# APPENDIX E.9.3

# 2021 AEMP Hydrometric Monitoring Report

# 2021 Hydrometric Monitoring Report

## Mary River Project

### Baffinland Iron Mines Corporation

| Version | Issue Date |
|---|---|
| 0 | March 18, 2022 |

Prepared by:
**North Water Environmental**

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## 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 2021. 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 2021 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, 2011-2021 | 250 | 532831 | 7946247 |
| H02 | Tom River near outlet to Mary Lake | 2006-2008, 2010-2021 | 210 | 555712 | 7915514 |
| H04 | Camp Lake Tributary (CLT-2) | 2006-2008, 2010-2021 | 8.3 | 557639 | 7915579 |
| H05 | Camp Lake Tributary (CLT-1) | 2006-2008, 2010-2021 | 5.3 | 558906 | 7915079 |
| H06 | Mary River | 2006-2008, 2010-2021 | 240 | 563922 | 7912984 |
| H07 | Mary River Tributary F | 2006-2008 2010, 2011, 2017-2021 | 14.7 | 564451 | 7913194 |
| H11 | Sheardown Lake Tributary (SDLT-1) | 2011-2021 | 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 at the time of 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 2021 is provided in the following section.

# 3 STAGE-DISCHARGE DATA

## 3.1 Overview

Reconnaissance of the hydrometric stations was initiated in June 2021 to monitor the onset and progression of snow melt and associated freshet flow. Each of the stations were installed as early as possible when the stream channels were ice-free. Additional site visits were conducted in 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 2021 were compared to the existing rating curves, which were last evaluated in the 2020 Hydrometric Monitoring Program Summary (North Water, 2021). 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 are extrapolated to the maximum recorded stage to capture the range of observed water level in a given year, relative to measured discharge. Rating curves for each station, inclusive of the data collected in 2021, are presented in Figures 2 to 8. A discussion of the 2021 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 21. A stage-discharge measurement was recorded at the time of installation and in July using dilution gauging. The flow during the September site visit was measured using a wading current meter and the area velocity technique and provided good validation of the lower portion of the rating curve. The 2021 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 2021 streamflow record.

## 3.3 H02 (Tom River)

The data logger / pressure transducer was installed at the H02 hydrometric station on June 14. Stage-discharge measurements were recorded at H02 during June, July, and August using dilution gauging. The highest flow measurement made in 2021 falls slightly below the existing rating curve and within the 15% range of uncertainty typically associated with dilution gauging techniques (Figure 3). The mid flow measurements are consistent with the 2012 rating curve (Figure 3) and it was used for the development of the 2021 flow record.

### 3.4 H04 (Camp Lake Tributary CLT-2)

The H04 hydrometric station was installed on June 22. 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 and later in the season occur over relatively short time periods. The rating relationship 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 2021 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 16. Stage-discharge measurements were recorded in June, July, August, and September using a wading current meter and the area-velocity technique. The measurements are consistent with the 2007 rating relationship (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 2021 flow record.

### 3.6 H06 (Mary River)

The H06 hydrometric station was installed on June 23. A stage-discharge measurement was recorded at H06 during the installation using dilution gauging and is consistent with the existing rating curve developed in 2007 (Figure 6). The rating relationship at H06 has been consistent since 2007 and the channel appeared to be stable throughout 2021. The 2021 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 2021 flow record.

### 3.7 H07 (Mary River Tributary F)

The H07 hydrometric station was installed on June 23. 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 further validate the low flow portion of the 2019 rating curve and it was used for the development of the 2021 flow record.

### 3.8 H11 (Sheardown Lake Tributary SDLT-1)

The H11 hydrometric station was installed on June 13. Stage-discharge measurements were recorded at H11 during June, July, August, and September. The lower flow discharge measurements were consistent with the rating curve updated in 2014, however the higher flows were not (Figure 8). It was previously noted that there was uncertainty around the higher stage-discharge conditions in the previous rating curve. The higher flow measurements obtained in 2021 provide validation of the rating relationship and suggest that the break-point proposed in 2014 may not apply. If the break-point is not considered, and the lower flow relationship extended, the higher flow measurements from 2021 are a very good fit. As such, the rating curve without a breakpoint was used for the development of the 2021 flow record. Future high flow measurements will further validate this portion of the curve.

# 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 2021 records of unit runoff generally agree well with each other, exhibiting similar timing and magnitude of runoff events and similar patterns to previous years. In July, the unit runoff at H11 gradually increased relative to other stations. This was due to a change in operations, where the flow along the Mine Haul Road was directed to a channel that eventually flows to H11 (SDLT-1). As such, the catchment area of H11 increased in 2021, which explains the proportional increase in unit runoff. The catchment area for unit runoff analysis will be updated for the 2022 monitoring program, when the construction of upstream water management infrastructure is complete.

As with previous programs, the stations were installed as soon as the streams became ice free and bulk of the snowmelt occurred 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 and the majority of the freshet occurred before stations were able to be installed at H01, H04, H05, and H11. The end of the freshet period was captured at the H02, H06, and H07 stations. A strong diurnal melt pattern is evident into mid July at these stations as they have higher elevation catchments. 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 gap in data collected at the H06 station in August due to a malfunctioning data logger.

The estimated mean monthly discharge and unit runoff for each station in 2021 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 2021 is shown on Figure 17. The total annual runoff recorded in 2021 at the H05 station was 20% below the average from 2006 to 2021 for concurrent periods of record. The flow measured in 2021 was below normal in June, 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 very close to average, albeit with fewer high magnitude flow events. The volume of flow measured during August 2021 was slightly higher than the 2006-2021 average.

**Table 2 Summary of 2021 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 | 14.2 | 7.1 | 4.3 | 1.9 | June 21 to September 11 |
| H02 | 210 | 31.8 | 12.6 | 6.0 | 2.6 | June 14 to September 12 |
| H04 | 8.3 | 0.32 | 0.18 | 0.13 | 0.07 | June 22 to September 10 |
| H05 | 5.3 | 0.16 | 0.13 | 0.12 | 0.05 | June 16 to September 12 |
| H06 | 240 | 40.4 | 13.1 | 8.2 | | June 23 to August 12 |
| H07 | 14.7 | 1.6 | 0.58 | 0.28 | 0.12 | June 23 to September 10 |
| H11 | 3.6 | 0.06 | 0.12 | 0.15 | 0.07 | June 13 to September 9 |

| STATION | Drainage Area ($km^2$) | Estimated Mean Monthly Unit Runoff ($l/s/km^2$) | | | | Period of Record |
|---|---|---|---|---|---|---|
| | | June | July | August | September | |
| H01 | 250 | 57 | 28 | 17 | 8 | June 21 to September 11 |
| H02 | 210 | 151 | 60 | 29 | 12 | June 14 to September 12 |
| H04 | 8.3 | 39 | 22 | 15 | 9 | June 22 to September 10 |
| H05 | 5.3 | 31 | 24 | 23 | 10 | June 16 to September 12 |
| H06 | 240 | 169 | 55 | 34 | | June 23 to August 12 |
| H07 | 14.7 | 106 | 40 | 19 | 8 | June 23 to September 10 |
| H11 | 3.6 | 18 | 32 | 43 | 18 | June 13 to September 9 |

## 5 SUMMARY AND RECOMMENDATIONS

The 2021 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). The data collected confirmed that the rating curves at all stations continue to be applicable, with slight modification at H11.

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, in some years (such as in 2021), the summer and fall peak flow events can occur over a very short period. In general, precipitation events of greater than 4 mm per day should continue to 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. As in August 2021, 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.

North Water Environmental (North Water), 2021. 2020 Hydrometric Monitoring Report, Mary River Project, Baffinland Iron Mines Corporation. March 25, 2021.

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:

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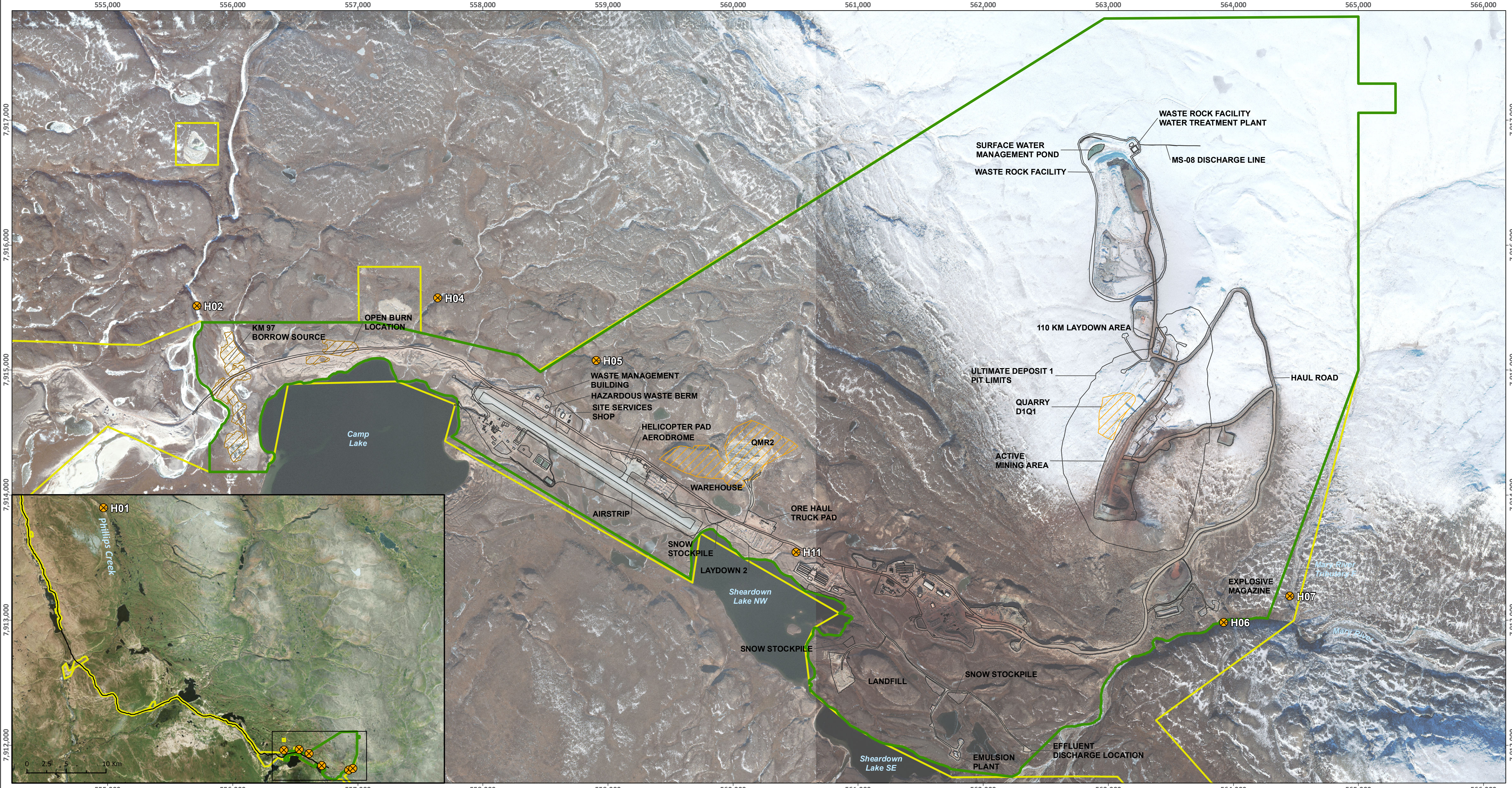
Senior Environmental Scientist / Hydrologist




**LEGEND**

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

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**2021 Hydrometric Monitoring Program Stations**

Projection: NAD 1983 UTM ZONE 17N.
Base Map: © 2022 Digital Globe, Inc.
Imagery and Infrastructure are representative as of July-September 2021.

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

Baffinland

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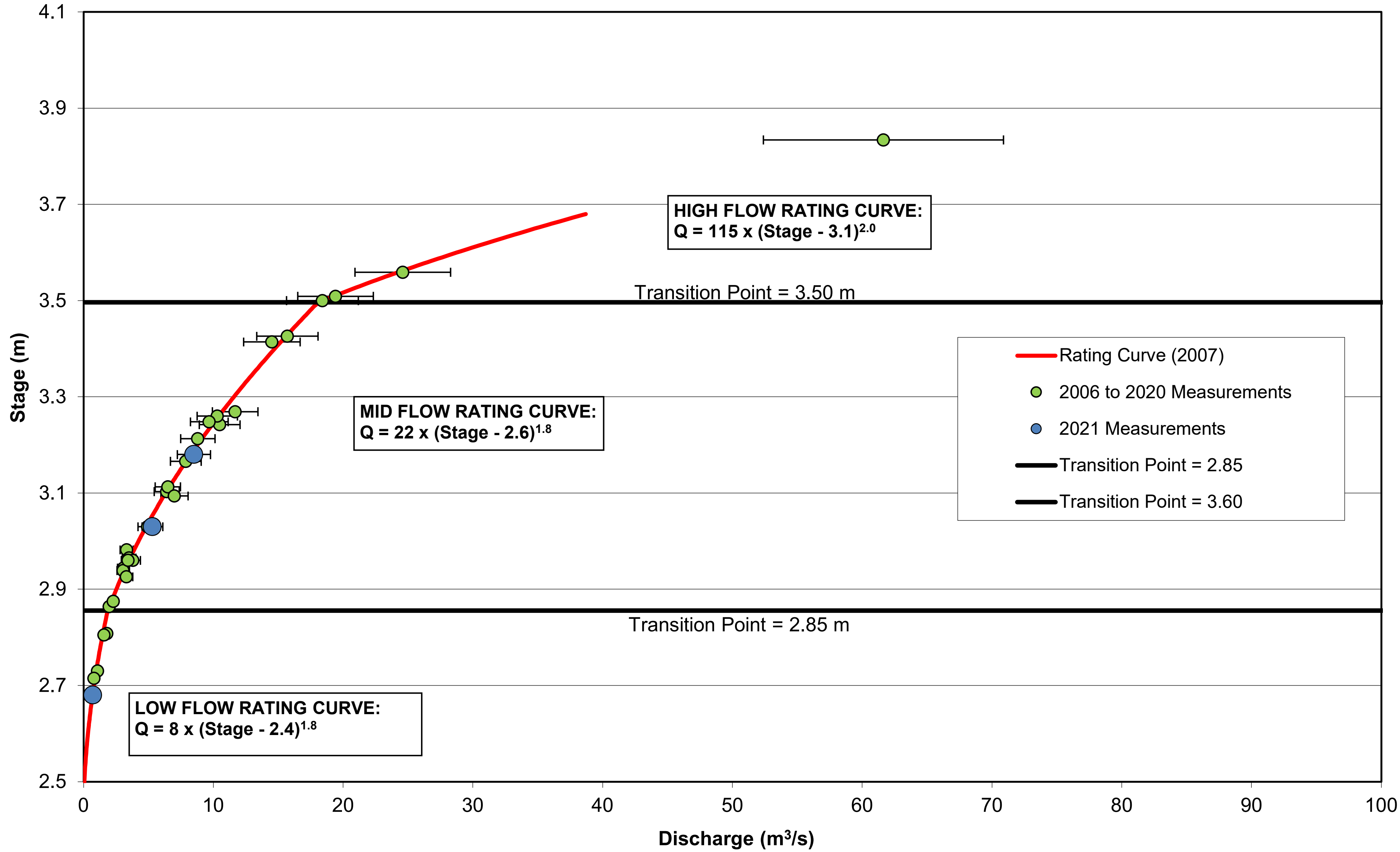
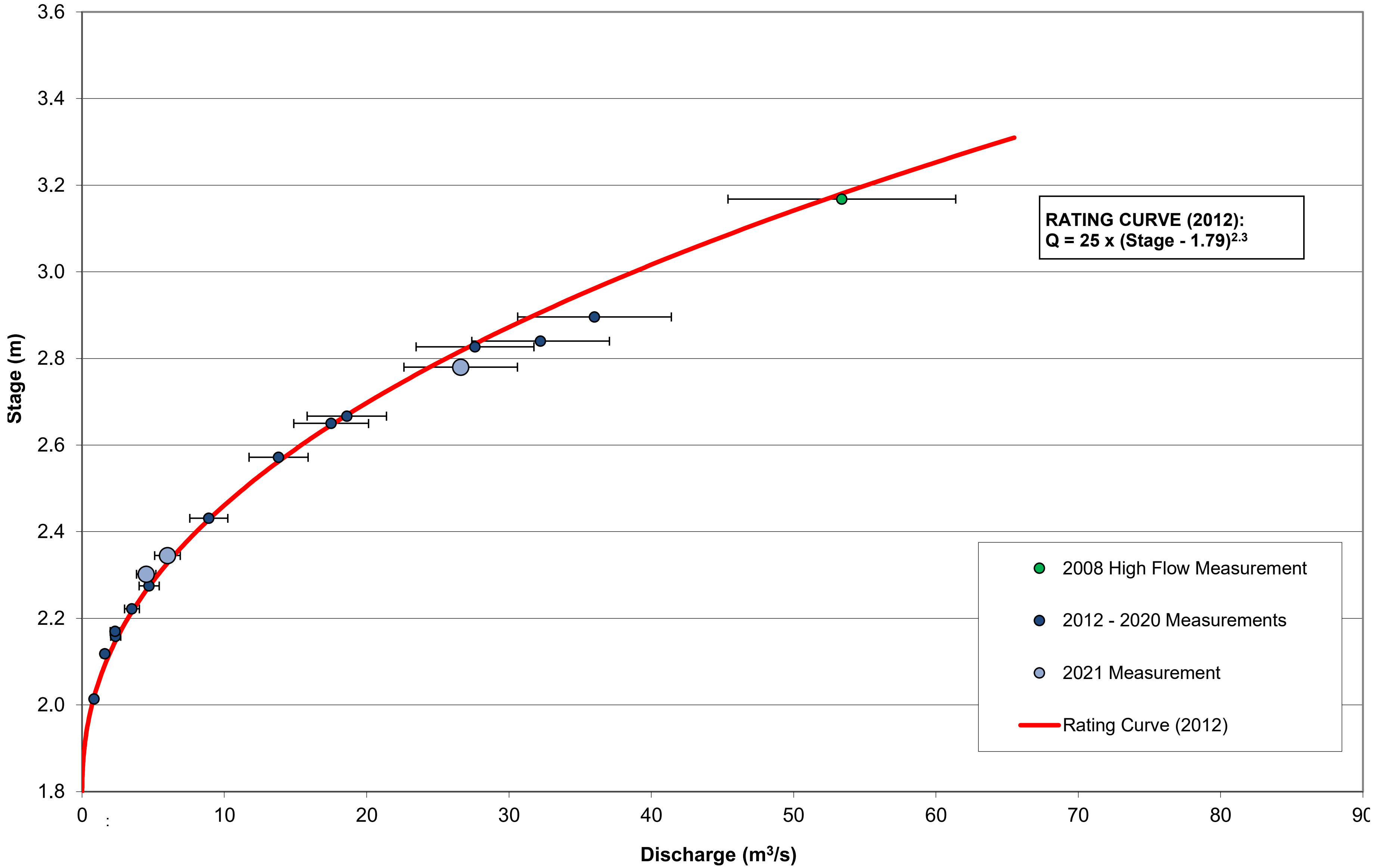
SAVED: C:\Users\katie.mcguire\Documents\4 - Maps\Reporting\1_Annual\Hydrometric\2021\BIM_Fig 1 MineSite.mxd; 17-Mar-22




**NOTE:**
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2021

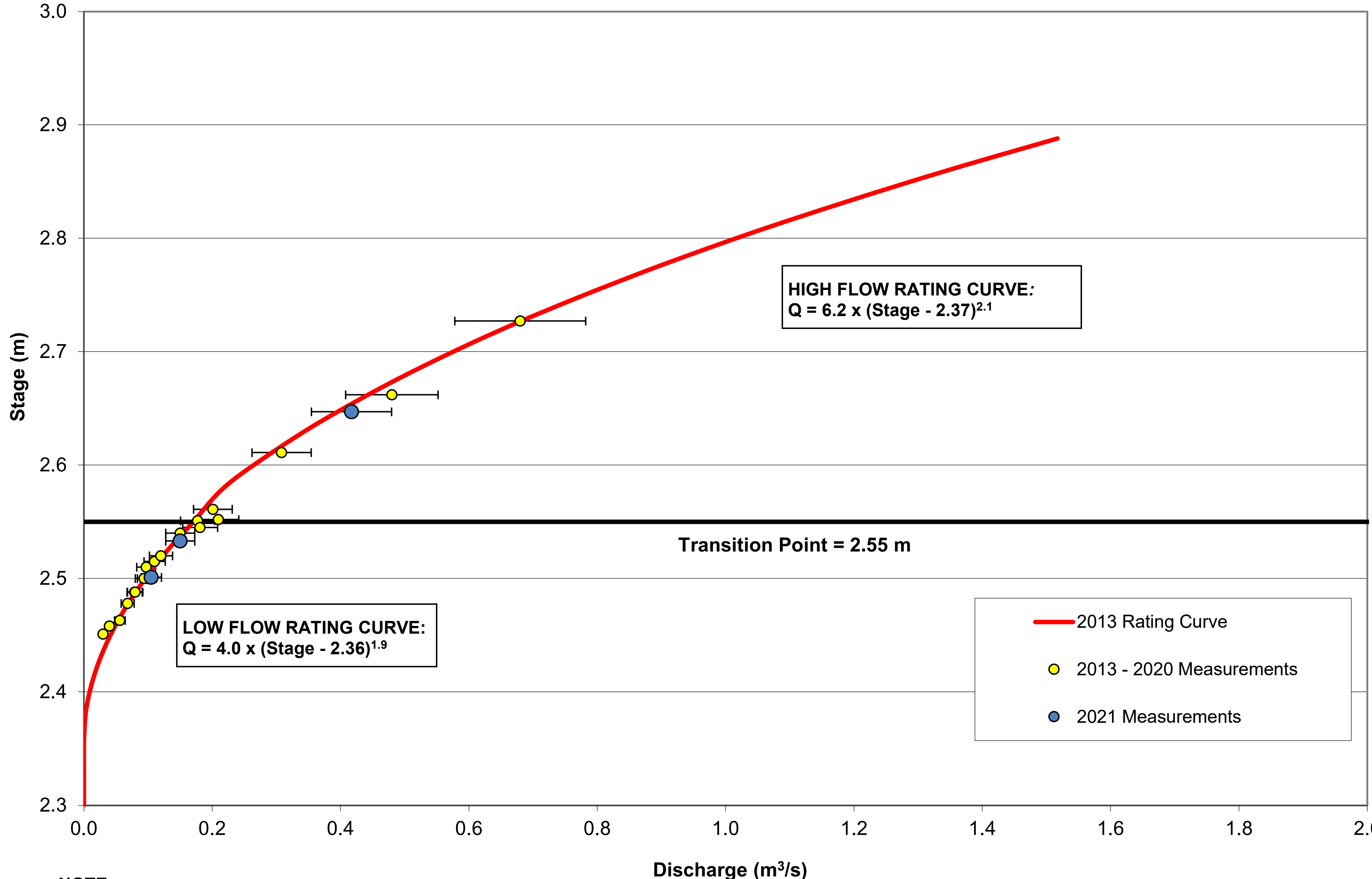
**Figure 2 H01 - Philips Creek Tributary Rating Curve**




**NOTE:**

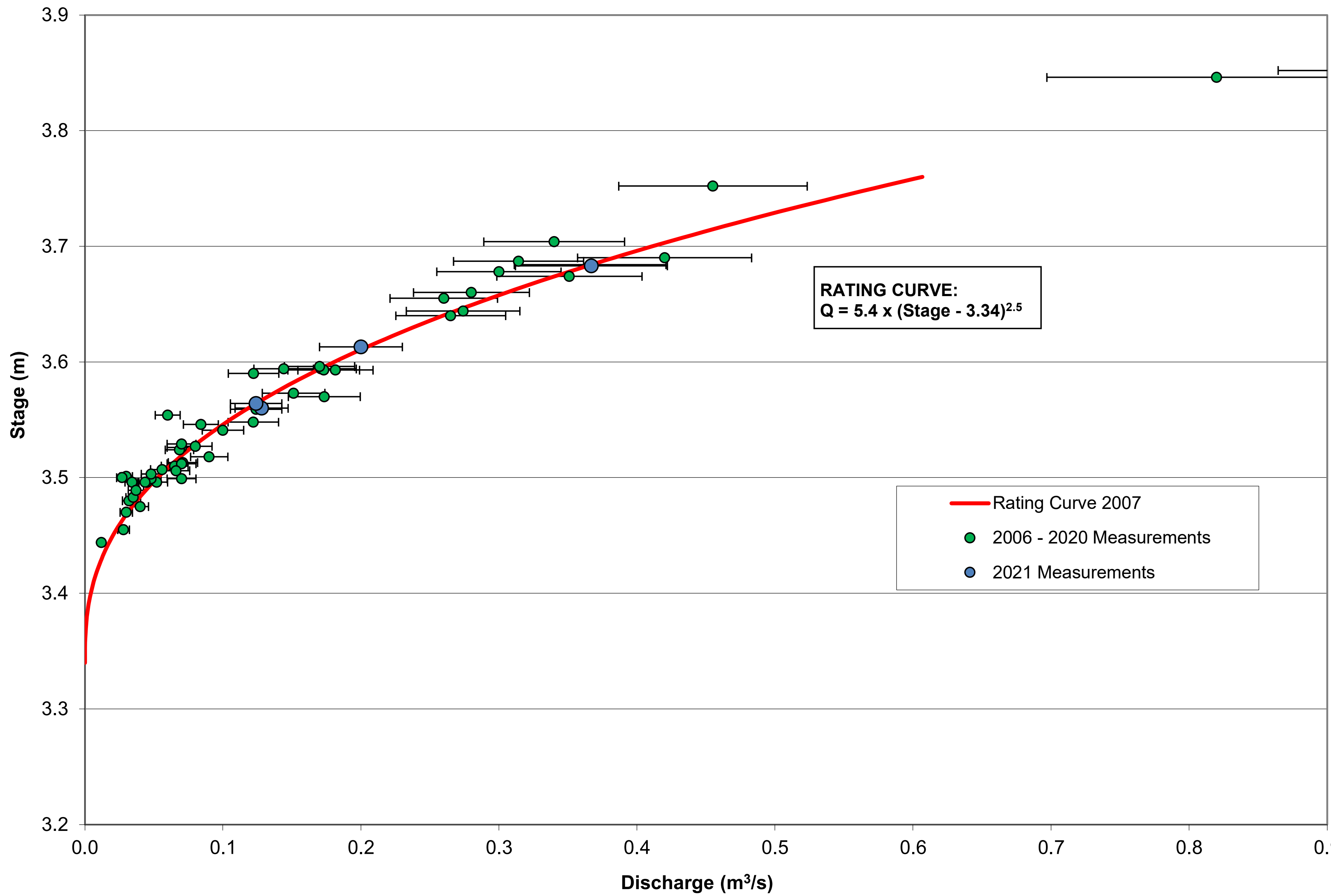
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2021

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



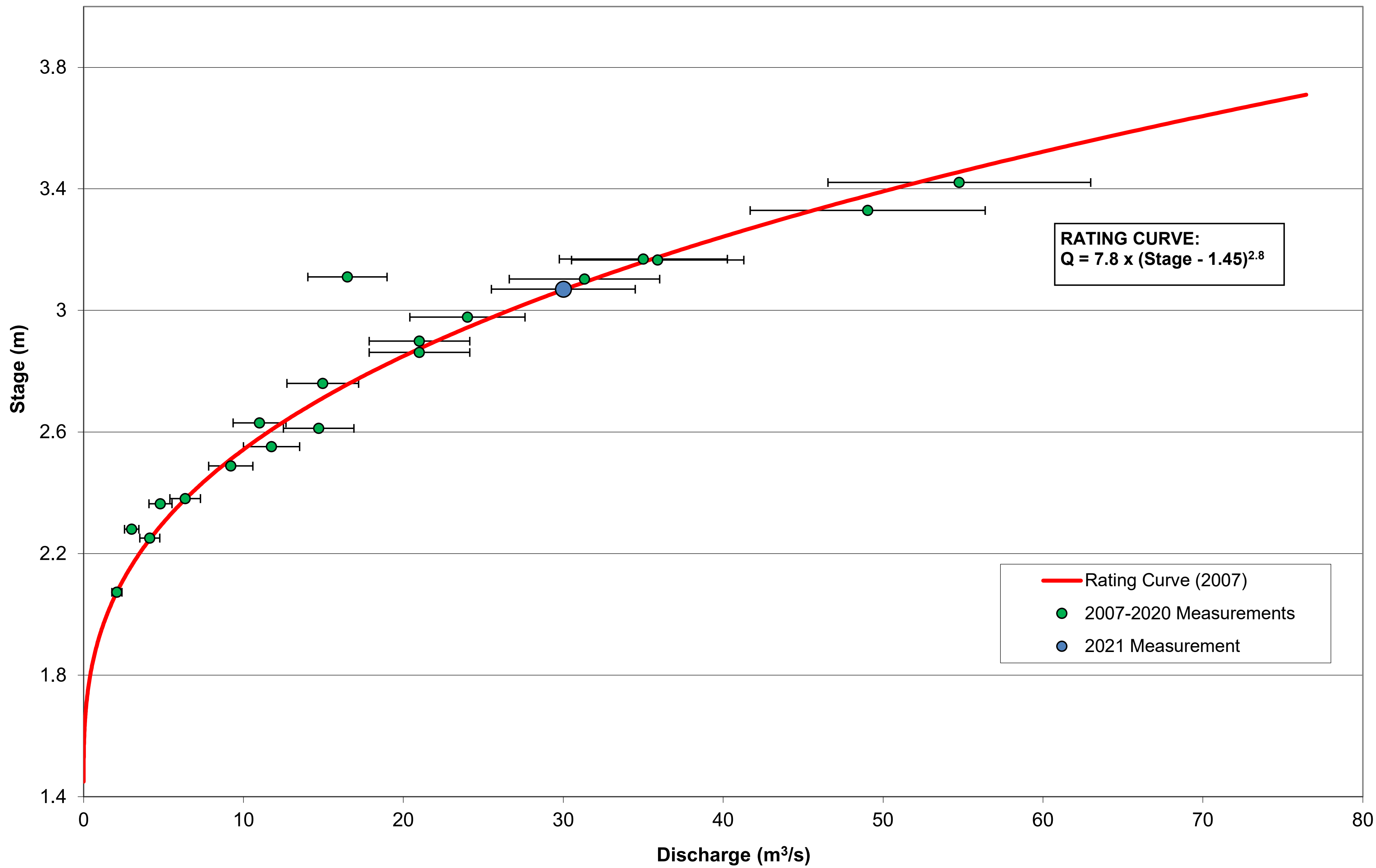

**NOTE:**
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2021

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



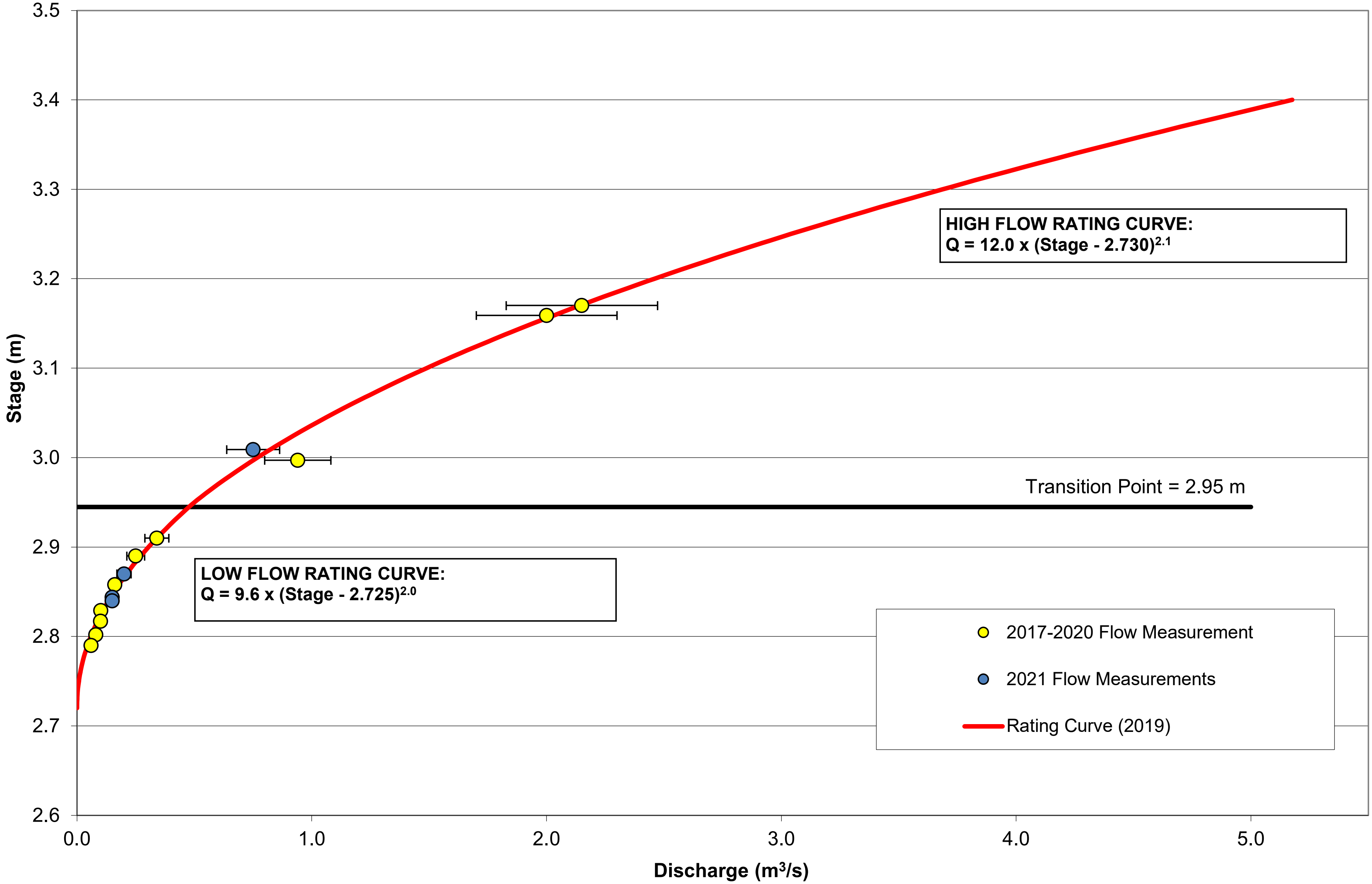

**NOTE:**
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2021

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



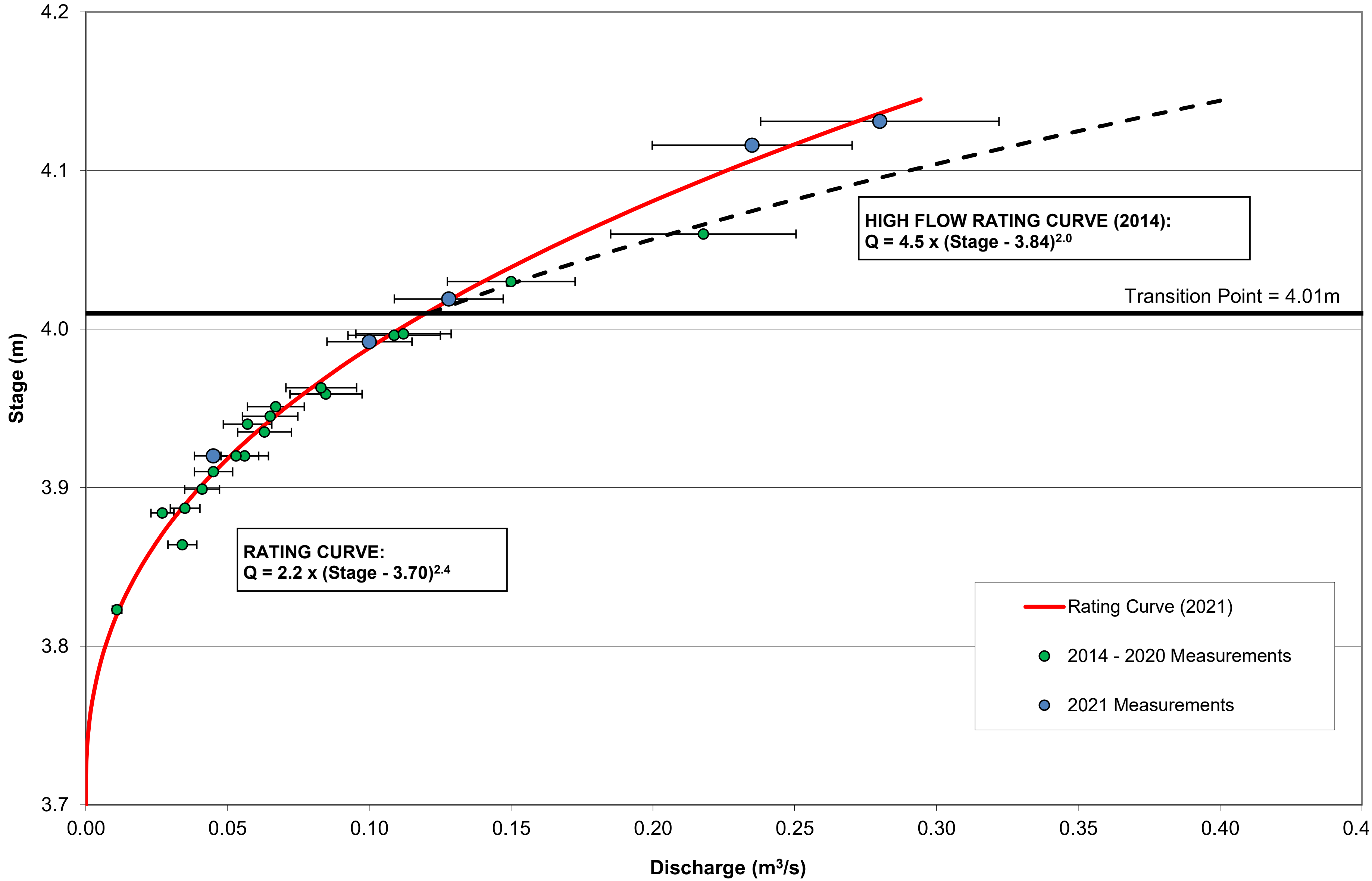

**NOTES:**
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2021

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




**NOTES:**
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2021

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




**NOTE:**
1. UPDATED RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2021

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

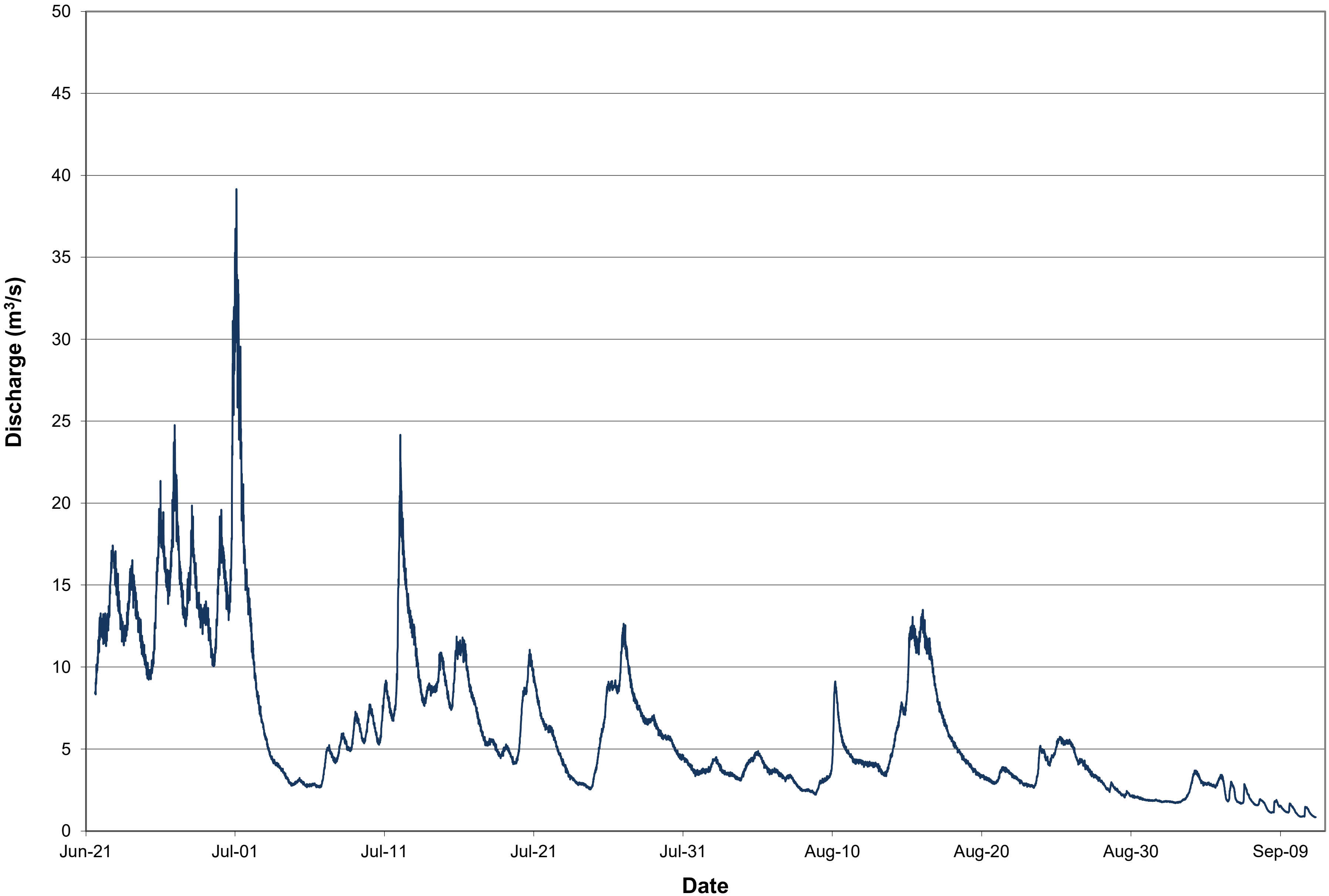



**Figure 9** **H01 - Philips Creek Tributary 2021 Streamflow Record**

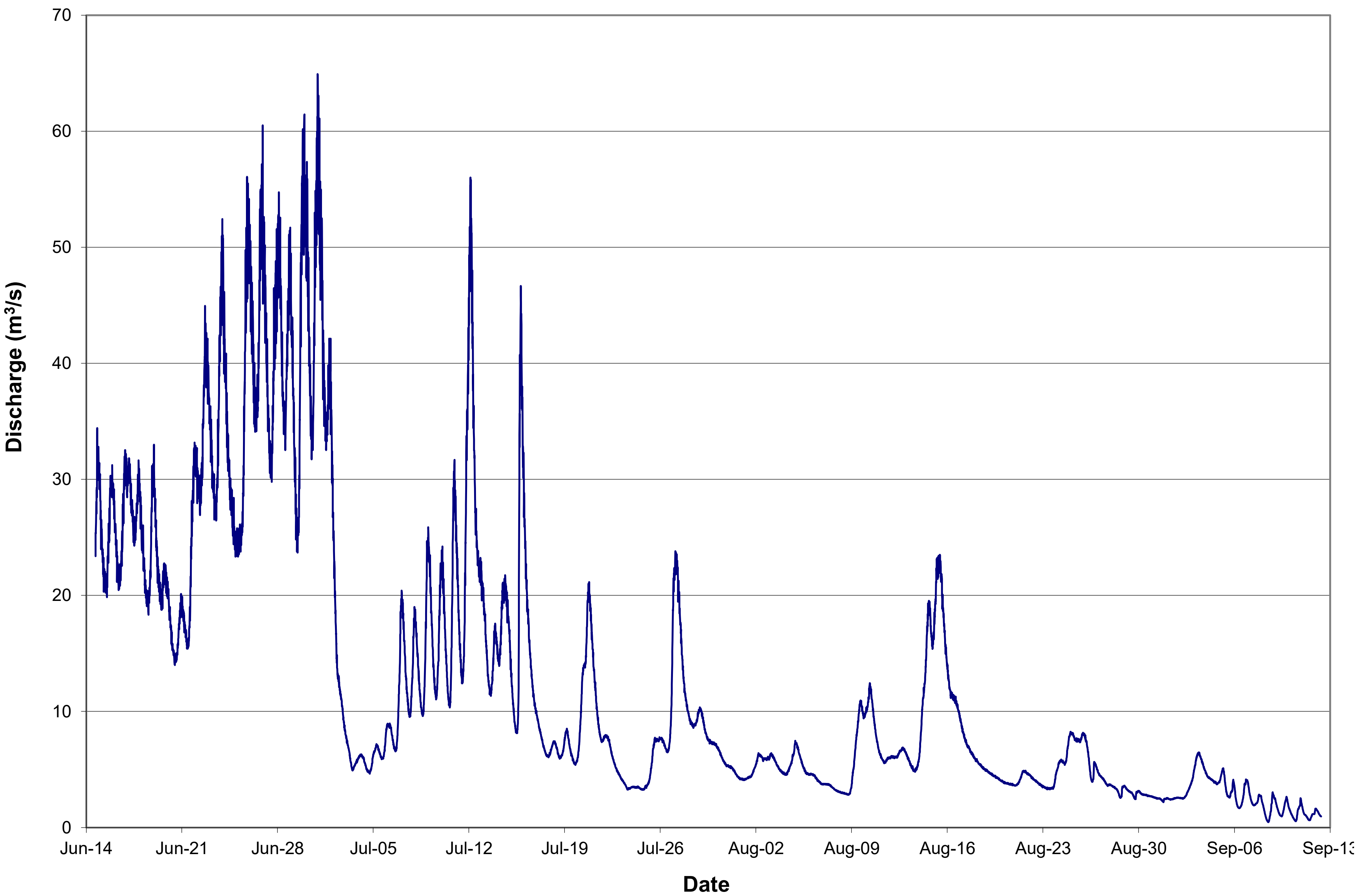



**Figure 10** **H02 - Tom River 2021 Streamflow Record**

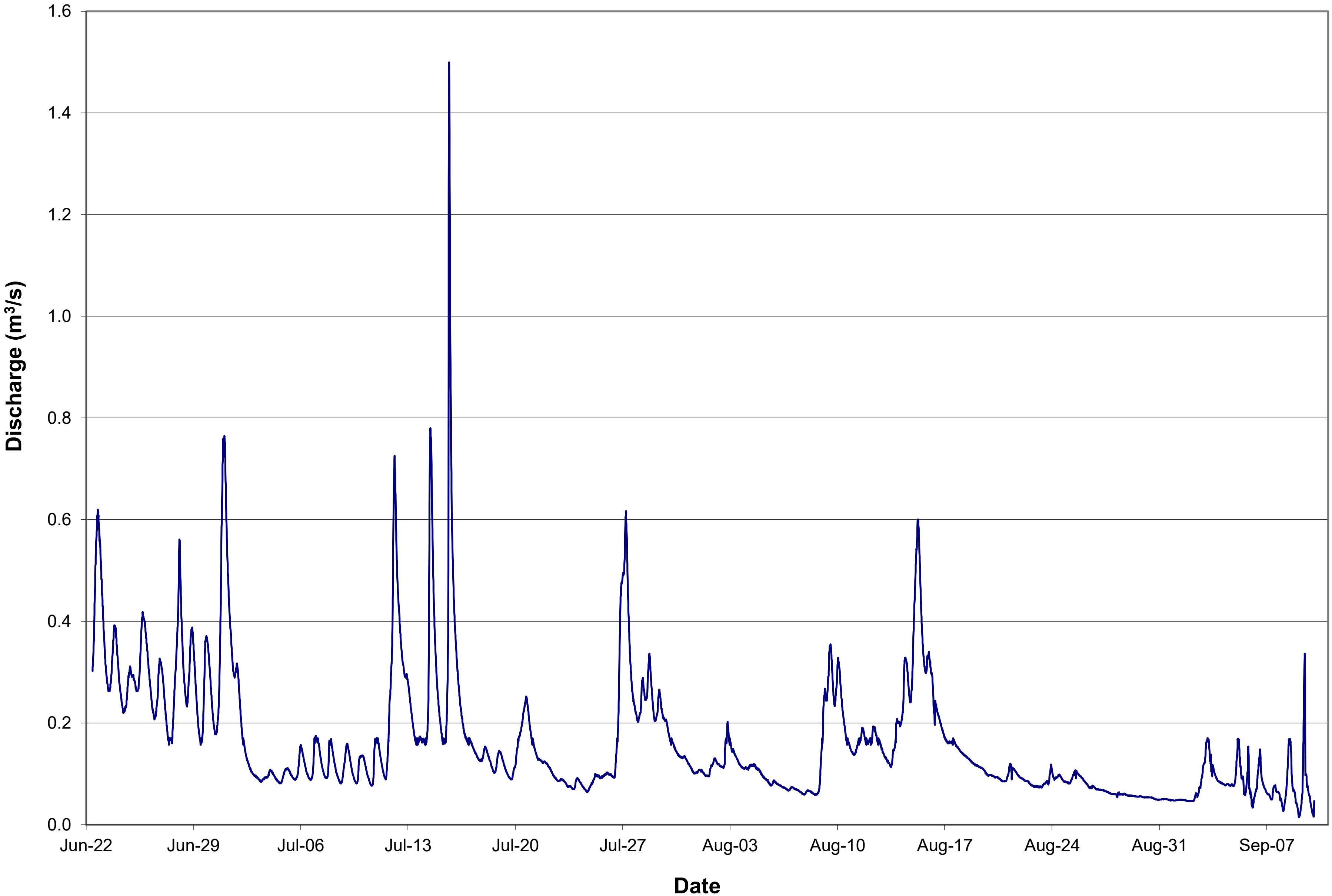



**Figure 11** **H04 - Camp Lake Tributary (CLT-2) 2021 Flow Record**

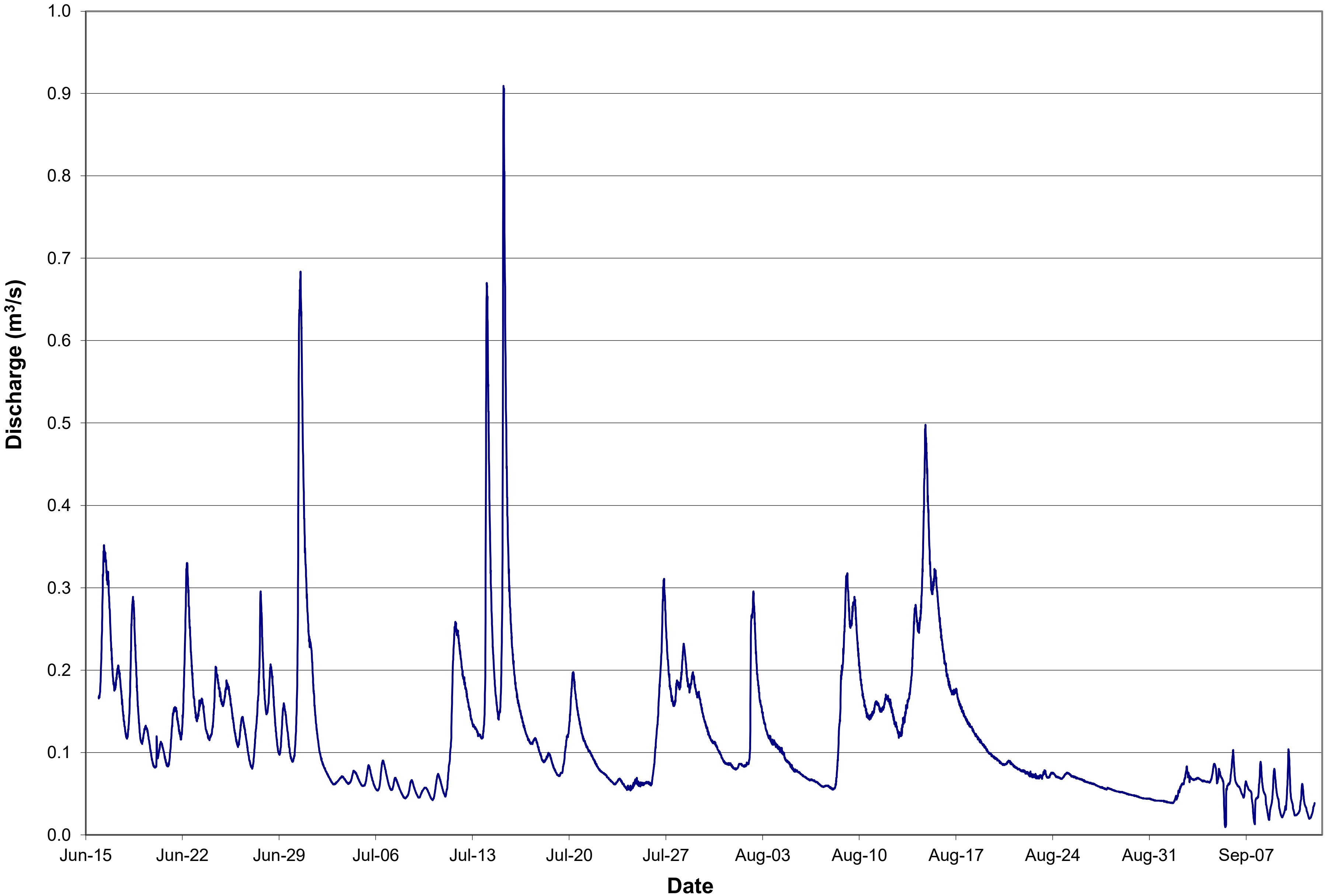



**Figure 12 H05 - Camp Lake Tributary (CLT-1) 2021 Flow Record**

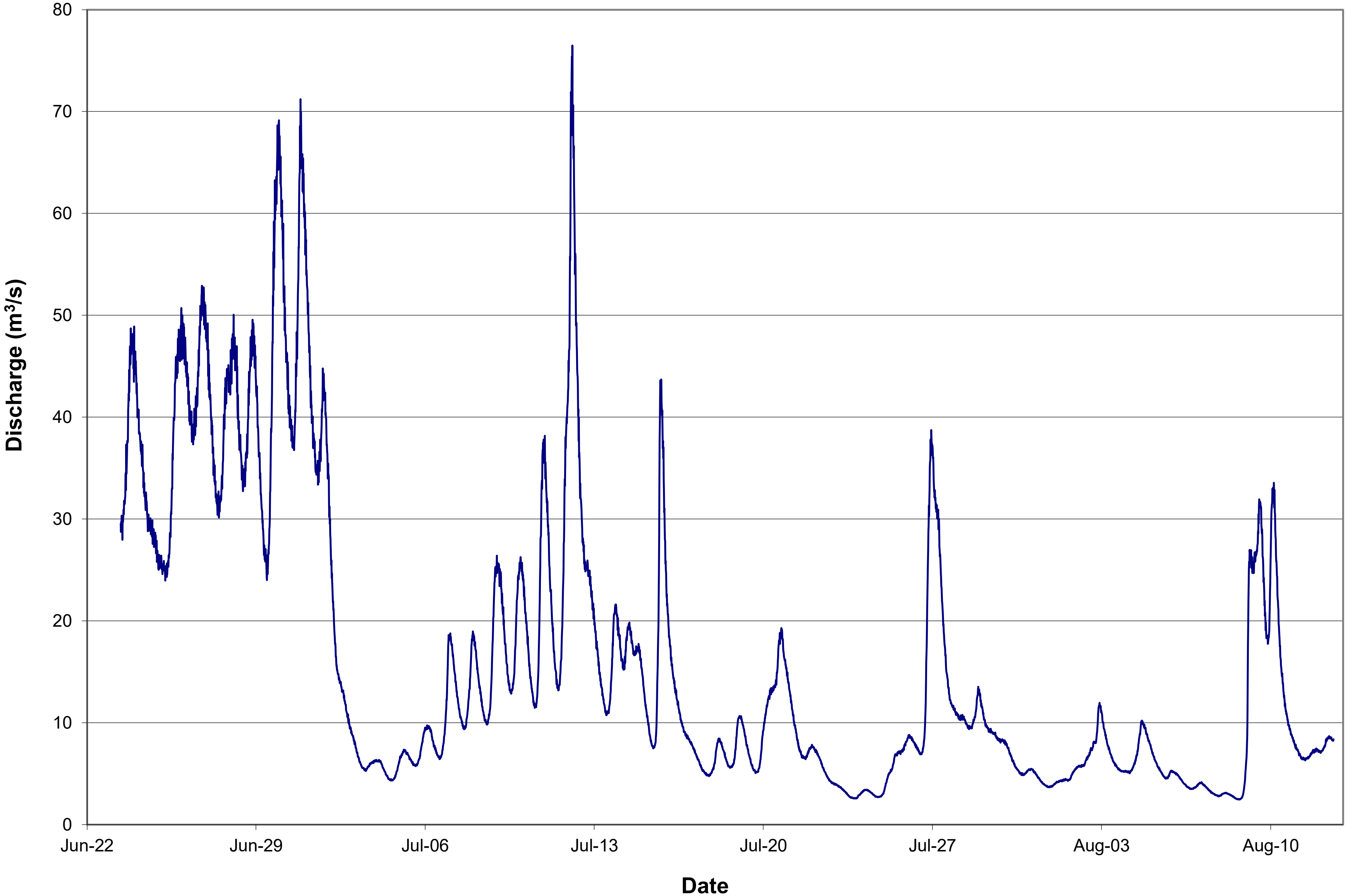



**Figure 13** **H06 - Mary River 2021 Flow Record**

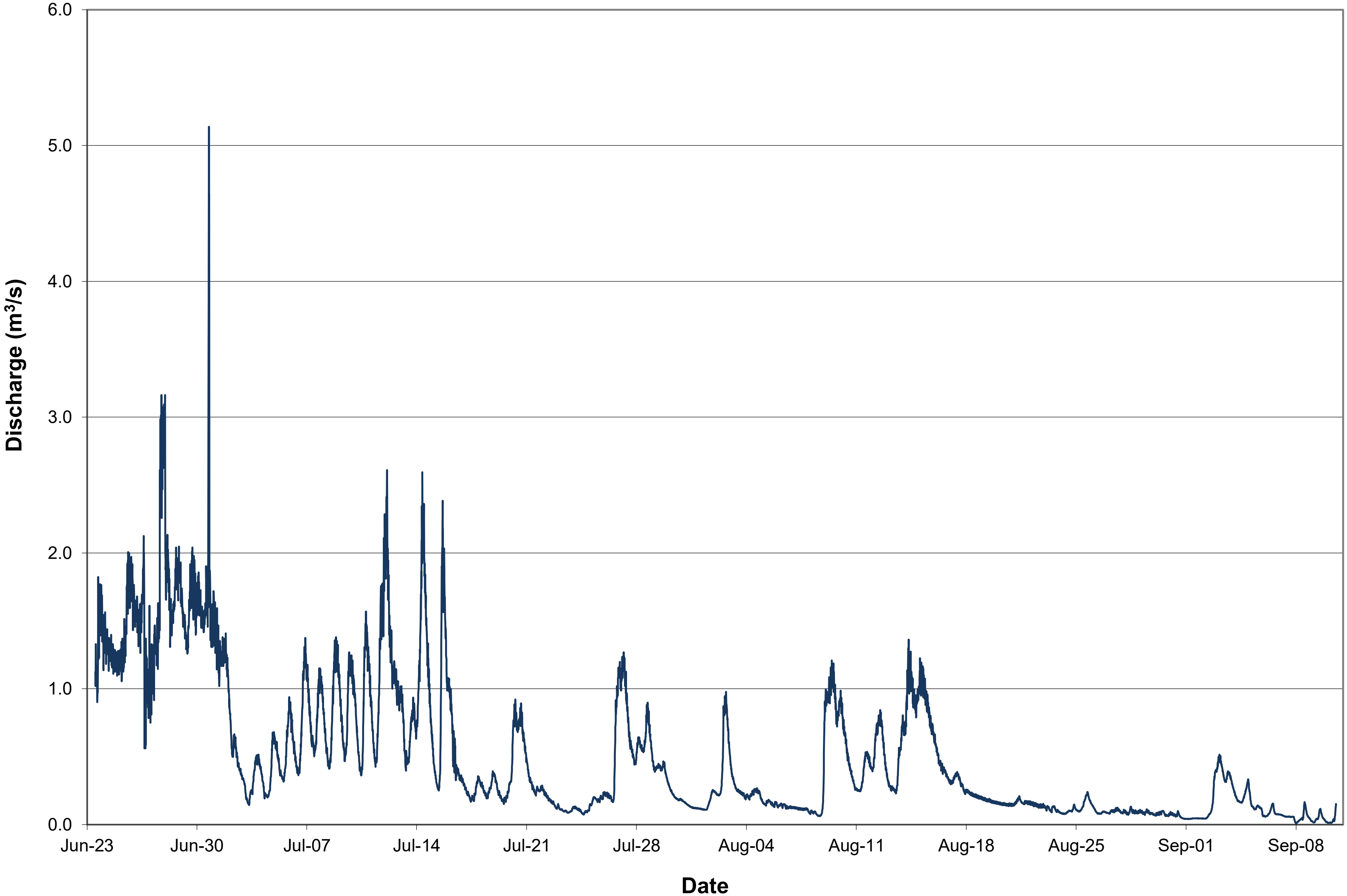



**Figure 14** **H07 - Mary River Tributary F 2021 Flow Record**

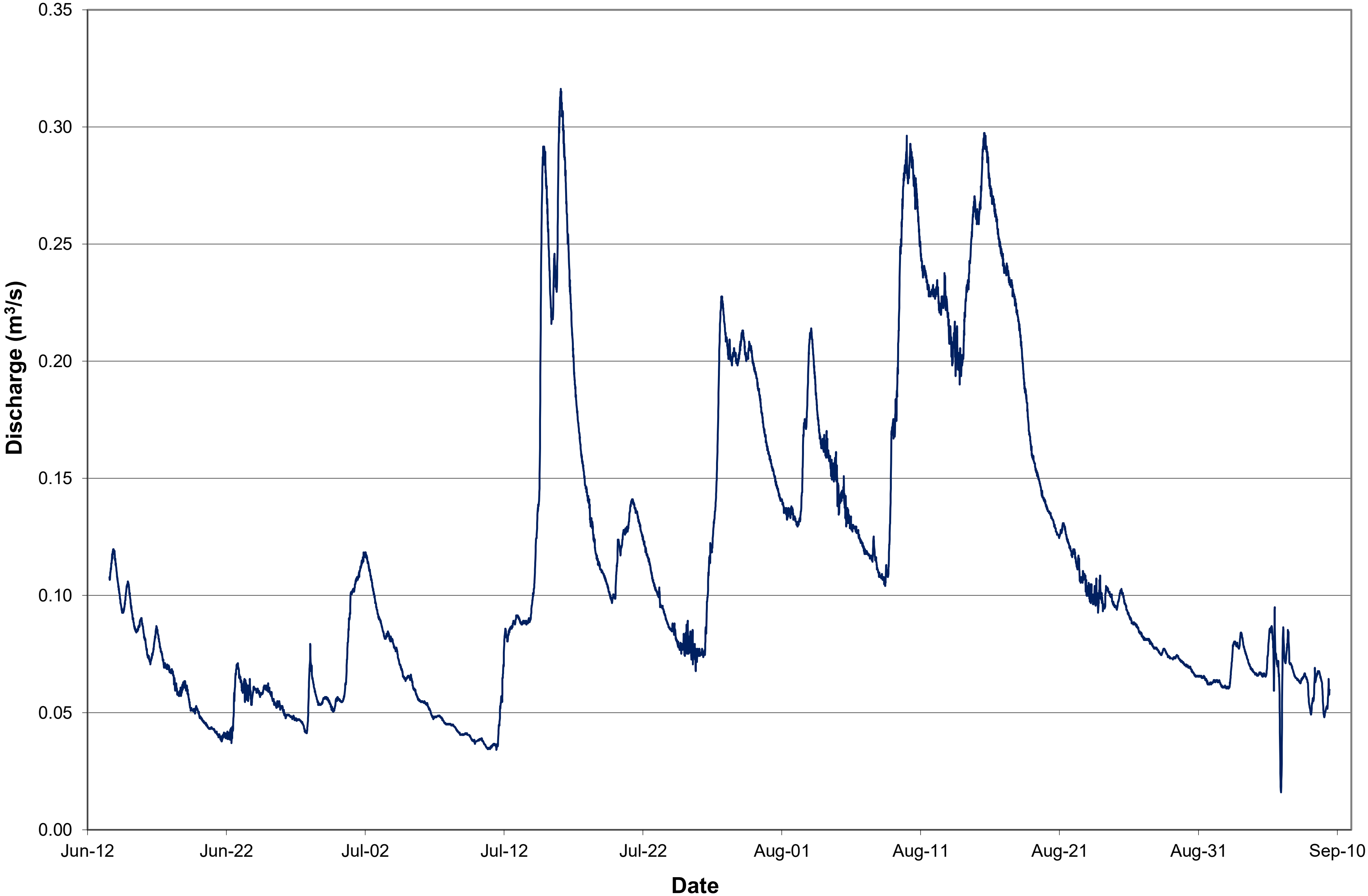



**Figure 15** **H11 - Sheardown Lake Tributary (SDLT-1) 2021 Streamflow Record**

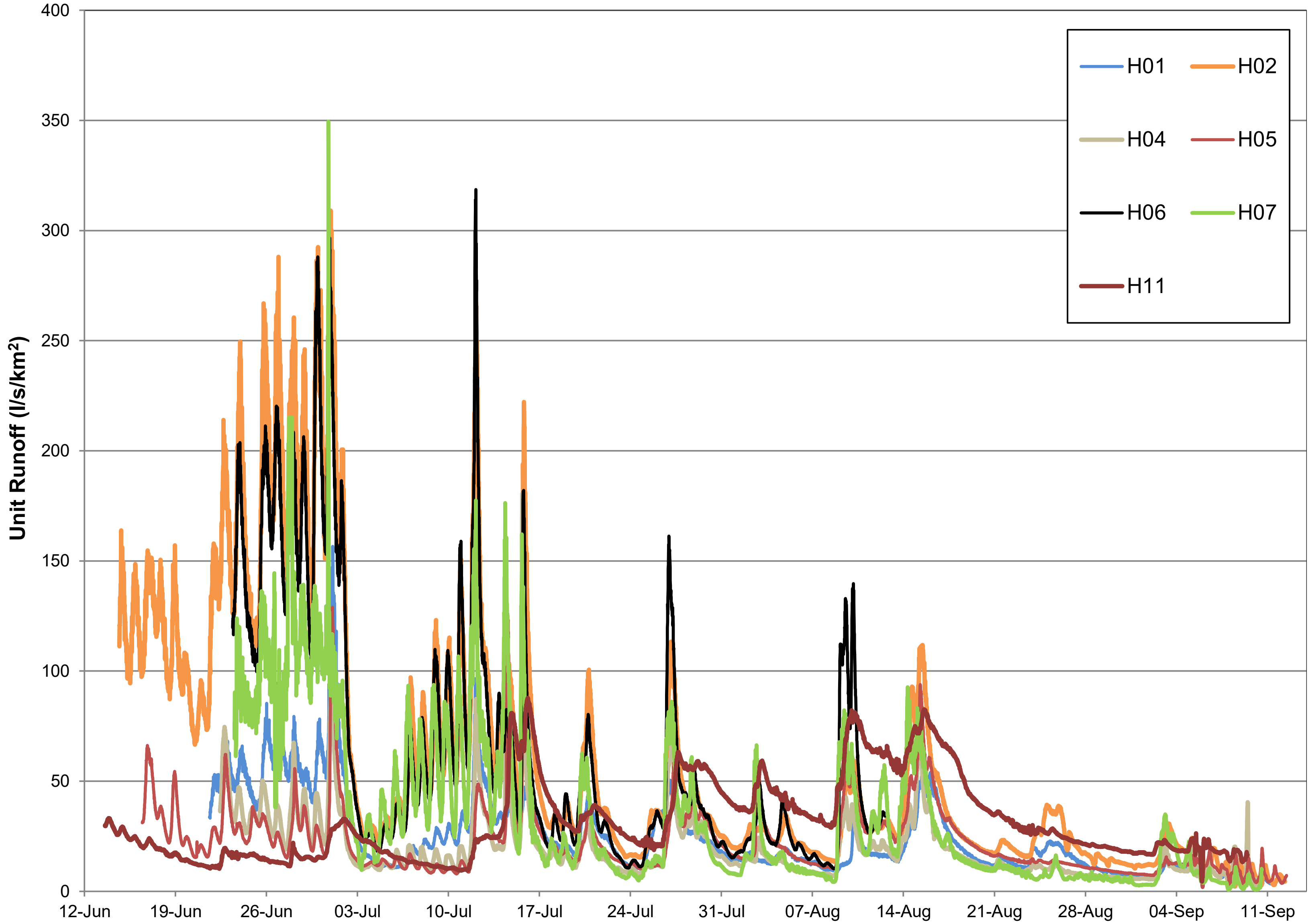



**Figure 16 Comparison of 2021 Unit Runoff**

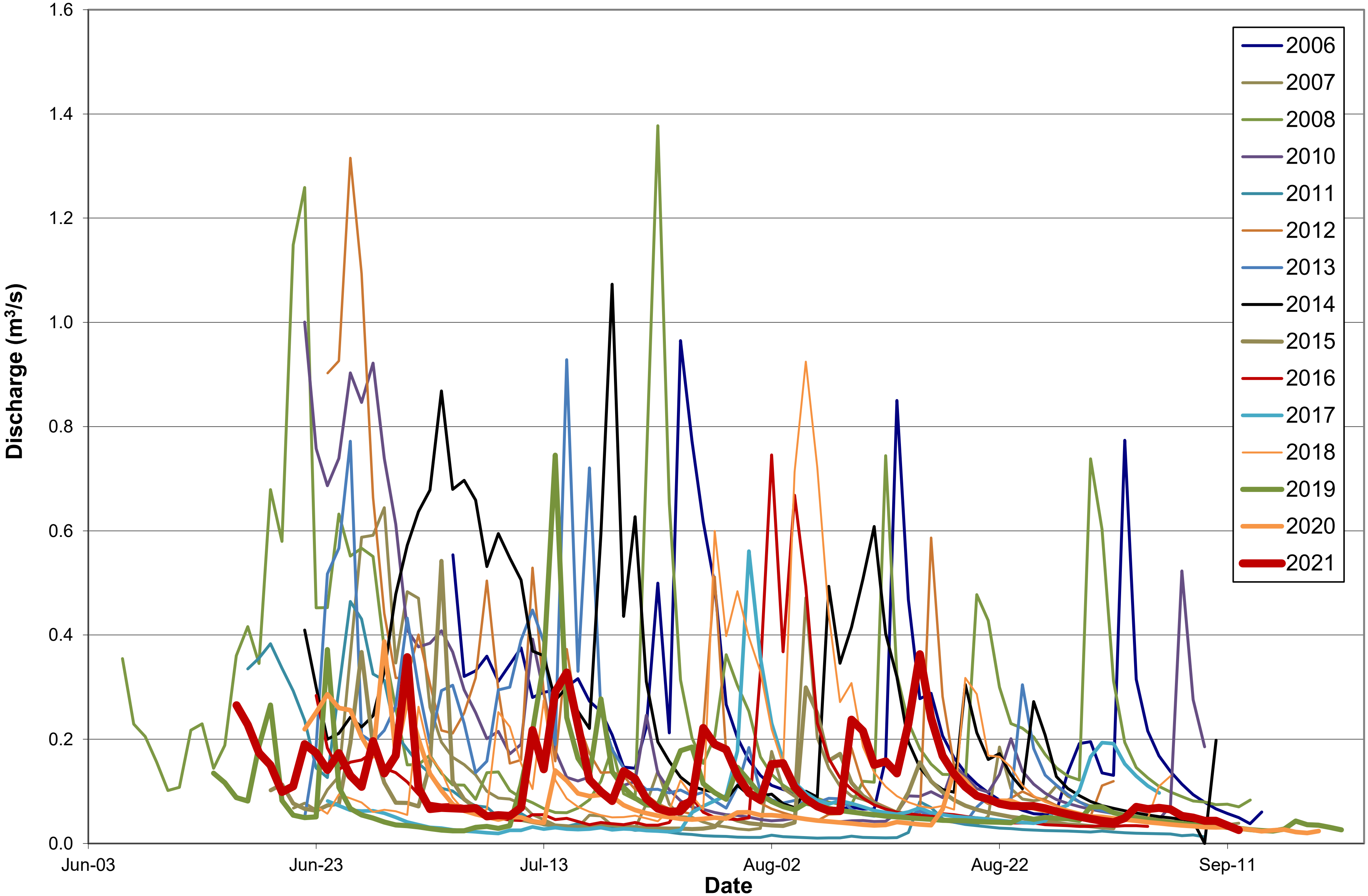



**Figure 17** **H05 - Camp Lake Tributary (CLT-1) Measured Streamflow Hydrographs 2006 - 2021**