m³/s)	0.46
Peak Flow Difference (m³/s)	0.22
Peak Flow Ratio (Sim/Meas)	1.91
Measured Volume (m³)	877462
Simulated Volume (m³)	787032
Volume Difference (m³)	-90430
Volume Ratio (Sim/Meas)	0.90
R^2	0.55
Nash-Sutcliffe	0.51

The same procedure was completed for Weslock Way using the field data obtained in 2019. Table 11 provides a statistical comparison of the peak flow and total volume in the Weslock trunk sewer based on the model simulation and field observed data. Note that only the selected events identified in Table 4 above were considered for this analysis. Visual plots of each of these selected events have been provided in Appendix G. This analysis found that the calibrated SWMHYMO overestimated the peak flows on average by 26%, and the total volume by 7%. The model had a coefficient of determination (R^2) of 0.78 and a Nash-Sutcliffe model efficiency coefficient of 0.69, which indicates that the model adequately replicates the conditions observed in the field.

Table 11 Weslock Way- 2019 Data - Calibration

Parameter	Value
Total Rainfall Volume (mm)	264.04
Minimum Peak Flow Ratio (Sim/Meas)	0.57
Average Peak Flow Ratio (Sim/Meas)	1.26
Maximum Peak Flow Ratio (Sim/Meas)	2.05
Measured Volume (m³)	46696
Simulated Volume (m³)	49824
Volume Difference (m³)	3128
Volume Ratio (Sim/Meas)	1.07
R^2	0.78
Nash-Sutcliffe	0.69

Table 12 provides a statistical comparison of the peak flow and total volume in the Campeau trunk sewer based on the model simulation and field observed data. Note that only the selected events identified in Table 4 above were considered for this analysis. Visual plots of each of these selected events have been provided in Appendix H. This analysis found that the calibrated SWMHYMO underestimated the peak flows on average by 5%, and the total volume by 8%. The model had a coefficient of determination (R^2) of 0.75 and a Nash-Sutcliffe model efficiency coefficient of 0.69, which indicates that the model is a reasonable representation of the conditions observed in the field at this location. Note that the rainfall volumes are different between Weslock Way and Campeau Drive due to the differences in the operational window.

Table 12: Campeau Drive - 2019 Data -Calibration

Parameter	Value
Total Rainfall Volume (mm)	239.43
Minimum Peak Flow Ratio (Sim/Meas)	0.64
Average Peak Flow Ratio (Sim/Meas)	0.95
Maximum Peak Flow Ratio (Sim/Meas)	1.31
Measured Volume (m³)	11714
Simulated Volume (m³)	10790
Volume Difference (m³)	-923
Volume Ratio (Sim/Meas)	0.92
R^2	0.75
Nash-Sutcliffe	0.69

6 CONCLUSIONS & RECOMMENDATIONS

The 2019 field monitoring program for the Kanata Golf and Country Club, and greater Beaver Pond subwatershed, consisted of one rain gauge on the Kanata Golf and Country Club site, two Stingray Portable Level-Velocity Loggers (Stingray) located within the existing storm sewer system, two level-loggers and one barometric logger located at the Beaver Pond.

The rainfall data obtained at the site was compared with rainfall recorded at the City of Ottawa's rain gauge at St Gabriel's school, located 1.6 km northwest of the subject site. This comparison showed a similar response for the respective rainfall events, with only slight differences in intensity, total volume and timing due to the differences in the variance in rainfall over a given area. The data obtained by the Stingray loggers located within the storm sewer network at Campeau Drive and Weslock Way were converted to flows, which were then used to calibrate the existing SWMHYMO model. Level loggers placed in the Beaver Pond to record the water levels throughout the year and were later converted to geodetic elevations, to enable the flows out of the pond to be calculated.

The calibrated AECOM (2015) hydrologic model (SWMHYMO) used in MVCA's Watts Creek / Kizell Drain Flood Plain Mapping Study was successfully re-calibrated using above rainfall and flow data. To ensure a reasonable fit, several model parameters were adjusted, and these changes have been documented in Table 8 of this report. The updated model calibration allowed for the removal of the two underground storage reservoirs that were previously inserted in the model to attenuate flows out of the Beaver Pond that were consistently being overestimated. Plots comparing the simulated and observed flows at the Beaver Pond, Weslock Way and Campeau Driver have been presented in Appendix F, G & H, respectively.

Statistical analyses were completed at all three locations which found that the re-calibrated model produced reasonable results when compared to the field data. For the 2019 data at the Beaver Pond, it was found that the model generally overestimated the peak flow out of the pond, although the total simulated and observed outflow volume for this window was still quite similar, with the simulated total volumes only 1% greater than the observed. For the 2013 data at the Beaver Pond, it was found that that the model generally overestimated the peak flow out of the pond, although the total simulated and observed outflow volume for this window was still quite similar, with the simulated total volumes only 10% less than the observed. For the 2019 data at Weslock Way, it was found that the calibrated SWMHYMO overestimated the peak flow by 26%, and the total volume by 7%. For the same dataset at Campeau Drive it was found that the calibrated SWMHYMO underestimated the peak flow by 5%, and the total volume by 8%.

For the 2019 data, it was found that all monitored locations had a coefficient of determination (R^2) of 0.72-0.78 and a Nash-Sutcliffe model efficiency coefficient 0.62-0.69, indicating that the model at these three locations provides a reasonable representation of the conditions observed in the field. As such this calibrated hydrologic model should be considered fit for use to further analyze potential future developments in the area.

7 JFSA STATEMENT OF LIMITATION

This report, which specifically includes all tables, figures and appendices, is based on data and information assembled by JFSA and provided by others. JFSA has relied in good faith on all information provided and does not accept responsibility for any deficiencies, misstatements, or inaccuracies contained in the report as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation and data. JFSA is not a guarantor of the accuracy, completeness or adequacy of this information provided by others. JFSA assumes no responsibility or liability for errors or omissions resulting from inaccuracies in the data received from others. JFSA assumes no responsibility for any negligence by others related to the data provided for this analysis. JFSA warrants only that its work was undertaken, and its report prepared in a manner consistent with the level of skill and diligence normally exercised by competent engineering professionals practicing in the Province of Ontario.

Ottawa. ON
Paris. ON
Gatineau. QB
Montréal. QB
Québec. QB

Appendix A

Kanata Golf & Country Club – 2018 Surface Water and Rainfall Monitoring Program

JFSA, February 2019

J.F. Sabourin and Associates Inc.
52 Springbrook Drive,
Ottawa, ON K2S 1B9
T 613-836-3884 F 613-836-0332
jfsa.com

Ottawa
Gatineau
Montréal
Québec City

February 6, 2019 Project #: P1581

David Schaeffer Engineering
120 Iber Road, Unit 103
Stittsville, ON, K2S 1E9

Attention: **Mr. Steve Pichette, P.Eng.**

Subject: **Kanata Golf & Country Club – 2018 Surface Water and Rainfall Monitoring Program**

A flow monitoring program was implemented at the Kanata Golf & Country Club in 2018 to better understand the hydrologic and hydraulic characteristics of this area. As part of this study, J.F Sabourin and Associates (JFSA) collected surface water and rainfall data at the Golf & Country Club located at 7000 Campeau Drive Kanata, Ontario from May 14th, 2018 to November 21st, 2018. As part of the monitoring program; three level loggers, one barometric logger, one Stingray Portable Level-Velocity Logger and one rain gauge was installed on the Kanata Golf & Country Club property. **Figure 1** outlines the general location of the respective field equipment. Due to project constrains, field equipment was only placed within the Kanata Golf and Country Club property.

The Stingray Portable Level-Velocity Logger was initially placed in the natural channel approximately 50m downstream of the Q1 culvert outlet. After initial review of the data collected by the Stingray Portable Level-Velocity Logger, it was found that both the depth and velocity receptors of this device were frequently getting blocked by channel sediment and organic material, greatly influencing the usability of the results. After initial review of the data collected by the Q1 level logger (located at the outlet of a 600 mm diameter concrete storm sewer pipe) it was found that the outlet of the culvert is often subject to backwater conditions, indicating that the level logger alone would not be sufficient to capture the flow from this culvert. As the location of the Stingray Portable Level-Velocity Logger was providing less than desirable results in the channel, it was relocated to the outlet of the storm sewer at Q1, providing both a depth and velocity measurement to ensure that flows could be calculated under all hydraulic conditions.

After relocating the Stingray Portable Level-Velocity Logger from its initial location, it was determined that it was still necessary to capture the total flow in the natural channel downstream of Q1, thus a level logger was installed at Q2. This logger was placed at the inlet of a 200mm PVC pipe at the end of the natural channel just upstream of the pond near holes 7 and 8. From field observations it was determined that this culvert would be primarily under inlet control, making it easy to calculate flow based on the culvert geometry and head alone. The location of the level logger at Q3 remained constant for the entire duration of the monitoring period.

The level logger at Q1 was fixed to an existing steel grate at the outlet of the storm sewer. The Stingray Portable Level-Velocity Logger was placed approximately 1 m inside the culvert, through the use of a PVC pipe. The level logger at Q2 was installed within a perforated PVC pipe which was mounted to a concrete block and placed on the bottom of the head wall apron. The level logger at Q3 was placed flush against the upstream side of the inlet apron and fixed to an existing large timber grate. The barometric logger was also fixed to the timber grate near the Q3 level logger. A tipping bucket rain gauge was located on the pumphouse roof next to the pond on the 9th hole. This rain gauge was located away from any tall trees or structures, to minimize potential interference. **Figures 2a-2e** show the installation/configuration for all field equipment used in this study.

During the monitoring period, JFSA conducted 21 site visits to; inspect the operation of the field equipment, download recorded data and measure instantaneous water levels and velocities. **Table 1** summarizes all dates JFSA staff were onsite and provides a brief description of the task(s) completed on that date.

Table 1: Site Visit Summary

Date	Description
May 14, 2018	Rain gauge installation
May 29, 2018	Rain gauge download, site selection for flow monitoring locations
June 6, 2018	Installation of level logger at Q3 & barometric logger
June 13, 2018	Installation of logger at Q1 and stingray downstream of Q1
June 20, 2018	Rain gauge, logger & stingray download
June 26, 2018	Logger & stingray download
June 29, 2018	Rain gauge, logger & stingray download
July 9, 2018	Relocating stingray to Q1
July 18, 2018	Rain gauge, logger & stingray download
July 25, 2018	Velocity measurements & site photos during high flow event
July 31, 2018	Rain gauge, logger & stingray download
August 15, 2018	Rain gauge, logger & stingray download. Installation of logger at Q2.
September 6, 2018	Rain gauge, logger & stingray download
September 12, 2018	Rain gauge, logger & stingray download
September 19, 2018	Installation of new rain gauge
October 12, 2018	Rain gauge, logger & stingray download
November 5, 2018	Rain gauge, logger & stingray download
November 7, 2018	Infiltration testing. Replacement of logger at Q1
November 8, 2018	Infiltration testing
November 15, 2018	Logger & stingray download. Removal of equipment from sites (Q1, Q2, Q3, stingray)
November 21, 2018	Rain gauge removal

Legend

- Kanata Golf Course Fairways
- Flow Monitoring Locations
- Rain Gauge
- Drainage Area to Q1 (3.56 ha)
- Drainage Area to Q2 (56.23 ha)
- Drainage Area to Q3 (73.13 ha)

NOTES:

Basemap Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Coordinate System: NAD 1983 MTM Zone 9

J.F. Sabourin and Associates Inc.
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS
52 Springbook Drive
Ottawa, ON, K2S 1B9
(613) 836-3884
www.jfsa.com

CLIENT:

DSEL
david schaeffer engineering ltd

SCALE:

0 100 200 300 400 m

LOCATION:

KANATA GOLF & COUNTRY CLUB

TITLE:

MONITORING LOCATIONS

FIGURE 1

PROJECT No.	1581-17
DRAWN:	PW
DATE:	06/02/2019

Figure 2a: Stingray and water level logger Installation on culvert grate at Q1

Figure 2b: Water level logger installation at Q2

Figure 2c: Water level logger installation at Q3

Figure 2d: Barometric Logger Installation at Q3

Figure 2e: Rain gauge installation

A tipping bucket rain gauge was installed on-site on May 14th, 2018 and removed on November 8th, 2018, providing 179 days of precipitation data for the year. The first instance of snowfall during this monitoring program occurred on October 27th, 2018. Considering that conventional tipping bucket rain gauges, like the one installed on site, are incapable of recording snowfall or determining snow water equivalent, the rainfall dataset has been truncated to a period of 166 days (May 14th, 2018 - October 27th, 2018). As the intended use of the data obtained from this monitoring program is to guide the calibration of a detailed hydrologic model of the existing subwatershed conditions, the subsequent level/flow monitor data obtained in the field has also been truncated to October 27th, 2018. **Table 2** is a summary of the rain gauge data collected in 2018 (from May 14th to October 27th) at Kanata Golf & Country Club.

Table 2: Kanata Golf and Country Club - 2018 Rain Gauge Data Summary

Start Date	End Date	Length (operational days)	Total Rain (mm)	Avg. Rainfall per Day (mm)
14-05-2018	27-10-2018	166	490.86	2.96

Table 3 is a summary of the rainfall duration and max intensity over the monitoring period. From this table it was found that both events on August 6th and July 24th/25th equate to greater than the 100-year return period for their respective durations. Do note that two IDF curves have been provided in Table **3** for this analysis. The City IDF curve has been taken from the City of Ottawa's 2012 Sewer Design Guidelines and is based on data from 1967-1997. The 2007 IDF curve is the latest official IDF curve and is based on data from 1967-2003. Attachment A contains the full hyetographs and the Intensity-Duration-Frequency (IDF) analysis.

Table 3: Kanata Golf and Country Club - Rainfall Duration/Max intensity Summary

Duration	Rainfall Intensity (mm/hr)	City IDF Return Period (Years)	2007 IDF Return Period (Years) 2007	Date (dd/mm/yyyy)
5 Minute	207.24	32.6	42.0	06/08/2018
10 Minute	155.10	38.7	49.3	06/08/2018
15 Minute	132.44	52.0	63.2	06/08/2018
30 Minute	94.38	>100.0	>100.0	06/08/2018
60 Minute	50.16	68.2	59.5	06/08/2018
2 Hour	29.15	57.4	49.2	25/07/2018
6 Hour	17.07	>100.0	>100.0	25/07/2018
12 Hour	11.37	>100.0	>100.0	25/07/2018
24 Hour	6.02	>100.0	>100.0	24-25/07/2018

As indicated in **Table 3** above, the event on July 25th was greater than a 100-year storm for durations of 6 hours, 12 hours and 24 hours. During this event JFSA staff were on site to take measurements and document the operation of the subwatershed during such large events. **Figure 3** provides a number of photos taken at key locations on that day and also provide a guide to the approximate location and direction of each photo. During this site visit it was observed that both the ponds near the 9th and 7th hole were overtopping. The flood extents observed at the 9th hole pond was far greater than its normal footprint, as indicated by the red water hazard golf stakes in **Figure 3** item 5. On this day it was also observed that there was a substantial amount of storage provided in the vegetated channel running along the western edge of the 9th hole upstream of the Q2 monitoring location, as indicated in **Figure 3** items 3 & 4.

During most field visits, the data recorded by the loggers were downloaded and water depths measured at each monitoring location. The barometric data obtained on site was used to account for the air pressure recorded by all level loggers. With the atmospheric pressure accounted for in the recorded data, these values were then converted to depths, as both the temperature of the water and the total hydrostatic pressure were known. The depth measurements obtained in the field were used to correct water level records to reflect continuous water depths at the monitored locations. **Table 4** is a summary of the minimum, maximum and average depth obtained during this monitoring period at the three locations. Attachment B contains plots of the continuous water levels, flows and the barometric pressure and temperate.

Table 4: Kanata Golf and Country Club 2018 Monitoring – Depth Summary

Site	Monitoring Duration (days)	Value	Water Depth (m)
Q1	91	Min	0.00
		Max	0.65
		Avg	0.10
Q2	73	Min	0.00
		Max	0.24
		Avg	0.06
Q3	143	Min	0.00
		Max	0.49
		Avg	0.03

As the field equipment used in this study only provides the continuous depth and velocity (only at Q1) this data needs to be converted to continuous flows. The following outlines the procedures used to derive the relationships between the recorded data and expected flows at the 3 monitoring locations. It should be noted that as the three monitoring locations were all hydraulically different, different approaches had to be taken to derive flow from the recorded data.

Flows at Q1 were calculated by simply taking the instantaneous velocity recorded by the Stingray and multiplying it by the flow cross-sectional area in the culvert obtained at the same time. The cross-sectional area was calculated by taking the water level depths recorded by the level logger at the culvert outlet.

Legend

- Photo Locations
- Direction Photo was Taken
- Kanata Golf Course Fairways

NOTES:

Basemap Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Field Photos taken by JFSA staff, July 25 2018

Coordinate System: NAD 1983 MTM Zone 9

J.F. Sabourin and Associates Inc.
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS
52 Springbook Drive
Ottawa, ON, K2S 1B9
(613) 836-3884
www.jfsa.com

CLIENT:

DSEL
david schaeffer engineering ltd

SCALE:

0 100 200 300 400 m

LOCATION:

KANATA GOLF & COUNTRY CLUB

TITLE:

SURFACE WATER STORAGE EXTENT - JULY 25 2018

FIGURE 3

PROJECT No.	1581-17
DRAWN:	PW
DATE:	06/02/2019

It was assumed that Q2 will be under inlet control due to its relatively small size, when compared to the 600mm Concrete Culvert and 350mm CSP upstream. A rating curve (depth/flow relationship) was derived for this culvert by applying the observed geometry to the culvert hydraulic analysis program HY-8. The model was simulated for a full range of flows to develop a detailed rating curve for this culvert. The derived rating curve was then compared with field recorded depths and flows which showed a good correlation between calculated and field observed flows. The detailed rating curved was simplified to a polynomial function that allowed all depth recordings to be easily converted to flow.

The outlet at Q3 is a complex hydraulic structure consisting of a non-uniform trapezoidal concrete weir like structure on the inlet apron, followed by a concrete wall consisting of 3 various sized rectangular openings. The geometry of both hydraulic structures were recorded as best as physically possible, given the access constraints. The hydraulic conveyance of both structures was assessed using fundamental hydraulic principals (weir & orifice equations). From this analysis it was determined that the second structure (the concrete wall with 3 openings) was the primary hydraulic constriction. A detailed rating curve was determined for this structure and compared with field recorded depths and flows, which showed good correlation between calculated and field observed flows. The detailed rating curved was simplified to a polynomial function that allowed all depth recordings to be easily converted to flow. A summary of the minimum, maximum and average and total flows recorded at the 3 key locations are provided in **Table 5**. Figures outlining the full rainfall and flow hydrographs have been provided in Attachment B.

Table 5: Kanata Golf and Country Club 2018 Monitoring – Flow Summary

Site	Monitoring Duration (days)	Value	Flow (m^3/s)
Q1	65*	Min	0.000
		Max	0.370
		Avg	0.001
Q2	73	Min	0.000
		Max	0.028
		Avg	0.004
Q3	143	Min	0.000
		Max	0.291
		Avg	0.009

*Monitoring days do not match value outlined in **Table 3**, as flow can only be calculated at this location when a velocity component is known (Stingray Portable Level-Velocity Logger)

After converting the obtained field data into flows, a total of 14 significant rainfall events (events greater than 5mm) were identified. The total runoff volumes at the three monitoring locations were calculated for each event. The drainage areas to each of the monitoring locations were approximated based on the existing topographic data and minor system drainage. The drainage areas to Q1, Q2, and Q3 were approximated to be 3.56 ha, 56.23 ha and 73.13 ha respectively. The total runoff volume measured in the field for each event was divided by the total rainfall volume over the respective drainage areas and in turn the runoff coefficients calculated. **Table 6** summarizes all significant rainfall events that occurred during the monitoring period, the total flow recorded at each logger and the calculated runoff coefficient for each event.

Table 6: Kanata Golf and Country Club Monitoring - Flow Summary 2018

(06 July 2018 - 26 October 2018)

Event Window				Rainfall	Total Runoff Volume			Runoff Coefficient		
Event	Start	End	Duration	(mm)	Q1 (m³)	Q2 (m³)	Q3 (m³)	Q1	Q2	Q3
1	14/07/2018 0:00	16/07/2018 0:00	2 days 0 hrs	11	201	-	-	0.52	-	-
2	23/07/2018 0:00	24/07/2018 12:00	1 days 12 hrs	27	362	-	489	0.38	-	0.03
3	22/07/2018 0:00	01/08/2018 12:00	10 days 12 hrs	187	1,979	-	22,969	0.30	-	0.17
4	01/08/2018 0:00	05/08/2018 12:00	4 days 12 hrs	20	131	-	3,671	0.18	-	0.25
5	06/08/2018 0:00	10/08/2018 12:00	4 days 12 hrs	58	516	-	7,472	0.25	-	0.18
6	21/08/2018 0:00	31/08/2018 12:00	10 days 12 hrs	29	502	4,443	5,271	0.49	0.28	0.25
7	03/09/2018 0:00	05/09/2018 0:00	2 days 0 hrs	5	88	304	821	0.49	0.11	0.22
8	05/09/2018 0:00	06/09/2018 7:00	1 days 7 hrs	8	115	519	650	0.38	0.11	0.10
9	10/09/2018 12:00	11/09/2018 12:00	1 days 0 hrs	5	38	527	581	0.22	0.19	0.16
10	21/09/2018 0:00	23/09/2018 0:00	2 days 0 hrs	22	-	1,250	1,201	-	0.10	0.07
11	25/09/2018 0:00	28/09/2018 0:00	3 days 0 hrs	11	-	1,563	1,791	-	0.24	0.21
12	28/09/2018 0:00	01/10/2018 0:00	3 days 0 hrs	7	-	1,145	1,599	-	0.28	0.30
13	01/10/2018 0:00	07/10/2018 0:00	6 days 0 hrs	15	-	3,017	3,321	-	0.37	0.31
14	08/10/2018 12:00	12/10/2018 12:00	4 days 0 hrs	5	-	1,358	2,003	-	0.49	0.56

Monitoring Location	Area (ha)	Theoretical RC	Observed RC
Q1	3.56	0.65	0.36
Q2	56.23	0.45	0.24
Q3	73.13	0.43	0.22

Runoff Coefficient Summary

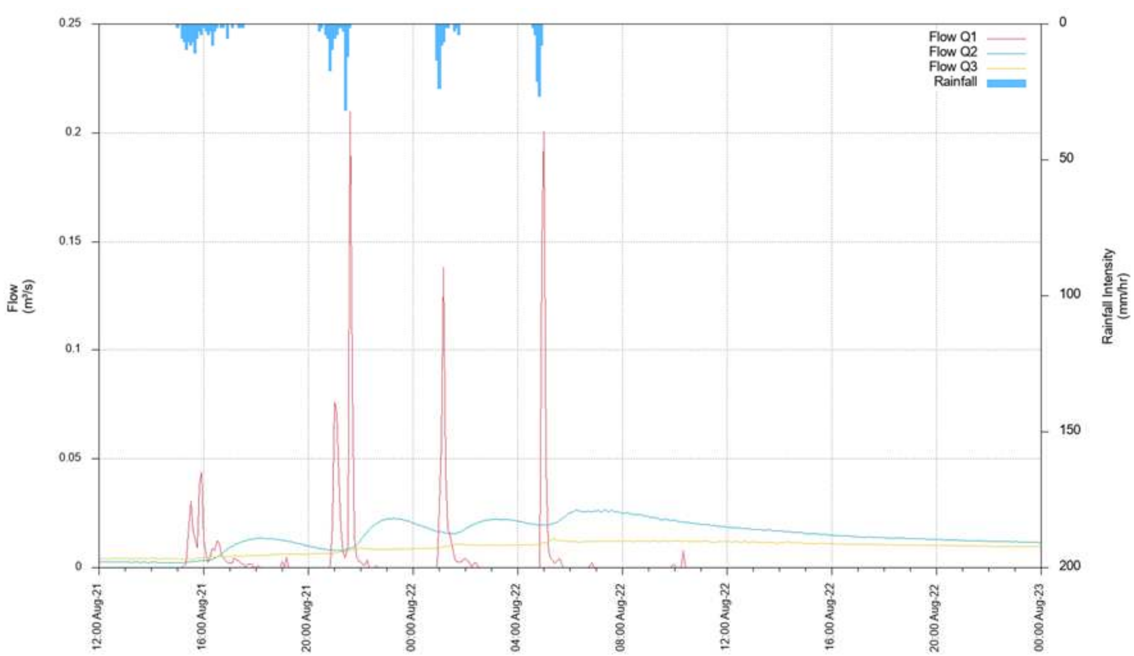
	Q1	Q2	Q3
Average	0.36	0.24	0.22
Standard Dev	0.13	0.13	0.13
Max	0.52	0.49	0.56
Min	0.18	0.10	0.03

Based on the analysis completed in **Table 6**, it was found that the average runoff coefficient for Q1, Q2 and Q3 are 0.36, 0.24 and 0.22 respectively. It should be noted that the calculated runoff coefficients for the three locations all have a standard deviation of ±0.13, indicating that there is some variance in runoff from event to event. Applying typical runoff coefficients to each drainage area based on existing land use types, the expected runoff coefficient for Q1, Q2, and Q3 would be 0.65, 0.45 and 0.43 respectively, which is substantially higher than that observed from the field measurement. This was even the case for monitoring location Q1, which has a drainage area consisting entirely of existing urban residential lands. It should be noted that for this area the majority of houses have roof leaders that discharged to pervious surfaces, allowing for additional infiltration.

The lower than expected runoff for this area, may be due to higher than expected soil infiltration rates. Given that the sample size of data obtained during the 2018 monitoring program was limited to a portion of the total drainage area, additional monitoring within the City storm sewer system would need to be undertaken to generalize the statement that the soils within the area have higher infiltration rates than typically expected. Thus, it is advised that additional monitoring be completed within the greater watershed in the future.

In addition to the above, the monitoring program has shown that there is substantial attenuation of flows within the site between monitoring locations. **Figure 4** below outlines the observed hydrographs at the three monitoring locations for a 26 mm event that occurred over a 14-hour period on August 21st and 22nd, 2018. From this figure it is evident that the golf course can substantially attenuate flows, with the peak flows recorded at Q1, Q2 and Q3 of 0.210 m^3/s, 0.027 m^3/s and 0.013 m^3/s respectively for this event. This attenuation also greatly shifts the timing of the peak, with these peaks at Q1, Q2 and Q3 occurring approximately 10 minutes, 2 hours and 5 hours after the peak of the rainfall event respectively.

Figure 4 : Recorded Rainfall and Flow - 21 August 2018 - 23 August 2018



The surface water and rainfall monitoring program implemented at the Kanata Golf & Country Club by JFSA in 2018 has provided some insight into the hydrologic and hydraulic characteristics of these lands. It was found that there is a significant amount of storage within the subject site, which can greatly attenuate runoff. This was visually confirmed by JFSA staff during the large rainfall event on July 25th and has also been reflected in the results obtained from the monitoring program as indicated in **Figure 4**. It was also determined that the runoff volumes for existing developed lands is lower than expected, which may indicate that the soils are better at infiltrating rainfall than normally assumed. The lower than expected runoff volumes from existing urban developments in conjunction with the substantial storage volumes available on site may provide some explanation as to why previous attempts to model measured responses to actual events were consistently over estimating existing peak flows and total runoff volumes within this watershed. Given the small sample size of monitoring data it is advised that the monitoring program be continued, with additional monitoring points implemented within the greater Beaver Pond subwatershed in locations outside of the Kanata Golf and Country Club.

Yours truly,

J.F Sabourin and Associates Inc.

Written by:	Reviewed by:	Approved by:
Jonathon Burnett, P.Eng	Bryan Willcott, P.Eng.	J.F.Sabourin, M.Eng., P.Eng.
Water Resources Engineer	Water Resources Engineer	President

Attachments:

Attachment A – Rainfall Data - Hyetographs + IDF Curve

Attachment B – Continuous Water Level, Flow, and Barometric Pressure Graphs

JFSA
WATER RESOURCES AND
ENVIRONMENTAL CONSULTANTS

Project Ref #:P1581
Client: David Schaeffer Engineering

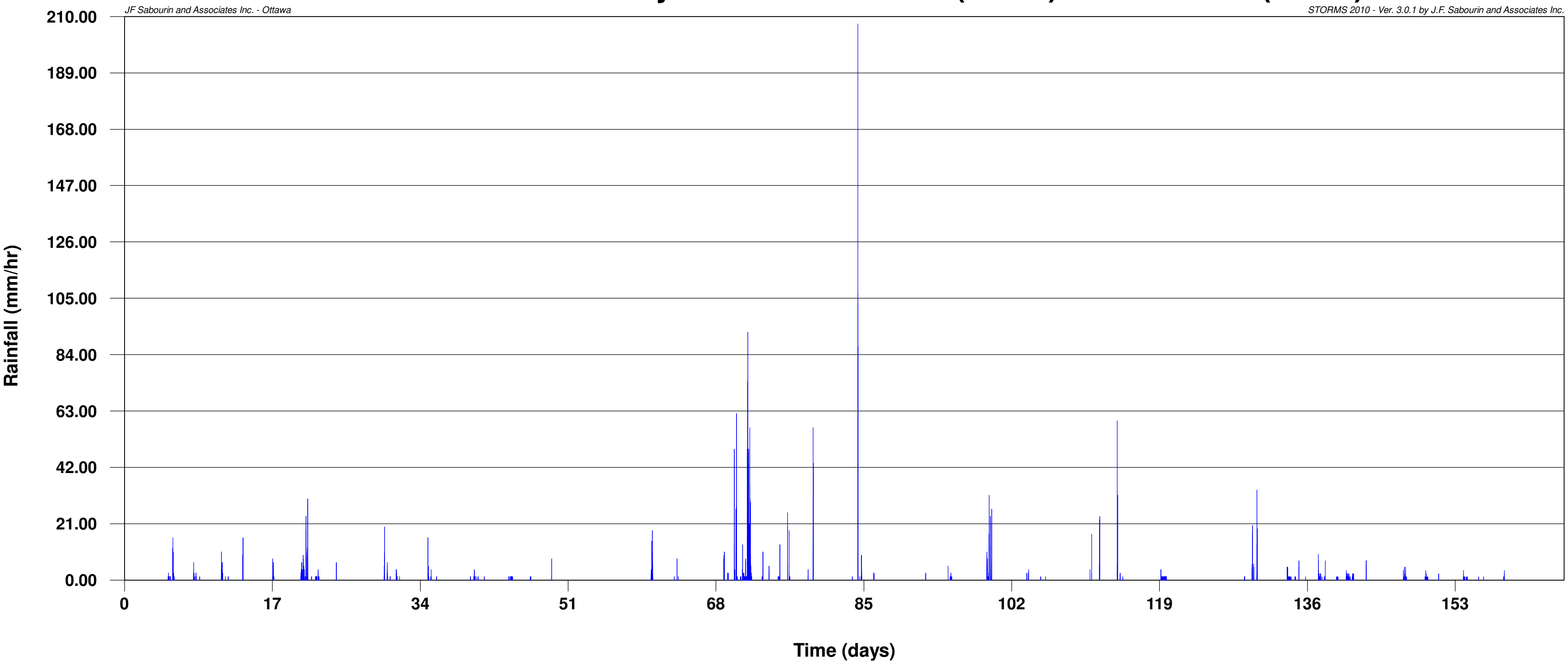
Ottawa
Gatineau
Montréal
Québec City

Attachment A

Rainfall Data Hyetographs + IDF Curve

February 2019

Kanata Golf & Country Club - 14/05/2018 (12:00) - 26/10/2018 (23:55)



Storm Statistics:

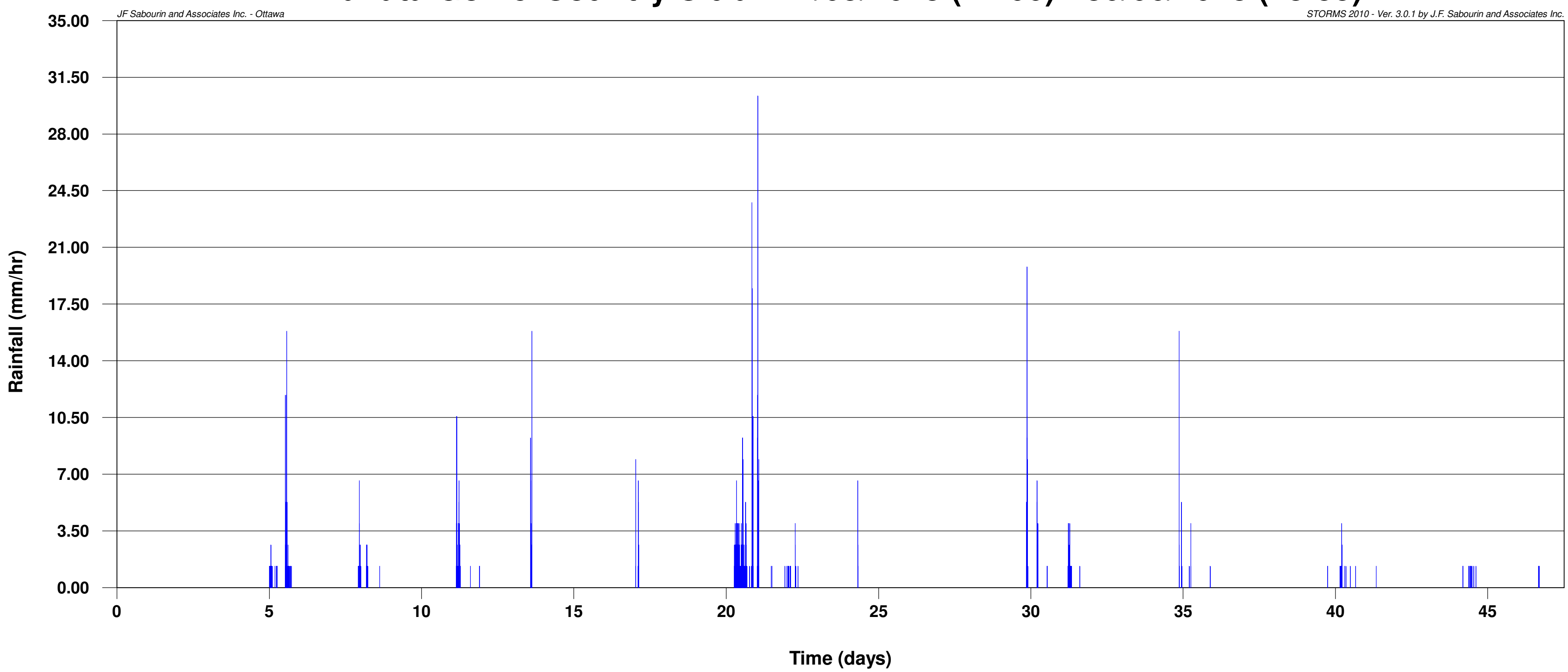
Storm Filename: T:\PROJ\1581-17\Design\Field\Rainfall Monitoring\Storm Files\20180514 - 20181026.stm
Storm File Comment: Kanata Golf & Country Club - 14/05/2018 (12:00) - 26/10/2018 (23:55)

Total Rain	=	490.86 (mm)
Storm Duration (hrs)	=	3972:05:00
Time Step	=	5 (minutes)
Ave. Intensity	=	0.12 (mm/hr)
Max. Intensity	=	207.24 (mm/hr) at 121415.00 (minutes)

Maximum Average Intensities: (mm/hr)

Durations	5 min	10 min	15 min	30 min	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
Max. Ave. Int. (mm/hr)	207.24	155.10	132.44	94.38	50.16	29.15	23.87	17.07	11.37	6.02

Kanata Golf & Country Club - 14/05/2018 (12:00) - 30/06/2018 (23:55)



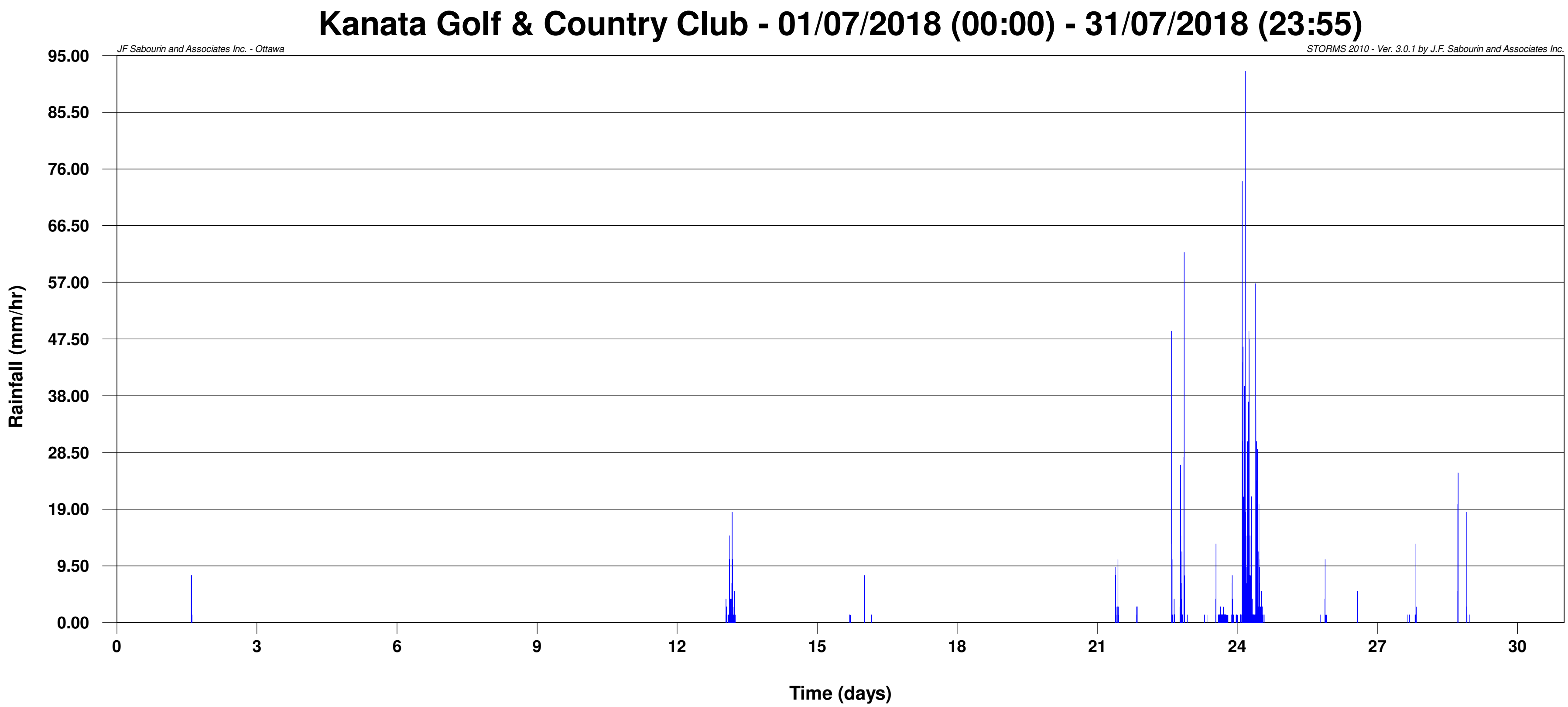
Storm Statistics:

Storm Filename: T:\PROJ\1581-17\Design\Field\Rainfall Monitoring\Storm Files\20180514 - 20180630.stm
Storm File Comment: Kanata Golf & Country Club - 14/05/2018 (12:00) - 30/06/2018 (23:55)

Total Rain	=	96.25 (mm)
Storm Duration (hrs)	=	1140:05:00
Time Step	=	5 (minutes)
Ave. Intensity	=	0.08 (mm/hr)
Max. Intensity	=	30.36 (mm/hr) at 30290.00 (minutes)

Maximum Average Intensities: (mm/hr)

Durations	5 min	10 min	15 min	30 min	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
Max. Ave. Int. (mm/hr)	30.36	21.12	18.92	11.44	8.80	4.51	3.30	2.79	2.03	1.64



Storm Statistics:

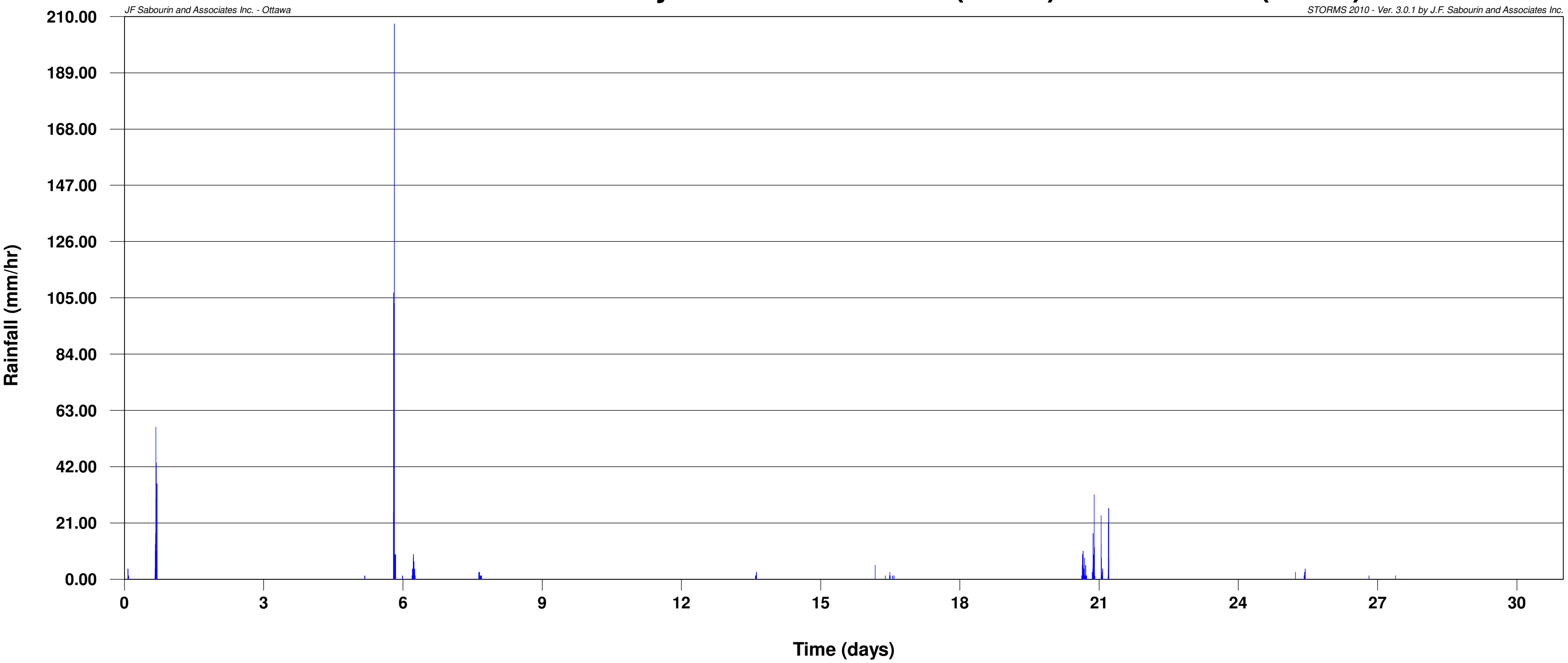
Storm Filename: T:\PROJ\1581-17\Design\Field\Rainfall Monitoring\Storm Files\20180701 - 20180731.stm
Storm File Comment: Kanata Golf & Country Club - 01/07/2018 (00:00) - 31/07/2018 (23:55)

Total Rain	=	199.87 (mm)
Storm Duration (hrs)	=	744:00:00
Time Step	=	5 (minutes)
Ave. Intensity	=	0.27 (mm/hr)
Max. Intensity	=	92.40 (mm/hr) at 34805.00 (minutes)

Maximum Average Intensities: (mm/hr)

Durations	5 min	10 min	15 min	30 min	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
Max. Ave. Int. (mm/hr)	92.40	67.98	55.44	45.98	30.25	29.15	23.87	17.07	11.37	6.02

Kanata Golf & Country Club - 01/08/2018 (00:00) - 31/08/2018 (23:55)



Storm Statistics:

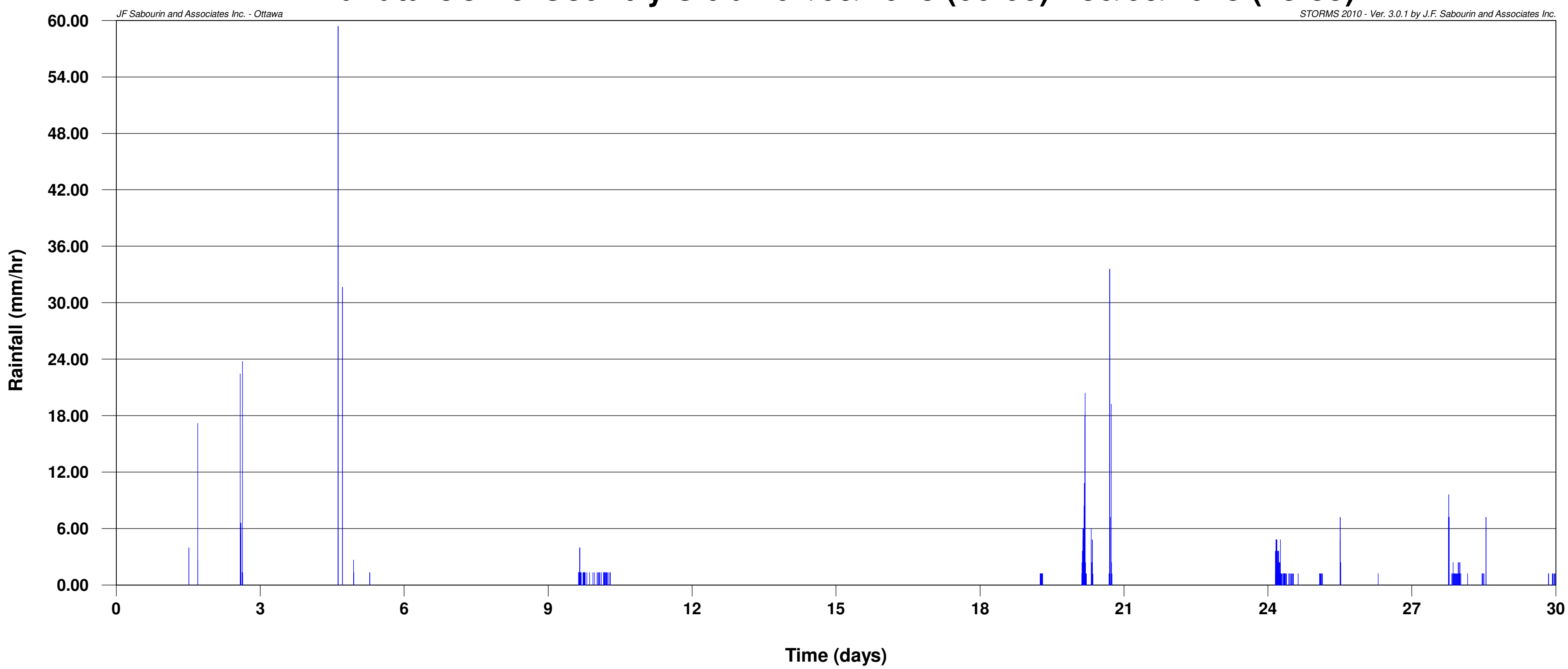
Storm Filename: T:\PROJ\1581-17\Design\Field\Rainfall Monitoring\Storm Files\20180801 - 20180831.stm
Storm File Comment: Kanata Golf & Country Club - 01/08/2018 (00:00) - 31/08/2018 (23:55)

Total Rain	=	108.79 (mm)
Storm Duration (hrs)	=	744:00:00
Time Step	=	5 (minutes)
Ave. Intensity	=	0.15 (mm/hr)
Max. Intensity	=	207.24 (mm/hr) at 8370.00 (minutes)

Maximum Average Intensities: (mm/hr)

Durations	5 min	10 min	15 min	30 min	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
Max. Ave. Int. (mm/hr)	207.24	155.10	132.44	94.38	50.16	25.47	16.98	8.51	4.69	2.35

Kanata Golf & Country Club - 01/09/2018 (00:00) - 30/09/2018 (23:55)



Storm Statistics:

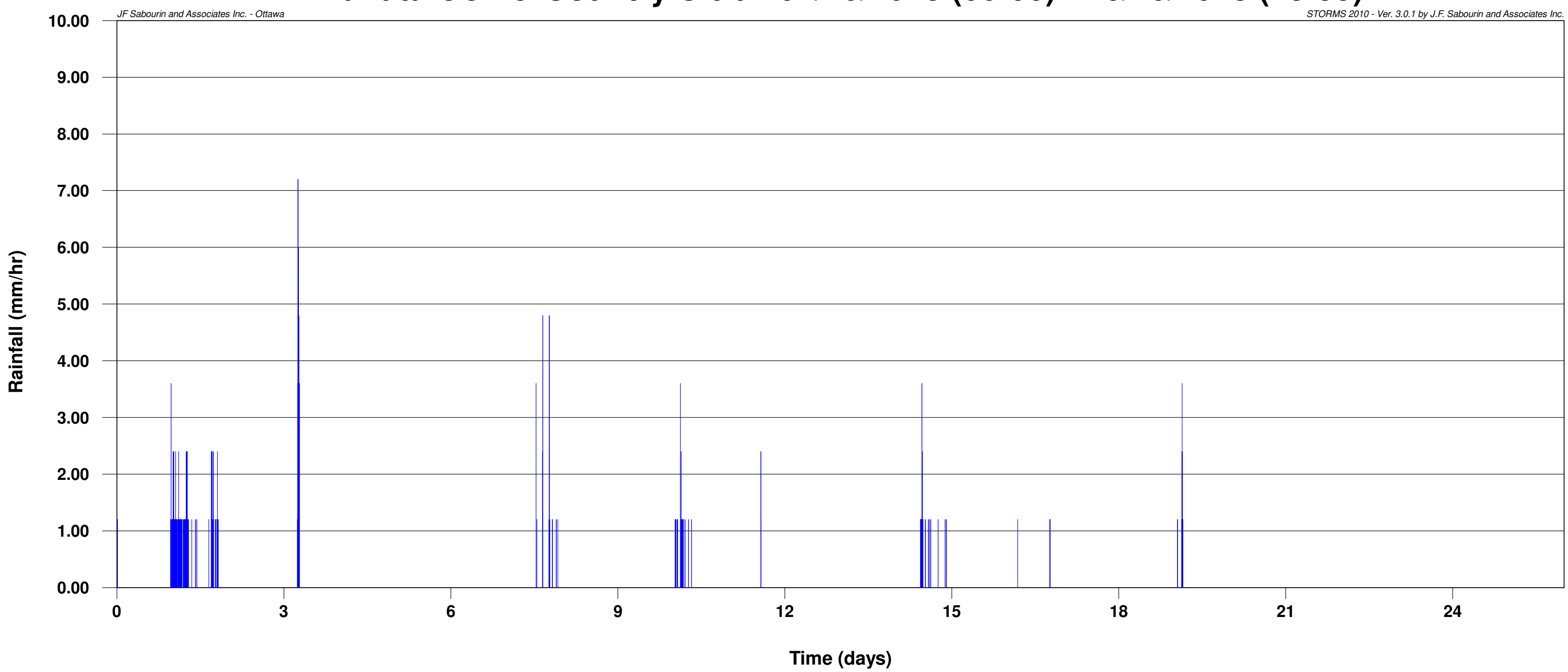
Storm Filename: T:\PROJ\1581-17\Design\Field\Rainfall Monitoring\Storm Files\20180901 - 20180930.stm
Storm File Comment: Kanata Golf & Country Club - 01/09/2018 (00:00) - 30/09/2018 (23:55)

Total Rain = 62.55 (mm)
Storm Duration (hrs) = 720:00:00
Time Step = 5 (minutes)
Ave. Intensity = 0.09 (mm/hr)
Max. Intensity = 59.40 (mm/hr) at 6655.00 (minutes)

Maximum Average Intensities: (mm/hr)

Durations	5 min	10 min	15 min	30 min	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
Max. Ave. Int. (mm/hr)	59.40	32.34	21.56	13.00	9.80	6.50	4.37	2.50	1.25	0.93

Kanata Golf & Country Club - 01/10/2018 (00:00) - 26/10/2018 (23:55)



Storm Statistics:

Storm Filename: T:\PROJ\1581-17\Design\Field\Rainfall Monitoring\Storm Files\20181001 - 20181026.stm
Storm File Comment: Kanata Golf & Country Club - 01/10/2018 (00:00) - 26/10/2018 (23:55)

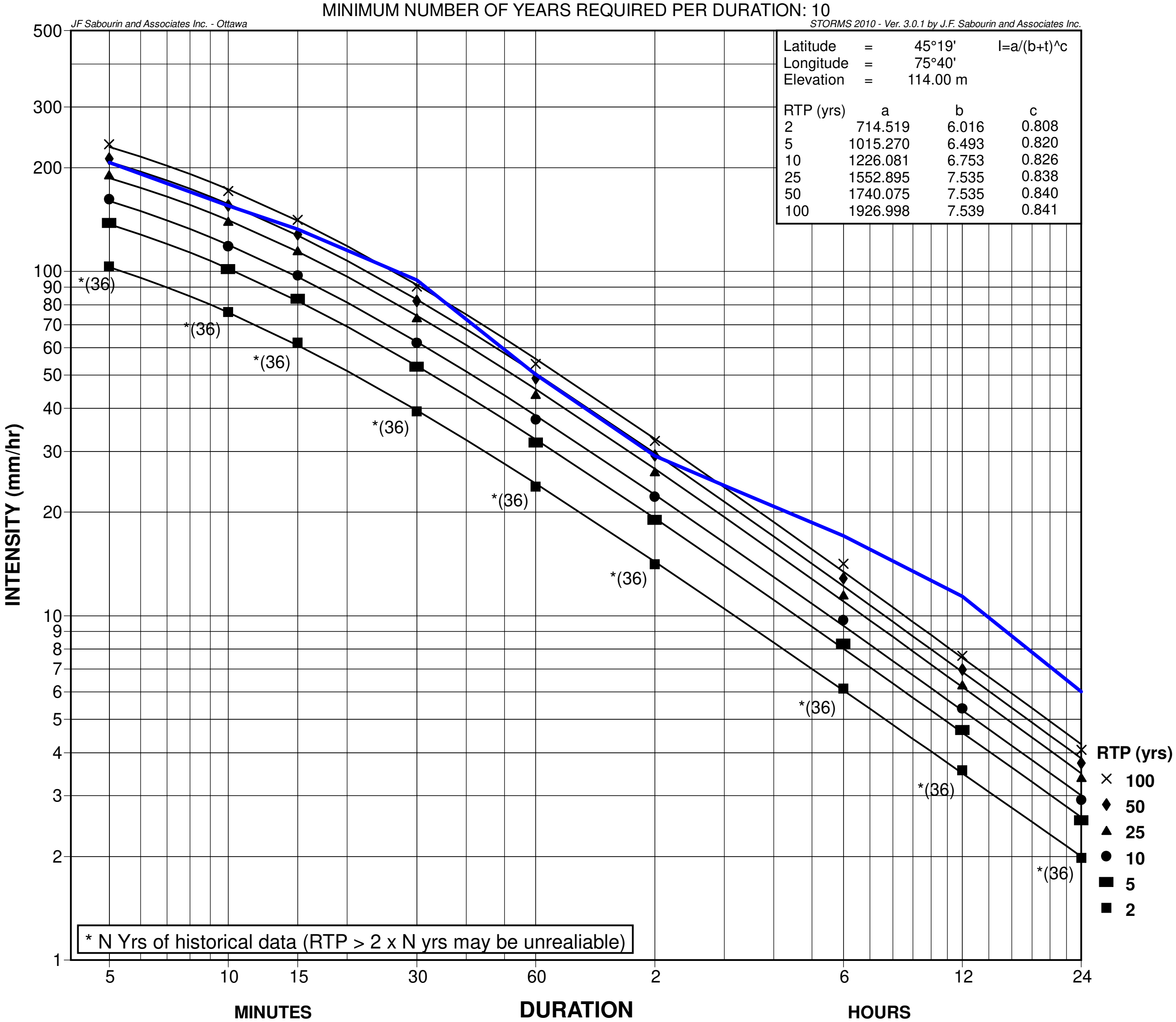
Total Rain = 23.40 (mm)
Storm Duration (hrs) = 624:00:00
Time Step = 5 (minutes)
Ave. Intensity = 0.04 (mm/hr)
Max. Intensity = 7.20 (mm/hr) at 4685.00 (minutes)

Maximum Average Intensities: (mm/hr)

Durations	5 min	10 min	15 min	30 min	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
Max. Ave. Int. (mm/hr)	7.20	7.20	6.80	5.80	4.40	2.20	1.47	0.88	0.62	0.42

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Measured Precipitation Event:
DAY # 1 (00:05) to
DAY # 166 (12:05)

Measured Statistics:

Total Precip.	=	490.86 mm
Storm Duration	=	3972:05:00
Maximum Intensity	=	207.24 mm/hr
Average Intensity	=	0.12 mm/hr

Duration Max. Ave. Int. RTP

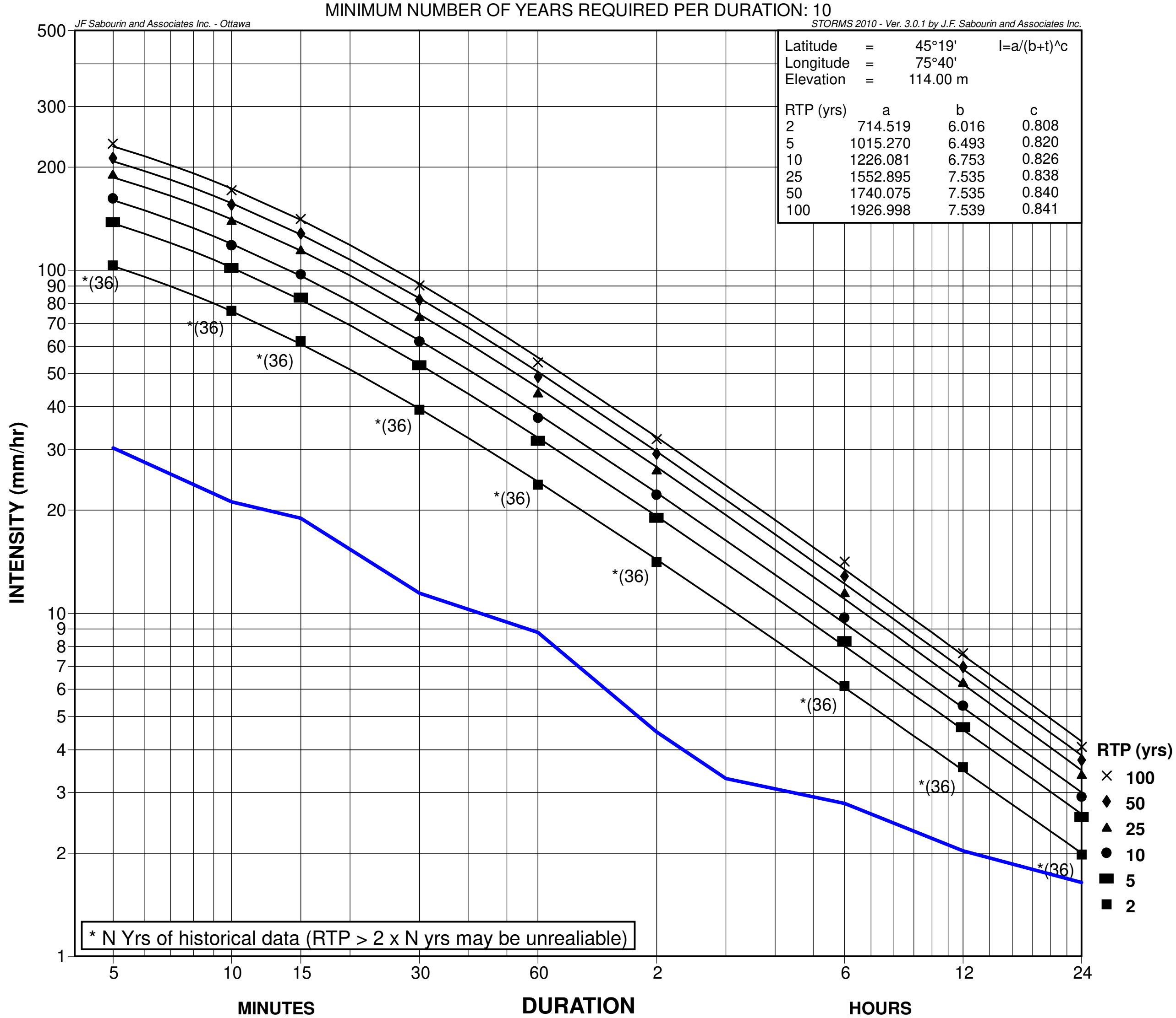
Duration	Max. Ave. Int.	RTP
5 min	207.24 mm/hr	= 42.0 yr
10 min	155.10 mm/hr	= 49.3 yr
15 min	132.44 mm/hr	= 63.2 yr
30 min	94.38 mm/hr	> 100.0 yr
60 min	50.16 mm/hr	= 59.5 yr
2 hr	29.15 mm/hr	= 49.2 yr
6 hr	17.07 mm/hr	> 100.0 yr
12 hr	11.37 mm/hr	> 100.0 yr
24 hr	6.02 mm/hr	> 100.0 yr

Storm Filename:
...\Storm Files\
20180514 - 20181026.stm

Storm Comment:
Kanata Golf & Country Club - 14/05/2018
(12:00) - 26/10/2018 (23:55)

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Measured Precipitation Event:
DAY # 1 (00:05) to
DAY # 48 (12:05)

Measured Statistics:

Total Precip. = 96.25 mm
Storm Duration = 1140:05:00
Maximum Intensity = 30.36 mm/hr
Average Intensity = 0.08 mm/hr

Duration Max. Ave. Int. RTP

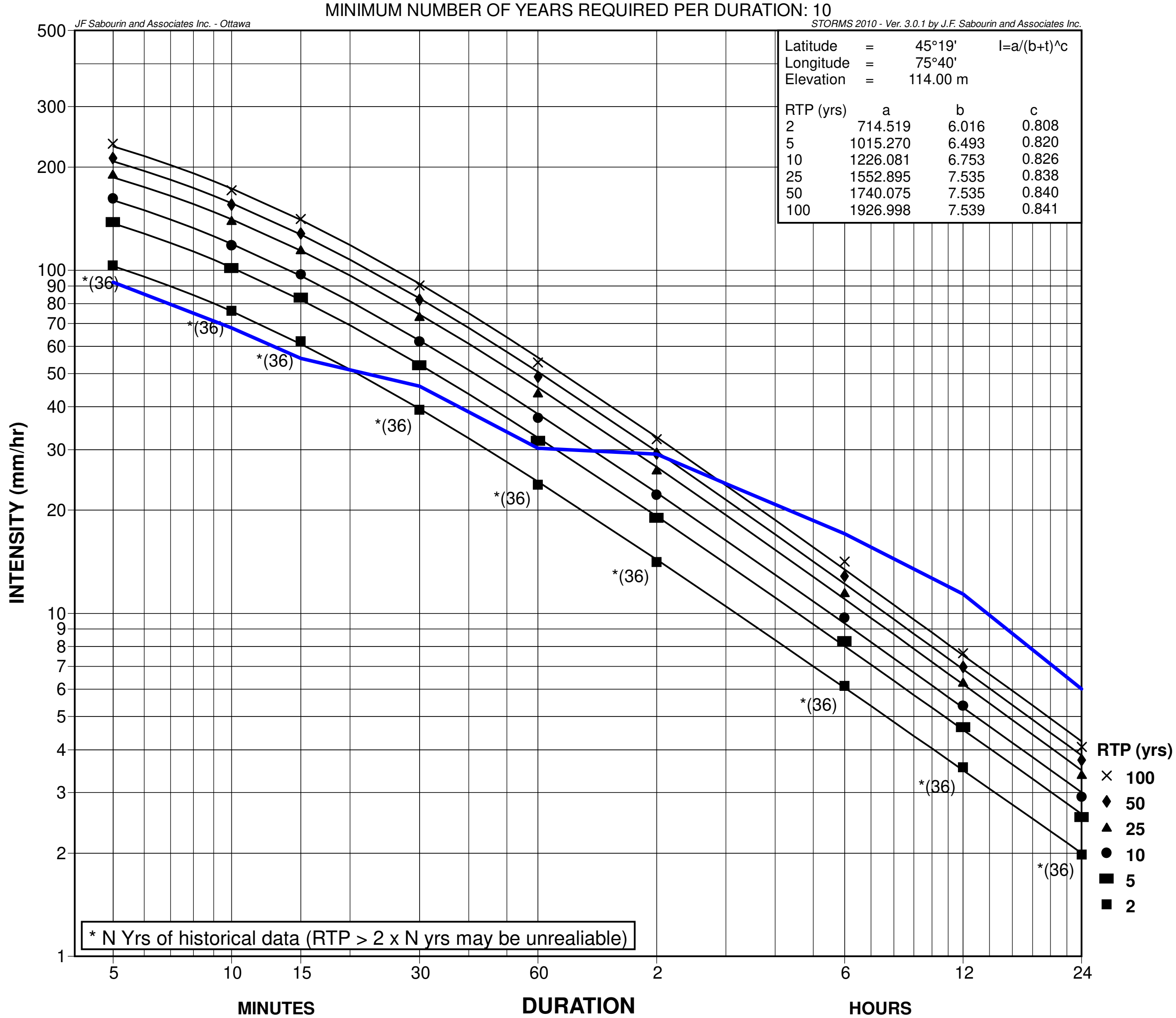
Duration	Max. Ave. Int.	RTP
5 min	30.36 mm/hr	< 2.0 yr
10 min	21.12 mm/hr	< 2.0 yr
15 min	18.92 mm/hr	< 2.0 yr
30 min	11.44 mm/hr	< 2.0 yr
60 min	8.80 mm/hr	< 2.0 yr
2 hr	4.51 mm/hr	< 2.0 yr
6 hr	2.79 mm/hr	< 2.0 yr
12 hr	2.03 mm/hr	< 2.0 yr
24 hr	1.64 mm/hr	< 2.0 yr

Storm Filename:
...\Storm Files\
20180514 - 20180630.stm

Storm Comment:
Kanata Golf & Country Club - 14/05/2018 (12:00) - 30/06/2018 (23:55)

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Measured Precipitation Event:
DAY # 1 (00:05) to
DAY # 31 (24:00)

Measured Statistics:

Total Precip.	=	199.87 mm
Storm Duration	=	744:00:00
Maximum Intensity	=	92.40 mm/hr
Average Intensity	=	0.27 mm/hr

Duration Max. Ave. Int. RTP

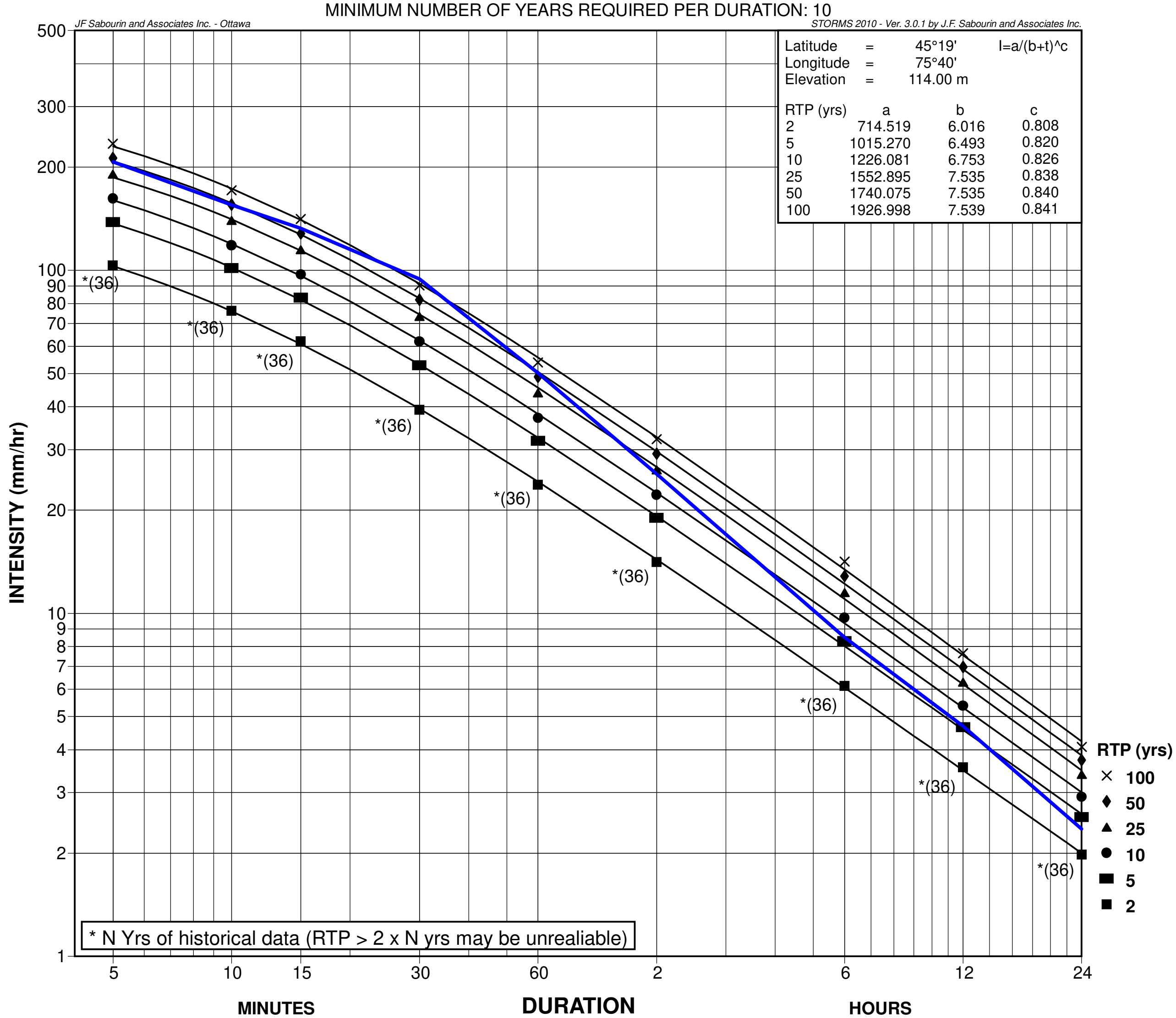
5 min	92.40 mm/hr	< 2.0 yr
10 min	67.98 mm/hr	< 2.0 yr
15 min	55.44 mm/hr	< 2.0 yr
30 min	45.98 mm/hr	= 3.1 yr
60 min	30.25 mm/hr	= 4.1 yr
2 hr	29.15 mm/hr	= 49.2 yr
6 hr	17.07 mm/hr	> 100.0 yr
12 hr	11.37 mm/hr	> 100.0 yr
24 hr	6.02 mm/hr	> 100.0 yr

Storm Filename:
...\Storm Files\
20180701 - 20180731.stm

Storm Comment:
Kanata Golf & Country Club - 01/07/2018
(00:00) - 31/07/2018 (23:55)

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Measured Precipitation Event:
DAY # 1 (00:05) to
DAY # 31 (24:00)

Measured Statistics:

Total Precip. = 108.79 mm
Storm Duration = 744:00:00
Maximum Intensity = 207.24 mm/hr
Average Intensity = 0.15 mm/hr

Duration Max. Ave. Int. RTP

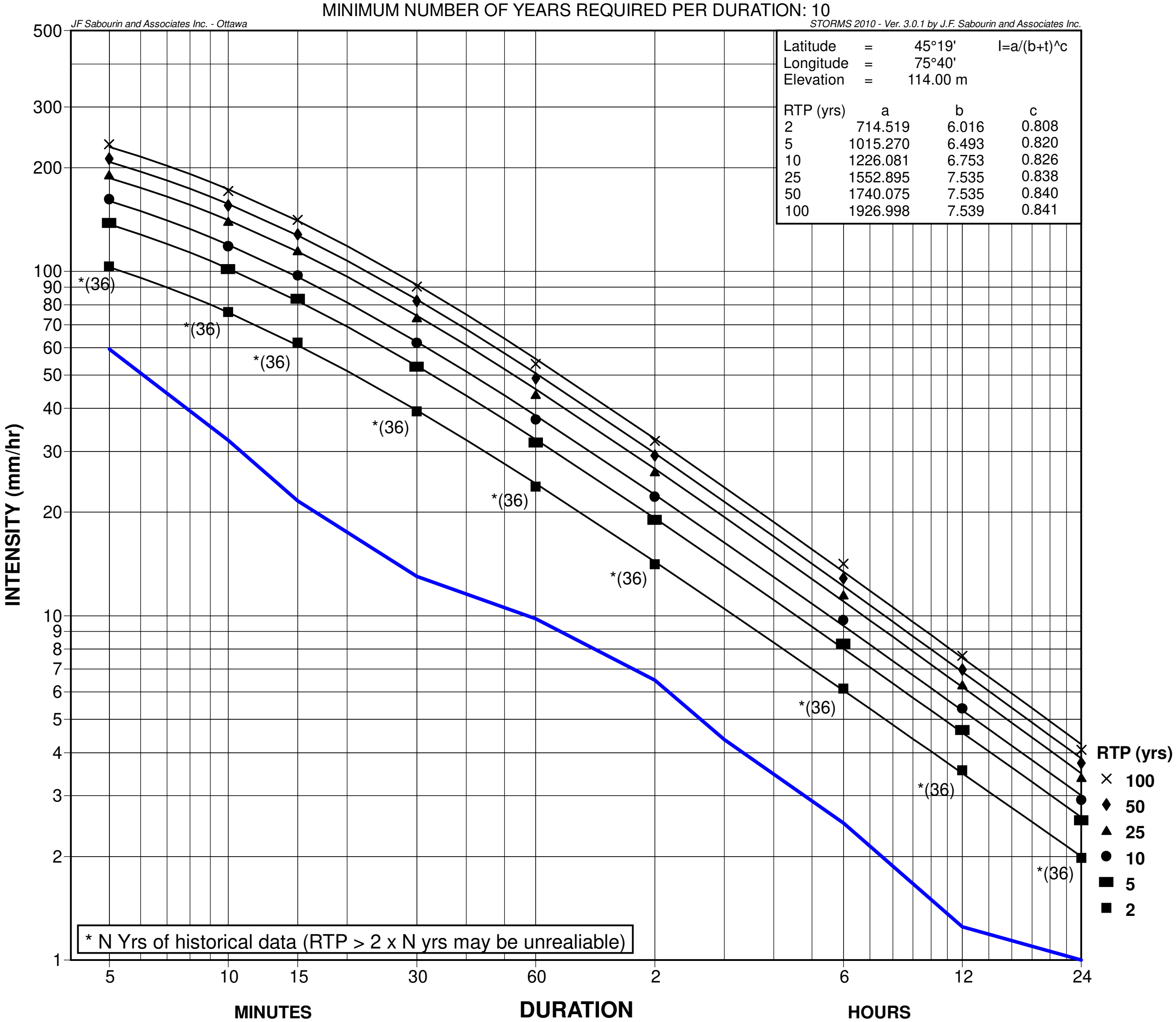
5 min 207.24 mm/hr = 42.0 yr
10 min 155.10 mm/hr = 49.3 yr
15 min 132.44 mm/hr = 63.2 yr
30 min 94.38 mm/hr > 100.0 yr
60 min 50.16 mm/hr = 59.5 yr
2 hr 25.47 mm/hr = 21.1 yr
6 hr 8.51 mm/hr = 5.6 yr
12 hr 4.69 mm/hr = 5.2 yr
24 hr 2.35 mm/hr = 3.6 yr

Storm Filename:
...\Storm Files\
20180801 - 20180831.stm

Storm Comment:
Kanata Golf & Country Club - 01/08/2018
(00:00) - 31/08/2018 (23:55)

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Measured Precipitation Event:
DAY # 1 (00:05) to
DAY # 30 (24:00)

Measured Statistics:

Total Precip.	=	62.55 mm
Storm Duration	=	720:00:00
Maximum Intensity	=	59.40 mm/hr
Average Intensity	=	0.09 mm/hr

Duration Max. Ave. Int. RTP

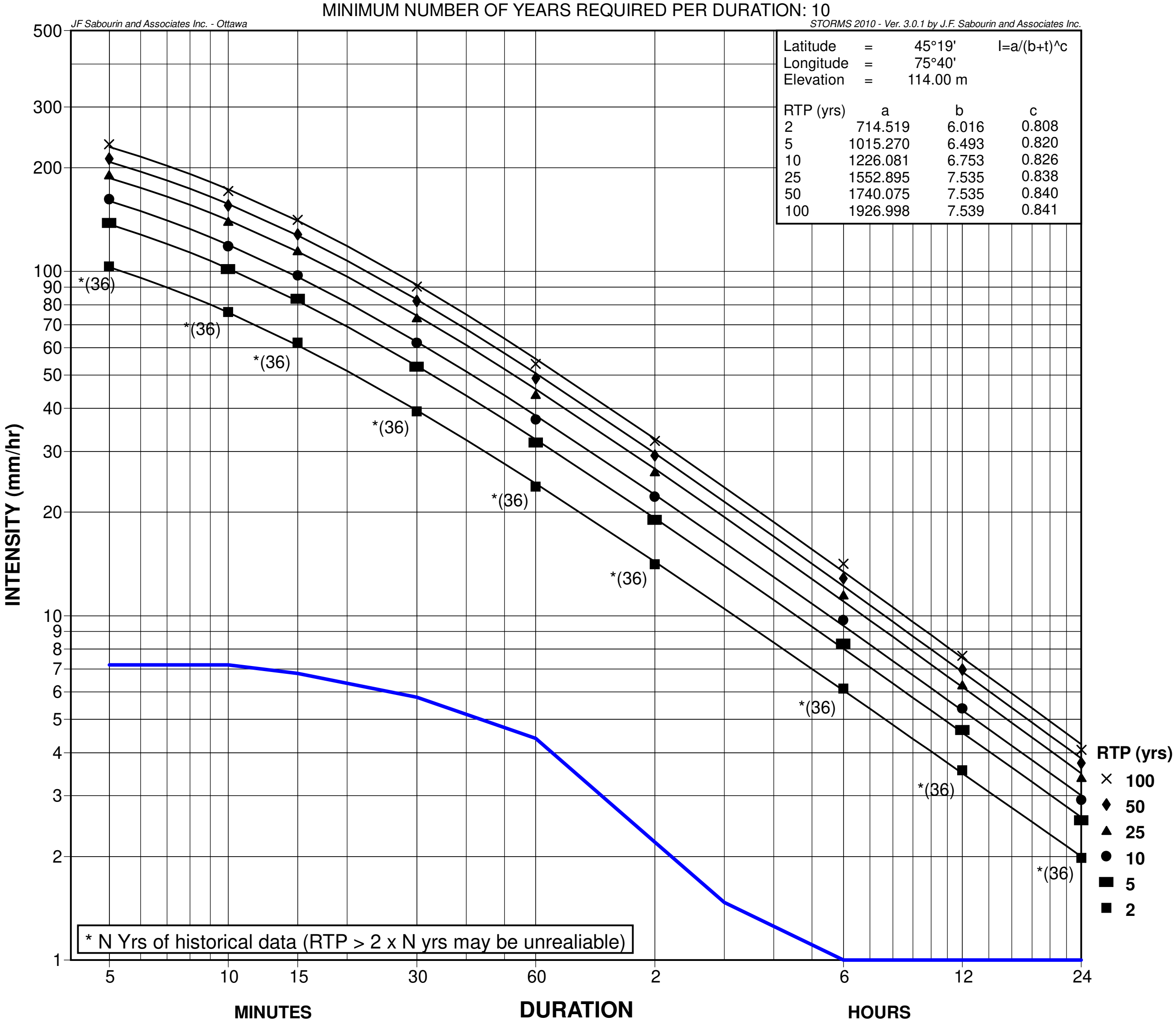
5 min	59.40 mm/hr	< 2.0 yr
10 min	32.34 mm/hr	< 2.0 yr
15 min	21.56 mm/hr	< 2.0 yr
30 min	13.00 mm/hr	< 2.0 yr
60 min	9.80 mm/hr	< 2.0 yr
2 hr	6.50 mm/hr	< 2.0 yr
6 hr	2.50 mm/hr	< 2.0 yr
12 hr	1.25 mm/hr	< 2.0 yr
24 hr	0.93 mm/hr	< 2.0 yr

Storm Filename:
...\Storm Files\
20180901 - 20180930.stm

Storm Comment:
Kanata Golf & Country Club - 01/09/2018 (00:00) - 30/09/2018 (23:55)

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Measured Precipitation Event:
DAY # 1 (00:05) to
DAY # 26 (24:00)

Measured Statistics:

Total Precip.	=	23.40 mm
Storm Duration	=	624:00:00
Maximum Intensity	=	7.20 mm/hr
Average Intensity	=	0.04 mm/hr

Duration Max. Ave. Int. RTP

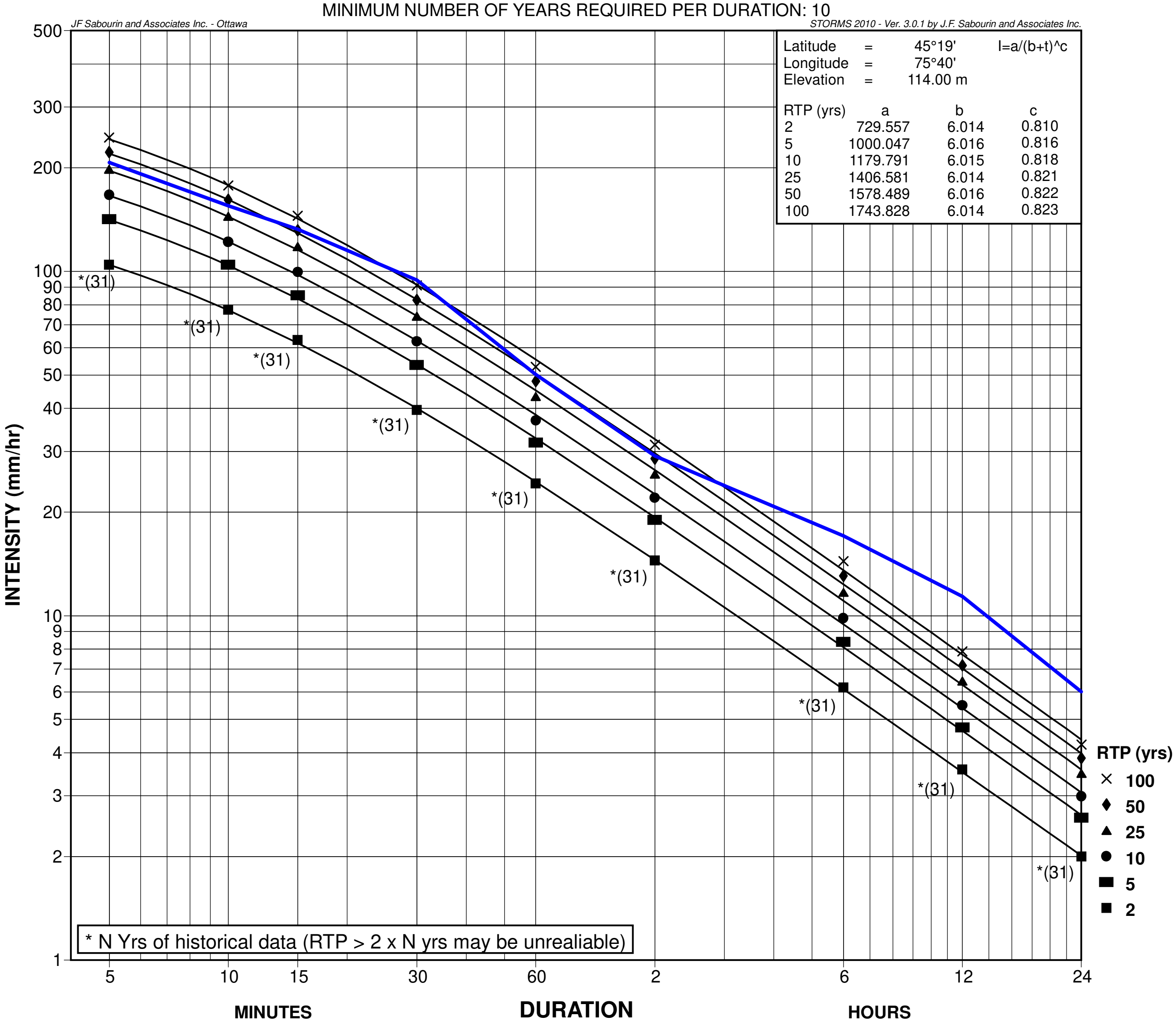
5 min	7.20 mm/hr	< 2.0 yr
10 min	7.20 mm/hr	< 2.0 yr
15 min	6.80 mm/hr	< 2.0 yr
30 min	5.80 mm/hr	< 2.0 yr
60 min	4.40 mm/hr	< 2.0 yr
2 hr	2.20 mm/hr	< 2.0 yr
6 hr	0.88 mm/hr	< 2.0 yr
12 hr	0.62 mm/hr	< 2.0 yr
24 hr	0.42 mm/hr	< 2.0 yr

Storm Filename:
...\Storm Files\
20181001 - 20181026.stm

Storm Comment:
Kanata Golf & Country Club - 01/10/2018
(00:00) - 26/10/2018 (23:55)

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Measured Precipitation Event:
DAY # 1 (00:05) to
DAY # 166 (12:05)

Measured Statistics:

Total Precip.	=	490.86 mm
Storm Duration	=	3972:05:00
Maximum Intensity	=	207.24 mm/hr
Average Intensity	=	0.12 mm/hr

Duration Max. Ave. Int. RTP

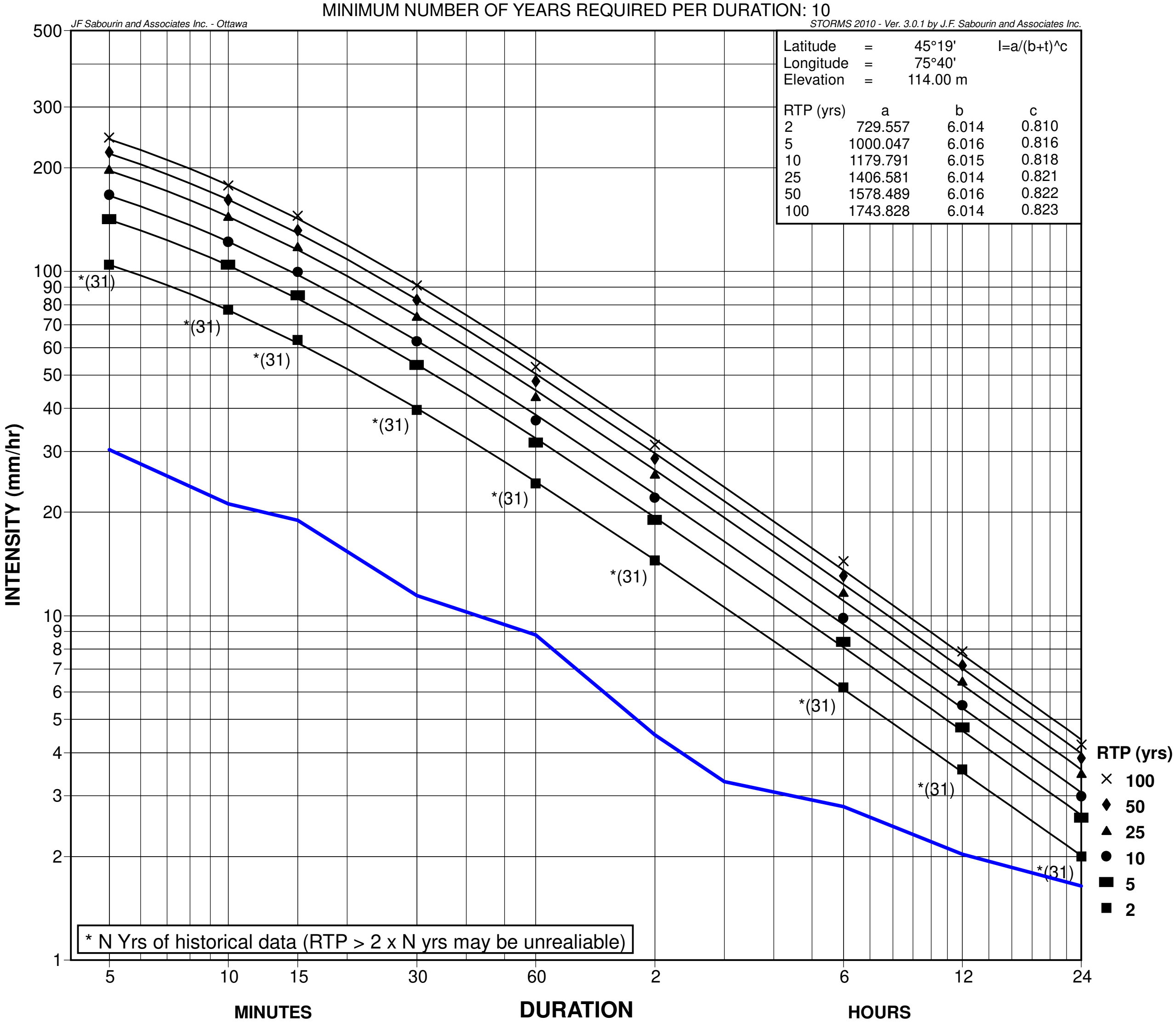
5 min	207.24 mm/hr = 32.6 yr
10 min	155.10 mm/hr = 38.7 yr
15 min	132.44 mm/hr = 52.0 yr
30 min	94.38 mm/hr > 100.0 yr
60 min	50.16 mm/hr = 68.2 yr
2 hr	29.15 mm/hr = 57.4 yr
6 hr	17.07 mm/hr > 100.0 yr
12 hr	11.37 mm/hr > 100.0 yr
24 hr	6.02 mm/hr > 100.0 yr

Storm Filename:
...\Storm Files\
20180514 - 20181026.stm

Storm Comment:
Kanata Golf & Country Club - 14/05/2018
(12:00) - 26/10/2018 (23:55)

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Measured Precipitation Event:
DAY # 1 (00:05) to
DAY # 48 (12:05)

Measured Statistics:

Total Precip.	=	96.25 mm
Storm Duration	=	1140:05:00
Maximum Intensity	=	30.36 mm/hr
Average Intensity	=	0.08 mm/hr

Duration Max. Ave. Int. RTP

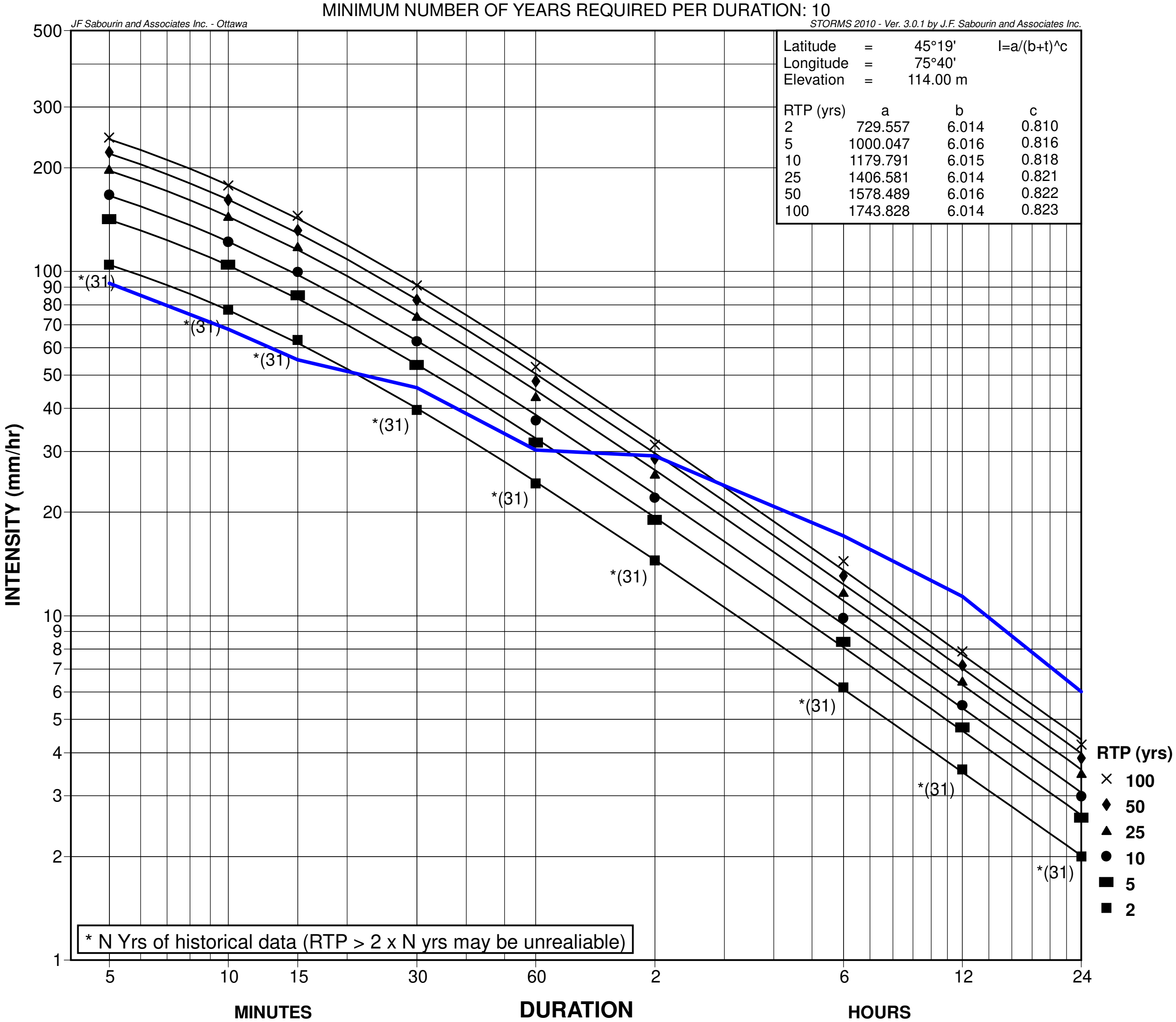
5	min	30.36 mm/hr	< 2.0 yr
10	min	21.12 mm/hr	< 2.0 yr
15	min	18.92 mm/hr	< 2.0 yr
30	min	11.44 mm/hr	< 2.0 yr
60	min	8.80 mm/hr	< 2.0 yr
2	hr	4.51 mm/hr	< 2.0 yr
6	hr	2.79 mm/hr	< 2.0 yr
12	hr	2.03 mm/hr	< 2.0 yr
24	hr	1.64 mm/hr	< 2.0 yr

Storm Filename:
...\Storm Files\
20180514 - 20180630.stm

Storm Comment:
Kanata Golf & Country Club - 14/05/2018 (12:00) - 30/06/2018 (23:55)

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Measured Precipitation Event:
DAY # 1 (00:05) to
DAY # 31 (24:00)

Measured Statistics:

Total Precip.	=	199.87 mm
Storm Duration	=	744:00:00
Maximum Intensity	=	92.40 mm/hr
Average Intensity	=	0.27 mm/hr

Duration Max. Ave. Int. RTP

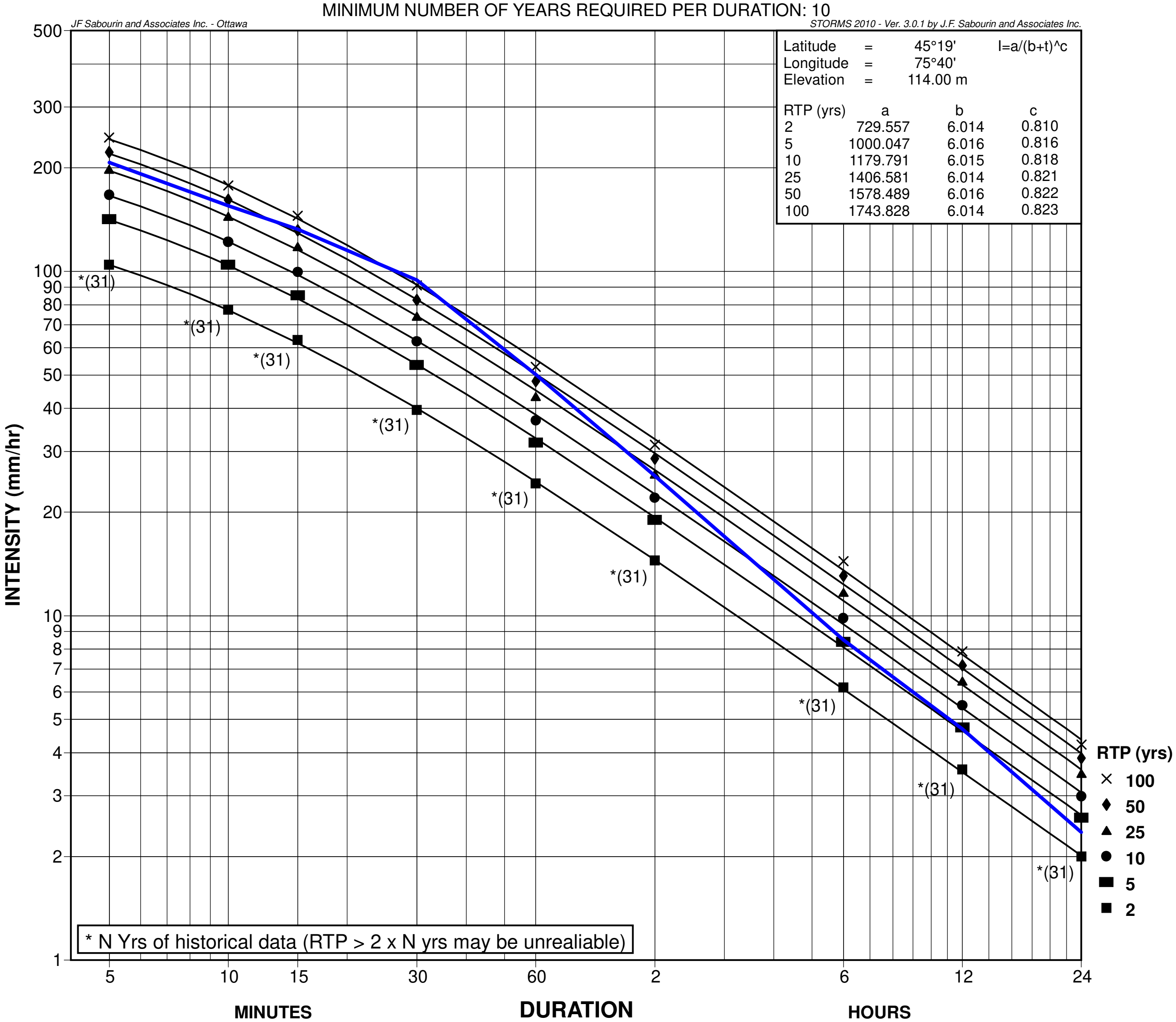
Duration		Max. Ave. Int.	RTP
5	min	92.40 mm/hr	< 2.0 yr
10	min	67.98 mm/hr	< 2.0 yr
15	min	55.44 mm/hr	< 2.0 yr
30	min	45.98 mm/hr	= 3.0 yr
60	min	30.25 mm/hr	= 4.1 yr
2	hr	29.15 mm/hr	= 57.4 yr
6	hr	17.07 mm/hr	> 100.0 yr
12	hr	11.37 mm/hr	> 100.0 yr
24	hr	6.02 mm/hr	> 100.0 yr

Storm Filename:
...\Storm Files\
20180701 - 20180731.stm

Storm Comment:
Kanata Golf & Country Club - 01/07/2018
(00:00) - 31/07/2018 (23:55)

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Measured Precipitation Event:
DAY # 1 (00:05) to
DAY # 31 (24:00)

Measured Statistics:

Total Precip.	=	108.79 mm
Storm Duration	=	744:00:00
Maximum Intensity	=	207.24 mm/hr
Average Intensity	=	0.15 mm/hr

Duration Max. Ave. Int. RTP

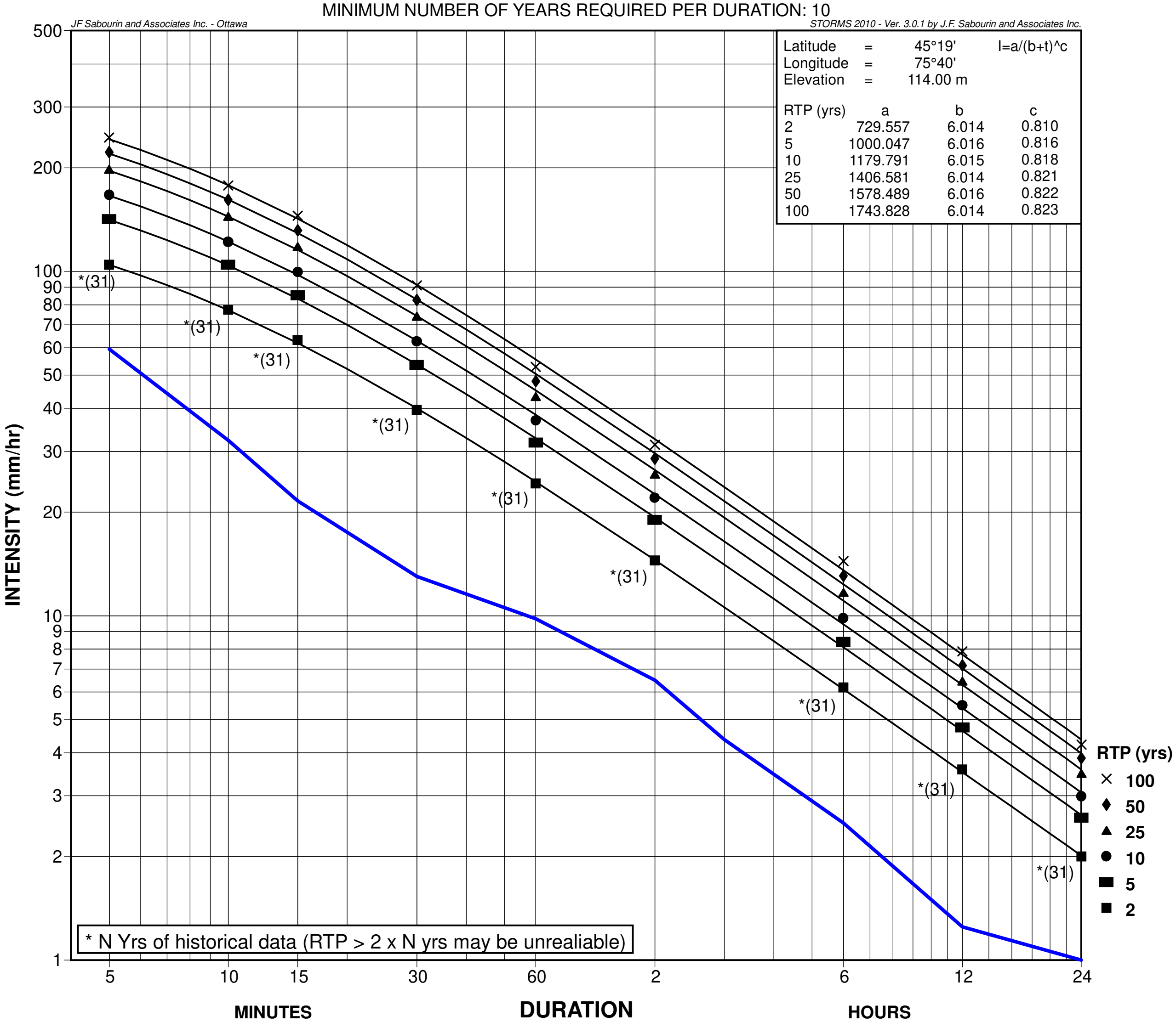
5 min	207.24 mm/hr = 32.6 yr
10 min	155.10 mm/hr = 38.7 yr
15 min	132.44 mm/hr = 52.0 yr
30 min	94.38 mm/hr > 100.0 yr
60 min	50.16 mm/hr = 68.2 yr
2 hr	25.47 mm/hr = 23.2 yr
6 hr	8.51 mm/hr = 5.3 yr
12 hr	4.69 mm/hr = 4.8 yr
24 hr	2.35 mm/hr = 3.4 yr

Storm Filename:
...\Storm Files\
20180801 - 20180831.stm

Storm Comment:
Kanata Golf & Country Club - 01/08/2018
(00:00) - 31/08/2018 (23:55)

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Measured Precipitation Event:
DAY # 1 (00:05) to
DAY # 30 (24:00)

Measured Statistics:

Total Precip.	=	62.55 mm
Storm Duration	=	720:00:00
Maximum Intensity	=	59.40 mm/hr
Average Intensity	=	0.09 mm/hr

Duration Max. Ave. Int. RTP

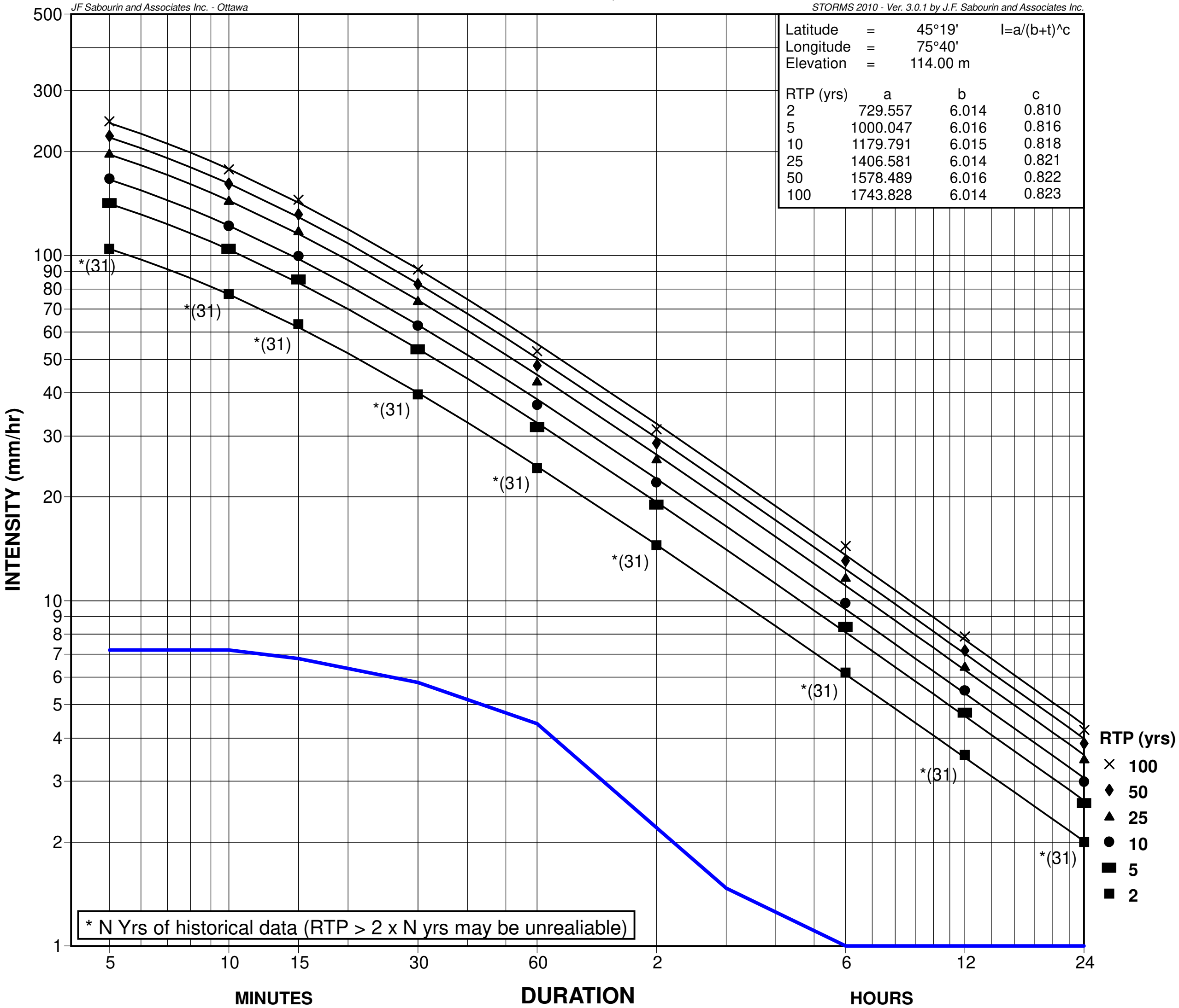
5 min	59.40 mm/hr	< 2.0 yr
10 min	32.34 mm/hr	< 2.0 yr
15 min	21.56 mm/hr	< 2.0 yr
30 min	13.00 mm/hr	< 2.0 yr
60 min	9.80 mm/hr	< 2.0 yr
2 hr	6.50 mm/hr	< 2.0 yr
6 hr	2.50 mm/hr	< 2.0 yr
12 hr	1.25 mm/hr	< 2.0 yr
24 hr	0.93 mm/hr	< 2.0 yr

Storm Filename:
...\Storm Files\
20180901 - 20180930.stm

Storm Comment:
Kanata Golf & Country Club - 01/09/2018
(00:00) - 30/09/2018 (23:55)

OTTAWA MACDONAL -Station ID: 6106000

SHORT DURATION RAINFALL INTENSITY - DURATION FREQUENCY CHART
TYPE I EXTREMAL DISTRIBUTION (GUMBEL)
MINIMUM NUMBER OF YEARS REQUIRED PER DURATION: 10



Latitude = 45°19'			I=a/(b+t)^c
Longitude = 75°40'			
Elevation = 114.00 m			
RTP (yrs)	a	b	c
2	729.557	6.014	0.810
5	1000.047	6.016	0.816
10	1179.791	6.015	0.818
25	1406.581	6.014	0.821
50	1578.489	6.016	0.822
100	1743.828	6.014	0.823

Measured Precipitation Event:

DAY # 1 (00:05) to
DAY # 26 (24:00)

Measured Statistics:

Total Precip. = 23.40 mm
Storm Duration = 624:00:00
Maximum Intensity = 7.20 mm/hr
Average Intensity = 0.04 mm/hr

Duration Max. Ave. Int. RTP

Duration	Max. Ave. Int.	RTP
5 min	7.20 mm/hr	< 2.0 yr
10 min	7.20 mm/hr	< 2.0 yr
15 min	6.80 mm/hr	< 2.0 yr
30 min	5.80 mm/hr	< 2.0 yr
60 min	4.40 mm/hr	< 2.0 yr
2 hr	2.20 mm/hr	< 2.0 yr
6 hr	0.88 mm/hr	< 2.0 yr
12 hr	0.62 mm/hr	< 2.0 yr
24 hr	0.42 mm/hr	< 2.0 yr

Storm Filename:

...\Storm Files\
20181001 - 20181026.stm

Storm Comment:

Kanata Golf & Country Club - 01/10/2018 (00:00) - 26/10/2018 (23:55)

JFSA
WATER RESOURCES AND
ENVIRONMENTAL CONSULTANTS

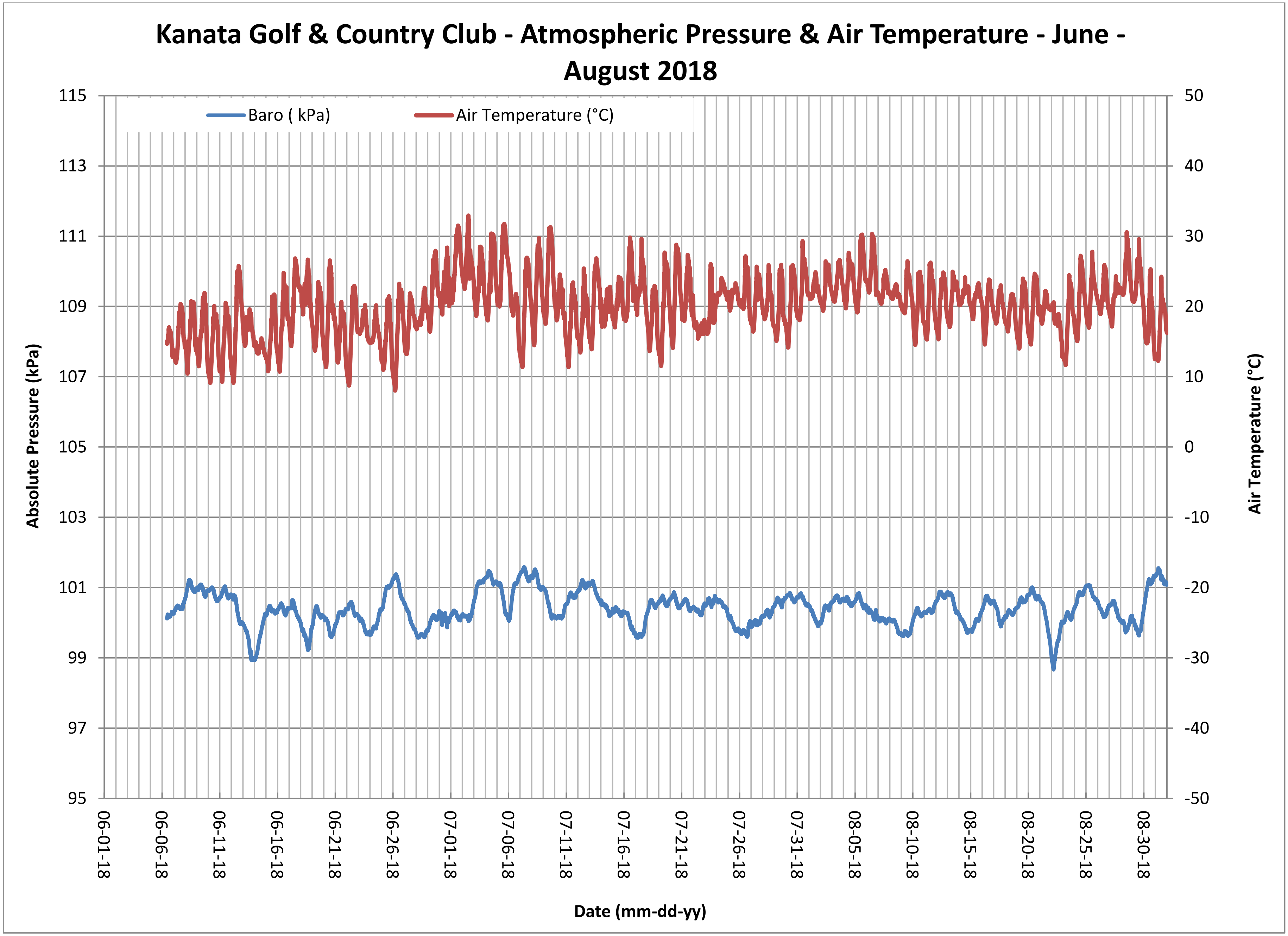
Project Ref #:P1581
Client: David Schaeffer Engineering

Ottawa
Gatineau
Montréal
Québec City

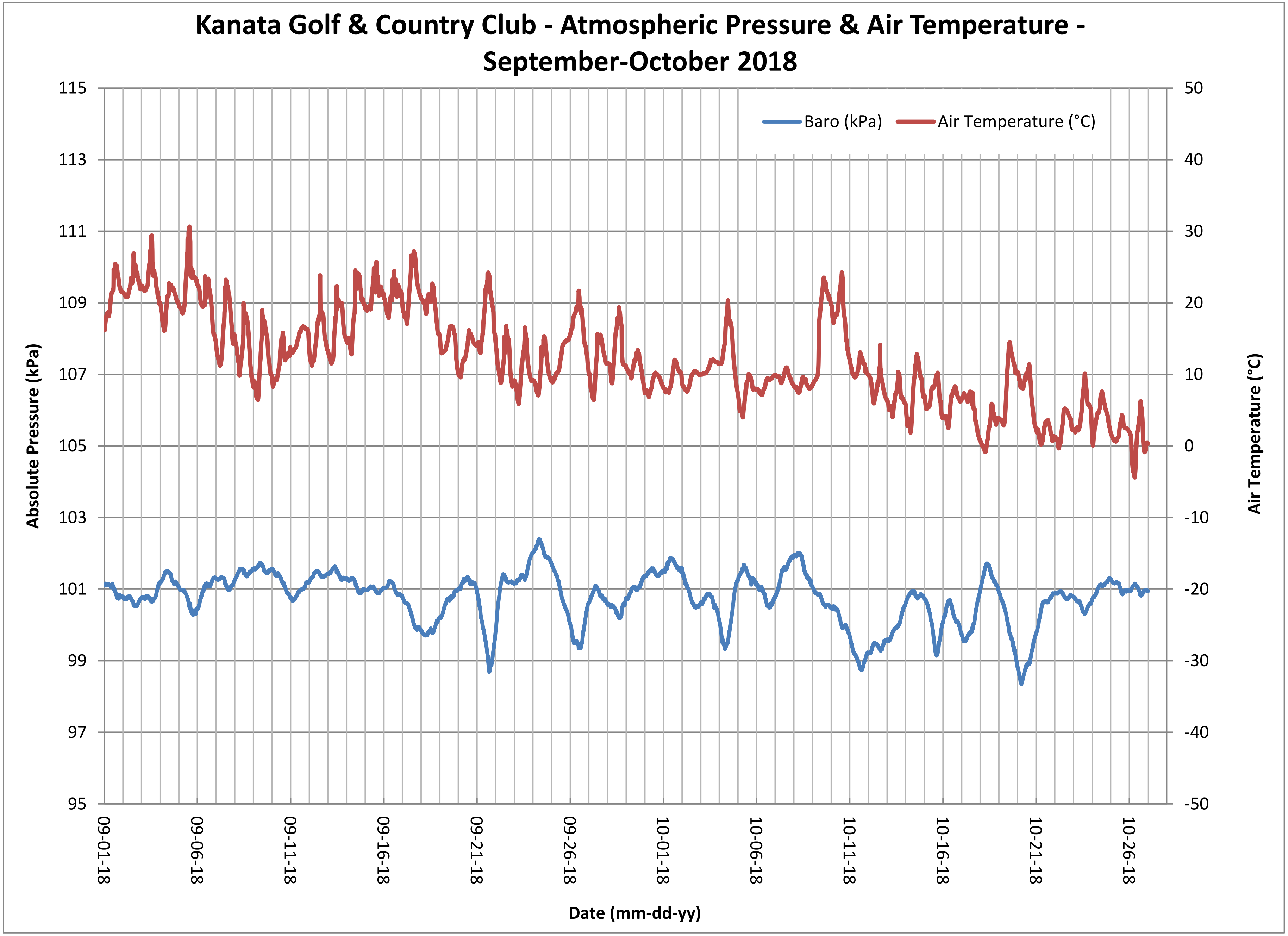
Attachment B

Continuous Water Level, Flow and Barometric Pressure Graphs

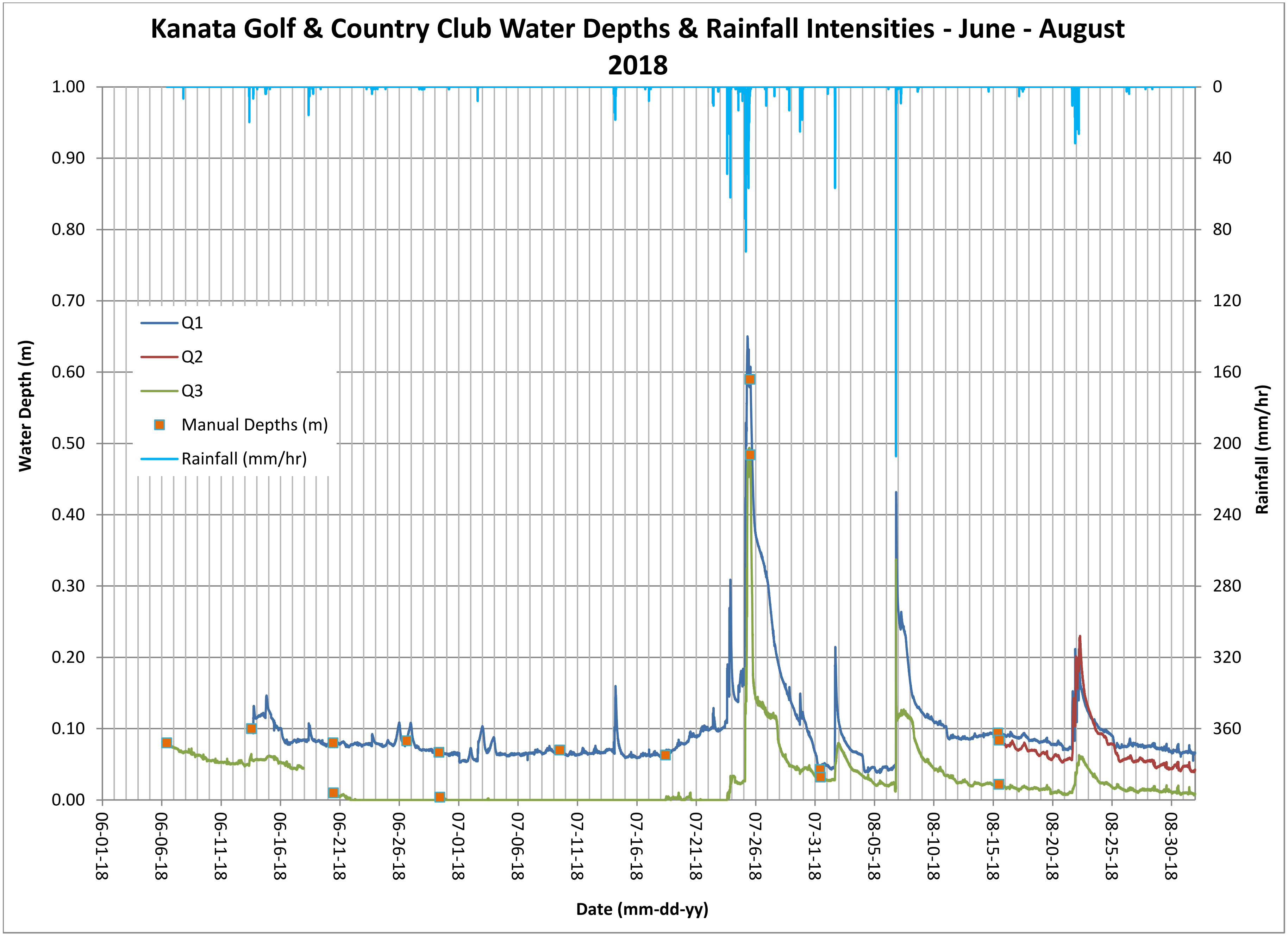
February 2019

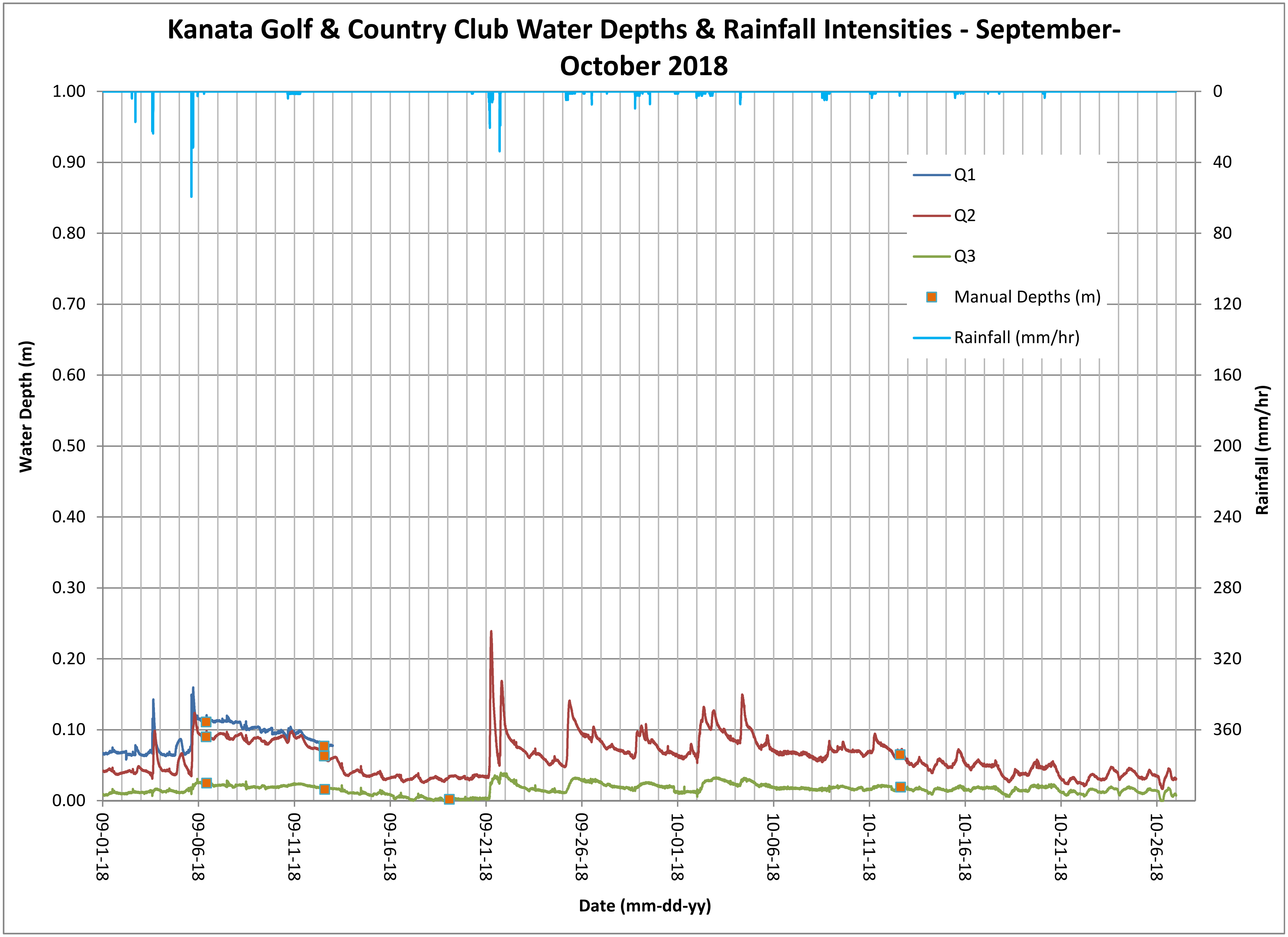


Kanata Golf & Country Club - Atmospheric Pressure & Air Temperature - June - August 2018
Baro (kPa)
Air Temperature (°C)
Absolute Pressure (kPa)
Air Temperature (°C)
115
113
111
109
107
105
103
101
99
97
95
50
40
30
20
10
0
-10
-20
-30
-40
-50
06-01-18
06-06-18
06-11-18
06-16-18
06-21-18
06-26-18
07-01-18
07-06-18
07-11-18
07-16-18
07-21-18
07-26-18
07-31-18
08-05-18
08-10-18
08-15-18
08-20-18
08-25-18
08-30-18
Date (mm-dd-yy)

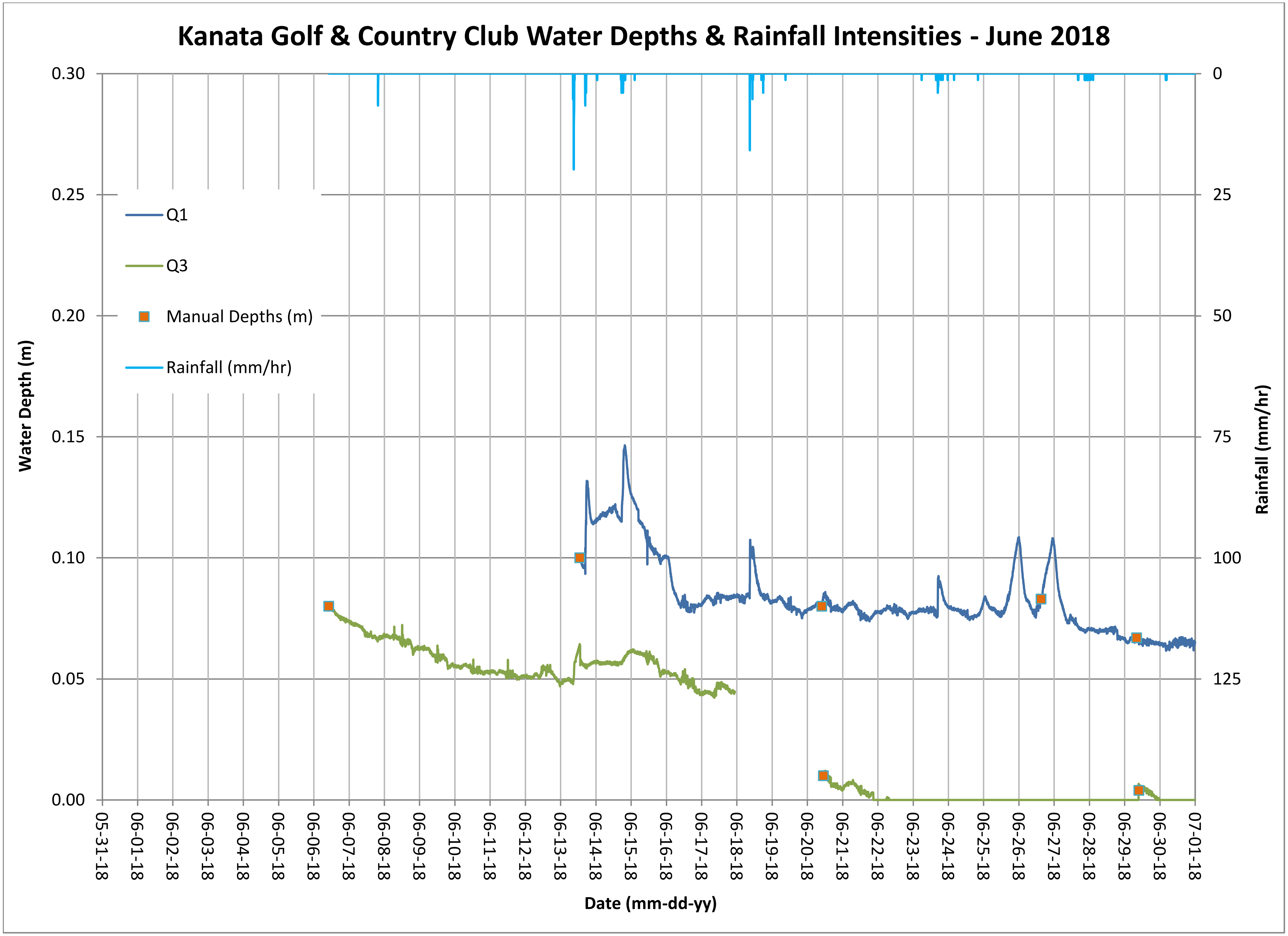


Kanata Golf & Country Club - Atmospheric Pressure & Air Temperature - September-October 2018
Baro (kPa)
Air Temperature (°C)
Absolute Pressure (kPa)
Air Temperature (°C)
Date (mm-dd-yy)
115
113
111
109
107
105
103
101
99
97
95
50
40
30
20
10
0
-10
-20
-30
-40
-50
09-01-18
09-06-18
09-11-18
09-16-18
09-21-18
09-26-18
10-01-18
10-06-18
10-11-18
10-16-18
10-21-18
10-26-18

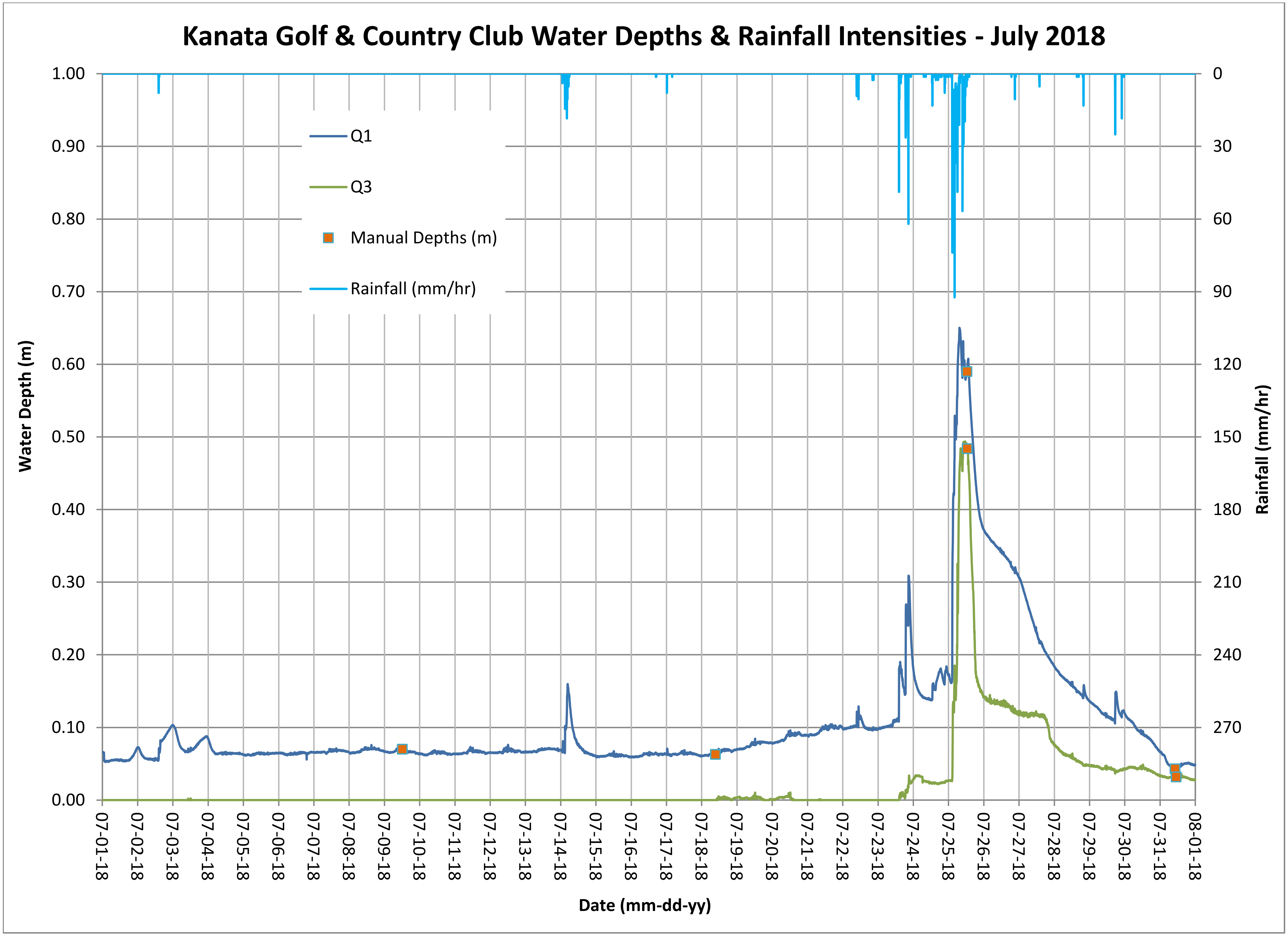

Kanata Golf & Country Club Water Depths & Rainfall Intensities - June - August 2018
Water Depth (m)
Rainfall (mm/hr)
Date (mm-dd-yy)
Q1
Q2
Q3
Manual Depths (m)
Rainfall (mm/hr)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
40
80
120
160
200
240
280
320
360
06-01-18
06-06-18
06-11-18
06-16-18
06-21-18
06-26-18
07-01-18
07-06-18
07-11-18
07-16-18
07-21-18
07-26-18
07-31-18
08-05-18
08-10-18
08-15-18
08-20-18
08-25-18
08-30-18



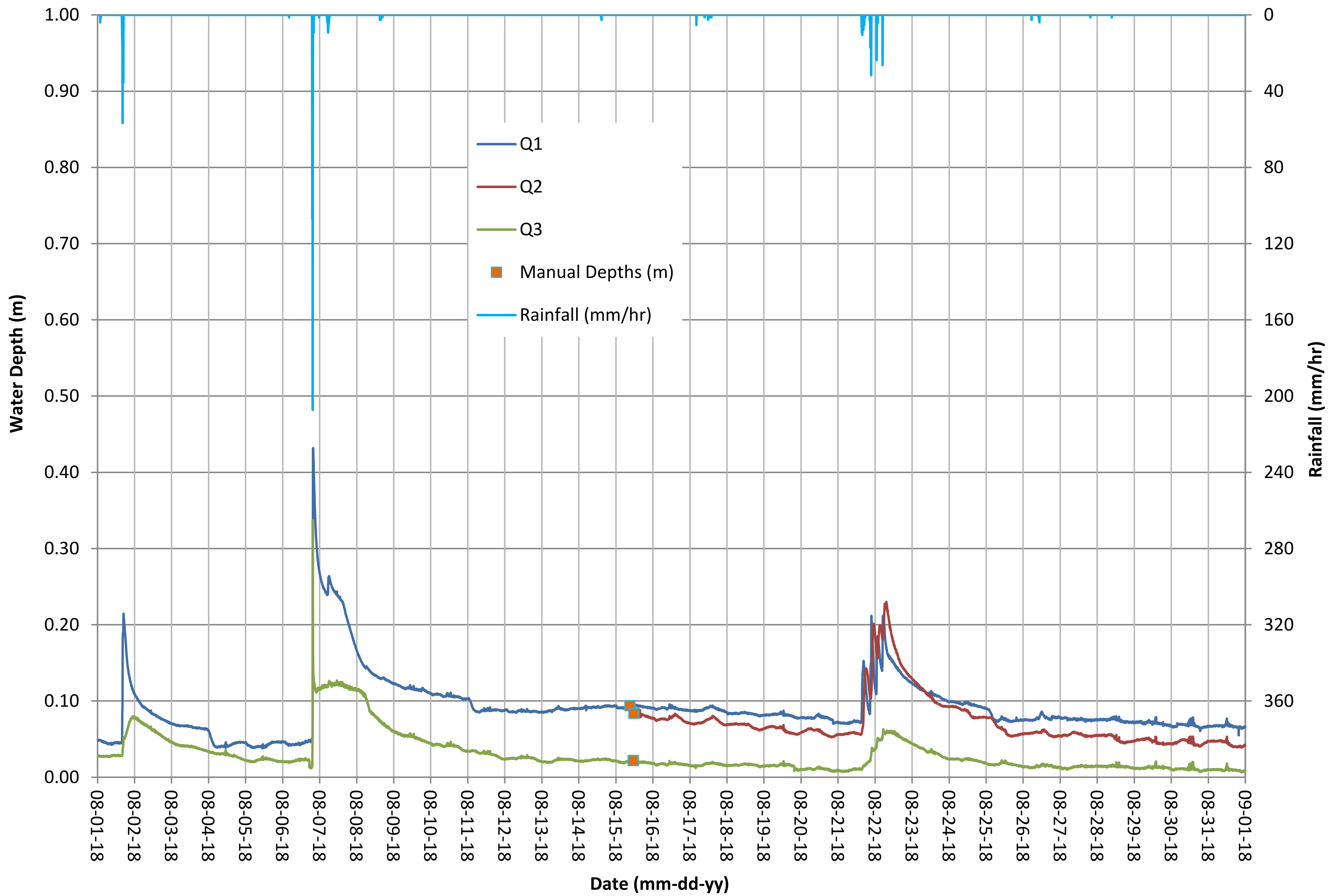
Kanata Golf & Country Club Water Depths & Rainfall Intensities - September-October 2018
Water Depth (m)
Rainfall (mm/hr)
Date (mm-dd-yy)
Q1
Q2
Q3
Manual Depths (m)
Rainfall (mm/hr)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
40
80
120
160
200
240
280
320
360
09-01-18
09-06-18
09-11-18
09-16-18
09-21-18
09-26-18
10-01-18
10-06-18
10-11-18
10-16-18
10-21-18
10-26-18

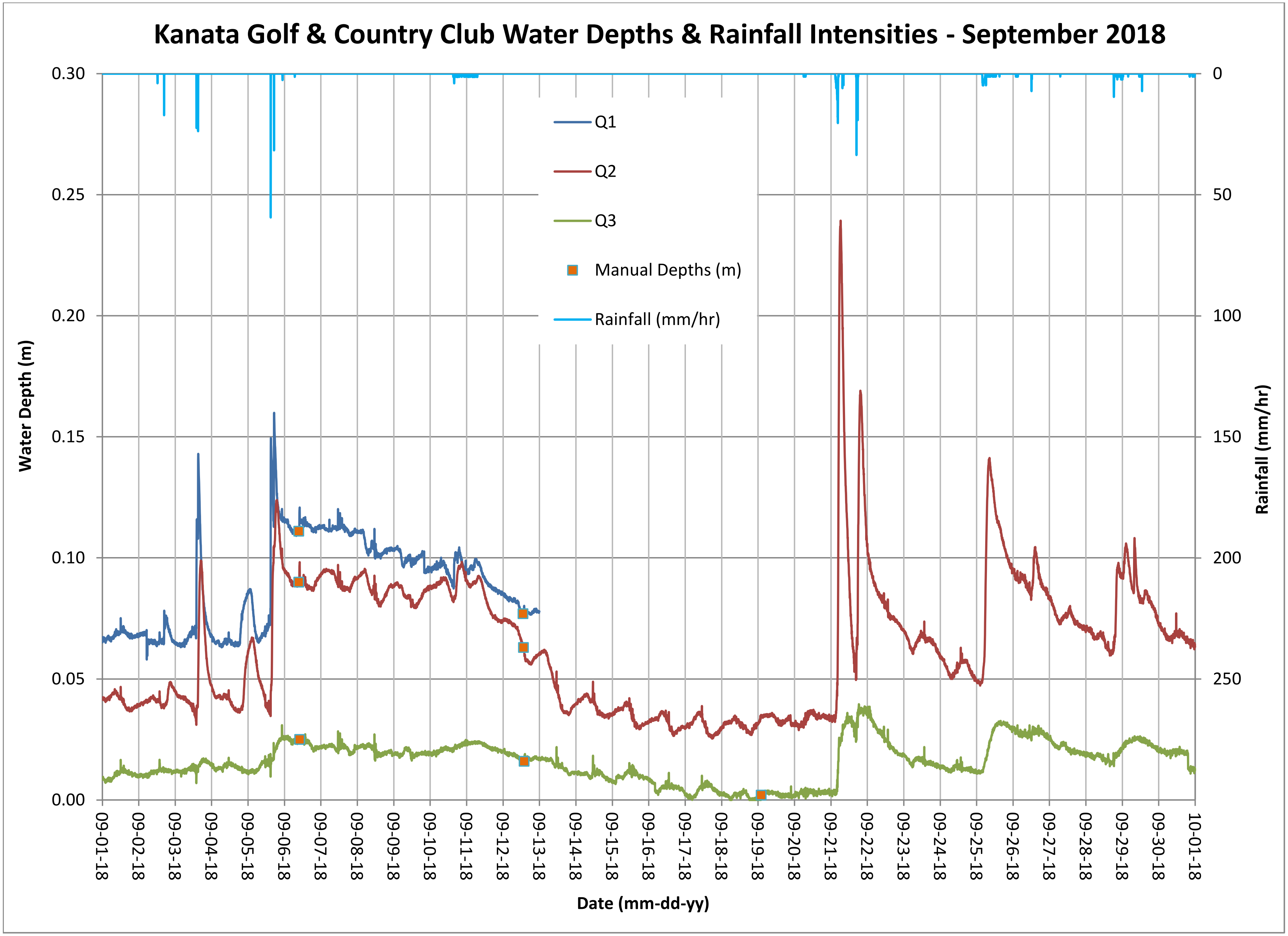


Kanata Golf & Country Club Water Depths & Rainfall Intensities - June 2018
Water Depth (m)
Rainfall (mm/hr)
Date (mm-dd-yy)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
25
50
75
100
125
05-31-18
06-01-18
06-02-18
06-03-18
06-04-18
06-05-18
06-06-18
06-07-18
06-08-18
06-09-18
06-10-18
06-11-18
06-12-18
06-13-18
06-14-18
06-15-18
06-16-18
06-17-18
06-18-18
06-19-18
06-20-18
06-21-18
06-22-18
06-23-18
06-24-18
06-25-18
06-26-18
06-27-18
06-28-18
06-29-18
06-30-18
07-01-18
Q1
Q3
Manual Depths (m)
Rainfall (mm/hr)


Kanata Golf & Country Club Water Depths & Rainfall Intensities - July 2018
Water Depth (m)
Rainfall (mm/hr)
Date (mm-dd-yy)
Q1
Q3
Manual Depths (m)
Rainfall (mm/hr)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
30
60
90
120
150
180
210
240
270
07-01-18
07-02-18
07-03-18
07-04-18
07-05-18
07-06-18
07-07-18
07-08-18
07-09-18
07-10-18
07-11-18
07-12-18
07-13-18
07-14-18
07-15-18
07-16-18
07-17-18
07-18-18
07-19-18
07-20-18
07-21-18
07-22-18
07-23-18
07-24-18
07-25-18
07-26-18
07-27-18
07-28-18
07-29-18
07-30-18
07-31-18
08-01-18

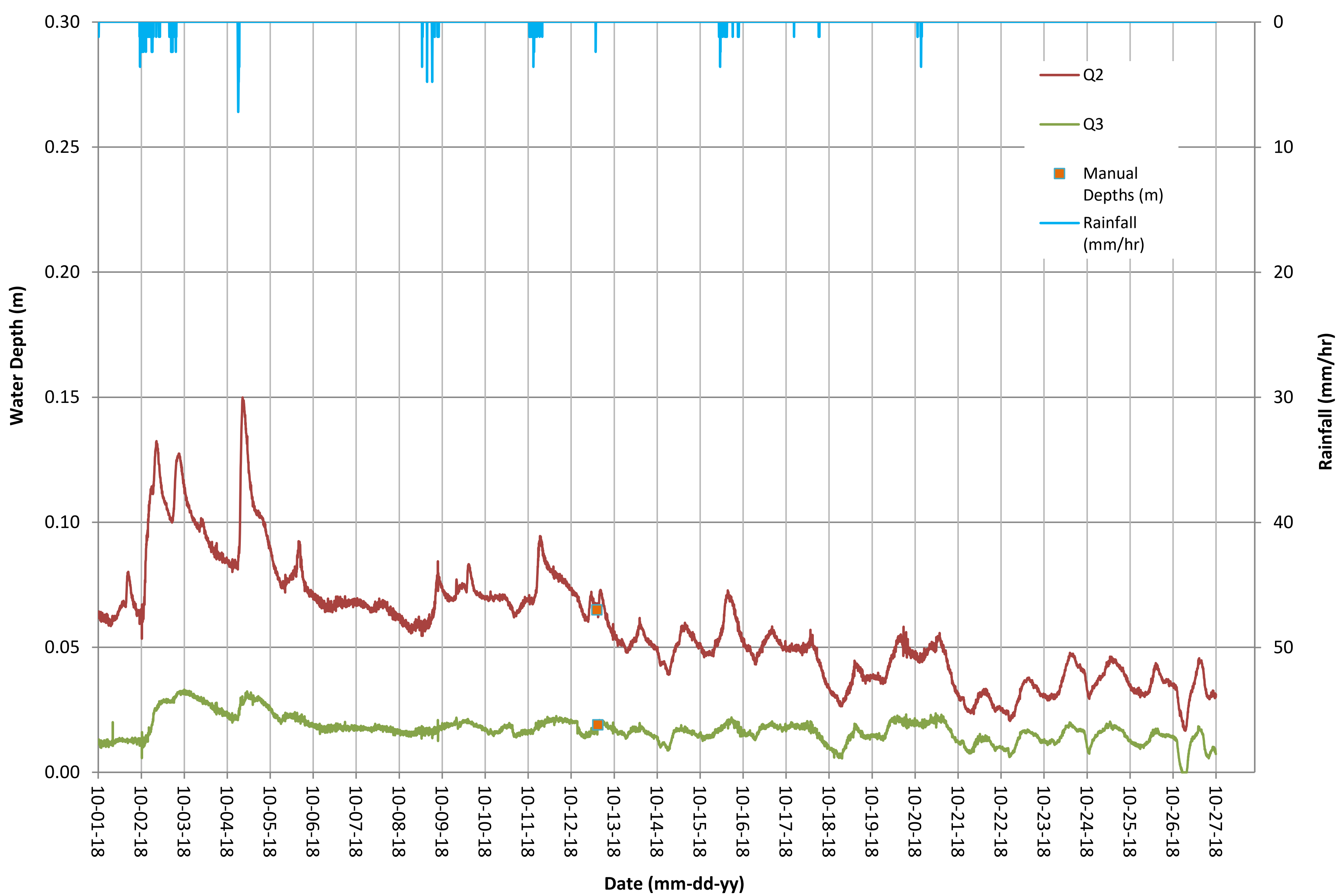
Kanata Golf & Country Club Water Depths & Rainfall Intensities - August 2018



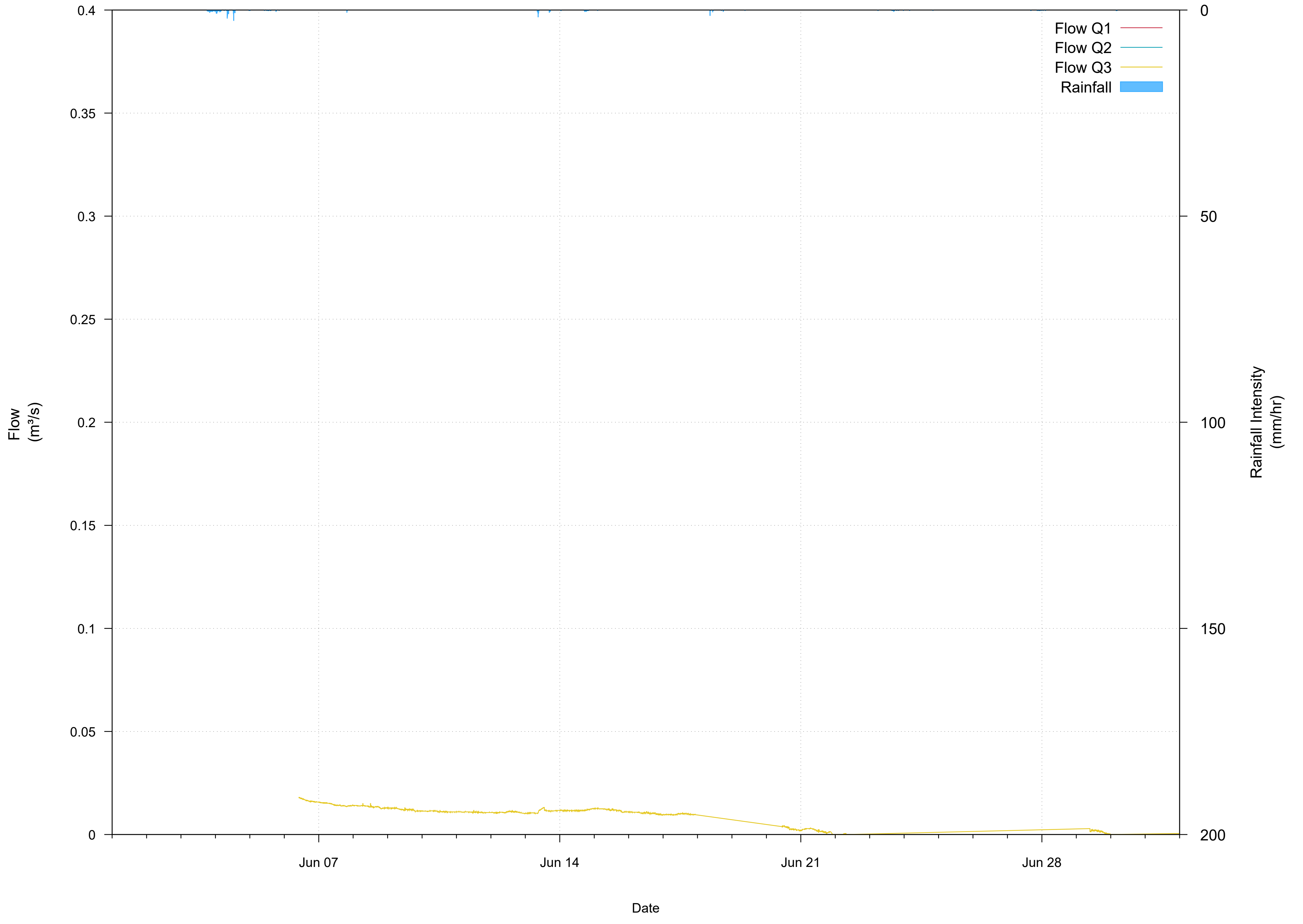


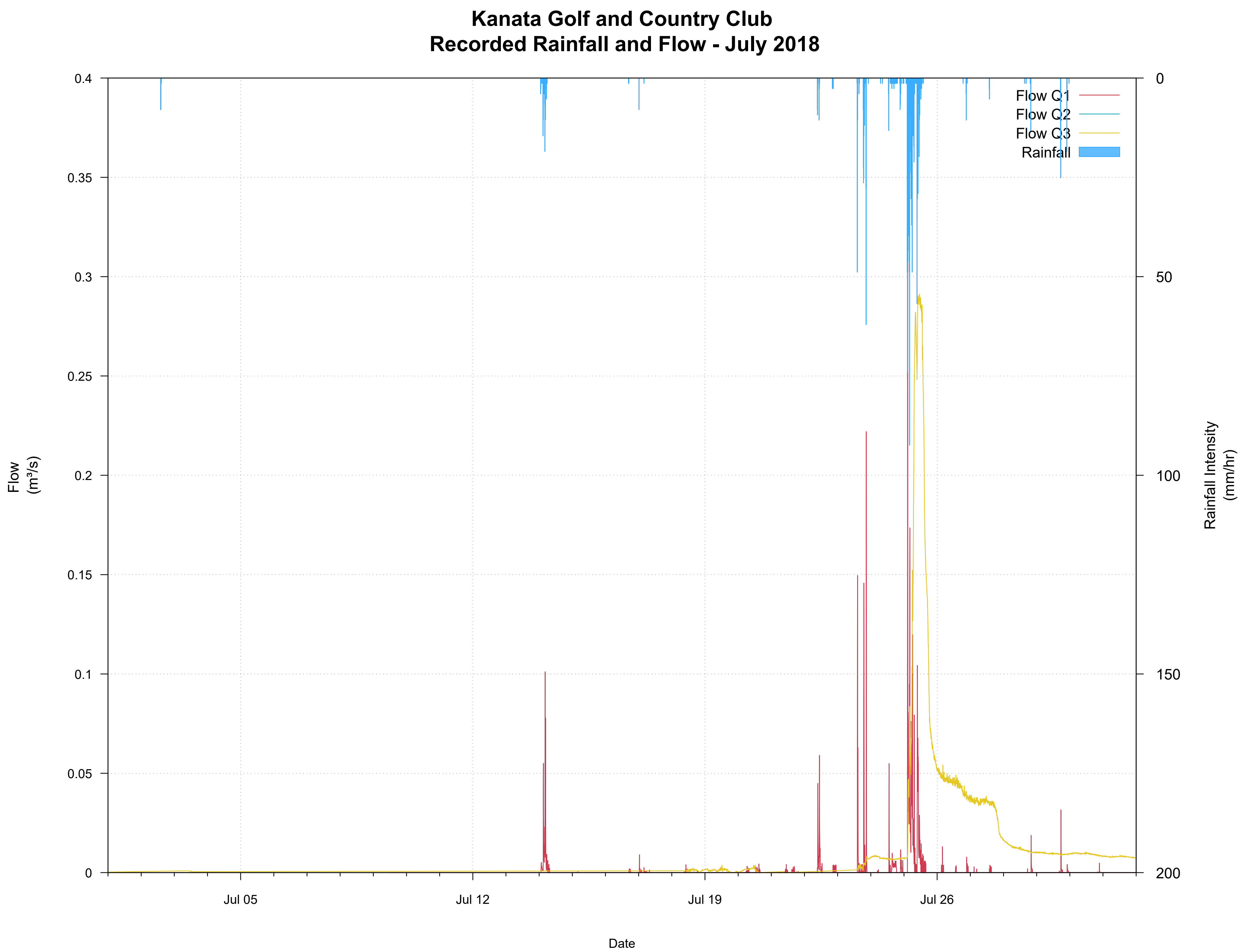
Kanata Golf & Country Club Water Depths & Rainfall Intensities - September 2018
Water Depth (m)
Rainfall (mm/hr)
Date (mm-dd-yy)
Q1
Q2
Q3
Manual Depths (m)
Rainfall (mm/hr)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0
50
100
150
200
250
09-01-18
09-02-18
09-03-18
09-04-18
09-05-18
09-06-18
09-07-18
09-08-18
09-09-18
09-10-18
09-11-18
09-12-18
09-13-18
09-14-18
09-15-18
09-16-18
09-17-18
09-18-18
09-19-18
09-20-18
09-21-18
09-22-18
09-23-18
09-24-18
09-25-18
09-26-18
09-27-18
09-28-18
09-29-18
09-30-18
10-01-18

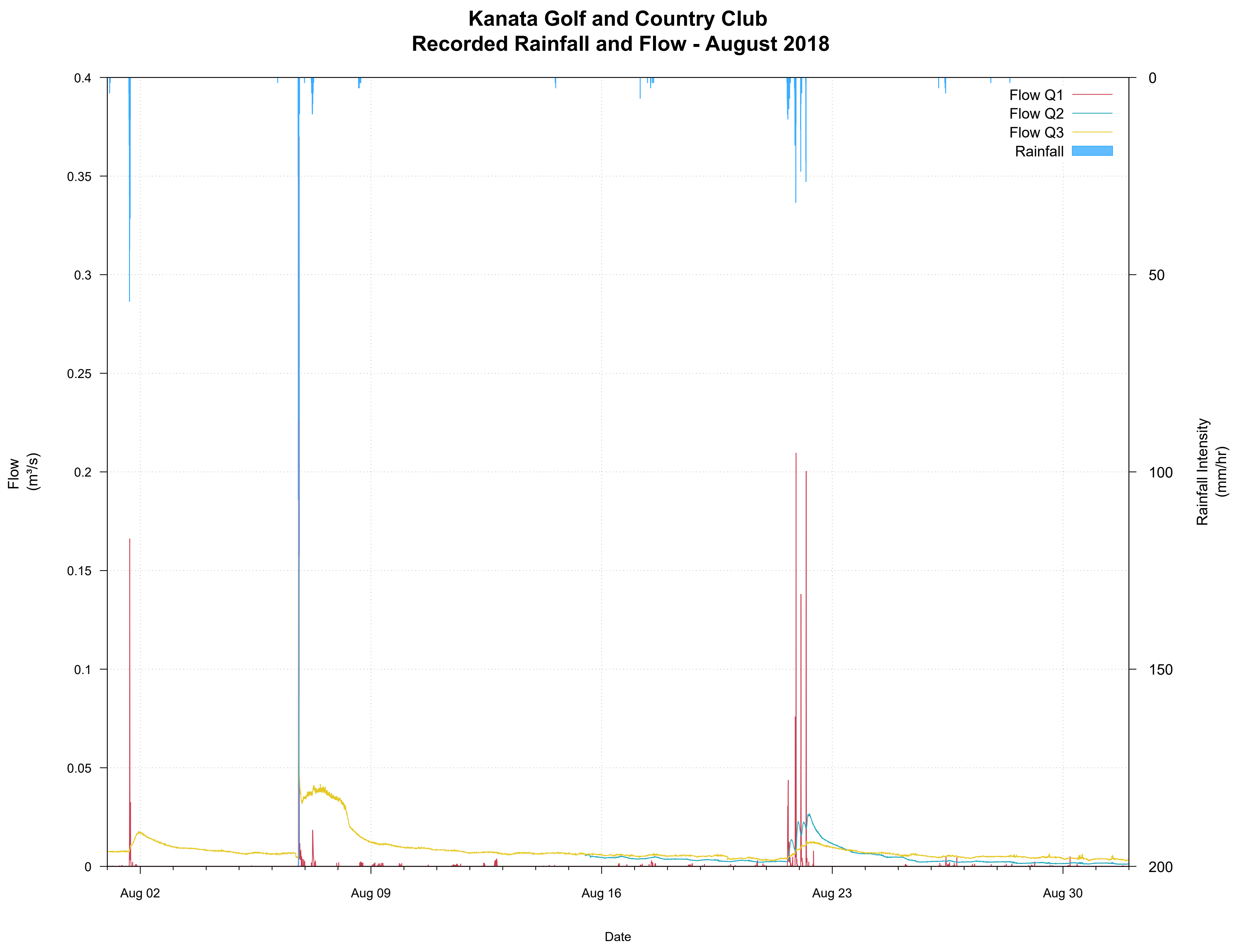
Kanata Golf & Country Club Water Depths & Rainfall Intensities - October

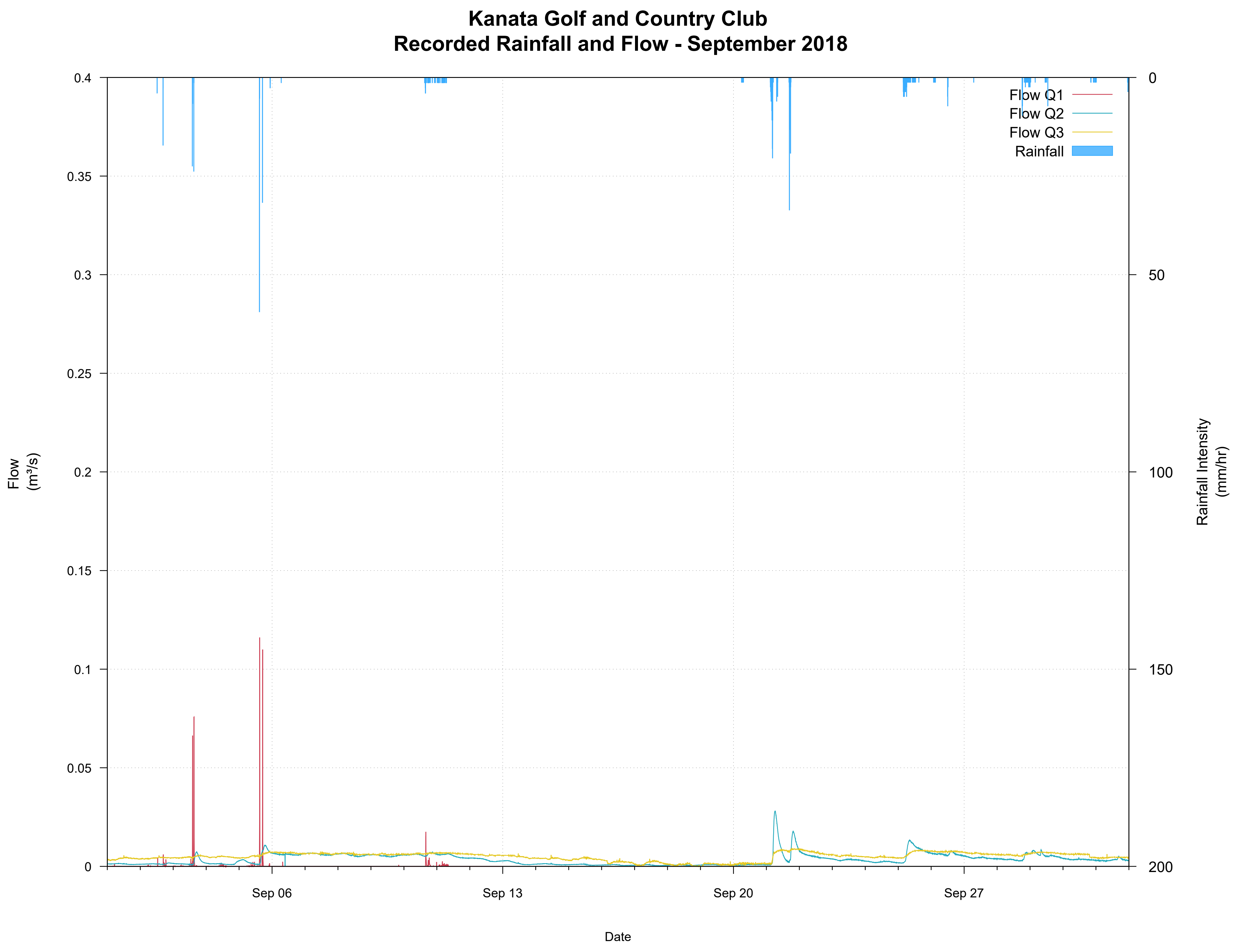


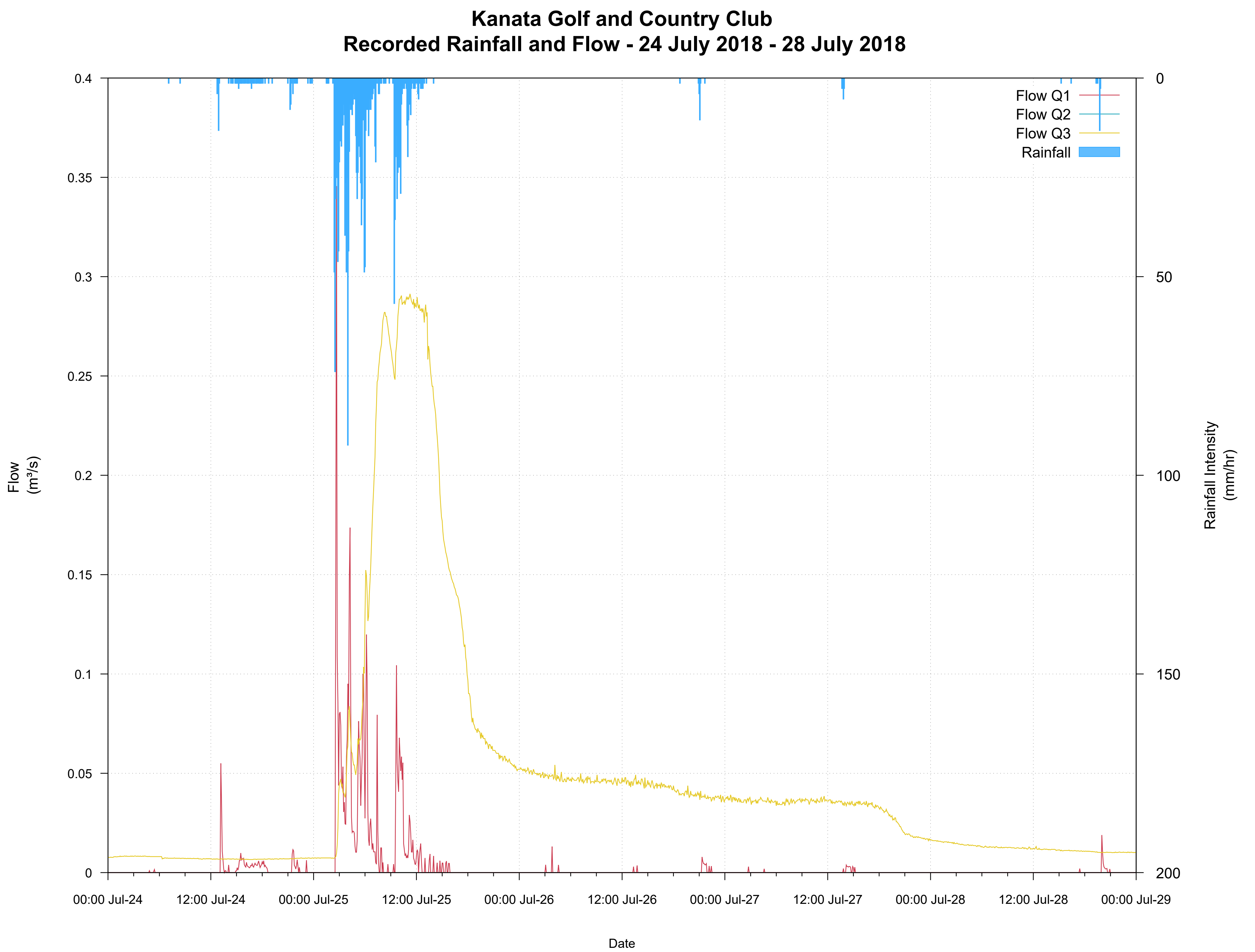
Kanata Golf and Country Club
Recorded Rainfall and Flow - June 2018

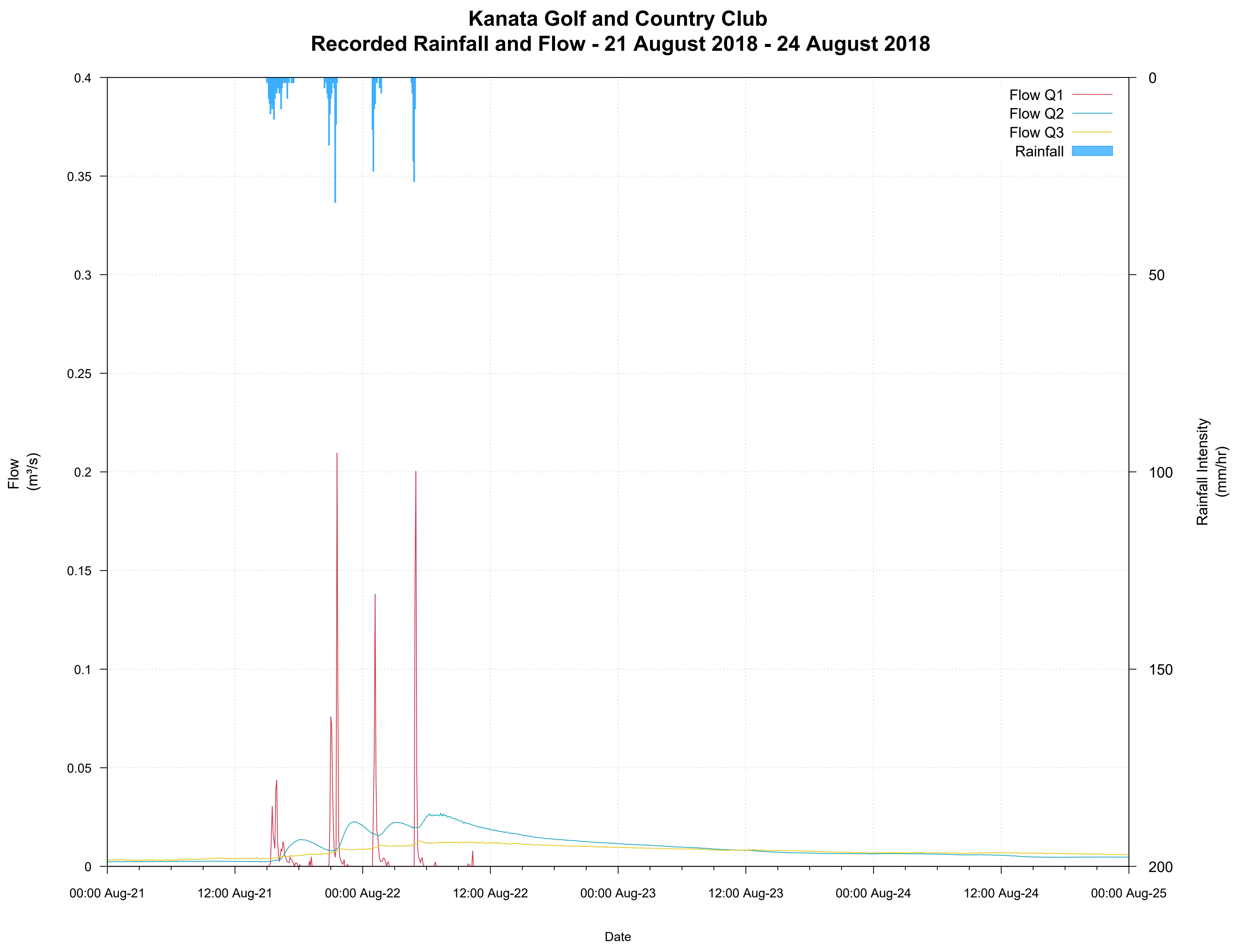



Kanata Golf and Country Club
Recorded Rainfall and Flow - July 2018
Flow (m³/s)
Rainfall Intensity (mm/hr)
Date
Jul 05
Jul 12
Jul 19
Jul 26
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0
50
100
150
200
Flow Q1
Flow Q2
Flow Q3
Rainfall


Kanata Golf and Country Club
Recorded Rainfall and Flow - August 2018
Flow
(m³/s)
Rainfall Intensity
(mm/hr)
Date
Flow Q1
Flow Q2
Flow Q3
Rainfall
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
Aug 02
Aug 09
Aug 16
Aug 23
Aug 30


Kanata Golf and Country Club
Recorded Rainfall and Flow - September 2018
Flow (m³/s)
Rainfall Intensity (mm/hr)
Date
Flow Q1
Flow Q2
Flow Q3
Rainfall
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
50
100
150
200
Sep 06
Sep 13
Sep 20
Sep 27


Kanata Golf and Country Club
Recorded Rainfall and Flow - 24 July 2018 - 28 July 2018
Flow
(m³/s)
Rainfall Intensity
(mm/hr)
Date
Flow Q1
Flow Q2
Flow Q3
Rainfall
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
00:00 Jul-24
12:00 Jul-24
00:00 Jul-25
12:00 Jul-25
00:00 Jul-26
12:00 Jul-26
00:00 Jul-27
12:00 Jul-27
00:00 Jul-28
12:00 Jul-28
00:00 Jul-29



Kanata Golf and Country Club
Recorded Rainfall and Flow - 21 August 2018 - 24 August 2018
Flow Q1
Flow Q2
Flow Q3
Rainfall
Flow
(m³/s)
Rainfall Intensity
(mm/hr)
Date
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0
50
100
150
200
00:00 Aug-21
12:00 Aug-21
00:00 Aug-22
12:00 Aug-22
00:00 Aug-23
12:00 Aug-23
00:00 Aug-24
12:00 Aug-24
00:00 Aug-25

JFSA
WATER RESOURCES AND
ENVIRONMENTAL CONSULTANTS

Ottawa. ON
Paris. ON
Gatineau. QB
Montréal. QB
Québec. QB

Appendix B

Kanata Golf & Country Club – 2018 Surface Infiltration testing

JFSA, February 2019

JFSA WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS
J.F. Sabourin and Associates Inc.
52 Springbrook Drive,
Ottawa, ON K2S 1B9
T 613-836-3884 F 613-836-0332
jfsa.com

Ottawa
Gatineau
Montréal
Québec City

February 6, 2019 Project #: P1581

David Schaeffer Engineering
120 Iber Road, Unit 103
Stittsville, ON, K2S 1E9

Attention: **Mr. Steve Pichette, P.Eng.**

Subject: **Kanata Golf & Country Club – 2018 Surface Infiltration Testing**

Testing equipment, site selection and methodology

In the fall of 2018, surface infiltration testing was conducted by JFSA at four sites on the Kanata Golf & Country Club in order to quantify the pre-development surface infiltration rates. Refer to **Figure 1** for site locations and the Test Locations section of this memorandum for a description of site selection. These surface infiltration measurements and observations may be used to inform the subsequent hydrologic modelling of the site, provide a better understanding of the runoff potential and to assess the feasibility to design and implement Low Impact Development (LID) measures for any future development.

Surface infiltration testing at all four sites was conducted at the ground surface using a Double-Ring Infiltrometer (DRI), manufactured by Turf-Tec and shown in **Figure 2**. The DRI setup consisted of a set of concentric rings inserted into the soil connected to a water supply, wherein water is ponded on the soil and Marriotte bottles (also manufactured by Turf-Tec) were used to replenish infiltrated water and maintain a constant water depth in the rings. The volume of water needed to maintain a constant water level in the inner ring indicates the volume of water infiltrated over time. Water in the outer ring acts as a buffer as it infiltrates into the soil, limiting lateral spread of infiltrating water in the inner ring and encouraging vertical infiltration. Climate conditions prior to and during the test are provided on **Table 1**. Results of the DRI tests are provided on **Table 3**.

In addition to the DRI tests, Single-Ring Infiltrometer (SRI) surface infiltration tests were conducted at each of the four sites. See **Figure 3** for an example of the SRI setup. Marriotte bottles were used to maintain a constant head during SRI tests. At sites 1 and 2, constant head SRI tests were successfully run. At sites 3 and 4, field staff were not able to complete constant head SRI tests as a constant head of water could not be sustained. At all 4 sites, falling-head SRI tests were run in the same vicinity as the DRI tests. SRI and falling head tests were completed to provide alternative methods to measure infiltration rates and for comparison with the DRI results. Refer to the Test Methodology section of this memorandum for a more detailed description of how each of the test types was run.

Figure 2: Double-Ring Infiltrometer Setup (15/30 cm rings, two Marriotte bottles)

Figure 3: Single Ring Infiltrometer Setup (12.7 cm diameter steel ring, single Marriotte bottle)

Test locations

Four sites were identified for surface infiltration testing. Site selection was based on an initial field survey conducted by Geofirma on November 5th, 2018 and based on areas assumed to describe the overall behaviour of infiltration that is generally representative across the site. Site selection was also done within the time and weather constraints present at the time of testing. Refer to **Table 2** for information about each of the four sites, including a general description of the soil at each test pit, a list of the tests undertaken at each site, and the soil temperature.

JFSA field crew conducted surface infiltration tests on November 7th and 8th, 2018. As previously discussed, multiple surface infiltration tests were undertaken at each site.

The four sites where field observations were made, and surface infiltration measurements collected are shown in **Figure 1**. The sites are numbered 1 through 4, and all tests at a given site were conducted within a few meters of each other. Due to aeration activities on the golf course fairways, all tests were conducted in the adjacent roughs, where the grasses were longer and the soils were undisturbed. Refer to **Table 1** for more information about climate conditions leading up to and during the testing period.

Table 1: Climate Data During Testing (Testing Days are Shaded in Grey)*

Day	Temperature (°C)			Rain (mm)	Snow (cm)	Precipitation (mm)	Snow on Ground (cm)
	Max	Min	Mean				
4	7.5	0.5	4.0	0.0	0.0	0.0	0
5	6.0	1.5	3.8	0.6	0.0	0.6	0
6	13.0	2.5	7.8	6.2	0.0	6.2	0
7	11.5	8.0	9.8	0.0	0.0	0.0	0
8	8.0	2.0	5.0	0.0	0.0	0.0	0

* Environment Canada Data, Ottawa CDA.

Table 2: Surface Infiltration Test Locations

Date	Testing Site ID	Soil Temperature (°C)	Location	General Description of Soil Observed in Test Pit Adjacent to Test Location
2018-11-07	1	8.3	Golf hole #1, 30 metres southwest of putting green. Testing took place in rough between cart path and fairway.	**0-5 cm:** Grass, roots, clayey soil. **5-15 cm:** Darker colour sand/clay mix. **15-30 cm:** Lighter colour sand /clay mix. Total depth of test pit: **30 cm**
2018-11-08	2	5.6	Golf hole #11, 25 metres southeast of putting green. Testing took place in rough on east side of fairway, between bunker and green.	**0-8 cm:** Grass, roots, high organic content, dark clayey sand. **8-30 cm:** Dark clayey sand. **30-35cm:** Light sandy soil, low clay content. Total depth of test pit: **35 cm**
2018-11-08	3	6.1	Golf hole #5, 55 metres southeast of putting green. Testing took place in rough on northeast side of fairway.	**0-8 cm:** Grass, roots, dark clayey sand. **8-15 cm:** Darker clayey sand. **15-30 cm:** Lighter colour, higher sand content, low clay content. Total depth of test pit: **30 cm**
2018-11-08	4	6.7	Golf hole #6, 150 metres northwest of putting green. Testing took place in rough on northeast side of fairway.	**0-4 cm:** Grass, roots, medium clay content. **4-15 cm:** Darker clayey sand. **15-30 cm:** Grey, tight clays. Total depth of test pit: **30 cm**

Test Methodology

Upon arrival at each site, a test pit was dug using a small spade in order to quantify the character of the soil column. Information about the different soil layers found at each site can be found in **Table 2**. All tests were completed within a few meters of the soil test pit, in order to ensure that the character of the soil underlying each test was known. Measurements of layer depths were completed using handheld tape measures. In preparation for each set of tests, soil temperature was measured using a small field thermometer at a depth of approximately 30 mm.

At each of the four test sites surface infiltration testing was conducted at the ground surface using 2-3 different methods. Metal rings were used for the various surface infiltration tests, and all rings were driven into the soil using a sledge hammer and a block of wood. Primarily, a DRI test was completed at each site. The DRI consists of two concentric galvanized steel rings including a 15.24 cm inner ring and a larger 30 cm diameter outer ring. At all four sites, the DRI was inserted into the ground to a depth of 5 cm. 10 liter Mariotte bottles were connected to each of the two rings by clear polypropylene tubes. Each ring was partially filled with water and then valves on the Mariotte bottles were opened to maintain the water in the rings at a constant level. The volume of water added to the inner ring to maintain the constant water level (constant head) was measured and recorded. In this way, the volume of water that infiltrated the soil could be recorded, and the dimensions of the instrument were used to compute surface infiltration rates. The volume infiltrated is converted to an incremental infiltration velocity which is equivalent to the surface infiltration rate. Refer to **Attachment 1** for details of the DRI tests.

It is noted that the DRI tests conducted by JFSA generally followed the ASTM-D3385-09 standard test method. However, the ASTM-D3385 guideline suggests larger metal rings be used for this type of test with inner and outer ring diameters of approximately 30 cm and 60 cm, respectively. It is JFSA's understanding that the use of smaller ring sizes for DRI tests could produce infiltration rates that are different, when compared to the same test using larger ring sizes. However, it is also understood that due to the variability of infiltration rates over a broad area, it is preferable to complete measurements in as many locations as possible. Making use of the suggested ring sizes per ASTM-D3385, the number of possible surface field measurements would be significantly limited due to the cumbersome size and excessive water requirements of such instruments particularly given the challenging site and weather conditions encountered. JFSA thereby decided to make use of the DRI with smaller ring sizes for field testing at each of the four sites.

Constant-head SRI tests were conducted in much the same way as the DRI tests, but only one ring and Marriotte bottle was used. At testing sites 1 and 2, constant-head SRI tests were successfully completed using a 12.7 cm diameter metal ring. At both of these sites, the single rings were inserted to a depth of 5 cm below ground surface.

Further to the two types of constant-head tests, falling-head single ring tests were completed at all four sites. Falling head tests were conducted using single metal rings, inserted to a depth of 5 cm. Water was ponded on the surface inside the ring, and the changes in depth were recorded at a chosen time interval throughout the duration of the test. Changes in the water level in the ring allow for a calculation of the volume of water infiltrated over a given amount of time. Water levels in the metal rings during falling-head tests were measured using handheld tape measures.

Test Results

Results of the DRI tests can be found in **Table 3**.

Table 3: Surface Infiltration Test Results

Date	Site ID	Test Type*	Ring Insertion Depth (cm)	Final Infiltration Rate (mm/hr)	Field Saturated Hydraulic Conductivity K_{fs} (cm/sec)
2018-11-07	1	Double-Ring Infiltrometer	5	27.4	1.6×10^{-4}
2018-11-08	2	Double-Ring Infiltrometer	5	36.1	2.3×10^{-4}
2018-11-08	3	Double-Ring Infiltrometer	5	121.5	7.6×10^{-4}
2018-11-08	4	Double-Ring Infiltrometer	5	3.0	1.8×10^{-5}

* It is noted that SRI and falling head tests were also completed. These results are not shown as the DRI tests provided on **Table 3** follow a more standardized and robust testing procedure than either the SRI or falling head tests performed. Refer to the Conclusions section of this report for additional information

Conclusions

Based on the soil types observed during the initial field survey of the property on November 5th, 2018 and the soils extracted at each of the four sites during testing on November 7th and 8th, the calculated field saturated hydraulic conductivities shown in **Table 3** are generally consistent with the soil types observed. For silty clay soils, the typical range is between 10^{-3} and 10^{-5} cm/s. Therefore, the DRI test results at surface are in the correct order of magnitude when compared to typical values. It is noted that the field saturated hydraulic conductivities for all SRI and falling head tests performed at the four test sites also fall within the same range of 10^{-3} and 10^{-5} cm/s. Only the results for the DRI tests are presented on **Table 3,** however**,** as those tests follow a more standardized and robust testing procedure than either the SRI or falling head tests performed. It is recommended that these results be considered for inclusion in future hydrologic modelling of pre-development conditions for this site.

Given the range of surface infiltration rates collected in the field as shown in **Table 3**, stormwater runoff appears to have the opportunity to infiltrate at surface under pre-development conditions. For post-development conditions, it may thereby be possible to implement LID measures that include an infiltration function, subject to the depth of the feature, the associated infiltration potential of underlying soils and appropriate site selection within the property.

This report was prepared, reviewed and approved by the undersigned:

Written by:	Reviewed by:	Approved by:
Paul Wilson, M.Sc.	Bryan Willcott, P.Eng.	J.F.Sabourin, M.Eng., P.Eng.
Hydrologist	Project Engineer	President

Figures:

Figure 1 - Monitoring Locations

Attachments:

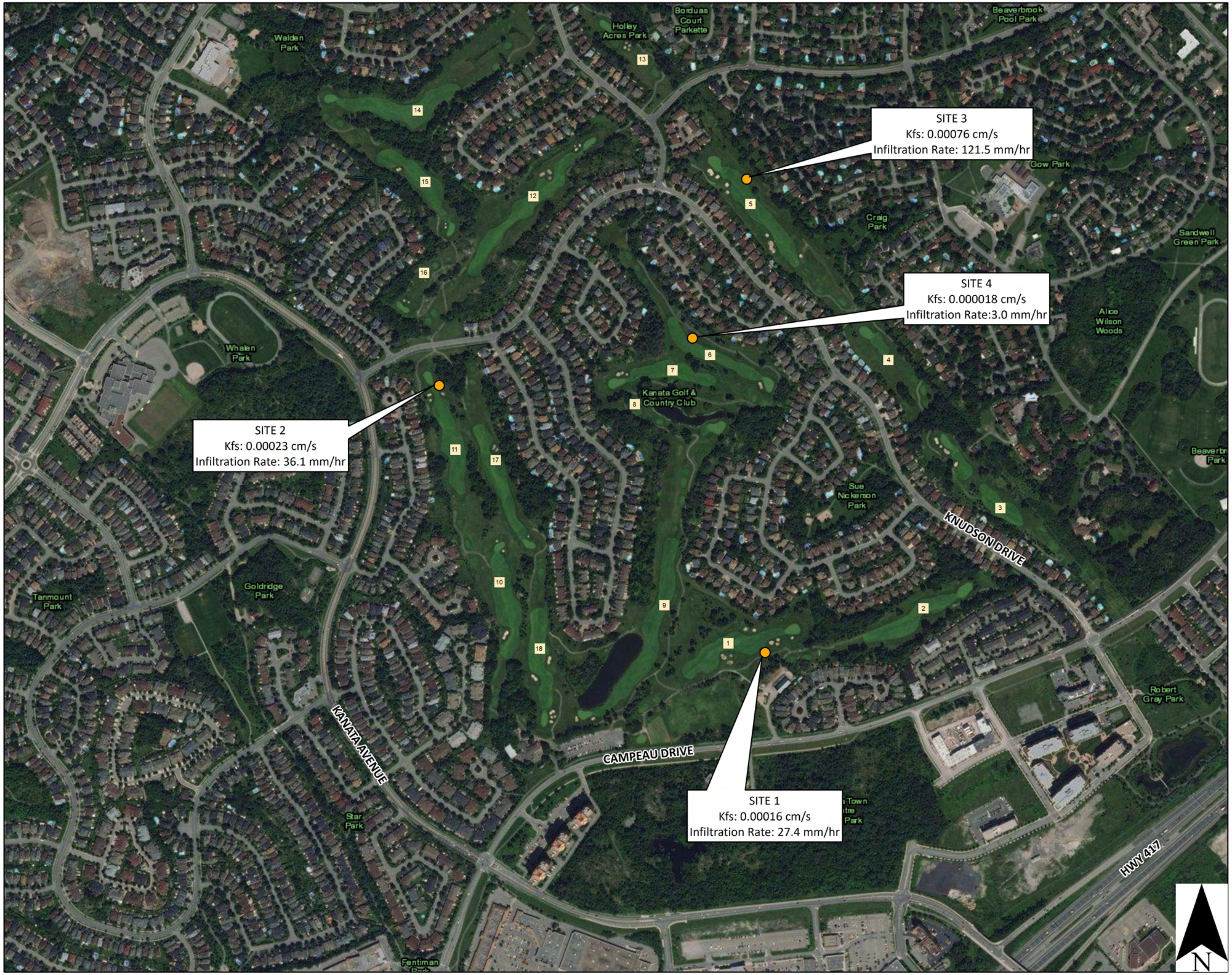
Attachment A – Infiltration testing data sheets – Double Ring Infiltrometer

References:

ASTM Standard D3385-09, 2009, "Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer," ASTM International, West Conshohocken, PA, 2009, DOI: 10.1520/D3385-09.

Reynolds WD and Elrick DE, 1986. "Ponded Infiltration from a Single Ring: I. Analysis of Steady Flow." Soil Sci. Soc. Am. J. 54: 1233-1241.

Braja M. Das, 2002. "Principles of Geotechnical Engineering" Fifth Edition.



Legend

- Surface Infiltration Testing Sites
- Kanata Golf Course Fairways

NOTES:

Basemap Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Field Saturated Hydraulic Conductivity (Kfs) given in cm/second.

Infiltration Rate given in mm/hour.

Reynolds & Elrick (1990) ring infiltrometer correction, Strong capillarity assumed.

Coordinate System: NAD 1983 MTM Zone 9

J.F. Sabourin and Associates Inc.
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS
52 Springbook Drive
Ottawa, ON, K2S 1B9
(613) 836-3884
www.jfsa.com

CLIENT:

DSEL
david schaeffer engineering ltd

SCALE:

0 100 200 300 400 m

LOCATION:

KANATA GOLF & COUNTRY CLUB

TITLE:

SURFACE INFILTRATION TESTING LOCATIONS

FIGURE 1

PROJECT No.	1581-17
DRAWN:	PW
DATE:	06/02/2019

Ottawa
Gatineau
Montréal
Québec City

Attachment A

Infiltration Testing Data Sheets – Double Ring Infiltrometer

February 2019

Turf-Tec International - Record Chart for IN8-W (6 & 12 Inch Infiltration Rings)

Project Identification:	1581 - Kanata Golf & Country Club		**Constants**	**Area cm2**	**Depth of Liquid (cm)**	**Liquid Container Number**	**Marriotte Tube Volume**
Test Location:	Site 1 (Hole #1)		**Inner Ring**	182	9.0	1	10000 ml
Liquid Used:	Tap Water	**pH: 7.62**	**Annular Space**	547	6.5	2	10000 ml
Tested By:	JFSA		**Liquid level maintained using:**	( ) Flow Valve ( ) Float Valve (X) Mariotte Tubes			
Depth to water table:	N/A		**Penetration Depth of Outer Ring:** 5 cm				

Trial #	Start / End	Date	Time HR:MIN	Elapsed Time Chg/(Total) Min	Flow Readings: Inner Ring Reading cm	Flow Readings: Maroitte Tube Flow (ml)	Flow Readings: Annular Space Reading cm	Flow Readings: Annular Space Marriotte Tube Flow (ml)	Liquid Temp C	Inner Infiltration Rate: Inner Infiltration Rate mm/h	Inner Infiltration Rate: Annular Infiltration Rate mm/h	Ground Temperature: Ground Temp Depth (mm)	Ground Temperature: Temp at Depth (c)	Remarks: Weather conditions Etc...
1	Start Test	11/07	0:00	0:00	9.7	125	6.5	311.5	10.0	51.4	42.7	30	8.3	Overcast, windy. Intermittent rainfall.
	End Test	11/07	0:08	**0:08**	9.0		6.5		10.0					
2	Start Test	11/07	0:08	0:00	9.0	67.5	6.5	567.5	10.0	13.9	38.9			
	End Test	11/07	0:24	**0:16**	9.0		6.5		10.0					
3	Start Test	11/07	0:24	0:00	9.0	125	6.5	317.5	10.0	45.7	38.7			
	End Test	11/07	0:33	**0:09**	9.0		6.5		10.0					
4	Start Test	11/07	0:33	0:00	9.0	125	6.5	359.25	10.0	29.4	28.1			
	End Test	11/07	0:47	**0:14**	9.0		6.5		10.0					
5	Start Test	11/07	0:47	0:00	9.0	125	6.5	325	10.0	37.4	32.4			
	End Test	11/07	0:58	**0:11**	9.0		6.5		10.0					
6	Start Test	11/07	0:58	0:00	9.0	125	6.5	250	10.0	37.4	24.9			
	End Test	11/07	1:09	**0:11**	9.0		6.5		10.0					
7	Start Test	11/07	1:09	0:00	9.0	125	6.5	325	10.0	37.4	32.4			
	End Test	11/07	1:20	**0:11**	9.0		6.5		10.0					
8	Start Test	11/07	1:20	0:00	9.0	125	6.5	325	10.0	37.4	32.4			
	End Test	11/07	1:31	**0:11**	9.0		6.5		10.0					
9	Start Test	11/07	1:31	0:00	9.0	125	6.5	325	10.0	37.4	32.4			
	End Test	11/07	1:42	**0:11**	9.0		6.5		10.0					
10	Start Test	11/07	1:42	0:00	9.0	125	6.5	317.5	10.0	34.3	29.0			
	End Test	11/07	1:54	**0:12**	9.0		6.5		10.0					
11	Start Test	11/07	1:54	0:00	9.0	125	6.5	325	10.0	31.6	27.4			
	End Test	11/07	2:07	**0:13**	9.0		6.5		10.0					
12	Start Test	11/07	2:07	0:00	9.0	125	6.5	325	10.0	27.4	23.8			
	End Test	11/07	2:22	**0:15**	9.0		6.5		10.0					
13	Start Test	11/07	2:22	0:00	9.0	125	6.5	325	10.0	27.4	23.8			
	End Test	11/07	2:37	**0:15**	9.0		6.5		10.0					

Turf-Tec International - Record Chart for IN8-W (6 & 12 Inch Infiltration Rings)

Project Identification:	1581 - Kanata Golf & Country Club	Constants	Area cm2	Depth of Liquid (cm)	Liquid Container Number	Marriotte Tube Volume
Test Location:	Site 2 (Hole #11)	Inner Ring	182	6.1	1	10000 ml
Liquid Used:	Tap Water pH: 7.71	Annular Space	547	6.0	2	10000 ml
Tested By:	JFSA	Liquid level maintained using:	( ) Flow Valve ( ) Float Valve (X) Mariotte Tubes			
Depth to water table:	N/A	Penetration Depth of Outer Ring: 5 cm				

Trial #	Start / End	Date	Time HR:MIN	Elapsed Time Chg/(Total) Min	Flow Readings: Inner Ring Reading cm	Maroitte Tube Flow (ml)	Annular Space Reading cm	Annular Space Marriotte Tube Flow (ml)	Liquid Temp C	Inner Infiltration Rate: Inner Infiltration Rate mm/h	Annular Infiltration Rate mm/h	Ground Temperature: Ground Temp Depth (mm)	Temp at Depth (c)	Remarks: Weather conditions Etc...
1	Start Test	11/08	0:00	0:00	6.1	125	6.0	1125	16.2	33.0	99.1	30	5.6	Sunny, Windy.
	End Test	11/08	0:12	0:12	6.1		6.0		16.2					
2	Start Test	11/08	0:12	0:00	6.1	125	6.0	1125	16.2	35.4	106.3			
	End Test	11/08	0:24	0:12	6.1		6.0		16.2					
3	Start Test	11/08	0:24	0:00	6.1	125	6.0	625	16.2	45.9	76.6			
	End Test	11/08	0:33	0:11	6.1		6.0		16.2					
4	Start Test	11/08	0:33	0:00	6.1	125	6.0	875	16.2	35.8	83.4			
	End Test	11/08	0:44	0:11	6.1		6.0		16.2					
5	Start Test	11/08	0:44	0:00	6.1	125	6.0	1125	16.2	33.6	100.7			
	End Test	11/08	0:56	0:12	6.1		6.0		16.2					
6	Start Test	11/08	0:56	0:00	6.1	125	6.0	1125	16.2	34.3	102.8			
	End Test	11/08	1:09	0:13	6.1		6.0		16.2					
7	Start Test	11/08	1:09	0:00	6.1	125	6.0	875	16.2	38.2	89.2			
	End Test	11/08	1:19	0:10	6.1		6.0		16.2					

Turf-Tec International - Record Chart for IN8-W (6 & 12 Inch Infiltration Rings)

Project Identification:	1581 - Kanata Golf & Country Club	Constants	Area cm2	Depth of Liquid (cm)	Liquid Container Number	Marriotte Tube Volume
Test Location:	Site 3 (Hole #5)	Inner Ring	182	7.0	1	10000 ml
Liquid Used:	Tap Water pH: 7.19	Annular Space	547	7.2	2	10000 ml
Tested By:	JFSA	Liquid level maintained using:	( ) Flow Valve ( ) Float Valve (X) Mariotte Tubes			
Depth to water table:	N/A	Penetration Depth of Outer Ring: 5 cm				

					Flow Readings					Inner Infiltration Rate		Ground Temperature		Remarks
Trial #	Start / End	Date	Time HR:MIN	Elapsed Time Chg/(Total) Min	Inner Ring Reading cm	Maroitte Tube Flow (ml)	Annular Space Reading cm	Annular Space Marriotte Tube Flow (ml)	Liquid Temp C	Inner Infiltration Rate mm/h	Annular Infiltration Rate mm/h	Ground Temp Depth (mm)	Temp at Depth (c)	Weather conditions Etc...
1	Start Test	11/08	0:00	0:00	7.0	125	7.0	625	12.7	146.0	243.3	30	6.1	Overcast, windy.
	End Test	11/08	0:03	0:03	7.0		7.2		12.7					
2	Start Test	11/08	0:03	0:00	7.0	125	7.2	625	12.7	153.2	255.4			
	End Test	11/08	0:05	0:02	7.0		7.2		12.7					
3	Start Test	11/08	0:05	0:00	7.0	125	7.2	657.25	12.7	112.1	196.5			
	End Test	11/08	0:09	0:04	7.0		7.2		12.7					
4	Start Test	11/08	0:09	0:00	7.0	125	7.2	657.25	12.7	114.7	201.1			
	End Test	11/08	0:13	0:04	7.0		7.2		12.7					
5	Start Test	11/08	0:13	0:00	7.0	125	7.2	625	12.7	120.9	201.5			
	End Test	11/08	0:16	0:03	7.0		7.2		12.7					
6	Start Test	11/08	0:16	0:00	7.0	125	7.2	625	12.7	114.2	190.3			
	End Test	11/08	0:20	0:04	7.0		7.2		12.7					
7	Start Test	11/08	0:20	0:00	7.0	125	7.2	625	12.7	98.7	164.5			
	End Test	11/08	0:24	0:04	7.0		7.2		12.7					
8	Start Test	11/08	0:24	0:00	7.0	125	7.2	625	12.7	147.7	246.2			1.75 L used to refill outer ring
	End Test	11/08	0:27	0:03	7.0		7.2		12.7					
9	Start Test	11/08	0:27	0:00	7.0	125	6.8	750	12.7	97.5	195.0			
	End Test	11/08	0:31	0:04	7.0		6.8		12.7					
10	Start Test	11/08	0:31	0:00	7.0	125	6.8	625	12.7	133.3	222.2			
	End Test	11/08	0:34	0:03	7.0		6.8		12.7					
11	Start Test	11/08	0:34	0:00	7.0	125	6.8	750	12.7	107.3	214.5			
	End Test	11/08	0:38	0:04	7.0		6.8		12.7					
12	Start Test	11/08	0:38	0:00	7.0	125	6.8	500	12.7	93.1	124.1			
	End Test	11/08	0:42	0:04	7.0		6.8		12.7					
13	Start Test	11/08	0:42	0:00	7.0	125	6.8	500	12.7	98.7	131.6			
	End Test	11/08	0:46	0:04	7.0		6.8		12.7					
14	Start Test	11/08	0:46	0:00	7.0	125	6.8	500	12.7	98.7	131.6			
	End Test	11/08	0:50	0:04	7.0		6.8		12.7					
15	Start Test	11/08	0:50	0:00	7.0	125	6.8	500	12.7	109.6	146.2			
	End Test	11/08	0:54	0:04	7.0		6.8		12.7					
16	Start Test	11/08	0:54	0:00	7.0	125	6.8	625	12.7	108.2	180.3			
	End Test	11/08	0:58	0:04	7.0		6.8		12.7					
17	Start Test	11/08	0:58	0:00	7.0	125	6.8	625	12.7	105.0	175.0			
	End Test	11/08	1:02	0:04	7.0		5.5		12.7					
18	Start Test	11/08	1:02	0:00	7.0	125	5.5	empty	12.7	103.7				
	End Test	11/08	1:06	0:04	7.0		4.8		12.7					
19	Start Test	11/08	1:06	0:00	7.0	125	4.8	empty	12.7	120.3				
	End Test	11/08	1:09	0:03	7.0		3.8		12.7					
20	Start Test	11/08	1:09	0:00	7.0	125	3.8	empty	12.7	122.7				
	End Test	11/08	1:13	0:04	7.0		3.0		12.7					

Turf-Tec International - Record Chart for IN8-W (6 & 12 Inch Infiltration Rings)

Project Identification:	1581 - Kanata Golf & Country Club	Constants	Area cm2	Depth of Liquid (cm)	Liquid Container Number	Marriotte Tube Volume
Test Location:	Site 4 (Hole #6)	Inner Ring	182	7.0	1	10000 ml
Liquid Used:	Tap Water pH: 7.30	Annular Space	547	7.2	2	10000 ml
Tested By:	JFSA	Liquid level maintained using:	( ) Flow Valve ( ) Float Valve (X) Mariotte Tubes			
Depth to water table:	N/A	Penetration Depth of Outer Ring: 5 cm				

Trial #	Start / End	Date	Time HR:MIN	Elapsed Time Chg/(Total) Min	Flow Readings: Inner Ring Reading cm	Maroitte Tube Flow (ml)	Annular Space Reading cm	Annular Space Marriotte Tube Flow (ml)	Liquid Temp C	Inner Infiltration Rate: Inner Infiltration Rate mm/h	Annular Infiltration Rate mm/h	Ground Temperature: Ground Temp Depth (mm)	Temp at Depth (c)	Remarks: Weather conditions Etc...
1	Start Test	11/08	0:00	0:00	9.0	68	6.5	311.5	7.4	3.0	4.6	30	6.7	Overcast, Windy
	End Test	11/08	1:15	1:15	9.0		6.5		7.4					

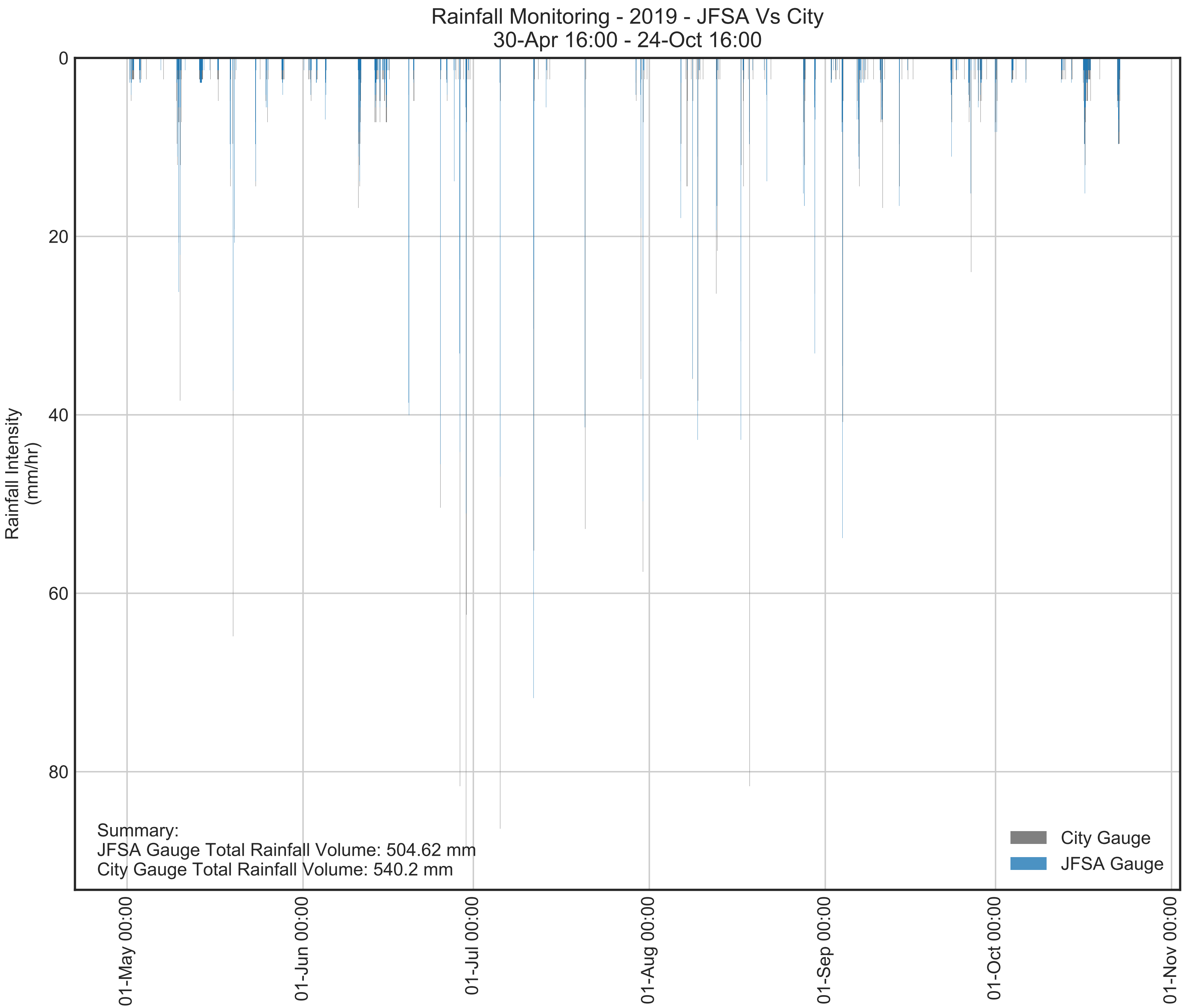
JFSA
WATER RESOURCES AND
ENVIRONMENTAL CONSULTANTS

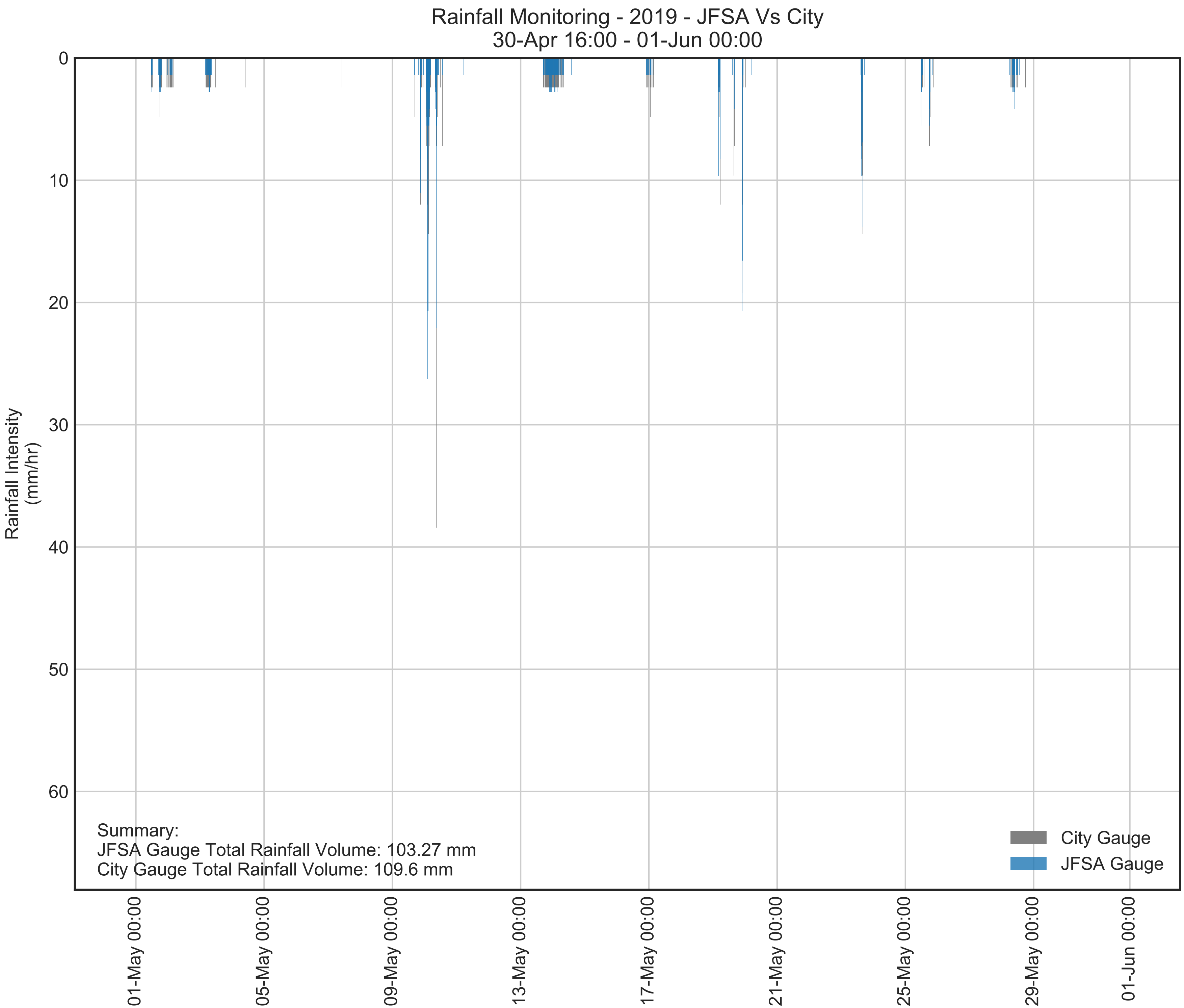
Project Ref #:P1581
Client: David Schaeffer Engineering

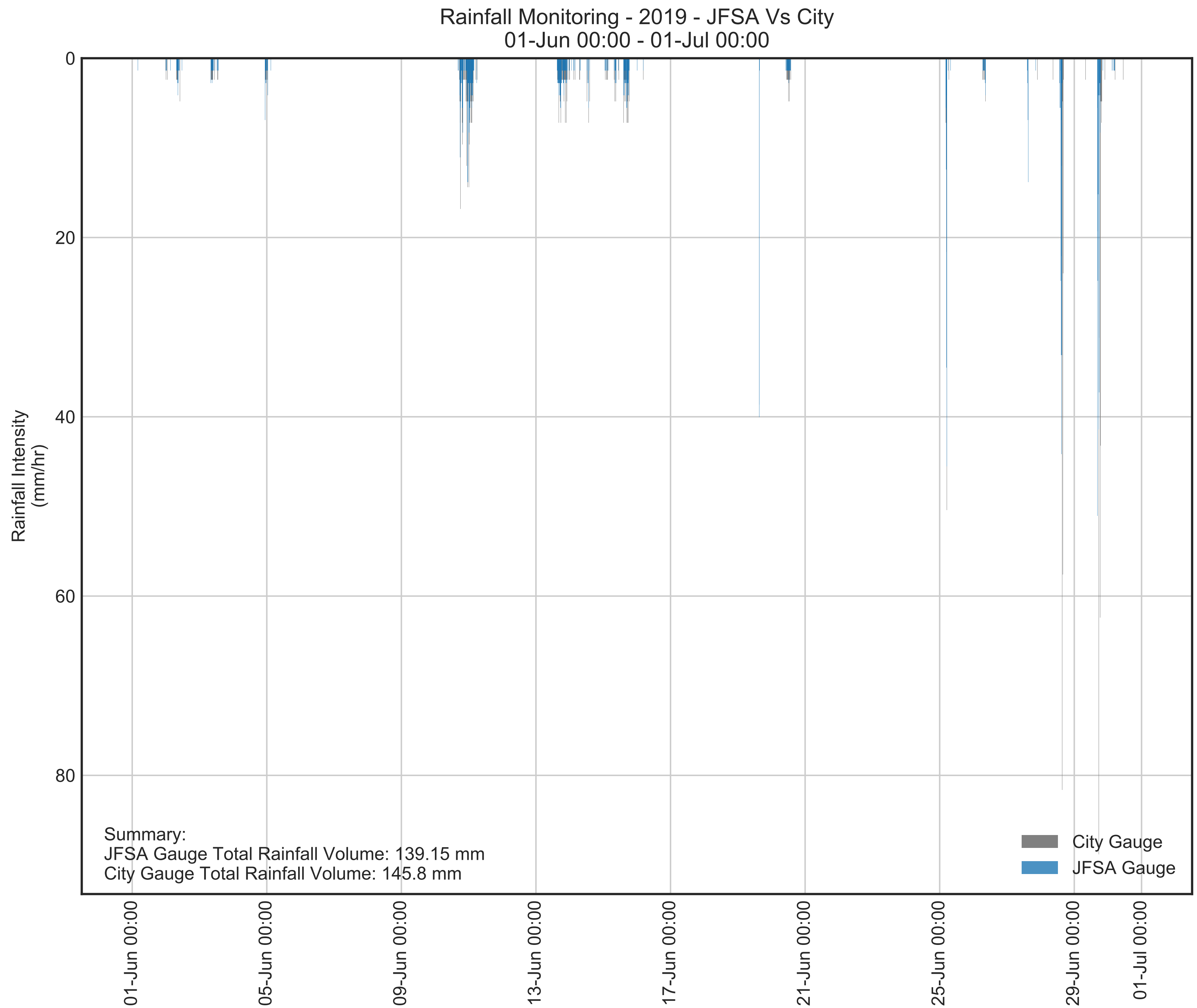
Ottawa. ON
Paris. ON
Gatineau. QB
Montréal. QB
Québec. QB

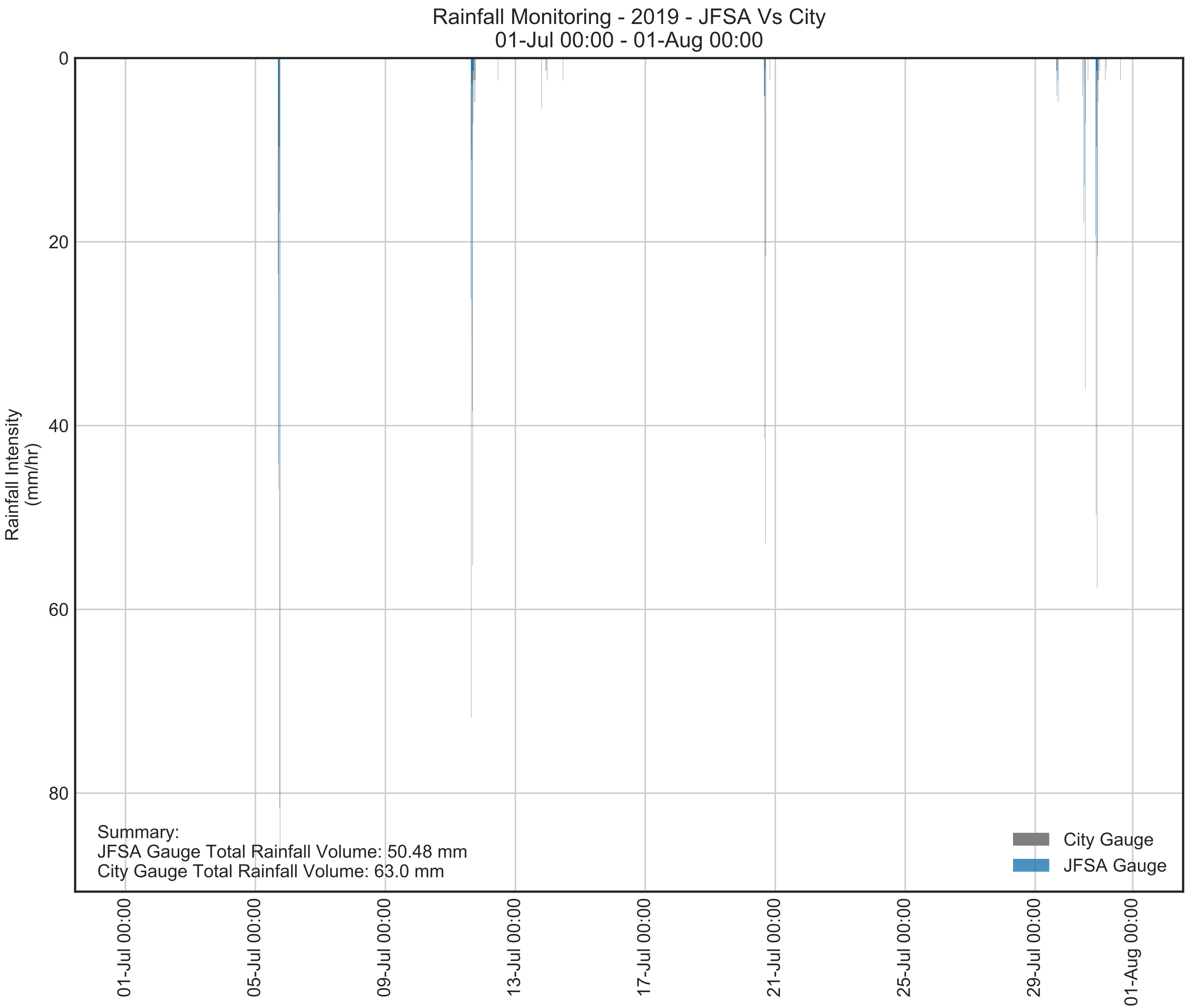
Appendix C

2019 Rainfall Hyetographs & IDF Curves

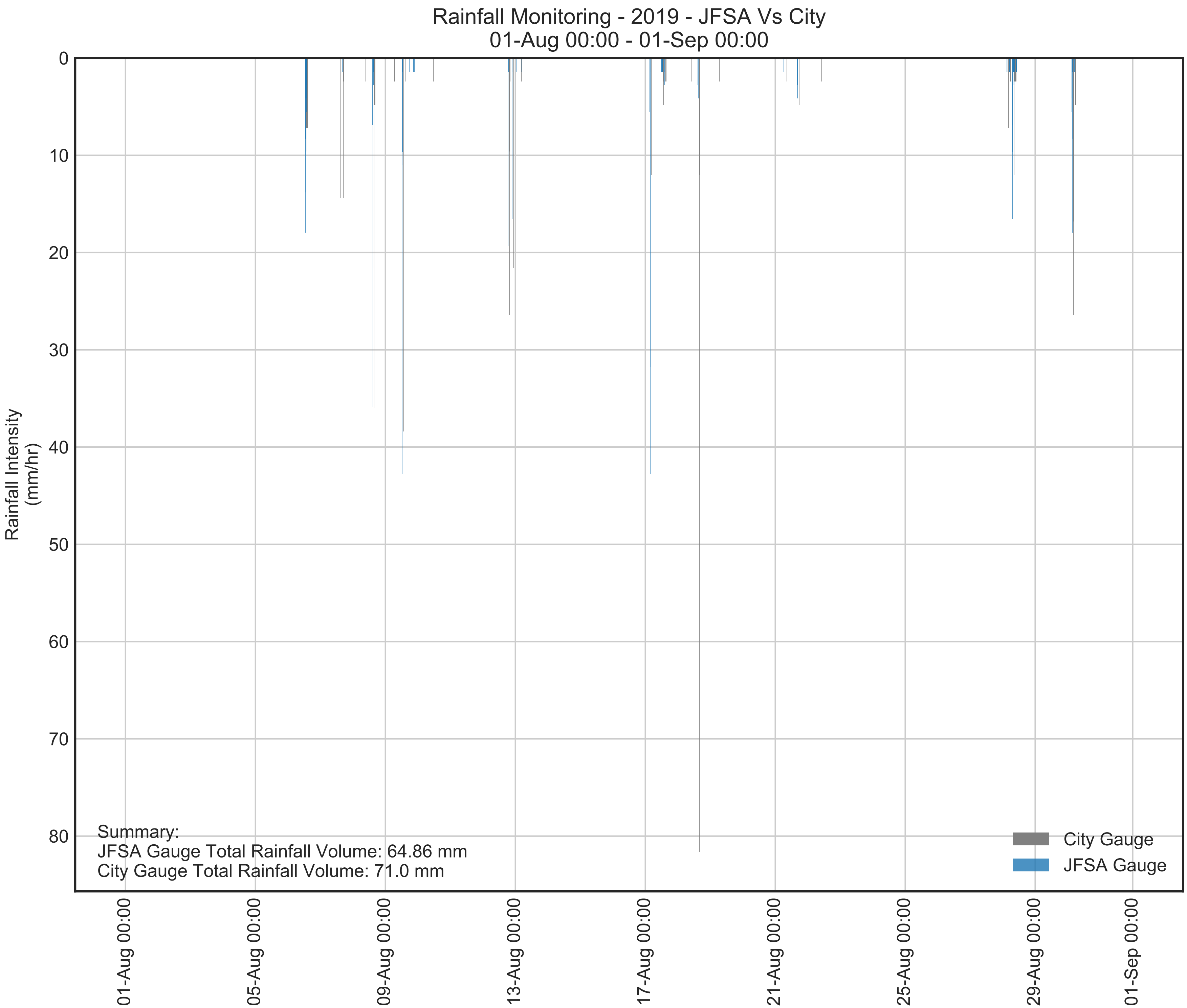

Rainfall Monitoring - 2019 - JFSA Vs City
30-Apr 16:00 - 24-Oct 16:00
Rainfall Intensity
(mm/hr)
0
20
40
60
80
01-May 00:00
01-Jun 00:00
01-Jul 00:00
01-Aug 00:00
01-Sep 00:00
01-Oct 00:00
01-Nov 00:00
City Gauge
JFSA Gauge
Summary:
JFSA Gauge Total Rainfall Volume: 504.62 mm
City Gauge Total Rainfall Volume: 540.2 mm


Rainfall Monitoring - 2019 - JFSA Vs City
30-Apr 16:00 - 01-Jun 00:00
Rainfall Intensity
(mm/hr)
0
10
20
30
40
50
60
01-May 00:00
05-May 00:00
09-May 00:00
13-May 00:00
17-May 00:00
21-May 00:00
25-May 00:00
29-May 00:00
01-Jun 00:00
Summary:
JFSA Gauge Total Rainfall Volume: 103.27 mm
City Gauge Total Rainfall Volume: 109.6 mm
City Gauge
JFSA Gauge

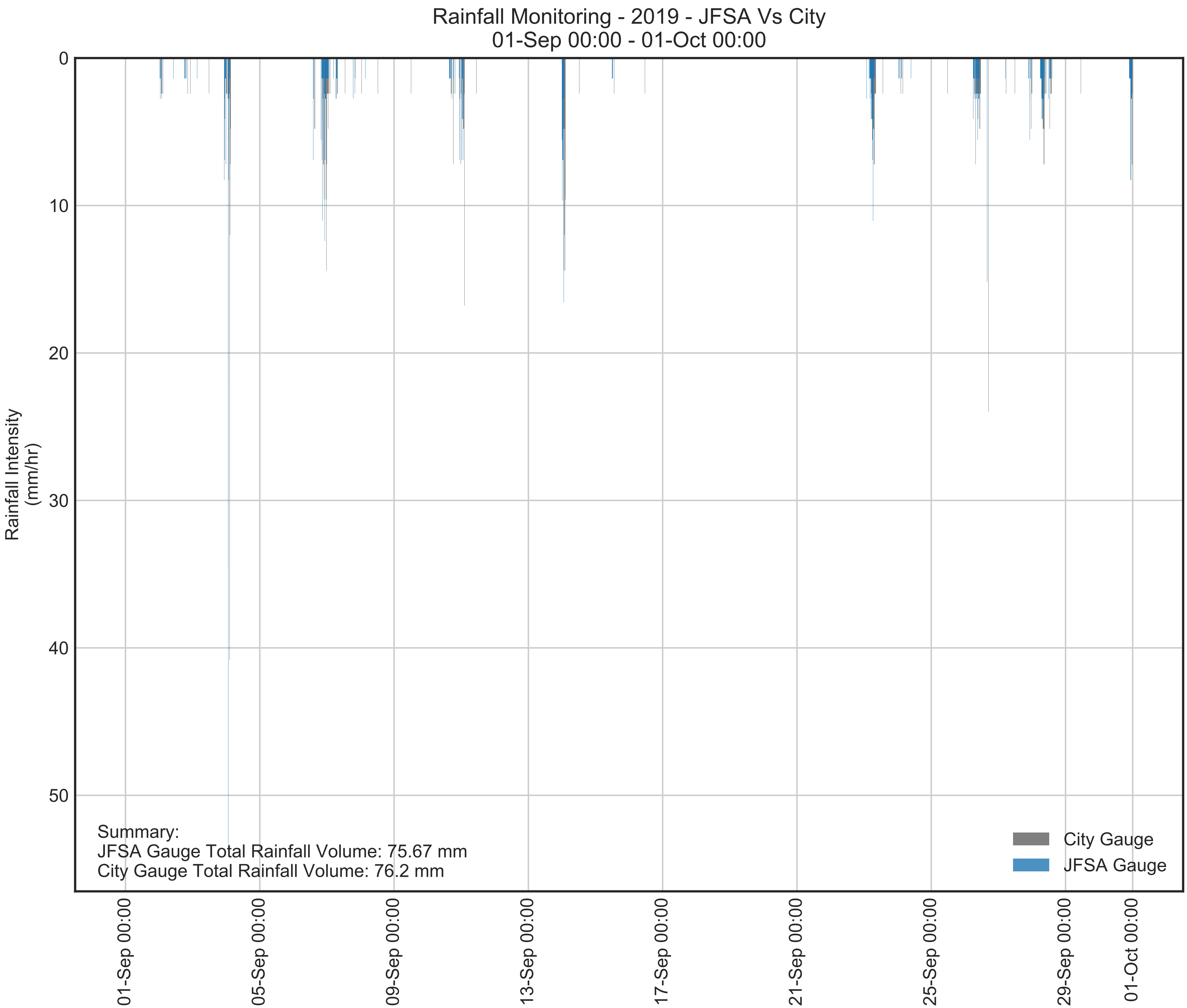

Rainfall Monitoring - 2019 - JFSA Vs City
01-Jun 00:00 - 01-Jul 00:00
Rainfall Intensity
(mm/hr)
0
20
40
60
80
01-Jun 00:00
05-Jun 00:00
09-Jun 00:00
13-Jun 00:00
17-Jun 00:00
21-Jun 00:00
25-Jun 00:00
29-Jun 00:00
01-Jul 00:00
City Gauge
JFSA Gauge
Summary:
JFSA Gauge Total Rainfall Volume: 139.15 mm
City Gauge Total Rainfall Volume: 145.8 mm

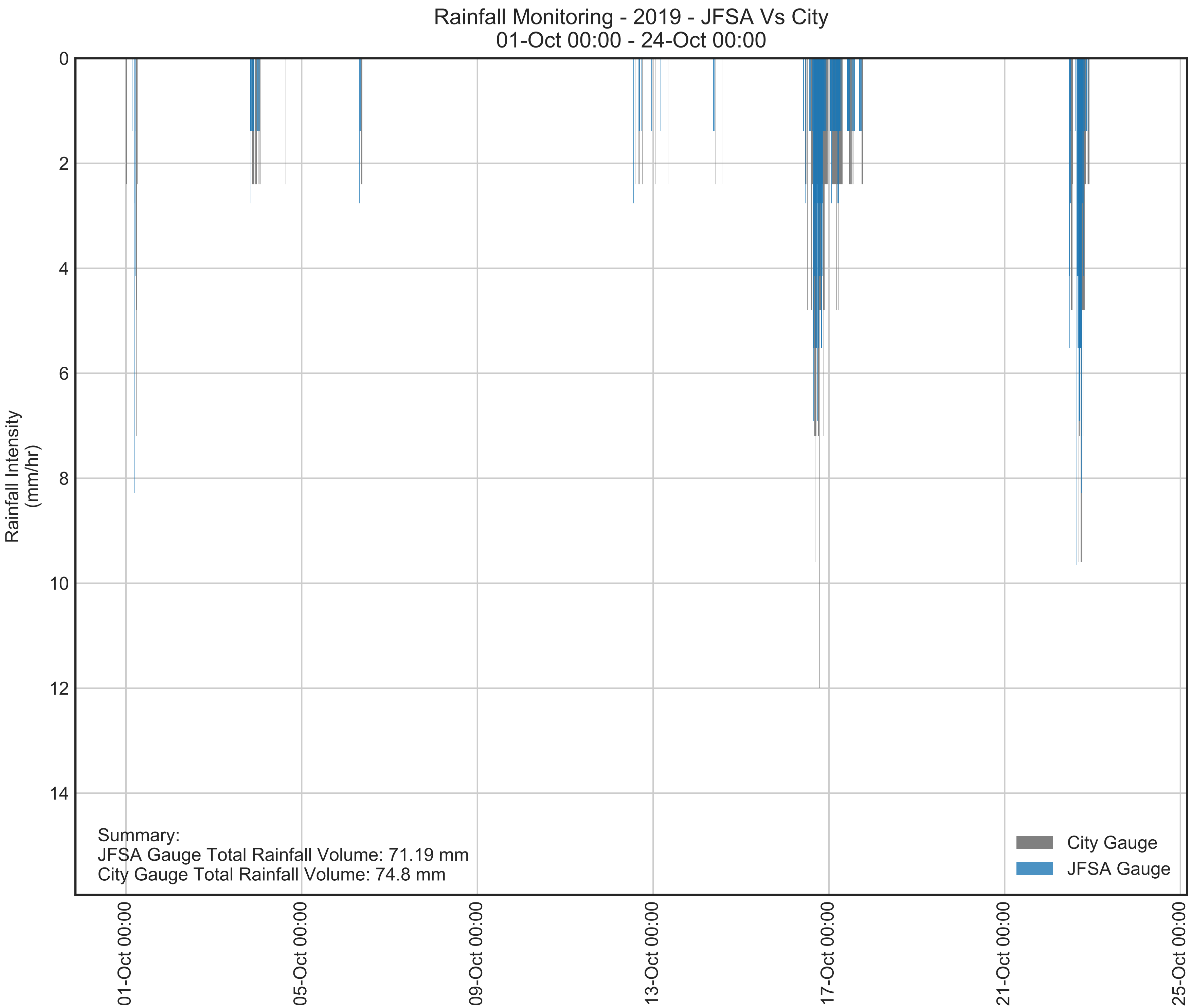


Rainfall Monitoring - 2019 - JFSA Vs City
01-Jul 00:00 - 01-Aug 00:00
Rainfall Intensity (mm/hr)
0
20
40
60
80
01-Jul 00:00
05-Jul 00:00
09-Jul 00:00
13-Jul 00:00
17-Jul 00:00
21-Jul 00:00
25-Jul 00:00
29-Jul 00:00
01-Aug 00:00
Summary:
JFSA Gauge Total Rainfall Volume: 50.48 mm
City Gauge Total Rainfall Volume: 63.0 mm
City Gauge
JFSA Gauge



Rainfall Monitoring - 2019 - JFSA Vs City
01-Aug 00:00 - 01-Sep 00:00
Rainfall Intensity
(mm/hr)
0
10
20
30
40
50
60
70
80
Summary:
JFSA Gauge Total Rainfall Volume: 64.86 mm
City Gauge Total Rainfall Volume: 71.0 mm
City Gauge
JFSA Gauge
01-Aug 00:00
05-Aug 00:00
09-Aug 00:00
13-Aug 00:00
17-Aug 00:00
21-Aug 00:00
25-Aug 00:00
29-Aug 00:00
01-Sep 00:00

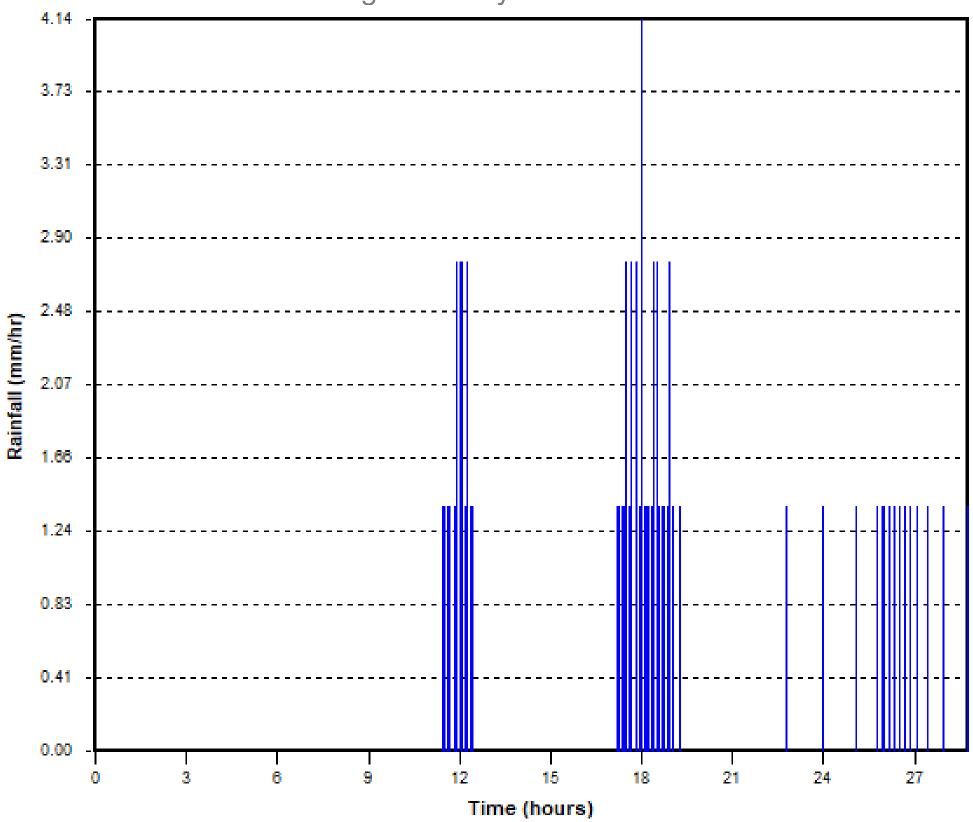

Rainfall Monitoring - 2019 - JFSA Vs City
01-Sep 00:00 - 01-Oct 00:00
Rainfall Intensity
(mm/hr)
0
10
20
30
40
50
Summary:
JFSA Gauge Total Rainfall Volume: 75.67 mm
City Gauge Total Rainfall Volume: 76.2 mm
City Gauge
JFSA Gauge
01-Sep 00:00
05-Sep 00:00
09-Sep 00:00
13-Sep 00:00
17-Sep 00:00
21-Sep 00:00
25-Sep 00:00
29-Sep 00:00
01-Oct 00:00



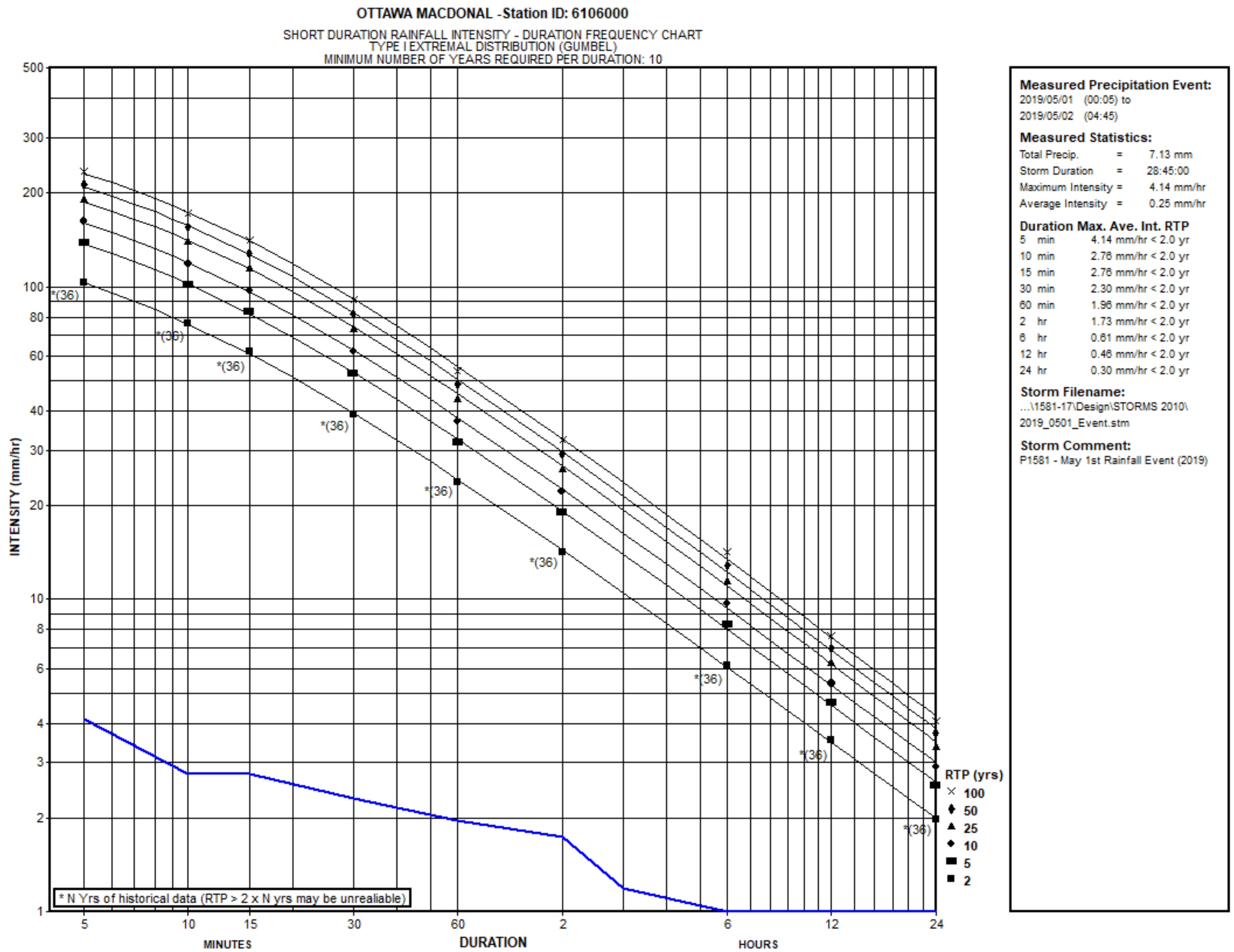
Rainfall Monitoring - 2019 - JFSA Vs City
01-Oct 00:00 - 24-Oct 00:00
Rainfall Intensity
(mm/hr)
0
2
4
6
8
10
12
14
Summary:
JFSA Gauge Total Rainfall Volume: 71.19 mm
City Gauge Total Rainfall Volume: 74.8 mm
City Gauge
JFSA Gauge
01-Oct 00:00
05-Oct 00:00
09-Oct 00:00
13-Oct 00:00
17-Oct 00:00
21-Oct 00:00
25-Oct 00:00

May 1st Rainfall Event (05/01/2019 00:00 – 05/01/2019 04:45)

Total Precipitation = 7.13 mm
Maximum Intensity 4.14 mm/hr
Average Intensity 0.25 mm/hr

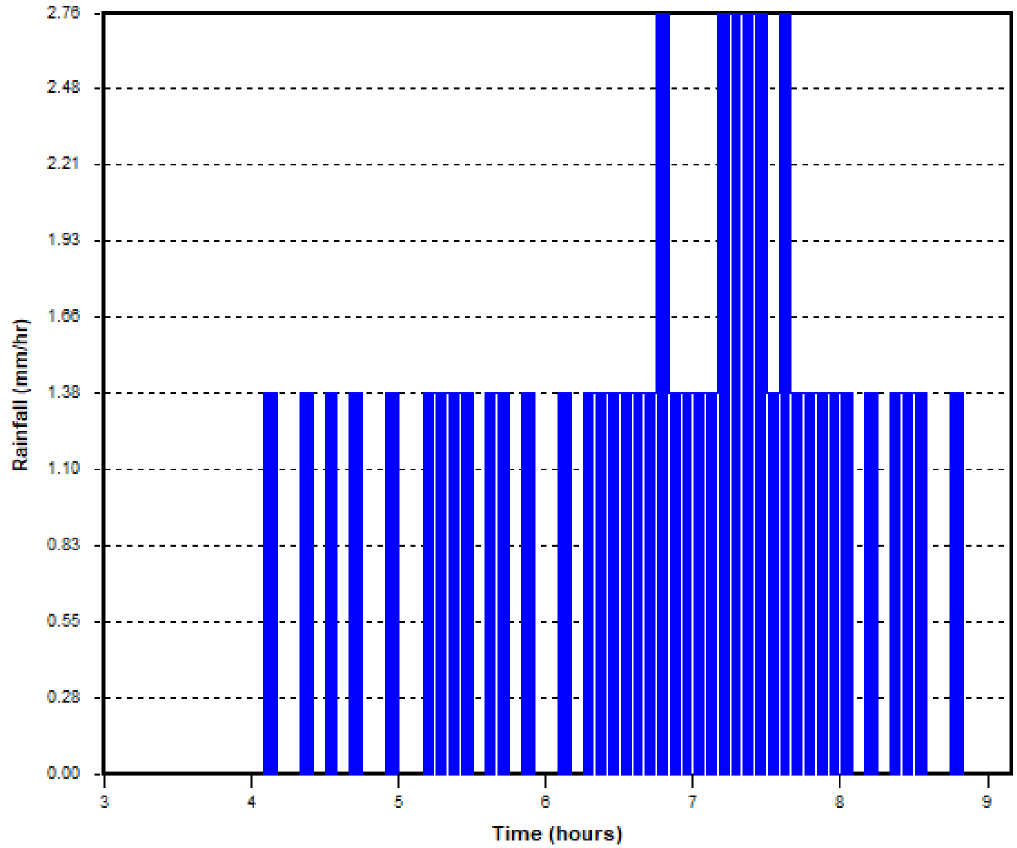


May 1st Duration Rainfall Intensity – Duration Frequency Chart (05/01/2019 00:00 – 05/01/2019 04:45)

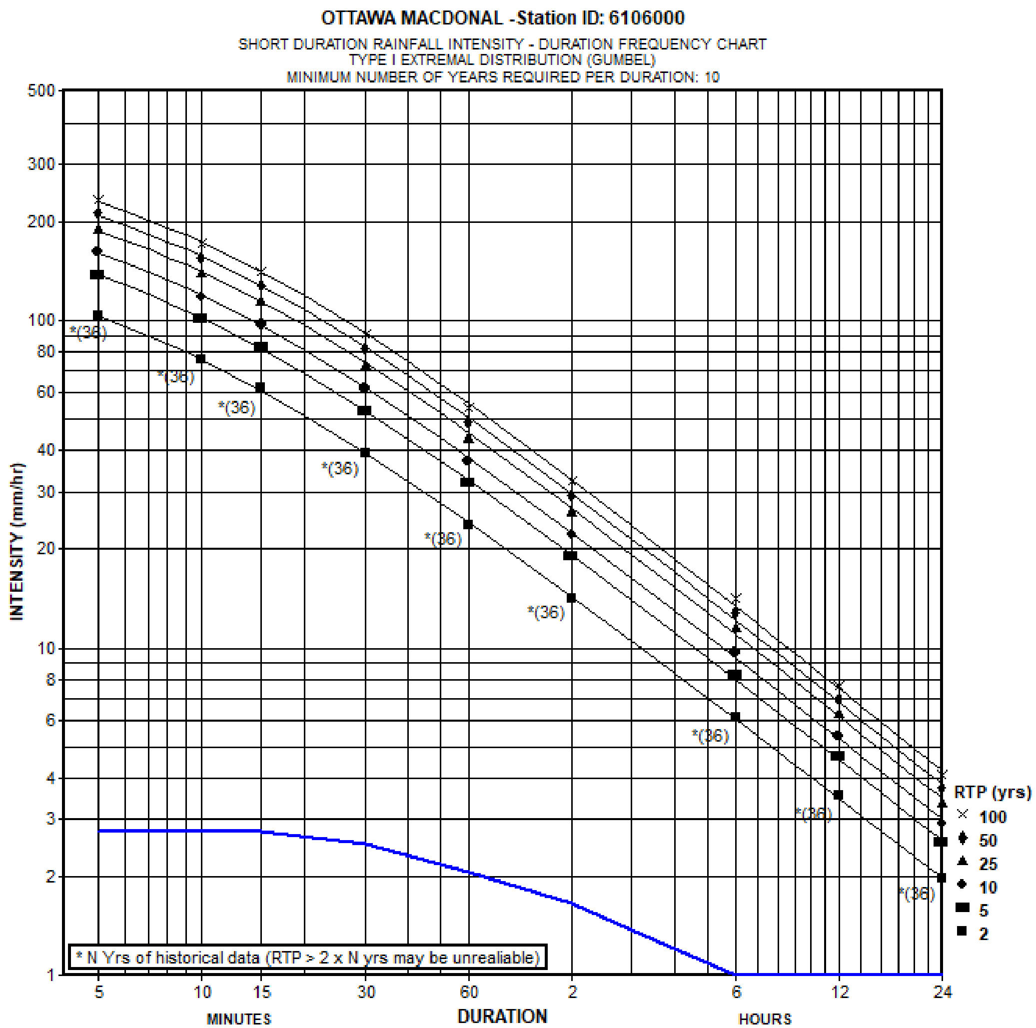


May 3rd Rainfall Event (05/03/2019 00:00 – 05/03/2019 09:00)

Total Precipitation = 5.29 mm
Maximum Intensity 2.76 mm/hr
Average Intensity 0.60 mm/hr



May 3rd Duration Rainfall Intensity – Duration Frequency Chart (05/03/2019 00:00 – 05/03/2019 09:00)



Measured Precipitation Event:
2019/05/03 (00:05) to
2019/05/03 (09:00)

Measured Statistics:

Total Precip.	=	5.29 mm
Storm Duration	=	9:10:00
Maximum Intensity	=	2.76 mm/hr
Average Intensity	=	0.58 mm/hr

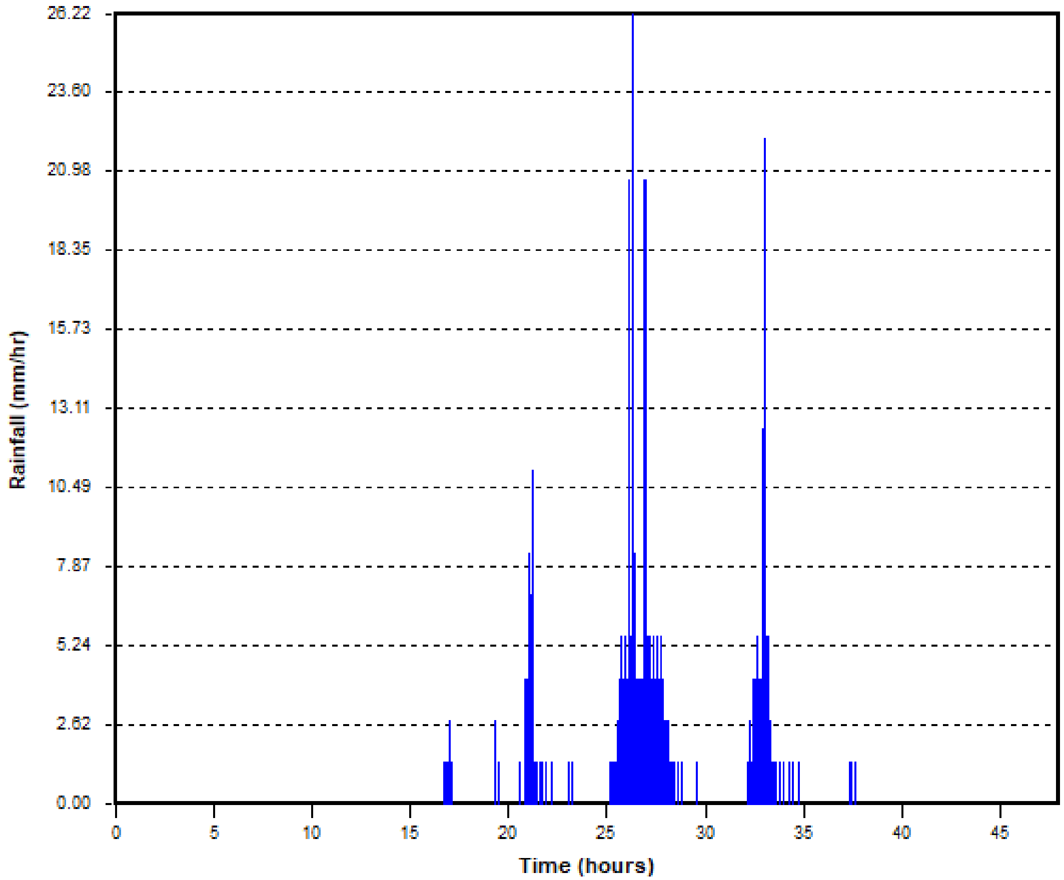
Duration	Max. Ave. Int.	RTP
5 min	2.76 mm/hr	< 2.0 yr
10 min	2.76 mm/hr	< 2.0 yr
15 min	2.76 mm/hr	< 2.0 yr
30 min	2.53 mm/hr	< 2.0 yr
60 min	2.07 mm/hr	< 2.0 yr
2 hr	1.67 mm/hr	< 2.0 yr
6 hr	0.88 mm/hr	< 2.0 yr
12 hr	0.44 mm/hr	< 2.0 yr
24 hr	0.22 mm/hr	< 2.0 yr

Storm Filename:
...\1581-17\Design\STORMS 2010\
2019_0503_Event.stm

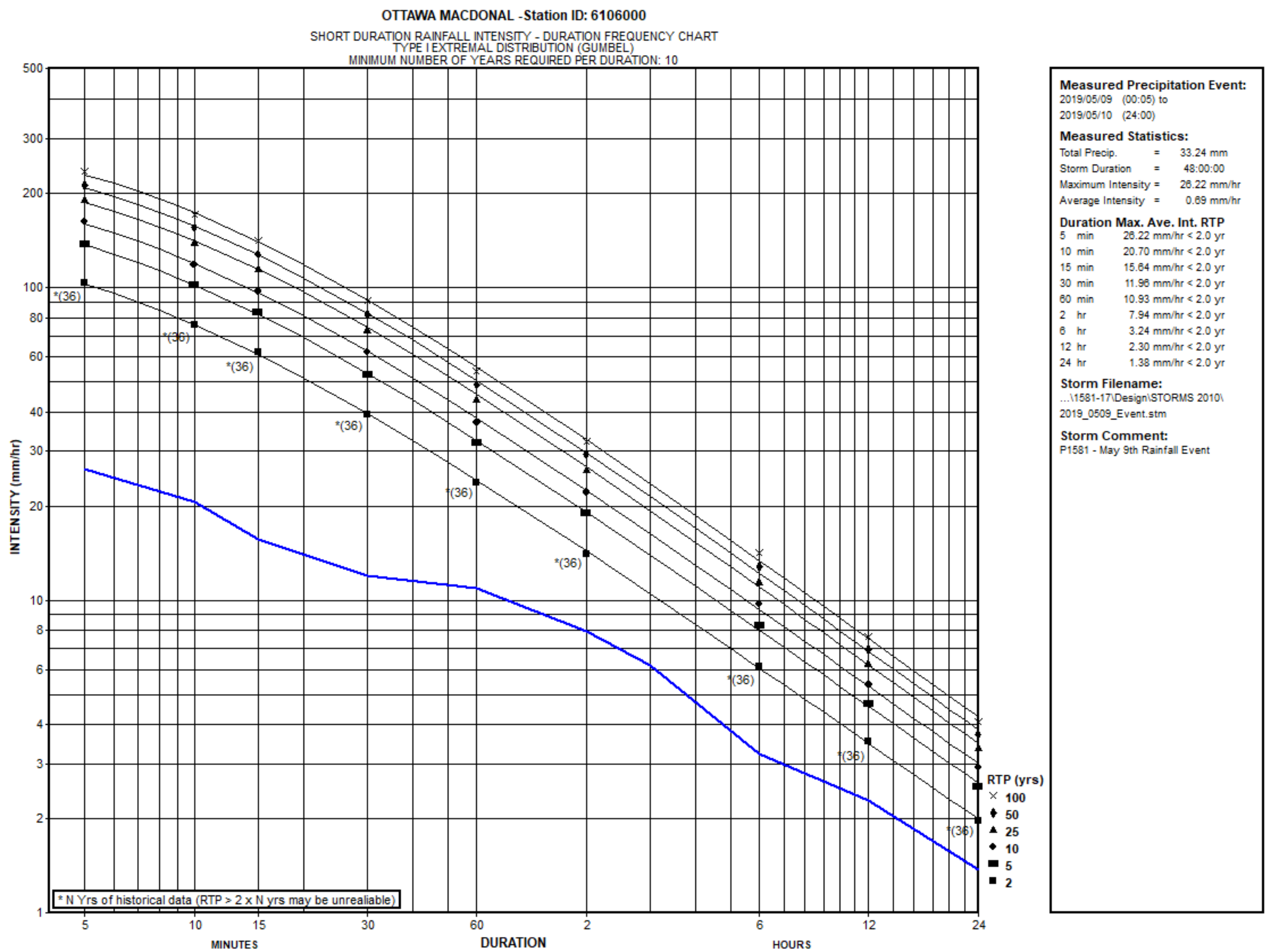
Storm Comment:
P1581 - May 3rd Rainfall Event

May 9th Rainfall Event (05/09/2019 00:00 – 05/10/2019 24:00)

Total Precipitation = 33.24 mm
Maximum Intensity = 26.22 mm/hr
Average Intensity = 0.69 mm/hr

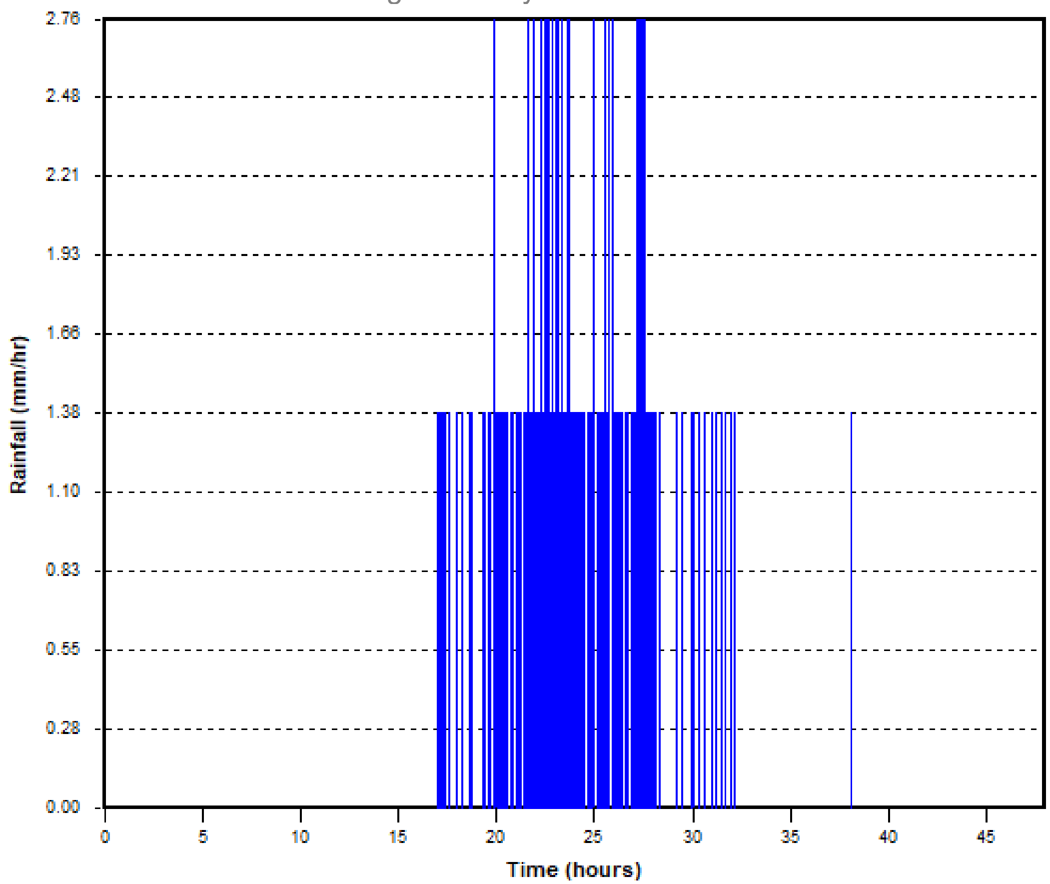


May 9th Duration Rainfall Intensity – Duration Frequency Chart (05/09/2019 00:00 – 05/10/2019 24:00)

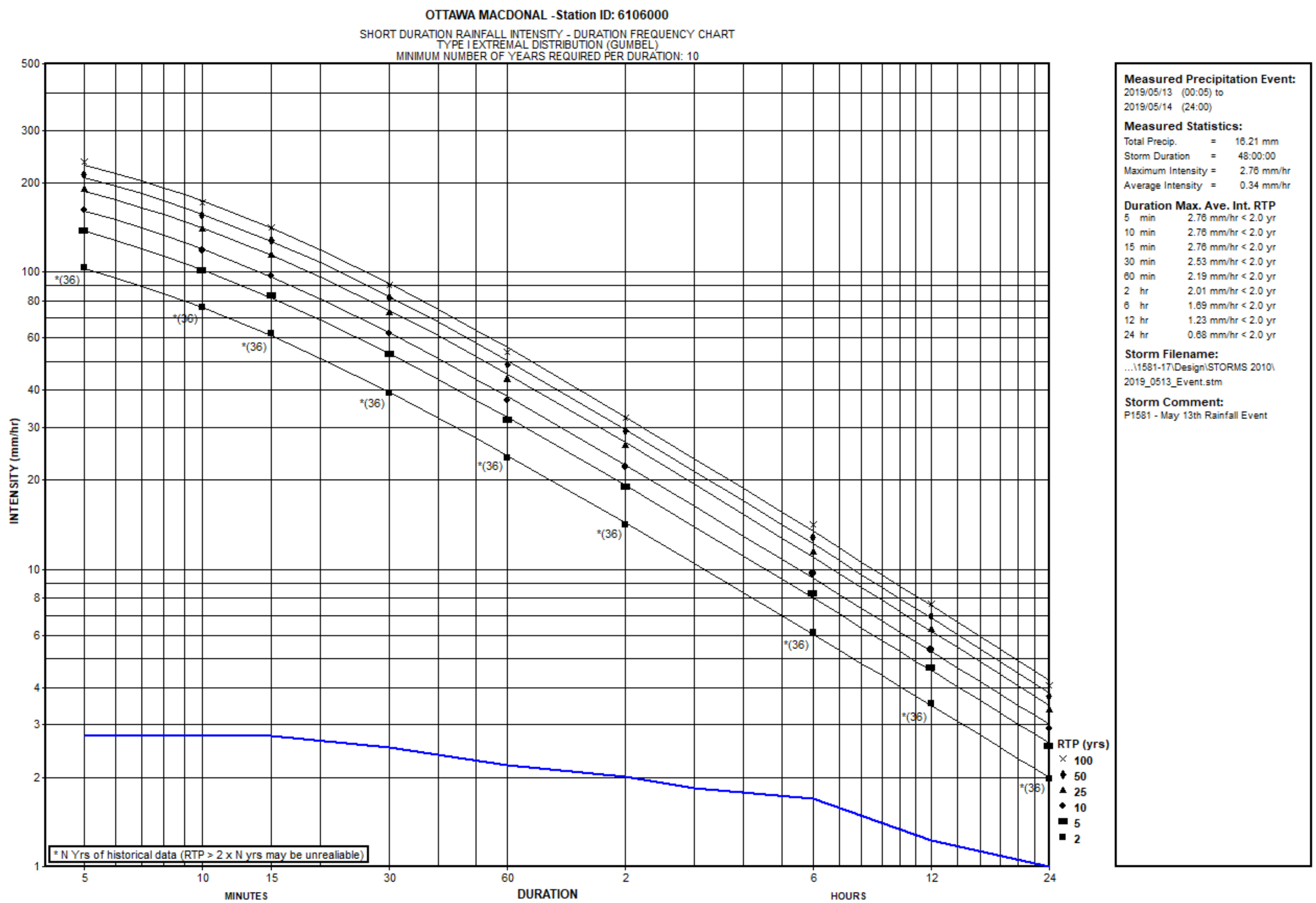


May 13th Rainfall Event (05/13/2019 00:00 – 05/14/2019 24:00)

Total Precipitation = 16.21 mm
Maximum Intensity = 2.76 mm/hr
Average Intensity = 0.34 mm/hr

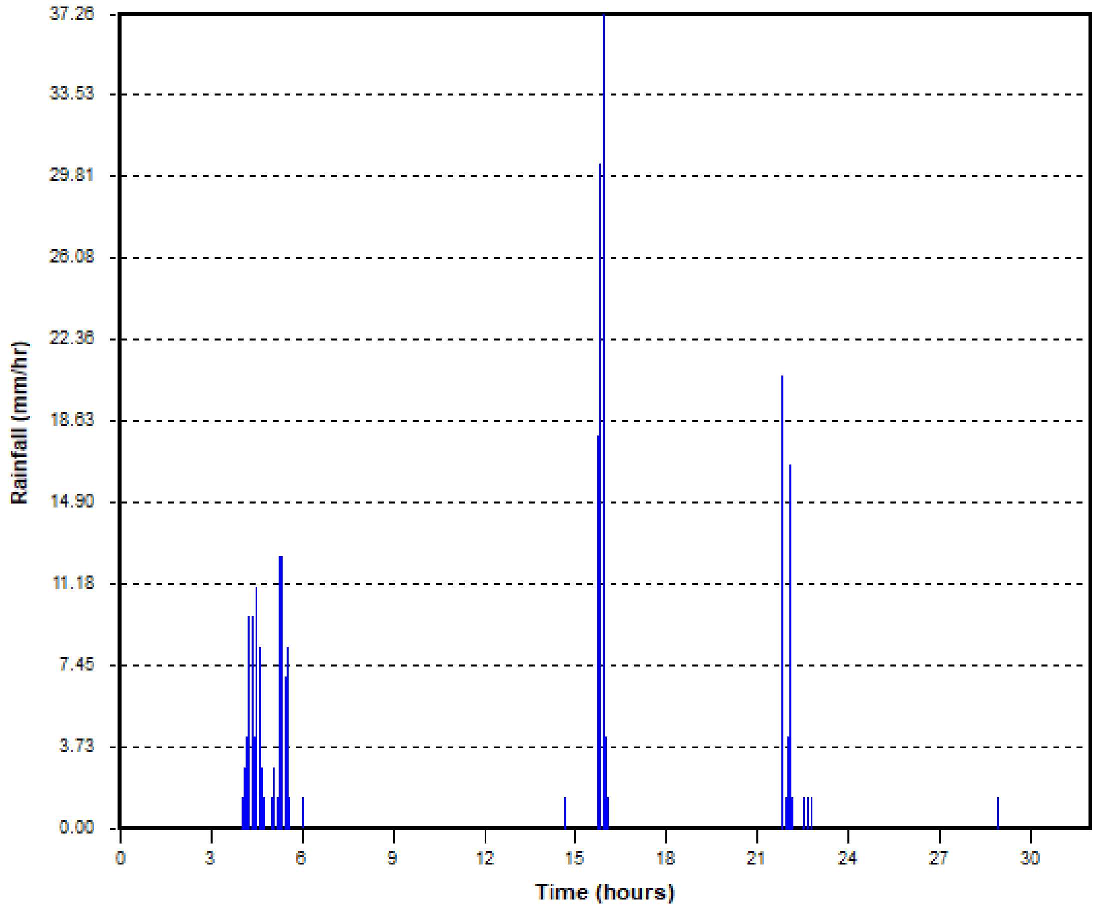


May 13th Duration Rainfall Intensity – Duration Frequency Chart (05/13/2019 00:00 – 05/14/2019 24:00)

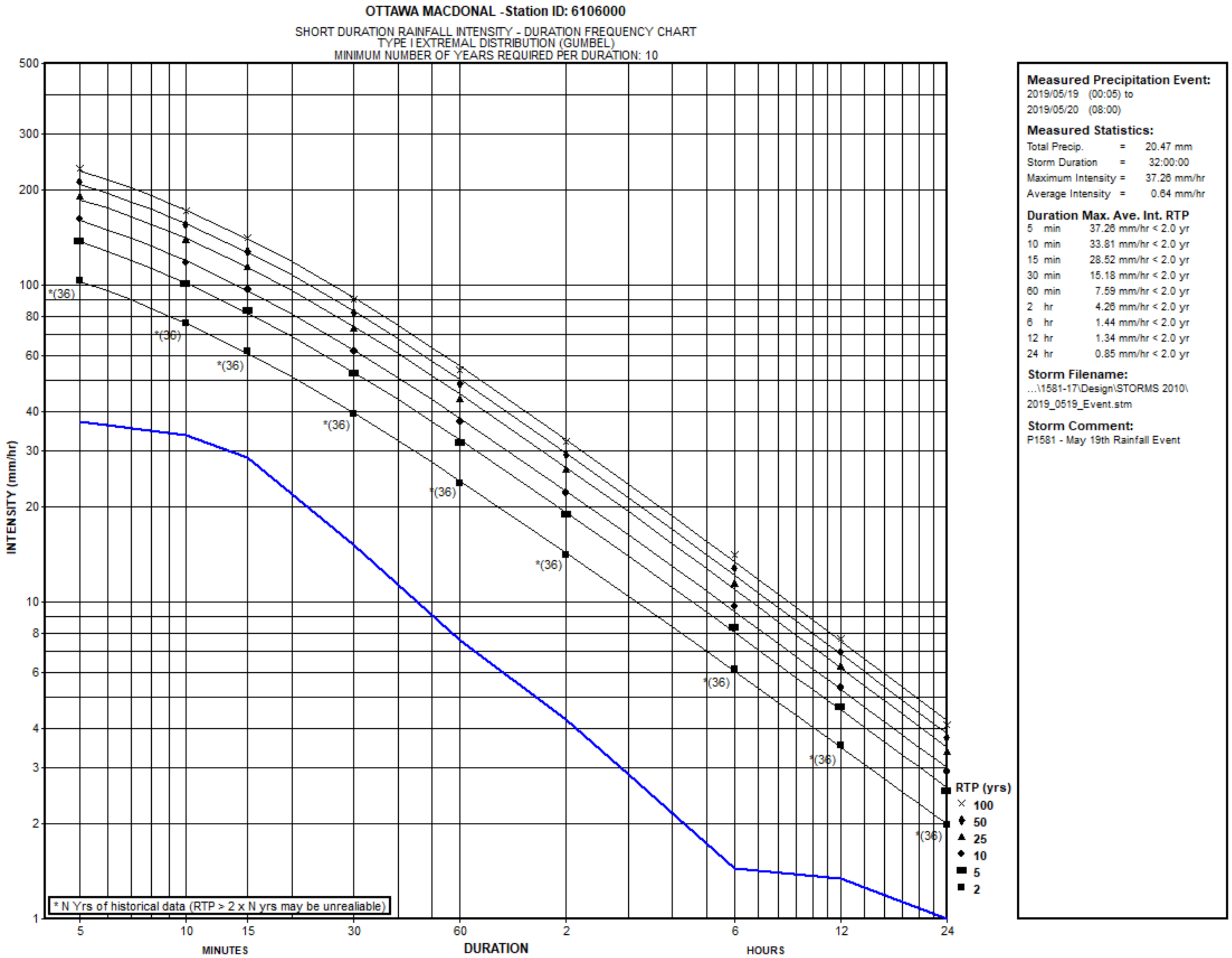


May 19th Rainfall Event (05/19/2019 00:00 – 05/20/2019 8:00)

Total Precipitation = 20.47 mm
Maximum Intensity = 37.26 mm/hr
Average Intensity = 0.64 mm/hr

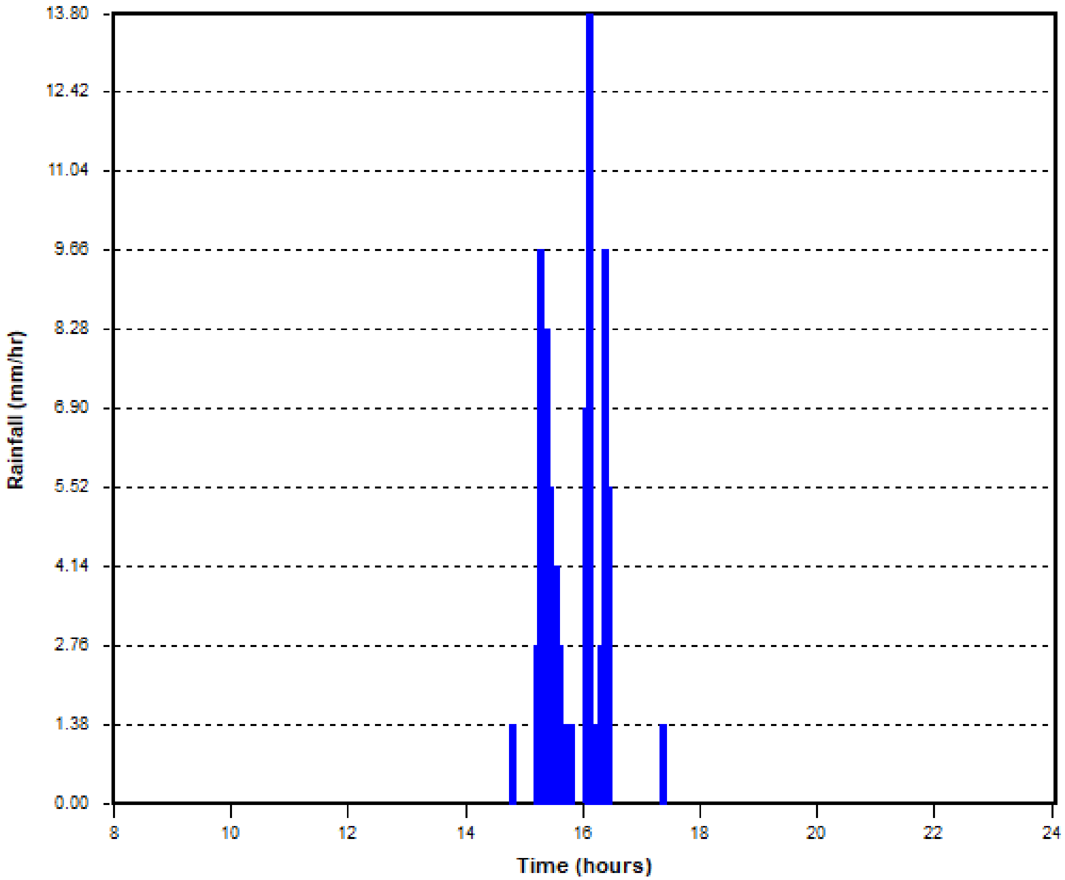


May 19th Duration Rainfall Intensity – Duration Frequency Chart (05/19/2019 00:00 – 05/20/2019 8:00)

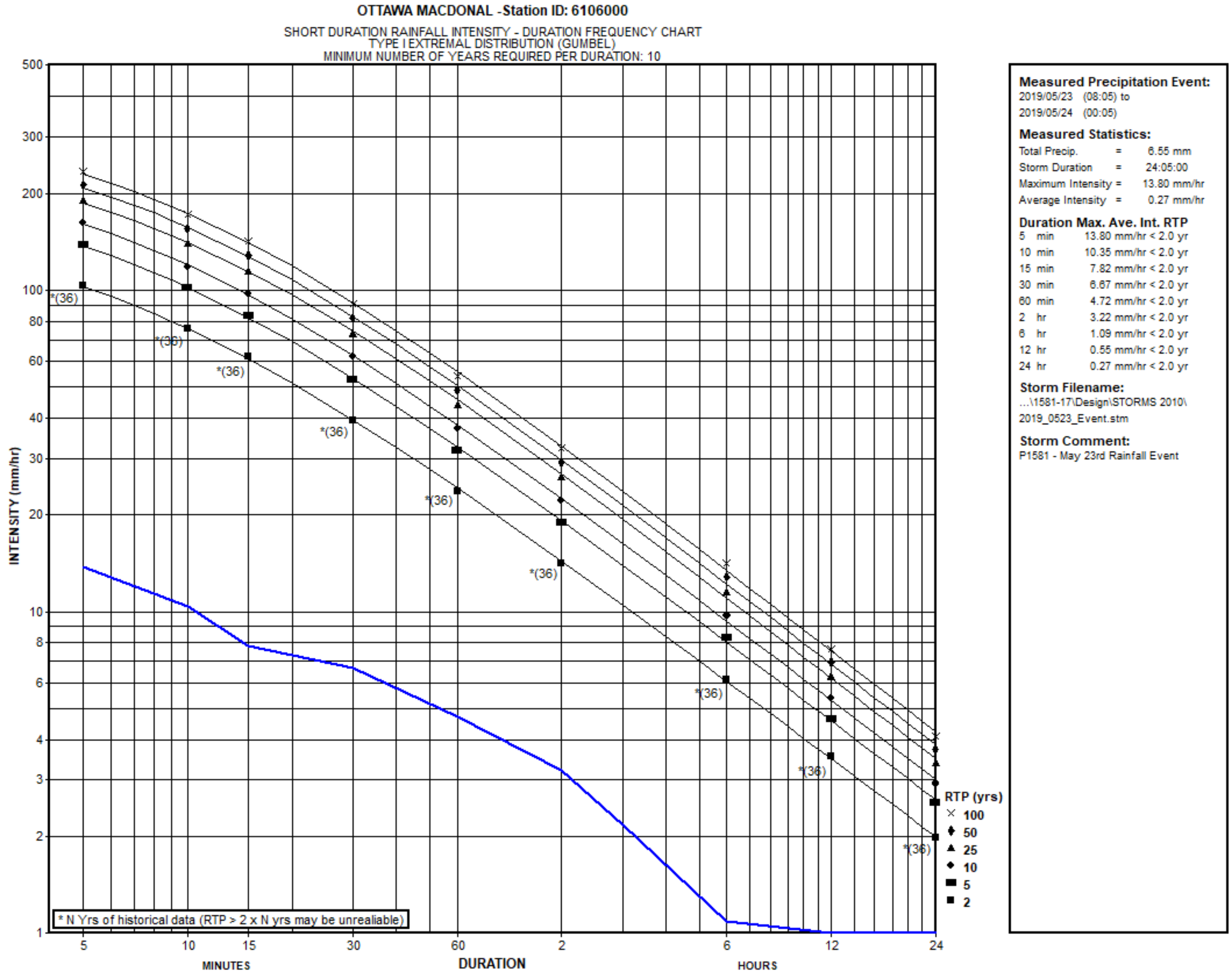


May 23rd Rainfall Event (05/23/2019 8:00 – 05/23/2019 24:00)

Total Precipitation = 6.55 mm
Maximum Intensity = 13.80 mm/hr
Average Intensity = 0.27 mm/hr

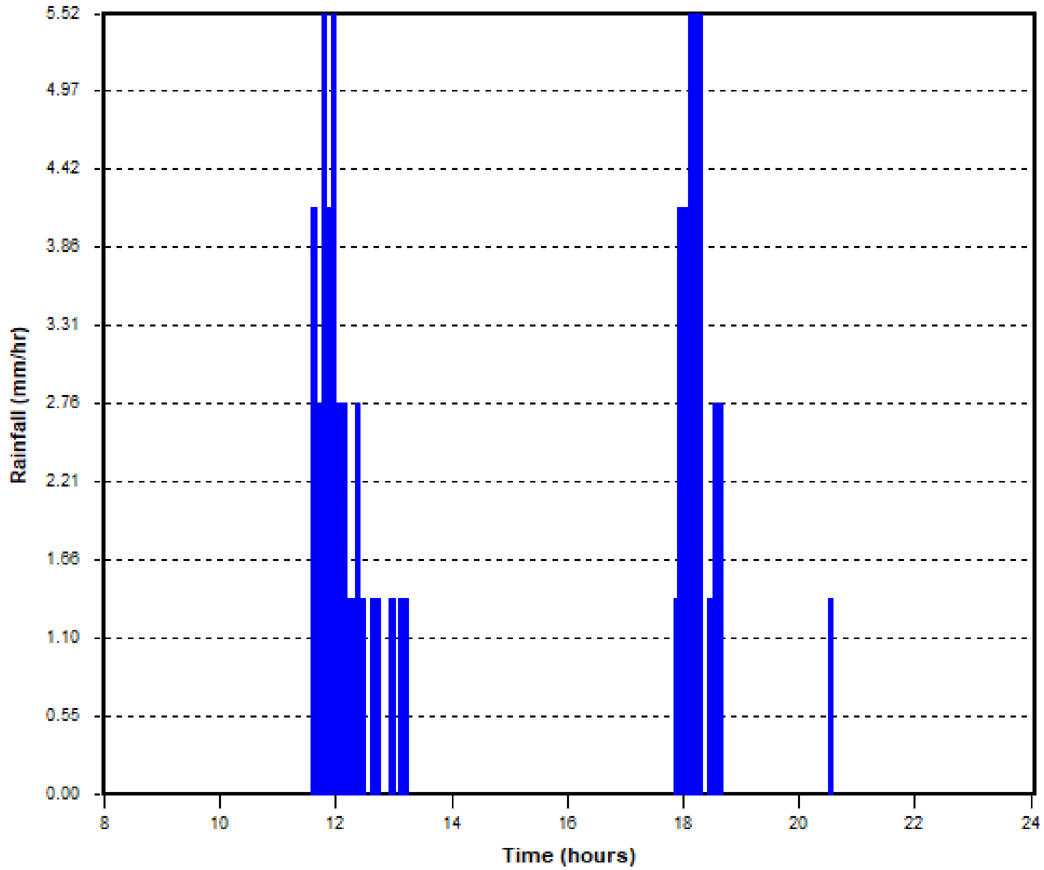


May 23rd Duration Rainfall Intensity – Duration Frequency Chart (05/23/2019 08:00 – 05/23/2019 24:00)

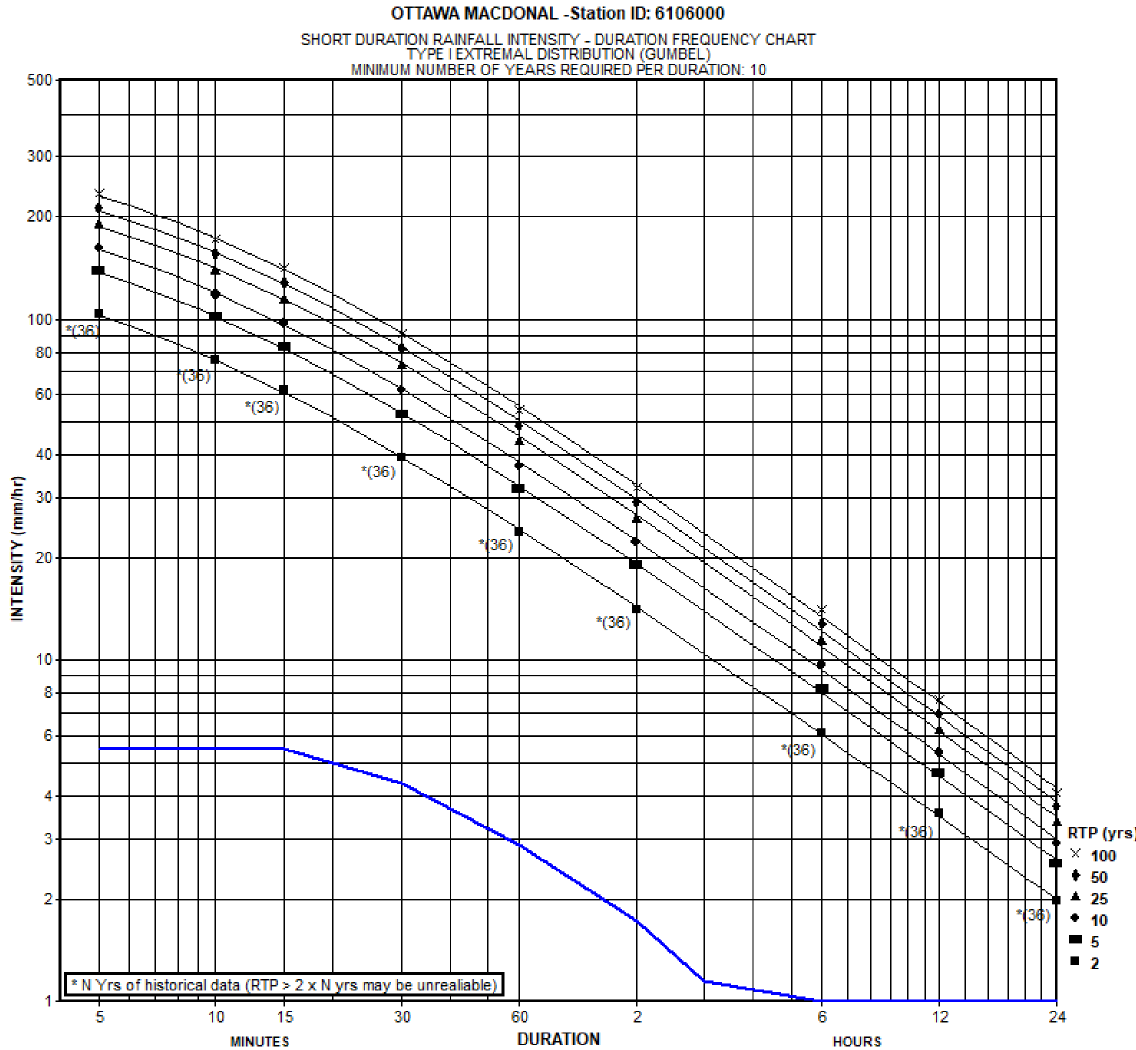


May 25th Rainfall Event (05/25/2019 8:00 – 05/26/2019 00:00)

Total Precipitation = 6.33 mm
Maximum Intensity = 5.52 mm/hr
Average Intensity = 0.26 mm/hr



May 25th Duration Rainfall Intensity – Duration Frequency Chart (05/25/2019 08:00 – 05/26/2019 00:00)



Measured Precipitation Event:
2019/05/25 (08:05) to
2019/05/26 (00:05)

Measured Statistics:

Total Precip.	=	6.33 mm
Storm Duration	=	24:05:00
Maximum Intensity	=	5.52 mm/hr
Average Intensity	=	0.26 mm/hr

Duration Max. Ave. Int. RTP

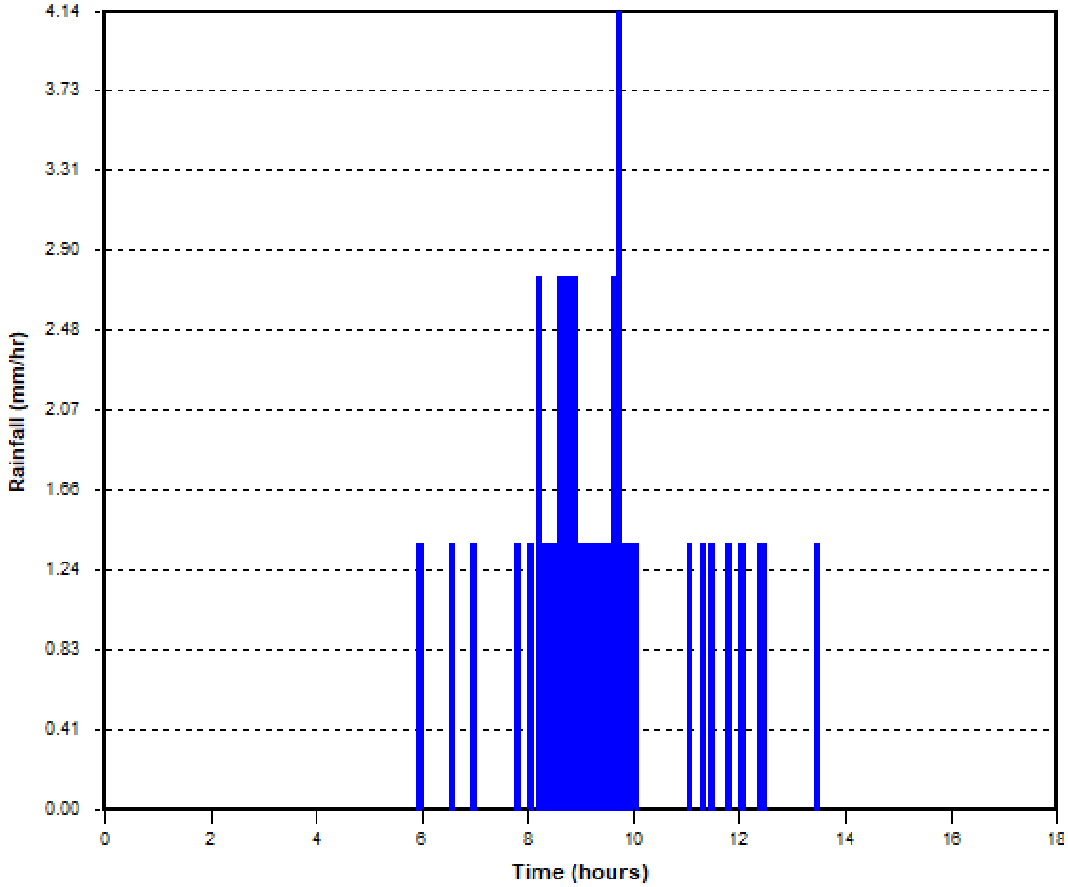
5	min	5.52 mm/hr	< 2.0 yr
10	min	5.52 mm/hr	< 2.0 yr
15	min	5.52 mm/hr	< 2.0 yr
30	min	4.37 mm/hr	< 2.0 yr
60	min	2.88 mm/hr	< 2.0 yr
2	hr	1.73 mm/hr	< 2.0 yr
6	hr	0.57 mm/hr	< 2.0 yr
12	hr	0.53 mm/hr	< 2.0 yr
24	hr	0.26 mm/hr	< 2.0 yr

Storm Filename:
...\1581-17\Design\STORMS 2010\
2019_0525_Event.stm

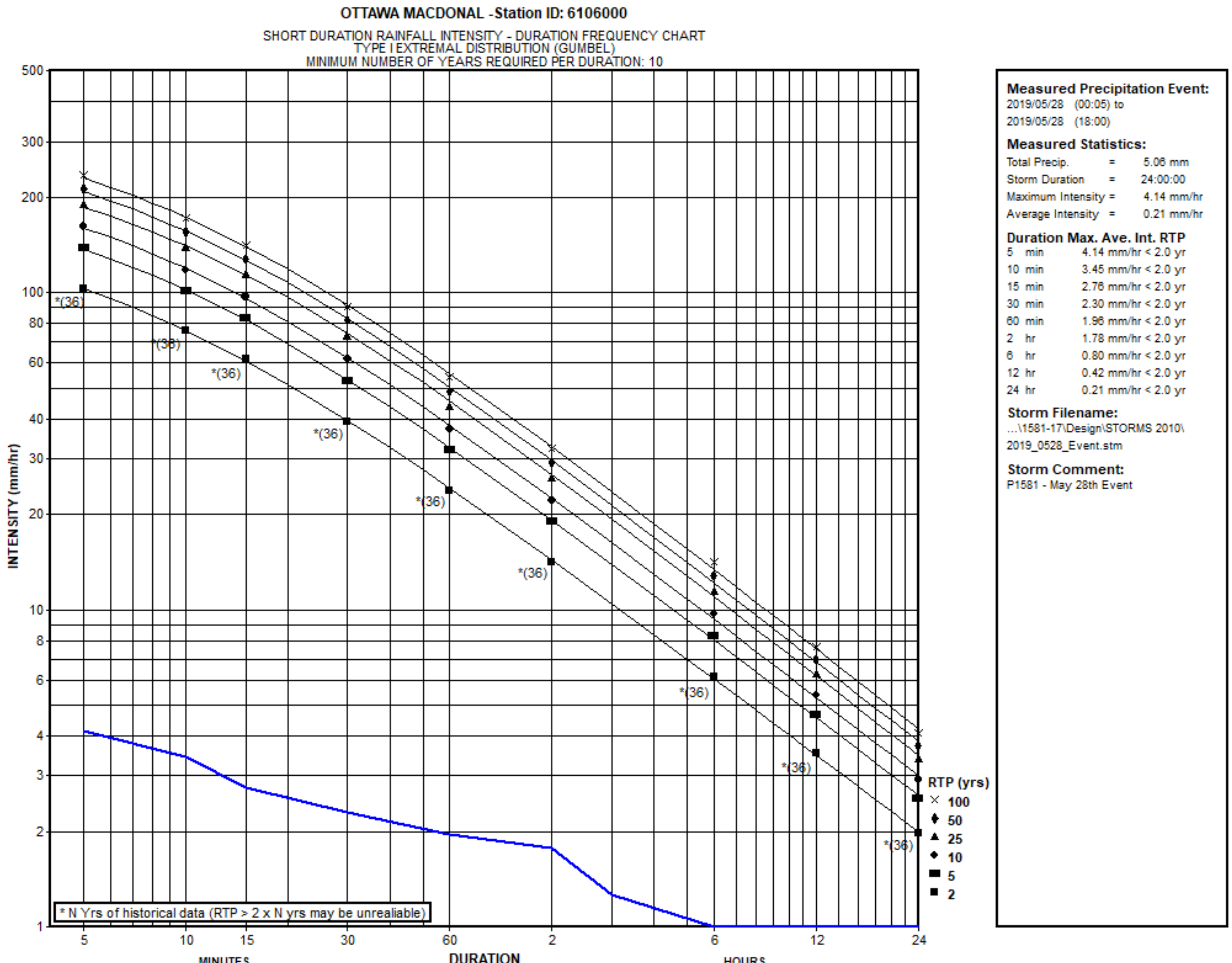
Storm Comment:
P1581 - May 25th Event

May 28th Rainfall Event (05/28/2019 00:00 – 05/28/2019 18:00)

Total Precipitation = 5.06 mm
Maximum Intensity = 4.14 mm/hr
Average Intensity = 0.21 mm/hr

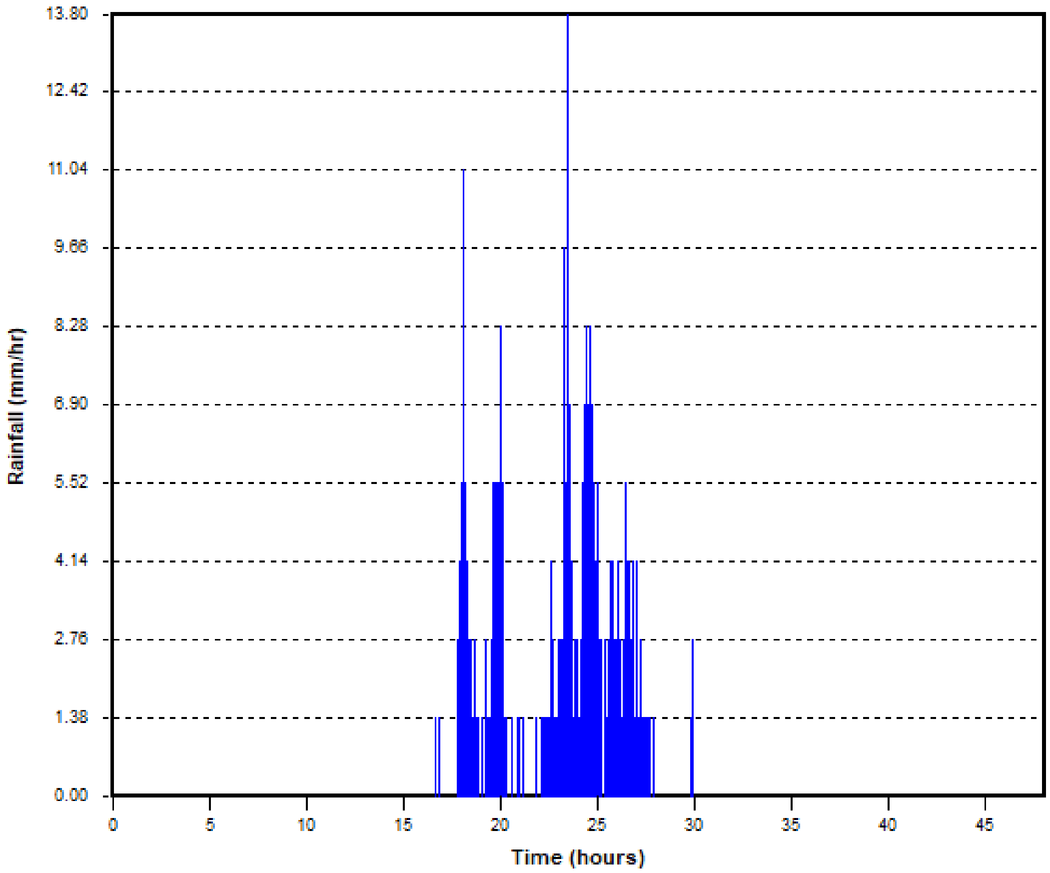


May 28th Duration Rainfall Intensity – Duration Frequency Chart (05/28/2019 00:00 – 05/28/2019 18:00)

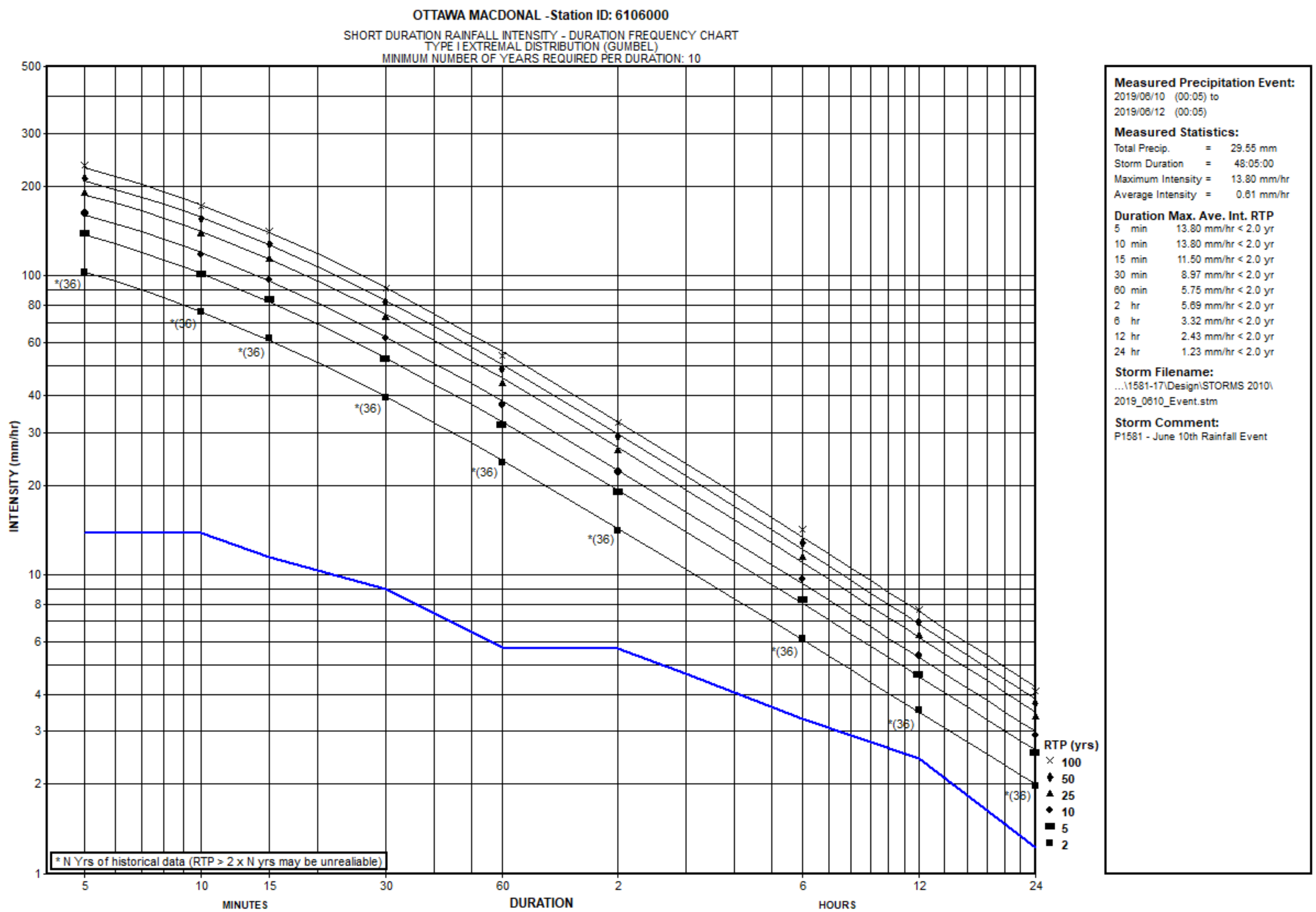


June 10th Rainfall Event (06/10/2019 00:00 – 06/12/2019 00:00)

Total Precipitation = 29.55 mm
Maximum Intensity = 13.80 mm/hr
Average Intensity = 0.61 mm/hr

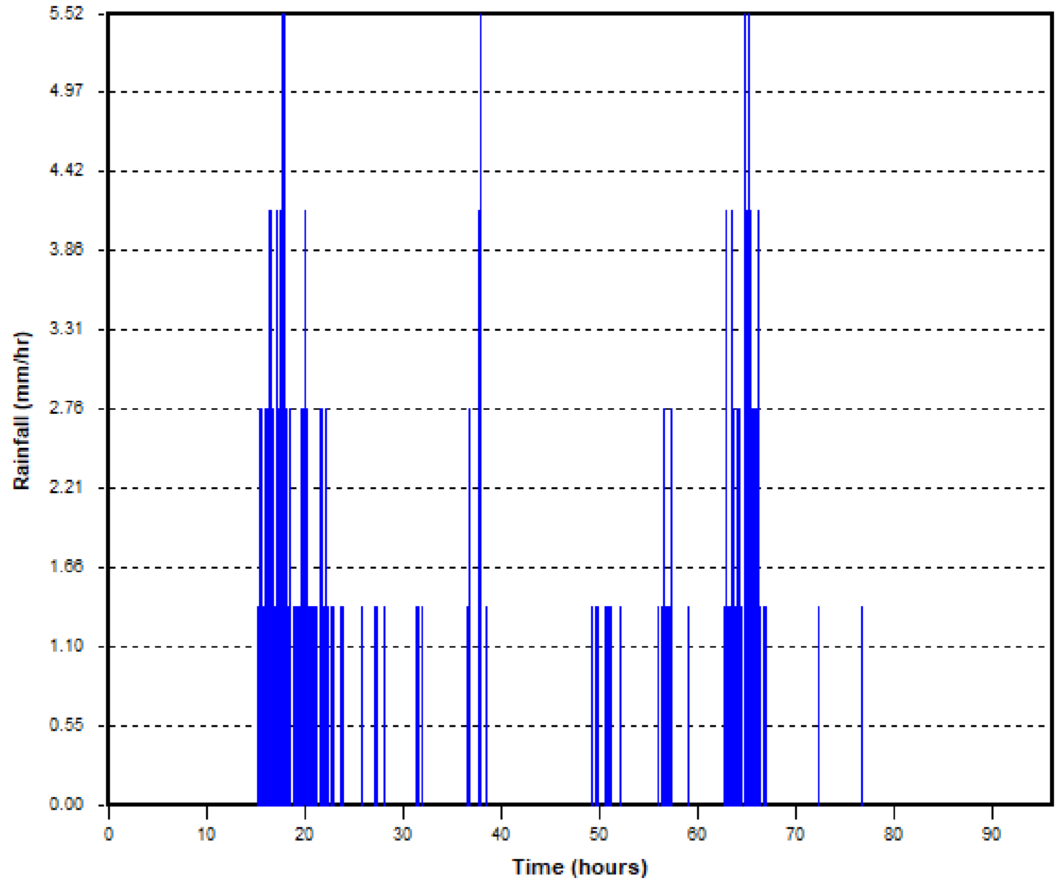


June 10th Duration Rainfall Intensity – Duration Frequency Chart (06/10/2019 00:00 – 06/12/2019 00:00)

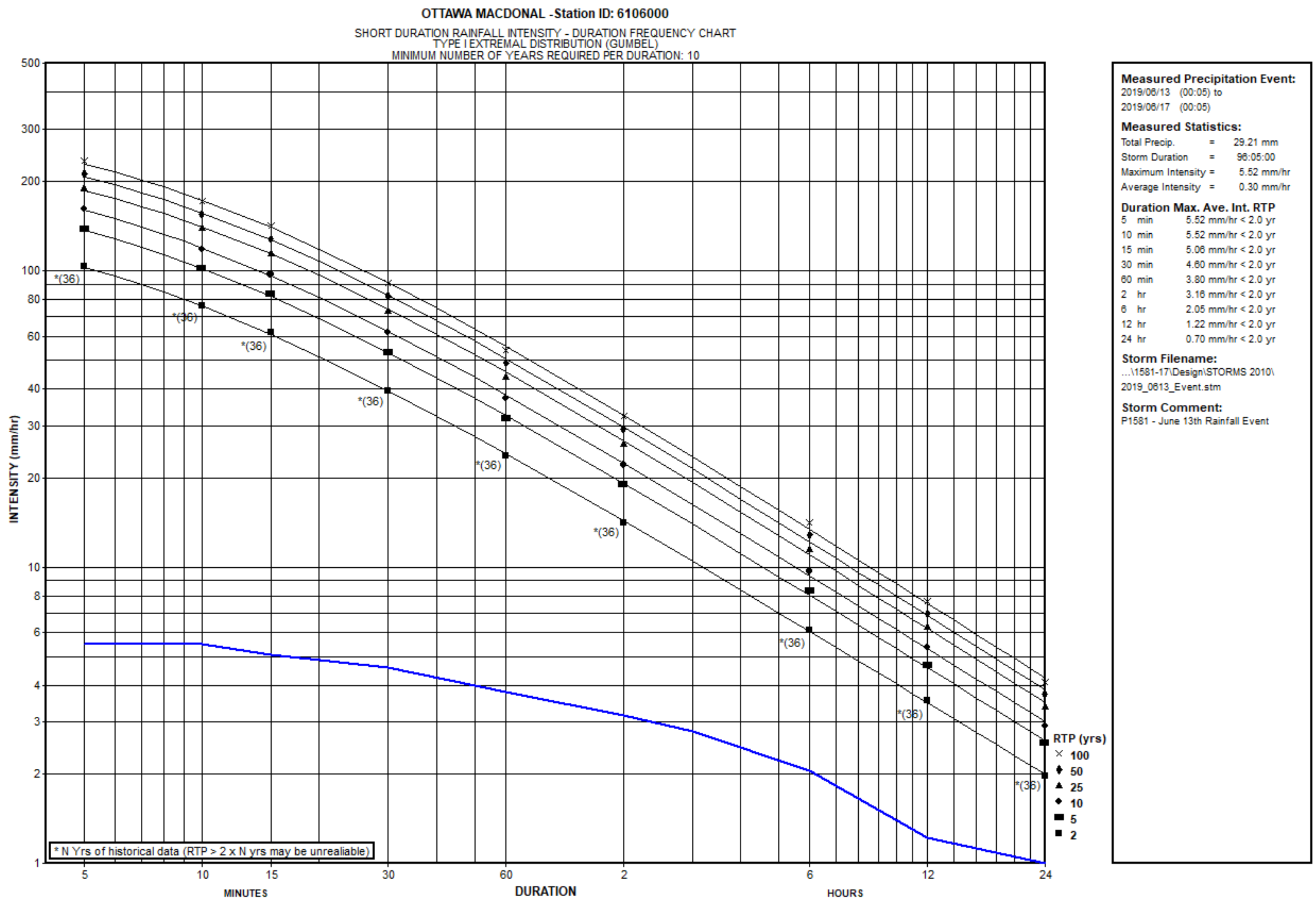


June 13th Rainfall Event (06/13/2019 00:00 – 06/17/2019 00:00)

Total Precipitation = 29.31 mm
Maximum Intensity = 5.52 mm/hr
Average Intensity = 0.30 mm/hr

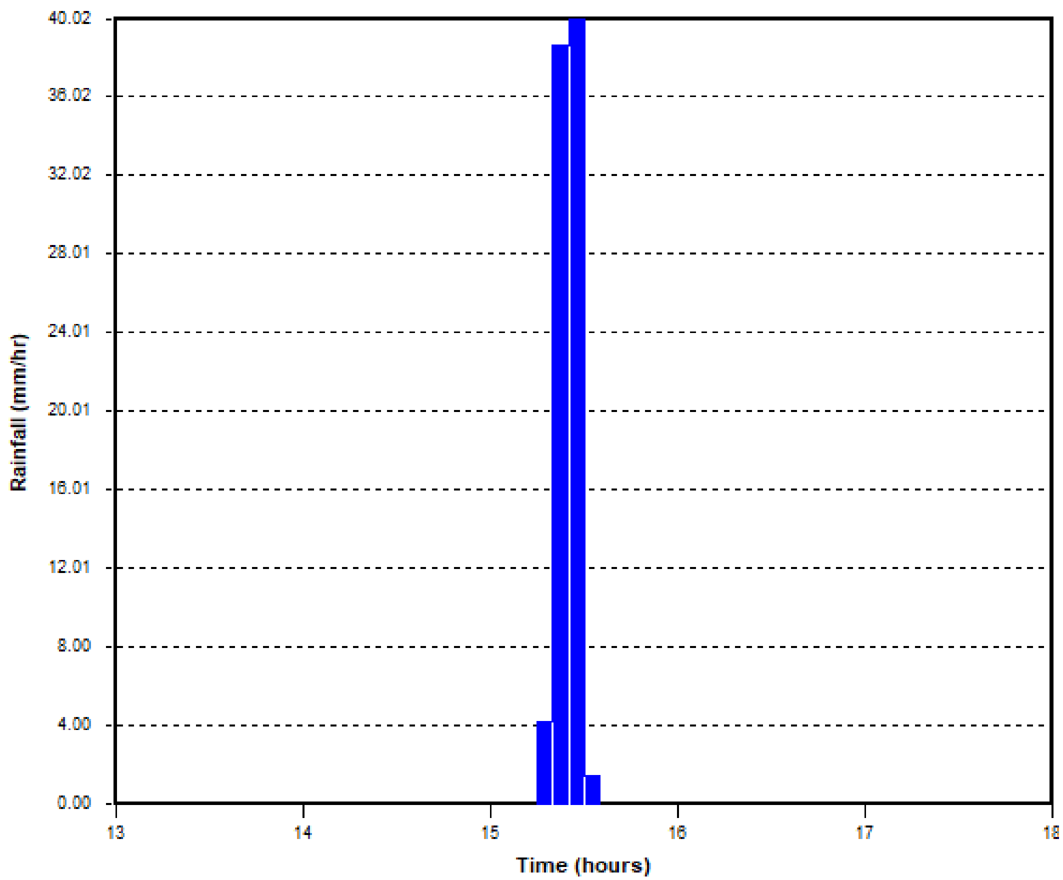


June 13th Duration Rainfall Intensity – Duration Frequency Chart (06/13/2019 00:00 – 06/17/2019 00:00)

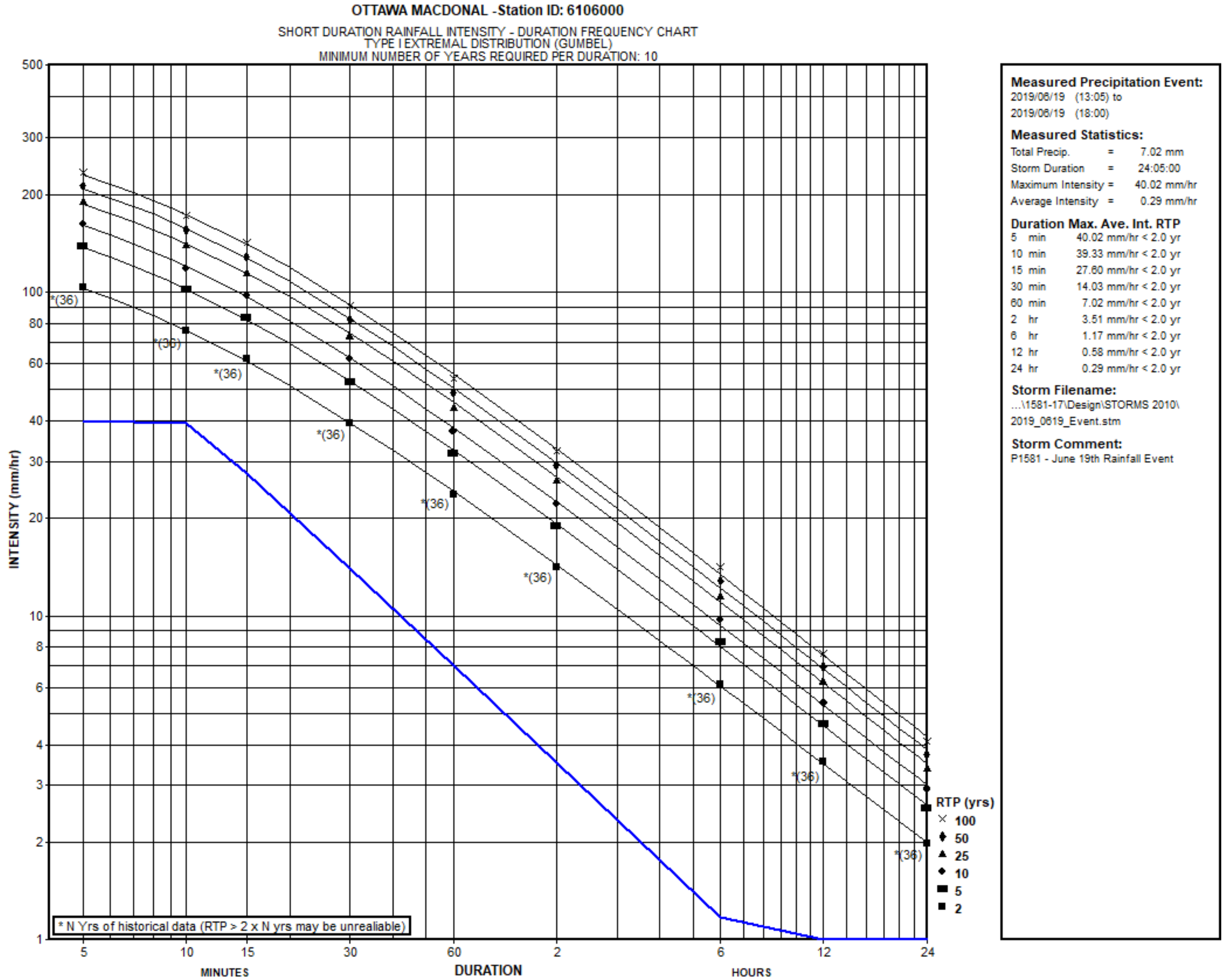


June 19th Rainfall Event (06/19/2019 13:00 – 06/19/2019 18:00)

Total Precipitation = 7.02 mm
Maximum Intensity = 40.02 mm/hr
Average Intensity = 0.29 mm/hr

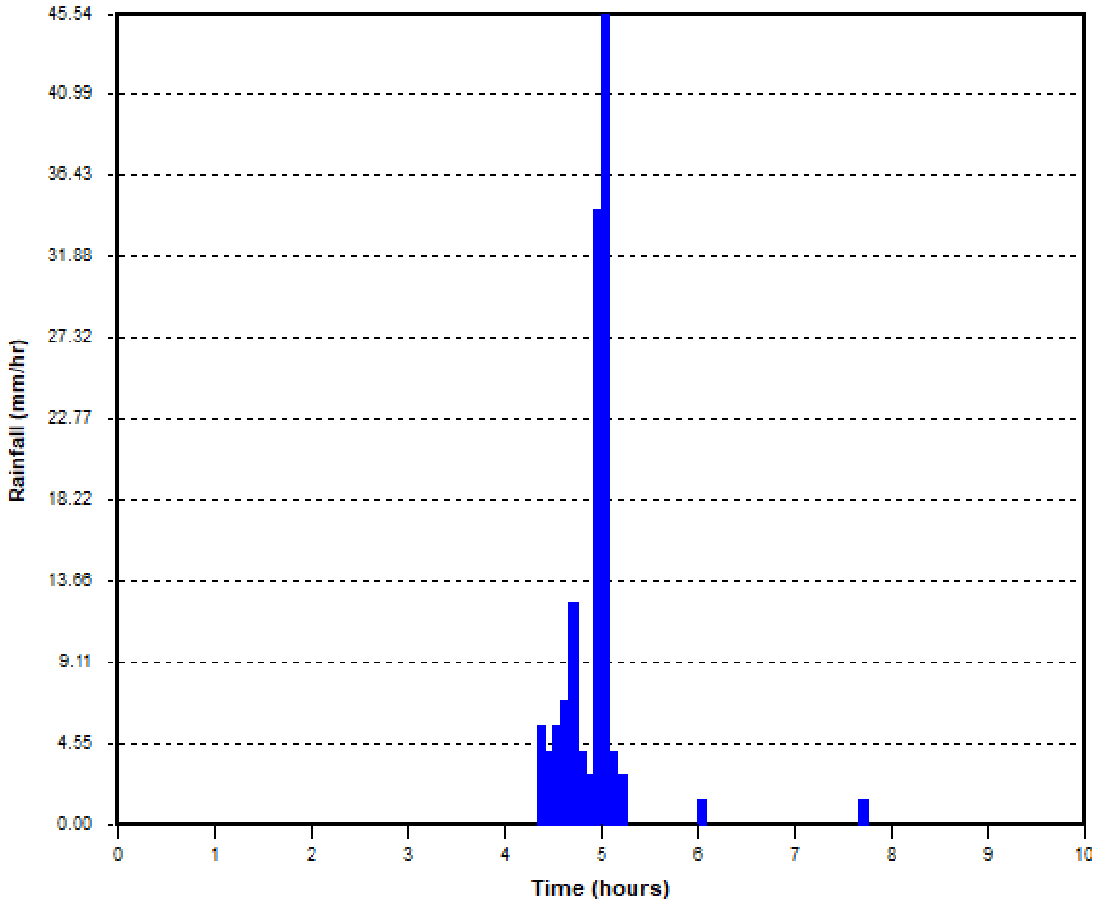


June 19th Duration Rainfall Intensity – Duration Frequency Chart (06/19/2019 13:00 – 06/19/2019 18:00)

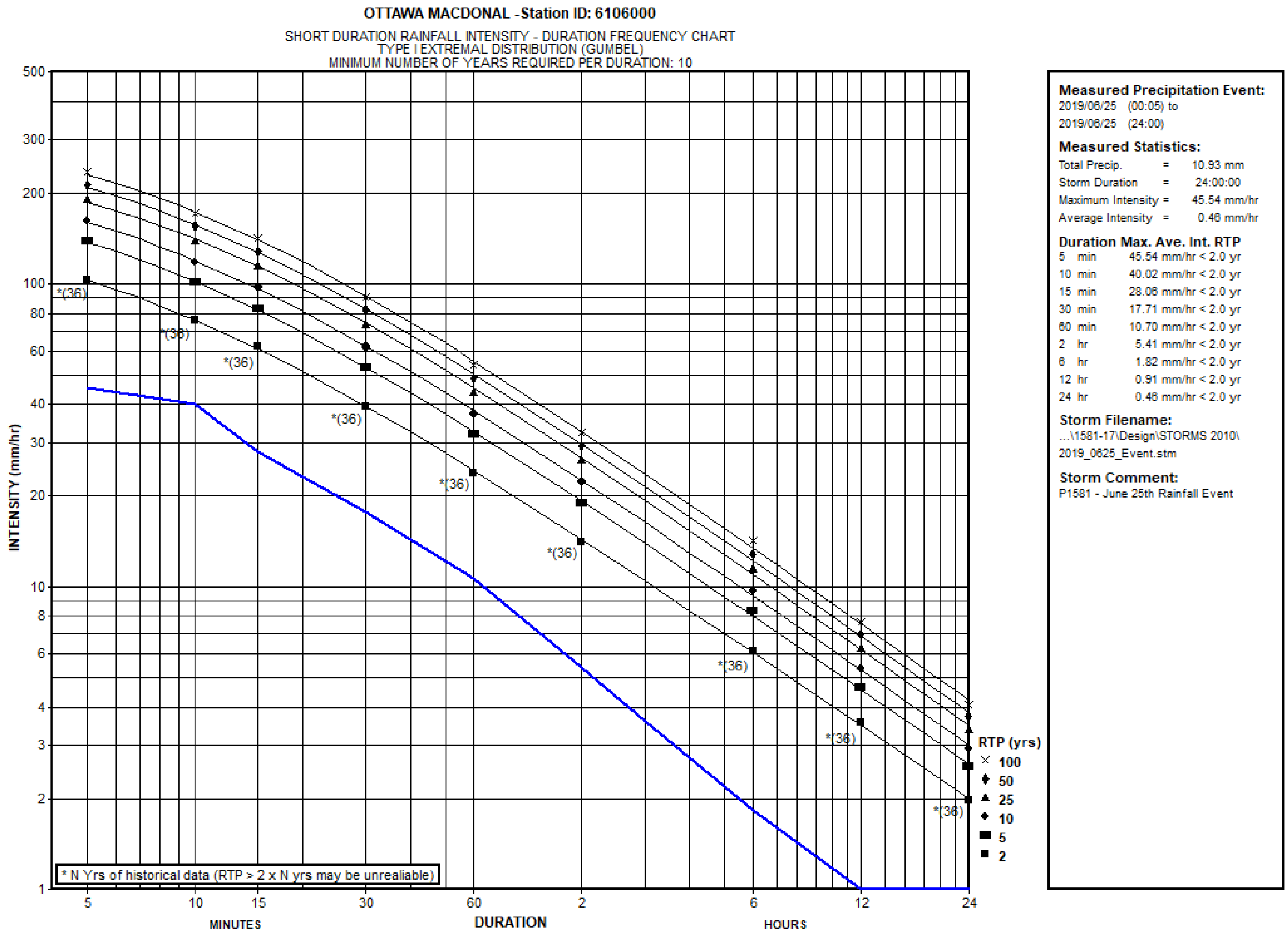


June 25th Rainfall Event (06/25/2019 00:00 – 06/25/2019 24:00)

Total Precipitation = 10.93mm
Maximum Intensity = 45.54 mm/hr
Average Intensity = 0.46 mm/hr

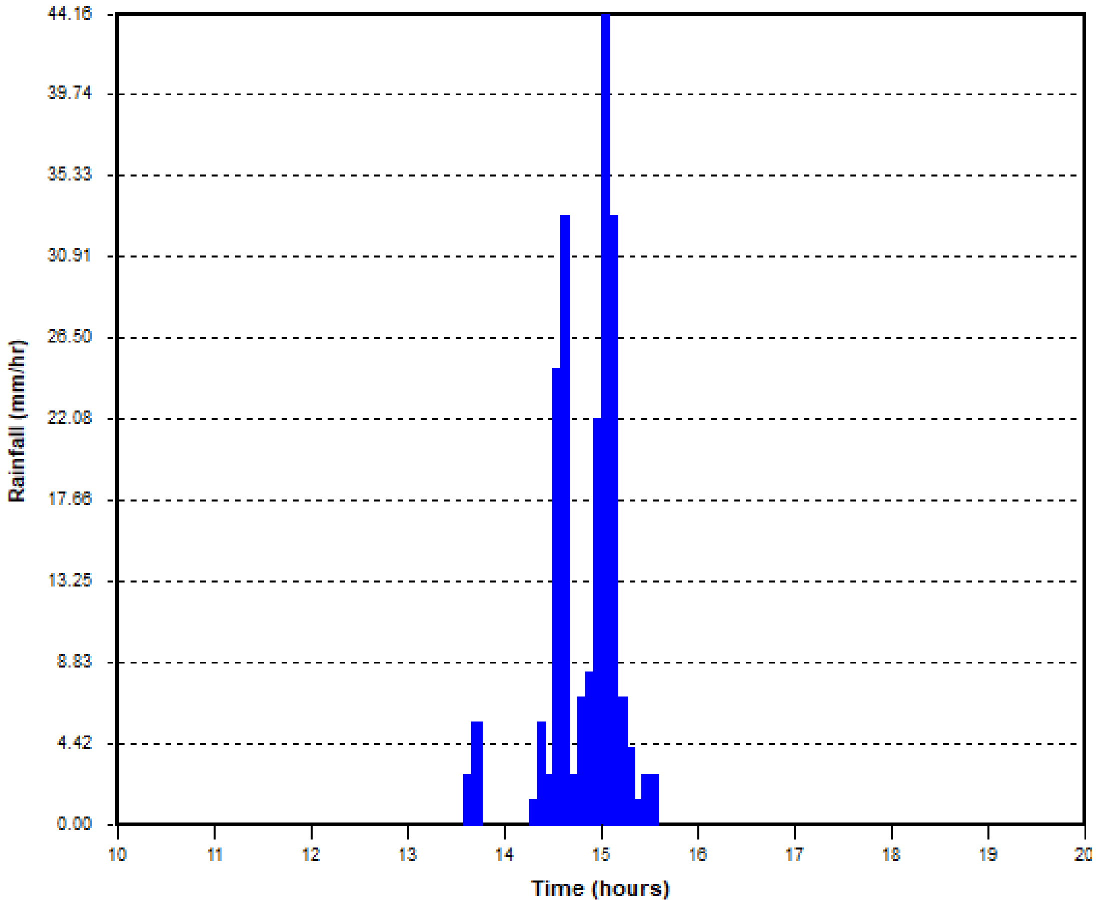


June 25th Duration Rainfall Intensity – Duration Frequency Chart (06/25/2019 00:00 – 06/25/2019 24:00)

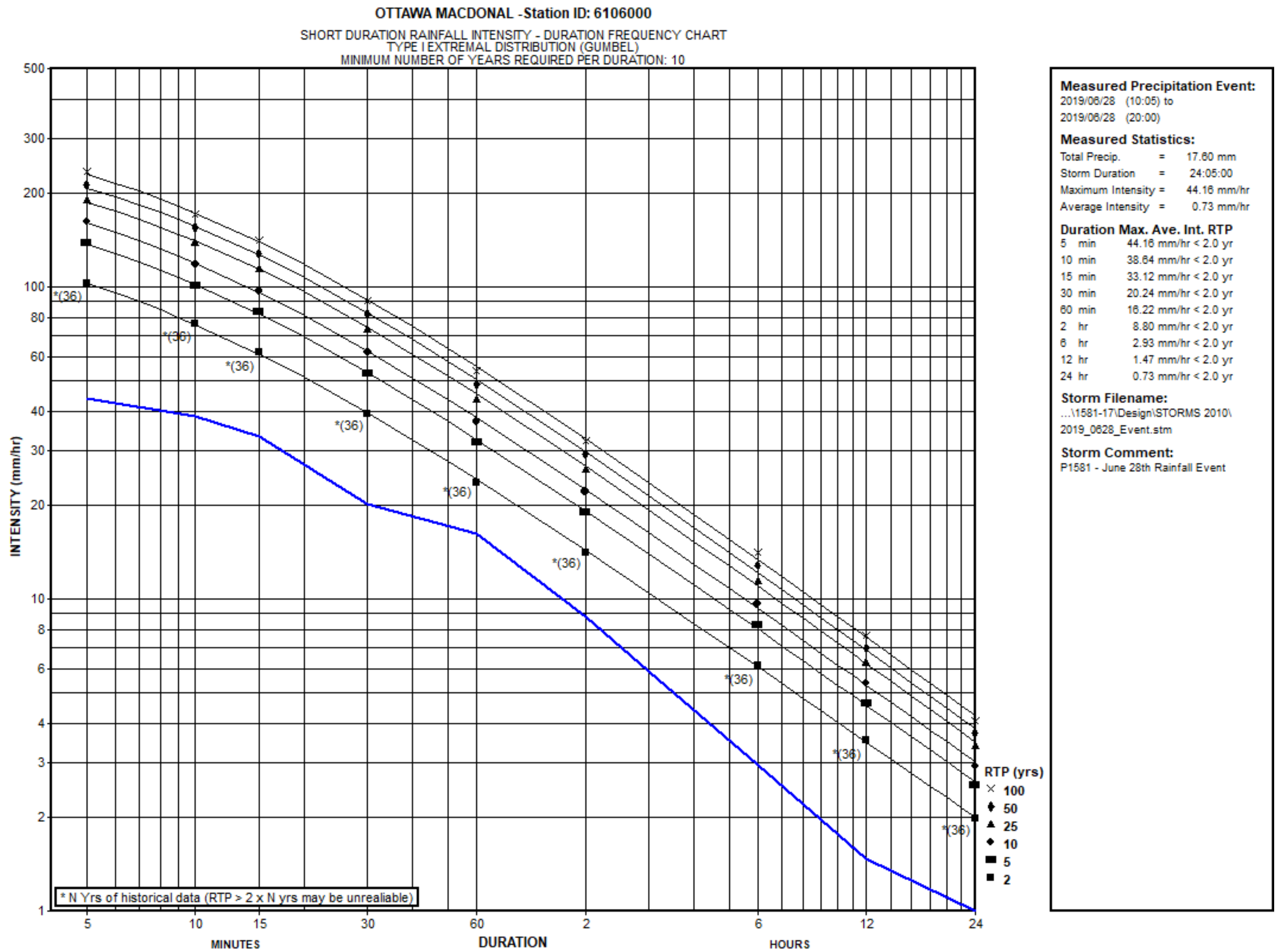


June 28th Rainfall Event (06/28/2019 10:00 – 06/28/2019 20:00)

Total Precipitation = 17.60 mm
Maximum Intensity = 44.16 mm/hr
Average Intensity = 0.73 mm/hr

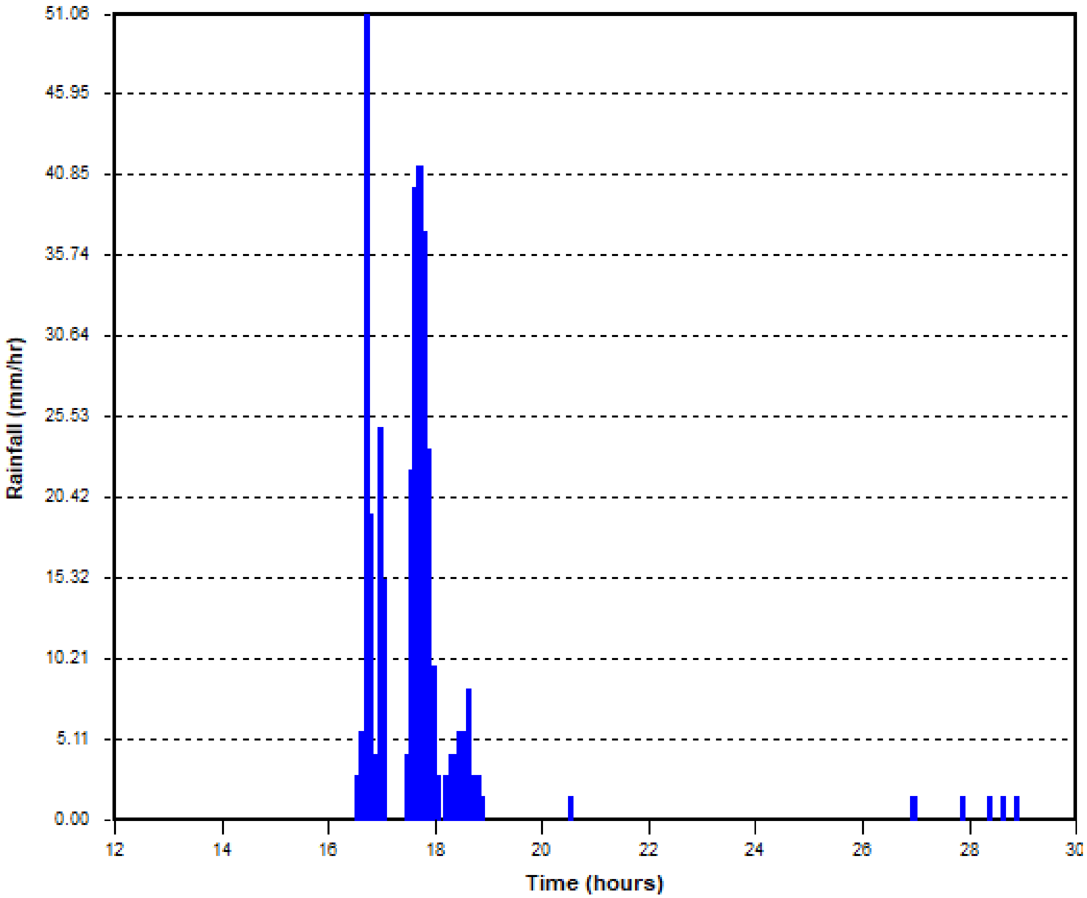


June 28th Duration Rainfall Intensity – Duration Frequency Chart (06/28/2019 00:00 – 06/28/2019 24:00)

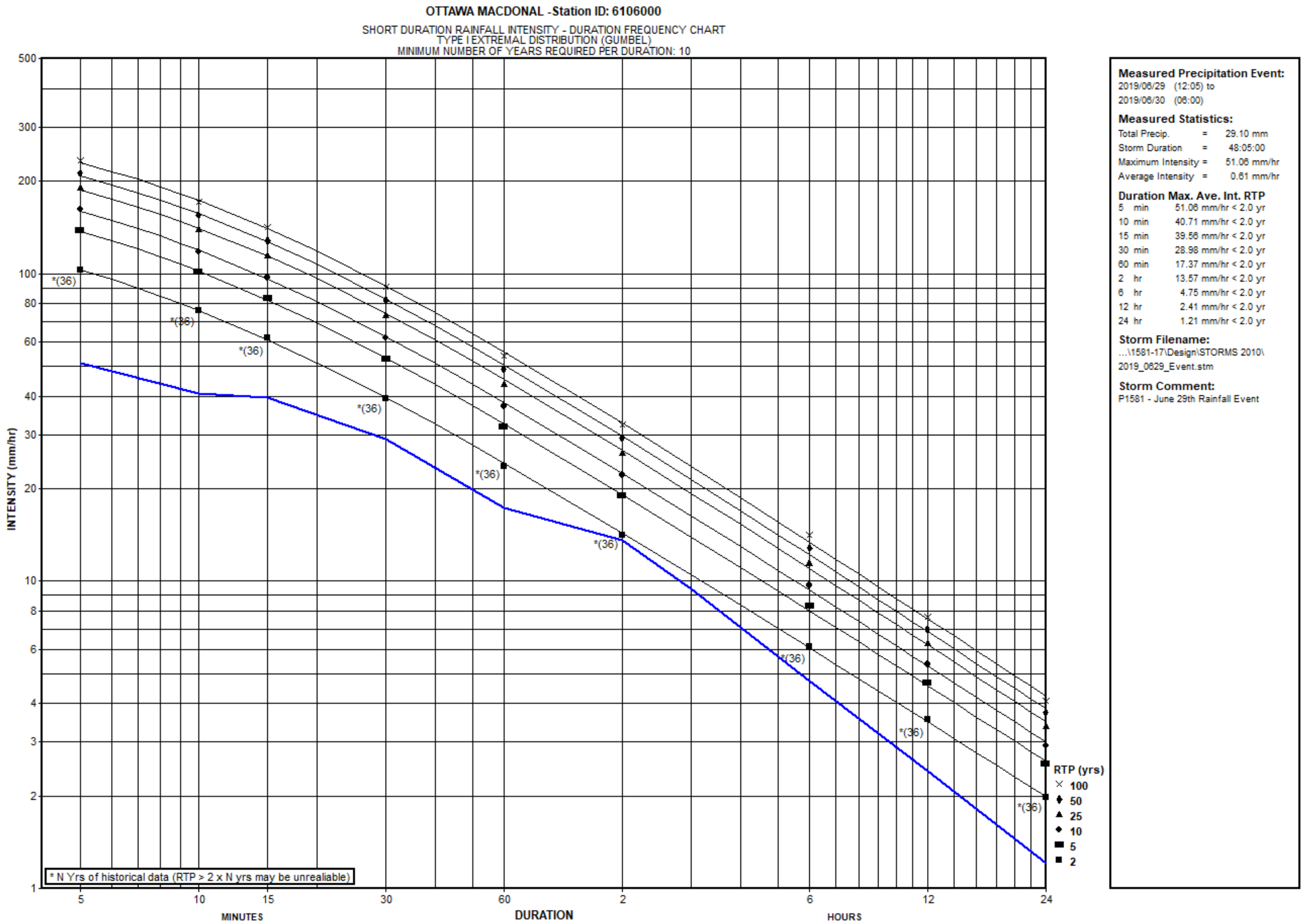


June 29th Rainfall Event (06/29/2019 12:00 – 06/30/2019 06:00)

Total Precipitation = 29.10 mm
Maximum Intensity = 51.06 mm/hr
Average Intensity = 0.61 mm/hr

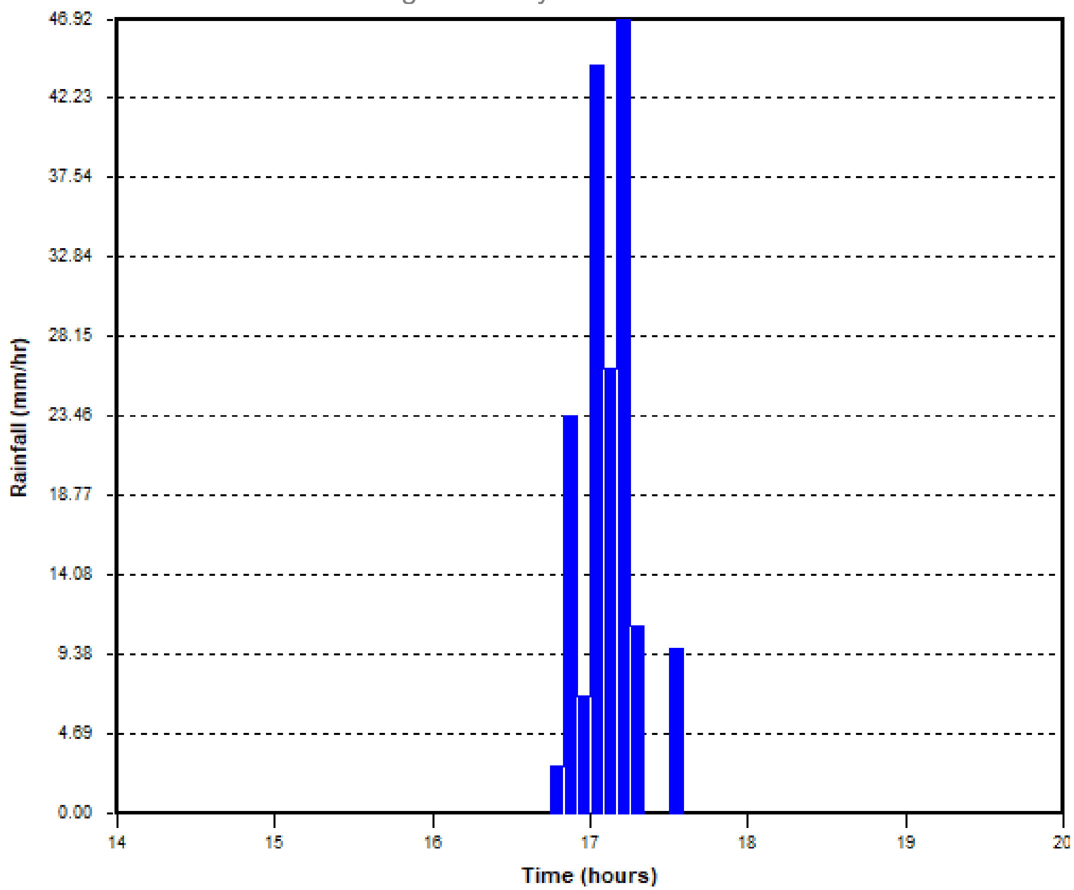


June 29th Duration Rainfall Intensity – Duration Frequency Chart (06/29/2019 12:00 – 06/30/2019 06:00)

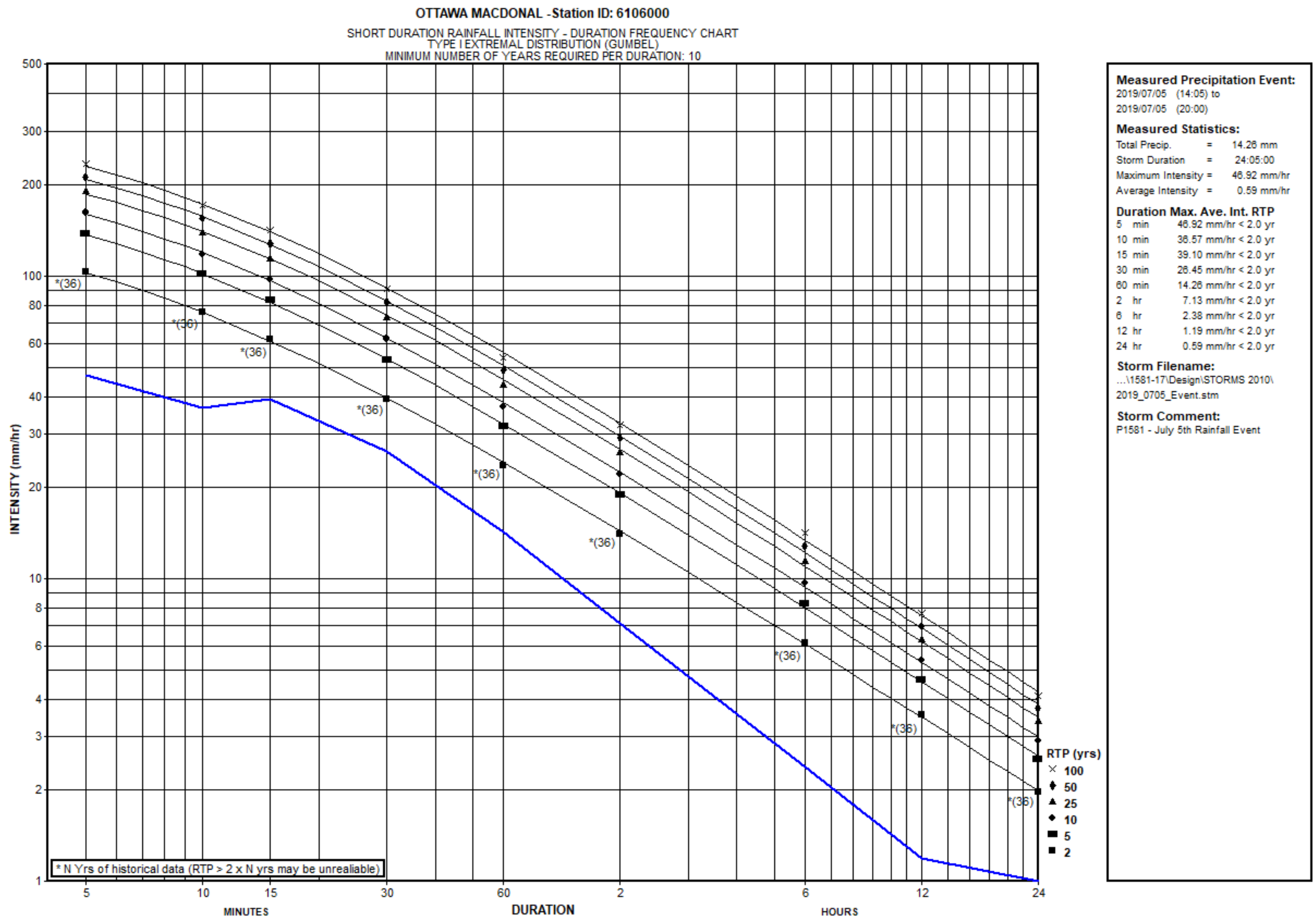


July 5th Rainfall Event (07/05/2019 14:00 – 07/05/2019 20:00)

Total Precipitation = 14.26 mm
Maximum Intensity = 46.92 mm/hr
Average Intensity = 0.59 mm/hr

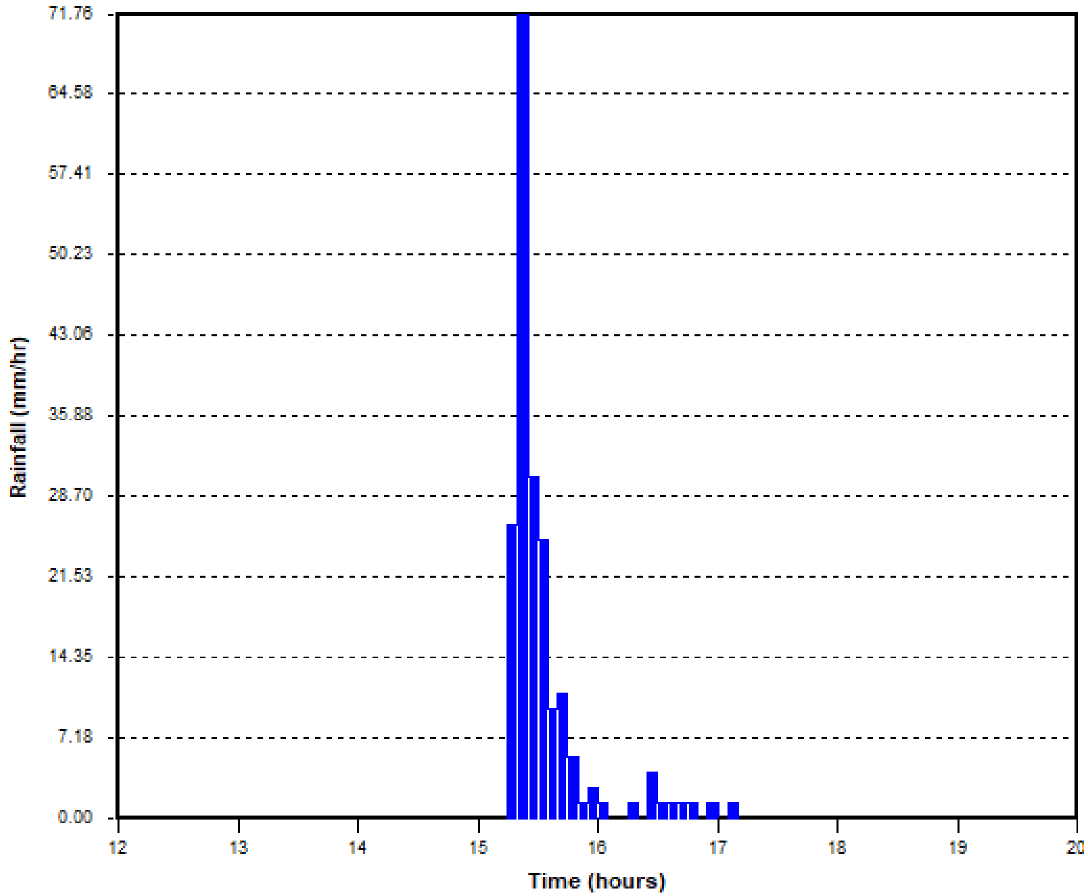


July 5th Duration Rainfall Intensity – Duration Frequency Chart (07/05/2019 14:00 – 07/05/2019 20:00)

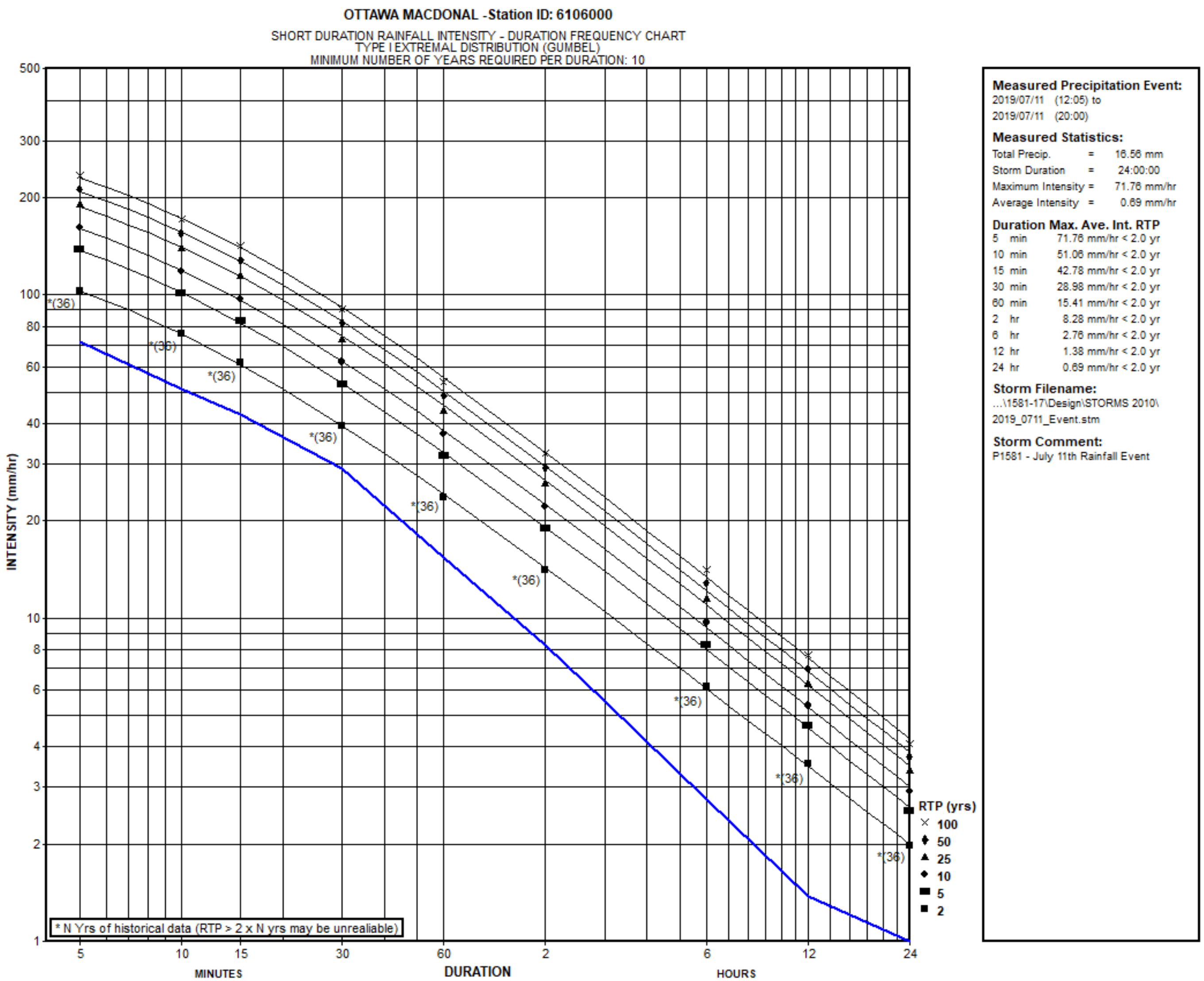


July 11th Rainfall Event (07/11/2019 12:00 – 07/11/2019 20:00)

Total Precipitation = 16.56 mm
Maximum Intensity = 71.76 mm/hr
Average Intensity = 0.69 mm/hr

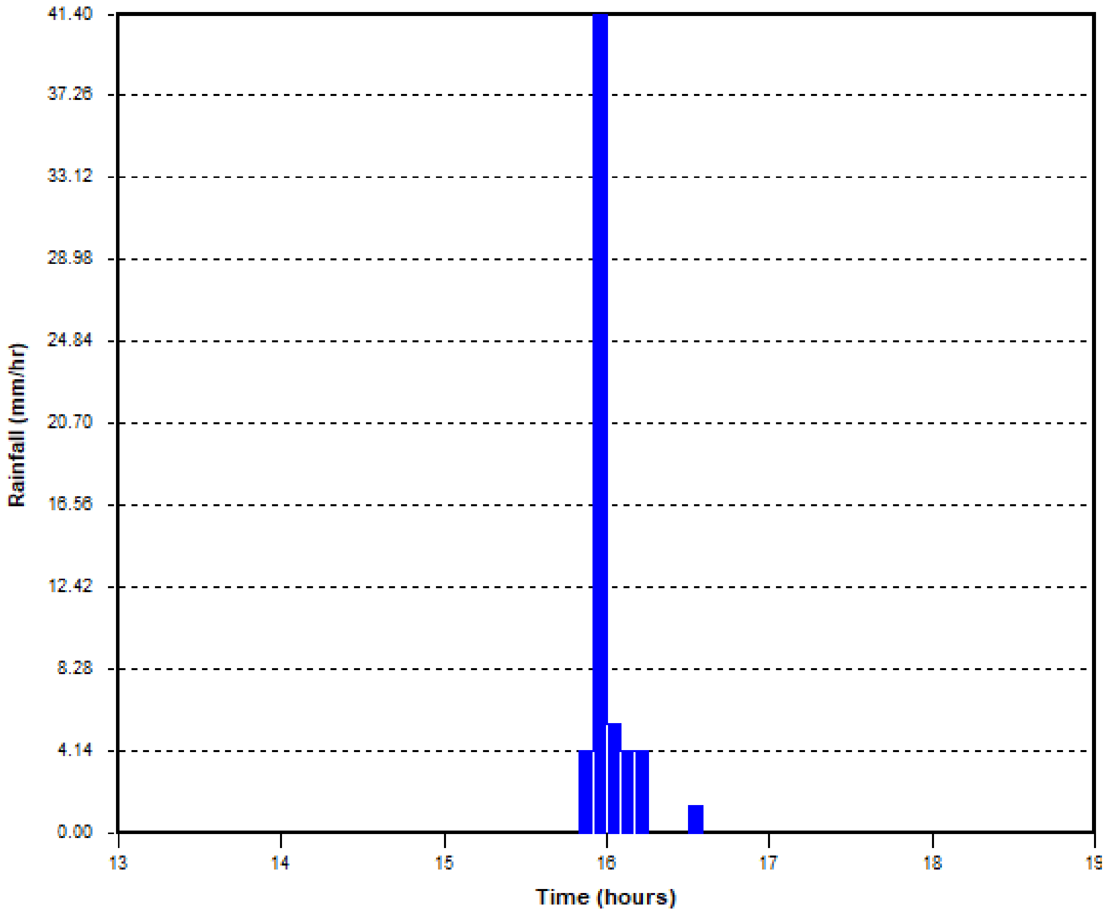


July 11th Duration Rainfall Intensity – Duration Frequency Chart (07/11/2019 12:00 – 07/11/2019 20:00)

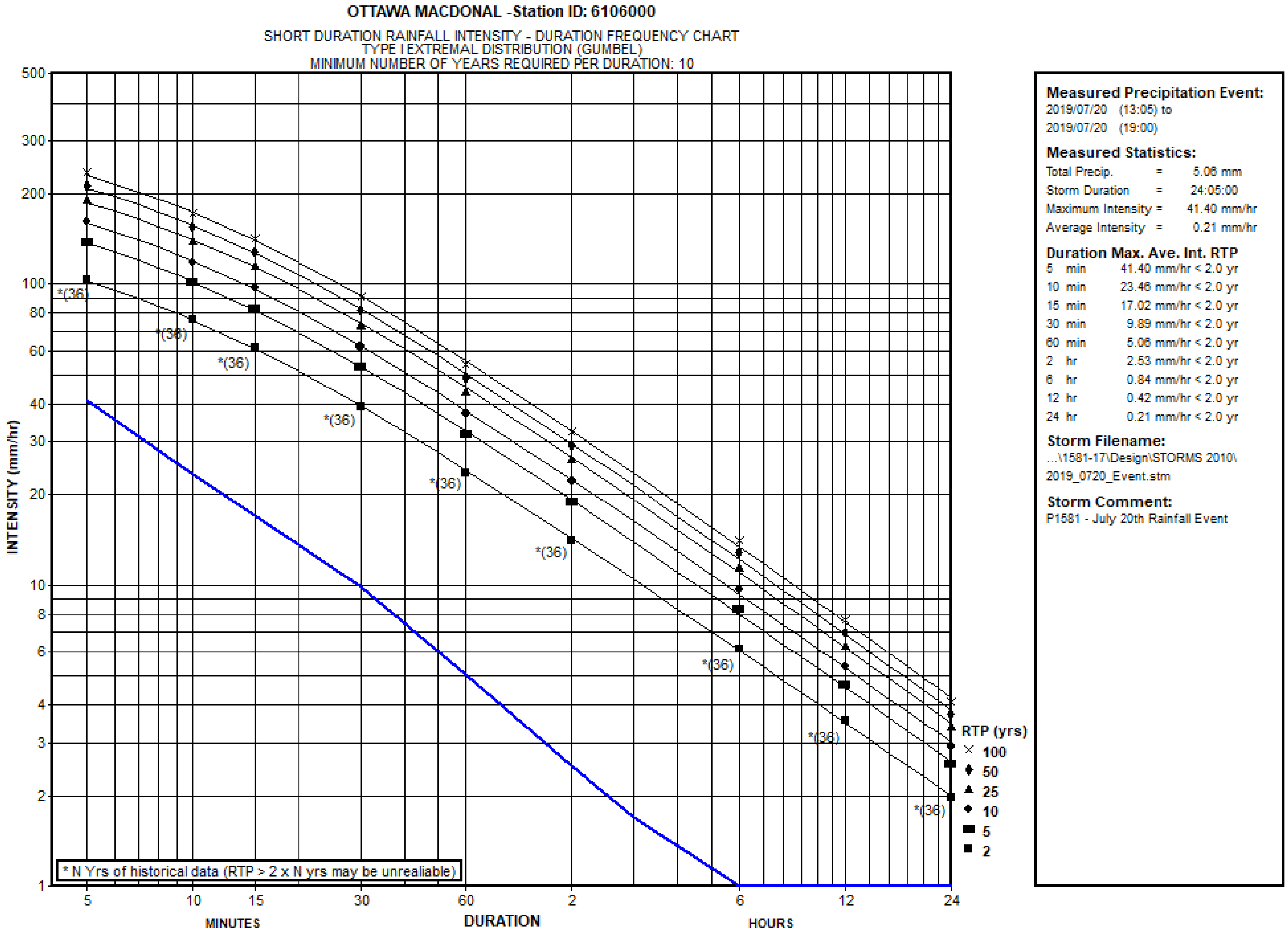


July 20th Rainfall Event (07/20/2019 13:00 – 07/20/2019 19:00)

Total Precipitation = 5.06 mm
Maximum Intensity = 41.40 mm/hr
Average Intensity = 0.21 mm/hr

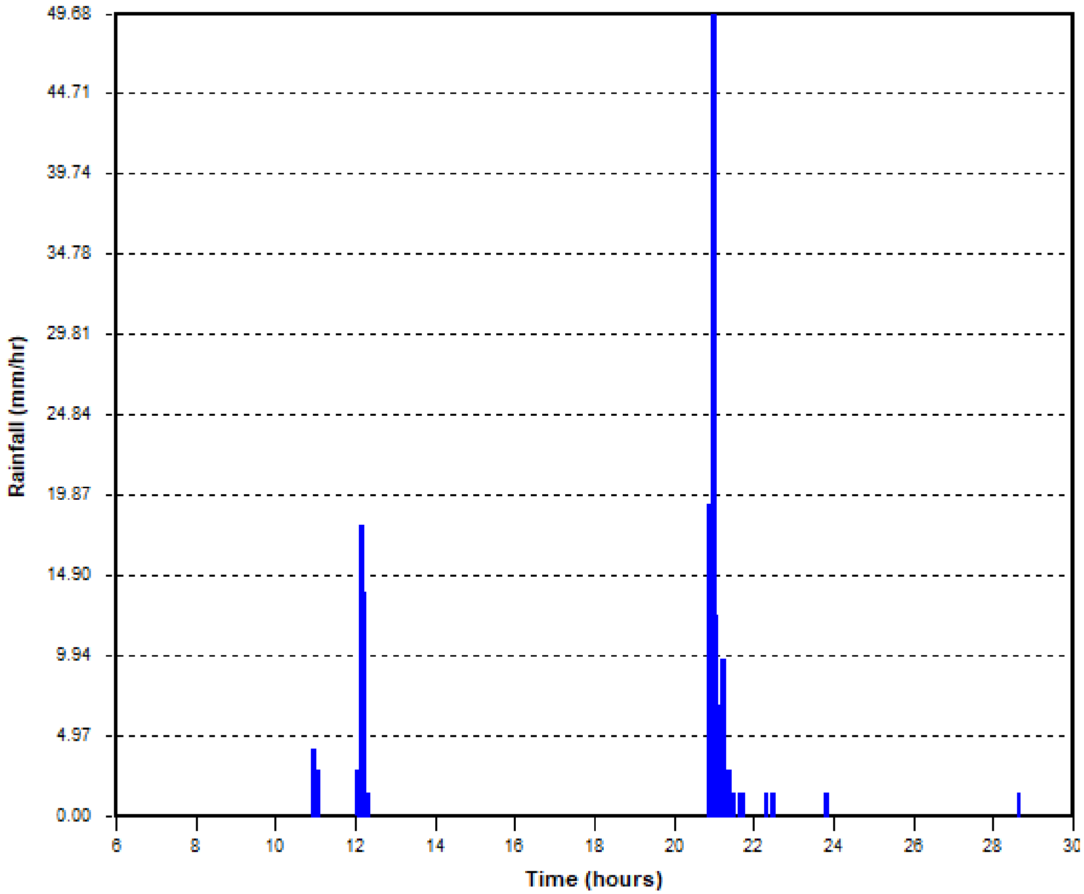


July 20th Duration Rainfall Intensity – Duration Frequency Chart (07/20/2019 13:00 – 07/20/2019 19:00)

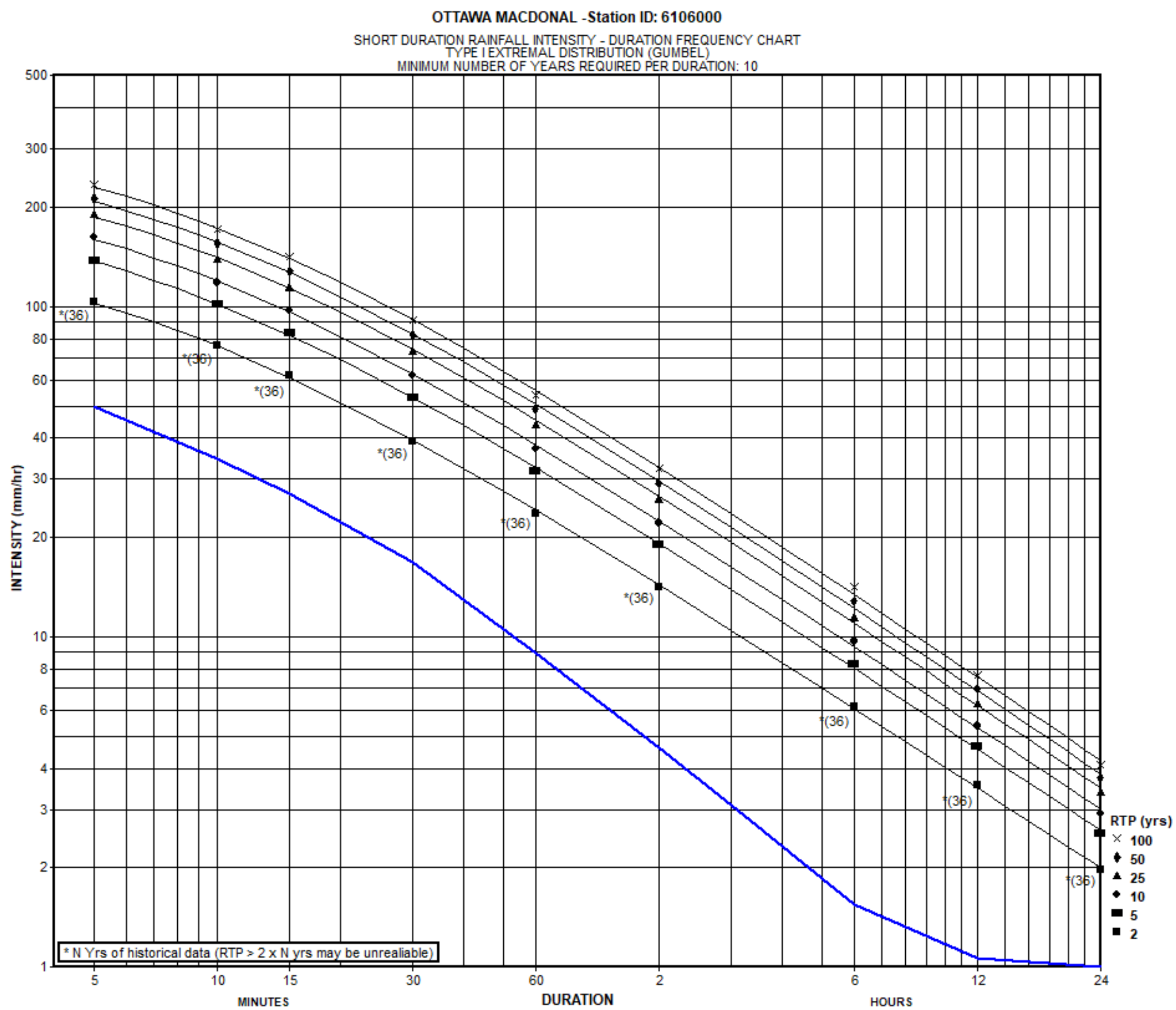


July 30th Rainfall Event (07/30/2019 06:00 – 07/31/2019 06:00)

Total Precipitation = 13.00 mm
Maximum Intensity = 49.68 mm/hr
Average Intensity = 0.27 mm/hr



July 30th Duration Rainfall Intensity – Duration Frequency Chart (07/30/2019 06:00 – 07/31/2019 06:00)



Measured Precipitation Event:
2019/07/30 (06:05) to
2019/07/31 (06:00)

Measured Statistics:

Total Precip.	=	13.00 mm
Storm Duration	=	48:05:00
Maximum Intensity	=	49.68 mm/hr
Average Intensity	=	0.27 mm/hr

Duration Max. Ave. Int. RTP

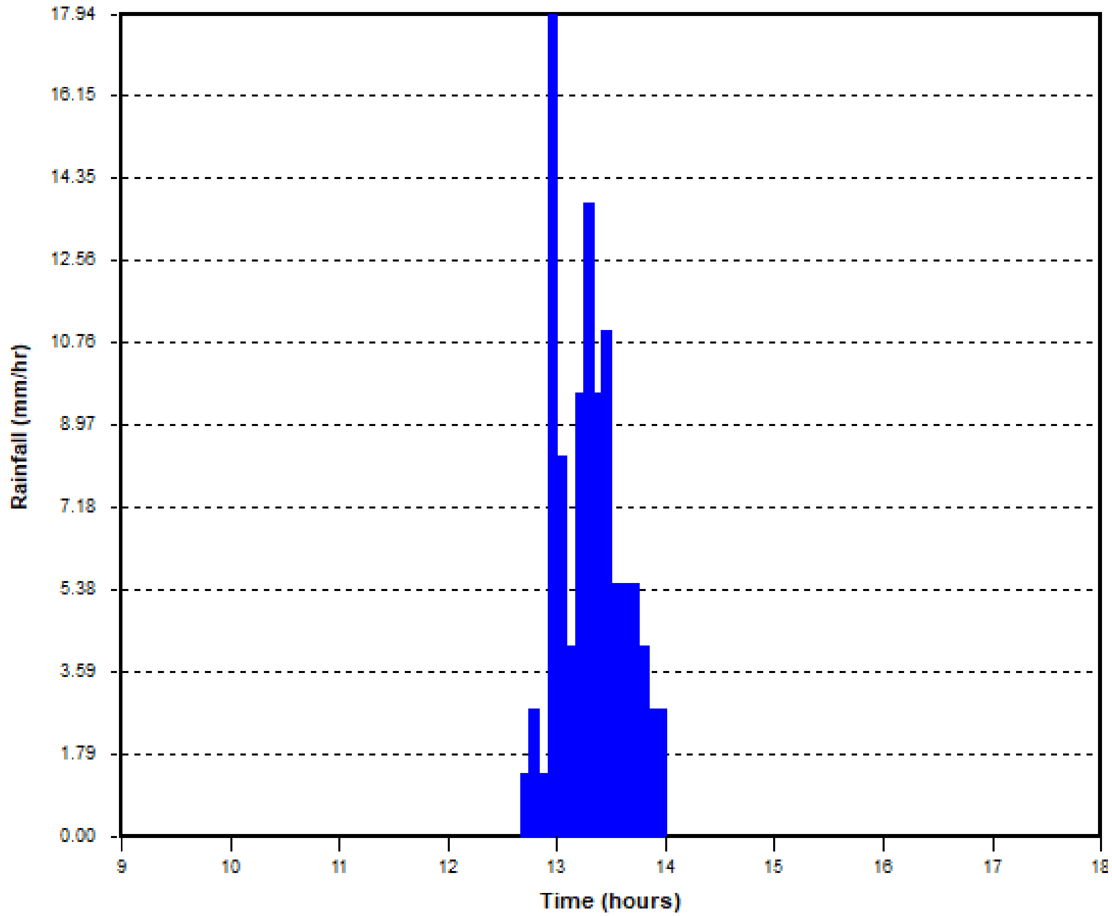
5 min	49.68 mm/hr	< 2.0 yr
10 min	34.50 mm/hr	< 2.0 yr
15 min	27.14 mm/hr	< 2.0 yr
30 min	16.79 mm/hr	< 2.0 yr
60 min	8.97 mm/hr	< 2.0 yr
2 hr	4.60 mm/hr	< 2.0 yr
6 hr	1.55 mm/hr	< 2.0 yr
12 hr	1.06 mm/hr	< 2.0 yr
24 hr	0.54 mm/hr	< 2.0 yr

Storm Filename:
...\1581-17\Design\STORMS 2010\
2019_0730_Event.stm

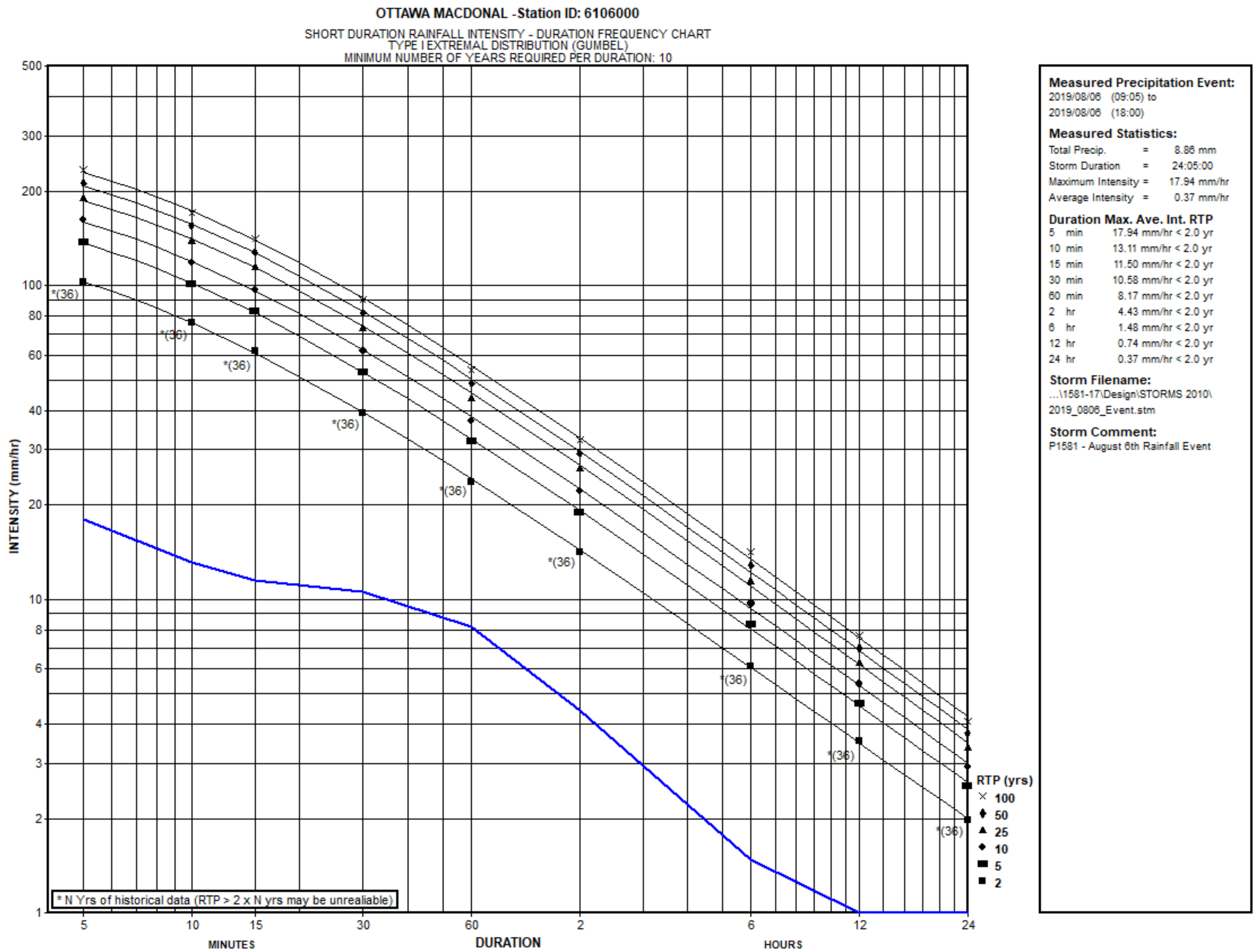
Storm Comment:
P1581 - July 30th Rainfall Event

August 6th Rainfall Event (08/06/2019 09:00 – 08/06/2019 18:00)

Total Precipitation = 8.86 mm
Maximum Intensity = 17.94 mm/hr
Average Intensity = 0.37 mm/hr

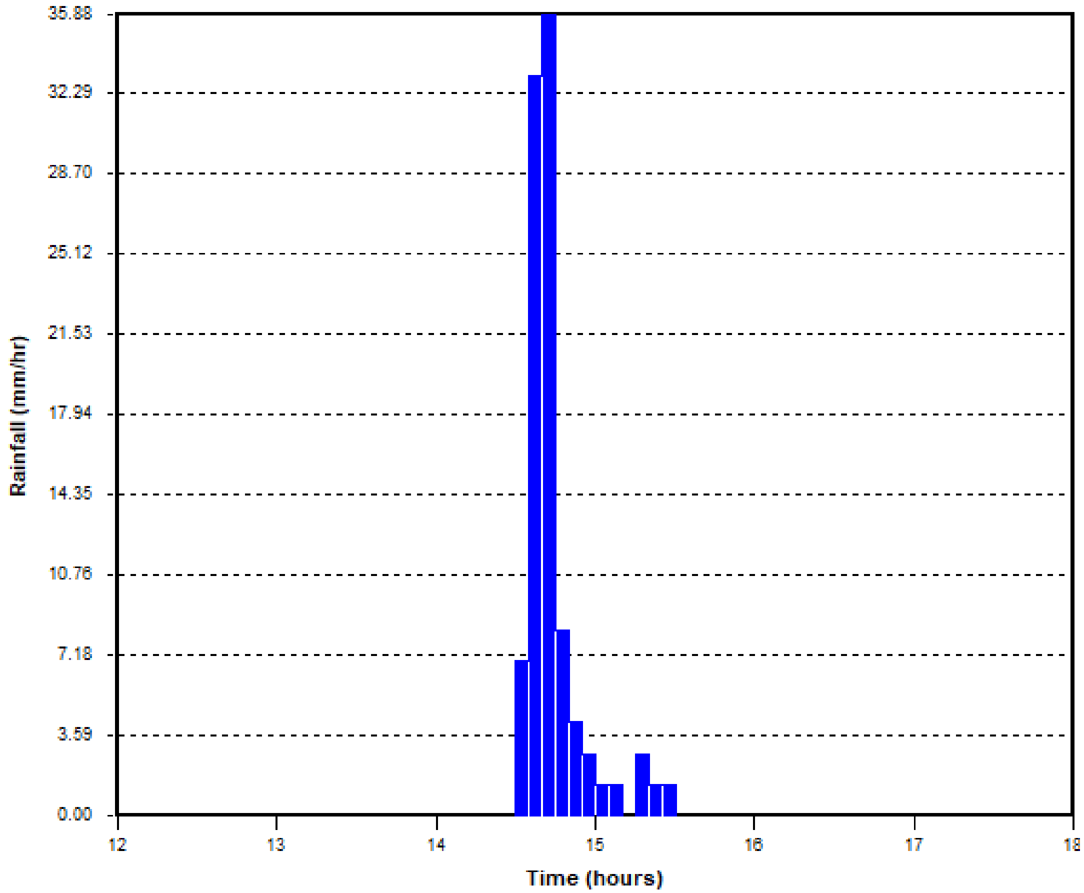


August 6th Duration Rainfall Intensity – Duration Frequency Chart (08/06/2019 09:00 – 08/06/2019 18:00)

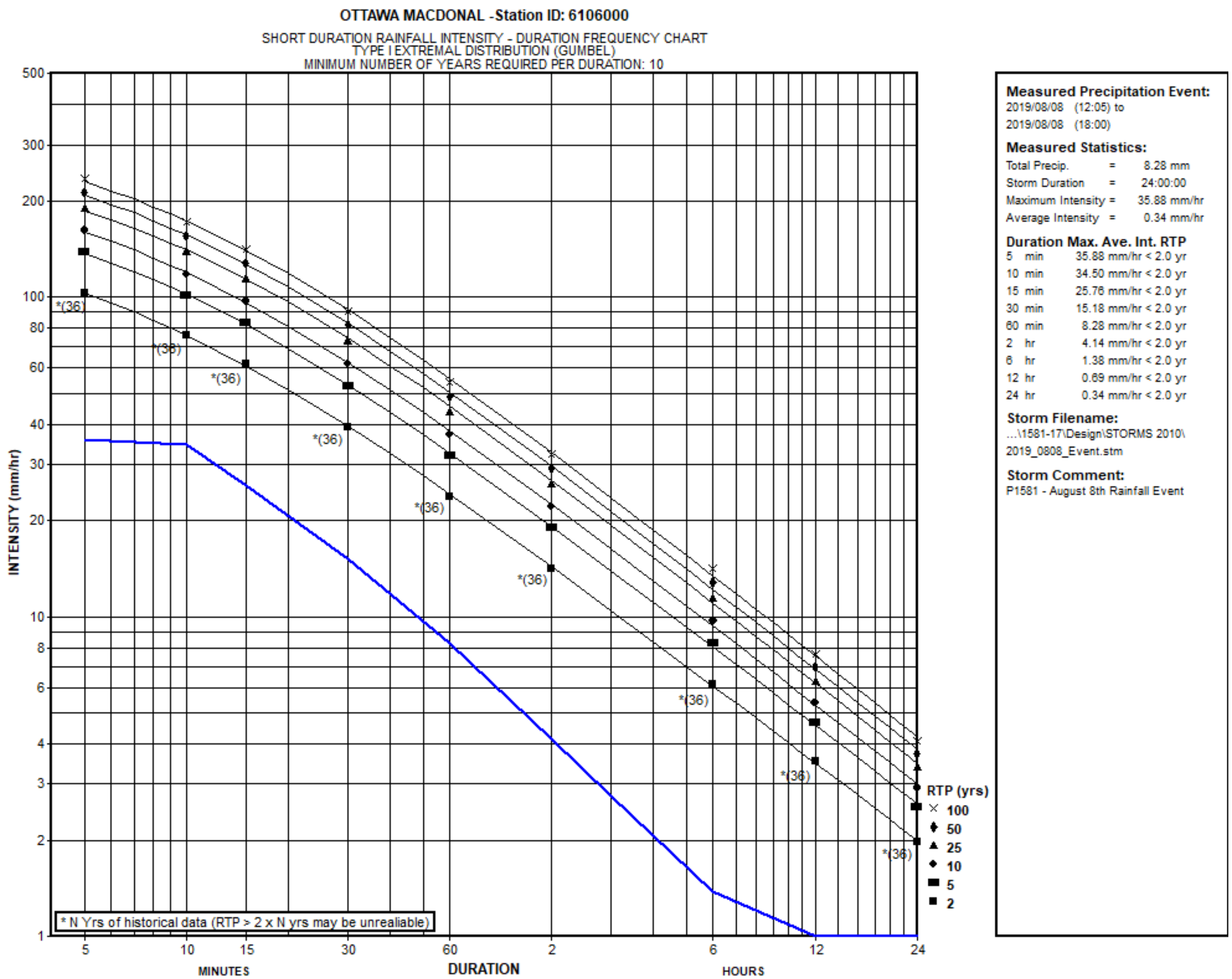


August 8th Rainfall Event (08/08/2019 12:00 – 08/08/2019 18:00)

Total Precipitation = 8.28 mm
Maximum Intensity = 35.88 mm/hr
Average Intensity = 0.34 mm/hr

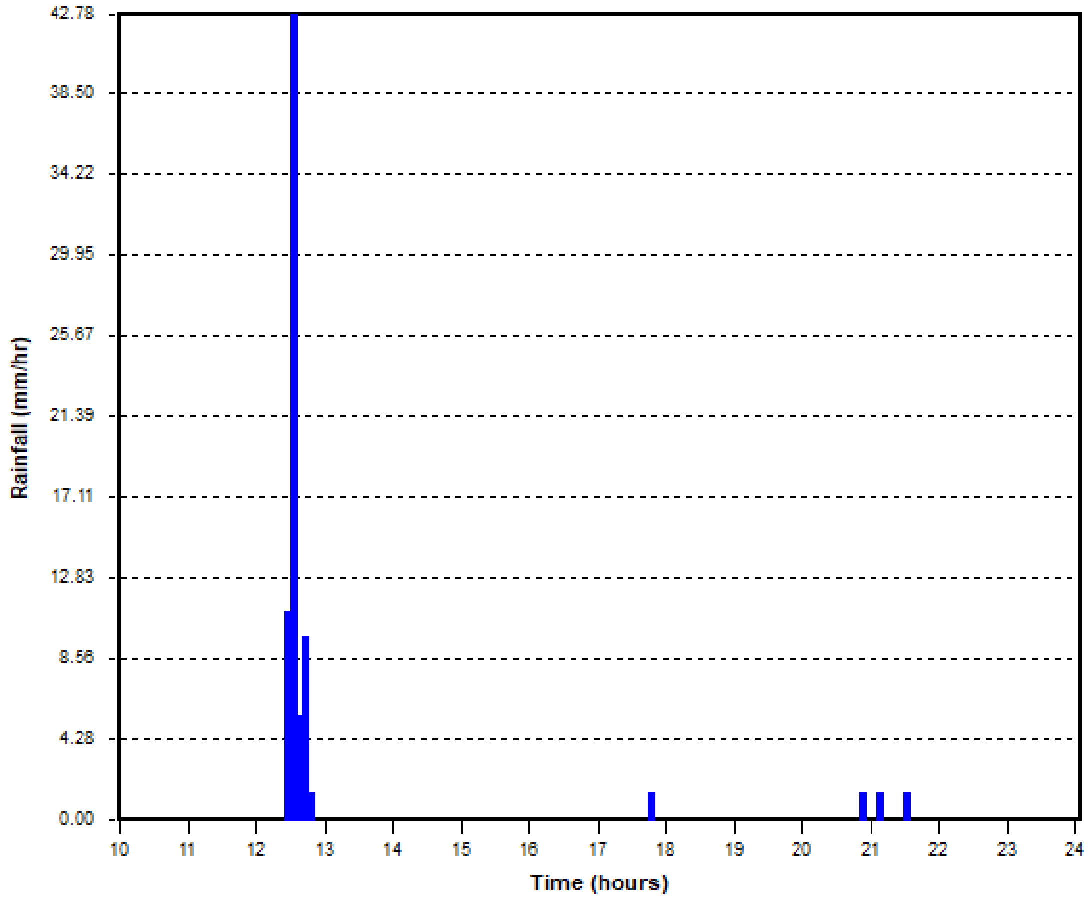


August 8th Duration Rainfall Intensity – Duration Frequency Chart (08/08/2019 12:00 – 08/08/2019 18:00)

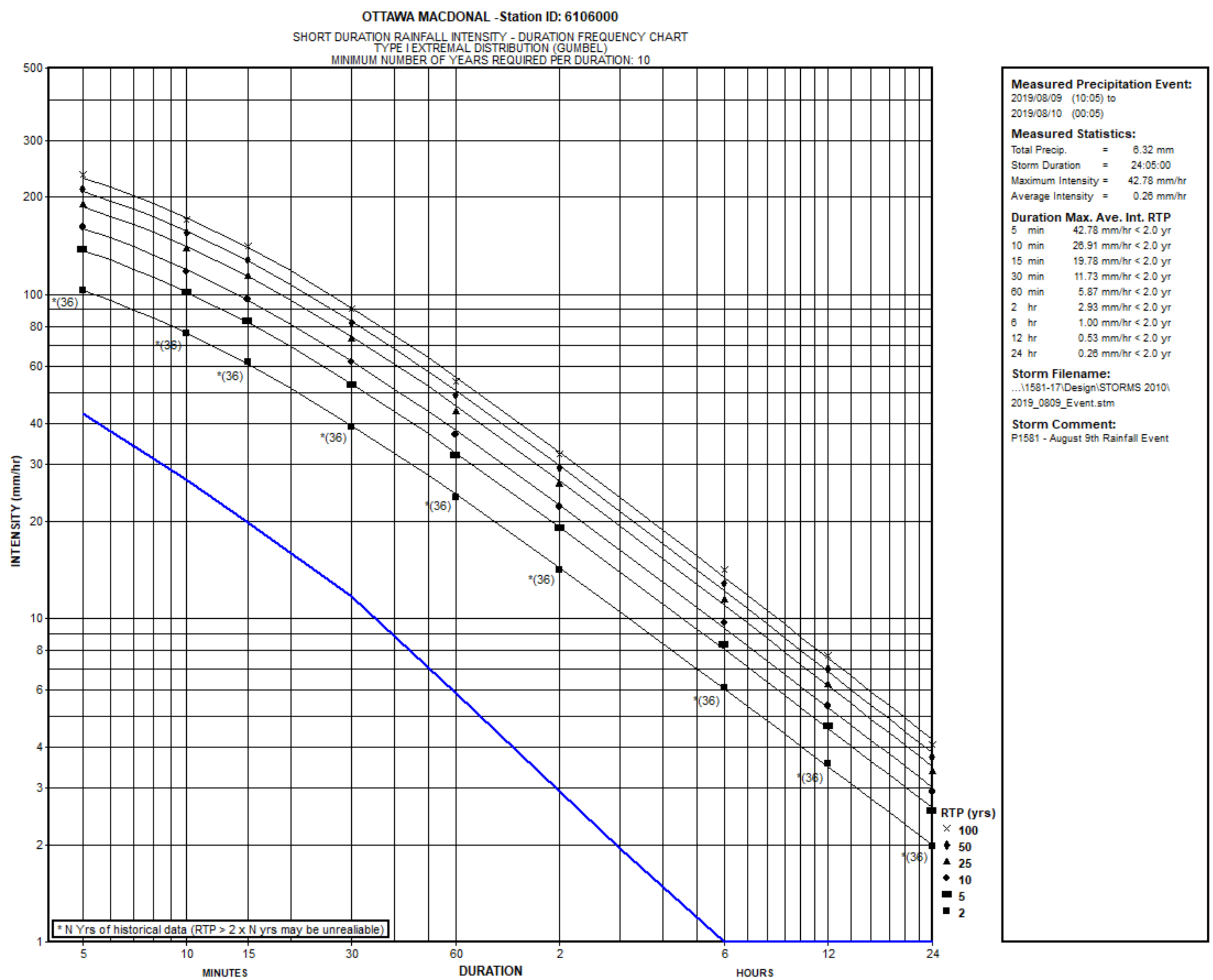


August 9th Rainfall Event (08/09/2019 10:00 – 08/10/2019 00:00)

Total Precipitation = 6.32 mm
Maximum Intensity = 42.78 mm/hr
Average Intensity = 0.26 mm/hr

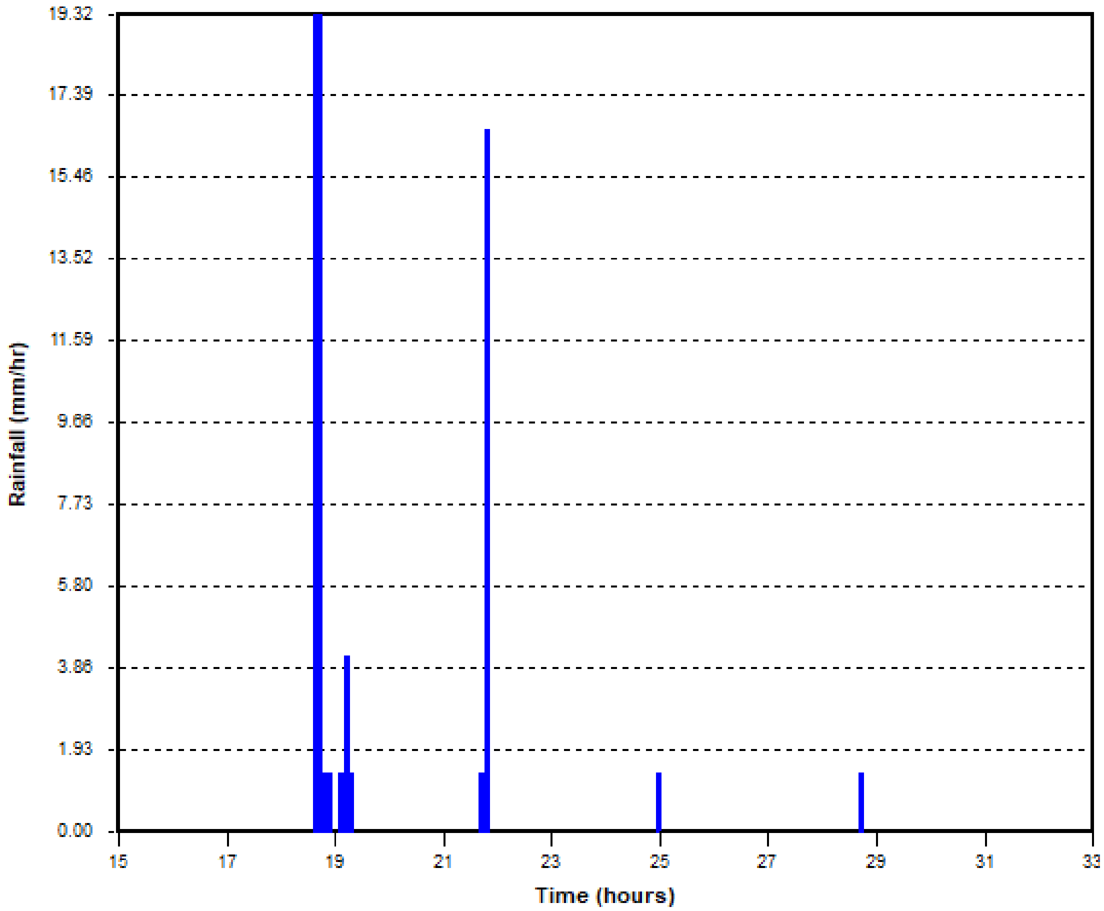


August 9th Duration Rainfall Intensity – Duration Frequency Chart (08/09/2019 12:00 – 08/09/2019 18:00)

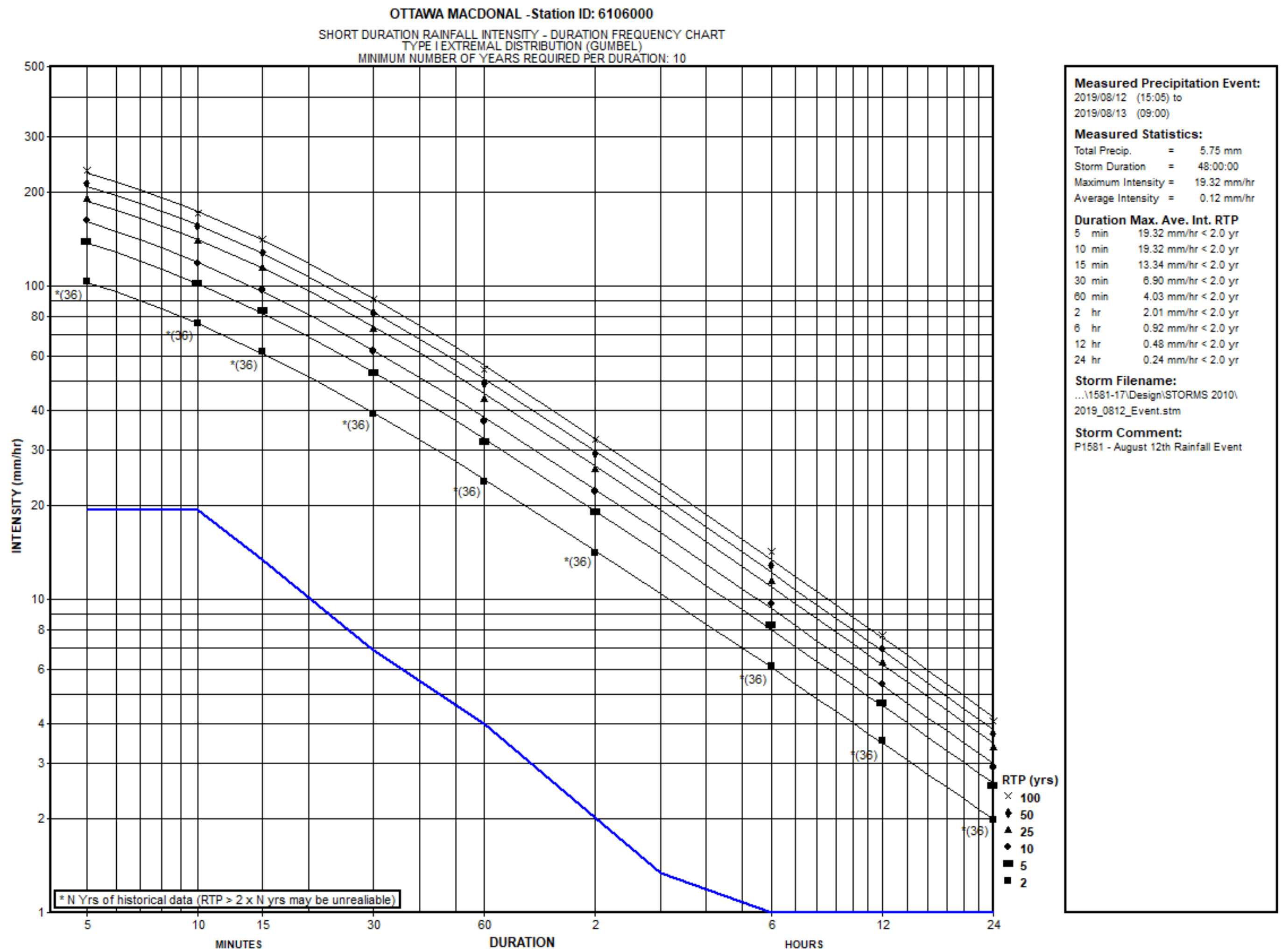


August 12th Rainfall Event (08/12/2019 15:00 – 08/13/2019 09:00)

Total Precipitation = 5.75 mm
Maximum Intensity = 19.32 mm/hr
Average Intensity = 0.12 mm/hr

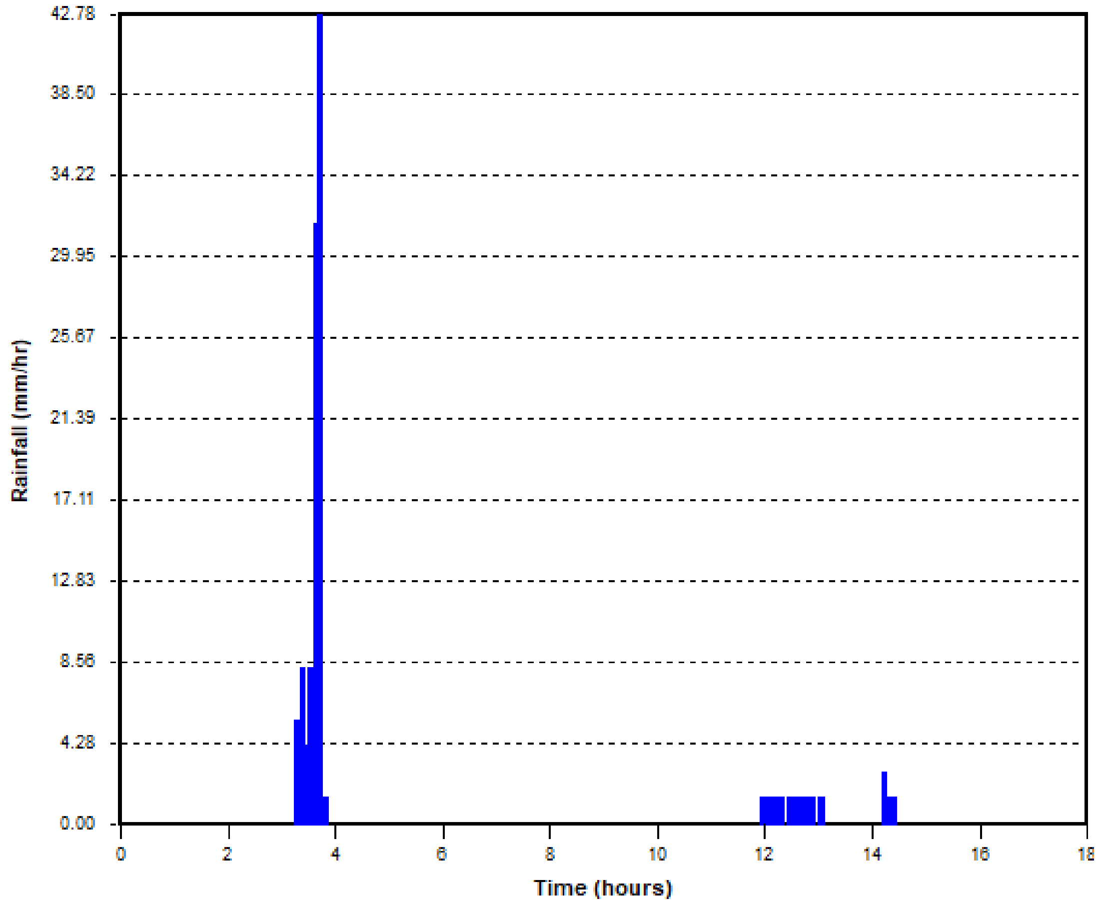


August 13th Duration Rainfall Intensity – Duration Frequency Chart (08/12/2019 15:00 – 08/13/2019 09:00)

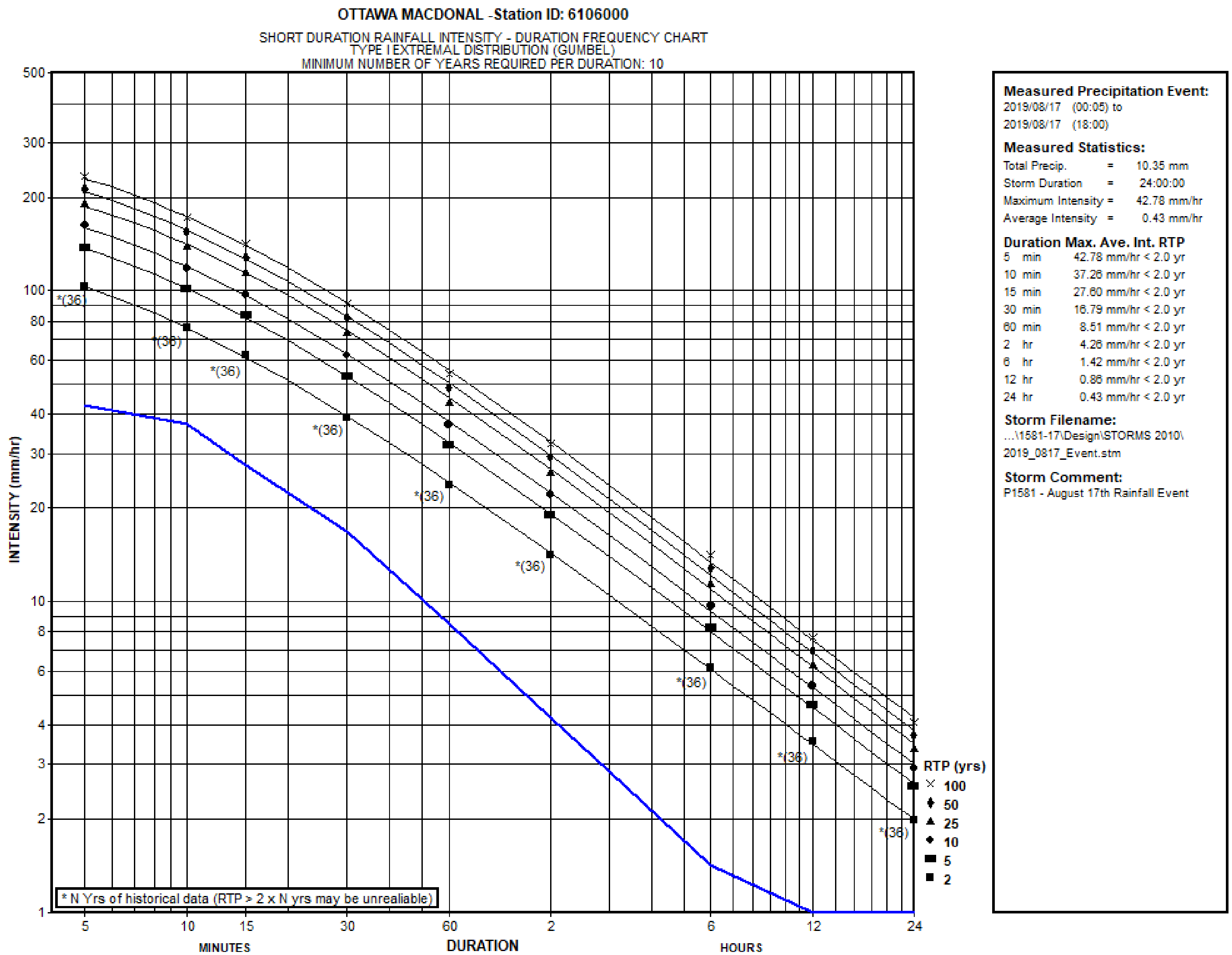


August 17th Rainfall Event (08/17/2019 00:00 – 08/17/2019 18:00)

Total Precipitation = 10.35 mm
Maximum Intensity = 42.78 mm/hr
Average Intensity = 0.43 mm/hr

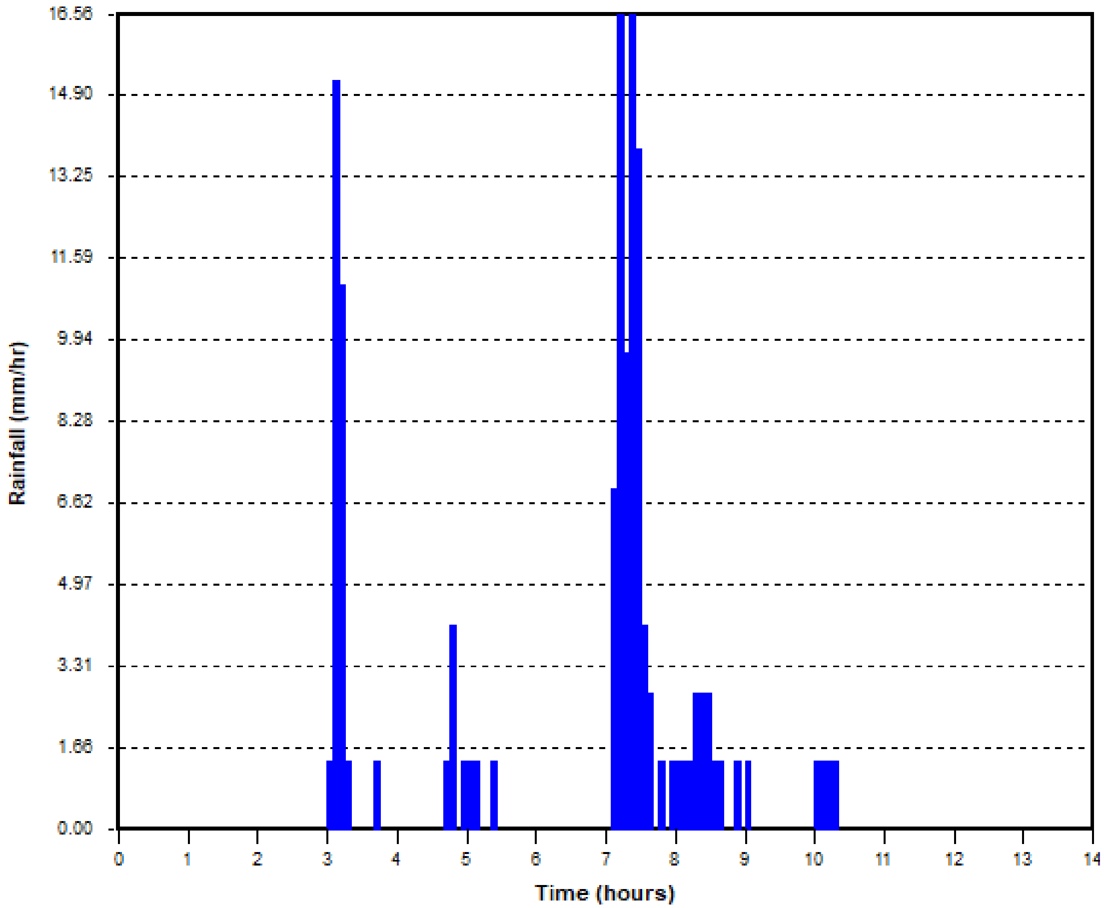


August 17th Duration Rainfall Intensity – Duration Frequency Chart (08/17/2019 00:00 – 08/17/2019 18:00)

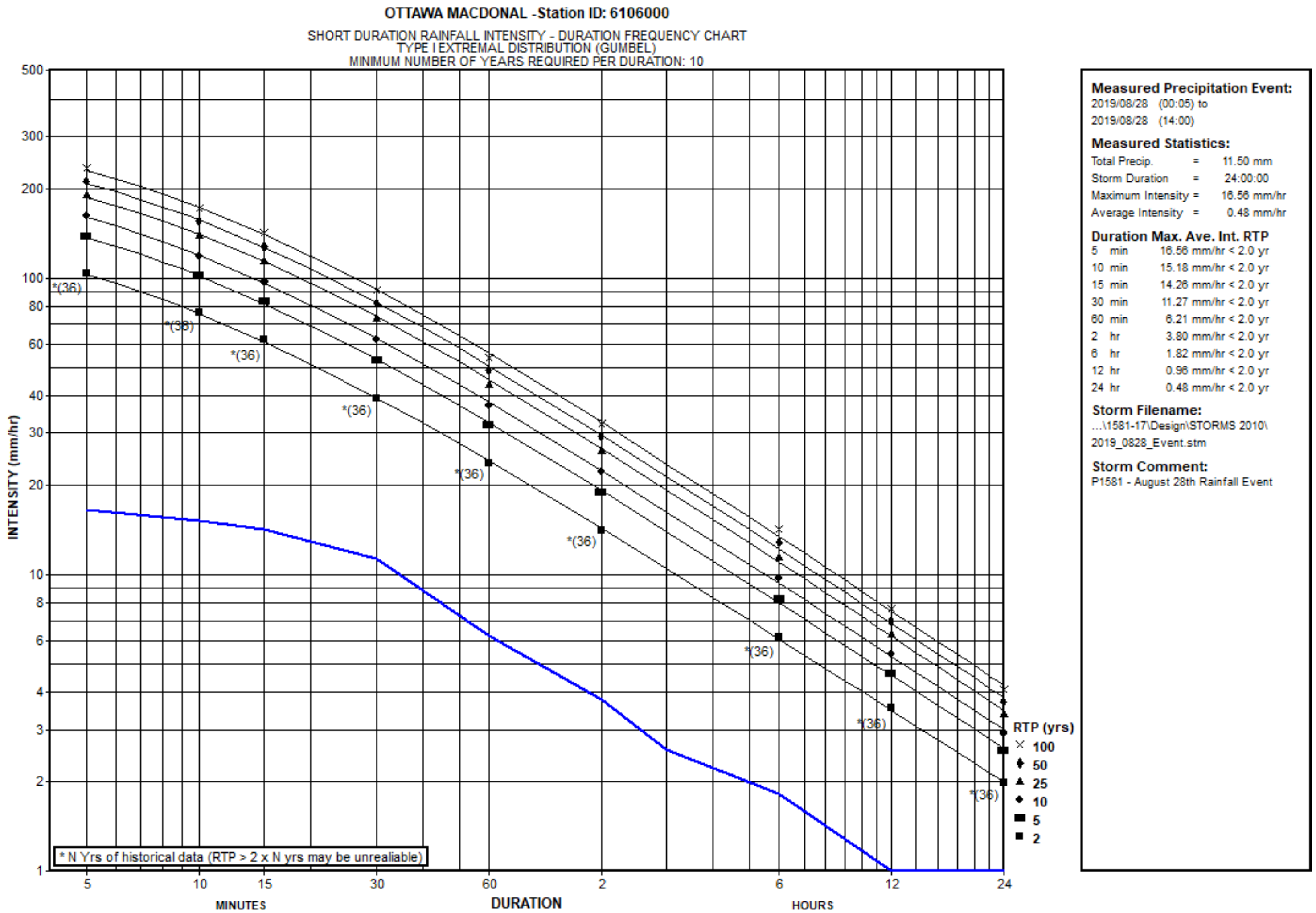


August 28th Rainfall Event (08/28/2019 00:00 – 08/28/2019 14:00)

Total Precipitation = 11.50 mm
Maximum Intensity = 16.56 mm/hr
Average Intensity = 0.48 mm/hr

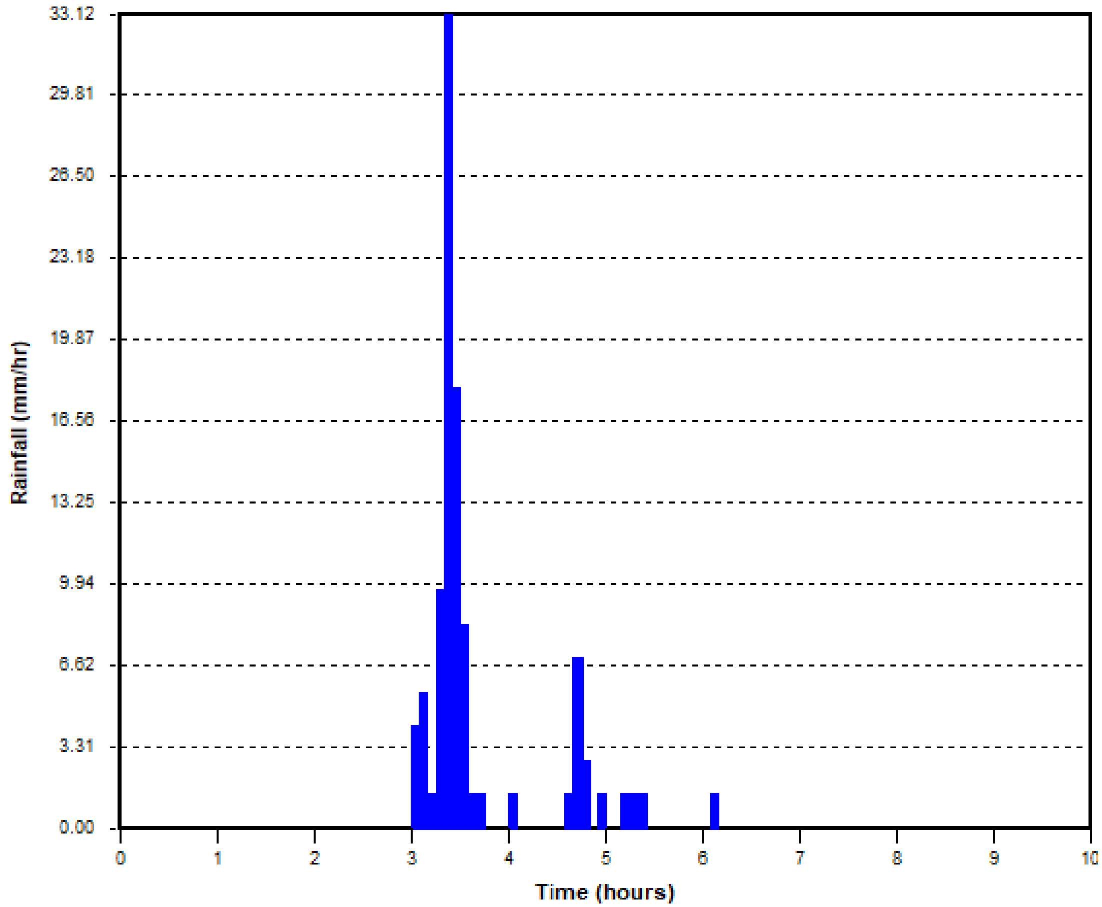


August 28th Duration Rainfall Intensity – Duration Frequency Chart (08/28/2019 00:00 – 08/28/2019 14:00)

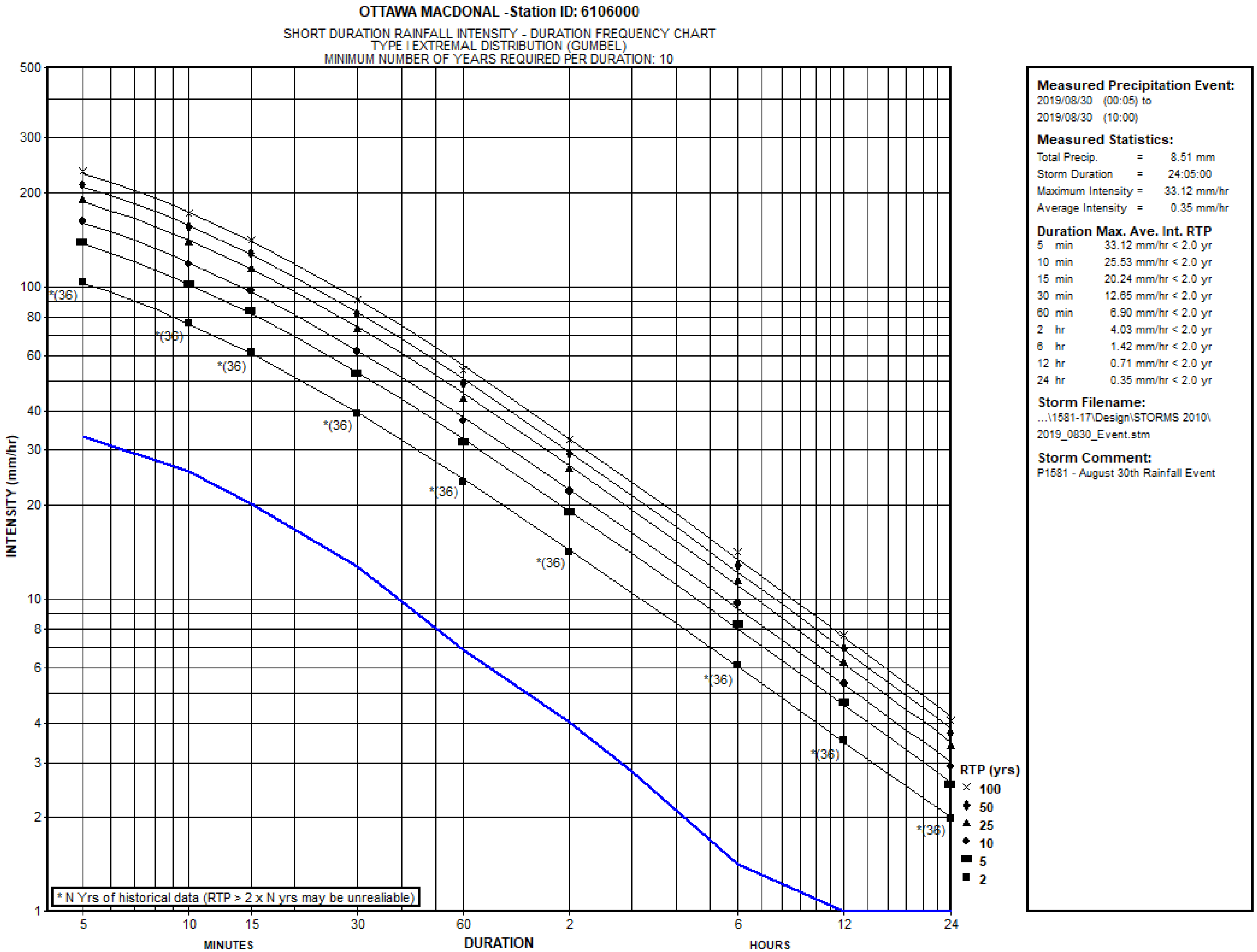


August 30th Rainfall Event (08/30/2019 00:00 – 08/30/2019 10:00)

Total Precipitation = 8.51 mm
Maximum Intensity = 33.12 mm/hr
Average Intensity = 0.35 mm/hr

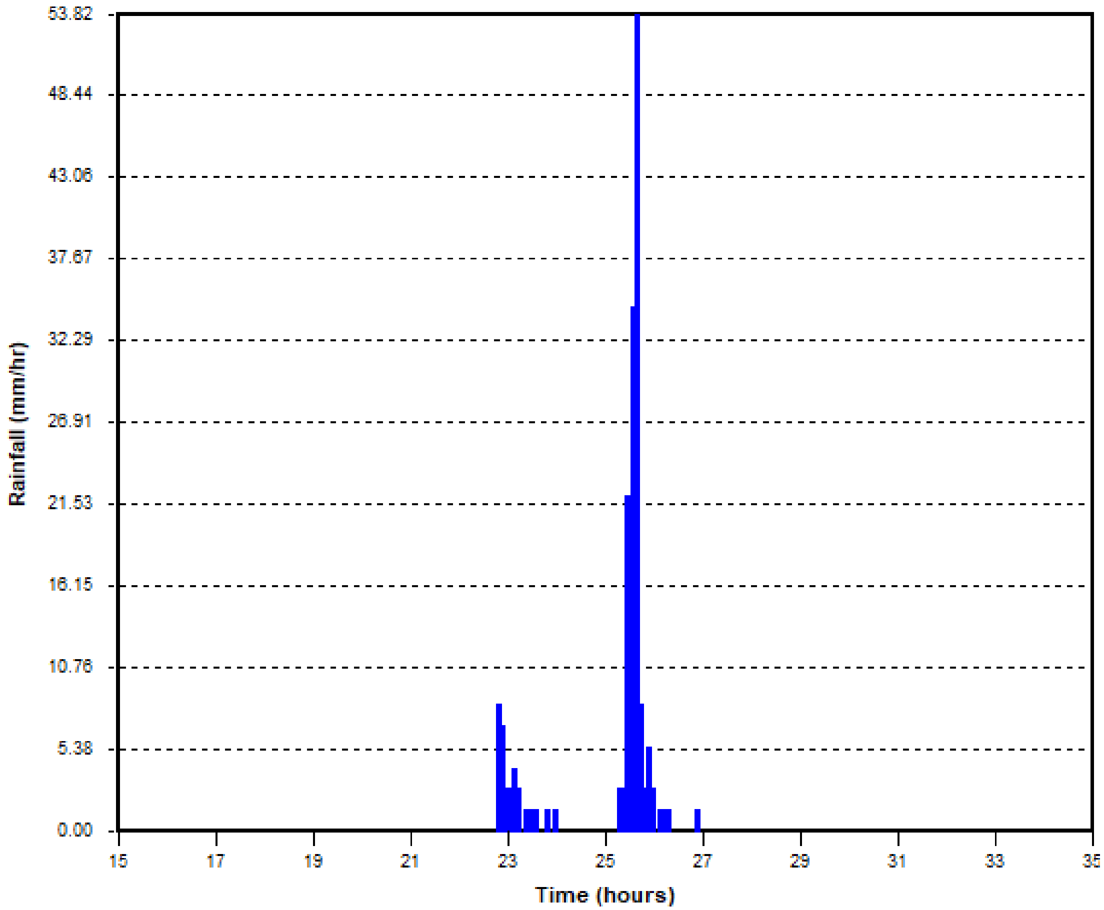


August 30th Duration Rainfall Intensity – Duration Frequency Chart (08/30/2019 00:00 – 08/30/2019 10:00)

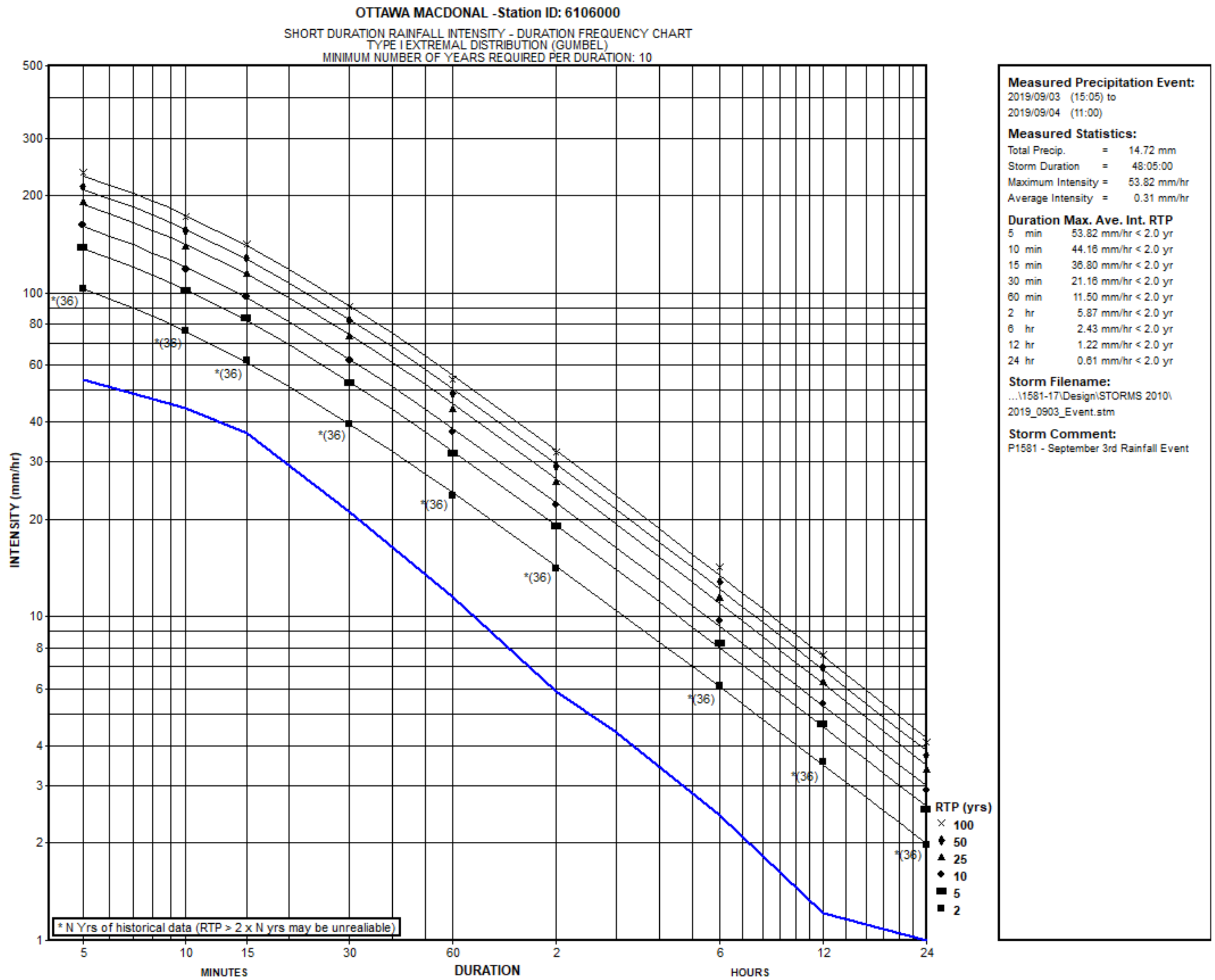


September 3rd Rainfall Event (09/03/2019 15:00 – 09/04/2019 11:00)

Total Precipitation = 14.72 mm
Maximum Intensity = 53.82 mm/hr
Average Intensity = 0.31 mm/hr

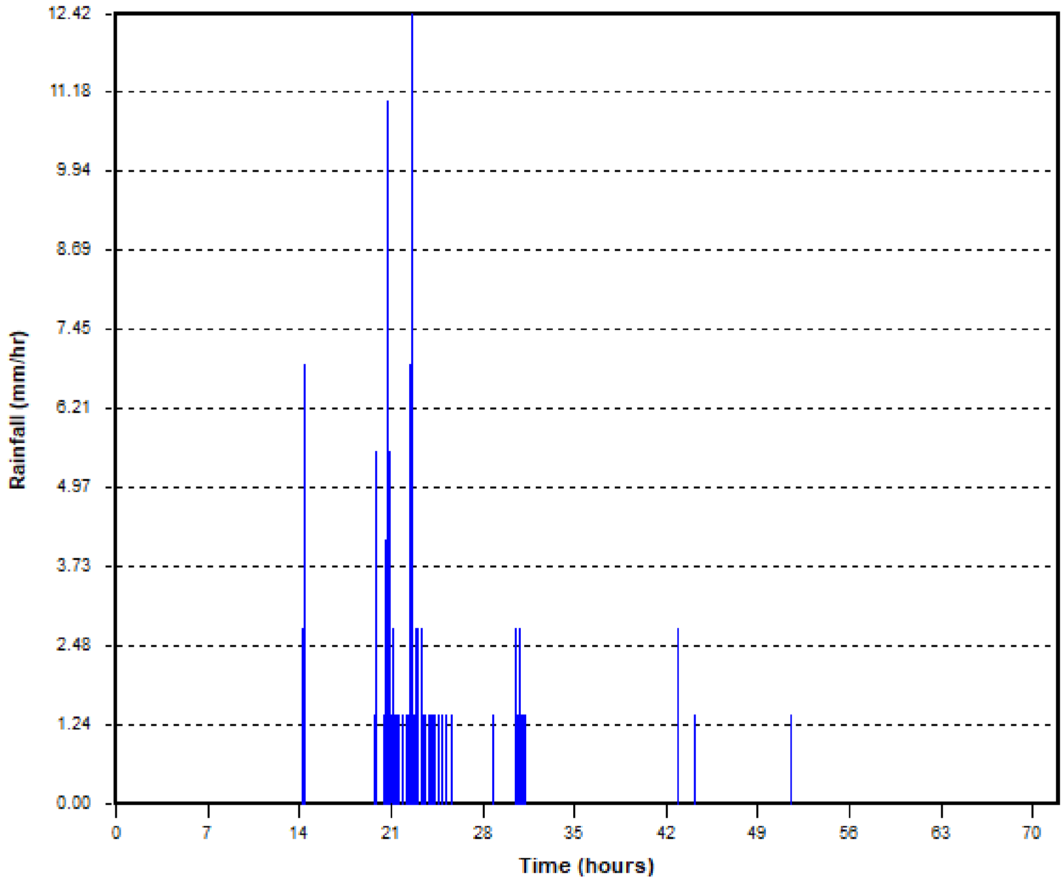


September 3rd Duration Rainfall Intensity – Duration Frequency Chart (09/03/2019 15:00 – 09/04/2019 11:00)

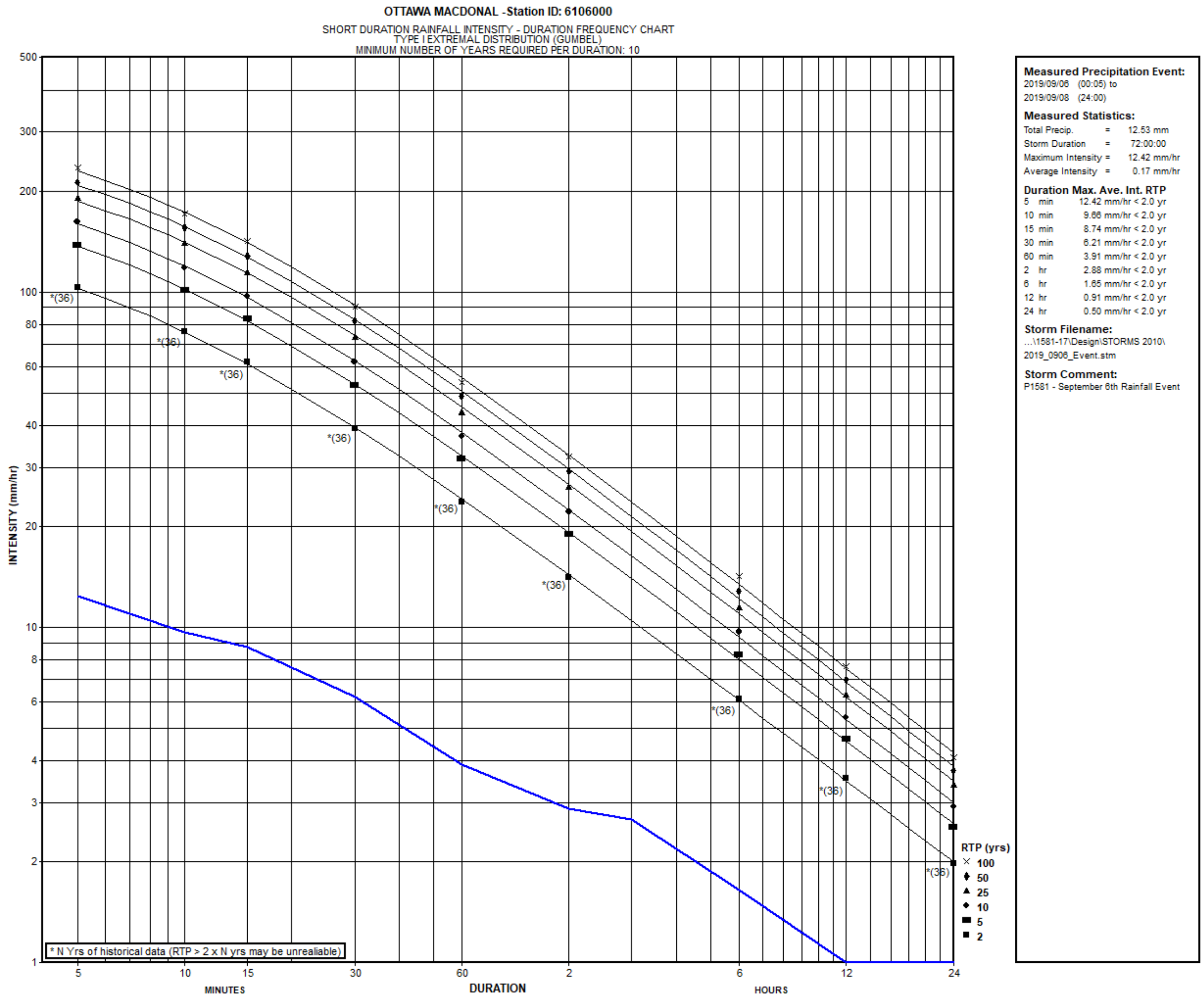


September 6th Rainfall Event (09/06/2019 00:00 – 09/06/2019 24:00)

Total Precipitation = 12.53 mm
Maximum Intensity = 12.42 mm/hr
Average Intensity = 0.17 mm/hr

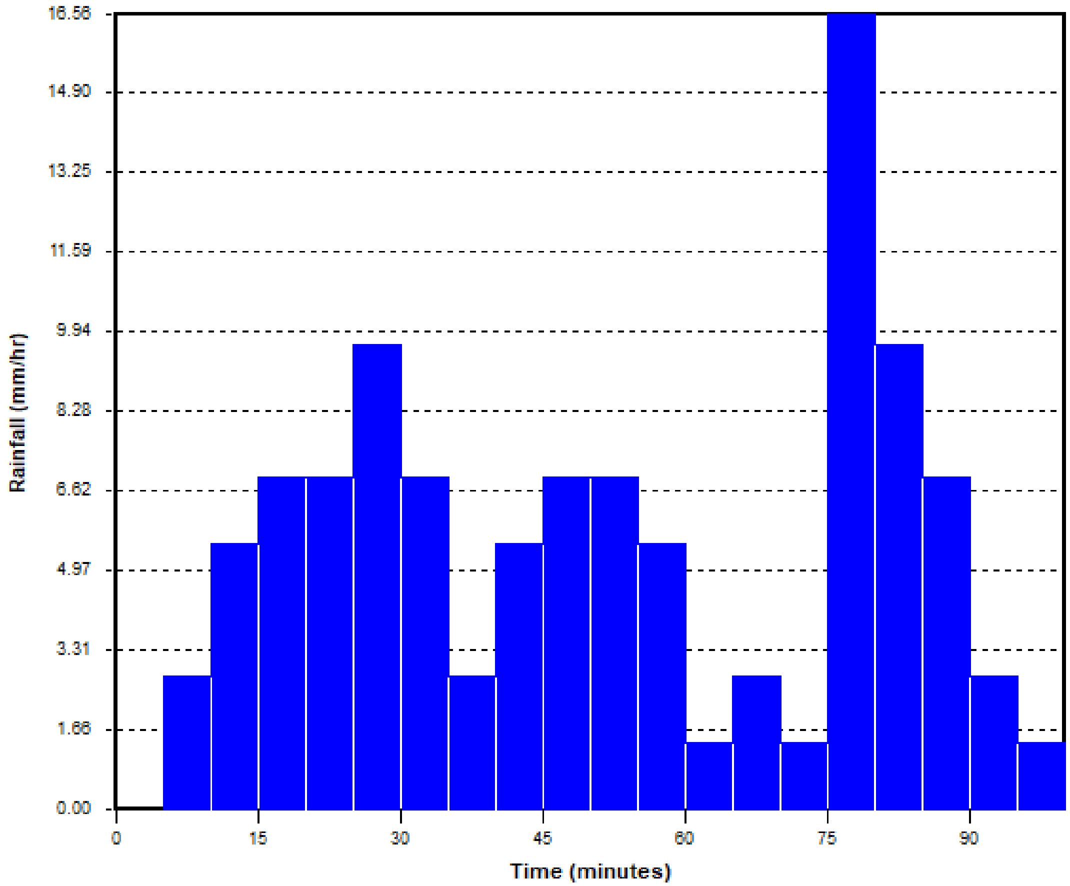


September 6th Duration Rainfall Intensity – Duration Frequency Chart (09/06/2019 00:00 – 09/06/2019 24:00)

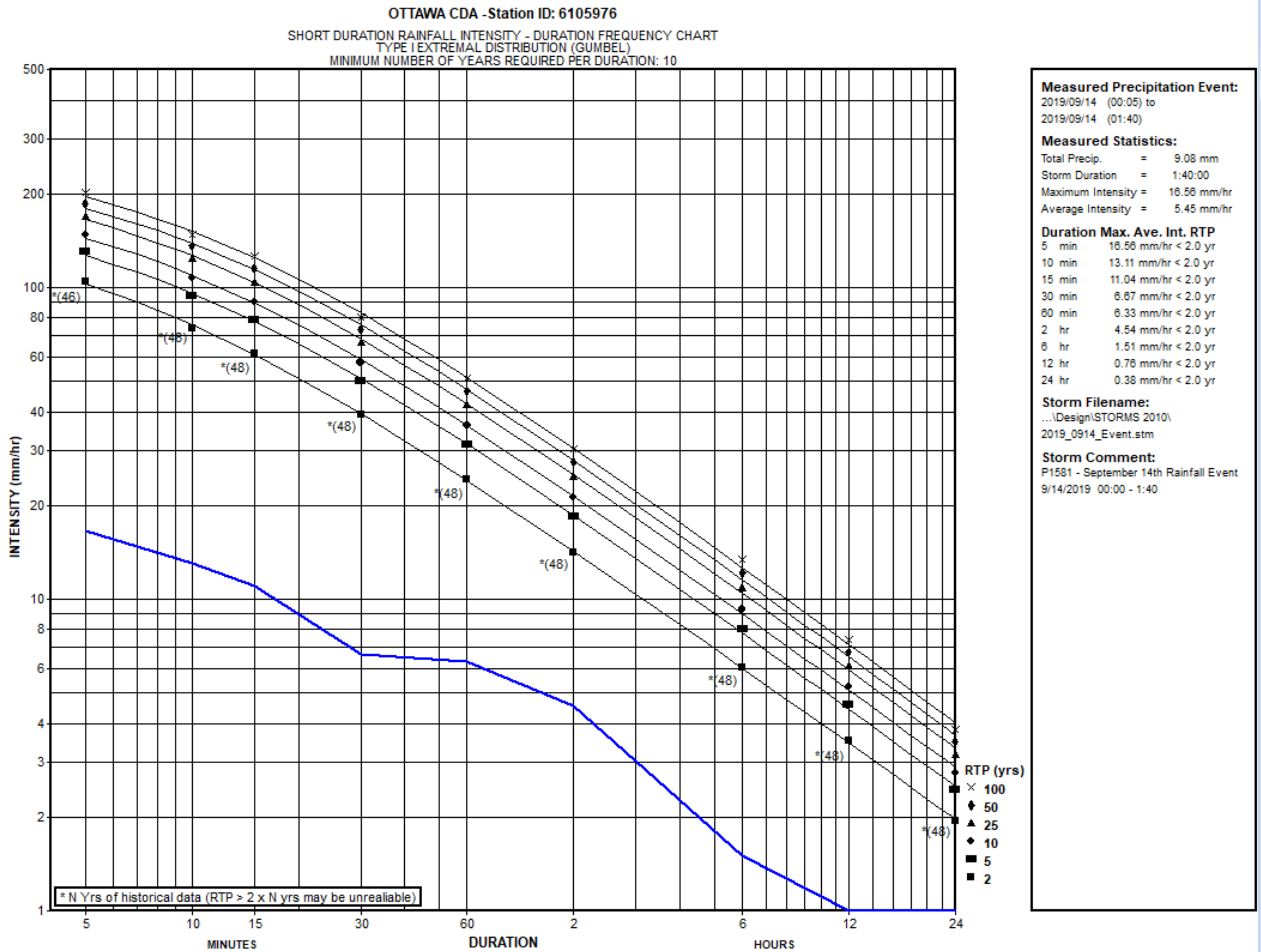


September 14th Rainfall Event (09/14/2019 00:00 – 09/14/2019 1:40)

Total Precipitation = 9.08 mm
Maximum Intensity = 16.56 mm/hr
Average Intensity = 5.45 mm/hr

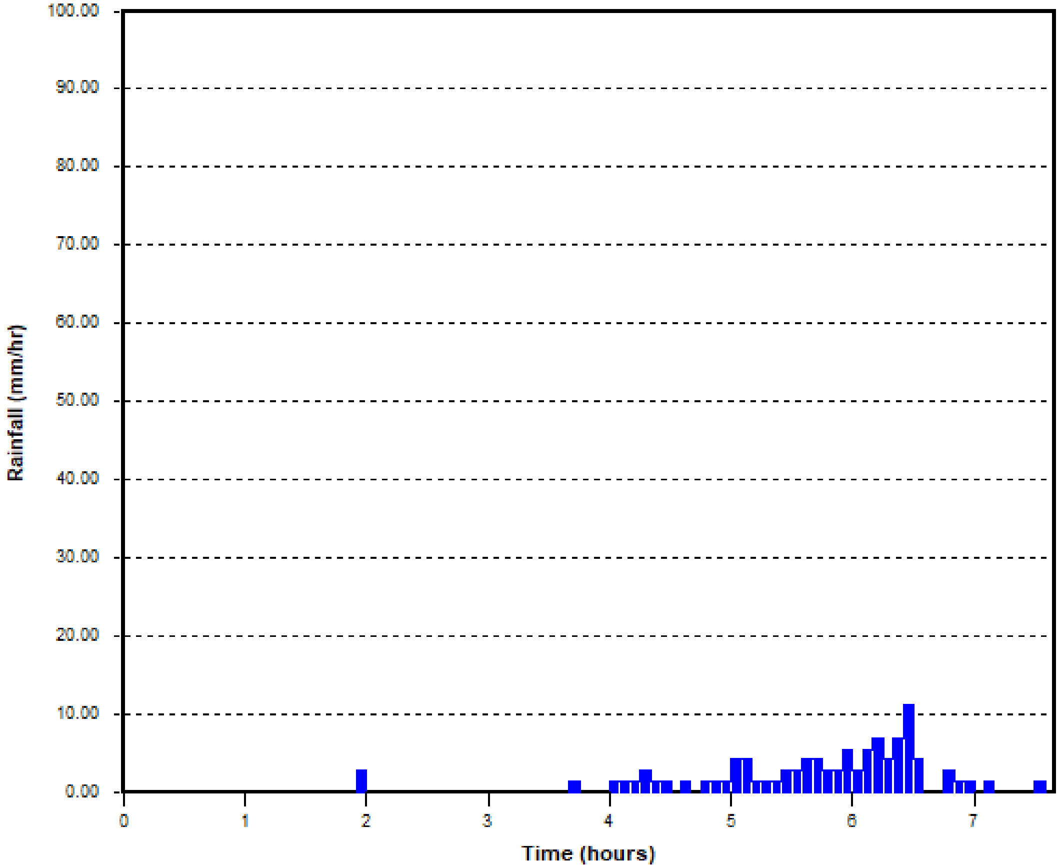


September 14th Duration Rainfall Intensity – Duration Frequency Chart (09/14/2019 00:00 – 09/14/2019 1:40)

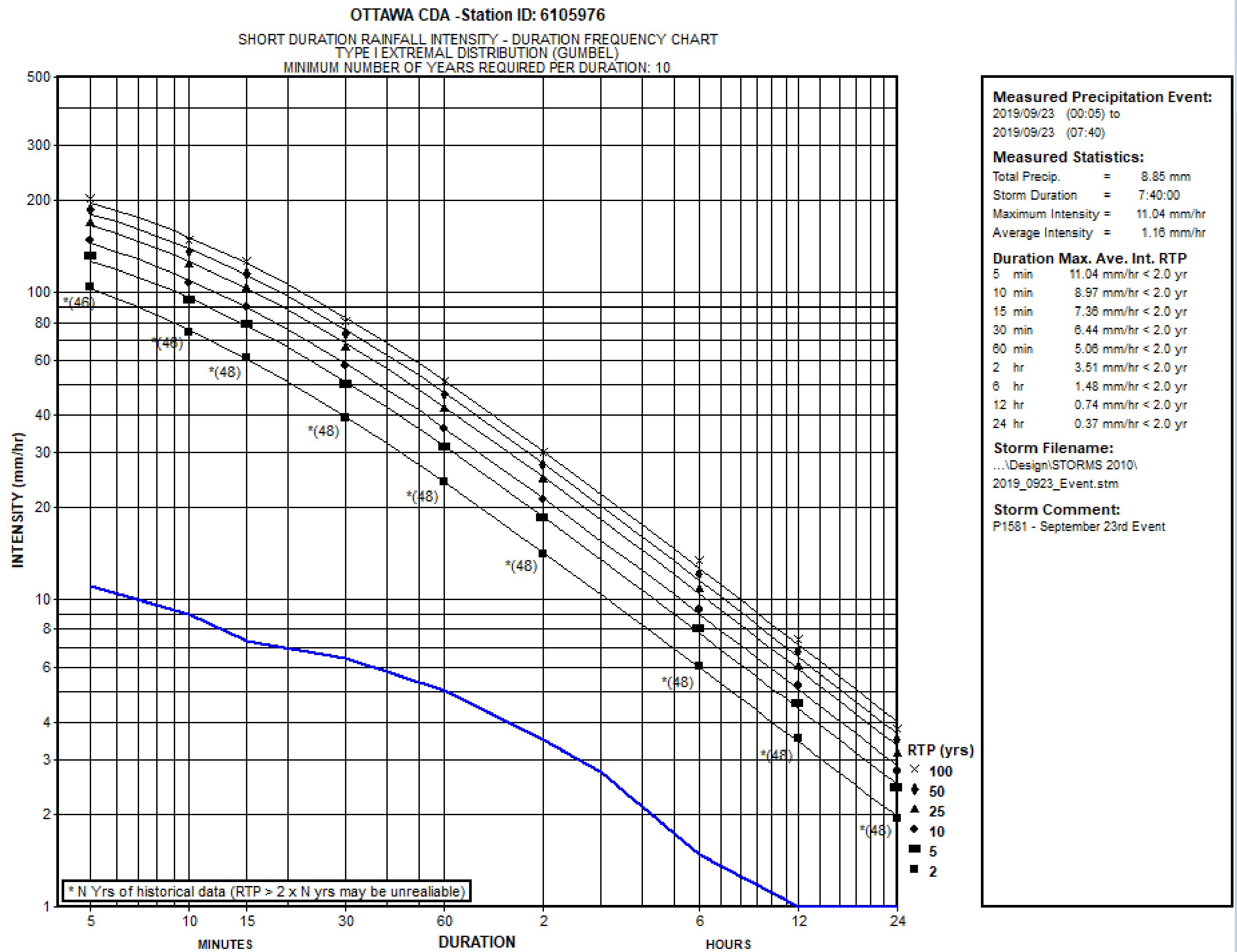


September 23rd Rainfall Event (09/23/2019 00:00 – 09/23/2019 7:30)

Total Precipitation = 8.85 mm
Maximum Intensity = 11.04 mm/hr
Average Intensity = 1.16 mm/hr

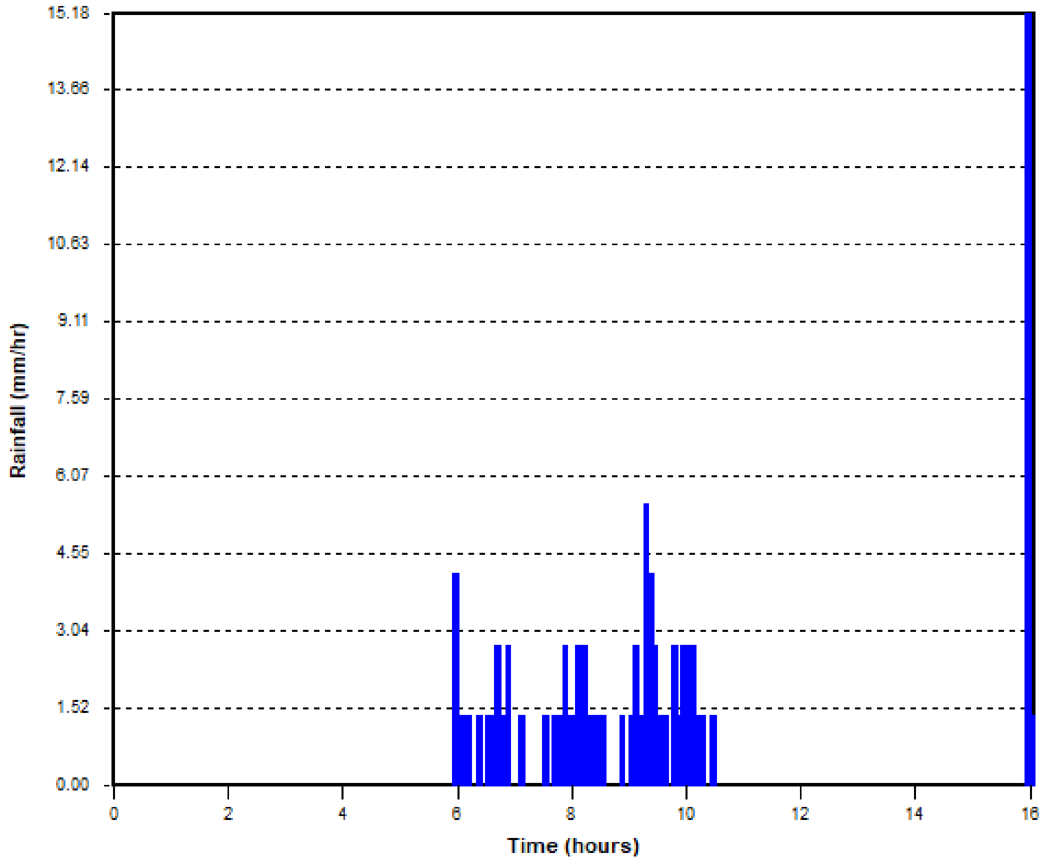


September 23rd Duration Rainfall Intensity – Duration Frequency Chart (09/23/2019 00:00 – 09/23/2019 7:30)

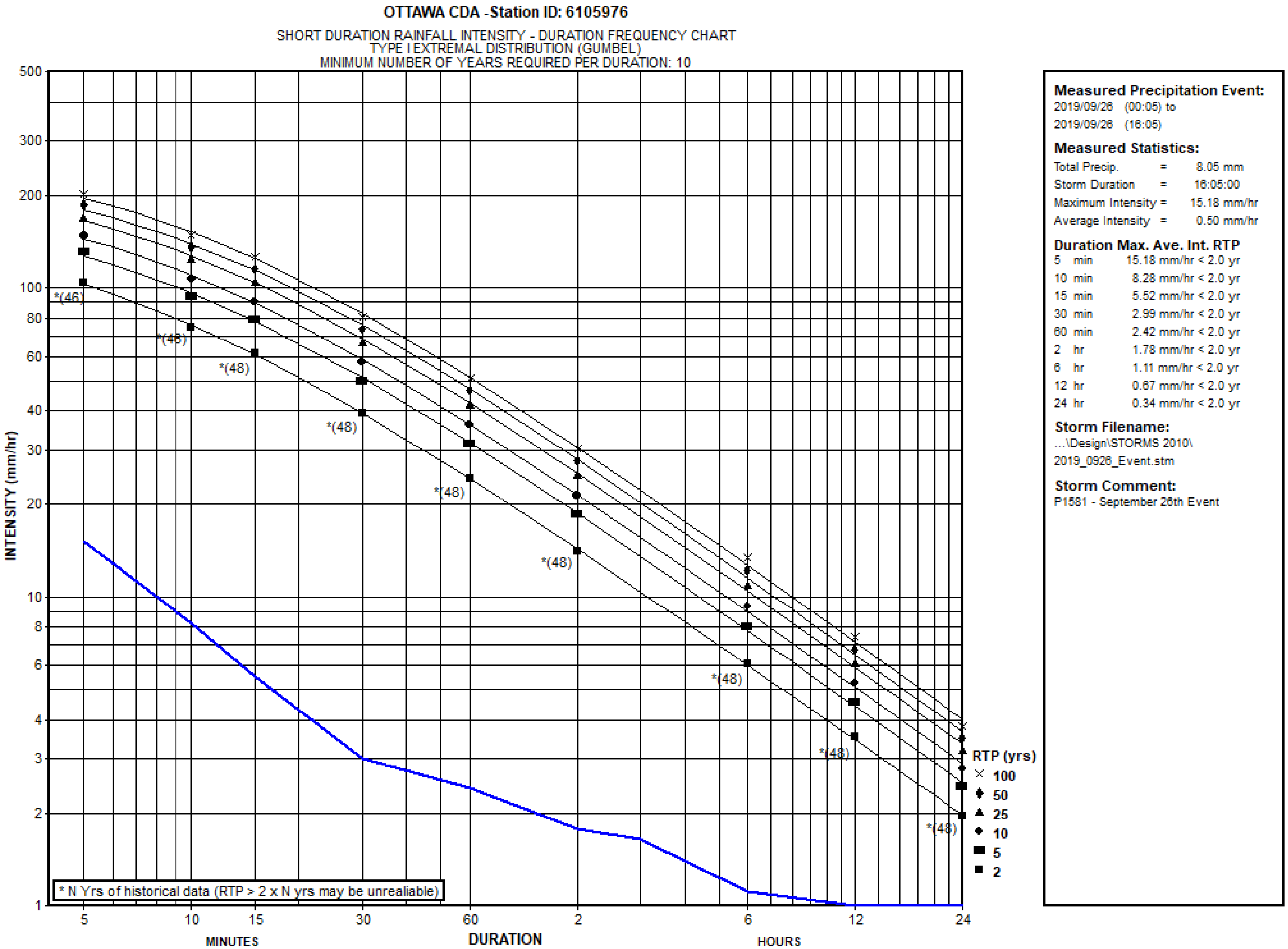


September 26th Rainfall Event (09/26/2019 00:00 – 09/26/2019 16:00)

Total Precipitation = 8.05 mm
Maximum Intensity = 15.18 mm/hr
Average Intensity = 0.50 mm/hr

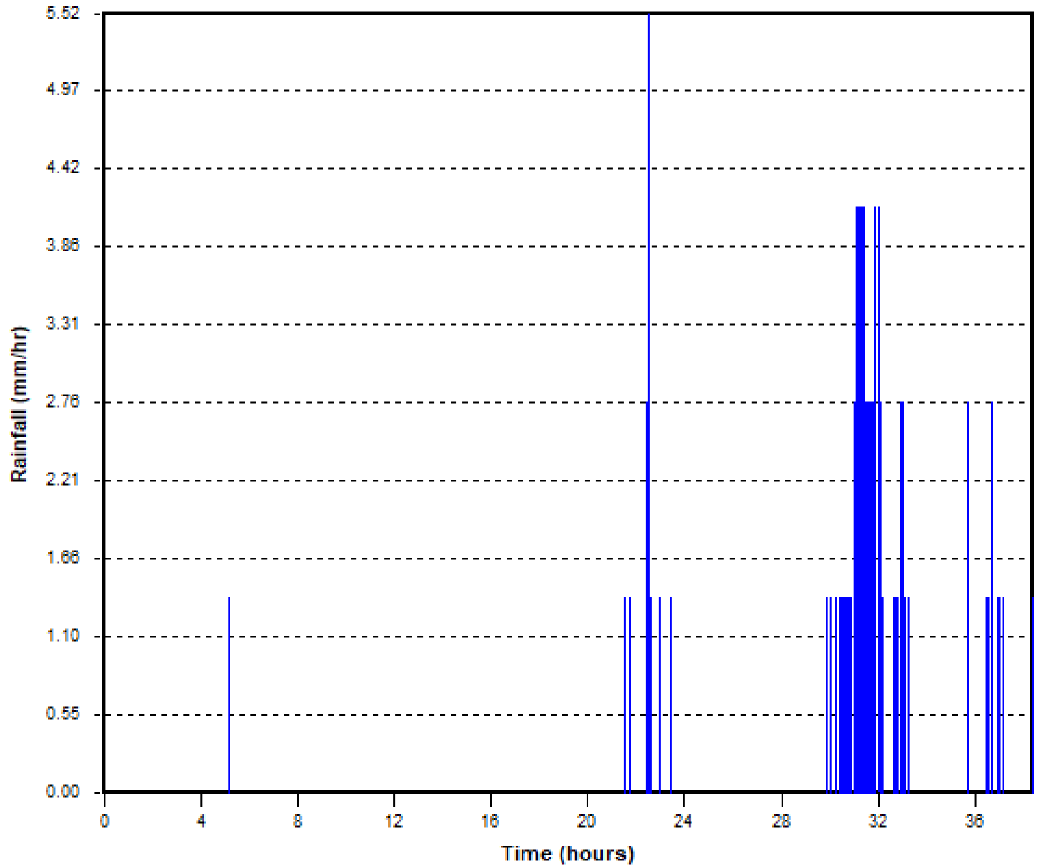


September 26th Duration Rainfall Intensity – Duration Frequency Chart (09/26/2019 00:00 – 09/26/2019 16:00)

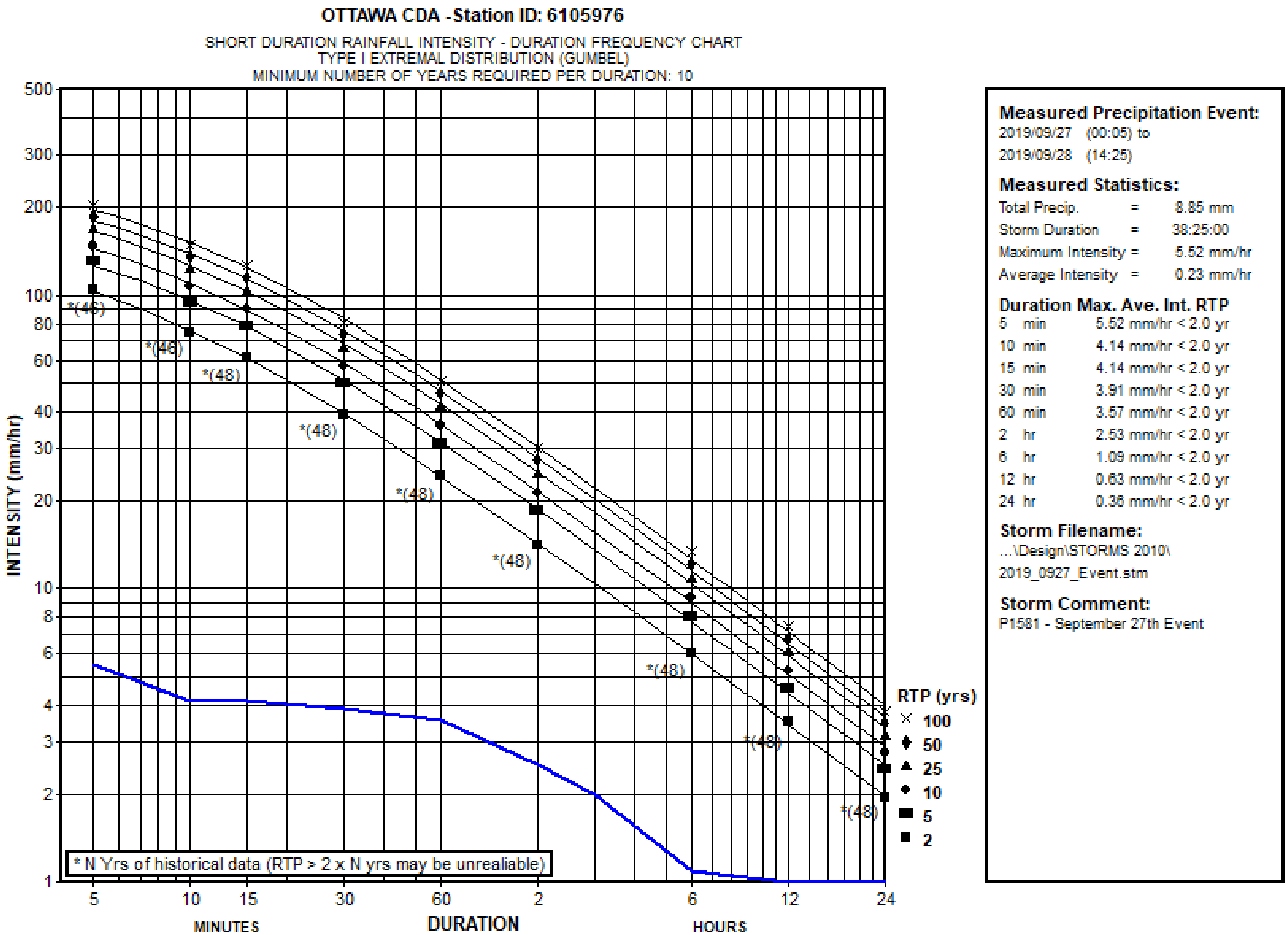


September 27th Rainfall Event (09/27/2019 00:00 – 09/28/2019 14:20)

Total Precipitation = 8.85 mm
Maximum Intensity = 5.52 mm/hr
Average Intensity = 0.23 mm/hr

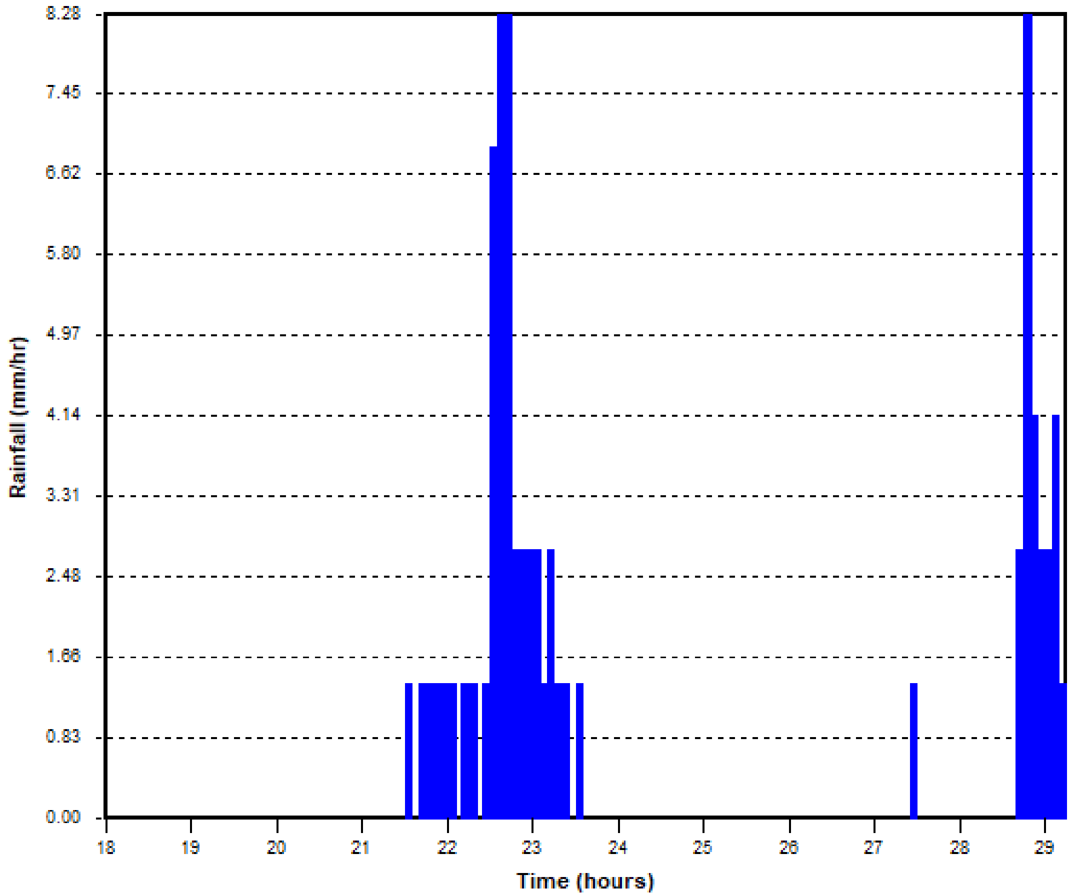


September 27th Duration Rainfall Intensity – Duration Frequency Chart (09/27/2019 00:00 – 09/28/2019 14:20)

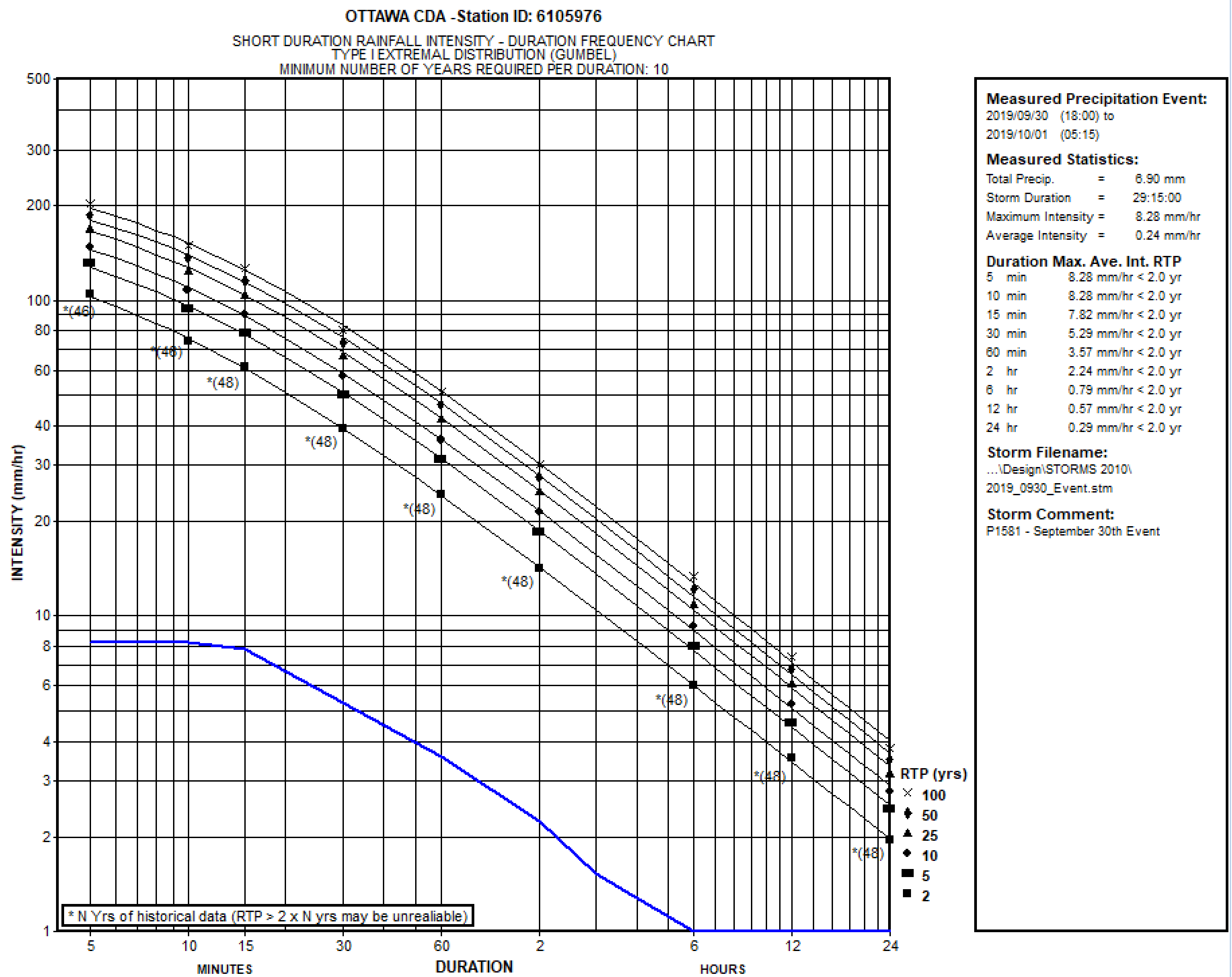


September 30th Rainfall Event (09/30/2019 18:00 – 10/01/2019 5:15)

Total Precipitation = 6.90 mm
Maximum Intensity = 8.28 mm/hr
Average Intensity = 0.24 mm/hr

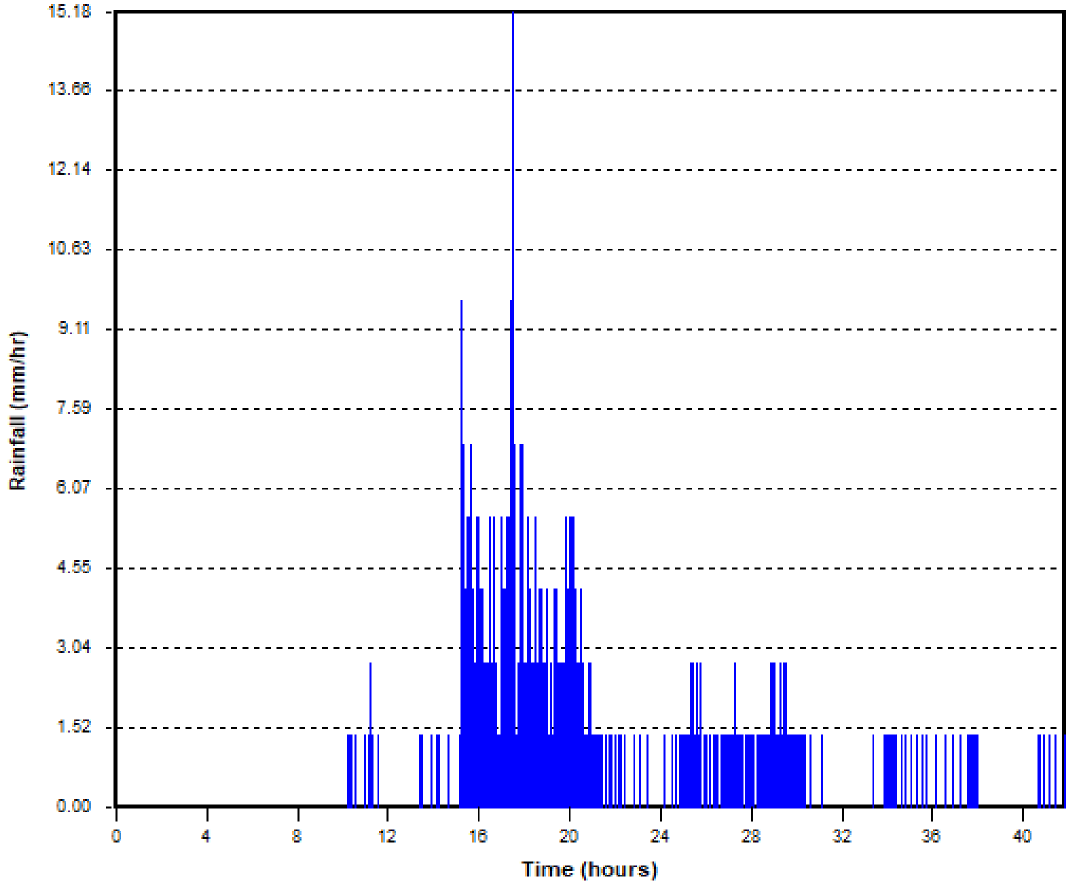


September 30th Duration Rainfall Intensity – Duration Frequency Chart (09/30/2019 18:00 – 10/01/2019 5:15)

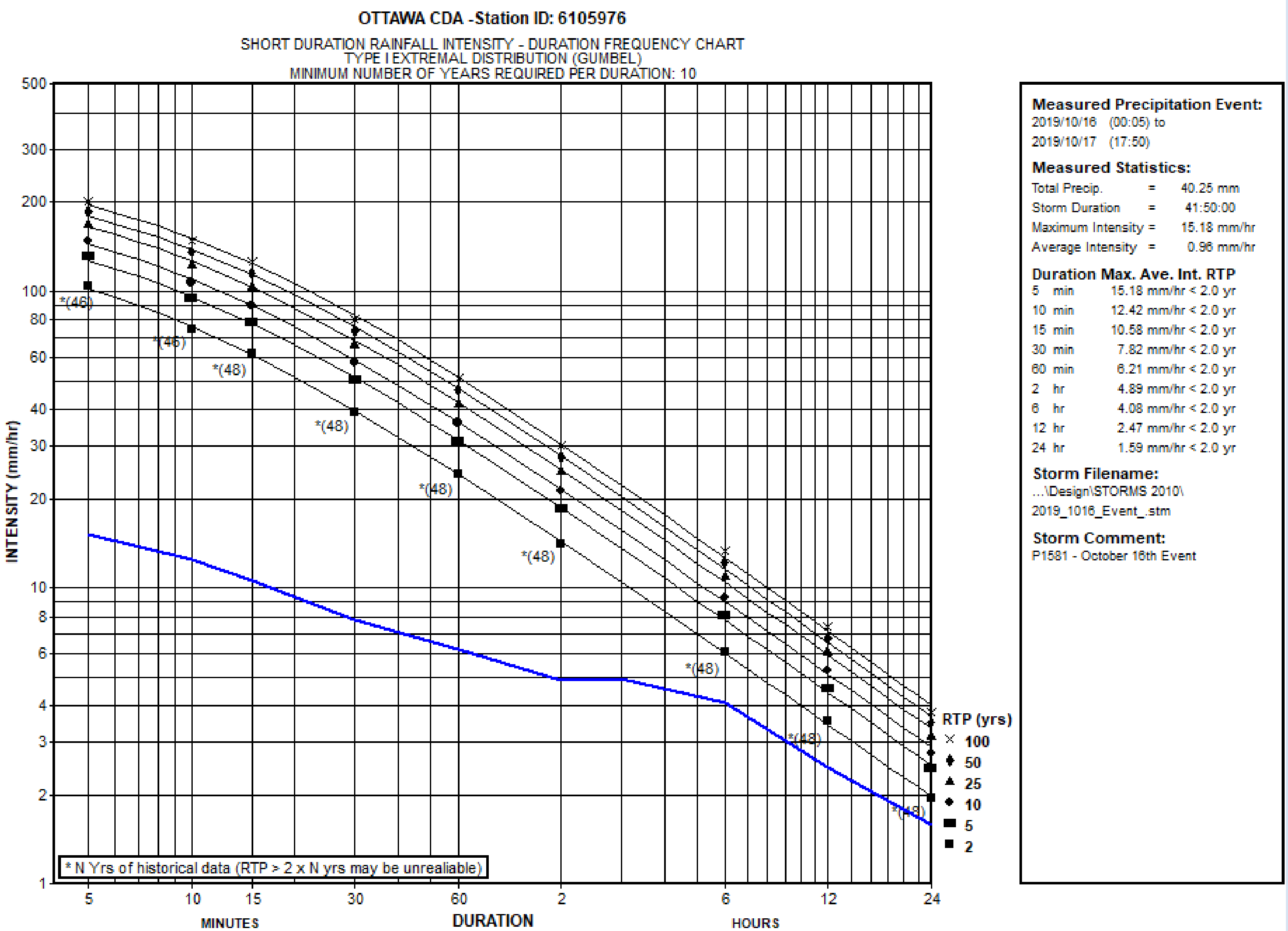


October 16th Rainfall Event (10/16/2019 00:00 – 10/16/2019 17:50)

Total Precipitation = 40.25 mm
Maximum Intensity = 15.18 mm/hr
Average Intensity = 0.96 mm/hr

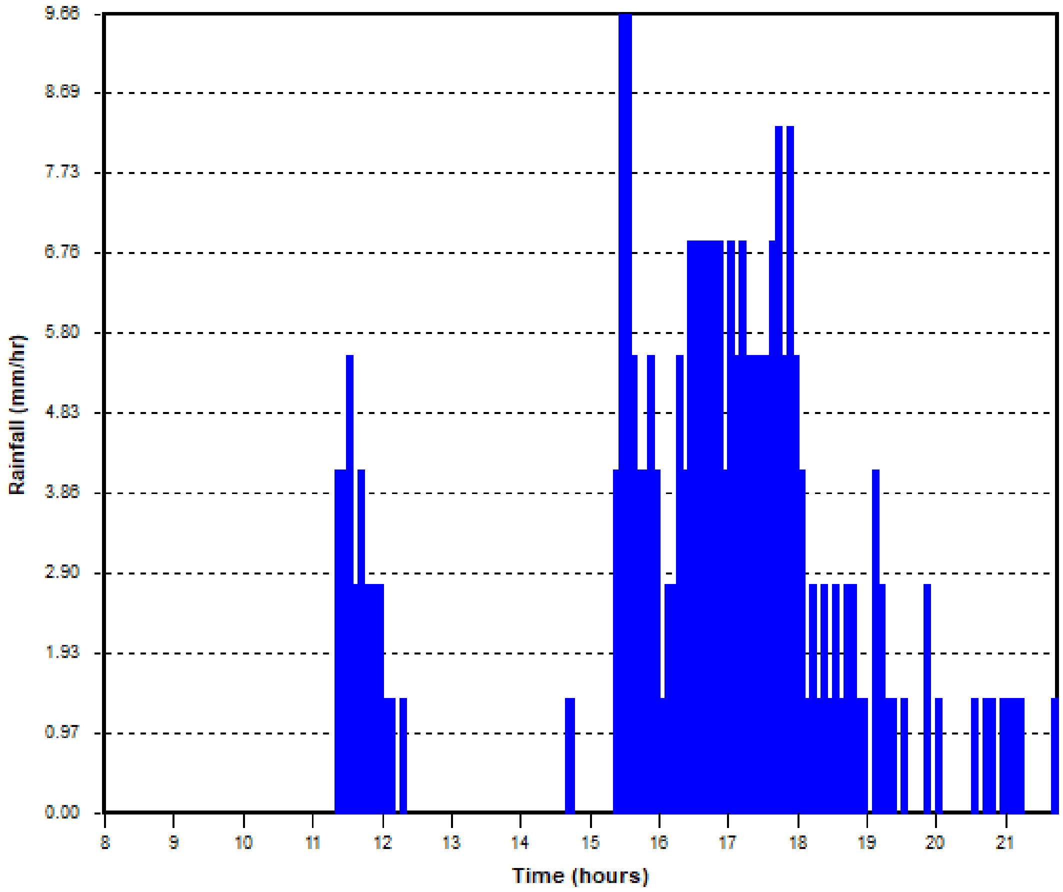


October 16th Duration Rainfall Intensity – Duration Frequency Chart (10/16/2019 00:00 – 10/16/2019 17:50)

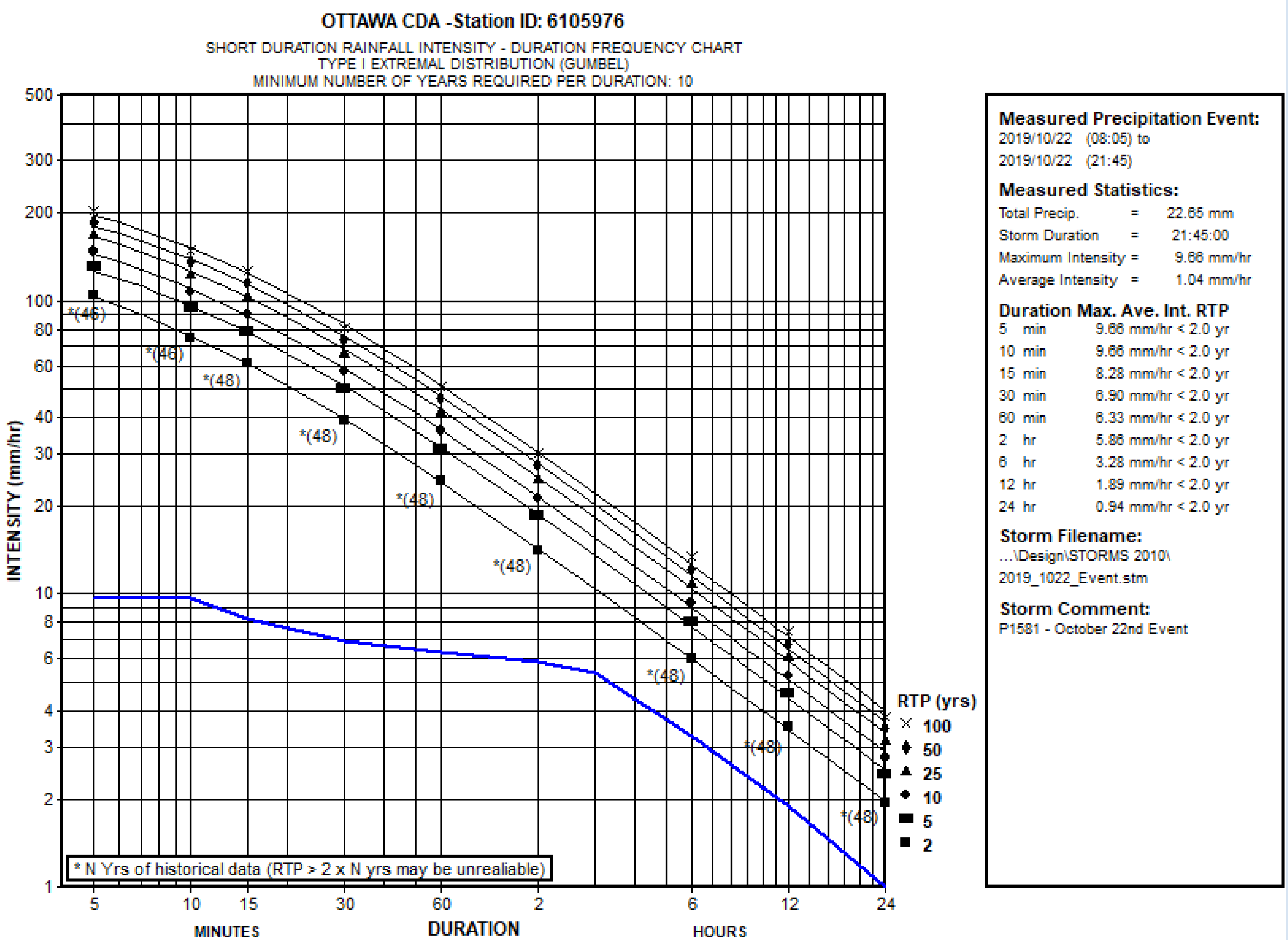


October 22nd Rainfall Event (10/22/2019 8:00 – 10/22/2019 21:45)

Total Precipitation = 22.65 mm
Maximum Intensity = 9.66 mm/hr
Average Intensity = 1.04 mm/hr



October 22nd Duration Rainfall Intensity – Duration Frequency Chart (10/22/2019 8:00 – 10/22/2019 21:45)



JFSA
WATER RESOURCES AND
ENVIRONMENTAL CONSULTANTS

Project Ref #:P1581
Client: David Schaeffer Engineering

Ottawa. ON
Paris. ON
Gatineau. QB
Montréal. QB
Québec. QB

Appendix D
Background Documentation

Intensity-Duration-Frequency Comparison

City of Ottawa SDG vs. 2013 & 2014 Storm Events

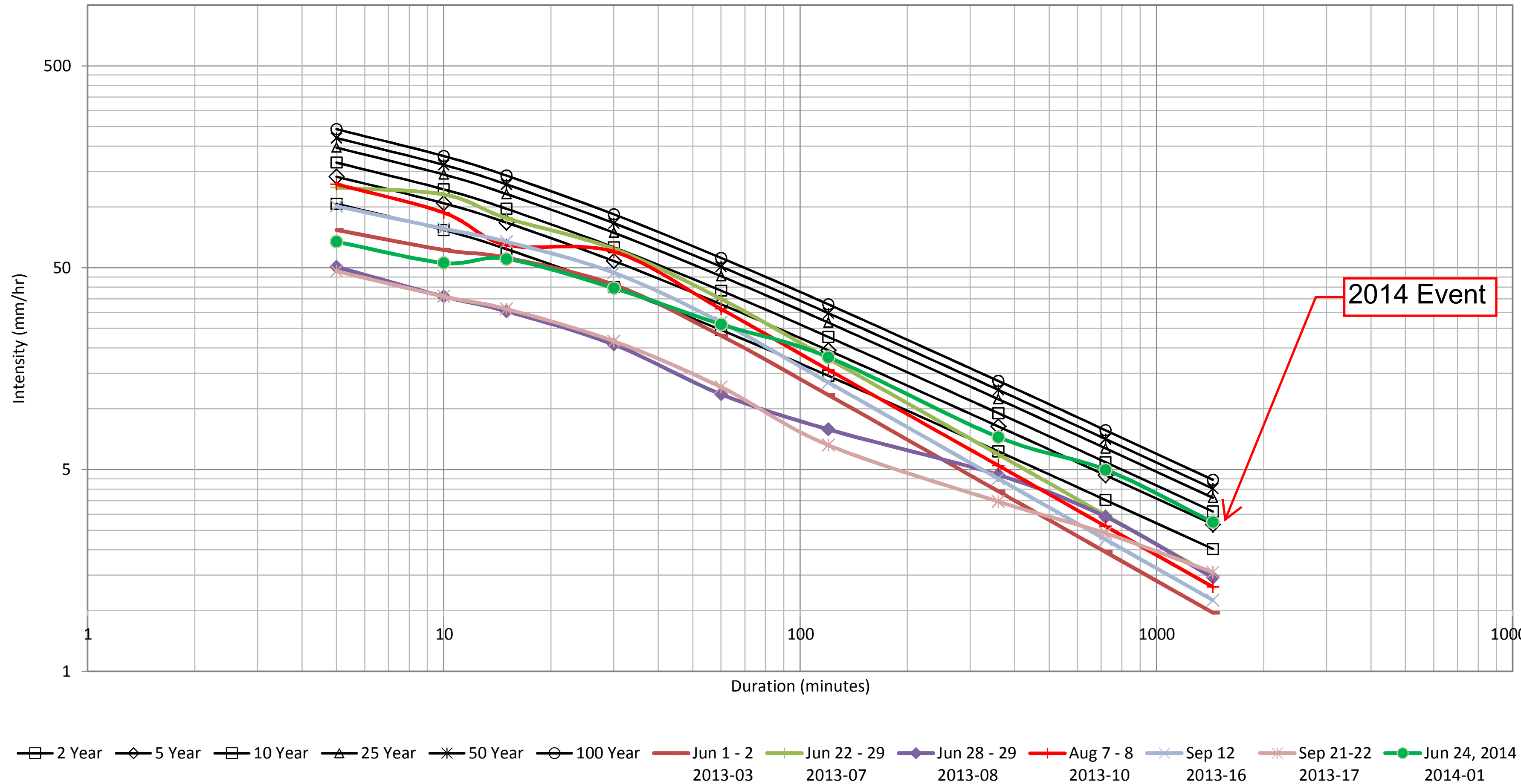


Figure C-5-1

From IBI Group

Beaver Pond Survey Data

Bottom of BP	87.63	m
Initial Depth	2.79	m

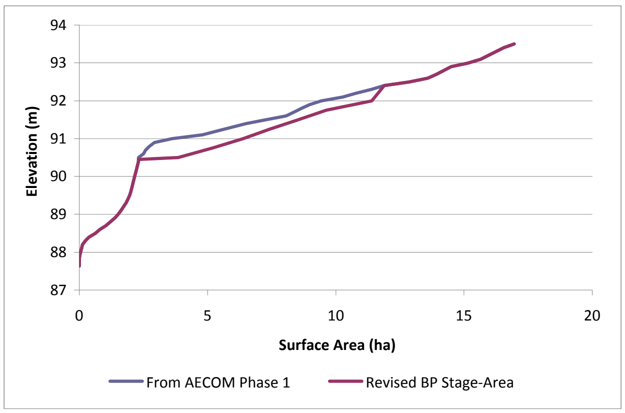
Beaver Pond Stage Area
From AECOM Phase 1

Elevation	Depth	Area (ha)
87.63	0	0.0001
87.70	0.068	0.0002
87.80	0.168	0.0003
87.90	0.268	0.0146
88.00	0.368	0.0444
88.10	0.468	0.0872
88.20	0.568	0.1288
88.30	0.668	0.2309
88.40	0.768	0.3783
88.50	0.868	0.6258
88.60	0.968	0.8016
88.70	1.068	1.0357
88.80	1.168	1.2162
88.90	1.268	1.3863
89.00	1.368	1.5083
89.10	1.468	1.6212
89.20	1.568	1.7271
89.30	1.668	1.8247
89.40	1.768	1.896
89.50	1.868	1.9549
89.60	1.968	2.0027
89.70	2.068	2.0432
89.80	2.168	2.0818
89.90	2.268	2.1193
90.00	2.368	2.1563
90.10	2.468	2.1932
90.20	2.568	2.2299
90.30	2.668	2.2664
90.40	2.768	2.3034
90.45	2.818	2.3035
90.50	2.868	2.3036
90.60	2.968	2.5089
90.70	3.068	2.5883
90.80	3.168	2.7353
90.90	3.268	2.935
91.00	3.368	3.6185
91.10	3.468	4.8076
91.20	3.568	5.3721
91.30	3.668	5.9197
91.40	3.768	6.5021
91.50	3.868	7.2709
91.60	3.968	8.0626
91.70	4.068	8.3753
91.80	4.168	8.6723
91.90	4.268	8.9692
92.00	4.368	9.4301
92.10	4.468	10.2698
92.20	4.568	10.7888
92.30	4.668	11.3862
92.40	4.768	11.8852
92.50	4.868	12.857
92.55	4.918	13.2219
92.60	4.968	13.5868
92.70	5.068	13.9225
92.80	5.168	14.2095
92.90	5.268	14.4942
93.00	5.368	15.1506
93.10	5.468	15.65
93.20	5.568	15.9507
93.30	5.668	16.2476
93.40	5.768	16.5421
93.50	5.868	16.9556

Survey from AOS
from "Surface Pond2015-01-27.xlsx" 2015-01-27
J:\28661-KanataSWM\5.9 Drawings\baseinfo\surfaces

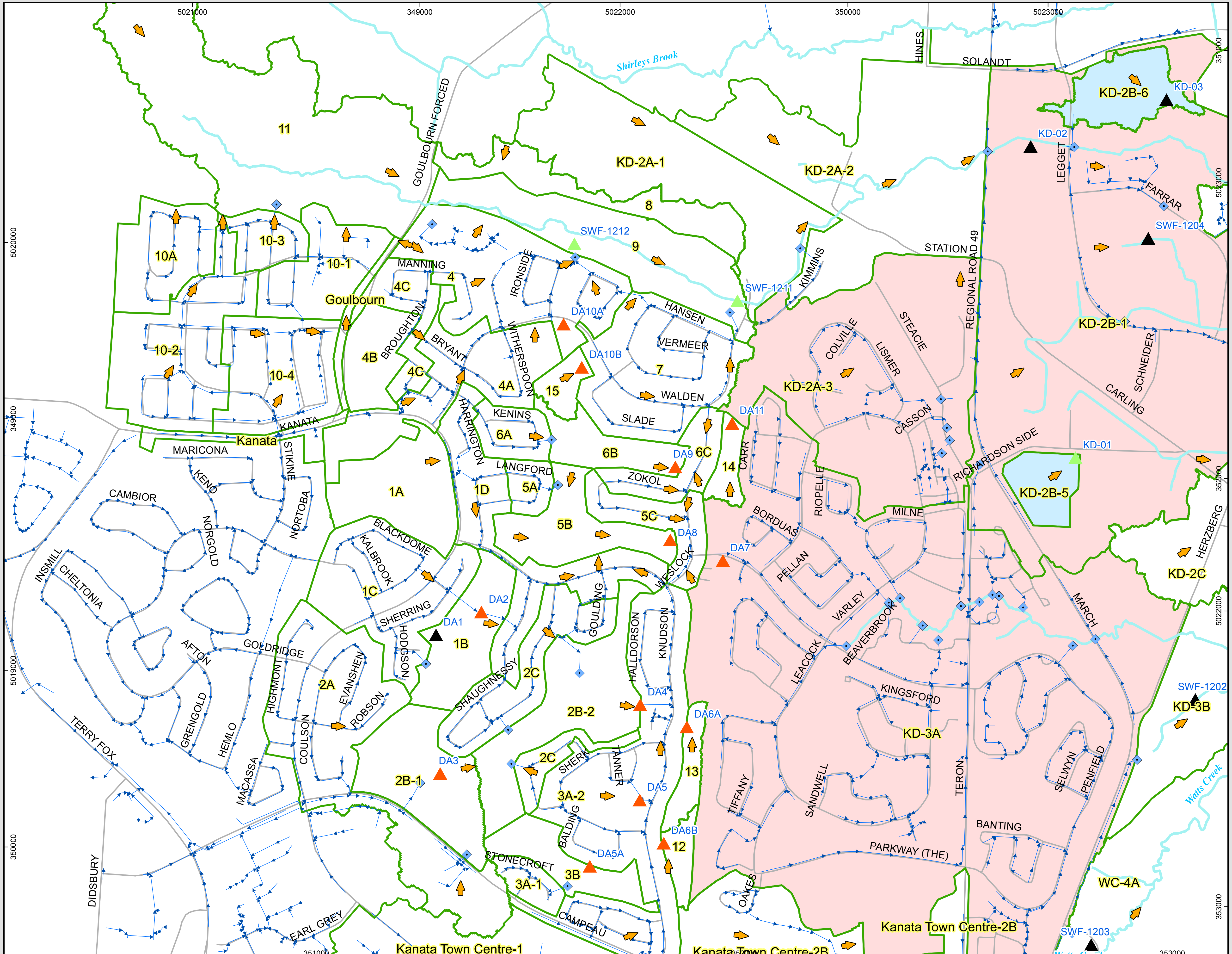
Elevation Contour (m)	Area (m2)	Area (ha)
90.50	38559.794	3.8559794
90.75	52011.028	5.2011028
91.00	63833.475	6.3833475
91.25	74401.041	7.4401041
91.50	85388.908	8.5388908
91.75	96365.566	9.6365566
92.00	114097.925	11.4097925

Note for blue highlight: Area at 91.00 m from accompanying excel file did not correspond with CAD area. Changed area to match CAD. CAD area was 9.76 m2 less than corresponding spreadsheet.



Revised BP Stage-Area

Elevation	Depth	Area (ha)
87.63	0	0.0001
87.70	0.068	0.0002
87.80	0.168	0.0003
87.90	0.268	0.0146
88.00	0.368	0.0444
88.10	0.468	0.0872
88.20	0.568	0.1288
88.30	0.668	0.2309
88.40	0.768	0.3783
88.50	0.868	0.6258
88.60	0.968	0.8016
88.70	1.068	1.0357
88.80	1.168	1.2162
88.90	1.268	1.3863
89.00	1.368	1.5083
89.10	1.468	1.6212
89.20	1.568	1.7271
89.30	1.668	1.8247
89.40	1.768	1.896
89.50	1.868	1.9549
89.60	1.968	2.0027
89.70	2.068	2.0432
89.80	2.168	2.0818
89.90	2.268	2.1193
90.00	2.368	2.1563
90.10	2.468	2.1932
90.20	2.568	2.2299
90.30	2.668	2.2664
90.40	2.768	2.3034
90.45	2.818	2.3035
90.50	2.87	3.8559794
90.75	3.12	5.2011028
91.00	3.37	6.3833475
91.25	3.62	7.4401041
91.50	3.87	8.5388908
91.75	4.12	9.6365566
92.00	4.37	11.4097925
92.40	4.768	11.8852
92.50	4.868	12.857
92.55	4.918	13.2219
92.60	4.968	13.5868
92.70	5.068	13.9225
92.80	5.168	14.2095
92.90	5.268	14.4942
93.00	5.368	15.1506
93.10	5.468	15.65
93.20	5.568	15.9507
93.30	5.668	16.2476
93.40	5.768	16.5421
93.50	5.868	16.9556

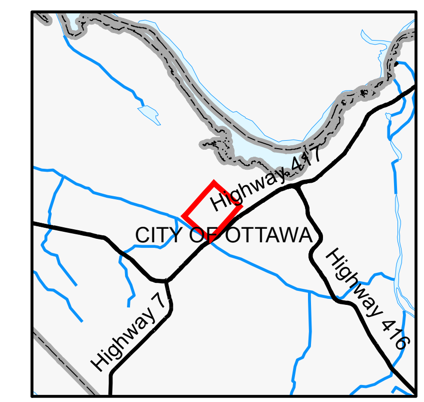


Legend

- Stream and River
- Urban Area with Site Level SWM
- Urban Area with No Identified SWM/ / No Available SWM Information
- Subcatchments

Available SWMF Information

- DETAILED
- PARTIAL
- NONE
- Storm Sewer
- Minor System Outlet
- Major System Flow Direction



Basemapping and orthophotography provided by the City of Ottawa.

m
0 62.5 125 250 375 500
1:12,000
NAD 83, MTM 9

Shirley s Brook & Watt s Creek Phase 2 SWM Study

Existing Conditions SWMHYMO Model - Kizell Drain Urban Area

February 2015
60264539

AECOM

Figure C-1-1

Path: P:\60264539\000-CADD\050 GIS WIP\MXDs\WorkingMXDs\20150204 - Revised Rep Figs\60264539_Existing_Conditions_SWMHYMO_Model-Watts_Urban C-1.mxd
Time: 5:20:31 PM Date: 2/5/2015

Watt's Creek/Upper Kizell SWMHYMO Model Schematics

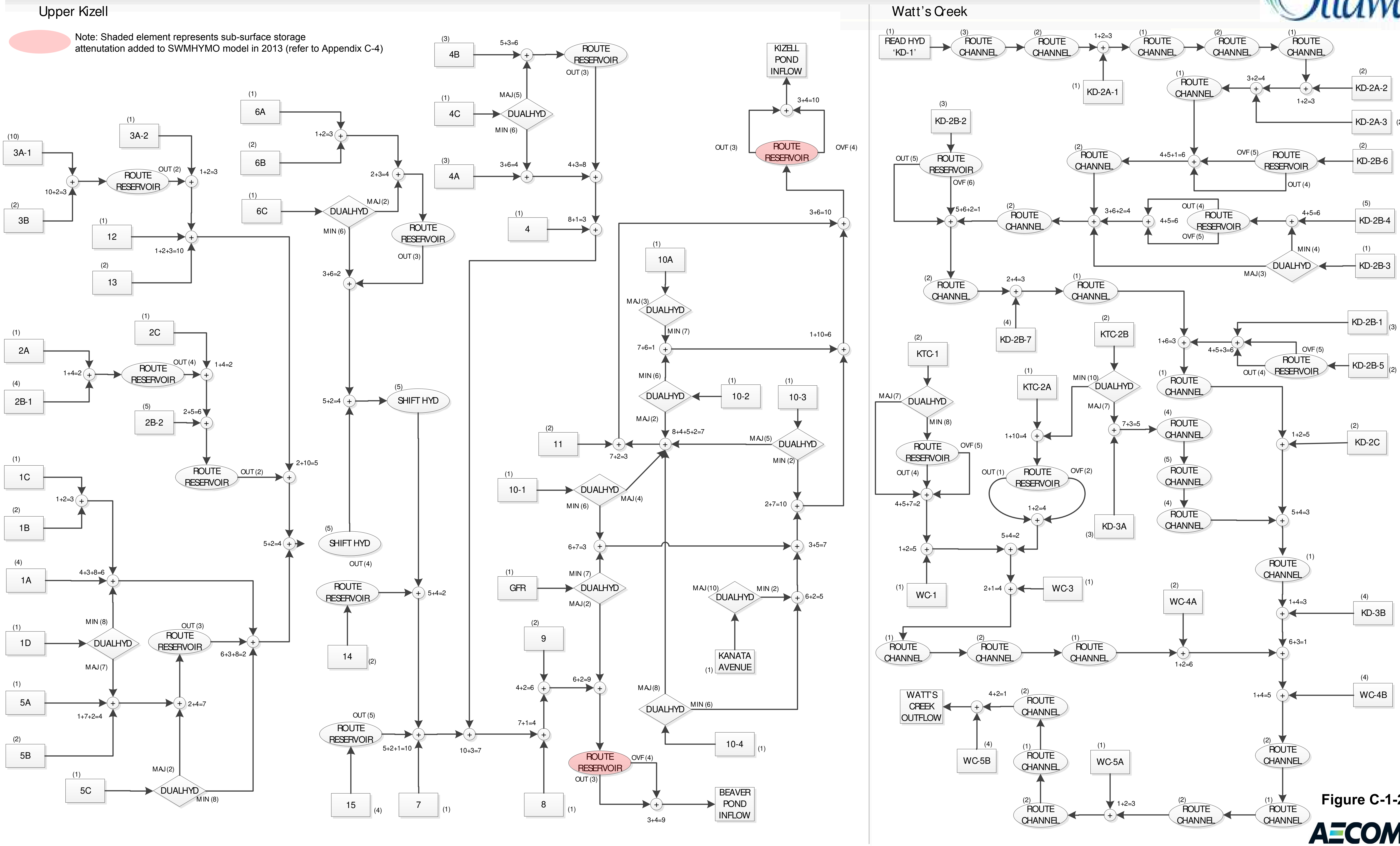


Figure C-1-2

AECOM

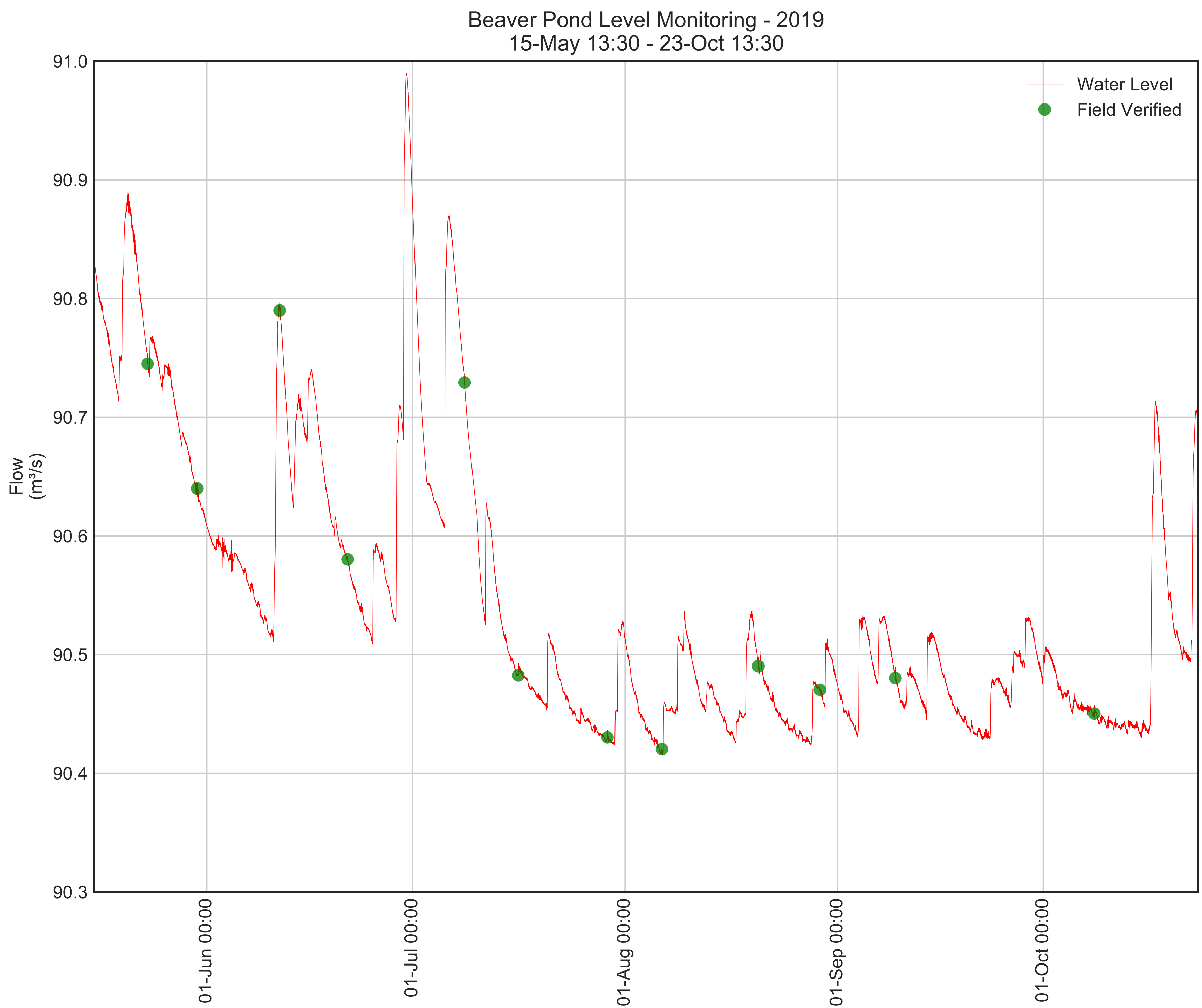
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS

Project Ref #:P1581
Client: David Schaeffer Engineering

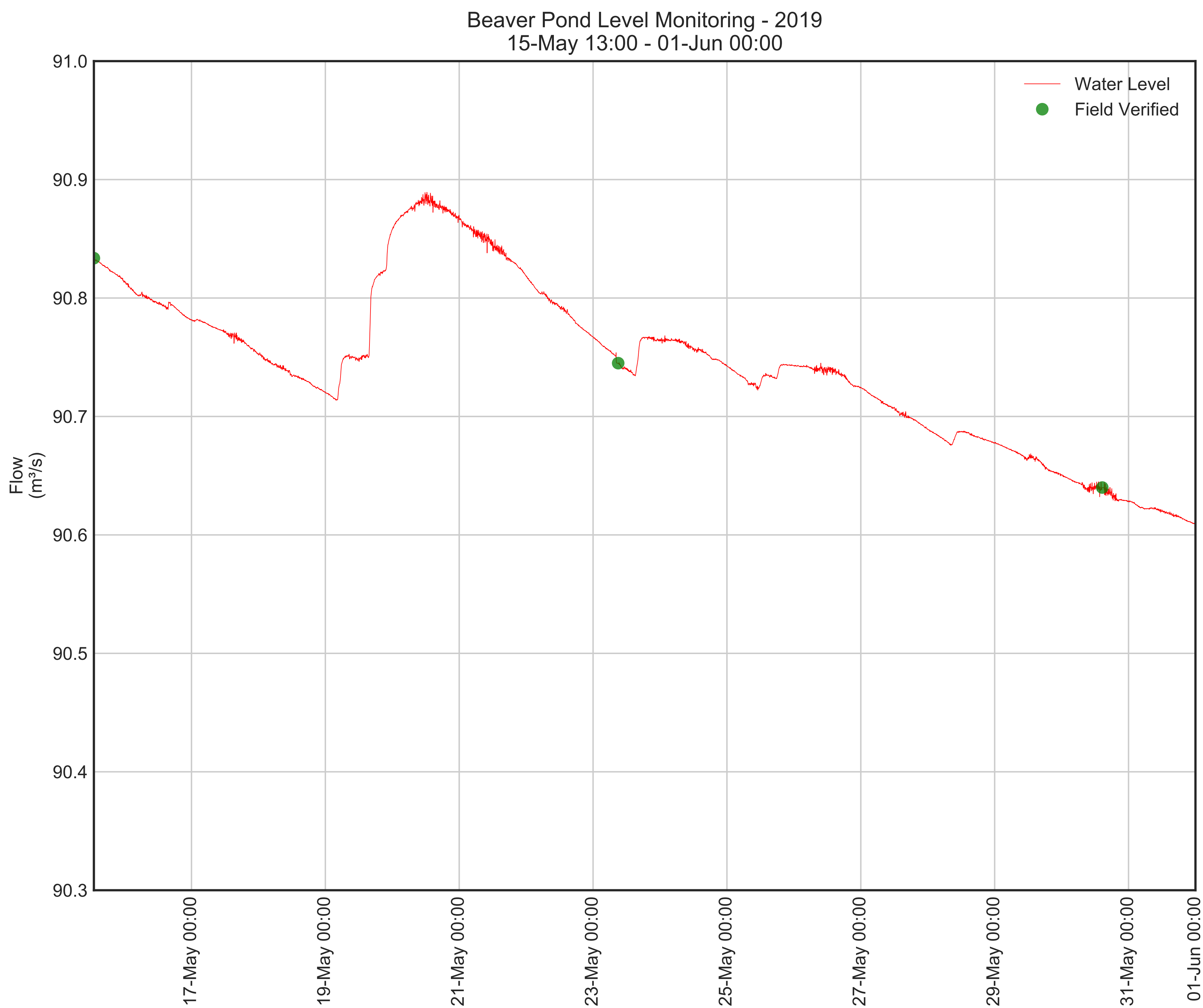
Ottawa. ON
Paris. ON
Gatineau. QB
Montréal. QB
Québec. QB

Appendix E

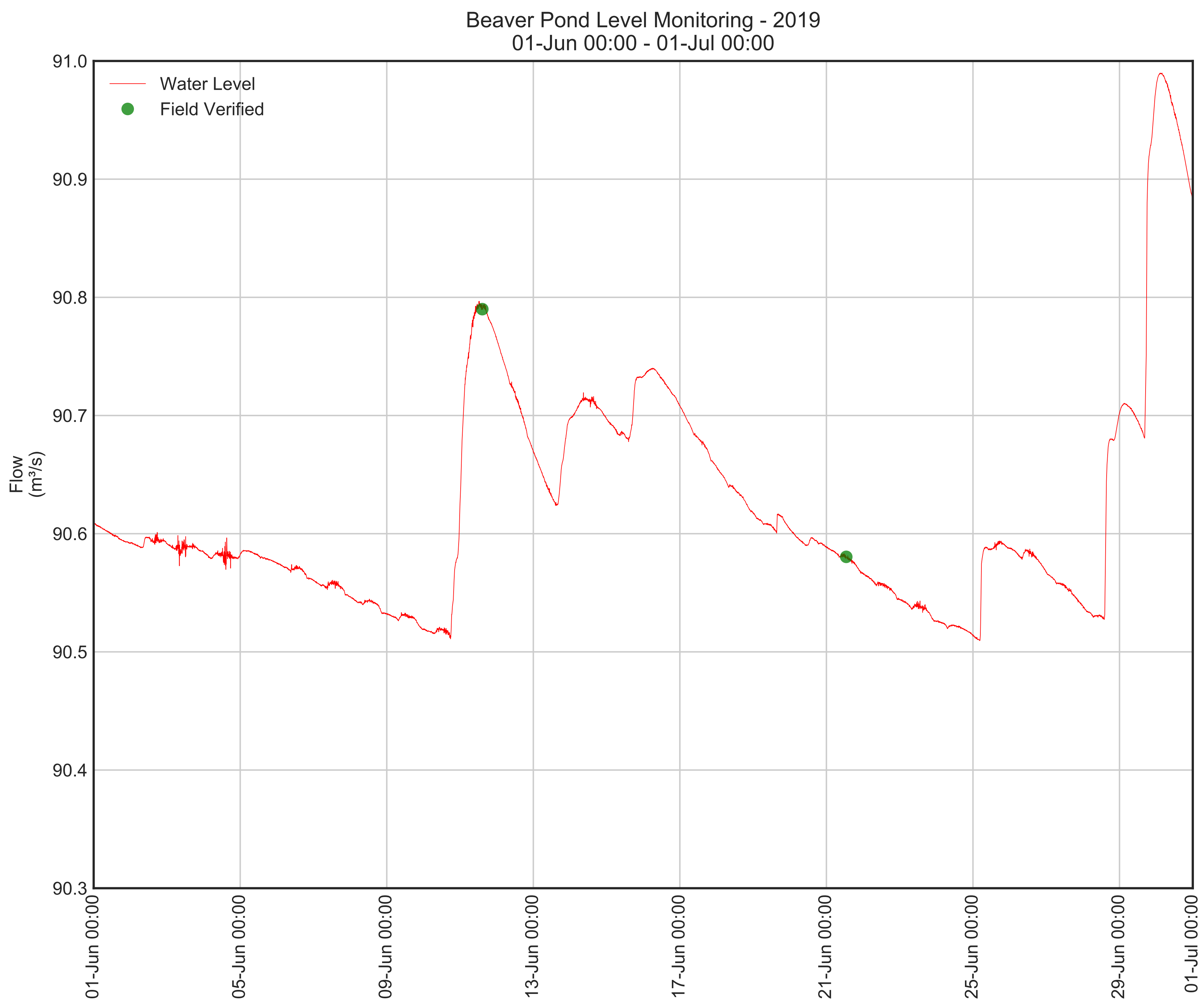
2019 Beaver Pond Water Levels

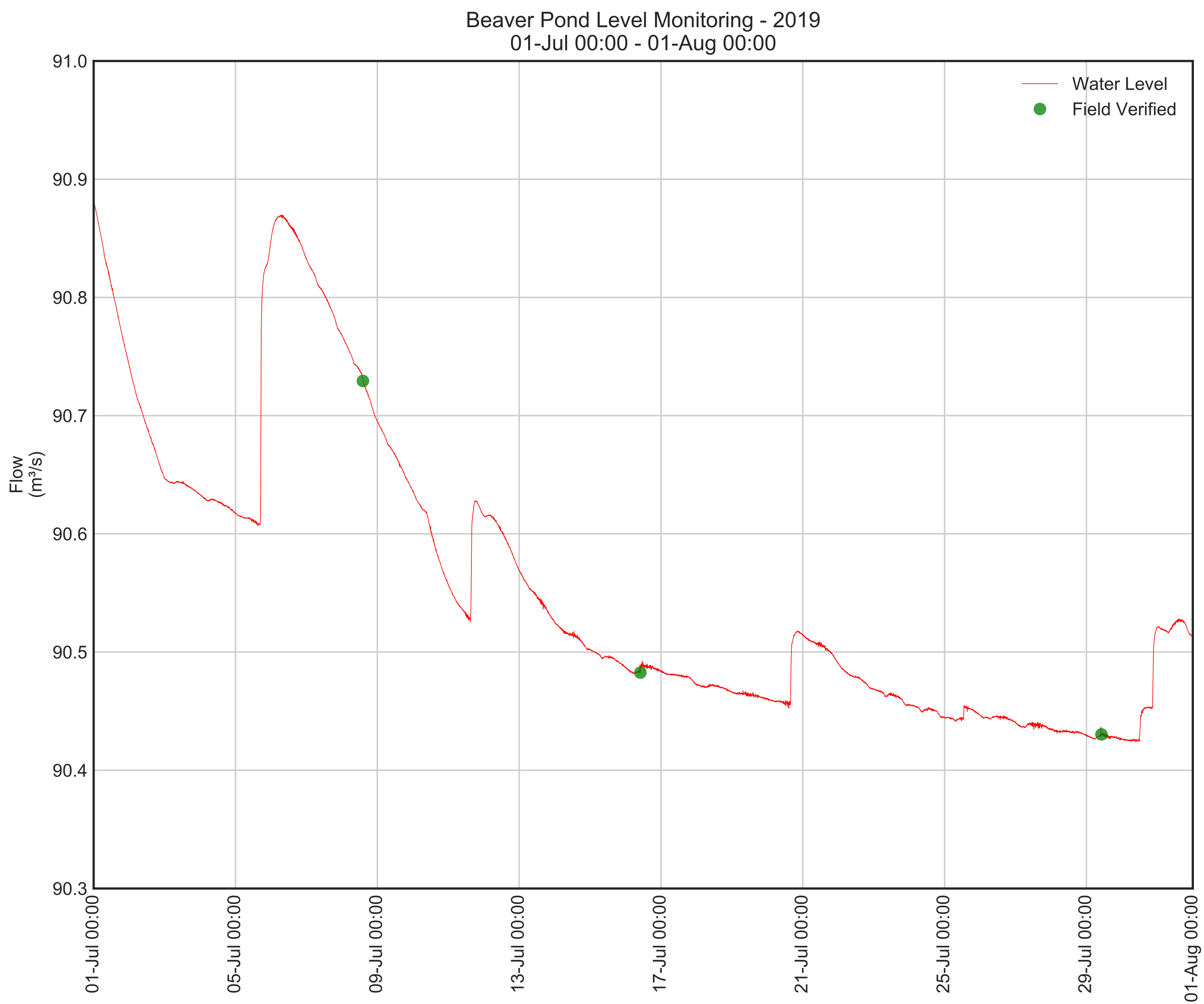


Beaver Pond Level Monitoring - 2019
15-May 13:30 - 23-Oct 13:30
Flow
(m³/s)
91.0
90.9
90.8
90.7
90.6
90.5
90.4
90.3
01-Jun 00:00
01-Jul 00:00
01-Aug 00:00
01-Sep 00:00
01-Oct 00:00
Water Level
Field Verified

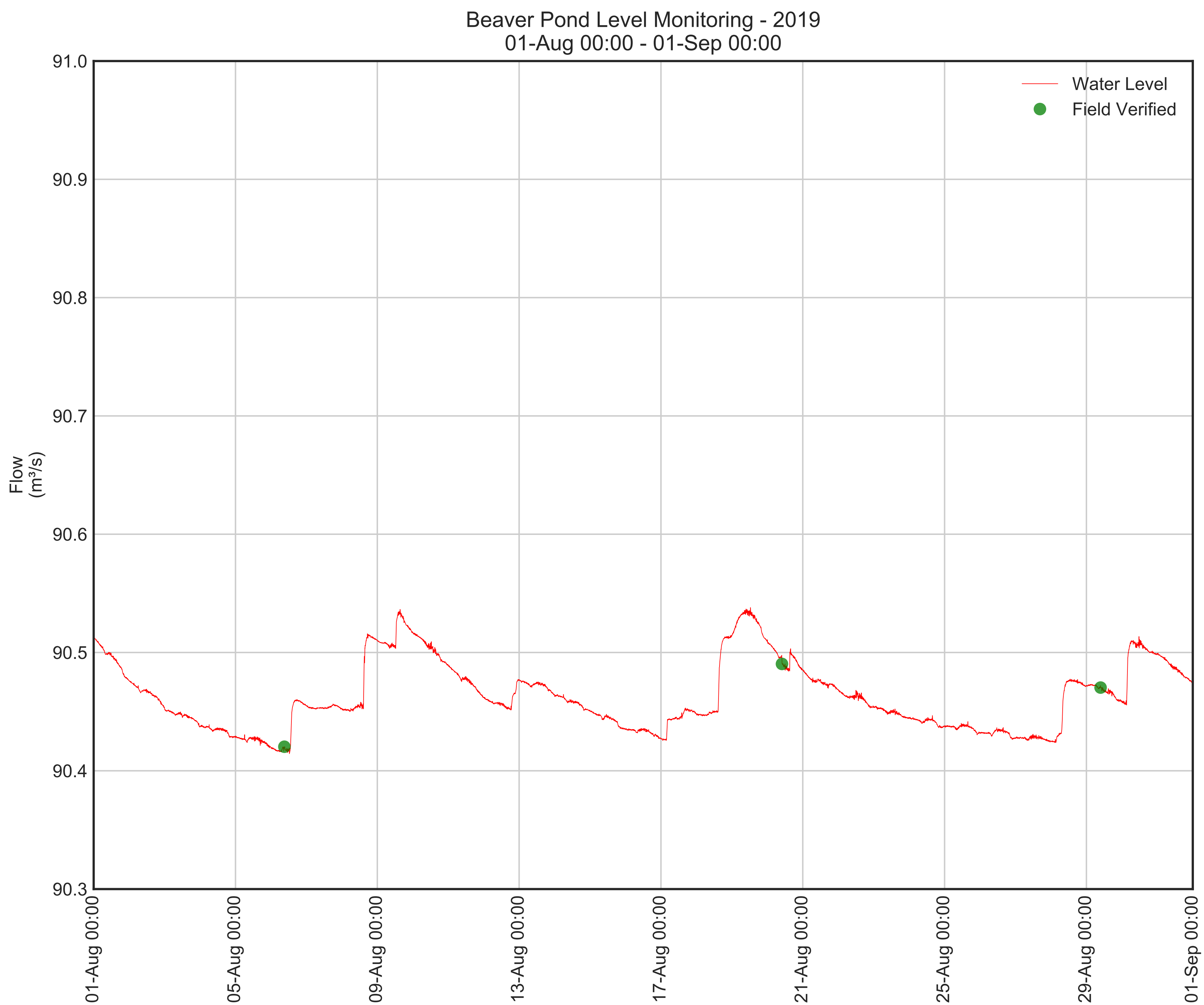


Beaver Pond Level Monitoring - 2019
15-May 13:00 - 01-Jun 00:00
Flow
(m³/s)
91.0
90.9
90.8
90.7
90.6
90.5
90.4
90.3
17-May 00:00
19-May 00:00
21-May 00:00
23-May 00:00
25-May 00:00
27-May 00:00
29-May 00:00
31-May 00:00
01-Jun 00:00
Water Level
Field Verified

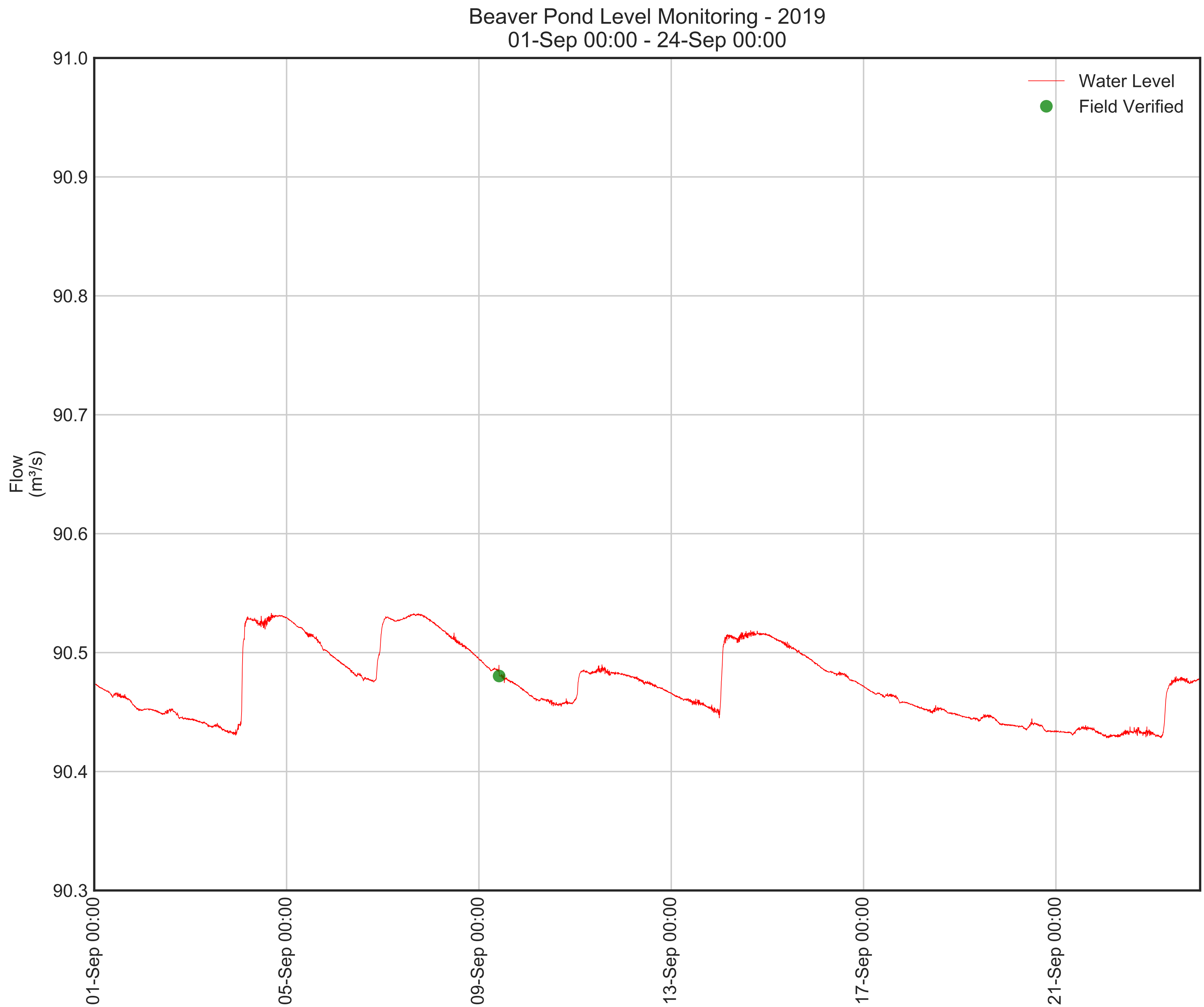

Beaver Pond Level Monitoring - 2019
01-Jun 00:00 - 01-Jul 00:00
Water Level
Field Verified
Flow
(m³/s)
91.0
90.9
90.8
90.7
90.6
90.5
90.4
90.3
01-Jun 00:00
05-Jun 00:00
09-Jun 00:00
13-Jun 00:00
17-Jun 00:00
21-Jun 00:00
25-Jun 00:00
29-Jun 00:00
01-Jul 00:00



Beaver Pond Level Monitoring - 2019
01-Jul 00:00 - 01-Aug 00:00
Flow
(m³/s)
91.0
90.9
90.8
90.7
90.6
90.5
90.4
90.3
01-Jul 00:00
05-Jul 00:00
09-Jul 00:00
13-Jul 00:00
17-Jul 00:00
21-Jul 00:00
25-Jul 00:00
29-Jul 00:00
01-Aug 00:00
Water Level
Field Verified



Beaver Pond Level Monitoring - 2019
01-Aug 00:00 - 01-Sep 00:00
Water Level
Field Verified
Flow
(m³/s)
91.0
90.9
90.8
90.7
90.6
90.5
90.4
90.3
01-Aug 00:00
05-Aug 00:00
09-Aug 00:00
13-Aug 00:00
17-Aug 00:00
21-Aug 00:00
25-Aug 00:00
29-Aug 00:00
01-Sep 00:00


Beaver Pond Level Monitoring - 2019
01-Sep 00:00 - 24-Sep 00:00
Flow
(m³/s)
91.0
90.9
90.8
90.7
90.6
90.5
90.4
90.3
Water Level
Field Verified
01-Sep 00:00
05-Sep 00:00
09-Sep 00:00
13-Sep 00:00
17-Sep 00:00
21-Sep 00:00

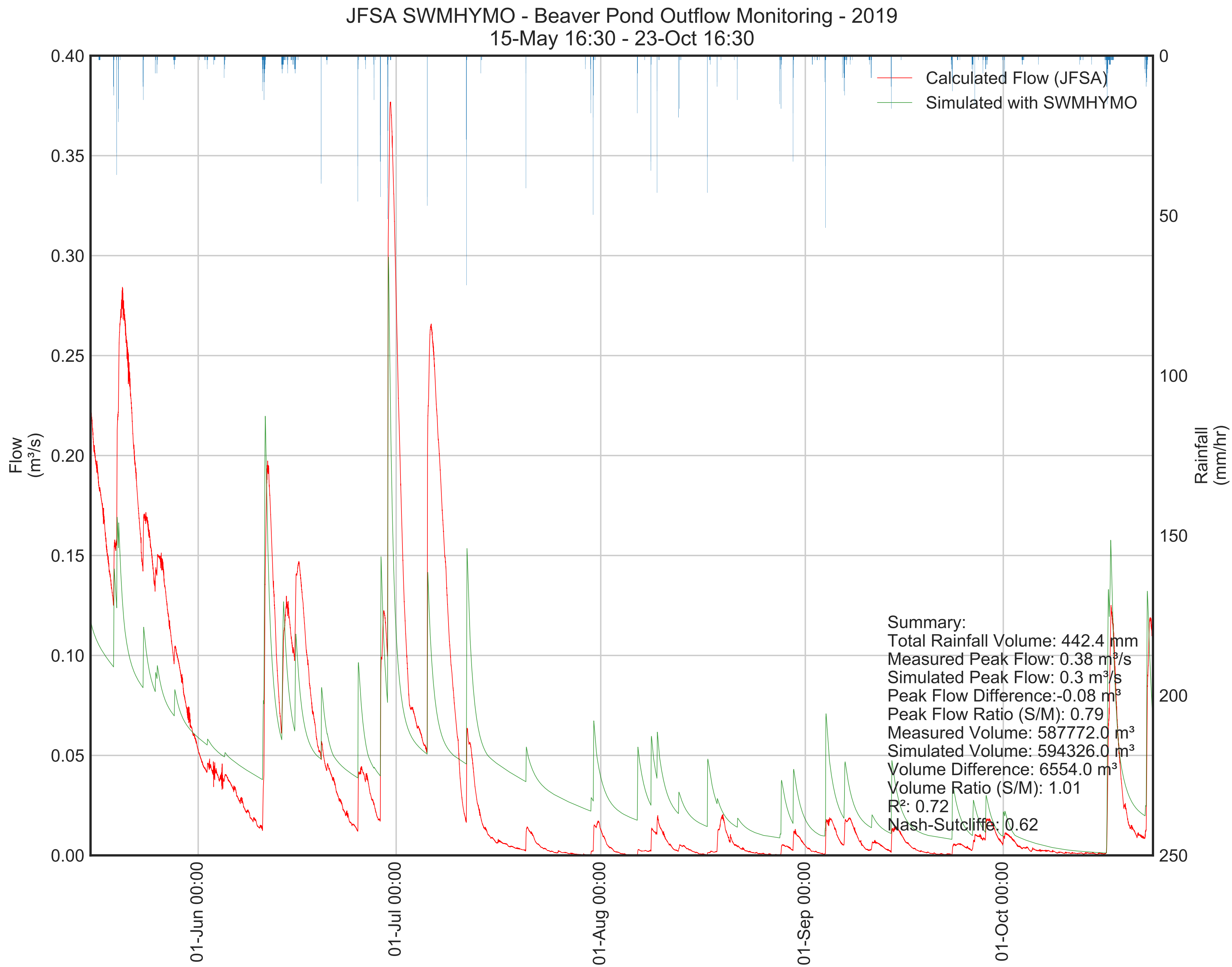
JFSA
WATER RESOURCES AND
ENVIRONMENTAL CONSULTANTS

Project Ref #:P1581
Client: David Schaeffer Engineering

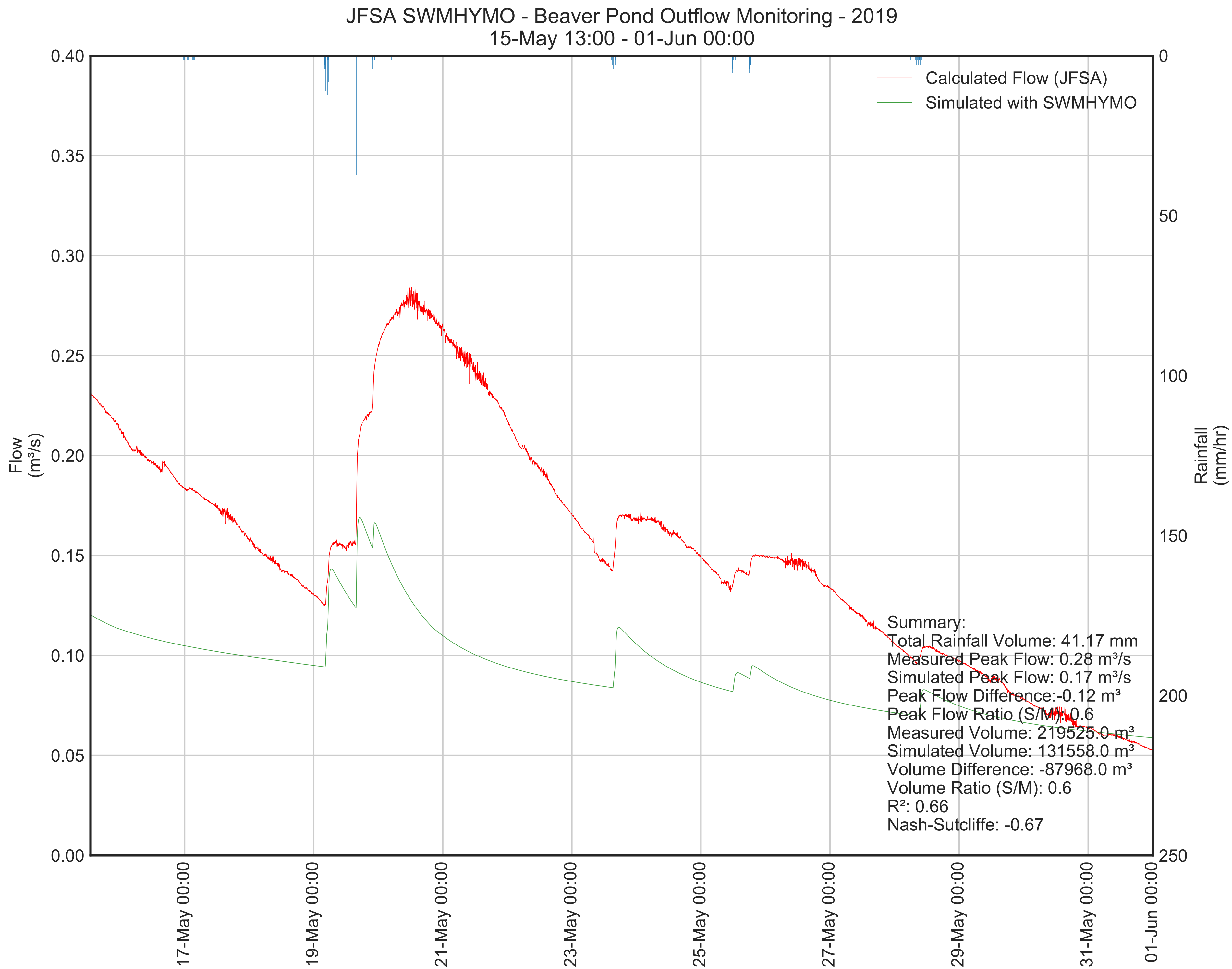
Ottawa. ON
Paris. ON
Gatineau. QB
Montréal. QB
Québec. QB

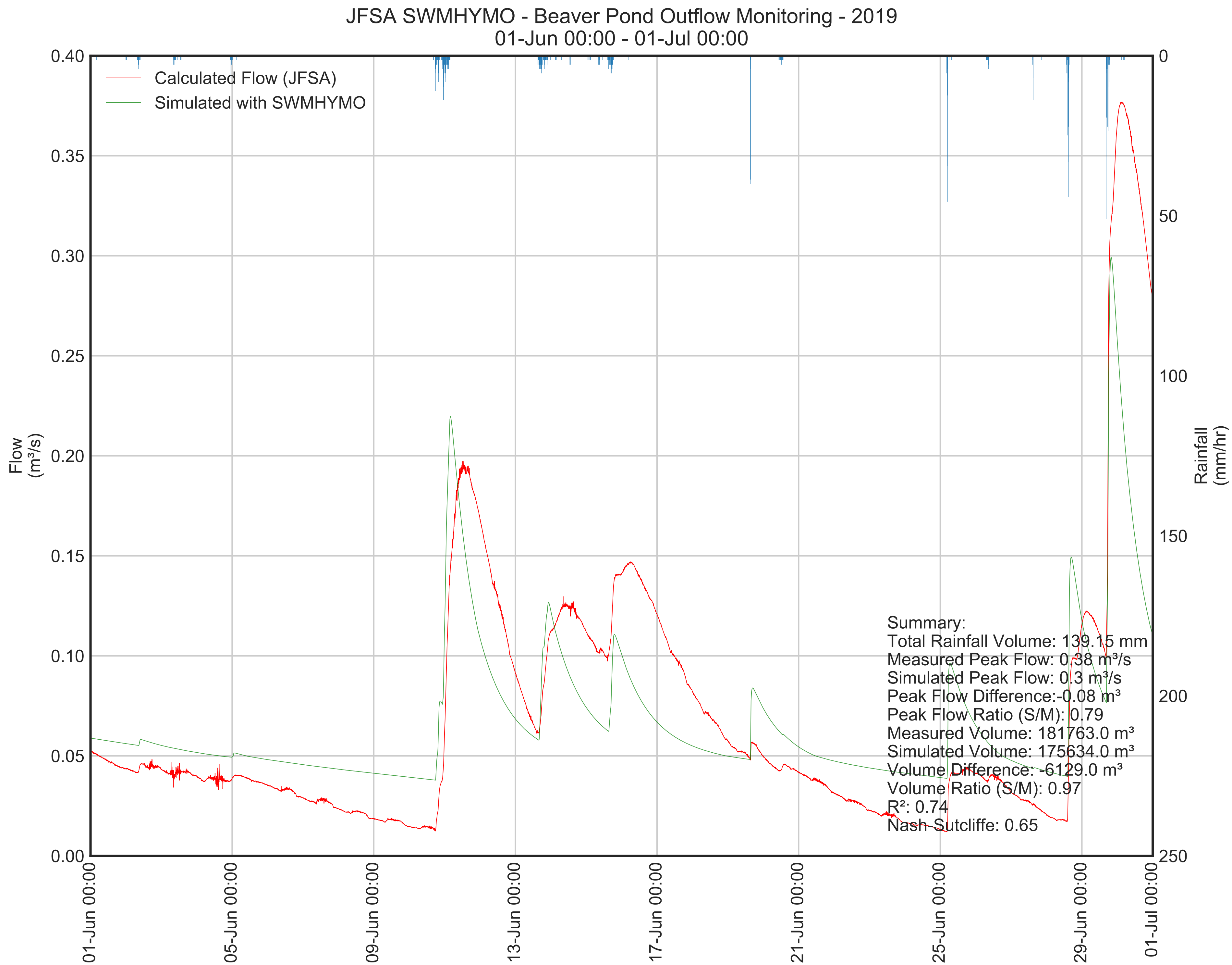
Appendix F

2013 & 2019 Beaver Pond Measured vs. Simulated Flow

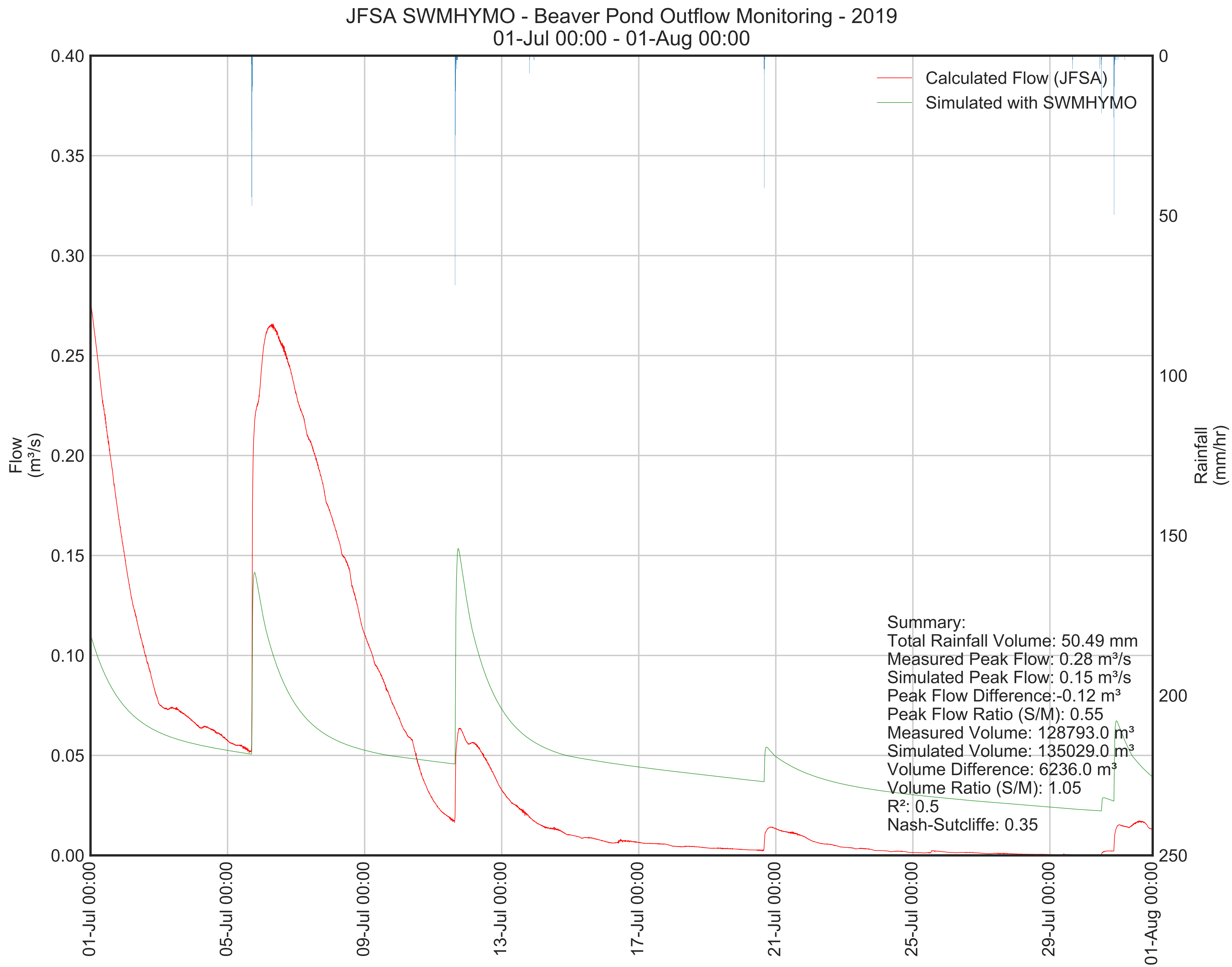


JFSA SWMHYMO - Beaver Pond Outflow Monitoring - 2019
15-May 16:30 - 23-Oct 16:30
Flow (m³/s)
Rainfall (mm/hr)
Calculated Flow (JFSA)
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 442.4 mm
Measured Peak Flow: 0.38 m³/s
Simulated Peak Flow: 0.3 m³/s
Peak Flow Difference:-0.08 m³
Peak Flow Ratio (S/M): 0.79
Measured Volume: 587772.0 m³
Simulated Volume: 594326.0 m³
Volume Difference: 6554.0 m³
Volume Ratio (S/M): 1.01
R²: 0.72
Nash-Sutcliffe: 0.62
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
01-Jun 00:00
01-Jul 00:00
01-Aug 00:00
01-Sep 00:00
01-Oct 00:00

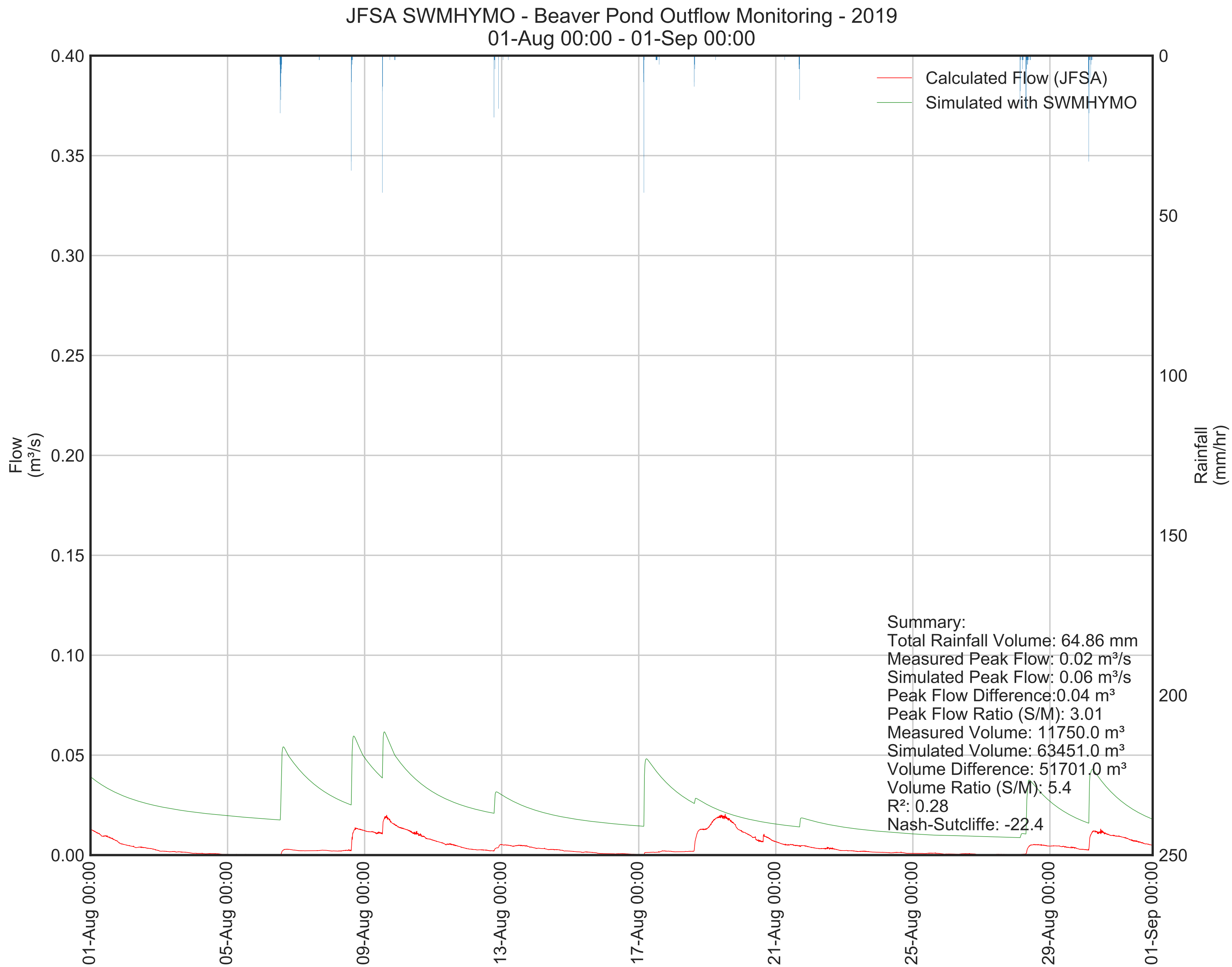

JFSA SWMHYMO - Beaver Pond Outflow Monitoring - 2019
15-May 13:00 - 01-Jun 00:00
Flow (m³/s)
Rainfall (mm/hr)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
17-May 00:00
19-May 00:00
21-May 00:00
23-May 00:00
25-May 00:00
27-May 00:00
29-May 00:00
31-May 00:00
01-Jun 00:00
Calculated Flow (JFSA)
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 41.17 mm
Measured Peak Flow: 0.28 m³/s
Simulated Peak Flow: 0.17 m³/s
Peak Flow Difference:-0.12 m³
Peak Flow Ratio (S/M): 0.6
Measured Volume: 219525.0 m³
Simulated Volume: 131558.0 m³
Volume Difference: -87968.0 m³
Volume Ratio (S/M): 0.6
R²: 0.66
Nash-Sutcliffe: -0.67

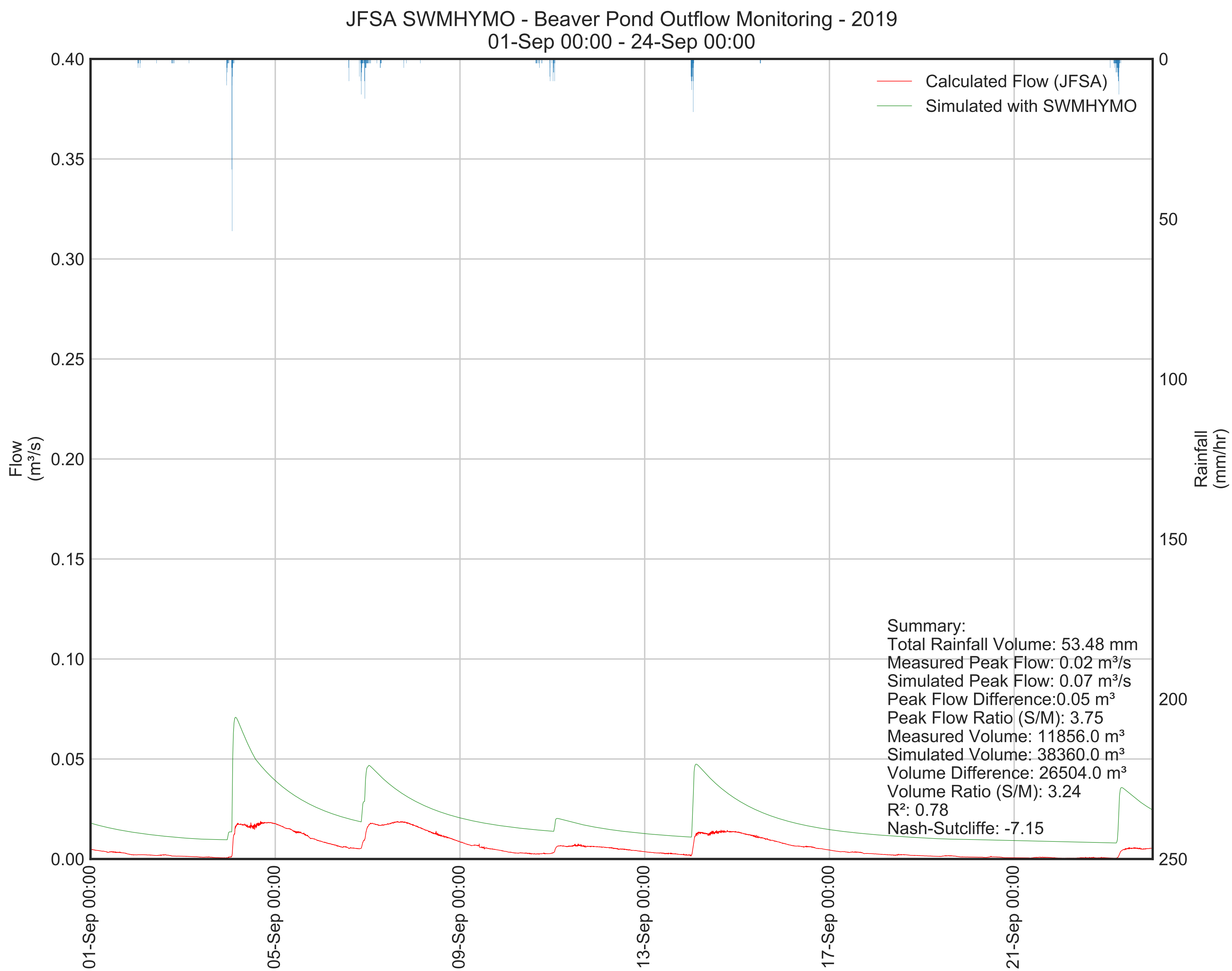


JFSA SWMHYMO - Beaver Pond Outflow Monitoring - 2019
01-Jun 00:00 - 01-Jul 00:00
Calculated Flow (JFSA)
Simulated with SWMHYMO
Flow (m³/s)
Rainfall (mm/hr)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
01-Jun 00:00
05-Jun 00:00
09-Jun 00:00
13-Jun 00:00
17-Jun 00:00
21-Jun 00:00
25-Jun 00:00
29-Jun 00:00
01-Jul 00:00
Summary:
Total Rainfall Volume: 139.15 mm
Measured Peak Flow: 0.38 m³/s
Simulated Peak Flow: 0.3 m³/s
Peak Flow Difference:-0.08 m³
Peak Flow Ratio (S/M): 0.79
Measured Volume: 181763.0 m³
Simulated Volume: 175634.0 m³
Volume Difference: -6129.0 m³
Volume Ratio (S/M): 0.97
R²: 0.74
Nash-Sutcliffe: 0.65

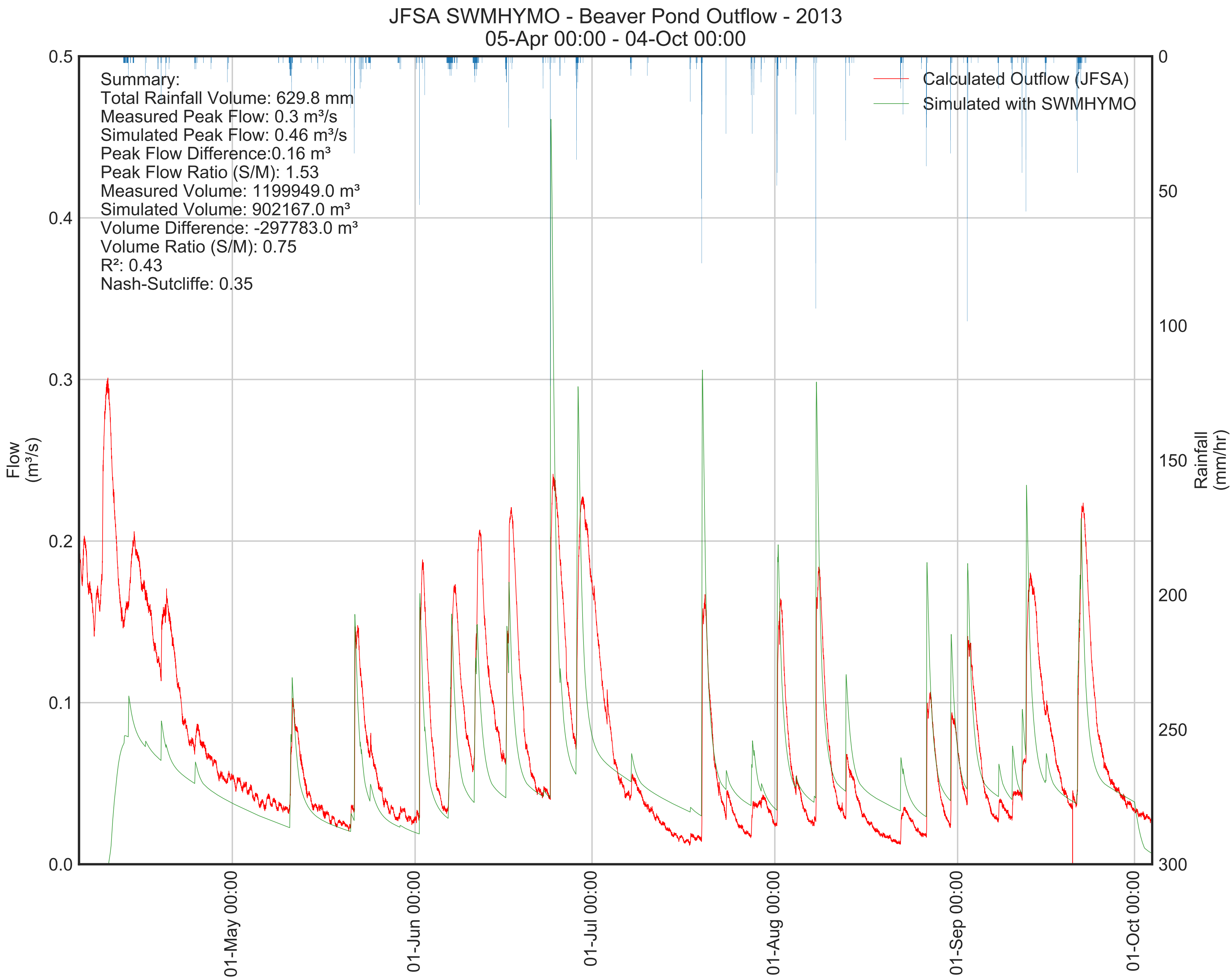


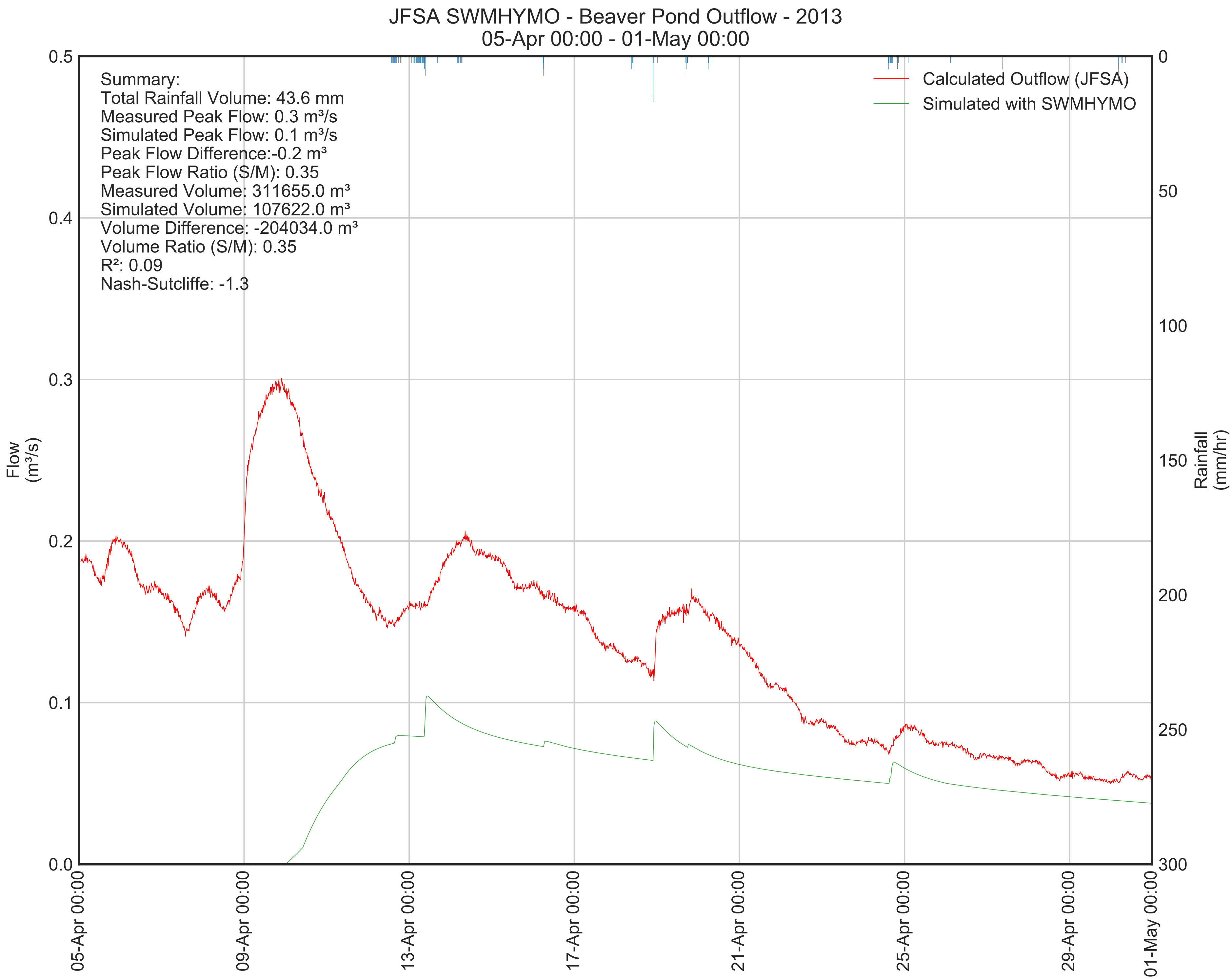
JFSA SWMHYMO - Beaver Pond Outflow Monitoring - 2019
01-Jul 00:00 - 01-Aug 00:00
Flow (m³/s)
Rainfall (mm/hr)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
01-Jul 00:00
05-Jul 00:00
09-Jul 00:00
13-Jul 00:00
17-Jul 00:00
21-Jul 00:00
25-Jul 00:00
29-Jul 00:00
01-Aug 00:00
Calculated Flow (JFSA)
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 50.49 mm
Measured Peak Flow: 0.28 m³/s
Simulated Peak Flow: 0.15 m³/s
Peak Flow Difference:-0.12 m³
Peak Flow Ratio (S/M): 0.55
Measured Volume: 128793.0 m³
Simulated Volume: 135029.0 m³
Volume Difference: 6236.0 m³
Volume Ratio (S/M): 1.05
R²: 0.5
Nash-Sutcliffe: 0.35


JFSA SWMHYMO - Beaver Pond Outflow Monitoring - 2019
01-Aug 00:00 - 01-Sep 00:00
Flow (m³/s)
Rainfall (mm/hr)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
01-Aug 00:00
05-Aug 00:00
09-Aug 00:00
13-Aug 00:00
17-Aug 00:00
21-Aug 00:00
25-Aug 00:00
29-Aug 00:00
01-Sep 00:00
Calculated Flow (JFSA)
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 64.86 mm
Measured Peak Flow: 0.02 m³/s
Simulated Peak Flow: 0.06 m³/s
Peak Flow Difference:0.04 m³
Peak Flow Ratio (S/M): 3.01
Measured Volume: 11750.0 m³
Simulated Volume: 63451.0 m³
Volume Difference: 51701.0 m³
Volume Ratio (S/M): 5.4
R²: 0.28
Nash-Sutcliffe: -22.4

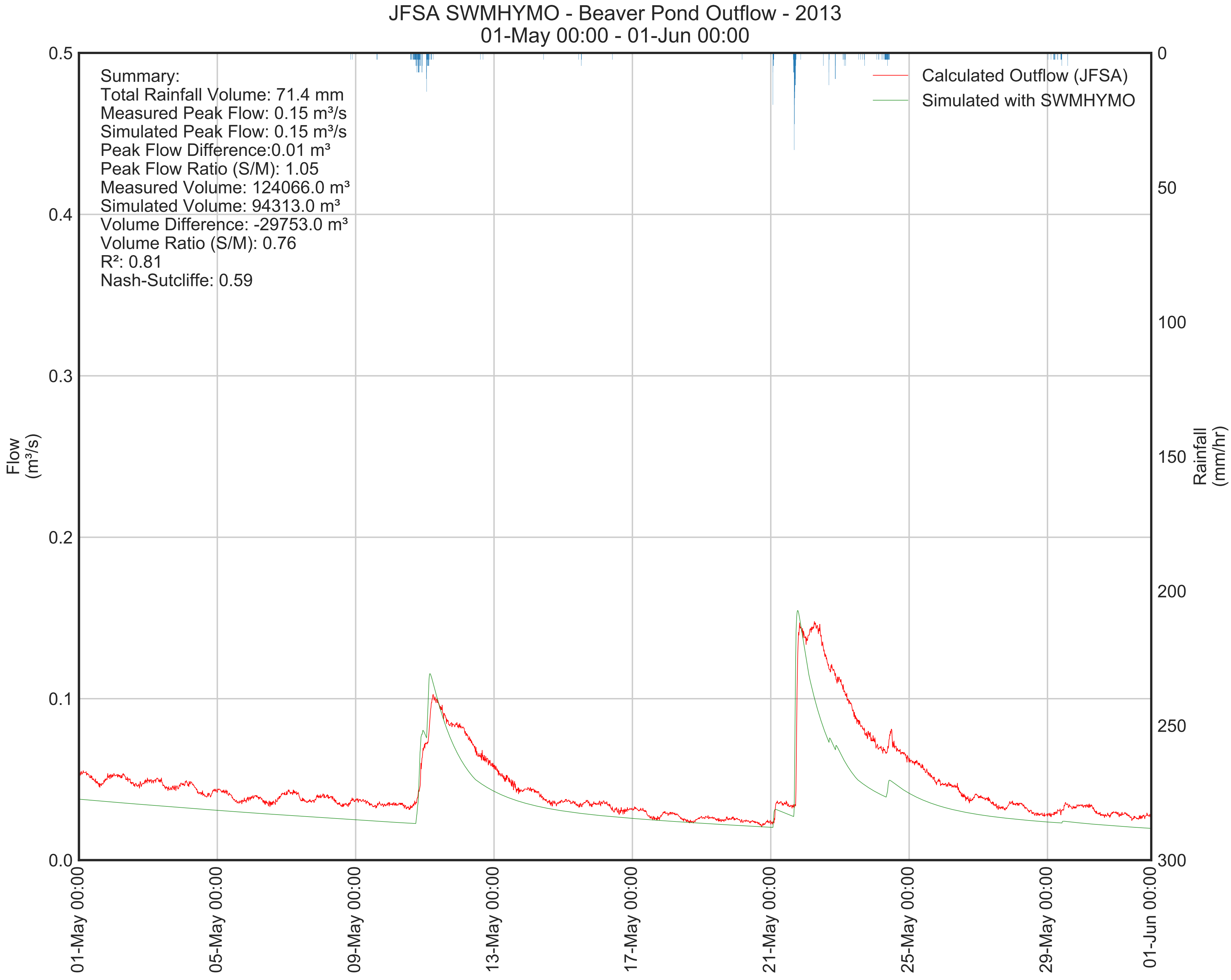


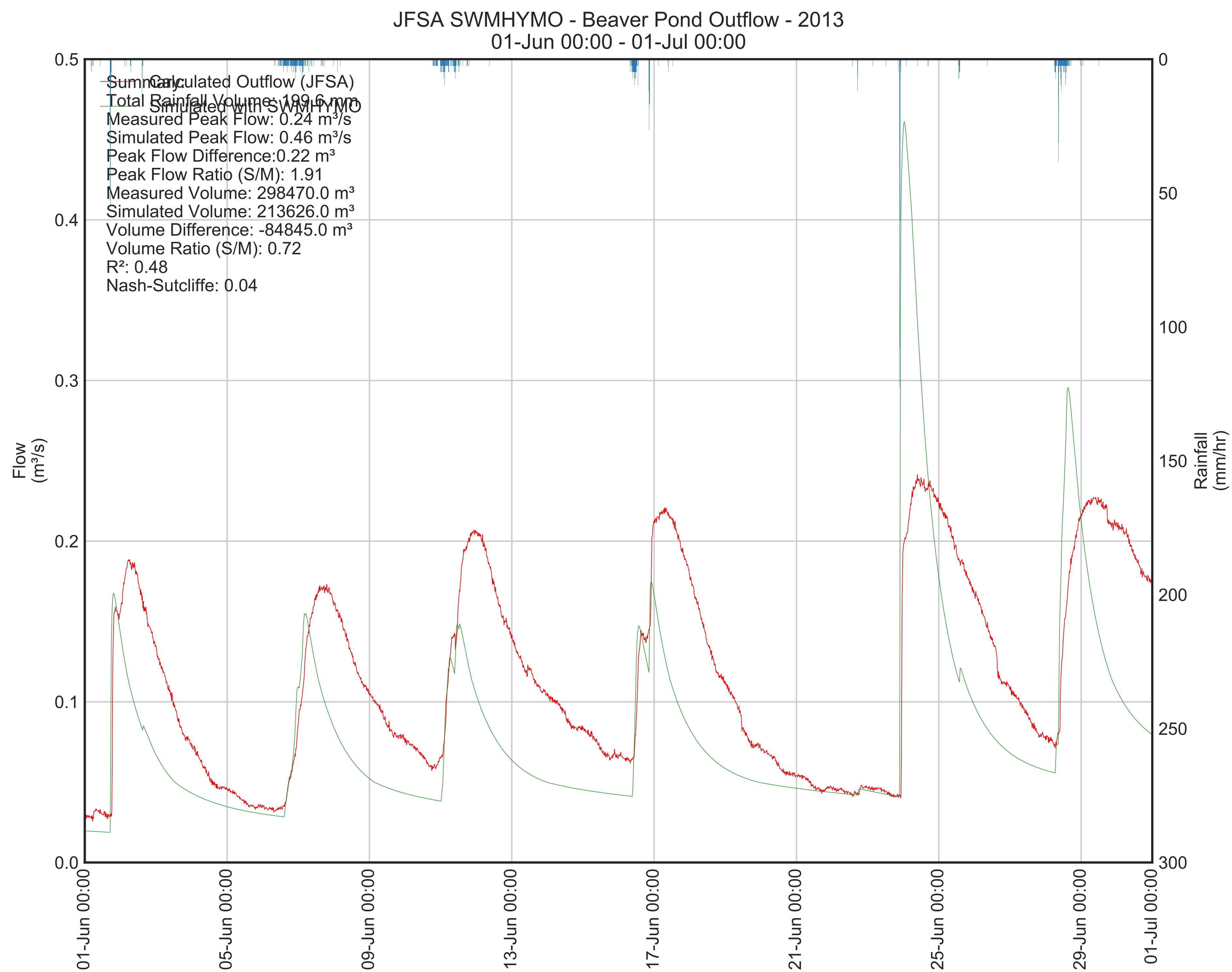
JFSA SWMHYMO - Beaver Pond Outflow Monitoring - 2019
01-Sep 00:00 - 24-Sep 00:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
Calculated Flow (JFSA)
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 53.48 mm
Measured Peak Flow: 0.02 m³/s
Simulated Peak Flow: 0.07 m³/s
Peak Flow Difference:0.05 m³
Peak Flow Ratio (S/M): 3.75
Measured Volume: 11856.0 m³
Simulated Volume: 38360.0 m³
Volume Difference: 26504.0 m³
Volume Ratio (S/M): 3.24
R²: 0.78
Nash-Sutcliffe: -7.15
01-Sep 00:00
05-Sep 00:00
09-Sep 00:00
13-Sep 00:00
17-Sep 00:00
21-Sep 00:00

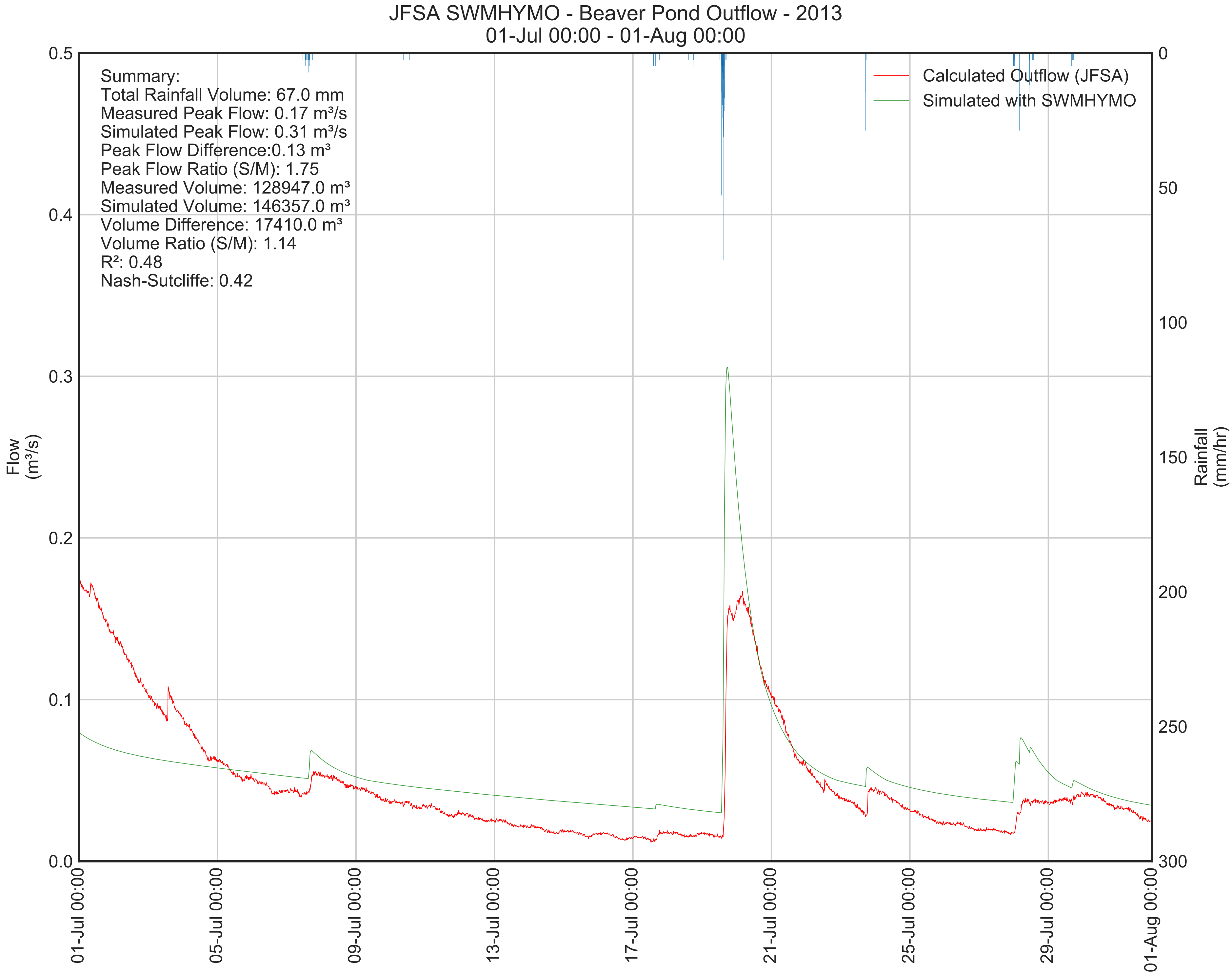

JFSA SWMHYMO - Beaver Pond Outflow - 2013
05-Apr 00:00 - 04-Oct 00:00
Summary:
Total Rainfall Volume: 629.8 mm
Measured Peak Flow: 0.3 m³/s
Simulated Peak Flow: 0.46 m³/s
Peak Flow Difference:0.16 m³
Peak Flow Ratio (S/M): 1.53
Measured Volume: 1199949.0 m³
Simulated Volume: 902167.0 m³
Volume Difference: -297783.0 m³
Volume Ratio (S/M): 0.75
R²: 0.43
Nash-Sutcliffe: 0.35
Calculated Outflow (JFSA)
Simulated with SWMHYMO
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0
50
100
150
200
250
300
01-May 00:00
01-Jun 00:00
01-Jul 00:00
01-Aug 00:00
01-Sep 00:00
01-Oct 00:00



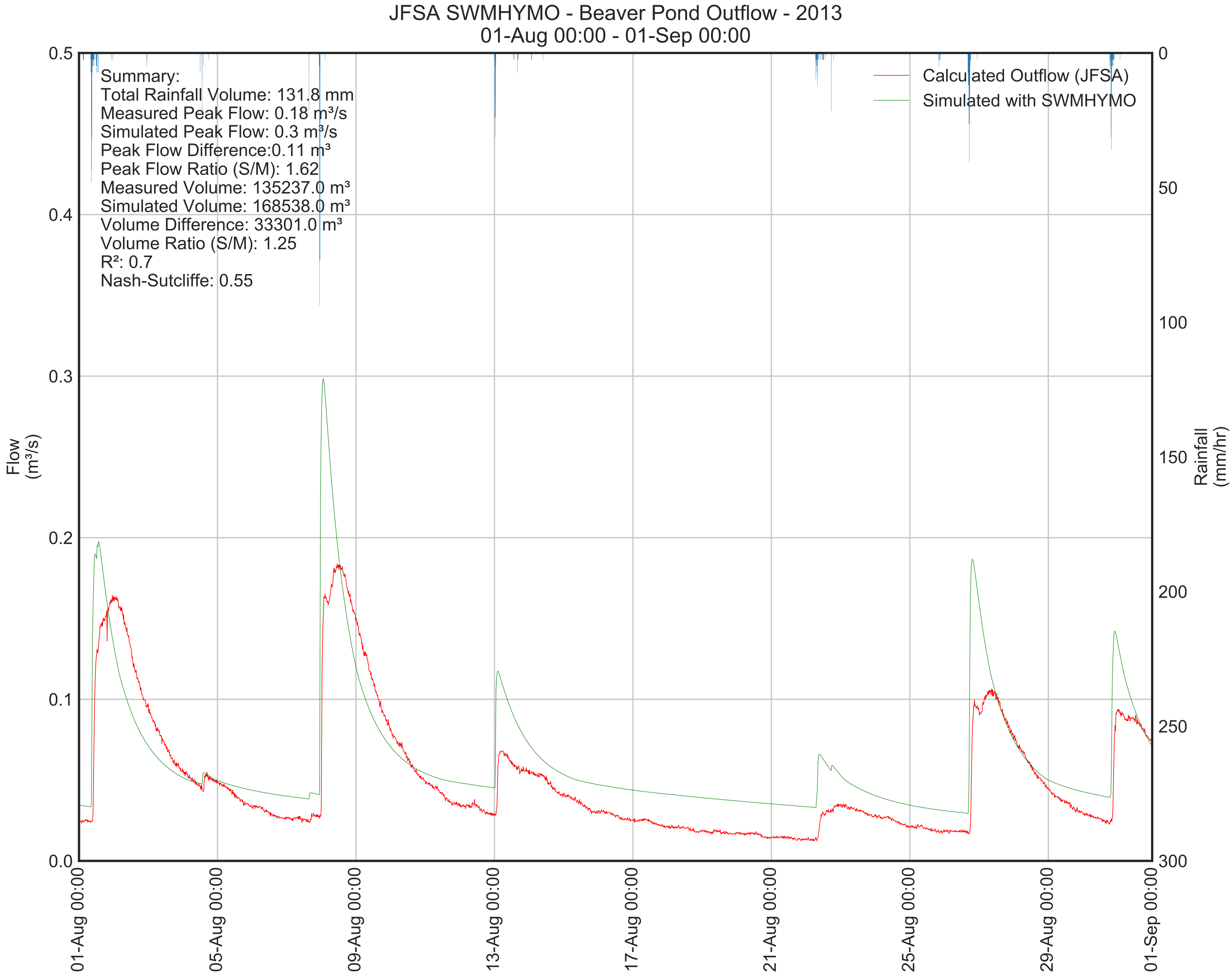
JFSA SWMHYMO - Beaver Pond Outflow - 2013
05-Apr 00:00 - 01-May 00:00
Summary:
Total Rainfall Volume: 43.6 mm
Measured Peak Flow: 0.3 m³/s
Simulated Peak Flow: 0.1 m³/s
Peak Flow Difference:-0.2 m³
Peak Flow Ratio (S/M): 0.35
Measured Volume: 311655.0 m³
Simulated Volume: 107622.0 m³
Volume Difference: -204034.0 m³
Volume Ratio (S/M): 0.35
R²: 0.09
Nash-Sutcliffe: -1.3
Calculated Outflow (JFSA)
Simulated with SWMHYMO
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0
50
100
150
200
250
300
05-Apr 00:00
09-Apr 00:00
13-Apr 00:00
17-Apr 00:00
21-Apr 00:00
25-Apr 00:00
29-Apr 00:00
01-May 00:00

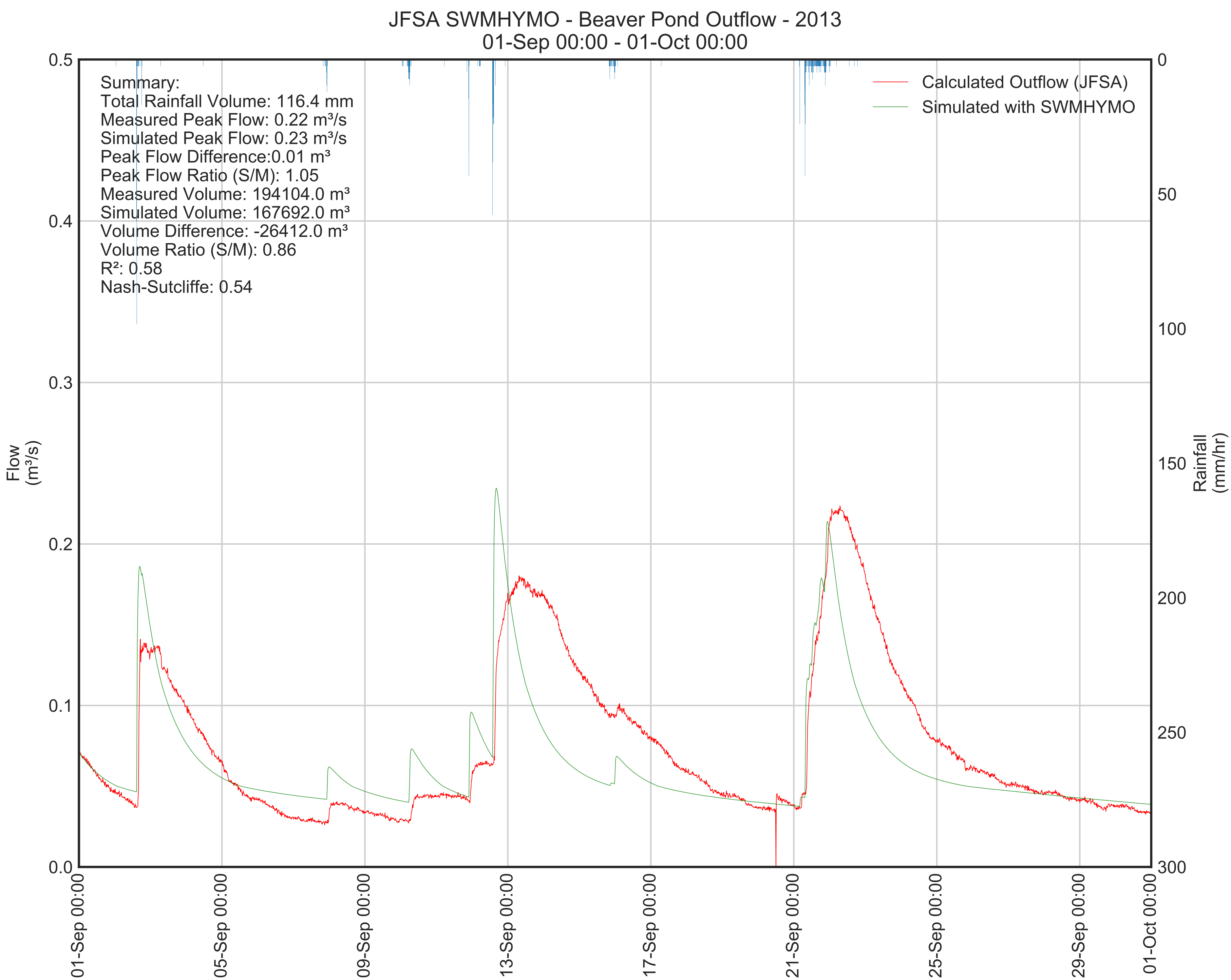

JFSA SWMHYMO - Beaver Pond Outflow - 2013
01-May 00:00 - 01-Jun 00:00
Summary:
Total Rainfall Volume: 71.4 mm
Measured Peak Flow: 0.15 m³/s
Simulated Peak Flow: 0.15 m³/s
Peak Flow Difference:0.01 m³
Peak Flow Ratio (S/M): 1.05
Measured Volume: 124066.0 m³
Simulated Volume: 94313.0 m³
Volume Difference: -29753.0 m³
Volume Ratio (S/M): 0.76
R²: 0.81
Nash-Sutcliffe: 0.59
Calculated Outflow (JFSA)
Simulated with SWMHYMO
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0
50
100
150
200
250
300
01-May 00:00
05-May 00:00
09-May 00:00
13-May 00:00
17-May 00:00
21-May 00:00
25-May 00:00
29-May 00:00
01-Jun 00:00

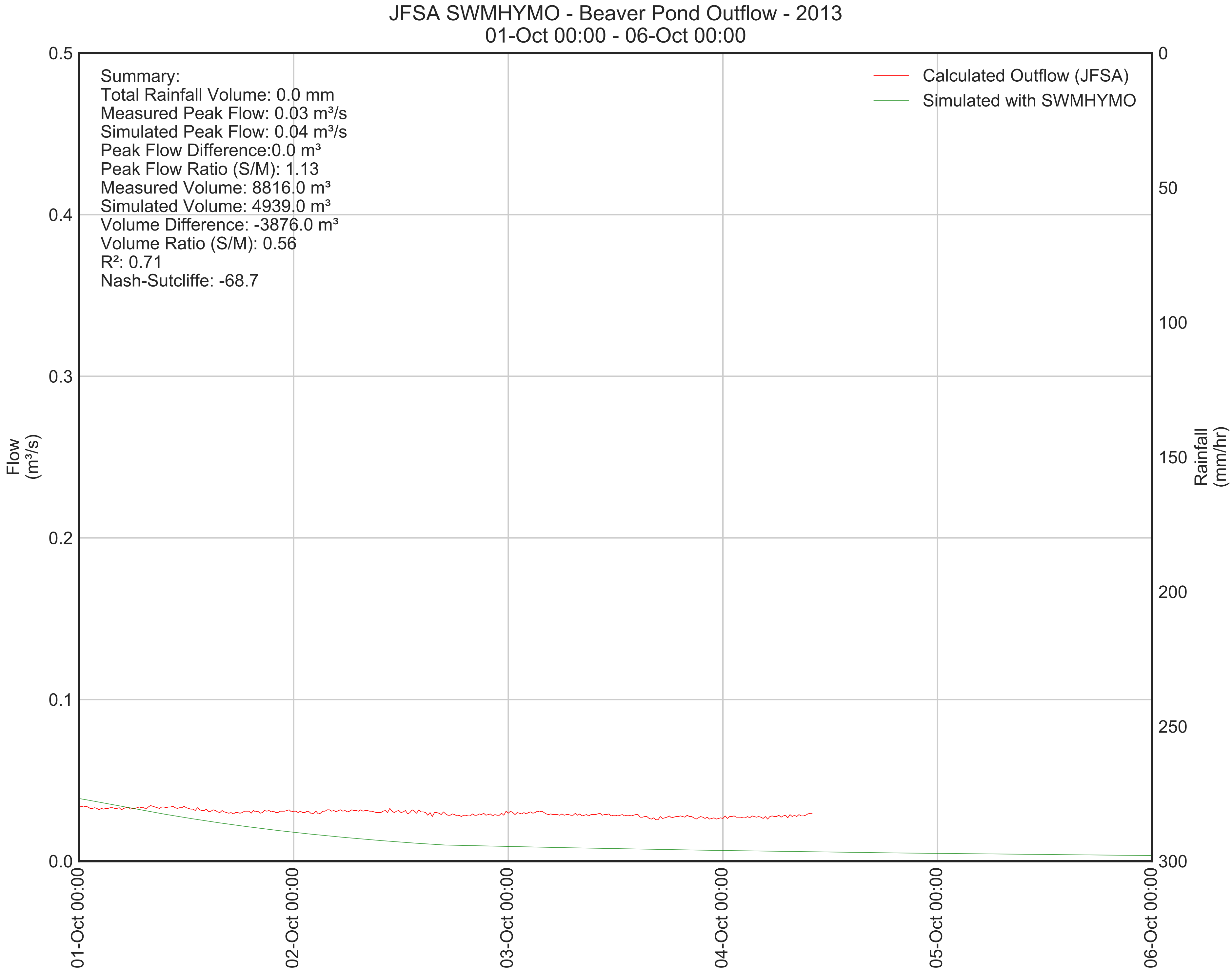

JFSA SWMHYMO - Beaver Pond Outflow - 2013
01-Jun 00:00 - 01-Jul 00:00
Calculated Outflow (JFSA)
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 199.6 mm
Measured Peak Flow: 0.24 m³/s
Simulated Peak Flow: 0.46 m³/s
Peak Flow Difference:0.22 m³
Peak Flow Ratio (S/M): 1.91
Measured Volume: 298470.0 m³
Simulated Volume: 213626.0 m³
Volume Difference: -84845.0 m³
Volume Ratio (S/M): 0.72
R²: 0.48
Nash-Sutcliffe: 0.04
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0
50
100
150
200
250
300
01-Jun 00:00
05-Jun 00:00
09-Jun 00:00
13-Jun 00:00
17-Jun 00:00
21-Jun 00:00
25-Jun 00:00
29-Jun 00:00
01-Jul 00:00



JFSA SWMHYMO - Beaver Pond Outflow - 2013
01-Jul 00:00 - 01-Aug 00:00
Summary:
Total Rainfall Volume: 67.0 mm
Measured Peak Flow: 0.17 m³/s
Simulated Peak Flow: 0.31 m³/s
Peak Flow Difference:0.13 m³
Peak Flow Ratio (S/M): 1.75
Measured Volume: 128947.0 m³
Simulated Volume: 146357.0 m³
Volume Difference: 17410.0 m³
Volume Ratio (S/M): 1.14
R²: 0.48
Nash-Sutcliffe: 0.42
Calculated Outflow (JFSA)
Simulated with SWMHYMO
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0
50
100
150
200
250
300
01-Jul 00:00
05-Jul 00:00
09-Jul 00:00
13-Jul 00:00
17-Jul 00:00
21-Jul 00:00
25-Jul 00:00
29-Jul 00:00
01-Aug 00:00


JFSA SWMHYMO - Beaver Pond Outflow - 2013
01-Aug 00:00 - 01-Sep 00:00
Summary:
Total Rainfall Volume: 131.8 mm
Measured Peak Flow: 0.18 m³/s
Simulated Peak Flow: 0.3 m³/s
Peak Flow Difference:0.11 m³
Peak Flow Ratio (S/M): 1.62
Measured Volume: 135237.0 m³
Simulated Volume: 168538.0 m³
Volume Difference: 33301.0 m³
Volume Ratio (S/M): 1.25
R²: 0.7
Nash-Sutcliffe: 0.55
Calculated Outflow (JFSA)
Simulated with SWMHYMO
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0
50
100
150
200
250
300
01-Aug 00:00
05-Aug 00:00
09-Aug 00:00
13-Aug 00:00
17-Aug 00:00
21-Aug 00:00
25-Aug 00:00
29-Aug 00:00
01-Sep 00:00


JFSA SWMHYMO - Beaver Pond Outflow - 2013
01-Sep 00:00 - 01-Oct 00:00
Summary:
Total Rainfall Volume: 116.4 mm
Measured Peak Flow: 0.22 m³/s
Simulated Peak Flow: 0.23 m³/s
Peak Flow Difference:0.01 m³
Peak Flow Ratio (S/M): 1.05
Measured Volume: 194104.0 m³
Simulated Volume: 167692.0 m³
Volume Difference: -26412.0 m³
Volume Ratio (S/M): 0.86
R²: 0.58
Nash-Sutcliffe: 0.54
Calculated Outflow (JFSA)
Simulated with SWMHYMO
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0
50
100
150
200
250
300
01-Sep 00:00
05-Sep 00:00
09-Sep 00:00
13-Sep 00:00
17-Sep 00:00
21-Sep 00:00
25-Sep 00:00
29-Sep 00:00
01-Oct 00:00


JFSA SWMHYMO - Beaver Pond Outflow - 2013
01-Oct 00:00 - 06-Oct 00:00
Summary:
Total Rainfall Volume: 0.0 mm
Measured Peak Flow: 0.03 m³/s
Simulated Peak Flow: 0.04 m³/s
Peak Flow Difference:0.0 m³
Peak Flow Ratio (S/M): 1.13
Measured Volume: 8816.0 m³
Simulated Volume: 4939.0 m³
Volume Difference: -3876.0 m³
Volume Ratio (S/M): 0.56
R²: 0.71
Nash-Sutcliffe: -68.7
Calculated Outflow (JFSA)
Simulated with SWMHYMO
Flow
(m³/s)
Rainfall
(mm/hr)
0.5
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
300
01-Oct 00:00
02-Oct 00:00
03-Oct 00:00
04-Oct 00:00
05-Oct 00:00
06-Oct 00:00

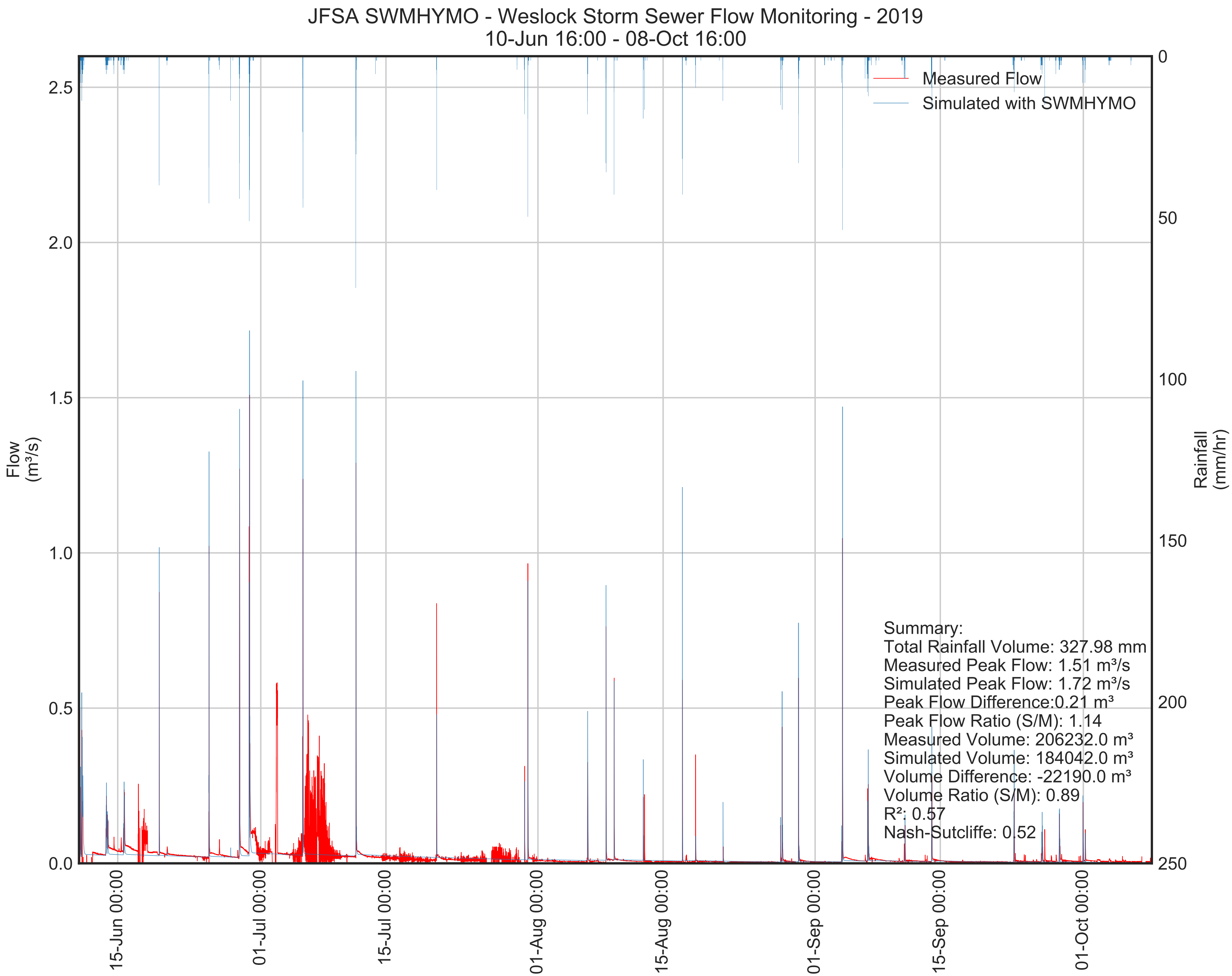
JFSA
WATER RESOURCES AND
ENVIRONMENTAL CONSULTANTS

Project Ref #:P1581
Client: David Schaeffer Engineering

Ottawa. ON
Paris. ON
Gatineau. QB
Montréal. QB
Québec. QB

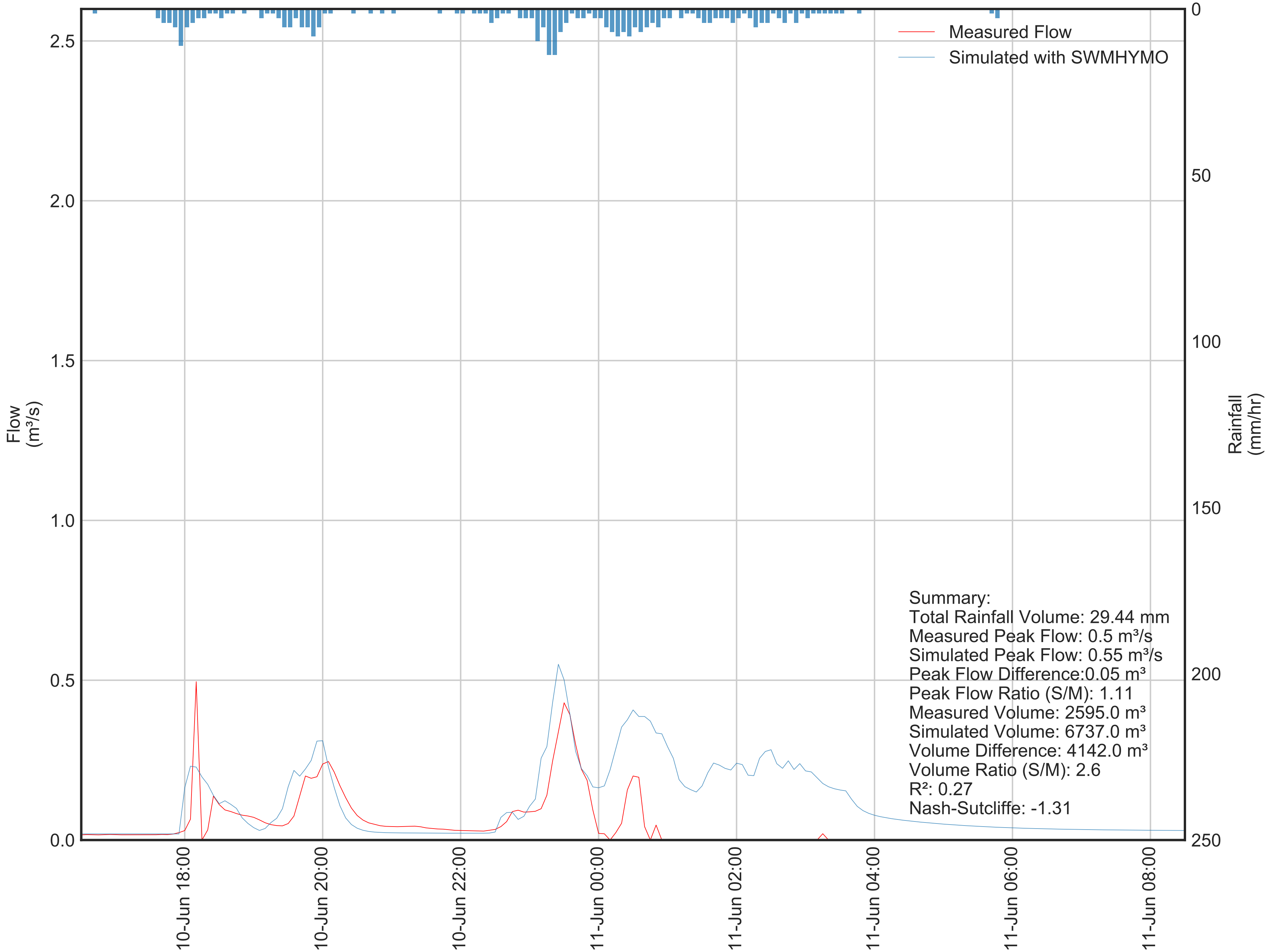
Appendix G

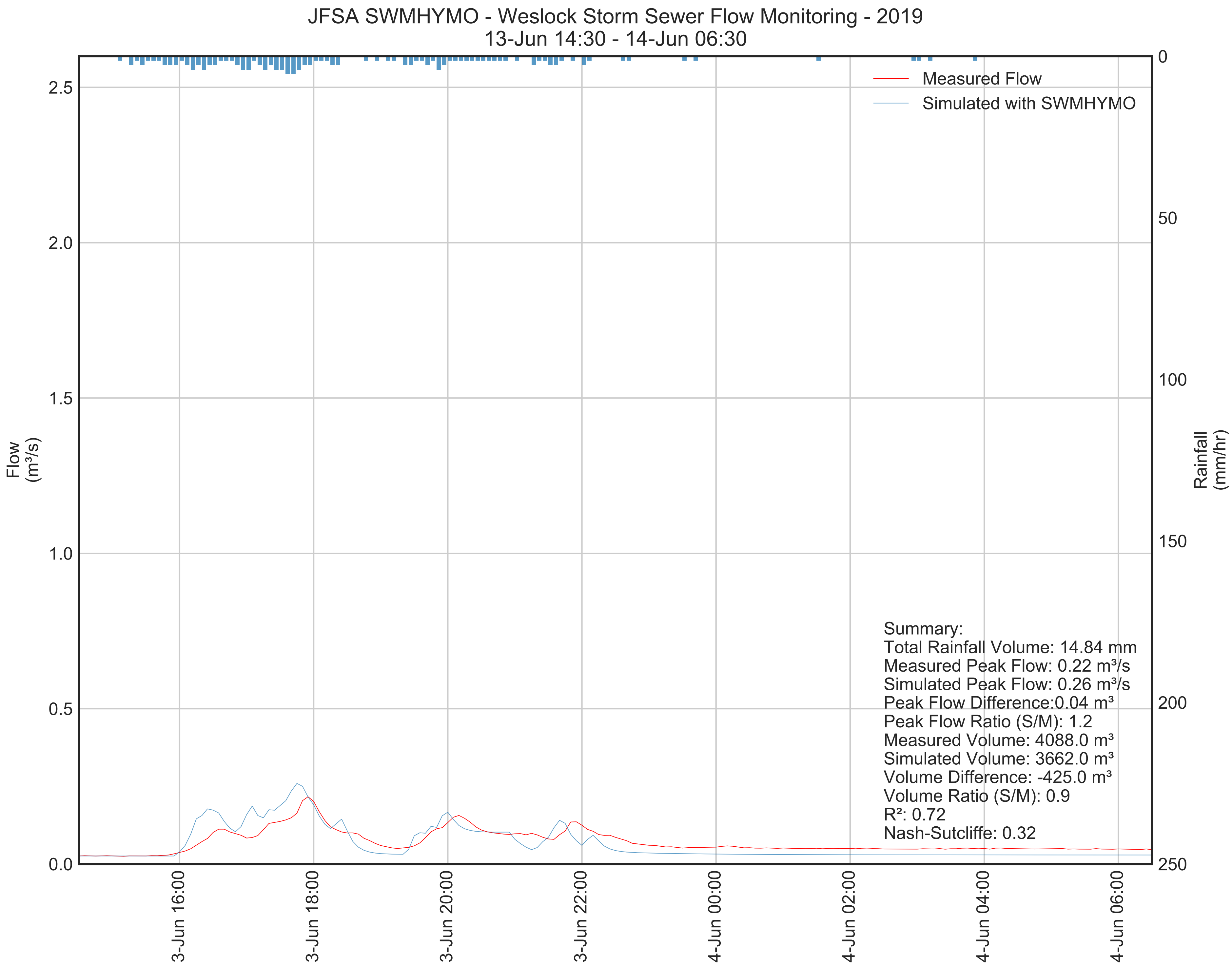
2019 Weslock Way
Measured vs. Simulated Flow

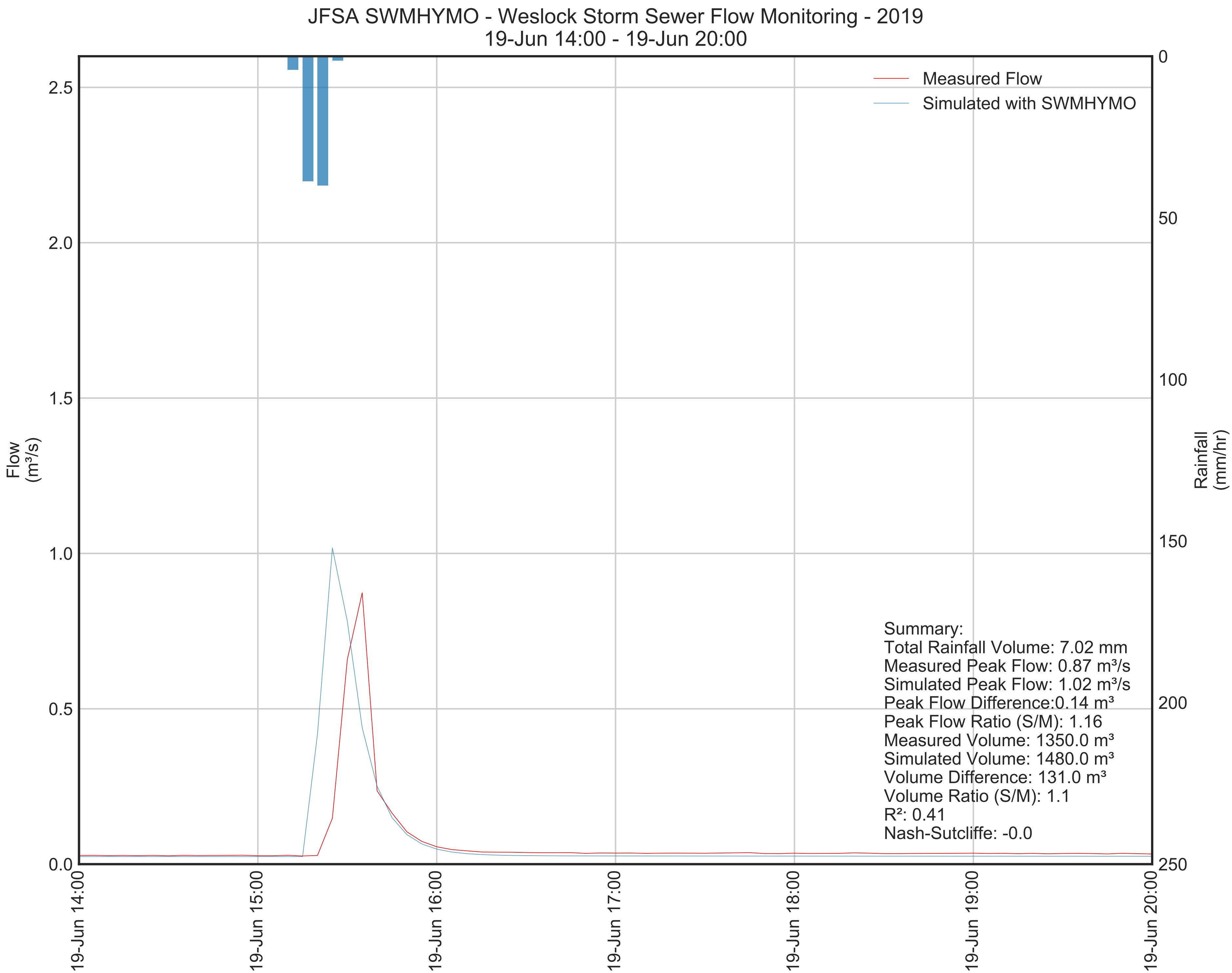


JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
10-Jun 16:00 - 08-Oct 16:00
Flow
(m³/s)
Rainfall
(mm/hr)
Measured Flow
Simulated with SWMHYMO
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
15-Jun 00:00
01-Jul 00:00
15-Jul 00:00
01-Aug 00:00
15-Aug 00:00
01-Sep 00:00
15-Sep 00:00
01-Oct 00:00
Summary:
Total Rainfall Volume: 327.98 mm
Measured Peak Flow: 1.51 m³/s
Simulated Peak Flow: 1.72 m³/s
Peak Flow Difference:0.21 m³
Peak Flow Ratio (S/M): 1.14
Measured Volume: 206232.0 m³
Simulated Volume: 184042.0 m³
Volume Difference: -22190.0 m³
Volume Ratio (S/M): 0.89
R²: 0.57
Nash-Sutcliffe: 0.52

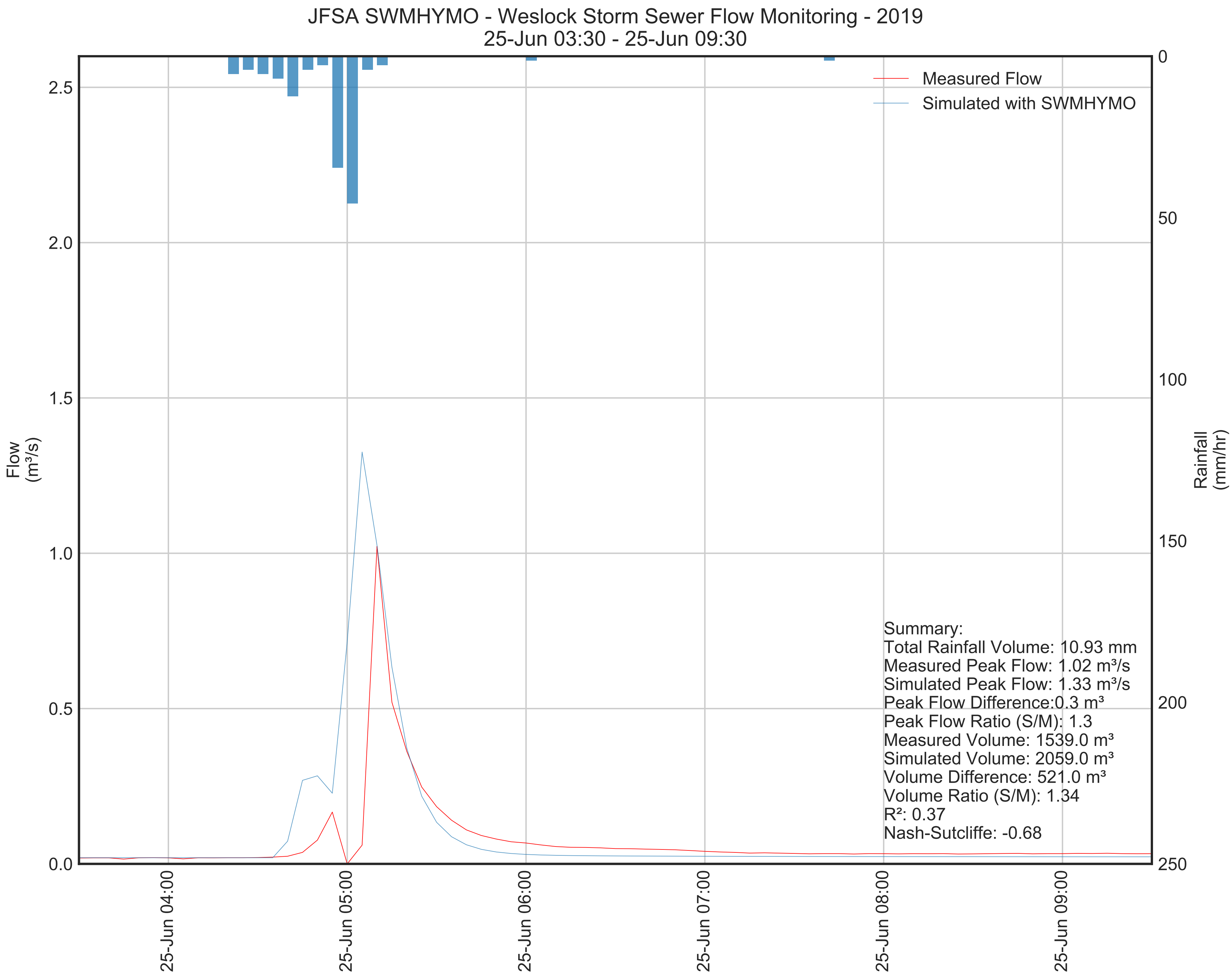
JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
10-Jun 16:30 - 11-Jun 08:30



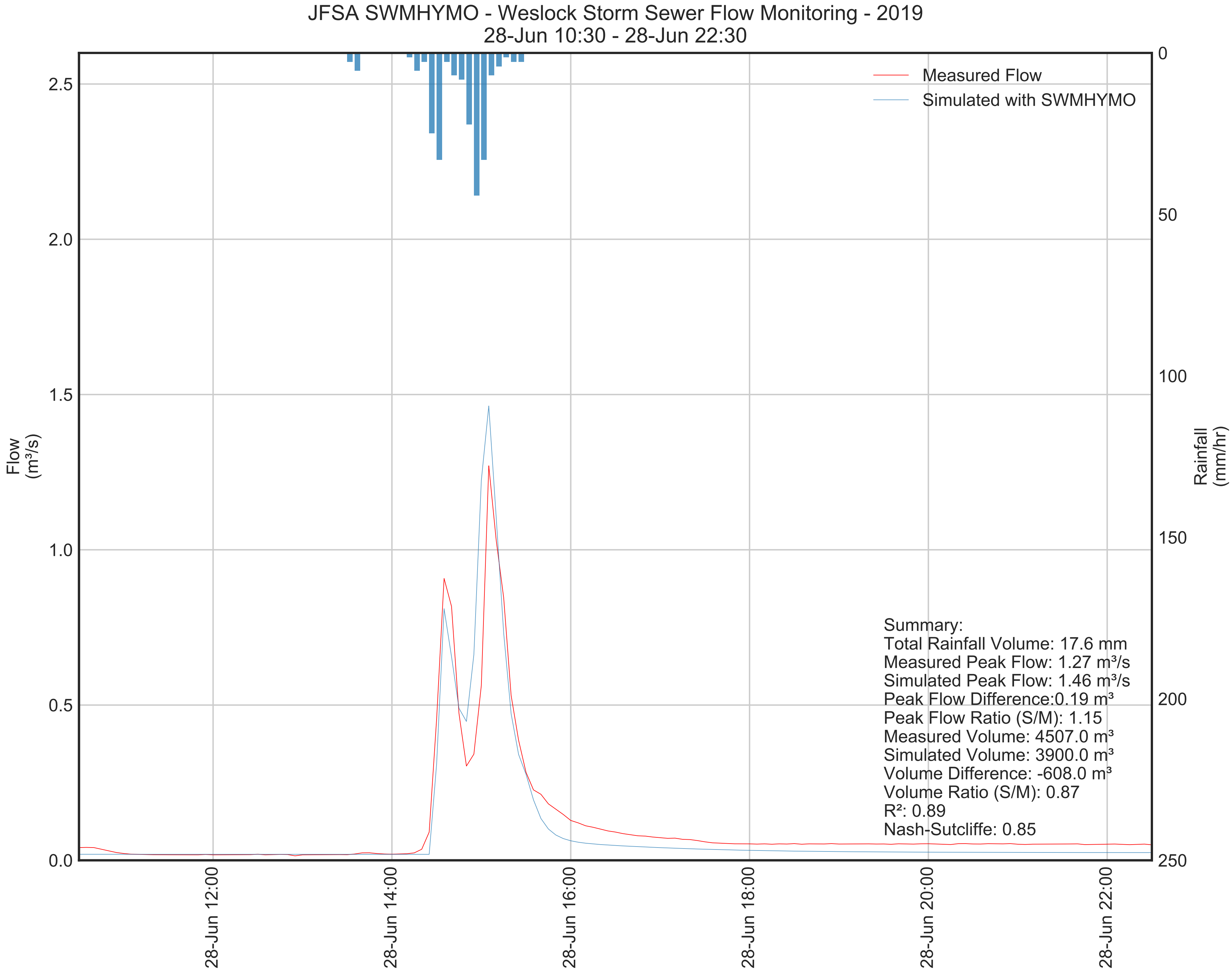

JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
13-Jun 14:30 - 14-Jun 06:30
Flow
(m³/s)
Rainfall
(mm/hr)
Measured Flow
Simulated with SWMHYMO
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
13-Jun 16:00
13-Jun 18:00
13-Jun 20:00
13-Jun 22:00
14-Jun 00:00
14-Jun 02:00
14-Jun 04:00
14-Jun 06:00
Summary:
Total Rainfall Volume: 14.84 mm
Measured Peak Flow: 0.22 m³/s
Simulated Peak Flow: 0.26 m³/s
Peak Flow Difference:0.04 m³
Peak Flow Ratio (S/M): 1.2
Measured Volume: 4088.0 m³
Simulated Volume: 3662.0 m³
Volume Difference: -425.0 m³
Volume Ratio (S/M): 0.9
R²: 0.72
Nash-Sutcliffe: 0.32



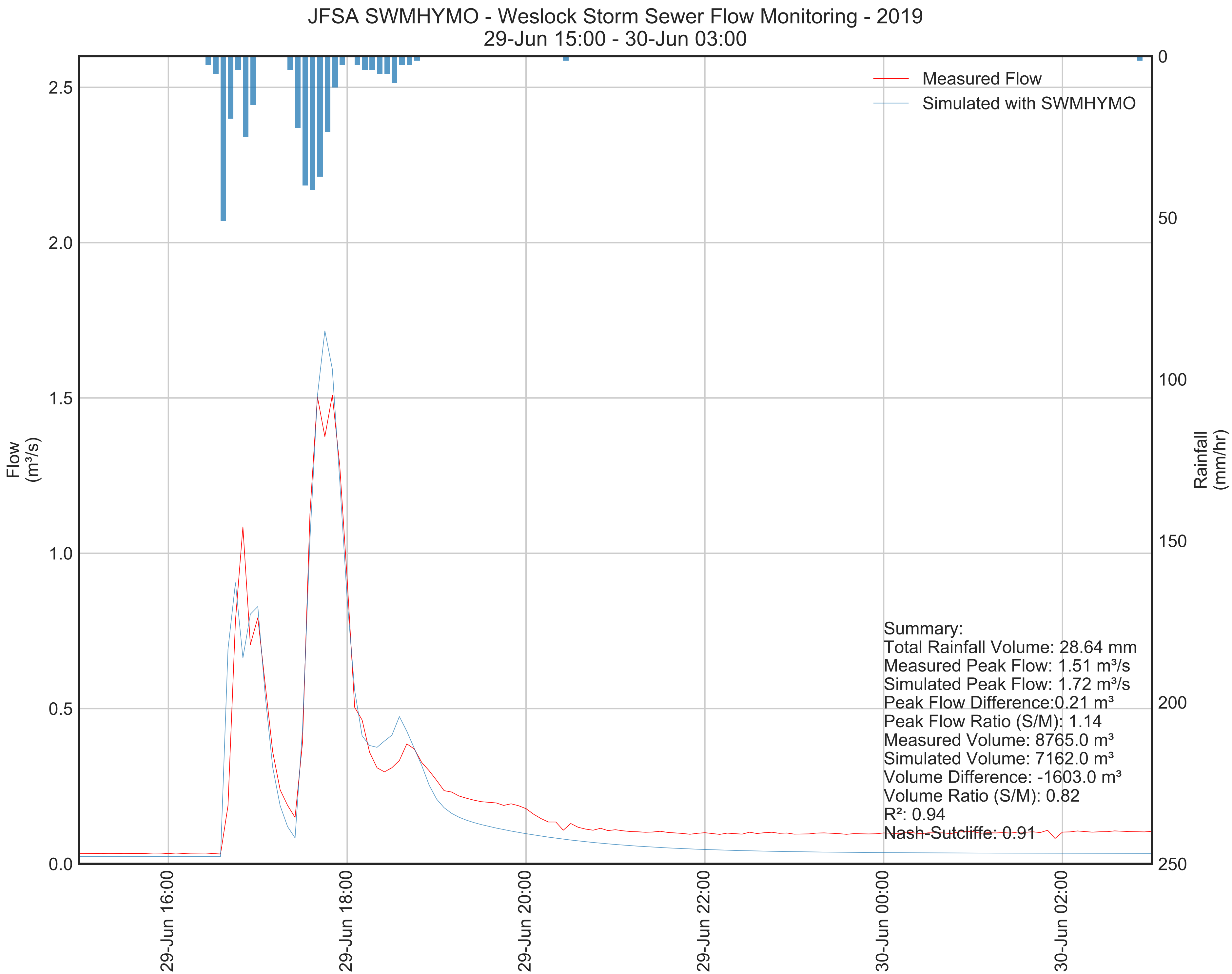
JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
19-Jun 14:00 - 19-Jun 20:00
Flow (m³/s)
Rainfall (mm/hr)
Measured Flow
Simulated with SWMHYMO
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
19-Jun 14:00
19-Jun 15:00
19-Jun 16:00
19-Jun 17:00
19-Jun 18:00
19-Jun 19:00
19-Jun 20:00
Summary:
Total Rainfall Volume: 7.02 mm
Measured Peak Flow: 0.87 m³/s
Simulated Peak Flow: 1.02 m³/s
Peak Flow Difference:0.14 m³
Peak Flow Ratio (S/M): 1.16
Measured Volume: 1350.0 m³
Simulated Volume: 1480.0 m³
Volume Difference: 131.0 m³
Volume Ratio (S/M): 1.1
R²: 0.41
Nash-Sutcliffe: -0.0



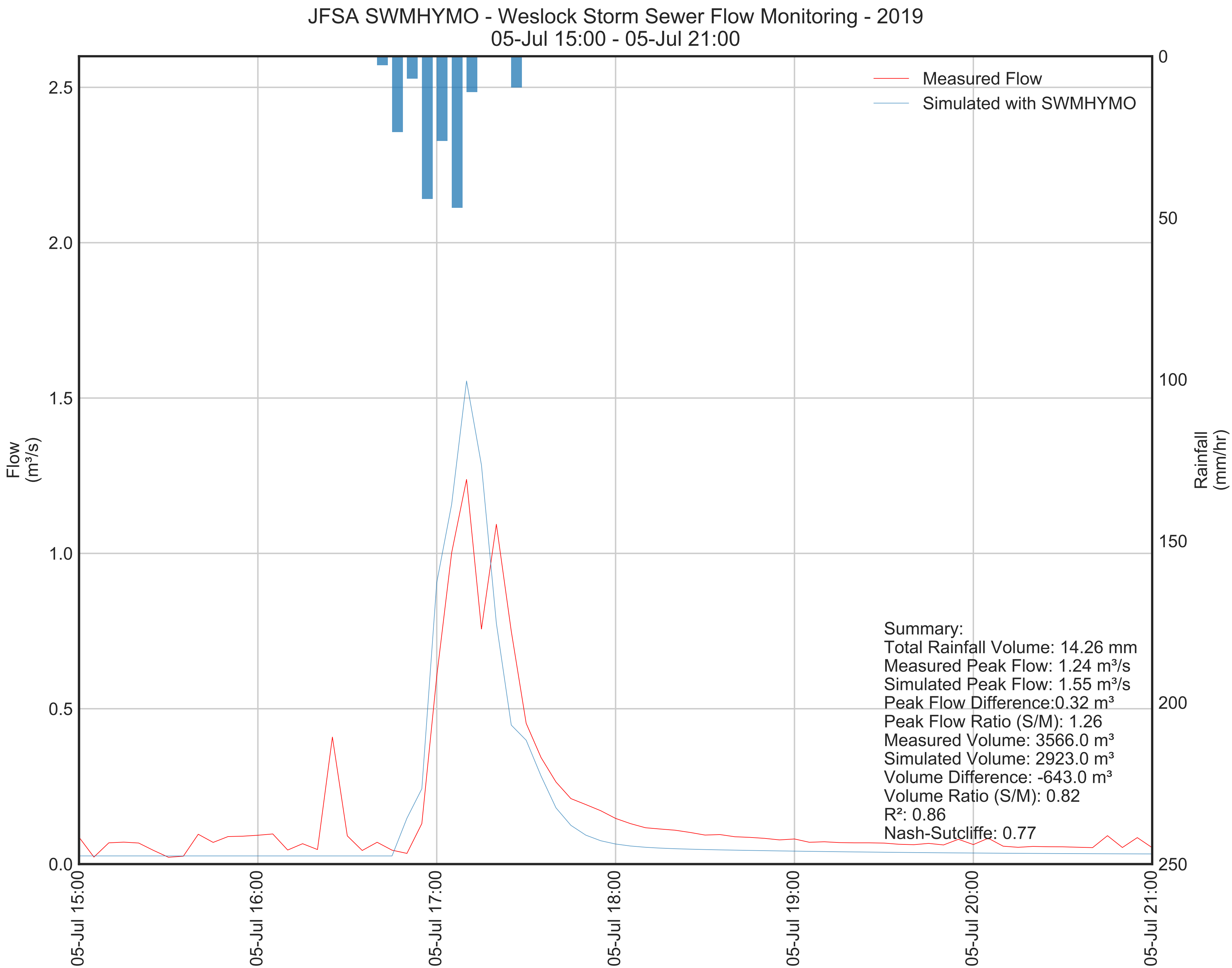
JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
25-Jun 03:30 - 25-Jun 09:30
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
25-Jun 04:00
25-Jun 05:00
25-Jun 06:00
25-Jun 07:00
25-Jun 08:00
25-Jun 09:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 10.93 mm
Measured Peak Flow: 1.02 m³/s
Simulated Peak Flow: 1.33 m³/s
Peak Flow Difference:0.3 m³
Peak Flow Ratio (S/M): 1.3
Measured Volume: 1539.0 m³
Simulated Volume: 2059.0 m³
Volume Difference: 521.0 m³
Volume Ratio (S/M): 1.34
R²: 0.37
Nash-Sutcliffe: -0.68

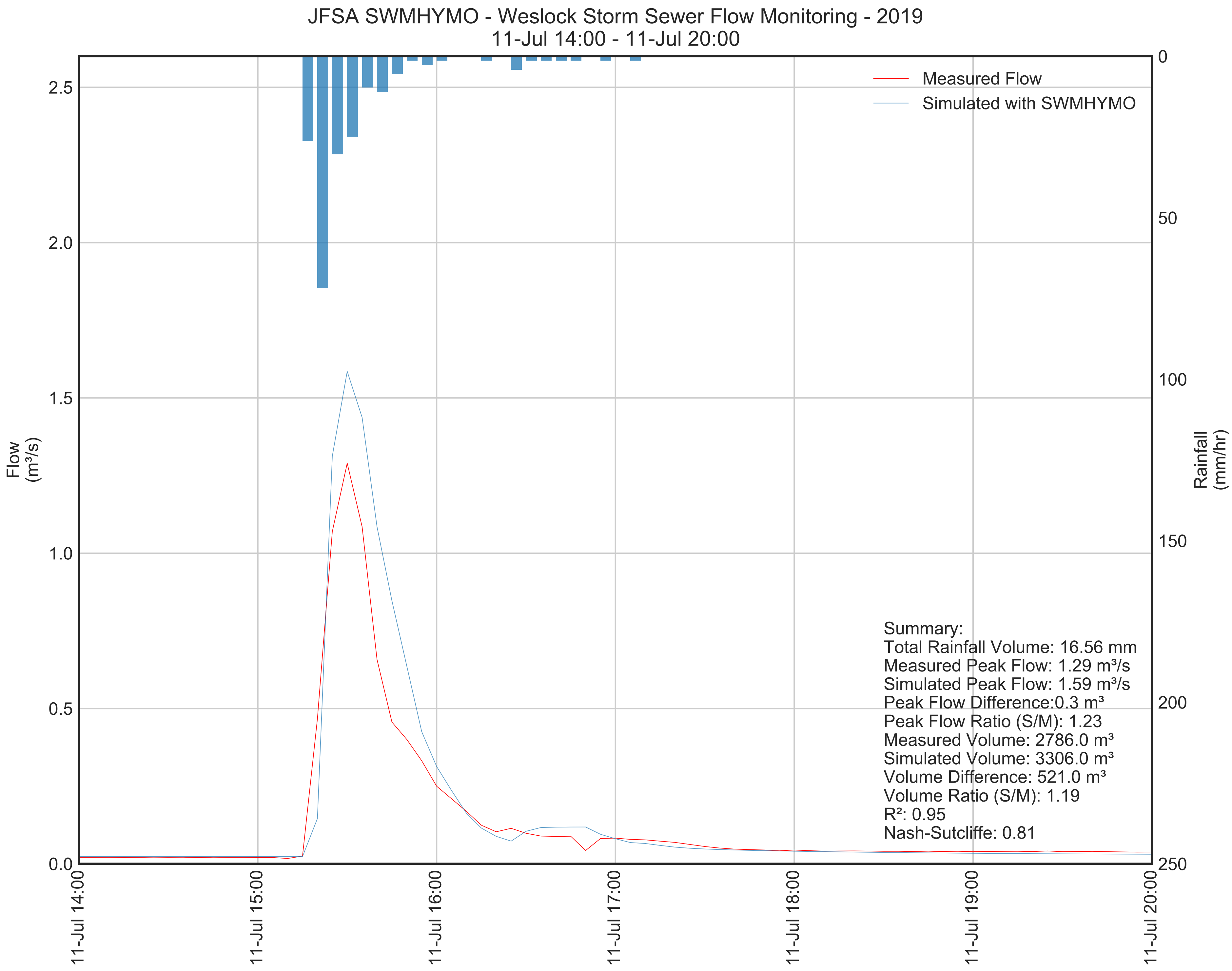


JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
28-Jun 10:30 - 28-Jun 22:30
Flow
(m³/s)
Rainfall
(mm/hr)
Measured Flow
Simulated with SWMHYMO
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
28-Jun 12:00
28-Jun 14:00
28-Jun 16:00
28-Jun 18:00
28-Jun 20:00
28-Jun 22:00
Summary:
Total Rainfall Volume: 17.6 mm
Measured Peak Flow: 1.27 m³/s
Simulated Peak Flow: 1.46 m³/s
Peak Flow Difference:0.19 m³
Peak Flow Ratio (S/M): 1.15
Measured Volume: 4507.0 m³
Simulated Volume: 3900.0 m³
Volume Difference: -608.0 m³
Volume Ratio (S/M): 0.87
R²: 0.89
Nash-Sutcliffe: 0.85

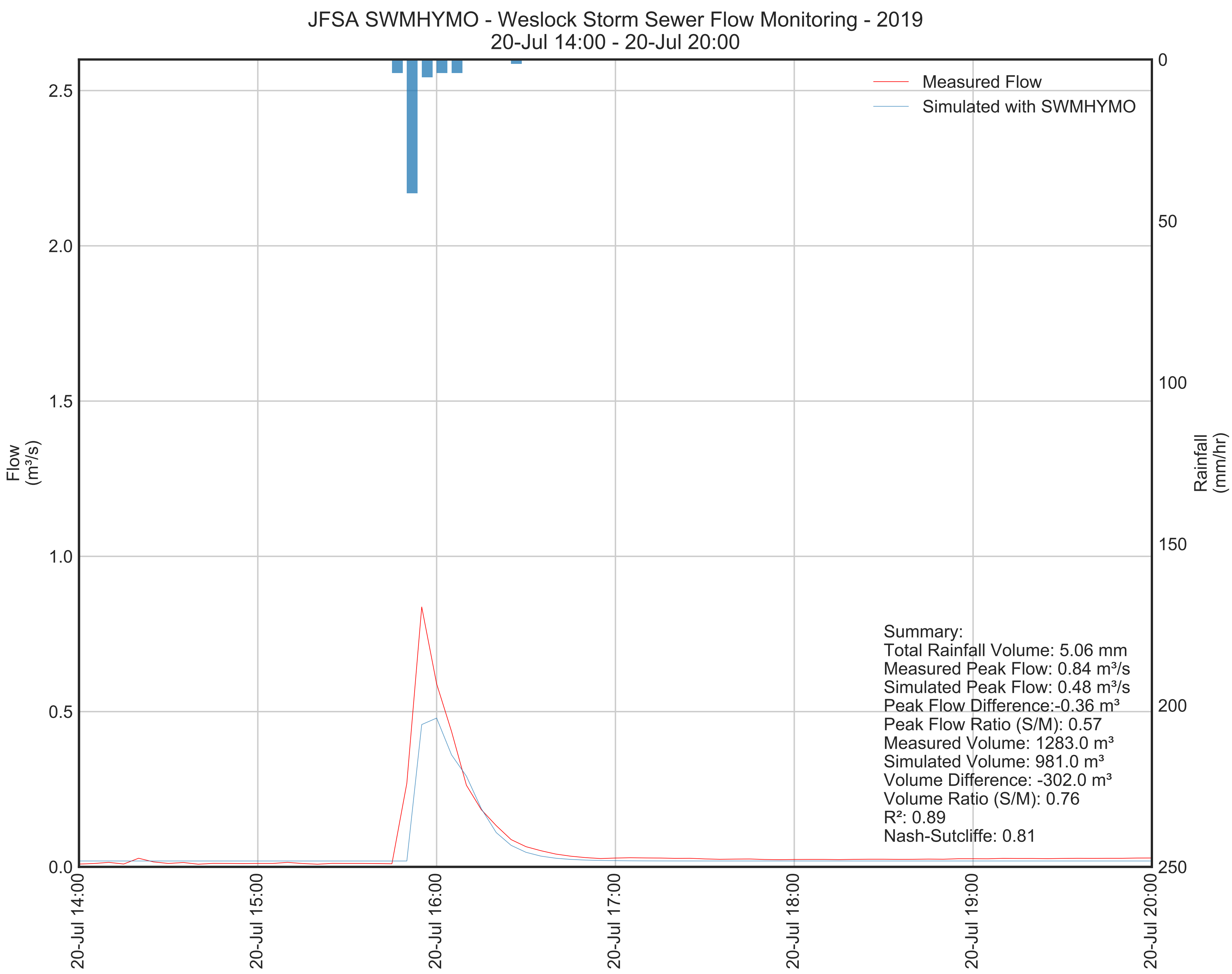


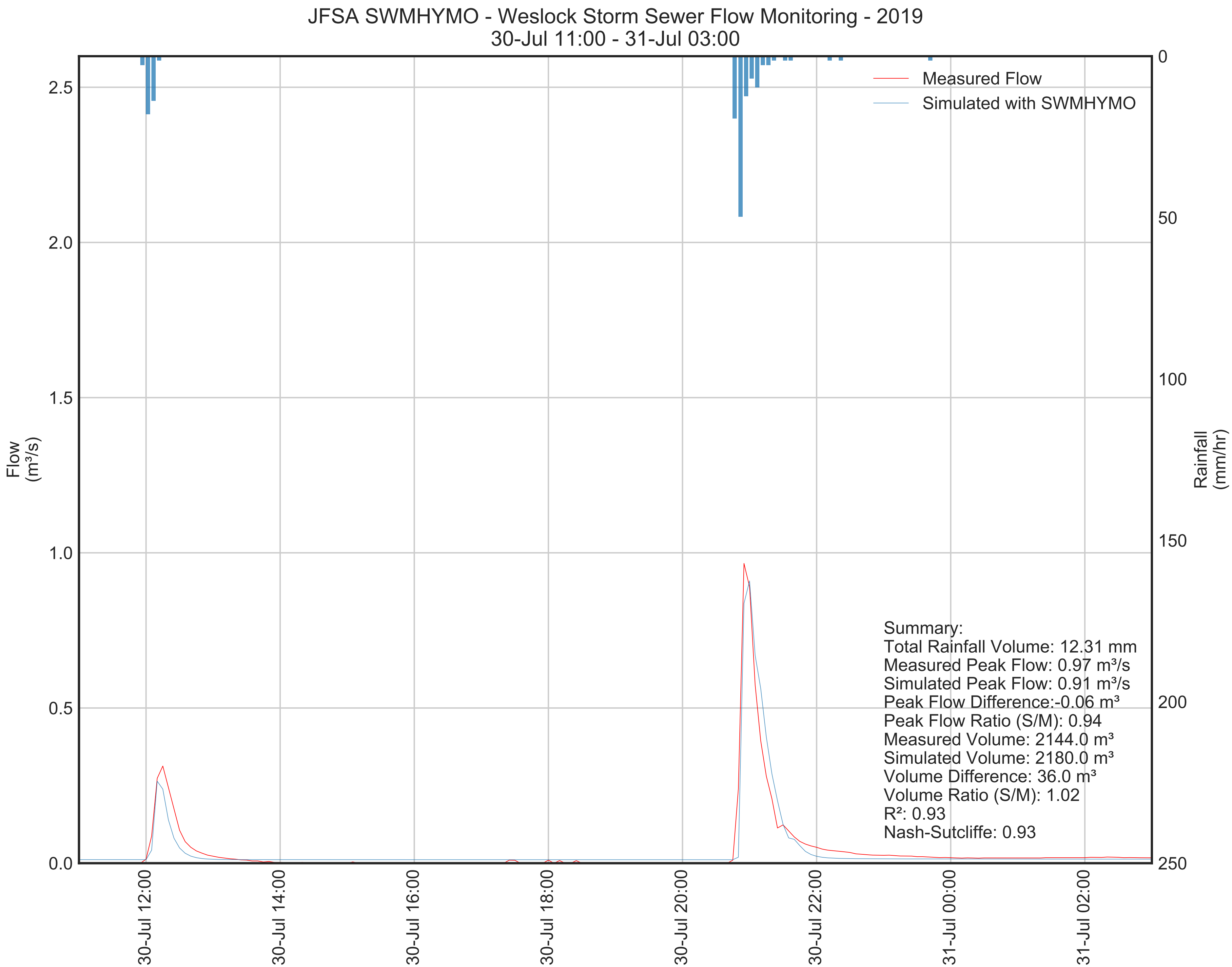
JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
29-Jun 15:00 - 30-Jun 03:00
Measured Flow
Simulated with SWMHYMO
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
29-Jun 16:00
29-Jun 18:00
29-Jun 20:00
29-Jun 22:00
30-Jun 00:00
30-Jun 02:00
Summary:
Total Rainfall Volume: 28.64 mm
Measured Peak Flow: 1.51 m³/s
Simulated Peak Flow: 1.72 m³/s
Peak Flow Difference:0.21 m³
Peak Flow Ratio (S/M): 1.14
Measured Volume: 8765.0 m³
Simulated Volume: 7162.0 m³
Volume Difference: -1603.0 m³
Volume Ratio (S/M): 0.82
R²: 0.94
Nash-Sutcliffe: 0.91


JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
05-Jul 15:00 - 05-Jul 21:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
05-Jul 15:00
05-Jul 16:00
05-Jul 17:00
05-Jul 18:00
05-Jul 19:00
05-Jul 20:00
05-Jul 21:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 14.26 mm
Measured Peak Flow: 1.24 m³/s
Simulated Peak Flow: 1.55 m³/s
Peak Flow Difference:0.32 m³
Peak Flow Ratio (S/M): 1.26
Measured Volume: 3566.0 m³
Simulated Volume: 2923.0 m³
Volume Difference: -643.0 m³
Volume Ratio (S/M): 0.82
R²: 0.86
Nash-Sutcliffe: 0.77

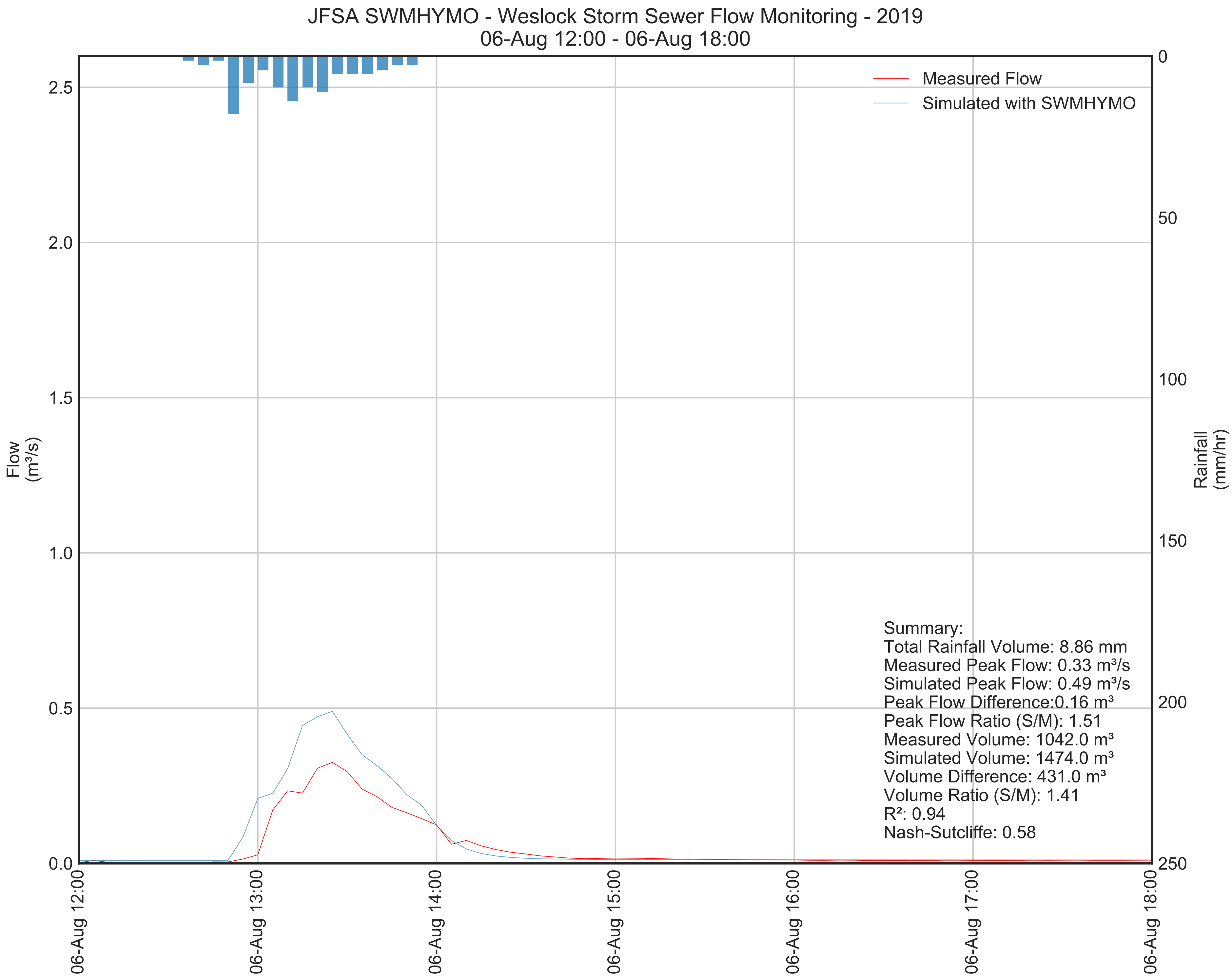


JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
11-Jul 14:00 - 11-Jul 20:00
Measured Flow
Simulated with SWMHYMO
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
11-Jul 14:00
11-Jul 15:00
11-Jul 16:00
11-Jul 17:00
11-Jul 18:00
11-Jul 19:00
11-Jul 20:00
Summary:
Total Rainfall Volume: 16.56 mm
Measured Peak Flow: 1.29 m³/s
Simulated Peak Flow: 1.59 m³/s
Peak Flow Difference:0.3 m³
Peak Flow Ratio (S/M): 1.23
Measured Volume: 2786.0 m³
Simulated Volume: 3306.0 m³
Volume Difference: 521.0 m³
Volume Ratio (S/M): 1.19
R²: 0.95
Nash-Sutcliffe: 0.81

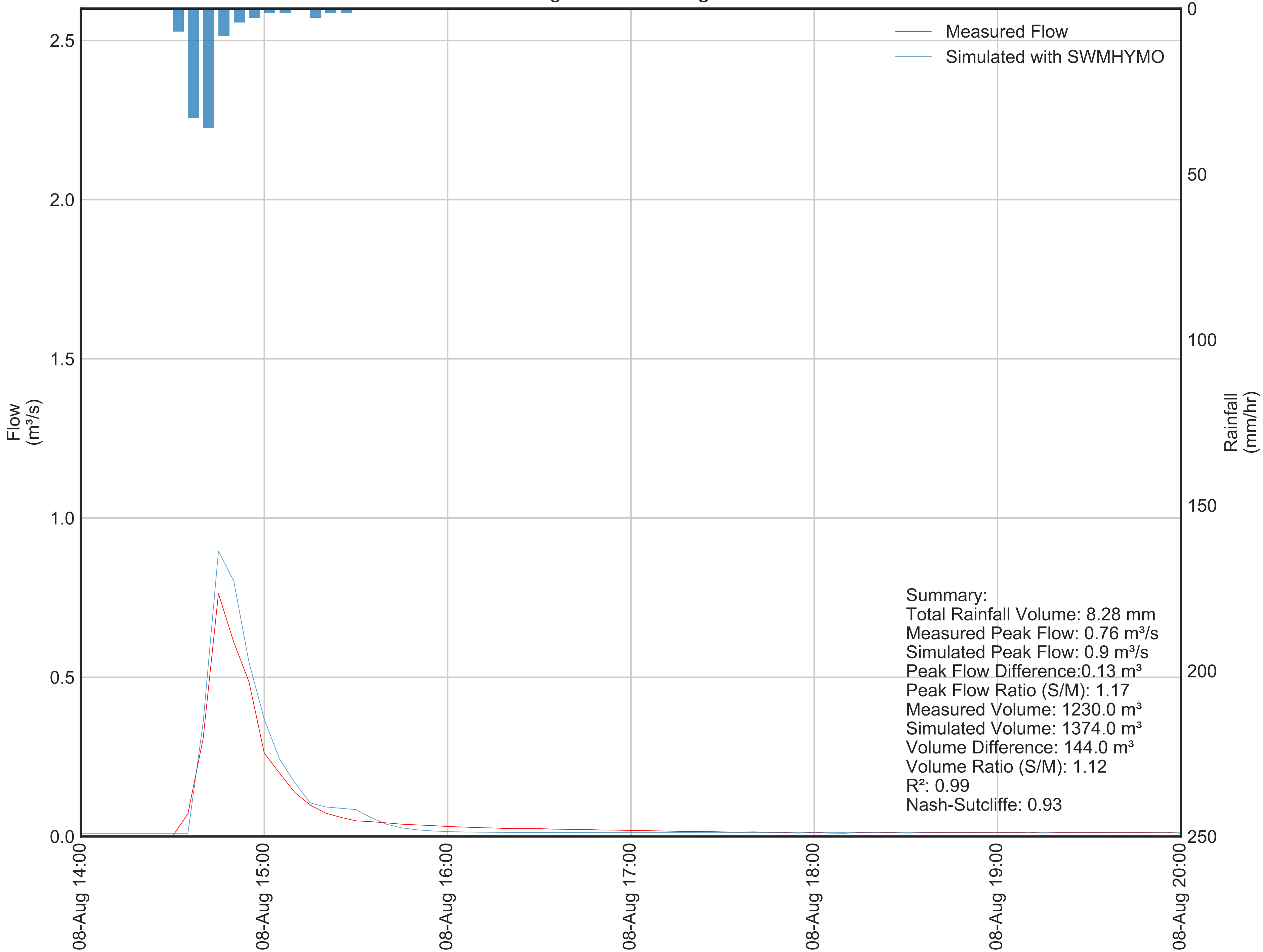

JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
20-Jul 14:00 - 20-Jul 20:00
Measured Flow
Simulated with SWMHYMO
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
20-Jul 14:00
20-Jul 15:00
20-Jul 16:00
20-Jul 17:00
20-Jul 18:00
20-Jul 19:00
20-Jul 20:00
Summary:
Total Rainfall Volume: 5.06 mm
Measured Peak Flow: 0.84 m³/s
Simulated Peak Flow: 0.48 m³/s
Peak Flow Difference:-0.36 m³
Peak Flow Ratio (S/M): 0.57
Measured Volume: 1283.0 m³
Simulated Volume: 981.0 m³
Volume Difference: -302.0 m³
Volume Ratio (S/M): 0.76
R²: 0.89
Nash-Sutcliffe: 0.81

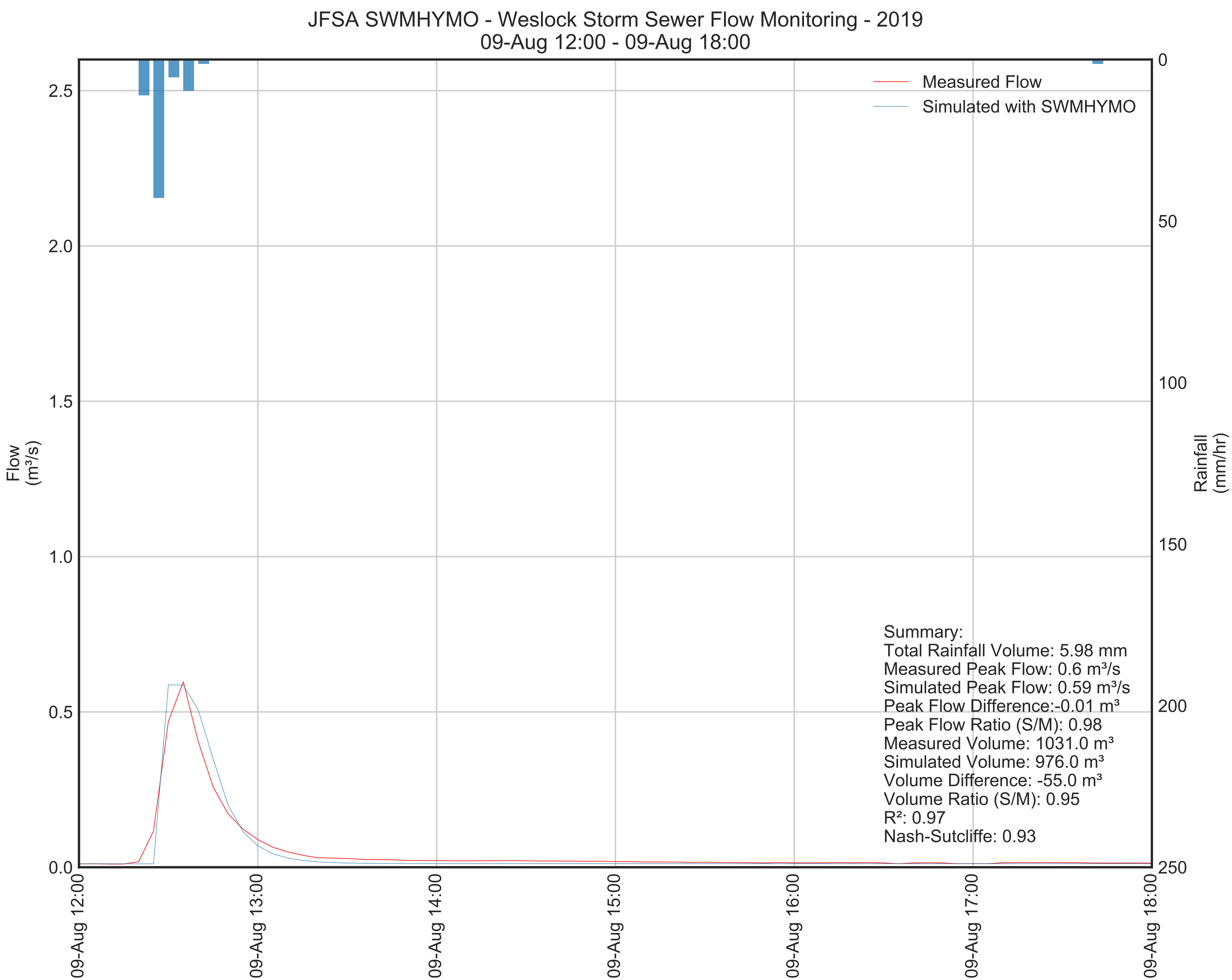


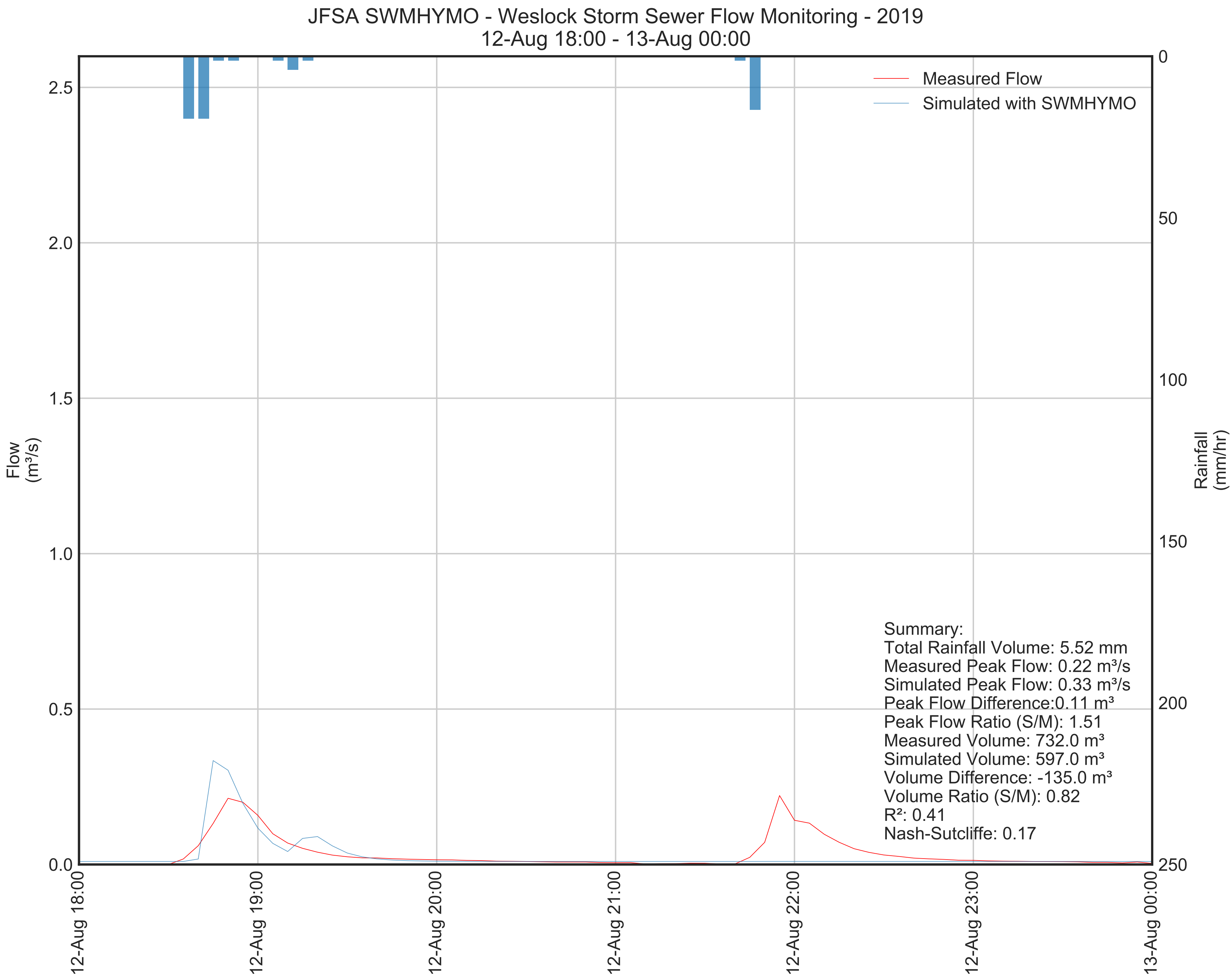
JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
30-Jul 11:00 - 31-Jul 03:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
30-Jul 12:00
30-Jul 14:00
30-Jul 16:00
30-Jul 18:00
30-Jul 20:00
30-Jul 22:00
31-Jul 00:00
31-Jul 02:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 12.31 mm
Measured Peak Flow: 0.97 m³/s
Simulated Peak Flow: 0.91 m³/s
Peak Flow Difference:-0.06 m³
Peak Flow Ratio (S/M): 0.94
Measured Volume: 2144.0 m³
Simulated Volume: 2180.0 m³
Volume Difference: 36.0 m³
Volume Ratio (S/M): 1.02
R²: 0.93
Nash-Sutcliffe: 0.93


JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
06-Aug 12:00 - 06-Aug 18:00
Measured Flow
Simulated with SWMHYMO
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
06-Aug 12:00
06-Aug 13:00
06-Aug 14:00
06-Aug 15:00
06-Aug 16:00
06-Aug 17:00
06-Aug 18:00
Summary:
Total Rainfall Volume: 8.86 mm
Measured Peak Flow: 0.33 m³/s
Simulated Peak Flow: 0.49 m³/s
Peak Flow Difference:0.16 m³
Peak Flow Ratio (S/M): 1.51
Measured Volume: 1042.0 m³
Simulated Volume: 1474.0 m³
Volume Difference: 431.0 m³
Volume Ratio (S/M): 1.41
R²: 0.94
Nash-Sutcliffe: 0.58

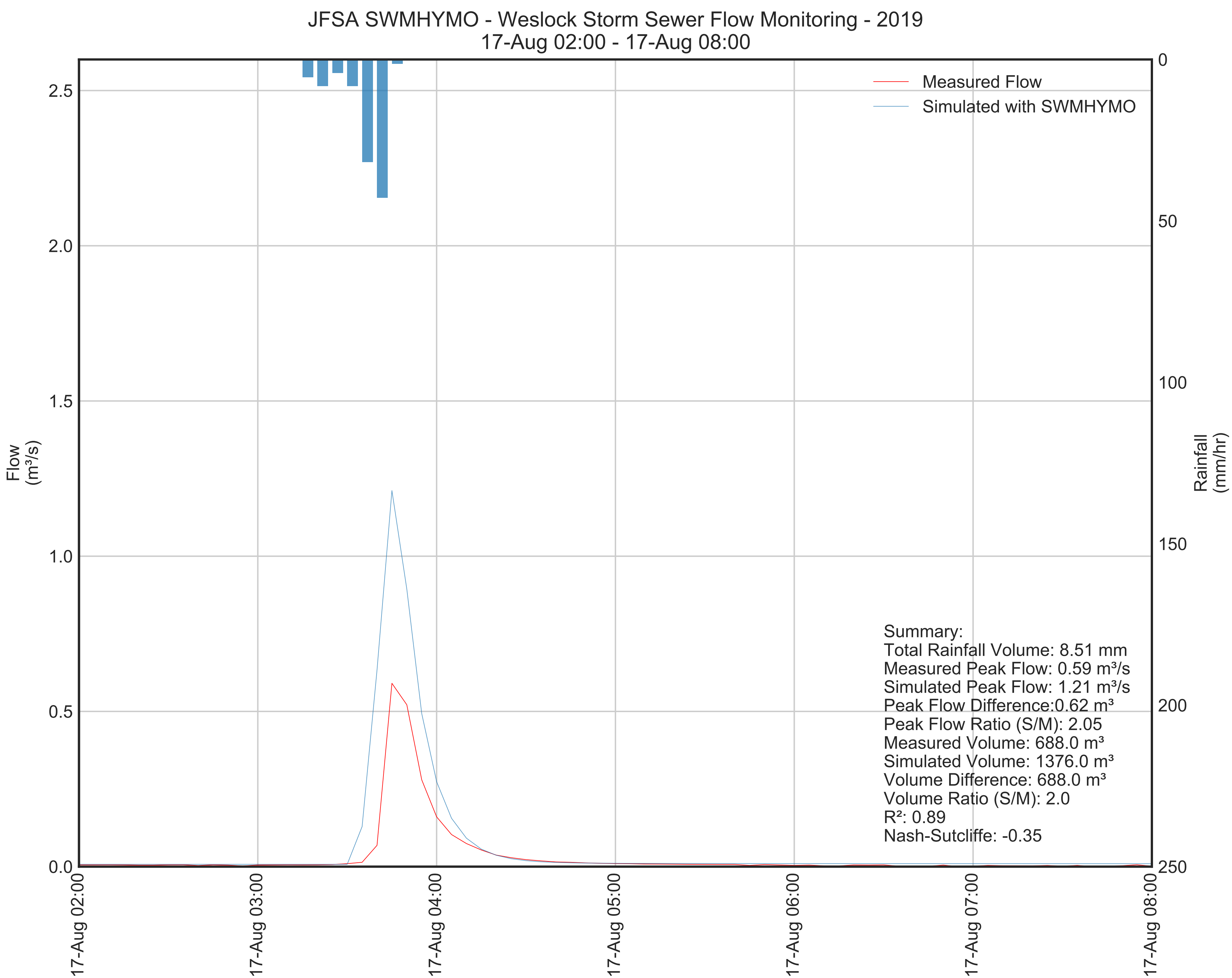
JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
08-Aug 14:00 - 08-Aug 20:00



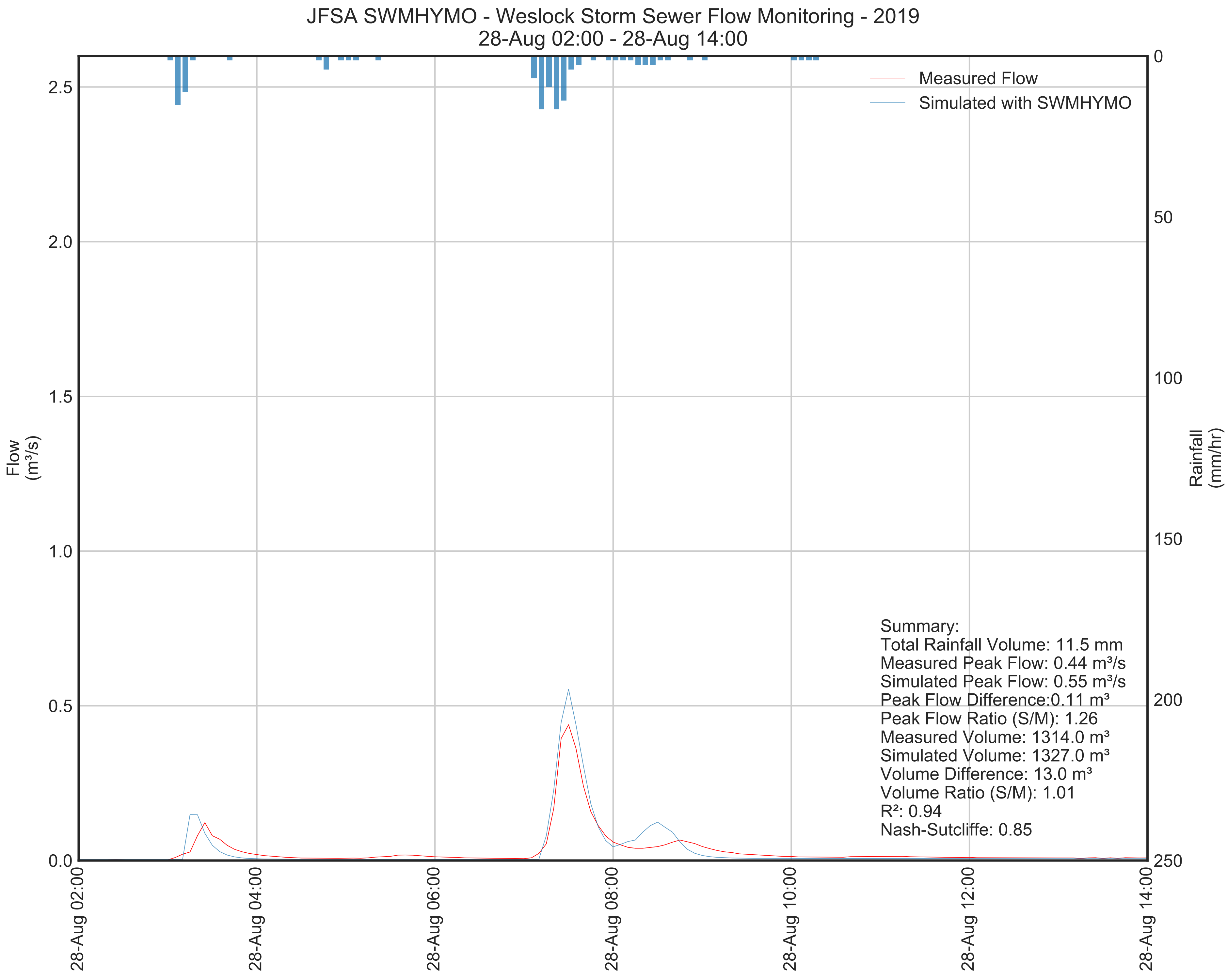

JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
09-Aug 12:00 - 09-Aug 18:00
Flow
(m³/s)
Rainfall
(mm/hr)
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 5.98 mm
Measured Peak Flow: 0.6 m³/s
Simulated Peak Flow: 0.59 m³/s
Peak Flow Difference:-0.01 m³
Peak Flow Ratio (S/M): 0.98
Measured Volume: 1031.0 m³
Simulated Volume: 976.0 m³
Volume Difference: -55.0 m³
Volume Ratio (S/M): 0.95
R²: 0.97
Nash-Sutcliffe: 0.93
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
09-Aug 12:00
09-Aug 13:00
09-Aug 14:00
09-Aug 15:00
09-Aug 16:00
09-Aug 17:00
09-Aug 18:00



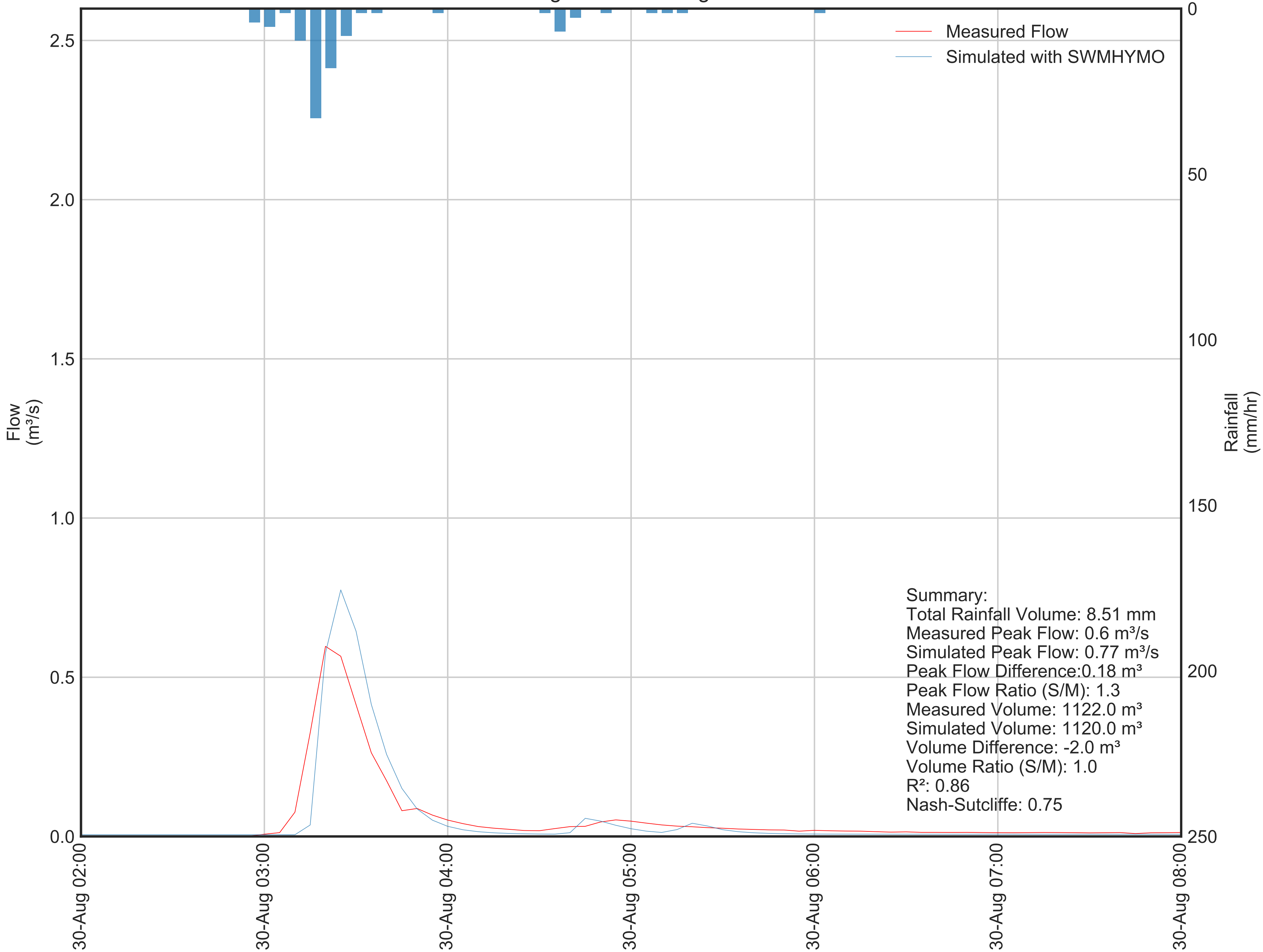
JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
12-Aug 18:00 - 13-Aug 00:00
Flow (m³/s)
Rainfall (mm/hr)
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 5.52 mm
Measured Peak Flow: 0.22 m³/s
Simulated Peak Flow: 0.33 m³/s
Peak Flow Difference:0.11 m³
Peak Flow Ratio (S/M): 1.51
Measured Volume: 732.0 m³
Simulated Volume: 597.0 m³
Volume Difference: -135.0 m³
Volume Ratio (S/M): 0.82
R²: 0.41
Nash-Sutcliffe: 0.17
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
12-Aug 18:00
12-Aug 19:00
12-Aug 20:00
12-Aug 21:00
12-Aug 22:00
12-Aug 23:00
13-Aug 00:00

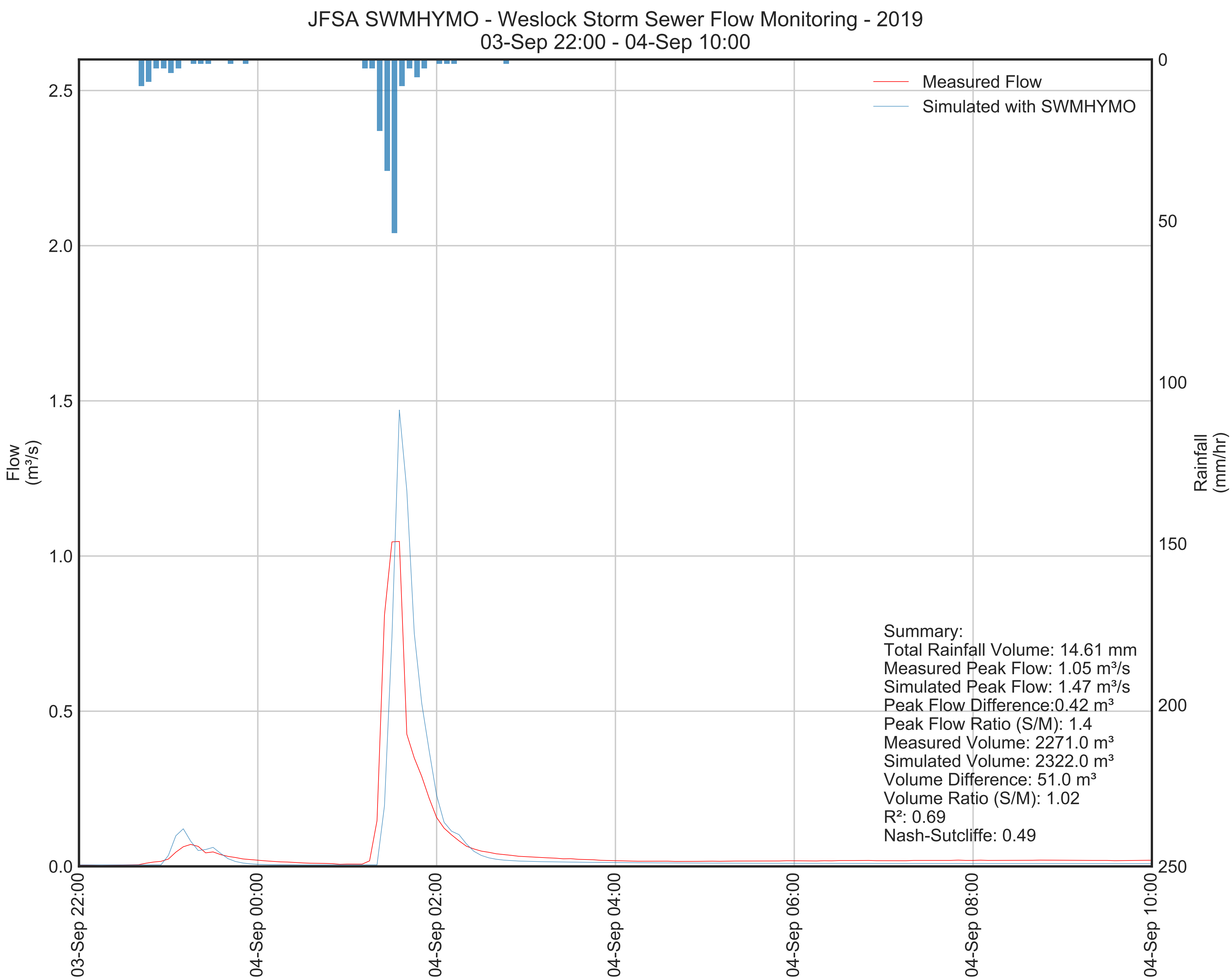


JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
17-Aug 02:00 - 17-Aug 08:00
Flow
(m³/s)
Rainfall
(mm/hr)
Measured Flow
Simulated with SWMHYMO
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
17-Aug 02:00
17-Aug 03:00
17-Aug 04:00
17-Aug 05:00
17-Aug 06:00
17-Aug 07:00
17-Aug 08:00
Summary:
Total Rainfall Volume: 8.51 mm
Measured Peak Flow: 0.59 m³/s
Simulated Peak Flow: 1.21 m³/s
Peak Flow Difference:0.62 m³
Peak Flow Ratio (S/M): 2.05
Measured Volume: 688.0 m³
Simulated Volume: 1376.0 m³
Volume Difference: 688.0 m³
Volume Ratio (S/M): 2.0
R²: 0.89
Nash-Sutcliffe: -0.35


JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
28-Aug 02:00 - 28-Aug 14:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
28-Aug 02:00
28-Aug 04:00
28-Aug 06:00
28-Aug 08:00
28-Aug 10:00
28-Aug 12:00
28-Aug 14:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 11.5 mm
Measured Peak Flow: 0.44 m³/s
Simulated Peak Flow: 0.55 m³/s
Peak Flow Difference:0.11 m³
Peak Flow Ratio (S/M): 1.26
Measured Volume: 1314.0 m³
Simulated Volume: 1327.0 m³
Volume Difference: 13.0 m³
Volume Ratio (S/M): 1.01
R²: 0.94
Nash-Sutcliffe: 0.85

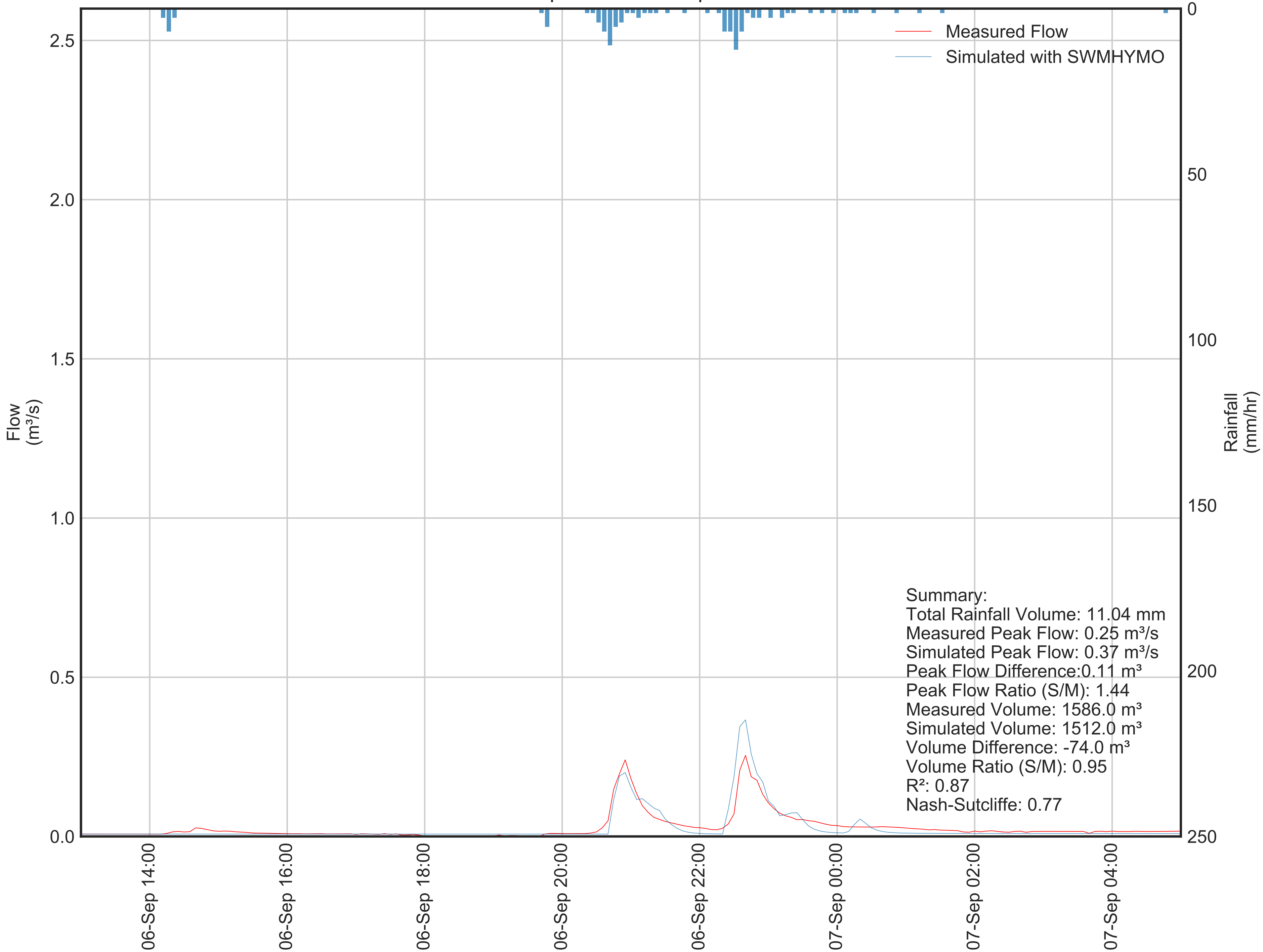
JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
30-Aug 02:00 - 30-Aug 08:00

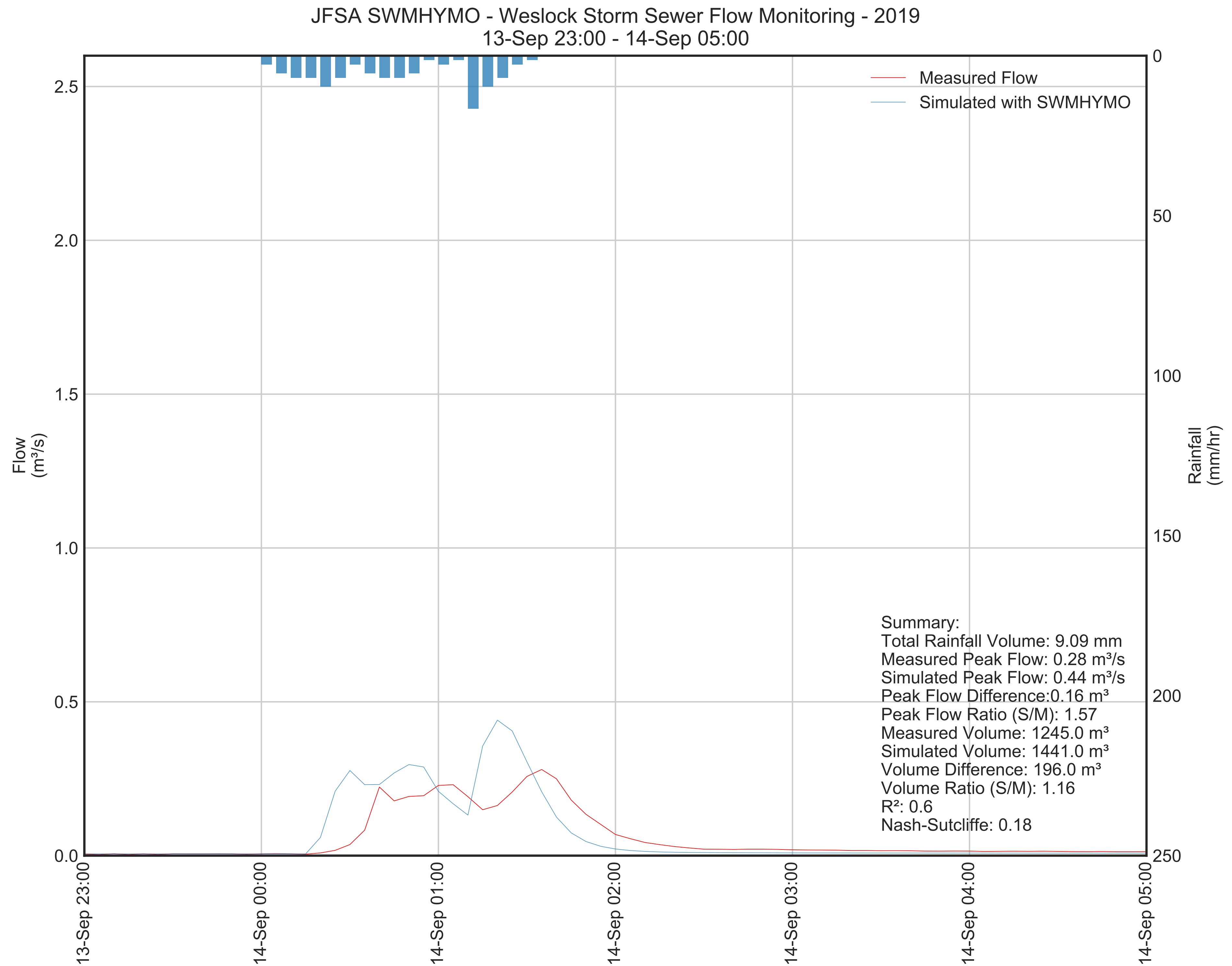


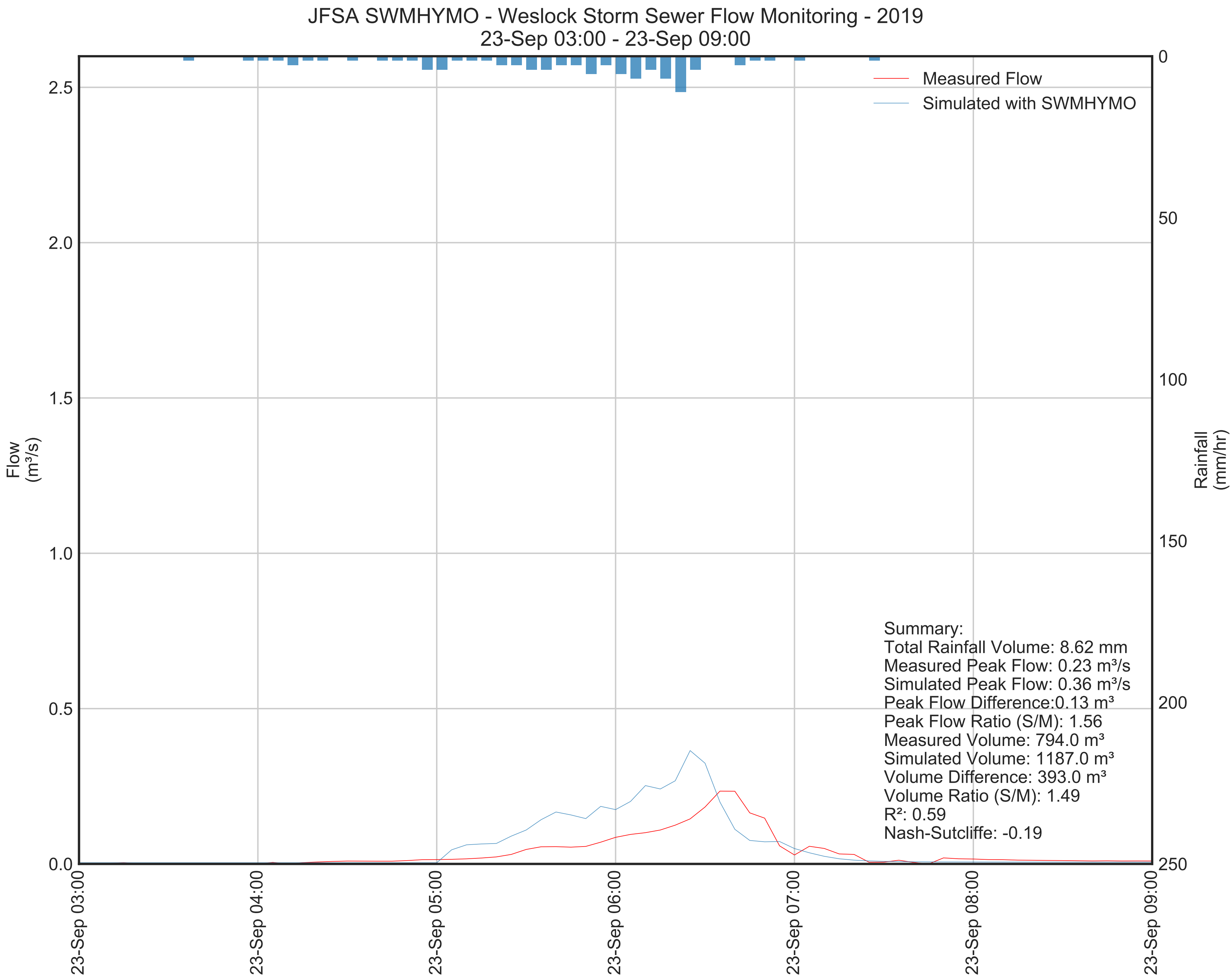


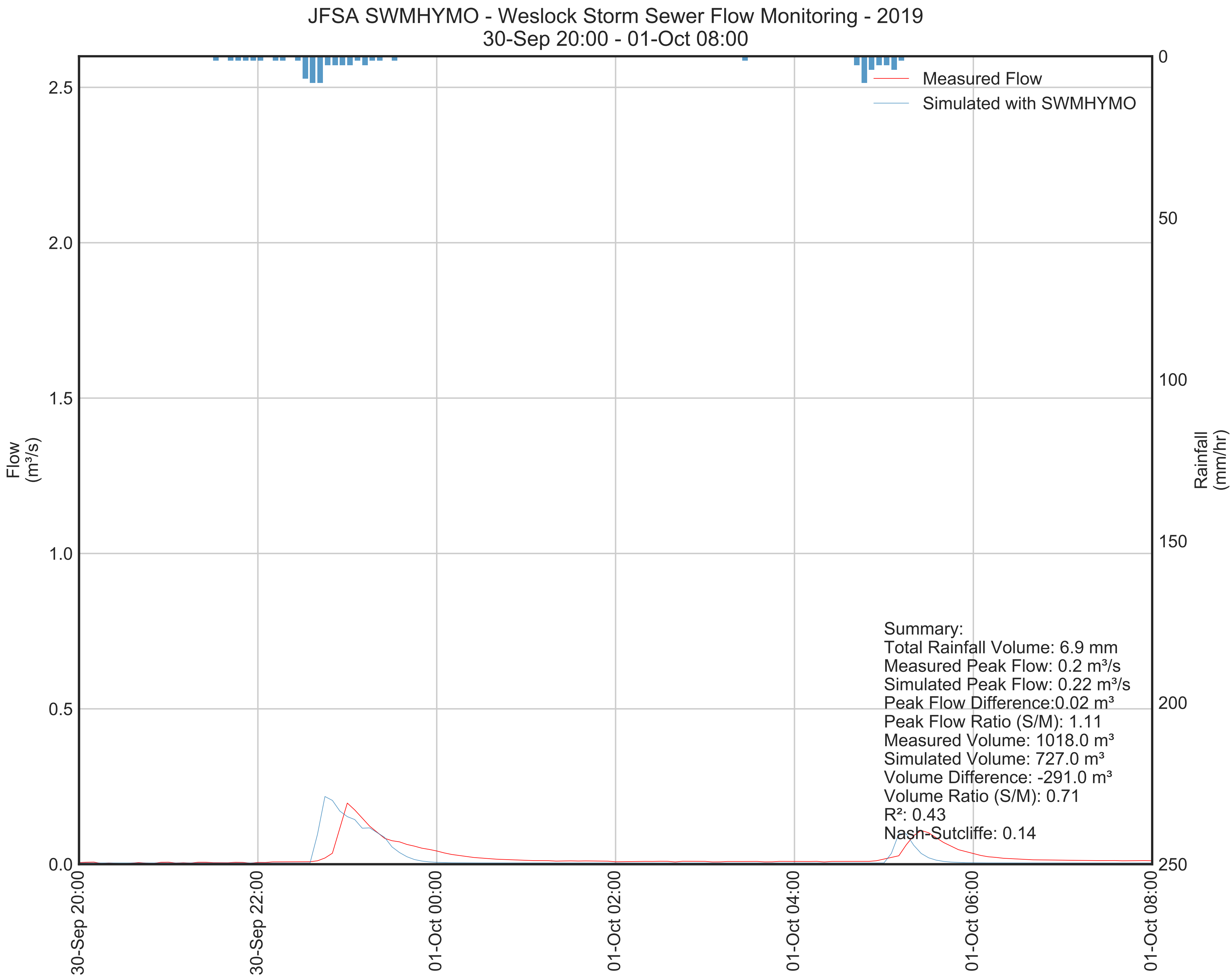
JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
03-Sep 22:00 - 04-Sep 10:00
Measured Flow
Simulated with SWMHYMO
Flow
(m³/s)
Rainfall
(mm/hr)
2.5
2.0
1.5
1.0
0.5
0.0
0
50
100
150
200
250
03-Sep 22:00
04-Sep 00:00
04-Sep 02:00
04-Sep 04:00
04-Sep 06:00
04-Sep 08:00
04-Sep 10:00
Summary:
Total Rainfall Volume: 14.61 mm
Measured Peak Flow: 1.05 m³/s
Simulated Peak Flow: 1.47 m³/s
Peak Flow Difference:0.42 m³
Peak Flow Ratio (S/M): 1.4
Measured Volume: 2271.0 m³
Simulated Volume: 2322.0 m³
Volume Difference: 51.0 m³
Volume Ratio (S/M): 1.02
R²: 0.69
Nash-Sutcliffe: 0.49

JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
06-Sep 13:00 - 07-Sep 05:00




JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
13-Sep 23:00 - 14-Sep 05:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
13-Sep 23:00
14-Sep 00:00
14-Sep 01:00
14-Sep 02:00
14-Sep 03:00
14-Sep 04:00
14-Sep 05:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 9.09 mm
Measured Peak Flow: 0.28 m³/s
Simulated Peak Flow: 0.44 m³/s
Peak Flow Difference:0.16 m³
Peak Flow Ratio (S/M): 1.57
Measured Volume: 1245.0 m³
Simulated Volume: 1441.0 m³
Volume Difference: 196.0 m³
Volume Ratio (S/M): 1.16
R²: 0.6
Nash-Sutcliffe: 0.18


JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
23-Sep 03:00 - 23-Sep 09:00
Flow
(m³/s)
Rainfall
(mm/hr)
Measured Flow
Simulated with SWMHYMO
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
23-Sep 03:00
23-Sep 04:00
23-Sep 05:00
23-Sep 06:00
23-Sep 07:00
23-Sep 08:00
23-Sep 09:00
Summary:
Total Rainfall Volume: 8.62 mm
Measured Peak Flow: 0.23 m³/s
Simulated Peak Flow: 0.36 m³/s
Peak Flow Difference:0.13 m³
Peak Flow Ratio (S/M): 1.56
Measured Volume: 794.0 m³
Simulated Volume: 1187.0 m³
Volume Difference: 393.0 m³
Volume Ratio (S/M): 1.49
R²: 0.59
Nash-Sutcliffe: -0.19



JFSA SWMHYMO - Weslock Storm Sewer Flow Monitoring - 2019
30-Sep 20:00 - 01-Oct 08:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.5
1.0
1.5
2.0
2.5
0
50
100
150
200
250
30-Sep 20:00
30-Sep 22:00
01-Oct 00:00
01-Oct 02:00
01-Oct 04:00
01-Oct 06:00
01-Oct 08:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 6.9 mm
Measured Peak Flow: 0.2 m³/s
Simulated Peak Flow: 0.22 m³/s
Peak Flow Difference:0.02 m³
Peak Flow Ratio (S/M): 1.11
Measured Volume: 1018.0 m³
Simulated Volume: 727.0 m³
Volume Difference: -291.0 m³
Volume Ratio (S/M): 0.71
R²: 0.43
Nash-Sutcliffe: 0.14

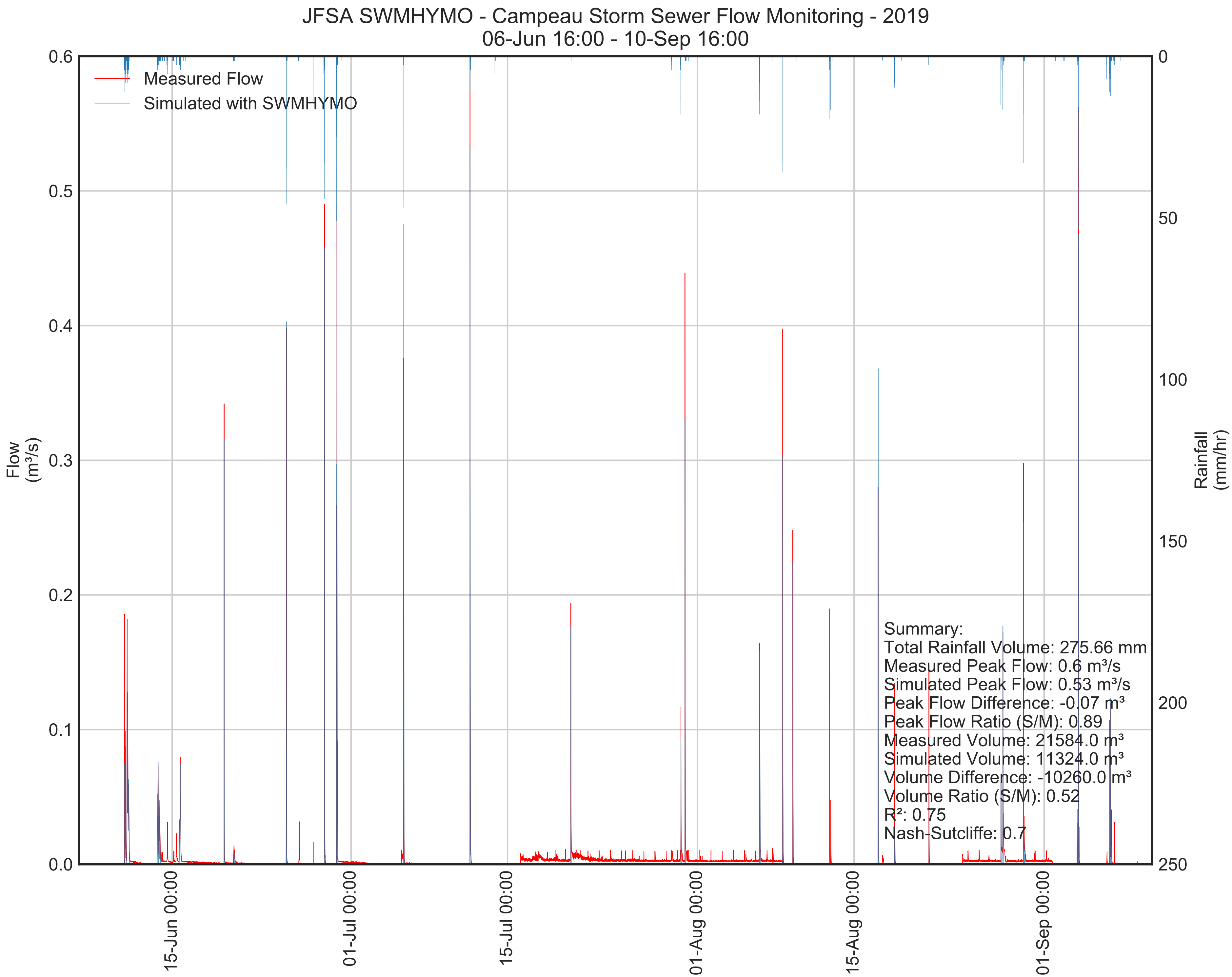
JFSA
WATER RESOURCES AND
ENVIRONMENTAL CONSULTANTS

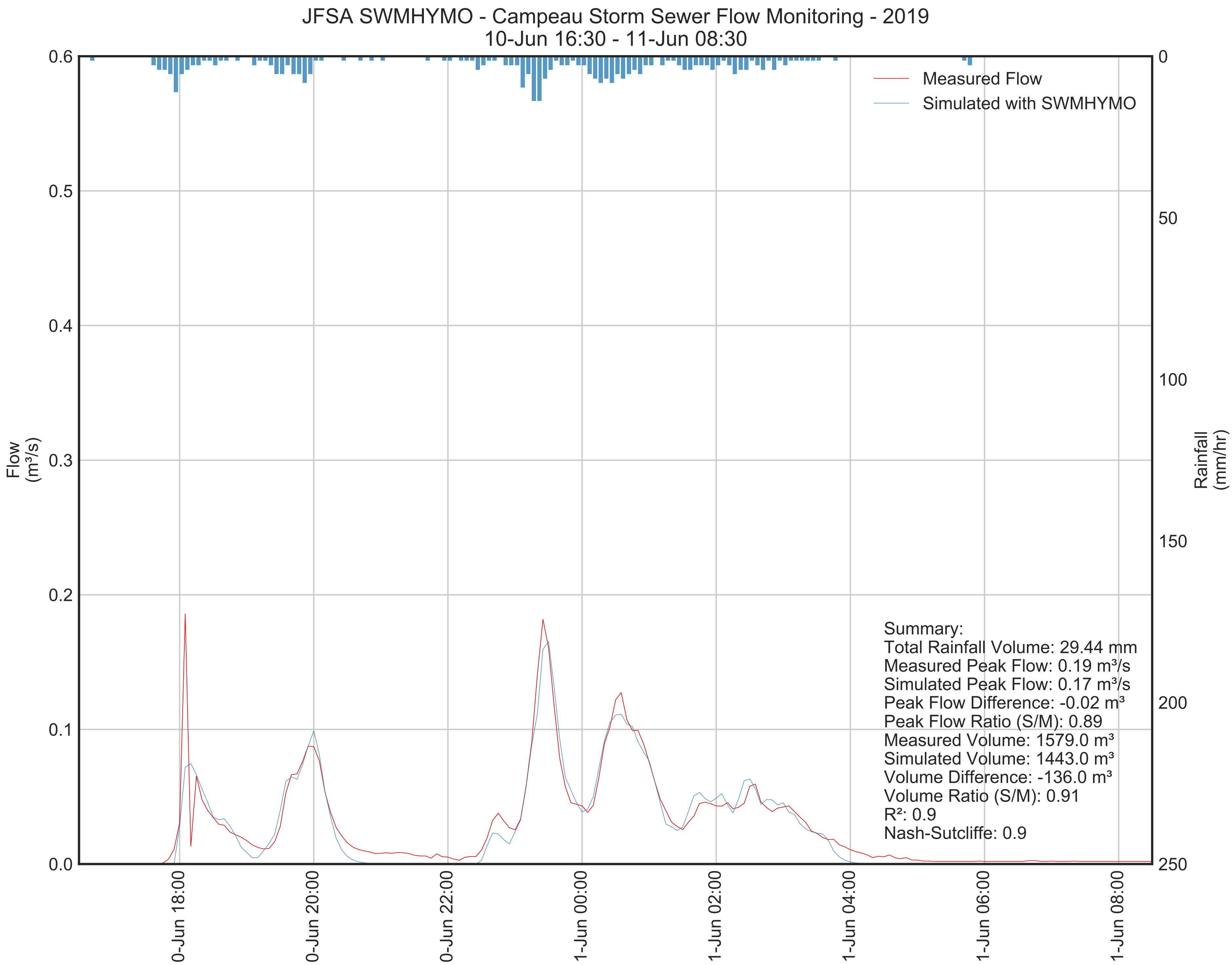
Project Ref #:P1581
Client: David Schaeffer Engineering

Ottawa. ON
Paris. ON
Gatineau. QB
Montréal. QB
Québec. QB

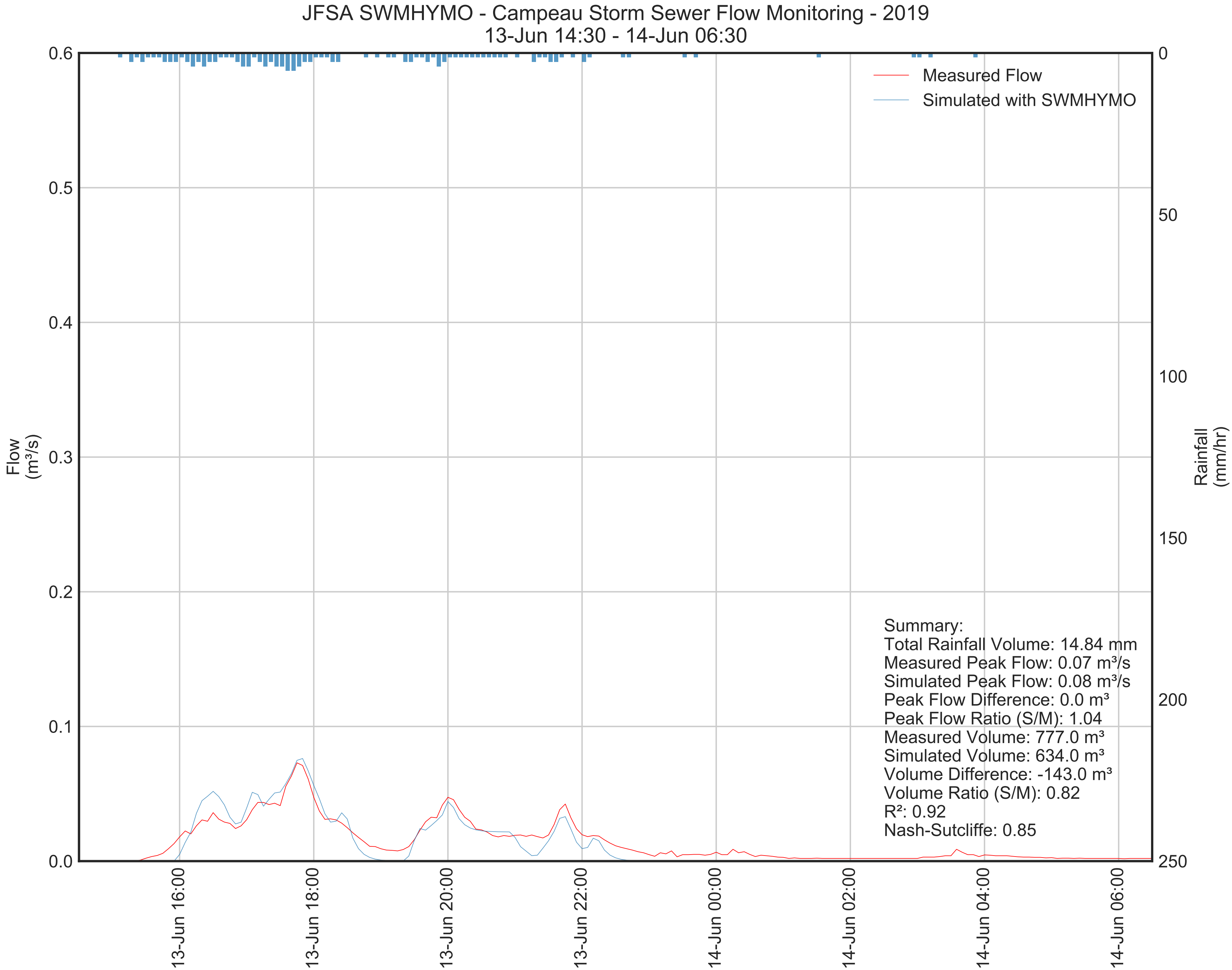
Appendix H

2019 Campeau Drive
Measured vs. Simulated Flow

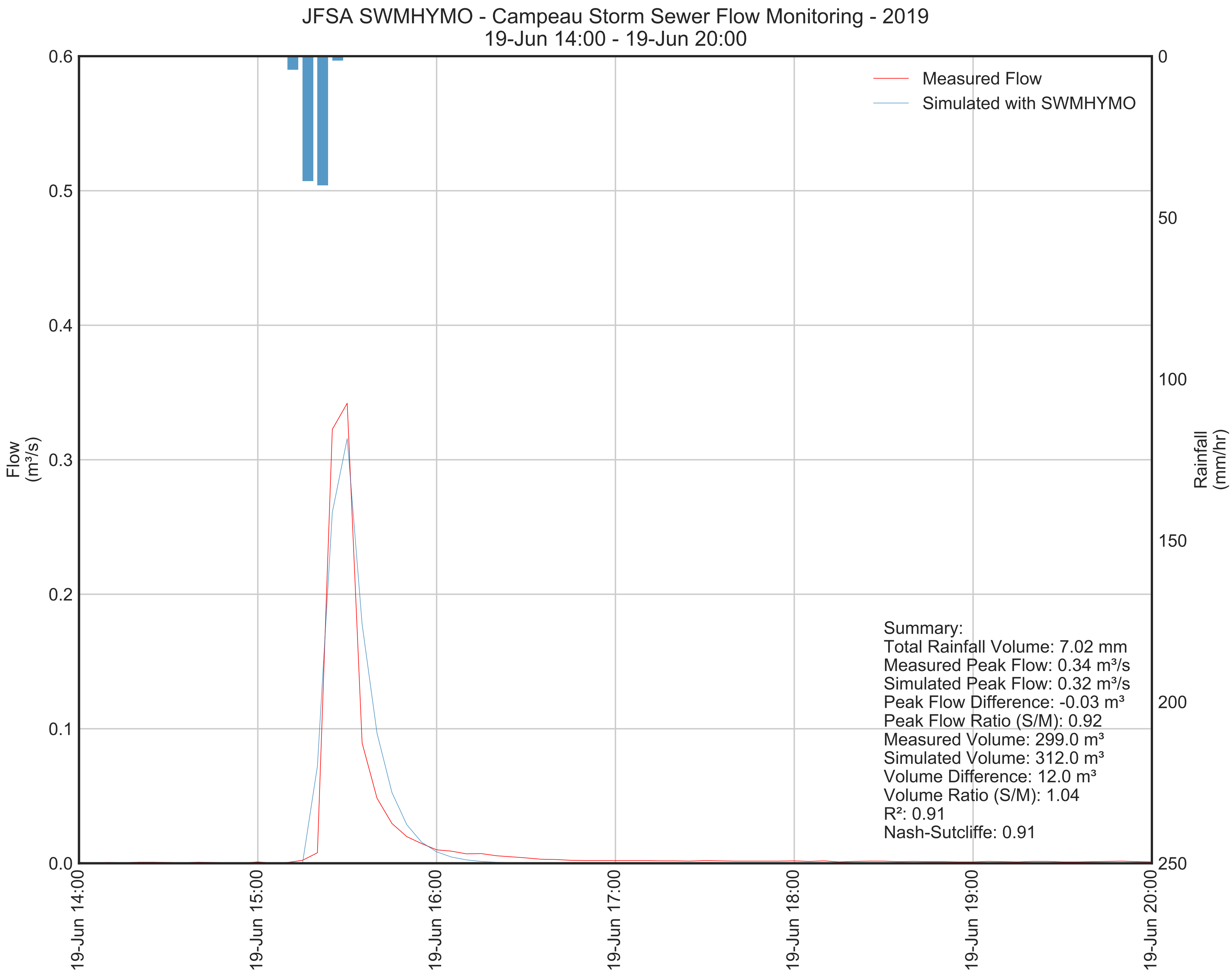

JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
06-Jun 16:00 - 10-Sep 16:00
Measured Flow
Simulated with SWMHYMO
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
15-Jun 00:00
01-Jul 00:00
15-Jul 00:00
01-Aug 00:00
15-Aug 00:00
01-Sep 00:00
Summary:
Total Rainfall Volume: 275.66 mm
Measured Peak Flow: 0.6 m³/s
Simulated Peak Flow: 0.53 m³/s
Peak Flow Difference: -0.07 m³
Peak Flow Ratio (S/M): 0.89
Measured Volume: 21584.0 m³
Simulated Volume: 11324.0 m³
Volume Difference: -10260.0 m³
Volume Ratio (S/M): 0.52
R²: 0.75
Nash-Sutcliffe: 0.7



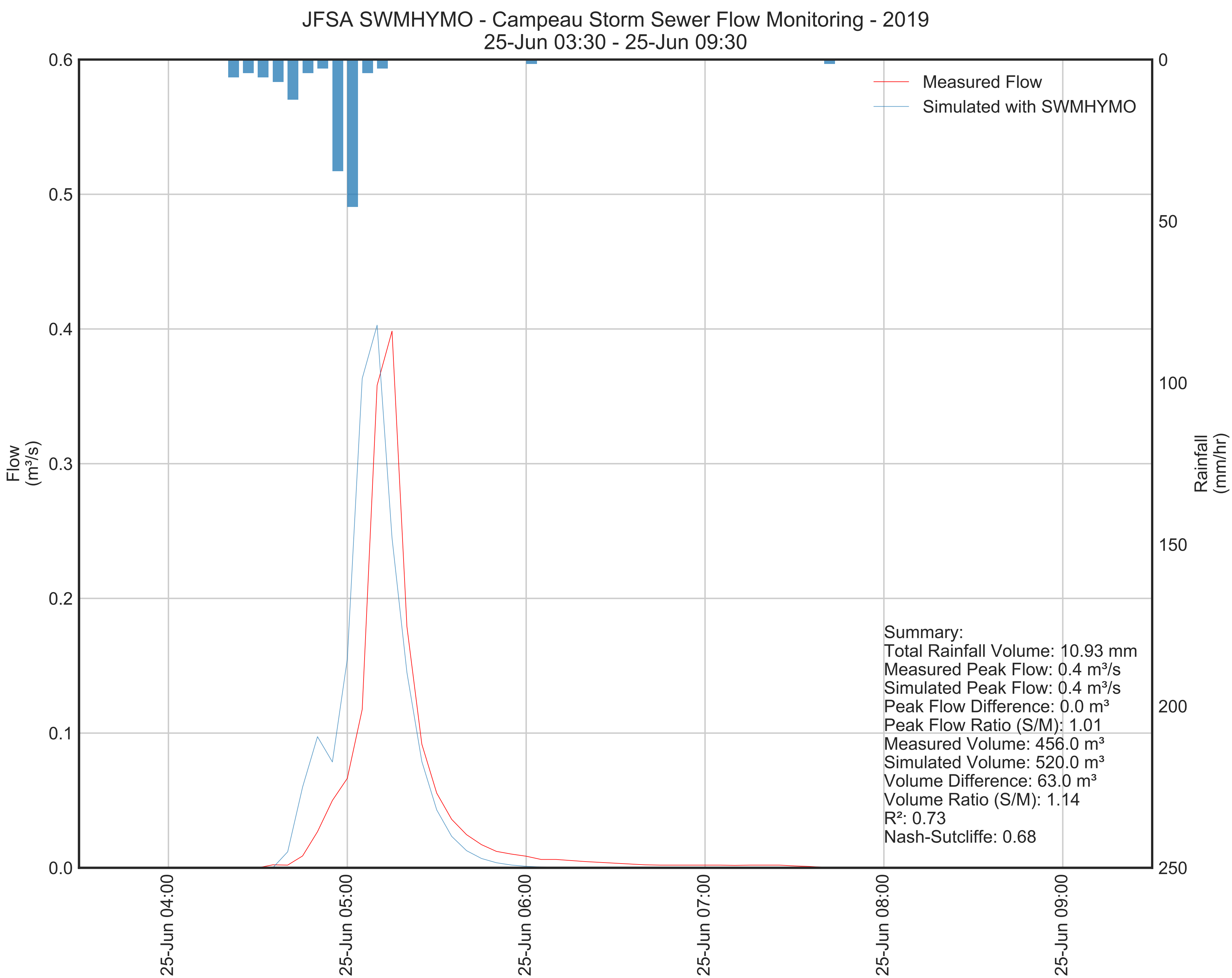
JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
10-Jun 16:30 - 11-Jun 08:30
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 29.44 mm
Measured Peak Flow: 0.19 m³/s
Simulated Peak Flow: 0.17 m³/s
Peak Flow Difference: -0.02 m³
Peak Flow Ratio (S/M): 0.89
Measured Volume: 1579.0 m³
Simulated Volume: 1443.0 m³
Volume Difference: -136.0 m³
Volume Ratio (S/M): 0.91
R²: 0.9
Nash-Sutcliffe: 0.9
10-Jun 18:00
10-Jun 20:00
10-Jun 22:00
11-Jun 00:00
11-Jun 02:00
11-Jun 04:00
11-Jun 06:00
11-Jun 08:00

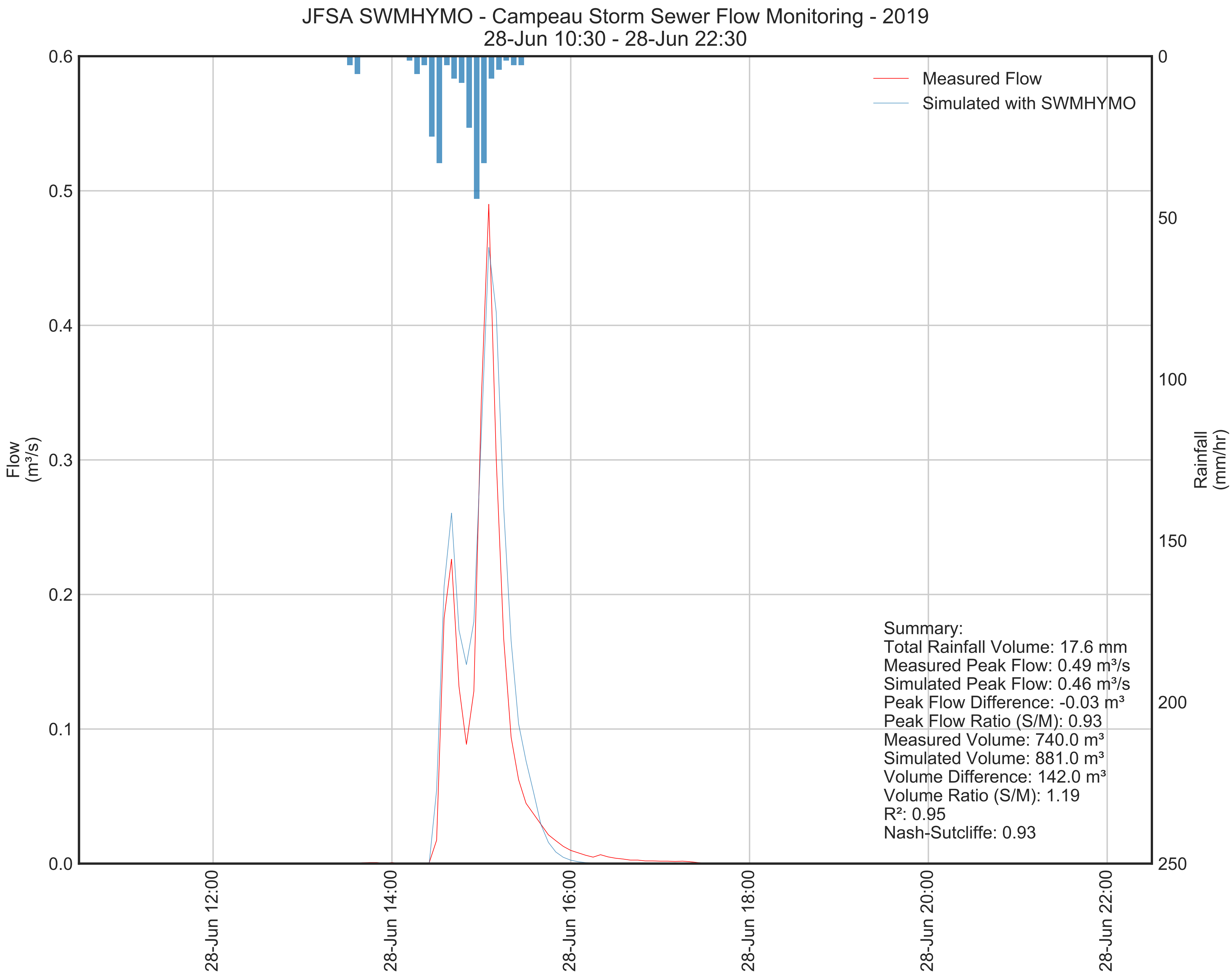


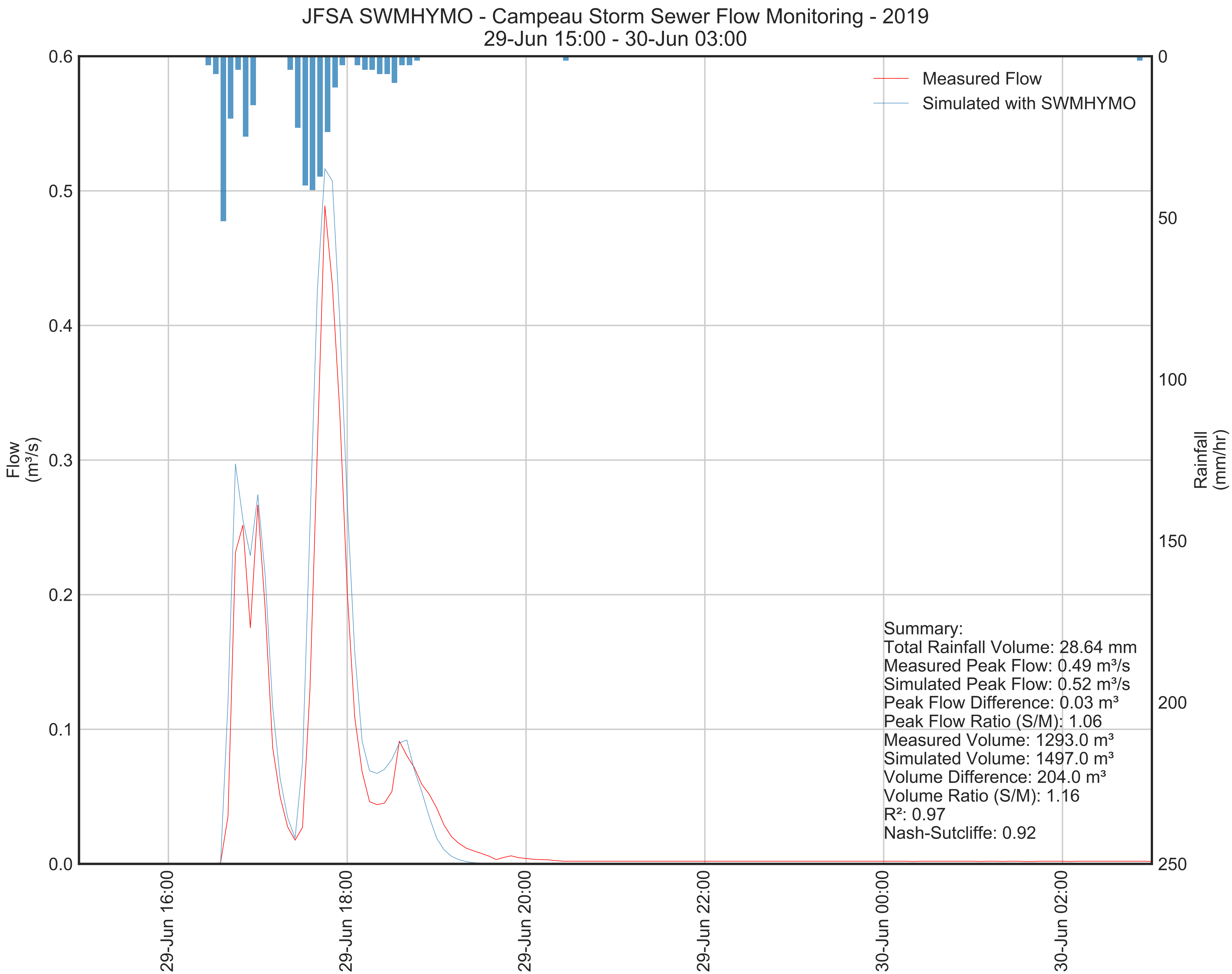
JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
13-Jun 14:30 - 14-Jun 06:30
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
13-Jun 16:00
13-Jun 18:00
13-Jun 20:00
13-Jun 22:00
14-Jun 00:00
14-Jun 02:00
14-Jun 04:00
14-Jun 06:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 14.84 mm
Measured Peak Flow: 0.07 m³/s
Simulated Peak Flow: 0.08 m³/s
Peak Flow Difference: 0.0 m³
Peak Flow Ratio (S/M): 1.04
Measured Volume: 777.0 m³
Simulated Volume: 634.0 m³
Volume Difference: -143.0 m³
Volume Ratio (S/M): 0.82
R²: 0.92
Nash-Sutcliffe: 0.85

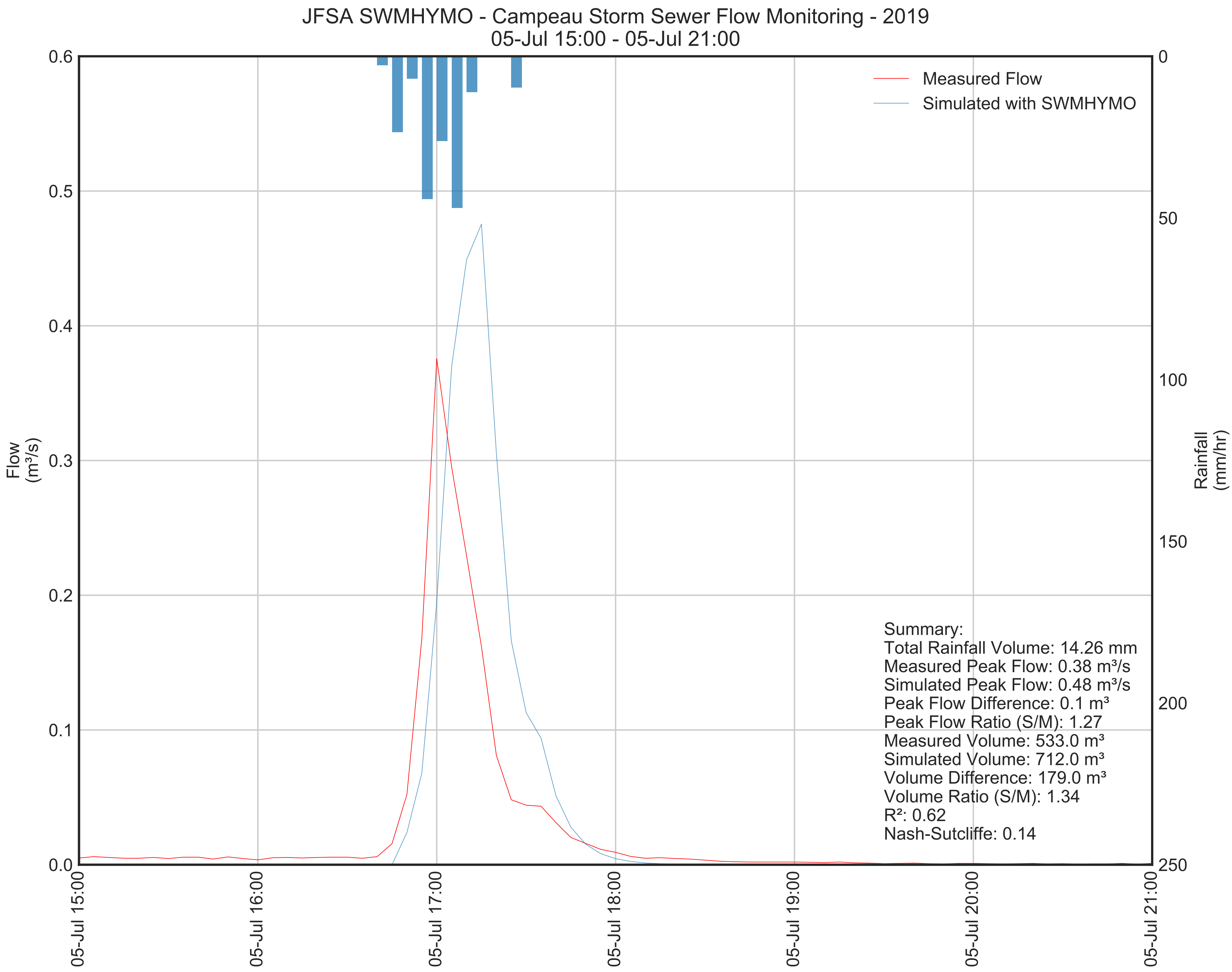


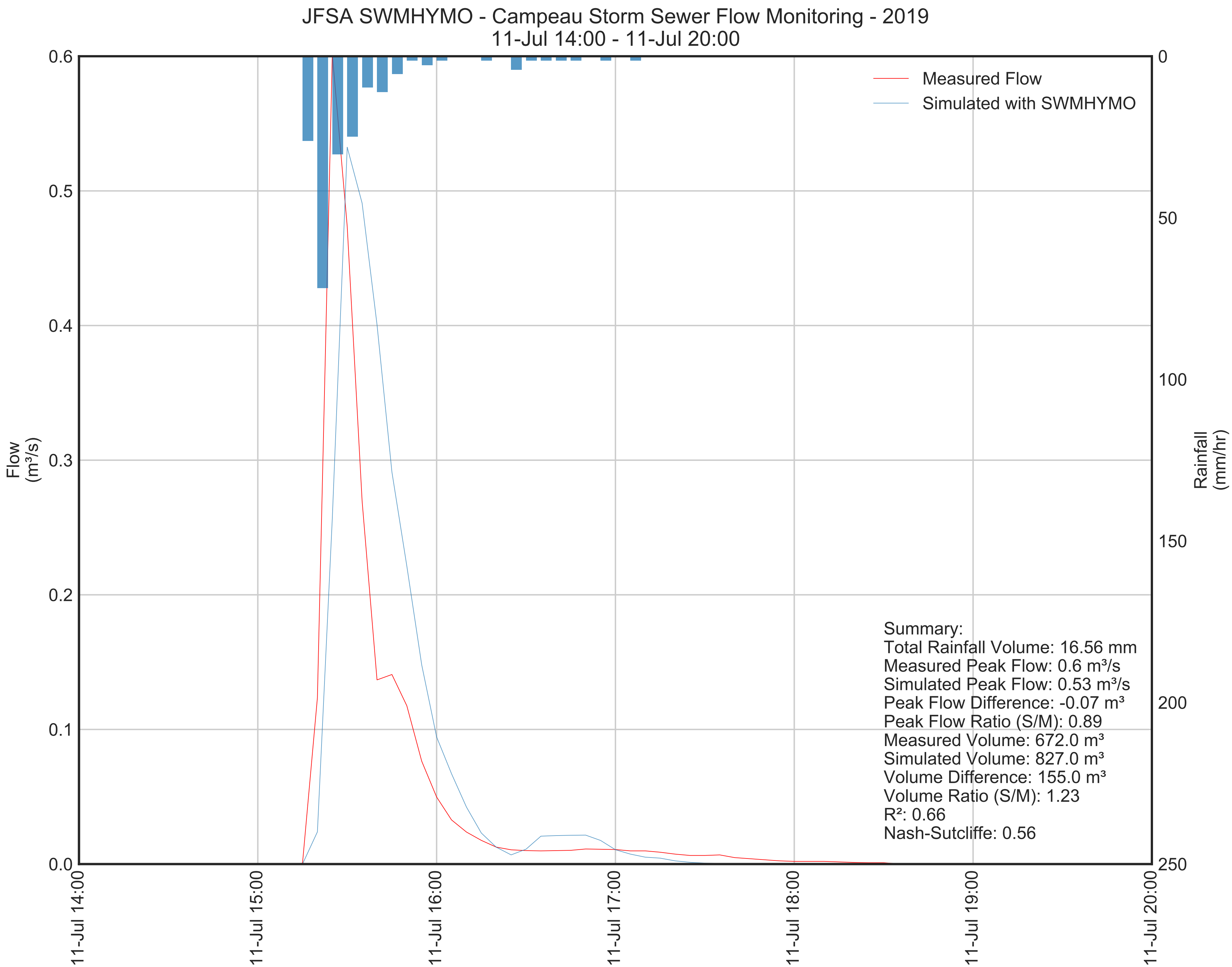
JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
19-Jun 14:00 - 19-Jun 20:00
Flow (m³/s)
Rainfall (mm/hr)
Measured Flow
Simulated with SWMHYMO
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
19-Jun 14:00
19-Jun 15:00
19-Jun 16:00
19-Jun 17:00
19-Jun 18:00
19-Jun 19:00
19-Jun 20:00
Summary:
Total Rainfall Volume: 7.02 mm
Measured Peak Flow: 0.34 m³/s
Simulated Peak Flow: 0.32 m³/s
Peak Flow Difference: -0.03 m³
Peak Flow Ratio (S/M): 0.92
Measured Volume: 299.0 m³
Simulated Volume: 312.0 m³
Volume Difference: 12.0 m³
Volume Ratio (S/M): 1.04
R²: 0.91
Nash-Sutcliffe: 0.91


JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
25-Jun 03:30 - 25-Jun 09:30
Flow (m³/s)
Rainfall (mm/hr)
Measured Flow
Simulated with SWMHYMO
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
25-Jun 04:00
25-Jun 05:00
25-Jun 06:00
25-Jun 07:00
25-Jun 08:00
25-Jun 09:00
Summary:
Total Rainfall Volume: 10.93 mm
Measured Peak Flow: 0.4 m³/s
Simulated Peak Flow: 0.4 m³/s
Peak Flow Difference: 0.0 m³
Peak Flow Ratio (S/M): 1.01
Measured Volume: 456.0 m³
Simulated Volume: 520.0 m³
Volume Difference: 63.0 m³
Volume Ratio (S/M): 1.14
R²: 0.73
Nash-Sutcliffe: 0.68

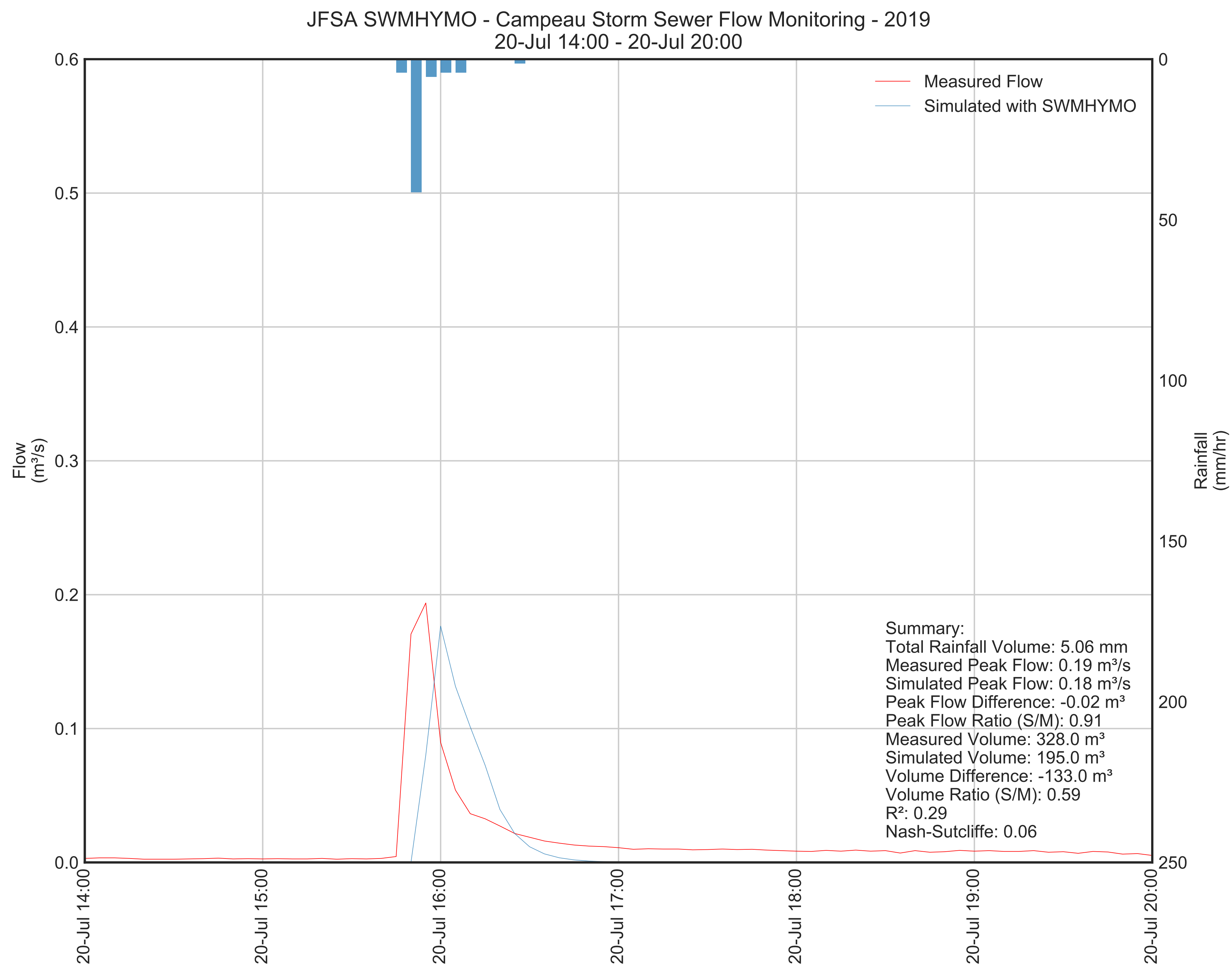

JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
28-Jun 10:30 - 28-Jun 22:30
Flow
(m³/s)
Rainfall
(mm/hr)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
28-Jun 12:00
28-Jun 14:00
28-Jun 16:00
28-Jun 18:00
28-Jun 20:00
28-Jun 22:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 17.6 mm
Measured Peak Flow: 0.49 m³/s
Simulated Peak Flow: 0.46 m³/s
Peak Flow Difference: -0.03 m³
Peak Flow Ratio (S/M): 0.93
Measured Volume: 740.0 m³
Simulated Volume: 881.0 m³
Volume Difference: 142.0 m³
Volume Ratio (S/M): 1.19
R²: 0.95
Nash-Sutcliffe: 0.93

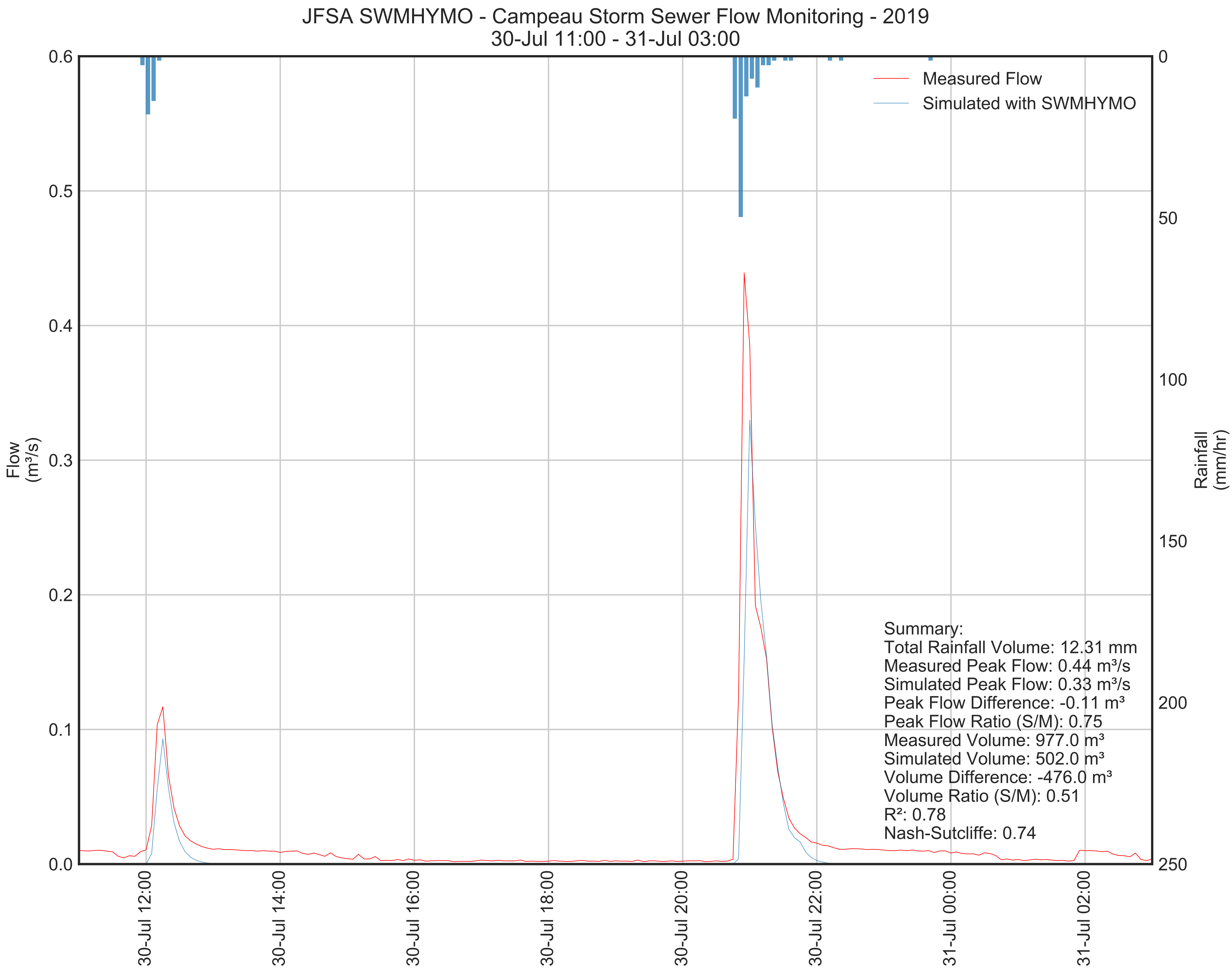

JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
29-Jun 15:00 - 30-Jun 03:00
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
29-Jun 16:00
29-Jun 18:00
29-Jun 20:00
29-Jun 22:00
30-Jun 00:00
30-Jun 02:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 28.64 mm
Measured Peak Flow: 0.49 m³/s
Simulated Peak Flow: 0.52 m³/s
Peak Flow Difference: 0.03 m³
Peak Flow Ratio (S/M): 1.06
Measured Volume: 1293.0 m³
Simulated Volume: 1497.0 m³
Volume Difference: 204.0 m³
Volume Ratio (S/M): 1.16
R²: 0.97
Nash-Sutcliffe: 0.92


JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
05-Jul 15:00 - 05-Jul 21:00
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 14.26 mm
Measured Peak Flow: 0.38 m³/s
Simulated Peak Flow: 0.48 m³/s
Peak Flow Difference: 0.1 m³
Peak Flow Ratio (S/M): 1.27
Measured Volume: 533.0 m³
Simulated Volume: 712.0 m³
Volume Difference: 179.0 m³
Volume Ratio (S/M): 1.34
R²: 0.62
Nash-Sutcliffe: 0.14
05-Jul 15:00
05-Jul 16:00
05-Jul 17:00
05-Jul 18:00
05-Jul 19:00
05-Jul 20:00
05-Jul 21:00



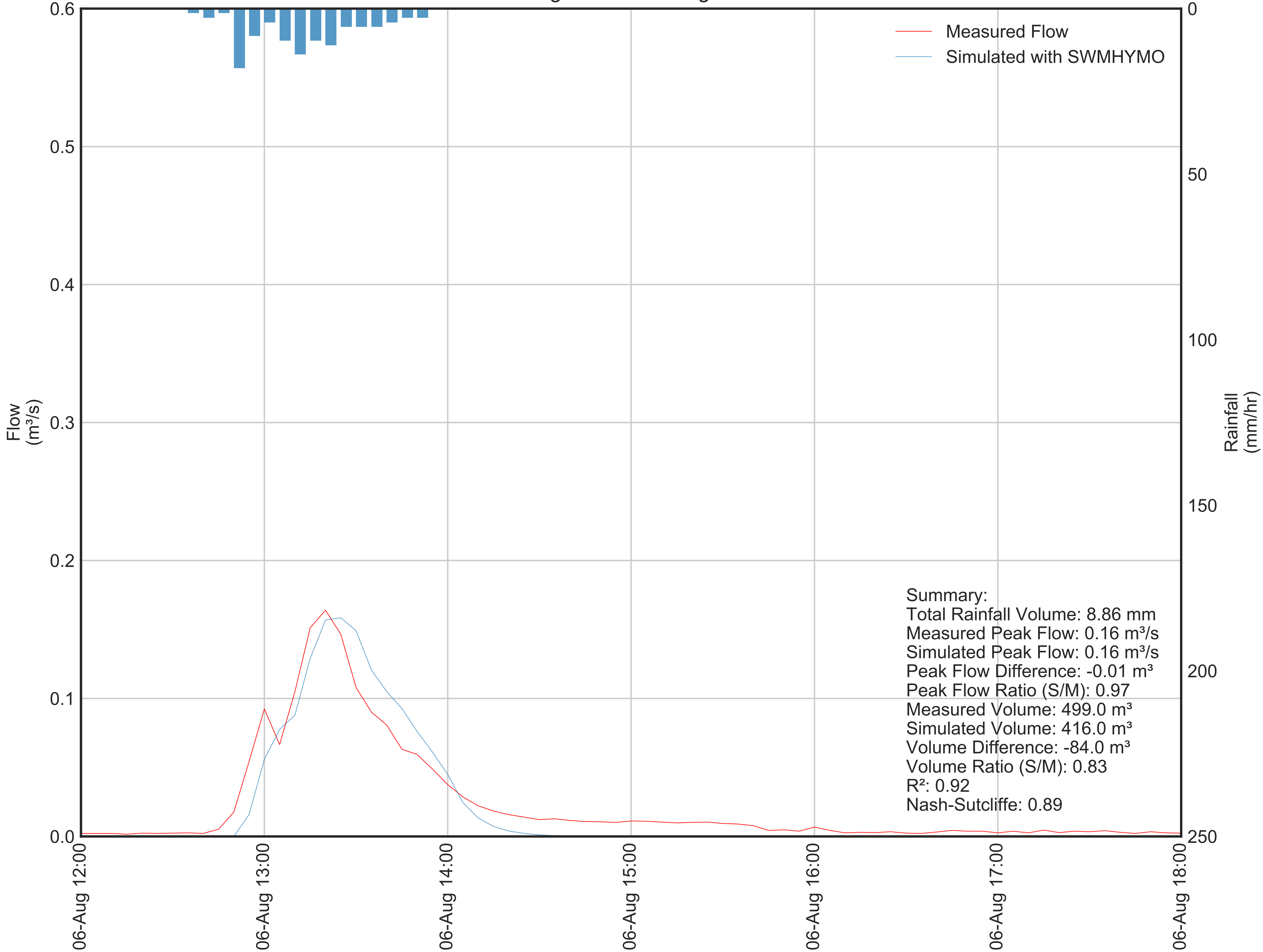
JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
11-Jul 14:00 - 11-Jul 20:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
11-Jul 14:00
11-Jul 15:00
11-Jul 16:00
11-Jul 17:00
11-Jul 18:00
11-Jul 19:00
11-Jul 20:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 16.56 mm
Measured Peak Flow: 0.6 m³/s
Simulated Peak Flow: 0.53 m³/s
Peak Flow Difference: -0.07 m³
Peak Flow Ratio (S/M): 0.89
Measured Volume: 672.0 m³
Simulated Volume: 827.0 m³
Volume Difference: 155.0 m³
Volume Ratio (S/M): 1.23
R²: 0.66
Nash-Sutcliffe: 0.56

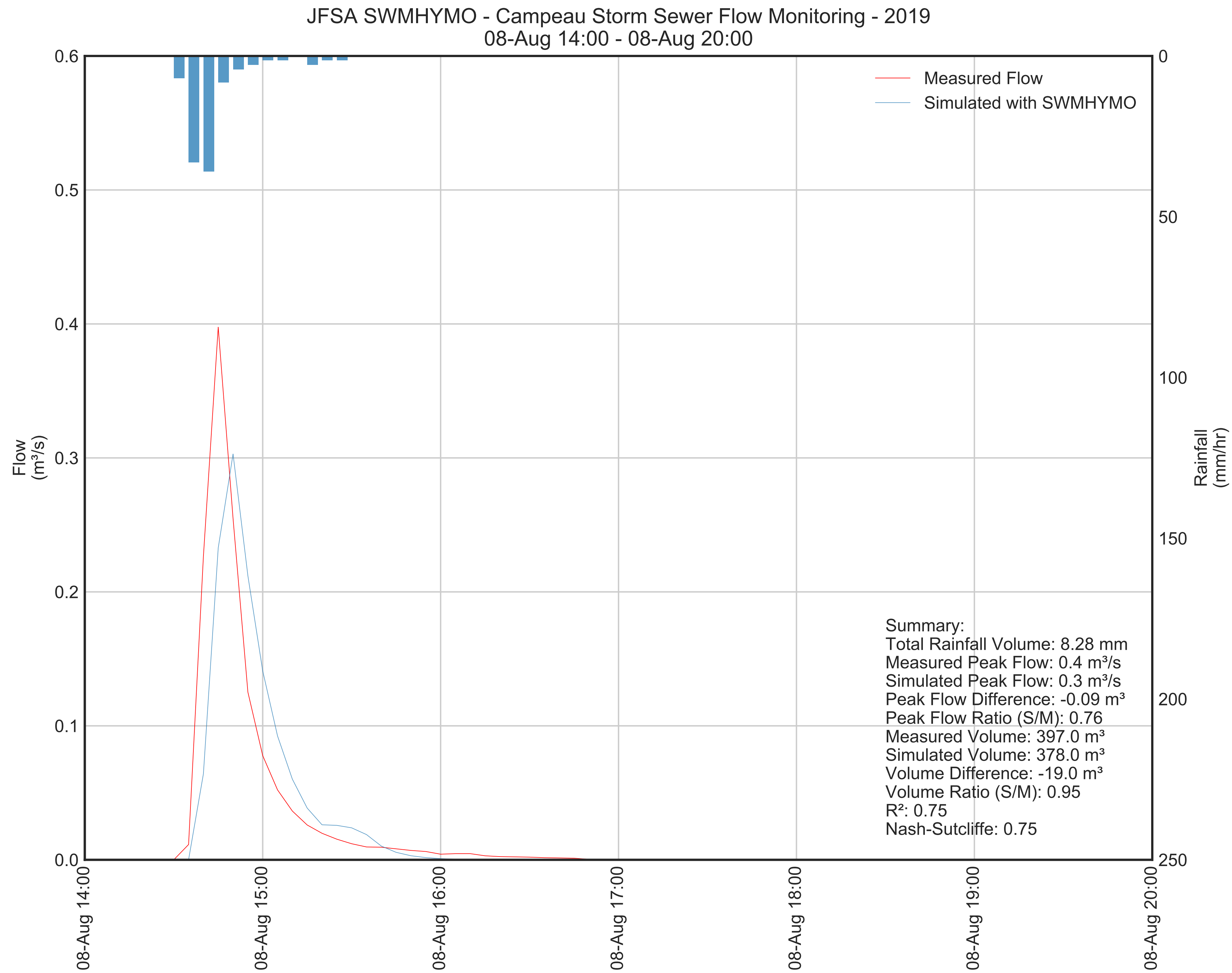

JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
20-Jul 14:00 - 20-Jul 20:00
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
20-Jul 14:00
20-Jul 15:00
20-Jul 16:00
20-Jul 17:00
20-Jul 18:00
20-Jul 19:00
20-Jul 20:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 5.06 mm
Measured Peak Flow: 0.19 m³/s
Simulated Peak Flow: 0.18 m³/s
Peak Flow Difference: -0.02 m³
Peak Flow Ratio (S/M): 0.91
Measured Volume: 328.0 m³
Simulated Volume: 195.0 m³
Volume Difference: -133.0 m³
Volume Ratio (S/M): 0.59
R²: 0.29
Nash-Sutcliffe: 0.06



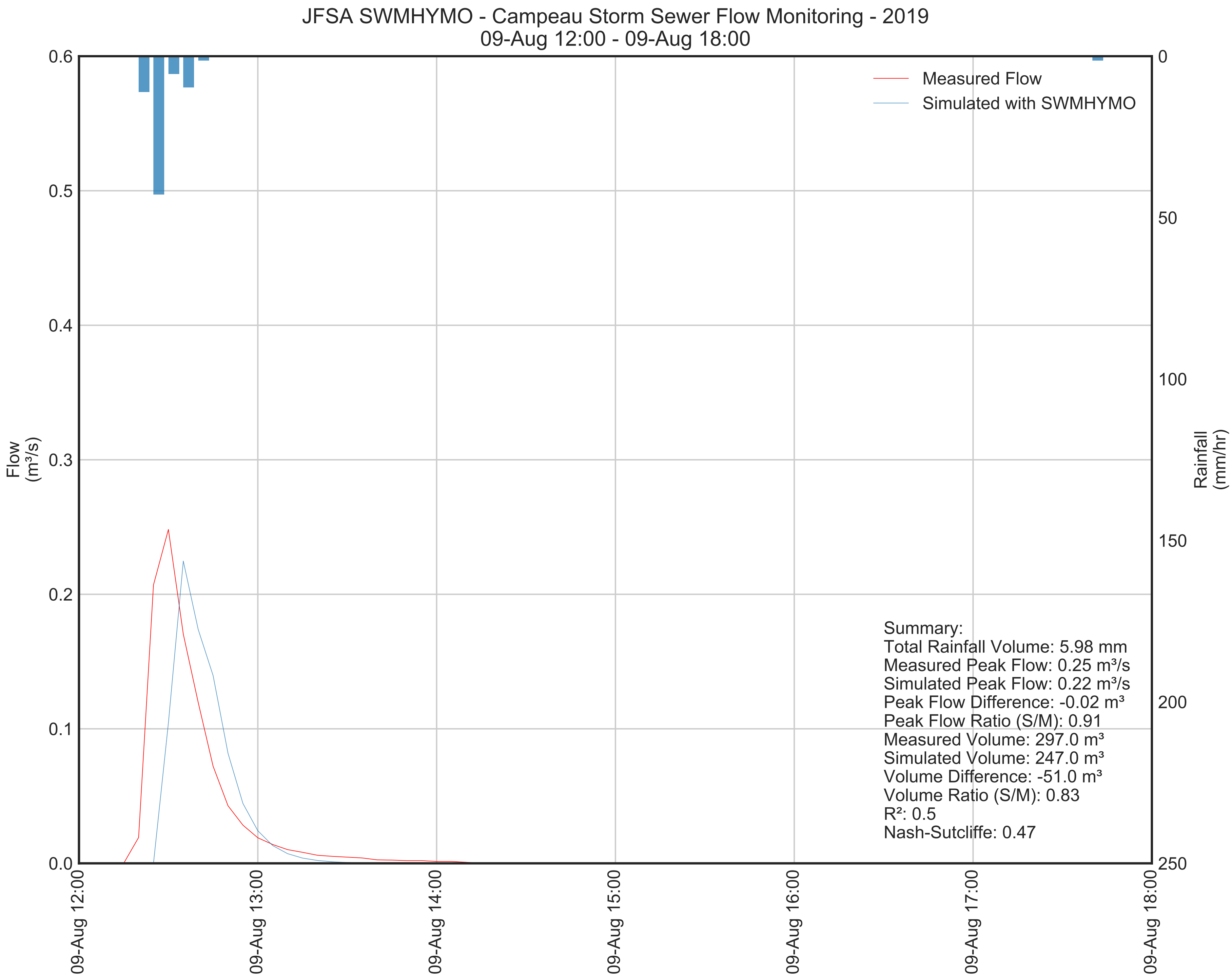
JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
30-Jul 11:00 - 31-Jul 03:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
30-Jul 12:00
30-Jul 14:00
30-Jul 16:00
30-Jul 18:00
30-Jul 20:00
30-Jul 22:00
31-Jul 00:00
31-Jul 02:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 12.31 mm
Measured Peak Flow: 0.44 m³/s
Simulated Peak Flow: 0.33 m³/s
Peak Flow Difference: -0.11 m³
Peak Flow Ratio (S/M): 0.75
Measured Volume: 977.0 m³
Simulated Volume: 502.0 m³
Volume Difference: -476.0 m³
Volume Ratio (S/M): 0.51
R²: 0.78
Nash-Sutcliffe: 0.74

JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
06-Aug 12:00 - 06-Aug 18:00

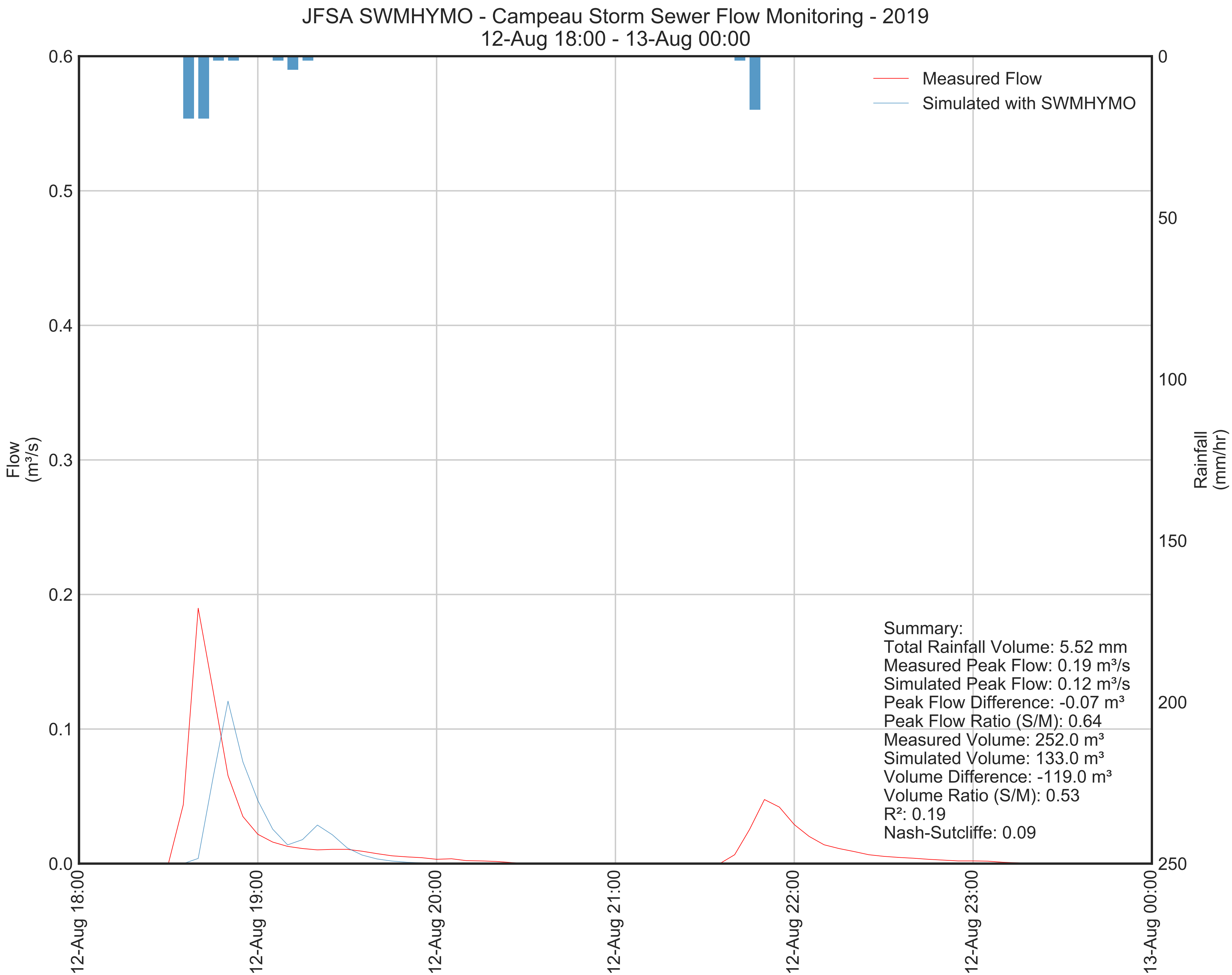




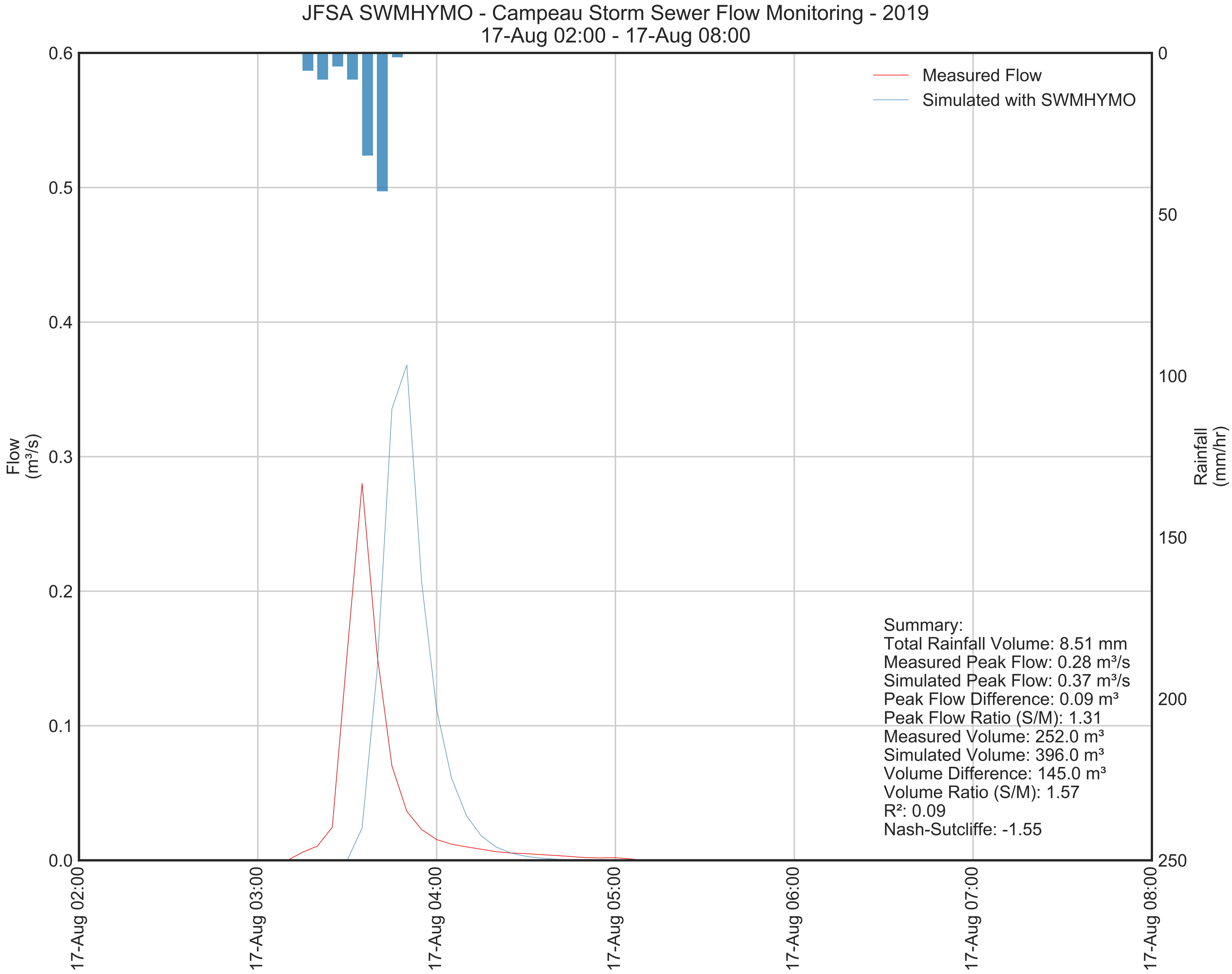
JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
08-Aug 14:00 - 08-Aug 20:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
08-Aug 14:00
08-Aug 15:00
08-Aug 16:00
08-Aug 17:00
08-Aug 18:00
08-Aug 19:00
08-Aug 20:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 8.28 mm
Measured Peak Flow: 0.4 m³/s
Simulated Peak Flow: 0.3 m³/s
Peak Flow Difference: -0.09 m³
Peak Flow Ratio (S/M): 0.76
Measured Volume: 397.0 m³
Simulated Volume: 378.0 m³
Volume Difference: -19.0 m³
Volume Ratio (S/M): 0.95
R²: 0.75
Nash-Sutcliffe: 0.75

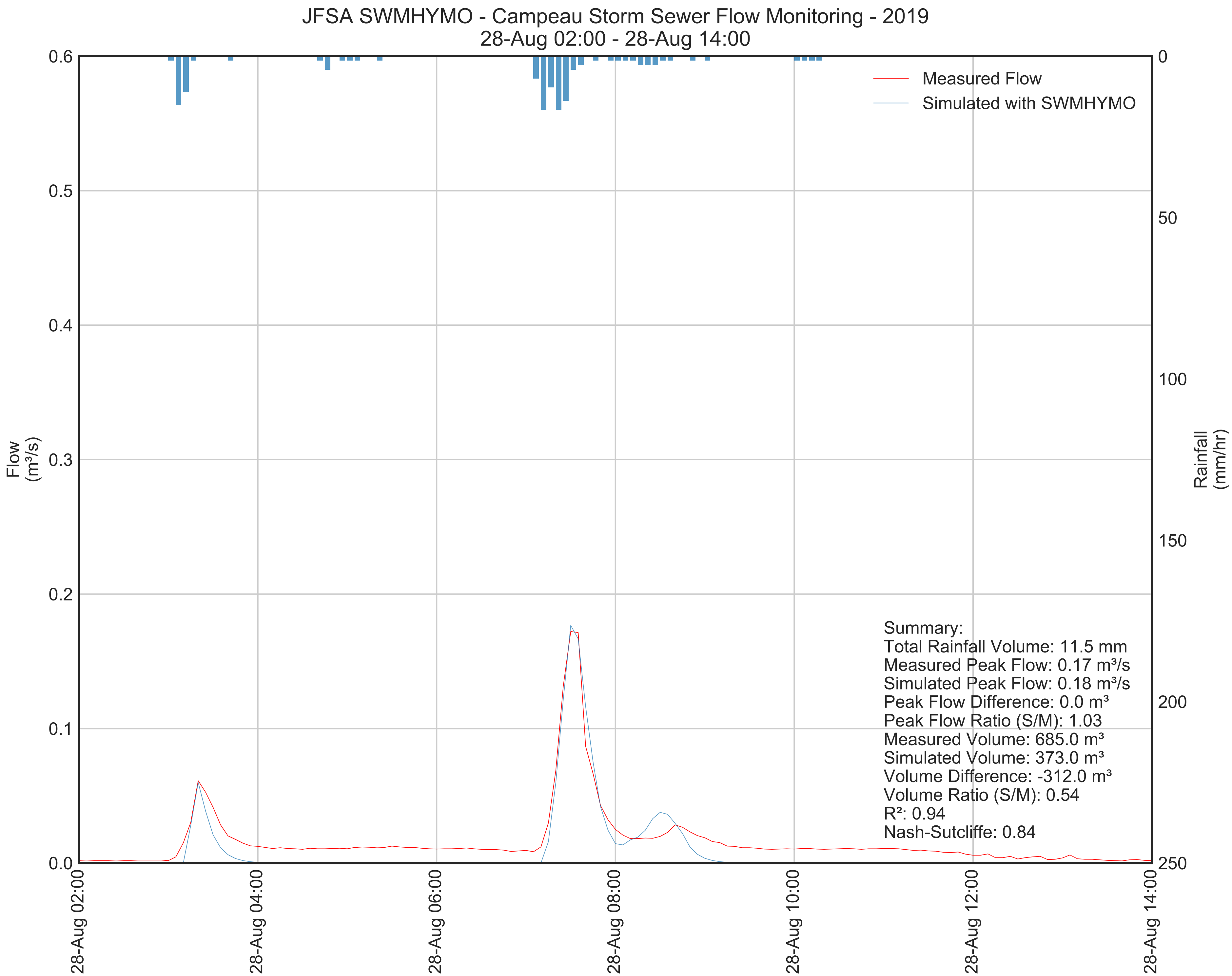


JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
09-Aug 12:00 - 09-Aug 18:00
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 5.98 mm
Measured Peak Flow: 0.25 m³/s
Simulated Peak Flow: 0.22 m³/s
Peak Flow Difference: -0.02 m³
Peak Flow Ratio (S/M): 0.91
Measured Volume: 297.0 m³
Simulated Volume: 247.0 m³
Volume Difference: -51.0 m³
Volume Ratio (S/M): 0.83
R²: 0.5
Nash-Sutcliffe: 0.47
09-Aug 12:00
09-Aug 13:00
09-Aug 14:00
09-Aug 15:00
09-Aug 16:00
09-Aug 17:00
09-Aug 18:00

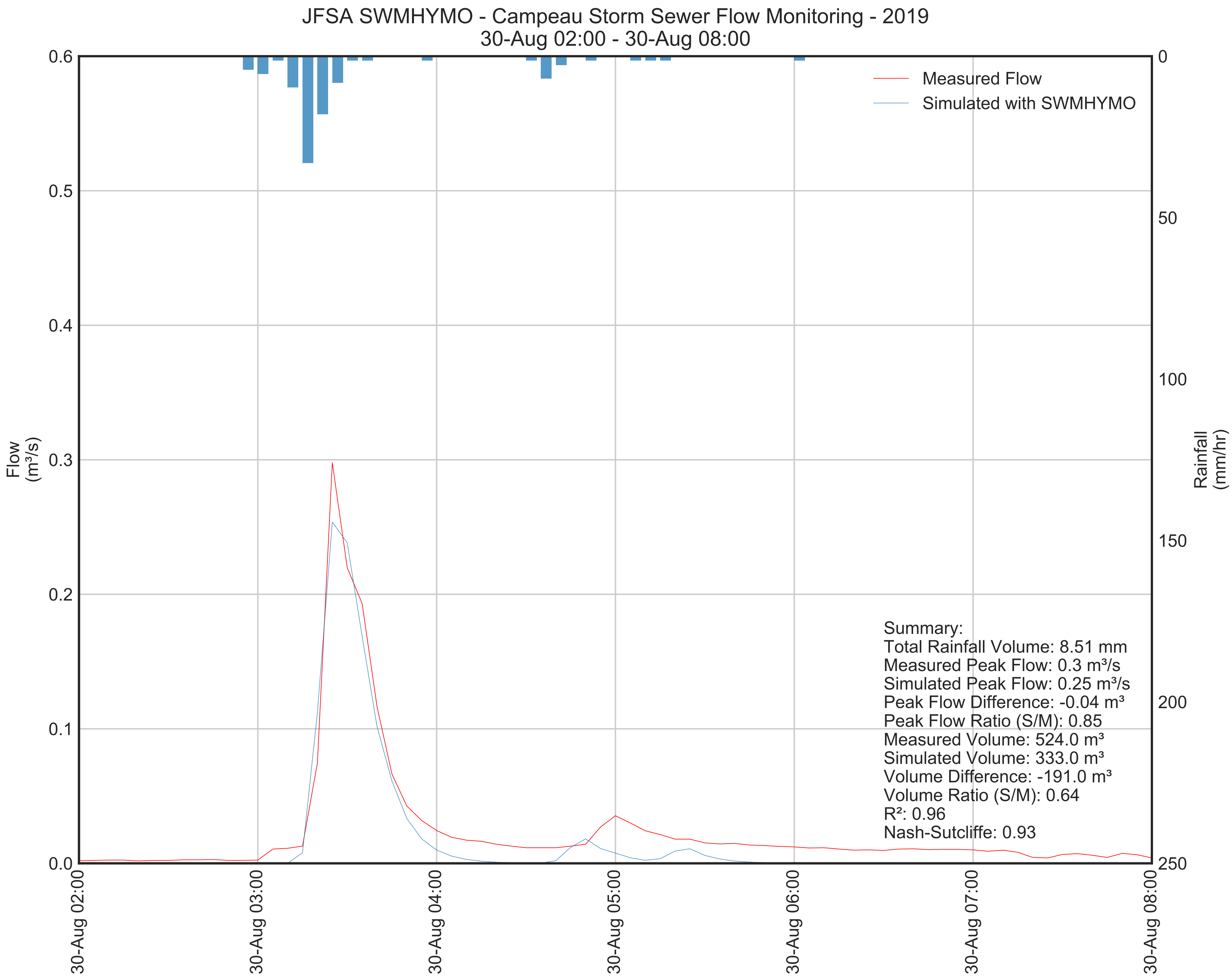


JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
12-Aug 18:00 - 13-Aug 00:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 5.52 mm
Measured Peak Flow: 0.19 m³/s
Simulated Peak Flow: 0.12 m³/s
Peak Flow Difference: -0.07 m³
Peak Flow Ratio (S/M): 0.64
Measured Volume: 252.0 m³
Simulated Volume: 133.0 m³
Volume Difference: -119.0 m³
Volume Ratio (S/M): 0.53
R²: 0.19
Nash-Sutcliffe: 0.09
12-Aug 18:00
12-Aug 19:00
12-Aug 20:00
12-Aug 21:00
12-Aug 22:00
12-Aug 23:00
13-Aug 00:00

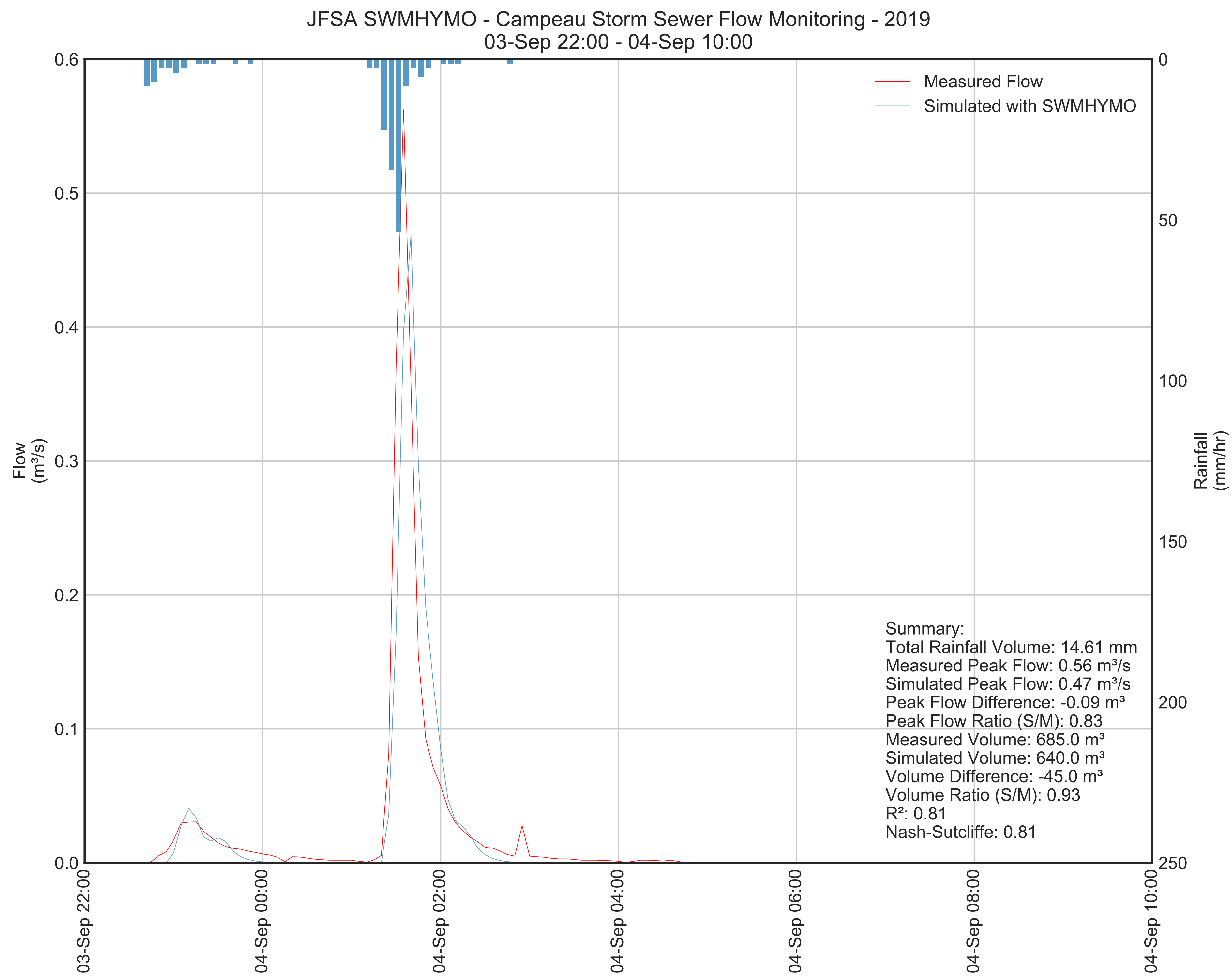

JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
17-Aug 02:00 - 17-Aug 08:00
Flow (m³/s)
Rainfall (mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
17-Aug 02:00
17-Aug 03:00
17-Aug 04:00
17-Aug 05:00
17-Aug 06:00
17-Aug 07:00
17-Aug 08:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 8.51 mm
Measured Peak Flow: 0.28 m³/s
Simulated Peak Flow: 0.37 m³/s
Peak Flow Difference: 0.09 m³
Peak Flow Ratio (S/M): 1.31
Measured Volume: 252.0 m³
Simulated Volume: 396.0 m³
Volume Difference: 145.0 m³
Volume Ratio (S/M): 1.57
R²: 0.09
Nash-Sutcliffe: -1.55



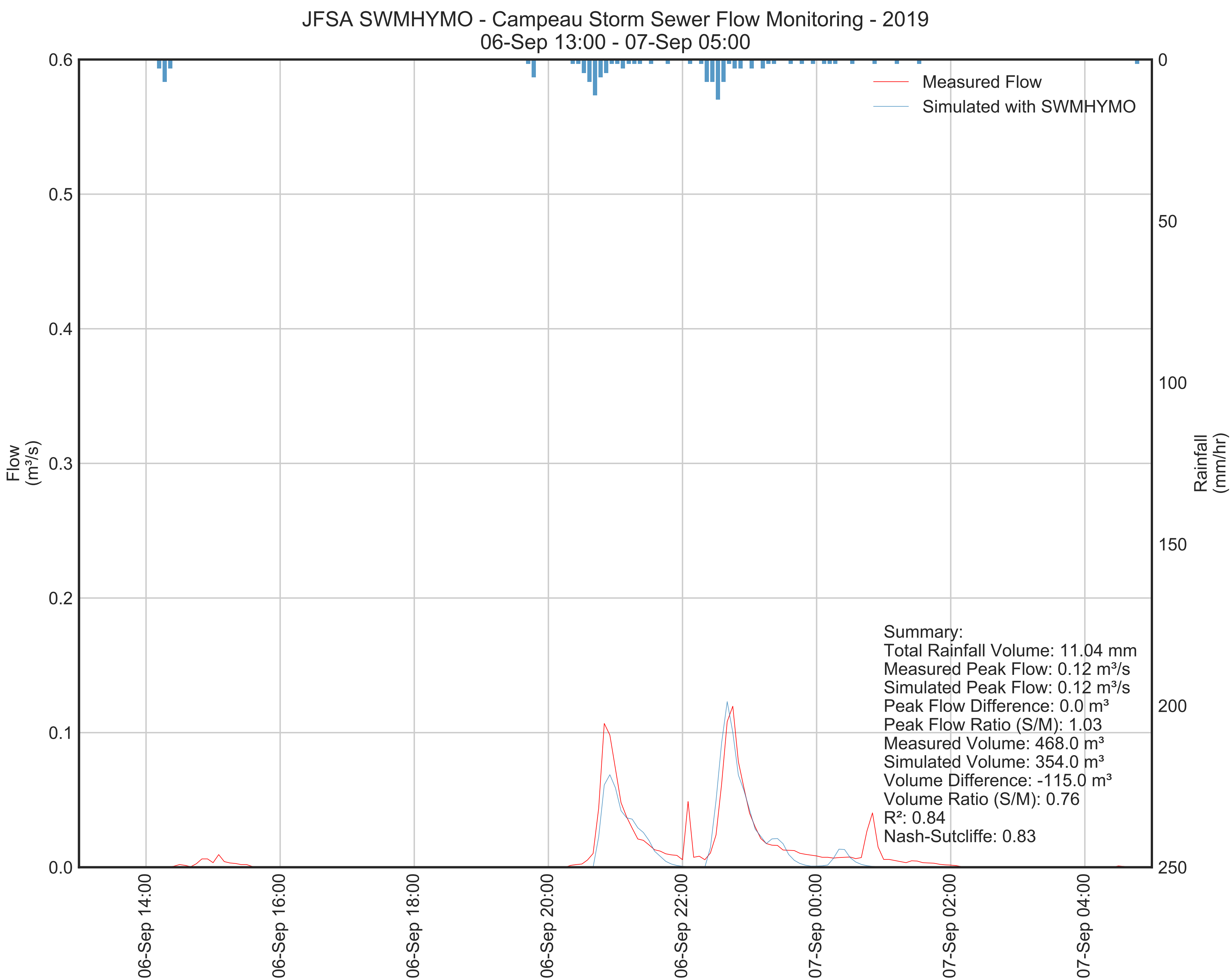
JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
28-Aug 02:00 - 28-Aug 14:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
28-Aug 02:00
28-Aug 04:00
28-Aug 06:00
28-Aug 08:00
28-Aug 10:00
28-Aug 12:00
28-Aug 14:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 11.5 mm
Measured Peak Flow: 0.17 m³/s
Simulated Peak Flow: 0.18 m³/s
Peak Flow Difference: 0.0 m³
Peak Flow Ratio (S/M): 1.03
Measured Volume: 685.0 m³
Simulated Volume: 373.0 m³
Volume Difference: -312.0 m³
Volume Ratio (S/M): 0.54
R²: 0.94
Nash-Sutcliffe: 0.84



JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
30-Aug 02:00 - 30-Aug 08:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
30-Aug 02:00
30-Aug 03:00
30-Aug 04:00
30-Aug 05:00
30-Aug 06:00
30-Aug 07:00
30-Aug 08:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 8.51 mm
Measured Peak Flow: 0.3 m³/s
Simulated Peak Flow: 0.25 m³/s
Peak Flow Difference: -0.04 m³
Peak Flow Ratio (S/M): 0.85
Measured Volume: 524.0 m³
Simulated Volume: 333.0 m³
Volume Difference: -191.0 m³
Volume Ratio (S/M): 0.64
R²: 0.96
Nash-Sutcliffe: 0.93



JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
03-Sep 22:00 - 04-Sep 10:00
Flow (m³/s)
Rainfall (mm/hr)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
03-Sep 22:00
04-Sep 00:00
04-Sep 02:00
04-Sep 04:00
04-Sep 06:00
04-Sep 08:00
04-Sep 10:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 14.61 mm
Measured Peak Flow: 0.56 m³/s
Simulated Peak Flow: 0.47 m³/s
Peak Flow Difference: -0.09 m³
Peak Flow Ratio (S/M): 0.83
Measured Volume: 685.0 m³
Simulated Volume: 640.0 m³
Volume Difference: -45.0 m³
Volume Ratio (S/M): 0.93
R²: 0.81
Nash-Sutcliffe: 0.81


JFSA SWMHYMO - Campeau Storm Sewer Flow Monitoring - 2019
06-Sep 13:00 - 07-Sep 05:00
Flow
(m³/s)
Rainfall
(mm/hr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
250
06-Sep 14:00
06-Sep 16:00
06-Sep 18:00
06-Sep 20:00
06-Sep 22:00
07-Sep 00:00
07-Sep 02:00
07-Sep 04:00
Measured Flow
Simulated with SWMHYMO
Summary:
Total Rainfall Volume: 11.04 mm
Measured Peak Flow: 0.12 m³/s
Simulated Peak Flow: 0.12 m³/s
Peak Flow Difference: 0.0 m³
Peak Flow Ratio (S/M): 1.03
Measured Volume: 468.0 m³
Simulated Volume: 354.0 m³
Volume Difference: -115.0 m³
Volume Ratio (S/M): 0.76
R²: 0.84
Nash-Sutcliffe: 0.83