Appendix V5-1B

Meteorology and Hydrology Baseline Doris North Project

Miramar MINING CORPORATION

Meteorology and Hydrology Baseline
Doris North Project
Nunavut, Canada

Prepared for:

Miramar Hope Bay Ltd
North Vancouver, BC

November 2003

Meteorology and Hydrology Baseline
Doris North Project

Nunavut, Canada

Prepared for:

Miramar Hope Bay Ltd.
889 Harbourside Drive
North Vancouver, BC
V7P 3S1

Prepared by:

AMEC Earth & Environmental Limited
2227 Douglas Road
Burnaby, BC
V5C 5A9

METEOROLOGY AND HYDROLOGY BASELINE

DORIS NORTH PROJECT
REVISION 1
SUPPORTING DOCUMENT 'D'
TO THE FINAL ENVIRONMENTAL IMPACT STATEMENT

Prepared for:

Miramar Hope Bay Ltd
North Vancouver, BC

Prepared by:

AMEC Earth & Environmental Limited
Burnaby, BC

November 2003

VM00259

TABLE OF CONTENTS

Page

EXECUTIVE SUMMARY III

1.0 INTRODUCTION 1

2.0 METEOROLOGY 2
- 2.1 AVAILABLE DATA 2
- 2.2 AIR TEMPERATURE 2
- 2.3 PRECIPITATION 3
  - 2.3.1 Monthly Precipitation 3
  - 2.3.2 Under-catch 8
  - 2.3.3 Design Rainfall Storm Events 10
- 2.4 EVAPORATION 10
  - 2.4.1 Project Site Data 10
  - 2.4.2 Regional Data 11
- 2.5 SUBLIMATION AND OTHER LOSSES 13

3.0 HYDROLOGY 14
- 3.1 SURFACE WATER DRAINAGE PATTERNS 14
- 3.2 AVAILABLE DATA 14
  - 3.2.1 Monitoring Stations 14
  - 3.2.2 Data Interpretation and Adjustments 15
  - 3.2.3 Discharge Hydrographs 16
  - 3.2.4 Extension of the Local Stations Period of Record 16

4.0 BASELINE SURFACE WATER QUANTITY SUMMARY 19

REFERENCES 20

LIST OF TABLES

Table 1: Meteorological Services of Canada Regional Stations 2
Table 2: Estimated Monthly Variation in Air Temperature 3
Table 3: Derived Monthly and Annual Rainfall for Doris North Project (mm) 4
Table 4. Derived Monthly and Annual Snowfall for Doris North Project (cm) 5
Table 5: Derived Monthly and Annual Precipitation for Doris North Project (mm) 6
Table 6. Mean Annual Precipitation at Doris North and Regional Stations (1959-2001) 8
Table 7: Average Under-catch Factors for Regional Climate Stations, 1947 – 1992 Data 8
Table 8: Mean Monthly Rainfall, Snowfall, and Precipitation for Doris North Project 9
Table 9: Design Rainfall Storm Events 10
Table 10: Boston Camp Evaporation Pan 1997 Data Summary 10
Table 11: Regional Lake Evaporation Estimates 11
Table 12: Doris North Project Average Monthly and Annual Lake Evaporation 12
Table 13: Local Basin Characteristics 13
Table 14: Summary of the Hydrometric Monitoring Stations for the Doris North Project 14

TABLE OF CONTENTS

Page

Table 15: Summary of Staff Gauge Location for Doris North Project 14
Table 16: Regional MSC Hydrometric Stations 15
Table 17: Estimated Annual Runoff (mm) 17
Table 18: Estimated Mean Monthly Local Runoff 17
Table 19: Mean Annual Local Water Balances 18
Table 20: Baseline Hydrological Conditions 18

LIST OF FIGURES

Figure 1: Project Location Plan
Figure 2: Locations of Climatic Stations and Regional Hydrometric Stations
Figure 3: Comparison of Measured and Estimated Mean Daily Air Temperature in °C at Boston Camp
Figure 4: Estimated Monthly Temperatures 1995-2001
Figure 5: Comparison of Measured and Estimated Monthly Rainfall (mm) at Boston Camp
Figure 6: Location of Specific Hydrometric Meteorological Stations and Catchment Areas
Figure 7: Unit Discharge and Rainfall 1997
Figure 8: Unit Discharge and Rainfall 1998
Figure 9: Unit Discharge and Rainfall 2000
Figure 10: Comparison of Weekly Runoff (mm) for Doris Outflow and Ellice River
Figure 11: Comparison of Weekly Runoff (mm) for Doris and Tail Outflows

LIST OF APPENDICES

Appendix A Discharge Measurements and Staff Gauge Readings
Appendix B Stage Hydrographs
Appendix C Rating Curves
Appendix D Discharge Hydrographs

EXECUTIVE SUMMARY

This document was prepared to present the baseline meteorology and hydrology available for the Doris North Project. Environmental baseline data were collected within the Hope Bay Belt from 1993 to 2000. Rescan Environmental Services Ltd. (Rescan) compiled the collected meteorology and hydrology data in a Data Compilation Report (Rescan, 2002), however, a baseline description of the meteorology and hydrology was not included in that work. The baseline preparation included review of Rescan's Data Compilation Report and validation of the data through detailed assessment of the underlying annual meteorologic and hydrologic data reports and the associated data files, supported by comparisons where possible with regional data.

The Doris North Project has a low arctic ecoclimate. The air temperature may fall below 0 °C on any day of the year. The monthly mean air temperature is typically above 0 °C between June and September with the peak in July, and is below freezing between October and May. The coldest day of the year typically occurs in February. The mean annual precipitation adjusted for under-catch is approximately 207 mm with roughly 41% occurring as rain between May and October and 59% as snow. The annual lake evaporation (typically occurring between June and September) was estimated to be 220 mm.

The peak flows in the project area typically occur in June due to snowmelt. A second smaller peak may occur in response to rainfall in late August or early September. The streams in the study area are usually frozen with negligible flow from November until May. The mean annual runoff for Tail, Doris, and Little Roberts Lake outflows is approximately 111, 134, and 134 mm, respectively.

1.0 INTRODUCTION

The Doris North Project is one of various prospective gold deposits located within the Hope Bay greenstone Belt explored by Miramar Hope Bay Ltd. (MHBL). It is located on Inuit owned land, in the West Kitikmeot region of Nunavut, approximately 160 km southwest of Cambridge Bay (Ikaluktutiak) and approximately 685 km northeast of Yellowknife. The nearest communities are Umingmaktok, located 65 km to the west and Bathurst Inlet (Kingauk) located 110 km southwest. The Doris North Project is the gold mine proposed for this deposit. The location of the project site is shown on Figure 1.

This document presents the baseline meteorology and hydrology available for the project. Environmental baseline data were collected within the Hope Bay Belt from 1993 to 2000. Rescan Environmental Services Ltd. (Rescan) compiled the collected meteorology and hydrology data in a Data Compilation Report (Rescan, 2002), however a baseline description of the meteorology and hydrology was not included in that work. The work involved in preparing this document included review of Rescan's Data Compilation Report and validation of the data through detailed assessment of the underlying annual meteorologic and hydrologic data reports and the associated data files, supported by comparisons where possible with regional data. AMEC staff conducted a site reconnaissance in August 2002 to observe hydrologic conditions, watershed characteristics, and the location and design of the data collection stations as a basis for interpreting the reported data.

2.0 METEOROLOGY

2.1 Available Data

Meteorologic data are available for the Boston Camp site, located about 50 km south of Doris North, and for several regional Meteorological Services of Canada stations. The Boston station was established during early exploration work conducted from Boston camp; therefore, to preserve data integrity the station was retained at that location. This station is considered to be close enough to represent the meteorology at the Doris North site. Meteorologic data collection began at the Boston station in August 1993, and continues in operation to the present. However, the data set available for this baseline report ends in June 2001. The data set is not continuous due to various problems including power failures and the tower being blown over.

Regional data were available from the Meteorological Services of Canada (MSC) stations shown in Table 1. The locations of the stations with respect to the Doris North Project are shown in Figure 2.

Table 1: Meteorological Services of Canada Regional Stations

Station Name	Station Number	Period of Record
Kugluktuk	A2300902	1978-2001
Coppermine	A2300900	1930-1977
Cambridge Bay	A2400600	1929-2001
Lupin	A23026HN	1982-2001
Contwoyo Lake	A2300850	1959-1981

The Kugluktuk station represents the continuation of the Coppermine station, and the Lupin station the continuation of the Contwoyto Lake station. The data for each of those two data sets were therefore combined, resulting in three datasets with a common period of record extending from 1959 to 2001:

- Kugluktuk and Coppermine;
- Lupin and Contwoyo Lake; and
- Cambridge Bay.

2.2 Air Temperature

The air temperature data available for Boston Camp extends from January 1995 to June 2001. Several approaches were examined to extend the Boston Camp period of record, by correlation with the regional stations. The best correlation was obtained by multiple regression of the Boston data with the data from all three MSC stations. The resulting best-fit equation is:

$$T_{Boston} = 0.3200T_{Kugluktuk} + 0.3326T_{Cambridge\ Bay} + 0.3512T_{Lupin}$$

where:

T is the daily air temperature at the respective stations.

The comparison of the actual recorded air temperature at Boston camp to that estimated by using the regression equation is shown in Figure 3. The R^2 value equals 0.95, indicating a relatively good fit between the measured values and those predicted by the equation.

The hourly maximum, the mean, and the hourly minimum air temperatures for each month extracted from the extended data set for Boston are reported in Table 2, and shown graphically in Figure 4. The values shown are derived entirely from application of the correlation equation.

Table 2: Estimated Monthly Variation in Air Temperature

Month	Air Temperature (°C)		
	Max	Mean	Min
January	-3.9	-31.6	-48.7
February	-6.8	-31	-50.1
March	-5.6	-28	-47.5
April	2.9	-18.9	-40.7
May	11.2	-7.1	-29.3
June	24.3	3.8	-13.8
July	29.8	9.5	-0.9
August	26.8	7.6	-4.8
September	17.0	1.1	-13.1
October	9.1	-9.2	-31.8
November	-0.5	-21.5	-39.4
December	-6.0	-27.6	-45.0

The air temperature in the Hope Bay Belt may fall below 0 °C on any day of the year. The monthly mean air temperature is typically above 0 °C between June and September with the peak in July, and is below freezing between October and May. The coldest day of the year typically occurs in February.

2.3 Precipitation

2.3.1 Monthly Precipitation

Rainfall data for Boston Camp are available from 1996 to 2001. The monthly data were extended by multiple regression with the data from the three MSC stations, in a manner similar to that used for temperature. The resulting best-fit equation was found to be:

$$R_{Boston} = 0.0600R_{Kugluktuk} + 0.1779R_{Cambridge\ Bay} + 0.3653R_{Lupin}$$

where

R is the monthly rainfall at the respective stations.

The correlation was done using only the summer months of June through September outside of which rainfall events are infrequent compared to snowfall events.

The comparison of the actual recorded rainfall at Boston Camp to that estimated by using the regression equation is shown in Figure 5. The R^2 value, which is a measure of the goodness of fit, equals 0.57. This is considerably less than the goodness of fit for the temperature correlation. This result reflects the fact that rainfall exhibits much greater spatial variability than temperature, with frequent cases of no rain at one location when there is rain at one or more of the other locations.

Table 3 provides the monthly rainfall data extending from 1959 to 2001, estimated using the multiple regression equation.

The snowfall data reported by Rescan for Boston are judged to be unreliable, as they are based not on direct measurements but on calculations and assumptions that cannot be validated. Snowfall (and total precipitation) was therefore estimated from regional station data. The best approach was considered to be application of the correlation relationship found for monthly rainfall. Tables 4 and 5 show the 1959 to 2001 estimated monthly values for snowfall and total precipitation, respectively, using that approach.

Table 3: Derived Monthly and Annual Rainfall for Doris North Project (mm)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1959	0.0	0.0	0.0	0.0	0.1	37.1	17.8	10.8	5.0	0.0	0.0	0.0	70.9
1960	0.0	0.0	0.0	0.0	0.5	4.6	25.9	34.3	9.1	0.3	0.0	0.0	74.7
1961	0.0	0.0	0.0	0.0	7.7	17.3	26.4	29.3	1.8	0.0	0.0	0.0	82.5
1962	0.0	0.0	0.0	0.0	0.5	5.4	14.5	10.9	8.9	0.5	0.0	0.0	40.7
1963	0.0	0.0	0.0	0.0	0.8	18.1	27.9	19.1	3.5	3.7	0.0	0.0	73.1
1964	0.0	0.0	0.0	0.0	0.2	5.4	30.5	12.4	12.1	0.6	0.0	0.0	61.2
1965	0.0	0.0	0.0	0.0	2.0	10.9	13.7	15.0	0.8	0.1	0.0	0.0	42.5
1966	0.0	0.0	0.0	0.0	4.3	7.2	22.6	30.5	22.7	1.0	0.0	0.0	88.2
1967	0.0	0.0	0.0	0.0	0.4	21.7	28.3	21.7	12.0	4.7	0.0	0.0	88.8
1968	0.0	0.0	0.0	0.0	3.0	2.2	7.8	15.6	14.8	0.3	0.1	0.0	43.7
1969	0.0	0.0	0.0	0.0	0.6	13.4	28.3	29.9	2.4	1.5	0.0	0.0	76.0
1970	0.0	0.0	0.0	0.0	1.0	15.3	7.4	35.0	17.3	0.6	0.0	0.0	76.7
1971	0.0	0.0	0.0	0.2	1.5	3.1	21.0	27.5	26.8	1.2	0.0	0.0	81.2
1972	0.0	0.0	0.0	0.0	2.0	3.8	18.3	23.7	1.9	0.3	0.0	0.0	49.9
1973	0.0	0.0	0.0	0.0	3.0	15.8	10.1	38.7	14.0	0.4	0.0	0.0	82.0
1974	0.0	0.0	0.0	0.0	5.0	17.3	20.6	9.3	7.7	0.0	0.0	0.0	59.9

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1975	0.0	0.0	0.0	2.4	1.6	2.4	12.1	24.4	4.3	0.0	0.0	0.0	47.2
1976	0.0	0.0	0.0	0.0	9.8	19.6	19.2	13.6	23.9	0.0	0.0	0.0	86.2
1977	0.0	0.0	0.0	0.0	5.6	6.8	9.3	21.6	7.6	1.9	0.0	0.0	52.8
1978	0.0	0.0	0.0	2.1	1.5	15.5	10.7	20.4	7.2	0.0	0.0	0.0	57.4
1979	0.0	0.0	0.0	0.0	7.7	6.1	19.7	20.0	9.0	0.0	0.0	0.0	62.5
1980	0.0	0.0	0.0	0.5	0.1	2.3	14.6	23.0	7.3	3.1	0.0	0.0	51.0
1981	0.0	0.0	0.0	0.0	1.1	13.6	21.8	19.5	19.6	4.6	0.0	0.0	80.3
1982	0.0	0.0	0.0	0.0	3.6	11.0	20.4	31.1	5.8	0.5	0.0	0.0	72.4
1983	0.0	0.0	0.0	0.0	0.0	4.5	34.0	34.3	22.0	0.0	0.0	0.0	94.9
1984	0.0	0.0	0.0	0.0	6.7	24.0	32.4	27.2	5.2	6.1	0.0	0.0	101.7
1985	0.0	0.0	0.0	0.0	1.3	7.3	38.7	16.6	16.7	0.1	0.0	0.0	80.6
1986	0.0	0.0	0.0	0.0	7.6	5.8	9.9	40.0	5.8	0.0	0.0	0.0	69.2
1987	0.0	0.0	0.0	0.0	1.5	31.0	25.0	26.8	18.9	0.0	0.1	0.0	103.3
1988	0.0	0.0	0.0	0.0	2.3	20.7	27.0	15.3	24.2	4.2	0.0	0.0	93.7
1989	0.0	0.0	0.0	0.0	0.2	5.2	17.5	12.4	11.7	0.3	0.0	0.0	47.4
1990	0.0	0.0	0.0	0.0	1.5	9.5	12.1	25.0	19.7	0.0	0.0	0.0	67.8
1991	0.0	0.0	0.0	0.0	1.0	5.3	22.8	34.2	7.3	0.1	0.0	0.0	70.7
1992	0.0	0.0	0.0	0.0	6.3	3.2	7.9	18.9	4.3	0.2	0.0	0.0	40.8
1993	0.0	0.0	0.0	0.0	4.2	10.2	41.4	16.0	7.2	0.7	0.0	0.0	79.8
1994	0.0	0.0	0.0	0.0	3.7	20.4	6.7	23.8	11.5	2.7	0.0	0.0	68.7
1995	0.0	0.0	0.0	0.0	0.4	13.1	17.0	31.5	8.2	0.4	0.0	0.0	70.5
1996	0.0	0.0	0.0	0.0	5.0	16.0	25.5	63.7	30.7	0.1	0.0	0.0	141.0
1997	0.0	0.0	0.0	0.0	2.8	12.7	13.6	25.4	11.0	0.3	0.0	0.0	65.8
1998	0.0	0.0	0.0	0.1	4.4	17.4	16.6	26.9	16.9	3.2	0.0	0.0	85.4
1999	0.0	0.0	0.0	0.8	2.0	10.3	33.1	23.2	30.1	0.1	0.0	0.0	99.7
2000	0.0	0.0	0.0	0.1	0.1	2.4	14.3	25.2	17.6	0.4	0.0	0.0	60.3
2001	0.0	0.0	0.0	0.0	2.1	1.2	26.5	24.0	6.9	0.7	0.0	0.0	61.3
Average	0.0	0.0	0.0	0.1	2.7	11.5	20.3	24.4	12.1	1.0	0.0	0.0	72.1

Table 4: Derived Monthly and Annual Snowfall for Doris North Project (cm)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1959	5.6	10.4	8.8	4.4	10.3	12.3	0.4	1.8	4.4	11.7	7.8	8.7	86.5
1960	3.6	6.7	5.9	5.7	4.2	0.0	0.1	0.1	18.8	21.7	5.2	6.2	78.2
1961	3.6	4.8	5.2	5.4	5.8	0.3	0.0	0.2	9.2	12.2	10.5	4.0	61.2
1962	3.2	1.7	7.3	4.5	6.0	0.1	0.0	0.0	0.6	16.3	13.9	5.6	59.1
1963	3.1	1.8	5.4	7.6	7.4	8.3	0.0	0.1	3.2	16.2	13.5	6.9	73.7
1964	4.6	6.1	3.2	11.7	5.9	3.5	0.1	0.0	2.1	14.6	4.3	12.1	68.2
1965	4.1	0.8	8.6	5.5	4.5	2.9	0.0	0.4	8.7	7.9	6.5	2.0	51.7
1966	0.6	2.8	5.6	2.2	3.1	0.0	0.0	0.0	0.4	4.8	4.1	4.7	28.3

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1967	3.2	2.9	2.5	2.3	8.4	2.3	0.0	0.6	22.1	11.9	6.1	6.4	68.7
1968	6.4	5.4	3.4	8.9	20.6	1.0	0.4	0.1	11.7	18.5	8.9	4.9	90.2
1969	3.0	4.9	3.0	6.1	5.1	5.0	0.0	0.0	2.2	1.4	13.0	5.1	48.6
1970	1.9	1.8	3.9	7.1	3.0	1.1	0.0	0.0	10.4	21.1	4.2	4.0	58.4
1971	4.0	16.5	10.2	7.9	10.5	0.2	0.0	0.3	6.1	16.7	6.4	6.9	85.5
1972	6.4	4.0	7.4	7.3	13.8	0.7	0.0	0.4	14.9	13.1	6.8	3.2	78.0
1973	6.1	3.3	9.9	3.9	2.9	0.0	0.0	1.2	2.4	17.2	6.7	1.7	55.2
1974	3.1	3.8	2.3	5.3	7.1	2.6	0.0	5.0	8.4	29.2	7.9	6.3	81.1
1975	2.8	2.4	1.3	4.7	10.6	0.2	0.0	1.5	6.8	17.1	8.6	6.3	62.3
1976	6.0	3.6	4.6	8.0	7.2	2.4	0.0	0.0	2.5	17.2	9.4	4.0	64.9
1977	7.7	8.2	7.0	14.1	4.2	0.0	0.0	0.0	0.1	8.6	8.4	16.1	74.5
1978	4.4	3.1	4.4	4.6	8.6	1.4	0.0	0.1	0.8	36.3	7.4	7.4	78.5
1979	5.5	0.1	4.6	10.5	6.1	2.1	0.0	0.5	1.9	12.7	6.9	8.6	59.6
1980	2.2	2.8	2.3	6.9	5.7	0.5	0.0	0.0	4.8	13.2	10.9	4.1	53.3
1981	2.3	8.5	12.2	1.6	2.6	0.2	0.0	1.5	6.8	8.1	10.8	1.9	56.6
1982	0.6	2.6	2.9	6.0	2.8	7.9	0.4	1.0	12.8	13.0	7.5	6.2	63.8
1983	10.6	2.9	6.4	8.3	7.8	0.6	0.0	0.1	17.5	19.6	5.0	4.1	83.0
1984	3.7	10.0	8.0	8.8	0.5	0.7	0.0	0.9	4.7	10.1	9.9	5.0	62.5
1985	6.1	5.7	6.3	10.7	6.6	2.5	1.4	8.4	6.4	12.8	5.9	3.9	76.7
1986	8.6	6.9	3.4	11.5	9.1	1.4	0.0	2.0	9.9	14.2	7.7	7.2	81.9
1987	7.1	4.2	3.8	6.5	3.9	1.8	0.0	2.6	3.6	15.5	19.2	11.4	79.7
1988	3.3	2.0	3.5	2.9	4.8	0.9	0.0	0.0	2.8	10.1	9.4	4.8	44.4
1989	10.4	5.3	5.7	3.1	16.3	0.8	0.0	0.0	6.9	9.1	6.3	7.0	70.9
1990	6.1	3.9	7.5	5.0	2.2	3.8	0.0	0.9	5.0	10.1	7.2	7.8	59.7
1991	5.0	11.2	6.7	12.5	7.2	2.4	0.5	1.1	13.7	13.8	8.9	10.8	93.7
1992	8.8	4.4	7.4	9.9	6.2	5.6	0.0	2.0	10.8	26.0	11.9	4.5	97.4
1993	6.3	8.9	9.1	3.4	12.9	1.9	0.0	1.6	8.6	9.1	6.7	6.3	74.7
1994	2.2	1.4	10.2	5.7	4.4	0.7	0.0	0.9	9.5	15.0	6.4	9.8	66.2
1995	3.1	2.8	21.1	3.3	5.4	0.0	0.0	1.2	11.3	20.8	6.4	11.2	86.8
1996	4.2	10.5	4.4	5.6	7.7	6.2	0.0	5.9	2.8	8.3	6.7	5.6	68.0
1997	5.0	4.2	3.7	6.9	9.8	1.5	0.0	1.1	4.3	23.8	7.0	9.4	76.8
1998	3.0	5.3	4.5	9.5	4.6	0.0	0.0	0.0	11.7	22.4	11.2	10.5	82.7
1999	5.1	4.6	8.7	10.6	10.4	0.3	0.8	1.4	7.9	13.2	7.9	15.6	86.4
2000	3.0	4.1	4.5	5.9	9.0	1.0	0.0	1.1	11.4	23.3	8.4	4.5	76.3
2001	6.5	4.2	12.0	13.0	17.9	3.3	0.0	0.1	1.3	10.4	14.2	7.8	90.8
Average	4.7	4.9	6.3	6.9	7.3	2.1	0.1	1.1	7.3	15.1	8.4	6.8	71.0

Table 5: Derived Monthly and Annual Precipitation for Doris North Project (mm)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1959	5.6	10.4	8.8	4.4	10.4	49.4	18.1	12.6	9.4	11.7	7.8	8.7	157.3
1960	3.6	6.7	5.9	5.7	4.7	4.6	25.9	34.4	27.9	22.0	5.2	6.2	152.9
1961	3.6	4.8	5.2	5.4	13.5	17.5	26.4	29.4	11.0	12.2	10.5	4.0	143.6
1962	3.2	1.7	7.3	4.5	6.5	5.5	14.5	10.9	9.5	16.7	13.9	5.6	99.8
1963	3.1	1.8	5.1	7.4	7.8	26.3	27.9	19.2	7.0	19.4	12.7	7.0	144.8
1964	4.6	5.9	2.9	10.8	6.2	9.1	30.5	12.4	13.8	14.7	3.9	11.2	126.0
1965	4.0	0.8	8.2	5.4	6.5	14.1	13.7	15.5	9.8	8.1	6.3	1.8	94.3
1966	0.6	2.7	5.5	2.1	7.4	7.2	22.6	30.5	23.1	5.1	3.8	4.5	115.0
1967	3.2	2.9	2.5	2.3	8.2	23.9	28.3	22.3	36.9	15.8	6.0	6.1	158.6
1968	6.3	5.4	3.2	8.7	23.6	3.1	8.2	15.7	25.8	18.0	8.4	4.6	130.9
1969	2.9	4.7	2.9	5.8	5.4	17.8	28.3	29.9	4.5	2.8	12.8	4.7	122.4
1970	1.9	1.8	3.8	6.4	3.7	16.3	7.4	35.0	27.3	20.5	3.7	3.3	131.2
1971	3.6	15.2	9.8	7.9	11.6	3.2	21.0	27.7	32.6	16.2	5.6	6.0	160.4
1972	5.8	3.9	6.0	7.3	14.5	4.4	18.3	24.0	15.2	12.6	6.2	2.8	120.9
1973	5.9	2.9	9.4	3.5	5.5	15.8	10.1	39.9	15.9	17.3	4.6	1.4	132.3
1974	2.4	3.6	2.1	4.9	12.0	19.6	20.6	14.3	15.9	29.1	6.9	6.1	137.6
1975	2.7	2.0	1.3	6.7	11.9	2.6	12.1	25.8	11.0	16.4	8.3	5.9	106.8
1976	5.8	3.6	4.4	8.2	16.9	22.0	19.2	13.6	26.3	17.1	9.1	3.9	150.0
1977	7.5	8.0	6.8	14.2	10.0	6.8	9.3	21.6	7.6	9.9	8.0	15.8	125.5
1978	4.0	2.6	4.0	6.4	10.4	16.9	10.7	20.5	7.9	35.7	7.1	7.0	133.4
1979	5.0	0.1	4.5	10.2	13.7	8.3	19.7	20.4	10.8	12.7	6.9	8.6	120.9
1980	2.2	2.6	2.3	7.3	5.7	2.8	14.6	23.0	12.1	16.3	10.8	4.1	103.8
1981	2.4	7.5	11.7	1.6	3.6	13.8	21.8	21.0	26.4	12.6	10.6	1.9	134.8
1982	0.6	2.4	2.6	5.7	6.2	18.9	20.8	32.1	18.6	13.5	7.2	6.2	134.9
1983	10.4	2.8	6.4	8.2	7.8	5.1	34.0	34.4	39.5	19.3	4.9	4.0	176.7
1984	3.7	9.5	7.6	8.4	7.2	24.8	32.4	28.2	9.9	15.8	9.3	4.3	160.9
1985	5.5	5.4	5.9	10.4	7.0	10.0	40.1	25.0	23.0	12.0	4.9	3.5	152.7
1986	8.3	6.5	3.3	11.2	16.7	7.2	9.9	42.1	15.7	13.7	7.1	6.3	147.9
1987	6.3	3.4	3.3	5.4	4.7	32.8	25.0	29.4	22.3	14.5	18.7	10.6	176.7
1988	3.1	1.9	2.4	2.6	6.3	21.6	27.0	15.3	27.1	14.0	9.1	4.2	134.5
1989	9.2	4.1	5.2	2.6	15.7	6.0	17.5	12.4	18.4	8.3	6.3	6.9	112.7
1990	5.8	3.3	6.7	4.8	3.3	13.2	12.1	26.0	24.8	8.9	5.6	7.3	121.7
1991	4.7	8.7	6.3	11.4	7.7	7.7	23.3	35.4	20.5	13.1	8.7	10.4	157.8
1992	8.4	4.1	6.7	9.7	11.5	8.9	7.9	20.9	14.6	24.3	9.9	3.7	130.6
1993	5.5	8.7	8.1	2.7	16.7	11.9	41.4	17.5	14.8	9.7	6.4	5.7	149.1
1994	2.1	1.4	9.9	5.3	7.9	21.1	6.7	24.7	20.5	17.3	6.1	9.3	132.1
1995	2.8	2.5	19.3	3.0	5.7	13.1	17.1	32.7	19.5	19.3	5.1	10.3	150.3
1996	3.8	9.3	3.8	4.5	12.5	22.1	25.5	69.6	33.4	7.6	5.8	4.7	202.5
1997	4.5	3.8	3.4	6.2	12.2	14.1	13.7	26.4	15.2	22.1	5.9	8.5	136.0

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1998	2.7	4.4	3.0	8.0	8.4	17.4	16.6	26.9	28.6	24.9	9.7	9.5	160.0
1999	4.4	3.7	8.1	10.5	11.8	10.6	34.0	24.6	37.8	10.4	6.6	13.6	176.1
2000	2.0	3.1	3.6	5.5	8.2	3.2	14.3	26.3	28.5	20.7	6.7	3.7	126.0
2001	5.0	3.1	10.5	12.2	18.6	4.3	26.5	24.1	8.2	9.3	12.0	6.1	139.8
Average	4.4	4.5	5.8	6.6	9.7	13.6	20.3	25.4	19.3	15.4	7.8	6.3	139.1

A summary of the estimated annual mean rainfall, snowfall and total precipitation for Doris North, compared to the observed values at Kugluktuk, Lupin and Cambridge Bay are provided in Table 6.

Table 6: Mean Annual Precipitation at Doris North and Regional Stations (1959-2001)

Precipitation	Stations			
	Doris North	Kugluktuk	Cambridge Bay	Lupin
Rainfall (mm)	72.1	120.7	71.2	143.2
Snowfall (cm)	71.0	145.9	81.7	130.3
Total (mm)	139.1	235.3	141.1	273.6

Table 6 indicates that the long term mean precipitation at Doris North is most like that at Cambridge Bay, which is to be expected on the basis of geographic proximity.

2.3.2 Under-catch

Evaluation of precipitation data for the Canadian north has led to the conclusion that the observed data generally provide an under-estimation of actual precipitation due to "under-catch" (Metcalfe *et al*., 1994). Under-catch is thought to occur due to wind effects as well as the high frequency in the north of "trace" events which add physical volume but have no recorded volume. Under-catch applies mainly to snowfall, but rainfall is also affected.

The rainfall, snowfall and precipitation data for climate stations archived and reported by Environment Canada consist of the observed data, not adjusted for under-catch. However, for some stations, corrections for under-catch have been made, as per the reference noted above. Evaluation of the under-catch factors by comparison of the archived and corrected data for two of the three regional stations (Kugluktuk and Cambridge Bay) used to extend the Hope Bay precipitation data has been made. The data available for the Lupin station was considered inadequate for a reliable evaluation of under-catch factors. The results are summarized in Table 7.

Table 7: Average Under-catch Factors for Regional Climate Stations, 1947 – 1992 Data

Climate Station	Rainfall	Snowfall	Total Precipitation
Kugluktuk	1.17	1.51	1.39
Cambridge Bay	1.21	1.91	1.66
Mean	1.19	1.71	1.53

The mean under-catch values are recommended for application at Hope Bay. Under-catch factors for individual years typically vary by up to about 15% from average values; however, it is impractical to attempt to apply yearly variations to predicted values.

Table 8 presents the estimates of mean monthly and annual values of rainfall, snowfall and total precipitation for the Doris North Project. The table presents both the estimates derived from regional station recorded values (from Tables 3, 4 and 5), and estimates of the values corrected for undercatch. The corrected values for rainfall and snowfall were estimated by application of the Table 7 mean annual correction factors to the values in Tables 3 and 4. In order to preserve data consistency, the corrected total precipitation values were derived by summation of the corrected rainfall and snowfall values.

Table 8: Mean Monthly Rainfall, Snowfall, and Precipitation for Doris North Project

Month	Rainfall (mm)		Snowfall (cm)		Precipitation (mm)	
	Recorded	Corrected	Recorded	Corrected	Recorded	Corrected
January	0.0	0.0	4.7	8.0	4.4	8.0
February	0.0	0.0	4.9	8.4	4.5	8.4
March	0.0	0.0	6.3	10.8	5.8	10.8
April	0.1	0.1	6.9	11.8	6.6	11.9
May	2.7	3.2	7.3	12.5	9.7	15.7
June	11.5	13.7	2.1	3.6	13.6	17.3
July	20.3	24.2	0.1	0.2	20.3	24.4
August	24.4	29.0	1.1	1.9	25.4	30.9
September	12.1	14.4	7.3	12.5	19.3	26.9
October	1.0	1.2	15.1	25.8	15.4	27.0
November	0.0	0.0	8.4	14.4	7.8	14.4
December	0.0	0.0	6.8	11.6	6.3	11.6
Annual	72.1	85.8	71.0	121.5	139.1	207.3

2.3.3 Design Rainfall Storm Events

Design rainfall storm events were estimated for Doris North using the 1959 to 2001 data for Kugluktuk, Cambridge Bay, and Lupin. A frequency analysis using the Generalized Extreme Value distribution was conducted on the maximum daily rainfall for each year for each of the three regional stations. The results are shown in Table 9. Adjustment for under-catch is not considered appropriate for single extreme event rainfalls, as under-catch is caused in large part by trace events and wetting losses accumulated over the season.
The storm events estimated for the regional stations were transferred to the project site using the equation:

$$S_{Boston} = 0.10S_{Kugluktuk} + 0.29S_{Cambridge\ Bay} + 0.61S_{Lupin}$$

where
S is the rainfall storm event at the respective stations.

The numerical factors used in the above equation were derived by assuming that the influence of each of the three regional stations was directly proportional to the coefficients of the multiple regression equation found for monthly rainfall.

Table 9: Design Rainfall Storm Events

Return Period (years)	Rainfall (mm)			
	Kugluktuk	Cambridge Bay	Lupin	Doris North
2	16.8	11.6	20.1	17.3
5	26.3	17.7	28.6	25.2
10	33.3	22.4	34	30.5
20	40.4	27.6	39.1	35.8
50	50.6	35.5	45.5	43.1
100	58.9	42.2	50.1	48.6
200	67.8	49.9	54.6	54.5
500	80.6	61.7	60.4	62.8

2.4 Evaporation

2.4.1 Project Site Data

Site evaporation pan data were collected by Rescan during the open water seasons for 1995, 1996, 1997, 1998 and 2000. For each year except 1997, significant data collection problems were reported, including reading errors, unrecorded water removed or added, and numerous days with missing data. Therefore, only the 1997 data should be considered. Those data, as reported by Rescan (Rescan, 2002), are shown in Table 10, along with AMEC adjusted values.

Table 10: Boston Camp Evaporation Pan 1997 Data Summary

Period	Days With Data	Days With Evap	Pan Evaporation (mm)			
			Reported Total	Adjusted Total	Fraction of Annual	Daily Average
June	15	15	43	43	0.16	2.87
July	31	31	116	116	0.43	3.74
August	28	31	91	95	0.35	3.06
September	10	30	12	17	0.06	0.57
Annual	85	105	261	271	1.00	2.58

Two adjustments were made to the reported values:

1. The missing days for August were estimated based on values for preceding and following days, and
2. The total for September was increased, at a rate declining to zero by the end of the month, to account for lake evaporation as continuing to the end of September.

Lake evaporation before June 15 was considered unrealistic as ice cover is thought to typically persist until that time.

Rescan estimated average annual lake evaporation equal to 288 mm, by assuming a 124-day open water season, and applying an assumed co-efficient of 0.75 to an average daily pan evaporation rate of 3.1 mm/day (Rescan, 2002), with the latter value obtained from the 1997 observed 261 mm over 85 days. The assumed 124-day open water period was judged to be too long. Given the uncertainty in this approach and the relatively small data set available, this estimate was set aside and a comparison with regional data was used to estimate lake evaporation.

2.4.2 Regional Data

Estimates of regional lake evaporation reported in the environmental assessment for the Snap Lake Diamond Project (De Beers, 2002) are summarized in Table 11. The tabulated values were derived from evaporation pan measurements as well as energy balance models.

Table 11: Regional Lake Evaporation Estimates

Year	Annual Evaporation for Small Lakes (mm)		
	Lupin Station Based on Study by Gibon et al. (1996)	Salmita Station Based on Study by Reid (1999)	Koala Station Based on Study by Rescan (1996)
1983	260[1]		
1984	320[1]		
1992	300		
1993	220		
1994		336	270[2]
1995		261	340[2]
1996		283	356[2]
1997		242	
1998		348	
1999		295	
Average	275	294	322

Notes:
1 Based on pan evaporation measurements and a computed correction factor of 0.81.
2 Based on pan evaporation measurements and a correction factor of 0.75.

The average annual values of 275 mm for Lupin and 294 mm for Salmita, located about 160 km south of Lupin, appear reasonable. The value of 322 mm for Koala appears too high, since it is more northerly than the Salmita station, and should therefore be discounted.

The Hope Bay area is located about 300 km northeast of Lupin. Annual lake evaporation decreases to the northeast (Hydrological Atlas of Canada, 1978), at a rate suggested by the Salmita and Lupin values, of perhaps 20 mm per 150 km. Thus a value of about 40 mm less than Lupin, or 235 mm, is indicated for the project site.

Re-estimation of the annual lake evaporation for the Hope Bay area using the 1997 adjusted pan evaporation of 271 mm from Table 8 over the ice-free season, and a pan coefficient of 0.81 as found for Lupin, yields 220 mm. This falls reasonably close to the value of 235 mm suggested by extrapolation of the regional trend. The proposed lake evaporation values distributed by month, based on the 1997 data, are given in Table 12.

Table 12: Doris North Project Average Monthly and Annual Lake Evaporation

Period	Days with Evaporation	Fraction of Annual Evaporation	Average Evaporation (mm)
June	15	0.16	35
July	31	0.43	95
August	31	0.35	77
September	30	0.06	13
Annual	105	1.00	220

One limitation of the above is that the proposed values are based on only one year of measurements. Review of the variation in annual values shown in Table 9 indicates that individual years can vary from the average by up to 20%. Thus it is possible that the 1997 Hope Bay value is up to 20 % above or below the true average. Based on comparison to the regional trend, the 1997 value appears to be about 7% below the average. However, no firm conclusions can be made as to how well the 1997 data represents the true average, and appropriate assumptions will need to be made by designers to ensure reasonably conservative results.

2.5 Sublimation and Other Losses

Losses not normally measured directly in surface water hydrology studies include sublimation from snow, evapotranspiration from land surfaces, and seepage.

Sublimation losses occur throughout the winter, mainly when snow is being transported by wind, which occurs often in the north. Direct estimation of sublimation losses is difficult and requires extensive local data. According to Pomeroy and Gray, "Blowing snow in open areas can remove up to three-fourths of annual snowfall. If fetches are large, most of this snow sublimates in transit (Pomeroy and Gray, 1995). Spring snow surveys can be used to estimate sublimation, by comparison of the pre-melt snow water equivalent with the accumulated snowfall corrected for under-catch.

Evapotranspiration (ET) is difficult to measure and if done generally applies only to small areas. The main difficulty with estimating ET is that it depends on the availability of water near the ground surface: once moisture is depleted, ET drops to zero, even though there may be sufficient energy available.

Seepage is considered to be neglible in the context of surface water hydrology, due to the presence of permafrost.

3.0 HYDROLOGY

3.1 Surface Water Drainage Patterns

The existing surface drainage pattern in the project area is presented on Figure 6. The proposed Doris North Project is located primarily within the Doris Lake outflow drainage basin. The Tail Lake catchment, a sub-basin of the Doris basin, is proposed to serve as the project's tailings containment area.

The outflow from Tail Lake flows northwest approximately 0.5 km into Doris Lake. Doris Lake discharges to the north towards Little Roberts Lake. Little Roberts Lake drains northwest to Roberts Bay. The total distance from the outlet of Tail Lake to Roberts Bay is approximately 6 km.

Table 13 presents the characteristics of Doris, Tail, and Little Roberts Lakes catchments. The drainage basins are relatively flat, with a large percentage of lake area and high ridges along basin boundaries formed by rock outcrops.

Table 13: Local Basin Characteristics

Stream name	Drainage Area (km^2)	Percent Lake Area	Highest Elevation (m)	Lowest Elevation (m)
Tail Ouflow	4.4	18	80	22
Doris Outflow	93.1	19	158	20
Little Robert Outflow	190.7	19	158	4

3.2 Available Data

3.2.1 Monitoring Stations

Hydrologic monitoring was conducted during open water conditions from 1993 until 2000 in the Doris North Project area. During the initial years of 1993 to 1995, water levels and/or streamflows were measured at various locations several times during each year, but continuous records were not obtained. Automated water level recorders were installed at some locations in 1996, and automated monitoring continued in 1997, 1998, and 2000, although not all stations were operated for all of those years. The locations of the hydrologic monitoring stations are shown on Figure 6. The summary of the available monitoring station data is given in Table 14.

Table 14: Summary of the Hydrometric Monitoring Stations for the Doris North Project

Station Name	Station ID	Drainage Area (km^2)	Available Data			
			1996	1997	1998	2000
Aimaoktak River	H10	769.0	06/13-08/06	06/15-09/13	05/31-08/21	
Doris Outflow	H3	93.1	08/03-08/22	07/15-09/12	06/30-08/21	06/16-09/11
Ogama Outflow	H2	71.9	08/02-08/22	06/17-09/12		
Ogama Inflow	H4	64.6		06/17-09/12		
Pelvic Outflow	H20	49.2				06/17-09/12
Glenn Outflow	H1	31.6	08/03-08/23	06/15-09/12	06/03-08/21	06/15-09/11
Tail Outflow	H21	4.4				06/16-09/12
Stickleback Outflow	H11	2.8		08/26-09/13	05/29-08/21	
Note: H denotes a hydrometric station						

At several locations, a staff gauge only was established, and water levels observed on an intermittent basis. Those stations are listed in Table 15 below.

Table 15: Summary of Staff Gauge Location for Doris North Project

Station Name	Station ID	Available Staff Gauge Data	
		1996	1997
Patch Lake	H8		07/26, 08/02, 08/10, 08/16, 08/26, 09/05
Doris Lake	H5	06/15, 07/04, 07/12, 07/19, 07/28, 08/06, 08/17, 08/26, 09/02	06/29, 07/09, 07/26, 08/02, 08/10, 08/16, 08/26, 09/05
Tail Lake	H6	06/15, 07/04, 07/12, 07/19, 07/28, 08/06, 08/17	06/29, 07/09, 07/26, 08/02, 08/10, 08/16, 08/26, 09/05
Windy Lake	H7		06/29, 07/09, 07/26, 08/02, 08/10, 08/16, 08/26, 09/05

3.2.2 Data Interpretation and Adjustments

The recorded water levels, upon which the discharges are based, consist of data logger records which were largely uncontrolled for drift and vertical movement of supporting structures (due to frost heaving and subsequent settlement). Periodic staff gauge readings were similarly uncontrolled. This presented a problem in terms of interpreting the data, since (1) recorded water levels could be incorrect, leading to incorrect discharges, and (2) rating curves used to calculate discharges from water levels could themselves be based on inaccurate water level readings. A comprehensive review of the available hydrometric data files was therefore undertaken, and adjustments made, to produce a revised hydrometric data set. Details of the adjustments are presented in Appendix A and B. Stage hydrographs and rating curves are in Appendix B and C, respectively.

3.2.3 Discharge Hydrographs

Discharge hydrographs were calculated for each of the four years of recorded data using the adjusted stage hydrographs and rating curves. Records in each year generally began in June after the snowmelt peak had passed and ended in August or September before freeze-up. Data records in most years are not continuous. Wherever possible, the gaps in the records were filled in by comparing the available data with data for the same period for one or more of the other local stations. The 1996 data gaps were too large to be estimated, thus the data were set aside as not useable for this baseline report. Discharges for the un-recorded beginning and end of the open water season were estimated by comparison with the Ellice River Water Survey of Canada (WSC) regional station. The selection of the Ellice River station for this purpose is discussed in the following section. The discharge hydrographs for each of the three years with completed discharge records (1997,1998, 2000) are shown in Appendix D. A comparison of unit discharges for the local and Ellice River stations for 1997, 1998, and 2000, are shown in Figures 7, 8 and 9, respectively. The solid lines in the figures represent the sections of the hydrographs based on recorded data. The dashed lines are based on estimates derived from other stations.

3.2.4 Extension of the Local Stations Period of Record

The three years of discharge hydrographs developed from the site data are insufficient to provide long-term estimates of runoff. Regional stations were therefore examined as a basis for extending the period of record for the runoff data for the Doris North Project. Table 16 provides the list of regional WSC hydrometric stations investigated.

Table 16: Regional WSC Hydrometric Stations

Station Name	Station Number	Drainage Area (km^2)	Period of Record
Ellice R. near the Mouth	10QD001	16900	1971-present[a]
Gordon R. near the Mouth	10QC002	1530	1977-1994
Back R. below Beechy Lake	10RA001	19600	1978-present
Baillie R. near the Mouth	10RA002	14500	1978-present
Hood R. near the Mouth	10QB001	15600	1993-present
Burnside R. near the Mouth	10QC001	16800	1976-present
Burnside R. at Outlet of Contwoyo Lake	10QC004	3230	1993-present

[a] Although data was available on Ellice River from 1971 to present, "during a quality Assurance Program audit in 2002, WSC found that streamflow was seriously underestimated at four sites prior to 1984, one of which was Ellice River." (Environment Canada, 2003) Therefore, only data from 1984 to present was used in the following analysis.

The Ellice and Gordon River gauges are the closest to the project site and were considered as being more likely to be representative of the Hope Bay area on the basis of the following factors:

- Proximity to the project site,
- Basin characteristics similar to those on the project site, and
- Similar response to spring snowmelt and rainfall events with respect to both timing and relative magnitude of peaks.

Gordon River flows to the northeast into Bathurst Inlet approximately 150 km south of the site and Ellice River flows north to Campbell Bay approximately 100 km northeast of the site.

As shown in Table 16, the period of record for the Ellice River (10QD001) gauge overlaps the period of record for the gauges established at the Doris North Project. The Gordon River gauge was discontinued in 1994 and thus does not cover the same time period. Therefore, only the data from the Ellice River gauge was of value in extending the data set from the Doris North Project gauge sites.

The stations for which the data were extended are the Doris and the Tail stations, since the facilities proposed for the project are located within the Doris and Tail watersheds.

Preliminary assessment of the data indicated that daily data should not be the basis for correlation, due to time lag effects, but that a weekly time period would be satisfactory. Figure 10 shows a comparison of weekly runoff for Ellice River and Doris Outflow for the weeks for which contemporaneous data for the two stations are available. The correlation relationship developed is:

$$Q_{Doris} = -0.0132Q_{Ellice}^{2} + 1.0572Q_{Ellice} \qquad R^2 = 0.91$$

where
Q = weekly runoff (mm).

A similar comparison was conducted between Doris and Tail outflows (with only data for the year 2000 available), as shown in Figure 11. The resulting relationship is:

$$Q_{Tail} = 0.2221Q_{Doris}^{1.5485} \qquad R^2 = 0.96$$

where
Q = weekly runoff (mm).

Long-term runoff characteristics were thus developed for Doris by correlation with the Ellice River data. Then long-term runoff characteristics were developed for Tail, by correlation with the estimated Doris data. The results are presented in Table 17.

Runoff characteristics for Little Roberts Lake outflow, the main drainage point downstream of Doris, were estimated to be the same as those for Doris, as plots of the runoff data for all the local stations, for all the three years of record available, showed no significant variation either with basin drainage area, or percentage of lake area.

Table 17: Estimated Annual Runoff (mm)

Stream Name	1:100 Year Dry Runoff	1:10 Year Dry Runoff	Mean Annual Runoff	1:10 Year Wet Runoff	1:100 Year Wet Runoff
Doris Outflow	88.1	97.0	134	188	309
Tail Outflow	63.8	74.1	111	159	246
Little Roberts Outflow	88.1	97.0	134	188	309

Based on the long-term records for the Ellice and Gordon Rivers, it is anticipated that the streams in the study area will be frozen, with zero discharge from the beginning of November until the end of May. Spring runoff is estimated to typically start in the first half of June, with the second week likely being most common. Table 18 shows the mean monthly runoff and the associated percentages of annual runoff expected to occur during each summer month for the key local basins.

Table 18: Estimated Mean Monthly Local Runoff

Stream	Doris Outflow		Tail Outflow		Little Roberts Outflow	
Month	Runoff (mm)	Percent of Mean Annual	Runoff (mm)	Percent of Mean Annual	Runoff (mm)	Percent of Mean Annual
June	57.4	43	60.0	54	57.4	43
July	35.6	27	28.3	26	35.6	27
August	15.0	11	8.8	8	15.0	11
September	19.2	14	11.0	10	19.2	14
October	6.7	5	2.9	2	6.7	5
Annual	134	100	111	100	134	100

4.0 BASELINE SURFACE WATER QUANTITY SUMMARY

The mean annual water balances for Doris and Tails catchments are provided in Table 19. As the annual runoff was estimated using the period of record from Ellice (1971-2000), the annual average rainfall and snowfall were taken for the same period. Therefore, the values presented in Table 19 are approximately 2.7% higher than those in Section 2.2.2, which are estimated for a record extending from 1959 to 2001. The precipitation values used in this table have been adjusted for under-catch. For this water balance it was assumed that:

Rainfall + Snowfall = Basin Discharge + Lake Evaporation + Sublimation and Other Losses.

Table 19: Mean Annual Local Water Balances

Lake Name	Doris Lake	Tail Lake
Rainfall (mm)	89	89
Snowfall water equivalent (mm)	122	122
Total Annual Input	211	211
Basin Discharge (mm)	134	111
Lake Evaporation	42	40
Sublimation and Other Losses (calculated)	35	71

Table 20 provides a description of the baseline hydrological characteristics in the vicinity of the proposed Doris North Project for existing conditions.

Table 20: Baseline Hydrological Conditions

Parameter	Characteristic
Annual Hydrograph Shape	• The majority of runoff occurs in June due to spring snowmelt. • Streams are frozen between November and May with no to negligible flow.
Flood Peaks	• The annual maximum flow occurs in June due to snowmelt. • A secondary peak may occur due to rainfall in late August or early September.
Low Flows	• Low open water flows typically occur in early August and October. • Discharges from small basins such as Tail Lake typically reach zero during mid to late summer. • Streams are frozen to the bottom through the winter.

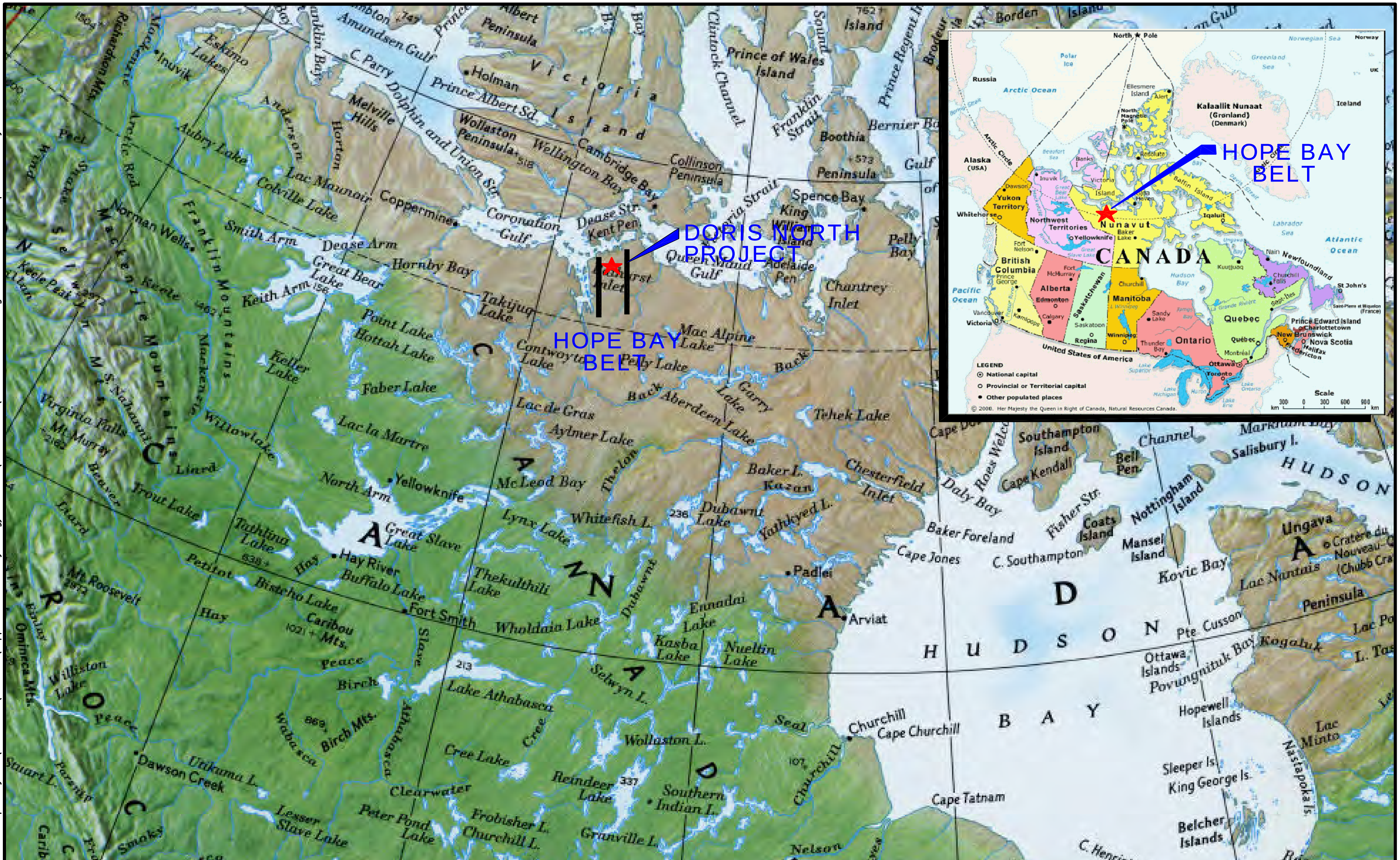
REFERENCES

Environment Canada. 2003: Letter re: *Doris North Draft EIS – Comments regarding water balance calculations*. From Colette Meloche, Environmental Protection Branch to Hugh Wilson, Miramar Hope Bay Ltd. 14 March 2003.

Metcalfe, J.R., S. Ishida and B.E. Goodison, 1994: *A Corrected Precipitation Archive for the Northwest Territories*. Environment Canada - Mackenzie Basin Impact Study, Interim Report #2, 110-117

Pomeroy and Gray. 1995. Snowcover Accumulation, Relocation, and Management, NHRI Science Report No. 7, 1995, p.120

Rescan. 2002. Hope Bay Belt Project, 1993-2002 Data Compilation Report for Meteorology and Hydrology. Prepared for Hope Bay Joint Venture. May 2002.



AMEC Earth & Environmental Limited
2227 Douglas Road
Burnaby, B.C.
V5C 5A9
Tel. 294-3811
Fax. 294-4664

Client
MIRAMAR HOPE BAY LIMITED

DWN BY:	SM
CHK'D BY:	KM
APP.	-
SCALE	NTS
PROJECT	METEOROLOGY AND HYDROLOLOGY BASELINE DORIS NORTH PROJECT
TITLE	PROJECT LOCATION PLAN
DATE:	JAN. 2003
PROJECT NO:	VM00259
REV. NO.:	-
FIGURE No.	FIG. 1

*PLOT 1:1=D S:\MIN\PROJECTS\VM00259 - Hope Bay EIA\DRAWINGS\FIGURES\support Doc D- Hydrology Baseline\CADD FILES\ 259-DDD-FIG1.dwg Sun. Jan. 19 2003 2:17pm Layout1 STeve.Milot

amec	AMEC Earth & Environmental Limited 2227 Douglas Road Burnaby, B.C. V5C 5A9 Tel. 294-3811 Fax. 294-4664

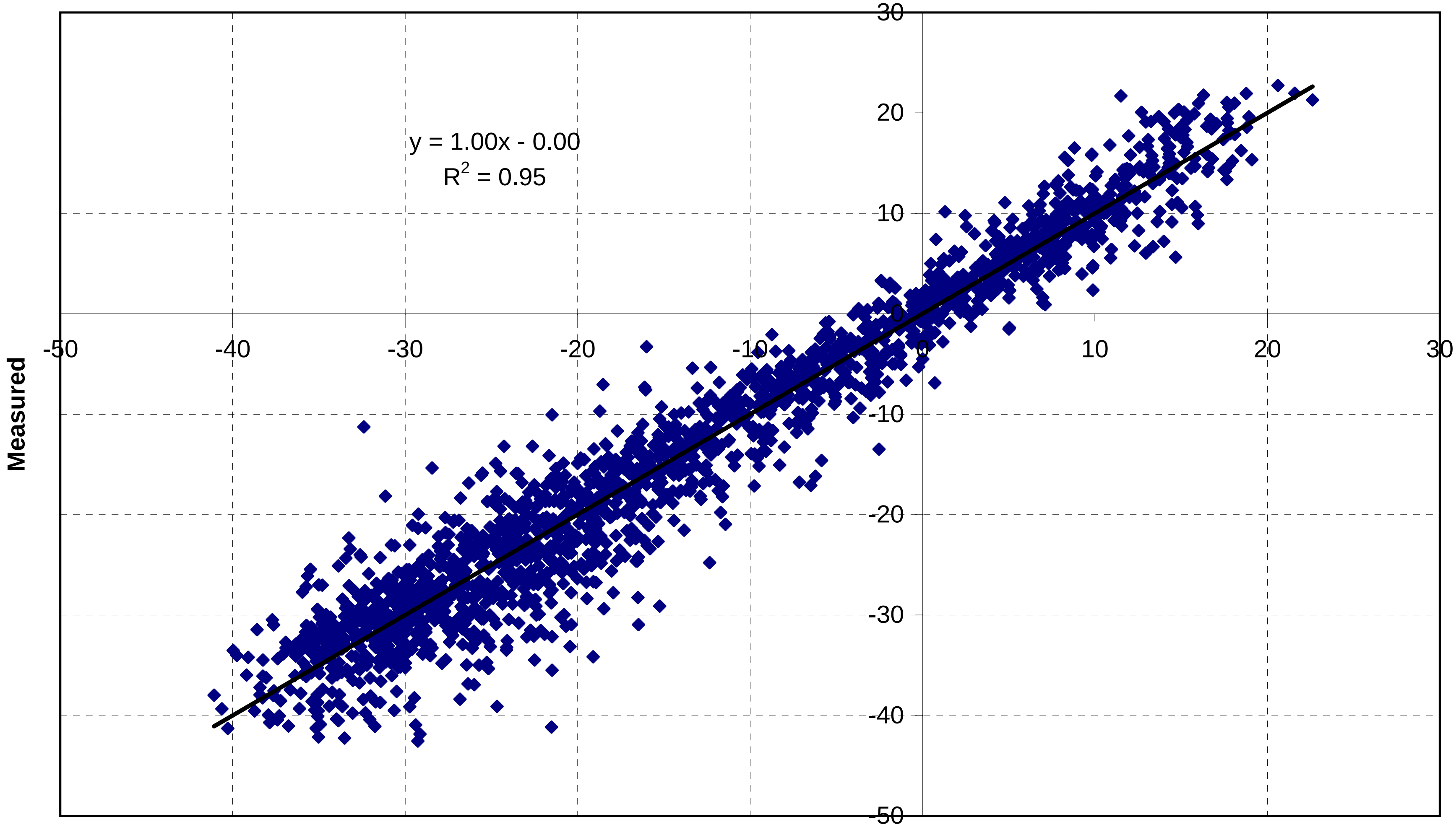
CLIENT
MIRAMAR HOPE BAY LIMITED

PROJECT
METEOROLOGY AND HYDROLOGY BASELINE
DORIS NORTH PROJECT

DWN BY:	CHK'D BY:	APP.	DATE:
SM	KM	-	JAN. 2003
PROJECT NO:	REV. NO.:	SCALE:	FIGURE No.
VM00259	-	NTS	FIG. 2

TITLE
LOCATIONS OF CLIMATIC STATIONS
AND REGIONAL HYDROMETRIC STATIONS

Figure 3. Doris North Project - Comparison of Measured and Estimated Mean Daily Air Temperature in °C at Boston Camp



Estimated Using a Regression Relationship Based on Kugluktuk, Cambridge Bay, and Lupin Data

Figure 4. Doris North Project - Estimated Monthly Temperatures 1959-2001

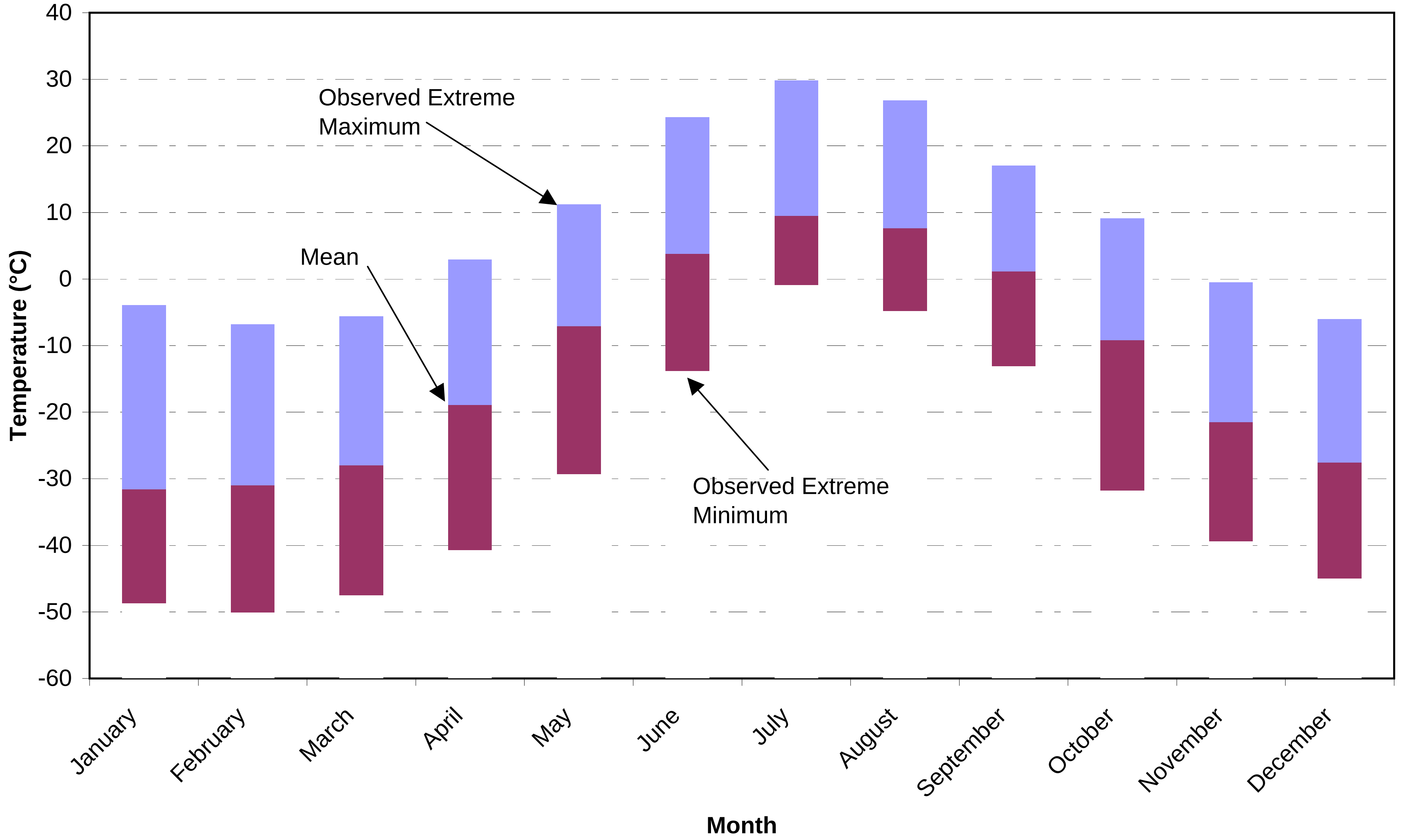
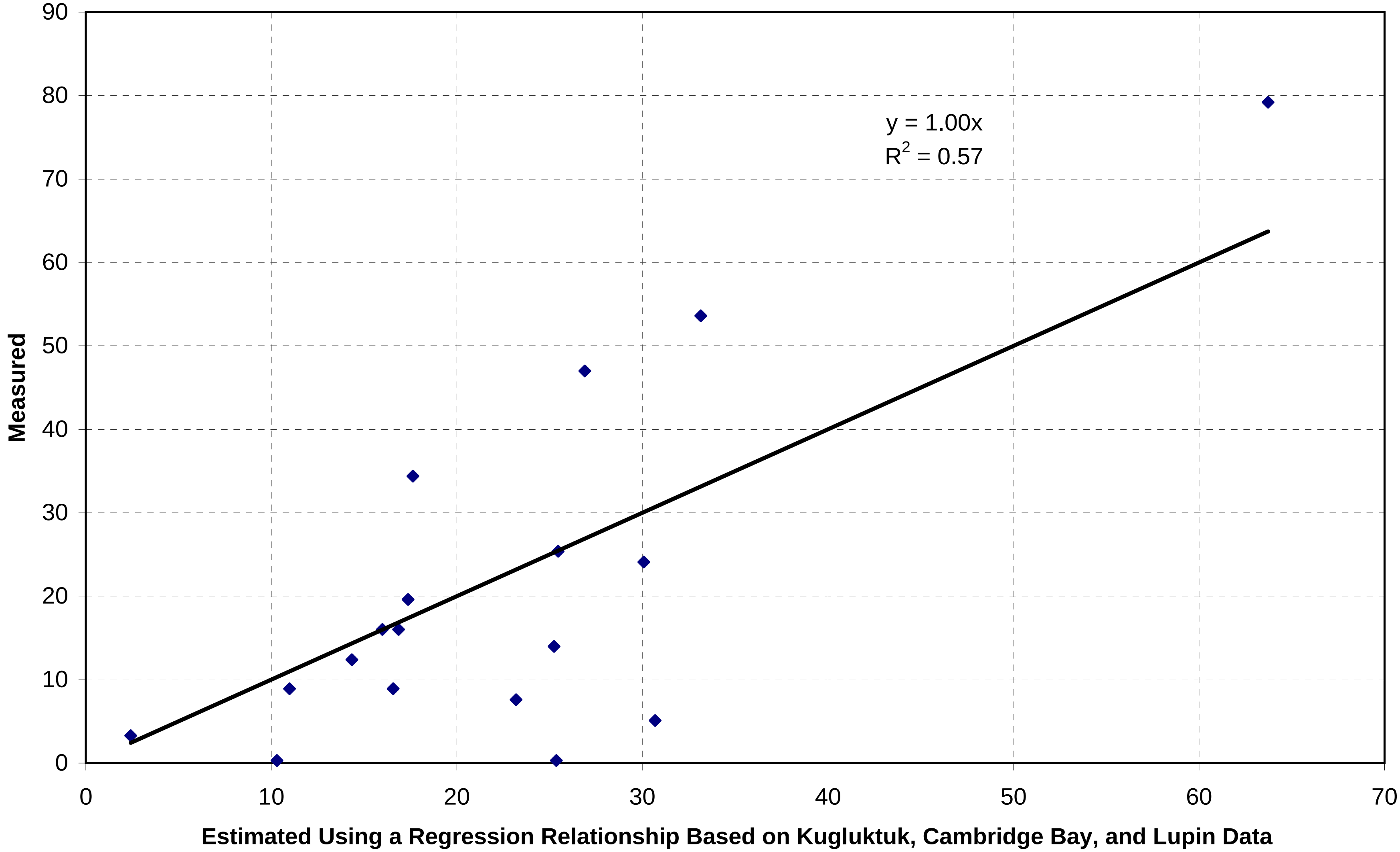
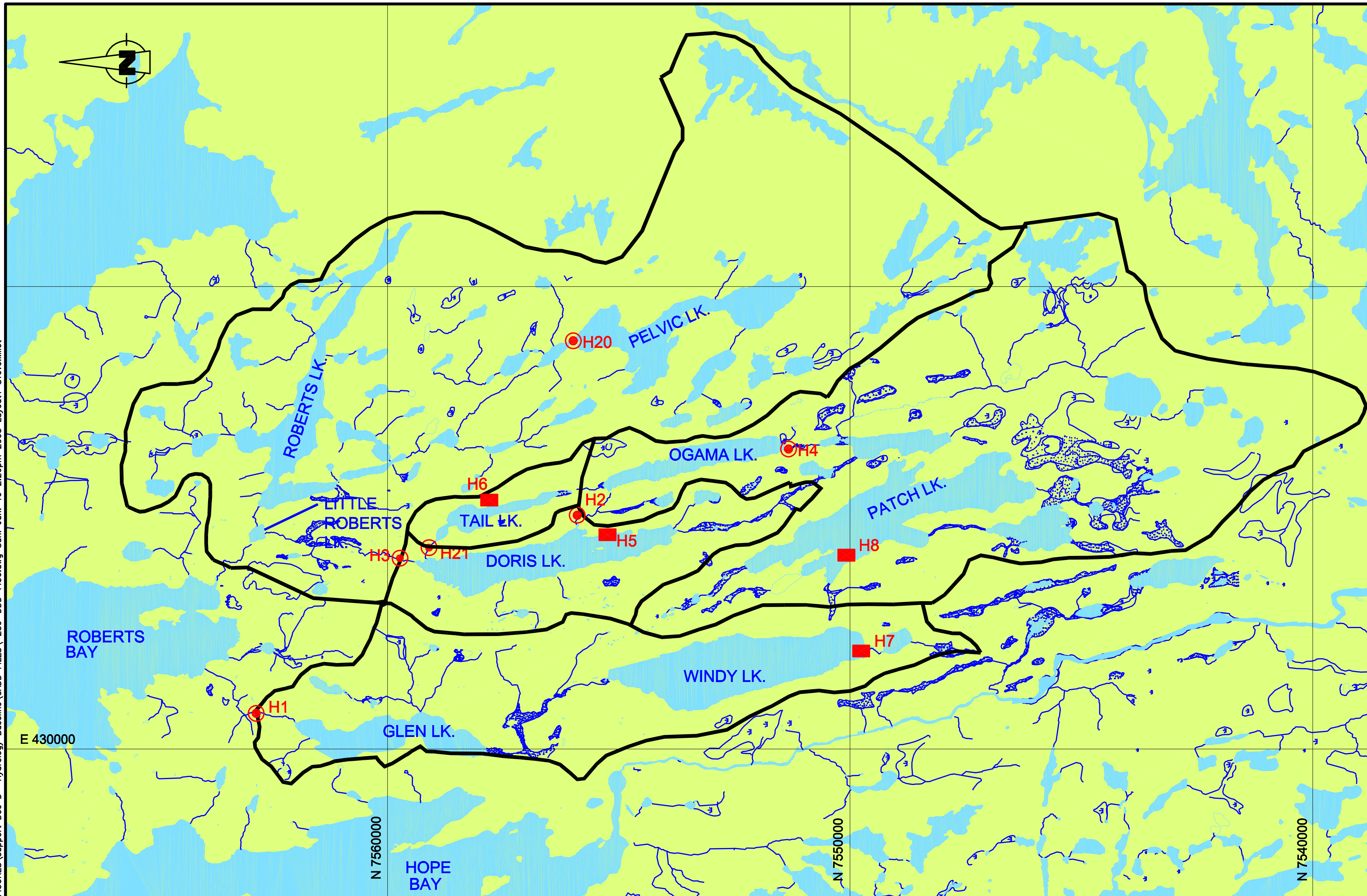
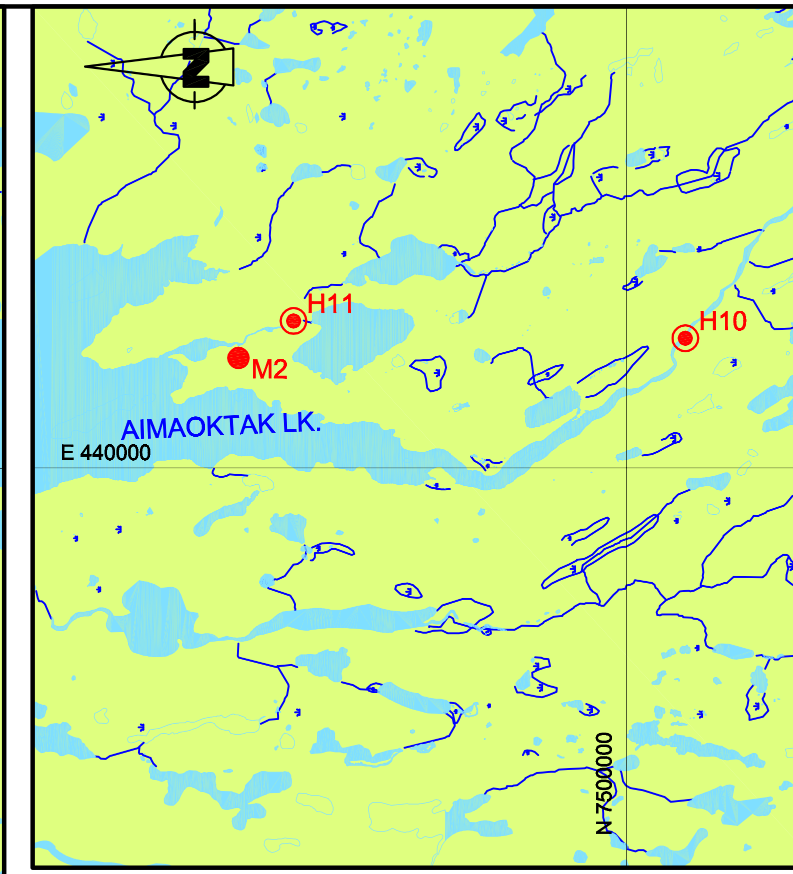


Figure 5. Doris North Project - Comparison of Measured and Estimated Monthly Rainfall (mm) at Boston Camp





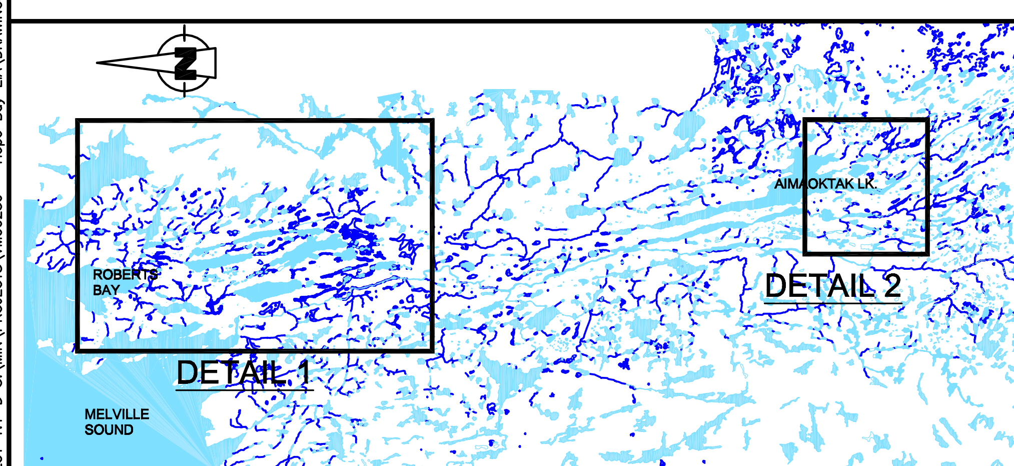
DETAIL 1 (1:100,000)



DETAIL 2 (1:100,000)

LEGEND

- ● AUTOMATED METEOROLOGY STATION
- ◉ AUTOMATED HYDROLOGY STATION
- ■ STAFF GAUGE
- ▬ DENOTES CATCHMENT BOUNDARY



KEY PLAN (NTS)

amec	AMEC Earth & Environmental Limited 2227 Douglas Road Burnaby, B.C. V5C 5A9 Tel. 294-3811 Fax. 294-4664	DWN BY: SM CHK'D BY: LR APP.: -	PROJECT: METEOROLOGY AND HYDROLOGY BASELINE DORIS NORTH PROJECT TITLE: LOCATION OF SPECIFIC HYDROMETRIC, METEOROLOGIC STATIONS AND CATCHMENT AREAS	DATE: NOV. 2002 PROJECT NO: VM00259 REV. NO.: -
Client	MIRAMAR HOPE BAY LIMITED	SCALE 1:200,000		FIGURE No. FIG. 6

Figure 7. Doris North Project - Unit Discharge and Rainfall (1997)

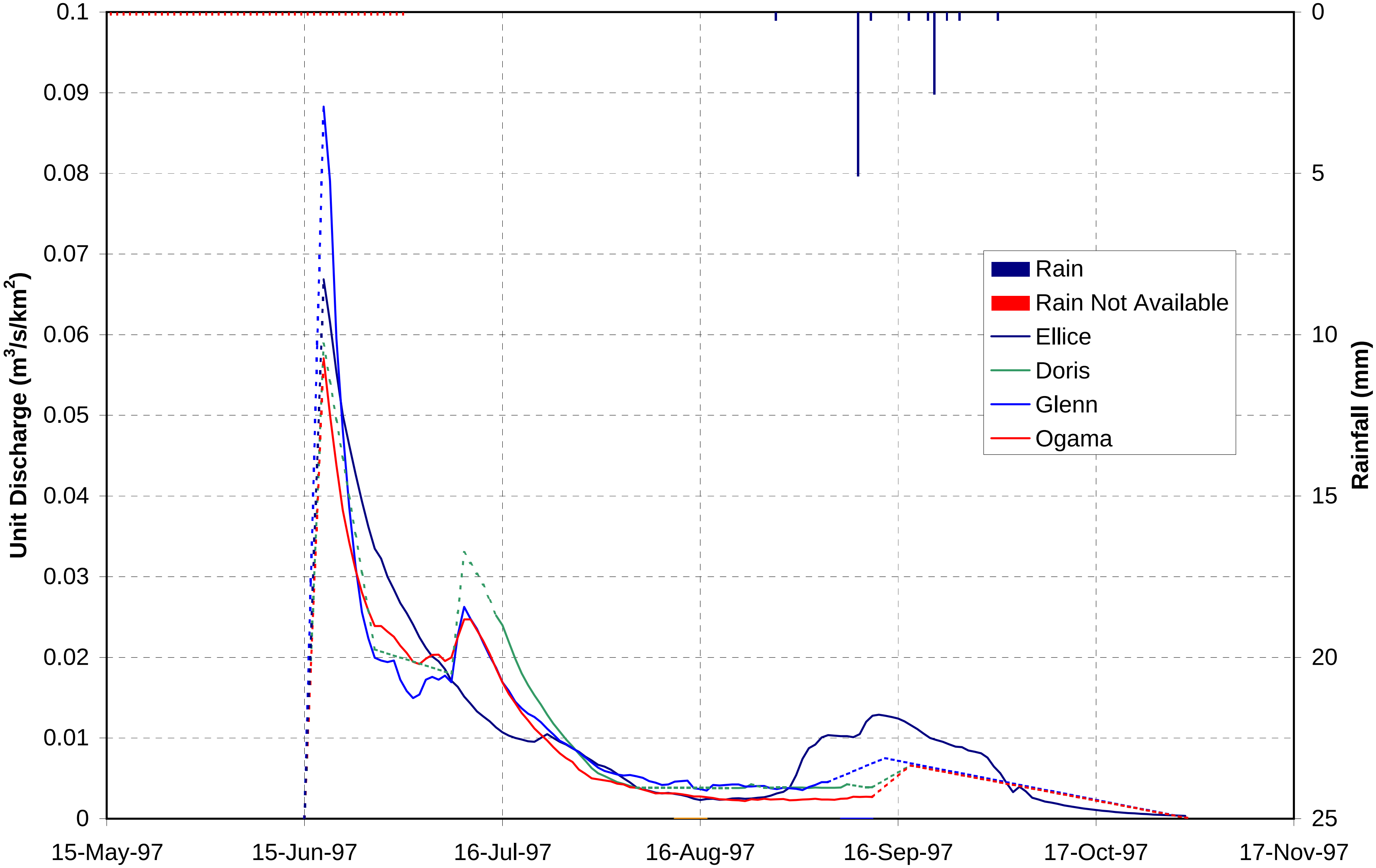


Figure 8. Doris North Project - Unit Discharge and Rainfall (1998)

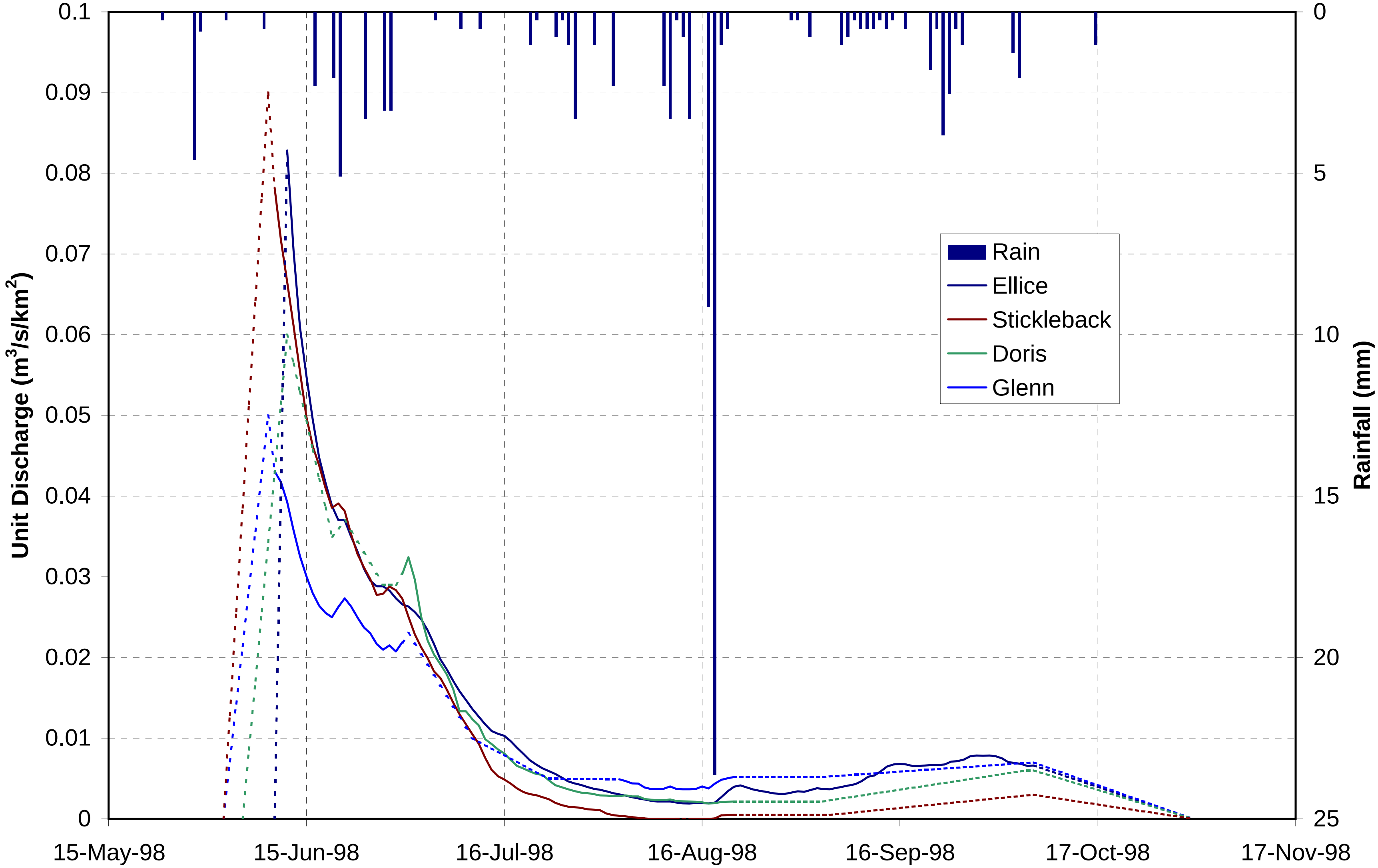


Figure 9. Doris North Project - Unit Discharge and Rainfall (2000)

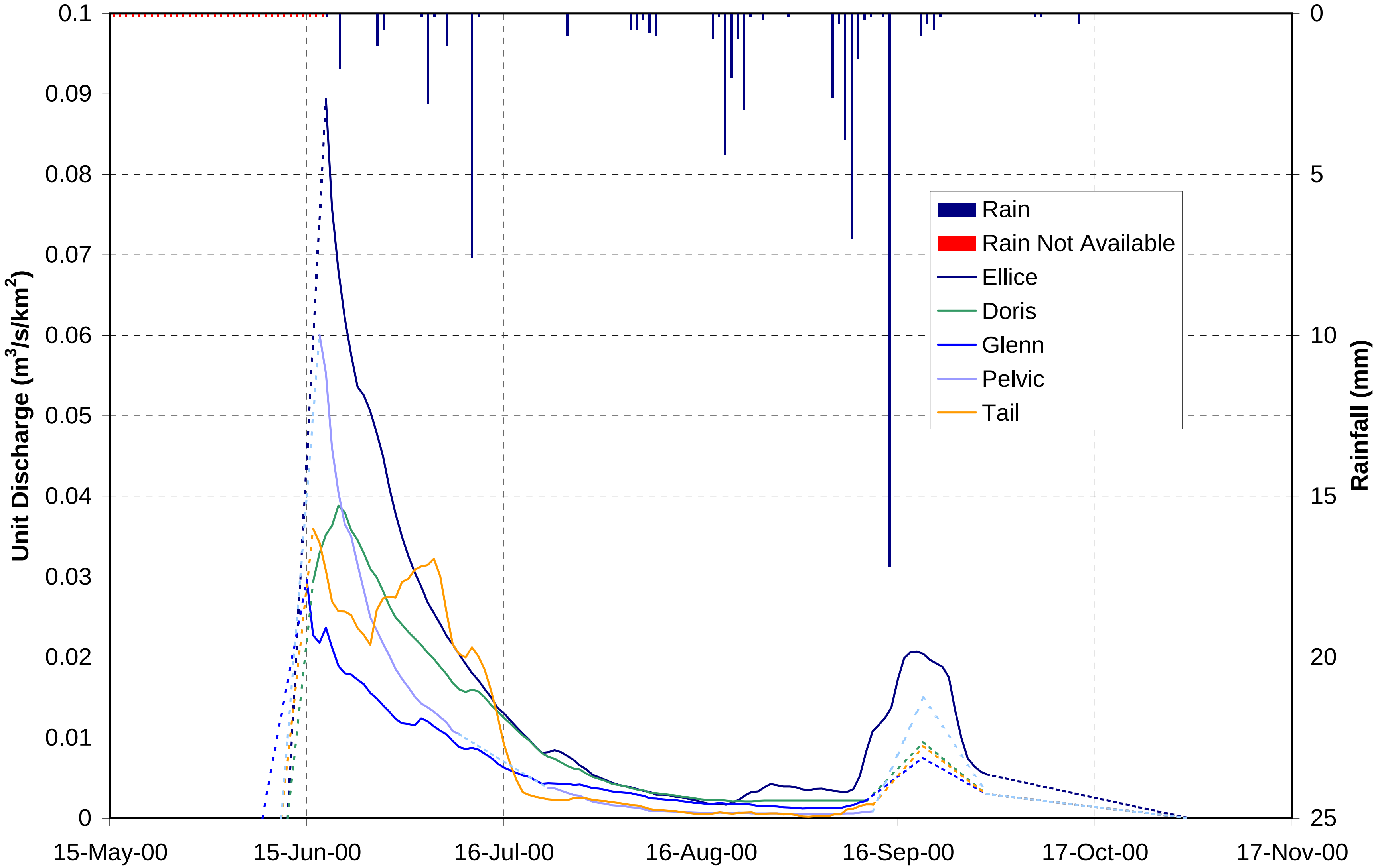
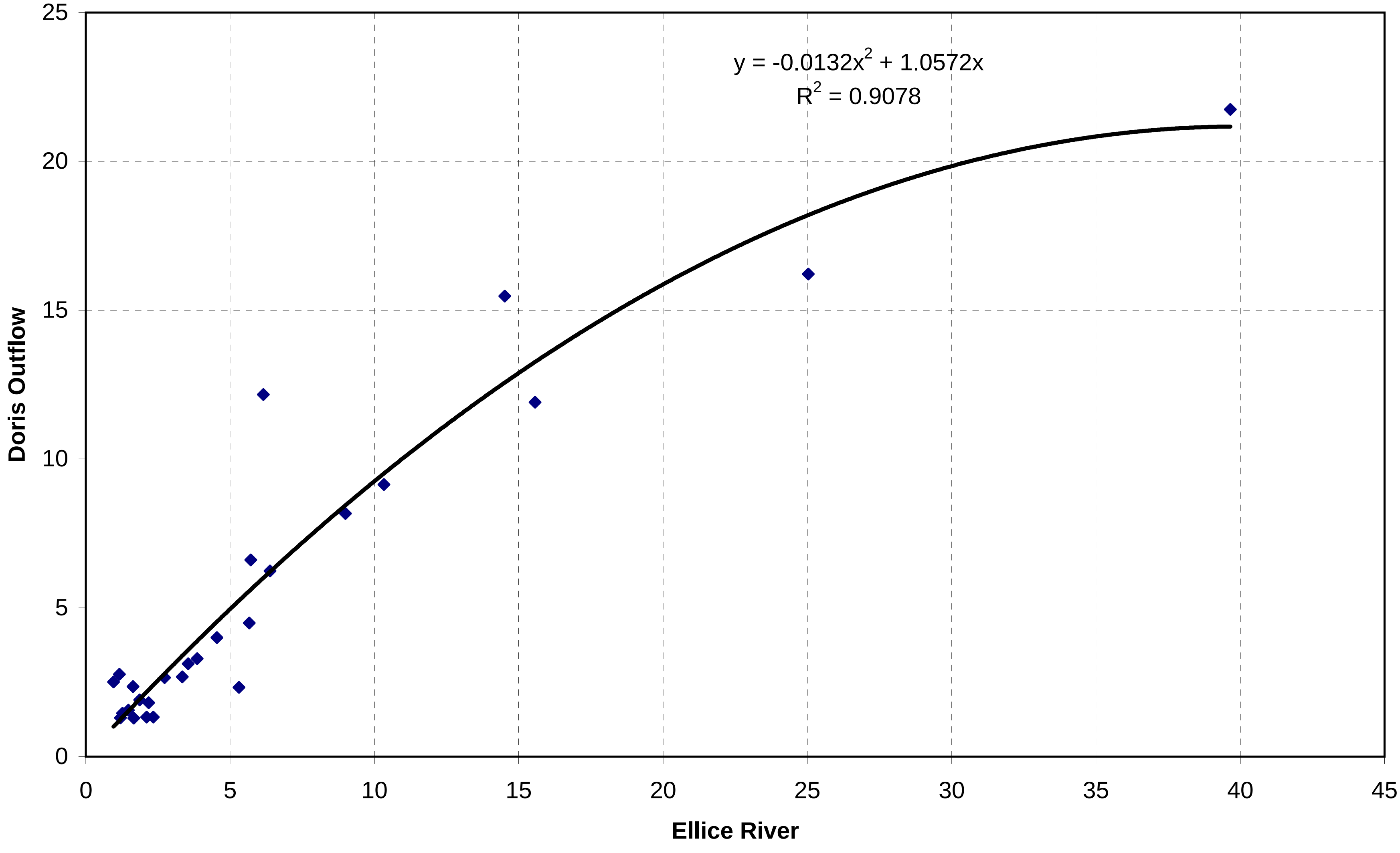


Figure 10. Comparison of Weekly Runoff (mm) for Doris Outflow and Ellice River



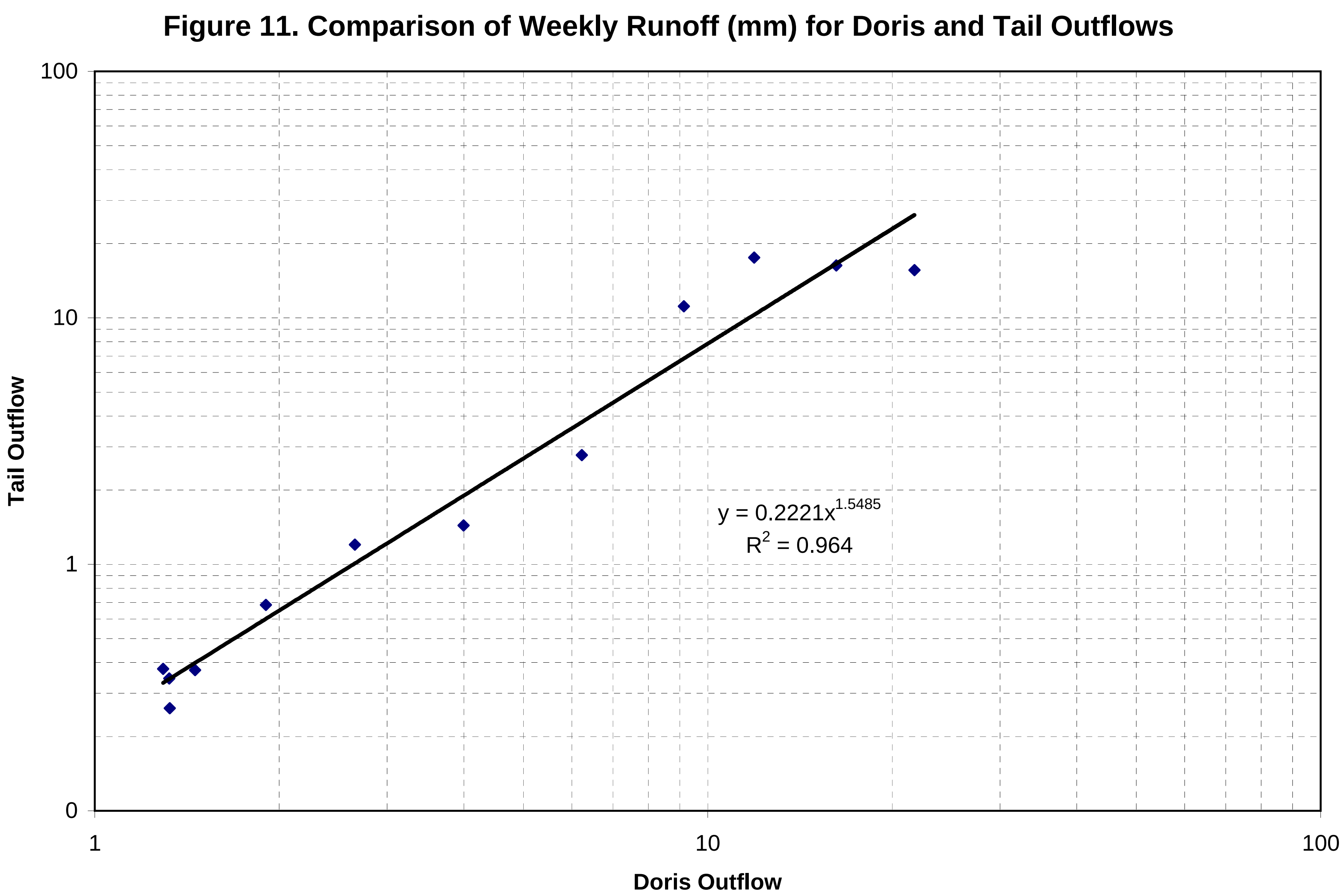


Figure 11. Comparison of Weekly Runoff (mm) for Doris and Tail Outflows
100
10
1
0
Tail Outflow
1
10
100
Doris Outflow
y = 0.2221x^1.5485
R^2 = 0.964

APPENDIX A

Discharge Measurements and Staff Gauge Readings

The following tables present: the discharge measurements; staff gauge readings; delta, the difference between the staff gauge reading (s.g.) and the datalogger recording (w.l.); and the period of record for the automated stations. Adjustments made to the staff gauge readings in these tables are provided in a footnote below the table.

Table A1: Hydrometric Monitoring at Glenn Outflow

Date	Discharge Measurement (m^3/s)	Staff Gauge Reading (m)	Delta (= s.g. – w.l.) (m)	Period of Record for Datalogger
16-Jun-96	2.851	0.575[a]	0.135	
18-Jun-96	1.552	0.480[a]		
04-Jul-96		0.275[a]		
12-Jul-96		0.225[a]		
19-Jul-96		0.195[a]		
28-Jul-96		0.165[a]		
03-Aug-96	0.214	0.150	0.133	Start
23-Aug-96				End
26-Aug-96		0.280		
02-Sep-96		0.210		
15-Jun-97				Start
18-Jun-97	2.556	0.600	0.080	
14-Jul-97	0.744	0.357	0.063	
20-Aug-97	0.121	0.170	0.031	
12-Sep-97	0.159	0.245	0.100	End
03-Jun-98	0.029			Start
30-Jun-98	0.674	0.375	-0.160	
03-Aug-98	0.154	0.266	-0.018	
21-Aug-98				End
15-Jun-00	1.221	0.510	0.212	Start
24-Jun-00	0.616	0.440	0.267	
22-Jul-00	0.222	0.297	0.190	
11-Sep-00	0.099	0.254	0.183	End

Notes:
* Staff gauge reading adjusted by 0.025 due movement of the pressure transducer.

Table A2: Hydrometric Monitoring at Ogama Outflow

Date	Discharge Measurement (m^3/s)	Staff Gauge Reading (m)	Delta (= s.g. – w.l.) (m)	Period of Record for Datalogger
15-Jun-96	1.762	0.78		
18-Jun-96	1.302	0.755		
04-Jul-96		0.640		
12-Jul-96		0.580		
19-Jul-96		0.530		
28-Jul-96		0.470		
02-Aug-96				Start
03-Aug-96	0.175	0.560	0.154	
22-Aug-96		0.500	0.047	End
26-Aug-96		0.640		
02-Sep-96		0.580		
17-Jun-97	4.805	0.900	0.040	Start
14-Jul-97	1.873	0.750		
20-Aug-97	0.113	0.442	0.051	
12-Sep-97	0.235	0.460	0.058	End

Table A3: Hydrometric Monitoring at Doris Outflow

Date	Discharge Measurement (m^3/s)	Staff Gauge Reading (m)	Delta (= s.g. – w.l.) (m)	Period of Record for Datalogger
16-Jun-96	2.55	0.680[b]	0.045	
18-Jun-96	2.32	0.650[b]		
04-Jul-96		0.460[b]		
12-Jul-96		0.360[b]		
19-Jul-96		0.300[b]		
28-Jul-96		0.250[b]		
03-Aug-96	0.33	0.218	0.057	Start
22-Aug-96				End
26-Aug-96		0.340		
2-Sep-96		0.380		
18-Jun-97	5.469	0.830	0.040	
19-Jun-97	5.397	0.990	0.020	
15-Jul-97	2.230	0.695	0.165	Start

Date	Discharge Measurement (m^3/s)	Staff Gauge Reading (m)	Delta (= s.g. – w.l.) (m)	Period of Record for Datalogger
20-Aug-97	0.295	0.145	0.145	
12-Sep-97	0.263	0.140[c]		End
30-Jun-98	2.217	0.886	-0.120	Start
03-Aug-98	0.367	0.220	-0.012	
21-Aug-98				End
16-Jun-00				Start
19-Jun-00	3.547	0.680	-0.154	
24-Jun-00	2.779	0.630	-0.139	
22-Jul-00	0.730	0.232	-0.129	
16-Aug-00	0.244	-0.105	-0.145	
11-Sep-00	0.196	-0.130	-0.144	End

Notes:

* Staff gauge moved down by 0.25 m on 3 August 1996; therefore, all data prior to that was increased by 0.25.

** Staff gauge was out of water. It was repositioned to 0.140 m.

Table A4: Hydrometric Monitoring at Pelvic Outflow

Date	Discharge Measurement (m^3/s)	Staff Gauge Reading (m)	Delta (= s.g. – w.l.) (m)	Period of Record for Datalogger
17-Jun-00	2.664	0.550[d]	-0.072	Start
24-Jun-00	1.392	0.450[d]	-0.064	
23-Jul-00	0.241	0.240[d]	-0.055	
16-Aug-00	0.043	0.110[d]	-0.062	
12-Sep-00	0.025	0.130[d]	-0.056	End

Notes:

* Staff gauge was destroyed by a bear between June 24 and July 23. However, it was reinstalled at the same location and elevation. Therefore, no adjustments were required.

Table A5: Hydrometric Monitoring at Tail Outflow

Date	Discharge Measurement (m^3/s)	Staff Gauge Reading (m)	Delta (= s.g. – w.l.) (m)	Period of Record for Datalogger
16-Jun-00	0.156	0.295	-0.042	Start
25-Jun-00	0.096	0.280	-0.050	
19-Jul-00	0.012	0.235	-0.028	
16-Aug-00	0.003	0.150	-0.030	
12-Sep-00	0.008	0.190	-0.034	End

Table A6 Hydrometric Monitoring at Spyder (Aimaoktok) Outflow

Date	Discharge Measurement (m^3/s)	Staff Gauge Reading (m)	Delta (= s.g. – w.l.) (m)	Period of Record for Datalogger
13-Jun-96		1.230[e]	0.049	Start
06-Aug-96	0.306	0.210[e]	0.192	End
18-Aug-96	0.378	0.110[e]		
14-Jun-97		1.870[f]	0.080	
15-Jun-97				Start
21-Jul-97		0.340[f]		
24-Aug-97	5.007	0.020[f]		
13-Sep-97	0.691	0.225[f]	0.045	End
29-May-98	2.5509			
31-May-98				Start
26-Jun-98	20.689	0.804	0.070	
27-Jun-98		0.798	0.079	
31-Jul-98	1.358	0.123	0.077	
21-Aug-98				End

Notes:

* The staff gauge readings were increased by 0.5 m to account for the staff gauge being out of water.

** The staff gauge was moved down by 0.12 m 13 Sept 1997. Therefore, all 1997 staff gauge readings were increased by 0.12 m.

Table A7: Hydrometric Monitoring at Stickleback Outflow

Date	Discharge Measurement (m^3/s)	Staff Gauge Reading (m)	Delta (= s.g. – w.l.) (m)	Period of Record for Datalogger
13-Jun-96	0.119			
14-Jun-96	0.275			
18-Aug-96	0.001			
14-Jun-97	0.280			
21-Jul-97	0.180			
26-Aug-97				Start
29-Aug-97	0.002	0.205	-0.027	
11-Sep-97	0.007	0.245	-0.032	
13-Sep-97				End
14-Sep-97	0.008	0.245		
29-May-98		0.645	-0.087	Start
26-Jun-98	0.057	0.430	-0.027	
27-Jun-98		0.438	-0.025	
29-Jun-98		0.435	-0.026	
30-Jul-98	0.005	0.215	-0.029	
21-Aug-98				End

APPENDIX B

Stage Hydrographs

The stage hydrographs were created using the staff gauge measurements and the water levels collected at the automated hydrometric stations for 1996, 1997, 1998, and 2000. The data collected using the dataloggers were adjusted to match the staff gauge readings. Where the difference between the staff gauge and the recorded datalogger readings (delta from Tables in Appendix A) varied throughout the year the adjustment was varied over the same time period. The adjustments made to the water level data are described in Tables B1 to B7.

Table B1: Adjustments to the Glenn Outflow Datalogger Record

Period	Adjustment to the Datalogger Record (m)	Comments
1996	0.135	Difference between staff gauge and datalogger readings
1997	0.069	Difference between staff gauge and datalogger readings
June 1998	-0.160	Difference between staff gauge and datalogger readings
June 1998	0.429	Movement between June and August, when a technical failure occurred
August 1998	-0.018	Difference between staff gauge and datalogger readings
2000	Varies	Based on delta values provided in Table 12
2000	-0.009	Both staff gauge and datalogger readings adjusted to provide better fit to rating curve discussed in Section 3.2.1

Table B2: Adjustments to the Ogama Outflow Datalogger Record

Period	Adjustment to the Datalogger Record (m)	Comments
1996	Varies	Based on delta values provided in Table 13
3 Aug 1996	0.154[a]	Staff gauge reading lowered from 0.560 to 0.406 to match the data logger reading.
1997	0.054	Difference between staff gauge and datalogger readings

Notes:
* Adjustment was made to the staff gauge reading.

Table B3: Adjustments to the Doris Outflow Datalogger Record

Period	Adjustment to the Datalogger Record (m)	Comments
1996	0.045	Difference between staff gauge and datalogger readings
1997	0.155	Difference between staff gauge and datalogger readings
1998	Varies	Based on delta values provided in Table 14
1998	-0.150	Both staff gauge and datalogger readings adjusted to provide better fit to rating curve discussed in Section 3.2.1
2000	-0.142	Difference between staff gauge and datalogger readings
2000	0.140	Both staff gauge and datalogger readings adjusted to account for negative staff gauge readings due to the staff gauge being dry.

Table B4: Adjustments to the Pelvic Outflow Datalogger Record

Period	Adjustment to the Datalogger Record (m)	Comments
2000	Varies	Based on delta values provided in Table 15

Table B5: Adjustments to the Tail Outflow Datalogger Record

Period	Adjustment to the Datalogger Record (m)	Comments
2000	Varies	Based on delta values provided in Table 16

Table B6: Adjustments to the Aimaoktak Outflow Datalogger Record

Period	Adjustment to the Datalogger Record (m)	Comments
1996	0.045	Difference between staff gauge and datalogger readings
1996	0.500	Datalogger readings adjusted to account for dry staff gauge
1997	0.051	Difference between staff gauge and datalogger readings
1998 – prior to 26 June	0.139	Datalogger was moved on June 26 therefore all readings prior to this date were increased
1998 – prior to 26 June	0.070	Difference between staff gauge and datalogger readings
1998 – after 27June	0.076	Difference between staff gauge and datalogger readings

Table B7: Adjustments to the Stickleback Outflow Datalogger Record

Period	Adjustment to the Datalogger Record (m)	Comments
1997	0.023	Difference between staff gauge and datalogger readings
1997	-0.131	Staff gauge and datalogger readings reduced to get the head over the weir, as the weir equation applies for calculating discharge
1998	-0.027	Difference between staff gauge and datalogger readings
1998 – prior to 26 June	0.111	Datalogger was moved on June 26 therefore all readings prior to this date were increased.
1998	-0.139	Staff gauge and datalogger readings reduced to get the head over the weir, as the weir equation applies for calculating discharge

Figure B-1: Doris Lake Outflow (1996)

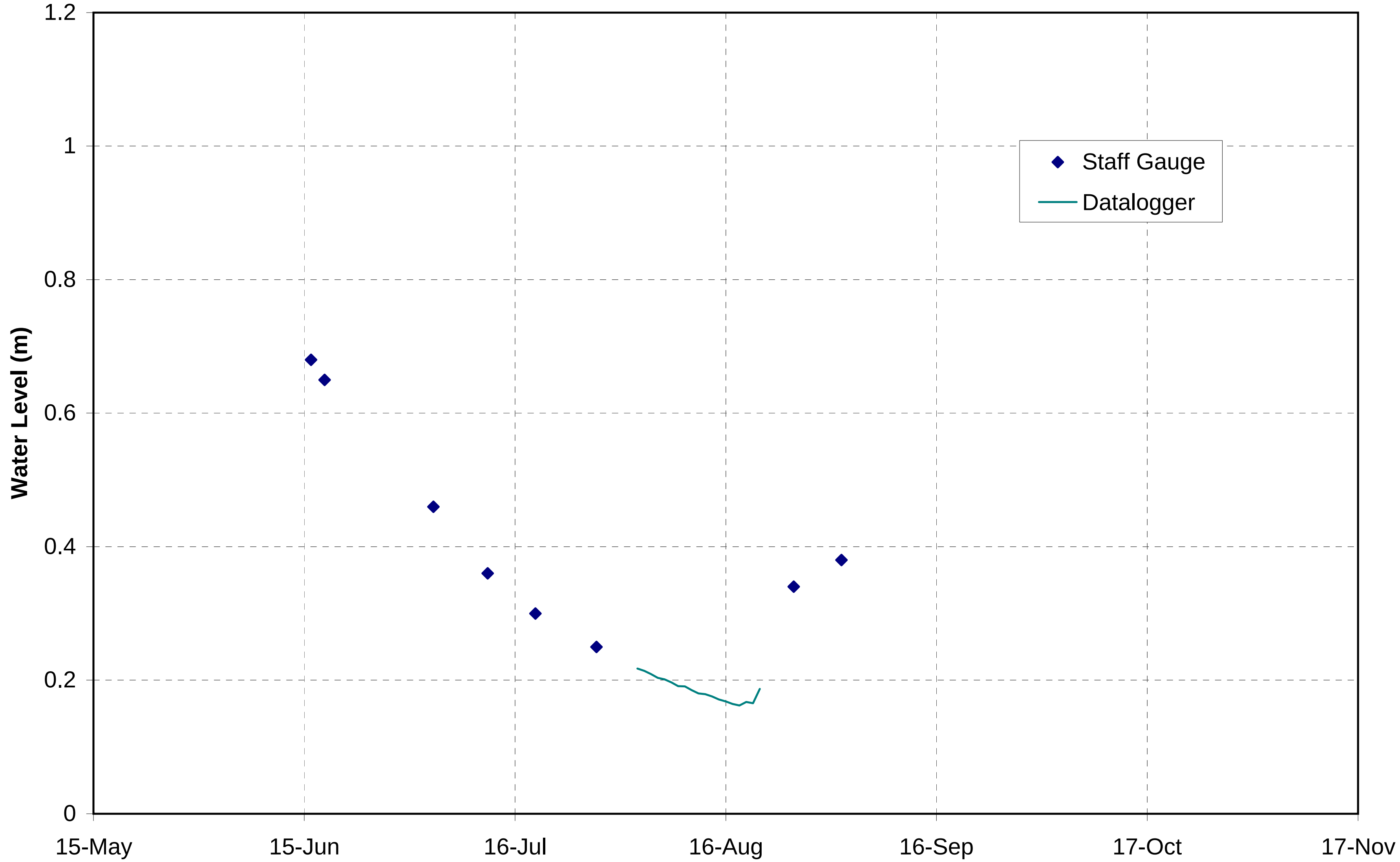


Figure B-2: Doris Lake Outflow (1997)

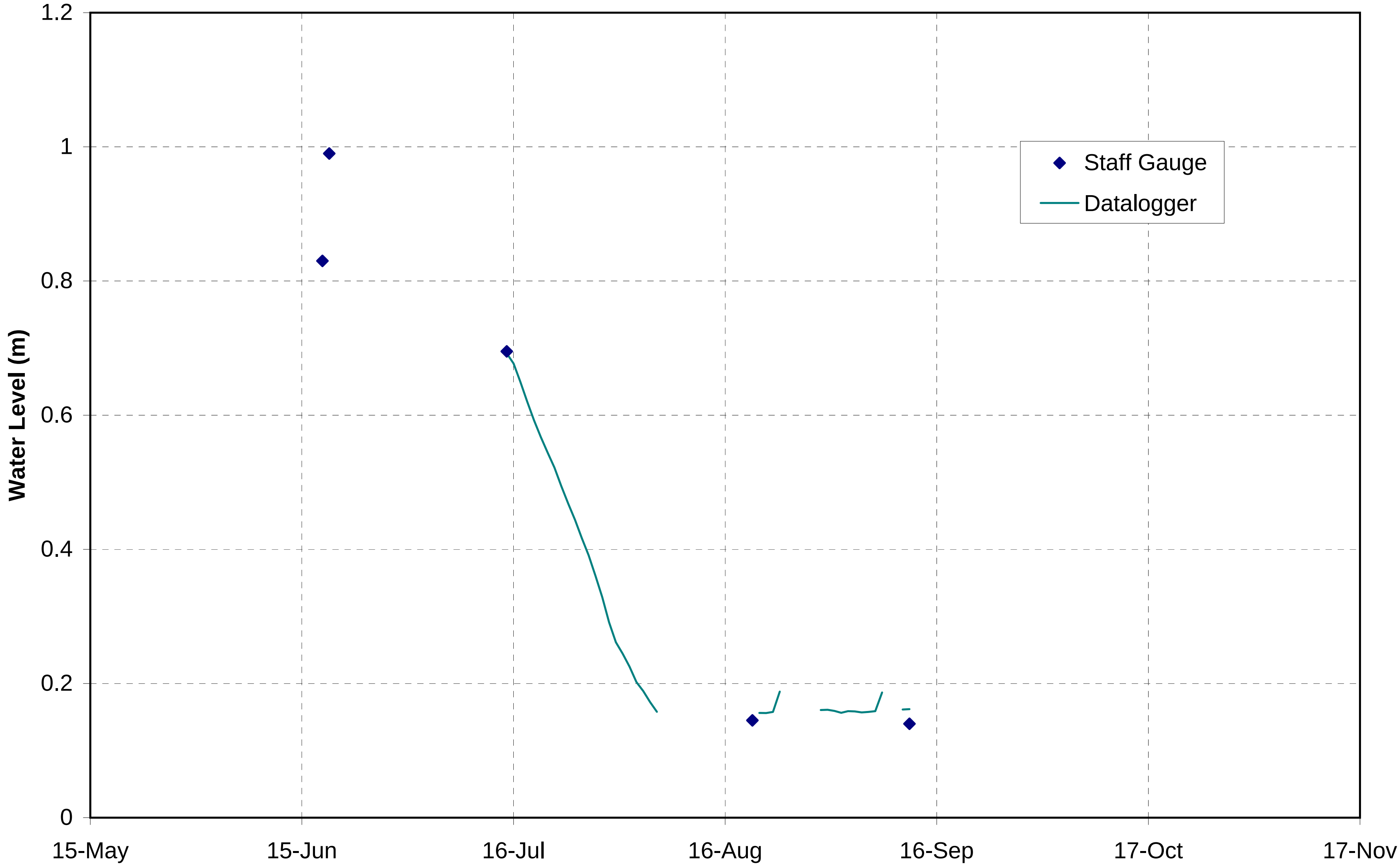


Figure B-3: Doris Lake Outflow (1998)

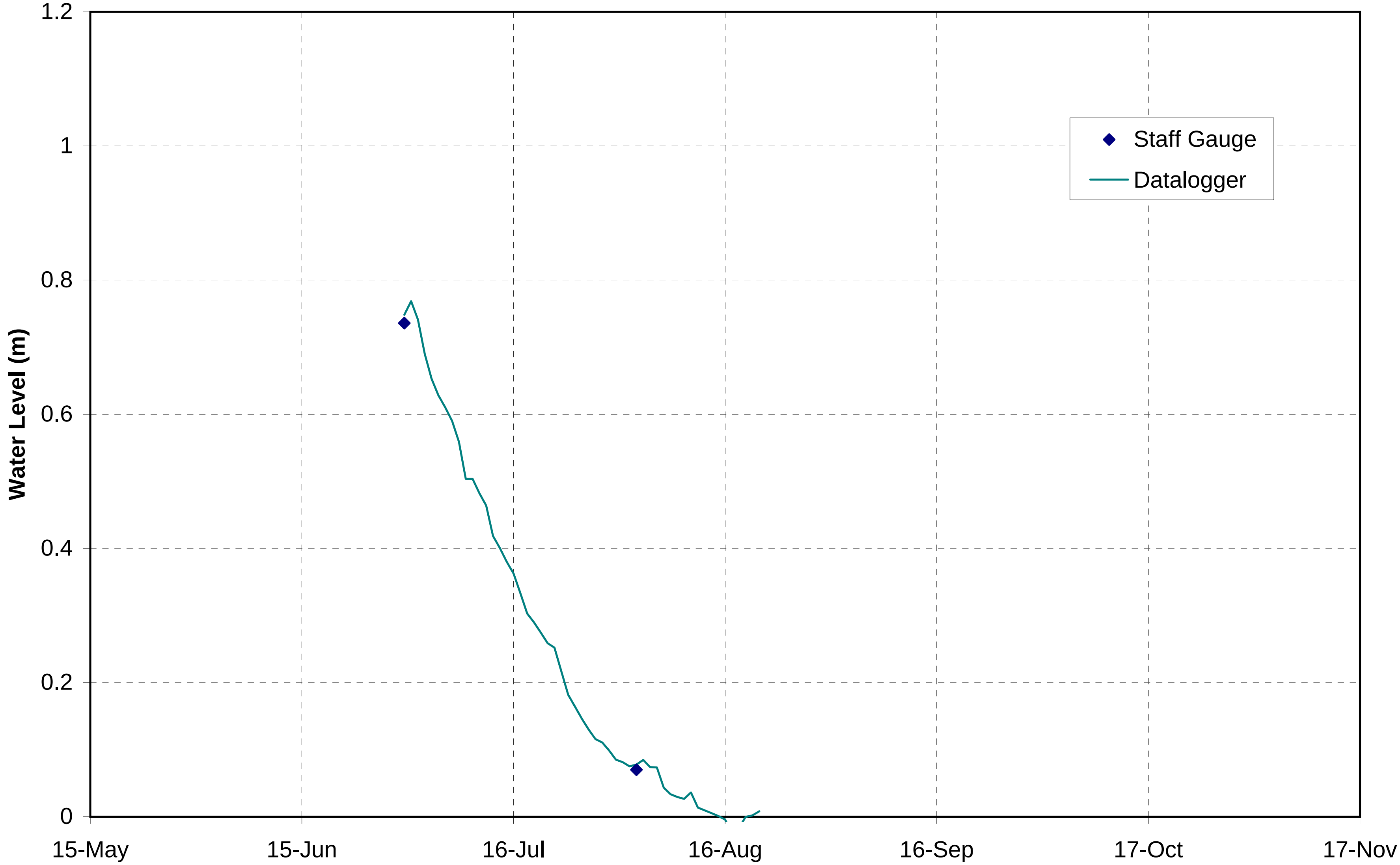
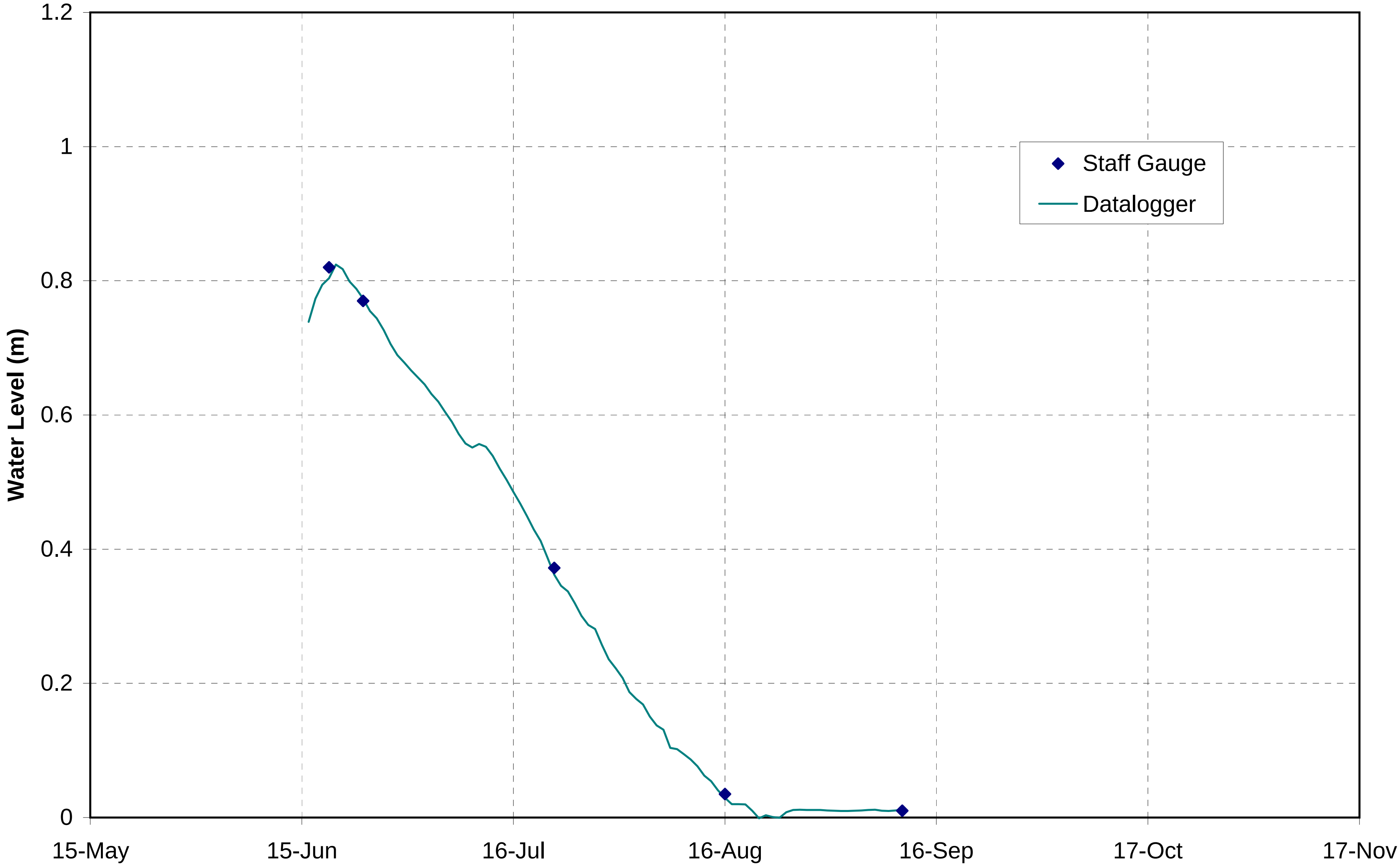


Figure B-4: Doris Lake Outflow (2000)



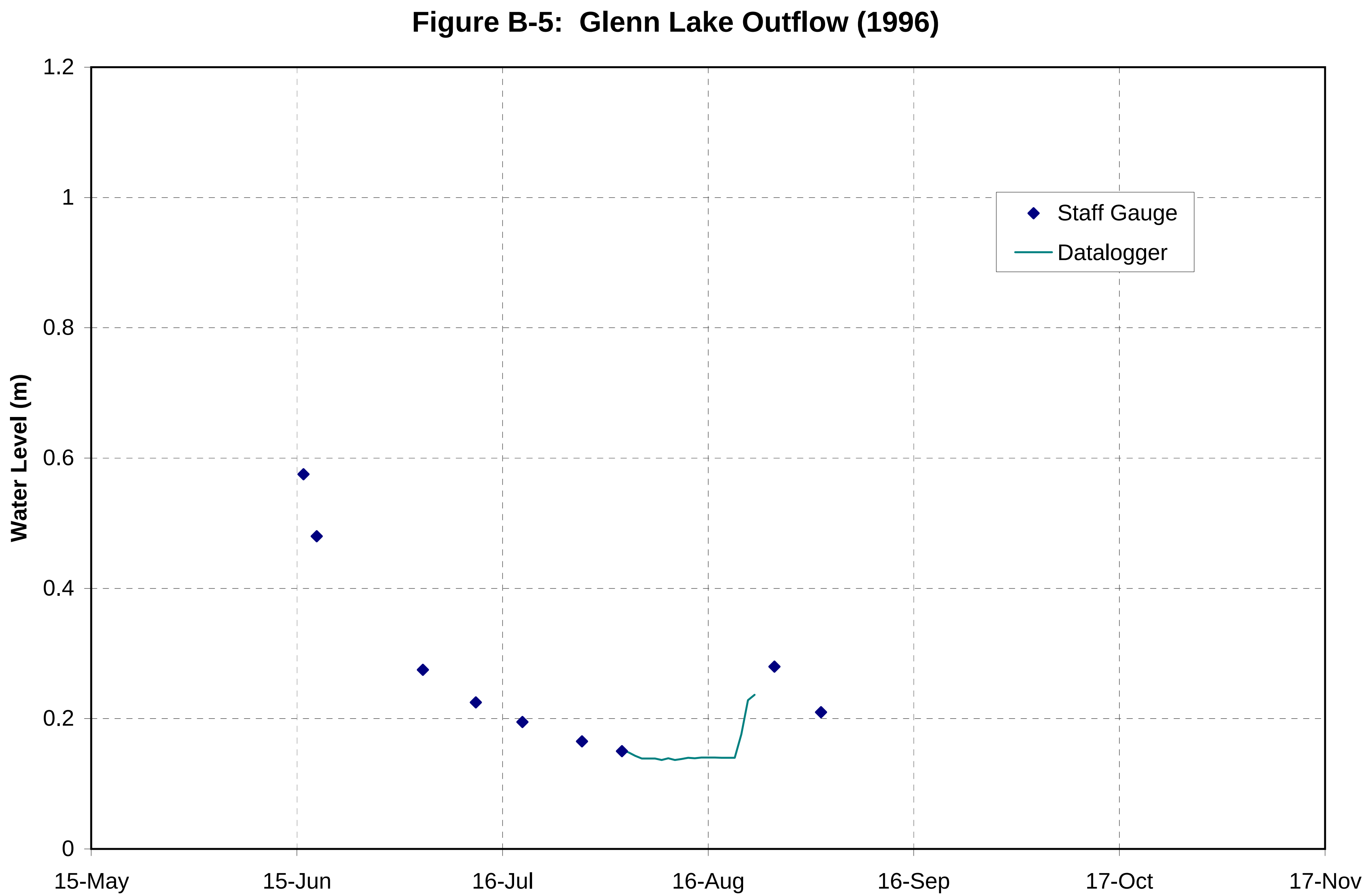


Figure B-5: Glenn Lake Outflow (1996)
Water Level (m)
1.2
1
0.8
0.6
0.4
0.2
0
15-May
15-Jun
16-Jul
16-Aug
16-Sep
17-Oct
17-Nov
Staff Gauge
Datalogger

Figure B-6: Glenn Lake Outflow (1997)

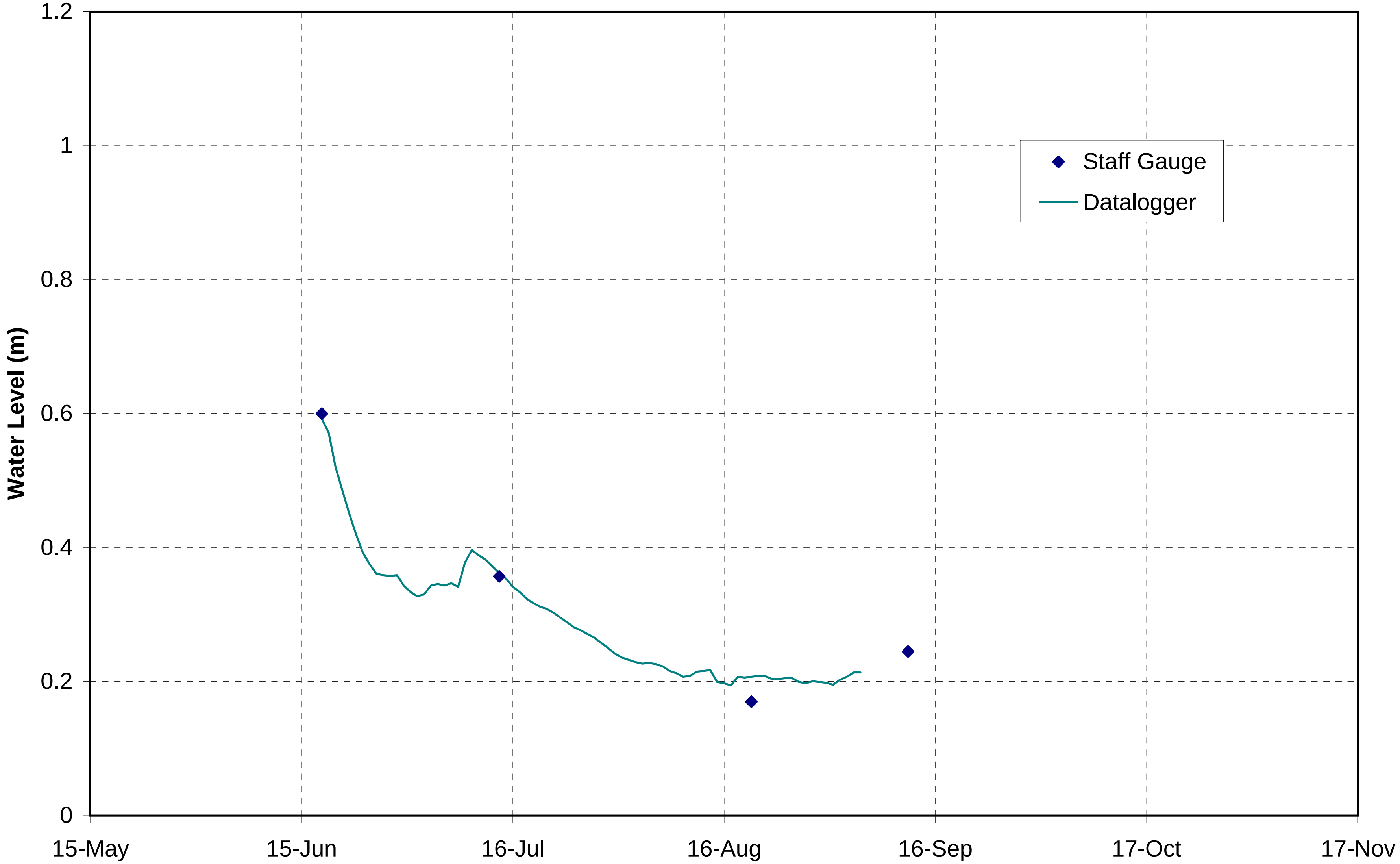


Figure B-7: Glenn Lake Outflow (1998)

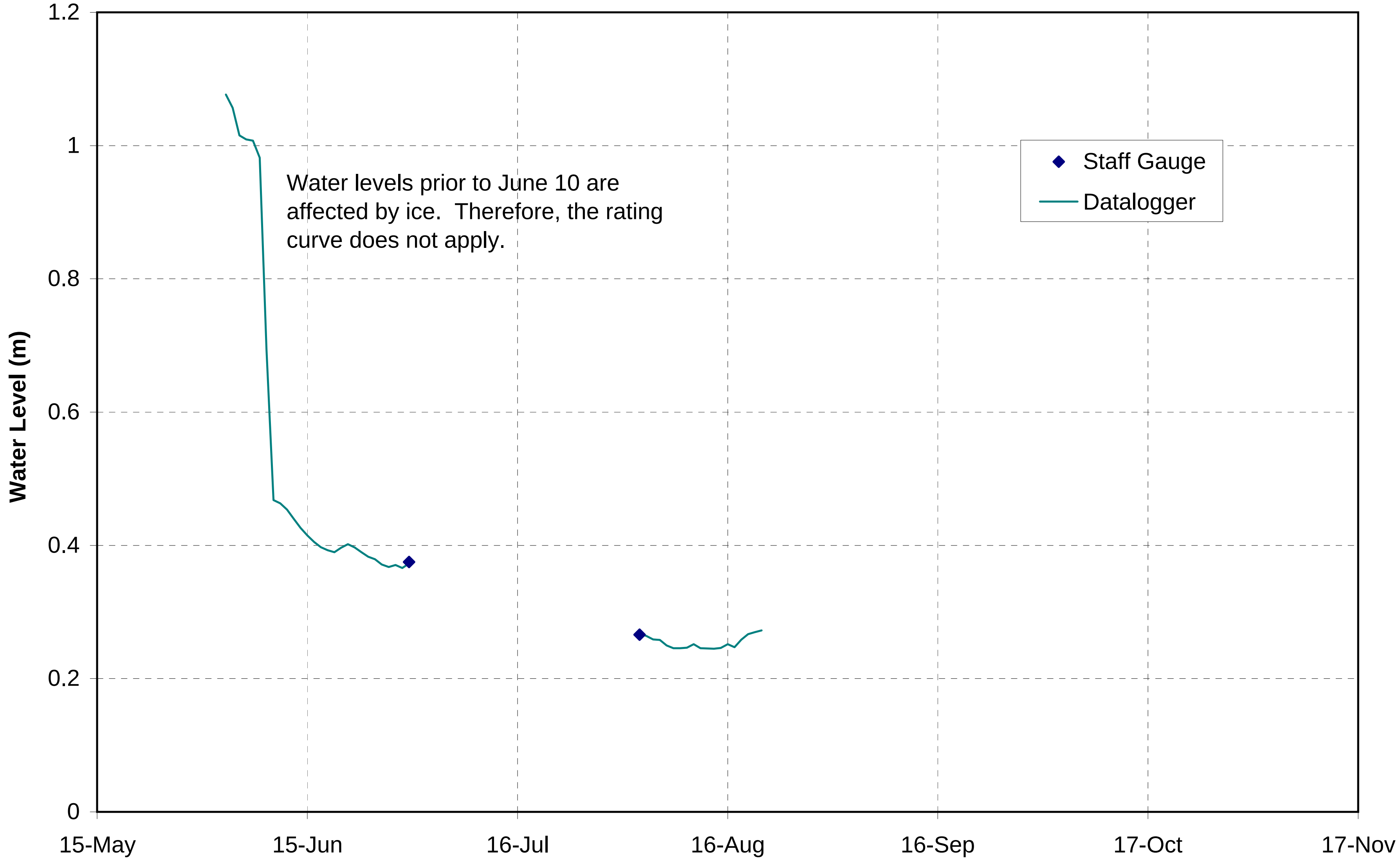
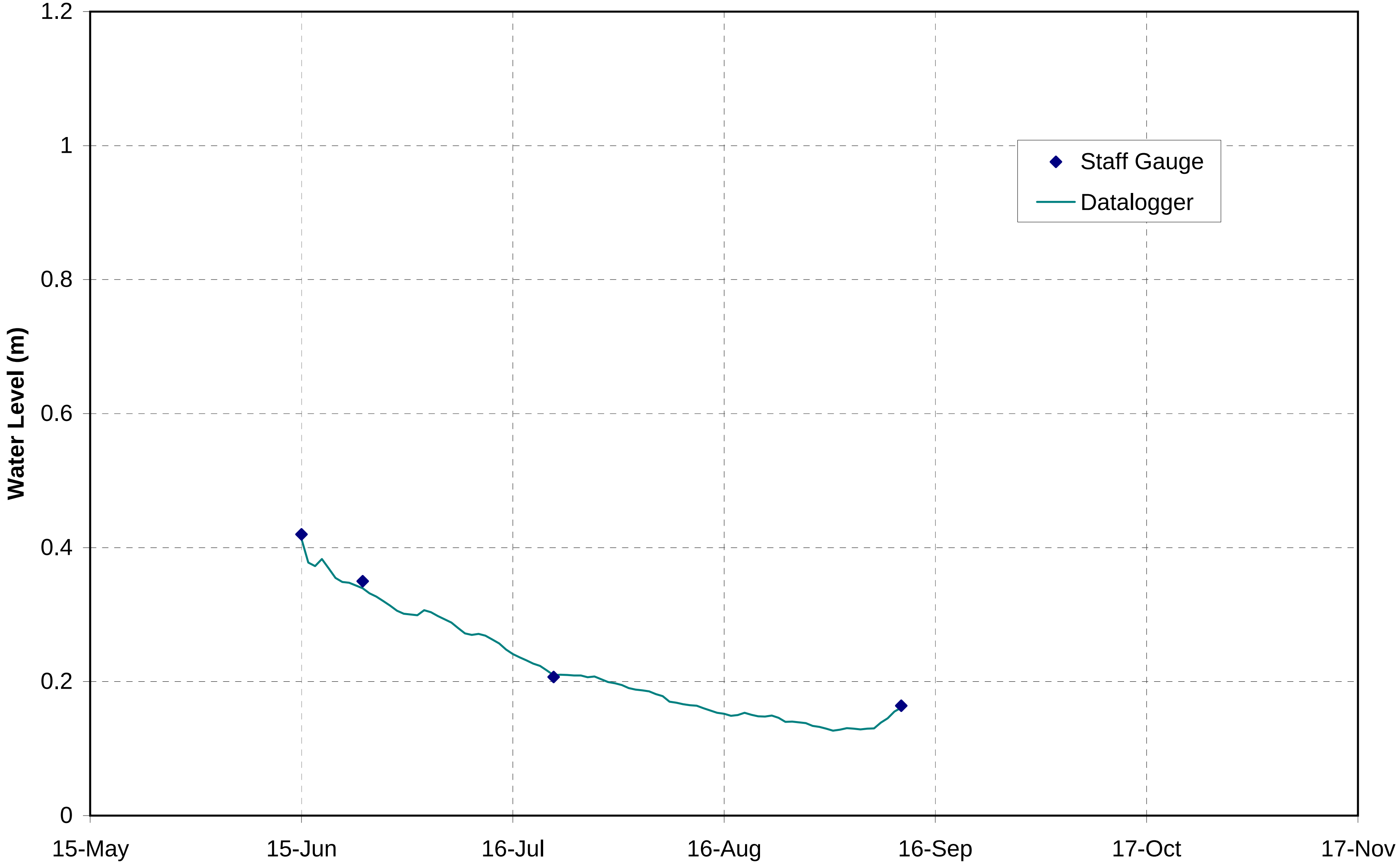


Figure B-8: Glenn Lake Outflow (2000)



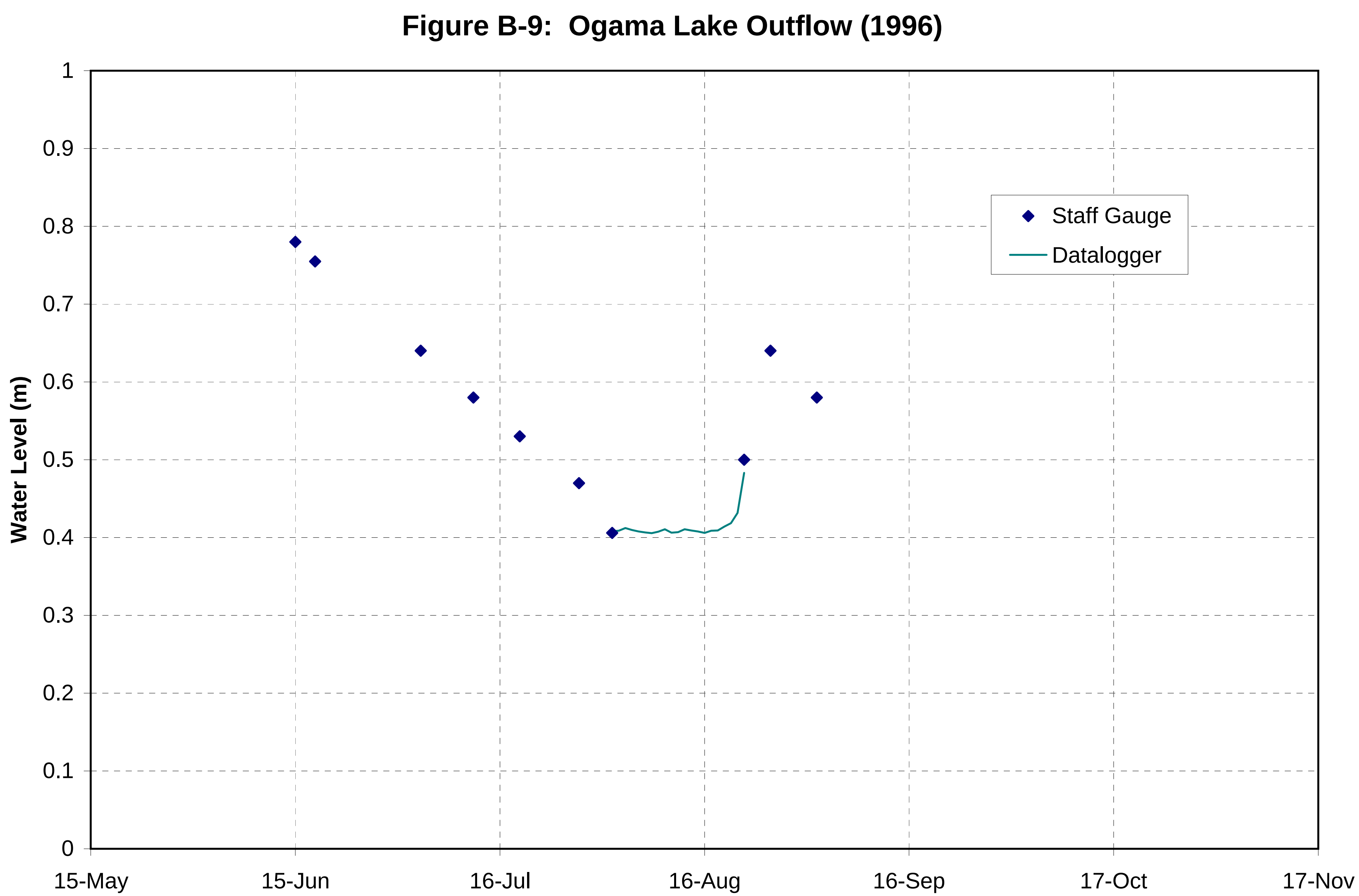


Figure B-9: Ogama Lake Outflow (1996)
Water Level (m)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
15-May
15-Jun
16-Jul
16-Aug
16-Sep
17-Oct
17-Nov
Staff Gauge
Datalogger

Figure B-10: Ogama Lake Outflow (1997)

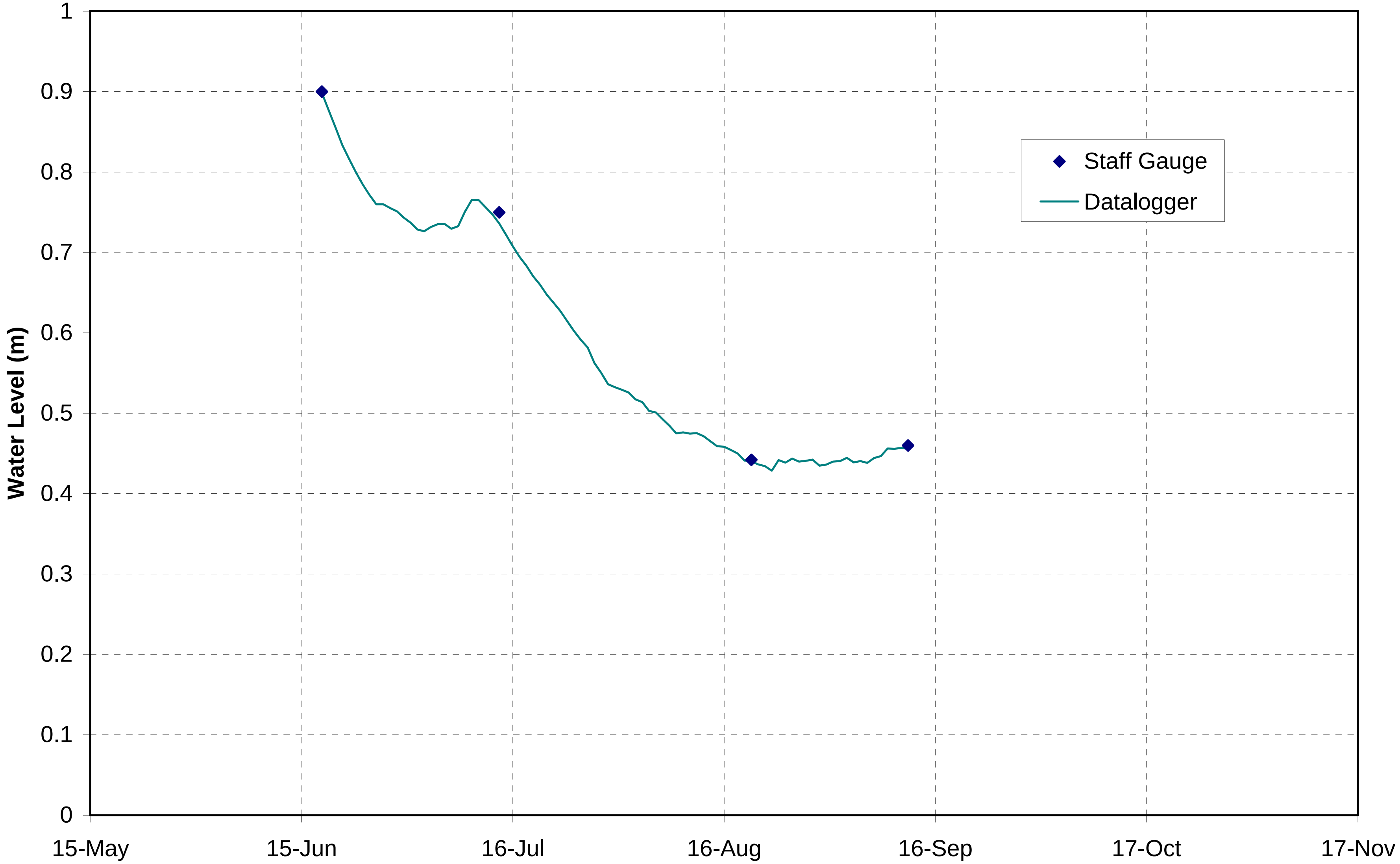
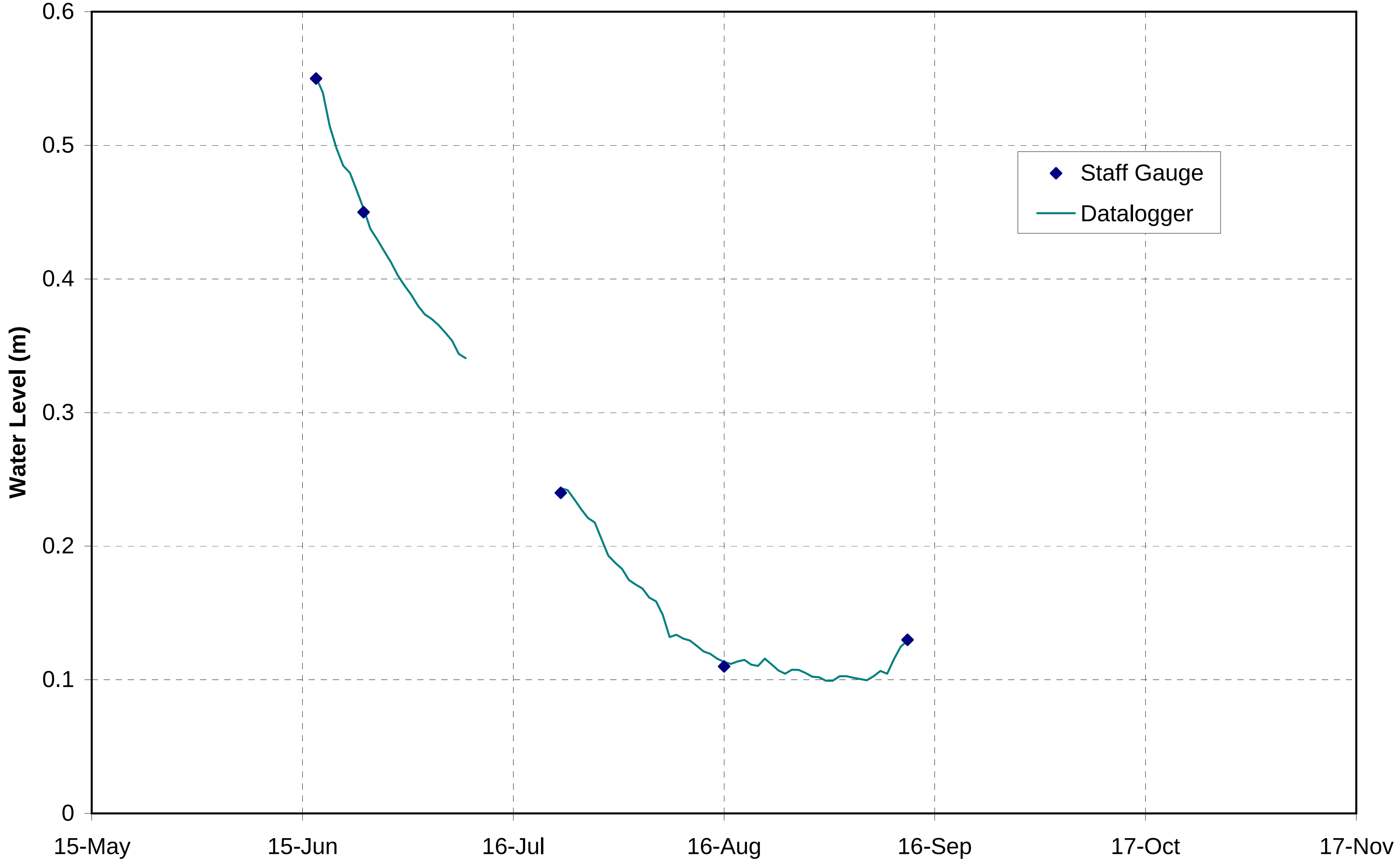


Figure B-11: Pelvic Lake Outflow (2000)



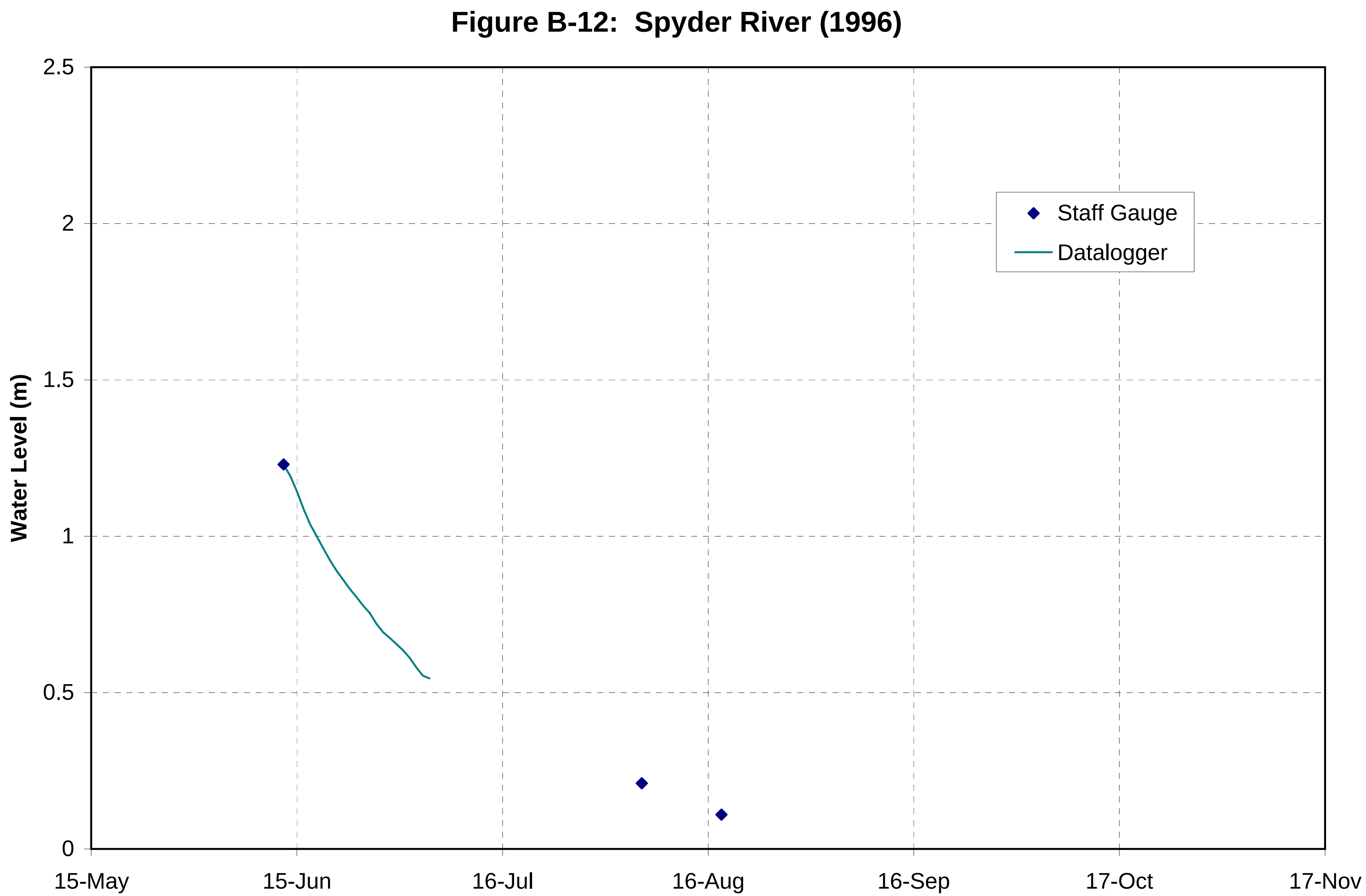
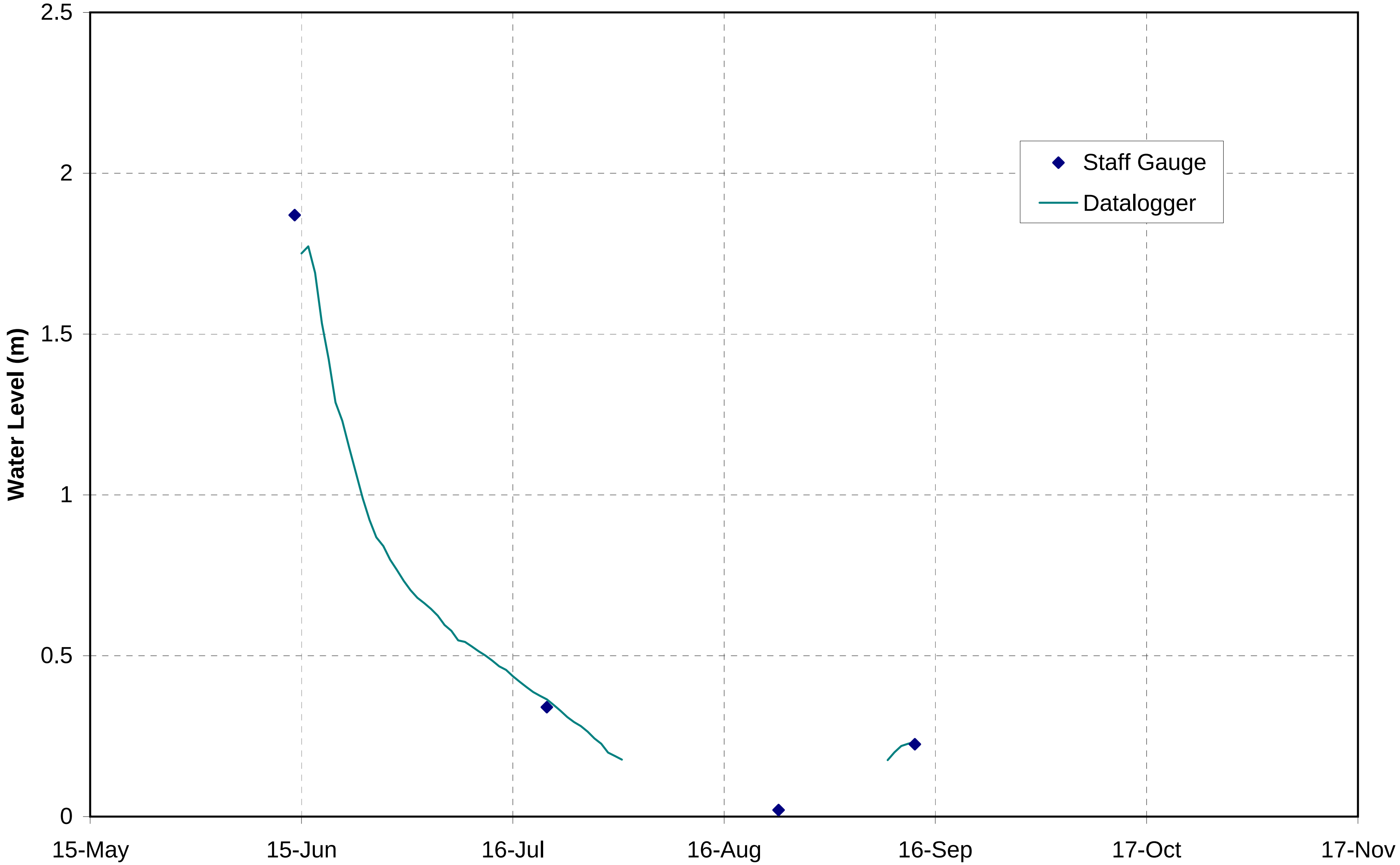


Figure B-12: Spyder River (1996)
Water Level (m)
2.5
2
1.5
1
0.5
0
15-May
15-Jun
16-Jul
16-Aug
16-Sep
17-Oct
17-Nov
Staff Gauge
Datalogger

Figure B-13: Spyder River (1997)



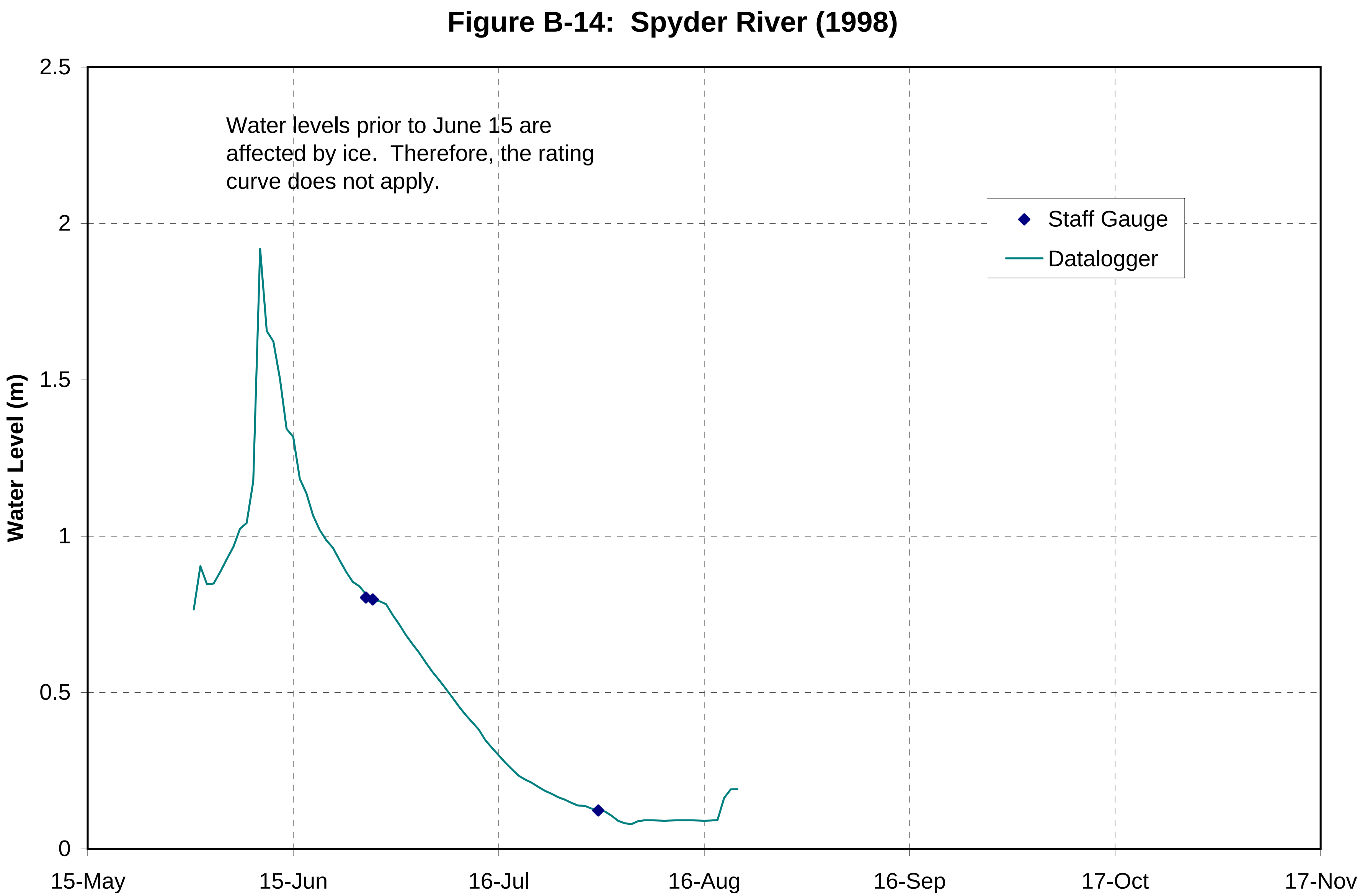


Figure B-14: Spyder River (1998)
Water levels prior to June 15 are
affected by ice. Therefore, the rating
curve does not apply.
Staff Gauge
Datalogger
Water Level (m)
2.5
2
1.5
1
0.5
0
15-May
15-Jun
16-Jul
16-Aug
16-Sep
17-Oct
17-Nov

Figure B-15: Stickleback (1997)

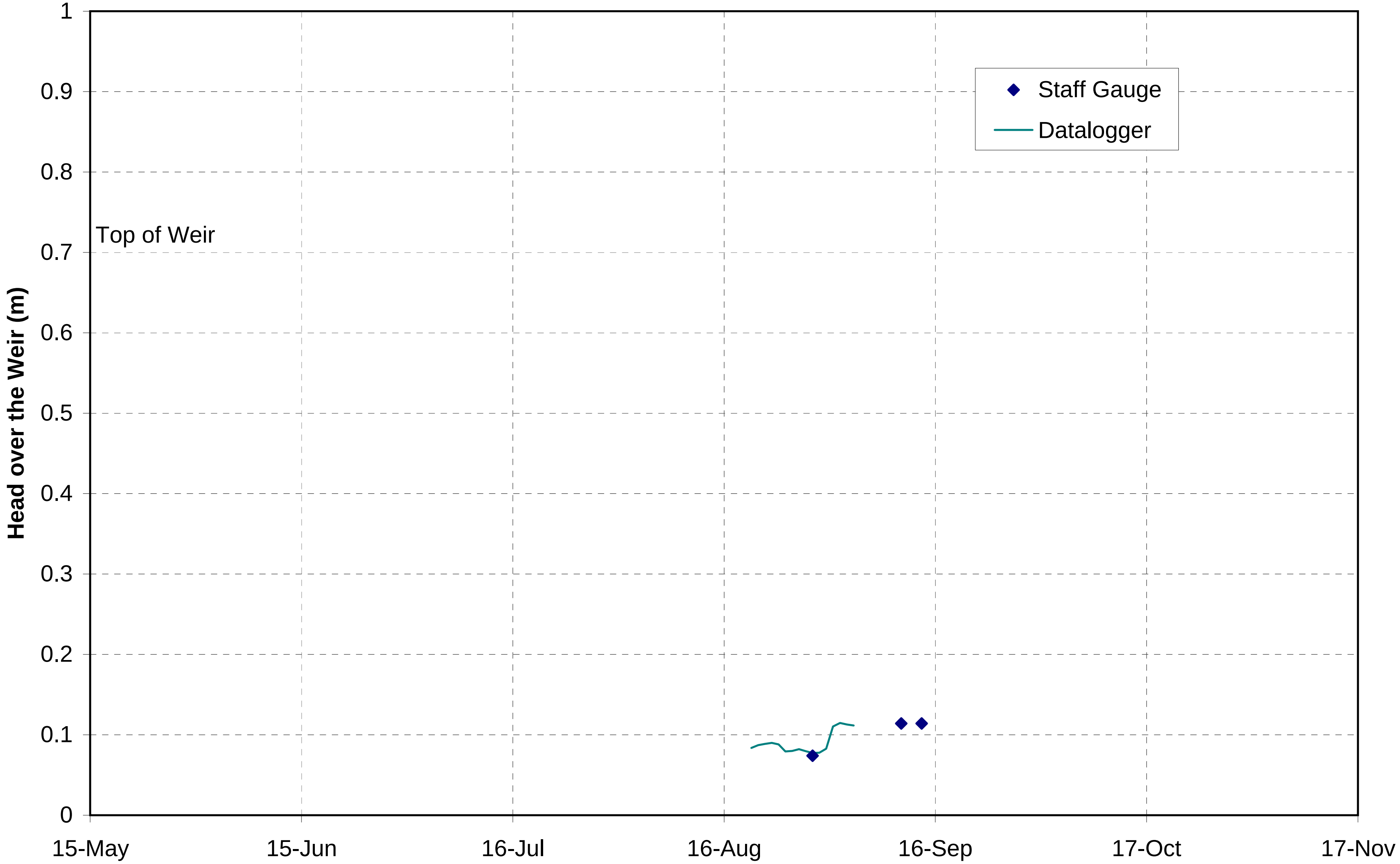


Figure B-16: Stickleback (1998)

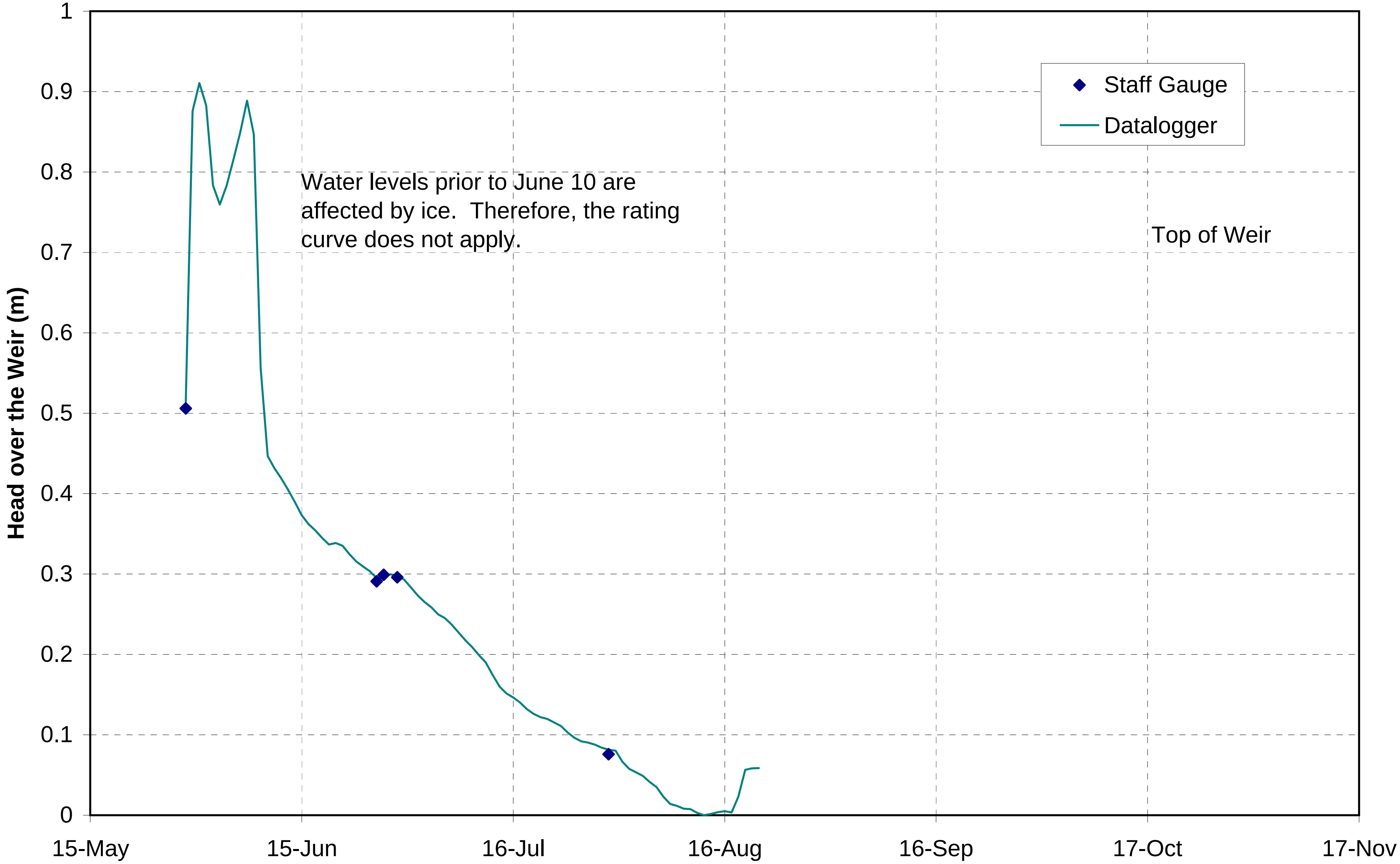
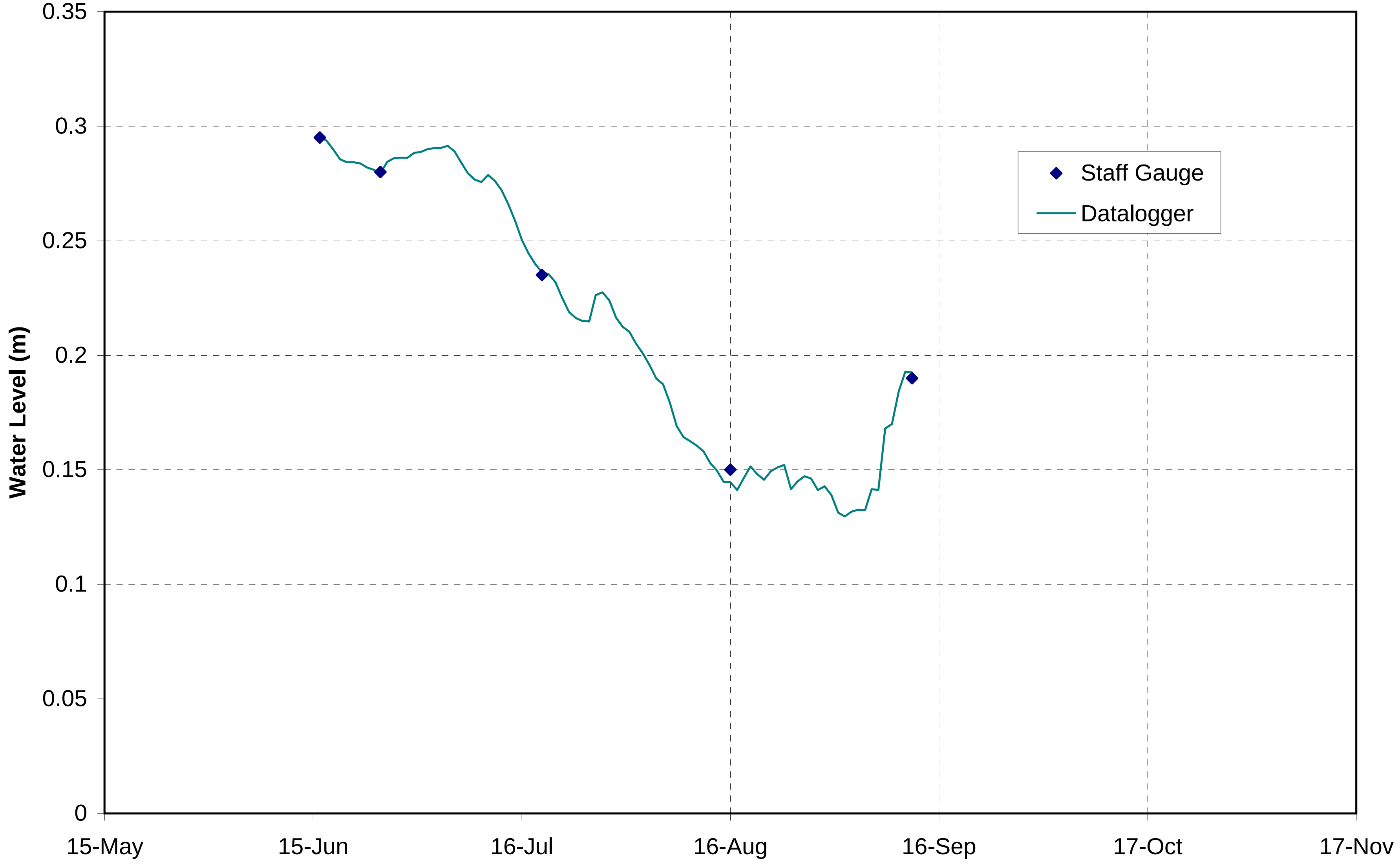


Figure B-17: Tails Lake Outflow (2000)



APPENDIX C

Rating Curves

The discharge measurements were used with staff gauge readings to develop rating curves (a relationship between stage and discharge). The rating curves prepared at the various sites are shown in the figures that follow. The equations for these curves are provided on the figures and in Table C1. The adjusted staff gauge readings discussed in Appendix B were used in developing the rating curves.

Table C1: Doris North Rating Curves

Station	Period of Record	Equationa
Glenn	1996-1998, 2000	$Q=12.215(sg+0.05)^{3.335}$
Ogama	1996, 1997	$Q=2.601E\text{-}03(sg+1)^{11.486}$
Doris	1996-1998, 2000	$Q=8.214E\text{-}11(sg+4)^{15.574}$
Pelvic	2000	$Q=9.275(sg+0.274)^{5.940}$
Tail	2000	$Q=0.106(sg-0.122)$ if $sg<0.235$ $Q=1.867(sg-0.229)$ if $0.235<sg<0.28$ $Q=4.000(sg-0.256)$ if $sg>0.28$
Aimaoktak	1997-1998	$Q=0.707(sg+1)^{5.936}$
Stickleback	1997-1998	$Q={}^{8}/_{15}(0.59)\sqrt{(2g)}\tan({}^{100^\circ}/_{2})h^{2.5}$ if $h<0.2$ m $Q={}^{8}/_{15}(0.583)\sqrt{(2g)}\tan({}^{100^\circ}/_{2})h^{2.5}$ if $h>0.2$ m

Notes:
* sg = staff gauge reading
h = head over the weir
g = 9.81 m/s^2

Figure C-1: Doris Outflow Rating Curve

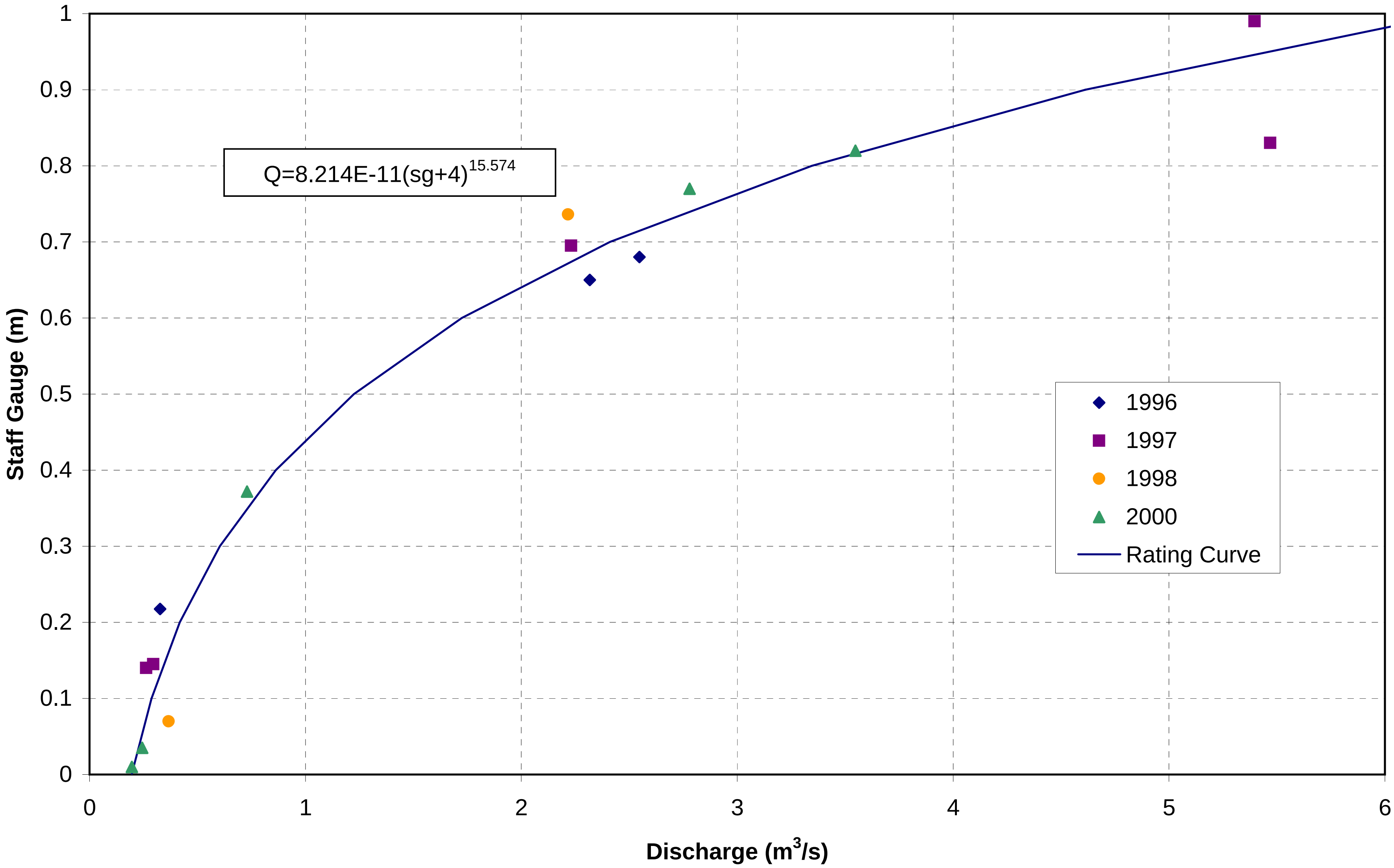
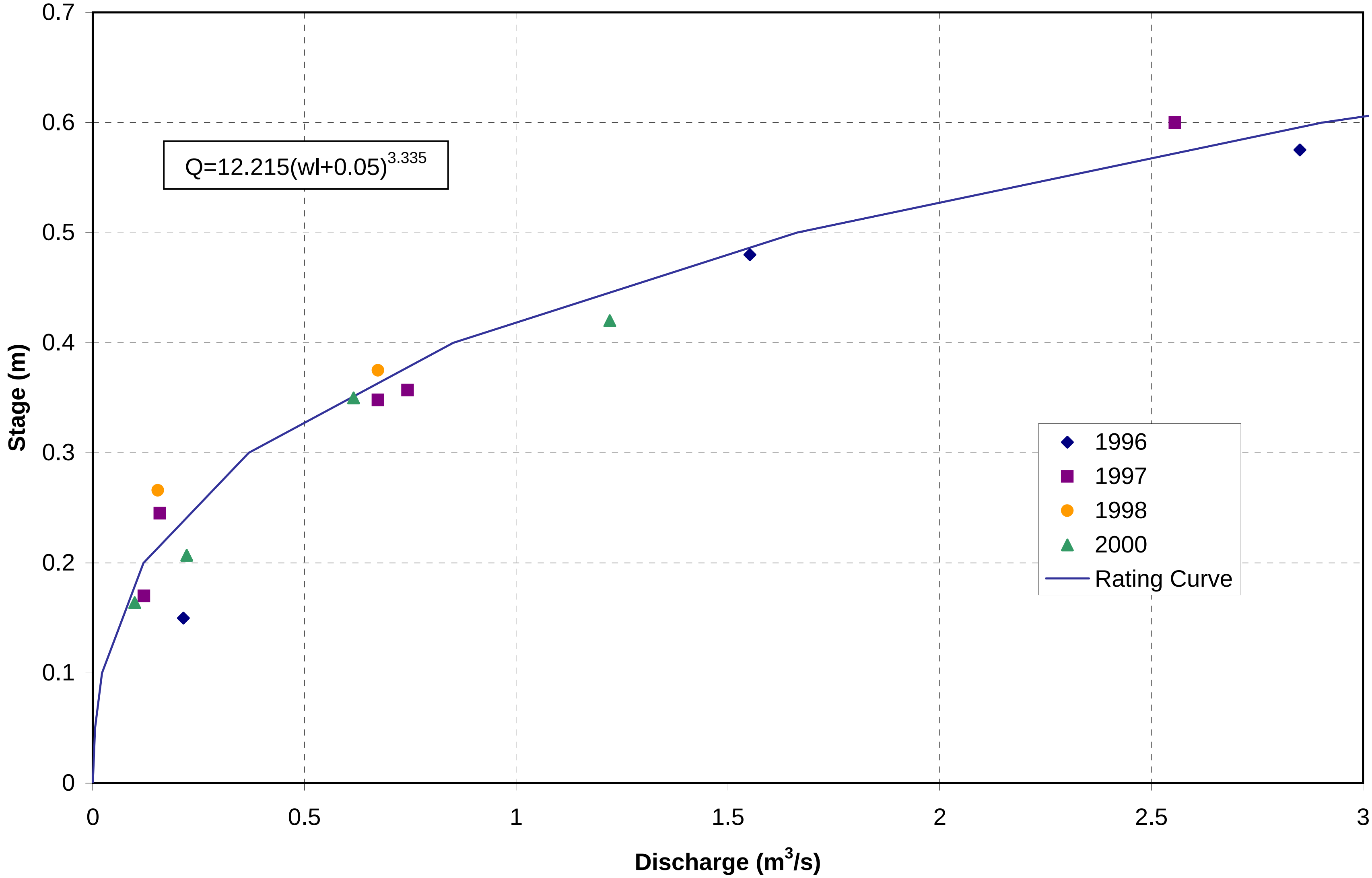


Figure C-2: Glenn Lake Outflow Rating Curve



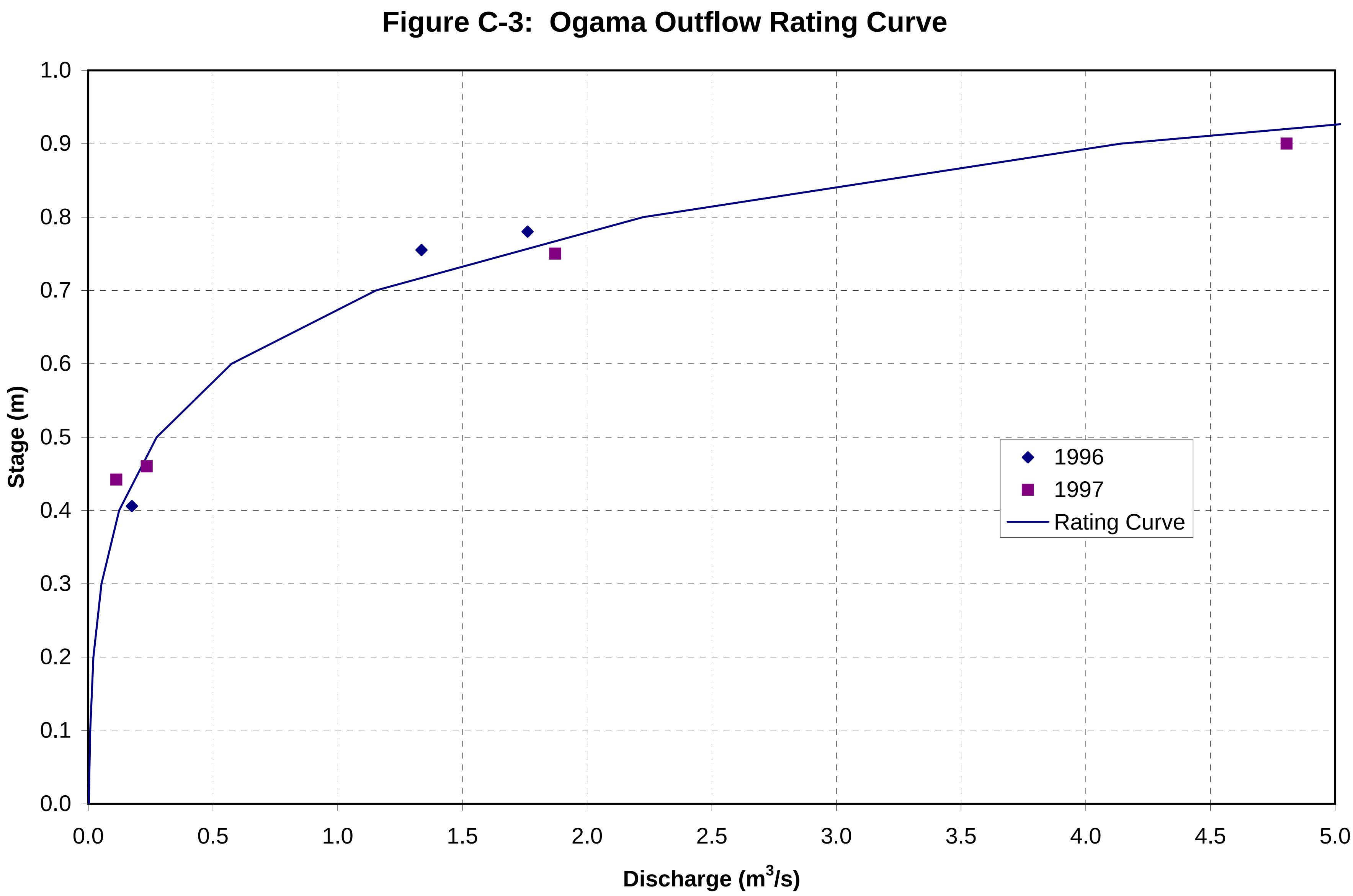


Figure C-3: Ogama Outflow Rating Curve
Stage (m)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Discharge (m3/s)
1996
1997
Rating Curve

Figure C-4: Pelvic Outflow Rating Curve

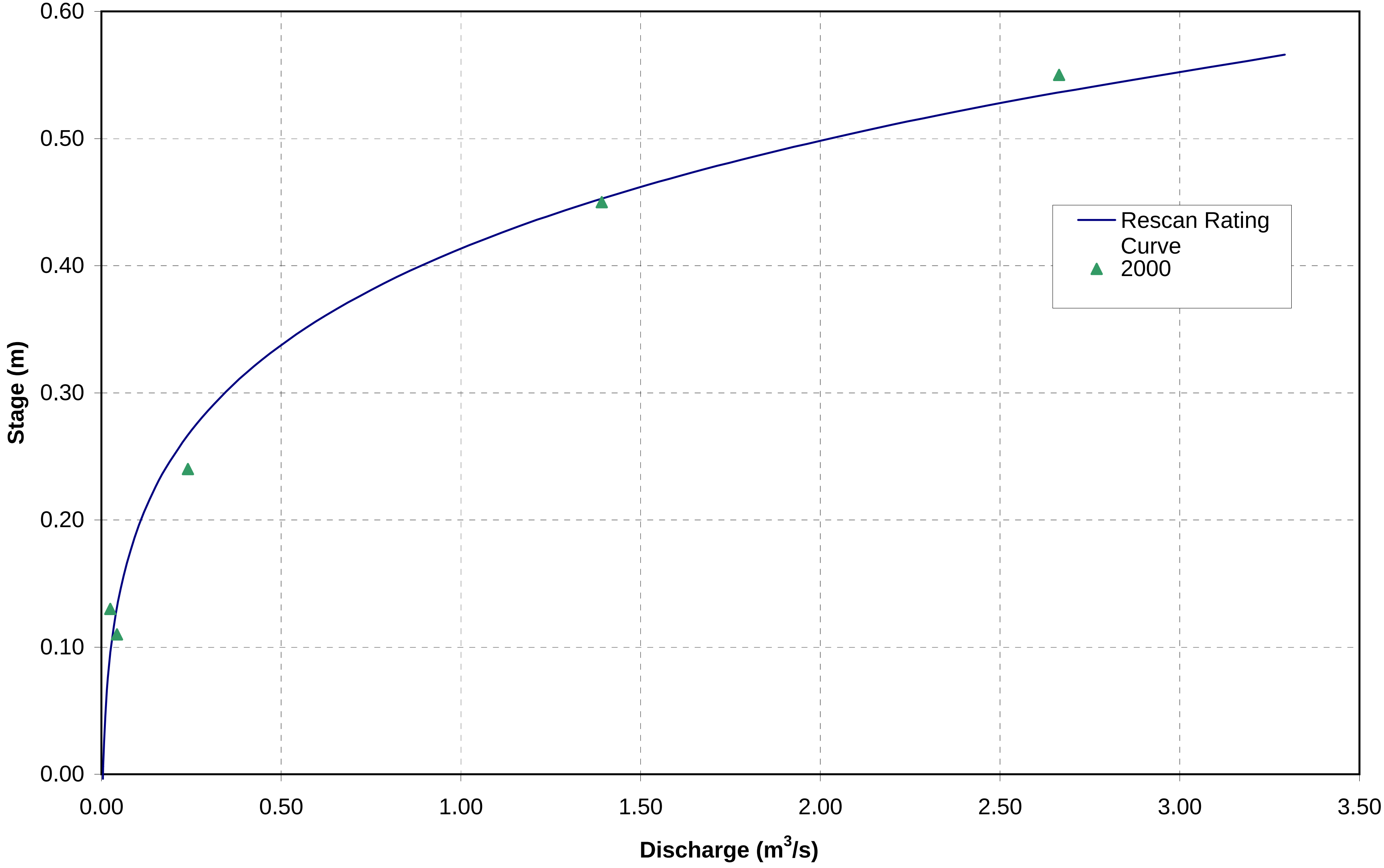
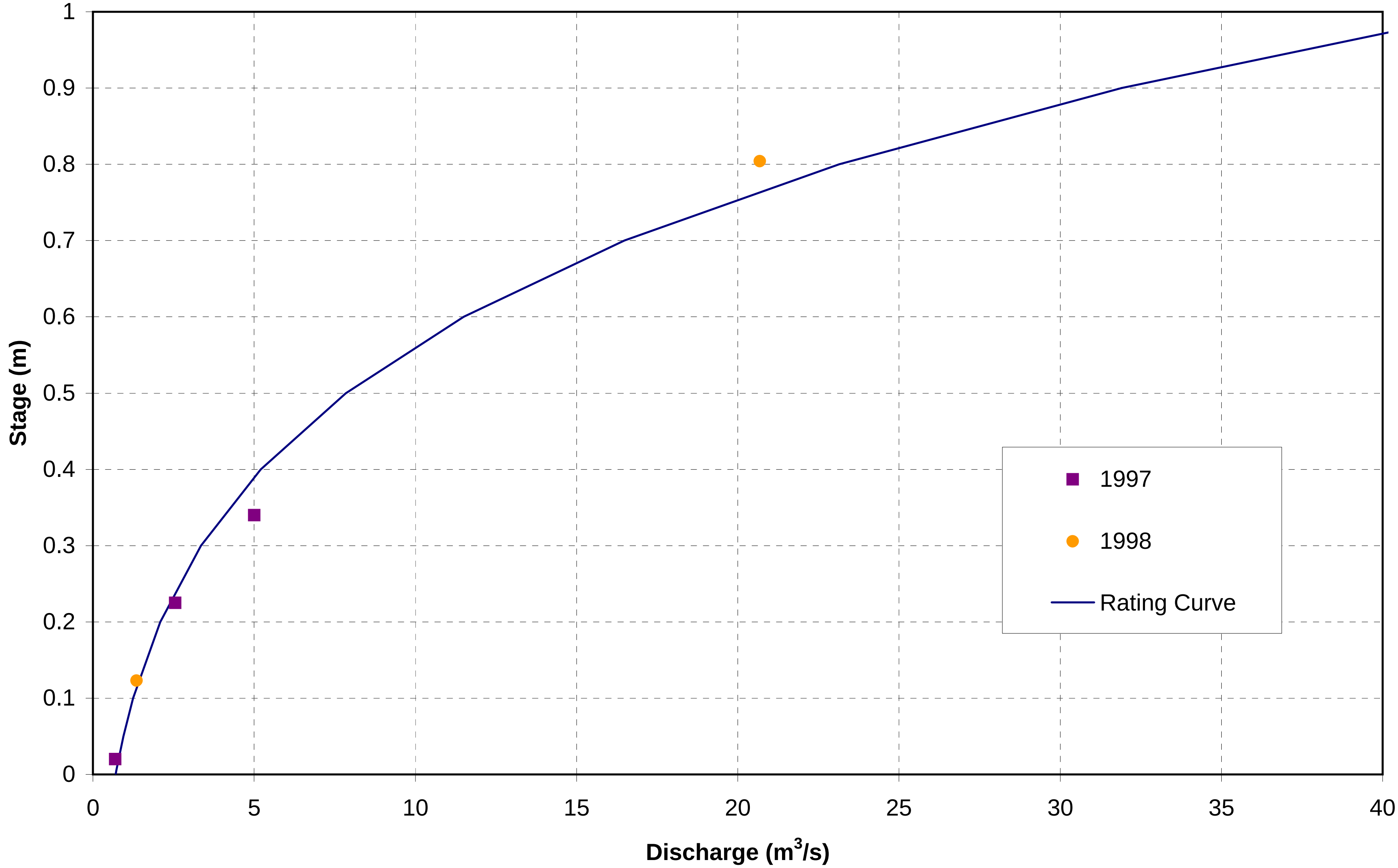


Figure C-5: Spyder River Rating Curve



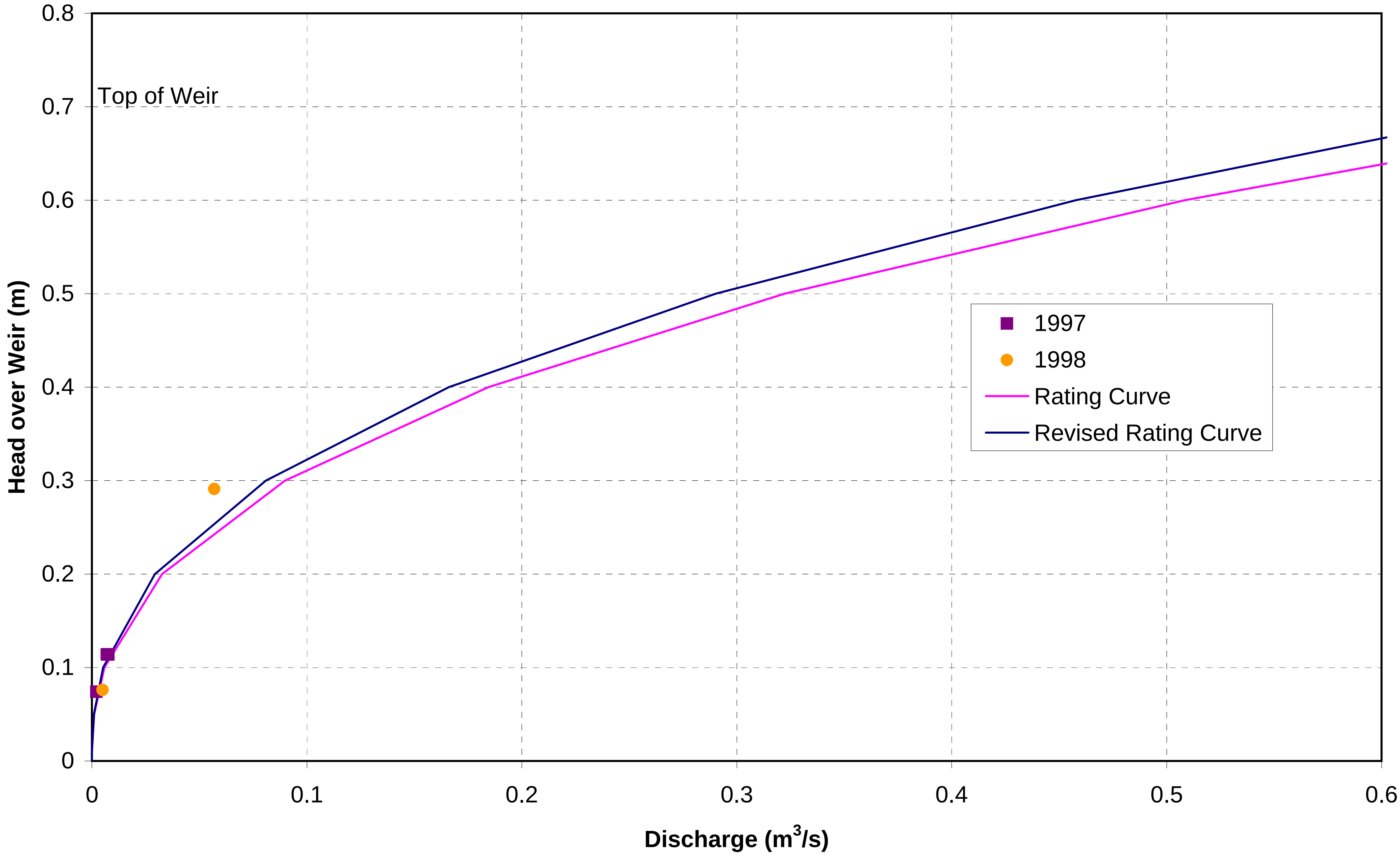


Figure C-6: Stickleback Rating Curve

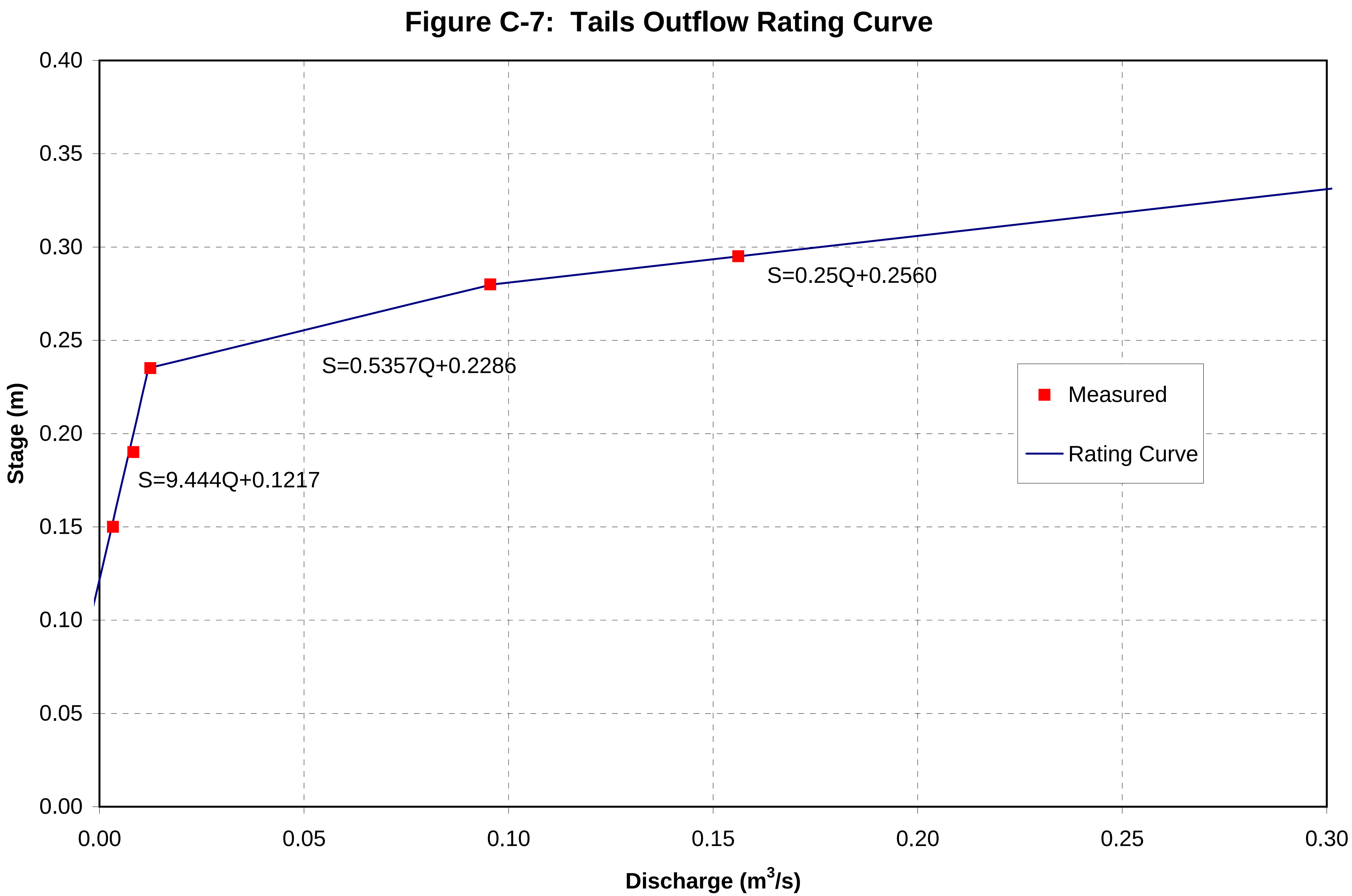


Figure C-7: Tails Outflow Rating Curve
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Stage (m)
S=0.25Q+0.2560
S=0.5357Q+0.2286
S=9.444Q+0.1217
Measured
Rating Curve
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Discharge (m3/s)

APPENDIX D

Discharge Hydrographs

Figure D-1: Doris Lake Outflow (1996)

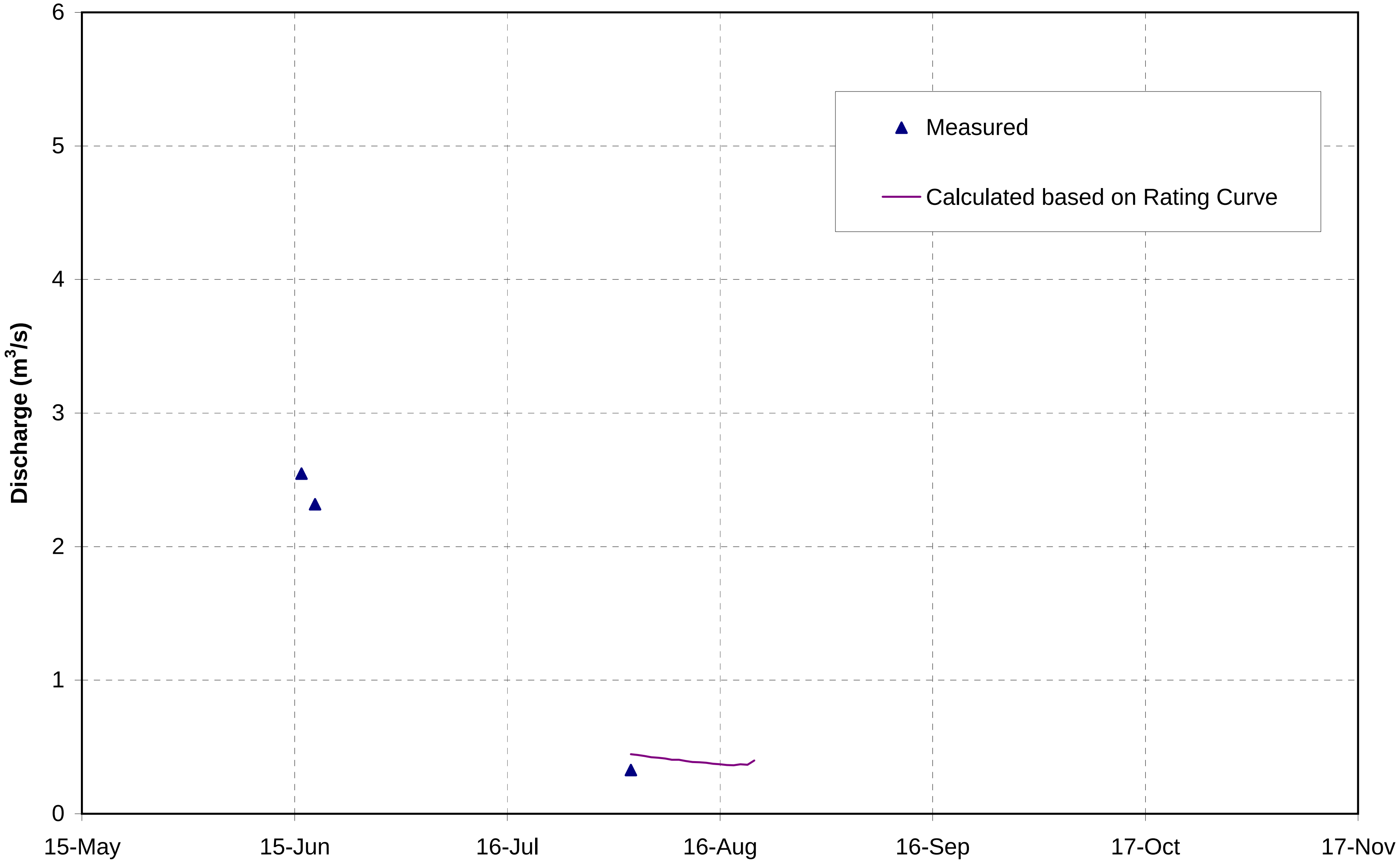


Figure D-2: Doris Lake Outflow (1997)

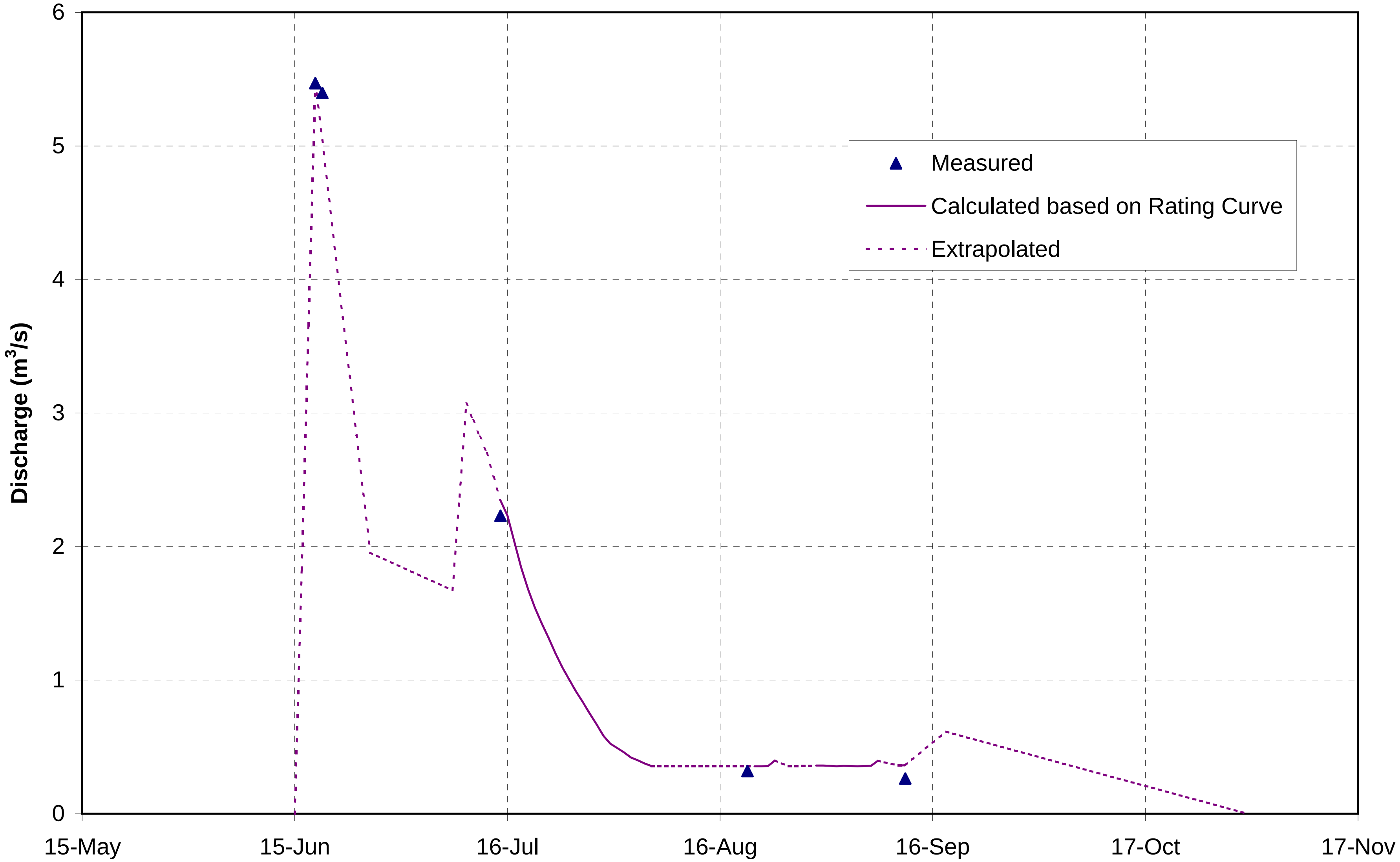


Figure D-3: Doris Lake Outflow (1998)

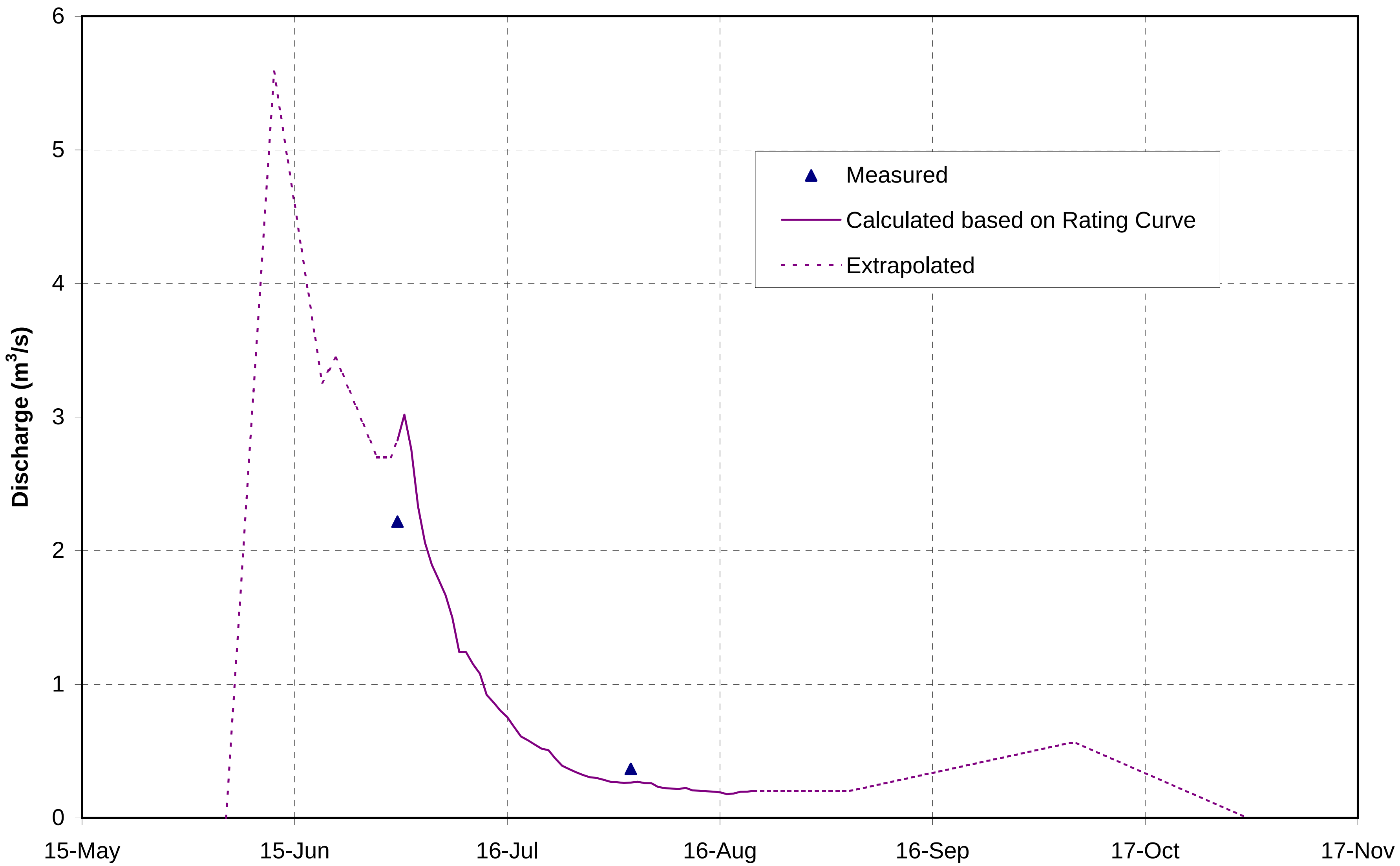


Figure D-4: Doris Lake Outflow (2000)

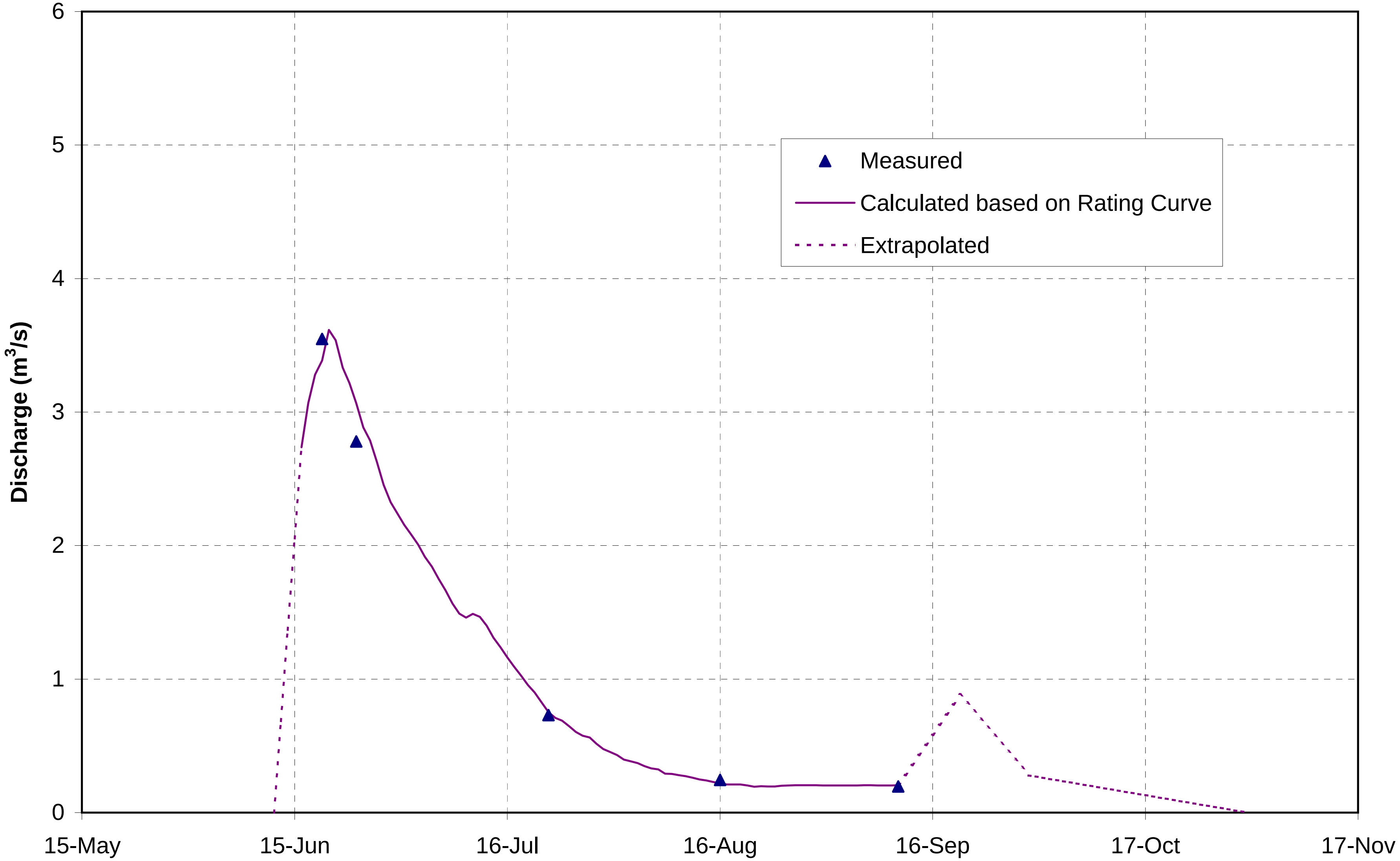


Figure D-5: Glenn Lake Outflow (1996)

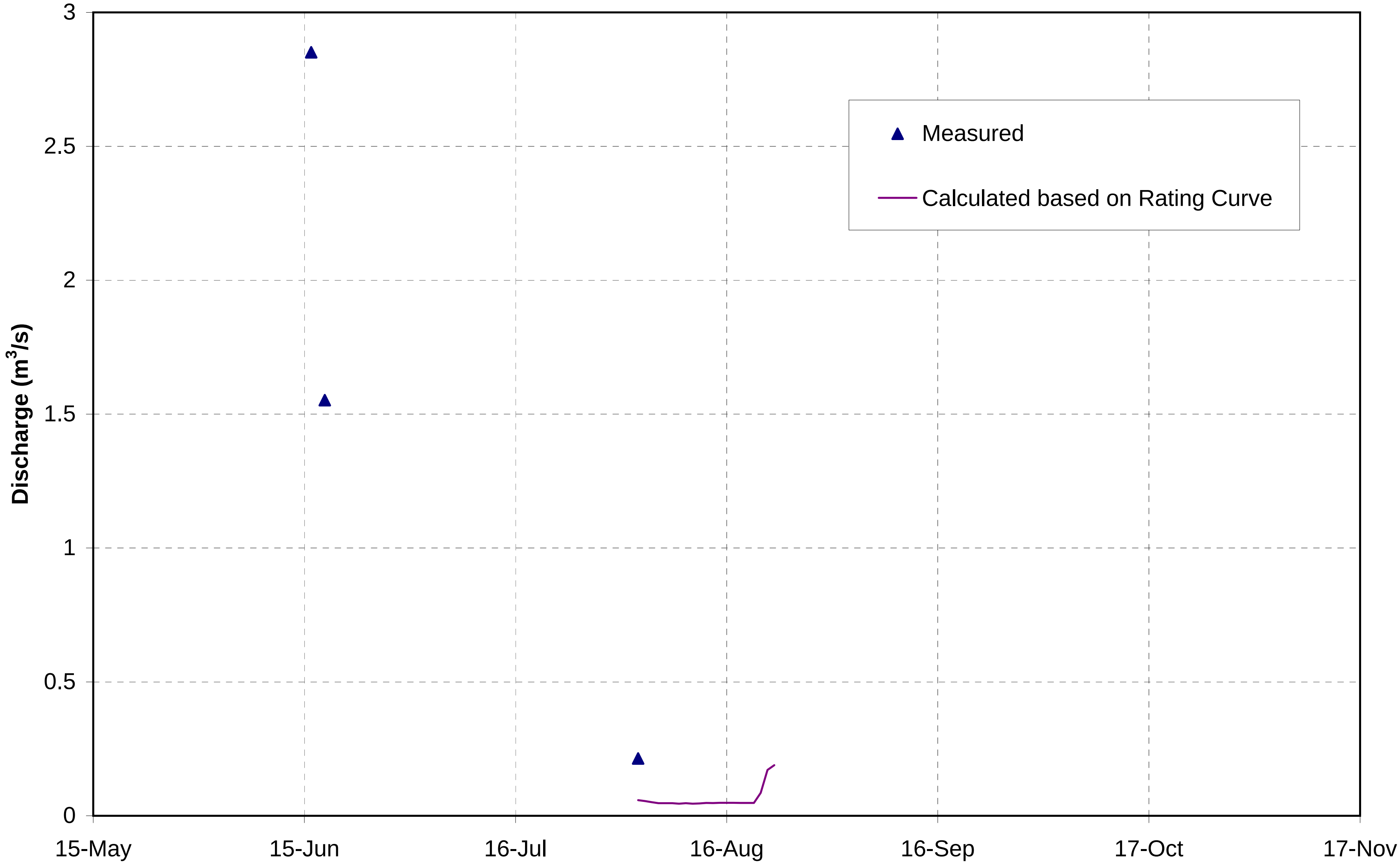


Figure D-6: Glenn Lake Outflow (1997)

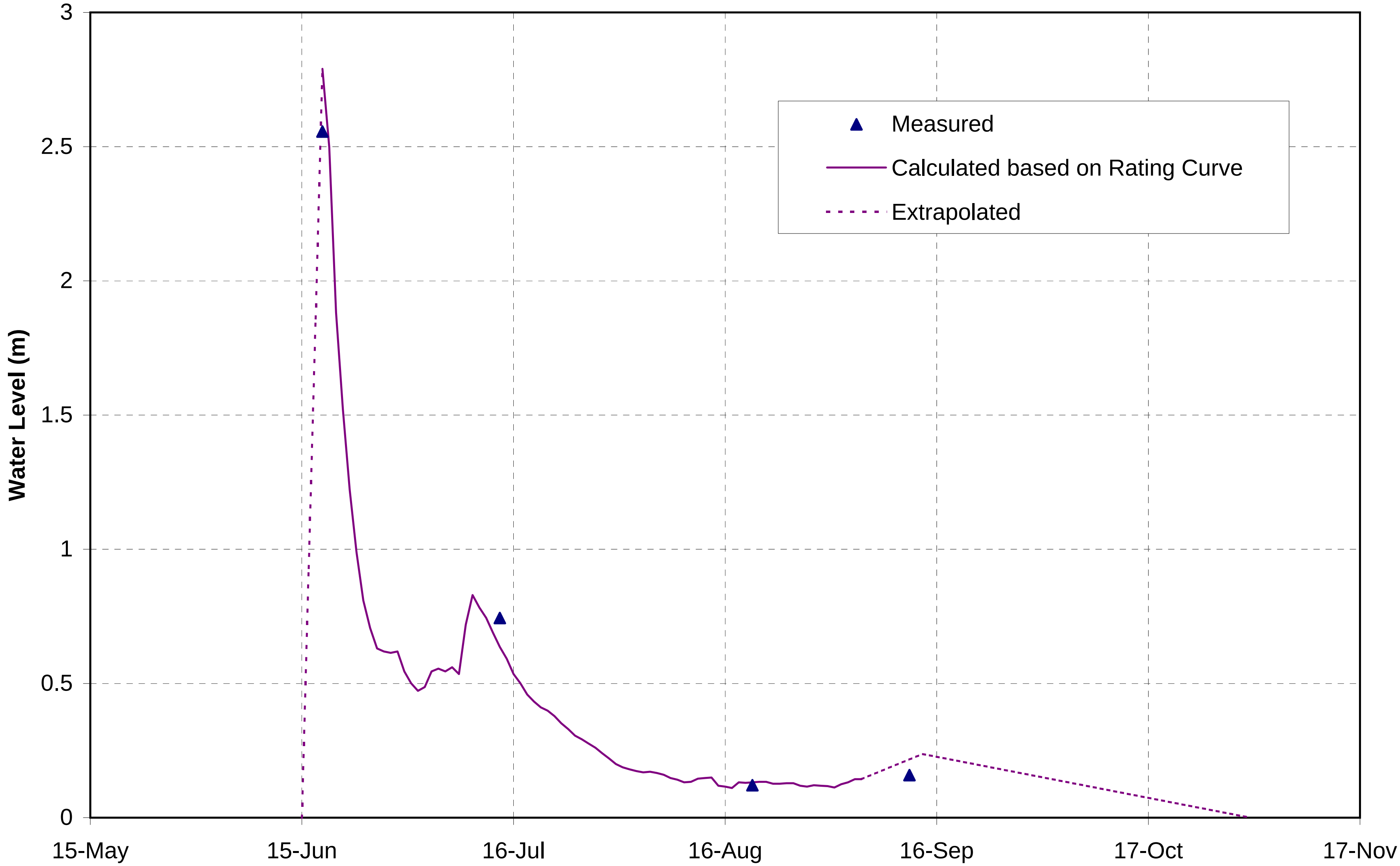


Figure D-7: Glenn Lake Outflow (1998)

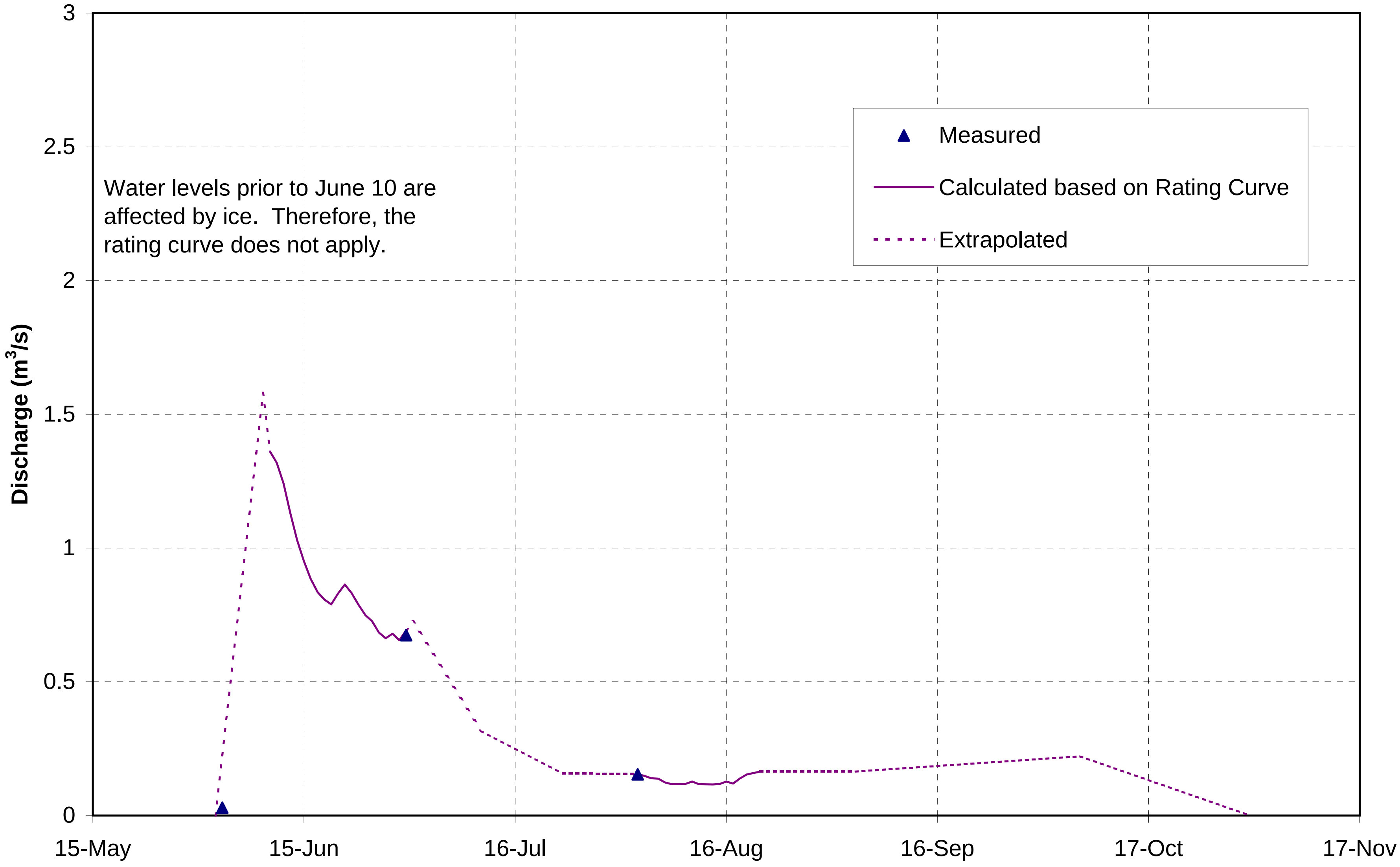


Figure D-8: Glenn Lake Outflow (2000)

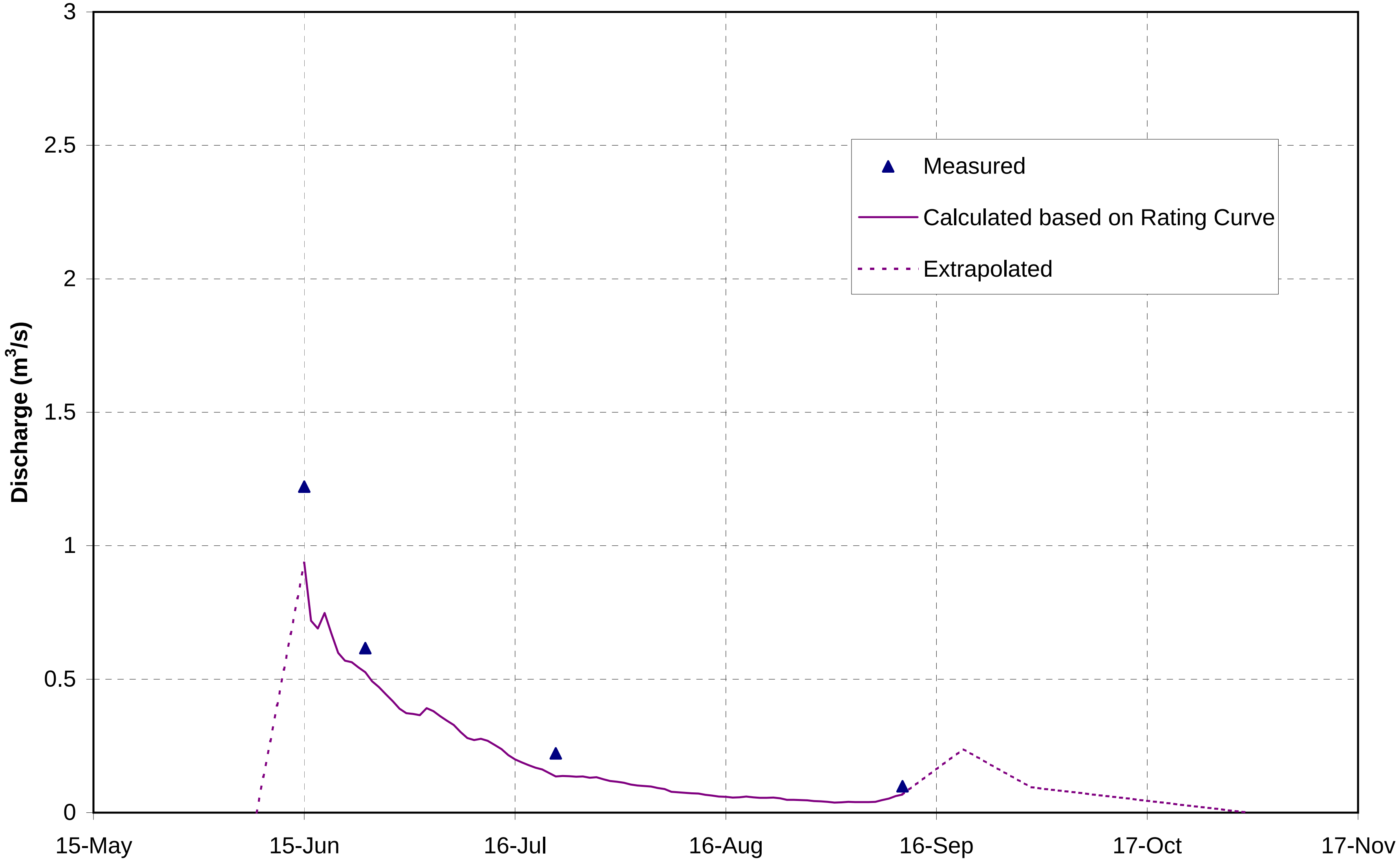


Figure D-9: Ogama Lake Outflow (1996)

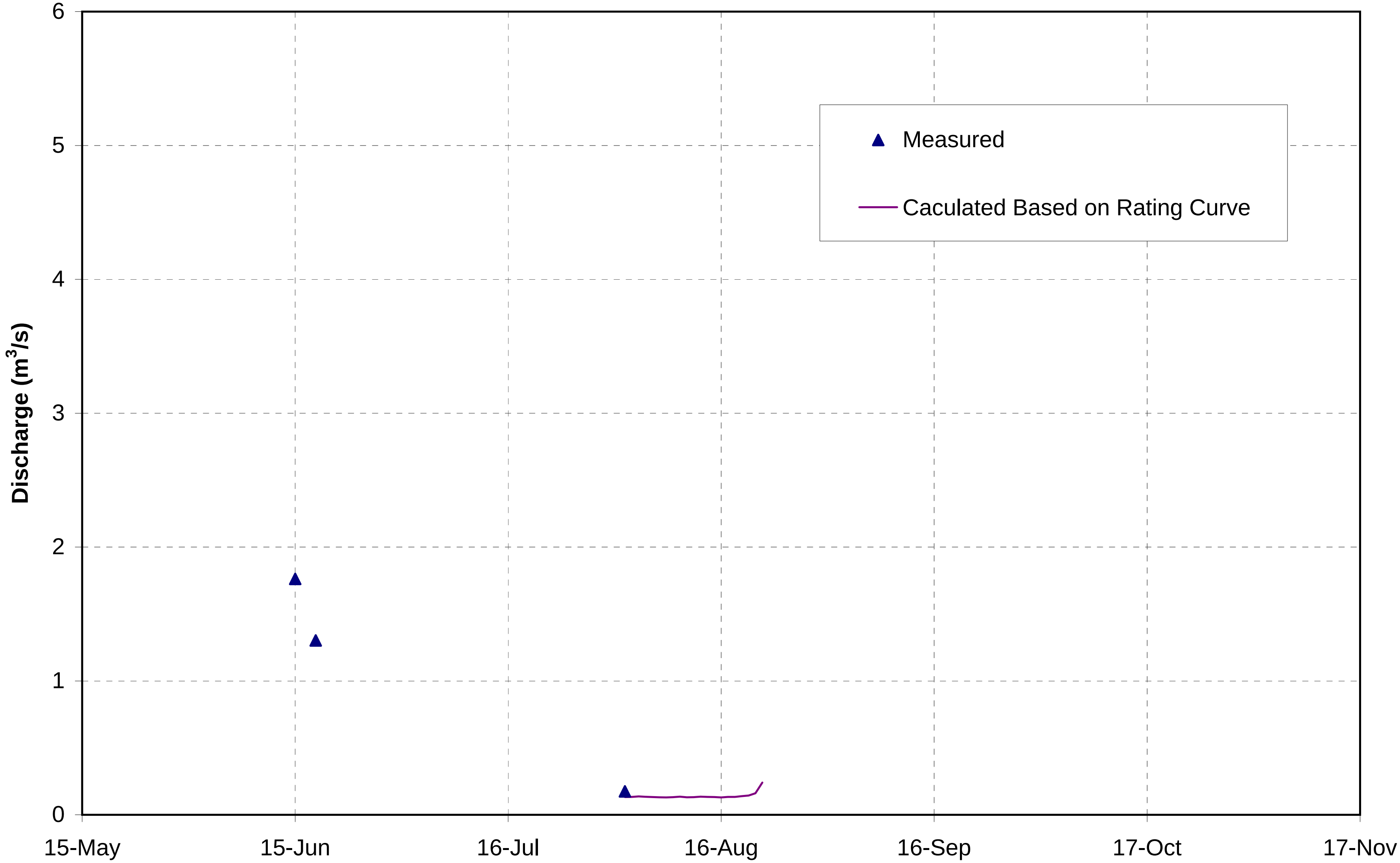


Figure D-10: Ogama Lake Outflow (1997)

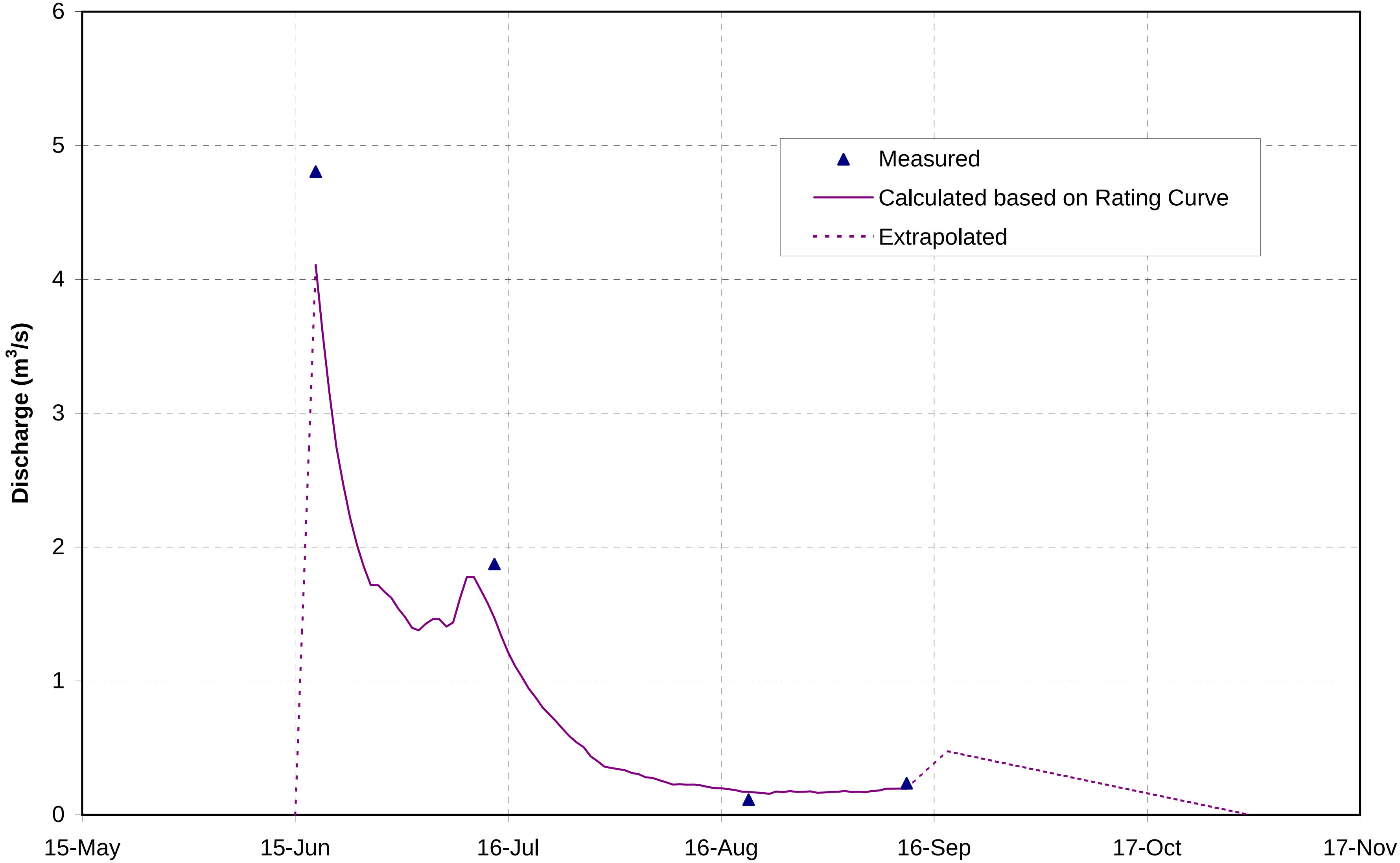


Figure D-11: Pelvic Lake Outflow (2000)

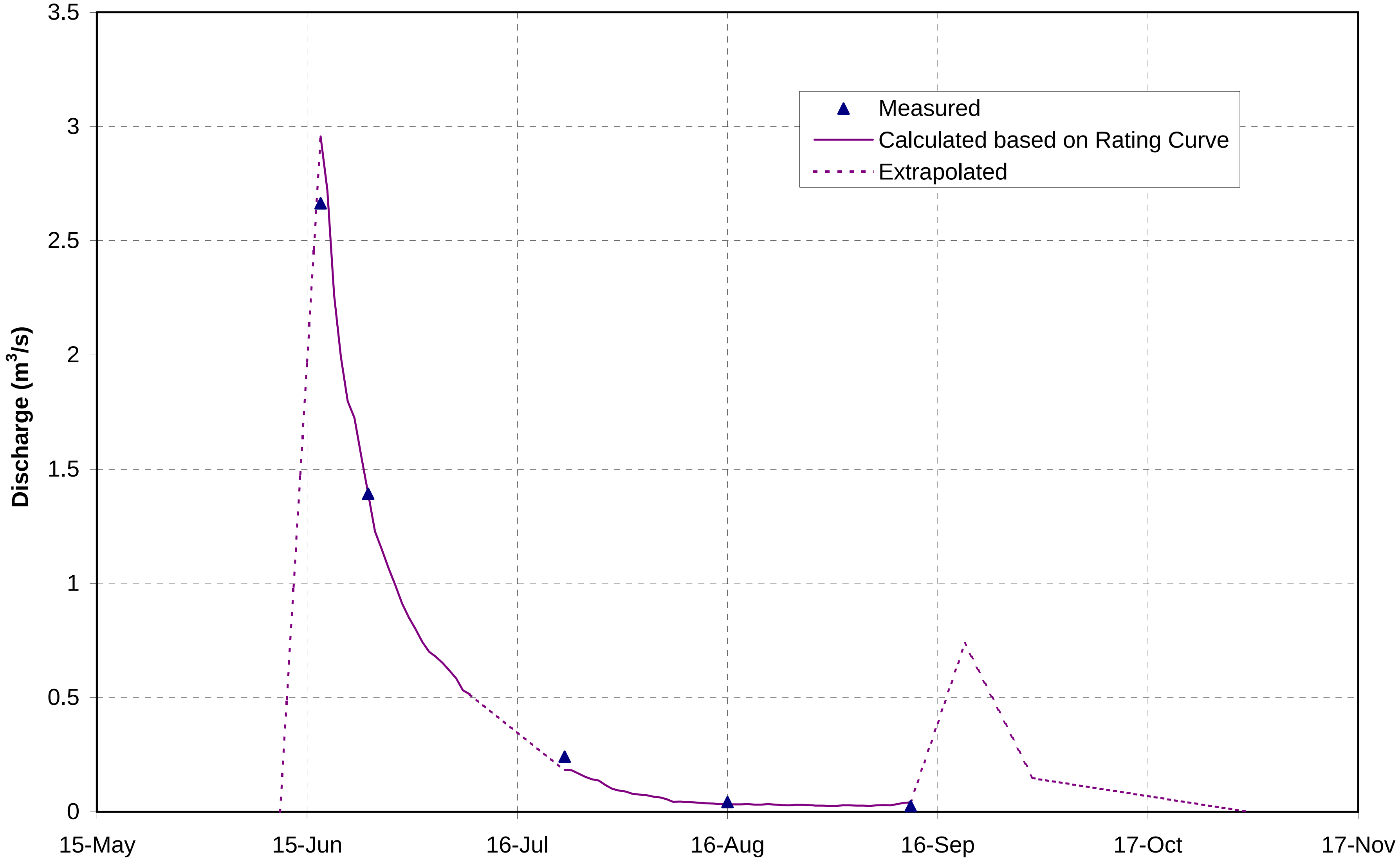


Figure D-12: Spyder River (1996)

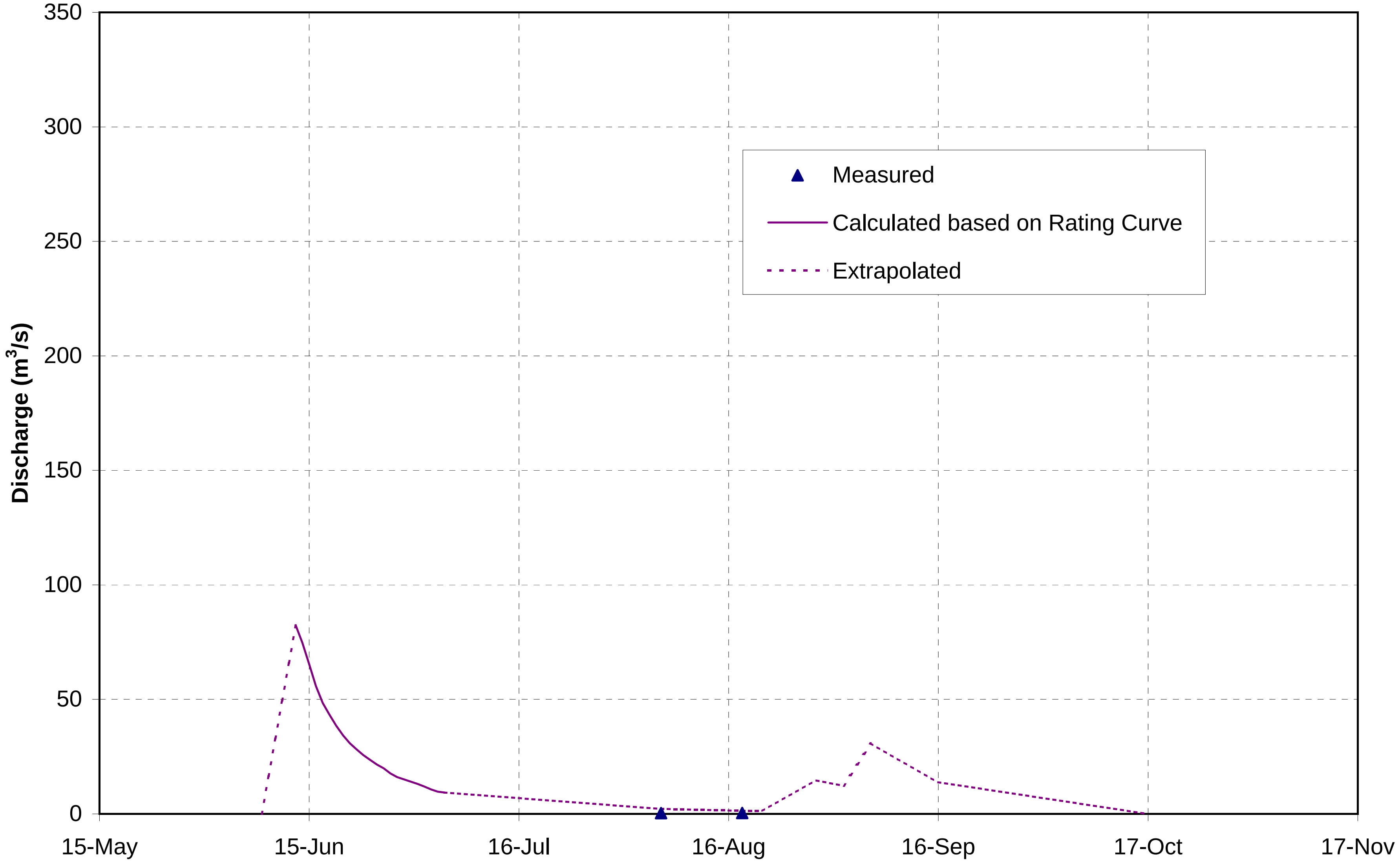


Figure D-13: Spyder River (1997)

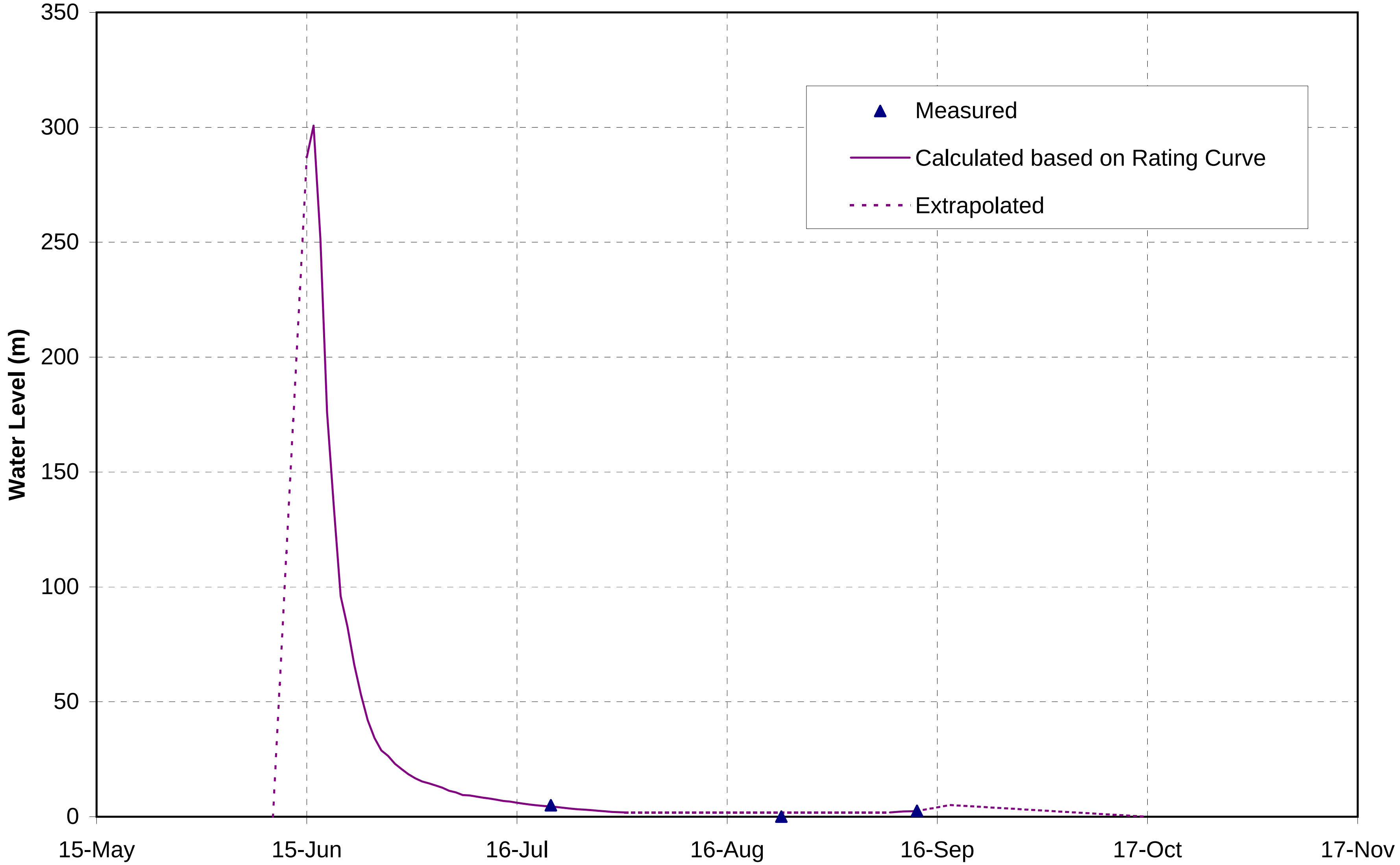


Figure D-14: Spyder River (1998)

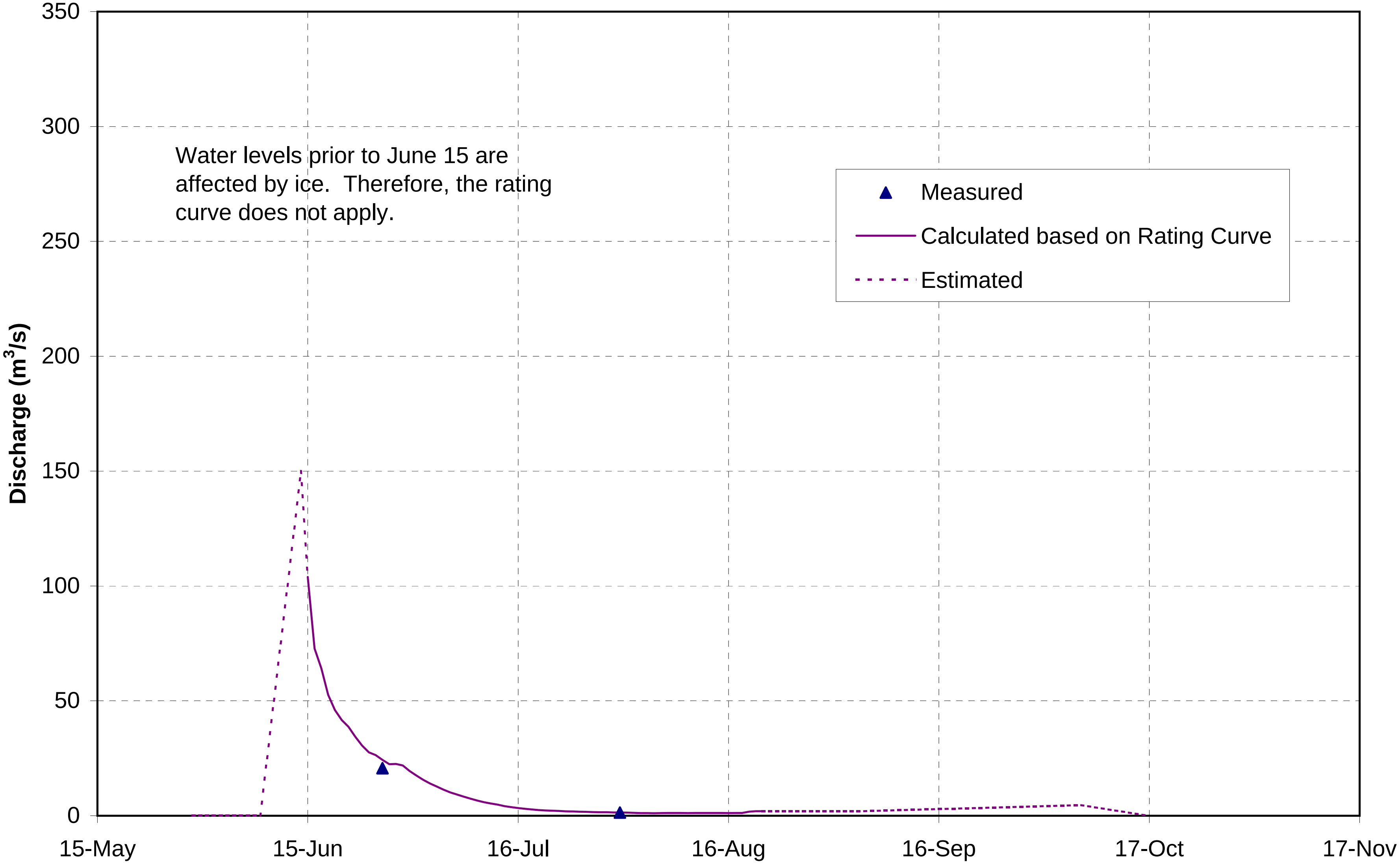


Figure D-15: Stickleback (1997)

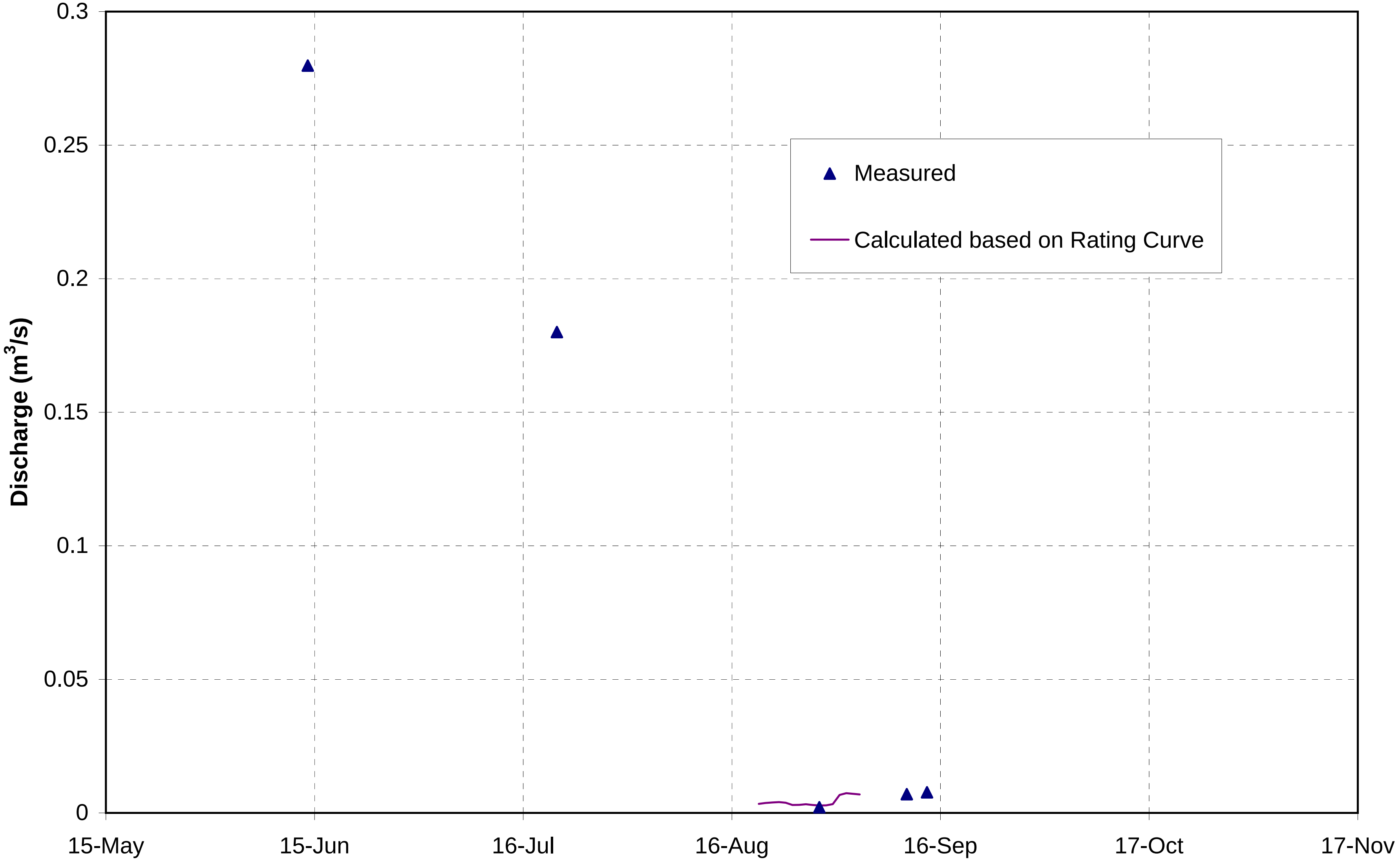


Figure D-16: Stickleback (1998)

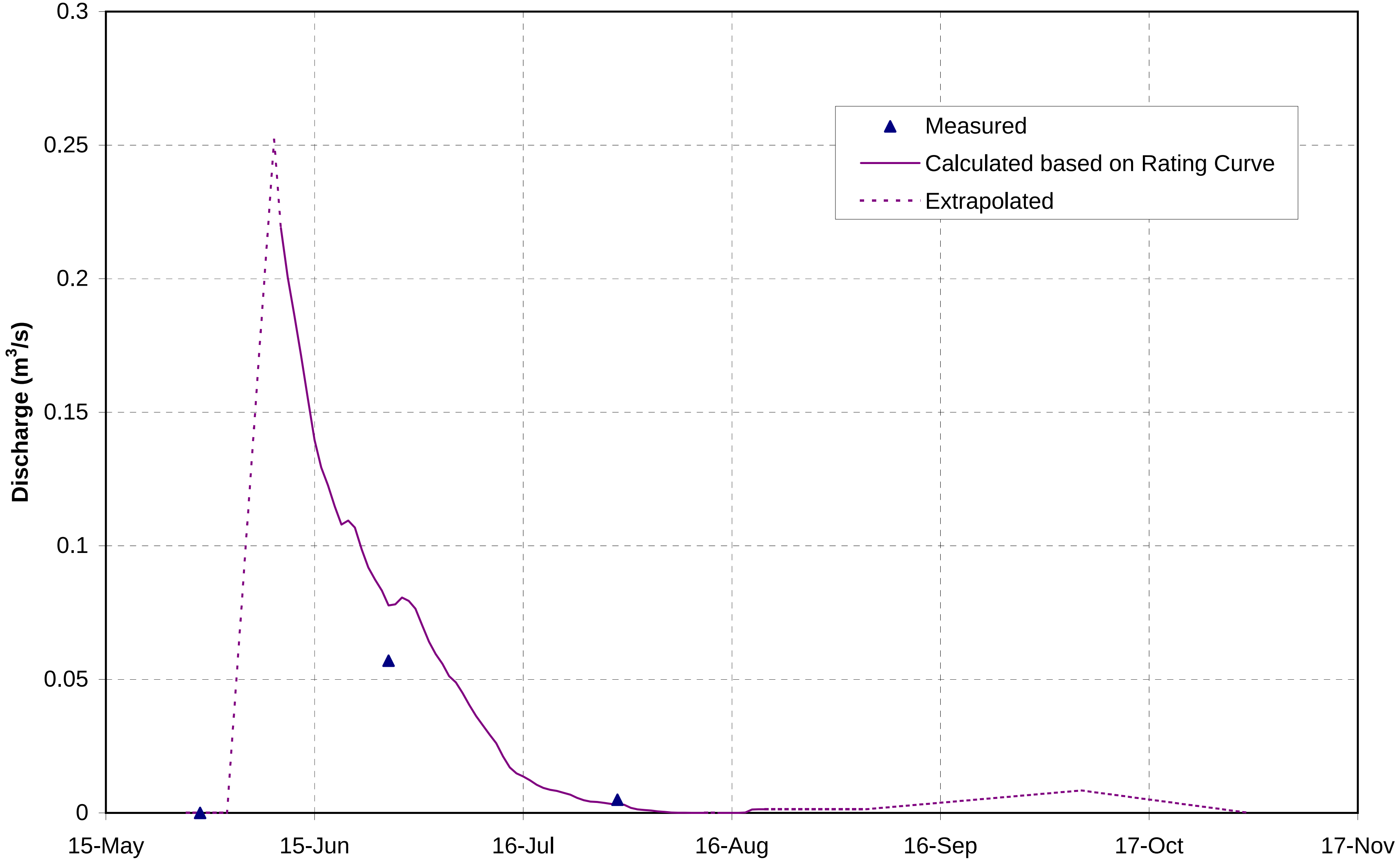


Figure D-17: Tails Lake Outflow (2000)