APPENDIX E.9.3

AEMP Hydrometric Report

2020 Hydrometric Monitoring Report

Mary River Project

Baffinland Iron Mines Corporation

Version	Issue Date
0	March 25, 2021

Prepared by:

North Water Environmental

TABLE OF CONTENTS

PAGE

TABLES

FIGURES (ATTACHED)

1 INTRODUCTION

Stream flow is monitored at the Mary River Project (Project) as part of the Hydrometric Monitoring Program, which is a component study of the Project's Aquatic Effects Monitoring Plan (AEMP, Baffinland, 2015). Hydrometric data were collected at seven stations during 2020. Station identifiers, names, period of records, drainage areas, and station coordinates are summarized in Table 1. The locations of the monitoring stations are shown on Figure 1.

Table 1 2020 Hydrometric Monitoring Program Stations

Station ID	Station Name	Period of Record	Drainage Area (km^2)	Coordinates (UTM)	
				Easting	Northing
H01	Phillips Creek Tributary	2006-2008, 2011-2020	250	532831	7946247
H02	Tom River near outlet to Mary Lake	2006-2008, 2010-2020	210	555712	7915514
H04	Camp Lake Tributary (CLT-2)	2006-2008, 2010-2020	8.3	557639	7915579
H05	Camp Lake Tributary (CLT-1)	2006-2008, 2010-2020	5.3	558906	7915079
H06	Mary River	2006-2008, 2010-2020	240	563922	7912984
H07	Mary River Tributary F	2006-2008 2010, 2011, 2017-2020	14.7	564451	7913194
H11	Sheardown Lake Tributary (SDLT-1)	2011-2020	3.6	560503	7913545

2 HYDROMETRIC MONITORING PROGRAM

The Hydrometric Monitoring Program consists of water level or stage being measured at each station using a pressure transducer and data logger (Seametrics PT2X), which record water level and temperature at 15-minute intervals. The pressure transducers are installed in a stilling well at each station. The water level is measured manually during each site visit relative to at least two benchmarks installed in bedrock. The benchmarks have been maintained throughout the life of each station and differential levelling surveys are conducted during each site visit to relate water level to a local datum. The dataloggers are downloaded and checked for proper operation during each site visit. The data logger water level data are related to the local datum at the end of the season using the survey data.

Where flows permit safe access to a watercourse's channel, a Hach FH950 wading current meter is used to measure stream velocity. Discharge is estimated from the current meter velocity using the area-velocity technique (mid-section method) per the Water Survey of Canada (WSC) guidelines (WSC, 1999). Whenever possible, the stream is divided into a minimum of 20 sections to measure depth and velocity with the objective of having less than 5% of the flow in each section. At least two cross sections of depth and velocity are measured during each site visit. Velocity is recorded at 0.6 of the stream depths where the stream depth is less than or equal to 0.75 m during each measurement.

Where higher flows prevent the use of a wading current meter, dilution gauging using Rhodamine WT is utilized to estimate discharge. The fluorescence of the Rhodamine WT is measured in-situ and recorded using a handheld fluorometer (YSI with 6130 Rhodamine Sensor). Two-point calibration of the fluorometer is conducted in the field using a known concentration of Rhodamine WT solution and stream water. For estimating discharge, Rhodamine WT is added upstream of the station as an instantaneous release of a known volume. The fluorescence is recorded at a sufficient distance downstream to allow for complete mixing of the tracer. At least two measurements are typically performed during each site visit. The stream discharge is estimated using the integration method.

A summary of the data collected in 2020 is provided in the following section.

3 STAGE-DISCHARGE DATA

3.1 Overview

Reconnaissance of the hydrometric stations was initiated in May 2020 to monitor the onset and progression of snow melt and associated freshet flow. Initial snowmelt was observed in late May at the lower elevation stations around the Project site. Snowfall and colder temperatures in early June delayed the onset of the freshet into mid-June. Reconnaissance site visits were conducted during the freshet and each of the stations were installed as early as possible when the stream channels were ice-free. Additional site visits were conducted in late June, July, August, and early September. The stations were decommissioned for winter as late as possible in September prior to (and in some cases during) freeze-up.

The stage-discharge data obtained in 2020 were compared to the existing rating curves, which were last evaluated in the 2019 Hydrometric Monitoring Program Summary (EAG, 2020). In general, rating curves are extrapolated to the maximum recorded stage to capture the range of observed water level in a given year, relative to measured discharge. The Water Survey of Canada Hydrometric Manual (EC, 2012) suggests that rating curves should not be extrapolated beyond twice the highest measured discharge. Where the observed water level is greater than twice the highest measured discharge, it is understood that flow data estimated from extrapolated rating curves are less reliable. Rating curves for each station, inclusive of the data collected in 2020, are presented in Figures 2 to 8. A discussion of the 2020 data collected at each station and an interpretation of the fit of the rating curves is provided in the following sections:

3.2 H01 (Phillip's Creek Tributary)

The H01 hydrometric station was installed on June 22. A stage-discharge measurement was recorded at the time of installation using dilution gauging. Additional site visits were made in July, August, and September during lower flow conditions using a wading current meter and the area velocity technique. The 2020 measurements are consistent with the existing rating curve presented in Figure 2. As such, no update to the rating curve was required and the existing curve developed in 2007 was used for the development of the 2020 streamflow record.

3.3 H02 (Tom River)

The data logger / pressure transducer was installed at the H02 hydrometric station on June 14 and data collection began on June 21 when the channel was completely ice-free. A stage-discharge measurement was recorded at H02 during high flow conditions in June using dilution gauging. Low flow measurements were made in July, August, and September using a wading current meter and the area velocity technique. The high flow measurement falls below the existing rating curve and just within the 15% range of uncertainty typically associated with dilution gauging techniques (Figure 3). A high flow measurement obtained in 2008 is consistent with the rating relationship, however additional high flow measurements should be collected in future seasons to assist with the validation of the rating curve. The mid and low flow measurements are consistent with the 2012 rating curve (Figure 3) and it was used for the development of the 2020 flow record.

3.4 H04 (Camp Lake Tributary CLT-2)

The H04 hydrometric station was installed on June 21. Measurement of discharge was not possible at the time of installation due to ice overhanging the channel. Stage-discharge measurements were recorded in July, August, and September using a wading current meter and the area-velocity technique. The measurements are consistent with the rating curve that was updated in 2013 (Figure 4). High flow conditions have not been measured frequently at the H04 station since the shift in the rating curve as they are difficult to capture under completely ice-free conditions. The rating relationship at H04 is based on stream channel geometry and the 2013 rating curve is a parallel to and a similar shape to the previous rating curve. The high flows measured in the past (that are part of the previous rating curve) are less than twice the extrapolated flow in 2020 and help confirm the applicability of the updated relationship. Measurements during higher flow conditions should continue to be targeted to improve the confidence in the upper portion of the rating curve.

3.5 H05 (Camp Lake Tributary CLT-1)

The H05 hydrometric station was installed on June 22. Stage-discharge measurements were recorded in June, July, August, and September using a wading current meter and the area-velocity technique. The measurements are generally consistent with the 2007 rating relationships with some of the measurements slightly above or below the curve (Figure 5). None of the points suggest a shift in the rating relationship and scatter has been observed in previous years due in part to the nature of the downstream control. The existing rating curve was used for the development of the 2020 flow record.

3.6 H06 (Mary River)

The H06 hydrometric station was installed on June 25. A stage-discharge measurement was recorded at H06 during the installation using dilution gauging and is not consistent with the existing rating curve developed in 2007 (Figure 6). The measurement was taken during high flow conditions and appears to underestimate flow estimated by the rating relationship. Surveyed water level and photographic records of previous flow conditions also suggest that the June 2020 measurement is an underestimation of flow. Dilution gauging relies on complete lateral mixing of the dye where the concentration is being recorded. Under high flow conditions, the terrain and width of the river at H06 makes it difficult to inject the rhodamine dye and get complete mixing. Incomplete mixing is likely the cause of the underestimation of the June flow measurement. The rating relationship at H06 has been consistent since 2007 and the channel appeared to be stable throughout 2020. The 2020 unit runoff (discharge per unit area) at H06 was compared to the unit runoff at H02 and the two data series were very similar, which is consistent with past observation and further validates the stability of the rating relationship. The existing rating curve was used for the development of the 2020 flow record.

3.7 H07 (Mary River Tributary F)

The H07 hydrometric station was installed on June 22. A stage-discharge measurement was recorded at H07 during the installation using dilution gauging but was not applied to the rating curve as the channel was not completely ice-free. Additional measurements were made in July, August, and September using a wading current meter and the area-velocity technique. The measurements are consistent with the 2019 rating curve (Figure 7). The data collected in 2020 further validate the low flow portion of the 2019 rating curve and it was used for the development of the 2020 flow record.

3.8 H11 (Sheardown Lake Tributary SDLT-1)

The H11 hydrometric station was installed on June 10. Stage-discharge measurements were recorded at H11 during June, July, August, and September and were consistent with the rating curve updated in 2014 (Figure 8). There remains some uncertainty around the higher stage-discharge conditions at H11 and as such, higher flow measurements should continue to be targeted to further validate the high flow portion of the rating curve. The 2014 rating curve was used for the development of the 2020 flow record.

4 STREAMFLOW HYDROGRAPHS

Streamflow records were developed for each station by applying the water level data to the corresponding rating curves. The discharge hydrographs for the H01, H02, H04, H05, H06, H07, and H11 hydrometric stations are presented in Figures 9 to 15.

The discharge records from all stations were converted to equivalent unit runoff (discharge per unit area) and are presented for comparison purposes on Figure 16. The 2020 records of unit runoff generally agree well with each other, exhibiting similar timing and magnitude of runoff events and similar patterns to previous years. The stations were installed as soon as the streams became ice free. The (H04, H05, and H11) stations were visited prior to installation and it was confirmed that the bulk of the snowmelt occured prior to the channels being free of ice. Flow monitoring is not possible with ice in the channel as the melting process continuously modifies the stage discharge relationship.

The bulk of the freshet period was captured at the H01, H02, H06, and H07 stations. A strong diurnal melt pattern is evident into mid July at these stations as they have higher elevation catchments. Generally similar unit runoff patterns are evident at all stations from mid-July into September, which suggests that the precipitation was generally consistent throughout the region. There was a short gap in data collection at the H04 station in August due to a malfunctioning data logger.

The estimated mean monthly discharge and unit runoff for each station in 2020 are summarized in Table 2.

The H05 station has been used since 2014 to provide a comparison of general flow conditions from year to year. The H05 station has been used for this purpose because it is positioned near the mine, has a relatively small drainage area, and has had a reliable rating curve and record of flow since 2006. A summary of flows at H05 from 2006 to 2020 is shown on Figure 17. The total annual runoff recorded in 2020 at the H05 station was less than the average from 2006 to 2020 for concurrent periods of record. The flow measured in 2020 was lower than normal in June and early July, due to the majority of freshet occurring prior to the channel being ice-free (and/or being less than normal). The volume of flow measured during summer (mid-July to mid-August) was also lower than normal (less than half of the average flow for this period). The volume of flow measured during August 2020 was similar to August 2019 and lower than the 2006-2020 average.

Table 2 Summary of 2020 Mean Monthly Estimated Discharge and Unit Runoff

STATION	Drainage Area (km^2)	Estimated Mean Monthly Discharge (m^3/s)				Period of Record
		June	July	August	September	
H01	250	40.8	7.6	3.1	2.1	June 18 to September 9
H02	210	52.3	10.6	3.2	2.2	June 21 to September 19
H04	8.3	0.61	0.12	0.07	0.03	June 21 to September 12
H05	5.3	0.24	0.08	0.06	0.03	June 22 to September 19
H06	240	48.5	10.6	3.4	2.4	June 25 to September 18
H07	14.7	2.34	0.42	0.15	0.07	June 24 to September 18
H11	3.6	0.060	0.050	0.042	0.027	June 14 to September 17

STATION	Drainage Area (km^2)	Estimated Mean Monthly Unit Runoff ($l/s/km^2$)				Period of Record
		June	July	August	September	
H01	250	163	31	13	9	June 18 to September 9
H02	210	249	51	15	11	June 21 to September 19
H04	8.3	73	15	9	4	June 21 to September 12
H05	5.3	46	15	11	6	June 22 to September 19
H06	240	202	44	14	10	June 25 to September 18
H07	14.7	159	29	10	5	June 24 to September 18
H11	3.6	17	14	12	8	June 14 to September 17

5 SUMMARY AND RECOMMENDATIONS

The 2020 iteration of the Project's Hydrometric Monitoring Program allowed for the continued monitoring of streamflow at hydrometric stations identified in the Project's AEMP (Baffinland, 2015). There were more flow measurements conducted at most stations in 2020 than in previous years. The data collected confirmed that the rating curves at all stations continue to be applicable.

It is recommended that future hydrometric monitoring continue to target low flow and/or high flow periods to maintain and further validate the rating relationships. Peak flows tend to occur in the spring but not always when the channels are ice-free or when conditions permit safe access for gauging. Peak flow in summer and fall months are good to target, however they tend to occur over a shorter time period than in the spring. In addition, in some years (such as in 2020), there may not be many peak flow events beyond the spring melt period. In general, precipitation events of greater than 4 mm per day should be noted as they typically result in an appreciable increase in flow, especially at the stations with smaller catchments. Precipitation events that last for more than one day, with cumulative precipitation over 10 mm, can result in much higher flow, especially earlier in the summer (mid-July to mid-August) before the active layer of permafrost fully develops. Site visits to more accessible sites H04, H05, and H11 should be made following any precipitation event that lasts more than one day and/or results total precipitation approaching or greater than 10 mm.

6 REFERENCES

Baffinland Iron Mines Corporation (Baffinland), 2015. Aquatic Effects Monitoring Plan – Rev. 1. October 30, 2015.

Environmental Applications Group (EAG), 2020. Memorandum to Connor Devereaux, Baffinland Iron Mines Corporation. Re: 2019 AEMP Hydrometric Monitoring Program. March 26. North Bay, Ontario.

Water Survey of Canada (WSC), 1999. Hydrometric Technician Career Development Program. Lesson Package No. 10.1 – Principles of Discharge Measurement. Environment Canada, Fredericton, NB.

Environment Canada (EC), 2012. Hydrometric Manual, Data Computations (Beta Version). Water Survey of Canada, Environment Canada, Ottawa, ON. qSOP-NA037, 2012-12-17

7 CERTIFICATION

This document was prepared by the undersigned.

Prepared by: ______________________________

Andrew Rees, Ph.D.
Senior Environmental Scientist / Hydrologist

LEGEND

- Borrow Area
- Quarry Area
- Project Development Area
- Commercial Lease Boundary
- Current Infrastructure
- Hydrometric Monitoring Station

ᓄᓇᕗᑦ ᐅᓯᑦᑎᐅᑉ MARY RIVER PROJECT

2020 Hydrometric Monitoring Program Stations

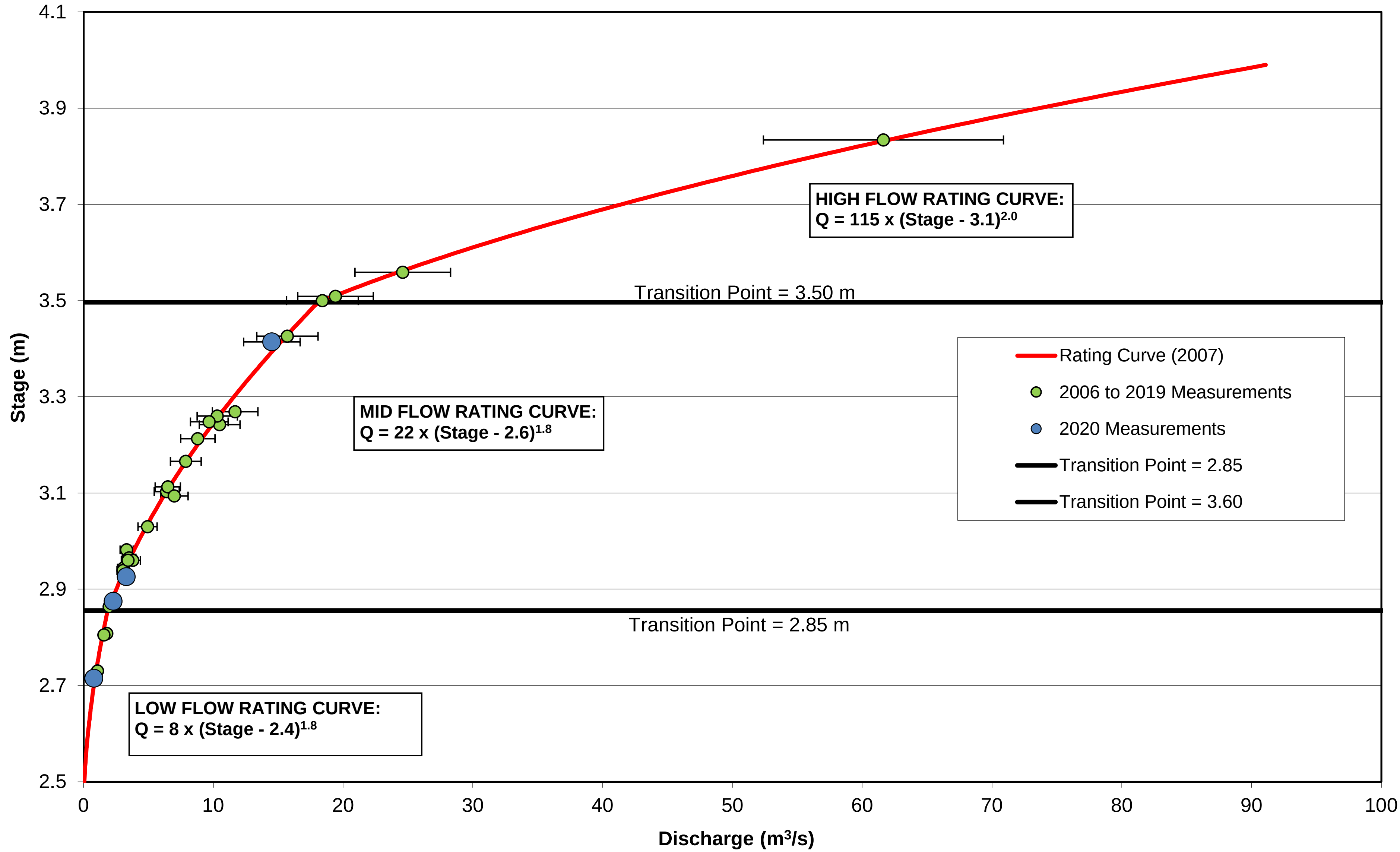
Projection: NAD 1983 UTM ZONE 17N.
Base Map: © 2019 Digital Global, Inc.
Imagery and Infrastructure are representative as of August 2019.

0 100 200 400 600 800 Meters
Scale 1:30,000
N

Baffinland

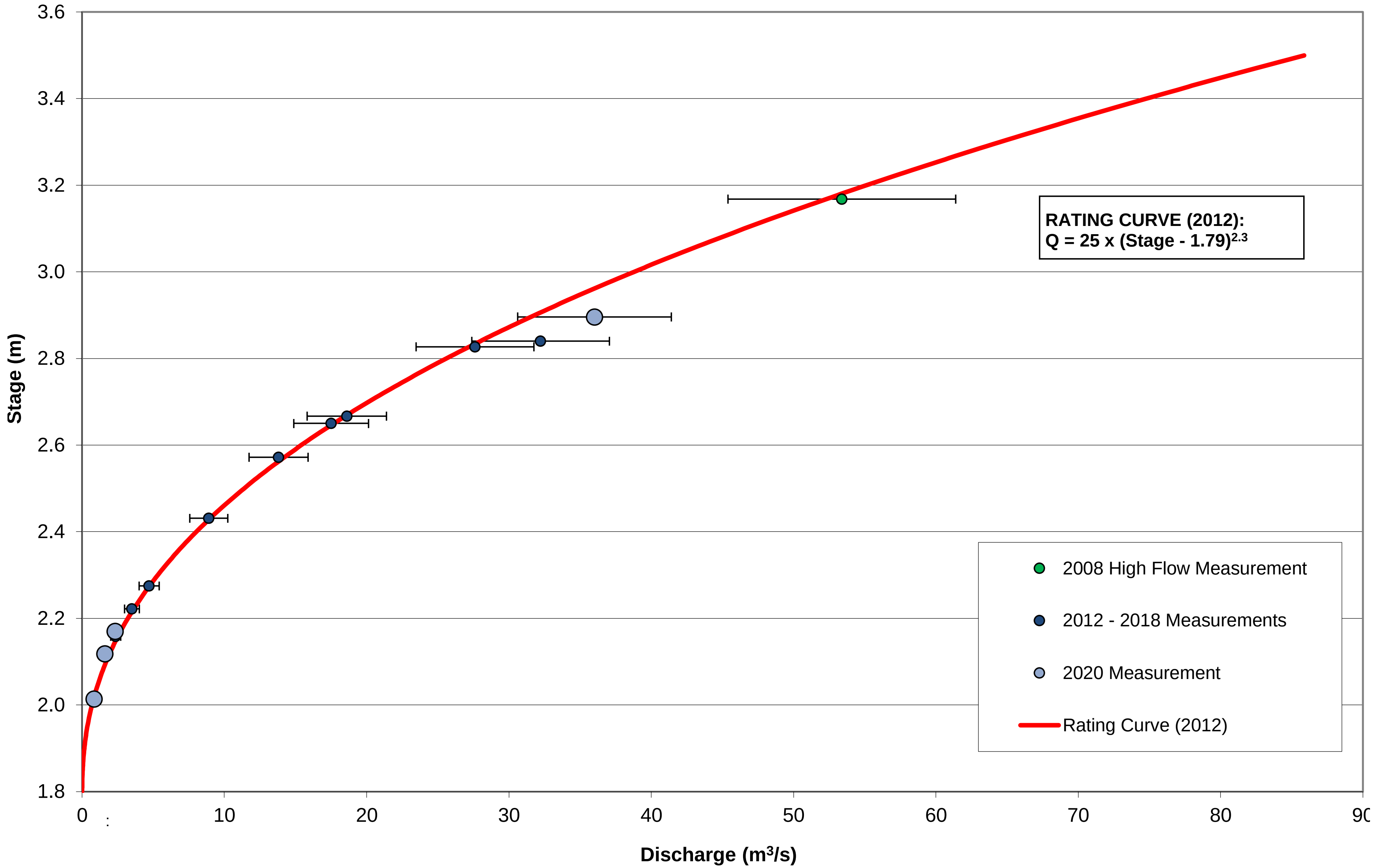
ᑎᑎᕋᐅᓯᐊᖅ FIGURE 1

SAVED: C:\Users\katie.mcguire\Documents\4 - Maps\Reporting\1_Annual\Hydrometric\BIM_Fig 1 MineSite.mxd; 24-Mar-20



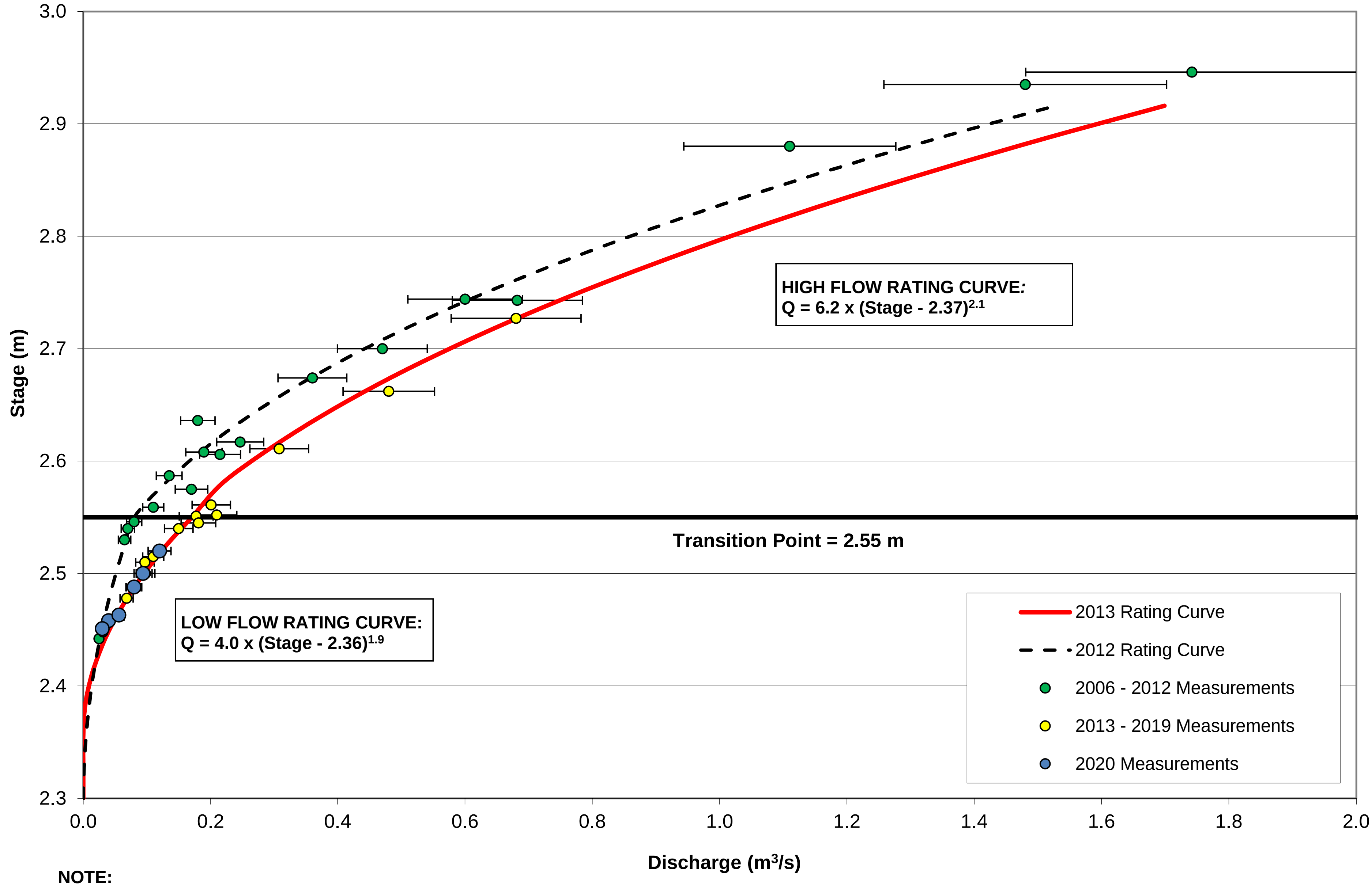
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2020

Figure 2 **H01 - Philips Creek Tributary Rating Curve**



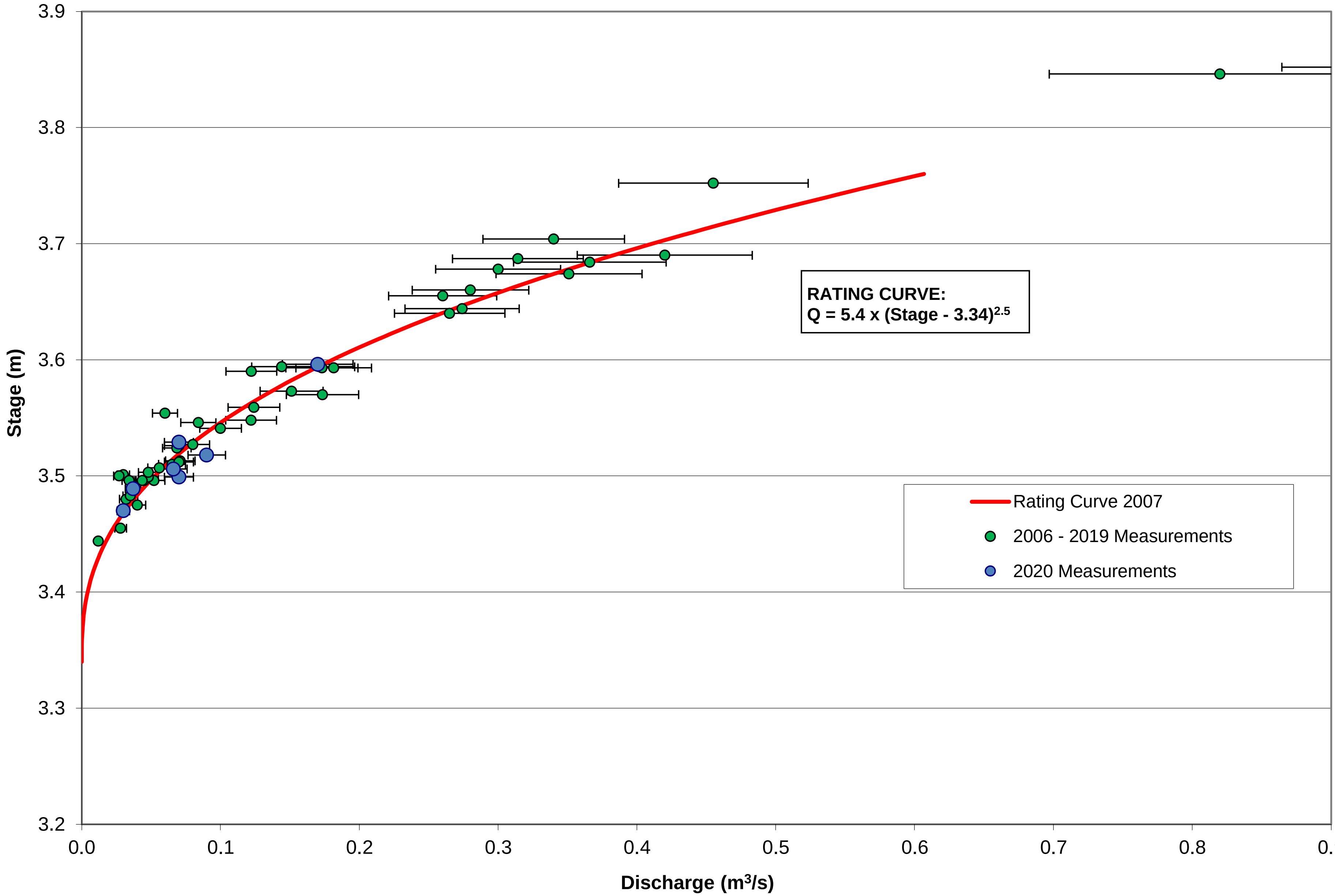
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2020

Figure 3 **H02 - Tom River Rating Curve**



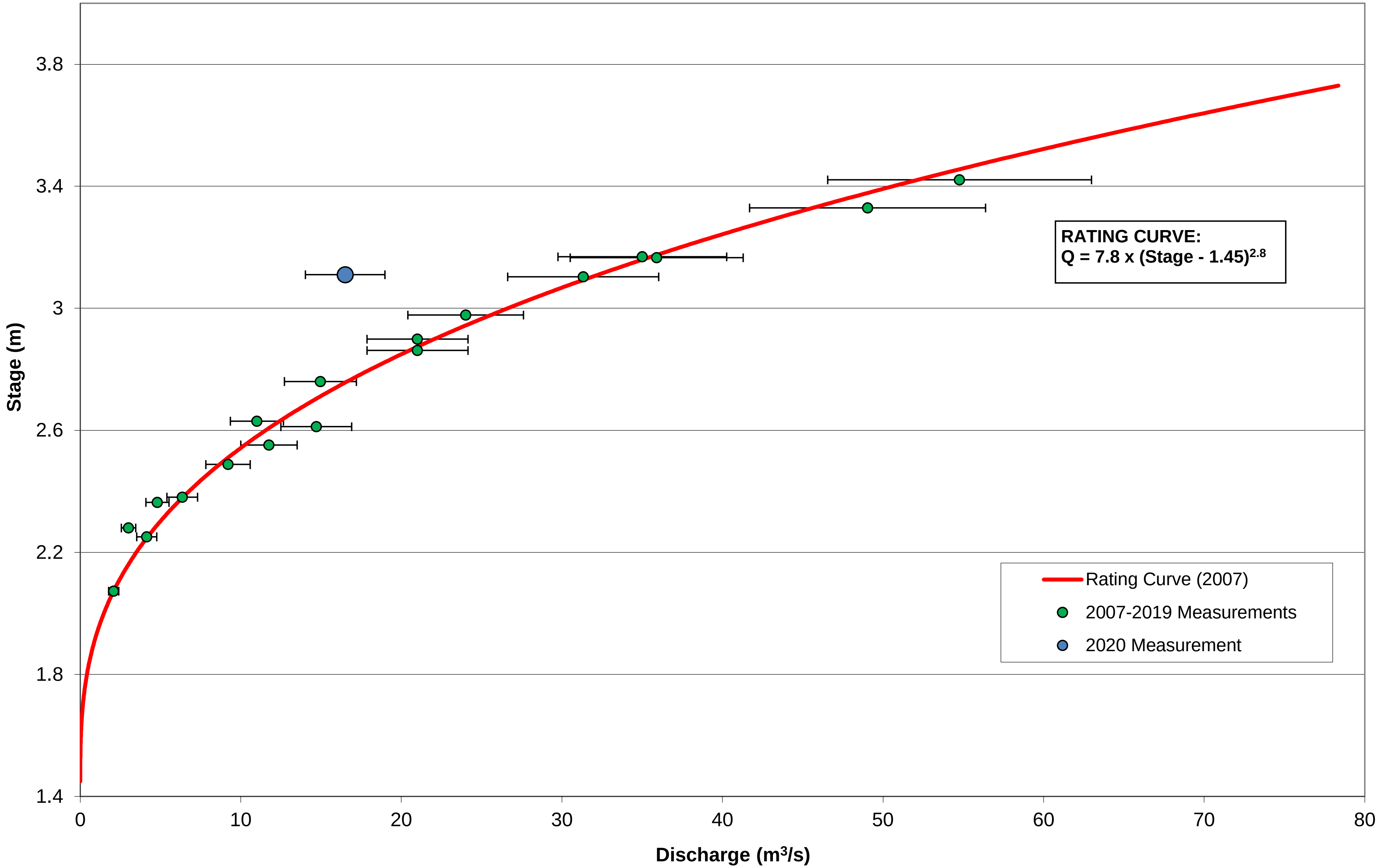
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2020

Figure 4 **H04 - Camp Lake Tributary (CLT-2) Rating Curve**



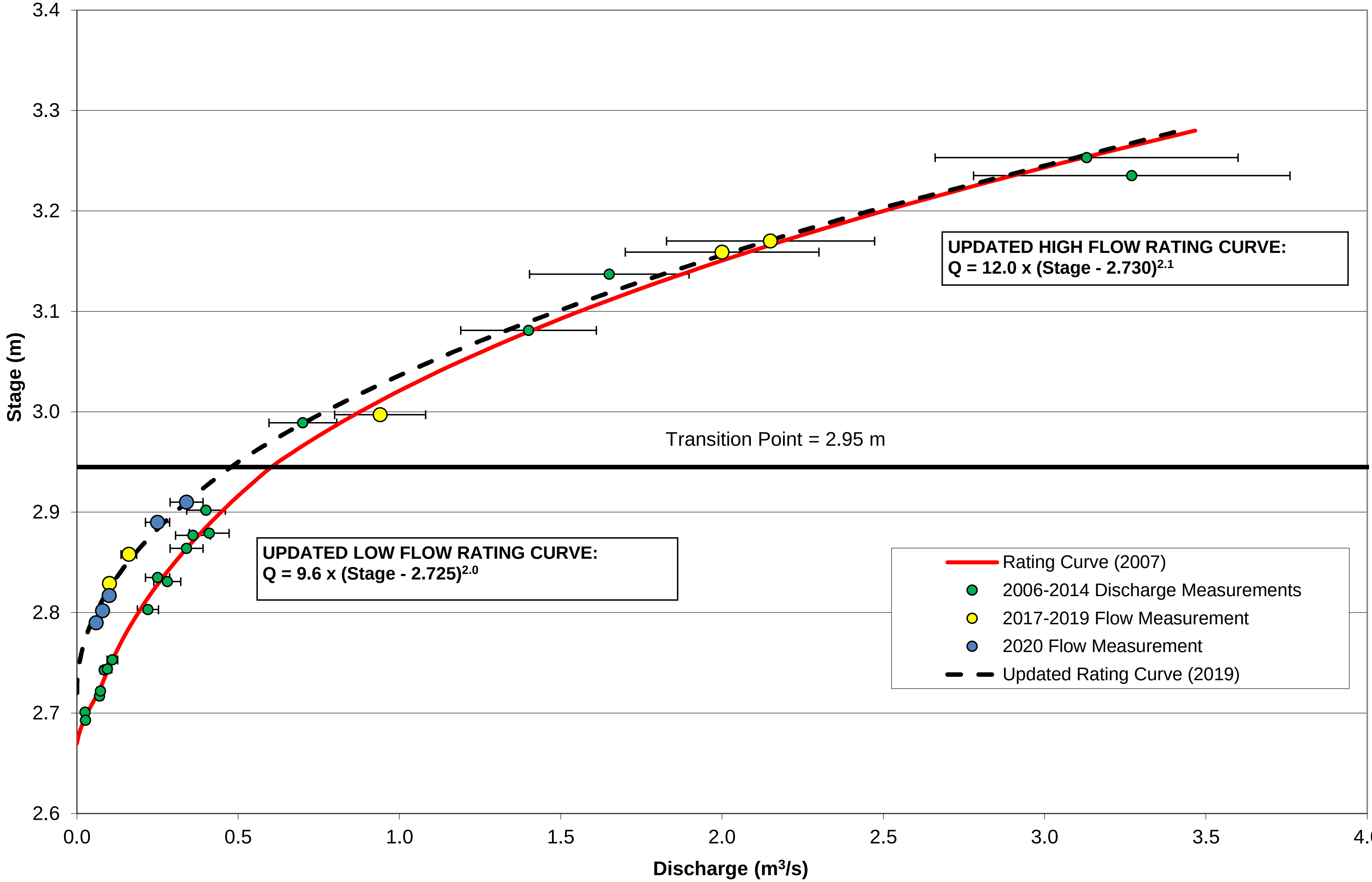
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2020

Figure 5 **H05 - Camp Lake Tributary (CLT-1) Rating Curve**



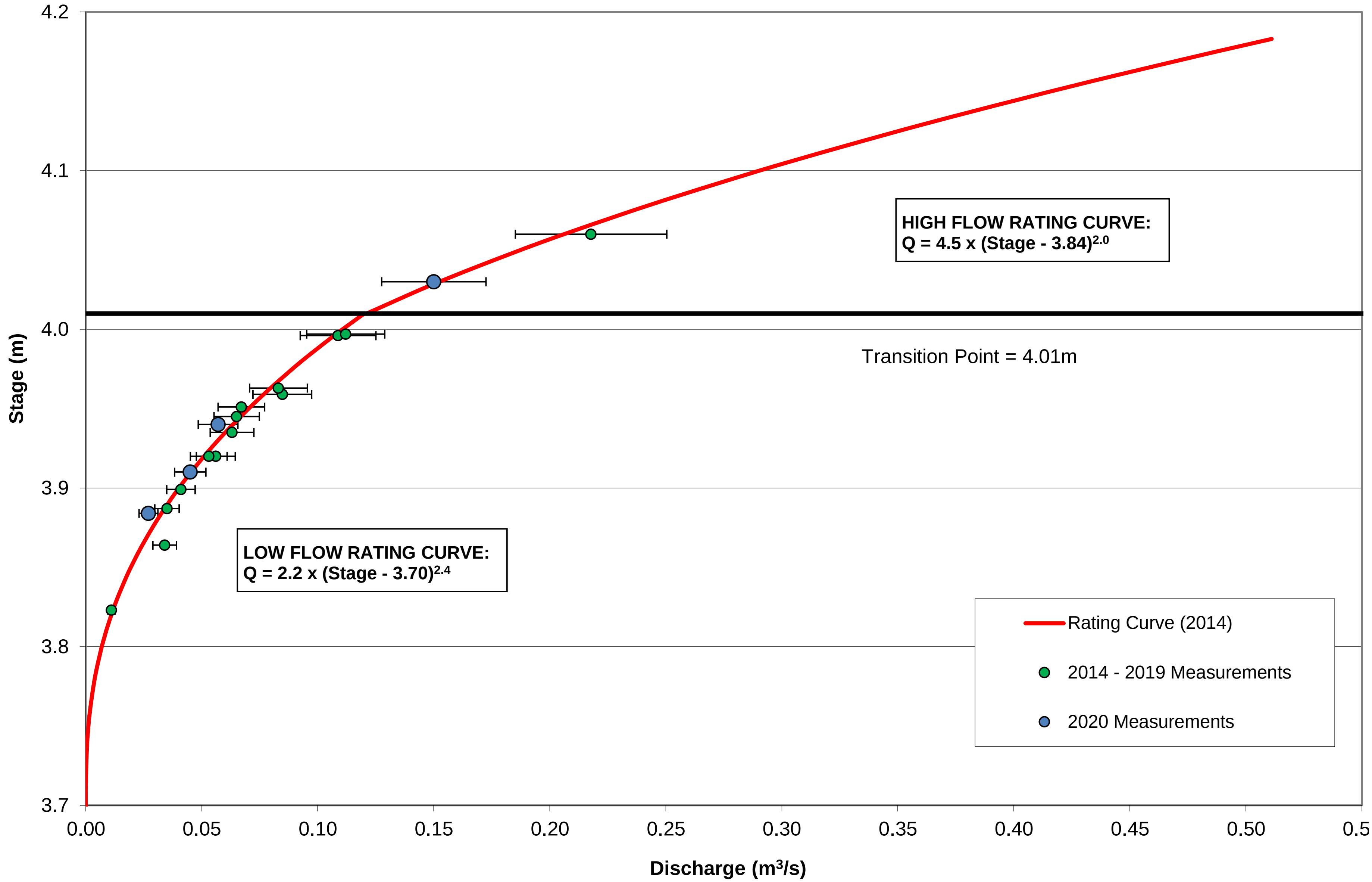
NOTES:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2020

Figure 6 **H06 - Mary River Rating Curve**



NOTES:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2020

Figure 7 **H07 - Mary River Tributary F Rating Curve**



NOTE:
1. UPDATED RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2020

Figure 8 H11 - Sheardown Lake Tributary (SDLT-1) Rating Curve

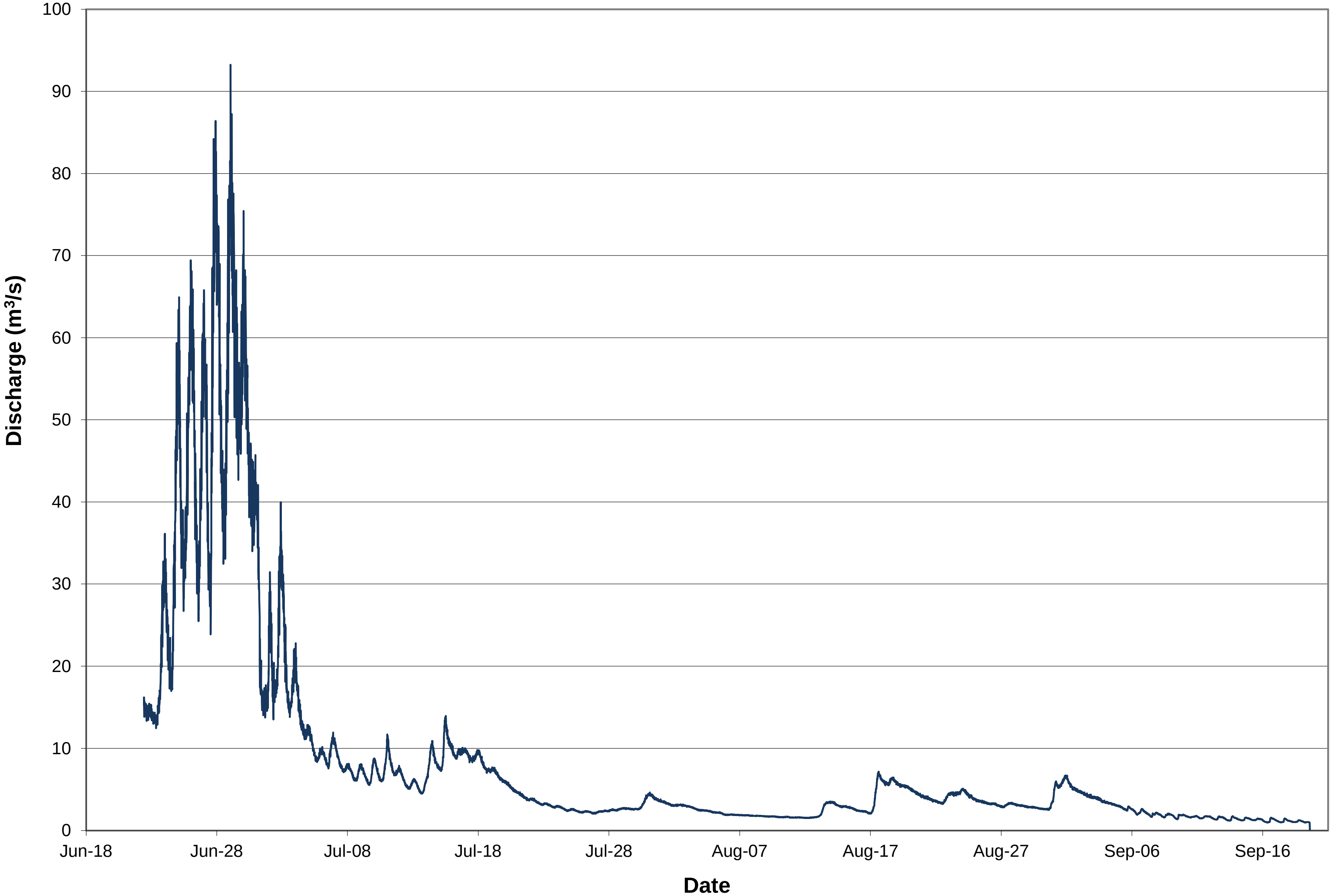


Figure 9 **H01 - Philips Creek Tributary 2020 Streamflow Record**

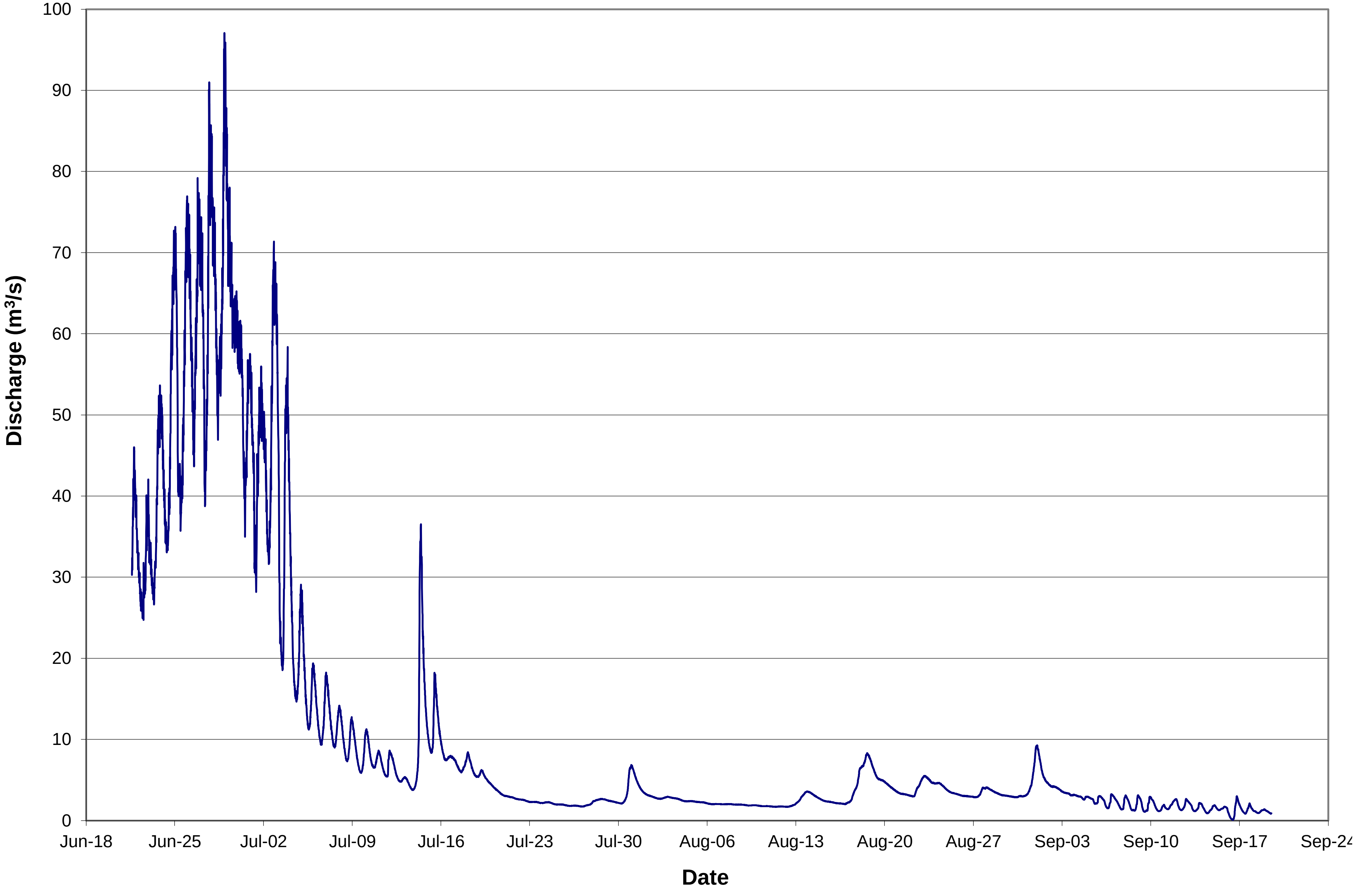


Figure 10 H02 - Tom River 2020 Streamflow Record

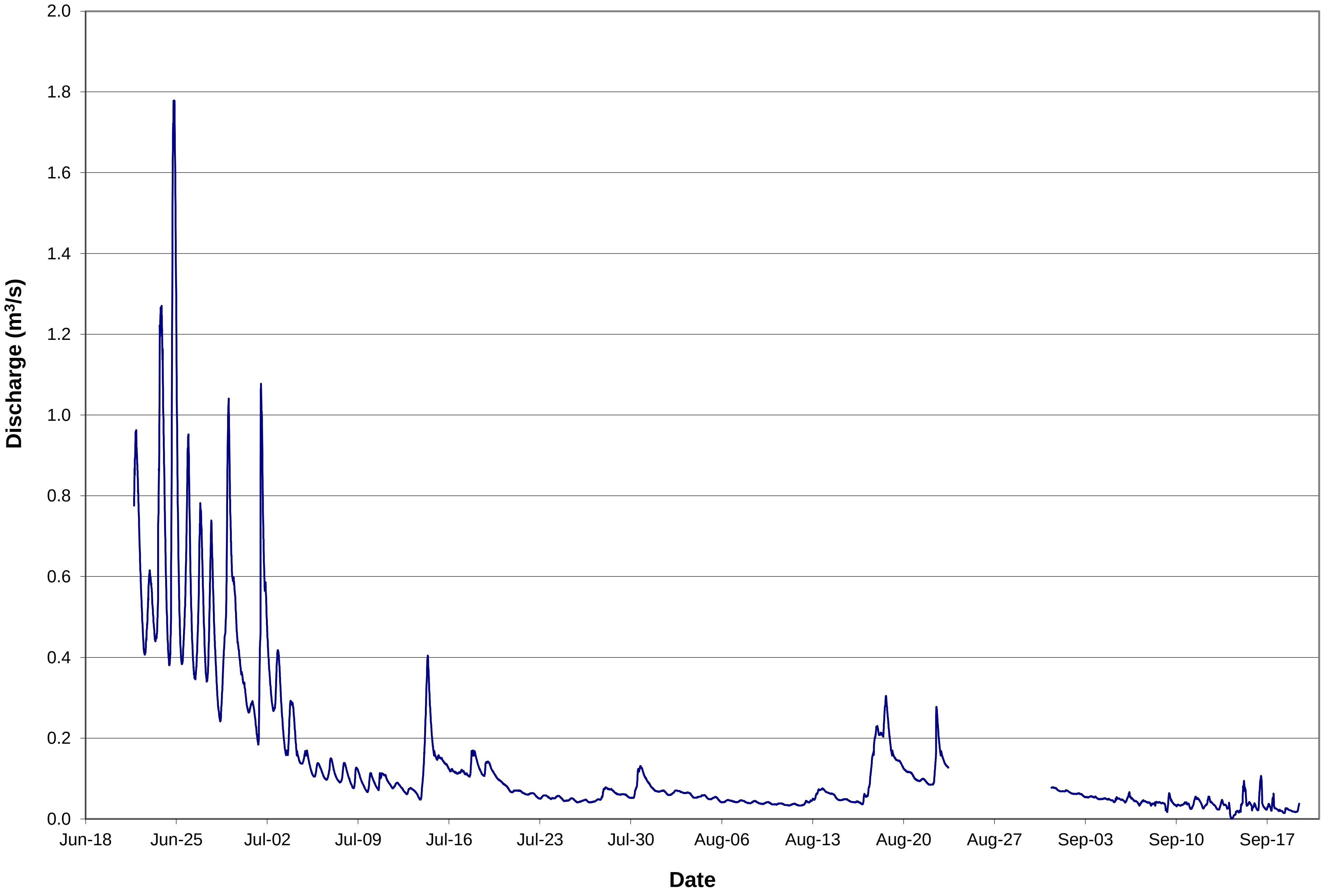


Figure 11 **H04 - Camp Lake Tributary (CLT-2) 2020 Flow Record**

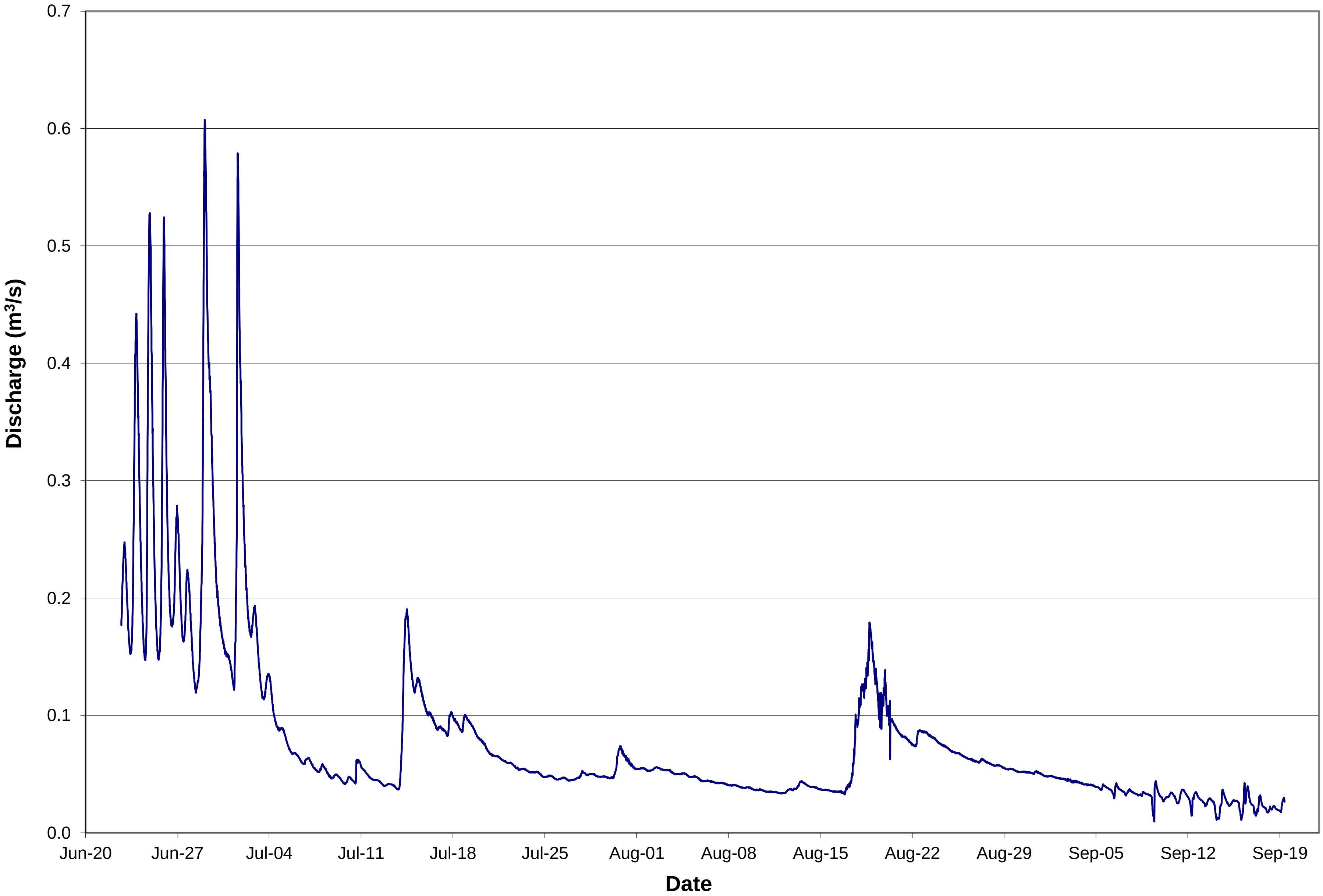


Figure 12 **H05 - Camp Lake Tributary (CLT-1) 2020 Flow Record**

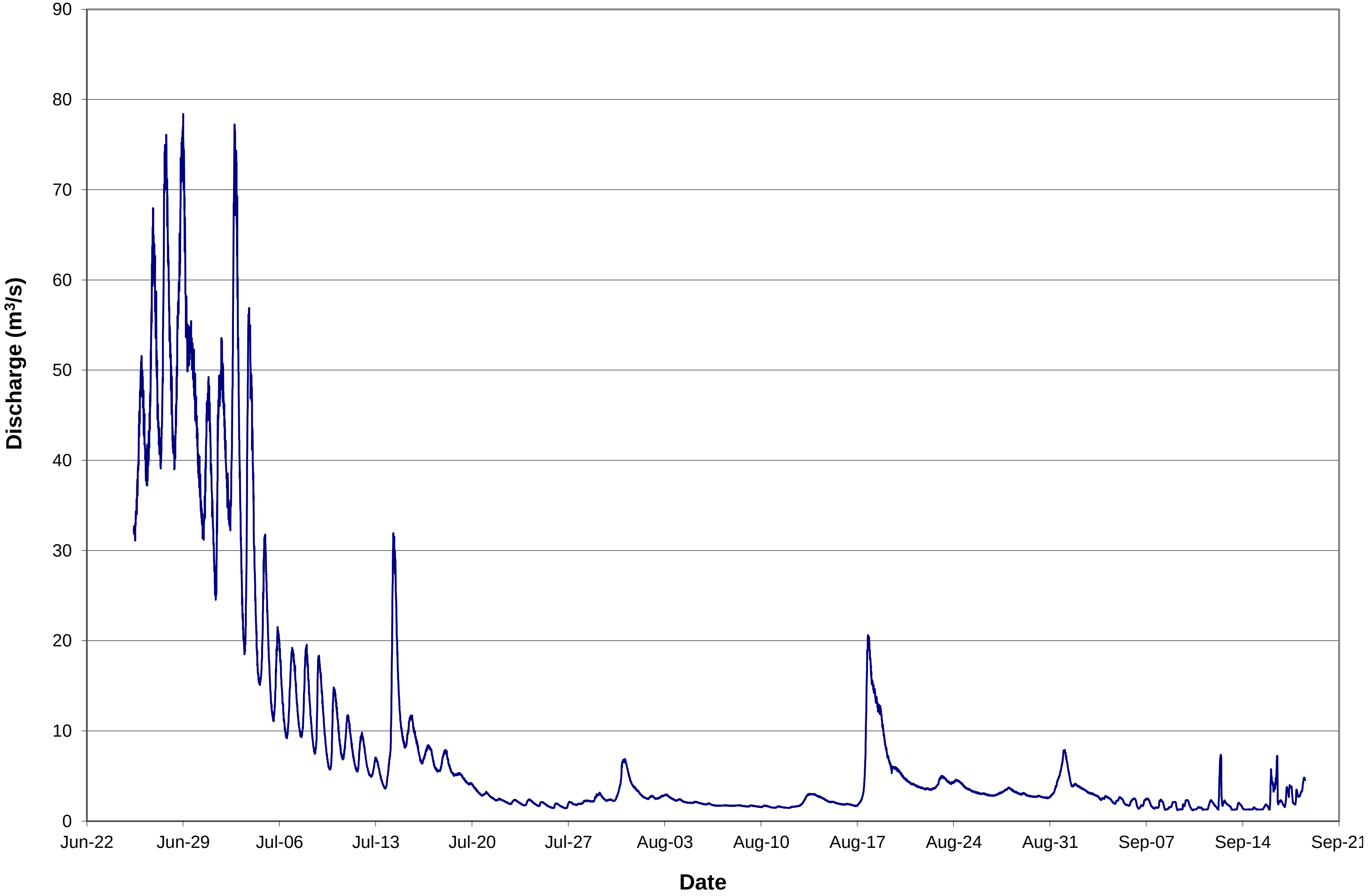


Figure 13 **H06 - Mary River 2020 Flow Record**

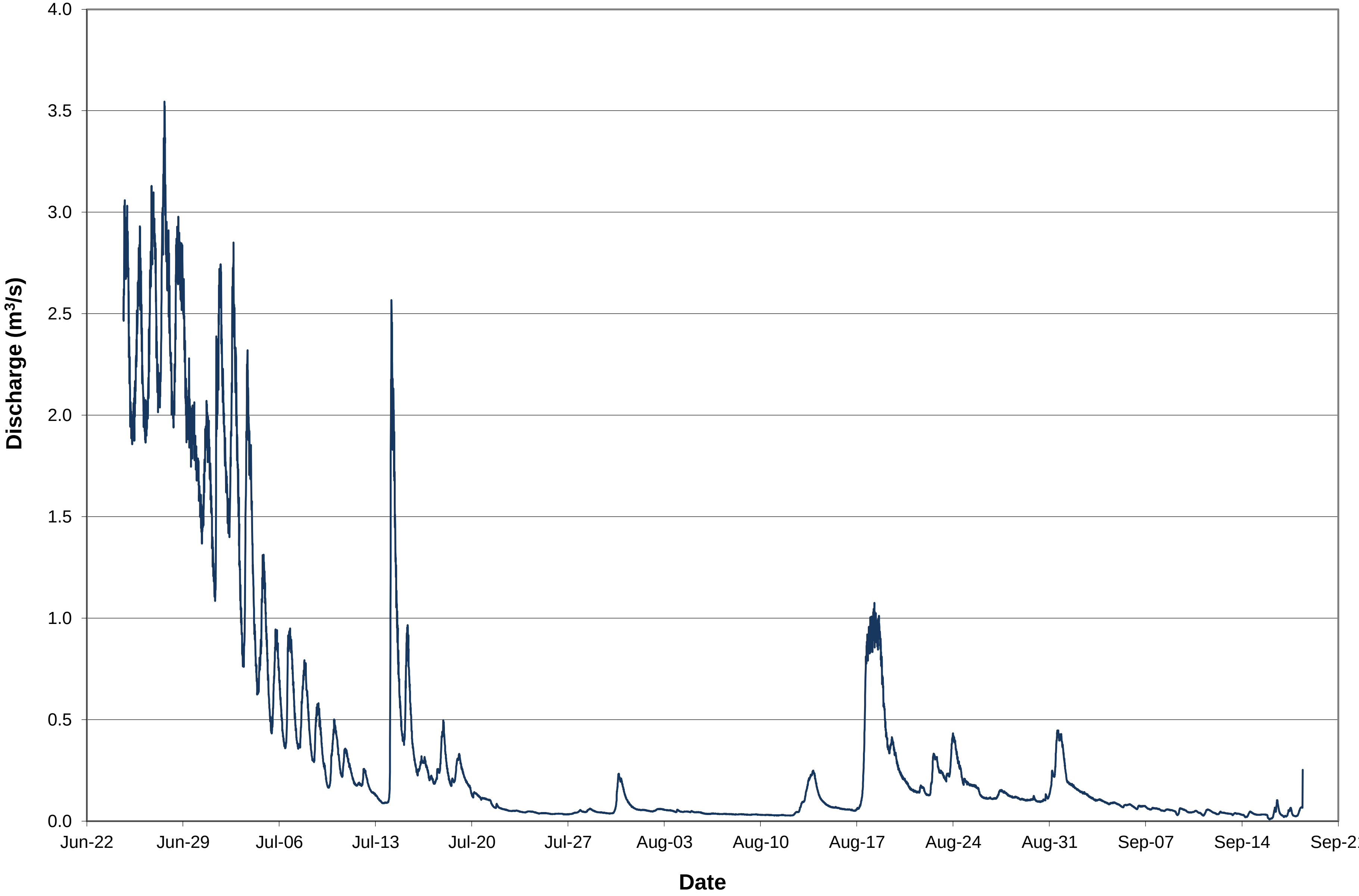


Figure 14 **H07 - Mary River Tributary F 2020 Flow Record**

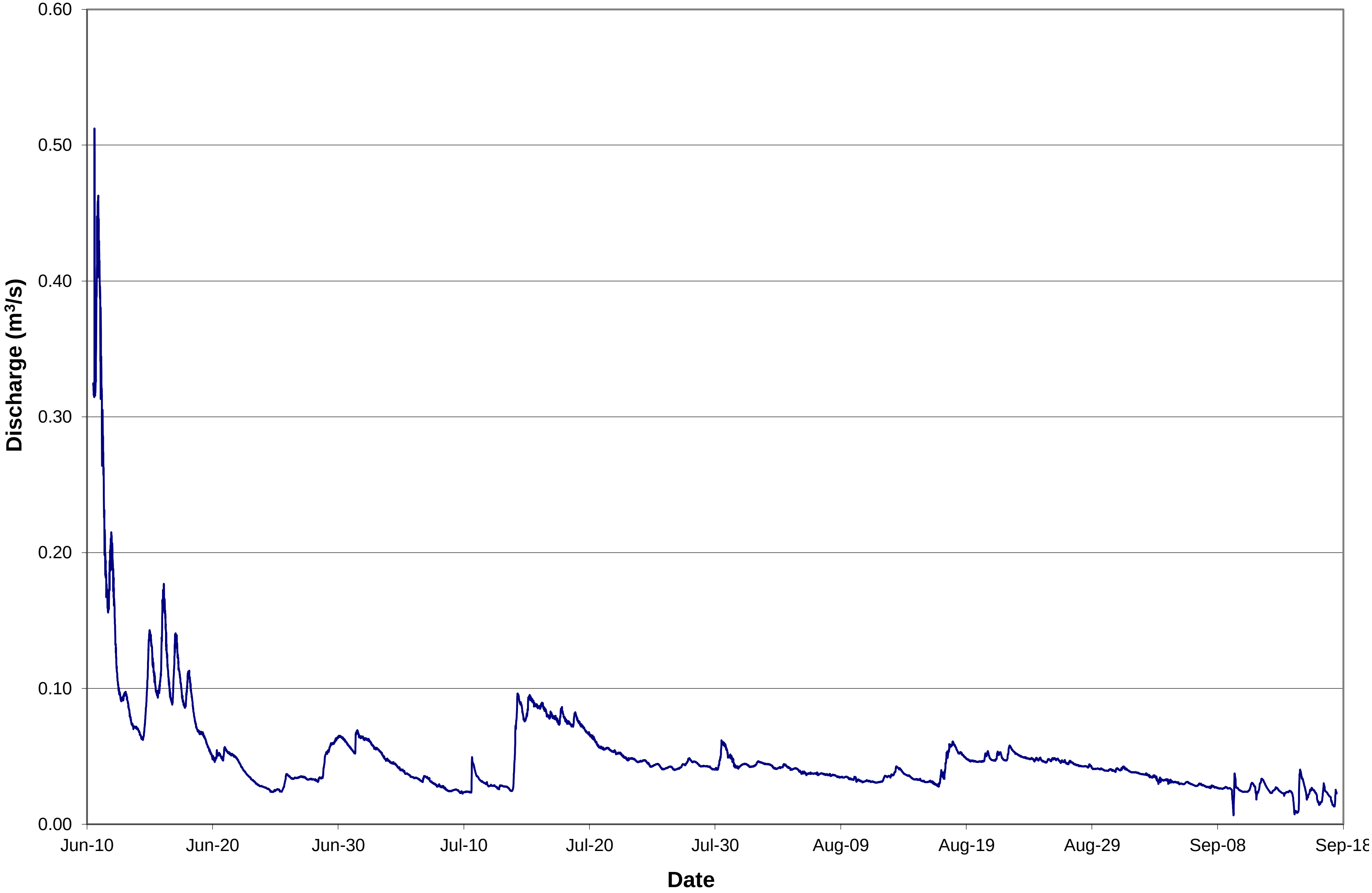


Figure 15 **H11 - Sheardown Lake Tributary (SDLT-1) 2020 Streamflow Record**

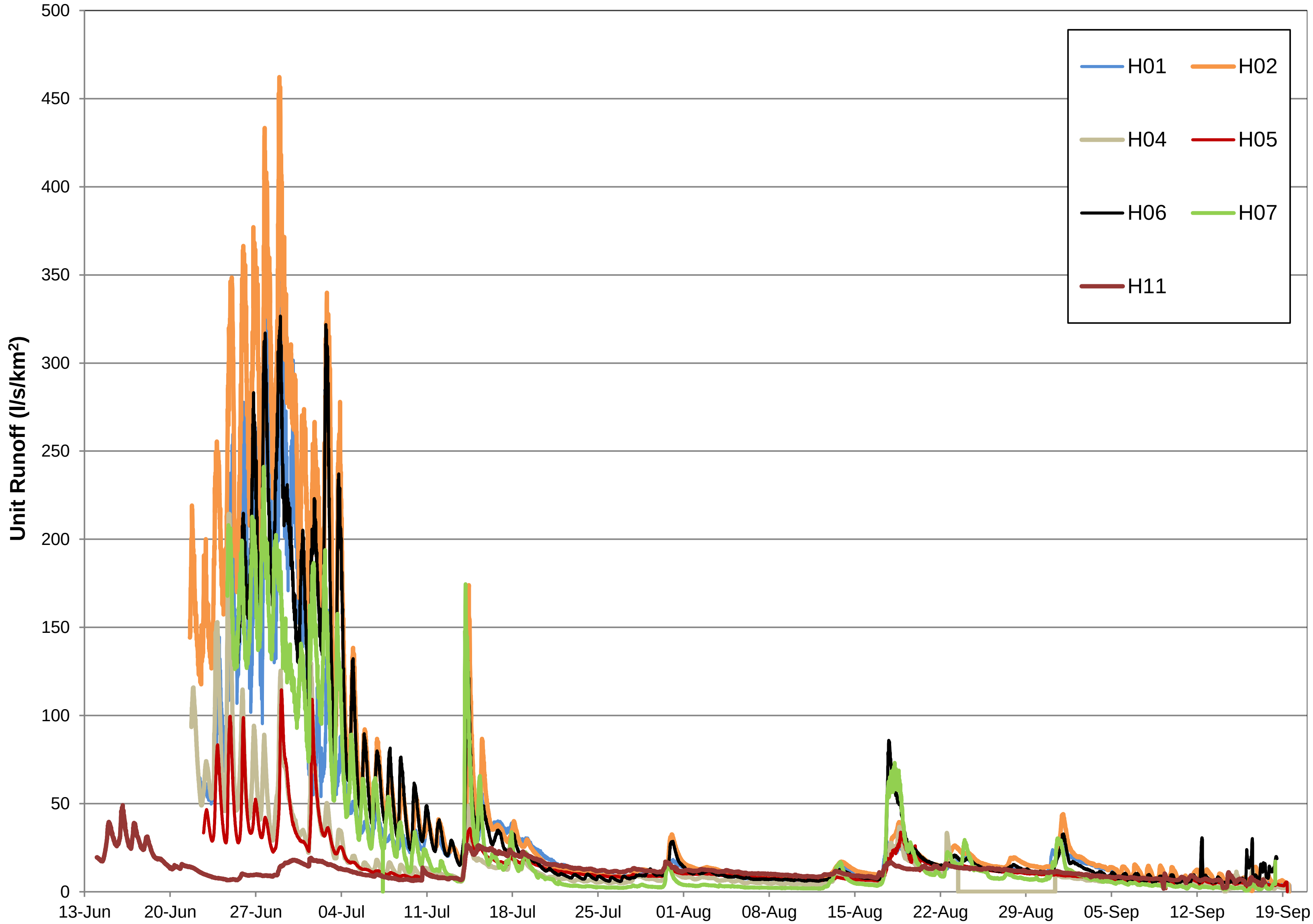


Figure 16 Comparison of 2020 Unit Runoff

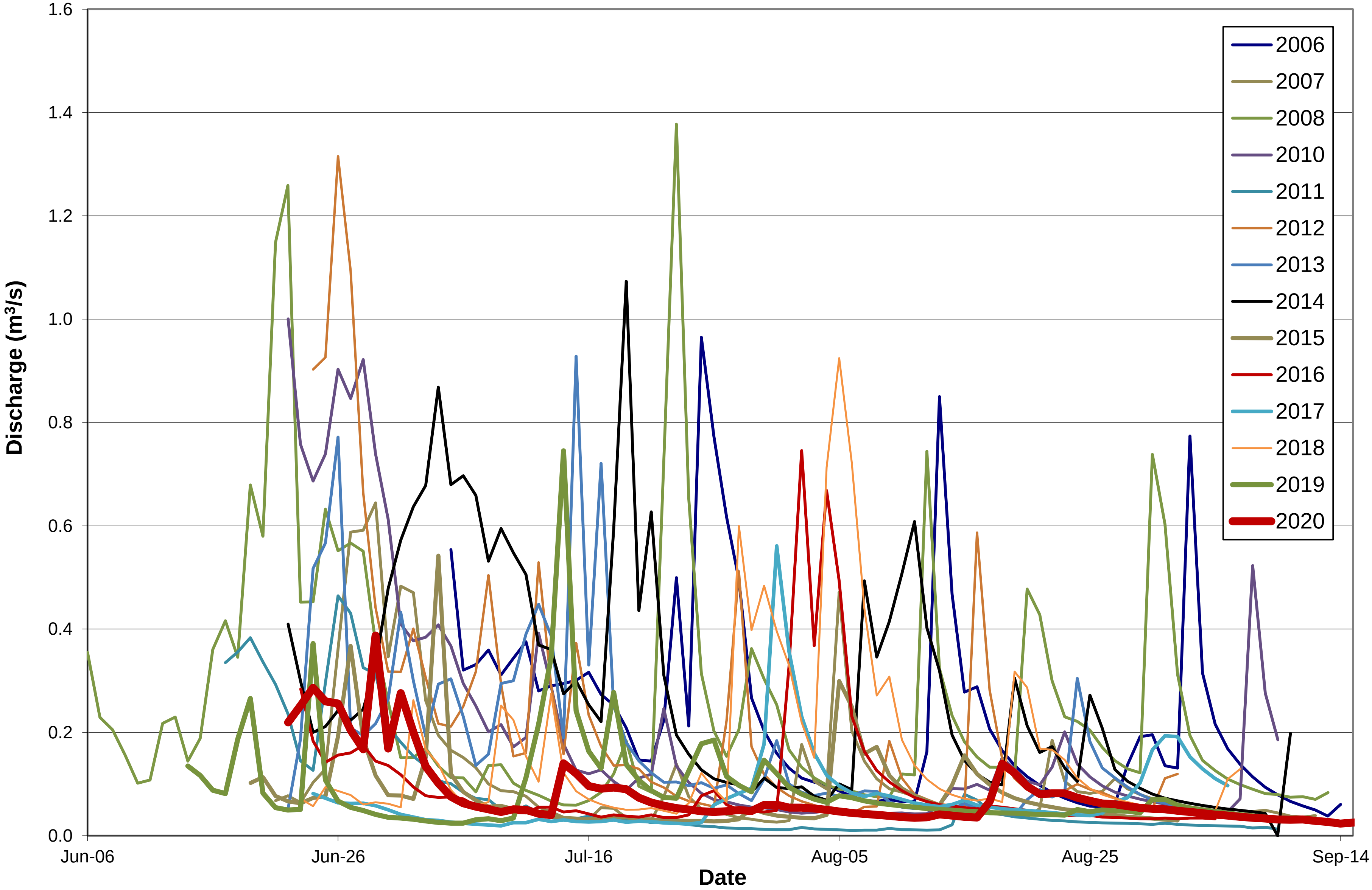


Figure 17 H05 - Camp Lake Tributary (CLT-1) Measured Streamflow Hydrographs 2006 - 2020