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Gordon River Monitoring Annual Report 2015–16

September 2016

Executive summary

This Gordon River Monitoring Annual Report presents the results of the monitoring undertaken on 16-17 April 2016 pursuant to the Gordon River Monitoring Program.

Hydrology and water management

System wide hydro generation in 2015-16 was the third lowest in the past twenty years. In contrast, Gordon Power Station generation in 2015-16 was the third highest in twenty years. Low system inflows, particularly in spring, combined with the Basslink outage for a six month period (20 December 2015 – 13 June 2016) resulted in greater generation from Gordon Power Station. High inflows in May and June subsequently increased storage in Lake Gordon, however it finished the end of June 2016 with substantially lower storage than at the same time in the previous year.

The flow in the Gordon River in 2015–16 was correlated with discharges from the Gordon Power Station. Higher than average discharges occurred from July to October 2015, and extended high discharges were common from January to March 2016. There were lower than average discharges from April to June 2016. During the months of July-August 2015 and April-June 2016 there were a greater proportion of downstream flows originating from tributaries following natural flow events.

One of the two peaking triggers (35-100 $m^3 s^{-1}$ peaking trigger) was exceeded late in July 2015, continuing the exceedance event that began in June 2015. This exceedance triggered the requirement for a monitoring event, which coincided with the biennial monitoring undertaken in April 2016, and is reported on here.

There was no obligation to implement mitigation measures (ramp-down rule or minimum environmental flow) whilst the Basslink cable was inoperable in the period from 20 December 2015 to 13 June 2016. The ramp-down rule was implemented successfully for all required periods, with all generation reductions being set at the 1 MW per minute ramping requirement. Full compliance was achieved as the generation control system automatically applied the rule whenever the conditions requiring its use were met. Short periods of generation reduction, where implementation of ramping was required, were in excess of the 1 MW per minute target (0.48%) due to intrinsic operational factors. These occurrences are not considered to be non-conformances as they were outside of operational control.

For the periods when the minimum environmental flow release was required, it was achieved 100% of the time in summer and 99.98% of the time in winter, when there was a one hour period where flows were lower than required.

Fluvial geomorphology

Geomorphology monitoring was completed between the Gordon Power Station and upstream of Sunshine Gorge on 16 April 2016. Monitoring results reflect the several periods of high discharge from the Gordon Power Station in the 18 month period since the previous sampling (October 2014 to April 2016), with erosion (rather than deposition) being predominantly recorded at the monitoring sites.

Evidence of scour in the river was widespread, but evidence of seepage erosion processes was very limited. This is attributable to the station being operated for extended periods at high discharge in the months prior to monitoring, rather than in a hydro-peaking regime. Immediately prior to monitoring there was a period of low discharge that promoted the deposition of mud and growth of algae on some of the bank toes in zones 1 and 2.

Most erosion pin sites recorded erosion, with a few sites in zones 3 and 4 recording some of the highest erosion rates since systematic monitoring began in 2001. Observations of increases in erosion were similar to those recorded in zones 3 and 4 in 2007-08 during the last very dry period in Tasmania. The higher erosion rates in the downstream zones (zones 3 and 4) as compared to the upstream zones (zones 1 and 2) suggests that erosion was jointly influenced by a lack of sediment inflow from the unregulated tributaries (as a result of the dry period) as well as the high power station discharge. The downstream zones are more dynamic as compared to the upstream zones. The flow in upstream zones is mostly from the power station discharge, and the banks have largely 'adjusted' to the power station regime in the absence of other inflows.

The increase in erosion in zones 3 and 4 was reflected in the photo monitoring results, with sand deposits on bank toes at erosion pin sites noticeably reduced in April 2016 as compared to October 2014. The photo monitoring results of the long term disturbance sites show little change between the current and previous monitoring periods. The changes that were noted are consistent with previous findings.

The April 2016 monitoring results are consistent with the understanding of geomorphic processes in the middle Gordon River. The overall bank morphology is trending towards one characterised by low angle banks extending to a break in slope, above which the bank has a steep slope and is stabilised by terrestrial vegetation above the power station controlled high water level.

Macroinvertebrates

Macroinvertebrates were sampled at eight sites in the Gordon River between the Gordon Power Station and the Franklin River junction. Six reference sites were also sampled in the Franklin, Denison, Maxwell and Jane rivers.

Quantitative surber samples were used to generate data on key metrics of abundance of taxa and total abundances and diversity for the aquatic insect orders Ephemeroptera, Plecoptera and Trichoptera (EPT). Rapid bioassessment samples were used to derive observed over expected (O/E) values for each site.

Patterns and trends in benthic macroinvertebrate metric values in the Gordon River were broadly similar to those observed in the four pre-Basslink years with the following exceptions:

- a new, major increase in the absolute and relative abundance of EPT species in zone 1, resulting in several metrics being above their upper pre-Basslink bounds; and
- a sustained reduction in the number and relative abundance of expected macroinvertebrate families (O/Erk) in zone 1.

The abundance of EPT continued to greatly exceed the pre-Basslink upper bounds which was consistent with observations in most post-Basslink years, but has shifted its location upstream of the Denison River confluence to zone 1. The increased abundance of EPT indicates an improvement in condition relative to the pre-Basslink period, but is also a dynamic response in the abundance of one species – the Hydropsychid 'snowflake' caddis *Asmicridea sp. AV1*.

The trigger exceedance for the O/Erk metric (falling below lower bounds) in 2015-16 followed a decline in this metric in zone 1 which commenced in 2013-14, influenced by the most persistent high flow conditions observed to date. The flow conditions in the 12 months preceding monitoring in autumn 2016, were of substantially lower magnitude than 2013-14, but were likely not conducive to the return to pre-Basslink levels for this metric.

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Acronyms and abbreviations

AEMO	Australian Energy Market Operator – founded in 2009 with NEMMCO as a founding entity
AETV	Aurora Energy Tamar Valley
AUSRIVAS	Australian River Assessment System
BBR	Basslink Baseline Report
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies)
FLOCAP	Flow calculator application to convert station output to flow
IIAS	Basslink Integrated Impact Assessment Statement: Potential Effects of Changes to Hydro Power Generation
LOAC	Level of acceptable change
NEMMCO	National Electricity Market Management Company – incorporated into AEMO in 2009
O/E	is a biological index of the 'observed' to 'expected' ratio which describes the proportion of macroinvertebrate taxa predicted to be at a site under undisturbed conditions that are actually found at that site. O/E scores range between 0, with no predicted taxa occurring at the site, to around 1, with all expected taxa being observed (i.e. a community composition equivalent to reference condition).
O/Epa	the O/E value calculated using an AUSRIVAS model based on presence-absence data
O/Erk	the O/E value calculated based on rank abundance category data
RBA	rapid biological assessment - macroinvertebrate sampling protocol
WOR	whole-of-river

Glossary

Bray-Curtis index	a measure of assemblage similarity between sites/samples
Cavitation	the formation and subsequent collapse of vapour bubbles (cavities) within water moving at high velocity. Cavitation is responsible for the pitting of turbine blades.
Confluence	the location when two rivers or tributaries flow together
Environmental flow	water which has been provided or released for the benefit of the downstream aquatic ecosystem and broader environment
Full gate	is the discharge which produces the maximum amount of energy by the turbine
Geomorphic	the study of the earth's shape or configuration
GordonRatingApp	the stand alone application used for calculating discharge from the Gordon Power Station
GWh	gigawatt hours (10^9 watt hours) – a standard measure of energy equivalent to the production of one gigawatt of power for one hour
Hydrology	the study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks and in the atmosphere
Hydro-peaking	variable flow in power station discharge on a daily scale
Inundation	an area of vegetation or bank which becomes covered by water associated with flows from either an upstream dam or tributary input
m^3s^{-1}	cubic metres per second, units for the measure of flow rate
MW	megawatts (10^6 watts) - a standard measure of power
Piezometer	an instrument for measuring pressure
Post-Basslink	the period following commissioning of the Basslink interconnector
Pre-Basslink	the period prior to commissioning of the Basslink interconnector
Riffle habitat	habitat comprising rocky shoal or sandbar lying just below the surface of a waterway
Rill	a small brook or natural stream of water smaller than a river
Tailrace	the outflow structure of the power station, from which water is discharged into the river
Taxon	a taxonomic category or group, such as a phylum, order, family, genus, or species
Temporal	change or pattern over time

1 Introduction and background

The purpose of this Gordon River Monitoring Annual Report is to present the results of the monitoring undertaken pursuant to the Monitoring and Reporting requirements in Hydro Tasmania's Special Licence Agreement. The biennial requirement to undertake monitoring was due in autumn 2016. In addition, the peaking hydrological trigger was exceeded in June-July 2015, requiring a monitoring response. Monitoring to satisfy both of these conditions was undertaken in April 2016; the results of which are presented in this report.

This is the tenth year of post-Basslink operation. The monitoring area is shown on Figure 1-1.

1.1 Context

The aims of the original Gordon River Basslink Monitoring Program were to:

- undertake pre-Basslink monitoring (2001–05) in order to extend the understanding gained during the 1999–2000 investigative years on the present condition, trends, and spatial and temporal variability of potentially Basslink-affected aspects of the middle Gordon River ecosystem;
- undertake six years of post-Basslink monitoring to determine the effects of Basslink operations on the environment of the Gordon River below the power station and to assess the effectiveness of mitigation measures; and
- obtain long-term datasets for aspects of the middle Gordon River ecosystem potentially affected by Basslink that will allow refinement of theories and more precise quantification of spatial and temporal variability, processes and rates.

The focus of the pre-Basslink monitoring program was to measure conditions under the existing operating regime, rather than attempting to relate them to 'natural' or 'pristine' conditions. This approach was an essential element of the monitoring program given the highly modified conditions that exist due to the presence of, and the flow regulation resulting from, the Gordon Power Scheme.

A major component of the post-Basslink monitoring program was to compare post-Basslink data with trigger values derived from pre-Basslink data and to assess the effectiveness of two operational mitigation measures; a minimum environmental flow and a power station discharge ramp-down requirement (ramp-down rule).

The subsequent Gordon River Interim Basslink Monitoring Program comprised a monitoring regime for two years from May 2012 to April 2014 to assess the effectiveness of the mitigation measures (ramp-down rule and minimum environmental flow). Continued monitoring beyond the original period was due to the revision of the ramp-down rule in mid-2012 which better aligned operational and environmental objectives. It was considered prudent to ensure that the aims of the revised ramp-down rule were being achieved, and monitoring continued with a focus on hydrology, fluvial geomorphology and macroinvertebrate disciplines.

The current Gordon River Monitoring focusses on hydrology, fluvial geomorphology and macroinvertebrate monitoring. The main aim of the current Gordon River Monitoring is to validate the conceptual models presented in the Basslink Review Report 2006-12 (Hydro Tasmania 2013) and improve our understanding of the responses if the power station is operating outside 'historical' ranges. Monitoring is to be undertaken on one occasion between February and April in 2016, 2018 and 2020.

Additional monitoring is required if one of the following hydrological triggers are exceeded:

- Flow at Gordon Compliance site over a 90 day period exceeds:
  - i. 100 m^3s^{-1} for more than 99% of the time; or
  - ii. 200 m^3s^{-1} for more than 93% of the time; and
- Gordon Power Station discharge over a 90 day period rises from:
  - i. 35 to 100 m^3s^{-1} in 4 hours or less on more than 75 occasions; or
  - ii. 35 to 200 m^3s^{-1} in 4 hours or less on more than 40 occasions.

1.2 Logistical considerations and monitoring in 2015–16

Site access presents significant challenges in this part of the Tasmanian Wilderness World Heritage Area. On-site monitoring activities require helicopter support due to the density of the terrestrial vegetation, the absence of access to infrastructure and the extent of the study area.

Power station outages are needed to conduct monitoring because the majority of viable helicopter landing sites are on cobble bars in the river bed that are exposed only when there is little or no discharge from the power station. Outages are also necessary because most of the biotic and geomorphic monitoring activities require measurements or sampling to take place within the river channel, which would not be possible under normal or high flow conditions.

The 2015–16 monitoring field trip was conducted on 16-17 April 2016.

1.3 Geographic datum

Map coordinates in this document use the 1966 Australian Geodetic Datum (AGD) which corresponds to topographic maps currently available for the area. A later datum, the Geocentric Datum for Australia (GDA), was subsequently adopted for new maps. Site references using the AGD will be approximately 200 m different (-112 m east and -183 m north) from those using the GDA.

1.4 Document structure

The report is organised into four chapters and four appendices.

This first chapter discusses the requirements, context, logistical considerations and constraints of the program. Chapters 2–4 report on the monitoring work that was undertaken during 2014–15, and present the consolidated results of each of the individual monitoring elements. These are:

- Hydrology and water management (Chapter 2);
- Fluvial geomorphology (Chapter 3); and
- Macroinvertebrates (Chapter 4).

The report also contains the following four appendices;

- Power station discharges graphed per month (Appendix A);
- Ramp-down rule exceedence events (Appendix B);
- Fluvial geomorphology photo-monitoring (Appendix C); and
- Macroinvertebrate data (Appendix D).

1.5 Authorship of chapters

The information presented in chapters 2–4 is based on field reports produced by scientists engaged to conduct the monitoring, as shown in Table 1-1. The efforts and original contributions of these researchers are duly acknowledged.

This document was collated by Malcolm McCausland (Entura), with review from Marie Egerrup and Greg Carson (Hydro Tasmania), and significant assistance from the researchers.

Table 1-1: Chapter numbers, titles and original authors from whose reports the information in chapters 2–4 was extracted.

Chapter	Chapter title	Lead Author(s)
2	Hydrology	Malcolm McCausland (Entura) and Roger Parkyn (Hydro Tasmania)
3	Fluvial geomorphology	Lois Koehnken (Technical Advice on Water)
4	Macroinvertebrates	Peter Davies and Laurie Cook (Freshwater Systems)

1.7 Site numbers

Throughout this report monitoring locations are identified by site number. These represent the approximate distance upstream from the Gordon River mouth at the south-eastern end of Macquarie Harbour. The monitoring work is conducted between sites 44 (immediately upstream of the Franklin confluence) and site 77 (the power station tailrace).

The fluvial geomorphology discipline uses zones rather than the standard site numbering system. This is because the work is associated with longer reaches of river bank than are suitable for the 'site' nomenclature.

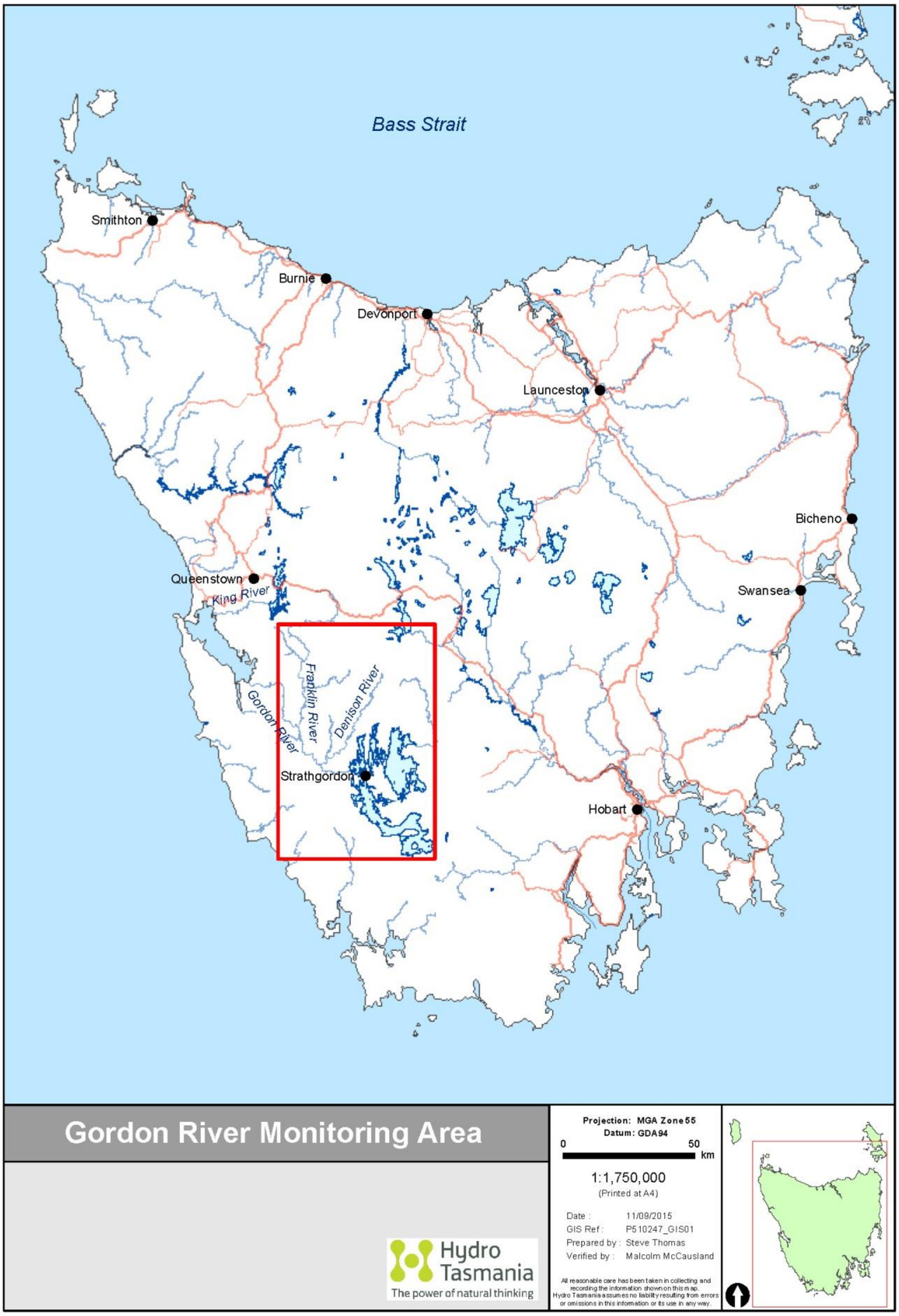

Figure 1-1: Gordon River monitoring area.

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2 Hydrology and water management

This chapter of the Gordon River Monitoring Annual Report provides an overview of the hydrological data from the Gordon River downstream of the Gordon Power Station for the period July 2015 to June 2016. Conformance with the two mitigation measures, namely the minimum environmental flow and the ramp-down rule, are presented. In addition, performance against the hydrological triggers is presented.

2.1 Factors affecting Gordon Power Station discharge

An overview of previous hydro generation drivers in previous years is shown in Figure 2-1. The Gordon Power Station running regime has always been heavily influenced by a number of factors including:

- inflows to Hydro Tasmania catchments (volume, distribution and temporal variation);
- overall storage position, in particular, the storage positions of Great Lake and Lake Gordon;
- National Electricity Market price signals;
- energy supply/demand in Tasmania; and
- system constraints (e.g. Basslink outage, bushfires).

The number and potential influence of factors on Gordon Power Station operation is very large, and the identification and quantification of the influence of each of these remains difficult to define.

In all but five of the last 20 years, Tasmanian electricity demand was higher than the annual hydro energy yield (Figure 2-2). The annual energy yield has varied between years, which in combination with variable generation (Figure 2-3), has influenced the overall system storage (Figure 2-4).

System wide hydro generation in 2015-16 (8,043 GWh) was the third lowest in the past twenty years, higher only than the years 2007-08 and 2008-09. In contrast, Gordon Power Station generation in 2015-16 was the third highest in twenty years (1,822 GWh) which was 71% higher than in 2014-15 and 24% higher than the long term median generation (1,471 GWh; Figure 2-3). Low system inflows, particularly in spring, combined with the Basslink fault for a six month period (20 December 2015 – 13 June 2016) resulted in greater generation from Gordon Power Station and a decline in energy in storage to very low levels in Lake Gordon, Great Lake and the rest of Hydro Tasmania system. High inflows in May and June subsequently increased storage in Lake Gordon, however it finished the end of the year substantially lower storage than the start of the year (Figure 2-4).

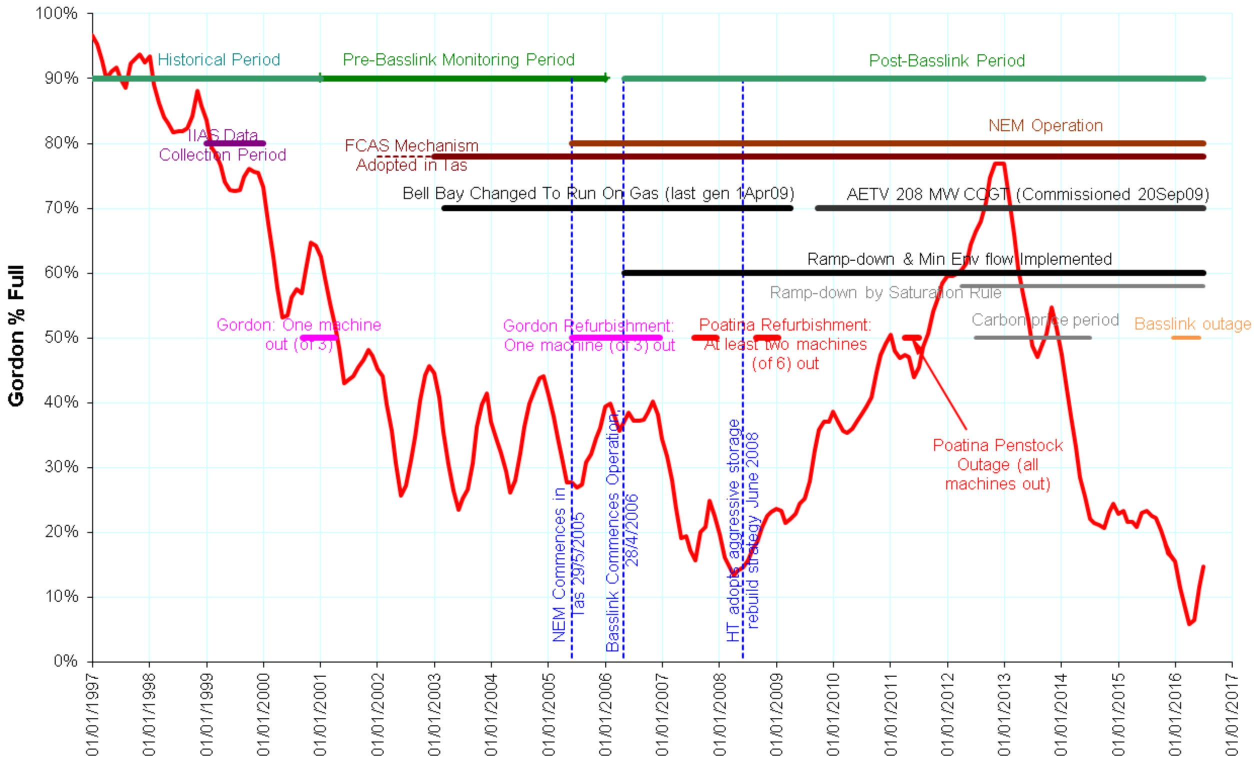

Figure 2-1: Timeline of significant factors affecting Gordon Power Station operation (including storage levels) relative to Basslink monitoring periods.

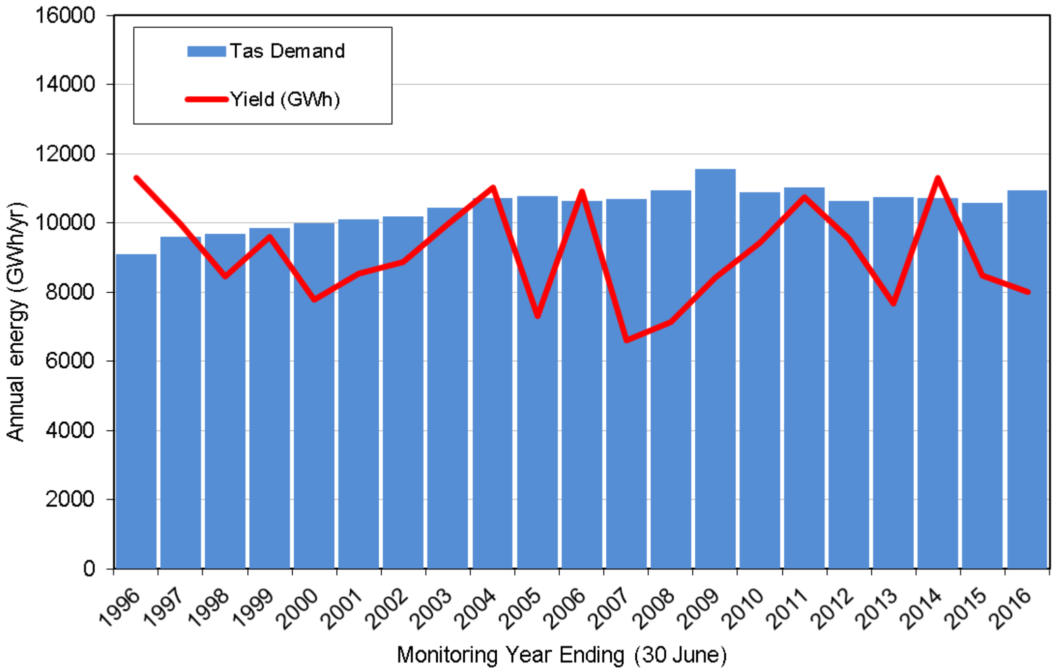

Figure 2-2: Annual Tasmanian electricity demand (total generation + net import or total generation – net export) and hydro energy yield representing system inflows converted to GWh.

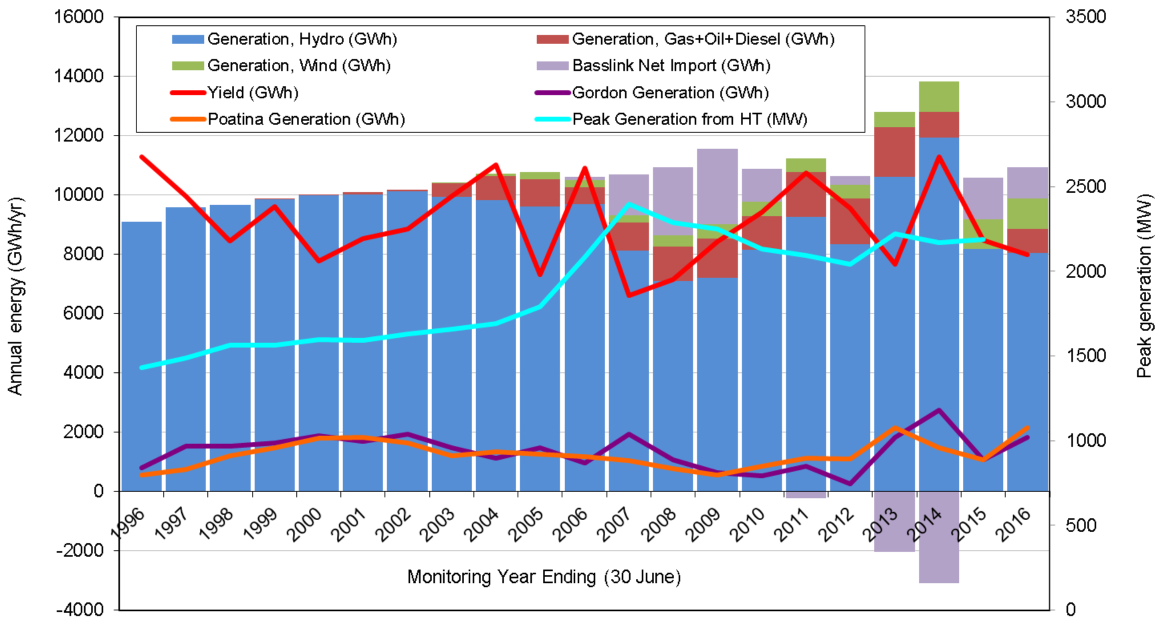

Figure 2-3: Hydro generation, wind and gas generation, Gordon and Poatina generation and net import (in GWh) and peak generation (in MW) for financial years from 1995–96 to 2015-16.

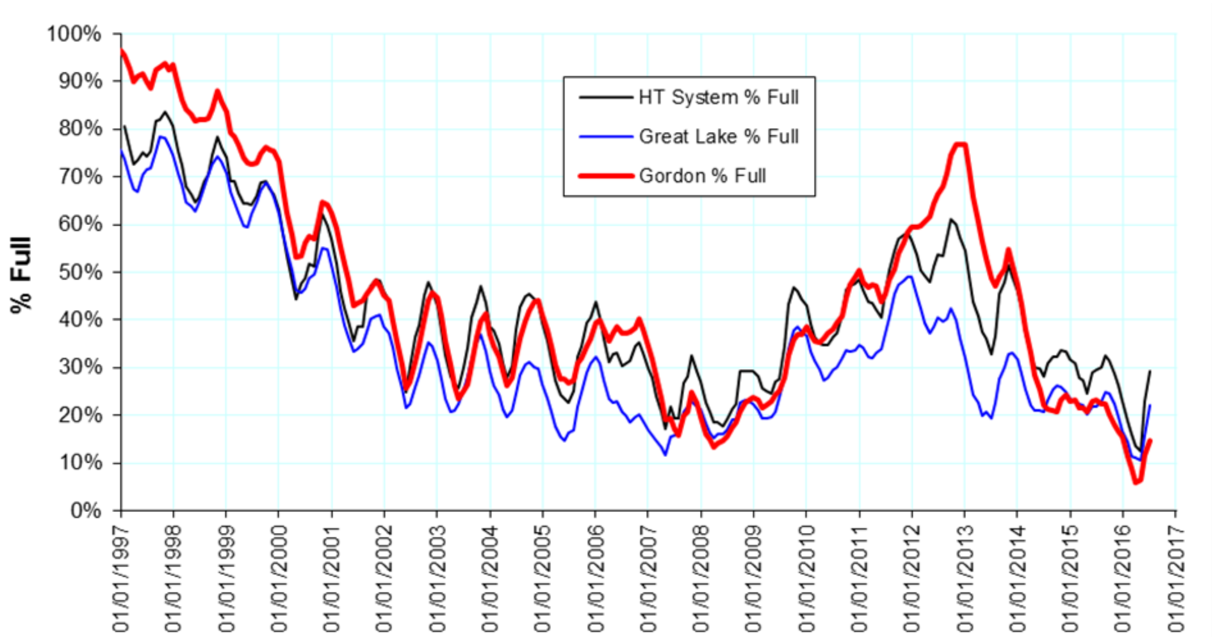

Figure 2-4: System, Lake Gordon and Great Lake water level presented as per cent full for 1997-2016.

2.2 Power output to flow ratings

Due to the difficulty in accurately measuring flow in the tailrace, flow records have been converted from power station output (MW) using a stand-alone rating application (GordonRatingApp). This application mimics the real-time tool used by the operators for the calculation of discharge from Gordon Power Station. It is the most accurate method of determining flow from the Gordon Power

Station and is presented in all analyses in this report. This application utilises the following input data to determine discharge from Gordon Power Station:

- Individual machine output;
- storage water height; and
- machine power-discharge rating.

The application sends discharge data to the hydrological database for each five-minute interval.

2.3 Site locations

The flow monitoring sites reported in this chapter are from gauged sites at Gordon above Franklin (site 44), Gordon above Denison (site 65; also known as the flow compliance site) as well as the derived flow for Gordon Power Station tailrace (site 77). Of these, site 44 was decommissioned on 11 June 2016 due to safety concerns associated with ongoing maintenance access.

The sites reported in this chapter are shown in Figure 2–5.

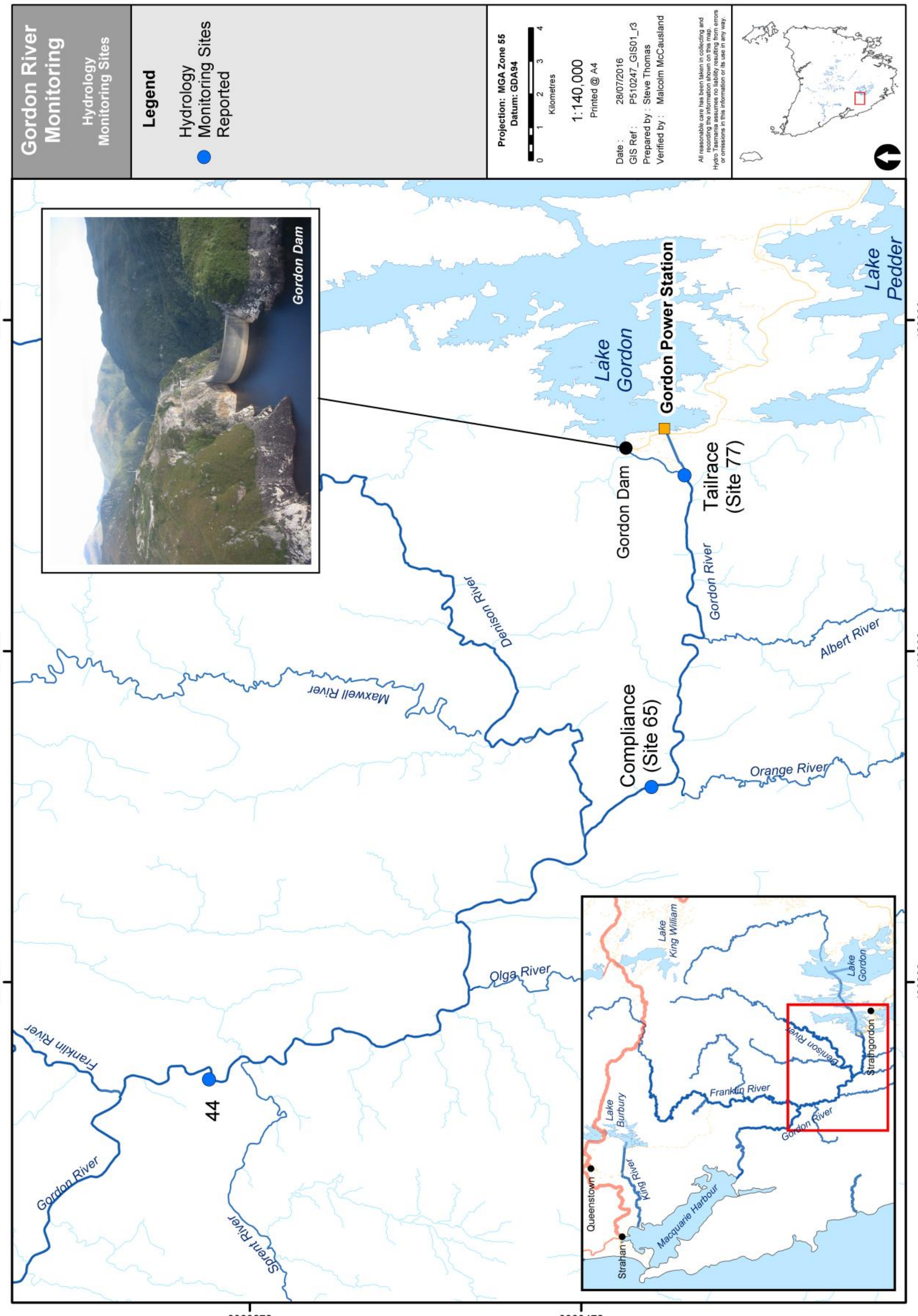

Figure 2-5: Gordon River hydrology monitoring sites

2.4 Data analysis

2.4.1 General flow analysis

For 2015–16, the power station discharge at site 77 (the tailrace), site 65 (compliance site) and site 44 (Gordon above Franklin) hourly flow data, median monthly flow and annual duration curves were plotted (Section 2.5.3, Section 2.5.4 and Section 2.5.5). These three sites are considered representative of the various river sections below the power station.

Analyses at sites 77, 65 and 44 have provided the comparison of data from the 2015–16 year to the long-term average at that site. The long-term average is calculated by using all available data at a site, which means that the date range for the long-term average figures will change for each site depending on when data records commenced. Additional duration curves for the pre-Basslink, post-Basslink and historical periods, as well as each of the individual post-Basslink years, are presented for power station discharge data.

2.4.2 Hydrological triggers

An analysis of the discharges relative to the hydrological triggers was undertaken for 2015-16 (Sections 2.5.3.5 and 2.5.4.5).

2.4.2.1 Peaking triggers

The peaking triggers are based on discharge from Gordon Power Station (site 77) in the previous 90 days and are exceeded when discharge increases from:

- 35 to 100 m^3s^{-1} in 4 hours or less on more than 75 occasions; or
- 35 to 200 m^3s^{-1} in 4 hours or less on more than 40 occasions.

The analysis of the data utilises aggregated hourly data and identifies the following conditions:

- discharge reduced below 35 m^3s^{-1}; and
- subsequently increased to greater than 100 m^3s^{-1} (trigger 1) or 200 m^3s^{-1} (trigger 2) within a four-hour period; and
- counting the number of occurrences these events that have occurred in the previous 90 days.

The data is presented in this report in Section 2.5.3.5 as a time-series of the number of occasions the peaking events have occurred in the past 90 days, and are compared to the trigger value.

2.4.2.2 High flow duration triggers

The high flow triggers are based on the flow measured at the Compliance Site (Site 65) in the previous 90 days and are exceeded when:

- flow is in excess of 100 m^3s^{-1} for 93 % (or more) of the preceding period; or
- flow is in excess of 200 m^3s^{-1} for 99% (or more) of the preceding period.

The analysis of the data identifies the following conditions at each hourly time-step:

- flow record for previous 90 days;
- duration analysis on the data set;
- determination of the percentile that each of the trigger flow values (100 or 200 m^3s^{-1}) constitutes for that period.

The data is presented in this report (Section 2.5.4.5) as a time-series of the percentile values of each of the trigger flows in the previous 90 day period.

2.4.3 Ramp-down rule

2.4.3.1 Background

A ramp-down rule mitigation measure has been in place at Gordon Power Station since the commissioning of Basslink in April 2006. A revised and improved ramp-down rule was implemented from 1 April 2012. Its aim is to limit the rate of seepage erosion.

The revised rule utilises a Bank Saturation Regression Model to determine when the ramp-down rule is required to be applied. The Bank Saturation Regression Model utilises real-time discharge data from the Gordon Power Station to predict the level of saturation of the banks at Site 71 (Gordon River below Albert).

The rule is as follows:

- whenever the bank saturation level at site 71, as calculated by the Bank Saturation Model, is greater than 2.75 m above the local datum and the discharge from the Gordon Power Station is greater than 150 m^3s^{-1}, the plant control system must be set to control any reductions in generation load at a rate of 1 MW per minute until the power station discharge is less than 150 m^3s^{-1}.

2.4.3.2 Test of compliance with ramp-down rule

The rule requires the ramp-down rule (i.e. to set the plant control system generation to avoid reductions exceeding 1 MW per minute) be applied when both:

- bank saturation level (from the Bank Saturation Model) exceeds 2.75 m; and
- power station discharge exceeds 150 m^3s^{-1}.

Hence the testing approach identified such periods (on a 5-minute basis) and, for them, determined if the plant control system was in place. In addition, while the plant control system was in place, comparison was made between the actual generation change-rate with the -1.0 MW/minute target. The results of the compliance test are presented in Section 2.5.3.6.

2.5 Results

2.5.1 Data availability

There was no missing data from sites 77 or 65 in the 2015-16 monitoring period. However for site 44, data is available only until 11 June 2016 due to the decommissioning of this site on this date for safety reasons.

2.5.2 General analysis

2.5.2.1 System yield

The inflows to Hydro Tasmania's state-wide system during the 2015–16 were below average levels. The total system inflows (system yield) of 8,002 GWh were 88 % of the long-term mean (1996–2016).

Figure 2-6 shows the monthly total system yield during 2015–16 compared with the long-term (1976–2015) median, 20th and 80th percentile inflows. The main features of the year were:

- inflows below the long term 20th percentile in July, September, October, November and December;
- below median inflows through summer and early autumn (January to April); and
- very high inflows in May and June 2016.

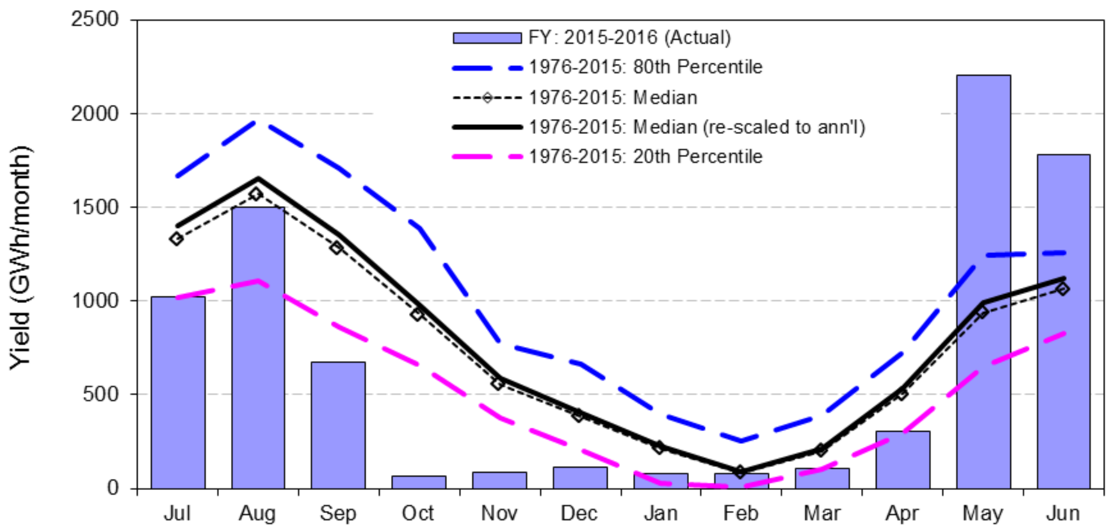

Figure 2-6: Monthly total system yield for 2015–16 compared to the long-term median, 20th and 80th percentiles for 1976–2015.

2.5.2.2 Strathgordon rainfall

The Strathgordon meteorological station has rainfall records beginning in 1970. These allow the calculation of long-term mean monthly values and comparisons with the monthly rainfall totals recorded for 2015–16.

Figure 2-7 shows the total monthly and long-term average monthly rainfall values. In 2015–16 the annual rainfall (2,312 mm) was lower than the long-term median (2,453 mm). The pattern of rainfall in Strathgordon throughout the year differed from the long term average in the following ways:

- September and October and January were very dry months, receiving less than half of the long term average monthly rainfall, well below the 20th percentile;
- May was a very wet month, receiving record rainfall for the month at three times the long term average; and
- June was a wet month, receiving above the long term 80th percentile.

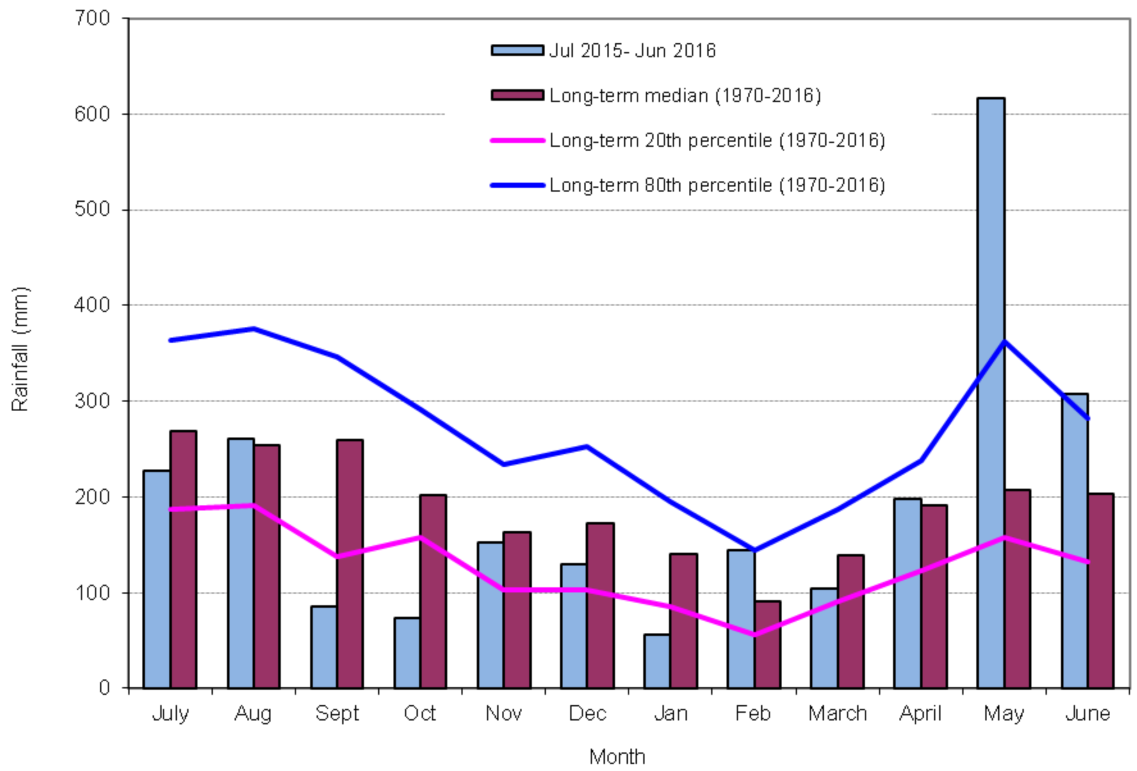

Figure 2-7: Total monthly rainfall values recorded at Strathgordon for 2015–16 compared with the long-term median (1970–2016).

2.5.3 Gordon Power Station operation

2.5.3.1 Discharge and power station operation

As previously discussed (see Section 2.1), the discharge pattern for the Gordon Power Station is driven by a number of factors. Figure 2-8 shows the discharge from the power station for 2015–16. More detailed monthly graphs are provided in Appendix A. A summary of some of the drivers of discharge conditions at Gordon Power Station is provided in Table 2-1. Significant points of interest in the 2015–16 discharge data is as follows :

- in July to late-September 2015 the discharge pattern consisted of periods of peaking between very high (>220 m^3s^{-1}) and low-mid range discharges (20-80 m^3s^{-1}) interspersed with a pattern of 2-3 turbine peaking with a small peak range of between 200 and 250 m^3s^{1}. Exceedance of the peaking trigger in June 2015 (Hydro Tasmania 2015) was maintained for a period in July 2015, as a result of the continued high range peaking (see Section 2.5.3.5);
- from late-September to late November 2015, there was a decline in peak range so that most peaks were between high (200 m^3s^{-1}) and mid-range (80-120 m^3s^{-1}) discharge, and a small proportion of reductions to lower discharge (<80 m^3s^{-1});
- a brief period from late November 2015 to late December 2015 was characterised by low discharge (< 50 m^3s^{-1}) with only a few peaks to mid to high discharge (80-200 m^3s^{-1});
- from late December 2015 to late March 2016, there were extended periods of high discharge(160-200 m^3s^{-1}) interspersed with weeks of mid-range flow (80-140 m^3s^{-1}), and very little high range peaking throughout the period; and
- from April to June 2016 the discharge was dominated by low or no discharge with occasional low level peaking.

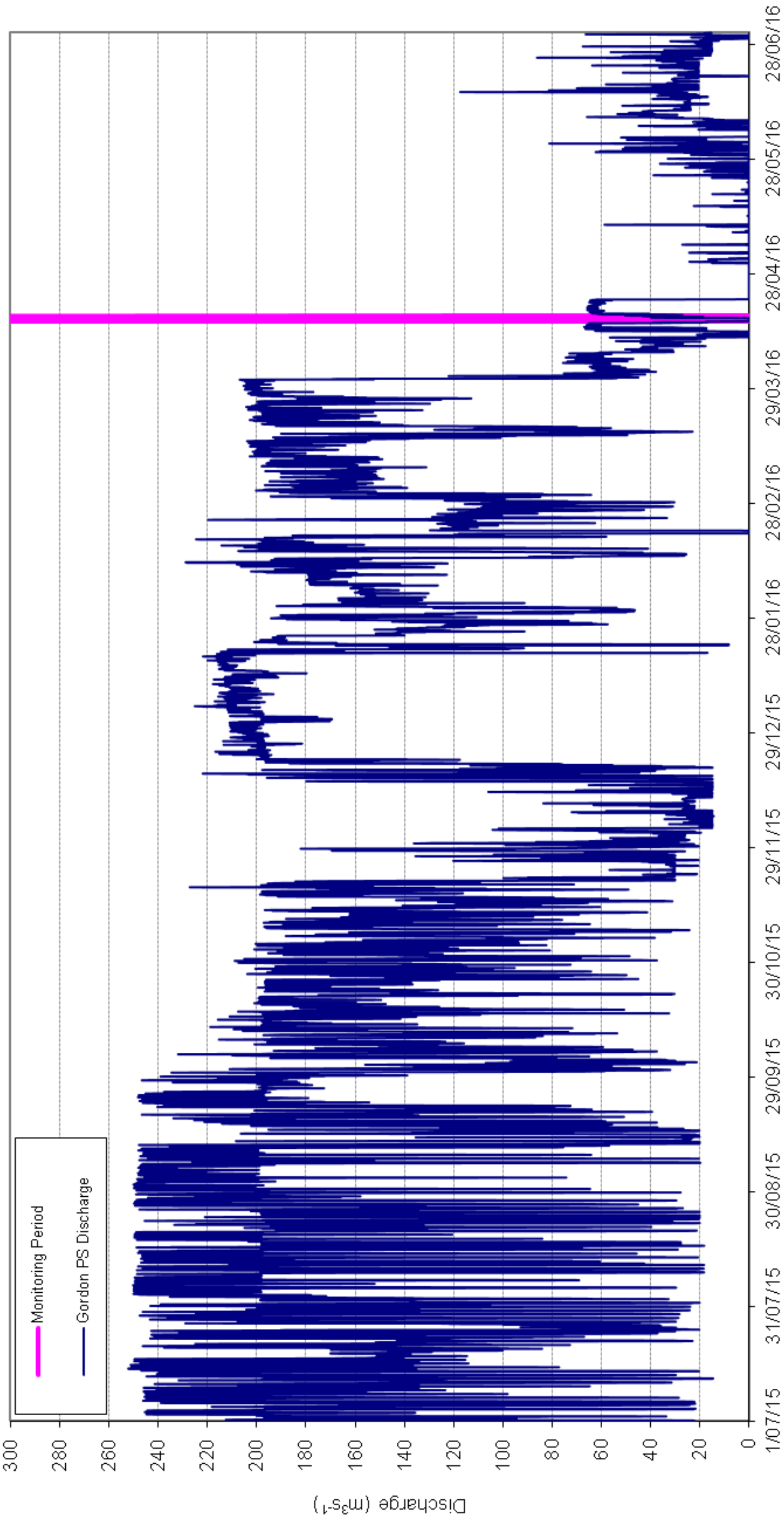

Figure 2-8: Gordon Power Station discharge (hourly data) from July 2015 to June 2016. Pink vertical line indicates the monitoring event.

Table 2-1: Summary information on discharge, weather conditions, market volatility and outages for 2015–16. Dry months are classified as months with values lower than the 20th percentile of the long-term values, and wet months are classified as months with values higher than the 80th percentile of the long-term values. Market volatility is based on daily average price and 30 minute prices.

Period	0-turbine operation % time	1-turbine operation % time	2-turbine operation % time	3-turbine operation % time	Strathgordon rainfall	System yield	Gordon operation and influential factors	Basslink Net Import (GWh) (negative = export, positive = import)
July 2015	0.0	2.2	35.2	62.6	< average	< average	Gordon on high load during peak periods.	-38.1
August 2015	0.0	11.4	11.6	77.0	< average	average	Gordon high average loading, mostly during peak periods	-156.9
September 2015	0.0	14.0	8.6	77.4	average	< average	Gordon high early and late in the month, peaking during middle of the month	28.2
October 2015	0.0	1.1	28.1	70.8	very dry	<< average	Gordon predominantly supplying Tasmanian load	320.5
November 2015	0.0	5.8	51.1	43.1	very dry	<< average	Gordon predominantly supplying Tasmanian load	325.4
December 2015	0.0	24.9	32.0	43.1	< average	<< average	Low running early in the month, prior to Christmas, then supplying Tasmanian load during Basslink outage	182.9
January 2016	0.0	24.9	32.0	43.1	< average	average	Gordon supplying Tasmanian load during Basslink outage	0.0
February 2016	2.6	2.3	48.6	46.6	dry	< average	Gordon supplying Tasmanian load during Basslink outage	0.0
March 2016	0.0	1.1	9.0	89.9	> average	< average	Gordon supplying Tasmanian load during Basslink outage	0.0
April 2016	37.5	49.9	12.2	0.4	dry	< average	Easing of the requirement for Gordon generation. Gas and increased diesel generation fulfilled needs	0.0
May 2016	82.3	17.1	0.7	0.0	< average	>> average	Gordon mostly not required for production. Gas/diesel early in month, and rain late in the month increased generation at other stations	0.0
June 2016	12.9	49.7	30.6	6.8	very wet	>> average	Gordon mostly required on low load only	-73.7

2.5.3.2 Power station outages

There were four power station maintenance and inspection outages in 2015–16. These were partial outages of only a few hours' duration, and all were within the period February-June 2016. A fifth outage for the downstream monitoring took place on 16 April 2016. The outage of the Basslink interconnector occurred between 20 December 2015 and 13 June 2016 (inclusive). During the Basslink outage there was no obligation under Hydro Tasmania's Special Licence Agreement to implement the Basslink mitigation measures – the ramp-down rule or the environmental flow.

2.5.3.3 Median monthly discharge

Figure 2-9 shows the median monthly discharge from the power station for 2015–16 compared with long-term values (since January 1997) and the previous nine years of the post-Basslink period. The 2015-16 median values had an annual pattern that differed from the long-term and other post-Basslink years. Discharges were substantially higher in winter and spring (July-October 2015) than in previous years. Median discharge throughout summer and early autumn (January-April 2016) were at similar high levels relative to previous years, while low discharges occurred in April-June 2016.

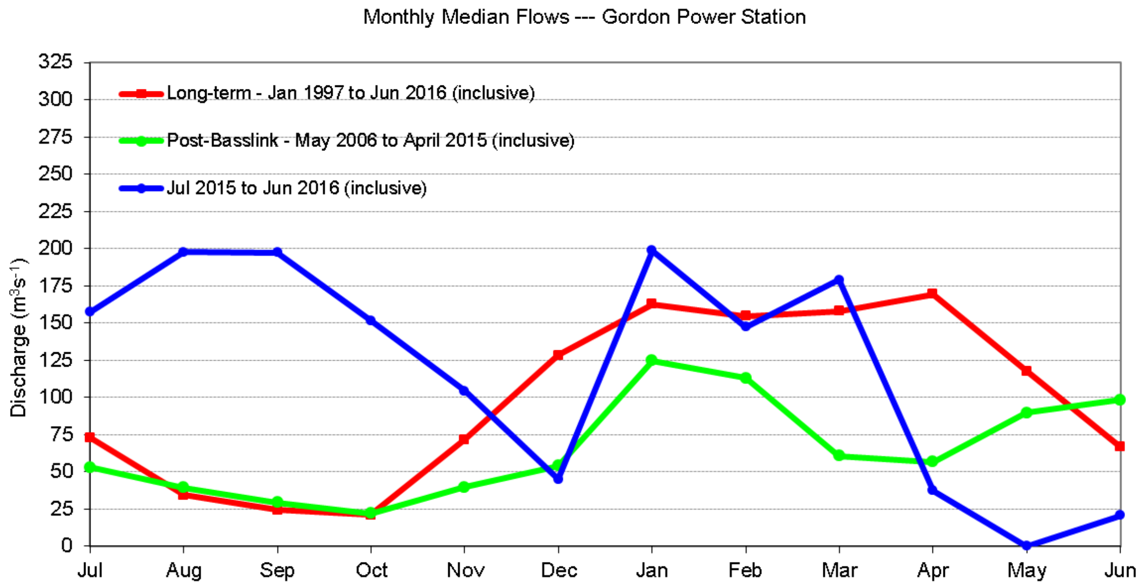

Figure 2-9: Median monthly discharge from the Gordon Power Station (site 77) for 2015–16 compared with long-term monthly median values and previous post-Basslink years.

2.5.3.4 Flow duration curves

Figure 2-10 to Figure 2-13 show the duration (percentage exceedance) curve for the power station discharge for:

- Whole of year (Figure 2-10);
- winter period (May–October; Figure 2-11);
- summer period (November–April; Figure 2-12); and
- years one to eight of post-Basslink annual data (Figure 2-13).

Various duration curves have been plotted against these periods (each period has been devised such that it is divisible by 12 months):

- long-term period (1 July 1997–30 June 2016);
- the historical period (1 January 1997–31 December 2000), incorporating the period when IIAS data were collected;
- the pre-Basslink period (1 January 2001–31 December 2005), when pre-Basslink data were collected;
- the post-Basslink period (1 May 2006–30 April 2015) prior to the current year ; and
- 2015–16 financial year (1 July 2015–30 June 2016).

The annual discharge curve in 2015–16 was a similar shape to the historical (1997-2000) and pre-Basslink (2001-2005) curves. Discharges had similar durations across most magnitudes. However, flow ranges with somewhat greater proportion of duration were around the 190-210 m^3s^{-1} and 10-50 m^3s^{-1} ranges. In addition, there was a greater proportion of no discharge relative to other post-Basslink years, similar to the historical and pre-Basslink operation.

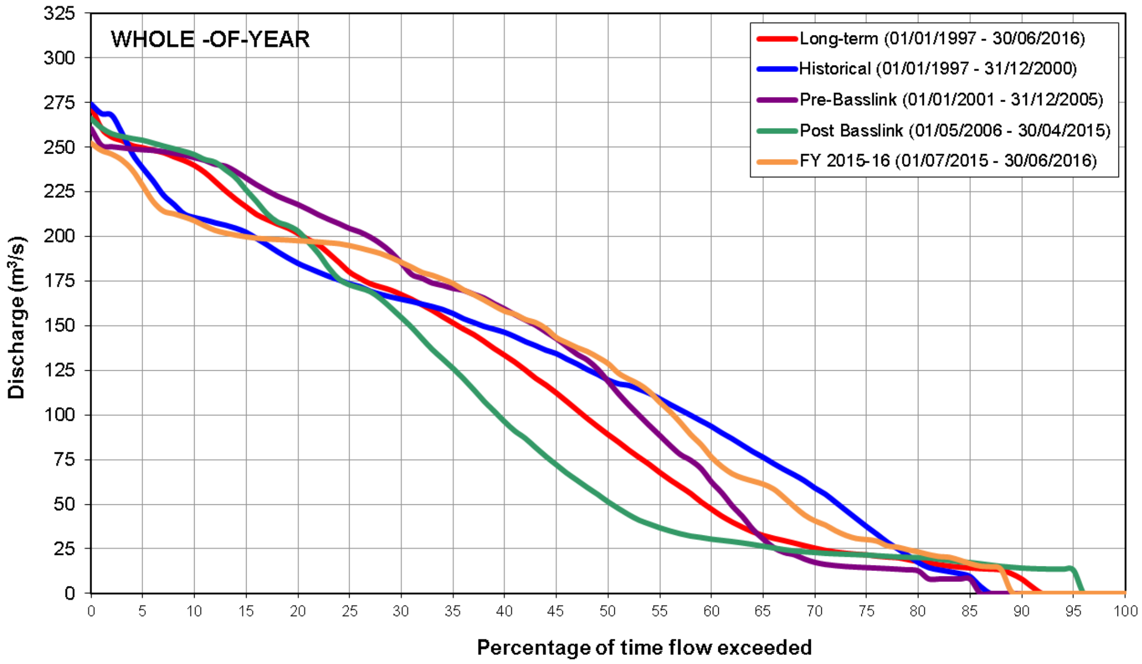

Figure 2-10: Duration curves for discharge from the power station using annual data for selected periods.

The 2015–16 winter discharge flow duration curve (Figure 2–11) was markedly different to the comparative curves. It indicated marked duration of flows around the 200 m^3s^{-1} and 20-50 m^3s^{-1} discharges. There were smaller periods of increased flow duration around the 60 m^3s^{-1} and 130 m^3s^{-1} discharges. This duration curve shape is indicative of the regular peaking pattern that was prevalent from July-October 2015. The high duration of zero discharge was the result of periods of no discharge in May 2016 during the Basslink outage.

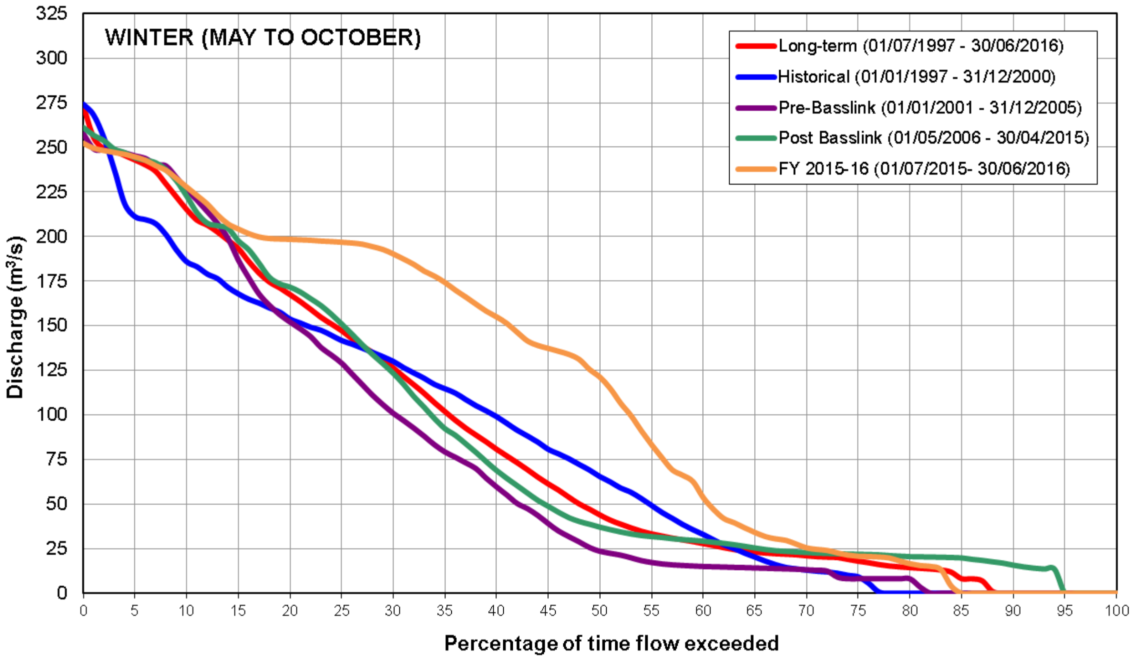

Figure 2-11: Duration curves for discharge from the Gordon Power Station using winter data (for the months of May to October inclusive) for selected periods.

The 2015–16 summer discharge flow duration curve (Figure 2-12) differed from all the comparative duration curves, having little duration at discharges greater than 225 m^3s^{-1}. The high magnitude discharges of summer 2015-16 were around 150-200 m^3s^{-1}, accounting for around 45% of flows. There was also a small degree of increased duration of flows < 65 m^3s^{-1}. The duration curve is indicative of the periods of continuous high flow over much of summer and the subsequent reduction to low flow throughout April 2016.

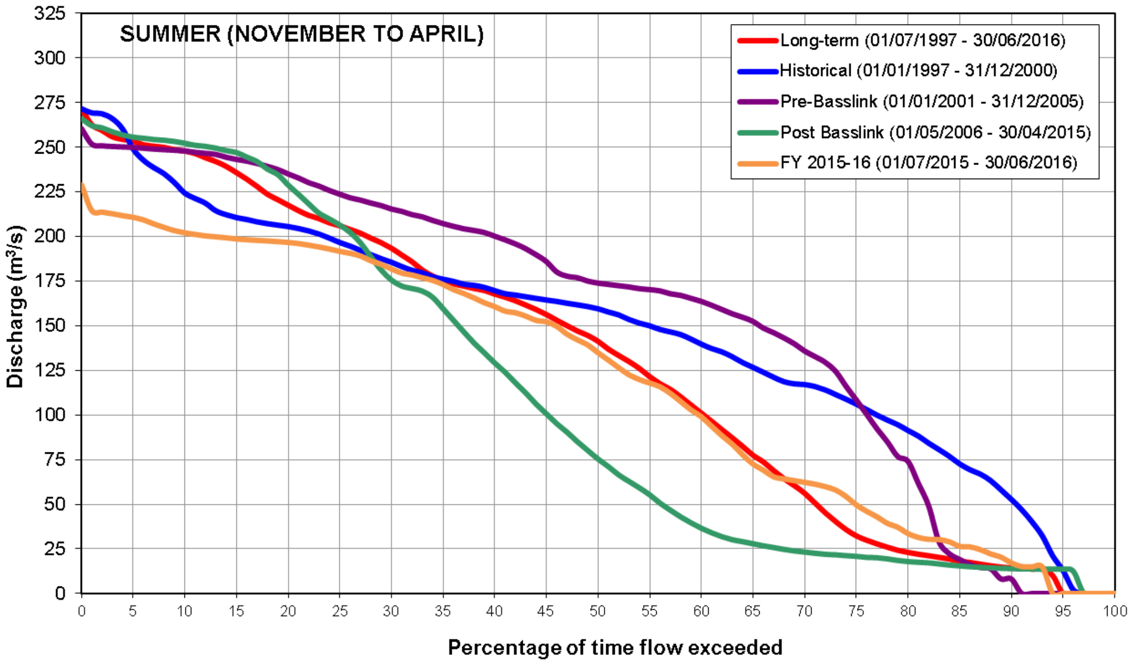

Figure 2-12: Duration curves for discharge from the Gordon Power Station using summer data (for the months of November to April inclusive) for selected periods.

Annual flow duration curves for each post-Basslink year are represented in Figure 2-13 to compare the reporting year to each of the previous post-Basslink monitoring years. As the post-Basslink period began on 1 May 2006, the annual periods for each of the post-Basslink duration curves are from May to April. Hence, the curve for 2015–16 differs slightly from the annual curve Figure 2-10 as it represents a 12-month period that is offset by two months. Comparison of the curves indicates the significant variability in flow discharge in the post-Basslink period. Compared to other years, 2015–16 had a flow duration that consisted of a high proportion of high and mid-range flows, and relatively few low flows.

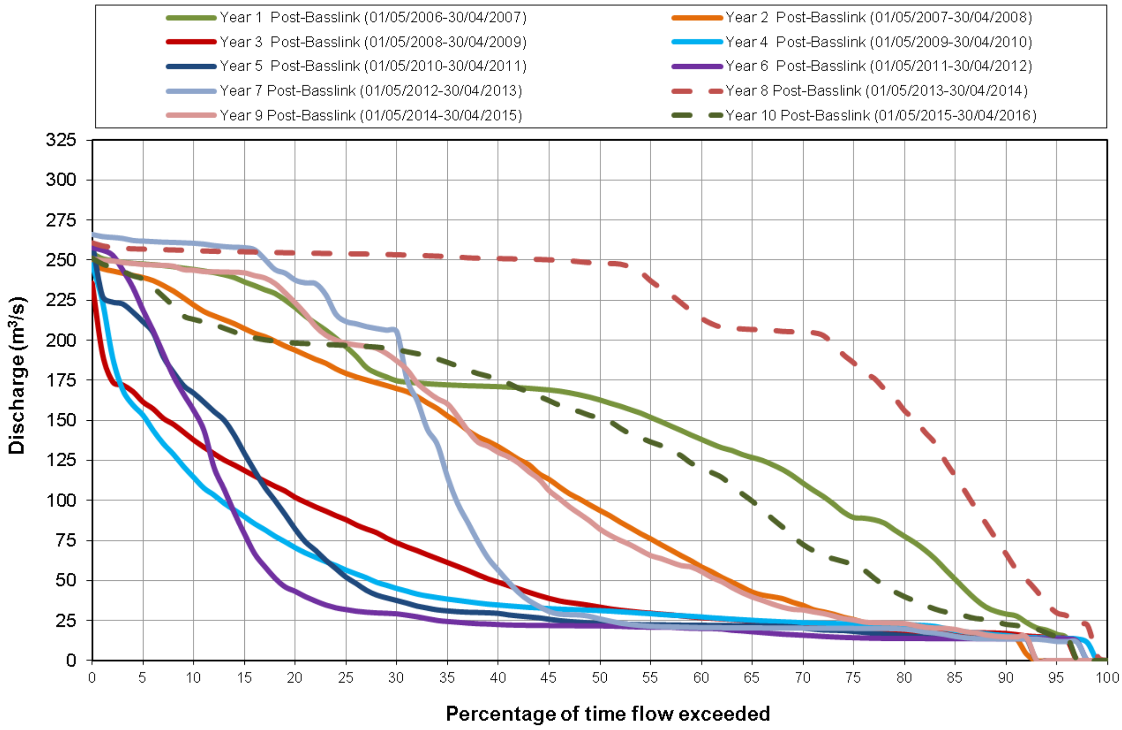

Figure 2-13: Annual duration curves for discharge from the Gordon Power Station for the ten years post-Basslink.

2.5.3.5 Peaking hydrological triggers

Time series of peaking event triggers are presented in Figure 2-14 and Figure 2-15. Peaking event exceedances in 2015-16 were observed for the 35-100 m^3s^{-1} trigger for most of July 2015. The maximum number of peaking events across 35-100 m^3s^{-1} range was 83 in the previous 90 day period. This continued the exceedance first observed in June 2015, following extended peaking operation that had begun in April 2015. Both peaking triggers followed a similar pattern, declining rapidly through the months of August to December 2015. The triggers remained low for the remainder of the year while more stable discharge patterns prevailed. Monitoring undertaken as a result of the exceedance was undertaken in April 2016 in conjunction with the scheduled biennial monitoring.

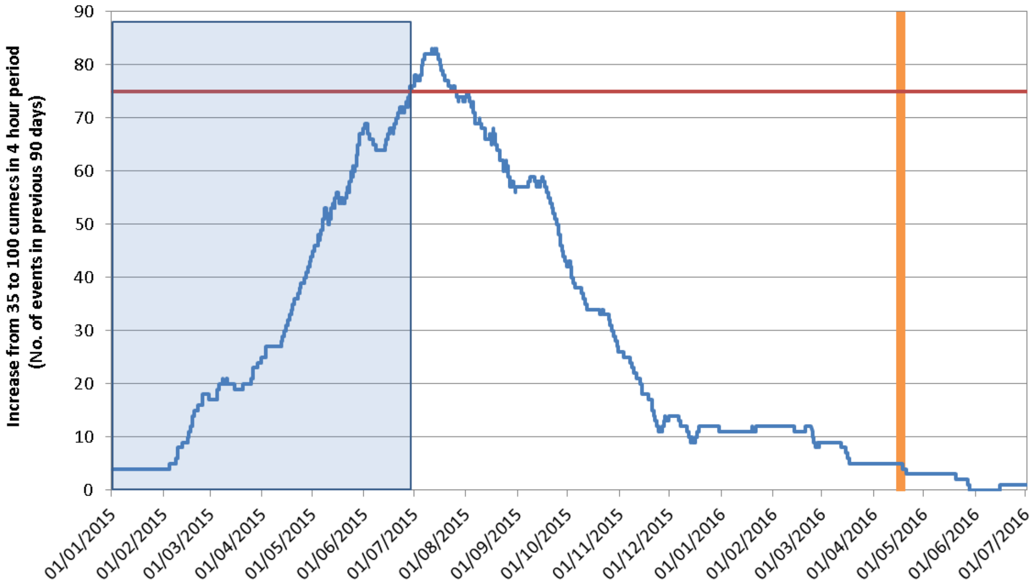

Figure 2-14: Time series (1 January 2015 -30 June 2016) of flow increases from 35 to 100 m^3s^{-1} in a four hour period, counted over the previous 90 days. Trigger value marked by red line, monitoring period marked by orange bar. Blue shaded area included in last year's hydrological monitoring period.

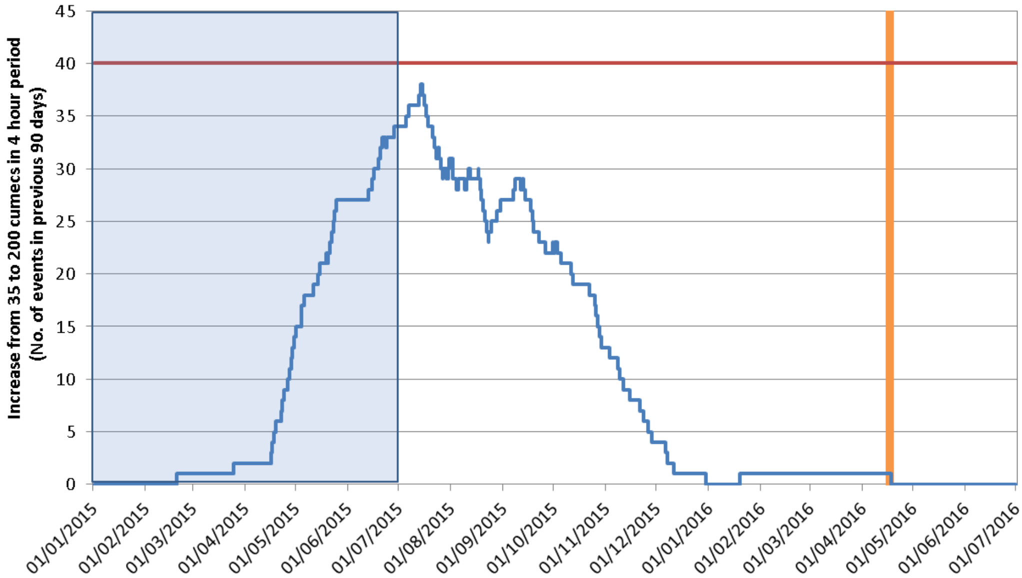

Figure 2-15: Time series (1 January 2015 -30 June 2016) of flow increases from 35 to 200 m^3s^{-1} in a four hour period, counted over the previous 90 days. Trigger value marked by red line, monitoring period marked by orange bar. Blue shaded area included in last year's hydrological monitoring period.

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2.5.3.6 Compliance with the ramp-down rule

Mitigation measures (ramp-down rule and minimum environmental flow) were excluded from analysis for the period corresponding to the Basslink outage (20 December 2015 to 13 June 2016). They were excluded as Hydro Tasmania has no obligation under the Special Licence Agreement to implement these during the temporary or permanent outage of Basslink.

In 2015-16, full compliance with the ramp-down rule was achieved. During the monitoring period (July 2015–June 2016) the ramp-down rule was required to be applied for 1,852 hours (i.e. while the bank water level was >2.75 m and the power station discharge was >150 m^3s^{-1}). The control system was correctly set for all of those periods, resulting in complete compliance.

2.5.3.7 Evaluation of rate of change in generation

While the control system was automatically set to reduce generation at a rate of 1 MW per minute, when the modelled saturation and flow conditions were exceeded, there were occasions when the rate of generation reduction exceeded this rate.

Of the 1,852 hours where ramping was required during flow reductions, those that exceeded 1 MW per minute occurred on 50 separate events (Appendix B), and totalled a little less than 9 hours (0.48 % of time that the ramp-down rule was applied). Of these events, the majority (82 % or 41 events) had a maximum reduction rate that was not in excess of 1.1 MW per minute. The exceedances of 1 MW per minute occurred as a result of over-riding causes that were beyond operator control, and are not considered to be non-conformances. There were two principal reasons for the exceedances of the target reduction rate of 1 MW per minute:

- **Frequency excursions in the NEM:** can prompt a machine governor response. Common causes of such excursions include Basslink reversal, customer load reductions, and major changes in plant output anywhere in the NEM. This is a local governor response outside the 1 MW per minute control. In such instances, the power station is being used to stabilise the frequency and voltage within the NEM. This governor response is an intrinsic aspect of the machine, and an essential aspect of maintaining a stable electrical system and is beyond the control of the operators; and
- **Machine trips (sudden, automatically triggered shutdowns):** These can be triggered by fault detection at the machine or by a power system network event that will automatically trip the machine. These trips over-ride other intended operation and are beyond operator control.

2.5.4 Gordon above Denison (site 65—environmental flow compliance site)

Site 65 is located in the Gordon River downstream of the power station, approximately 2 km upstream of the Denison confluence. This site monitors the minimum environmental flow required under the Special Water Licence Agreement.

2.5.4.1 Flow

Figure 2-16 shows the flow recorded at site 65 for 2015–6 and indicates close concordance with power station discharge to which peak values (the result of high flows from tributary streams, such as the Albert and Orange Rivers) are added.

Notable high tributary inflows were seen in July 2015 and May 2016, with a number of smaller inflows evident in June 2016. The departure of the hydrograph from that of the Gordon Power Station discharge is indicative of these tributary inflows.

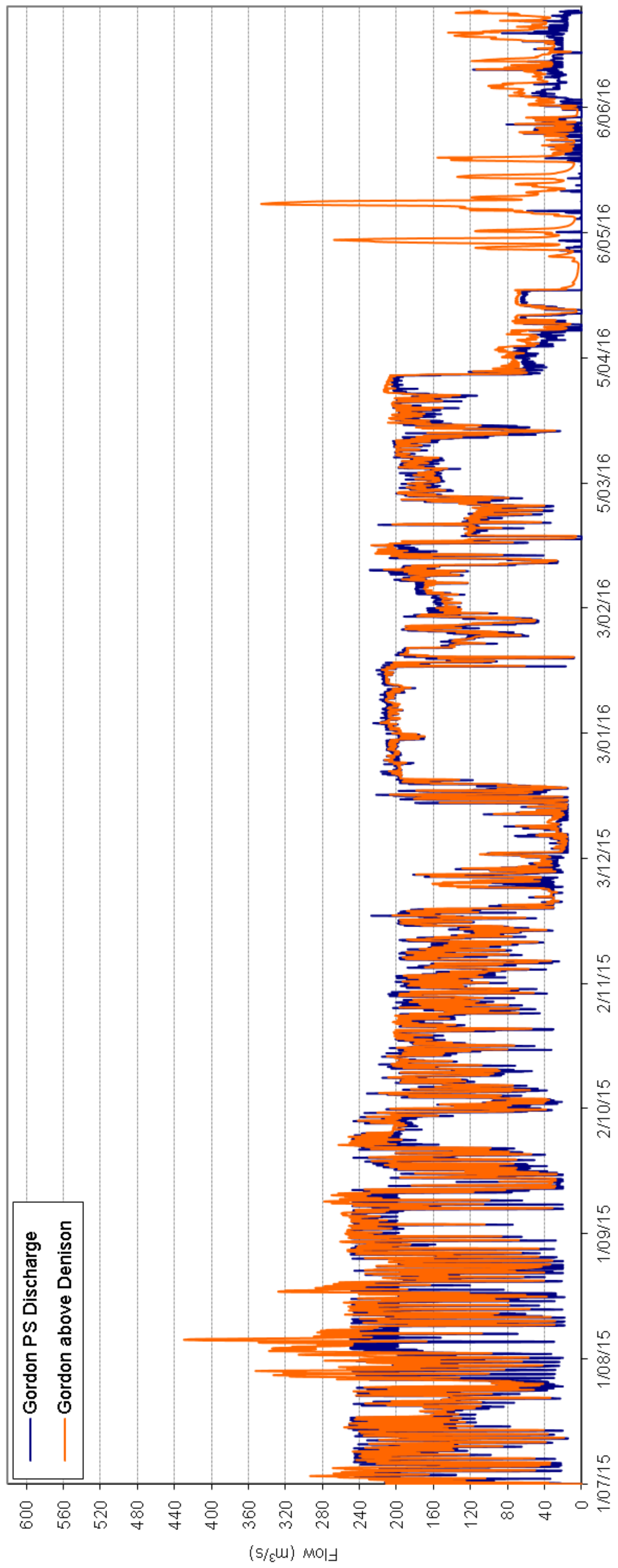

Figure 2-16: Flow recorded (hourly data) at site 65 (Gordon above Denison) showing full scale of flows, from July 2015 to June 2016.

2.5.4.2 *Median monthly flows*

The median monthly flow for site 65 (Gordon above Denison) is shown in Figure 2-17. Comparison with historic average (2003–16) patterns shows monthly median flows from July to November 2015 were well above average. December 2015 to April 2016 flows were near long term median values. The period May to June 2016 had median flows that were lower than the long term average. These followed a very similar pattern to those of the Gordon Power Station discharges.

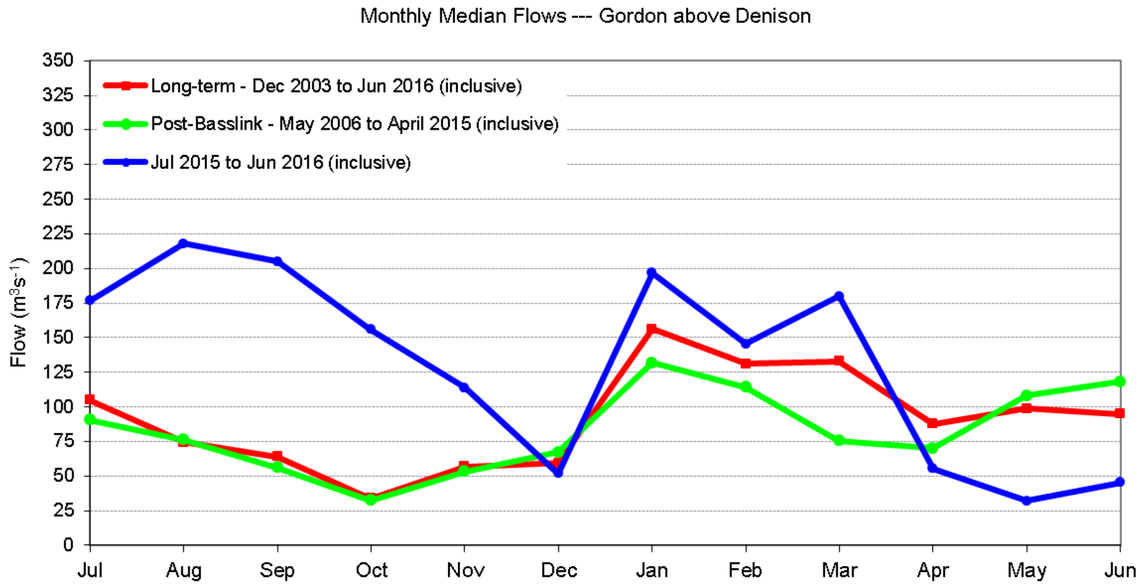

Figure 2-17: Median monthly flow at site 65 (Gordon above Denison) for 2015–16 compared with long-term median values and previous post-Basslink years.

2.5.4.3 Duration curves

The duration curve for site 65 is shown in Figure 2-18. Comparison of the 2015-16 duration curve with the post Basslink curve shows a very similar distribution of flows. There are no remarkable features of the duration curve in 2015-16.

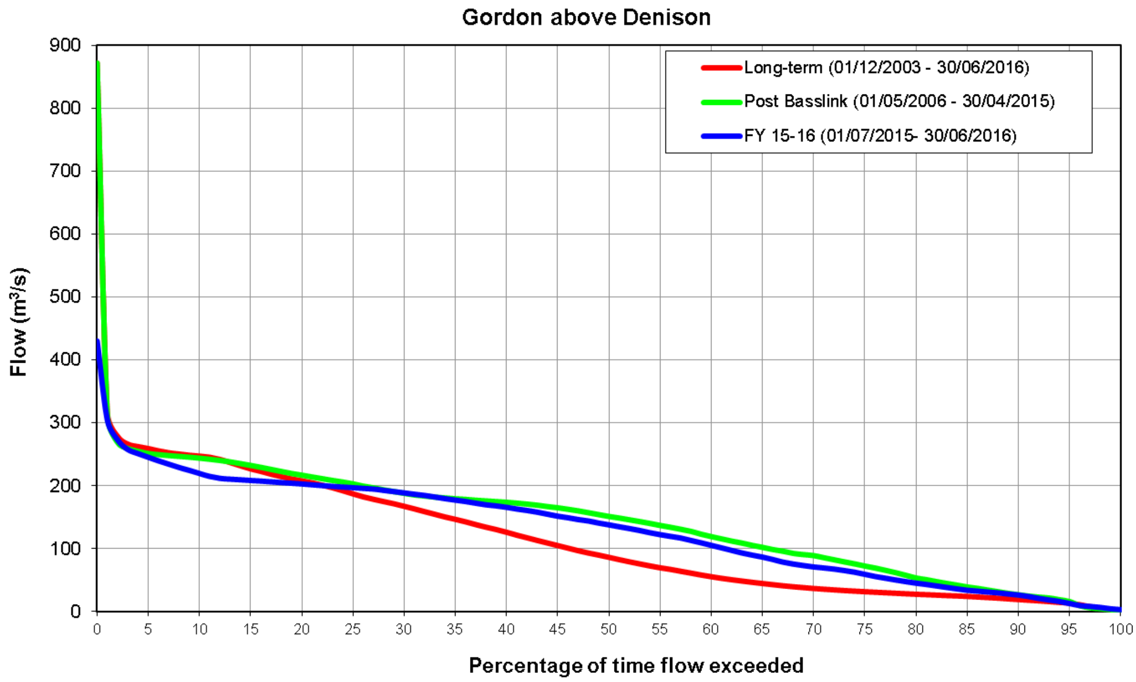

Figure 2-18: Flow duration curve for Gordon above Denison for 2015–16 compared with long-term and previous post-Basslink years.

2.5.4.4 *Environmental flow compliance*

Mitigation measures (ramp-down rule and minimum environmental flow) were excluded from analysis for the period corresponding to the Basslink outage (20 December 2015 to 13 June 2016). They were excluded as Hydro Tasmania has no obligation under the Special Licence Agreement to implement these during the temporary or permanent outage of Basslink. Periods of the Basslink outage as well as other exempt conditions (shutdown of the Gordon Power Station due to maintenance, AEMO conformance testing, and/or monitoring) have been excluded from the analysis, as indicated in Figure 2-19 by the reduction of minimum environmental flow requirement to zero.

For the period from December to May the minimum environmental flow required is 10 m^3s^{-1}, and for the periods from June to November the minimum environmental flow required is 20 m^3s^{-1}.

The analysis of hourly flows at site 65, taking exempt periods into consideration (Figure 2-19) shows that during the winter periods (July–November 2015 and June 2016), flow requirements were met 99.98% of the time, with a single hour on 12 July when flows were measured at 19.3 m^3s^{-1} (0.7 m^3s^{-1} below the required flow). During the summer period (December 2015–May 2016), flow requirements were met 100 % of the time.

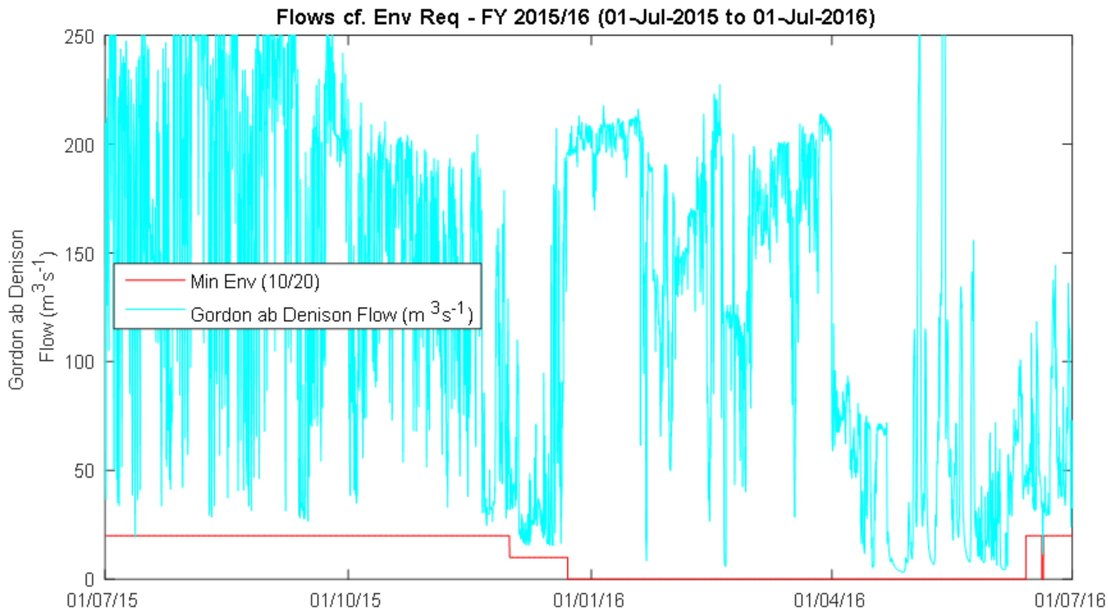

Figure 2-19:Flow recorded (hourly data) at site 65 (Gordon above Denison), from July 2015 to June 2016, and analysis of non-conforming flows. Red line indicates the flow requirement to be met.

2.5.4.5 High flow hydrological triggers

Flows at the compliance site remained below the high flow hydrological triggers for the whole of the 2015-16 period (Figure 2-20, Figure 2-21).

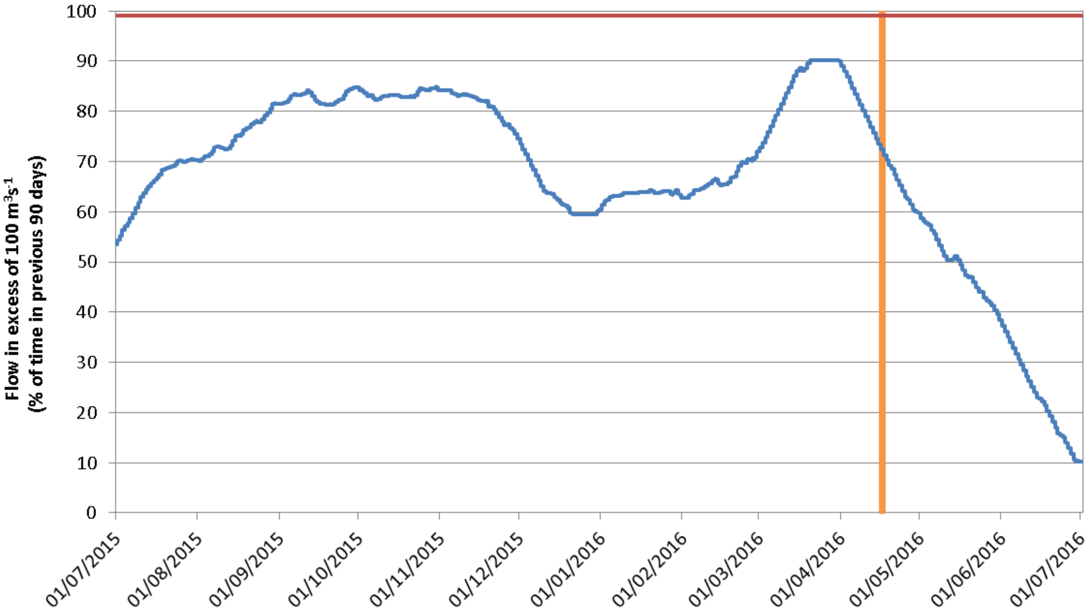

Figure 2-20: Time series (July 2015-June 2016) of percentage of time in previous 90 days in excess of 100 m^3s^{-1}. Trigger value (99%) marked by red line, monitoring period marked by orange bar.

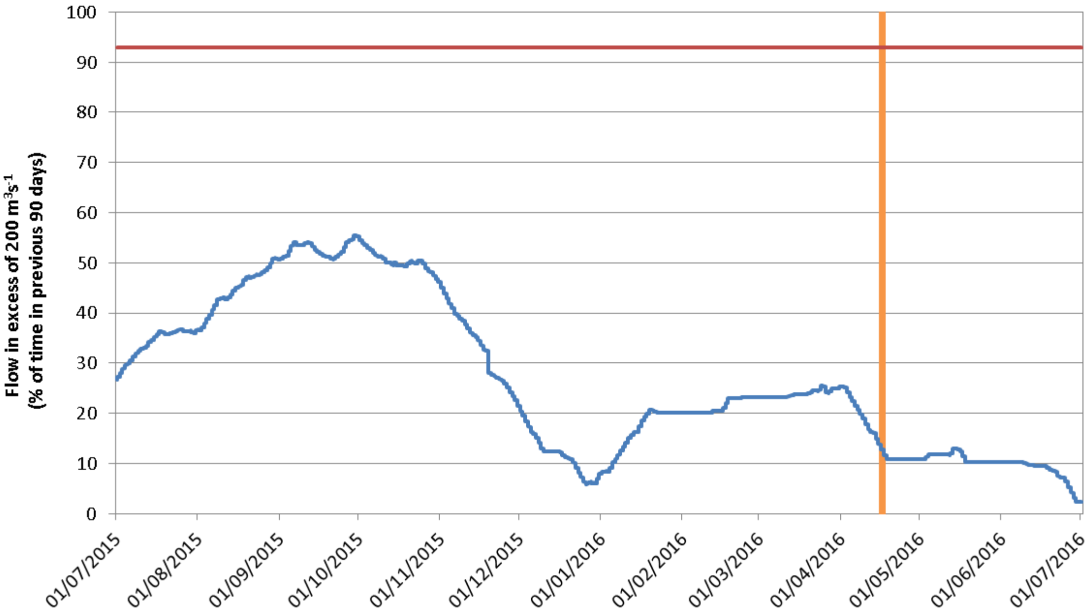

Figure 2-21: Time series (July 2015-June 2016) of percentage of time in previous 90 days in excess of 200 m^3s^{-1}. Trigger value (93%) marked by red line, monitoring period marked by orange bar.

2.5.5 Gordon above Franklin (site 44)

The Gordon above Franklin site (site 44) is the furthest downstream monitoring site on the Gordon River. Power station discharges travel 33 km down the Gordon River before passing the gauge at site 44. The measured flow at this point is a combination of the power station discharge as well as the input from a number of significant tributaries, including the Albert, Orange, Denison, Maxwell, Olga and Sprent rivers. The Franklin River joins the Gordon downstream of site 44 and therefore is not included in the gauged data. Data from site 44 provides an indication of the influence of tributary streams and flow attenuation of the power station discharge on hydrology of the lower reaches of the river. The Site was closed on 11 June 2016 due to safety concerns.

2.5.5.1 Flow

Figure 2-22 shows the hourly flows at site 44 for 2015–16 compared with discharge from the Gordon Power Station.

The flow rating at this site is based on only a small number of gaugings undertaken during monitoring periods. Of these, few gaugings have been taken at high flows, and it is acknowledged that the flow estimation, particularly at higher flows, may be an under-estimate. In 2015–16, power station discharge continued to be a major flow component at site 44. However, there were some substantial divergences in hydrographs on a number of occasions where tributary flows (i.e. Denison River) provided a major proportion of the flow. High tributary flows occurred in July-August 2015, and the highest tributary inflows were seen in April, May and June 2016. The maximum flow of 970 m^3s^{-1} for the year occurred on 13 May 2016.

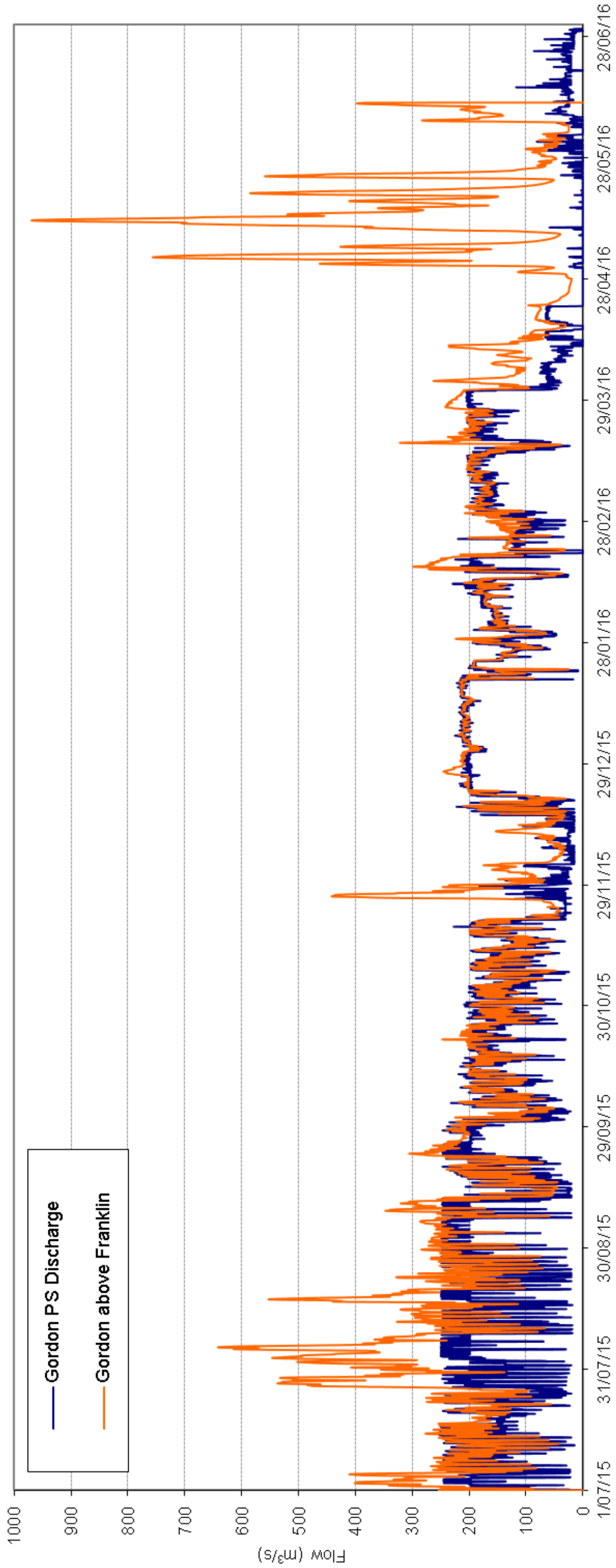

Figure 2-22: Flow recorded (hourly data) at site 44 (Gordon above Franklin) and Gordon Power Station discharge during 2015–16.

2.5.5.2 Median monthly flows

Figure 2-23 shows the median monthly flow for the data at site 44 over the 2015–16 year, compared with the long-term post-dam (since January 1978) and post-Basslink patterns. Monthly median values in the monitoring year were higher than long term and post-Basslink periods from July to October 2015. The remainder of the year had similar median values with the exception of April, which had a lower than normal flow due both to low power station discharge and low tributary inflows.

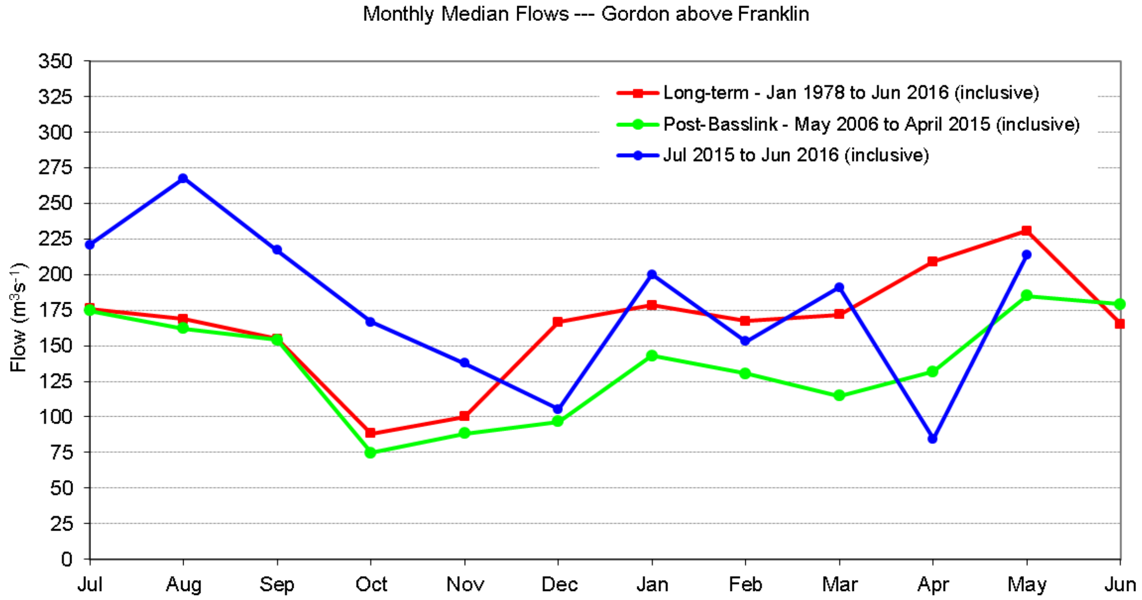

Figure 2-23: Median monthly flow at site 44 (Gordon above Franklin) for 2015–16 compared with long-term median values and previous post-Basslink years.

2.5.5.3 Duration curves

The duration curve for site 44 is shown in Figure 2-24. Comparison with the long-term curve is indicative of the similar distribution, with similar flows to those of the long term record.

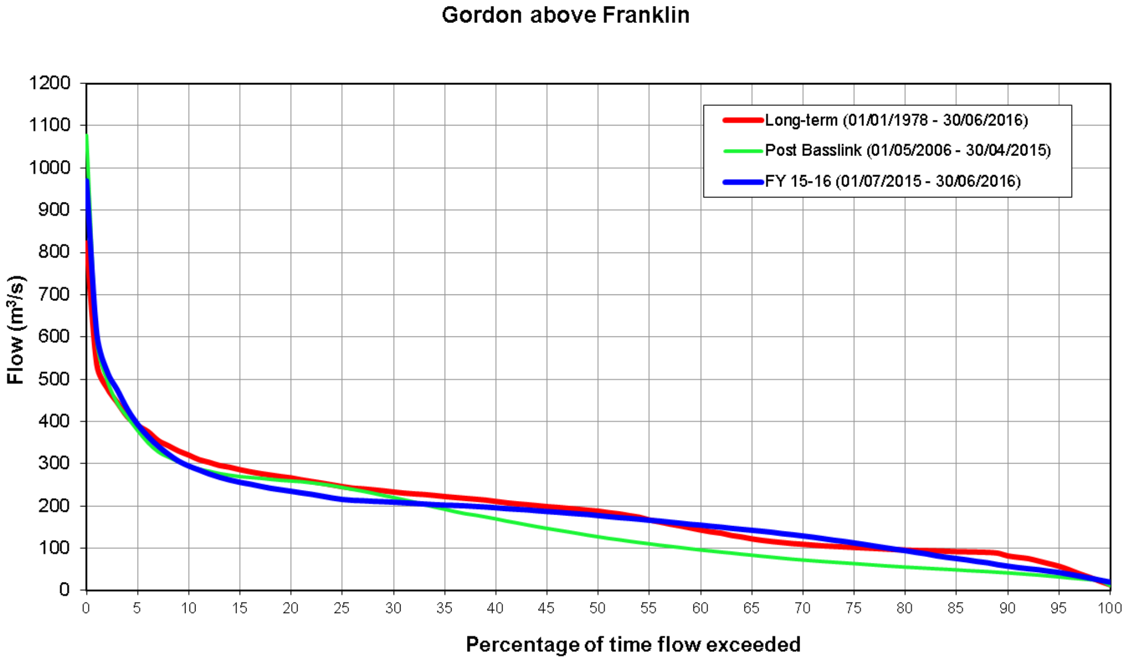

Figure 2-24: Flow duration curve for Gordon above Franklin (Site 44) for 2015–16 compared with long-term and previous post-Basslink years.

2.6 Conclusions

Discharges from Gordon Power Station were substantially higher than the long term averages in July-September 2015, and substantially lower than the long-term average in April to June 2016.

Mitigation measures (ramp-down rule and minimum environmental flow) were excluded from analysis for the period corresponding to the Basslink outage (20 December 2015 to 13 June 2016). Mitigation measures were excluded, as Hydro Tasmania has no obligation under the Special Licence Agreement to implement these during the temporary or permanent outage of Basslink.

For all periods outside the Basslink outage date range, the ramp-down rule continued to be applied successfully in 2015-16. All ramping was consistent with the water licence requirements, as the system for controlling the rate of generation reduction was automatically activated under all trigger conditions (>2.75 m modelled bank level, >150 m^3s^{-1} discharge).

For all periods outside the Basslink outage date range, the minimum environmental flow requirements of 10 m^3s^{-1} in the summer period and 20 m^3s^{-1} in winter period were met 100 % of the time in summer and 99.98% of the time in winter.

One of the four hydrological peaking triggers (peaking between 35-100 m^3s^{-1}) was exceeded in June and July 2015.

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3 Fluvial geomorphology

3.1 Introduction

This chapter summarises the 16 April 2016 monitoring results and relates the findings to the current understanding of geomorphic processes in the middle Gordon River.

The aims of geomorphology monitoring in the Gordon River include:

- to document fluvial geomorphological processes and changes in the middle Gordon River between the power station tailrace and Sunshine Gorge (upstream of the confluence with the Olga River);
- to relate these changes to power station operations, including the ramp-down rule or other factors wherever possible; and
- to compare results with previous results to enhance the present understanding of the interaction between flow components and fluvial geomorphic response.

Twice yearly fluvial geomorphic monitoring was conducted in the middle Gordon River from October 2001 to 2014. Under a revised, on-going program, monitoring has continued at a reduced number of the geomorphic sites every 1-2 years, depending on the power station discharge regime.

The main aim of the on-going monitoring program is to use the results to continue to validate the conceptual model and to ascertain if and how the rates and trends, tracked by the monitoring program, are changing.

Field work completed in April 2016 included field observations, the measurement of the long-term erosion pin monitoring sites and photo monitoring.

3.2 Methods

Basslink geomorphology monitoring methods are described in detail in the first pre-Basslink fluvial geomorphology monitoring report (Koehnken and Locher, 2002) and the Basslink Baseline Report (Hydro Tasmania 2005a, 2005b) and these documents should be consulted for a detailed description and background material pertaining to the monitoring program. Descriptions of the zones, bank types and processes operating in the middle Gordon River are contained in the initial Basslink IIAS report (Koehnken et al. 2001) and the Basslink Baseline Report (Hydro Tasmania, 2005a, 2005b). A history of monitoring in the middle Gordon associated with the Basslink monitoring program is shown in Table 3-1.

The current sub-set of erosion pin and photo-monitoring sites (Figure 3-1 to Figure 3-5, Table 3-2) were selected for continued monitoring based on the following criteria:

- the sites selected reflect a range of geomorphic properties considered to be representative of the middle Gordon River and monitoring results have shown a clear relationship between power station operations and geomorphic processes at these sites;
- the banks of these sites reflects one of the recognised stages of 'bank progression' linked to power station operations (e.g. stabilised by tea tree, loss of tea tree, onset of seepage/scour processes depending on bank slope, reduction in slope of bank toe, increase in slope of bank face etc.);

- a long historic monitoring record and stability of erosion pins over time; and
- their accessibility.

Table 3-1: Summary of geomorphology monitoring activities in the middle Gordon River between 1999 and present.

Monitoring Type	Season	Dates	Monitoring completed
Pre-Basslink		11 December 1999 18 December 1999 4 March 2000 25 March 2000 22 July 2000 2 September 2000 4 August 2001	Investigations for IIAS: Field observations Erosion pin measurements Photo monitoring Scour chains Painted cobbles
Pre-Basslink	Spring 2001	23 November 2001 9 December 2001	Field observations Erosion pin measurements
Pre-Basslink	Autumn 2002	10 February 2002 9 March2002	Field observations Erosion pin measurements Photo monitoring
Pre-Basslink	Spring 2002	5 October 2002 16 December 2002	Field observations Erosion pin measurements
Pre-Basslink	Autumn 2003	29 March 2003	Field observations Erosion pin measurements Photo monitoring
Pre-Basslink	Spring 2003	18 October 2003	Field observations Erosion pin measurements
Pre-Basslink	Autumn 2004	6 March 2004	Field observations Erosion pin measurements Photo monitoring
Pre-Basslink	Spring 2004	9 October 2004	Field observations Erosion pin measurements Bank profiling
Pre-Basslink	Autumn 2005	2 April 2005	Field observations Erosion pin measurements Photo monitoring
Pre-Basslink	Spring 2005	15 October 2005	Field observations Erosion pin measurements
Transition	Autumn 2006	11 March 2006	Field observations Erosion pin measurements Photo monitoring
Post-Basslink	Spring 2006	17 October 2006	Field observations Erosion pin measurements
Post-Basslink	Autumn 2007	17 March 2007	Field observations Erosion pin measurements Photo monitoring
Post-Basslink	Spring 2007	20 October 2007	Field observations Erosion pin measurements
Post-Basslink	Spring 2007	1 December 2007	Field observations
Post-Basslink	Autumn 2008	1 March 2008	Field observations Erosion pin measurements Photo monitoring
Post-Basslink	Spring 2008	17 -19 October 2008	Field observations Erosion pin measurements
Post-Basslink	Autumn 2009	21-22 March 2009	Field observations Erosion pin measurements Photo monitoring
Post-Basslink	Spring 2009	17 October 2009 (zones 3&4) & 31 October 2009 (zones 1,2,5)	Field observations Erosion pin measurements

Monitoring Type	Season	Dates	Monitoring completed
Post Basslink	Autumn 2010	12-14 March 2010	Field observations Erosion pin measurements Photo monitoring
Post-Basslink	Spring 2010	19-20 October 2010	Field observations Erosion pin measurements Establishment of vegetation transects at subset of geomorphology monitoring sites in zones 2 – 4.
Ramp-rule investigations	Summer 2011	7-days in January and March 2011	Observations of ramp-downs and draw downs at varying levels of bank saturation associated with investigations to revise ramp-rule.
Post-Basslink	Autumn 2011	26-27 February 2011	Field observations Erosion pin measurements Photo monitoring
Post-Basslink	Spring 2011	5-6 November 2011	Field observations Erosion pin measurements Combined geomorph & vegetation monitoring
Post-Basslink	Autumn 2012	25 -26 February 2012	Field observations Erosion pin measurements Photo monitoring
Interim monitoring	Spring 2012	6 October 2012	Field observations zones (1-4, limited in zone 5) Erosion pin measurements (zones 1-4 only)
Interim monitoring	Autumn 2013	17 March 2013	Field observations Erosion pin measurements Photo monitoring (zones 1-5)
Interim monitoring	Spring 2013	9 November 2013	Field observations Erosion pin measurements (zones 1-5)
Interim monitoring	Autumn 2014	29 March 2014	Field observations Erosion pin measurements Photo monitoring (zones 1-5)
On-going monitoring	Spring 2014	14 October 2014	Field observations Erosion pin measurements Photo monitoring (zones 1-4)
On-going monitoring	Autumn 2016	16 April 2016	Field observations Erosion pin measurements Photo monitoring (zones 1-4)

Table 3.1 continued

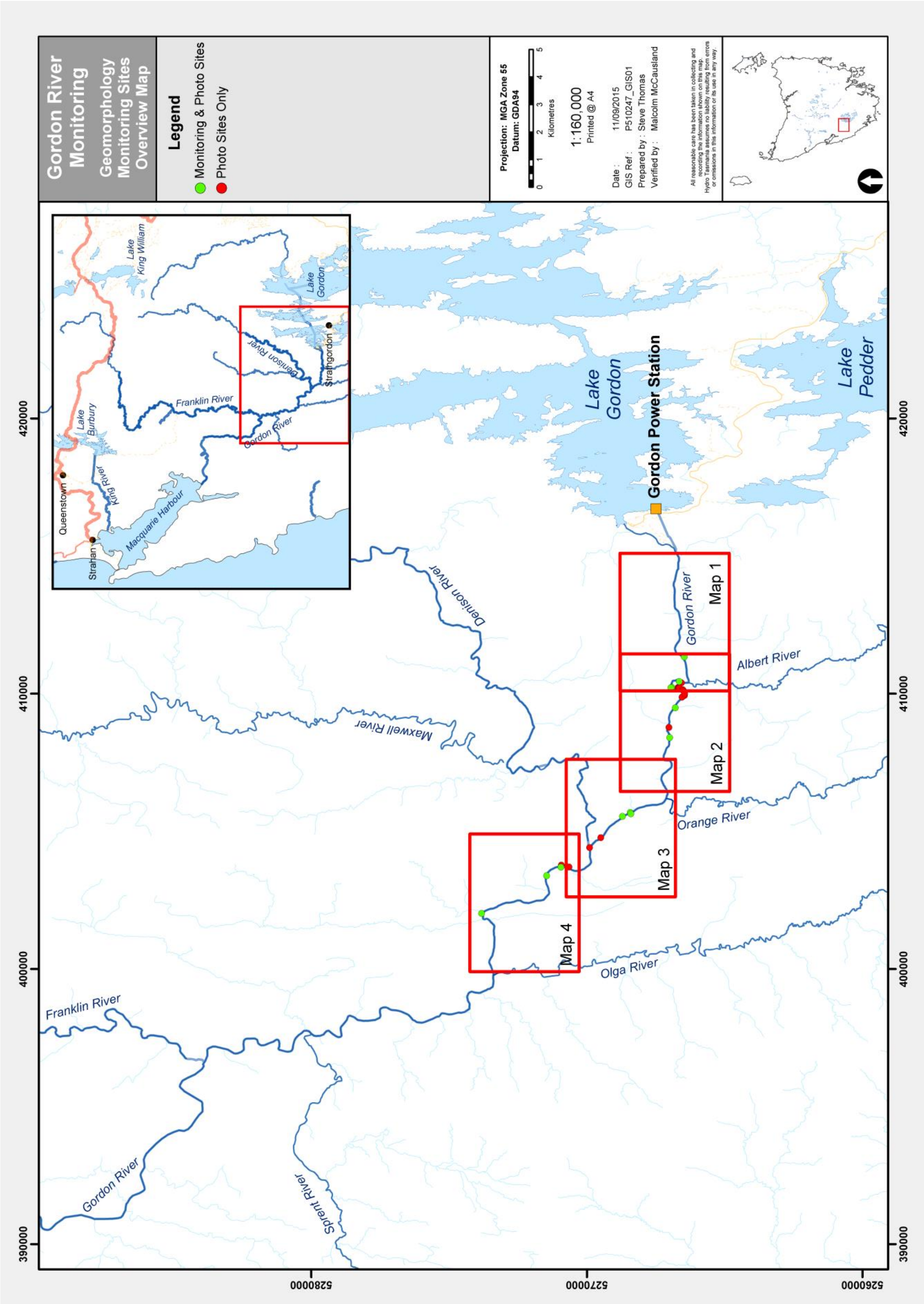

Figure 3-1: Overview of Gordon River geomorphology monitoring sites.

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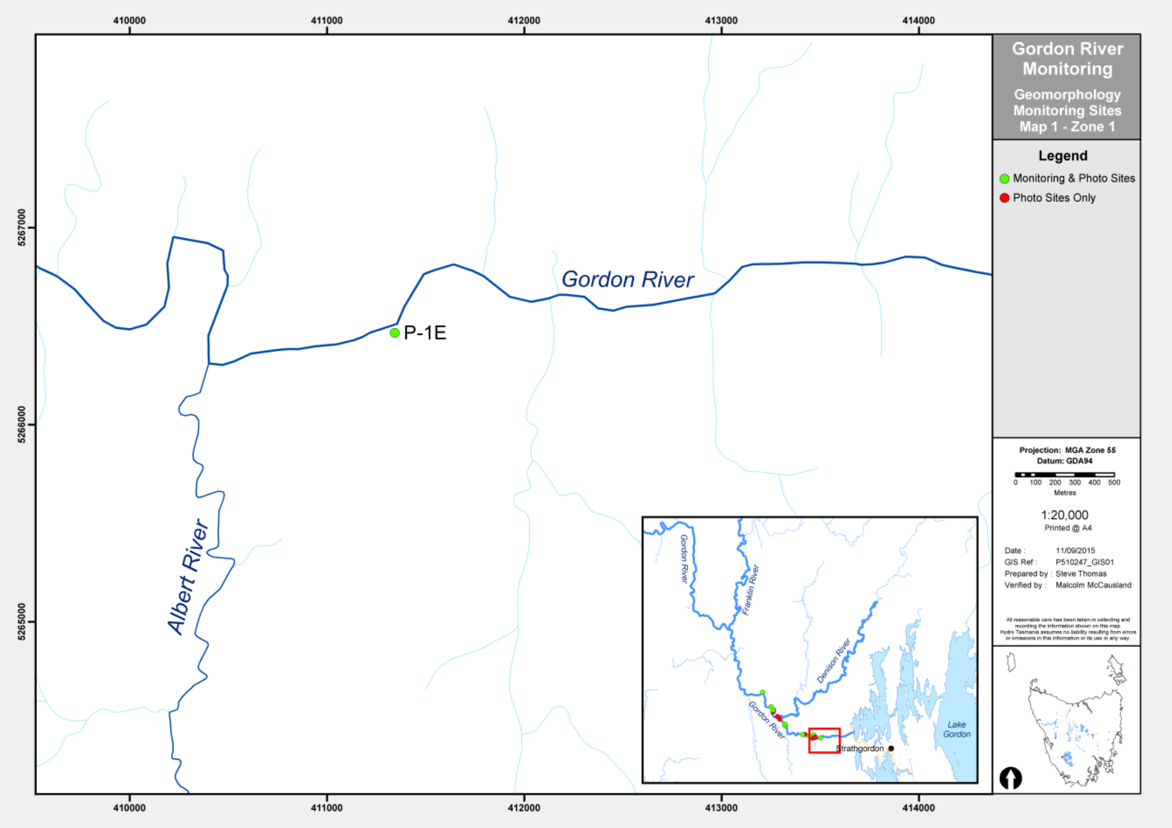

Figure 3-2: Gordon River geomorphology monitoring sites, zone 1.

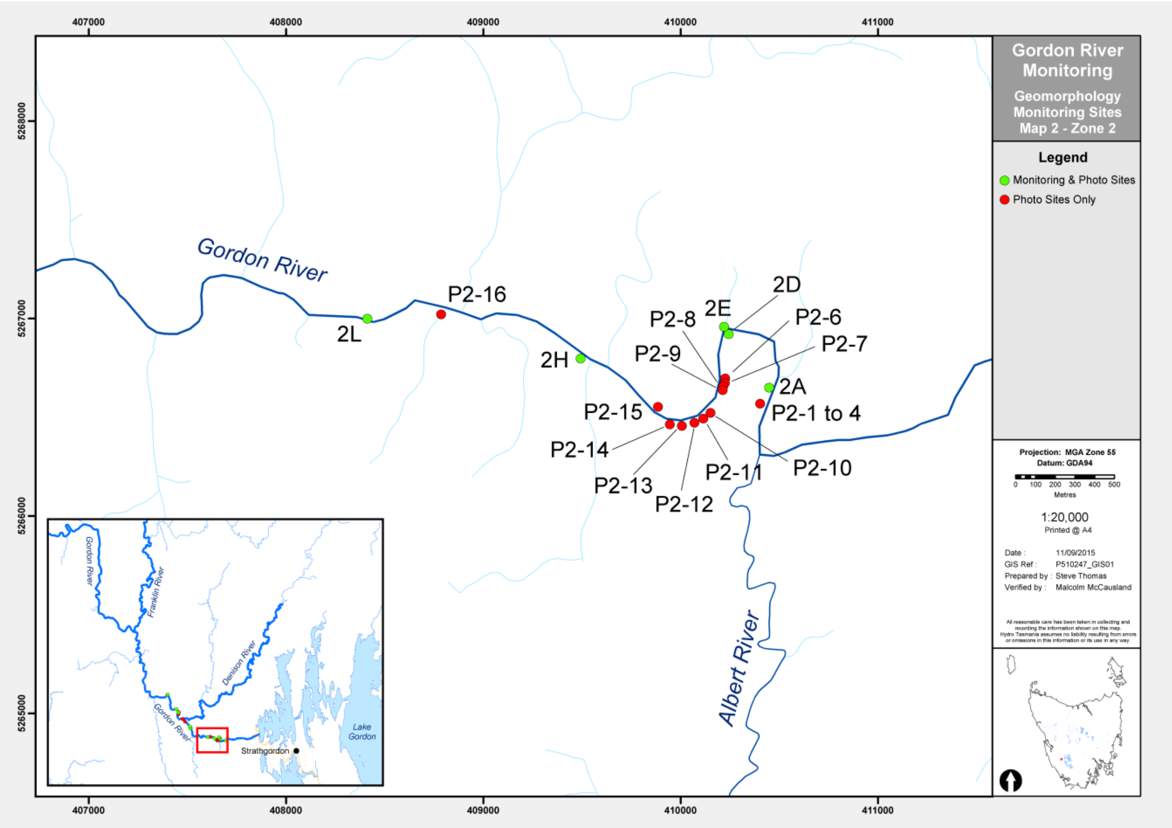

Figure 3-3: Gordon River geomorphology monitoring sites, zone 2.

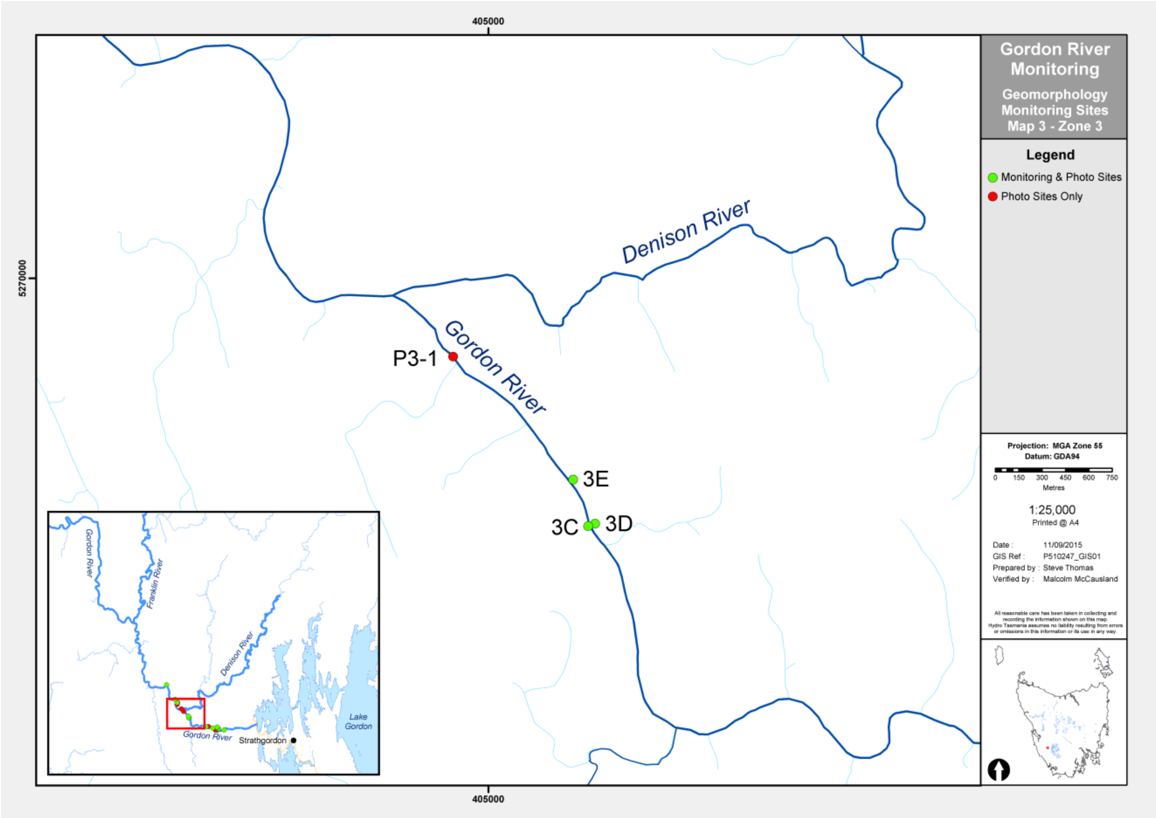

Figure 3-4: Gordon River geomorphology monitoring sites, zone 3.

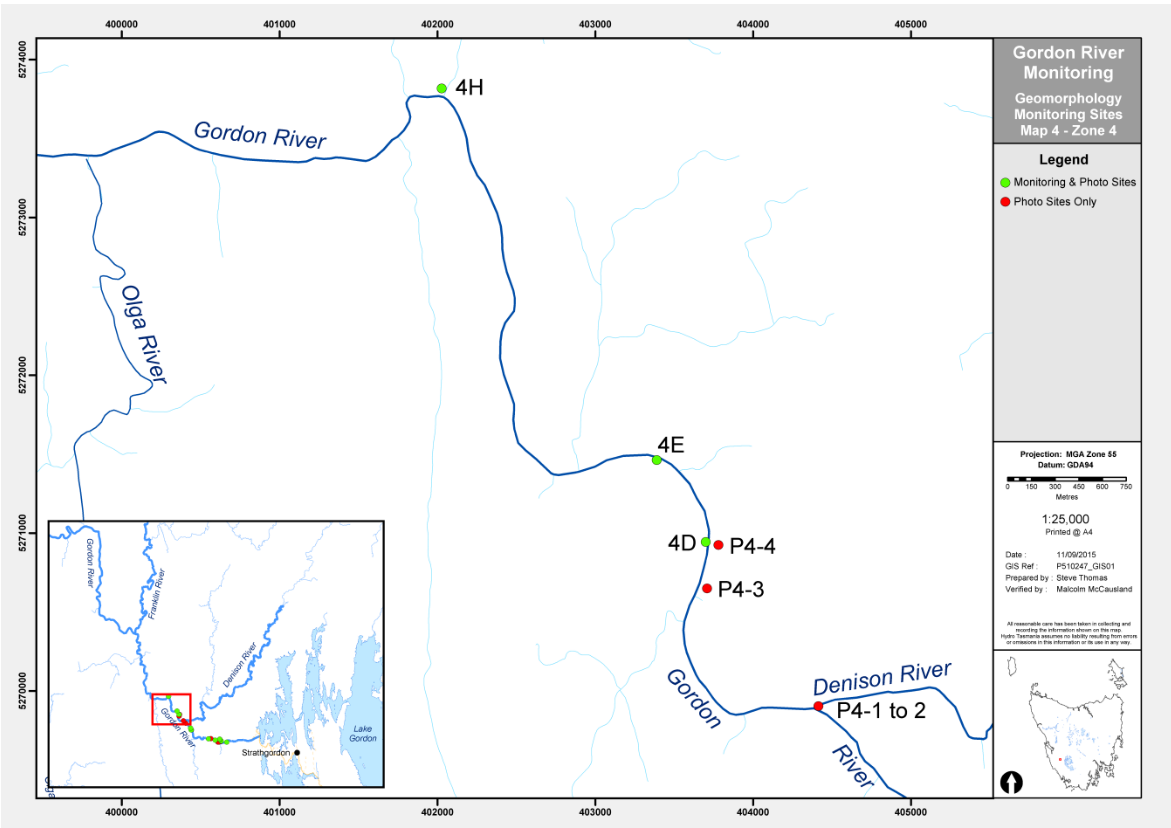

Figure 3-5: Gordon River geomorphology monitoring sites, zone 4.

Table 3-2: Number of monitoring sites and erosion pins in each geomorphology zone.

Zone	No. combined monitoring and photo sites	No. photo-only sites	No. erosion pins
Zone 1	1	0	13
Zone 2	5	16	36
Zone 3	3	1	22
Zone 4	3	4	18
Total	12	21	89

3.3 Monitoring in autumn 2016

The autumn 2016 geomorphology monitoring was undertaken on 16 April 2016. The erosion pins at the long-term sites in zones 1 to 4 were measured and photo monitoring was completed. Water level in the Gordon River was relatively low, with only one of the erosion pins on a bank toe partially submerged (site 3E).

All pins were located and measured. Pin 4E/1 had eroded out of the bank and was lying next to its original position as a result of the high erosion that occurred at this location. At the previous monitoring in October 2014, there had been substantial erosion (281 mm) between March and October 2014. This erosion appears to have continued resulting in the collapse of the pin by April 2016. This pin was re-established at this location in April 2016 and monitoring can continue into the future.

3.4 Overview of hydrology November 2014 to April 2016

A detailed discussion of the hydrology of the Gordon River in the 2015-2016 monitoring year is presented in Chapter 2. The following short discussion highlights hydrologic characteristics relevant to the geomorphology monitoring results in the period since monitoring was last undertaken.

Discharge from the Gordon Power Station between October 2014 and April 2016 (Figure 3-6) is compared to flow at the Gordon above Franklin gauging site (Figure 3-7). The hydrographs show the following features of relevance to the geomorphic investigations:

- The power station was operated intermittently and at generally low volumes through the summer of 2014-2015. This would be expected to produce low levels of erosion and promote the growth of vegetation on the banks;
- Between April 2015 and September 2015, the discharge from the power station was characterised by short-duration high discharge events. This operating pattern can increase the risk of seepage processes if the banks are saturated, and increases the risk of bank scour due to the large number of times the water level passes over the bank face;
- In October and November 2015, discharge decreased and the number of shut-downs was limited, which likely reduced seepage risks following the extend period of high discharge;
- During the summer of 2015-16, the power station operation was characterised by long-duration high flow events which can promote scour of the bank faces;

- Immediately prior to April 2016 monitoring, the power station discharge was low, and sufficiently high natural inflows would have had the potential to deposit material on the bank toes;
- There were few natural high flow events in the lower catchment since the previous monitoring. The lack of high flow events would have reduced the risk of erosion, but also limited the amount of sediment entering from the tributaries during the winter and spring period.

Overall, a large volume of water was discharged through the power station in the 18 month period preceding monitoring. The power station discharge magnitude in 2015-16, as indicated by the flow duration curve was similar to the period during the extended period of low rainfall in Tasmania, in 2006-07 (Figure 2-13).

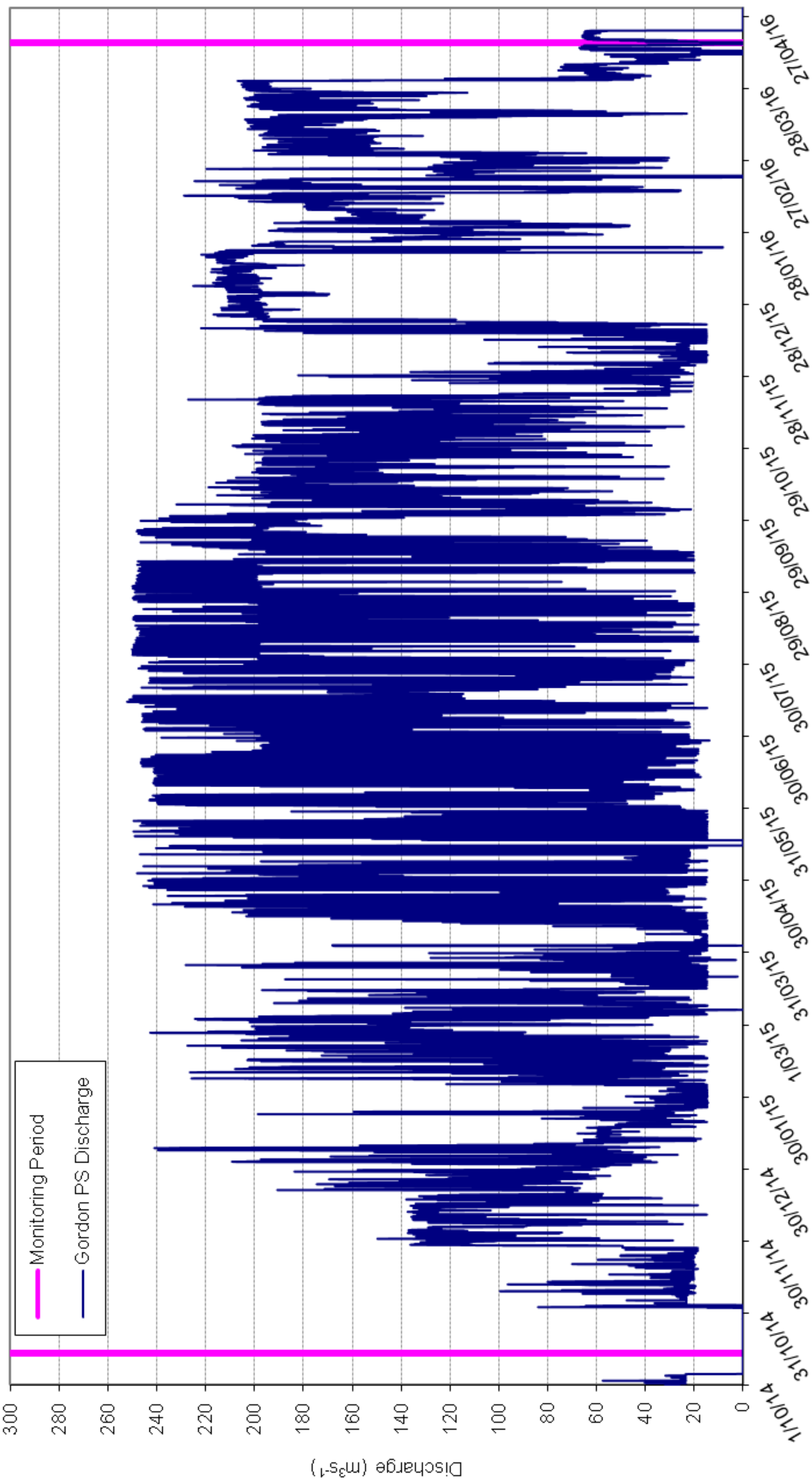

Figure 3-6: Hydrograph of discharge from the Gordon Power Station for 18-month period prior to April 2016 monitoring. Purple bar indicates date of previous and most recent monitoring

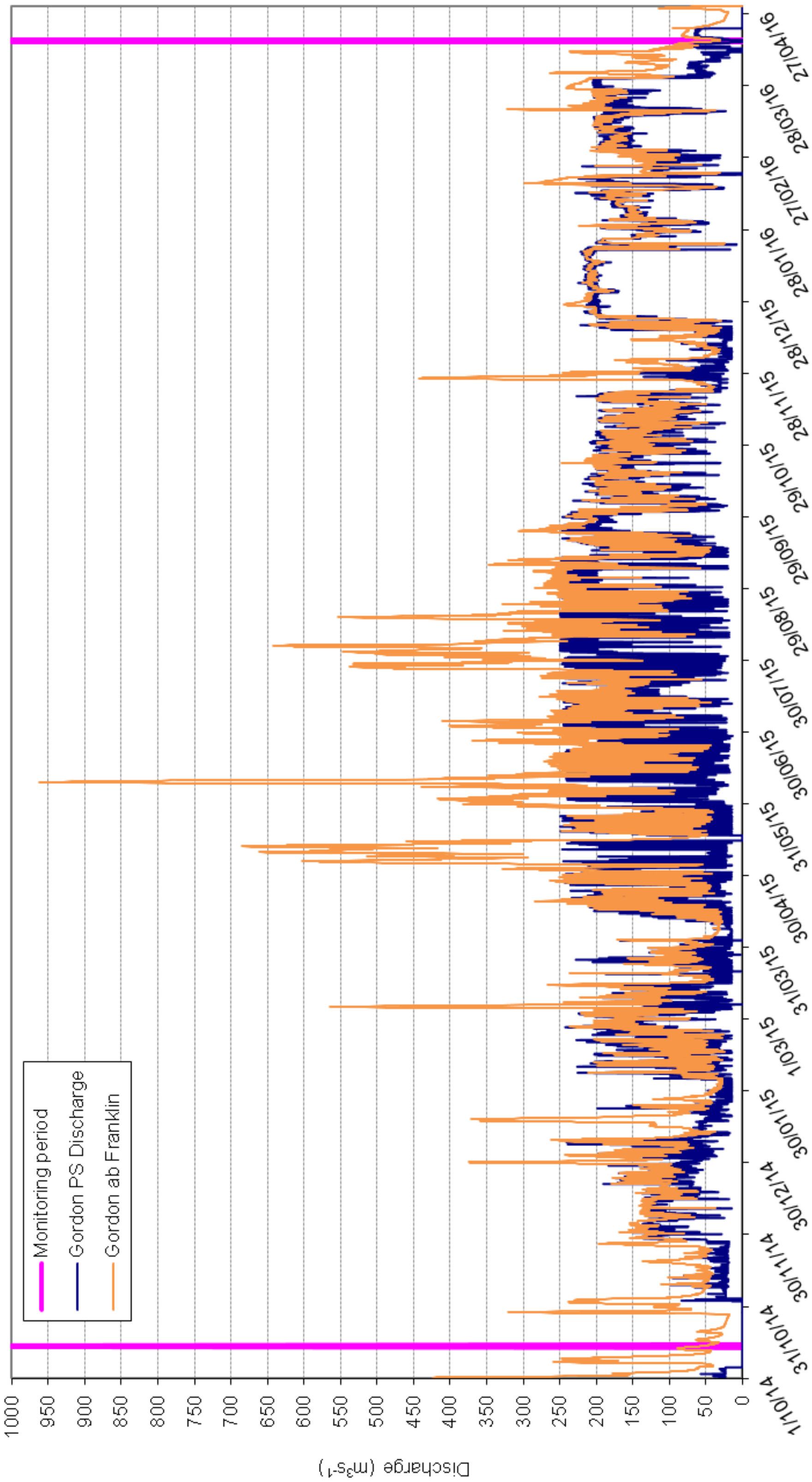

Figure 3-7: Flow at the Gordon Power Station, and the Gordon above Franklin River sites for 18-month period prior to April 2016 monitoring. Pink bars indicate date of previous and most recent monitoring.

The rate of water level change is also relevant to bank stability. To minimise potential seepage erosion, ramping rules are in place to limit the draw down rate at the Gordon Power station when bank saturation and the risk of seepage erosion is high. While these rules are effective at reducing seepage processes, a large number of water level fluctuations can also contribute to scour due to the regularity with which the longitudinal water surface slope increases (increasing the shear stress of the water) as it flows over the bank faces.

Figure 3-8 shows the number of hours that discharge changed by a given amount between successive hours during high power station discharge. The analysis for flow variation (Figure 3-8) shows that for 1 April 2015 to 1 October 2015 (dark blue line) there was a high rate of water level changes with the largest number of hours recorded where discharge decreased by >30 $m^3s^{-1}h^{-1}$. This pattern of flow reductions was similar to operation during the extended period of low rainfall in 2007. This does not imply that the ramp rule was not adhered to, or that seepage processes increased, as flow reductions of this magnitude are permitted under the rule as long as the bank saturation conditions are within a certain range

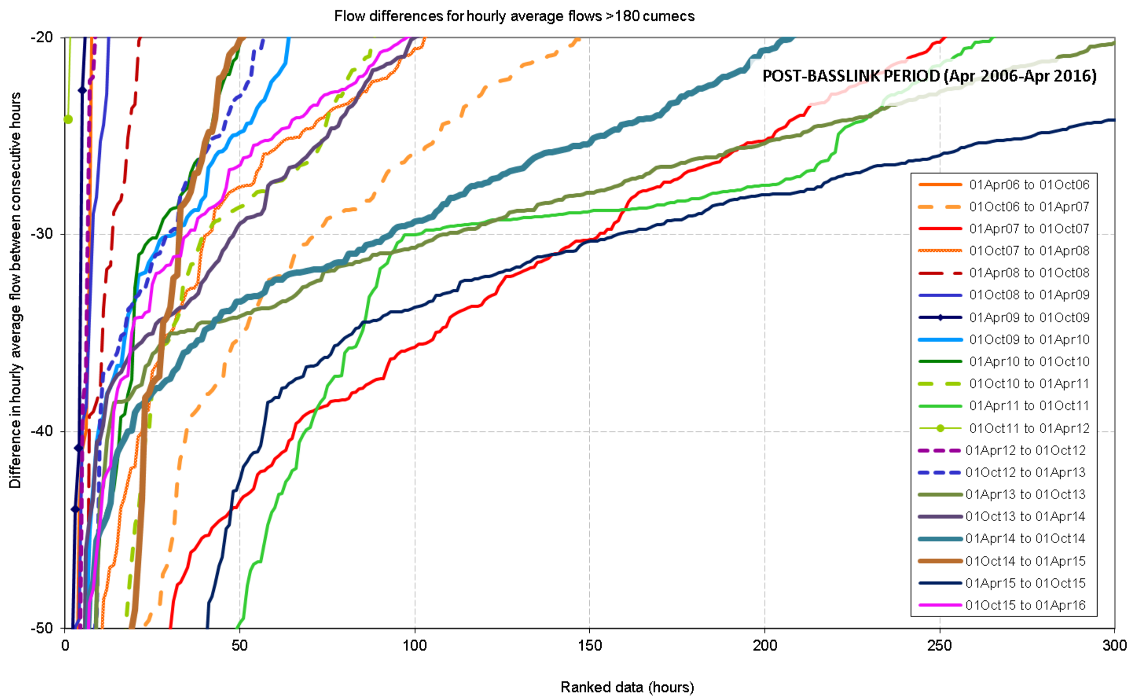

Figure 3-8: The number of hours average hourly flow change in the range -50 to -20 m^3s^{-1} for 6-month periods between April 2006 and April 2016.

3.5 Monitoring results

3.5.1 Field observations in autumn 2016

Field observations in autumn 2016 included the following:

- The exposed sand bar at the upstream end of zone 2 (in the pool downstream of the Albert River and upstream of the first riffle) that was first noted in October 2014 remains exposed. Assuming it has been present since first observed, it is likely that this new bar is related to the altered hydraulics of the river following increased discharge from the Gordon Power Station rather than a one-off event in the catchment in 2014;

- There was widespread evidence of erosion through bank scour; smooth bank surfaces lacked any evidence of deposition, and there was a large reduction in the amount of sand on some banks, especially in zones 3 and 4 (Figure 3-9, Figure 3-10);
- Mud veneers and algae growth were present on bank toes in zones 1 and 2 but were not observed in zones 3 and 4. These deposits and growth are likely due to the low discharge from the power station in the month prior to monitoring (Figure 3-11);

Figure 3-9: Examples of bank toes showing scour and lack of deposition of organic debris at sites 2D (left) and 3E (right).

Figure 3-10: Comparison of erosion pin site 4D in October 2014 (left) and April 2016 (right) showing a large reduction in sand deposits.

Figure 3-11: Algal growth and mud on bank toe in zone 2 (site 2A).

Figure 3-12: Three trees located at the water's edge in zone 2 that have recently died.

Figure 3-13: Large Huon Pine that is located upstream of erosion pin site 2L (left). Site of recent Huon Pine collapse in zone 3 (right).

3.5.2 Erosion pin results

Erosion pin measurements were collected from 12 sites in geomorphic zones 1 – 4. The results from autumn 2016 are shown for each pin at each site along with the historic results for each pin (Figure 3-15 to Figure 3-20).

Most of the sites recorded erosion, with some sites in zones 3 and 4 recording some of the highest rates since systematic monitoring began in 2001. Figure 3-14 shows the erosion pin results from pin 4E/1 from site 4E which is located on the left bank near the Bell Neilson Cave. This pin shows large increases in erosion around 2007 – 2008 and in 2014, and was eroded out of the bank between 2014 and the April 2016 monitoring (the pin is 1.25 m long). The periods of increased erosion coincide with extended low rainfall in Tasmania, and associated periods of high power station discharge.

It is notable that zones 3 and 4 recorded relatively higher rates of erosion compared to zones 1 (albeit with only 1 erosion pin site) and zone 2. This suggests that the large increase in erosion recorded in zones 3 and 4 that occurred during the periods of extended low rainfall is linked to the increase in high flow discharge from the power and to lower sediment loads entering the Gordon from the unregulated tributaries during these dry times. This reflects the greater influence of the tributaries in the downstream zones as compared to the upstream zones where the power station controls virtually all of the flow, and the banks have largely 'adjusted' to the power station regime in the absence of other inflows.

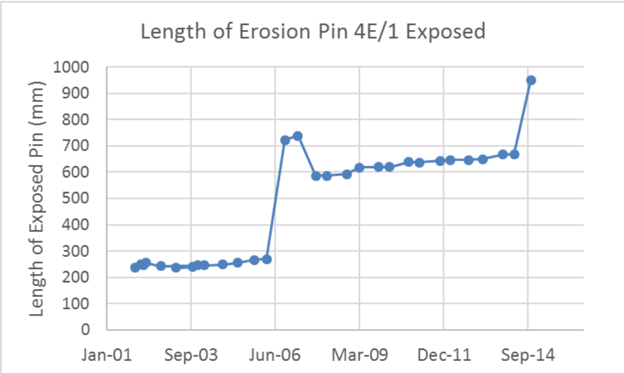

Figure 3-14. Erosion pin results for pin 4E/1 showing cyclic erosion coinciding with periods of elevated power station usage during dry weather periods in Tasmania

3.5.2.1 Erosion pin results by site

Site 1E is located on an alluvial bank which is stabilised by tea tree and a root mat that is being lost through scour. Initially there were benches at discrete turbine levels present on the bank, but these are being removed as the bank reduces in slope through slow seepage processes. The erosion of the bank face and reduction in slope of the bank toe continues, as shown by the erosion recorded by the pins on the bank face (1, 2, 6, 7 and duplicate pins 8, 9) and the deposition recorded by the lower pins - 3, 4, 5 and duplicate pins 12, 13 (Figure 3-15). The trends are consistent with the long-term results at the site.

Site 2A is also located on a bank supporting tea tree. The bank separates the main channel from a back channel which is active when the power station is in use. Pins 1 – 4 and pin 8 are on the river side, with pins 5 – 7 on the back channel side (Figure 3-16). The April 2016 results are consistent with previous findings, with the river side of the site showing low rates of change except at the toe pin

(pin 8) where considerable erosion was recorded. The back channel side shows the flattening of the bank with Pins 5, 6 and recording deposition.

Site 2D is located on the inside of a sharp bend and the site has shown cycles of flattening of the bank toe (pin D4) and erosion of the upper bank followed by erosion of the toe (Figure 3-16). A photo of the site (Figure 3-9) shows erosional features on the bank toe. Deposition was recorded at pins located downslope of the break in slope at the rear of the bank, consistent with the erosion of the bank face and deposition downslope.

Site 2E is located on the opposite bank from site 2D and is on a very active bank with respect to seepage erosion processes (Figure 3-17). The toe recorded a long period of deposition, associated with seepage processes, but in the past few years has shown erosion. This may reflect the exhaustion of material available for seepage, or an increase in scour, as the morphology of the bank is becoming more concave (Figure 3-18). Pin E1 is located in a cavity on the bank, and its variability is partially attributable to difficulties associated with measuring. The recent erosion pin results reflect the hummocky topography of the bank, and the reduction in slope of the bank face.

Site 2H contains 2 parallel profiles of erosion pins. One set (Pins H1 – H3) is in a tea tree bank, and the other (H4 - H7) is immediately downstream in an area where the tea tree has been lost and the steep bank is prone to seepage processes. The erosion pin results have captured the movement of a large Huon pine down slope that buried pin H4, and the flattening of the seepage affected bank. The erosion pin results in April 2016 show an increased level of erosion in the 'tea tree' pins (1-3), and continued flattening of the bank through deposition at pins H5 and H6 (Figure 3-17).

Site 2L is the most downstream site in zone 2, and is subjected to the largest water level fluctuations. The erosion pins have captured the removal of a muddy root mat through erosion and reduction in slope of the upper bank as 'benches' associated with turbine levels are removed (Figure 3-17). The site has recorded little change since October 2014, with the exception of pin L1 which is in a cavity and very difficult to measure. During periods of high flow, this site is in the backwater of the 'Splits'. Due to this, it may experience lower water velocities and hence lower rates of scour.

Sites 3C is located on the right bank in Zone 3 just upstream of the compliance site. This site is affected by inflows from the Orange River, and backwater effects from the Denison River. Pin C1 is in a cavity and has been lost due to bank collapse. Pin C55, which was also located at approximately the 55 m^3s^{-1} flow level has also been lost most likely due to erosion (based on high level of erosion recorded in March 2014). In April 2016, Site 3C has recorded erosion of the bank toe and some deposition on the bank face at Pin 3, but otherwise little change. The low rates of change are likely attributable to the presence of a remnant root mat over much of the site.

Site 3D is located on the left bank, opposite from site 3D upstream of the Compliance site. Pin D1 is in a cavity, pin D4 is horizontal in the steep bank face, and both recorded erosion between October 2014 and April 2016, consistent with high rates of scour. The remaining pins that are located on the bank face and toe show erosion of the toe (D3) and flattening through deposition on the upper bank (Figure 3-19).

Site 3E is located half way down zone 3 on the right bank, and is composed of a large sandy bank toe with tea tree on the higher bank. The bank frequently records erosion, but deposition has occurred in the past following large unregulated inflows (Figure 3-19). The recent monitoring results show high rates of erosion, with the rates being the highest recorded at some of the pins (photo of bank toe shown in Figure 3-9). This is consistent with the site experiencing high rates of scour due to high levels of power station usage, and a lack of tributary inflows.

Site 4D is located mid-way down zone 4 on the left bank at the downstream end of a cobble bar. The toe of the bank is buttressed by a large log which in the past has stabilised the bank toe, and promoted the deposition of sands. Pin 3 (toe) has recorded small scale cycles of deposition and erosion. The upper bank is undergoing a reduction in slope through seepage processes. The recent monitoring shows high rates of erosion (Figure 3-10). The erosion is the result of low sediment inflows from tributaries during the extended dry weather combined with high levels of power station discharge (Figure 3-20).

Site 4E is located on the left bank at an inside bend across from Kayak Cavern. This steep site has generally shown erosion due to scour. Pin 4E/1, which has been discussed earlier in this section, experienced high rates of erosion (Figure 3-20). Pin 4E/2 also recorded a large increase in erosion over the past 18 months. Since it was established in March 2002, pin 4E/2 has recorded 700 mm of erosion, or roughly 50 mm yr^{-1}. The bank at this site is relatively steep, which may also be a contributing factor to the high erosion rates. Other pins at the site have shown similar rates of change since 2007, when a very large flood event greatly altered the site.

Site 4H is located at the downstream end of zone 4, upstream of Sunshine Gorge near the confluence of the Harrison and Smith Creeks with the Gordon River. With the exception of toe pin 4H/5, the erosion pins have shown a flattening of the site over time (Figure 3-20). The curve of the results for the toe pin has the same shape as pin 4E/1 showing elevated rates of erosion coinciding with periods of extended dry weather and high power station discharge.

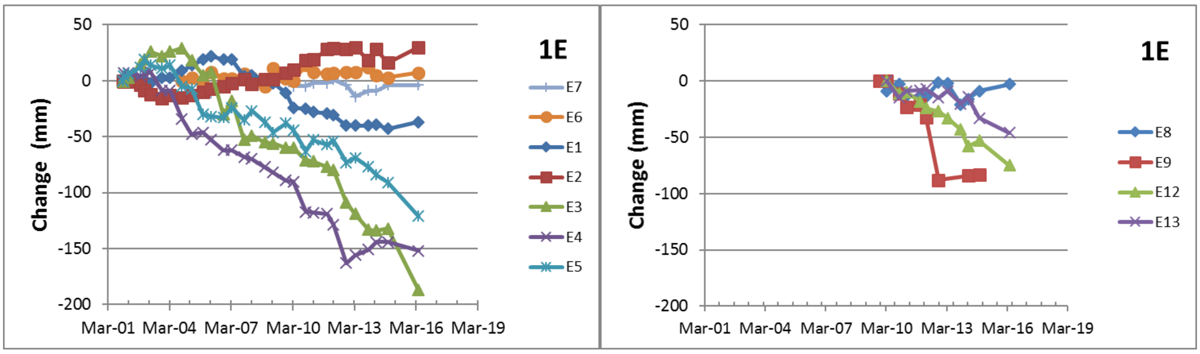

Figure 3-15: Erosion pin results for site 1E. Pins in graph on left form one profile down bank; pins in graph on right are duplicates. Legend shows approximate order of erosion pins from upslope to downslope.

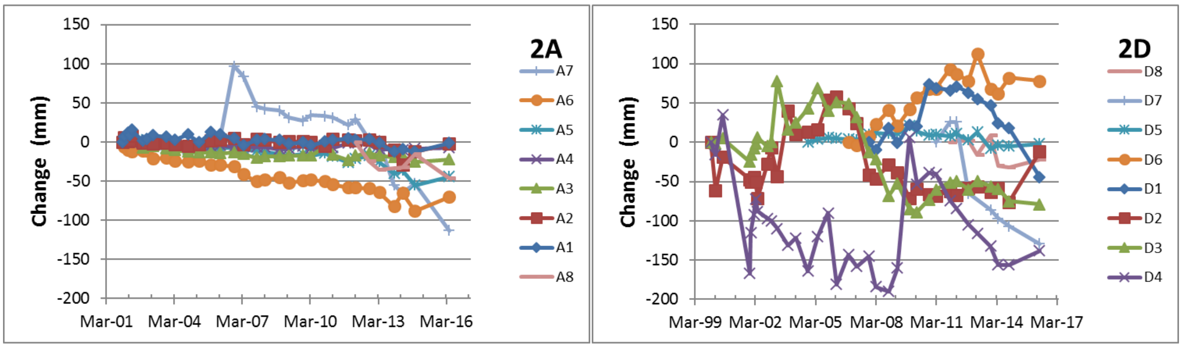

Figure 3-16: Erosion pin results for sites 2A and 2D. For site 2A, legend shows pins in order on bank from backwater to river side of the bank. For site 2D, legend shows approximate order of erosion pins from upslope to downslope

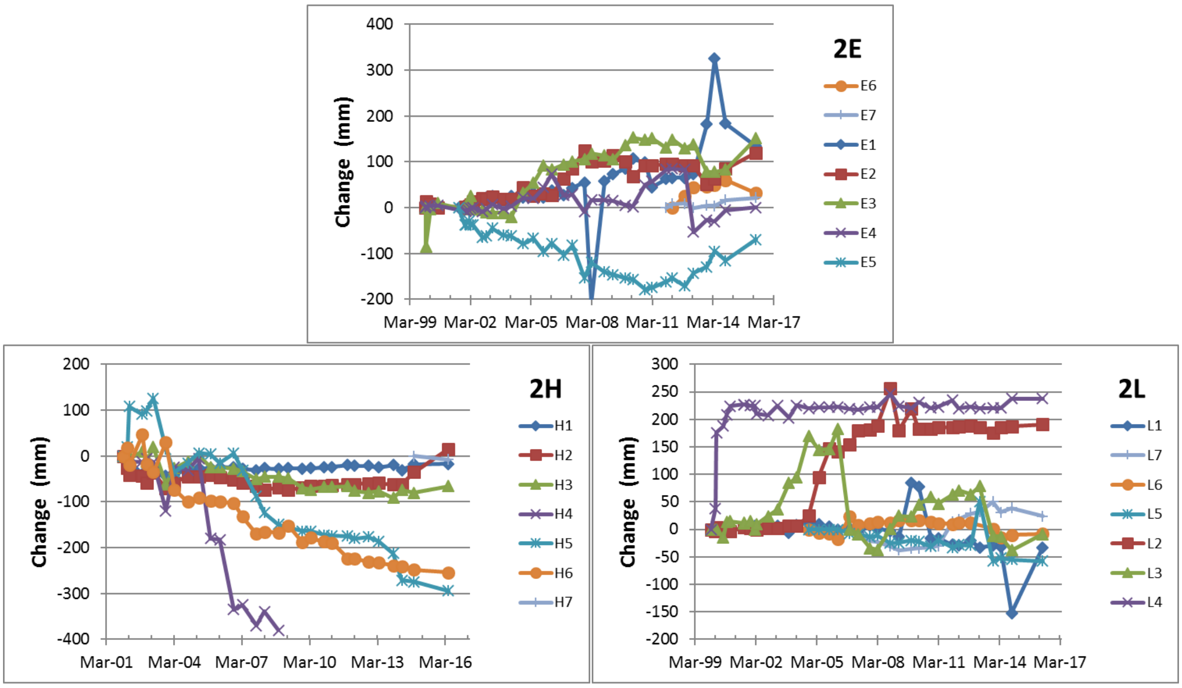

Figure 3-17: Erosion pin results for sites 2E, 2H and 2L. Legends for both sites show approximate order of erosion pins from upslope to downslope

Figure 3-18. Photo of erosion pin site 2E showing hummocky topography and flattening of bank face.

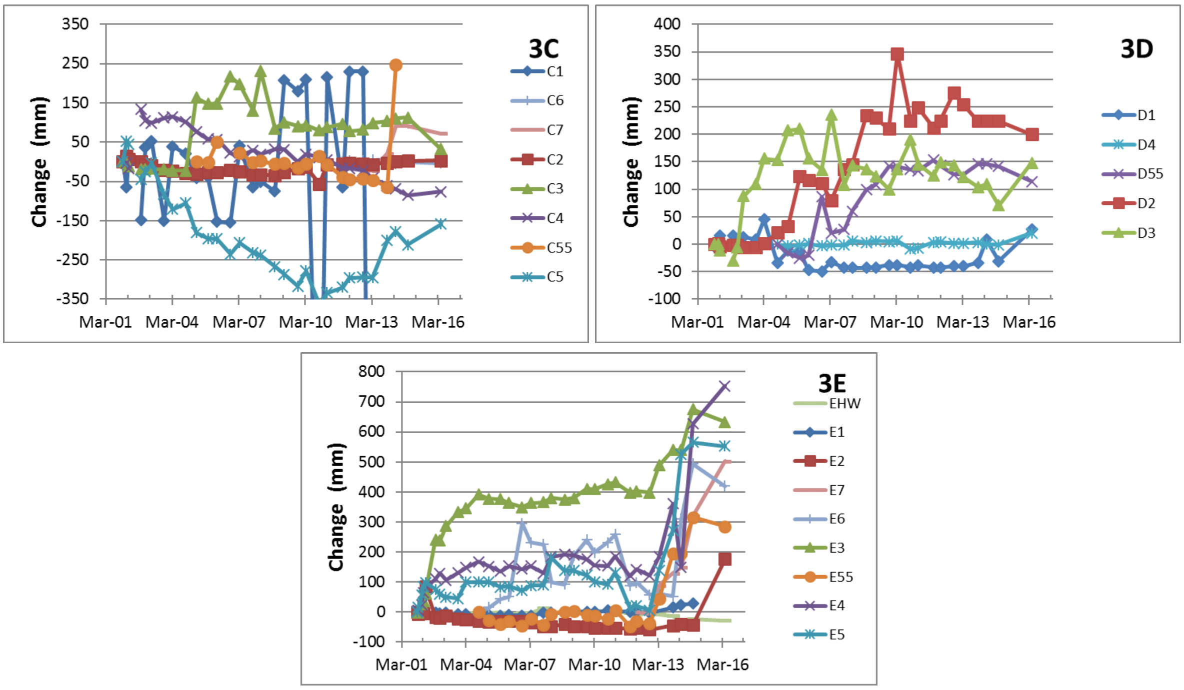

Figure 3-19: Erosion pin results for sits 3C, 3D and 3E. Legend shows approximate order of erosion pins from upslope to downslope.

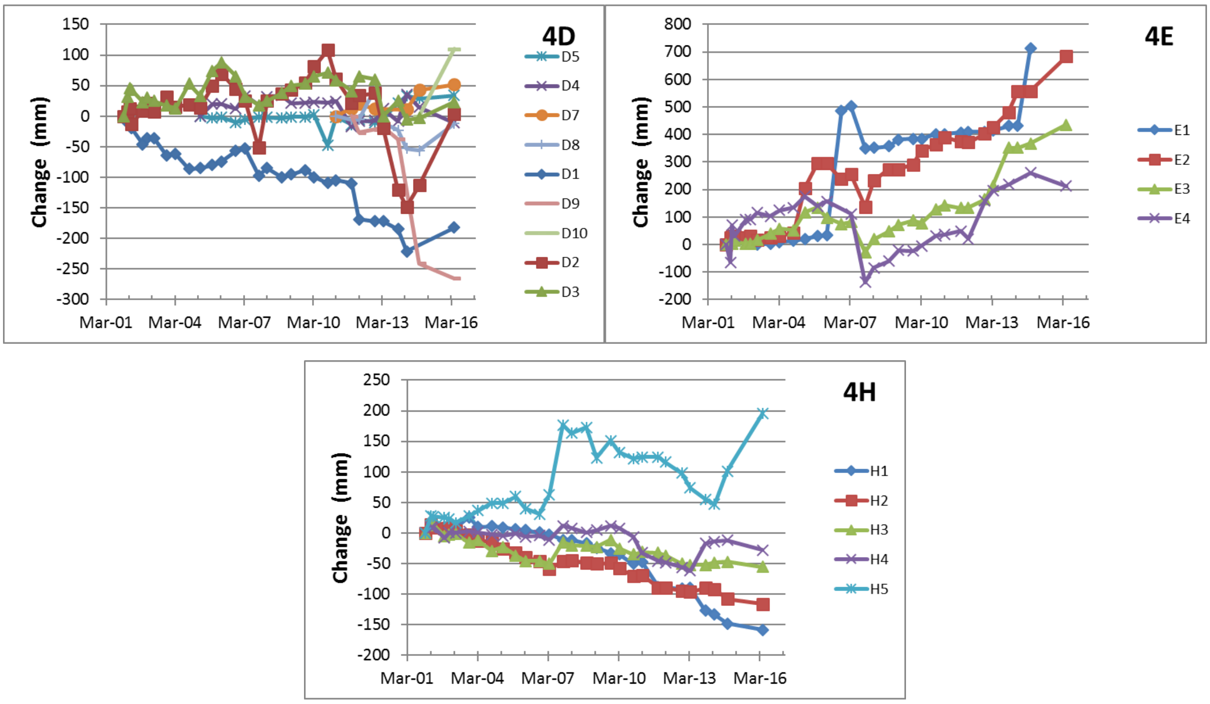

Figure 3-20: Erosion pin results for site 4D, 4E and 4H. Legend shows approximate order of erosion pins from upslope to downslope.

3.5.2.2 *Erosion pin summary*

The erosion pin results are consistent with the understanding of geomorphic processes in the river, and the relationship between power station operations and the response of alluvial banks in the middle Gordon River. Recorded erosion rates in zones 1 and 2 were similar to previous results, but erosion rates in zone 3 and 4 were higher than usually recorded, with some pins recording the largest erosion rates since monitoring began. In general, bank morphologies are moving towards lower slopes with 'deposition' being recorded on toes, and erosion on the upper bank face.

The April 2016 monitoring provided additional evidence about the importance of tributary inflows in maintaining the river banks downstream of the Splits. During the extended dry weather periods of 2007-08 and 2015-16, erosion rates in the river increased below the Splits, through a combination of scour due to extended and high discharge from the power station, combined with a lack of sediment input from the tributaries. A similar increase in erosion has not been recorded in zones 1 and 2, which have 'adjusted' to the power station operating regime in the absence of unregulated sediment inputs. These findings are consistent with the understanding that downstream of the Splits the Gordon River is a more dynamic system with respect to fluvial geomorphology.

At the 'bank' scale, sites characterised by tea tree and associated root-mats continue to exhibit more stability, owing to the presence of the vegetation and associated root-mat. Under periods of high power station discharge, these sites are affected by scour of the root-mat, and 'flattening' of the bank toe downslope of the root-mat through both scour and seepage erosion processes. Banks which lack tea tree cover typically show scour of the bank in the 2-3 turbine power station operating level and a reduction in the slope of the bank toe through seepage process which are recorded as deposition by the erosion pins.

3.5.3 Photo monitoring

Photo monitoring of the erosion pin sites and prominent disturbance features, such as land slips, was completed in April 2016. Many of the sites correspond to features included in the Basslink and Interim Monitoring programs, and historical photos are contained in the Annual Basslink Monitoring Reports (Hydro Tasmania 2014 - Photo Monitoring Appendices). Photos obtained in March 2014, October 2014 and April 2016 are included in Appendix C. There was one site where the photo was not obtained and one site where the photo is of poor quality (2-12, and 2H respectively).

Compared to the photo monitoring results obtained in March 2014 and October 2014, the observed changes in April 2016 were generally small. This is consistent with the long -term results that have overwhelmingly indicated that once a disturbance occurs, there is little additional upstream or downstream disturbance, with subsequent changes typically limited to the loss, addition or re-arrangement of woody debris on bank toes, the loss of overhanging vegetation (attributable to very strong root mats present in the Gordon River), and an increase in vegetation on the disturbance upslope of the power station controlled high water level. An exception is site 2-15 where a large tree-fall in ~2000 induced additional vegetation loss and bank changes for approximately a decade. The site is now showing low levels of change (Figure 3-21).

The changes observed in the April 2016 photos relative to the October 2014 photos include the following (site names with letters are erosion pin sites; site names with only numbers are photo monitoring points):

- Increase in algae on bank toe and in the backwater at site 2A (likely due to the low power station usage prior to monitoring): sites 2A, 2-2, 2-3;
- Mud deposited on bank toe (possibly due to back water from Splits): site 2L;
- Movement or removal of large and small woody debris from bank faces and bank toes: sites 1-5, 2-8, 2-9, 2-14, 2-15, 2L, 3-1, 4-4;
- Scour of bank toes: sites 3C, 3E, 4D, 4H;
- Loss of vegetation above the power station controlled high water level: sites 2-5, 2-14, 4E; and

- Increased growth of vegetation upslope of the power station controlled high water level: site 2-10;

Figure 3-21: Photo monitoring site 2-15 in 2002 (top left), 2014 (top right) and 2016 (bottom).

3.6 Conclusion

The April 2016 monitoring results are consistent with the understanding of geomorphic processes in the middle Gordon River, and how these processes relate to power station discharge. In the 18 months preceding monitoring, the extended periods of high power station discharge, as well as periods of hydro-peaking in combination with a period of extended dry weather had a two-fold effect on bank erosion. Firstly, the large number of peaking events (April to September 2015) increased the risk of seepage erosion and the subsequent periods of extended high flow (late December 2015 to March 2016) resulted in additional scour erosion. Secondly, i the dry weather conditions reduced tributary sediment inflows into the river. The lack of deposition on bank toes in zones 3 and 4 (and probably 5) contributed to a sharp increase in the level of net erosion.

Evidence of scour was widespread in the river but evidence of seepage erosion processes was very limited. This is likely attributable to the station being operated for prolonged periods at high discharge in the months prior to monitoring, rather than in a hydro-peaking regime. Immediately prior to monitoring there was a period of low discharge that promoted the deposition of mud and growth of algae on some of the bank toes in zones 1 and 2.

The overall bank morphology is trending towards one characterised by low angle banks extending to an abrupt break in slope, above which the bank is characterised by a steep slope stabilised by terrestrial vegetation above the power station controlled high water level. In April 2016, field observations were consistent with previous observations which suggest that the long process of geomorphic adjustment to a slightly higher flow regime is on-going.

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4 Macroinvertebrates

4.1 Introduction

Macroinvertebrate sampling was conducted in autumn (16-17 April) 2016 using the methods established under the Basslink Monitoring Program for the Gordon River. Both quantitative (surber) and rapid bioassessment (RBA) sampling was conducted at monitoring sites in the Gordon River between the power station and the Franklin River confluence. This sampling was also conducted at six established reference sites located in tributaries within the Gordon River catchment.

This chapter reports on the results of field sampling for macroinvertebrates in autumn 2016, provides a comparison of these results with those for the pre-Basslink period - years (2001-2005) and describes trends over the monitoring period to date.

Results were also compared with the autumn season trigger values derived from pre-Basslink period data, as detailed in the Basslink baseline report.

4.2 Methods

4.2.1 Sample sites

The locations of the monitoring and reference sites are listed in Table 4-1 and shown in Figure 4-1.

Table 4-1: Sites sampled in autumn 2016.

River	Site Name	Site code	Distance from power station (km)	Easting	Northing
Gordon	Gordon R ds Albert Gorge (G4)	75	2	412980	5266630
	Gordon R ds Piguenit R (G4A)	74	3	412311	5266383
	Gordon R in Albert Gorge (G5)	72	5	410355	5266524
	Gordon R us Second Split (G6)	69	8	408005	5266815
	Gordon R ds Denison R (G9)	60	17	402896	5271211
	Gordon R us Smith R (G10)	57	20	402083	5273405
	Gordon R ds Olga R (G11A)	48	29	398178	5278476
	Gordon R @ Devil's Teapot (G15)	42	35	396804	5282486
Franklin	Franklin R ds Blackman's bend (G19)	Fr11	-	398562	5291239
Franklin	Franklin R @ Flat Is (G20)	Fr21	-	397939	5296733
Denison	Denison ds Maxwell R (G21)	De7	-	407206	5272718
Denison	Denison R us Truchanas Reserve (D1)	De35	-	417400	5282900
Maxwell	Maxwell River (M1)	Ma7	-	409011	5276009
Jane	Jane R (J1)	Ja7	-	408100	5300400

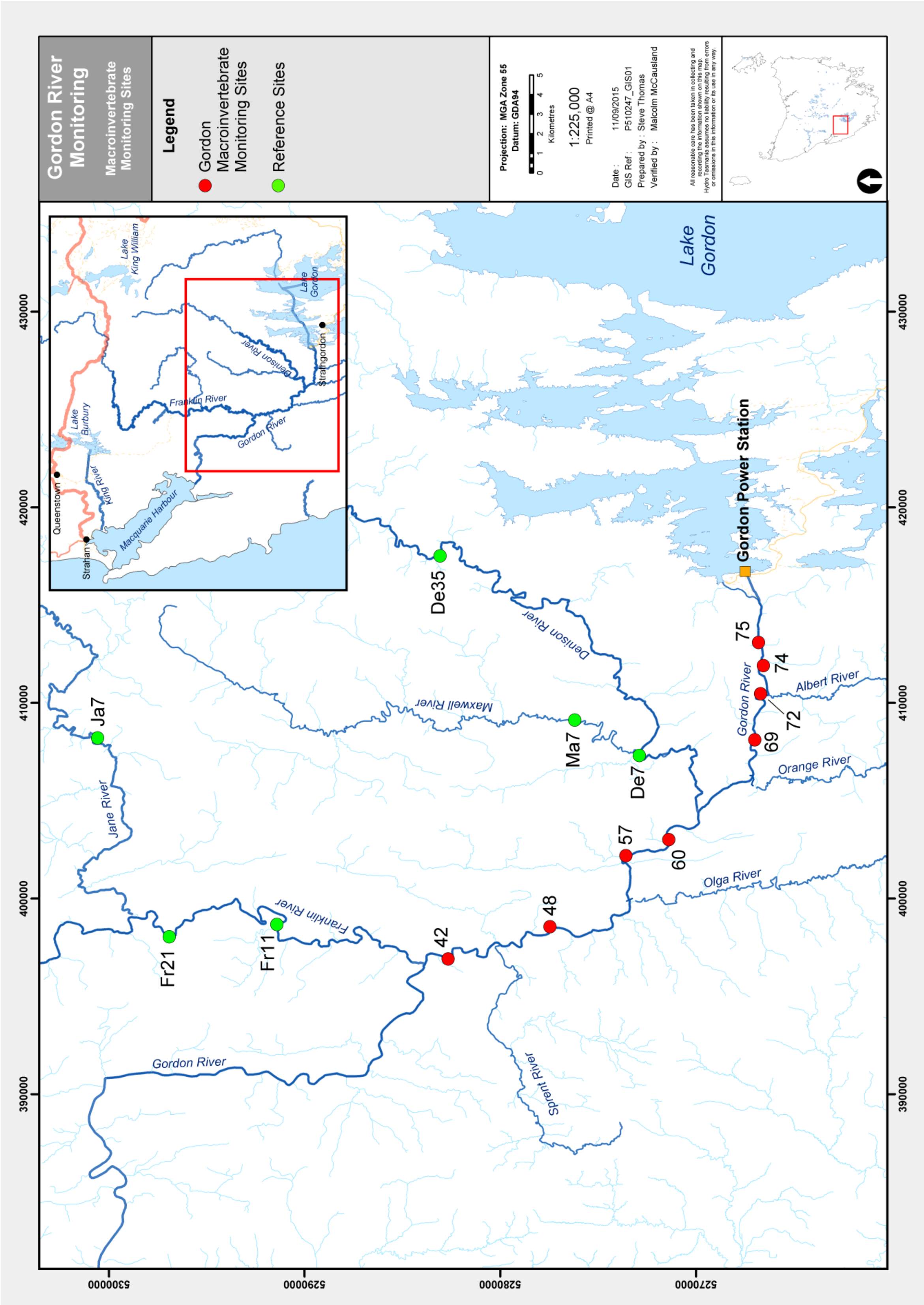


Figure 4-1: Map of locations of macroinvertebrate monitoring sites in the Gordon River and reference sites in the Denison and Franklin rivers

4.2.2 Macroinvertebrate sampling

Sampling of Gordon River sites and of Franklin River reference sites was conducted on 16-17 April 2016.

Quantitative sampling (surber sampling) and rapid bioassessment kick sampling (RBA) methods were conducted. Thus, at each site at low flows, riffle habitat was selected and sampled by:

- Collecting 10 surber samples (30 x 30 cm area, 500 micron mesh) by disturbing the substrate within the quadrate by hand to a depth of 10cm whereby attached macroinvertebrates are swept into the net; and
- Disturbing substrate by foot and hand immediately upstream of a standard 250 micron kick net over a distance of 10m (RBA).

All surber samples from a site were pooled and preserved (10% formalin) prior to lab processing. Samples were elutriated with a saturated calcium chloride solution and then sub-sampled to 20% using random cell selection from a Marchant box subsampler. The subsamples were then hand-picked and all fauna identified to 'family level' with the exception of oligochaetes, Turbellaria, Hydrozoa, Hirudinea, Hydracarina, Copepoda and Tardigrada. Chironomids were identified to sub-family. Identification to genus and species level was conducted for the aquatic insect orders Ephemeroptera, Plecoptera, Trichoptera - the 'EPT' group fauna - using the most current taxonomic keys.

All analyses were conducted using the 20% (0.18 m^2) sub-sample data.

Two RBA samples were collected at each site. All RBA samples were live-picked on site for 30 minutes, with pickers attempting to maximise the number of taxa recovered. All taxa were identified to the family taxonomic level as described above.

4.2.3 Habitat variables

A set of standard habitat variables were recorded at each site and a number of variables were recorded from 1:25 000 maps. The habitat variables recorded are:

- per cent cover of substrate types (boulder, cobble, pebble, gravel, sand, silt and clay);
- per cent of site area covered by algae, moss, silt and detritus;
- site depth, temperature, conductivity, wetted width, bankfull width, flow and water clarity;
- extent of aquatic, overhanging, trailing and riparian vegetation; and
- per cent of site in habitat categories (riffle, run, pool and snag habitats).

4.2.4 Analysis

All RBA data was analysed using the autumn season Hydro RIVPACS models developed by Davies et al. (1999), with O/Epa and O/Erk values derived using the RBA macroinvertebrate data in combination with key 'predictor' habitat variables. O/Epa is derived using presence/absence data and models derived from presence/absence reference site data. O/Erk is derived using rank abundance category data and models derived from rank abundance category reference data.

O/Epa and O/Erk scores range between 0 and 1. A zero value represents the condition where no expected taxa are found in the sample and a value of 1.0 represent the condition where all expected taxa are found. This range is divided into impairment bands for reporting purposes:

- D – extremely impaired;
- C – severely impaired;
- B – significantly impaired;
- A – unimpaired, or equivalent to reference; and
- X – more diverse than reference

Trigger values were those derived for the Basslink program as detailed in the Basslink Baseline Report (Hydro Tasmania, 2005a). Values of each metric derived from the autumn 2016 data were compared against the relevant autumn season trigger values (shown graphically in this report). Plots of temporal trends in metric values and abundances of selected families are also presented.

4.3 Results

4.3.1 Quantitative data

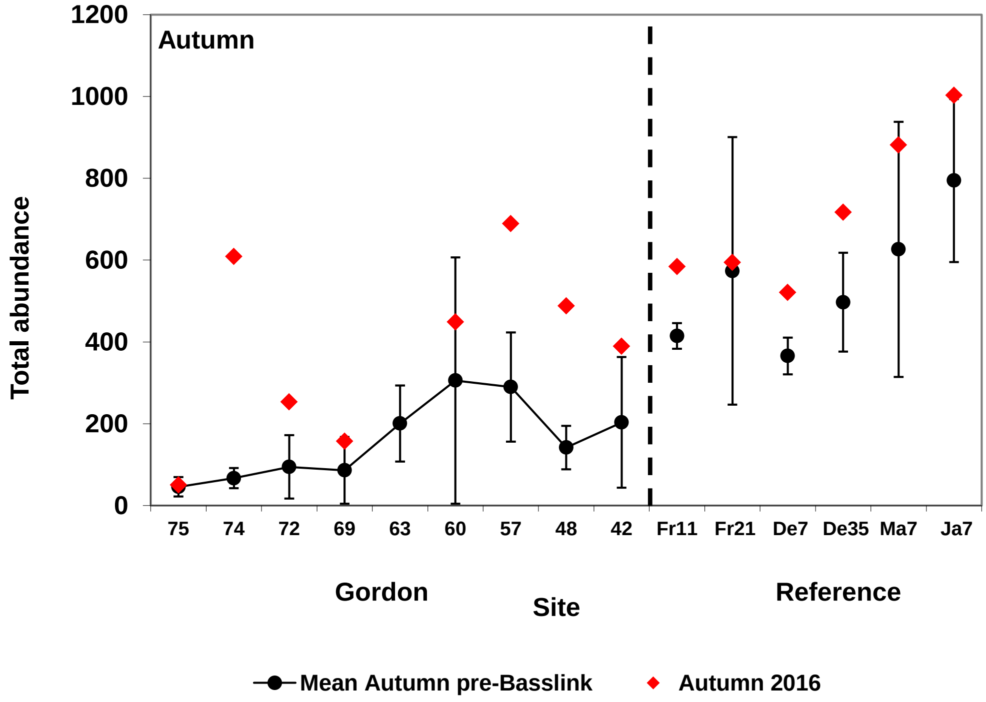
The Autumn 2016 season quantitative surber sample data for family and EPT species are shown in Appendix D.1 and Appendix D.2, respectively.

Diversity in the Gordon River at both family and species level fell generally within or close to the range observed in previous years across most sites (Figure 4-2, Figure 4-3). Reduced diversity (< 15 families and < 10 species) was observed for several reference sites in the lower Franklin and Denison rivers, which is not unexpected after the prolonged period of low natural flows during the summer of 2015/16.

Abundances in the Gordon River were raised at several sites, and the abundance (absolute and proportional) of the EPT group was particularly elevated in Zone 1 (Figure 4-2, Figure 4-4) which was mainly due to high densities of Hydropsychid caddis of the genus *Asmicridea* (Appendix D.1 and Appendix D.2). High densities of simuliid (blackfly) larvae were also recorded in the lower Gordon River (sites 42 to 60) and in all reference rivers (Appendix D.1) which indicates a substantial natural recruitment event during summer 2015/16.

The diversity of EPT species in autumn 2016 was similar to the pre-Basslink means in the Gordon River (Figure 4-3). By contrast, EPT species richness was lower than the pre-Basslink means at all reference sites (Figure 4-3).

The community compositional similarity of all zone 1 Gordon River sites relative to the reference sites was generally similar to the pre-Basslink means, as measured by the mean Bray Curtis Similarity measure based on both abundance and presence/absence EPT species data, with sites 42 and 48 being more similar to reference sites than pre-Basslink (Figure 4-5).



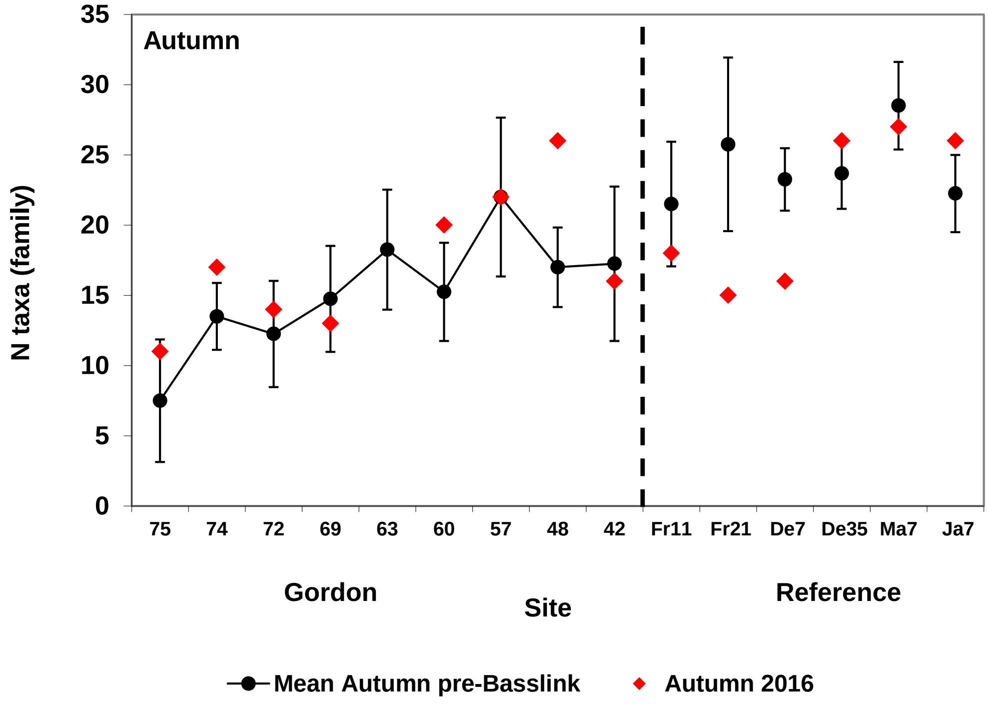
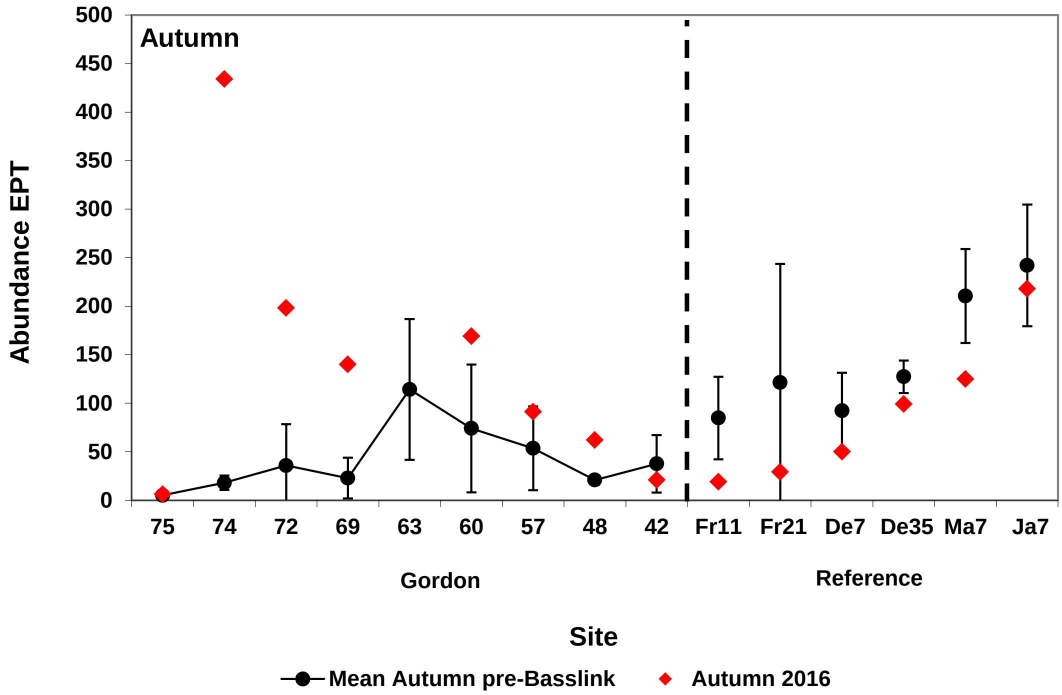


Figure 4-2 Comparison of total abundance of all benthic macroinvertebrates and diversity (number of taxa at family level) for autumn 2016 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the pre-Basslink values for site 63 are shown for completeness, though sampling at this site was discontinued in 2012.



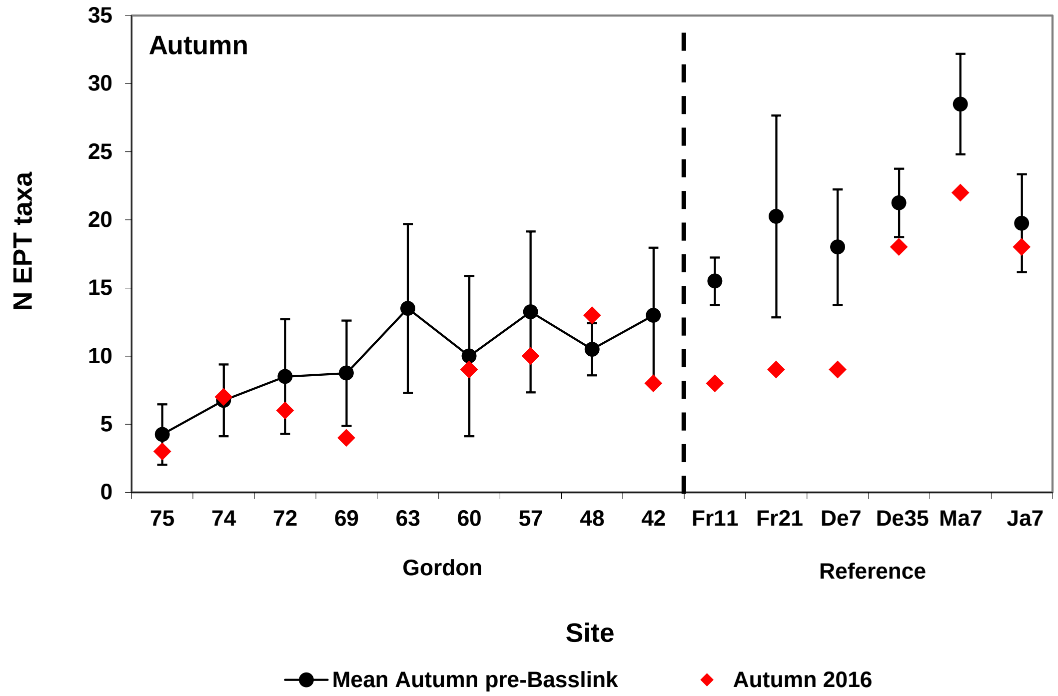


Figure 4-3 Comparison of total abundance and number of benthic EPT taxa (genus and species) for autumn 2016 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the pre-Basslink values for site 63 are shown for completeness, though sampling at this site was discontinued in 2012.

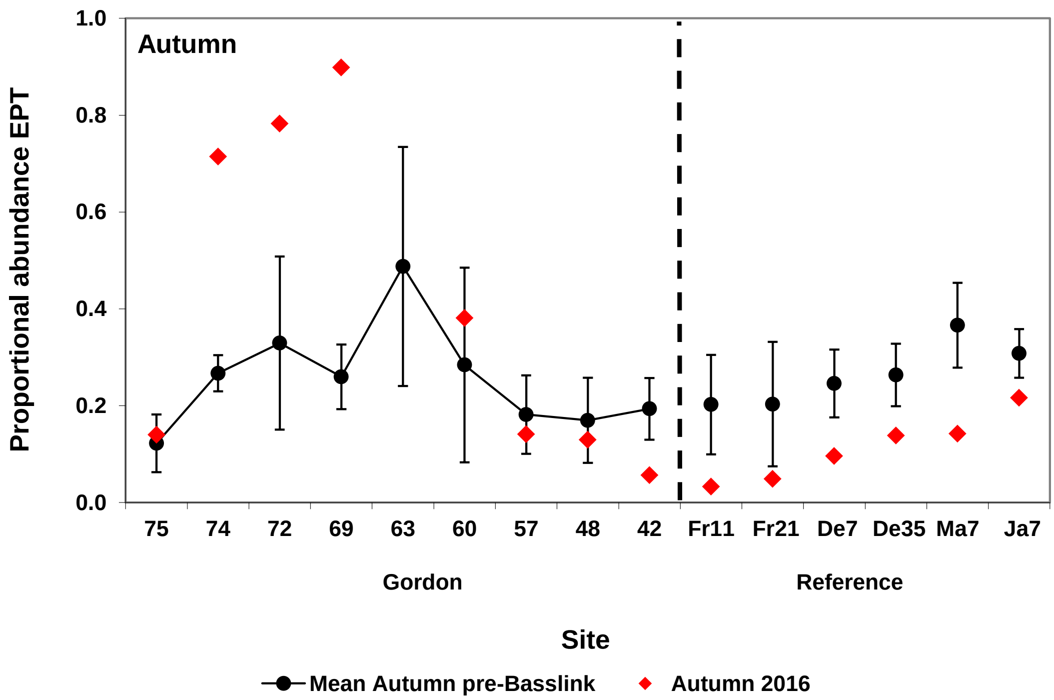
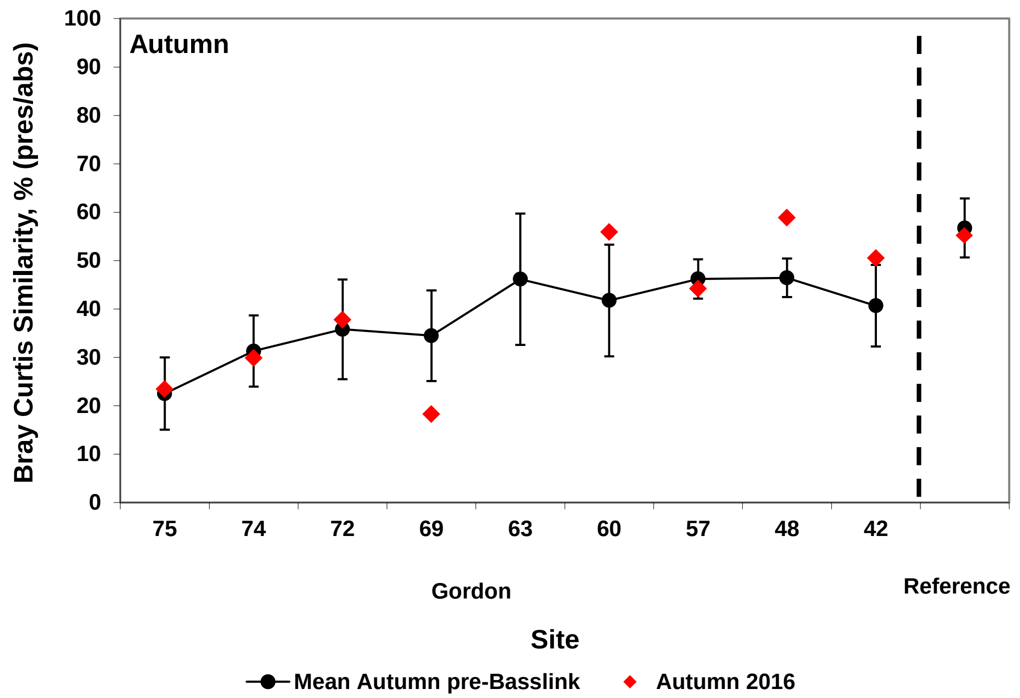


Figure 4-4 Comparison of proportion of total benthic macroinvertebrate abundance represented by EPT species for autumn 2016 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the pre-Basslink values for site 63 are shown for completeness, though sampling at this site was discontinued in 2012.



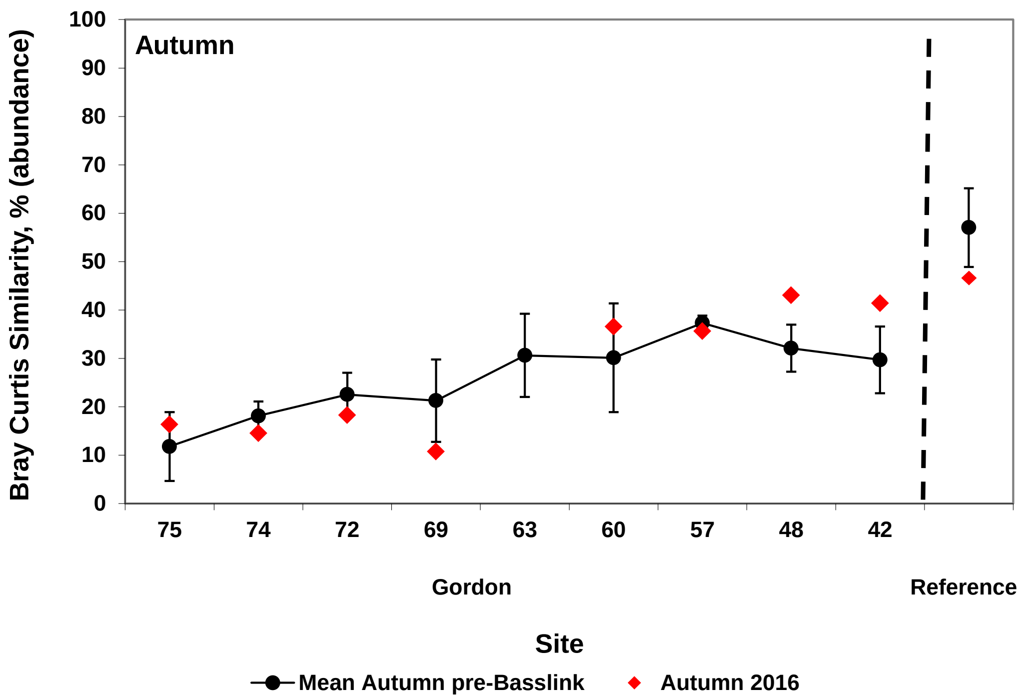


Figure 4-5 Comparison of values for the mean Bray Curtis Similarity between each sampled site and the reference sites for autumn 2016 with autumn values from previous years. Similarities are calculated with either abundance data (square root transformed) or presence/absence data. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the value for reference sites represents the mean of Similarities between each reference site and the other reference sites sampled at the same time

4.3.2 RBA data

The autumn 2016 season RBA data set is shown in Appendix D.3. O/Epa and O/Erk values and their impairment bands are presented in Figure 4-6 and Table 4-2.

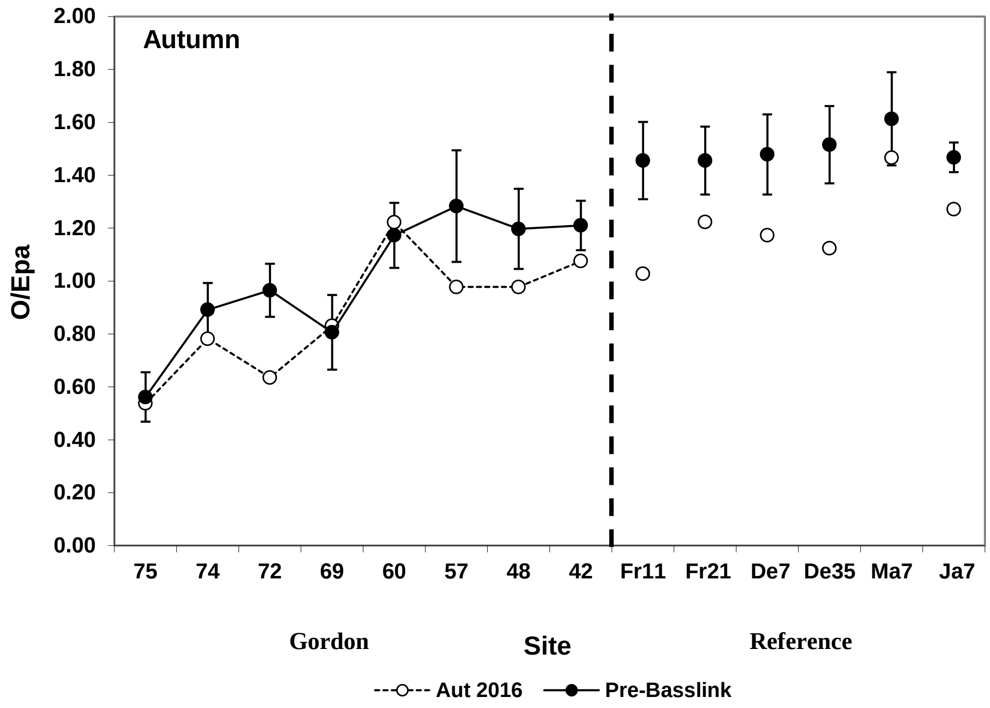
O/Epa and O/Erk values in autumn 2016 fell below the pre-Basslink standard deviation for the zone 1 Gordon River sites 72 and 74, and for zone 2 sites 42 to 57 (Figure 4-6). O/Epa values in the Gordon River were not significantly different from pre-Basslink means (by paired t-test of autumn pre-Basslink means with 2016 values, $p > 0.01$). By contrast, the O/Erk values were significantly lower in 2016 in the Gordon than pre-Basslink (means of 0.88 and 1.01 respectively; $t = 3.56$, $df = 7$, $p = 0.037$).

Five of the six reference sites sampled also had O/E values below pre-Basslink means for these two metrics in autumn 2016 (Figure 4-6). Reference site values for O/Epa and O/Erk were significantly lower than pre-Basslink means for autumn 2016 (by t-test of autumn pre-Basslink means with 2016 values, $p < 0.0016$ and 0.02 respectively; $df = 6$; $t = 6.23$ and 3.24 respectively).

These results show that in autumn 2016, low O/E values were observed in the Gordon River relative to the pre-Basslink period. A similar, observation was made at the reference sites, though the losses of different families indicate different likely causes.

Table 4-2: O/Epa and O/Erk values for all sites sampled in autumn 2016. Individual replicate and mean values are provided with corresponding impairment bands.

River	Site	Replicate	Autumn 2016			
			O/Epa	Band	O/Erk	Band
Gordon R	75	1	0.49	C	0.40	C
		2	0.59	B	0.45	B
		Mean	**0.54**	**C**	**0.43**	**B**
	74	1	0.68	B	0.35	C
		2	0.88	A	0.56	B
		Mean	**0.78**	**B**	**0.45**	**B**
	72	1	0.59	B	0.30	C
		2	0.68	B	0.35	C
		Mean	**0.64**	**A**	**0.33**	**B**
	69	1	0.78	B	0.62	B
		2	0.88	A	0.57	B
		Mean	**0.83**	**A**	**0.60**	**B**
	60	1	1.08	A	0.81	B
		2	1.37	X	0.96	A
		Mean	**1.22**	**X**	**0.88**	**A**
	57	1	0.78	B	0.55	B
		2	1.17	A	0.86	A
		Mean	**0.98**	**A**	**0.71**	**B**
	48	1	0.98	A	0.79	B
		2	0.98	A	0.74	B
		Mean	**0.98**	**A**	**0.77**	**A**
	42	1	1.08	A	0.76	B
		2	1.08	A	0.65	B
		Mean	**1.08**	**X**	**0.71**	**A**
Franklin R	Fr11	1	1.08	A	0.86	A
		2	0.98	A	0.81	B
		Mean	**1.03**	**A**	**0.83**	**A**
	Fr21	1	1.37	X	1.06	A
		2	1.08	A	0.91	A
		Mean	**1.22**	**X**	**0.98**	**A**
Denison R	De7	1	1.27	X	1.01	A
		2	1.08	A	0.91	A
		Mean	**1.17**	**A**	**0.96**	**A**
	De35	1	1.17	A	0.96	A
		2	1.08	A	0.91	A
		Mean	**1.12**	**X**	**0.93**	**A**
Maxwell R	Ma7	1	1.56	X	1.16	A
		2	1.37	X	1.26	X
		Mean	**1.47**	**X**	**1.21**	**A**
Jane R	Ja7	1	1.37	X	1.06	A
		2	1.17	X	0.96	A
		Mean	**1.27**	**X**	**1.01**	**A**



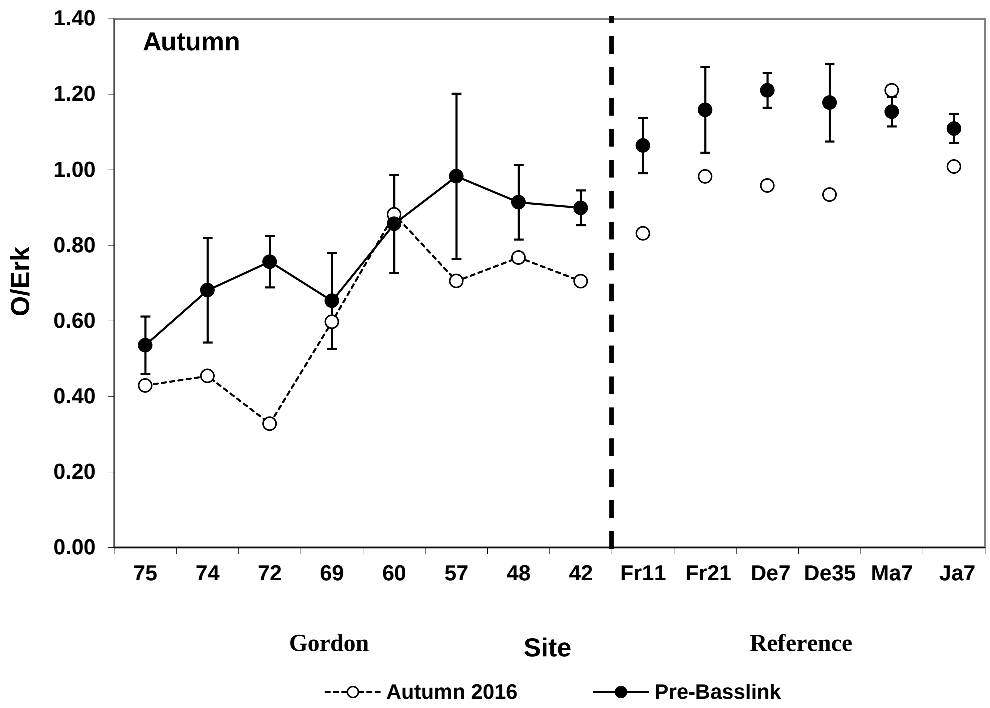


Figure 4-6 Comparison of O/Epa and O/Erk values for autumn 2016 with values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean.

4.3.3 Summary

Overall, the diversity at family level and the abundance and diversity of EPT species, as well as measures of compositional similarity to reference, were similar to pre-Basslink values for Gordon River sites in autumn 2016.

A notable change in autumn 2016 was the major increase in abundance of two insect families. Hydropsychid *Asmicridea* caddis were present in very high densities in Zone 1 downstream of site 75, and simuliids had high densities in the lower Gordon and reference sites. The former is likely due to the persistent base flow and higher flows in zone 1, coupled with organic inputs from the zone 1 tributaries. The latter is due to a substantial natural recruitment event that probably occurred due to the warm dry conditions during the 2015/16 summer.

Both measures of the presence and relative abundance of expected macroinvertebrate families (O/Epa and O/Erk) were generally lower than pre-Basslink means and ranges in the Gordon River. This implies a loss of expected families, coupled with a reduction in their relative abundance, compared with pre-Basslink values. A similar magnitude of decline was also observed for the reference sites.

4.4 Comparisons with Triggers

4.4.1 Results

Nine metrics were developed for assessing the degree of any changes in benthic macroinvertebrates in the Gordon River due to Basslink operations. These metrics are grouped into five overall components as outlined in Table 4-3.

Table 4-3 Macroinvertebrate components and metrics identified for assessing change.

Components	Metrics
Community Structure	Bray Curtis (abundance) O/Erk
Community Composition	Bray Curtis (pres/abs data) O/Epa
Taxonomic richness	N Taxa (fam) N EPT Species
Ecologically significant species	Proportion of total Abundance as EPT Abundance EPT
Biomass / productivity	Total abundance

Trigger values for these biological metrics were established based on the 95th percentile of pre-Basslink values. These trigger values are used in reporting on whether limits of acceptable change (LOAC) have been exceeded post-Basslink. Triggers were developed for each individual site in the Gordon River, as well as for the entire river (‘whole of river’, WOR) and zones within the river. Two zones have been described for benthic macroinvertebrates:

- zone 1-upstream of the Denison River junction (incorporating sites 69 to 75); and
- zone 2-downstream of the Denison River junction (incorporating sites 42 to 60).

Values of all metrics for autumn 2016 are shown in Appendix D.4. Plots of the trigger levels for each metric are shown in Figure 4-7 to Figure 4-11 along with the value for the metric recorded in autumn 2016 at whole of river (WOR) and zone levels.

4.4.2 Trigger status

The following section summarises and comments on the observations for autumn 2016 in comparison with the biological trigger values.

4.4.2.1 Community Structure

Bray Curtis (abundance): All values fall within trigger bounds (Figure 4-7).

Comment – Compliant with trigger bounds.

O/Erk: Values for whole of river (WOR) and for zone 1 fell just below the lower trigger bound (Figure 4-7). This is the third such trigger exceedance for this metric, following autumn and spring 2014 values that were also below the trigger bound. It indicates loss of several expected families and a reduced relative abundance of remaining families.

The value for zone 2 fell just within the trigger bounds.

Comment – Below trigger bounds in zone 1.

4.4.2.2 Community Composition

Bray Curtis (pres/abs data): WOR and zone 1 values fell within trigger bounds (Figure 4-8), with the value for zone 2 exceeding the upper bound.

Comment – Overall within trigger bounds, with a slight exceedance in zone 2.

O/Epa: All values were within the lower trigger bounds (Figure 4-8).

Comment – Compliant with trigger bounds.

4.4.2.3 Taxonomic richness

N Taxa (fam): Values for zones 1 and 2 fell within trigger bounds (Figure 4-9), however the WOR and case fell just above the upper trigger bound.

Comment – Overall within trigger bounds, with a slight exceedance for the WOR case.

N EPT Species: All values fell within the trigger bounds.

Comment – Compliant with trigger bounds.

4.4.2.4 Ecologically significant species

Proportion of total abundance as EPT: Values for WOR and zone 2 were within trigger bounds (Figure 4-10). The value for zone 1 was well above the upper trigger bound due to high densities of the Hydropsychid caddis species *Asmicridea sp. AV1*.

Comment – Within or exceeding trigger bounds, with the zone 1 exceedance not of concern.

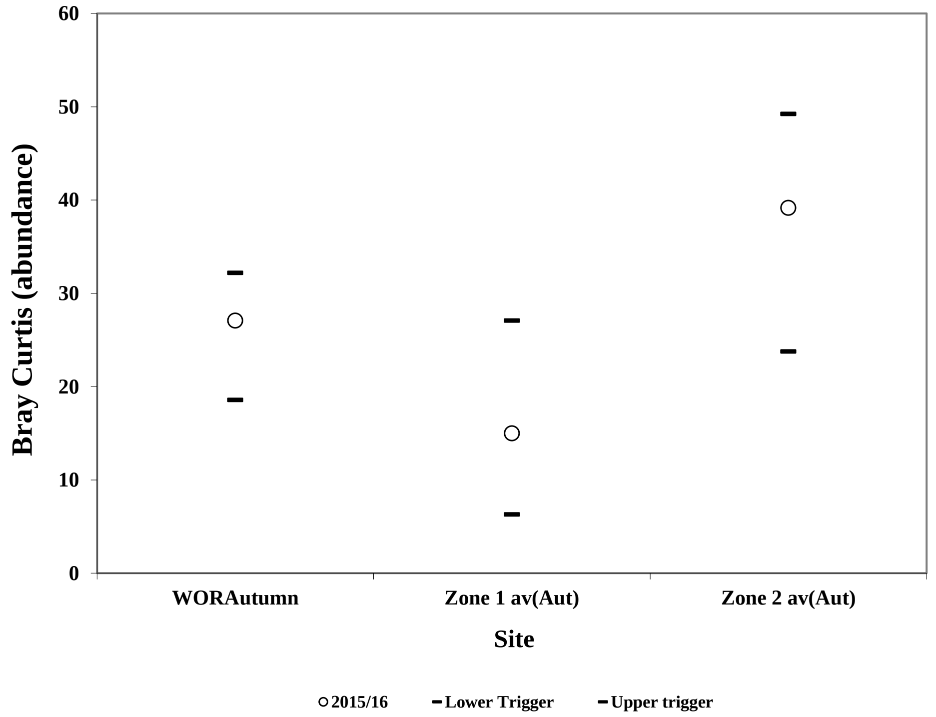
Abundance EPT: Values exceeded the upper trigger bound for WOR and both zones (Figure 4-10). Very large exceedances at WOR and in zone 1 due to high densities of the Hydropsychid caddis species *Asmicridea sp. AV1*.

Comment – Large exceedances which represent a significant compositional shift, which are not of concern.

4.4.2.5 Biomass/productivity

Total abundance: Values fell in the upper part of the range within trigger bounds for zones 1 and 2 (Figure 4-11). As a result, the value for the Whole of River case substantially exceeded the upper trigger bounds. This is caused by substantially increased densities of Hydropsychid caddis *Asmicridea sp. AV1* in zone 1 and of blackfly (simuliid) larvae in zone 2 (due to natural causes).

Comment – Within trigger bounds for both zones. WOR exceedance not of environmental concern.



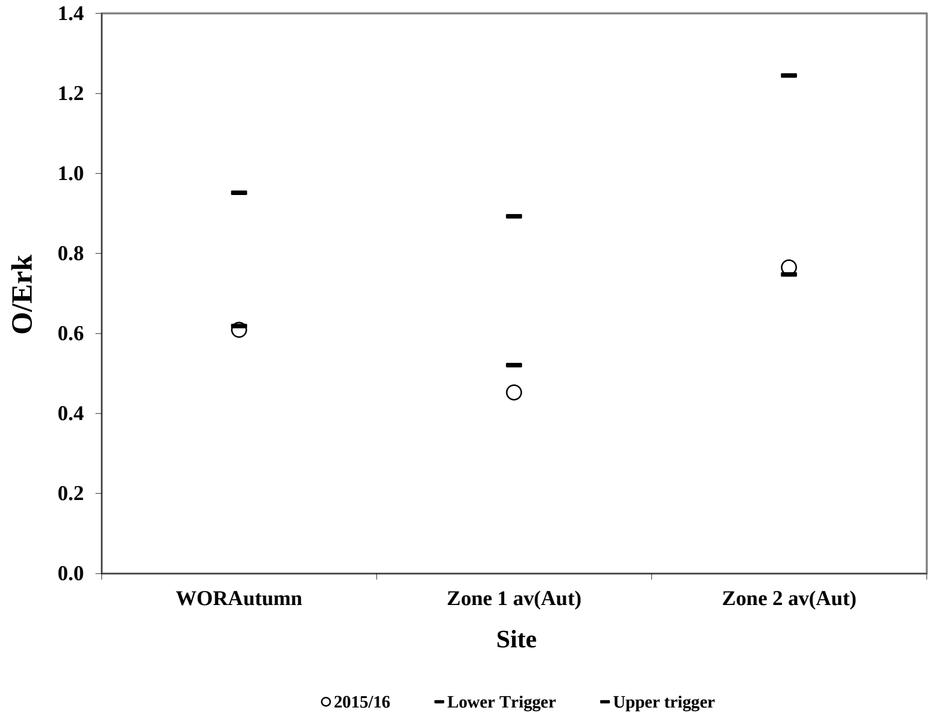


Figure 4-7 Community structure metric values for autumn 2016 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = Whole of River (autumn season), Zones 1 and 2 (autumn season). Trigger values based on the 95 percentile of pre-Basslink data.

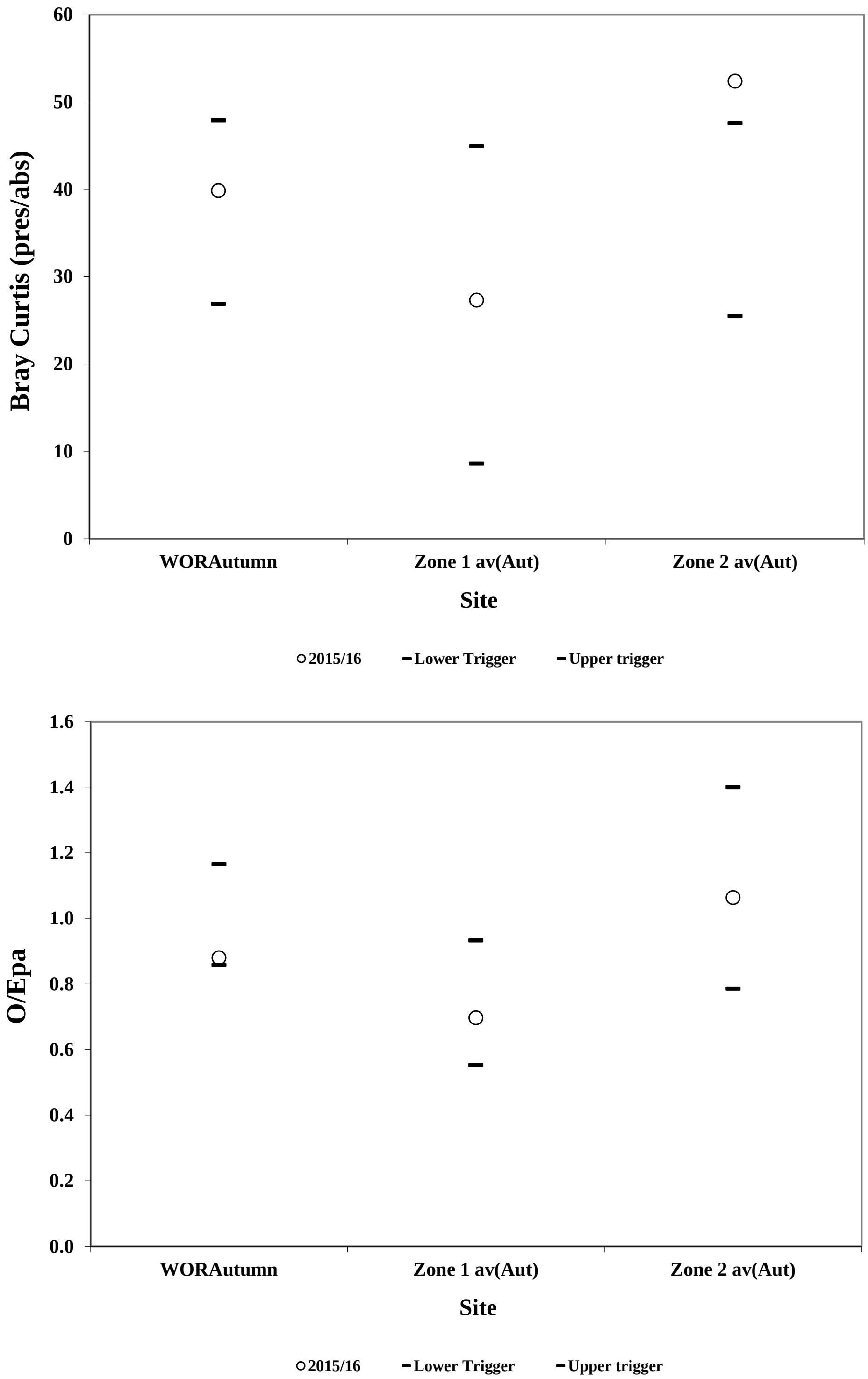
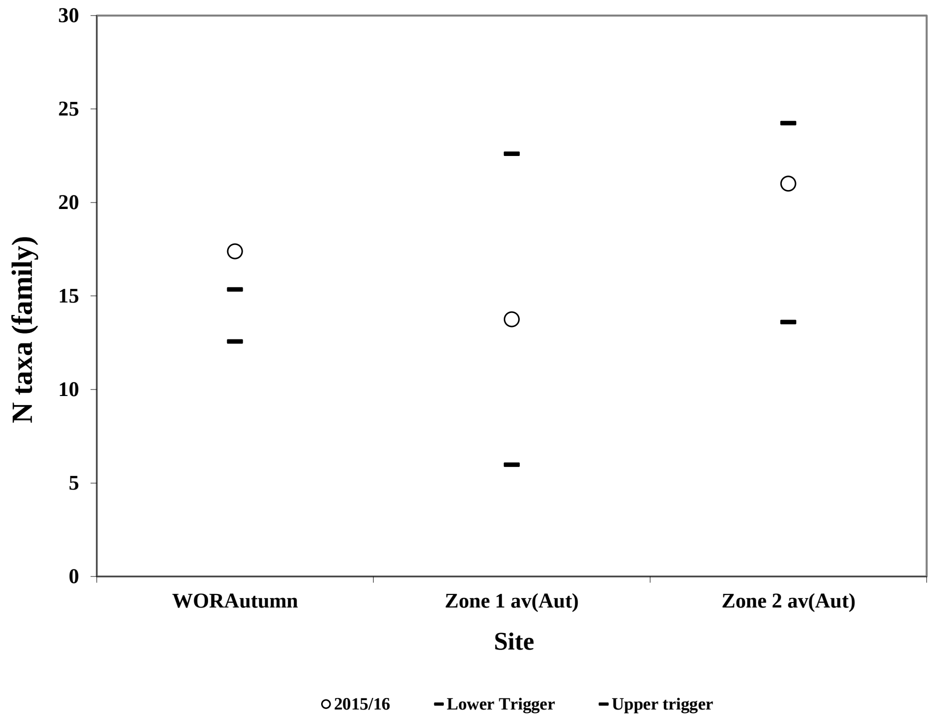


Figure 4-8 Community Composition metric values for autumn 2016 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = Whole of River (autumn season), Zones 1 and 2 (autumn season). Trigger values based on the 95 percentile of pre-Basslink data.



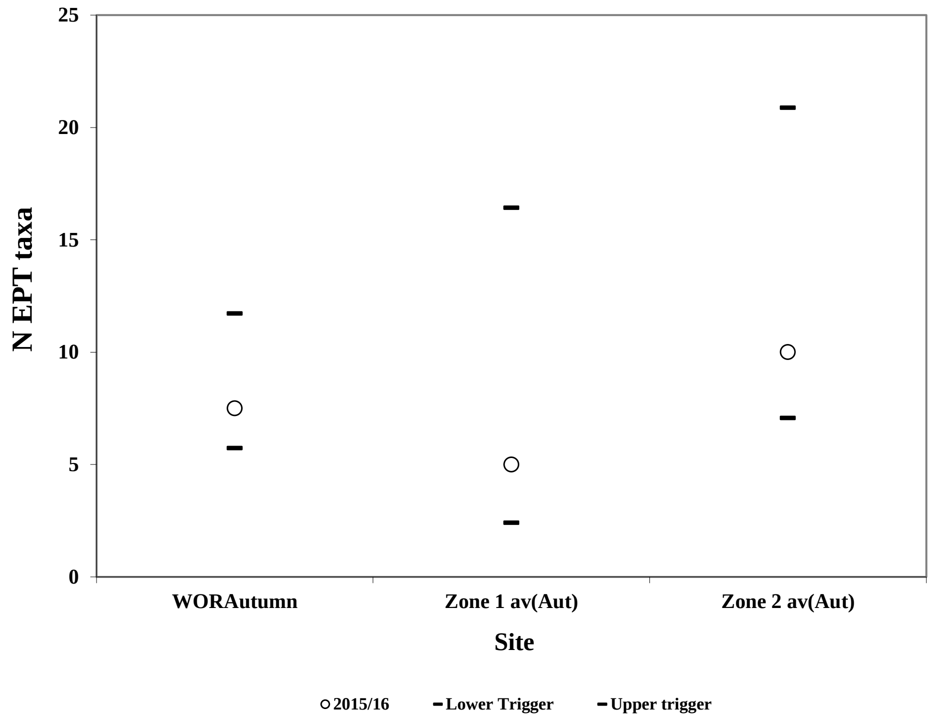
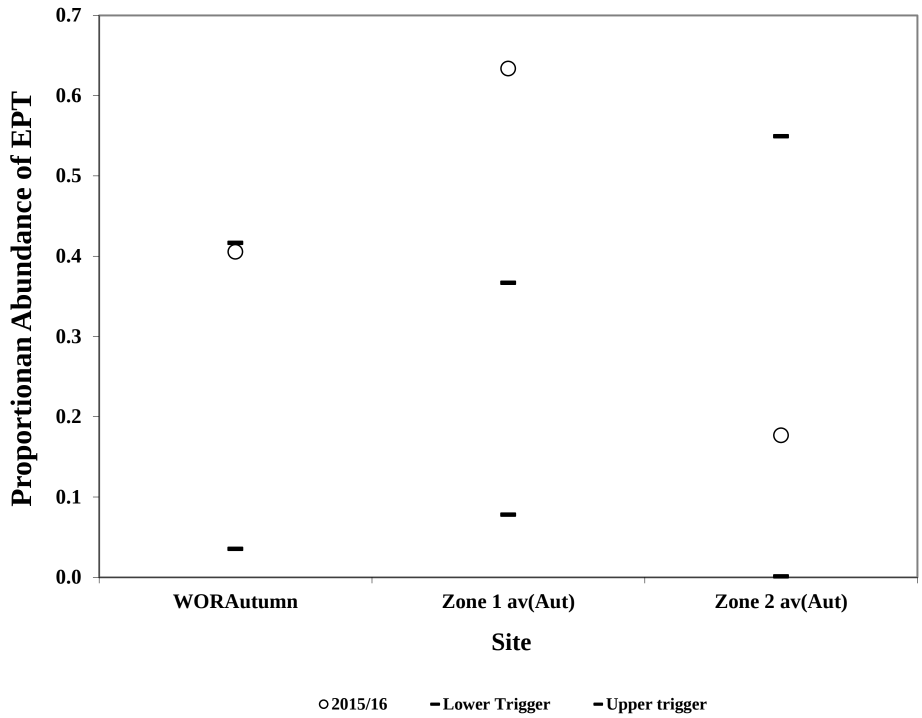


Figure 4-9 Taxonomic Richness metric values for autumn 2016 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = Whole of River (autumn season), Zones 1 and 2 (autumn season). Trigger values based on the 95 percentile of pre-Basslink data.



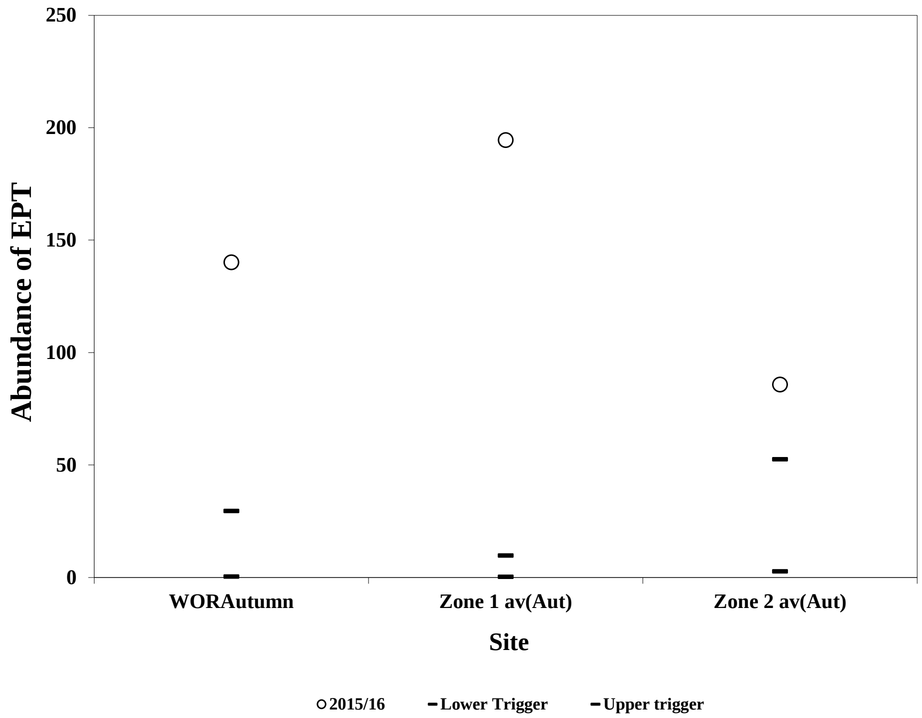


Figure 4-10 Ecologically significant species metric values for autumn 2016 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = Whole of River (autumn season), Zones 1 and 2 (autumn season). Trigger values based on the 95 percentile of pre-Basslink data.

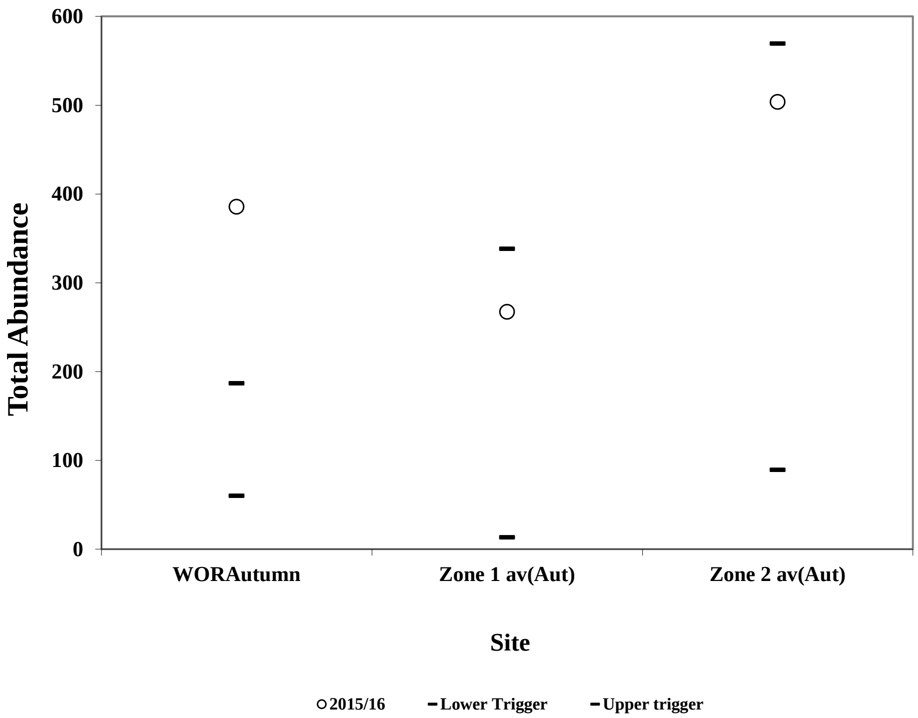


Figure 4-11 Biomass/Productivity metric values for autumn 2016 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = Whole of River (autumn season), Zones 1 and 2 (autumn season). Trigger values based on the 95 percentile of pre-Basslink data.

4.5 Long-term trends

4.5.1 Univariate indicators

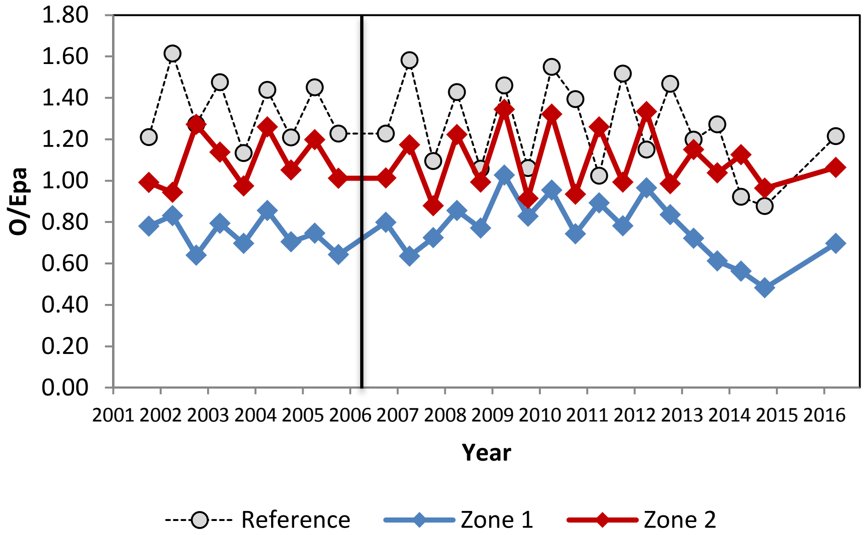
Trends in all metrics are shown in Figure 4-12 to Figure 4-16. As in previous years, the value of all metrics is predominantly highest in reference sites, lowest in zone 1 and intermediate in zone 2. Most metrics show no overall monotonic trend over the entire sampling period in the Gordon River and are broadly consistent in values with time (with zone 1 being a recent exception). However, some recent post-Basslink trends are apparent.

Values of O/Epa, O/Erk and the number of EPT species and their proportional abundance in 2013-14 fell to levels not experienced previously (Figure 4-12, Figure 4-13, Figure 4-14). The zone 1 values for O/Epa showed a slight recovery in autumn 2016 from the low levels in 2013-14, while the number of EPT species remained low. O/Erk values declined further in autumn 2016 in zone 1 and this is the only metric that remains outside the pre-Basslink range. By contrast, the proportional and absolute abundance of EPT species increased dramatically in zone 1 in autumn 2016 (Figure 4-14). This is due to the rise in abundance of the filter feeding Hydropsychid caddis *Amsicridea sp. AV1*, whose abundance is greatly favoured by reduced occurrence of flow peaking and a steady supply of organic food.

No substantive overall post-Basslink changes in metric values have been observed in zone 2. The decline in number of EPT species observed in spring 2014 has been partially reversed in autumn 2016 (Figure 4-13). The abundance of EPT species in zone 2 increased in autumn 2016 relative to the lower levels observed in 2013-14 (Figure 4-14).

Zone 2 continues to be biologically intermediate between zone 1 and the reference rivers in macroinvertebrate composition and temporal dynamics, reflecting the substantial influence of the Denison River and other tributary rivers. This is also reflected in its Bray Curtis similarity to reference rivers which are generally higher than for zone 1 (Figure 4-15). This is also reflected in the year to year changes in abundance of simuliid larvae, which are highly similar in zone 2 and the reference rivers. This latter phenomenon indicates that some of the larger scale macroinvertebrate community dynamics occurring in the larger Franklin-Gordon catchment still persist in the lower Gordon under the post-Basslink operation of the Gordon power station.

Metric values for reference rivers have continued to be more stable over the entire monitoring period than for the Gordon River (Figure 4-12 to Figure 4-16).



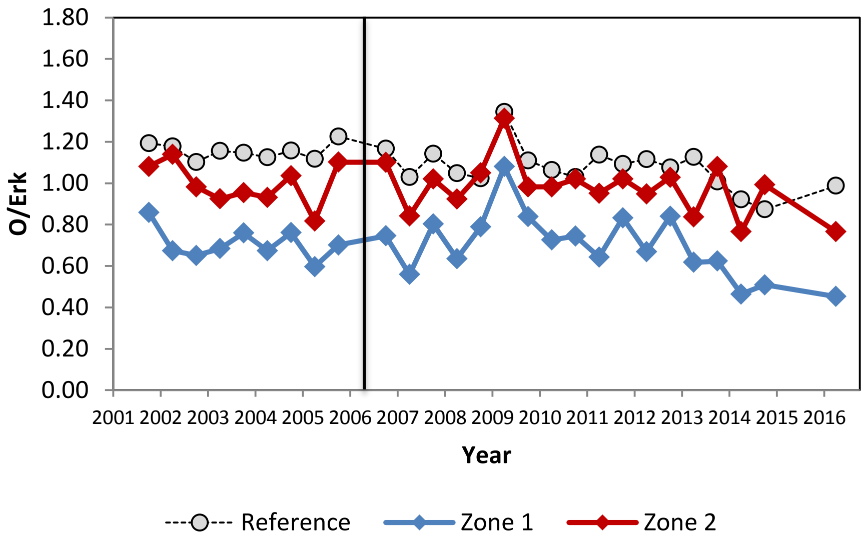
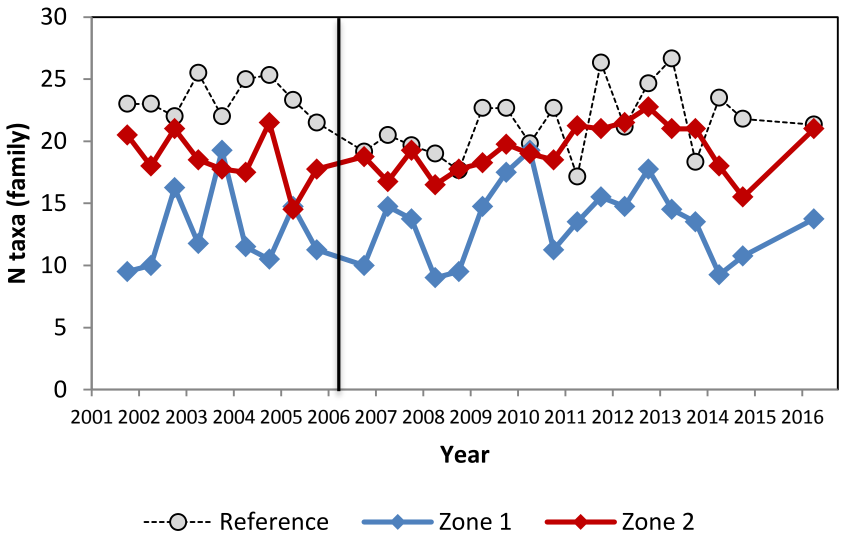


Figure 4-12 Mean O/Epa and O/Erk metric values for each zone in the Gordon river and reference rivers on each sampling occasion. Vertical line indicates initiation of Basslink operations.



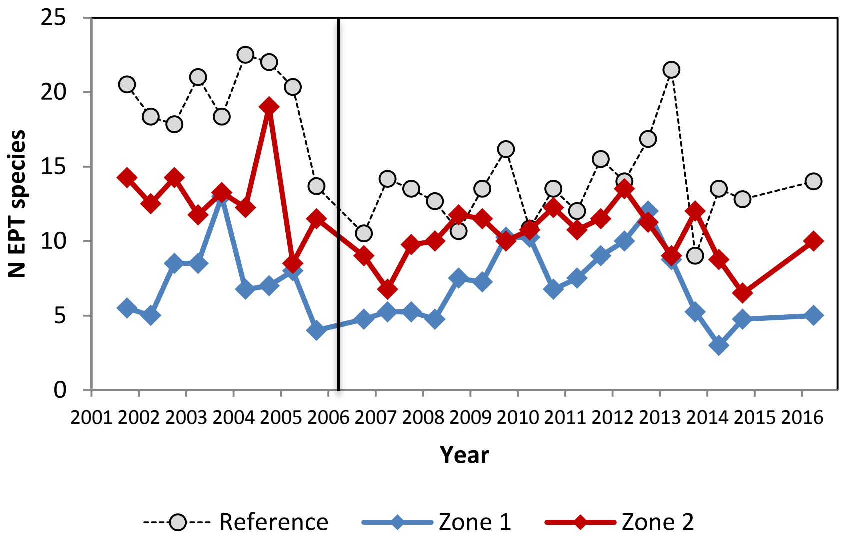
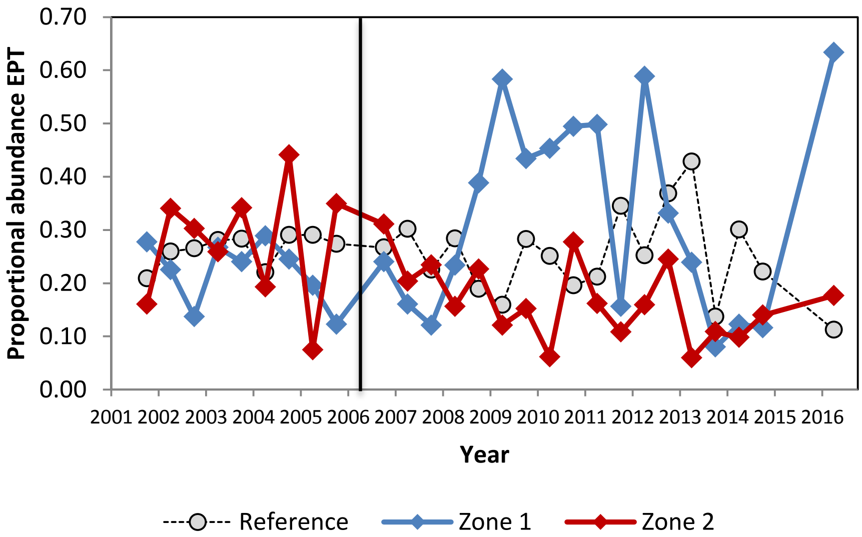


Figure 4-13 Mean N taxa (family) and N EPT species metric values for each zone in the Gordon River and reference rivers on each sampling occasion. Vertical line indicates initiation of Basslink operations.



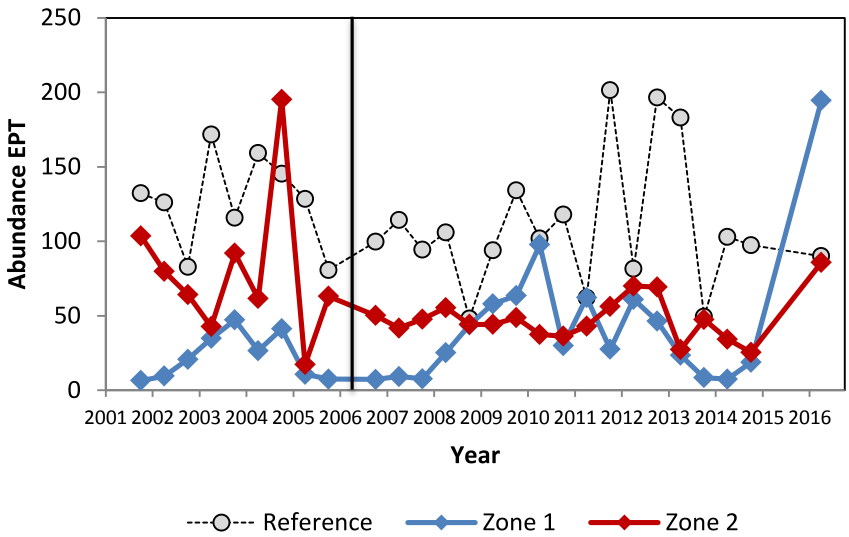


Figure 4-14 Mean Proportional abundance and absolute abundance of EPT taxa metric values for each zone in the Gordon River and reference rivers on each sampling occasion. Vertical line indicates initiation of Basslink operations.

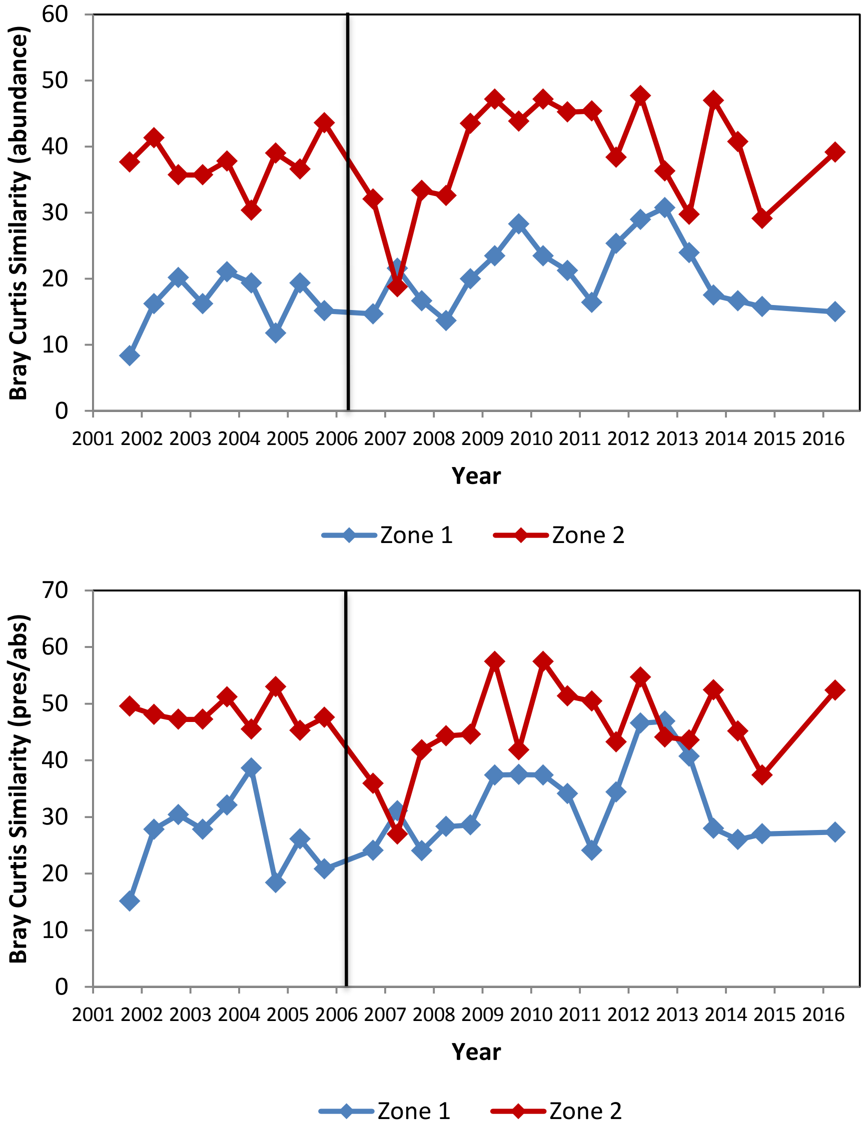


Figure 4-15 Mean Bray Curtis Similarity metric values between each zone in the Gordon River and the reference rivers on each sampling occasion. Vertical line indicates initiation of Basslink operations.

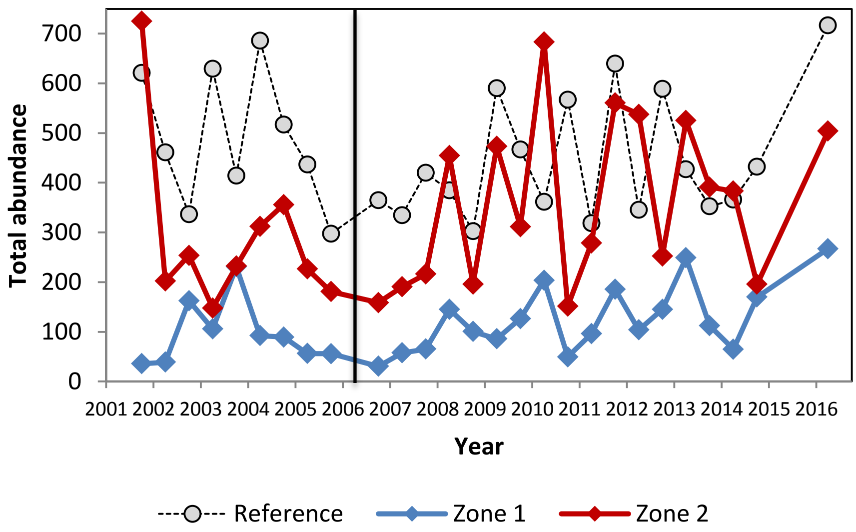


Figure 4-16 Mean total benthic macroinvertebrate abundance metric values for each zone in the Gordon River and reference rivers on each sampling occasion. Vertical line indicates initiation of Basslink operations.

4.6 Conclusion

Sampling was conducted successfully according to the requirements of the Gordon River monitoring program for all sites.

The current status for the tenth year of the post-Basslink period is:

- three of the nine macroinvertebrate metrics had all values within trigger bounds;
- one metric (O/Erk) was just below the lower bound for zone 1;
- large upper trigger bound exceedances for both abundance of EPT metrics (proportional and absolute); and
- three metrics (Bray-Curtis presence/absence, N-taxa family, total abundance) with values slightly above the upper trigger bounds.

The trigger exceedance for the O/Erk metric (falling below lower bounds) in 2015-16 follows a decline in this in zone 1 which commenced in 2013-14, following the most persistent high flow conditions observed to date. The flow conditions in the 12 months preceding monitoring in autumn 2016 were likely not conducive to the return to pre-Basslink levels for this metric. These flow conditions consisted of periods of regular, high level power station peaking between 35 and 200 m^3s^{-1} between April and September 2015 and subsequent periods of extended high power station discharge (> 100 cumec m^3s^{-1}) during the summer of 2015-16. The low value of O/Erk metric remains of ecological significance.

The increases in total abundance and abundance of EPT species are not of concern and can be regarded as representing improvement in biological condition relative to pre-Basslink conditions. The increases in abundance are largely driven by a spike in the abundance of the Hydropsychid caddis *Asmicridea sp. AV1*. The increases in this species are likely influenced by the reduction in hydro-peaking since September 2015.

Exceedances above the upper trigger bounds were also observed in autumn 2016 for the Bray Curtis similarity to reference in zone 2 and the number of families at the Whole of River scale. Both exceedances reflect slight and transient increases in diversity at family level in zone 2, which partially mimic changes in the reference rivers, and are not of ecological significance.

5 References

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A Appendix A: Power station discharges graphed per month

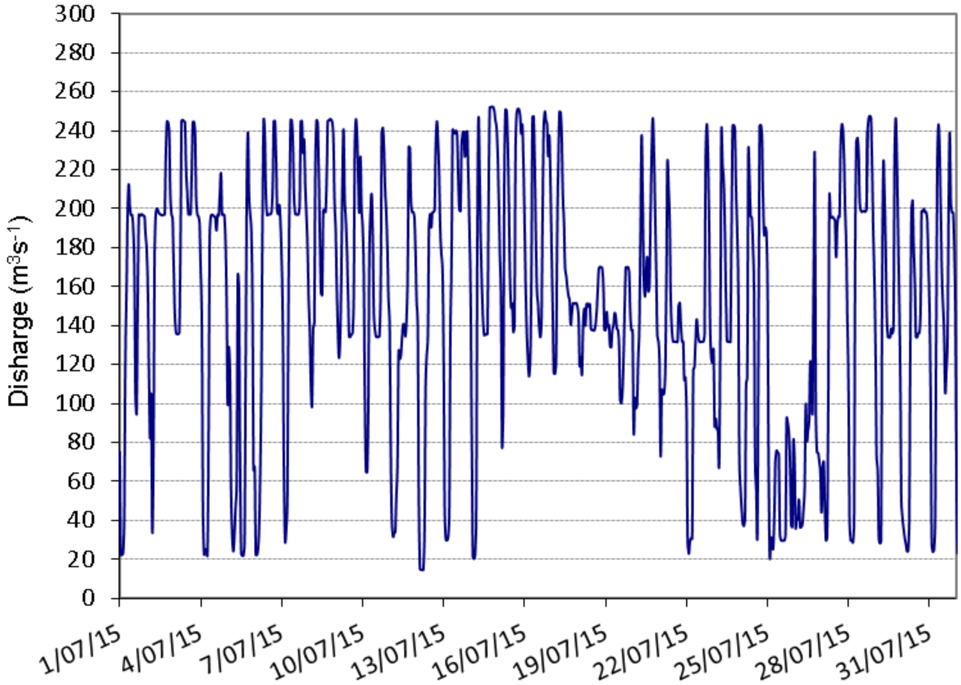

Figure A.1: Gordon Power Station discharge (hourly data) for July 2015.

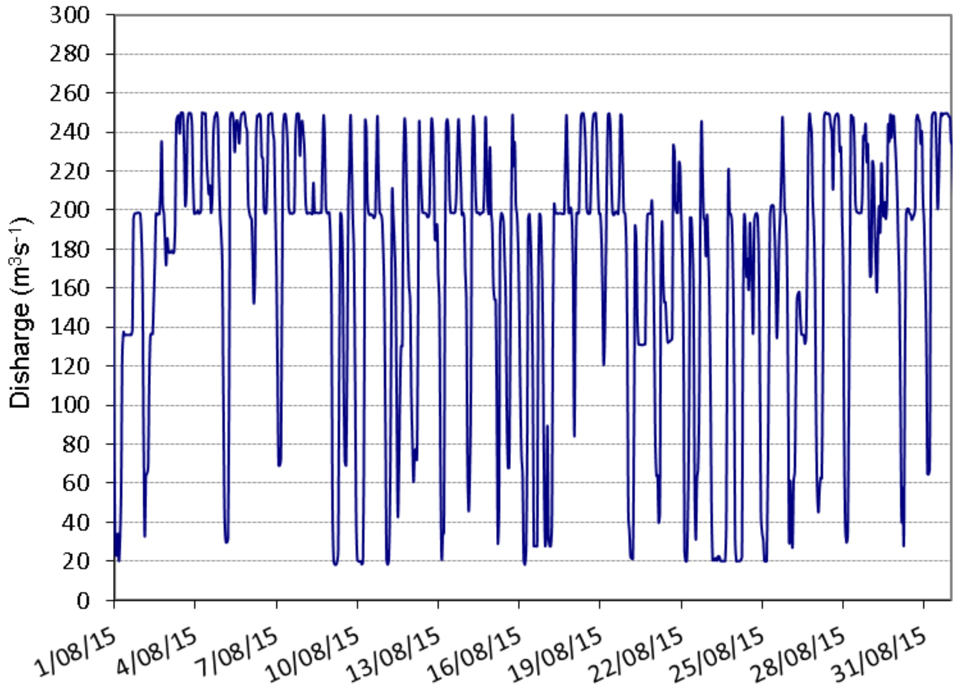

Figure A.2: Gordon Power Station discharge (hourly data) for August 2015.

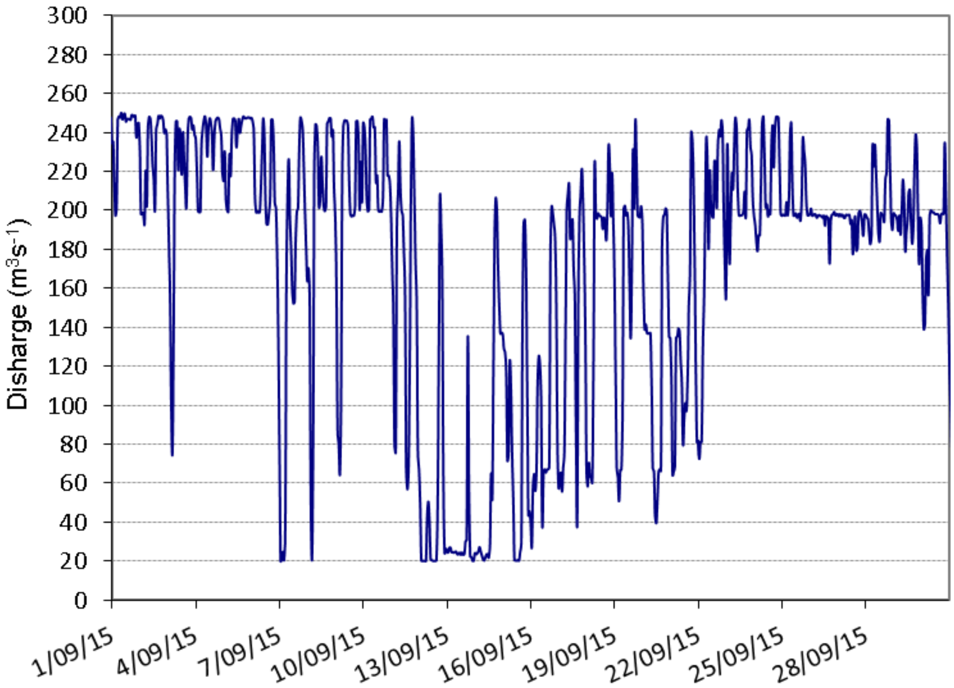

Figure A.3: Gordon Power Station discharge (hourly data) for September 2015.

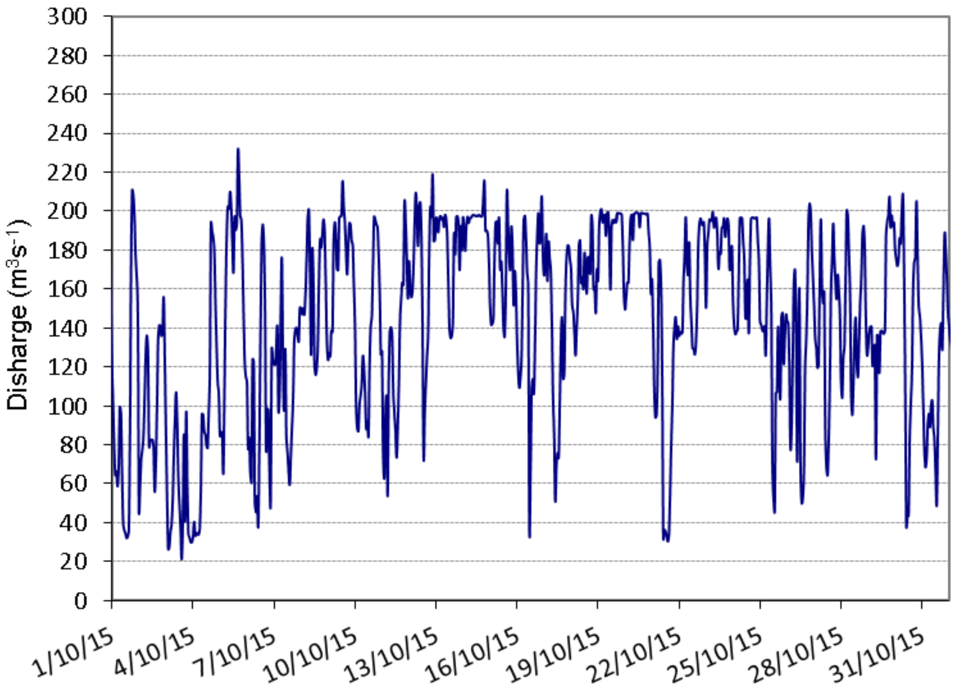

Figure A.4: Gordon Power Station discharge (hourly data) for October 2015.

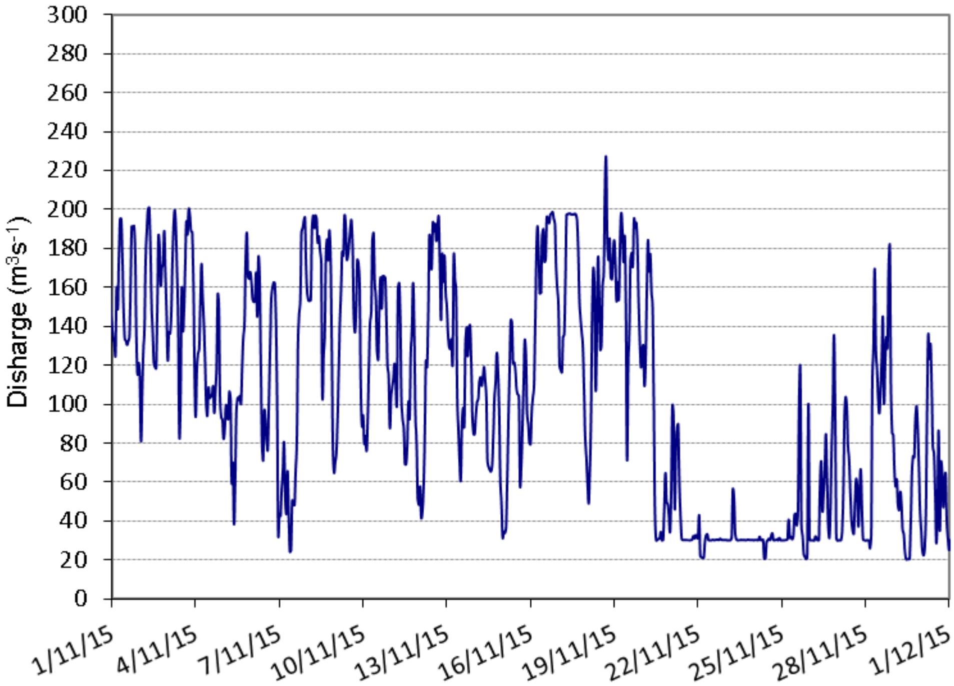

Figure A.5: Gordon Power Station discharge (hourly data) for November 2015.

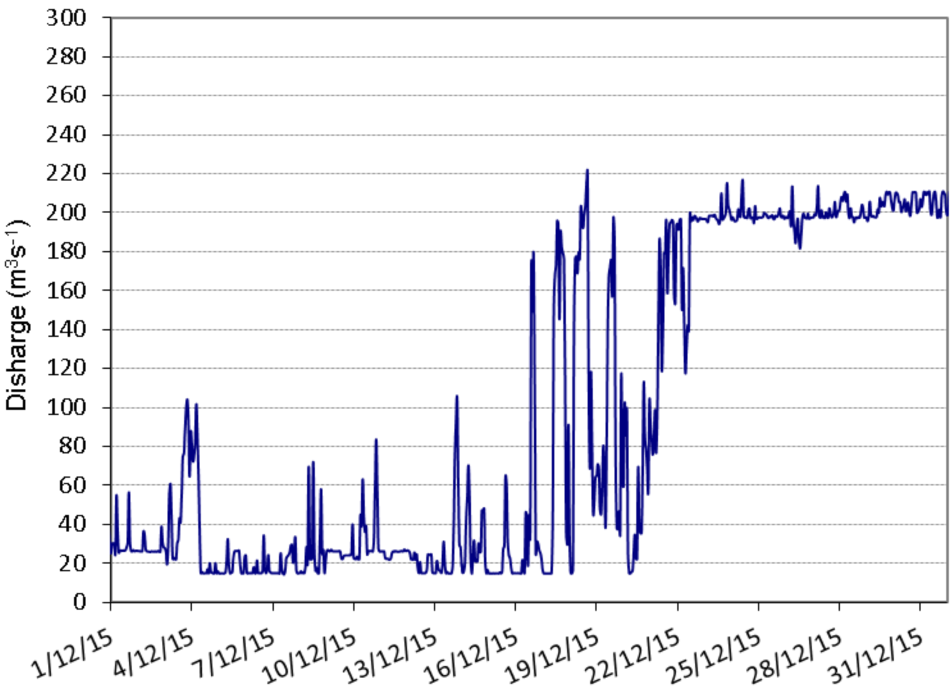

Figure A.6: Gordon Power Station discharge (hourly data) for December 2015.

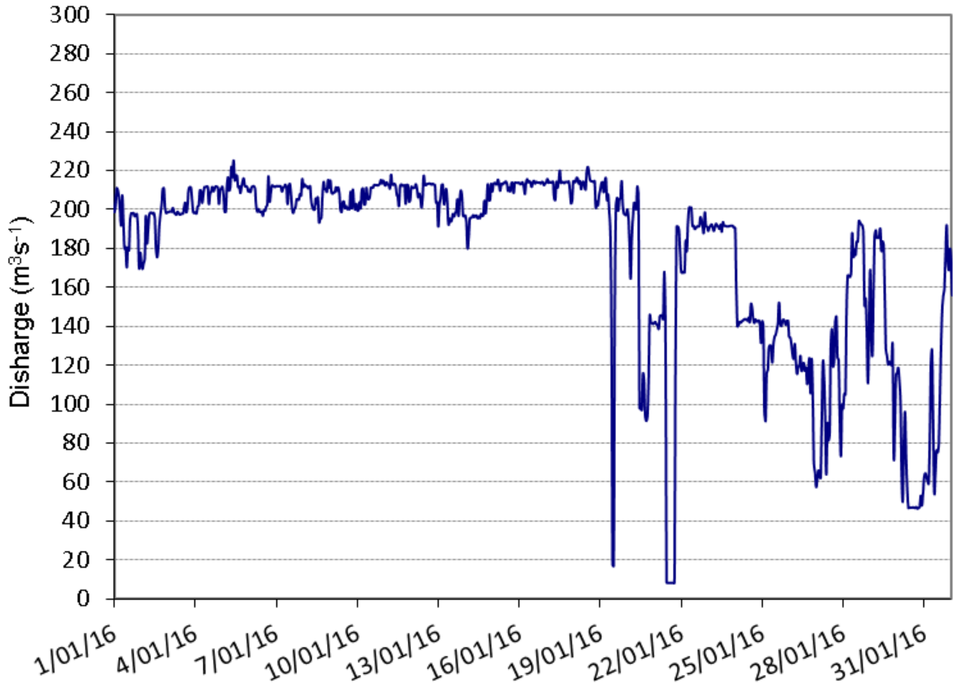

Figure A.7: Gordon Power Station discharge (hourly data) for January 2016.

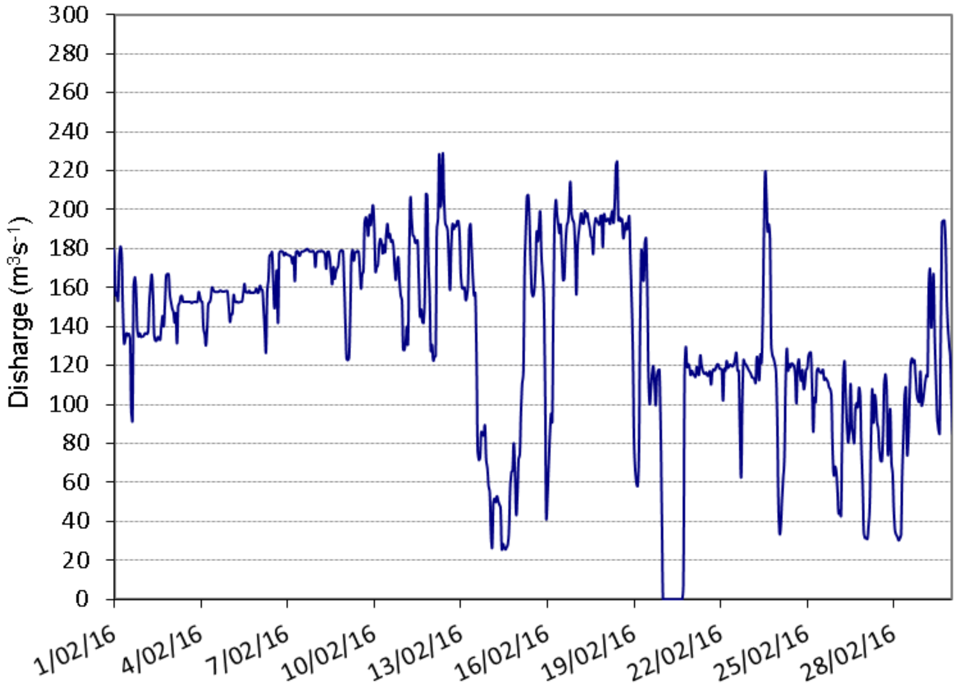

Figure A.8: Gordon Power Station discharge (hourly data) for February 2016.

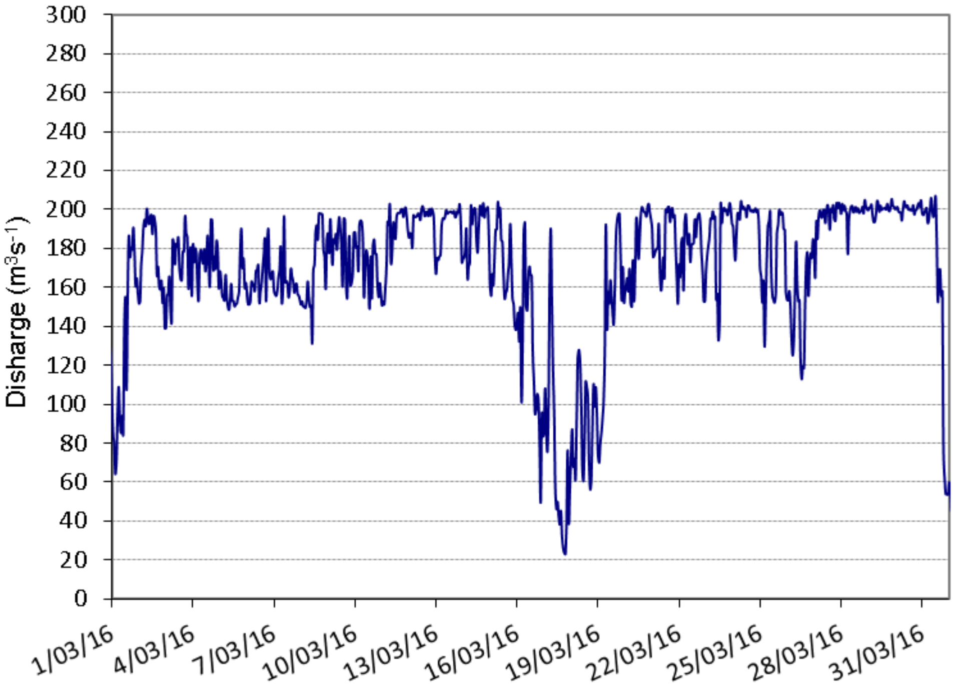

Figure A.9: Gordon Power Station discharge (hourly data) for March 2016.

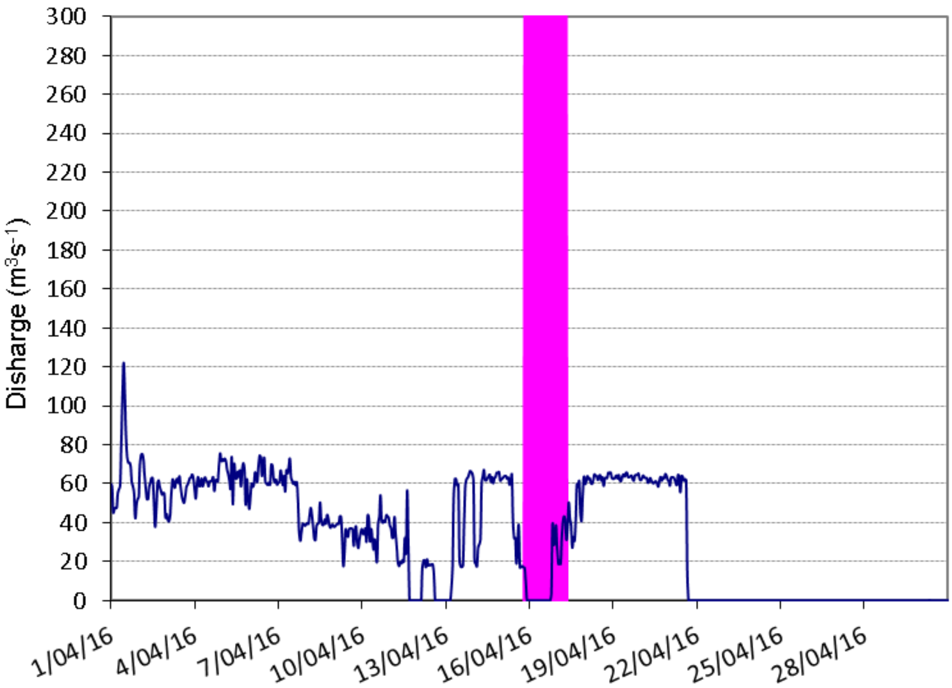

Figure A.10: Gordon Power Station discharge (hourly data) for April 2016. Pink block indicates field monitoring period.

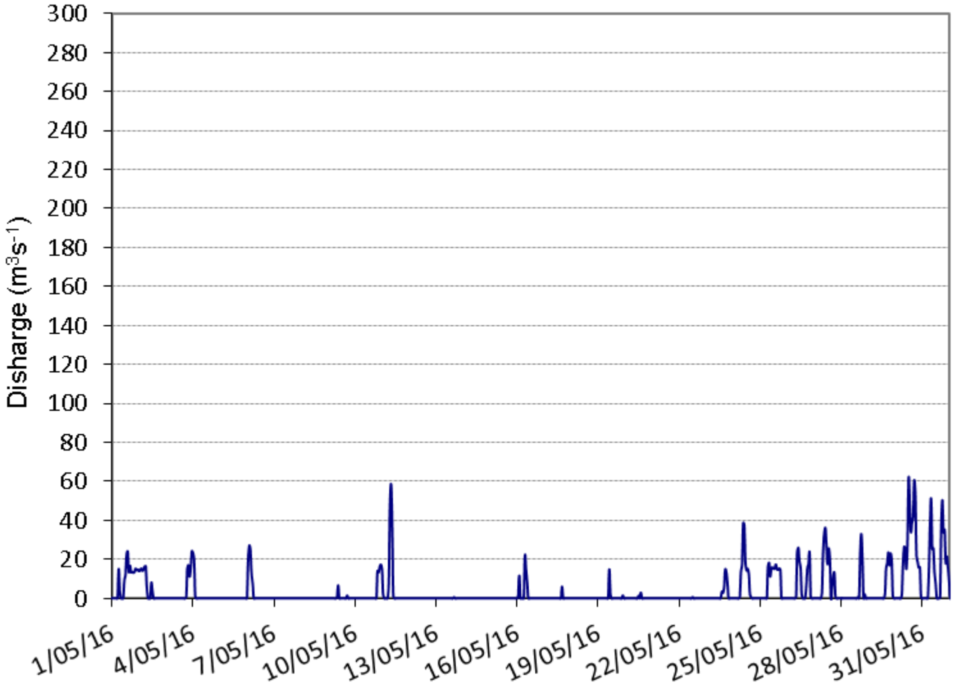

Figure A.11: Gordon Power Station discharge (hourly data) for May 2016.

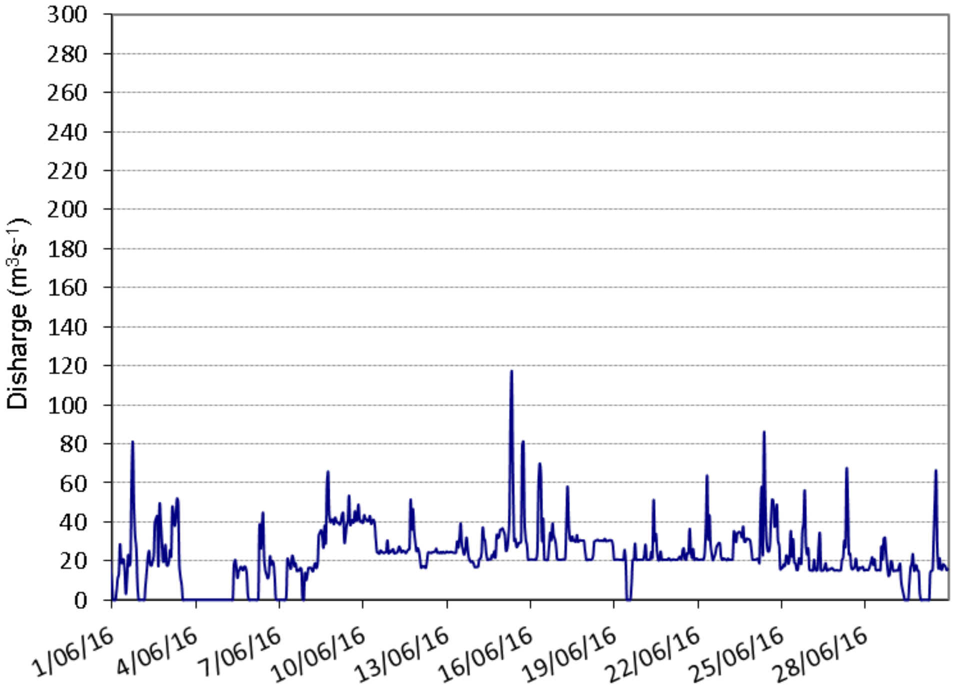

Figure A.12: Gordon Power Station discharge (hourly data) for June 2016.

B Appendix B: Fast ramp-down events

Table B.1: Fast ramp-down events at Gordon Power Station for 1 July 2015 to 30 June 2016.

Event no.	Date	Duration (minutes)	Maximum Generation reduction rate (MW/min)	Average Generation reduction rate (MW/min)	Starting level of piezometer (m)
1	05/07/2015	5	-1.02	-1.02	2.92
2	14/07/2015	10	-1.00	-1.00	3.20
3	15/07/2015	5	-1.01	-1.01	3.44
4	15/07/2015	15	-1.24	-1.16	3.44
5	16/07/2015	25	-1.17	-1.11	3.38
6	20/07/2015	5	-1.00	-1.00	3.00
7	20/07/2015	10	-1.04	-1.02	3.01
8	22/07/2015	15	-1.14	-1.07	3.03
9	23/07/2015	5	-1.02	-1.02	3.23
10	31/07/2015	10	-1.04	-1.02	2.98
11	05/08/2015	5	-1.02	-1.02	3.36
12	10/08/2015	5	-1.01	-1.01	2.79
13	10/08/2015	5	-1.01	-1.01	3.24
14	13/08/2015	10	-1.09	-1.06	3.30
15	15/08/2015	5	-1.01	-1.01	3.42
16	20/08/2015	10	-1.05	-1.03	3.46
17	21/08/2015	15	-1.06	-1.05	2.81
18	21/08/2015	10	-1.01	-1.01	2.80
19	25/08/2015	10	-1.04	-1.04	3.10
20	28/08/2015	10	-1.07	-1.06	3.29
21	07/09/2015	5	-1.04	-1.04	3.61
22	08/09/2015	10	-1.10	-1.08	3.60
23	09/09/2015	10	-1.09	-1.05	3.70
24	19/09/2015	5	-1.14	-1.14	3.08
25	19/09/2015	5	-1.03	-1.03	2.92
26	20/09/2015	5	-1.03	-1.03	3.03
27	20/09/2015	5	-1.01	-1.01	3.03
28	21/09/2015	15	-1.09	-1.08	2.84
29	21/09/2015	15	-1.03	-1.02	2.89

Event no.	Date	Duration (minutes)	Maximum Generation reduction rate (MW/min)	Average Generation reduction rate (MW/min)	Starting level of piezometer (m)
30	21/09/2015	10	-1.11	-1.09	2.94
31	22/09/2015	15	-1.11	-1.09	2.76
32	22/09/2015	10	-1.01	-1.01	2.80
33	22/09/2015	20	-1.10	-1.04	3.09
34	22/09/2015	5	-1.01	-1.01	3.10
35	27/09/2015	5	-1.06	-1.06	3.23
36	30/09/2015	5	-1.02	-1.02	3.28
37	07/10/2015	15	-1.06	-1.04	2.78
38	09/10/2015	5	-1.03	-1.03	3.10
39	12/10/2015	10	-1.02	-1.01	2.96
40	15/10/2015	15	-1.21	-1.12	2.98
41	18/10/2015	15	-1.04	-1.02	3.04
42	22/10/2015	20	-1.09	-1.06	2.92
43	24/10/2015	10	-1.08	-1.05	3.24
44	27/10/2015	25	-1.10	-1.04	2.90
45	28/10/2015	5	-1.00	-1.00	3.00
46	30/10/2015	30	-1.04	-1.02	3.09
47	09/11/2015	5	-1.02	-1.02	2.90
48	18/11/2015	15	-1.04	-1.02	2.76
49	18/11/2015	10	-1.02	-1.01	2.77
50	19/11/2015	10	-1.04	-1.04	2.98

C Appendix C: Geomorphology photo monitoring

C.1 Zone 1

Site 1E

March 2013

October 2014

April 2016

C.2 Zone 2

Site 2A

March 2013 (no photo from Mar 2014)

October 2014

April 2016

Site 2–1: Upstream view of cobble bar from site 2A


March 2014


October 2014


April 2016

Site 2–2: Downstream view of cobble bar from site 2A


March 2014


October 2014


April 2016

Site 2–3: Backwater view upstream at site 2A


March 2014


October 2014


April 2016

Site 2–4: Backwater view upstream at site 2A


March 2014 (further d/s –moved to pins 6 and 7)


October 2014


April 2016

Site 2–5: Landslip (previously P2 new 1)


March 2014


October 2014


April 2016

Site 2D


March 2014


October 2014


April 2016

Site 2E


March 2014


October 2014


April 2016

Site 2–6


March 2014


October 2014


April 2016

Site 2–7: Left bank


March 2014 (different angle)


October 2014


April 2016

Site 2–8: Left bank – close up of 2–7


October 2014 (not obtained in March 2014)


April 2016

Site 2–9: Left bank (old P2-2new)


March 2014


October 2014


April 2016

Site 2–10: Left bank (old P2-2b)


March 2014


October 2014


April 2016

Site 2–11: Left bank (old P2–4)


March 2014


October 2014


April 2016

Site 2–12: Left bank

No suitable photo obtained in April 2016


P2 - 12: Left bank, March 2014


P2 - 12: Left Bank, October 2014

Site 2–13: Left bank


March 2014


October 2014


April 2016

Site 2–14: Left bank


March 2014


October 2014


April 2016

Site 2–15: Right bank (old P2–5)


March 2014


October 2014


April 2016

Site 2H


March 2014


October 2014


April 2016 (poor photo)

Site 2–16: Left bank


March 2014


October 2014


April 2016

Site 2L


March 2014


October 2014


April 2016

C.3 Zone 3

Site 3C


March 2014


October 2014


October 2014

Site 3D


March 2014


October 2014


October 2014

Site 3E


March 2014


October 2014


April 2016

Site 3–1


March 2014


October 2014


April 2016

C.4 Zone 4

Site 4–1: Landslip at Denison confluence

November 2013

October 2014

April 2016

Site 4–2: Landslip at Denison confluence


October 2013


October 2014


October 2014

Site 4–3: (Old P4–1)


November 2013


October 2014


April 2016

Site 4–4: Right bank landslip


October 2013


October 2014


April 2016

Site 4D


March 2014


October 2014


April 2016

Site 4E

March 2014

October 2014

April 2016

Site 4H

October 2013

October 2014

April 2016

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D Appendix D: Macroinvertebrate data

Appendix D.1. Quantitative macroinvertebrate 'family level' data – autumn 2016

Table D.1: Abundances as n per 0.18 m^2 for middle Gordon River and reference sites sampled in autumn 2016

			River :	Gordon R								Franklin R		Denison R		Maxwell R	Jane R
			Site code:	75	74	72	69	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
			Old site code:	G4	G4a	G5	G6	G9	G10	G11B	G15	G19	G20	G21	D1	M1	J1
Class	Order	Family	Sub family														
Cnidaria	Hydrozoa			1	1												
Platyhelminthes	Turbellaria			2	2			2	1	2						4	6
Nematoda							1		1		2						
Mollusca	Bivalvia	Sphaeriidae													1		
	Gastropoda	Hydrobiidae			1			2	1	1						6	
Annelida	Oligochaeta			1	37	12	2	30	71	55	49	117	90	32	32	37	90
Arachnida	Acarina																2
Crustacea	Amphipoda	Paramelitidae						1	1	1				4		1	
		Neoniphargidae			2		1										
	Isopoda	Janiridae		11	75	15	2	1	3	4	3	1		1			1
		Phreatoicidea					1										
Insecta	Plecoptera	Eustheniidae		1			2		1	1					4	1	4
		Gripopterygidae			7	1	1	4	4	1			1		4	18	13
	Ephemeroptera	Leptophlebiidae				1		6	12	8	6	8	14	23	31	36	36
		Baetidae						3	1	1	2	2	7	11	16	13	72
	Diptera	Chironomidae:	*Chironominae*		1	13	2		3	3		5			21	1	11
		Chironomidae:	*Orthocladiinae*	1	2	2	5	2	1	5	3	6	4		3	12	14
		Chironomidae:	*Podonominae*						2	1	2	1	1	1	4	3	37
		Chironomidae:	*Aphroteniinae*							1				1	1		4
		Simuliidae		24	50	7	2	218	470	315	289	403	455	376	342	399	331
		Tipulidae				1						1			1	1	
		Blephariceridae								2	3		7	1	3		
		Ceratopogonidae										1	1	1		1	
		Chaoboridae		3													
		Empididae			1			1							5	1	1
		Dip. Unid. Pup.			1	1		9	15	19	13		1		4	6	
	Trichoptera	Calocidae								1					9	3	12
		Conoesucidae					1	4	4	1					1	29	8
		Glossosomatidae															23
		Helicophidae													1		1
		Hydrobiosidae		1	13	3			17	8	3	4	4	6	2	1	5
		Hydropsychidae		4	411	192	136	149	55	36	9	3	1		2	12	2
		Hydroptilidae														6	
		Leptoceridae		1	3	1	1	1	3	4	1	1	2	6	15	5	38
		Philorheithridae						2		1		1		4	14	1	3
		Trich. Unid. Pup.			1			2		1	1						
	Coleoptera	ElmidaeA				1			4	2	2		2		1	23	51
		ElmidaeL						1	8	3		11	2	25	76	147	190
		ScirtidaeL				3		7	13	11	2	16	4	28	96	81	91
		PsepheniidaeL				1					1	1			6	5	3
			Total abundance	**50**	**609**	**253**	**157**	**449**	**689**	**488**	**389**	**584**	**594**	**521**	**717**	**881**	**1003**
			N Taxa (families)	**11**	**17**	**14**	**13**	**20**	**22**	**26**	**16**	**18**	**15**	**16**	**26**	**27**	**26**

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Appendix D.2. Quantitative 'species level' data for EPT taxa – autumn 2016

Table D.2: Ephemeroptera, Plecoptera and Trichoptera for middle Gordon River and reference sites sampled in autumn 2016 (abundances as n per 0.18 m^2).

		River :	Gordon R								Franklin R		Denison R		Maxwell R	Jane R
		Site code:	75	74	72	69	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
x = formerly Baetid Genus 2 MVsp3		Old site code:	G4	G4a	G5	G6	G9	G10	G11B	G15	G19	G20	G21	D1	M1	J1
Order	Family	Genus/Species														
Ephemeroptera	Baetidae	Offadens hickmani (see x)					3	1	1	2	2	7	11	16	13	72
		Nousia sp. AV5/6			1		5	12	7	5	7	9	18	25	31	29
		Nousia sp. AV7							1			2	3	2		2
		Nousia sp. AV9												2	4	
		Tillyardophlebia sp AV2					1			1	1	3	2	2	1	5
	Eustheniidae	Eusthenia costalis				2		1	1					3	1	4
		Eusthenia spectabilis												1		
	Gripopterygidae	Cardioperla incerta												1	8	6
		Cardioperla media/lobata					1	4				1			4	4
		Dinotoperla serricauda													2	2
		Leptoperla varia				1										
		Trinotoperla zwicki		7	1		3		1					3	4	1
		Austrocercoides sp														1
Trichoptera		Tamasia variegata							1					9	3	12
	Conoesucidae	Conoesucus brontensis													1	
		Conoesucus norelus				1	4	3	1					1	22	8
		Costora delora													1	
		Costora luxata													1	
		Costora rotosca													1	
		Hampa patona													3	
	Glossosomatidae	Agapetus sp. AV1														23
		Allocoella longispina												1		1
		Apsilochorema gisbum						1								
		Ethochorema nesydrion													1	
		Moruya opora		3				4	3	1						
		# Taschorema apobamum		1					1	1	3		1			
		# Taschorema asmanum			2								1	1		
		Taschorema ferulum grp (includes all #)	1	2	1			7		1	1	3	4			5
		Ulmerochorema rubiconum		7					4			1		1		
	Hydropsychidae	Asmicridea sp. AV1	4	411	192	136	149	55	36	9	3	1		2	12	2
		Oxyethira mienica													6	
		Notalina sp.AV1							4		1	2	6	11	2	38
		Notalina sp.	1	3	1		1	3		1				4	3	
		Tasmanthrus sp.					2		1		1		4	14	1	3
		Abundance EPT	**6**	**434**	**198**	**140**	**169**	**91**	**62**	**21**	**19**	**29**	**50**	**99**	**125**	**218**
		N EPT Taxa	**3**	**7**	**6**	**4**	**9**	**10**	**13**	**8**	**8**	**9**	**9**	**18**	**22**	**18**

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Appendix D.3. RBA macroinvertebrate data – autumn 2016

Table D.3: Abundances per live picked sample for middle Gordon River and reference sites sampled in autumn 2016.

			River :	Gordon R																Franklin R				Denison R				Jane R		Maxwell R	
			Site :	75		74		72		69		60		57		48		42		Fr11		Fr21		De7		De35		Ja7		Ma7	
Class	Order	Family	Sub-Family	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Platyhelminthes	Turbellaria																				2				1						
Mollusca	Gastropoda	Hydrobiidae													1																
		Gastr. Unid.								1																					
Annelida	Oligochaeta				1	1	6	10	17	5	7	12	23	11	15	40	24	9	15	12	24	18	14	13	12	9	2	18	16	3	
Arachnida	Acarina													1										1	1						1
Crustacea	Amphipoda	Paramelitidae				1	2			2	1			2	1	3								2	1			1		3	4
	Isopoda	Phreatoicidea								3	6																				
Insecta	Plecoptera	Eustheniidae				4	1			1	1	2	1		1	1	4	1	1		1	1					4			2	
		Austroperlidae																		1											
		Gripopterygidae			3	15	24	1			1	5	9			7	2	6	7		2	5	2			1		4	5	9	20
	Ephemeroptera	Leptophlebiidae						1	1	11	3	13	26	9	22	34	15	17	10	30	17	29	25	62	48	38	26	35	34	40	43
		Baetidae										5	6		1	4	3	5	2	6	5	37	19	16	12	30	9	41	28	40	34
		Siphlonuridae																							1					2	2
	Odonata	Telephlebiidae				1																									
	Diptera	Chironomidae:	*Chironominae*	1							1									1		1	1			2	4				
		Chironomidae:	*Orthocladiinae*									2				3	1	2	3		1	4	3			1	1	3	1	9	2
		Chironomidae:	*Podonominae*									5	4	2	4					1	5	14	8	9	9	20	14	14	14		26
		Chironomidae:	*Tanypodinae*							1																					
		Simuliidae		33	86	3	7	2	1	2	3	36	58	61	56	81	71	76	107	45	29	54	46	22	30	47	13	11	11	20	
		Tipulidae											2					1		1	2										4
		Athericidae																													1
		Blephariceridae																	3												
		Ceratopogonidae																1				1	2								
		Dixidae									1																				
		Dolichopodidae																	1				1			1		2			
		Dip. Unid. Pup.																									2				1
	Trichoptera	Calocidae								1	1																1				
		Conoesucidae																		1		1								2	3
		Ecnomidae				2																									
		Hydrobiosidae		45	33	16	31	6	6	6	10	16	18	9	19	26	28	31	18	11	13	10	11	10	7	8	3	6	7	15	6
		Hydropsychidae		36	41	144	76	83	126	20	73	18	8	3	2	5	8		1												
		Leptoceridae		1			4				1		2		1		1		2		4	7	4	26	3	1		2	11	25	15
		Philorheithridae										1	1	1						2		2		4	3	1	2	1	6	3	3
		Trich. Unid. Pup.					3				3	5			1		2	2													
	Coleoptera	ElmidaeA		1	2		4					3	6		1			4				2	5	22		11	4	8	6	10	17
		ElmidaeL																				1	1	7	6	1		3	7	4	9
		ScirtidaeL							2				3		1			2		16		5	2	19	4	13	4	11	32	17	14
		PsepheniidaeL							1											1				1			1	3		3	11
		DytiscidaeL																										1			
			N Taxa	**6**	**6**	**9**	**10**	**6**	**7**	**11**	**14**	**13**	**14**	**9**	**14**	**10**	**11**	**13**	**12**	**13**	**12**	**17**	**15**	**14**	**14**	**15**	**15**	**17**	**13**	**17**	**20**

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Appendix D.4. Trigger value metrics

Table D-4: Values of all metrics for each site sampled in autumn 2016

			Spring 2013								
			Community Structure		Community Composition		Taxonomic richness		Ecologically significant species		Biomass / productivity
River	Site code	Old code	Bray Curtis (abundance)	O/Erk	Bray Curtis (pres/abs data)	O/Epa	N Taxa (fam)	N EPT species	Propn abundance EPT	Abundance EPT	Total abundance
Gordon											
	75	G4	16.35	0.43	23.41	0.54	11	3	0.140	6	50
	74	G4a	14.54	0.45	29.86	0.78	17	7	0.714	434	609
	72	G5	18.29	0.33	37.74	0.64	14	6	0.783	198	253
	69	G6	10.75	0.60	18.28	0.83	13	4	0.898	140	157
	60	G9	36.58	0.88	55.90	1.22	20	9	0.381	169	449
	57	G10	35.63	0.71	44.21	0.98	22	10	0.141	91	689
	48	G11B	43.04	0.77	58.86	0.98	26	13	0.129	62	488
	42	G15	41.39	0.71	50.48	1.08	16	8	0.057	21	389
Reference											
Franklin	Fr11	G19	43.42	0.83	58.59	1.03	18	8	0.033	19	584
	Fr21	G20	50.33	0.98	57.42	1.22	15	9	0.049	29	594
Denison	De7	G21	53.22	0.96	57.00	1.17	16	9	0.096	50	521
	De35	D1	43.70	0.93	49.64	1.12	26	18	0.138	99	717
Maxwell	Ma7	M1	42.28	1.21	48.19	1.47	27	22	0.142	125	881
Jane	Ja7	J1	47.33	1.01	60.44	1.27	26	18	0.216	218	1003