APPENDIX D.9.3

2016 HYDROMETRIC MONITORING PROGRAM

STORY environmental inc

MEMO

To:	Jim Millard Environmental Manager Baffinland Iron Mines	**From:**	Andrew Rees, Ph.D., EP Senior Environmental Scientist
Re:	2016 Hydrometric Monitoring Program	**Date:**	28 February 2017
		Proj No:	199-03-09

1 Introduction

The 2016 Mary River Hydrometric Monitoring Program was initiated in late June around the onset of the spring melt period. Site visits were conducted by Story Environmental Inc. ("SEI") to re-install pressure transducers and conduct flow measurements at the six previously established monitoring stations (Table 1.1). The hydrometric stations are a part of the streamflow monitoring program supporting the Aquatic Effects Monitoring Plan ("AEMP").

Table 1.1 2016 Hydrometric Monitoring Stations

Station ID	Station Name	Period of Record	Drainage Area (km^2)	Coordinates (UTM)	
				Easting	Northing
H01	Phillips Creek Tributary	2006-2008, 2011-2016	250	532831	7946247
H02	Tom River near outlet to Mary Lake	2006-2008, 2010-2016	210	555712	7915514
H04	Camp Lake Tributary (CLT-2)	2006-2008, 2010-2016	8.3	557639	7915579
H05	Camp Lake Tributary (CLT-1)	2006-2008, 2010-2016	5.3	558906	7915079
H06	Mary River	2006-2008, 2010-2016	240	563922	7912984
H11	Sheardown Lake Tributary (SDLT-1)	2011-2016	3.6	560503	7913545

During the June site visit, benchmark and water level surveys were conducted and pressure transducers were installed. Discharge was measured using the velocity-area technique and a wading current meter where lower flows permitted safe access to the channel and using dilution gauging where higher flows were present. Final site visits were made by Baffinland Iron Mines ("BIM") staff between 3 and 7 September to remove the stations prior to winter freeze-up.

2 Stage-Discharge Measurements

The stage-discharge data obtained in 2016 were compared to the existing rating curves summarized in the 2015 Hydrometric Monitoring Program Summary (SEI, 2016). The rating curves for each station, inclusive of the 2016 measurements, are provided on Figures 1 to 6. A discussion and interpretation of the fit of the current data to the existing rating curves is provided in the following sections:

- **H01 (Phillip's Creek Tributary)** - A stage-discharge measurement was recorded at H01 during the June site visit using dilution gauging and is consistent with the existing rating curve (Figure 1). As such, the existing rating curve was used for the development of the 2016 streamflow record.
- **H02 (Tom River)** - A stage-discharge measurement was recorded at H02 during the June site visit using dilution gauging and the flow measured plots lower than the previous rating curve (Figure 2). As noted in SEI, 2015, the data from 2013 to 2015 suggested that there has been a shift in the rating curve. The 2016 discharge measurement also supports this shift in the rating curve and an updated rating curve has been developed and was used for the development of the 2016 flow record. Additional high flow measurements are recommended to verify the upper half of the rating curve
- **H04 (Camp Lake Tributary CLT-2)** - A stage-discharge measurement was recorded at H04 during the June site visit and is consistent with the updated rating curve proposed in SEI, 2016 (Figure 3). The June measurement was during higher flow than previous measurements and helps validate the upper half of the rating curve. There is less confidence in the accuracy of the rating curve for flows above 0.7 m^3/s. Additional high flow measurements are recommended to further validate the updated rating curve at H04. The updated rating curve was used for the development of the 2016 flow record.
- **H05 (Camp Lake Tributary CLT-1)** – The stage-discharge measurement recorded at H05 during the June site visit was consistent with the existing rating curve (Figure 4). The rating curve was used for the development of the 2016 flow record.
- **H06 (Mary River)** – A stage-discharge measurement was recorded at H06 during the June site visit using dilution gauging and is generally consistent with the existing rating curve (Figure 5). The discharge measurement demonstrates that the rating curve for H06 remains valid and that the channel appears to be stable. The existing rating curve was used for the development of the 2016 flow record.
- **H11 (Sheardown Lake Tributary SDLT-1)** – A stage-discharge measurements was recorded at H11 during the June site visit and is consistent with the rating curve updated in 2014 (Figure 6). There remains some uncertainty around higher stage-discharge conditions at H11 due to the lack of field measurements for validation. In future years, higher flow measurements should be obtained at H11 to validate the updated rating curve. The updated rating curve was used for the development of the 2016 flow record.

3 Streamflow Hydrographs

Streamflow records were developed for each station by applying the water level records to the corresponding rating curves. The discharge hydrographs for H01, H02, H04, H05, H06, and H11 are presented on Figures 7 to 12. Each water level record underwent a quality review and periods affected by channel ice or other anomalies were removed from the record.

The discharge records were converted to equivalent unit runoff (discharge per unit area) and are compared to the daily precipitation records on Figure 13. The records of unit runoff generally agree well with each other, exhibiting similar timing and magnitude of runoff events and similar patterns to previous years. As during previous years, the station at H11, with a generally lower elevation catchment, exhibited a much smaller freshet and muted response to precipitation events.

A strong diurnal melt pattern is evident through the end of June and first half of July. The snowmelt at lower elevations and the peak of freshet flows occurred earlier than normal at the stations with smaller and lower elevation catchment areas (H04, H05, and H11) and was not captured in the data. The peak freshet flows at the stations with larger catchments (H01, H02, and H06) occurred in late June. The peak flows at H01, H02, and H06 were similar to 2015 but lower than previous years and occurred over a typical duration. A summary of flows at H05 from 2006 to 2016 is shown on Figure 14. The total annual runoff in 2016 at the H05 station was greater than in 2015 but the third lowest recorded from 2006 to 2016. Both 2015 and 2016 had lower than normal flows in mid-July and from mid-August to early September. The estimated mean monthly discharge and unit runoff for each station in 2016 are summarized in Table 3.1.

Table 3.1 Summary of 2016 Mean Monthly Estimated Discharge and Unit Runoff

STATION	Estimated Mean Monthly Discharge (m^3/s)				Period of Record
	June	July	August	September	
H01	18.1*	8.3	5.7	1.7*	June 25 to September 5
H02	25.5*	6.7	3.9	0.5*	June 26 to September 5
H04	0.59*	0.17	0.23	0.09*	June 23 to September 4
H05	0.17*	0.05	0.13	0.03*	June 23 to September 4
H06	36.5*	13.1	7.2	1.7*	June 26 to September 4
H11	0.03*	0.04	0.13	0.04*	June 24 to September 3

STATION	Estimated Mean Monthly Unit Runoff ($l/s/km^2$)				Period of Record
	June	July	August	September	
H01	72.6*	33.2	22.9	6.8*	June 25 to September 5
H02	121.4*	31.9	18.9	2.4*	June 26 to September 5
H04	71.9*	20.4	27.8	11.6*	June 23 to September 4
H05	32.5*	10.5	26.2	6.3*	June 23 to September 4
H06	152.1*	54.7	30.2	7.2*	June 26 to September 4
H11	8.7*	11.0	38.2	10.6*	June 24 to September 3

Note:

1. Months with incomplete data records are indicated with an asterix.

4 Summary

The 2016 Hydrometric Monitoring Program allowed for the continued monitoring of streamflow at the AEMP hydrometric stations. The data collected confirmed the rating curves at all stations. It is recommended that future hydrometric monitoring includes more frequent site visits during the season to ensure the proper operation of data loggers and to confirm or improve rating curves, especially during summer high flow events.

5 References

Story Environmental Inc. (SEI), 2016. Memorandum to Jim Millard, Baffinland Iron Mines Corporation. Re: *2015 Hydrometric Monitoring Program*. February 2. Haileybury, Ontario. Ref. No. 199-01-09.

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Reviewed by:

Maria Story, P.Eng.
President

Attachments:

Figure 1	H01 - Phillip's Creek Tributary Rating Curve
Figure 2	H02 - Tom River Rating Curve
Figure 3	H04 - Camp Lake Tributary (CLT-2) Rating Curve
Figure 4	H05 - Camp Lake Tributary (CLT-1) Rating Curve
Figure 5	H06 - Mary River Rating Curve
Figure 6	H11 - Sheardown Lake Tributary (SLDT-1) Rating Curve
Figure 7	H01 – Phillip's Creek Tributary 2016 Streamflow Record
Figure 8	H02 - Tom River 2016 Streamflow Record
Figure 9	H04 - Camp Lake Tributary (CLT-2) 2016 Streamflow Record
Figure 10	H05 - Camp Lake Tributary (CLT-1) 2016 Streamflow Record
Figure 11	H06 - Mary River 2016 Streamflow Record
Figure 12	H11 - Sheardown Lake Tributary (SLDT-1) 2016 Streamflow Record
Figure 13	2016 Unit Runoff and Daily Precipitation
Figure 14	H05 - Measured Streamflow Hydrographs 2006-2016

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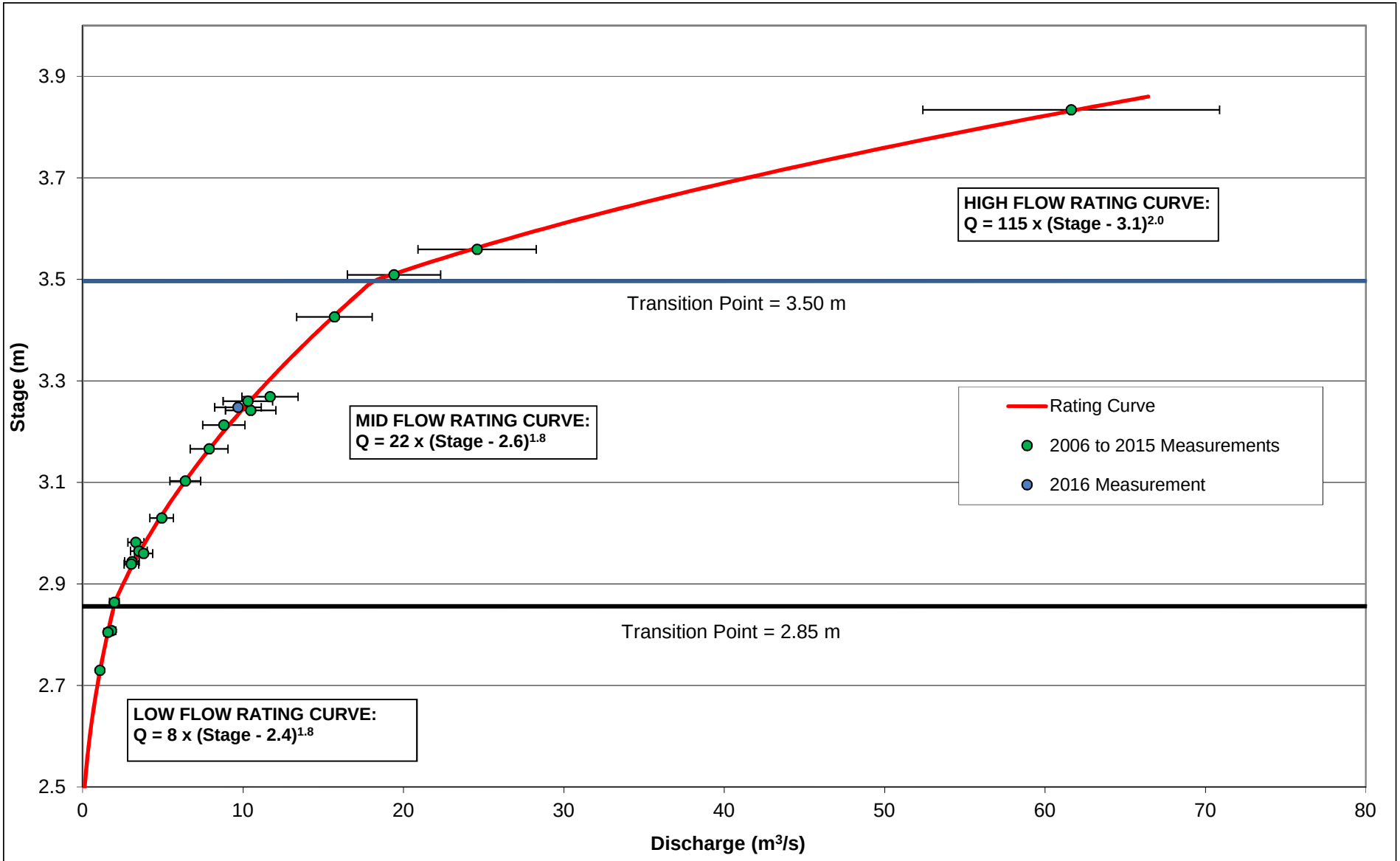
Attachments



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

Figure 1 H01 - Philips Creek Tributary Rating Curve

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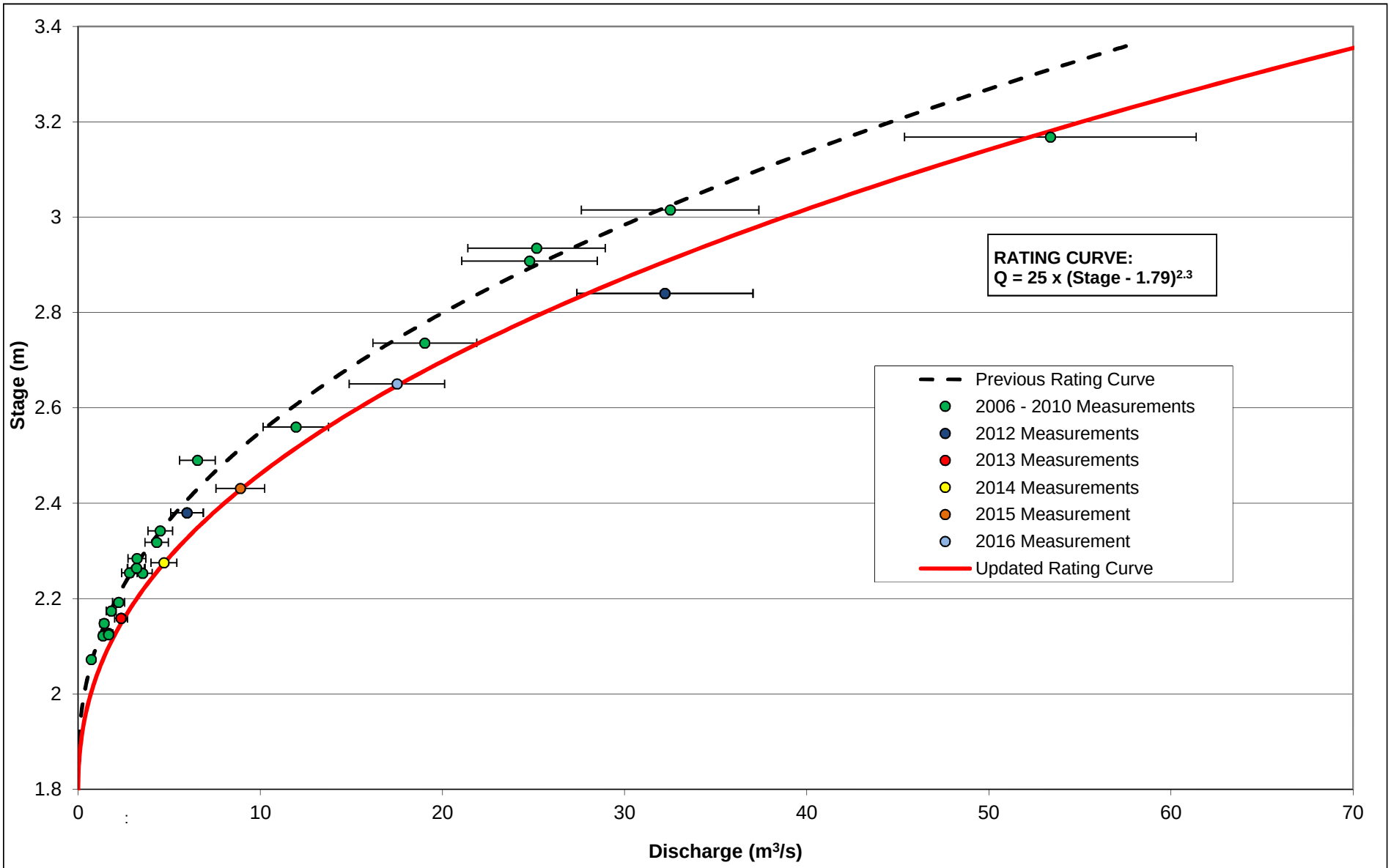

NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE.

Figure 2 H02 - Tom River Rating Curve

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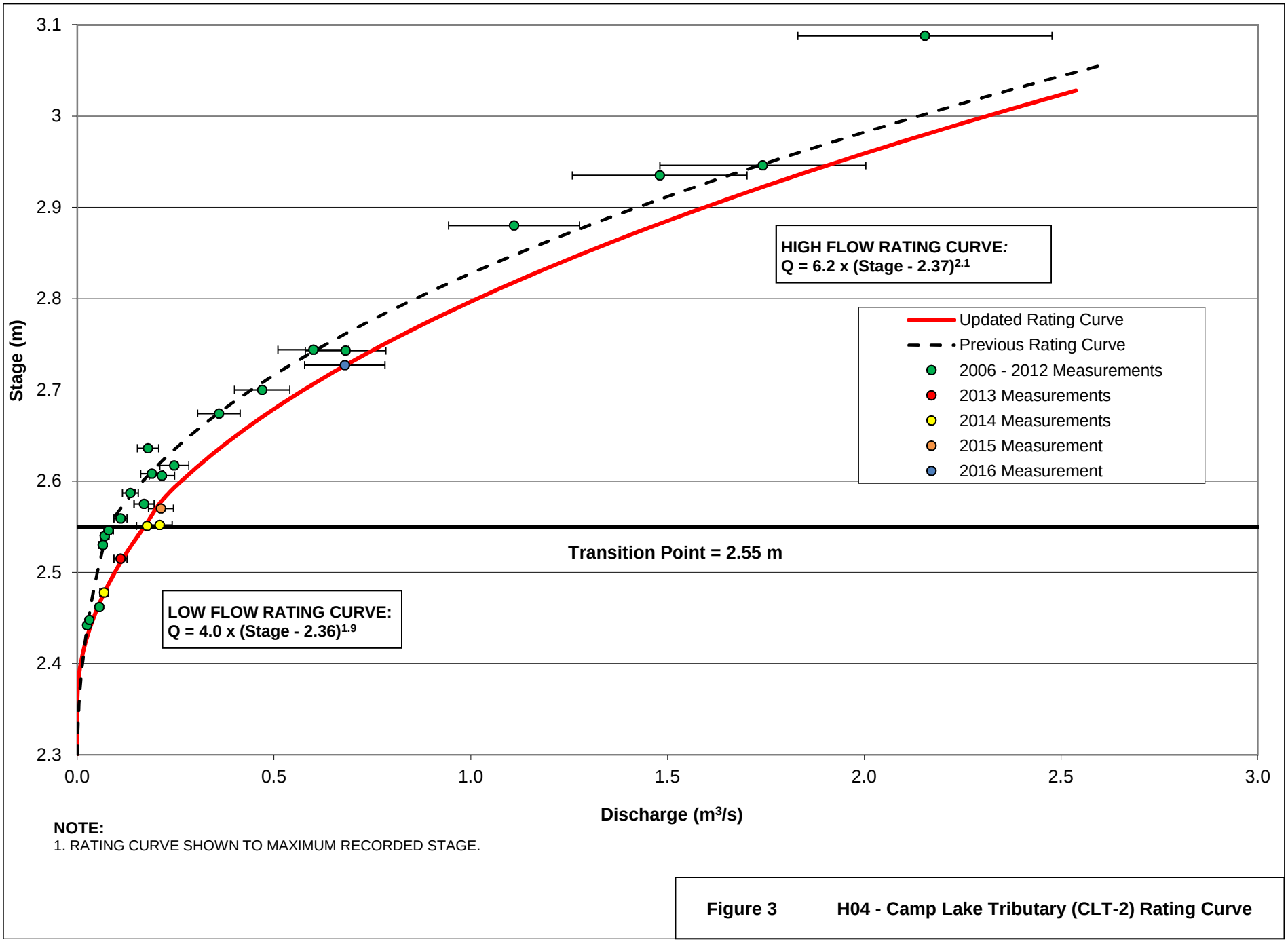

NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE.

Figure 3 H04 - Camp Lake Tributary (CLT-2) Rating Curve

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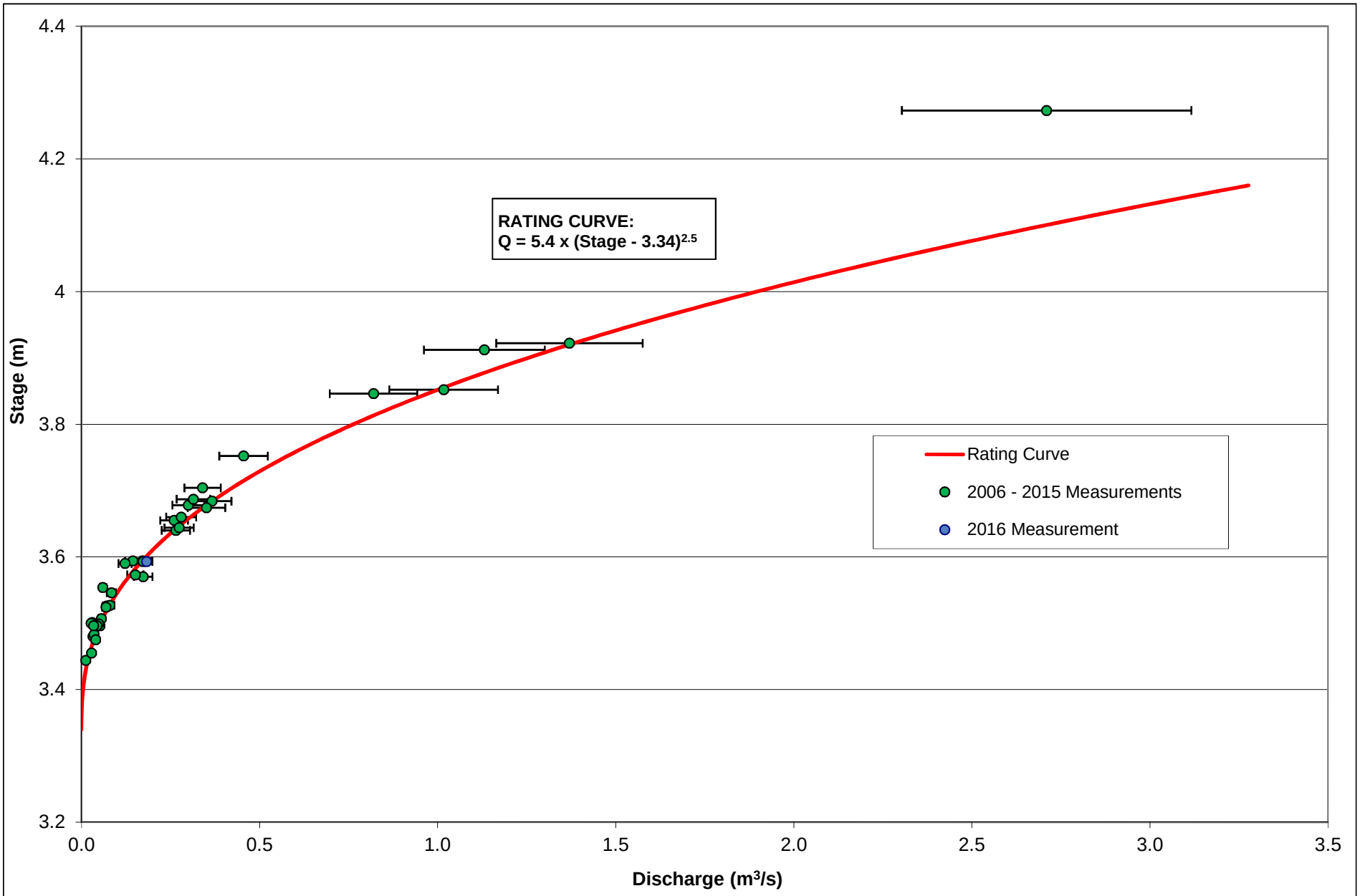

NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE.

Figure 4 H05 - Camp Lake Tributary (CLT-1) Rating Curve

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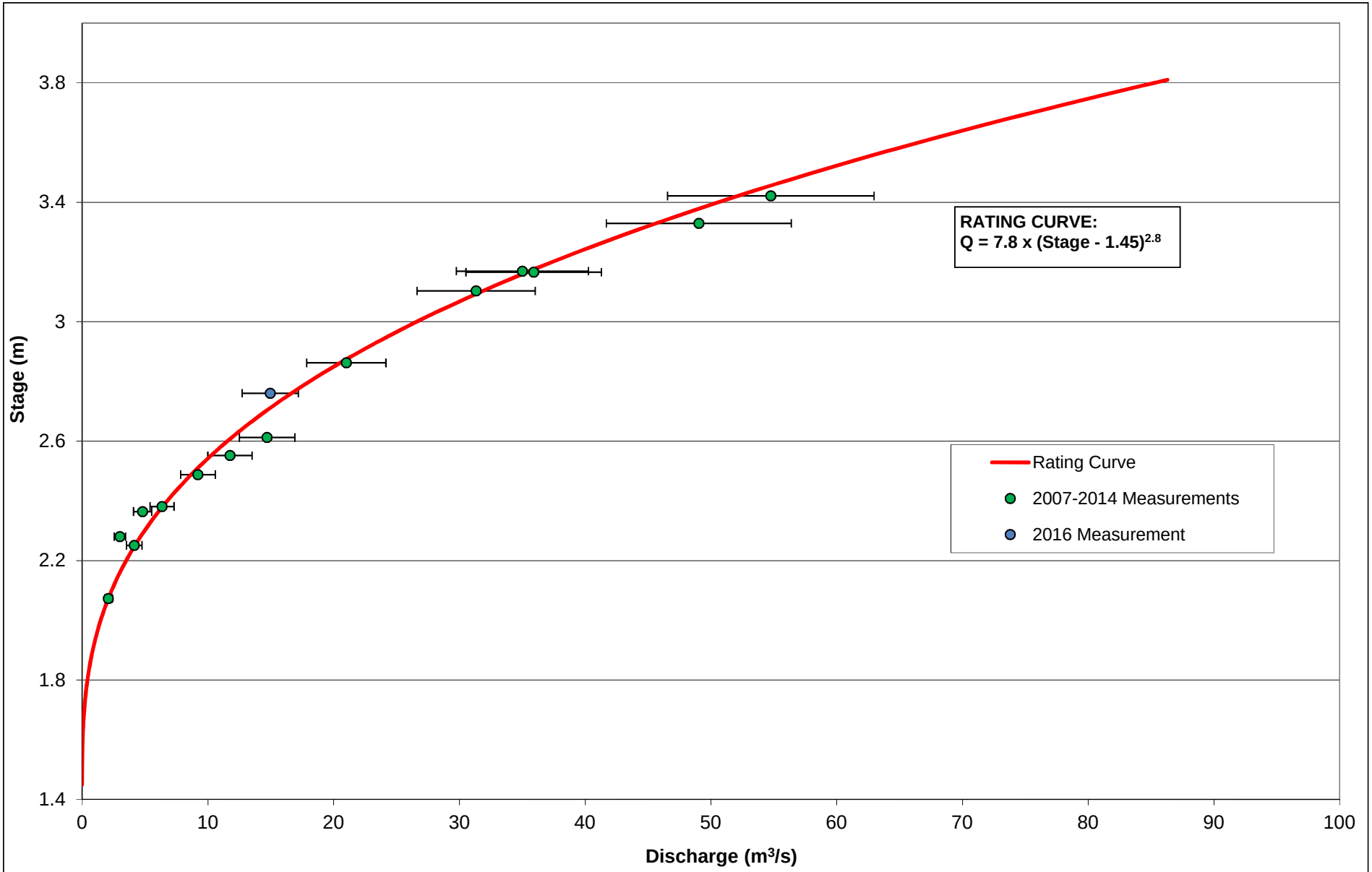

NOTES:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE.

Figure 5 H06 - Mary River Rating Curve

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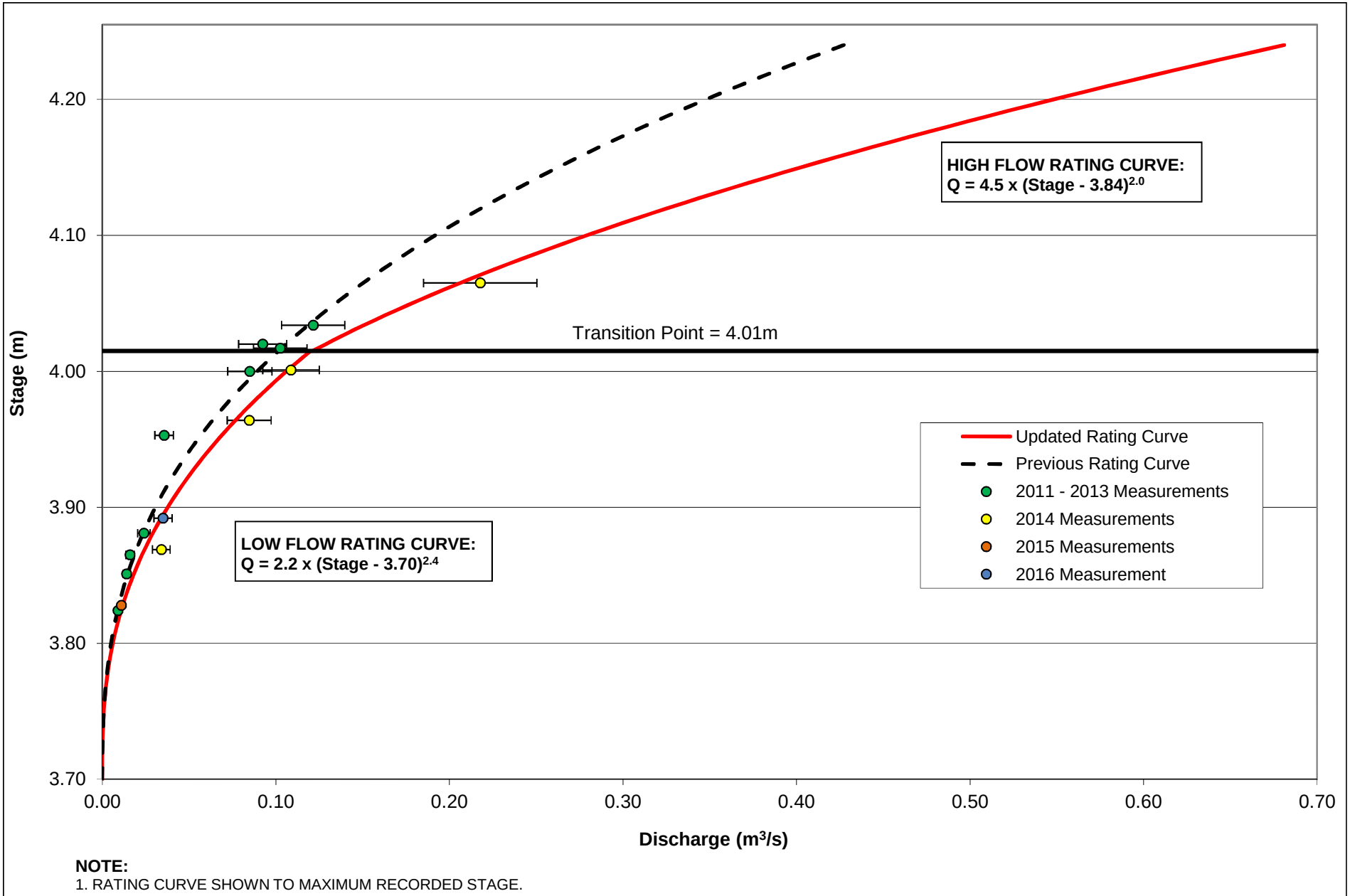

NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE.

Figure 6 H11 - Sheardown Lake Tributary (SDLT-1) Rating Curve

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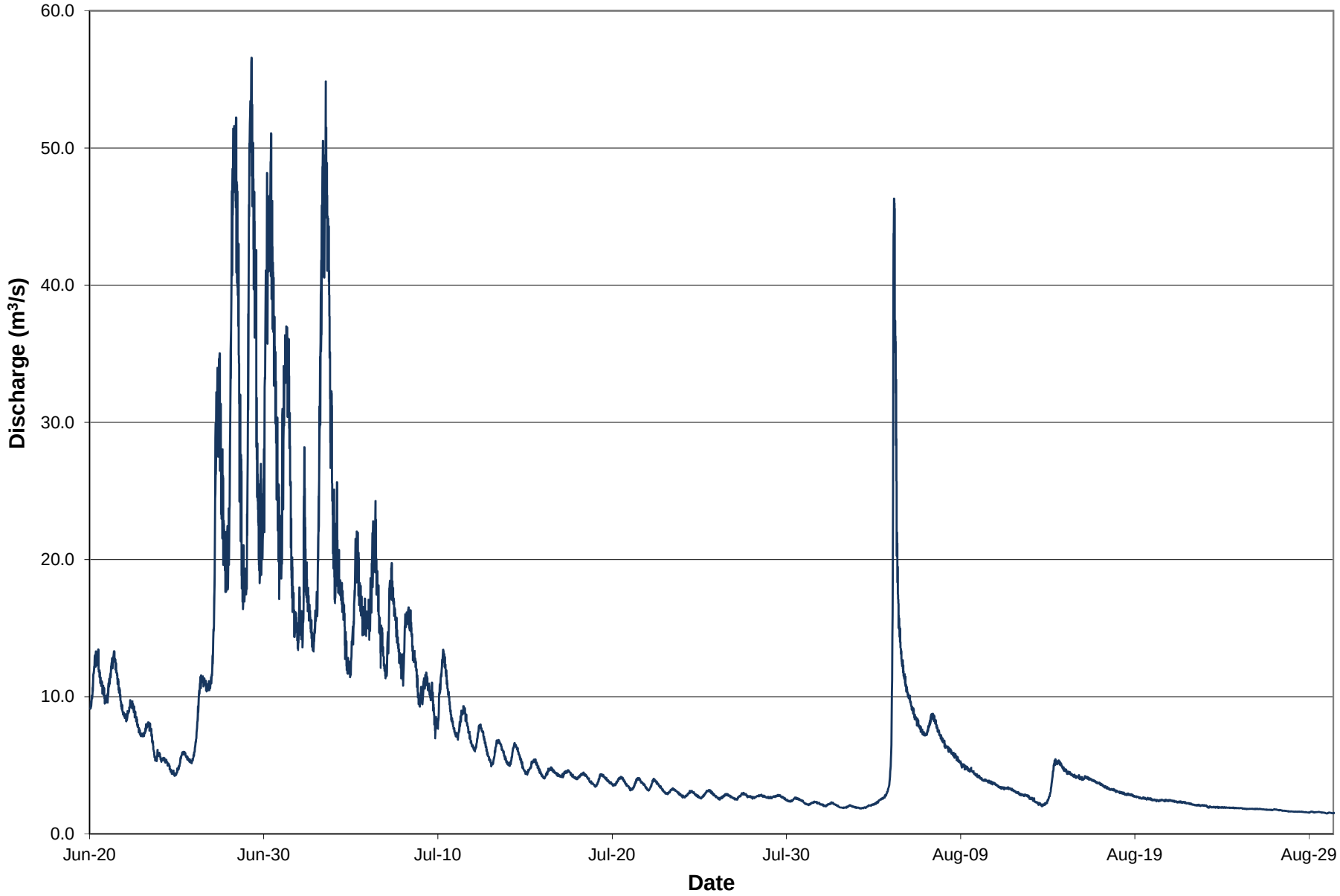

Figure 7 **H01 - Philips Creek Tributary 2016 Streamflow Record**

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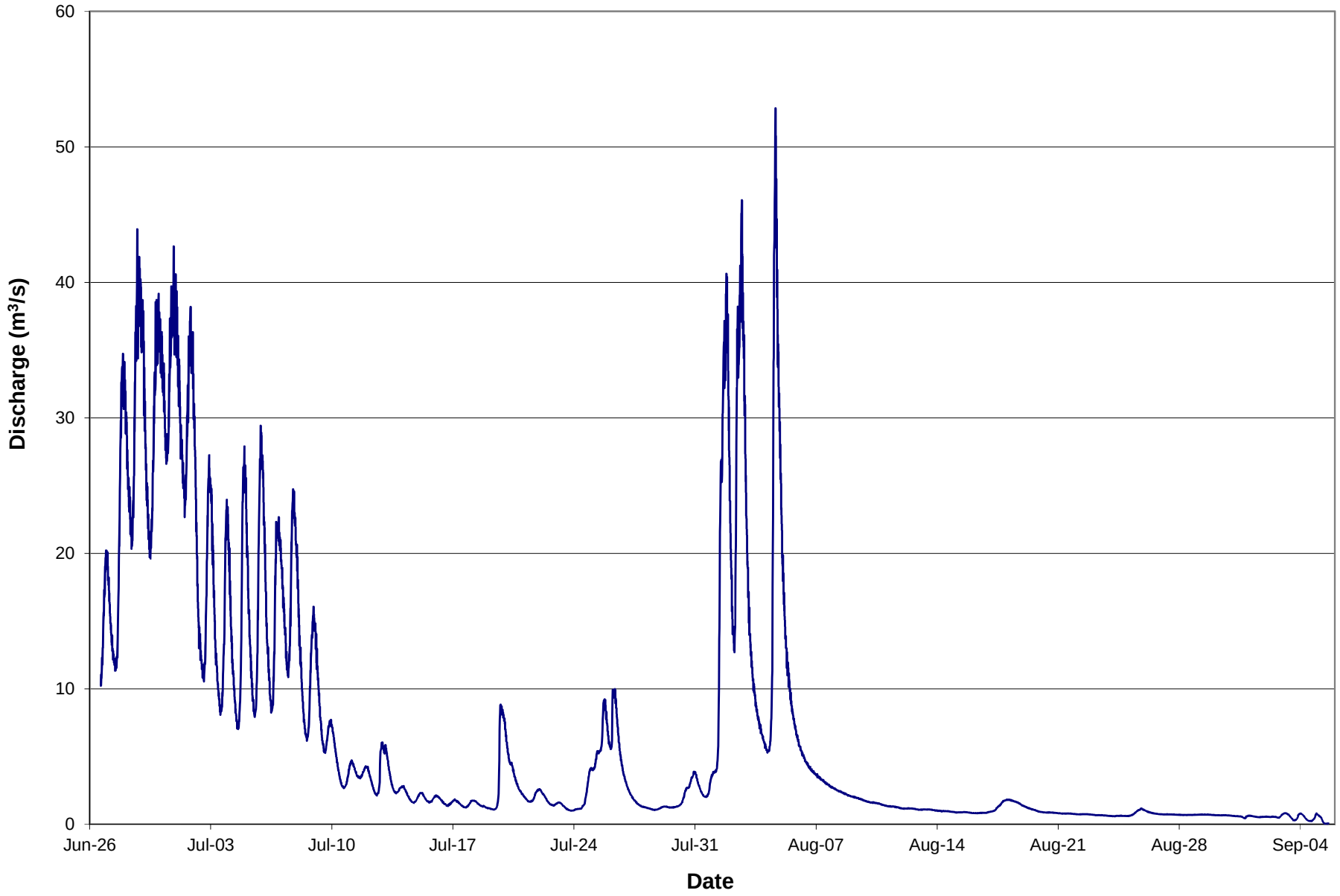

Figure 8 **H02 - Tom River 2016 Streamflow Record**

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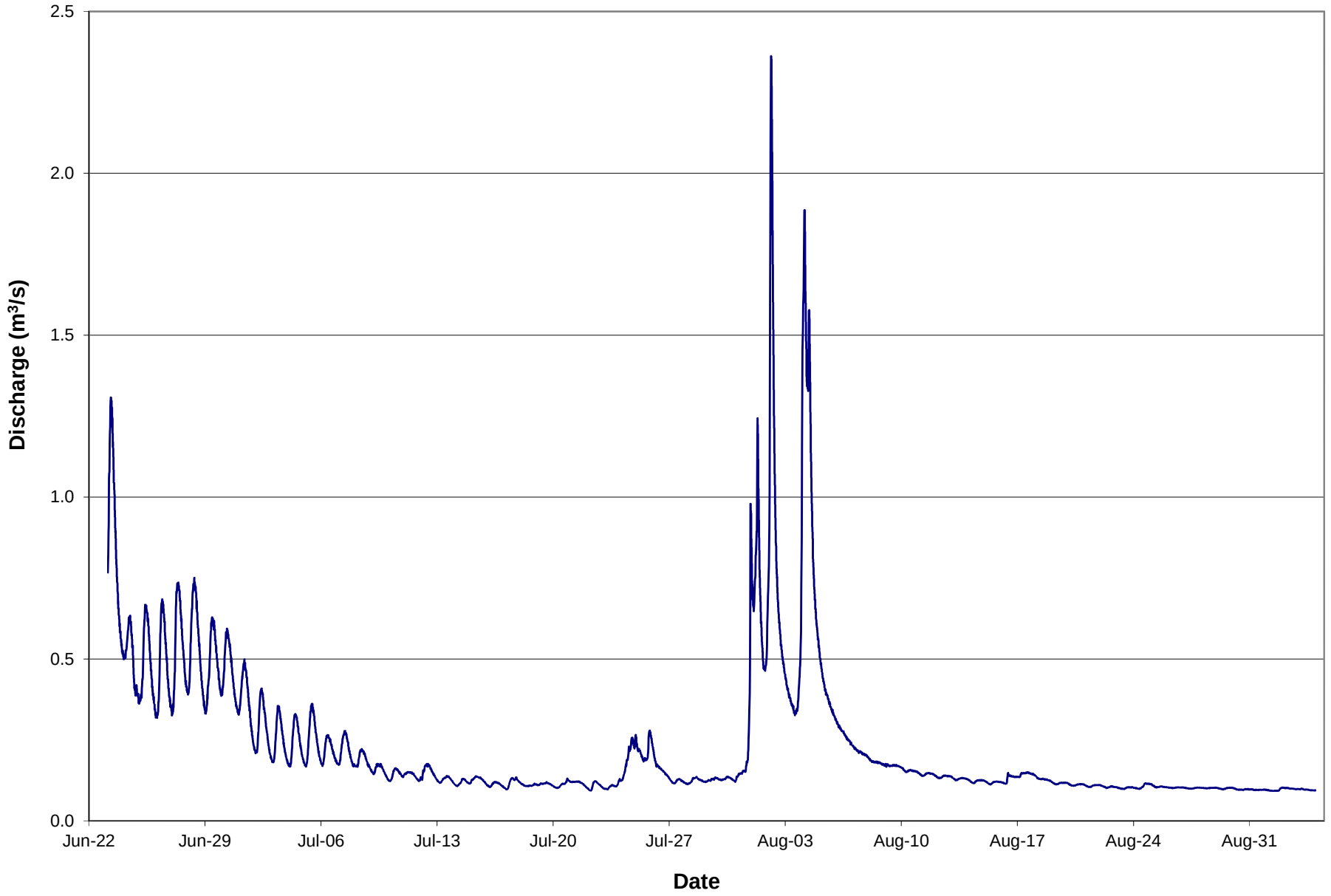

Figure 9 **H04 - Camp Lake Tributary (CLT-2) 2016 Flow Record**

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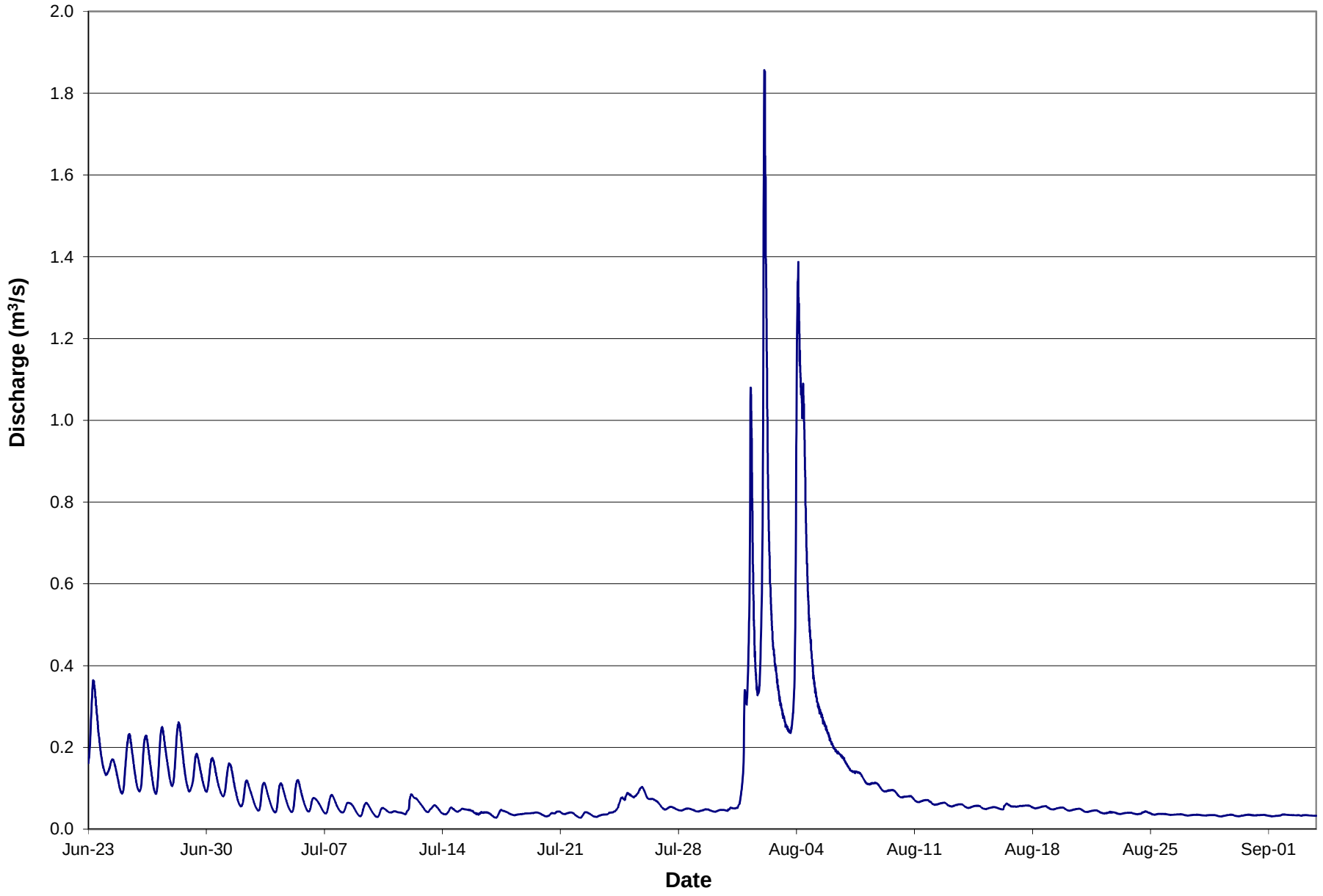

Figure 10 **H05 - Camp Lake Tributary (CLT-1) 2016 Flow Record**

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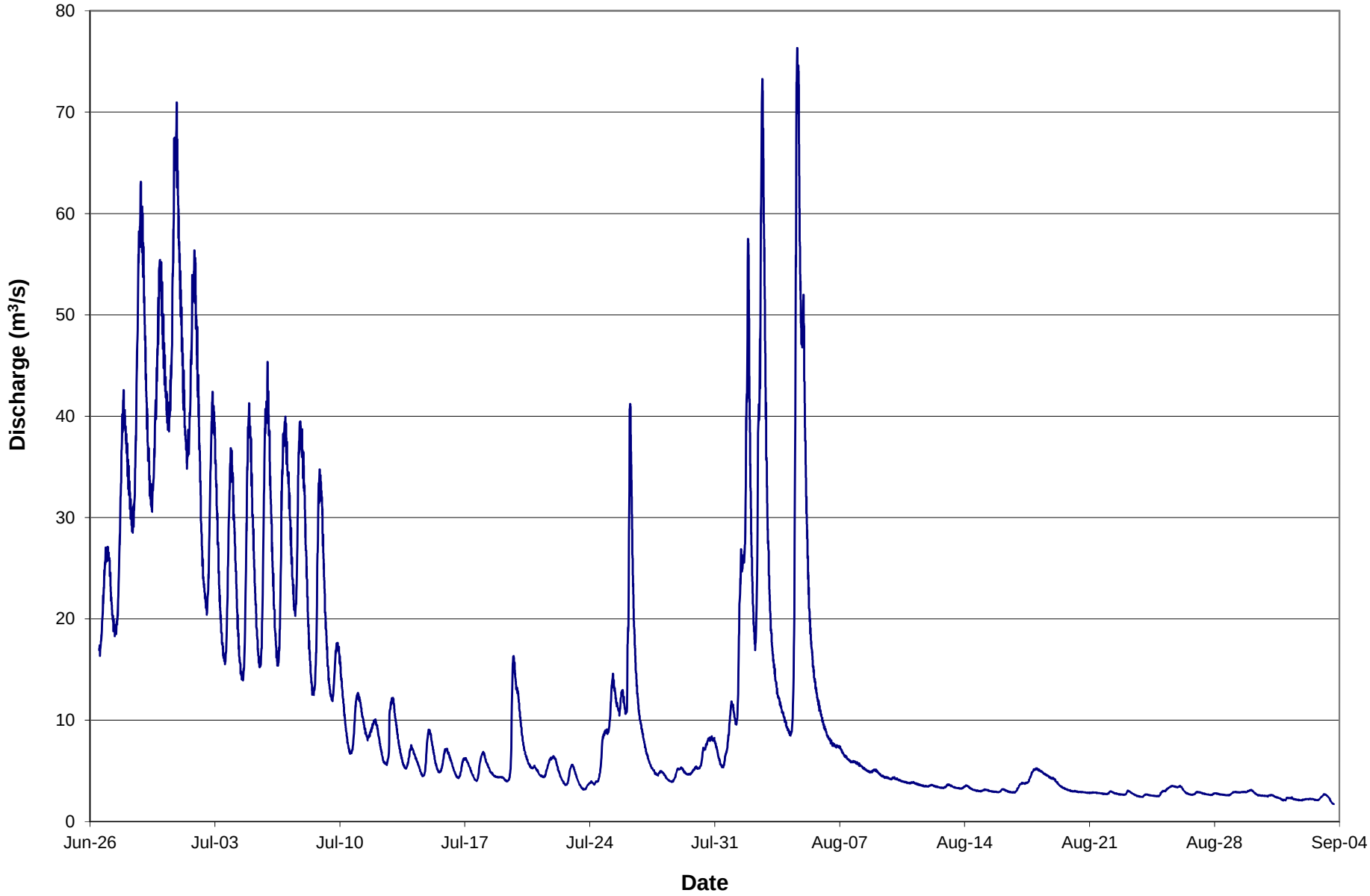

Figure 11 H06 - Mary River 2016 Flow Record

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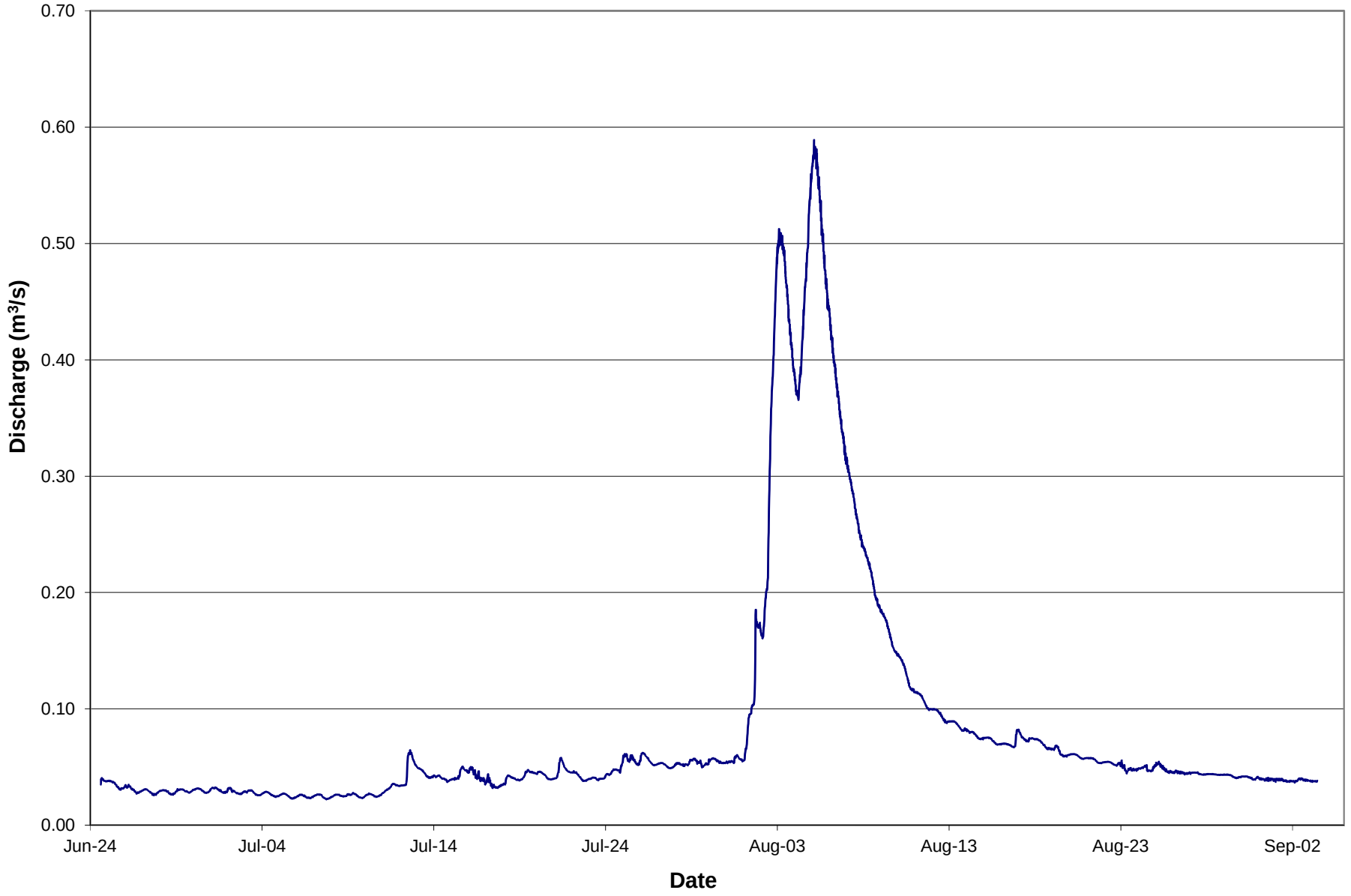

Figure 12 **H11 - Sheardown Lake Tributary (SDLT-1) 2016 Streamflow Record**

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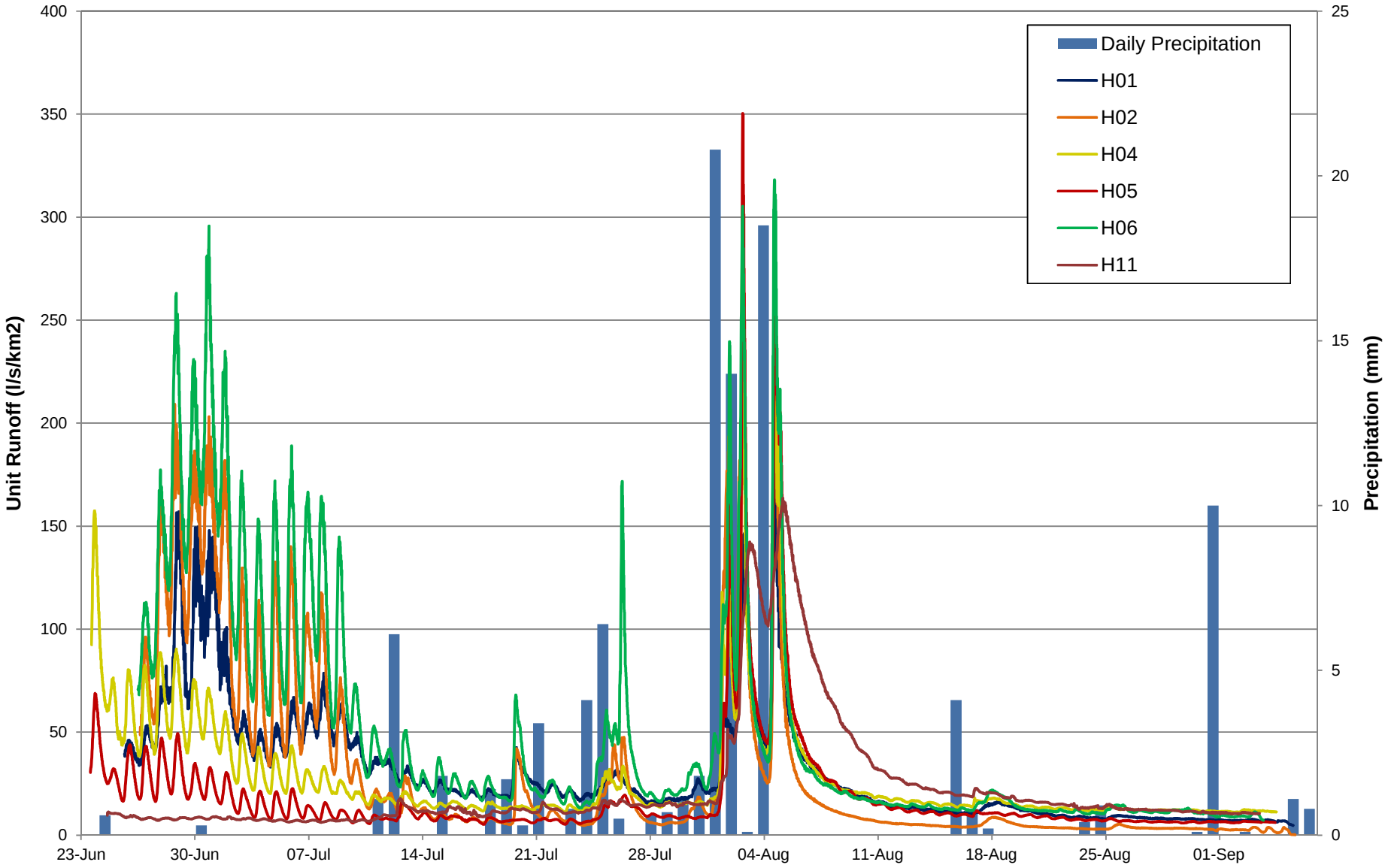

Figure 13 2016 Unit Runoff and Daily Precipitation

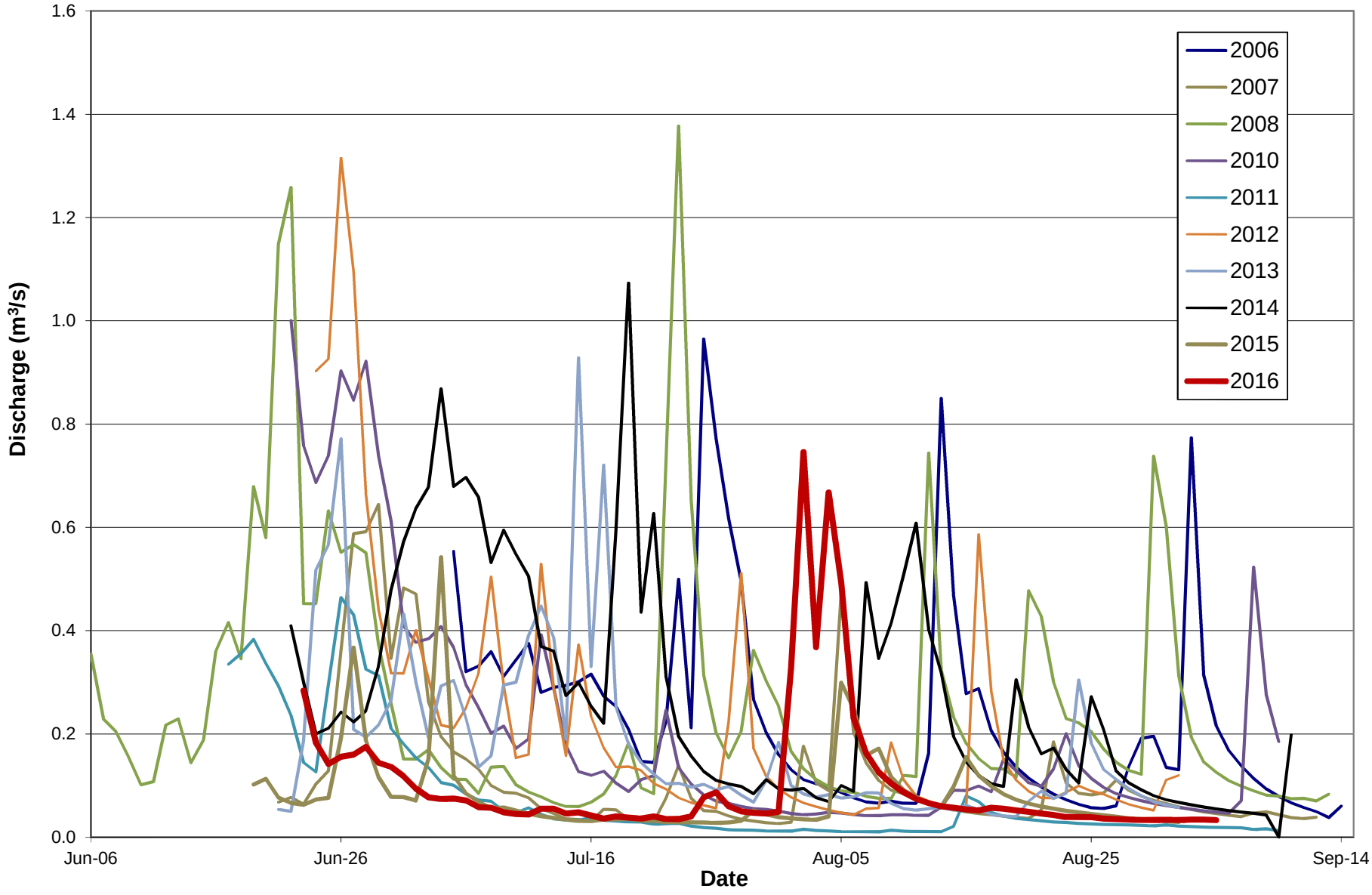

Figure 14 H05 - Measured Streamflow Hydrographs 2006 - 2016

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