Marathon Palladium Project Environmental Hydrology Updated Baseline Report

November 13, 2020
File: 129673006

Prepared for:

Generation PGM Inc. (GenPGM)

Prepared by:

Stantec Consulting Ltd.

Table of Contents

1.0 INTRODUCTION 1.1
1.1 PROJECT LOCATION 1.1
1.2 PROJECT OVERVIEW 1.2
1.3 STUDY OBJECTIVES 1.4

2.0 PREVIOUS CHARACTERIZATION OF EXISTING CONDITIONS 2.1
2.1 HYDROLOGY DESKTOP ASSESSMENT 2.1
2.1.1 Climate 2.1
2.1.2 Local Watersheds 2.2
2.1.3 Regional Hydrology 2.3
2.1.4 Hydrology Field Program 2.5

3.0 REGULATORY SETTING 3.1

4.0 STUDY AREA 4.1
4.1 SITE STUDY AREA (SSA) 4.1
4.2 LOCAL STUDY AREA (LSA) 4.1
4.3 REGIONAL STUDY AREA (RSA) 4.1

5.0 METHODOLOGY 5.1
5.1 BASELINE STREAM FLOW MONITORING 5.1
5.2 HYDROMETRIC MONITORING STATIONS 5.1
5.3 HYDROMETRIC MONITORING RESULTS 5.2
5.4 HYDROLOGY DESKTOP ASSESSMENT 5.1
5.4.1 Regional Hydrology Assessment 5.1
5.4.1 Local Hydrology Assessment 5.2

6.0 UPDATED BASELINE HYDROLOGY CONDITIONS 6.1
6.1 HYDROLOGY DESKTOP ASSESSMENT 6.1
6.1.1 Climate 6.1
6.1.2 Climate Change 6.5
6.1.3 Local Watersheds 6.7
6.1.4 Regional Hydrology Assessment Results 6.8
6.1.5 Local Hydrology Assessment 6.18

7.0 SUMMARY AND CONCLUSIONS 7.1

8.0 REFERENCES 8.1

LIST OF GRAPHS

Graph 2.1: 2009 to 2011 Hydrographs of Station S11 (Calder, 2012a) 2.6
Graph 5.1: S11 Stage-Discharge relationship 5.4
Graph 5.2: Estimated flow and manual measurements at S11 (2016) 5.4
Graph 5.3: Hare Lake Water Depth Fluctuations 5.5
Graph 6.1: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station (Schardong et al., 2020) 6.4
Graph 6.2: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station – RCP4.5, Projection Period 2010-2040 (Schardong et al., 2020) 6.6
Graph 6.3: Flow Duration Curve for WSC Stations 6.12
Graph 6.4: Homogeneity Test – Flood Index Approach with 95% Confidence Interval....6.13
Graph 6.5: Regional Station Relationship Between Mean Annual Flows and Catchment Area....6.15
Graph 6.6: Regional Station Relationships Between Catchment Area and Peak Flows 6.17
Graph 6.7: Regional Station Relationship Between Catchment Area and Low Flows 6.18
Graph 6.8: 1970-2019 Annual Precipitation 6.25

LIST OF TABLES

Table 2.1: Regional Climatic Station Used in Calder (2012a) 2.1
Table 2.2: Mean Monthly Precipitation at the Marathon Weather Station (Calder, 2012a) 2.1
Table 2.3: Local Watersheds Used in Calder (2012a)....2.2
Table 2.4: Regional Hydrometric Stations Used in Calder (2012a) 2.3
Table 2.5: Instantaneous Peak Flows for Regional Hydrometric Stations (Calder, 2012a) 2.4
Table 2.6: Estimated Low Flows for Regional Hydrometric Stations (Calder, 2012a)....2.4
Table 2.7: Instantaneous Peak Flows for Watersheds (Ungauged Streams) (Calder, 2012a) 2.7
Table 2.8: Instantaneous Peak Flows for Gauged Steams (Calder, 2012a)....2.7
Table 2.9: Estimated 7-Day Duration Low Flows for Ungauged Streams (Calder, 2012a) 2.8
Table 2.10: Estimated 7-Day Duration Low Flows for Gauged Streams (Calder, 2012a)....2.8
Table 5.1: Hydrometric Monitoring Stations 2008-2020 ....5.1
Table 5.2: Stage-Discharge Relationships for hydrometric stations 5.3
Table 5.3: Tessman Method Rules 5.3
Table 6.1: Regional Climatic Stations (Environment Canada, 2020)....6.2
Table 6.2: Climate Data Summary at Combined Marathon, Marathon Airport, and Pukaskwa (AUT) Stations 6.3
Table 6.3: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station (Schardong et al., 2020) 6.4
Table 6.4: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station – RCP4.5, Projection Period 2010-2040 (Schardong et al., 2020) 6.5
Table 6.5: Local Watersheds Within SSA 6.8
Table 6.6: Water Survey of Canada Station Summary....6.11
Table 6.7: Homogeneity Test for Index Low Flow (7Q10) 6.14

Table 6.8: Regional Station Relationship Between Mean Monthly Flows and Catchment Area....6.16
Table 6.9: Summary of Mean Annual Flows (m^3/s) for Watersheds within the LSA....6.19
Table 6.10: Summary of Mean Monthly Flows (m^3/s) for Watersheds within the LSA....6.20
Table 6.11: Summary of Peak Flows (m^3/s) for Watersheds within the LSA....6.21
Table 6.12: Summary of Low Flows (m^3/s) for Watersheds within the LSA....6.21
Table 6.13: Environmental Flow (m^3/s) calculation example for Watershed 101....6.23
Table 6.14: Summary of Environmental Flows (m^3/s) for Watersheds within the LSA....6.24
Table 6.15: Environmental Water Balance Input Parameters....6.26
Table 6.16: 1981-2010 Climate Normal Environmental Water Balance....6.26

LIST OF APPENDICES

APPENDIX A FIGURES

APPENDIX B HYDROMETRIC STATION SUMMARY SHEETS

APPENDIX C CLIMATE CHANGE DATA

Abbreviations

CEAA, 2012	Canadian Environmental Assessment Act, 2012
CIAR	Canadian Impact Assessment Registry
CRA	commercial, recreational, and Aboriginal
DEM	digital elevation models
DFO	Fisheries and Oceans Canada
EC	Environment Canada
ECCC	Environment and Climate Change Canada
EIS	Environmental Impact Statement
GenPGM	Generation PGM Inc
IDF	Intensity-Duration-Frequency
LIDAR	light detection and ranging
LRIA	Lakes and Rivers Improvement Act
LSA	Local Study Area
MAF	Mean Annual Flow
MDMER	Metal and Diamond Mining Effluent Regulations
MECP	Ministry of the Environment, Conservation and Park
MMF	Mean Monthly Flow
MNRF	Ministry of Natural Resources and Forestry
MOE	Ontario Ministry of Environment
MRSA	Mine Rock Storage Area
NAG	non-acid generating
NPA	Navigation Protection Act
OFAT	Ontario Flow Assessment Tool
OWRA	Ontario Water Resources Act
PAG	potentially acid generating
PSMF	Process Solids Management Facility
RCPs	representative concentration pathways
RSA	Regional Study Area

SSA	Site Study Area
the Project	Marathon PGM project
USGS	United States Geological Survey
VEC	Value Ecosystem Component

1.0 INTRODUCTION

Generation PGM Inc. (GenPGM) proposes to develop the Marathon Palladium Project (the “Project”), which is a platinum group metals (PGM) and copper (Cu) open-pit mine and milling operation near the Town of Marathon, Ontario. The Project is being assessed in accordance with the *Canadian Environmental Assessment Act* (CEAA, 2012) and Ontario’s *Environmental Assessment Act* (EA Act) through a Joint Review Panel (the Panel) pursuant to the *Canada-Ontario Agreement on Environmental Assessment Cooperation* (2004).

Stantec Consulting Ltd. (Stantec) has been retained by GenPGM to conduct an updated assessment of hydrological baseline conditions for the Project. This report provides an update to the baseline conditions as described in the information currently on the record, including:

- Supplemental Information Document No.20: Baseline Hydrologic Conditions at the Marathon PGM-Cu Project Site prepared by Calder Engineering Ltd. (2012) (Calder 2012a) (CIAR # 227)
- Responses to IR24,9, IR24,10, IR24, 11, IR24.13 and 24.14 (CIAR # 380)

This hydrology baseline study has been completed to inform the Addendum to the Marathon PGM-Cu Environmental Impact Statement (EIS Addendum) as input to the Joint Review Panel process. It has been prepared pursuant to the *Canadian Environmental Assessment Act, 2012* and in consideration of the *Guidelines for the Preparation of an Environmental Impact Statement – Marathon Platinum Group Metals and Copper Mine Project* (EIS Guidelines) (Canadian Environmental Assessment Agency (CEAA) and Ontario Ministry of Environment (MOE), 2011).

The information presented in this report is intended to summarize and document changes to the existing environmental conditions relating to hydrology, relative to those conditions considered in the previous assessment, in order to support the updated assessment of potential environmental effects provided in the EIS Addendum.

The information presented herein was obtained from a review of historical information and the updated design plans for the Project provided by GenPGM.

1.1 PROJECT LOCATION

The Project is located approximately 10 km north of the Town of Marathon, Ontario (Figure 1, Appendix A). Marathon is a community of approximately 3,300 people (Statistics Canada, 2017) located adjacent to the Trans-Canada Highway (Highway 17) on the northeast shore of Lake Superior approximately 300 km east of Thunder Bay and 400 km northwest of Sault Ste. Marie. The center of the Project footprint sits at approximately 48° 47’ N latitude, 86° 19’ W longitude (UTM NAD83 N16 Easting 550197 and Northing 5403595). The footprint of the proposed mine location is roughly bounded by Highway 17 and the Marathon Airport to the south, the Pic River and Camp 19 Road to the east, Hare

Lake to the west, and Bamoos Lake to the north (Figure 1, Appendix A). Access is currently gained through Camp 19 Road.

The Project is proposed within an area characterized by relatively dense vegetation, comprised largely of a birch and spruce-dominated mixed wood forest. The terrain is moderate to steep, with frequent bedrock outcrops and prominent east-west oriented valleys. Several watercourses and lakes traverse the area, with drainage flowing either eastward to the Pic River or westward to Lake Superior. The climate of this area is typical of northern areas within the Canadian Shield, with long winters and short, warm summers.

The Project is proposed on Crown Land, with GenPGM holding surface and mineral rights for the area. Regional land-use activities in the area include hunting, fishing, trapping, and snowmobiling, as well as mineral exploration (and mining) and forestry. Other localized land uses in the area include several licensed aggregate pits, the Marathon Municipal Airport, the Marathon Landfill, a municipal works yard, and several commercial and residential properties.

The primary industries in the area have historically been forestry, pulp and paper, mining, and tourism. Exploration for copper and nickel deposits in the area extend as far back as the 1920s. A large copper-PGM deposit was discovered in 1963. Advanced exploration programs have continued across the site since then. These programs have been supported by various feasibility studies to confirm the economic viability of extracting the deposits.

Several First Nations and Métis groups were originally identified as having a potential interest in the Project based on Treaty Rights, asserted traditional territory and proximity to the Project. Traditional uses which they have identified as occurring in the area include hunting, trapping, fishing, and plant harvesting, with activities generally focused on the larger waterways, such as the Pic River, Bamoos Lake, and Hare Lake.

1.2 PROJECT OVERVIEW

The Project is based on the development of an open pit mining and milling operation for copper and platinum group metals. Ore will be mined from the pits and processed (crushed, ground, concentrated) at an on-site processing facility. Final concentrates containing copper and platinum group metals will be transported off-site via existing roadways and/or rail to a smelter and refinery for subsequent metal extraction and separation. An iron sulfide concentrate may also be produced, depending upon the results of further metallurgical testing and market conditions at that time.

The construction workforce will average approximately 450-550 people, with a peak workforce of an estimated 900 people, and will be required for between 18 and 24 months. During operations, the workforce will comprise an estimated 350 workers. The mine workforce will reside in local and surrounding communities, as well as in an accommodations complex that will be constructed off-site.

Most of the mine rock[1] produced through mining activities is non-acid generating (NAG) and will be permanently stored in a purposefully built Mine Rock Storage Area (MRSA). The NAG (also referred to as Type 1 mine rock) will also be used in the construction of access roads, dams, and other site infrastructure, as needed. Drainage from the MRSA will be collected in a series of collection basins and treated, as necessary, to meet applicable water quality criteria prior to discharge to the Pic River. The remaining small portion of the mine rock is considered to be potentially acid generating (PAG) (also referred to as Type 2 mine rock) and will be stored in the open pits or the Process Solids Management Facility (PSMF). This will ensure that drainage from the Type 2 mine rock will be contained during operations. Following closure, the Type 2 mine rock will be permanently stored below water by flooding the open pits and maintaining saturated conditions in the PSMF to prevent acid generation in the future.

Most of the process solids[2] produced at the site will be NAG (Type 1 process solids) with the minority being PAG (Type 2 process solids). Both the Type 1 and Type 2 process solids will be stored in the PSMF and potentially within the open pits. In both cases, the Type 2 process solids will be managed to prevent acid generation during both the operation and closure phases of the Project. Water collected within the PSMF as well as water collected around the mine site (other than the MRSA), such as water pumped from the pits or run-off collected from the plant site, will be managed within the PSMF. Excess water not needed for processing ore will be discharged, following treatment as necessary, to Hare Lake.

Access to the Project is currently provided by the Camp 19 Road, opposite Peninsula Road at Highway 17. The existing road will be upgraded and utilized from its junction with Highway 17 to a new road running north that will be constructed to access the Project site. The Project will also require the construction of a new 115 kV transmission line that will connect to the Terrace Bay-Manitouwadge transmission line (M2W Line). The width of the transmission corridor will be approximately 30 m.

Disturbed areas of the Project footprint will be reclaimed in a progressive manner during all Project phases. Natural drainage patterns will be restored as much as possible. The ultimate goal of mine decommissioning will be to reclaim land within the Project footprint to permit future use by resident biota and as determined through consultation with the public, Indigenous people, and government. A certified Closure Plan for the Project will be prepared as required by Ontario Regulation (O. Reg.) 240/00 as amended by O. Reg. 194/06 “Mine Development and Closure under Part VII of the Mining Act” and “Mine Rehabilitation Code of Ontario”.

A further description of the Project and associated activities and phases will be provided under separate cover in the EIS Addendum.

---

[1] Mine rock: rock that has been excavated from active mining areas but does not have sufficient ore grades to process for mineral extraction.
[2] Process solids: solids generated during the ore milling process following extraction of the ore (minerals) from the host material.

1.3 STUDY OBJECTIVES

This updated hydrology baseline study provides information to inform the EIS Addendum for the Project. The objectives of this update were to describe and present available information and to characterize changes to the baseline conditions of climate, hydrology, and site conditions in the study area. The scope of the updated hydrology baseline study includes the following:

- summary of findings of the existing baseline studies (Section 2.0)
- identification of regulatory guidance for the collection of baseline data (Section 3.0)
- confirmation of spatial boundaries (Section 4.0)
- description of the data collection methods and a review of available background information and data, including any additional and/or on-going data collection efforts (Section 5.0)
- analysis of information to characterize existing baseline conditions for climate, hydrology, and site surface water: groundwater interactions to determine any changes that have occurred since 2012 (Section 6.0)
- provide an updated summary of baseline conditions in the Site Study Area (SSA), Local Study Area (LSA) and Regional Study Area (RSA) specific to conditions relevant to the effects being assessed in the EIS Addendum (Section 7.0)

2.0 PREVIOUS CHARACTERIZATION OF EXISTING CONDITIONS

Previous characterization of existing climate and hydrological conditions was undertaken by Calder (2012a). The previous existing conditions detailed in Calder (2012a) are summarized below and included an assessment of local climate, and regional and local field-based hydrological assessments.

2.1 HYDROLOGY DESKTOP ASSESSMENT

2.1.1 Climate

The Calder (2012a) baseline report provided a table summarizing four climatic stations from Environment Canada within 35 km of the Project (Marathon, Marathon Airport, Pukaskwa National Park, and Hemlo Battle Mountain) with the exclusion of the Marathon A stations. The Marathon A stations were determined to have a limited data set at the time of the report. The climatic station that was selected to represent the LSA was Marathon (Station ID 6044959), which had a long dataset and was the closest of the four to the Project site. Marathon (Station ID 6044959) climatic data is summarized in Table 2.1 below from the Calder (2012a) report.

Table 2.1: Regional Climatic Station Used in Calder (2012a)

Station ID	Station Name	Latitude	Longitude	Records Period (Total)	Elevation (m)	Distance from LSA	Average Annual Precipitation (mm)	Average Annual Snowfall (mm)	Mean Temperature Range (˚C)
6044959	Marathon	48.7167˚N	86.4000˚W	1952-1983 (32)	189.0	8 km (SW)	826.5	238.1	-13.9 to 14.6

Average annual precipitation was broken down into monthly means for the Marathon (Station ID 6044959) weather station.

Table 2.2: Mean Monthly Precipitation at the Marathon Weather Station (Calder, 2012a)

Month	Mean Monthly Precipitation (mm)
January	67.3
February	49.9
March	59.3
April	55.7
May	65.7

Table 2.2: Mean Monthly Precipitation at the Marathon Weather Station (Calder, 2012a)

Month	Mean Monthly Precipitation (mm)
June	79.9
July	74.7
August	80.1
September	90.6
October	75.6
November	65.6
December	62.0
Total:	826.5

As the Marathon Station (ID 6044959) ceased operations in 1983, subsequent Information Requests (24.13) asked for consideration to extend the operative climate dataset to current conditions and to consider whether other climate stations farther afield should be included. Subsequently, an ensemble of nine regional climate stations was developed extending to stations in Geraldton in the northwest and White River in the southeast. When the regional ensemble dataset was compared with the local station dataset a 6.9% difference in precipitation was observed and the assessment concluded that a local ensemble of climate stations comprised of Marathon (6044959), Marathon Airport (6044961), Pukaskwa National Park (6046770), Hemlo Battle Mountain (6043452), Terrace Bay (6048230), and Terrace Bay A (6048231) represented a contiguous daily record from 1952 to 2006 with limited data gaps.

2.1.2 Local Watersheds

The Calder (2012a) baseline report identified eight watersheds covering most of the SSA, presented in Table 2.3. The watersheds were further divided into minor watersheds at node locations.

Table 2.3: Local Watersheds Used in Calder (2012a)

Watershed ID	Drainage Area (km^2)	Drainage Path/Outlet
101	4.35	Pic River
102	3.47	Pic River
103	2.11	Pic River
104	3.39	Pic River
105	48.44	Lake Superior at Port Munroe
106	10.98	Lake Superior at Sturdee Cove
107	0.49	Pic River
108	0.53	Pic River

2.1.3 Regional Hydrology

There is limited regional hydrologic data in the project area and available data is representative of large river systems. Hydrologic data from stations within a 35 km radius of the Project area were used to assess regional hydrologic characteristics. These included the Little Pic River near Coldwell (02BA003), the Pic River near Marathon (02BB003), the Black River near Marathon (02BB002), and Cedar Creek near Hemlo (02BB004) summarized in Table 2.4.

Table 2.4: Regional Hydrometric Stations Used in Calder (2012a)

Station ID	Station Name	Latitude	Longitude	Records Period (Total)	Average Yearly Flow (m^3/s)	Drainage Area (km^2)
02BA003	Little Pic River near Coldwell	48.5056˚N	86.3625˚W	1972-2010 (38)	15.7	1320
02BB003	Pic River near Marathon	48.4626˚N	86.1747˚W	1970-2010 (40)	51.5	4270
02BB002	Black River near Marathon	48.4120˚N	86.1245˚W	1967-1990 (23)	26.6	1980
02BB004	Cedar Creek near Hemlo	48.4222˚N	86.5433˚W	1984-2010 (26)	2.26	201

The regional hydrometric stations represent typically larger drainage basins (e.g., Pic River with a drainage area of 4,270 km^2 upstream of the project site). To compare them with stream flow datasets from the project site, a ratio of the monthly mean stream flow (Q) in m^3/s to the drainage area (A) in hectares was computed for each regional station. The Q/A ratios were calculated from January to December months for all four hydrometric stations.

2.1.3.1 Flood Frequency Analysis

For each regional station, the peak instantaneous flow for the 2-year through 100-year return periods were calculated using the Log-Pearson III distribution summarized in Table 2.5. Peak flow values are in cubic metres per second in Table 2.5.

Table 2.5: Instantaneous Peak Flows for Regional Hydrometric Stations (Calder, 2012a)

Location	Return Period (years)					
	2	5	10	25	50	100
Little Pic River near Coldwell	124	180	217	263	296	329
Pic River near Marathon	391	541	610	672	705	729
Black River near Marathon	189	233	253	271	281	289
Cedar Creek near Hemlo	15	23	28	34	39	43

Notes: Values presented in m^3/s.

2.1.3.2 Low Flow Conditions

Low flow conditions were determined by reviewing a report prepared for the Ministry of the Environment (MOE) on low flow characteristics in Ontario (Cumming Cockburn Ltd. 1990). Consecutive 7-day and 30-day duration average low flows for the 2-year through 200-year return periods are summarized in Table 2.6. The estimated 7Q20 low flows are 2.945 m^3/s, 4.448 m^3/s, and 0.070 m^3/s for Black River near Marathon, Pic River near Marathon, and Little Pic River near Coldwell, respectively. In Table 2.6, all flows are reported in cubic metres per second. Low flow statistics were not estimated for Cedar Creek near Hemlo.

Table 2.6: Estimated Low Flows for Regional Hydrometric Stations (Calder, 2012a)

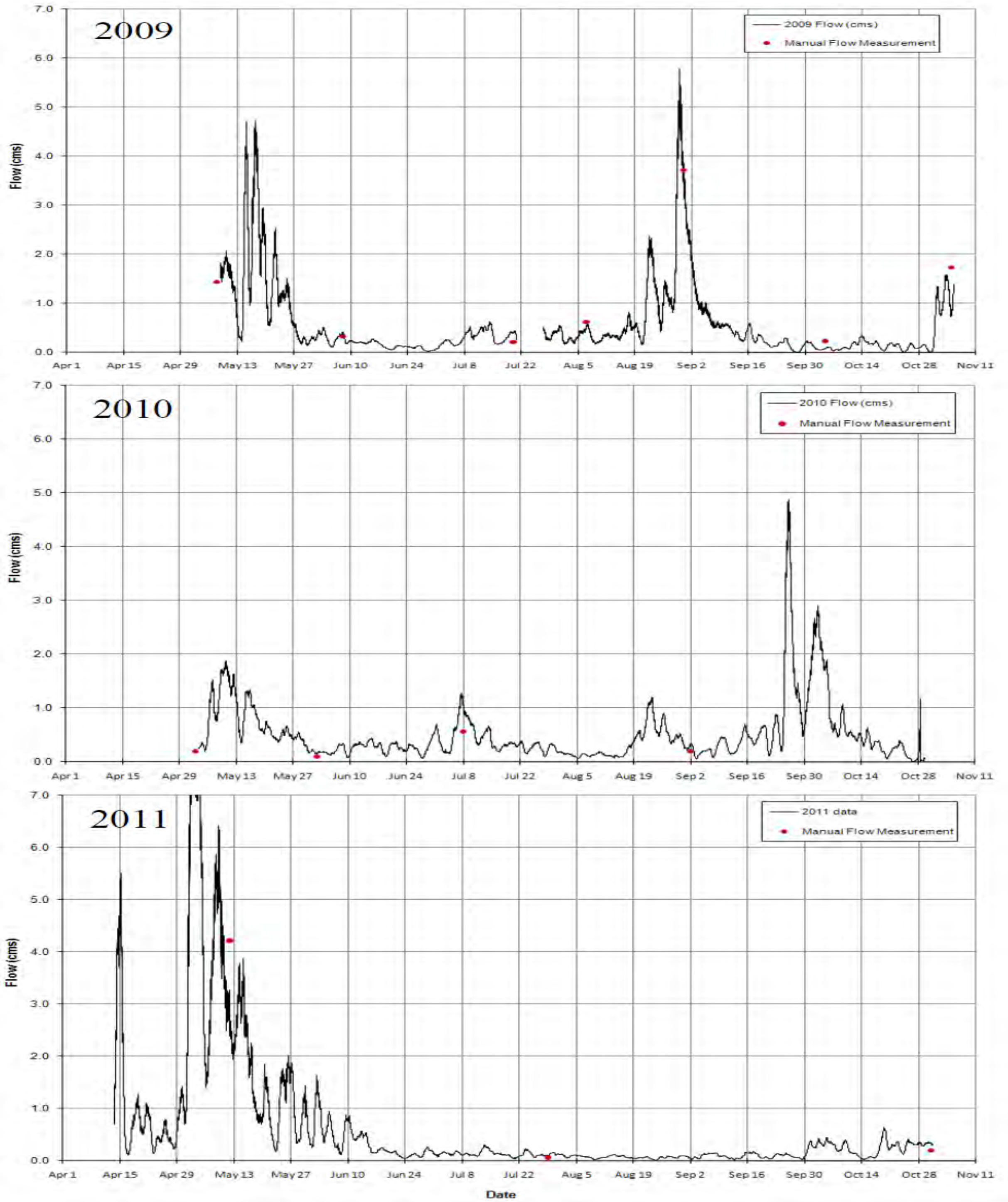
Return Period (years)	Black River near Marathon		Pic River near Marathon		Little Pic River near Coldwell	
	7-day[1]	30-day[2]	7-day	30-day	7-day	30-day
2	4.010	4.258	7.353	7.852	2.778	2.945
5	3.382	3.568	5.586	5.838	2.344	2.454
10	3.120	3.259	4.893	5.058	2.178	2.248
20	2.945	3.040	4.448	4.558	2.074	2.109
50	2.793	2.836	4.080	4.149	1.990	1.987
100	2.716	2.727	3.904	3.955	1.951	1.925
200	2.661	2.646	3.784	3.823	1.925	1.881

Note:
1. The value represents 7 consecutive day average low flow, corresponding to various recurrence intervals.
2. The value represents 30 consecutive day average low flow, corresponding to various recurrence intervals.

2.1.4 Hydrology Field Program

The hydrology field program included a total of 41 field stations throughout the LSA used to represent and characterize local hydrological conditions from 2008 - 2011. Field stations included 11 continuously monitored stations (S1, S2, S3, S4, S6, S8, S9, S10, S11, S13, S14) instrumented with pressure transducers and dataloggers recording water levels during open water conditions. At each of these instrumented sites, in-situ depth, velocity, and flow measurements were collected periodically for use in developing stage:discharge relationships (rating curves). Select instrumented stations were equipped with barometric pressure transducers to compensate the submerged transducers for barometric pressure. Additionally, at 38 other stations, spot flow measurements were collected. Graph 2.1 presents open water season hydrographs of Station S11 from 2009 – 2011.

Graph 2.1: 2009 to 2011 Hydrographs of Station S11 (Calder, 2012a)



2.1.4.1 Flood Flow Analysis

Flood flow analysis was completed using Northern Ontario Hydrology Method described in the MTO's Drainage Management Manual for each watershed in Calder (2012a) (Ministry of Transportation of Ontario 1997). The method was developed for both ungauged and gauged streams. The instantaneous peak flows were calculated for the 2, 5, 10, 25, 50 and 100-year return periods and are summarized in Table 2.7 and Table 2.8. Flood flow values are in cubic metres per second.

Table 2.7: Instantaneous Peak Flows for Watersheds (Ungauged Streams) (Calder, 2012a)

Watershed	Outlet Node	Return Period (years)					
		2	5	10	25	50	100
101	**S2**	2.566	3.755	4.539	5.539	6.282	7.025
102	**S4**	2.121	3.103	3.750	4.576	5.190	5.804
103	**S6**	1.251	1.820	2.195	2.674	3.029	3.385
104	**Outlet**	1.464	2.111	2.524	3.035	3.408	3.770
105	**S30**	9.821	13.644	16.027	18.817	20.768	22.619
106	**S31**	6.470	9.544	11.571	14.156	16.077	17.998
107	**Outlet**	0.642	0.951	1.155	1.415	1.609	1.803
108	**Outlet**	0.681	1.008	1.224	1.500	1.705	1.911

Table 2.8: Instantaneous Peak Flows for Gauged Steams (Calder, 2012a)

Outlet Node	Max Measured Flow		Years of Flow Data	Return Period (years)					
	Year	Flow		2	5	10	25	50	100
S15	**2008**	**0.031**	**1**	1.566	2.301	2.786	3.404	3.863	4.323
S22	**2008**	**0.532**	**1**	1.497	2.156	2.578	3.097	3.477	3.844
S10	**2009**	**0.766**	**1**	2.142	3.082	3.678	4.409	4.939	5.449
S41	**2009**	**1.511**	**2**	2.103	2.816	3.245	3.730	4.057	4.360
S11	**2011**	**15.261**	**3**	9.088	12.602	14.755	17.299	19.068	20.753
S14	**2009**	**0.238**	**3**	3.057	4.489	5.433	6.638	7.533	8.429

2.1.4.2 Low Flow Conditions

The low flow condition was assessed by applying the unit area average low flow relationships established for the Northwestern Region of Ontario (Cumming Cockburn Ltd. 1990) for ungauged and gauges streams and are summarized in Table 2.9 and Table 2.10. Low flow values are in cubic metres per second.

Table 2.9: Estimated 7-Day Duration Low Flows for Ungauged Streams (Calder, 2012a)

Watershed	Outlet Node	Return Period (years)			
		2	5	10	20
101	**S2**	0.009	0.006	0.005	0.004
102	**S4**	0.007	0.005	0.004	0.003
103	**S6**	0.004	0.003	0.002	0.002
104	**Outlet**	0.007	0.005	0.004	0.003
105	**S30**	0.096	0.069	0.057	0.048
106	**S31**	0.022	0.016	0.013	0.011
107	**Outlet**	0.001	< 0.001	< 0.001	< 0.001
108	**Outlet**	0.001	< 0.001	< 0.001	< 0.001

Table 2.10: Estimated 7-Day Duration Low Flows for Gauged Streams (Calder, 2012a)

Outlet Node	Min Measured 7-Day Flow		Years of Flow Data	Return Period (years)			
	Year	Flow		2	5	10	20
S15	**2008**	**< 0.001**	**1**	0.004	0.003	0.002	0.002
S22	**2008**	**0.002**	**1**	0.007	0.005	0.004	0.004
S10	**2009**	**0.015**	**1**	0.011	0.008	0.007	0.006
S41	**2010**	**0.048**	**2**	0.028	0.020	0.017	0.014
S11	**2011**	**0.048**	**3**	0.091	0.066	0.054	0.046
S14	**2011**	**0.003**	**3**	0.010	0.007	0.006	0.005

3.0 REGULATORY SETTING

Since preparation of the original baseline reports and completion of the EIS, some regulatory changes or updates have been implemented by federal and provincial authorities. The most current standards, criteria or guidelines have been applied as part of this review to characterize existing conditions, as follows:

Fisheries Act

The *Fisheries Act*, administered primarily by Fisheries and Oceans Canada (DFO) with some provisions administered by Environment and Climate Change Canada (ECCC, formerly Environment Canada), focuses on protecting the productivity and sustainability of commercial, recreational, and Aboriginal (CRA) fisheries. Any alteration of fish habitat must not result in "serious harm" to fish that are part of, or support a CRA fishery, otherwise an authorization and associated offsetting is required. The *Fisheries Act* applies to the Project through protection of fish habitat.

The Metal and Diamond Mining Effluent Regulations (MDMER) are promulgated under the *Fisheries Act*. The MDMER defines effluent concentration limits for metal mines, monitoring parameters, minimum flow thresholds for applicability, and environmental effects monitoring requirements.

Navigation Protection Act

The *Navigation Protection Act* (NPA), administered by Transport Canada, applies to the construction of works that affect the navigability of waters. Approval from the Minister of Transport is required for construction of any structure in, over, under, or through navigable water that would interfere with navigation (e.g., bridge, boom, pipeline, outfall, effluent diffuser, or dam).

Lakes and Rivers Improvement Act

The *Lakes and Rivers Improvement Act* (LRIA), administered by the Ministry of Natural Resources and Forestry (MNRF), applies to the design, construction, operation, maintenance, and safety of waterbodies and watercourses in Ontario. For the purposes of the LRIA, this includes online dams, channelizations, water crossings, enclosures, and pipeline installations. Approval is required from the Minister of Natural Resources and Forestry for the construction of dams which may alter fish habitat, natural amenities, and riparian owner rights.

Ontario Water Resources Act and Related Regulations

The *Ontario Water Resources Act* (OWRA) is the principal statute governing water quality and quantity in Ontario. It is a general management statute that applies to groundwater and surface water. Administered by the Ministry of the Environment, Conservation and Parks (MECP), the OWRA contains important regulations that protect water resources, including:

- *Ontario Regulation 387/04: Water Taking and Transfer Regulation* (O.Reg. 387/04), which requires a permit for water takings of more than a total of 50,000 L/d (with some exceptions). Section 34 of the OWRA requires the proponent to obtain a Permit to Take Water and Section 9 of O.Reg. 387/04 requires all permit holders to collect, record, and report data on daily volumes of water withdrawals.

4.0 STUDY AREA

For the purposes of this assessment, the spatial boundaries considered include the direct and indirect effects related to site preparation, construction, operation, and decommissioning/closure of the Project. These areas are generally consistent with the spatial boundaries used in the EIS (2012) and associated supporting information documents, with appropriate revisions/refinements and rationale provided below.

4.1 SITE STUDY AREA (SSA)

The Site Study Area (SSA) is the direct footprint of the Project. Based on refinements to the Project footprint, and in recognition of project components originally located outside of the SSA, a revised SSA has been developed that encompasses the immediate area in which Project activities and components may occur and, as such, represents the area within which direct physical disturbance may occur as a result of the Project, whether temporary or permanent. The SSA is consistent for all VECs as depicted on Figure 1 (Appendix A).

4.2 LOCAL STUDY AREA (LSA)

The LSA defines the area in which there is a potential for changes to the local hydrology due to Project effects. The LSA for the hydrological baseline update, presented on Figure 2, Appendix A, follows the Pic River on the eastern border starting near Bamoos Lake south until it is approximately in line with Three Finger Lake. The LSA includes the discharge pathways from the western watersheds included in the SSA and encapsulates Hare Lake and Bamoos Lake to the north, extending downstream from Hare Creek and Angler Creek to Lake Superior.

The LSA defined for this baseline update differs slightly from originally delineated, with additional watersheds that may be potentially affected by the Project. Updates to the hydrology baseline report herein include changes to the delineated watersheds as indicated in Section 6.1.3.

4.3 REGIONAL STUDY AREA (RSA)

The Regional Study Area (RSA) is the area within which residual environmental effects from Project activities and components may interact cumulatively with the residual environmental effects of other past, present, and future (i.e., certain, or reasonably foreseeable) physical activities. The RSA is based on the potential for interactions between the Project and other existing or future potential projects. The RSA for Hydrology is depicted on Figure 2 (Appendix A).

The RSA used in this baseline report has been refined from the RSA used in the EIS and Calder (2012; Supporting Information Document No. 21). Refinements to the RSA were made to better be consistent with the LSA, with the RSA extending just past the LSA within the ultimate receivers, as presented on Figure 2 (Appendix A).

5.0 METHODOLOGY

5.1 BASELINE STREAM FLOW MONITORING

The baseline streamflow monitoring program was implemented from May through November during open-water conditions to characterize annual and seasonal variations in surface water hydrology and update the existing conditions. The program operated from 2008 to 2018 by True Grit and continued by Stantec from 2018 to 2020. The streamflow monitoring program included manual flow measurements and the installation of water pressure recorders. The manual measurements of streamflow were undertaken using the Mid-Section Area-Velocity Method (Botma and Struyk 1971) where the discharge is calculated from multiple velocity measurements and cross-section areas. Manual measurements were subsequently processed in Aquarius™ hydrometric analysis software to develop station rating curves (Stage:discharge relationships). Continuous water level data was recorded at 15-minute intervals using water pressure recorders. Barometric pressure data was collected by installing a HOBO Water Level Data Logger in air above the water. Rating curves were subsequently applied to water level records to derive flows and hydrographs at each station. The program continued from 2012 to 2020 at select field hydrology stations. With the continuation of field hydrometric monitoring, rating curve confidence was increased and the subsequent confidence of monitored flow measurements.

5.2 HYDROMETRIC MONITORING STATIONS

Summarized in Table 5.1, manual flow measurements and continuous streamflow measurements were made at 11 stream locations and 1 lake location to update baseline conditions. The continuous sampling period as well as the number of manual flow measurements at each monitoring station are shown in Table 5.1. A hydrometric station summary sheet is shown for each station in Appendix B.

Table 5.1: Hydrometric Monitoring Stations 2008-2020

Station	Latitude	Longitude	Drainage Area (km^2)	Continuous Sampling Period	Manual Measurement Period	Number of Spot Measurements
S1	48.77431° N	86.32303° W	1.84	2016 (June - August), 2017 (May- August), 2019 (September - October)	August 2009 - July 2016	12
S2	48.77022° N	86.29717° W	6.26	2016 (June - August), 2017 (May- August)	June 2015 - July 2017	5
S3	48.79066° N	86.31923° W	2.04	2016 (June - August)	October 2009 - July 2017	6

Table 5.1: Hydrometric Monitoring Stations 2008-2020

Station	Latitude	Longitude	Drainage Area (km^2)	Continuous Sampling Period	Manual Measurement Period	Number of Spot Measurements
S4	48.79729° N	86.29055° W	1.93	2012 (March-September), 2016 (June - August), 2017 (May - June)	July 2008 - August 2017	23
S6	48.79736° N	86.29064° W	1.93	2012 (March-September)	June 2008 – May 2013	12
S8	48.81973° N	86.31663° W	1.97	2016 (June - August)	July 2008 - July 2016	20
S9	48.79002° N	86.36775° W	3.92	2016 (June - August)	September 2008 – July 2016	14
S10	48.78870° N	86.37562° W	4.67	2016 (June - August)	August 2009 - September 2015	7
S11	48.77603° N	86.40774° W	44.1	2012 (March-August), 2014 (June-September), 2016 (May-August), 2019 (June-September), 2020 (June-July)	July 2008 - June 2018	29
S13	48.78068° N	86.34673° W	0.653	2016 (June - August), 2019 (August - October)	June 2015 - August 2017	7
S14	48.77024° N	86.38135° W	4.86	2014 (June - September), 2016 (May-August), 2019 (June-September), 2020 (June - July)	April 2012 - July 2017	14
Hare Lake	45.4859° N	78.8438° W	-	2012 (May – September)	-	-

5.3 HYDROMETRIC MONITORING RESULTS

A flow rating curve was developed for each stream monitoring station using the best fitted regression equation. The regression equations were fitted to the observed water depth, velocity, and flow measurements. The accuracy of regression equations in estimating flow based on the spot measurements data was determined by the coefficient of determination (R^2) (Cox 1972) as follows:

$$R^2 = \frac{\sum_{i=1}^{n}(X_i - Mean)^2}{\sum_{i=1}^{n}(Y_i - Mean)^2}$$

where: i is the number of timesteps, n is the total timesteps, X is predicted value for observation i, Y is the observed value, and $Mean$ represents the mean of observed values. R^2 values closer to 1.0 represent a lower variance between the observed and predicted data. Table 5.2 summarizes the rating curve equations and R^2 values at each station where X accounts for the water depth (m). Appendix B presents a technical summary for each hydrometric station including the channel geometry and developed and rating curves plots. All stations had R^2 values between 0.82 to 0.98 indicating a sufficient estimation of flows.

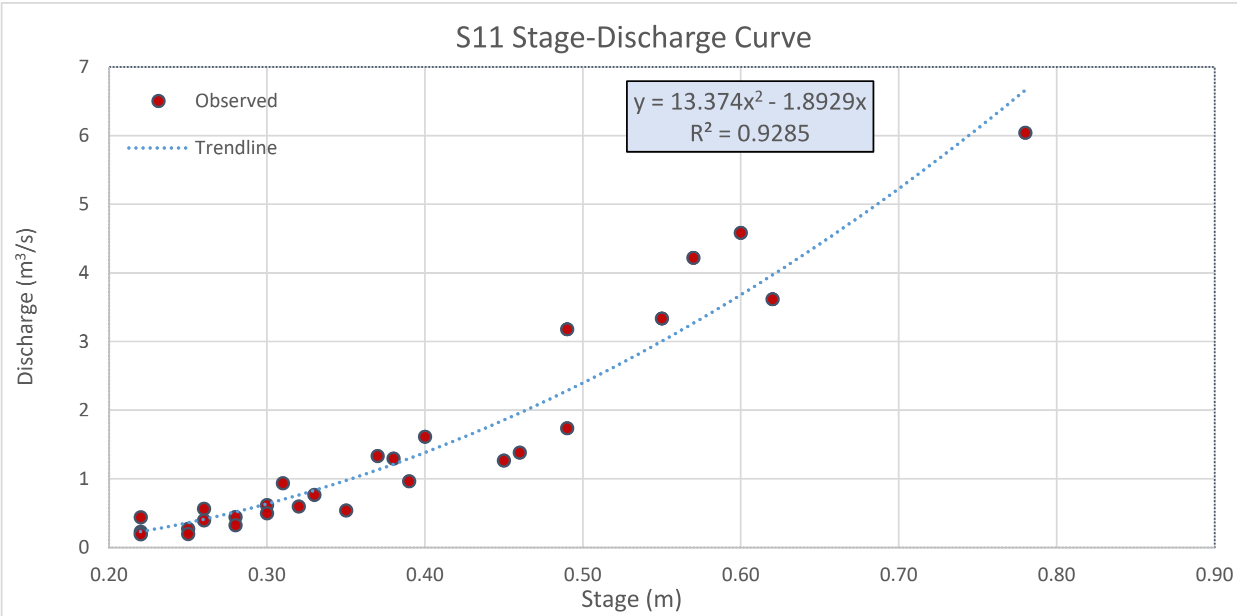
Table 5.2: Stage-Discharge Relationships for hydrometric stations

Station	Rating Curve Equation	R^2
S1	$1.2284X^2 – 0.08X$	0.85
S2	$0.0018\ e^{14.154X}$	0.98
S3	$0.0004\ e^{15.618X}$	0.86
S4	$0.1204X^2 – 0.1184X$	0.89
S6	$0.578X^2 + 0.1403X$	0.94
S8	$0.9907X^2 - 0.0866X + 0.0001$	0.90
S9	$2.4269X^3 - 0.8549X^2 + 0.0852X$	0.92
S10	$0.3954X$	0.97
S11	$13.374X^2 – 1.8929X$	0.93
S13	$0.7384X - 0.0622$	0.83
S14	$2.6492X^2 - 0.343X$	0.99

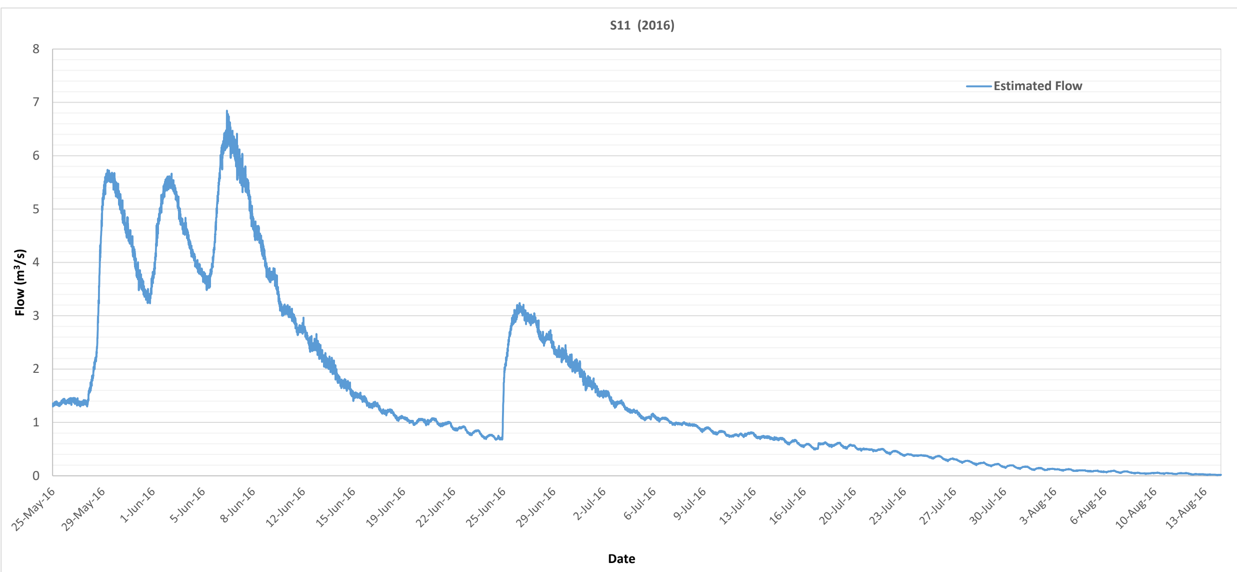
As shown in Appendix B, rating curves had good visual agreement. The rating curves were applied to the compensated water level logger data and observed hydrographs for the monitoring stations represented a similar pattern of high and low flows as well as a good match to the observed manual measurements.

In the following, the stream gauging field monitoring results for S11 are presented as an example. Shown in Graph 5.1, the stage-discharge relationship for the hydrometric monitoring station S11 was developed based on 29 in-situ measurements under open channel flow conditions. The dashed line represents the rating curve. The continuous monitoring period at this station is summarized in Table 5.1. The monitored water level data were compensated and converted into continuous flows using the developed rating curve. Daily average flow calculated for S11 in 2016 is shown in Graph 5.2. The estimated flow at S11 ranged from 0 m^3/s to 6.84 m^3/s with a mean annual flow of 0.54 m^3/s. The highest flow estimation was in June and is expected to be the result of rainfall runoff and the recession limb of the spring freshet.

Graph 5.1: S11 Stage-Discharge relationship



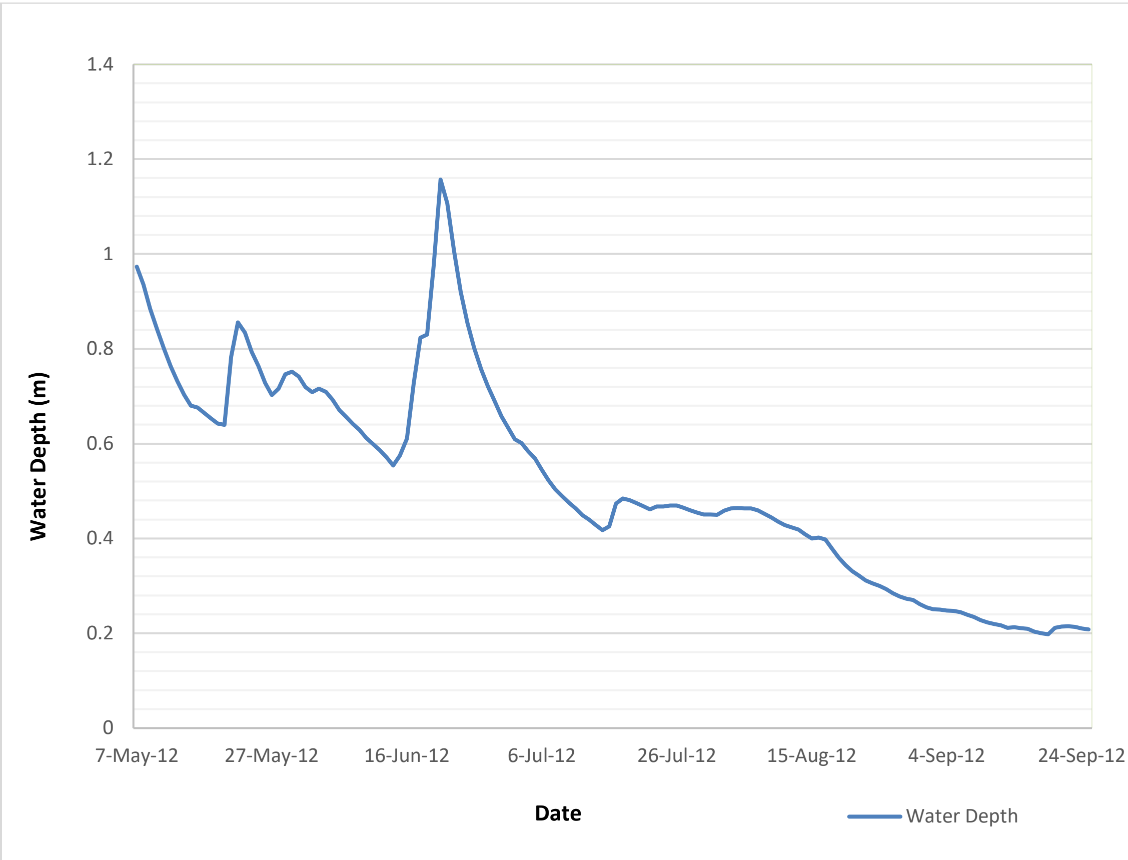
Graph 5.2: Estimated flow and manual measurements at S11 (2016)



5.3.1.1 Lake Depths

Continuous water level data was recorded at 15-minute intervals using water pressure recorders at L-Hare station in 2012. Using the barometric pressure data, daily water depths in the lake were calculated. Daily water depth fluctuations are shown in Graph 5.3.

Graph 5.3: Hare Lake Water Depth Fluctuations



5.4 HYDROLOGY DESKTOP ASSESSMENT

5.4.1 Regional Hydrology Assessment

5.4.1.1 Homogeneity Tests for Selected WSC Stations

A regional hydrology assessment is used to present a relationship between regional WSC stations and the local watersheds in the LSA. A series of homogeneity tests is typically completed for the selected regional WSC stations to refine the datasets to be representative of the local hydrological conditions. The following homogeneity tests were completed to evaluate the regional WSC stations:

- Mean Slope: The mean slopes of the watersheds associated with each of the WSC stations were obtained from the Ontario Flow Assessment Tool Version 3 (OFAT) (MNRF, 2015). OFAT is an online spatially-based application generating watershed areas and stream flow statistics of a watercourse at a location of interest within Ontario.
- Percent Area of Waterbodies: The percent area of the WSC station watersheds that are dominated by waterbodies was obtained for each WSC station from OFAT.
- Average Annual Precipitation: Precipitation for each WSC station was obtained from OFAT to visually assess which stations meet the threshold for average annual precipitation homogeneity of +/-10% the local value, discussed in Section 7.1.1.
- Unit Flow: Unit flows were calculated for each WSC station by dividing the mean annual flow by the associated catchment area to provide a unit of flow per square kilometre of catchment area.
- Flow Duration Curve (FDC): a flow duration curve is an analytical tool used to study the variability of stream flows. The flow duration curve presents the ratio of the daily flow divided by the mean annual flow versus the exceedance probability of that ratio.
- Index Flood Flow: The index flood flow is a technique used in flood studies to assess the homogeneity of WSC stations based on the return interval of the regionally-based 10-year flood flow and the station period of record. The method below follows the technique used by Dalrymple (1960) and Harvey et al. (1985) with the homogeneity test using an Extreme Value Type 1 (EV1) distribution by Gumbel (1958).
- The regionally based 10-year flood flow is calculated by dividing each station's 10-year flood flow by the index flood flow (2.33-year return period flood flow or the mean annual flood flow), which is averaged over the data set. The mean annual flood flow is multiplied by the averaged unitless 10-year flood flow divided by the mean annual flood flow to yield the regionally-based 10-year flood flow. A flood frequency curve is plotted for the regionally-based 10-year flood flow to develop a relationship between the flood flow and return period for each station. A station-based return period is then calculated for each station to plot against the station period of record and compared to the upper and lower limit curves.

- Index Low Flow: The index low flow is a homogeneity test described by Pilon (1990) which is performed using a three-parameter Weibull distribution (W3) to calculate low flows for $7Q_{100}$, $7Q_{12.5}$, $7Q_{10}$ and $7Q_2$. After low flows are calculated, the $7Q_{100}$, $7Q_{12.5}$, and $7Q_2$ are made unitless by dividing by the $7Q_{10}$ for the associated station. The median values are determined for the applicable return periods to calculate variables presented by Pilon (1990) to obtain parameters for a dimensionless curve, used to calculate the non-exceedance ratio. The non-exceedance ratio is applied to the $7Q_2$ for each station to determine the regional $7Q_{10}$.

5.4.1.2 Regional Flow Assessment

A regional flow assessment completed for the selected WSC stations allows for a relationship to be developed to apply to the local data set. As part of the regional flow assessment, the mean annual flow, mean monthly flows, peak flows, and low flows can be developed. The mean annual flow is calculated by determining the mean flow for each year and averaging the values over the dataset. Mean monthly flows are calculated consistent to mean annual flows for each month rather than each year.

Peak flows are calculated using the instantaneous flows from the regional WSC stations. The instantaneous peak flow for each year is input into the hydrological frequency analysis (HYFRAN) software (EI Adlouni and Bobee 2015) to calculate the peak flow for various return periods (2, 5, 10, 25, 50, and 100 year). A Log-Pearson Type III distribution with Method of Moments was used. Peak flow estimates are typically used as the design flow for project infrastructure.

Low flows are typically used in assimilative capacity studies as the worst-case scenario to observe potential water quality effects of the project on the surrounding surface water. Low flows were calculated using the running 7-day average of the daily discharge data for each station. The lowest 7-day average is selected for each year and run through HYFRAN to compute the 10-year ($7Q_{10}$) and 20-year ($7Q_{20}$) return periods. Consistent with the peak flow calculations, HYFRAN was run using the Log-Pearson Type III distribution with Method of Moments.

5.4.1 Local Hydrology Assessment

Environmental Flows

The relationships derived throughout a regional flow assessment can be used to characterize the local hydrology. The 16 local watersheds presented in Section 7.1.1 were assessed as part of the baseline local hydrological update. The environmental flows were calculated for each local watershed using the Tessman method (Tessman, 1980), which is an extension of the Tennant method and is based on a combination of monthly flow and mean annual flow. The Tessman method is simplified in Table 5.3.

Table 5.3: Tessman Method Rules

Recommended Minimum Flow	Criteria
Mean Monthly Flow (MMF)	If MMF < 40% Mean Annual Flow (MAF)
40% of MAF	If MMF > 40% MAF and 40% MMF < 40% MAF
40% MMF	If 40% MMF > 40% MAF

Baseflow Index (BFI)

The Baseflow Index (BFI) is a measure of the ratio of long-term baseflow to total stream flow and it represents the slow continuous contribution of groundwater to river flow. The Streamflow Analysis and Assessment Software (SAAS) was used to conduct the baseflow analyses and calculate the baseflow index (Metcalfe and Schmidt 2016). The BFI was estimated based on local field stream flow data collected during the open water monitoring periods and thus only represents the open water portion of the year.

Environmental Water Balance

A monthly environmental water balance model was calculated using the United States Geological Survey (USGS) monthly water balance model, which is based on the Thornthwaite equation (Thornthwaite and Mather 1957; McCabe and Wolock 1999). The monthly environmental water balance can be used to estimate evapotranspiration, surface runoff, and streamflow in the LSA by inputting monthly precipitation, average monthly temperature, runoff factor, soil moisture storage capacity, and snow/rainfall temperature thresholds for the LSA. Local data climate stations were used to populate the water balance model from 1990-2019 and were included if less than 20 data points were missing as indicated in Section 2.1.1.

The Ontario Ministry of the Environment (MOE) Stormwater Management Planning and Design Manual (2003) was used as a reference manual for the Thornthwaite equation input parameters. Average watershed topographic slopes and vegetation cover types were obtained from OFAT, while soil types for the LSA were determined from other reports to be predominantly glaciolacustrine clays and silts (True Grit, 2012). The OFAT parameters and soil characteristics were used in conjunction with the MOE (2003) guide to determine applicable input values (soil moisture storage capacity, run-off factor). Other input parameters (direct run-off factor, maximum melt rate) have default values recommended by Wolock and McCabe (1999) used as a standard industry practice.

6.0 UPDATED BASELINE HYDROLOGY CONDITIONS

6.1 HYDROLOGY DESKTOP ASSESSMENT

6.1.1 Climate

Climatic data, such as precipitation and air temperature, strongly influence hydrology as they affect the quantity and timing of runoff in the LSA. Climatic conditions for the Project are continental with significant variation between annual highs and lows. Continental climates typically have short, warm summers and long, cold winters.

Historical climate stations from Environment Canada (2020) were used to supplement barometric pressure data, where required, and to calculate the average annual precipitation and mean temperature range for the Project. The historical climate stations in Table 6.1 are all within a 40 km range of the LSA and were compared with each other to determine the climate data best representing the Project area and to form an ensemble of stations to represent conditions to present. The Marathon A stations were identified by Calder (2012a) to be in the proximity of the project but had limited data sets at the time of the Calder baseline hydrology report and were therefore not used to compensate raw water level data.

Average annual precipitation and mean temperatures were determined for all stations in Table 6.1 if applicable data was provided. The Marathon, Marathon Airport, Pukaskwa National Park, and Hemlo Battle Mountain average annual precipitation and mean temperature range from the Calder report (2012a) was found to be highly consistent with the updated data presented in Table 6.1, as all four stations did not have data updated since 2012. The Pukaskwa (AUT) stations have more recent data sets and were not included in the Calder report as they did not have a robust data set at the time of the report.

Table 6.1: Regional Climatic Stations (Environment Canada, 2020)

Station ID	Station Name	Coordinates	Records Period (Total)	Data Interval	Elevation (m)	Distance from LSA (km)	Average Annual Precipitation (mm)	Mean Temperature Range (˚C)
6044962	Marathon A	48.7553˚N 86.3444˚W	2007-2014 (8)	Hourly	314.60	33.10	N/A	-13.3 to 17.3
6044963	Marathon A	48.7572˚N 86.3458˚W	2014-2020 (7)	Hourly	314.60	33.10	N/A	N/A
6044967	Marathon A	48.7572˚N 86.3458˚W	2014-2020 (7) 2018-2020 (3)	Hourly Daily	314.60	33.10	N/A	-14.3 to 15.6
6044961	Marathon Airport	48.7556˚N 86.3444˚W	2007 (1) 1988-1999 (12) 1988-1999 (12)	Hourly Daily Monthly	315.50	33.10	858.3	-15.1 to 14.9
6044959	Marathon	48.7167˚N 86.4000˚W	1945-1984 (40) 1945-1984 (40)	Daily Monthly	189.00	35.29	845.3	-13.6 to 14.8
6046767	Pukaskwa (AUT)	48.5883˚N 86.2947˚W	1994-2012 (19) 1996-2012 (17) 2005-2006 (2)	Hourly Daily Monthly	207.60	44.50	686.7	-12.2 to 16.0
6046768	Pukaskwa (AUT)	48.6078˚N 86.2872˚W	2012-2020 (9) 2011-2020 (10)	Hourly Daily	191.50	43.50	701.1	-12.2 to 15.3
6046770	Pukaskwa Natl Park	48.6000˚N 86.3000˚W	1983-2005 (23) 1983-2005 (23)	Daily Monthly	192.00	43.56	797.0	-13.5 to 15.6
6043452	Hemlo Battle Mountain	48.7000˚N 85.8833˚W	1985-2001 (17) 1985-2001 (17)	Daily Monthly	335.00	66.50	760.8	-14.7 to 16.8

Note: N/A indicates that the applicable data set did not provide enough information for statistics to be calculated

The mean temperature ranges for the eight (8) stations in which a range was able to be computed were all relatively consistent. Average annual precipitation was only able to be calculated for the six (6) stations in which daily data intervals were provided with moderately complete data sets. It was observed that the Marathon Airport and Marathon climate stations showed comparable average annual precipitation, while the Pukaskwa, Pukaskwa National Park, and Hemlo Battle Mountain climate stations showed a larger range of average annual precipitation. The Pukaskwa, Pukaskwa National Park, and Hemlo Battle Mountain climate stations are all additionally located more than 17 km farther from the LSA than the Marathon Airport and Marathon climate stations.

Therefore, consistent with the Calder (2012a) report, Marathon (Station ID 6044959) and Marathon Airport (Station ID 6044961) were found to provide comparable data, with Marathon providing a more robust dataset. To provide a dataset that also captured more recent years, the Marathon dataset (1945-1984) was combined with the Marathon Airport (1988-1999) and both Pukaskwa (AUT) stations (2000-2020). Of the 67 available years of data, 41 years (ranging from 1953-2019) were found to have enough daily precipitation data to include in the average annual precipitation statistical analysis (less than 20 of 365 days/year missing). The average annual precipitation was found to be 818.2 mm, relatively consistent with what was presented in Calder (2012a) of 826.5 mm for Marathon. The mean temperature ranged from -13.4˚C in January to 15.1˚C in August, which was also found to be consistent with what was presented in Calder (2012a) of -13.9˚C in January to 14.6˚C in August.

Comparing the driest and wettest years of average annual precipitation for the combined Marathon, Marathon Airport, and Pukaskwa (AUT) stations over the applicable years showed a wettest annual precipitation of 1,155.6 mm which occurred in 1979, and a driest annual precipitation of 558.3 mm which occurred in 1981. The range of average annual precipitation during the wettest to driest years indicates there is considerable variability in precipitation within the Project area.

The Marathon A stations in Table 6.1 (Marathon A Station ID 6044962 and 6044967) were the closest to the LSA and were used to obtain hourly atmospheric pressure data to supplement atmospheric pressure obtained in the field through installed barologgers to barometrically compensate raw water level data. The two Marathon A stations were used together to obtain data from 2012 – 2020, as there was no one station that had barometric pressure data for the complete active period.

Table 6.2 presents the monthly breakdown of climate data for combined Marathon, Marathon Airport, and Pukaskwa (AUT) stations. The mean monthly precipitation is reasonably consistent with the data provided by Calder (2012a) for Marathon.

Table 6.2: Climate Data Summary at Combined Marathon, Marathon Airport, and Pukaskwa (AUT) Stations

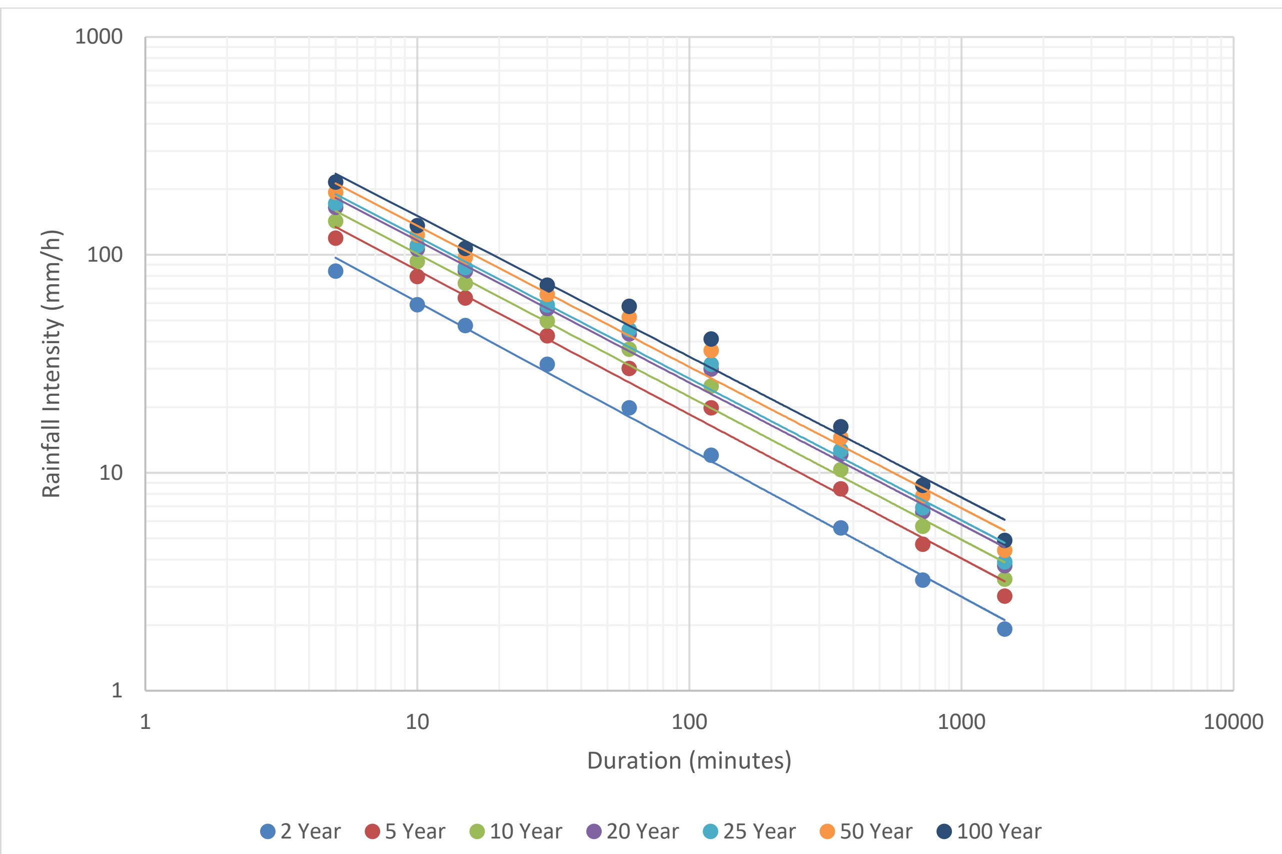
Month	**Mean Monthly Precipitation (mm)**	**Temperature** ˚C
January	64.7	-13.4
February	47.6	-11.7
March	56.6	-6.0
April	49.8	1.4
May	67.7	7.4
June	71.4	11.7
July	74.6	14.1
August	73.0	15.1
September	94.4	11.0
October	90.0	5.5
November	63.4	-2.3
December	65.0	-10.0
Total:	**818.2**	**2.0**

An intensity-duration-frequency (IDF) curve was obtained from the IDF_CC Tool 4.0 (Schardong et al., 2020) using the Gumbel distribution. The Pukaskwa National Park IDF station is the closest station within 20 km to the Project and has 21 years of available data from 1983 to 2007 which is presented in Table 6.3 and Graph 6.1.

Table 6.3: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station (Schardong et al., 2020)

Duration	Total Rainfall (mm)						
	2 Year	5 Year	10 Year	20 Year	25 Year	50 Year	100 Year
5 minute	7.03	9.96	11.9	13.75	14.34	16.16	17.97
10 minute	9.83	13.27	15.55	17.73	18.43	20.56	22.68
15 minute	11.86	15.86	18.51	21.05	21.85	24.33	26.8
30 minute	15.74	21.23	24.87	28.35	29.46	32.87	36.25
1 hour	19.86	30.08	36.86	43.35	45.41	51.76	58.06
2 hour	24.11	39.69	50	59.89	63.03	72.69	82.29
6 hour	33.55	50.69	62.03	72.92	76.37	87.01	97.57
12 hour	38.64	56.4	68.16	79.44	83.01	94.04	104.98
24 hour	46.17	65.28	77.93	90.07	93.92	105.78	117.56

Graph 6.1: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station (Schardong et al., 2020)



6.1.2 Climate Change

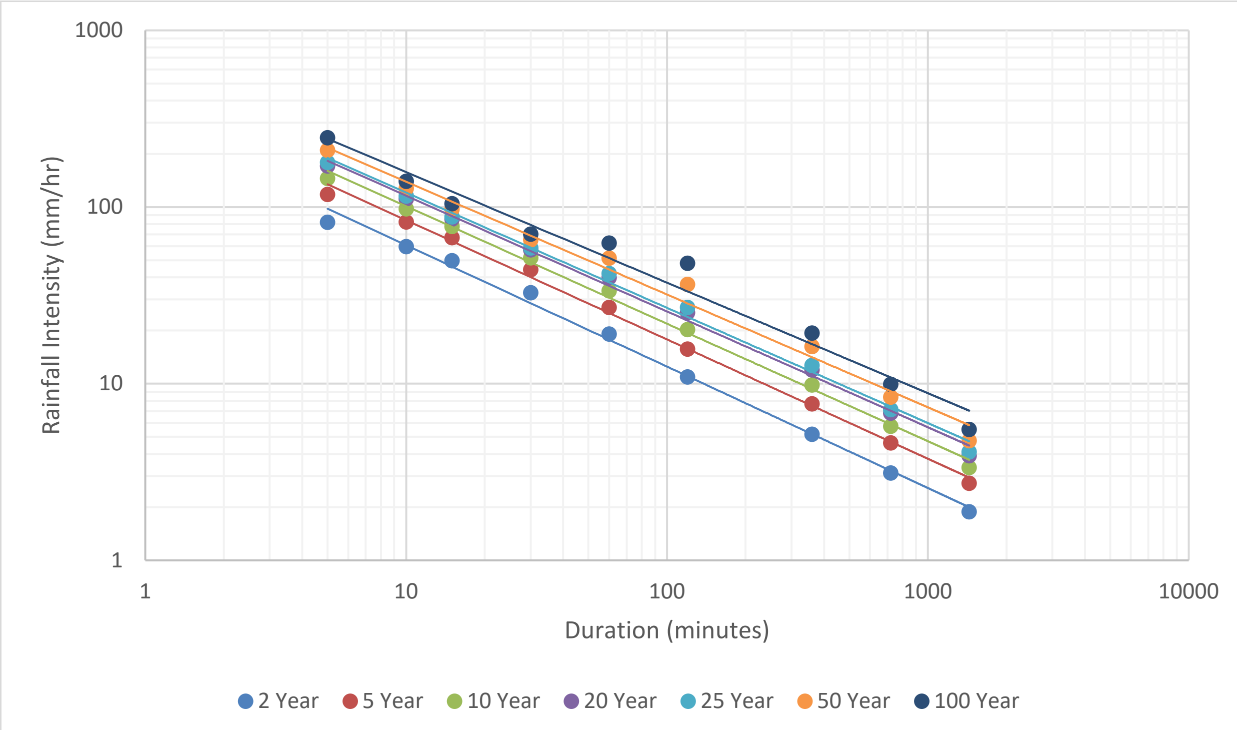
Climate change is a scientifically recognized issue that has already seen Ontario's climate warm by up to 1.6˚C over the past 63 years and is projected to continue increasing the temperature and change precipitation patterns in the years to come (Colombo et al., 2007). In addition, precipitation in northwestern Ontario has been observed to have increased by up to 50% during spring over a 60-year period (McDermid et al., 2015). Increased precipitation events require careful consideration when constructing structures that require the consideration of stormwater.

Climate projections for the next 20 years were researched to review the changing conditions over the active period of the Project prior to post-closure in the LSA. Three representative concentration pathways (RCPs) were focused on to provide the best-case scenario (RCP2.6), intermediate-case scenario (RCP4.5), and worst-case scenario (RCP8.5) for the Project area. RCP2.6 represents a medium-low scenario with the assumption that aggressive mitigation occurs during the period of interest, while RCP4.5 is a medium stabilization scenario with average means of curbing emissions, and RCP8.5 is a very high emission scenario that assumes a failure to curb global warming. The IDF_CC Tool 4.0 (Schardong et al., 2020) was used to predict the projection period from 2010 to 2040 using the Environment Canada (2020) Pukaskawa National Park station with a Gumbel distribution and using the CanESM2 model recommended by the Ministry of Natural Resources and Forestry (MNRF) (McDermid et al., 2015). The IDF curves for RCP2.6 and RCP8.5 are presented in Appendix C, while the IDF curves for RCP4.5 are presented in Table 6.4 and Graph 6.2 below.

Table 6.4: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station – RCP4.5, Projection Period 2010-2040 (Schardong et al., 2020)

Duration	Total Rainfall (mm)						
	2 Year	5 Year	10 Year	20 Year	25 Year	50 Year	100 Year
5 minute	6.83	9.85	12.11	14.24	14.93	17.5	20.57
10 minute	9.97	13.74	16.27	18.55	19.24	21.33	23.35
15 minute	12.45	16.77	19.43	21.35	22.01	24.37	26.11
30 minute	16.38	22.14	25.78	28.61	29.4	32.66	35.18
1 hour	19.13	27.06	33.57	39.87	42.03	51.44	62.68
2 hour	21.86	31.39	40.6	50.52	54.15	72.95	96.1
6 hour	31.01	46.17	59.04	71.88	76.34	97.58	116.26
12 hour	37.45	55.44	68.94	81.67	85.81	101.09	119.18
24 hour	45.27	65.58	80.39	94.16	98.56	114.53	132.36

Graph 6.2: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station – RCP4.5, Projection Period 2010-2040 (Schardong et al., 2020)



Some significant changes are observed from the baseline IDF curves presented in Section 7.1.1 when compared to the intermediate-case scenario RCP4.5. A comparison of the total rainfall (mm) showed that 25 of the 63 rainfall intensities for various IDF show a decrease in total rainfall, while the remaining 38 show an increase in total rainfall. Generally, lower duration with shorter return periods and higher durations with longer return periods saw the increased total rainfall, while medium duration for all return periods saw a decrease in total rainfall. The maximum reduction in total rainfall is 21% (8.3 mm) for a 5-year return period with a 2-hour duration and the maximum increase in total rainfall is 19% (18.69 mm) for a 100-year return period with a 6-hour duration.

As the rainfall intensities are used to calculate the total rainfall, the statistical changes for the rainfall intensities reflect that of the total rainfall. The maximum reduction in rainfall intensity is 21% (4.15 mm/hr) for a 5-year return period with a 2-hour duration and the maximum increase in rainfall intensity is 19% (3.12 mm/hr) for a 100-year return period with a 6-hour duration.

When comparing the total rainfall of the RCP4.5 scenario with the RCP2.6 scenario, the 2-year, 5-year, and 10-year return periods for all durations are observed to decrease between 1% to 7%, while the 20-year, 25-year, 50-year, and 100-year typically show increases in total rainfall for RCP4.5 from 1% to 17%. Comparing the RCP4.5 total rainfall scenario to the RCP8.5 scenario shows an increase in total rainfall for RCP8.5 for almost all return periods and durations of 1% to 8%.Comparing the rainfall intensity of RCP4.5 scenario with the RCP2.6 and RCP8.5 shows consistent results with the total rainfall comparison above.

Therefore, even under the best-case scenario, climate change is expected to have some significant changes to precipitation events, with higher total rainfall and rainfall intensities occurring more frequently. It is recommended that the RCP4.5 IDF curves be used to estimate Project conditions as they reflect realistic precipitation changes due to climate change for an intermediate stabilization scenario.

6.1.3 Local Watersheds

Naming convention for the watersheds for this baseline hydrology update were kept consistent with the Calder (2012a) report for consistency. However, changes to the existing watersheds were identified, with the inclusion of an additional 8 watersheds (109-117) delineated to define the original SSA more fully (Appendix A). Revisions to the SSA since the Calder (2012a) reflect refinements in project design and to more closely follow the project footprint. With the revised SSA, watersheds 107, 110, 113, 114, 115, and 117 no longer have portions of their watersheds within the SSA and therefore do not require assessment, although the local hydrology assessment completed for the identified watersheds outside of the SSA have been left in this baseline report.

The watershed delineations were updated from the original baseline report (Calder 2012a) using a satellite light detection and ranging (LIDAR) derived digital elevation mode (DEM) as the topographic data source. This was done in order to enhance the accuracy of the watershed boundaries from the best available data source and resulted in some minor shifts in the watershed boundaries. The original watershed boundaries were delineated using 5 m contours which had been derived from the satellite LIDAR derived DEM. Using the contours rather than the source data (DEM) as the topographic data input caused a degree of generalization to be introduced to the watershed delineation. Elevation changes of less than 5 m were generalized out of the original sub watersheds. Using the DEM from the raw data source has allowed for the elevation changes to be factored back into the watershed delineation and represents the best practice for watershed delineation.

One of the additional watersheds (117) was previously included in Calder (2012a) as part of watershed 103. Upon further inspection, the original watershed 103 was observed to have two separate watercourses discharging to the Pic River and therefore two separate watersheds, which are now both reflected.

A field-based assessment of the watershed delineation for the project area was completed as a quality assurance/quality control measure. Clarification was requested with respect to the lake network southeast of Rag Lakes in watershed 109, which is shown on Figure 2 (Appendix A) to be disconnected from a stream system. Visual inspection on site of this lake network showed water flowing south towards a wetland with no discharge pathway, indicating a possible connection into the groundwater system at the south end of the lake network. As such, the lake network south of Rag Lakes was kept within watershed 109 as the flow pattern was not directed towards watersheds 101 or 116.

A field-based inspection was completed to confirm the watershed delineation around Canoe Lake, which receives water from headwaters to the north, and discharges to both the east and west due to beaver activity within the lake. At the time of the visual inspection, Canoe Lake was observed to be flowing predominantly to the west into watershed 105 and has therefore been left within watershed 105 for the updated baseline condition report.

The summary of the local watersheds is presented in Table 6.5 with area from LIDAR data and watershed characterizations from OFAT and is shown on Figure 2 (Appendix A).

Table 6.5: Local Watersheds Within SSA

Watershed ID	Area (km2)	Mean Slope (%)	Area of Waterbodies (%)	Land Cover
101	4.538	17.307	3%	Deciduous Trees (38.1%)
102	3.495	20.918	4%	Mixed Trees (35.4%)
103	1.867	13.27	4%	Deciduous Trees (45.0%)
104	3.457	18.733	4%	Deciduous Trees (52.1%)
105	47.826	17.846	11%	Mixed Trees (45.1%)
106	10.523	11.025	3%	Mixed Trees (39.8%)
107	0.501	18.811	0%	Deciduous Trees (45.3%)
108	0.567	22.153	0%	Deciduous Trees (34.8%)
109	12.037	6.795	9%	Coniferous Trees (30.8%)
110	0.133	12.242	0%	Deciduous Trees (60.7%)
111	0.121	19.041	0%	Deciduous Trees (76.5%)
112	0.109	23.742	0%	Deciduous Trees (83.5%)
113	0.240	17.75	0%	Deciduous Trees (82.3%)
114	1.344	20.16	2%	Deciduous Trees (43.1%)
115	0.311	15.515	0%	Deciduous Trees (54.8%)
116	2.935	12.431	0%	Deciduous Trees (50.3%)
117	0.261	13.575	0%	Deciduous Trees (72.5%)

In comparison to the Calder (2012a) watersheds (Table 2.3), watershed 103 has an area 13% smaller than originally presented and watershed 108 has an area 7% greater. The remaining identified 6 watersheds (101, 102, 104 through 107) are reasonably consistent in area.

6.1.4 Regional Hydrology Assessment Results

Regional relationships were developed for hydrologic data extracted from the Water Survey of Canada (WSC) regional flow gauging stations to apply to local hydrological conditions. The WSC stations were initially selected based on criteria including catchment area, station location, flow regime, and period of record. Homogeneity tests were then conducted and validated through assessments of annual precipitation, watershed slope, percent of watershed area covered by waterbodies, unit flows, flow duration curves, index flood flow, and index low flow.

Validated WSC stations were used to complete a regional hydrology assessment to develop a relationship for mean annuals flows, mean monthly flows, peak flows, and low flows for the watersheds within the LSA.

Five WSC stations were chosen in addition to the ones originally presented by Calder (2012a), with Black River near Marathon (Station ID 02BB002) removed from the stations list as it had a large catchment area (1980 km^2). This baseline hydrology update focused on bringing smaller WSC stations into the preliminary dataset to better represent the smaller catchment areas of the local watersheds.

The results of the homogeneity tests for the selection of the regional WSC stations and the associated regional relationships are discussed below.

6.1.4.1 WSC Station Homogeneity Test Results

The WSC stations initially selected and the associated homogeneity test results are summarized in Table 6.1 and discussed below.

<u>Mean Slope</u>

The mean slopes provide a comparison of a subset of the local physiography and are shown in Graph 6.3. The mean slopes of the regional WSC watersheds range from 5.52% to 12.0%, for a total variable difference of 6.5%. Mean slopes identified for the local watersheds range from 11.0% to 23.7%, with an average slope of 17.2% in comparison (Table 6.5).

<u>Area of Waterbodies</u>

The area of the WSC station watersheds dominated by waterbodies range from 6% to 31%, with Station 02BA005 (Whitesand River Above Schreiber at Minova Mine) with the lowest percentage of area and Station 02BB004 (Cedar Creek Near Hemlo) with the highest percentage of area. The area of waterbodies identified for the local watersheds range from 0% to 11% in comparison.

<u>Annual Precipitation</u>

The mean annual precipitation for the selected WSC stations range between 812 mm to 903 mm, except for Station 02BD006 (Wawa Creek at Wawa) with a mean annual precipitation of 947 mm. A threshold of +/-10% from the annual precipitation determined for the LSA in Section 6.1.1 as 818.2 mm was used for the regional WSC stations. Therefore, all of the WSC stations with the exception of Station 02BD006 fall within the mean annual precipitation threshold.

Unit Flows

The unit flow for each regional WSC station was calculated per square kilometre of catchment area and range between 11.11 L/s/km^2 (Station 02BA005) to 13.39 L/s/km^2 (Station 02BC006), with the exception of Station 02BD006. Station 02BD006 (Wawa Creek at Wawa) has a unit flow of 14.97 L/s/km^2, which is 22.7% higher than the average unit flow of 12.2 L/s/km^2 for the rest of the seven WSC stations presented in Table 6.6.

Table 6.6: Water Survey of Canada Station Summary

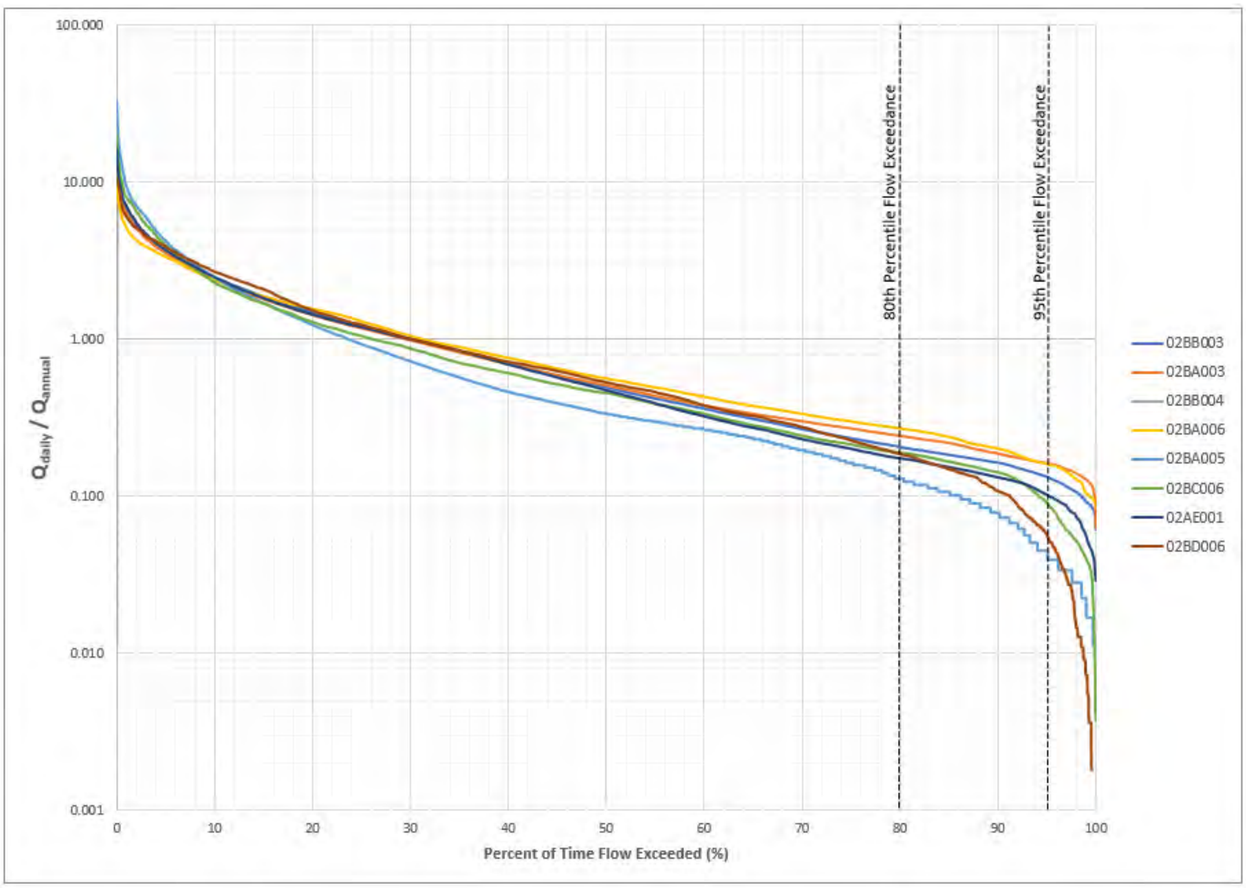
Station Name	Station Number	Location	Distance to Site (km)	Drainage Area (km2)	Period of Record	Record length (years)	Regulation Type	Mean Slope (%)	Area of Waterbodies (%)	Annual Precipitation (mm)	Unit Flow L/s/km2
Pic River Near Marathon	02BB003	48° 46' 26" N 86° 17' 47" W	3.4	4220	1970 - 2020	51	Natural	6.33	20	812	12.47
Little Pic River Near Coldwell	02BA003	48° 50' 56" N 86° 36' 25" W	20.3	1320	1972 - 2020	49	Natural	7.97	16	829	12.81
Cedar Creek Near Hemlo	02BB004	48° 42' 19" N 85° 54' 28" W	32.9	210	1984 - 2020	37	Regulated	5.52	31	812	12.76
Steel River Below Santoy Lake	02BA006	48° 48' 49" N 86° 51' 33" W	37.6	1190	2003 - 2020	18	Natural	9.40	12	835	11.53
Whitesand River Above Schreiber at Minova Mine	02BA005	48° 58' 41" N 87° 22' 36" W	78	10.8	1989 - 2020	32	Natural	8.87	6	851	11.11
Pukaskwa River Below Fox River	02BC006	48° 09' 37" N 85° 43' 51" W	84.2	407	2006 - 2020	15	Natural	10.7	8	903	13.39
Gravel River Near Cavers	02AE001	48° 55' 33" N 87° 41' 24" W	99.4	608	1974 - 2020	36	Natural	11.1	9	830	11.33
Wawa Creek at Wawa	02BD006	47° 59' 21" N 84° 46' 05" W	147	31.4	1989 - 2020	18	Regulated	12.0	25	974	14.97

Flow Duration Curve (FDC)

The flow duration curve (FDC) is used to study the variability of stream flows. The shape of the FDC reflects the composite effect of the physiographic (including geologic) and climatic influences on stream flow and hence watershed response. The slope of the FDC at each extreme end shows the high flow (upper end) and low flow (lower end) variability. The FDC for the regional WSC stations is shown in Graph 6.3 below.

Station 02BD006 (Wawa Creek at Wawa) is observed to cross the flow duration curves for all other stations along the length of Graph 6.3, indicating that the variability of flow for station 02BD006 is not consistent with the other stations.

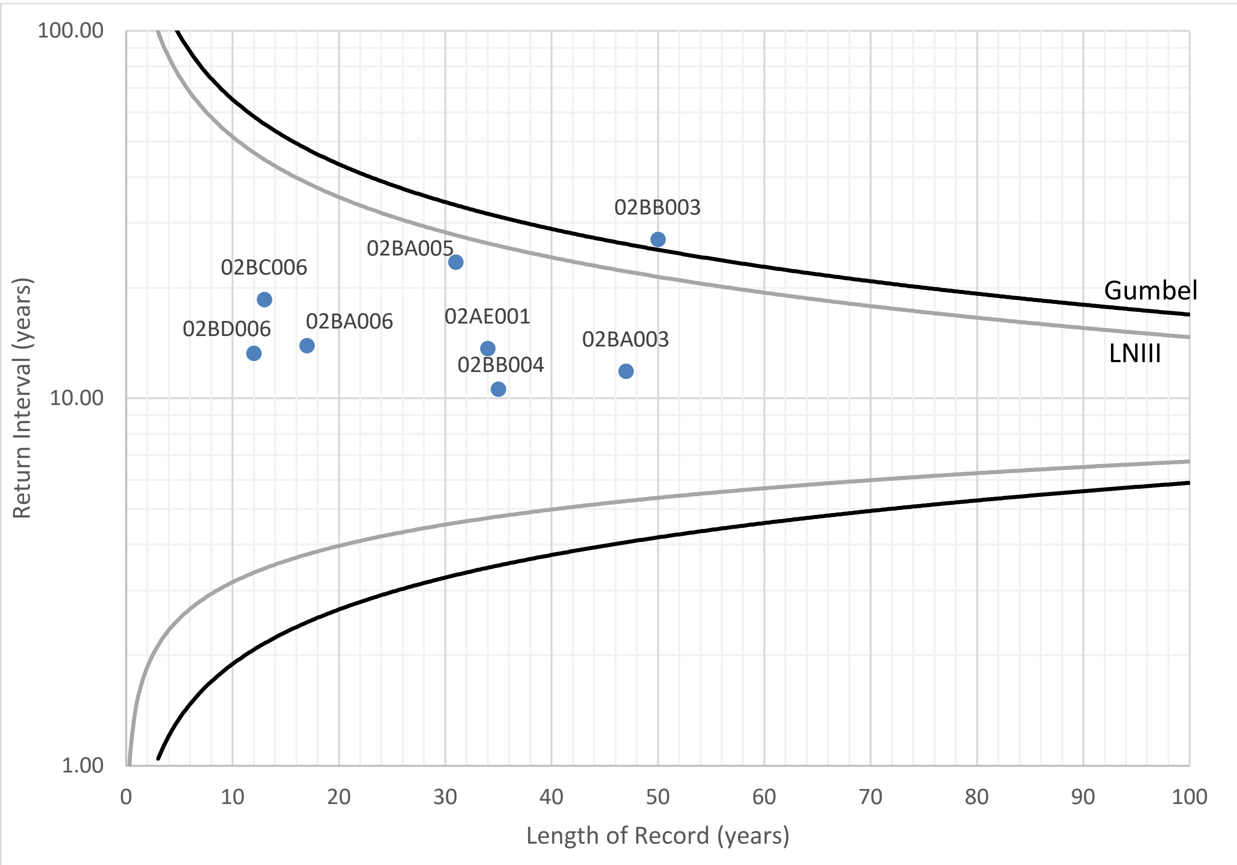
Graph 6.3: Flow Duration Curve for WSC Stations



Index Flood Flow

The flood index homogeneity test for the regional WSC stations shows that Station 02BB003 (Pic River) has the lowest homogeneity of flood flow relative to the regional dataset. However, the Pic River watershed is the only watershed that covers part of the LSA and the reason it fails the homogeneity test is partially due to the fact that it has the largest length of record for all stations, which puts it into a narrower interval range. The Gumbel 95th percentile upper and lower limits show that the longer the period of record a station has, the narrower the log distribution for the return interval has to fall between.

Graph 6.4: Homogeneity Test – Flood Index Approach with 95% Confidence Interval



Index Low Flow

The results of the index low flow test, presented in Table 6.7, demonstrate that the homogeneity for the WSC stations is relatively low. Station 02BD006 (Wawa Creek at Wawa) and Station 02BA005 (Whitesand River Above Schreiber at Minova Mine) have the lowest homogeneity for the regional data set.

Table 6.7: Homogeneity Test for Index Low Flow (7Q10)

Station Name	7Q10 at site (m³s)	7Q10 based on regional discharge estimate (m³s)	% Difference
02BB003	4.47	4.20	-6%
02BA003	1.73	1.55	-10%
02BB004	0.527	0.204	-61%
02BA006	1.51	1.49	-1%
02BA005	0.0029	0.0074	158%
02BC006	0.128	0.238	86%
02AE001	0.457	0.464	2%
02BD006	0.0106	0.028	168%

<u>Selection of the WSC Stations for the Regional Hydrological Assessment</u>

Limited gauging station information is available in northern Ontario for the regional WSC selection near the LSA. Selection of WSC gauging stations was made based on initial selection criteria (catchment area, distance to project site, flow regime) and was tested to determine the homogeneity of the data set. Station 02BD006 (Wawa Creek at Wawa) was determined throughout the homogeneity test process to have the highest mean watershed slope, the highest unit flow, did not meet the threshold for average annual precipitation, had the least homogeneous flow duration curve, and the least homogeneous index low flow. As a result, Station 02BD006 did not pass several of the homogeneity tests and it was removed from the WSC stations selected for the regional hydrology assessment moving forward.

Station 02BB003 (Pic River Near Marathon) showed the least homogeneous results for the index flood flow test, and station 02BA005 (Whitesand River Above Schreiber at Minova Mine) showed low homogeneity for the index low flow test. However, as each station only failed one of the several test methods, they are included in the regional hydrology assessment below.

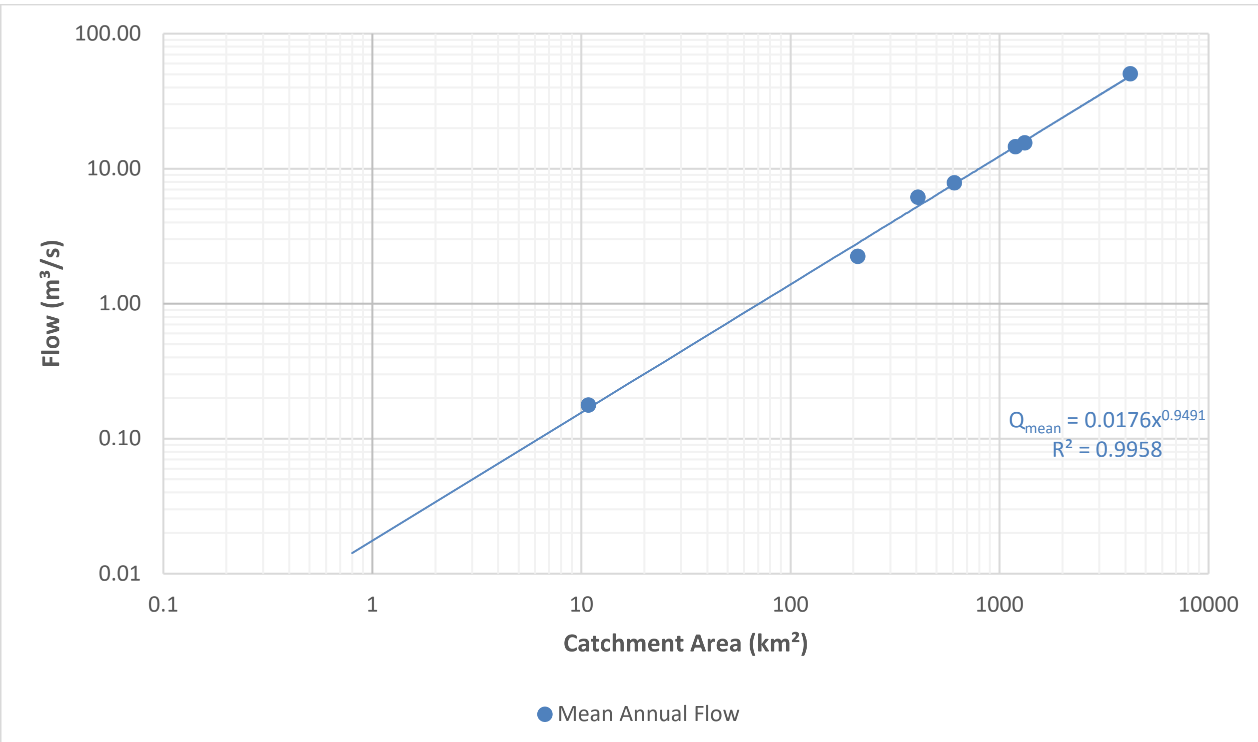
6.1.4.2 Regional Hydrology Assessment Results

As indicated in Section 7.1.3.1, seven regional WSC stations were selected following a series of homogeneity tests to complete the regional hydrology assessment. The regional hydrology assessment is used to calculate a relationship between flow and catchment area to be used to estimate local hydrological conditions in the LSA. Hydrological relationships were calculated for the mean annual flow, mean monthly flow, peak flows, and low flows, as presented below. Environmental flows were estimated using the Tessman method at a monthly scale using a decision matrix of mean monthly and mean annual flows.

Mean Annual Flow

The mean annual flow for the seven selected regional WSC stations range were plotted versus their associated catchment areas on a log-log graph (Graph 6.5). The trendline of the plotted stations was used to provide a relationship that can be applied to the local hydrological station catchment areas to estimate mean annual flow. The correlation coefficient of the relationship between flow and catchment area is 0.9958, which indicates a high level of correlation.

Graph 6.5: Regional Station Relationship Between Mean Annual Flows and Catchment Area



Mean Monthly Flows

The mean monthly flows for the seven selected regional WSC stations range were plotted versus their associated catchment areas on a log-log graph, similar to the mean annual flow. The correlation coefficient of the relationship between the mean monthly flows and catchment areas ranges between 0.9694 to 0.9968, which indicates a high level of correlation for all months (Table 6.8). An exponential relationship was used for the mean monthly flow regression relationships as opposed to a linear relationship in the Calder (2012a) report. The exponential relationship showed a higher coefficient of correlation than the linear relationship presented in Calder (2012a), which ranged from 0.94 to 0.99 with an average of 0.965.

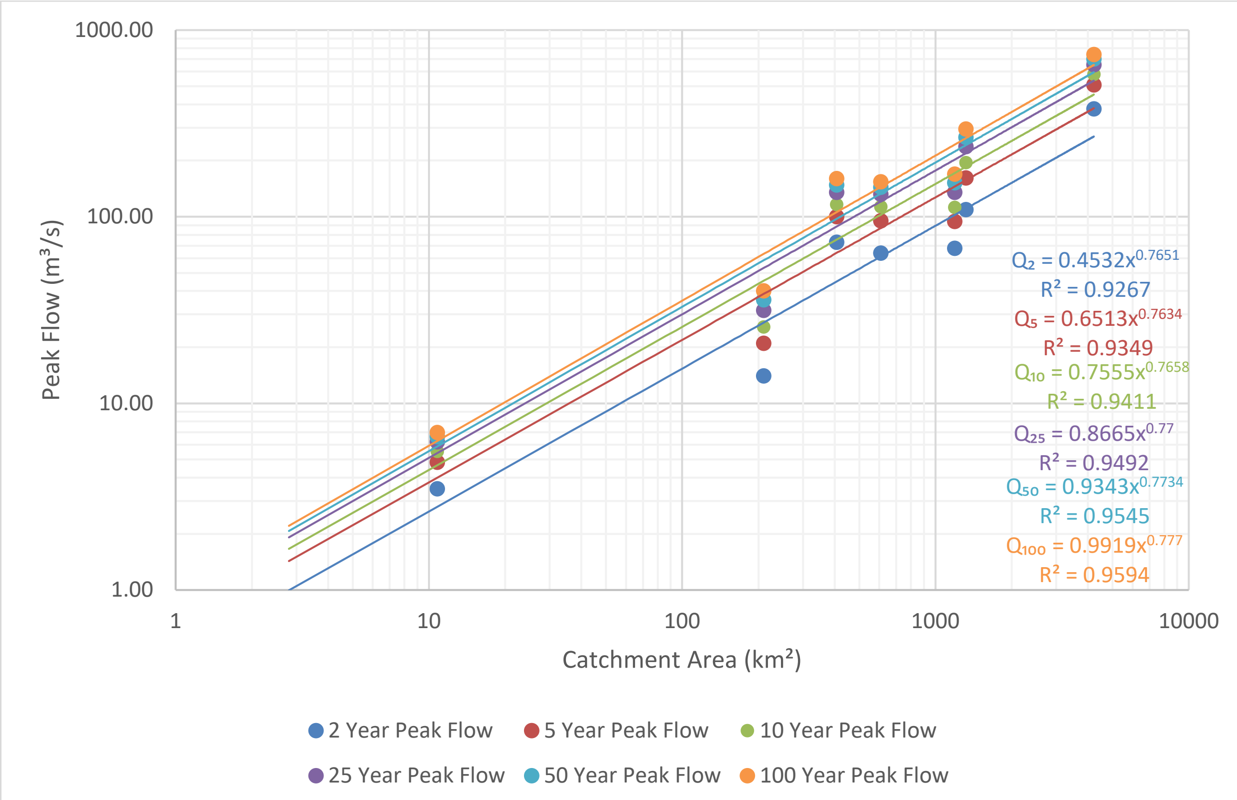
Table 6.8: Regional Station Relationship Between Mean Monthly Flows and Catchment Area

Month	Mean Monthly Flow Regression Equation	R^2
January	$Q_{JanuaryMean}=0.0028x^{1.0589}$	0.9854
February	$Q_{FebruaryMean}=0.0022x^{1.0439}$	0.9879
March	$Q_{MarchMean}=0.0078x^{0.9011}$	0.9694
April	$Q_{AprilMean}=0.0433x^{0.8945}$	0.9872
May	$Q_{MayMean}=0.0573x^{0.9395}$	0.9940
June	$Q_{JuneMean}=0.0138x^{1.0265}$	0.9925
July	$Q_{JulyMean}=0.0077x^{1.0368}$	0.9944
August	$Q_{AugustMean}=0.0047x^{1.0285}$	0.9930
September	$Q_{SeptemberMean}=0.0135x^{0.9235}$	0.9823
October	$Q_{OctoberMean}=0.0323x^{0.8896}$	0.9909
November	$Q_{NovemberMean}=0.0221x^{0.9285}$	0.9968
December	$Q_{DecemberMean}=0.0074x^{1.0063}$	0.9892

Peak Flow

Instantaneous flows were used from the seven regional WSC stations to calculate the peak flow for various return periods (2, 5, 10, 25, 50, and 100 year) as shown on Graph 6.6. The correlation coefficient of the relationship between the peak flows and catchment areas ranges between 0.9267 to 0.9594, which indicates a high level of correlation for all return periods.

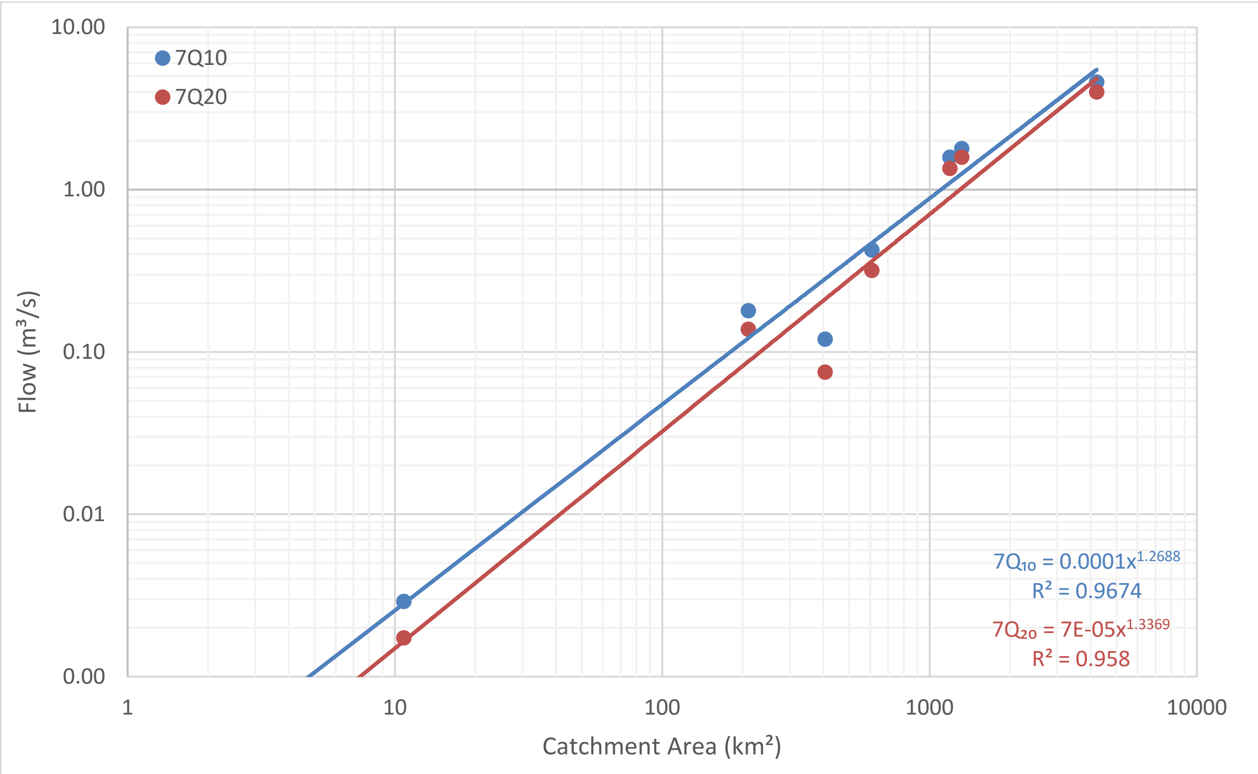
Graph 6.6: Regional Station Relationships Between Catchment Area and Peak Flows



Low Flows

The $7Q_{10}$ (7-day average low flow for a 10-year return period) and $7Q_{20}$ (7-day average low flow for a 20-year return period) are typical indicators of drought conditions. The $7Q_{10}$ and $7Q_{20}$ low flow vs catchment area relationships are presented in Graph 6.7 for the selected regional WSC stations.

Graph 6.7: Regional Station Relationship Between Catchment Area and Low Flows



6.1.5 Local Hydrology Assessment

The relationships derived from the regional hydrology assessment were used to characterize the local hydrology. Mean annual flows, mean monthly flows, peak flows, and low flows were calculated for the local watersheds, and used to determine the environmental flows and environmental water balance for the project. The updated local hydrology is presented below in Table 6.9 for the mean annual flow, Table 6.10 for the mean monthly flows, Table 6.11 for the peak flows, and Table 6.12 for the low flows. An example of the process to determine environmental flows in accordance with the Tessman method is provided in Table 6.13, with the final environmental flows for the local watersheds provided in Table 6.14.

Table 6.9: Summary of Mean Annual Flows (m^3/s) for Watersheds within the LSA

Sub Watershed ID	Catchment Area (km2)	Mean Annual Flow (m^3/s)
101	4.54	0.074
102	3.50	0.058
103	1.87	0.032
104	3.46	0.057
105	47.83	0.691
106	10.52	0.164
107	0.50	0.009
108	0.57	0.010
109	12.04	0.187
110	0.13	0.003
111	0.12	0.002
112	0.11	0.002
113	0.24	0.005
114	1.34	0.023
115	0.31	0.006
116	2.94	0.049
117	0.26	0.005

Table 6.10: Summary of Mean Monthly Flows (m^3/s) for Watersheds within the LSA

Month		Area (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Flows (m3/s)	**101**	4.54	0.014	0.011	0.030	0.168	0.237	0.065	0.037	0.022	0.055	0.124	0.090	0.034
	102	3.50	0.011	0.008	0.024	0.133	0.186	0.050	0.028	0.017	0.043	0.098	0.071	0.026
	103	1.87	0.005	0.004	0.014	0.076	0.103	0.026	0.015	0.009	0.024	0.056	0.039	0.014
	104	3.46	0.010	0.008	0.024	0.131	0.184	0.049	0.028	0.017	0.042	0.097	0.070	0.026
	105	47.8	0.168	0.125	0.254	1.377	2.169	0.731	0.425	0.251	0.480	1.008	0.802	0.363
	106	10.5	0.034	0.026	0.065	0.355	0.523	0.155	0.088	0.053	0.119	0.262	0.197	0.079
	107	0.50	0.001	0.001	0.004	0.023	0.030	0.007	0.004	0.002	0.007	0.017	0.012	0.004
	108	0.57	0.002	0.001	0.005	0.026	0.034	0.008	0.004	0.003	0.008	0.019	0.013	0.004
	109	12.04	0.039	0.030	0.073	0.401	0.593	0.177	0.102	0.061	0.134	0.295	0.223	0.090
	110	0.13	0.0003	0.0003	0.001	0.007	0.009	0.002	0.001	0.001	0.002	0.005	0.003	0.001
	111	0.12	0.0003	0.0002	0.001	0.007	0.008	0.002	0.001	0.001	0.002	0.005	0.003	0.001
	112	0.11	0.0003	0.0002	0.001	0.006	0.007	0.001	0.001	0.0005	0.002	0.004	0.003	0.001
	113	0.24	0.001	0.0005	0.002	0.012	0.015	0.003	0.002	0.001	0.004	0.009	0.006	0.002
	114	1.34	0.004	0.003	0.010	0.056	0.076	0.019	0.010	0.006	0.018	0.042	0.029	0.010
	115	0.31	0.001	0.0007	0.003	0.015	0.019	0.004	0.002	0.001	0.005	0.011	0.007	0.002
	116	2.94	0.009	0.007	0.021	0.113	0.158	0.042	0.024	0.014	0.036	0.084	0.060	0.022
	117	0.26	0.001	0.001	0.002	0.013	0.016	0.003	0.002	0.001	0.004	0.010	0.006	0.002

Table 6.11: Summary of Peak Flows (m^3/s) for Watersheds within the LSA

Watershed ID	Area (km^2)	Q2 (m^3/s)	Q5 (m^3/s)	Q10 (m^3/s)	Q25 (m^3/s)	Q50 (m^3/s)	Q100 (m^3/s)
101	4.54	1.44	2.07	2.41	2.78	3.01	3.21
102	3.50	1.18	1.69	1.97	2.27	2.46	2.62
103	1.87	0.73	1.05	1.22	1.40	1.51	1.61
104	3.46	1.17	1.68	1.95	2.25	2.44	2.60
105	47.83	8.74	12.47	14.61	17.03	18.60	20.02
106	10.52	2.74	3.93	4.58	5.31	5.77	6.18
107	0.50	0.27	0.38	0.45	0.51	0.55	0.58
108	0.57	0.29	0.42	0.49	0.56	0.60	0.64
109	12.04	3.04	4.35	5.08	5.89	6.40	6.86
110	0.13	0.10	0.14	0.16	0.18	0.20	0.21
111	0.12	0.09	0.13	0.15	0.17	0.18	0.19
112	0.11	0.08	0.12	0.14	0.16	0.17	0.18
113	0.24	0.15	0.22	0.25	0.29	0.31	0.33
114	1.34	0.57	0.82	0.95	1.09	1.17	1.25
115	0.31	0.19	0.27	0.31	0.35	0.38	0.40
116	2.94	1.03	1.48	1.72	1.99	2.15	2.29
117	0.26	0.16	0.23	0.27	0.31	0.33	0.35

Peak flows were compared to the Calder (2012a) peak flows for watersheds 104, 107, and 108, which were calculated for the entirety of the watershed rather than at a stream gauge node as with watersheds 101, 102, 103, 105, and 106. It was found that there was a significant difference with the updated hydrology peak flows showing a range of 20% to 68% smaller peak flows than that calculated by Calder (2012a), with the difference in watershed area only ranging from a 2% to 7% increase when comparing the updated hydrology peak flows to Calder's (2012a). Therefore, the difference in watershed area did not account for the significant difference observed in the peak flows.

Table 6.12: Summary of Low Flows (m^3/s) for Watersheds within the LSA

Watershed ID	Area (km^2)	7Q10 (m^3/s)	7Q20 (m^3/s)
101	4.54	0.00068	0.000529
102	3.50	0.00049	0.000373
103	1.87	0.00022	0.000161
104	3.46	0.00048	0.000368
105	47.83	0.01353	0.012321
106	10.52	0.00198	0.001628
107	0.50	0.00004	0.000028
108	0.57	0.00005	0.000033
109	12.04	0.00235	0.001948
110	0.13	0.00001	0.000005

Table 6.12: Summary of Low Flows (m^3/s) for Watersheds within the LSA

Watershed ID	Area (km^2)	7Q10 (m^3/s)	7Q20 (m^3/s)
111	0.12	0.00001	0.000004
112	0.11	0.00001	0.000004
113	0.24	0.00002	0.000010
114	1.34	0.00015	0.000104
115	0.31	0.00002	0.000015
116	2.94	0.00039	0.000295
117	0.26	0.00002	0.000012

When comparing low flows to the Calder (2012a) low flows for watershed 104, it was found that there was a significant difference with the updated hydrology peak flows. Watersheds 107 and 108 were not included in the comparison as Calder (2012a) reported them to be <0.001. The difference between the Calder (2012a) low flows and updated hydrology low flows showed a range of 88% for both $7Q_{10}$ and $7Q_{20}$, with a 2% difference in watershed area.

Environmental Flows

An example of the flows chosen in accordance with the Tessman method (Tessman 1980) to represent environmental flows is provided in Table 6.13 below. A decrease in surface water quantity below environmental flow thresholds could affect sustainability of freshwater ecosystems. Selected flows are highlighted in green and are included in Table 6.14.

Table 6.13: Environmental Flow (m^3/s) calculation example for Watershed 101

Flow	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MMF	0.014	0.011	0.030	0.168	0.237	0.065	0.037	0.022	0.055	0.124	0.090	0.034
40% MMF	0.006	0.004	0.012	0.067	0.095	0.026	0.015	0.009	0.022	0.050	0.036	0.014
MAF	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074
40% MAF	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030

Note:

* MAF – mean annual flows; MMF - mean monthly flows

Table 6.14: Summary of Environmental Flows (m^3/s) for Watersheds within the LSA

Month		Area (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Environmental Flows (m^3/s)	**101**	4.54	0.014	0.011	0.030	0.067	0.095	0.030	0.030	0.022	0.030	0.050	0.036	0.030
	102	3.50	0.011	0.008	0.023	0.053	0.074	0.023	0.023	0.017	0.023	0.039	0.028	0.023
	103	1.87	0.005	0.004	0.013	0.030	0.041	0.013	0.013	0.009	0.013	0.023	0.016	0.013
	104	3.46	0.010	0.008	0.023	0.053	0.074	0.023	0.023	0.017	0.023	0.039	0.028	0.023
	105	47.8	0.168	0.125	0.254	0.551	0.867	0.292	0.277	0.251	0.277	0.403	0.321	0.277
	106	10.5	0.034	0.026	0.065	0.142	0.209	0.066	0.066	0.053	0.066	0.105	0.079	0.066
	107	0.50	0.001	0.001	0.004	0.009	0.012	0.004	0.004	0.002	0.004	0.007	0.005	0.004
	108	0.57	0.002	0.001	0.004	0.010	0.013	0.004	0.004	0.003	0.004	0.008	0.005	0.004
	109	12.04	0.039	0.030	0.073	0.160	0.237	0.075	0.075	0.061	0.075	0.118	0.089	0.075
	110	0.13	0.0003	0.0003	0.001	0.003	0.003	0.001	0.001	0.001	0.001	0.002	0.001	0.001
	111	0.12	0.0003	0.0002	0.001	0.003	0.003	0.001	0.001	0.001	0.001	0.002	0.001	0.001
	112	0.11	0.0003	0.0002	0.001	0.002	0.003	0.001	0.001	0.0005	0.001	0.002	0.001	0.001
	113	0.24	0.001	0.000	0.002	0.005	0.006	0.002	0.002	0.001	0.002	0.004	0.002	0.002
	114	1.34	0.004	0.003	0.009	0.023	0.030	0.009	0.009	0.006	0.009	0.017	0.012	0.009
	115	0.31	0.001	0.001	0.002	0.006	0.008	0.002	0.002	0.001	0.002	0.005	0.003	0.002
	116	2.94	0.009	0.007	0.020	0.045	0.063	0.020	0.020	0.014	0.020	0.034	0.024	0.020
	117	0.26	0.001	0.0005	0.002	0.005	0.006	0.002	0.002	0.001	0.002	0.004	0.003	0.002

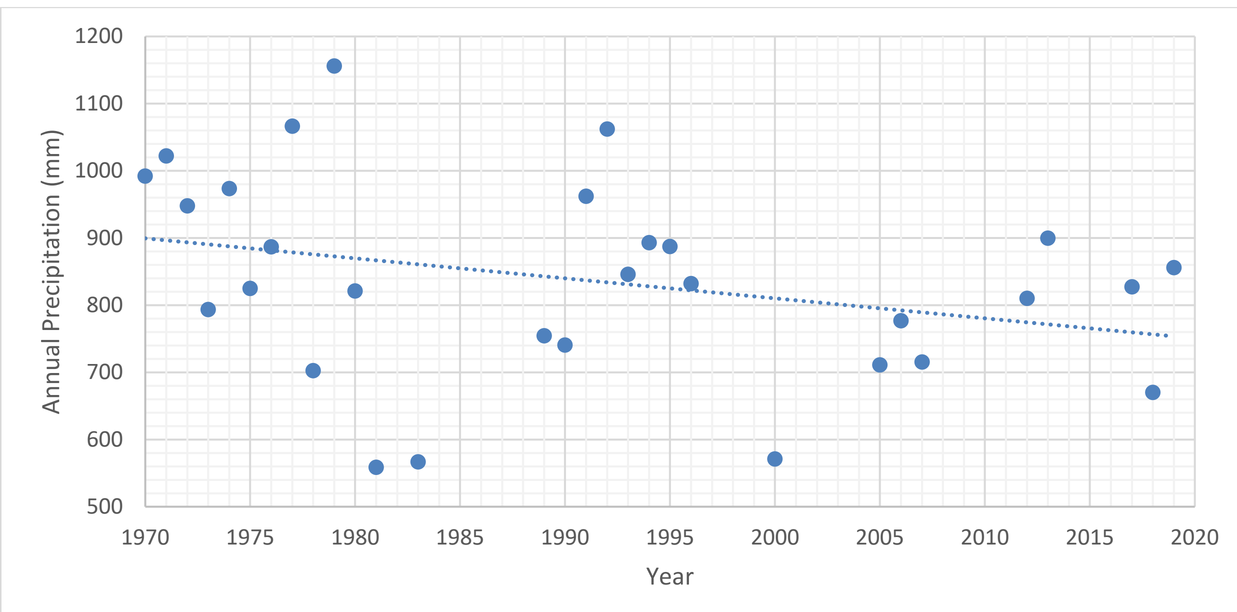
Baseflow Index

Baseflow was considered by calculating the BFIs from the open water season flow data from S1, S4, and S11 with the longest continuous open water measurement records availability. Baseflow contributions to total flow at these stations for its period of record were found to vary from 13% (S1) to 26% (S11). The BFI calculated for the S1, S4, and S11 were 13%, 17%, and 26% of total streamflow for the open water period, respectively. The BFI is considered applicable to the LSA with some potential variations that may include higher BFI in streams located near lakes (i.e., S11 which is located close to Hare Lake).

Environmental Water Balance

The environmental water balance was modelled based on the available 1990-2019 local climate conditions for the combined Marathon Airport (Station ID 6044961) and Pukaskwa AUT (Station ID 6046768) climate stations. Graph 6.8 shows the annual precipitation plotted against the available years of data from 1970 to 2019 which have less than 20 days/year of missing data. The annual precipitation over the last 50 years demonstrates the variability and illustrates what appears to be a drying trend, although climate change predictions indicate larger storm events should expect higher total precipitation.

Graph 6.8: 1970-2019 Annual Precipitation



Input parameters into the Thornthwaite equation used by the United Stations Geological Survey (USGS) are presented in Table 6.15. The soil moisture storage capacity value was based on the value for silt loam in forested regions (400 mm) but was adjusted for the relatively shallow veneer of soil over bedrock in the LSA to be 150 mm assuming an average silt loam soil depth of 375 mm over bedrock.

Table 6.15: Environmental Water Balance Input Parameters

Input Parameters (Units)	Values
Run-off Factor (-)	0.60
Total Water (-)	1
Topography Factor (-)	0.1
Soils Factor (-)	0.1
Cover Factor (-)	0.2
Direct Run-off Factor (-)	0.05
Soil Moisture Storage Capacity (mm)	150 (400 mm/m based on soil depth of 375 mm)
Latitude of Location (˚)	48
Rain Temperature Threshold (˚C)	0.0
Snow Temperature Threshold (˚C)	0.0
Maximum Melt Rate (-)	0.5

Note: '-' indicates there is no associated unit for the input parameter

Table 6.16: 1981-2010 Climate Normal Environmental Water Balance

Parameters (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation	63.1	42.3	43.3	43.6	69.7	73.1	80.8	65.3	106.4	100	60.1	68.1	815.8
Actual Evapotranspiration	4.9	6.3	13.4	27.7	53.8	77.9	87	76.2	43.1	22.4	9.5	5.0	427.2
Excess Precipitation	58.2	36.0	29.9	15.9	15.9	-4.8	-6.2	-10.9	63.3	77.6	50.6	63.1	388.6

The environmental water balance presented in Table 6.16 shows an annual precipitation of 815.8 mm, with an actual evapotranspiration of 427.2 mm. The actual evapotranspiration is mostly consistent with the evapotranspiration reported by Calder (2012a) of 488.2 mm annually, which is 12% greater than the actual evapotranspiration reported in Table 6.16. Subtracting the actual evapotranspiration from the annual precipitation provides the excess precipitation for the Project area. Excess precipitation incorporates snow storage, overland runoff, and infiltration all of which will eventually report to surface watercourses as total streamflow. Based on the Thornthwaite model, of the 388.6 mm of precipitation that was not evaporated, 76% was overland flow and 24% was infiltration for aquifer recharge and eventual groundwater discharge back to surface water. In general, the environmental water balance estimates that total streamflow is derived from overland flow and groundwater discharge at a 3:1 ratio, implying that overland flow is the dominant hydrological component of total streamflow. Notwithstanding that the BFI was estimated on open water season flow data, the BFI's tend to indicate that baseflows are a smaller proportional component of total streamflow.

The net flow recharge rate for the Project area estimated in the baseline hydrogeology report was 79 mm/year (True Grit, 2012) which equates to 9.6% of the total mean annual precipitation determined in True Grit (2012) to be 830 mm. Based on the USGS Thornthwaite environmental water balance, approximately 24% of excess precipitation (90 mm of 378.2 mm) infiltrated and recharged local aquifers. With a calculated excess precipitation of 378.2 mm, the 79 mm/year recharge rate equates to a 20.9% excess precipitation recharge rate, consistent with the 24% recharge rate calculated by the environmental water balance, whereas the environmental water balance approach estimates a 24% recharge rate. Thus, the True Grit (2012) recharge estimate aligns well with the current environmental water balance estimate.

The runoff coefficient for the environmental water balance can be determined by dividing the excess precipitation (388.6 mm) by the total annual precipitation (815.8 mm), which provides a runoff coefficient of 0.48. The runoff coefficient from the water balance can be compared to the runoff coefficient determined from the regional WSC station data. The regional stations presented in Table 6.6 with the exception of Wawa have unit flows that range from 11.11 L/s/km^2 to 13.39 L/s/km^2, with an average unit flow of 12.20 L/s/km^2. Multiplying the unit flow by the number of seconds per year, converting to millimetres, and dividing by the average annual precipitation estimated for the area of 818.2 mm, provides a runoff coefficient of 0.47. Therefore, the runoff coefficient computed from the unit flows is consistent with what was modelled through the environmental water balance, and consistent with that calculated by Calder (2012a) which was also found to be 0.47 for the regional hydrology assessment.

7.0 SUMMARY AND CONCLUSIONS

This report aimed to conduct an updated assessment of hydrological baseline conditions for the Marathon Palladium project located near the Town of Marathon, Ontario. Information reviewed to update the baseline condition included a review of historical information, supplemental field studies conducted by Stantec in 2019-2020 and True Grit in 2008-2018, and the updated design plans for the Project provided by GenPGM (2020). Highlights of this report are summarized below:

- Longer continuous and spot measurement periods were considered to estimate local stream flows at ungauged stations improved the estimation of local stream flows.
- Longer precipitation data records were considered from additional weather stations. Gaps in data time series were filled using available data from nearby stations. Climate data still proved to be consistent with that reported by Calder (2012a).
- Hydrological relationships were calculated to assess the regional hydrology. The correlation coefficient of the relationship between flow and catchment area indicated a high level of correlation (R^2=0.99). High correlation coefficient between the mean monthly flows and catchment areas ($0.97< R^2$) showed a high level of correlation for all months. Peak flows and catchment areas relationships presented a high level of correlation for all return periods ($0.93<R^2<0.96$)
- The results of the climate change analyses showed that lower duration with shorter return periods and higher durations with longer return periods had the increased total rainfall, while medium duration for all return periods had a decrease in total rainfall. The maximum reduction in total rainfall is 21% (8.3 mm) for a 5-year return period with a 2-hour duration and the maximum increase in total rainfall is 19% (18.69 mm) for a 100-year return period with a 6-hour duration.
- Based on the use of multiple assessments methods including regional hydrological assessment, local field hydrology, baseflow index assessment, environmental water balance and estimates of groundwater recharge conducted in True Grit (2012), there is reasonable alignment regarding the nature of local hydrological flows indicating that overland flow is the dominant component of total streamflow and recharge and groundwater discharge plays a less proportional role.
- In general, with the continuation of field hydrometric monitoring, rating curve confidence was increased and longer precipitation data records resulted in improved understanding of the local hydrology. The improved hydrological data resulted in changes in the peak flows and low flows presented by Calder (2012a).

8.0 REFERENCES

Environment Canada (EC). 2020. Engineering Climate Datasets, available at http://climate.weather.gc.ca/prods_servs/engineering_e.html, accessed September 2020.

Calder Engineering Ltd. (Calder). 2012a. Final Report Baseline Hydrology, Marathon PGM-Cu Project Site.

Calder Engineering Ltd. (Calder). 2012b. Marathon PGM-Cu Project – Surface Water Hydrologic Impact Assessment.

Colombo, S.J., D.W. McKenney, K.M. Lawrence and P.A. Gray. 2007. Climate Change Projections for Ontario: Practical Information for Policymakers and Planners. Ontario Ministry of Natural Resources. Application Resources Development Branch, Sault Ste. Marie, Ontario. Climate Change Research Report CCRR-05. 37p.

Dalrymple, T. 1960. Flood Frequency Analysis, U.S. Geol. Survey Water Supply Paper 1543-A, 80p.

Harvey, K, D., Condie, R., & Pilon, P.J. 1985. Regional Flood Frequency Analysis with the Three-Parameter Lognormal Distribution. Proc. CSCE 7th Canadian Hydrotechnical Conference (Saskatoon, Saskatchewan, 27 May-1 June).

McCabe, G.J. and D.M. Wolock. 1999. Future snowpack conditions in the western United States derived from general circulation model climate simulations. Journal of the American Water Resources Association, 35(6): 1473-1484.

McDermid, J., S. Fera and A. Hogg. 2015. Climate Change Projections for Ontario: An Updated Synthesis for Policymakers and Planners. Ontario Ministry of Natural Resources and Forestry, Science and Research Branch, Peterborough, Ontario. Climate Change Research Report CCRR-44.

Ministry of Natural Resources and Forestry (MNRF). 2015. Ontario Flow Assessment Tool Version 3 (OFAT).

Schardong, A., S. P. Simonovic, A. Gaur, and D. Sandink. 2020. Web-based Tool for the Development of Intensity Duration Frequency Curves under Changing Climate at Gauged and Ungauged Locations: Water, Special Issue Extreme Value Analysis of Short-Duration Rainfall and Intensity–Duration–Frequency Models, 12, 1243; doi:10.3390/w12051243, https://www.idf-cc-uwo.ca/idfstation

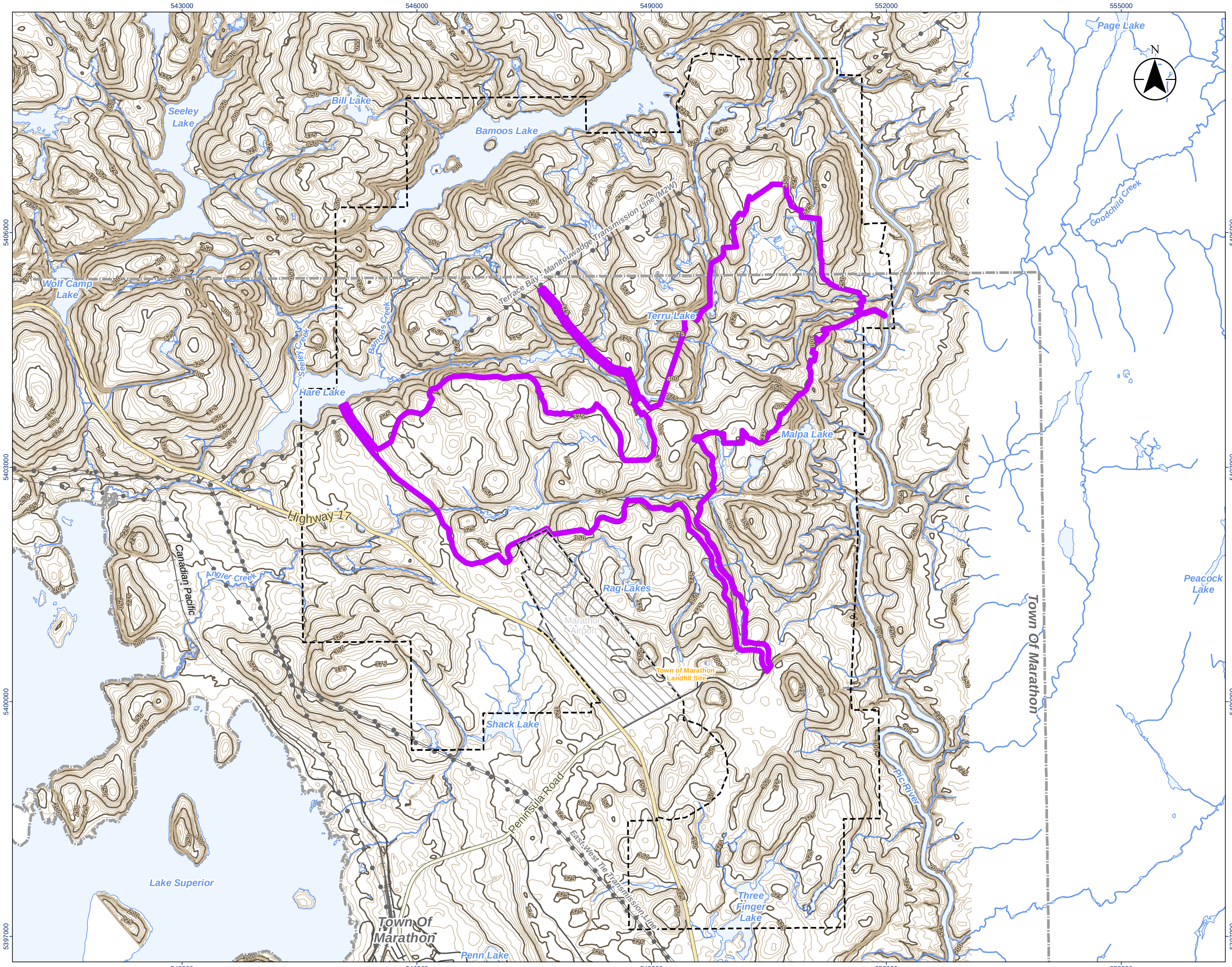
Tessman, S.A. 1980. Environmental Assessment, Technical Appendix E, In Environmental Use Sector Reconnaissance Elements of the Western Dakota Region of South Dakota Study. Water Resources Research Institute, South Dakota State University, Brookings, South Dakota.

Thornthwaite, W. and Mather, J.R. 1957. The Water Balance, Publications in Climatology, Vol. X, No.3, Drexel Institute of Technology, Centerton, NJ.

True Grit Consulting Ltd. (True Grit). 2012. Stillwater Canada Inc. Marathon PGM- Cu Project. Supporting Information Document No. 14- Baseline Report, Hydrogeology, Marathon PGM-Cu Project.

Wolock, D.M. and McCabe, G.J. 1999. Effects of Potential Climatic Change on Annual Run-off in the Conterminous United States. *Journal of the American Water Resources Association.* 35:1341-1350.

APPENDIX A
Figures



Stantec

Legend

- Project Boundary (MLAS, MENDM Changed 2017)
- Site Study Area Boundary
- Topographic Contour (5 m Intervals)
- Topographic Contour (25 m Intervals)
- Highway
- Major Road
- Minor Road
- Hydro Line
- Railway
- Watercourse
- Airport
- Municipal Boundary, Lower Tier
- Waterbody

0 1 2 km

1:50,000 (At original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 UTM Zone 16N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.

Project Location
Marathon

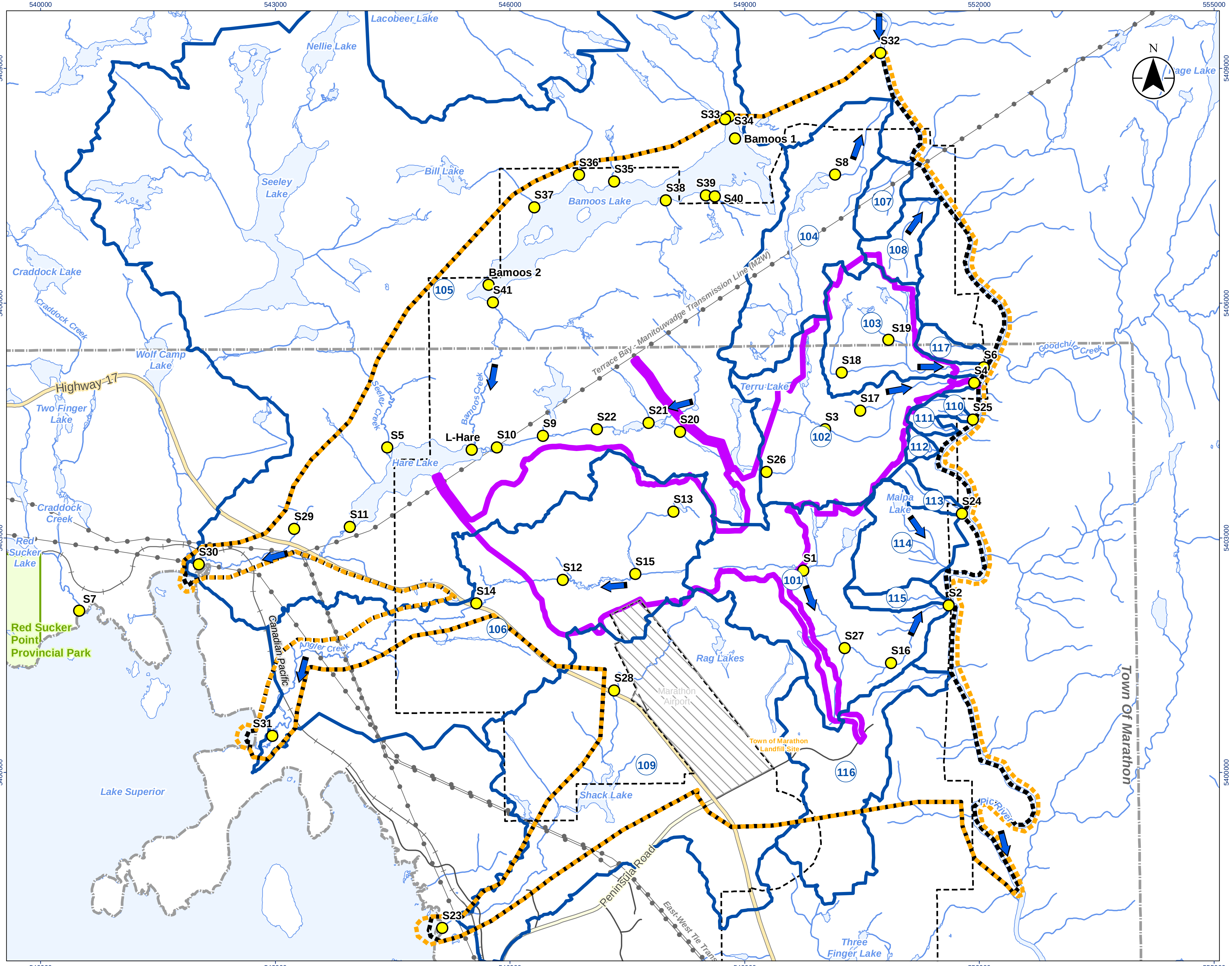
129673006 REVA
Prepared by SW on 2020-11-12
Technical Review by DH on 2020-09-16
Independent Review by ABC on yyyy-mm-dd

Client/Project
GENERATION PGM INC.
MARATHON PALLADIUM PROJECT

Figure No.
1

Title
Site Study Area

V:\01609\active_Other_PCs_Active\1296 - Manitoba\129673006 Marathon PGM\gis_cad\gis\mxds\SurfaceWater\report_figures\Baseline_2020\129673006_Fig1_Site_Location.mxd Revised: 2020-11-12 By: dharvey



Stantec

Legend

Type

- Local Study Area
- Regional Study Area
- Approximate Limit of Surface Rights (current and/ or planned)
- Site Study Area Boundary
- Surfacewater Quantity Sampling Station
- Surface Water Flow Direction
- Highway
- Major Road
- Minor Road
- Hydro Line
- Railway
- Watercourse
- Airport
- Municipal Boundary, Lower Tier
- Provincial Park
- Waterbody
- Watershed Boundary

0 1 2 km

1:50,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 UTM Zone 16N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.

Project Location: Marathon

129673006 REVA

Prepared by DH on 2020-11-12

Technical Review by ABC on yyyy-mm-dd

Independent Review by ABC on yyyy-mm-dd

Client/Project

GENERATION PGM INC.

MARATHON PALLADIUM PROJECT

Figure No.

2

Title

Local and Regional Study Area

V:\01609\active\...\129673006_Marathon PGM\gis_cad\gis\mxds\SurfaceWater\report_figures\Baseline_2020\129673006_FIG2_LSA_and_RSA_20201111.mxd Revised: 2020-11-12 By: dharvey

APPENDIX B

Hydrometric Station Summary Sheets

Hydrometric Monitoring Station S1 Summary

Station ID	S1	**Annual Mean Temperature**	2.10 °C
GPS Coordinates	48.77431° N, 86.32303° W	**Period of Spot Measurement Record**	August 2009 - July 2016
Drainage Area	1.84 km^2	**Period of Logger Record**	2016 (June - August), 2017 (May- August), 2019 (September - October)
Mean Annual Flow	0.02 m3/s	**Number of Spot Measurments**	12
Annual Precipitation	837.00 mm	**Measurements**	Temperature, Water level, Atmospheric Pressure, Flow, Depth

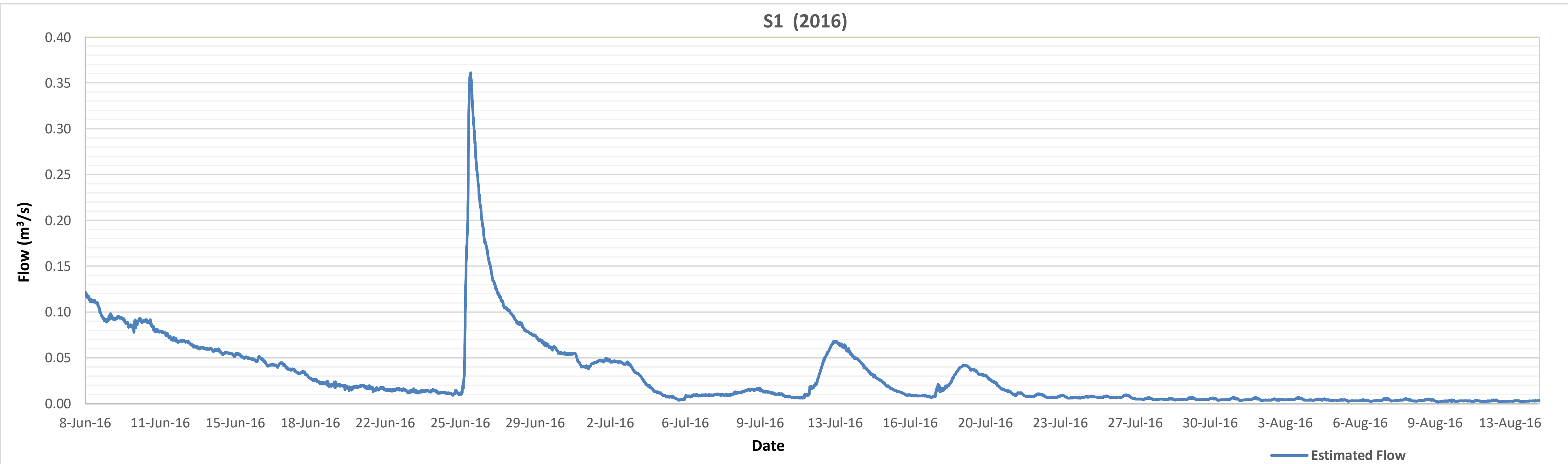
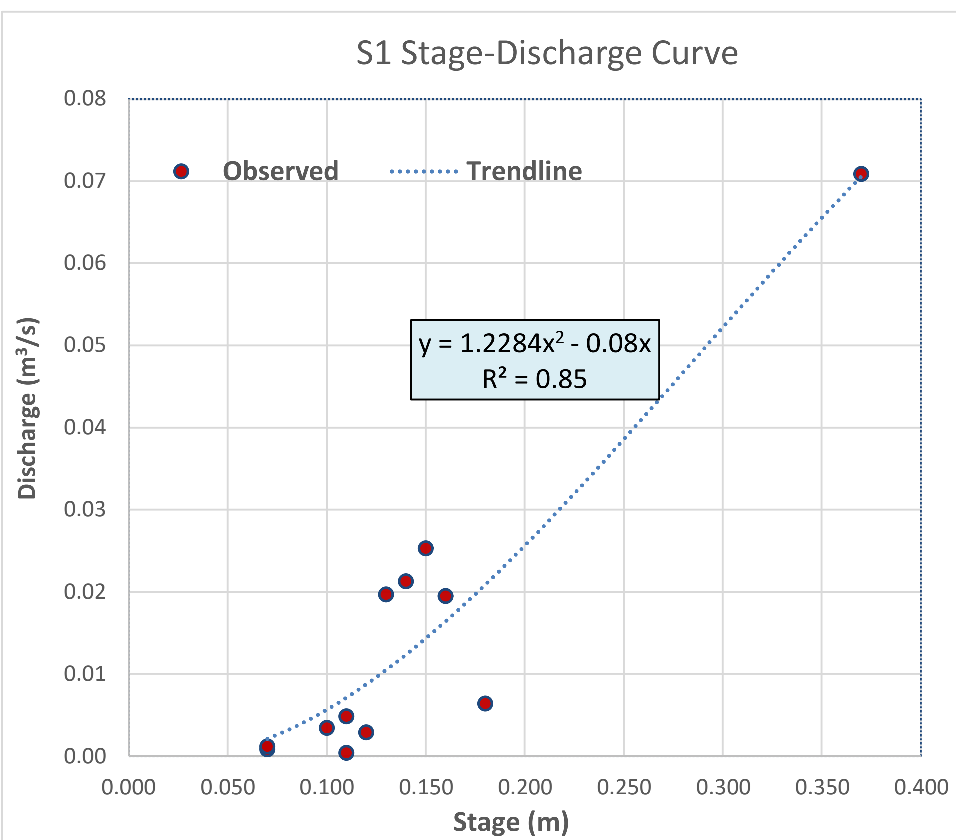
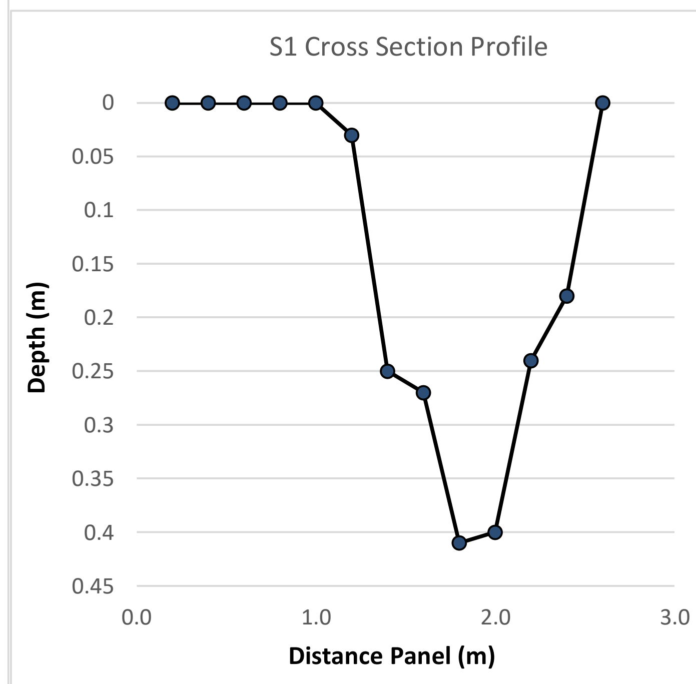
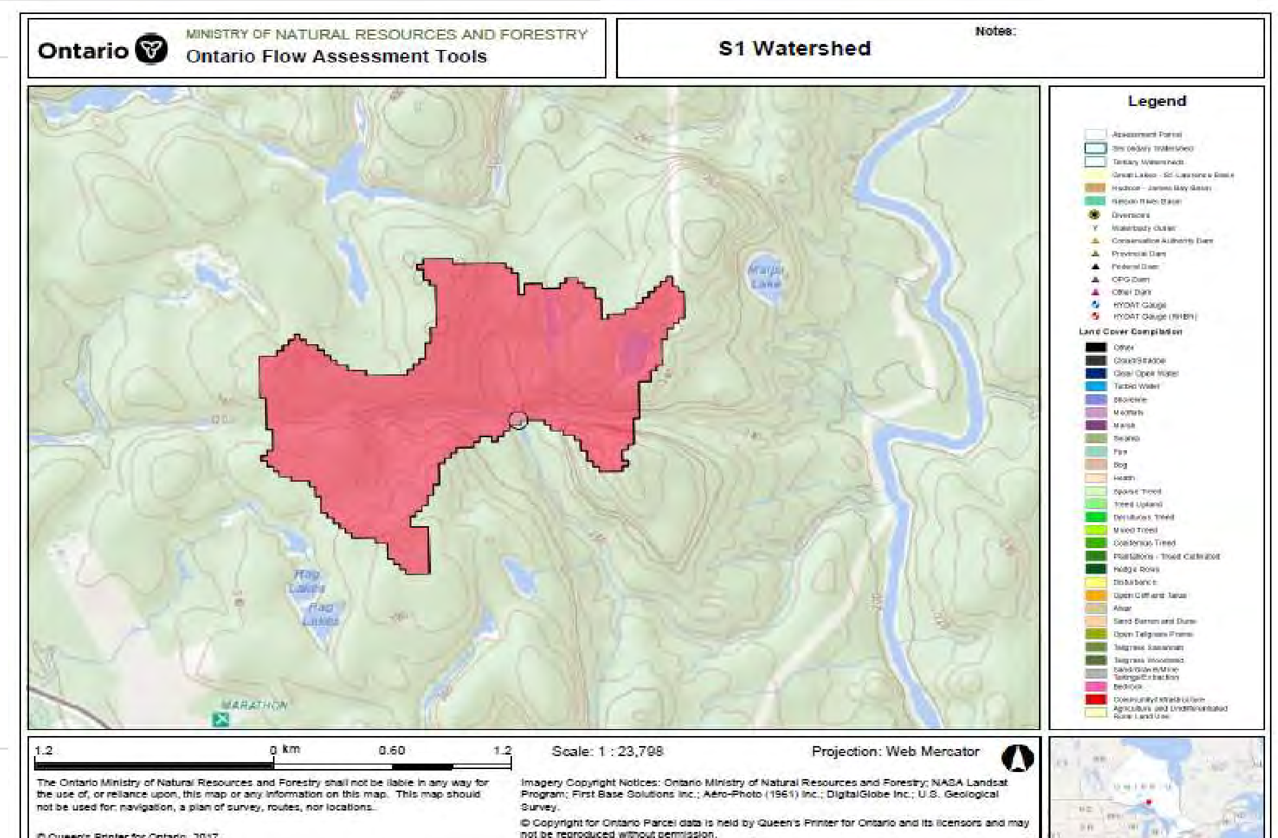


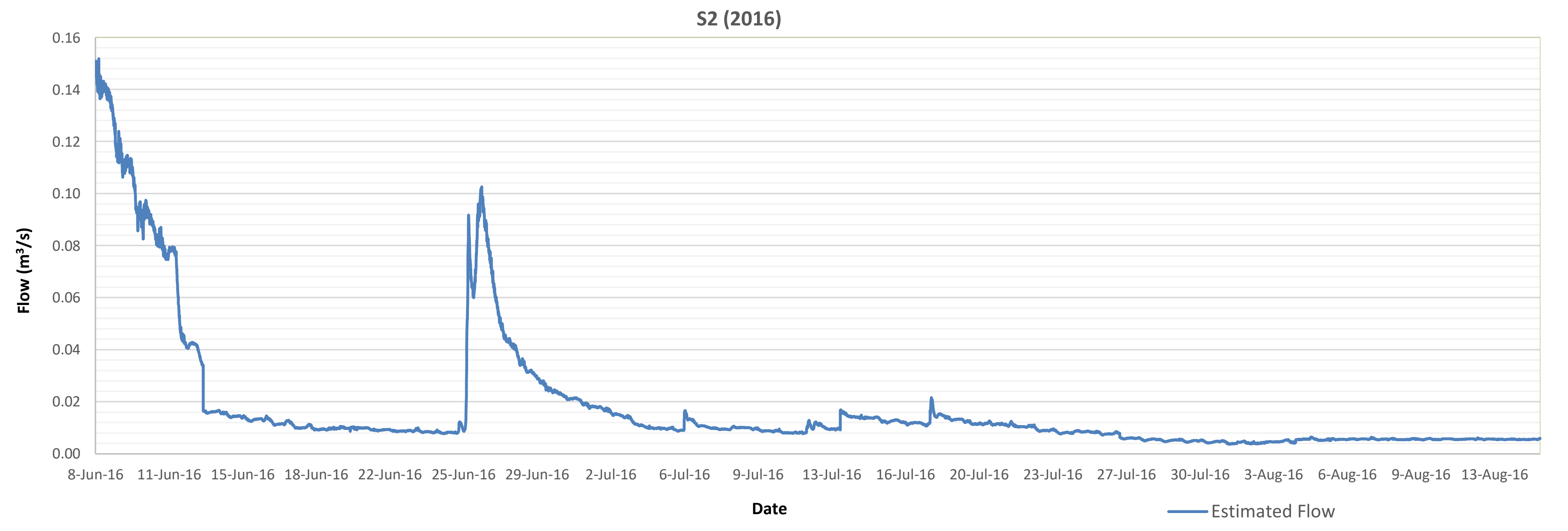

Photo: S1 Field activity

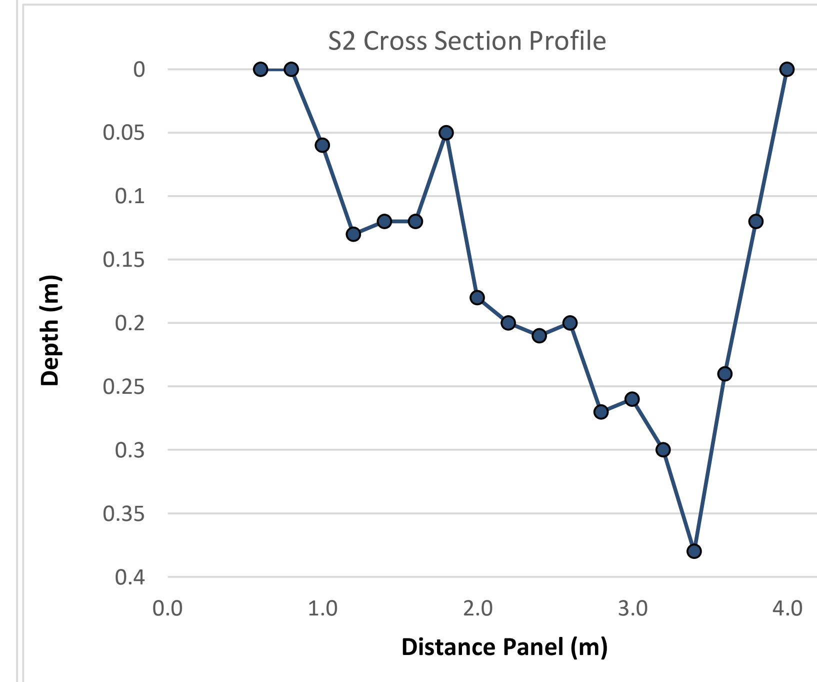


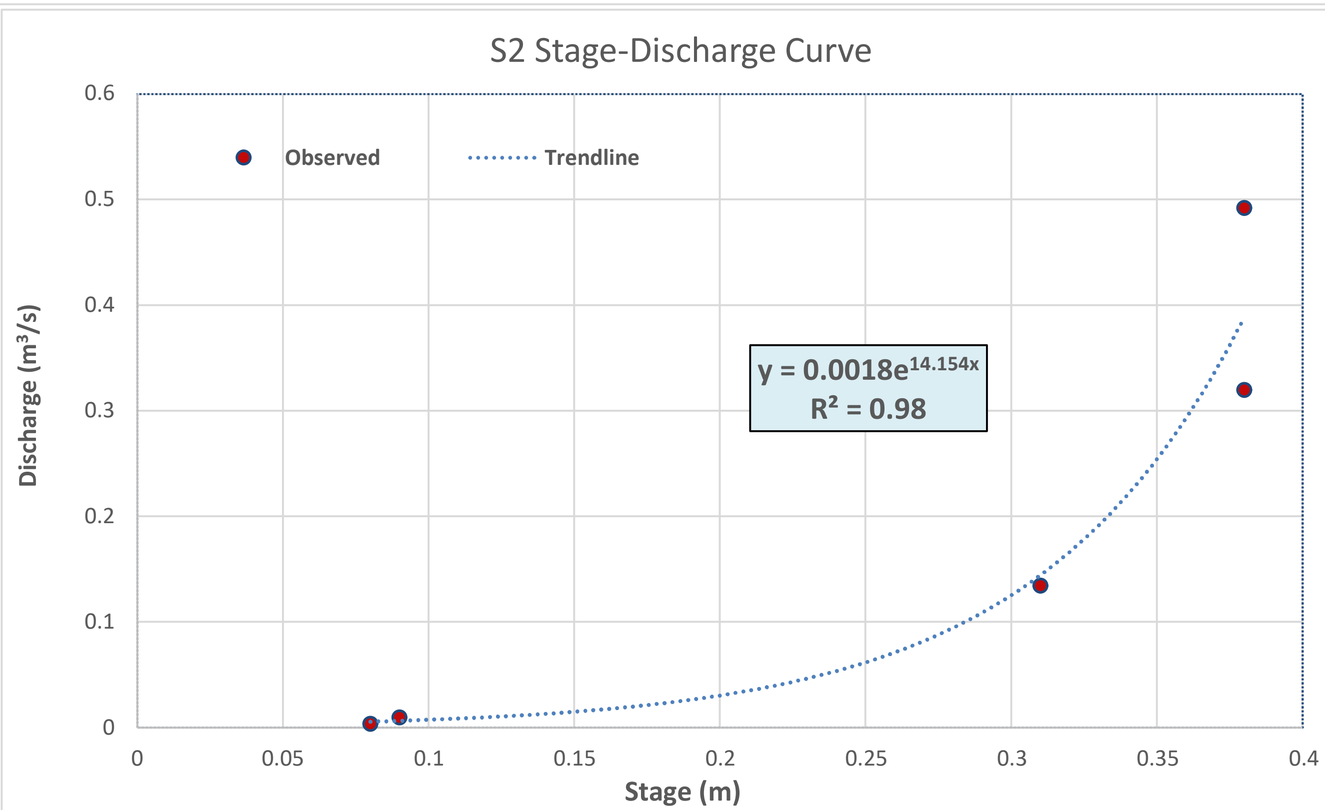


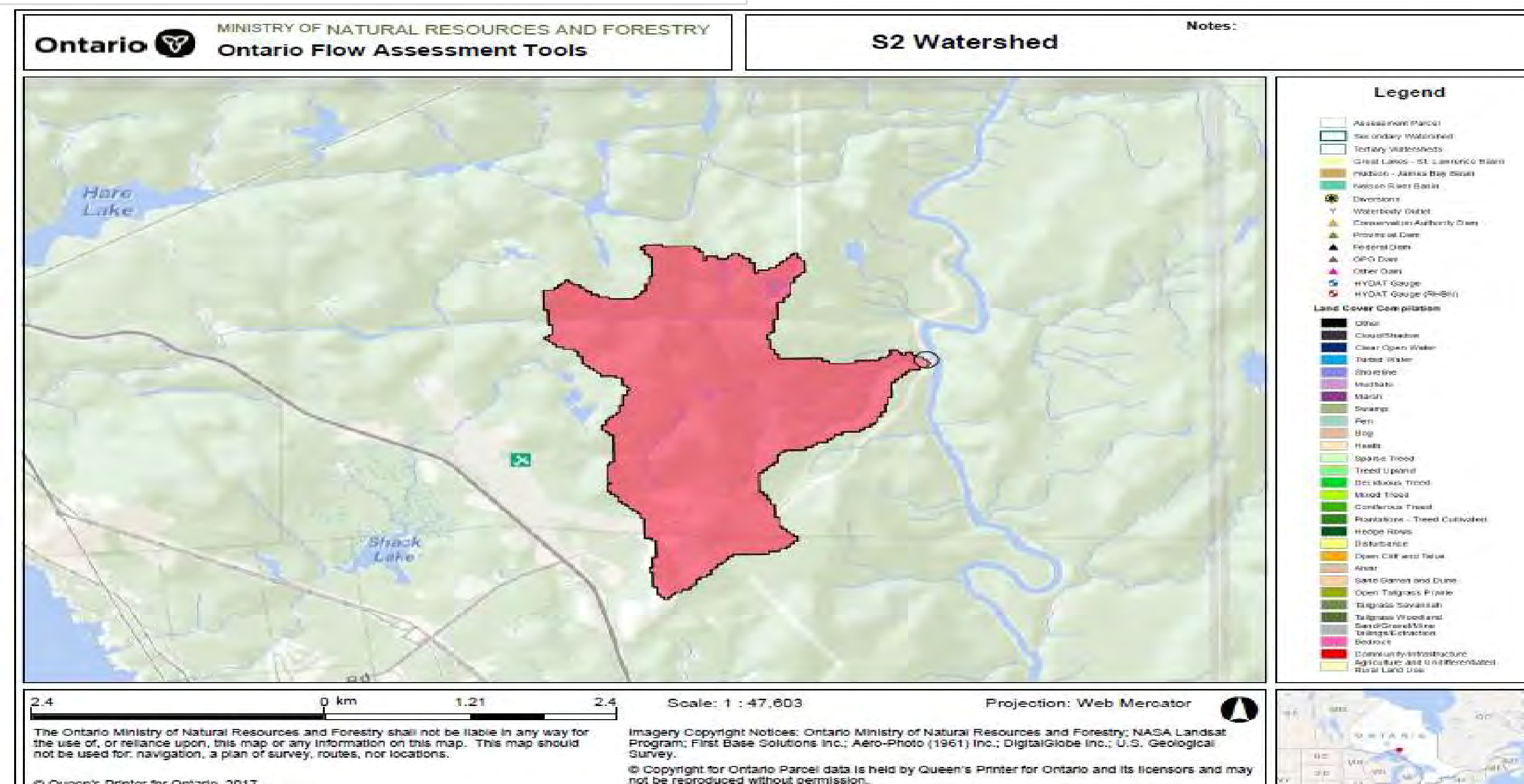


Hydrometric Monitoring Station S2 Summary			
Station ID	S2	**Annual Mean Temperature**	2.1 °C
GPS Coordinates	48.77022° N, 86.29717° W	**Period of Spot Measurement Record**	June 2015 - July 2017
Drainage Area	6.26 km^2	**Period of Logger Record**	2016 (June - August), 2017 (May- August)
Mean Annual Flow	0.08 m3/s	**Number of Spot Measurments**	5
Annual Precipitation	837.00 mm	**Measurements**	Temperature, Water level, Atmospheric Pressure, Flow, Depth









Hydrometric Monitoring Station S3 Summary

Station ID	S3	**Annual Mean Temperature**	2.00 °C
GPS Coordinates	48.79066° N, 86.31923° W	**Period of Spot Measurement Record**	October 2009 - July 2017
Drainage Area	2.04 km^2	**Period of Logger Record**	2016 (June - August)
Mean Annual Flow	0.03 m3/s	**Number of Spot Measurments**	6
Annual Precipitation	837.00 mm	**Measurements**	Temperature, Water level, Atmospheric Pressure, Flow, Depth

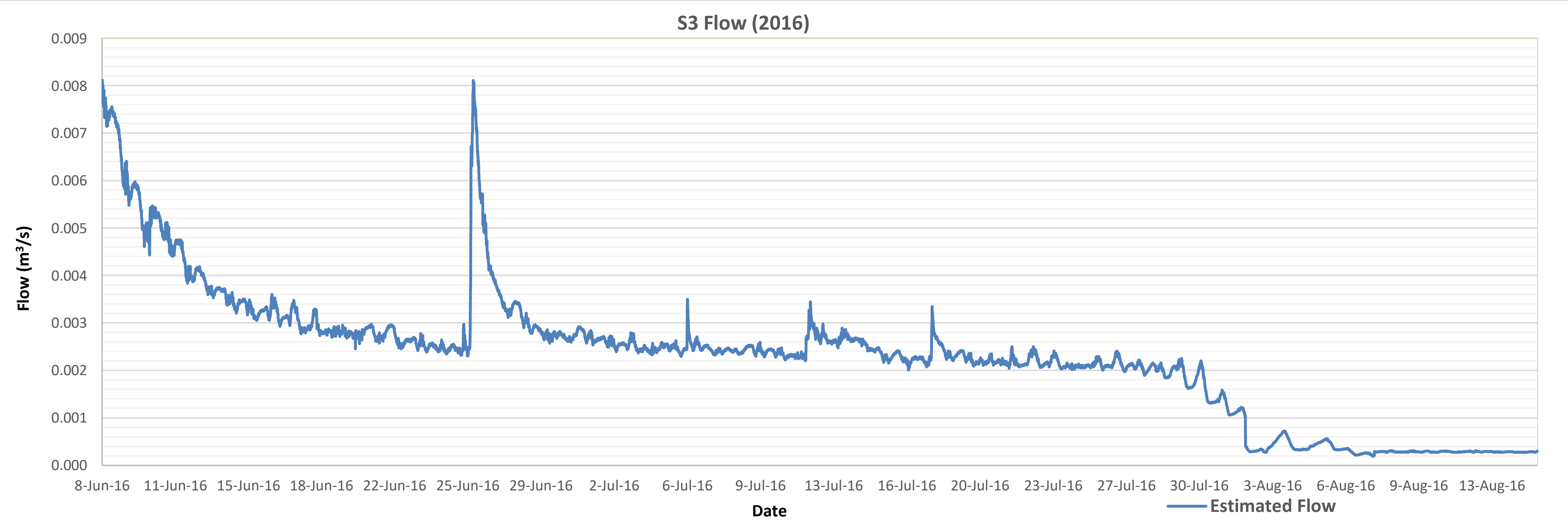
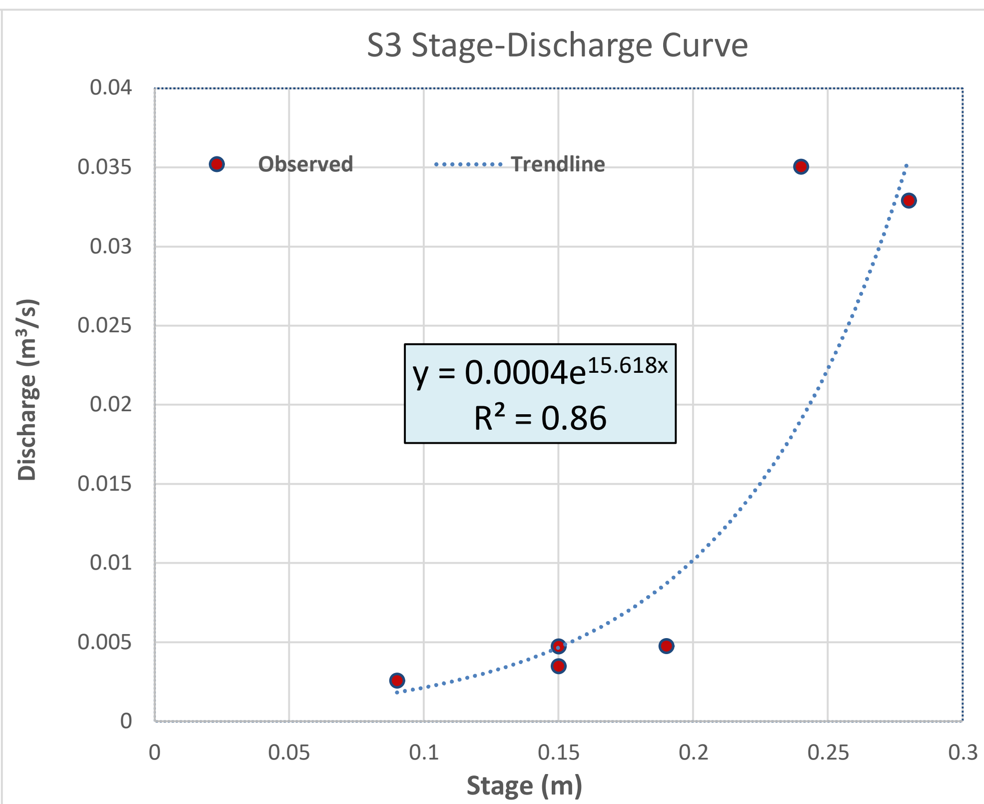
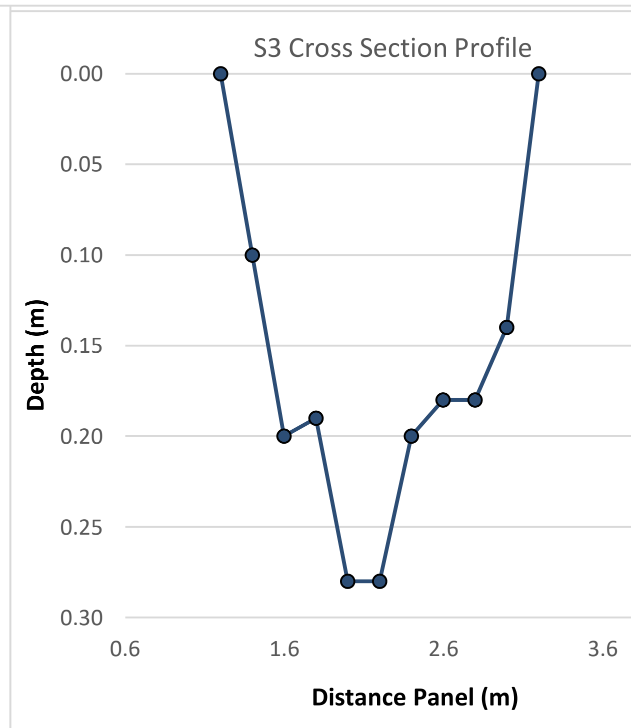
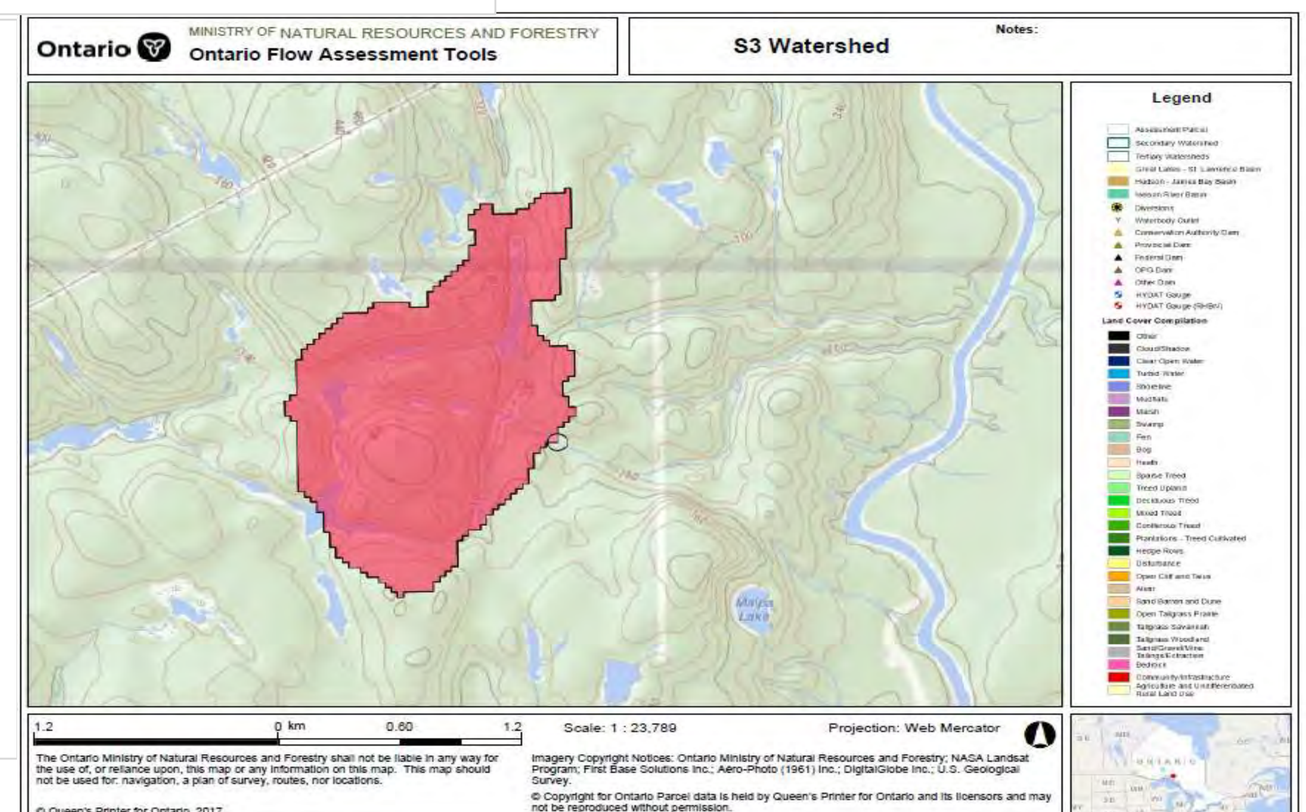


Photo: S3 Field activity







Hydrometric Monitoring Station S4 Summary			
Station ID	S4	**Annual Mean Temperature**	2.00 °C
GPS Coordinates	48.79729° N, 86.29055° W	**Period of Spot Measurement Record**	July 2008 - August 2017
Drainage Area	1.93 km^2	**Period of Logger Record**	2012 (March- September), 2016 (June - August), 2017 (May - June)
Mean Annual Flow	0.02 m3/s	**Number of Spot Measurments**	23
Annual Precipitation	837.00 mm	**Measurements**	Temperature, Water level, Atmospheric Pressure, Flow, Depth

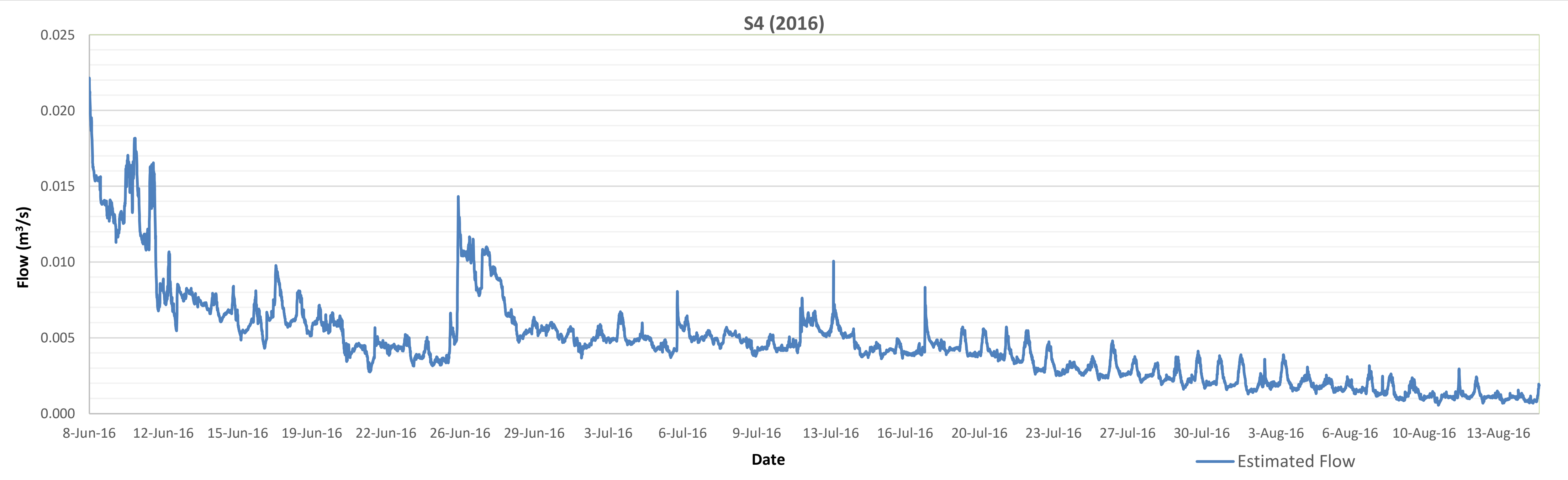
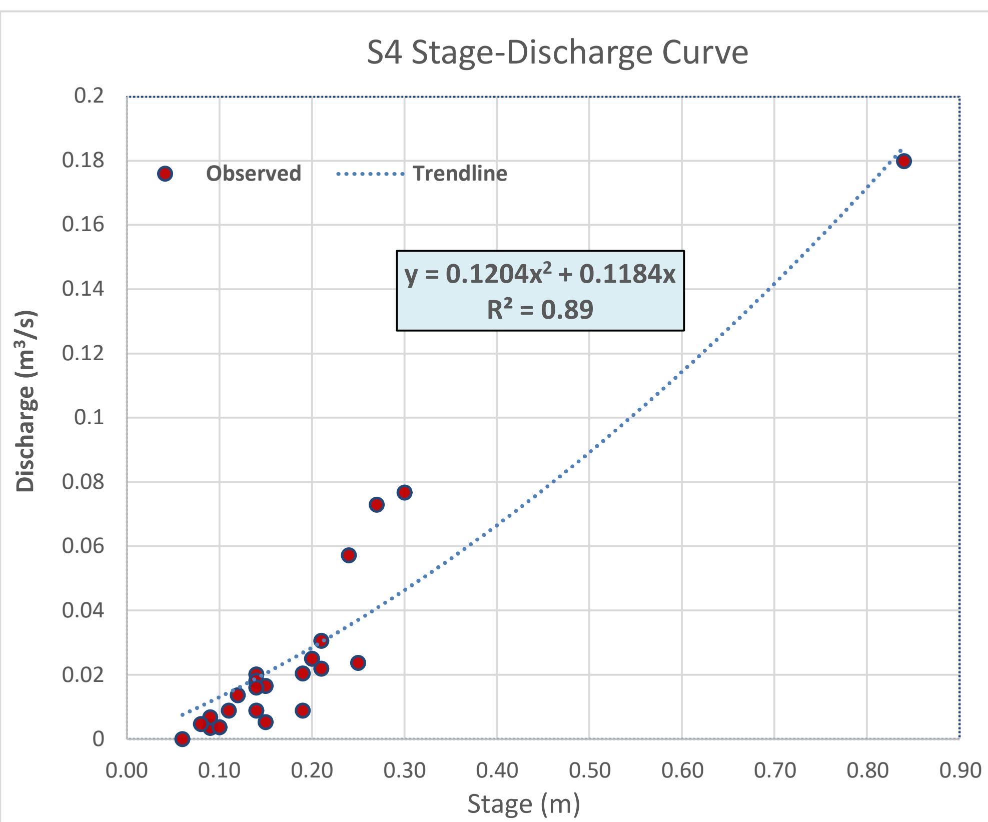
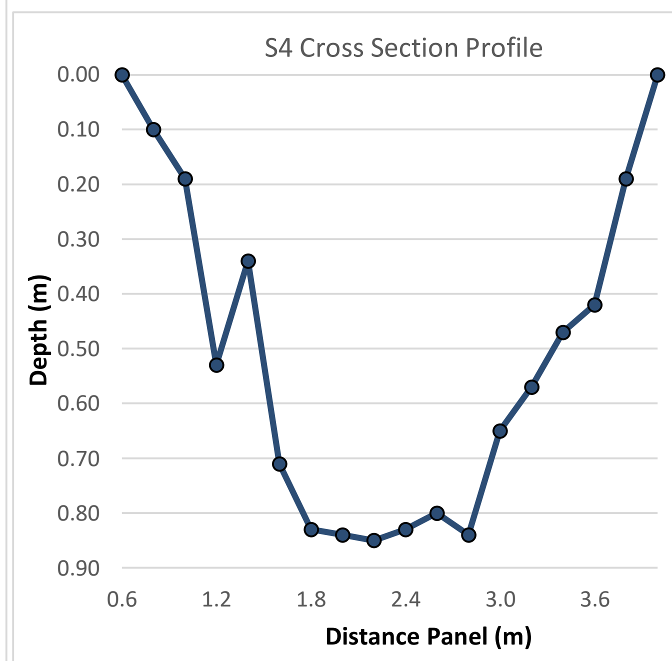
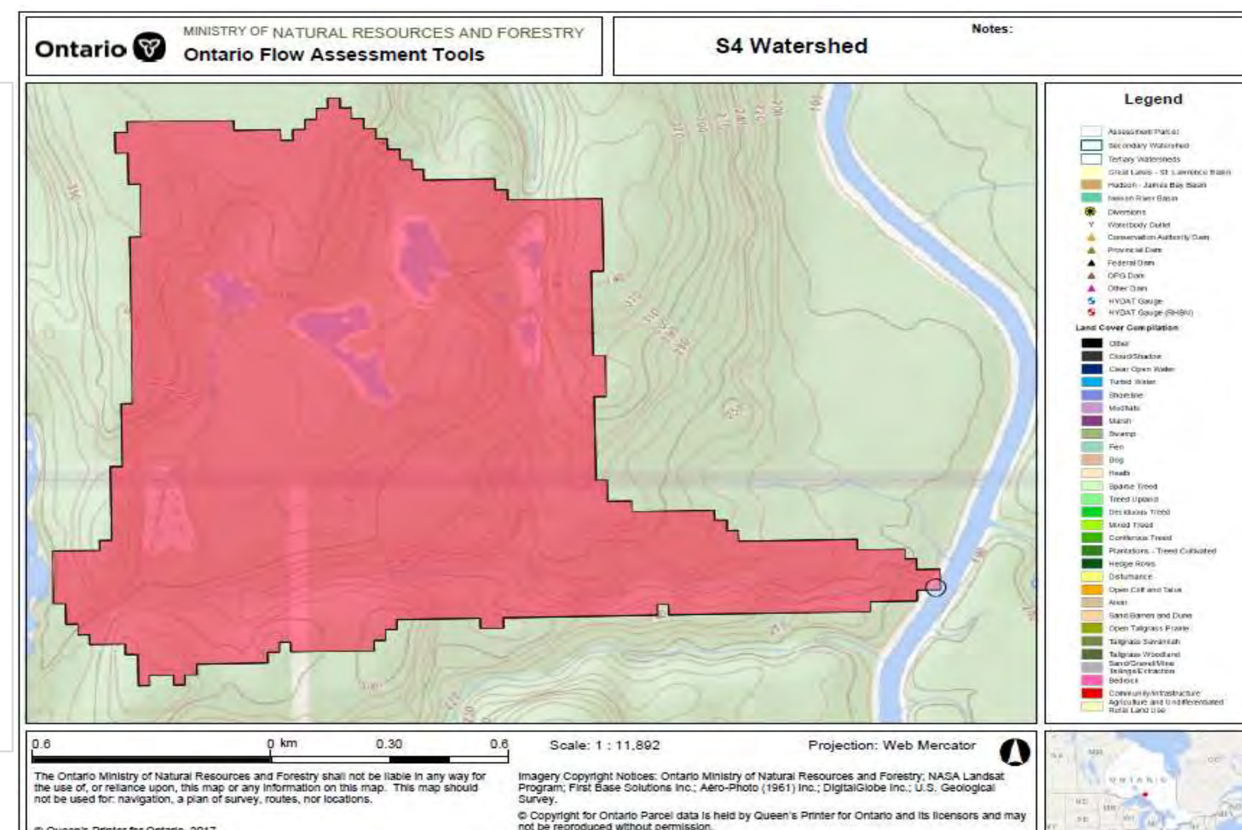


Photo: S4 Field activity







Hydrometric Monitoring Station S6 Summary

Station ID	S6	**Annual Mean Temperature**	2.00 °C
GPS Coordinates	48.79736° N, 86.29064° W	**Period of Spot Measurement Record**	June 2008 - May 2013
Drainage Area	1.93 km^2	**Period of Logger Record**	2012 (March- September)
Mean Annual Flow	0.02 m3/s	**Number of Spot Measurments**	12
Annual Precipitation	837.00 mm	**Measurements**	Temperature, Water level, Atmospheric Pressure, Flow, Depth

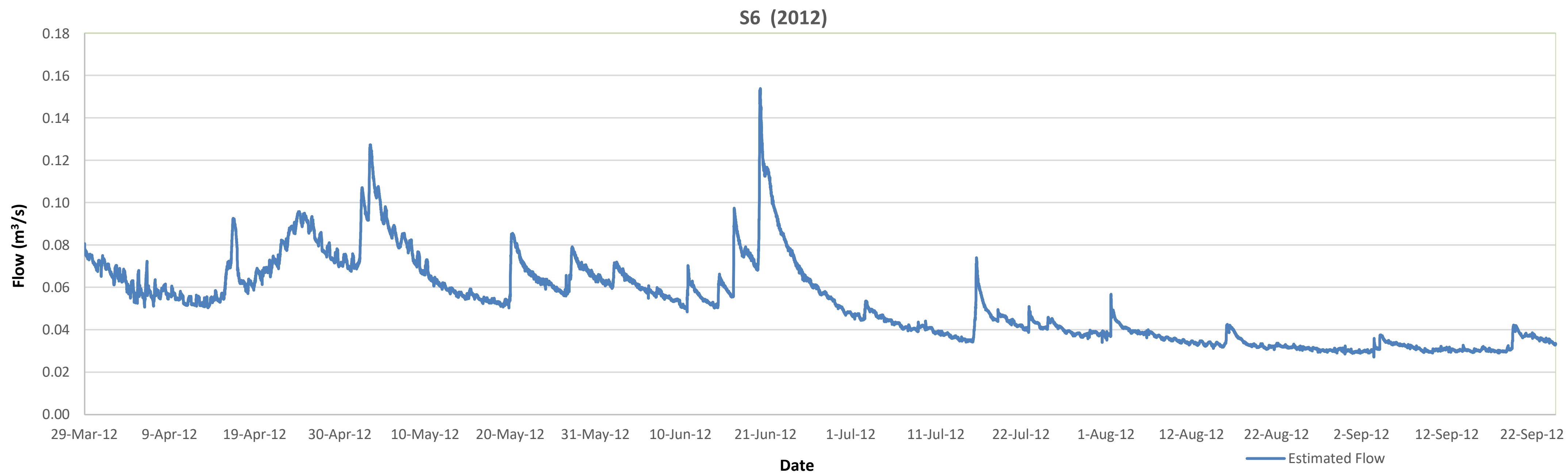
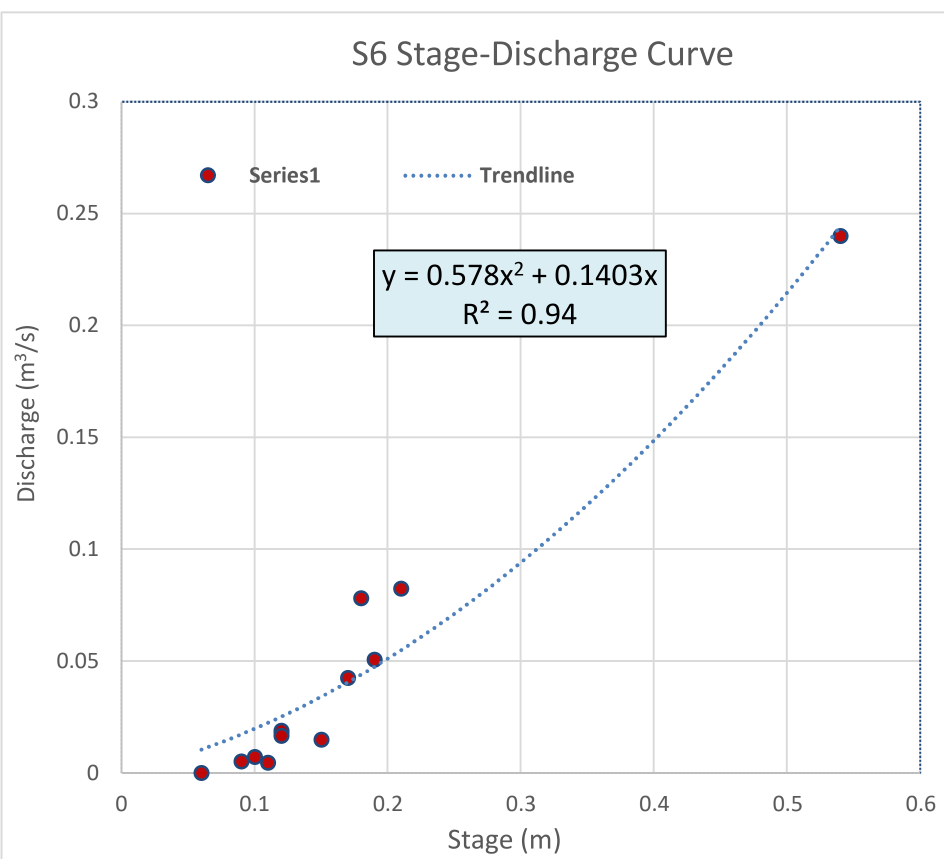
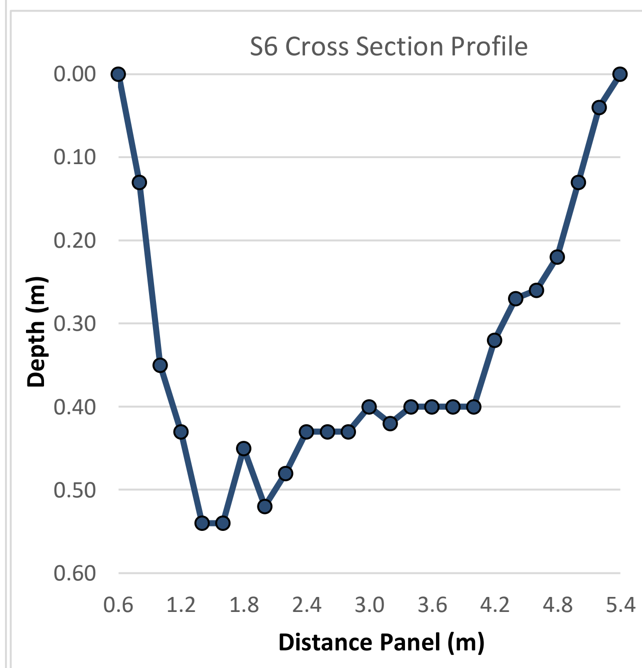
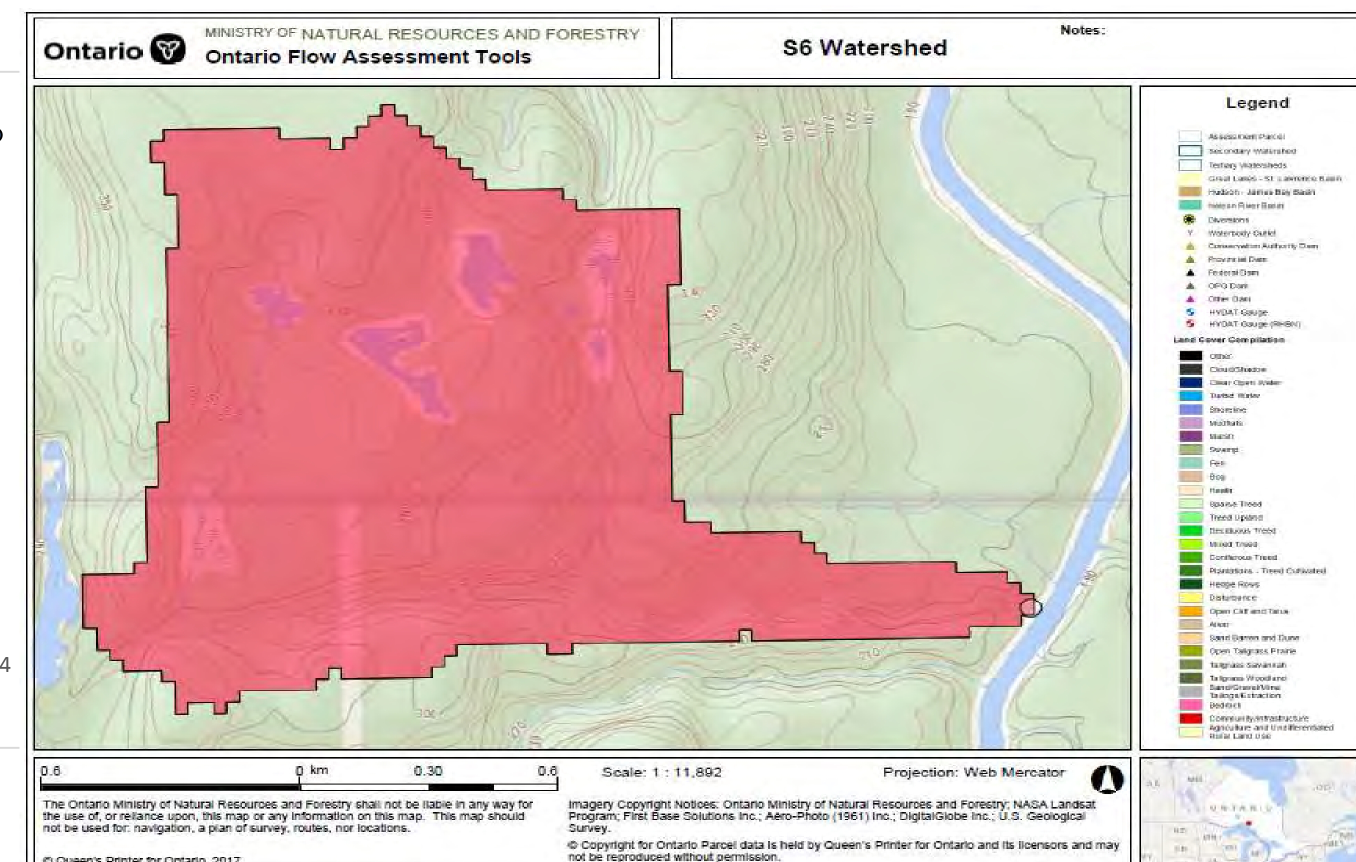


Photo: S6 Field activity







Hydrometric Monitoring Station S8 Summary			
Station ID	S8	**Annual Mean Temperature**	2.00°C
GPS Coordinates	48.81973° N, 86.31663° W	**Period of Spot Measurement Record**	July 2008 - July 2016
Drainage Area	1.97 km^2	**Period of Logger Record**	2016 (June - August)
Mean Annual Flow	0.02 m3/s	**Number of Spot Measurments**	20
Annual Precipitation	837.00 mm	**Measurements**	Temperature, Water level, Atmospheric Pressure, Flow, Depth

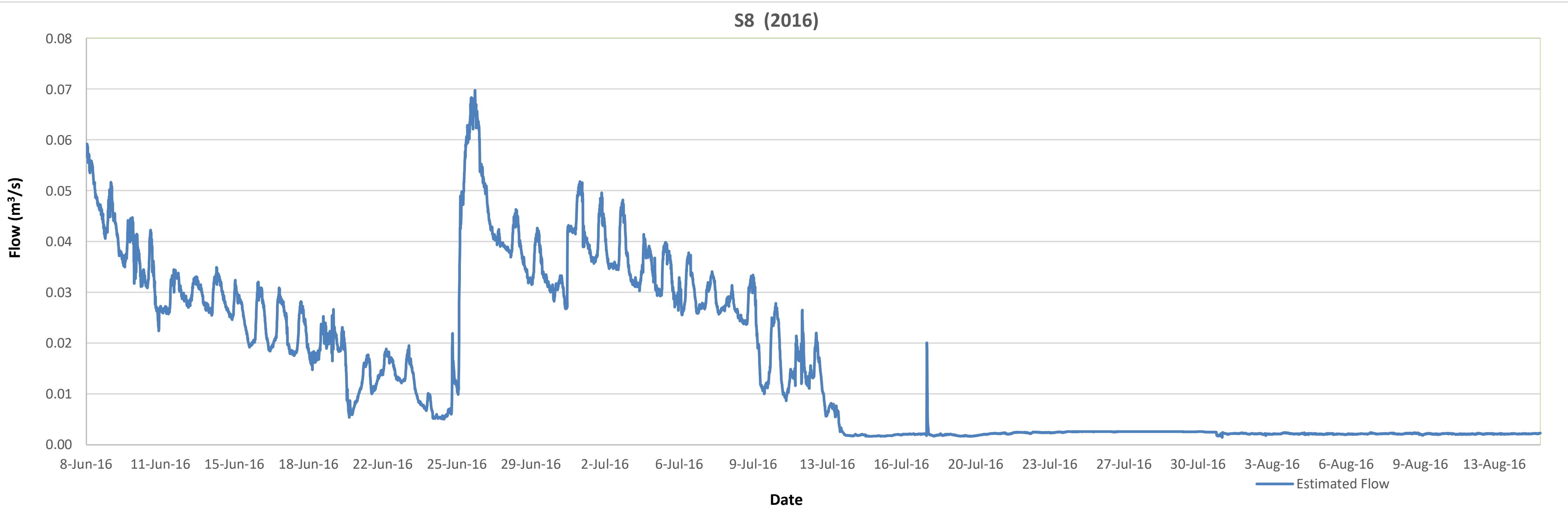
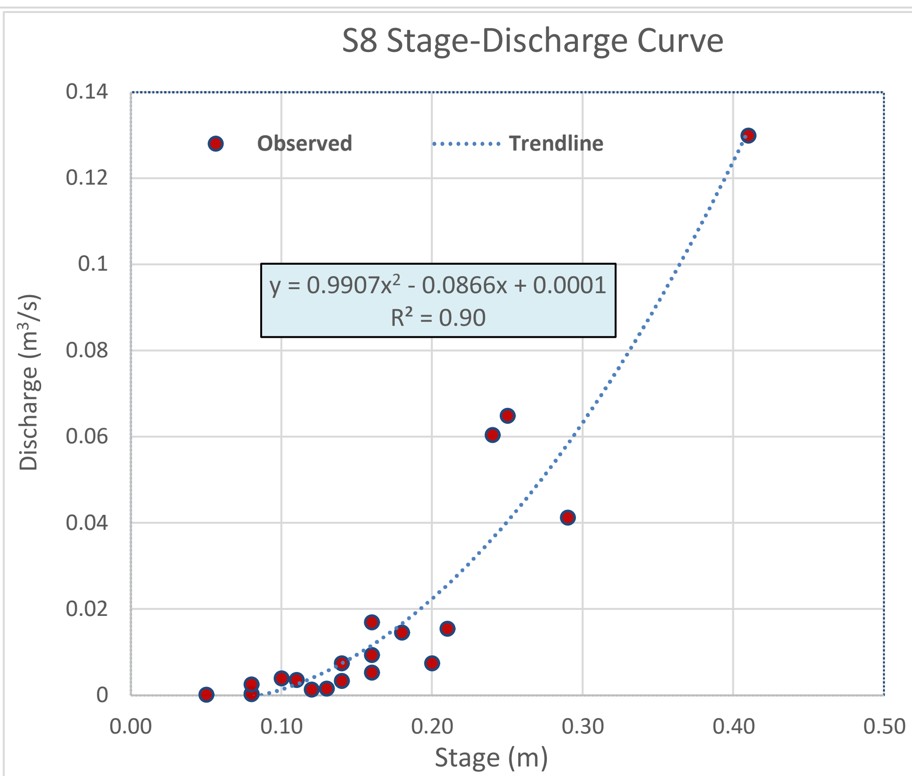
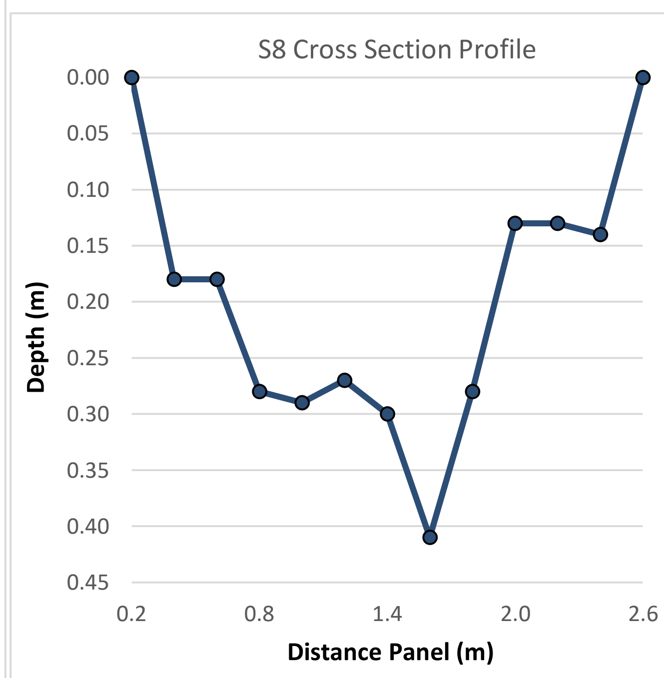
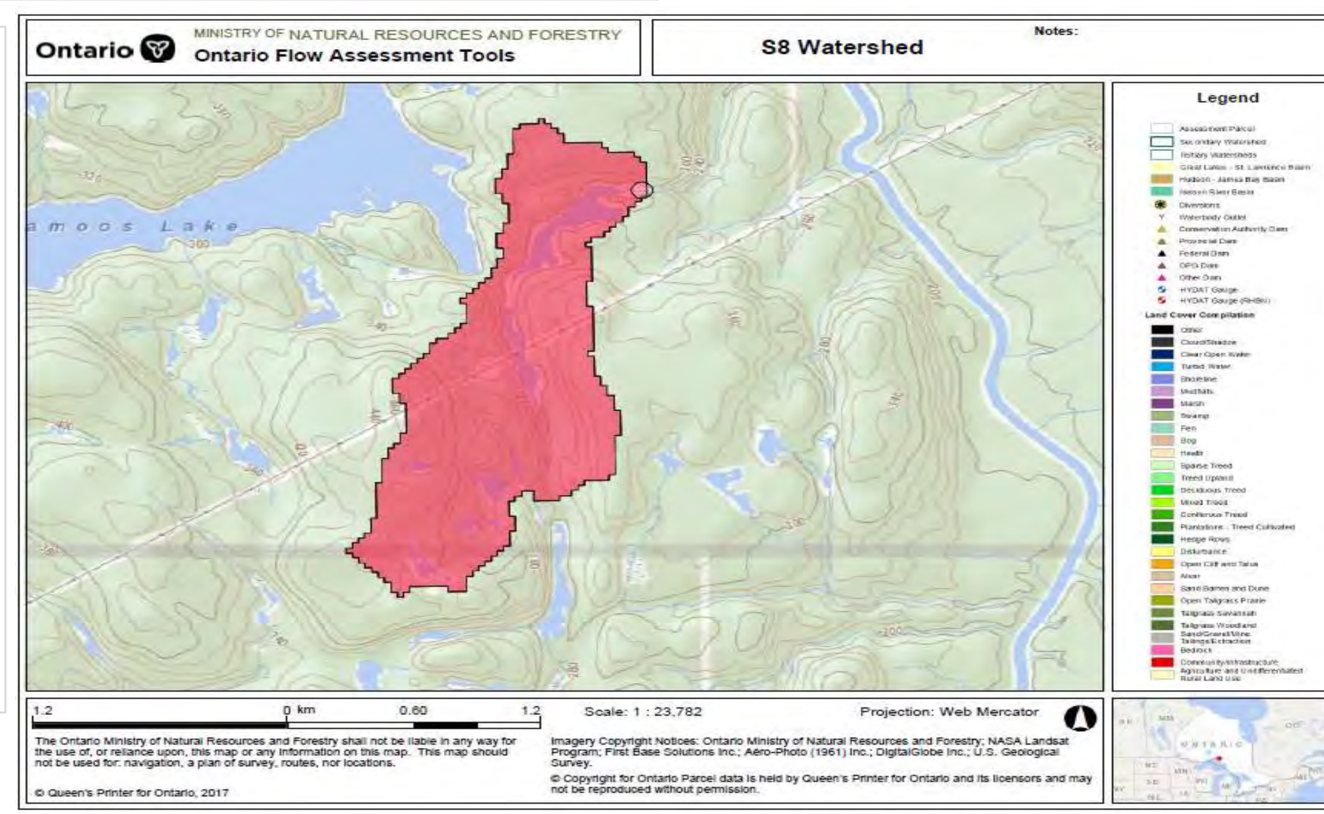


Photo: S8 Field activity







Hydrometric Monitoring Station S9 Summary			
Station ID	S9	**Annual Mean Temperature**	1.90 °C
GPS Coordinates	48.79002° N, 86.36775° W	**Period of Spot Measurement Record**	September 2008 - July 2016
Drainage Area	3.92 km^2	**Period of Logger Record**	2016 (June - August)
Mean Annual Flow	0.05 m3/s	**Number of Spot Measurments**	14
Annual Precipitation	837.00 mm	**Measurements**	Temperature, Water level, Atmospheric Pressure, Flow, Depth

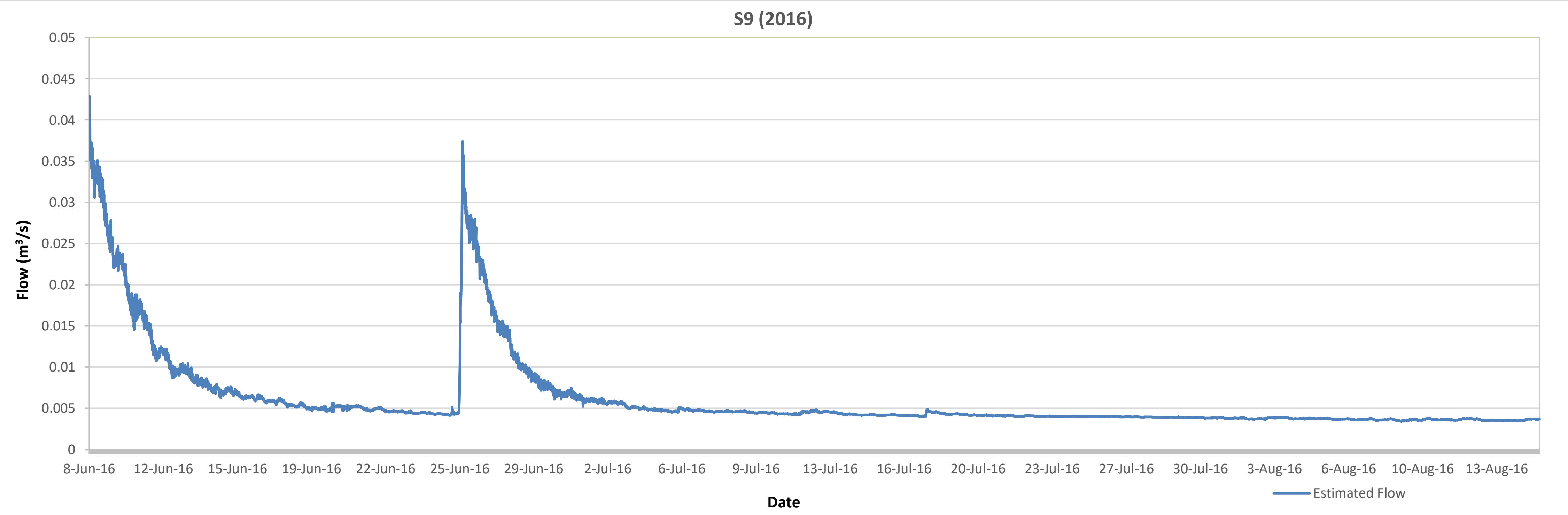
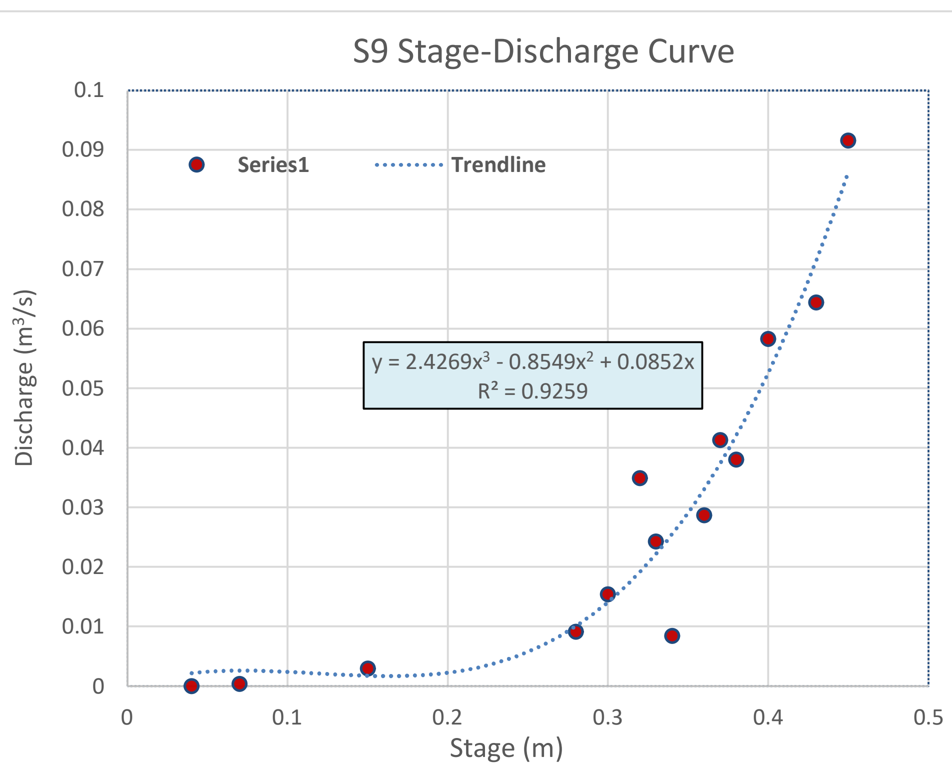
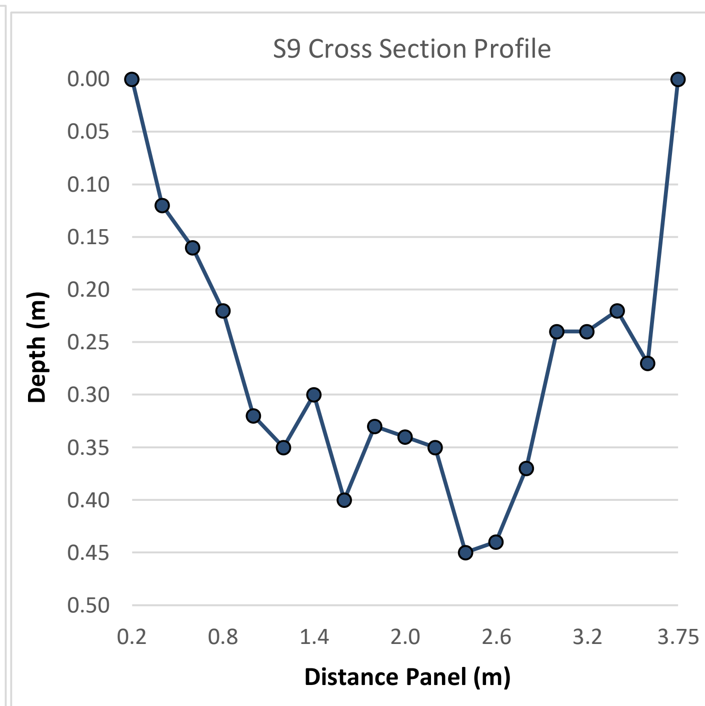
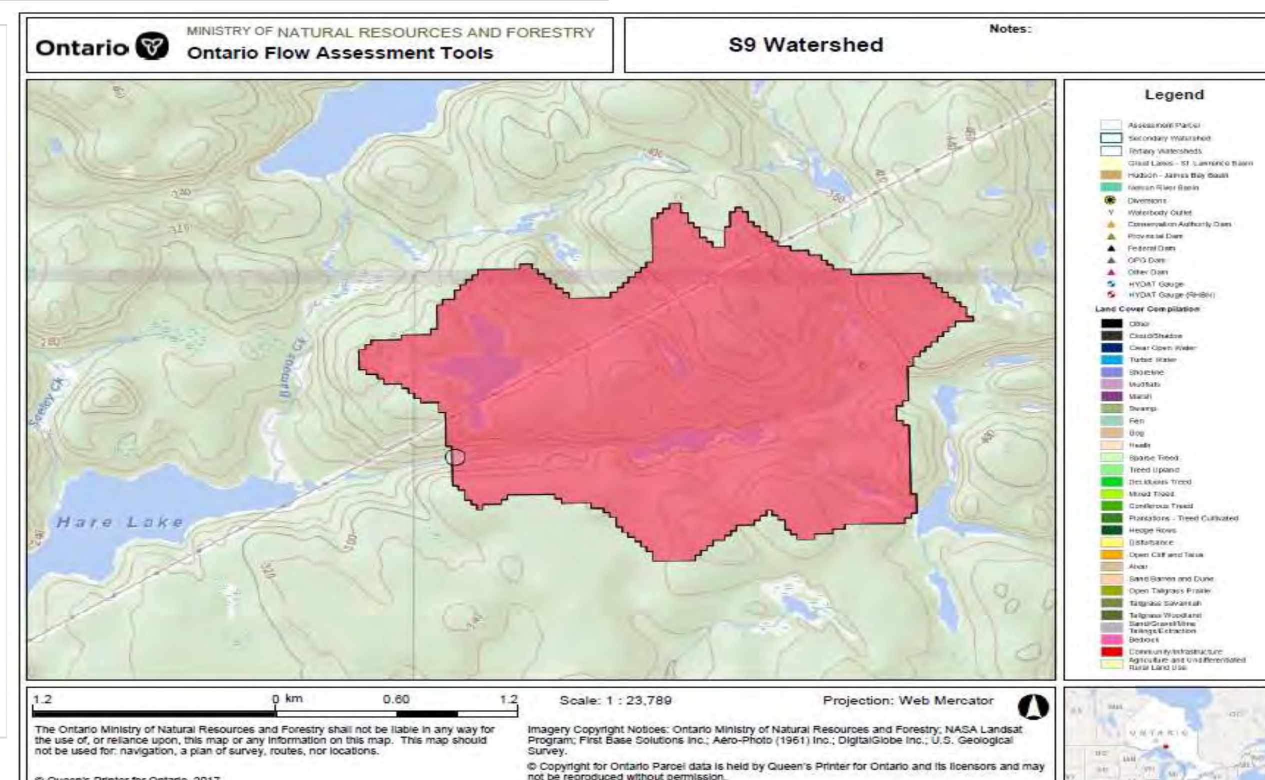


Photo: S9 Field activity







Hydrometric Monitoring Station S10 Summary			
Station ID	S10	**Annual Mean Temperature**	1.90 °C
GPS Coordinates	48.78870° N, 86.37562° W	**Period of Spot Measurement Record**	August 2009 - September 2015
Drainage Area	4.67 km^2	**Period of Logger Record**	2016 (June - August)
Mean Annual Flow	0.06 m3/s	**Number of Spot Measurments**	7
Annual Precipitation	837.00 mm	**Measurements**	Temperature, Water level, Atmospheric Pressure, Flow, Depth

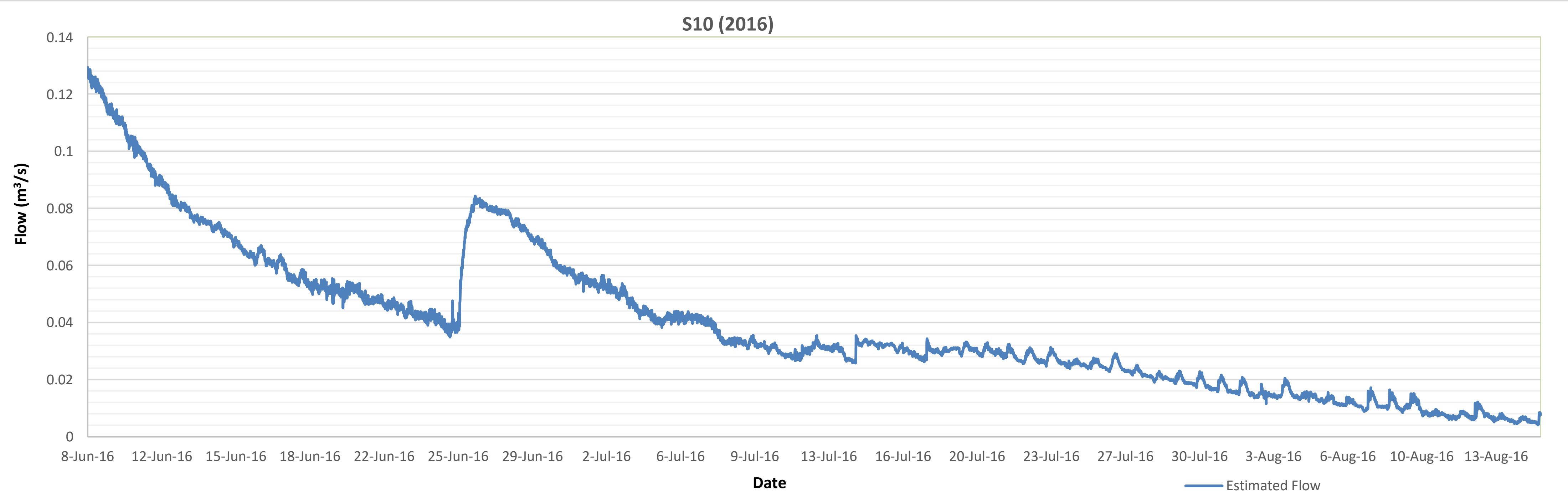
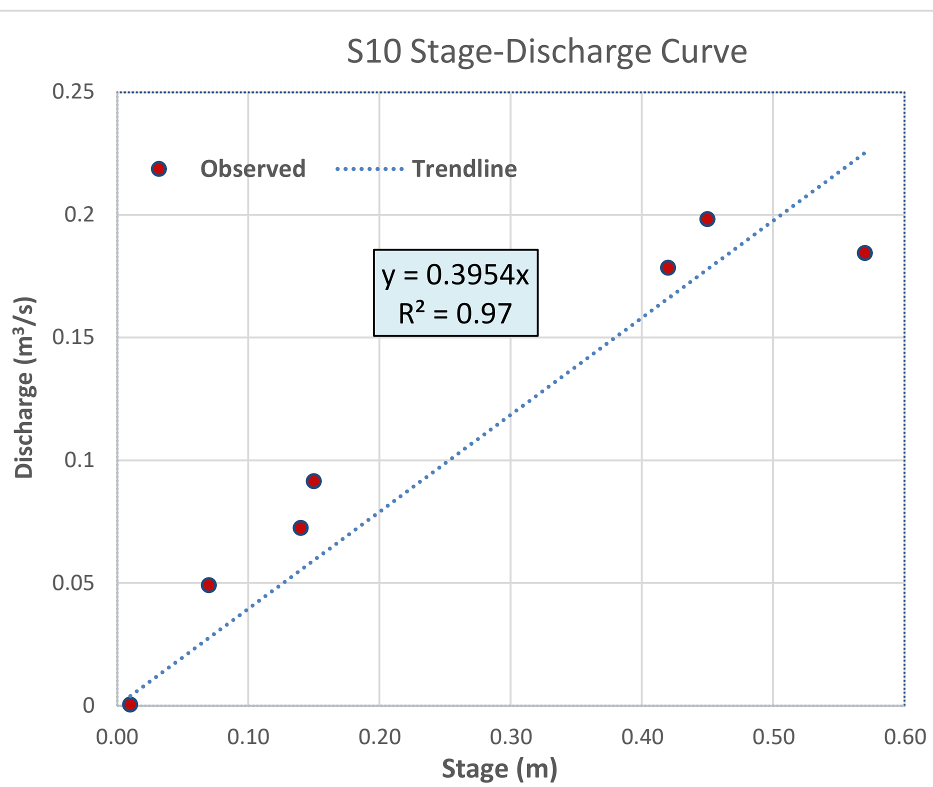
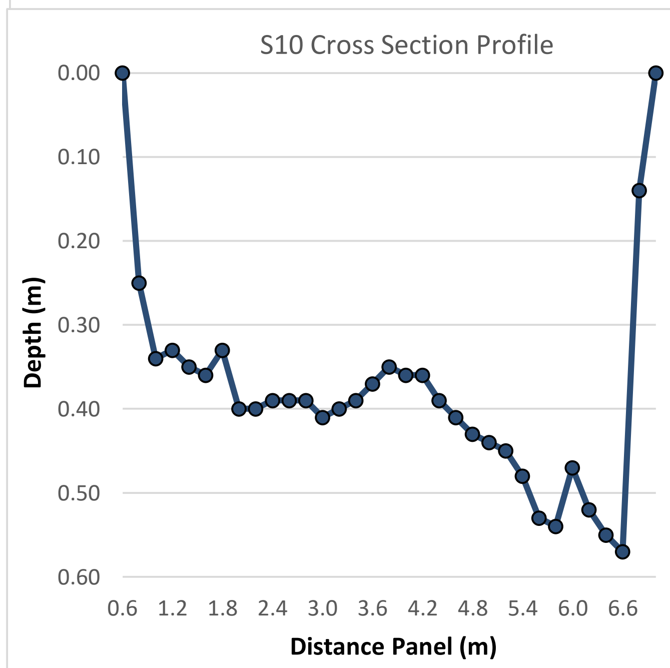
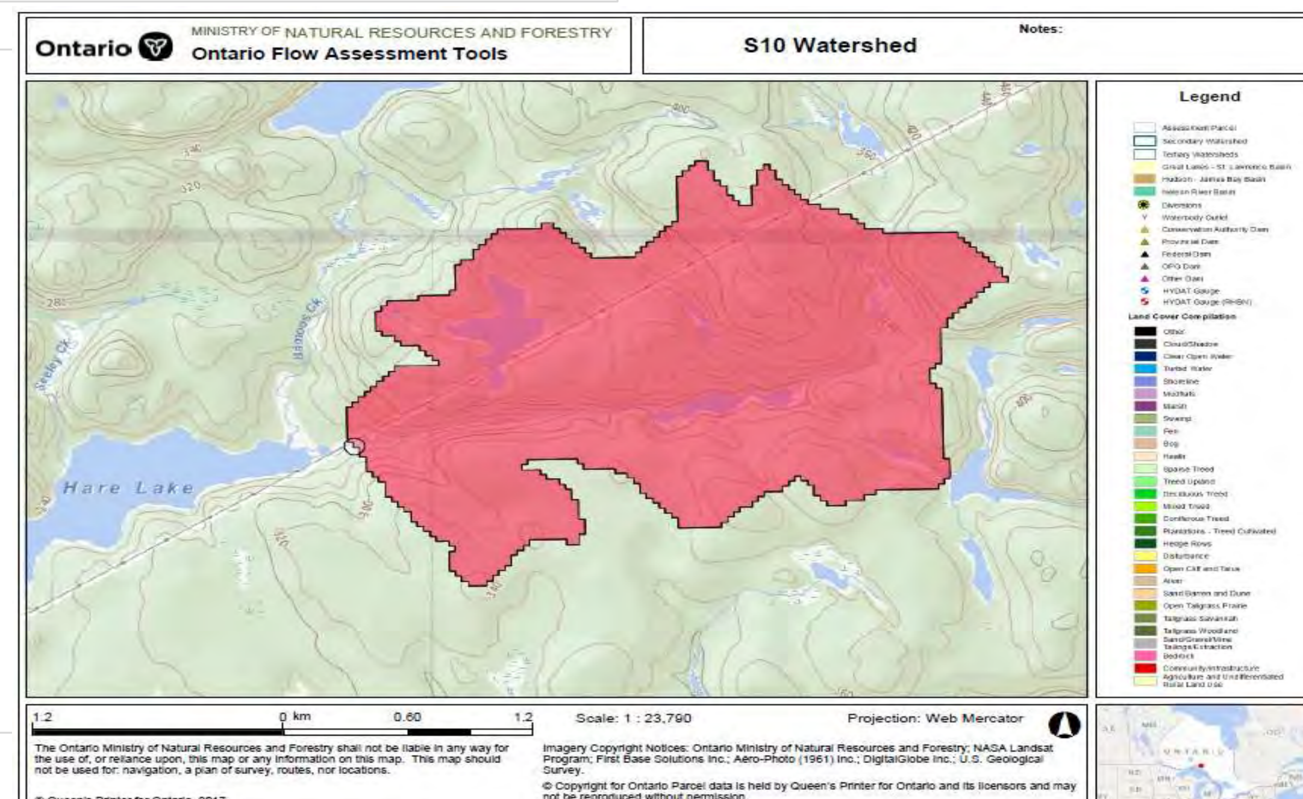


Photo: S10 Field activity







Hydrometric Monitoring Station S11 Summary			
Station ID	S11	**Annual Mean Temperature**	1.90 °C
GPS Coordinates	48.77603° N, 86.40774° W	**Period of Spot Measurement Record**	July 2008 - June 2018
Drainage Area	44.1 km^2	**Period of Logger Record**	2012 (March-August), 2014 (June- September), 2016 (May-August), 2019 (June-September), 2020 (June-July)
Mean Annual Flow	0.54 m3/s	**Number of Spot Measurments**	29
Annual Precipitation	837.00 mm	**Measurements**	Temperature, Water level, Atmospheric Pressure, Flow, Depth

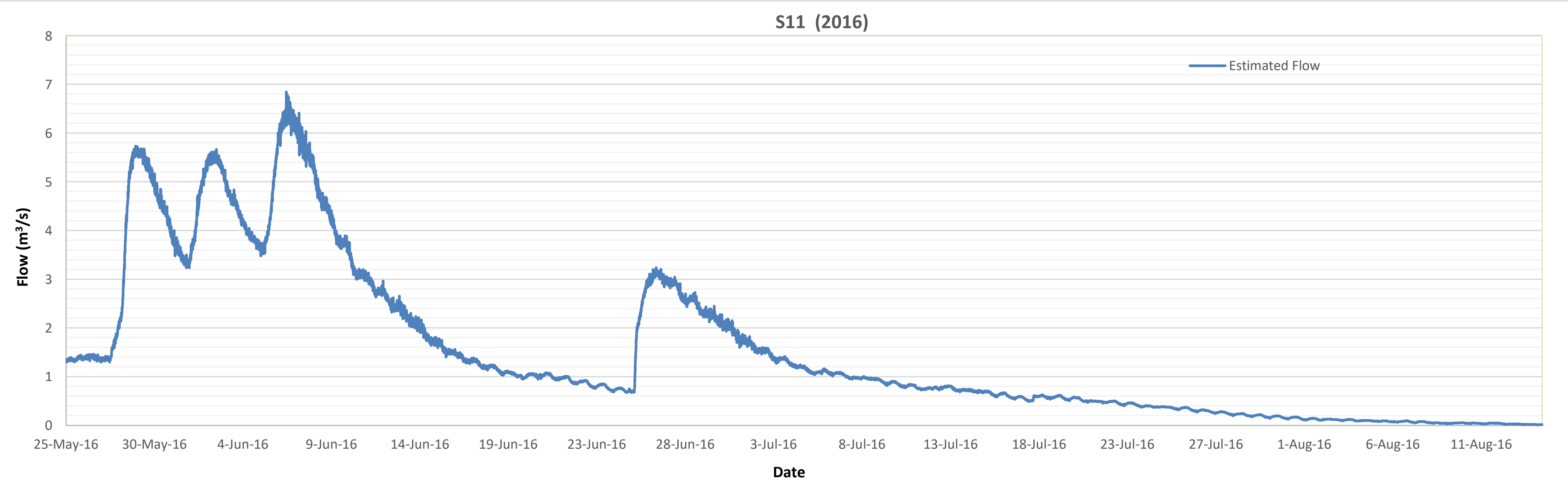
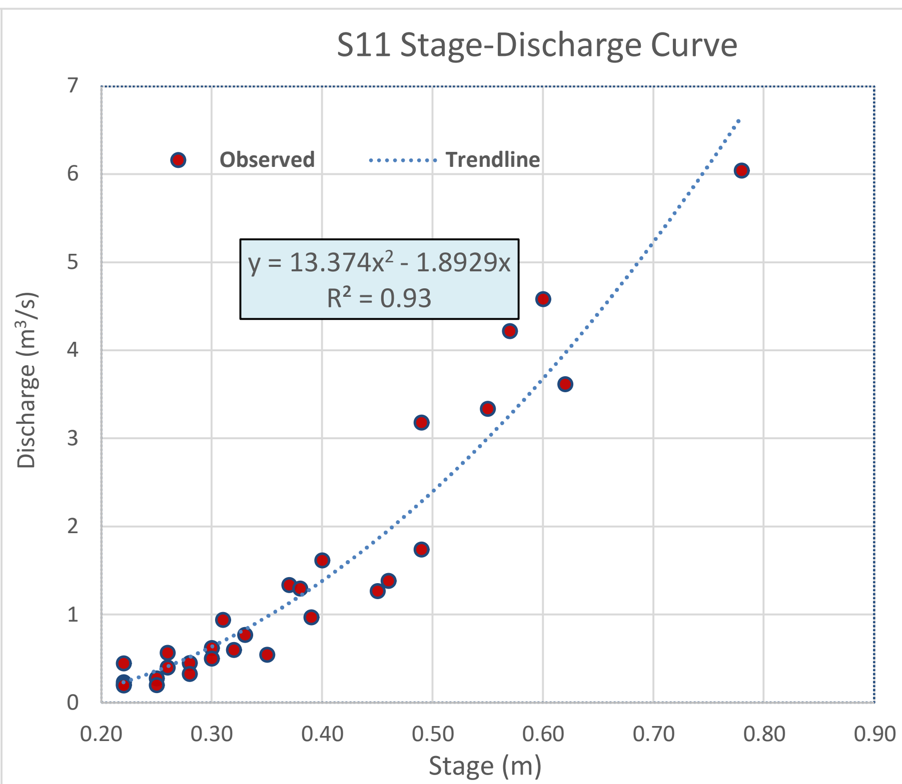
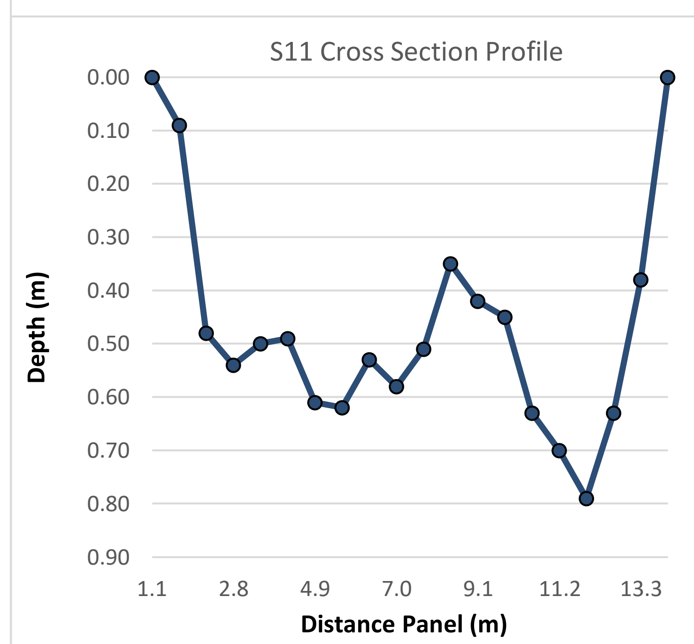
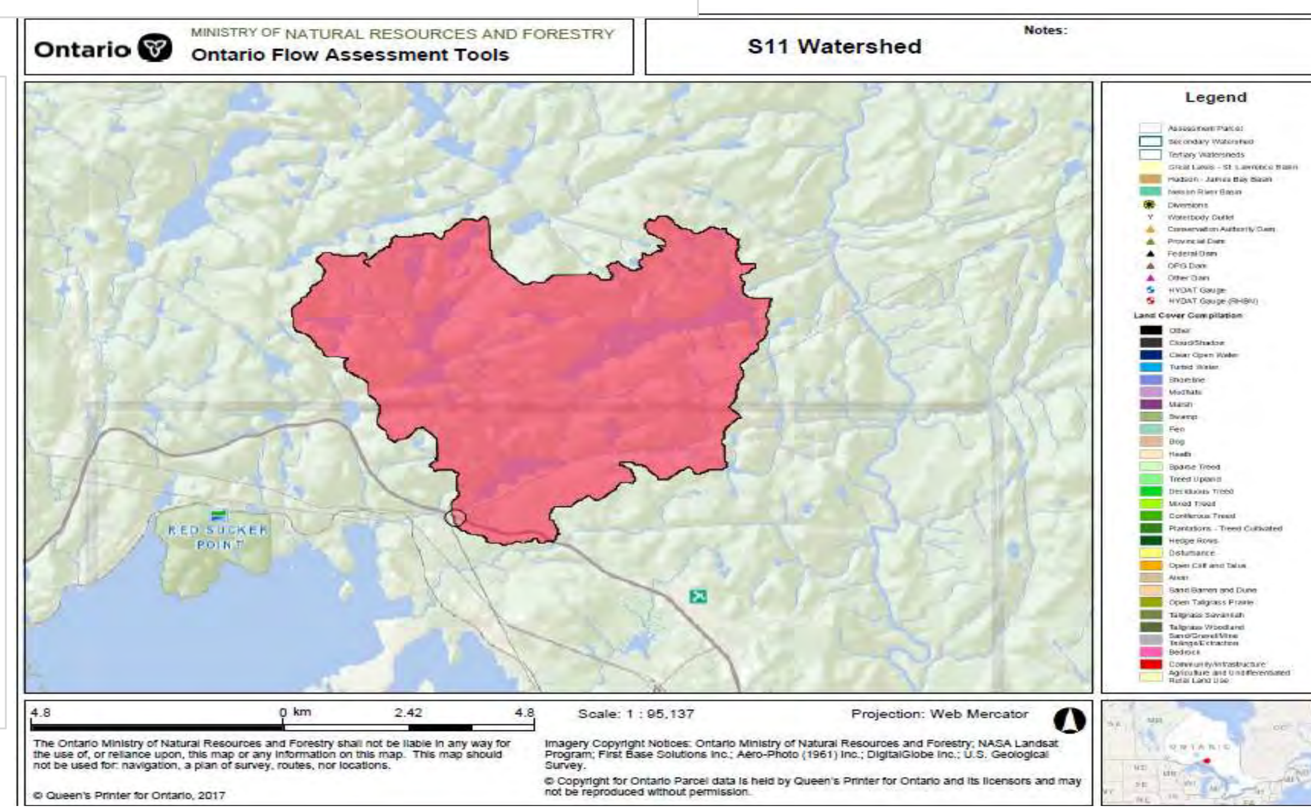


Photo 1: S11

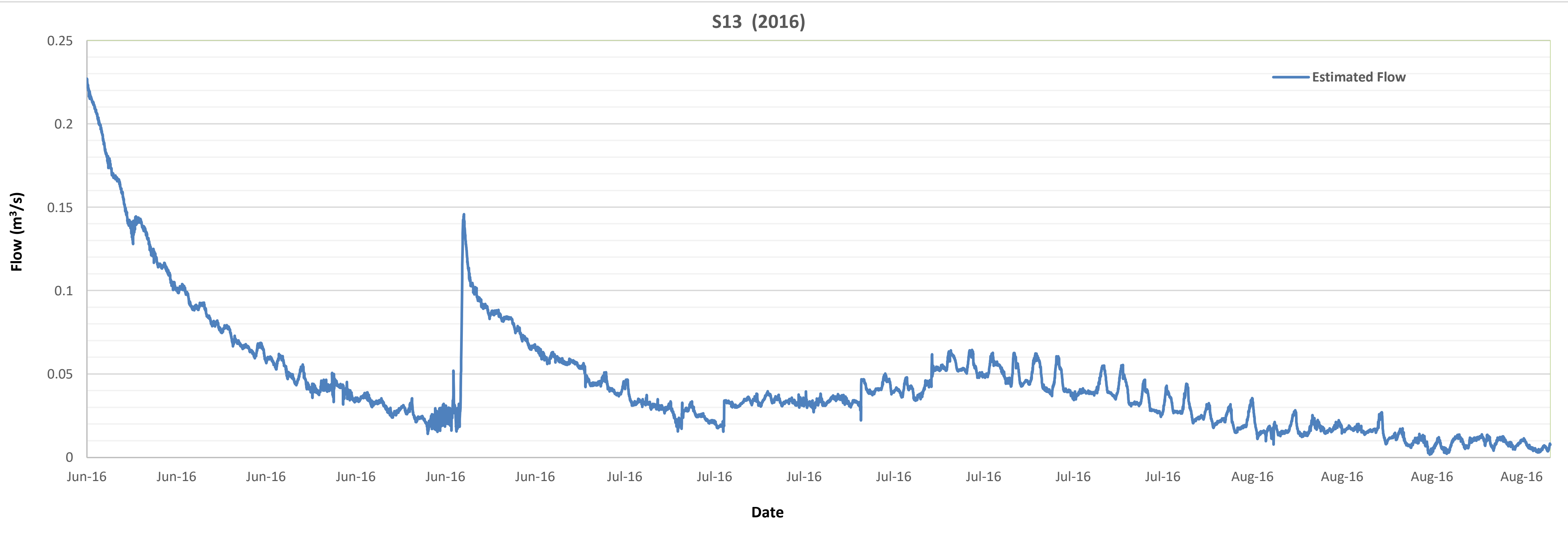


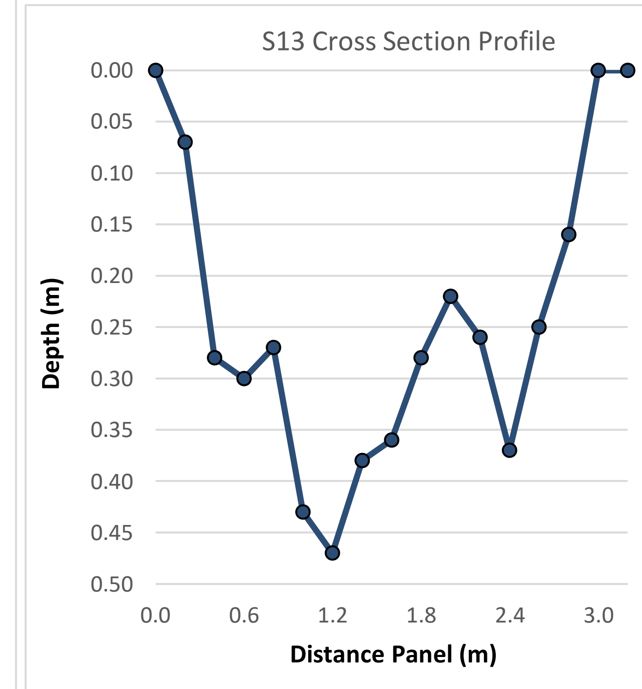


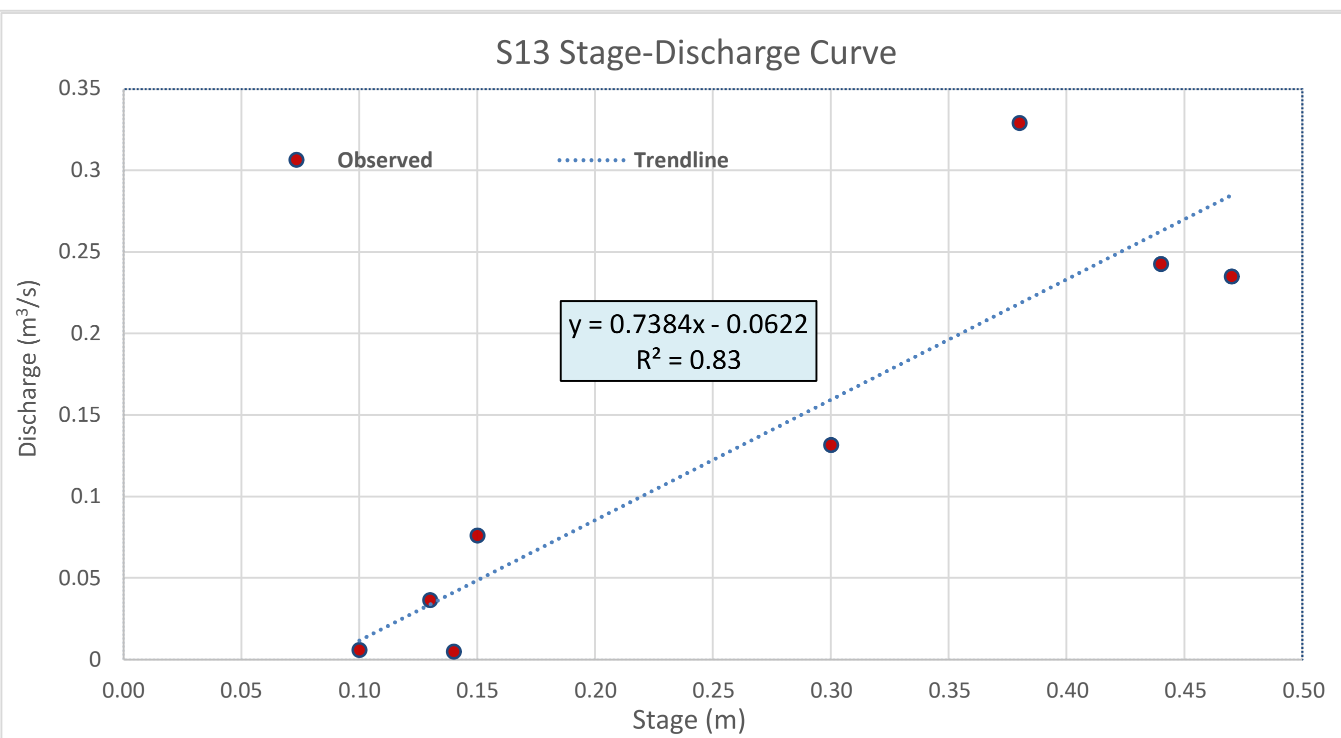


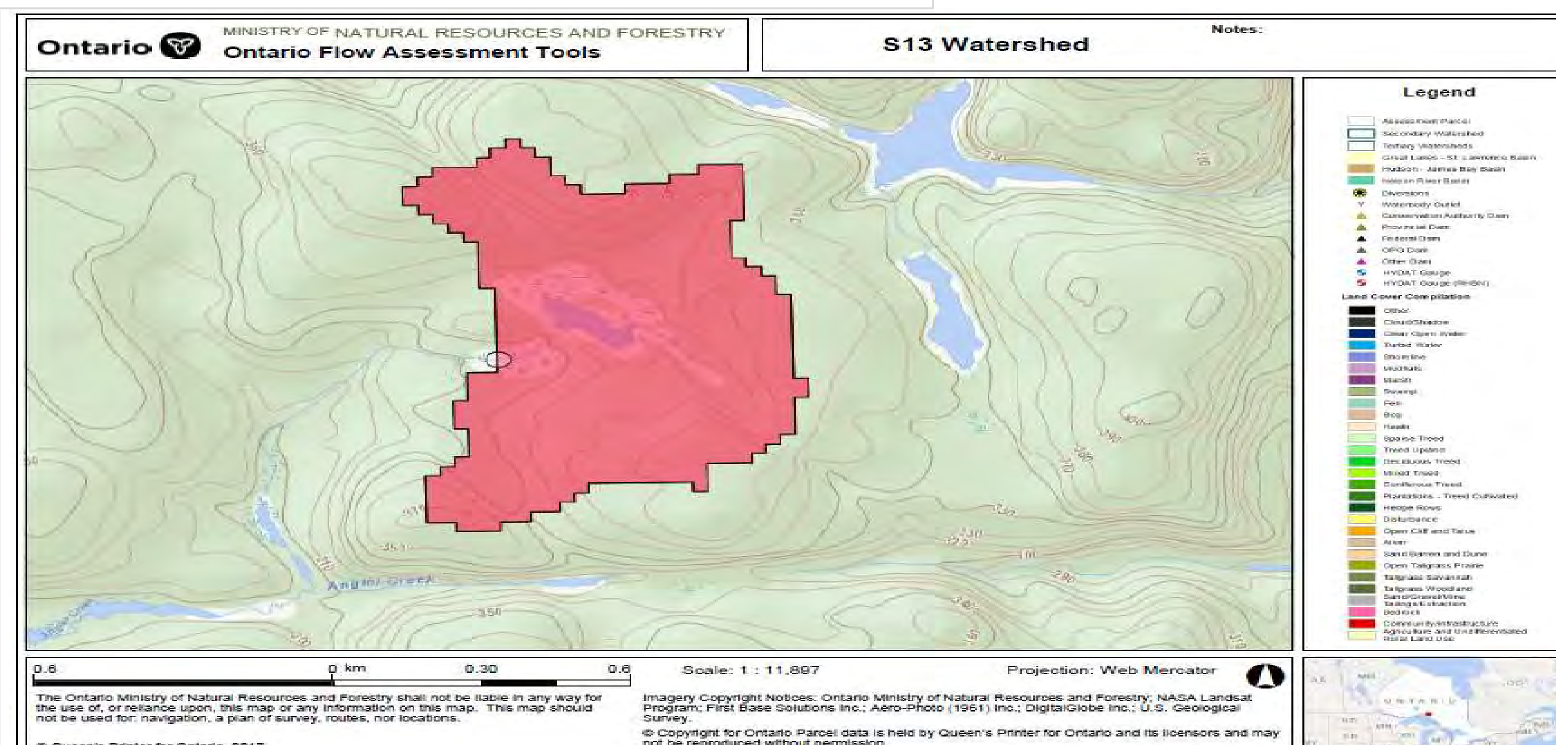
Hydrometric Monitoring Station S13 Summary

Station ID	S13	**Annual Mean Temperature**	2.00 °C
GPS Coordinates	48.78068° N, 86.34673° W	**Period of Spot Measurement Record**	June 2015 - August 2017
Drainage Area	0.653 km^2	**Period of Logger Record**	2016 (June - August)
Mean Annual Flow	0.01 m3/s	**Number of Spot Measurments**	7
Annual Precipitation	837.00 mm	**Measurements**	Temperature, Water level, Atmospheric Pressure, Flow, Depth









Hydrometric Monitoring Station S14 Summary			
Station ID	S14	**Annual Mean Temperature**	1.90 °C
GPS Coordinates	48.77024° N, 86.38135° W	**Period of Spot Measurement Record**	April 2012 - July 2017
Drainage Area	4.86 km^2	**Period of Logger Record**	2014 (June - September), 2016 (May-August), 2019 (June-September), 2020 (June - July)
Mean Annual Flow	0.06 m3/s	**Number of Spot Measurments**	14
Annual Precipitation	837.00 mm	**Measurements**	Temperature, Water level, Atmospheric Pressure, Flow, Depth

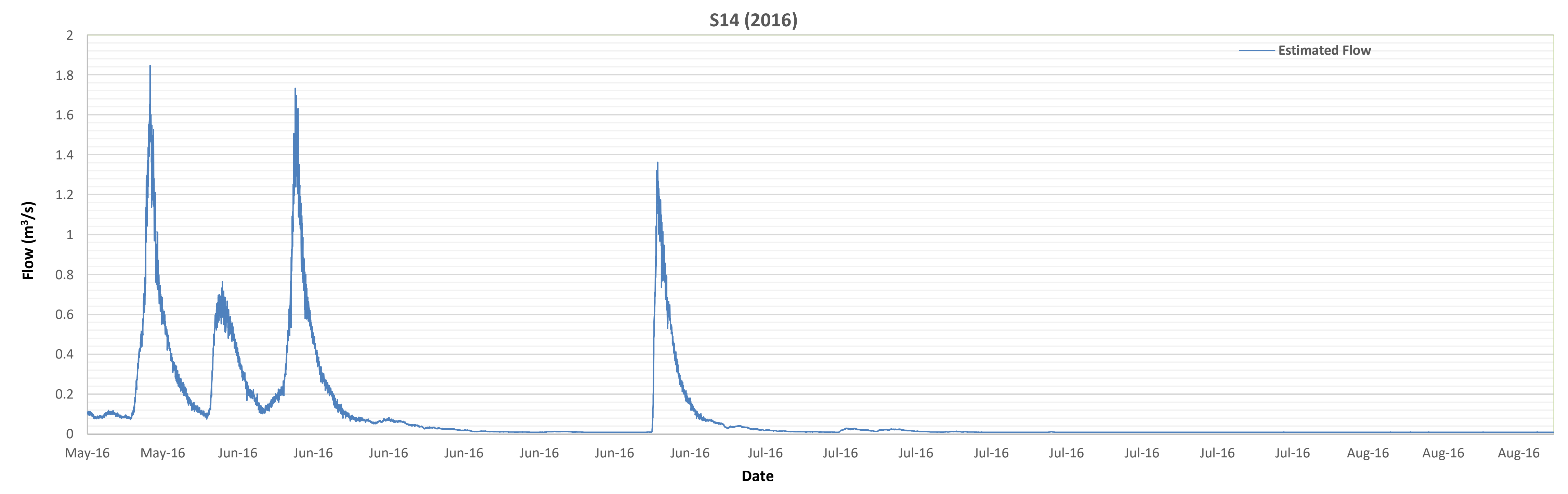
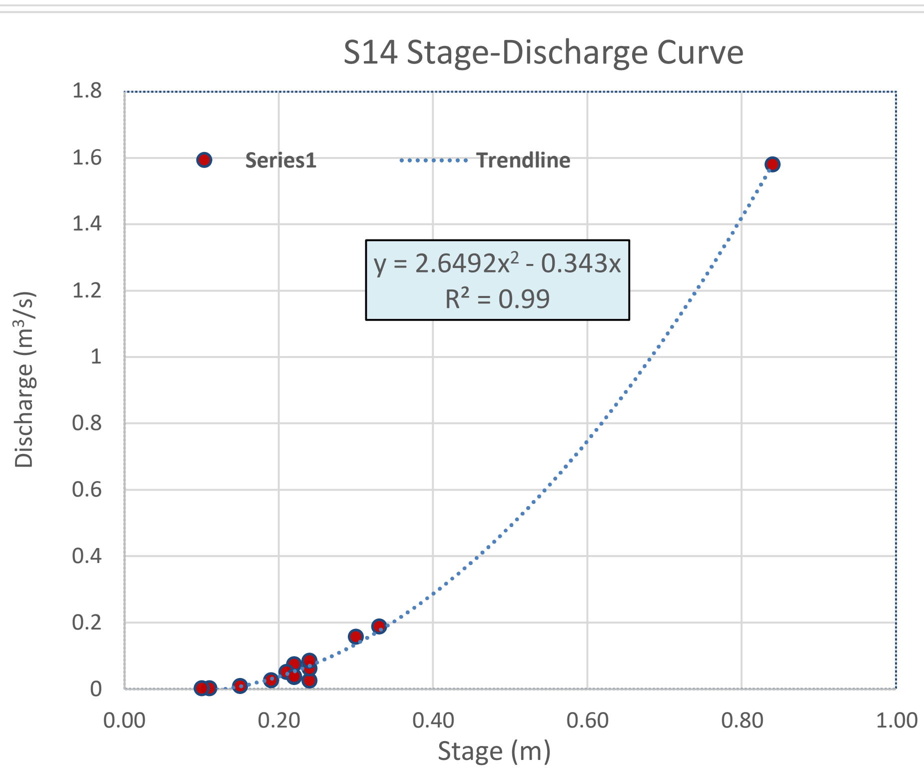
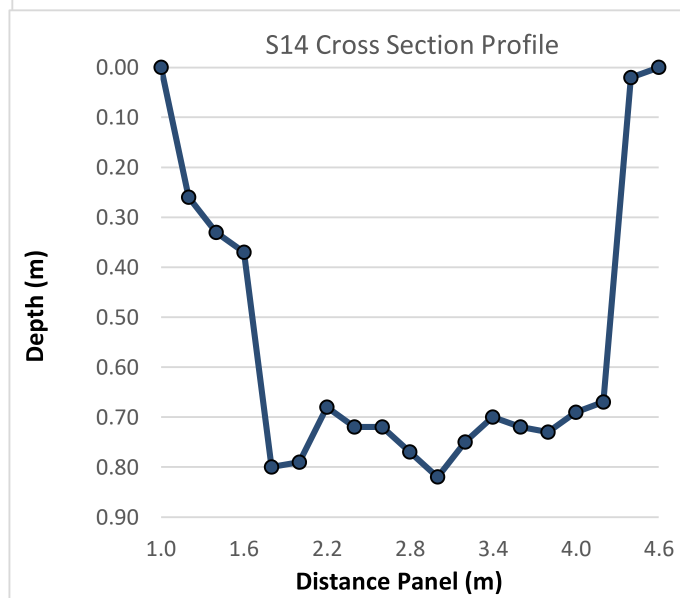
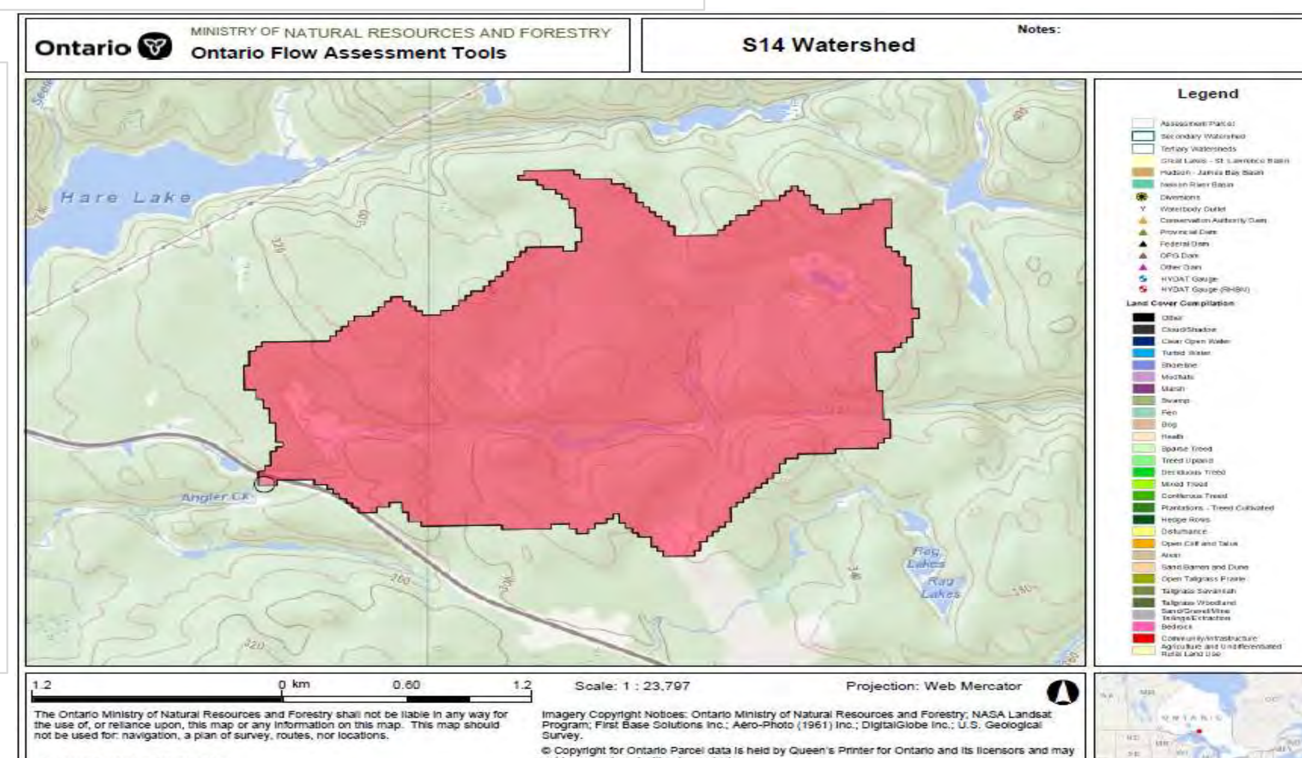


Photo: S14 Field activity







APPENDIX C
Climate Change Data

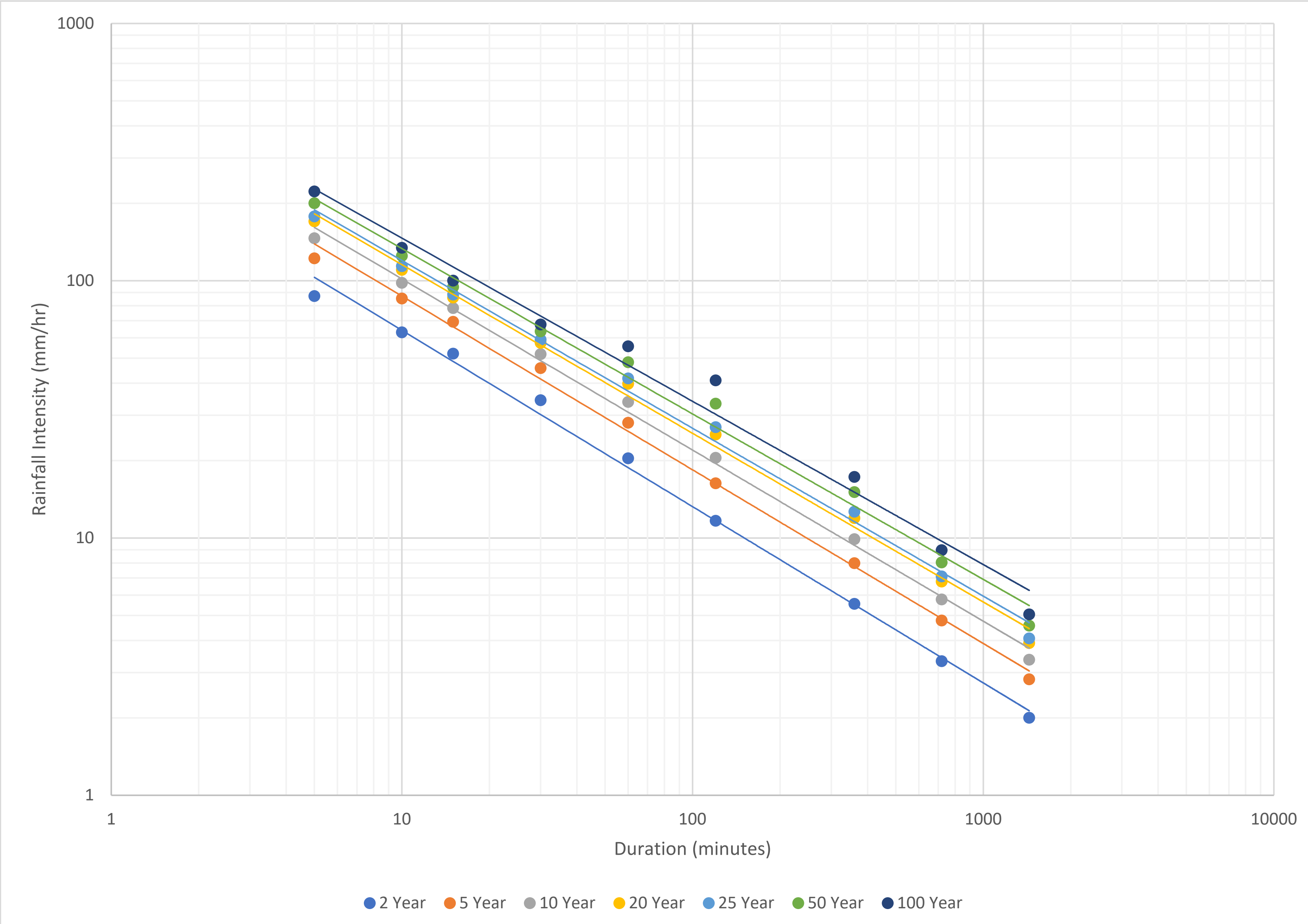


Figure C.1: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station - RCP2.6, Projection Period 2010-2040 (Schardong et al, 2020)

Table C.1: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station - RCP2.6, Projection Period 2010-2040 (Schardong et al, 2020)

Duration	Total Rainfall (mm)						
	2 Year	5 Year	10 Year	20 Year	25 Year	50 Year	100 Year
5 minute	7.25	10.18	12.17	14.15	14.81	16.67	18.51
10 minute	10.5	14.19	16.35	18.37	18.99	20.82	22.38
15 minute	13.0	17.31	19.54	21.49	22.05	23.64	25.02
30 minute	17.16	22.86	25.92	28.65	29.45	31.75	33.79
1 hour	20.39	28.01	33.8	39.7	41.68	48.21	55.58
2 hour	23.35	32.6	41.0	50.42	53.89	66.49	81.95
6 hour	33.21	47.83	59.42	71.59	75.92	90.47	103.69
12 hour	39.82	57.33	69.22	81.17	85.05	96.32	107.52
24 hour	48.0	67.79	80.69	93.5	97.62	109.47	120.84

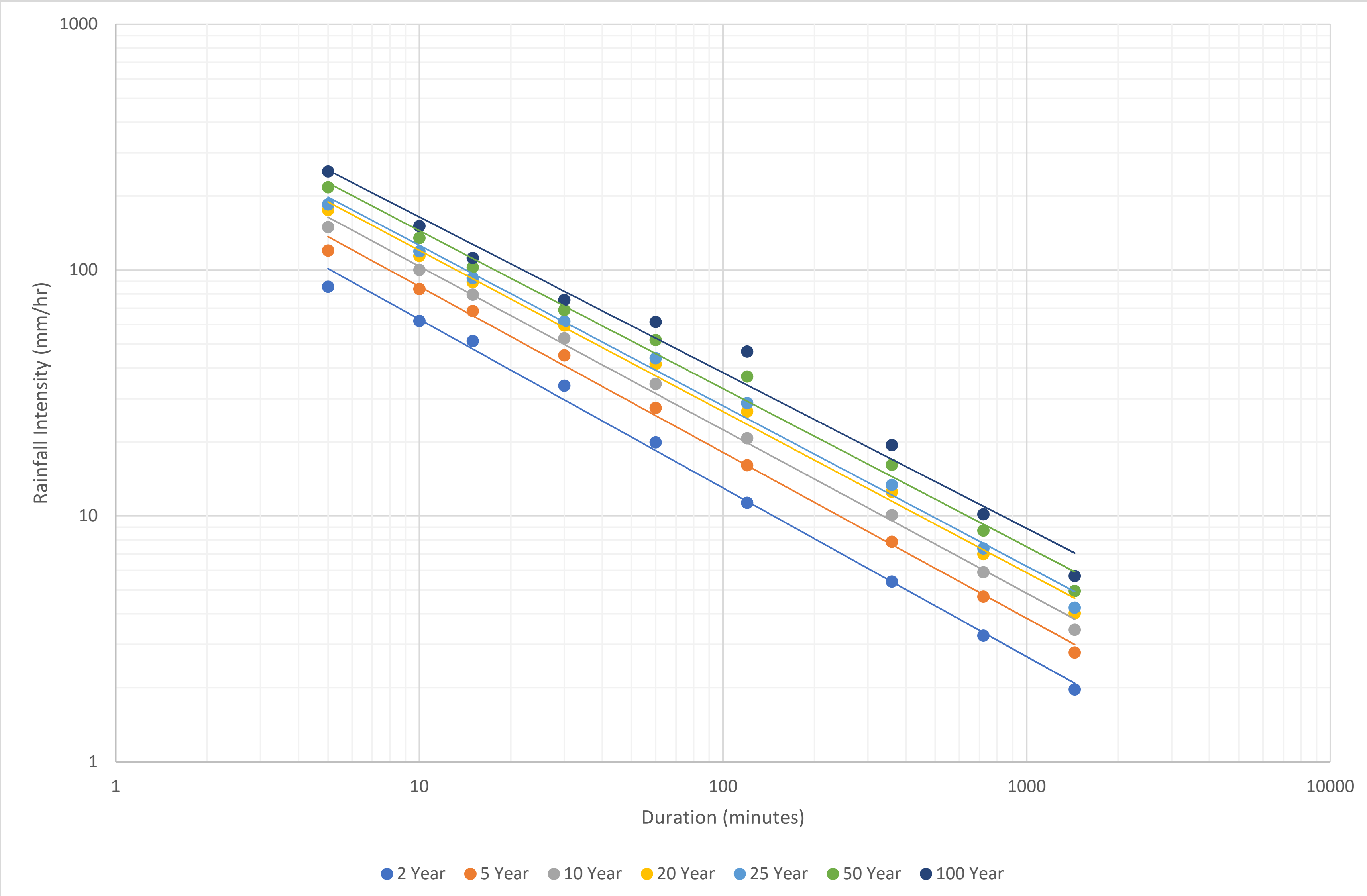


Figure C.2: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station - RCP8.5, Projection Period 2010-2040 (Schardong et al, 2020)

Table C.2: Intensity-Duration-Frequency Curves for Pukaskwa National Park Station - RCP8.5, Projection Period 2010-2040 (Schardong et al, 2020)

Duration	Total Rainfall (mm)						
	2 Year	5 Year	10 Year	20 Year	25 Year	50 Year	100 Year
5 minute	7.12	10.01	12.45	14.64	15.43	18.1	20.98
10 minute	10.35	13.96	16.67	19.04	19.89	22.51	25.14
15 minute	12.84	17.06	19.87	22.34	23.17	25.65	27.99
30 minute	16.94	22.51	26.37	29.75	30.92	34.42	37.78
1 hour	19.94	27.51	34.41	41.5	43.82	51.88	61.44
2 hour	22.6	32.11	41.42	53.14	57.56	73.77	93.26
6 hour	32.39	47.08	60.47	75.21	80.15	96.92	116.49
12 hour	39.09	56.41	70.81	83.92	88.61	104.55	121.74
24 hour	47.18	66.68	82.52	96.57	101.82	118.72	136.6