Gordon River Monitoring Annual Report 2012–13

Basslink Interim Monitoring Program

Date 30 September 2013

Executive summary

Hydrology

The flow in the Gordon River in 2012–13 was influenced by the bi-modal operation of the power station that resulted in the first six months of the year having low discharge and the second six months having very high continuous discharges. High discharges were maintained to take advantage of the ability to raise additional income following the implementation of the fixed carbon price.

In the months of July, August, November and December 2012, the discharge from Gordon Power Station was typified by a regular peaking pattern from environmental flow levels to levels corresponding to two-turbine operation. The intervening period in September and October saw little peaking and was dominated by the discharge of low flows to maintain the 20 $m^3 s^{-1}$ environmental flow. Very high flows were discharged from January to June 2013 of which there were regular fluctuations within the high discharge ranges between March and June.

The application of the revised ramp-down rule was undertaken successfully in its first full year of operation, with all generation reductions being compliant with the 1 MW per minute ramping requirements. Complete 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 (0.12%) due to intrinsic operational factors or unforeseeable machine trips. These occurrences are not considered to be non-compliant as they were outside of operational control.

The minimum environmental flow was achieved 99.75% of the time in summer. There was one non-compliant flow event during summer that lasted 11 hours. In winter, there was also one non-compliant flow event that lasted 3 hours and accounted for a winter compliance rate of 99.93%. The causes of the non-compliances were the requirement to turn off a transmission line to assist with fighting bushfires (summer) and operator misjudgment in returning the discharge from the power station to the environmental flow following a tributary inflow event (winter).

Flow patterns at downstream sites were generally reflective of flows from the power station with the same distinctive bi-modal annual pattern. In July to December 2012, there was a greater proportion of flows originating from tributaries, particularly during natural flow events in August and September 2012. The very high flows from January to June 2013 dominated the proportion of flows passing these sites.

Fluvial Geomorphology

Geomorphology monitoring in zones 1–4 was completed in October 2012 and in all zones (1–5) in March 2013. The monitoring included the same erosion pin and photo-monitoring sites as monitored previously.

Field observations in October 2012 were consistent with observed low levels of power station usage combined with high winter inflows, and included relatively large sand and mud deposits on banks and cobble bars, increased vegetation on banks within the power station operating range and abundant algae on bank toes within the range of the environmental flow.

Field observations in March 2013 were consistent with high power station discharge and high levels of bank saturation, with evidence of scour and seepage processes associated with bank draining. Sediment flows due to seepage erosion were present at sites where seepage features have previously been regularly documented. No new large seepage flows were observed. Other field observations included evidence of scour and the deposition of sands downstream of tributary confluences and upstream of the gorges.

Bank saturation remained low until October 2012, and increased substantially after January 2013 due to the extended power station usage. The piezometers showed a high risk of seepage on two occasions. However, seepage processes were not as widespread as observed in 2000–2001 when the power station operating patterns also included long periods of high discharge, suggesting the ramp-down rule is reducing the risk of seepage processes.

In October 2012, the erosion pin results for zones 1 through 4 showed decreased erosion (or increased deposition) relative to the February 2012 results, suggesting the deposition associated with the winter inflows was maintained in the absence of high power station discharge in the spring. The net erosion pin results for all zones fell below predictions based on pre-Basslink monitoring results. Erosion results have been lower than expected for several years in zones 2–4, however this was the first monitoring period in which the zone 1 results also fell outside of the predicted range.

Annualised erosion rates for zone 3, and for the 2–3 turbine bank level in zones 2 and 3 (combined) were the highest recorded since monitoring began. These results suggest that scour, rather than seepage processes were the dominant processes affecting the banks. The high erosion rates were likely attributable to the long duration high flows leading to high shear stress on the banks, a limited number of power station shutdowns, and possibly the depletion of sediment available for transport via seepage processes due to the ongoing adjustment of the banks. In zones 4 and 5 there was little net change and results were well within previous findings, although interpretation is limited by the absence of results from zone 5 in October 2012.

Photo-monitoring results showed changes had occurred at a slightly higher percentage of the sites as compared to all post-Basslink years, but similar to the percentage of sites showing changes pre-Basslink. Observed changes included the movement, deposition or removal of woody debris on bank toes, bank slumping (4 sites) and the deposition of sand near tributary confluences or upstream of channel constrictions at the Splits and Sunshine Gorge.

Overall, the response of the Gordon River to the flow patterns in the 2012–13 monitoring year is consistent with the fluvial geomorphic understanding of the river. The relative contributions of seepage and scour in the river may reflect a progression in bank adjustment, with seepage processes becoming less common, and scour dominating changes to the banks. However, the implementation of the revised ramp-down rule combined with the low number of power station shutdowns have undoubtedly also contributed to the relative reduction of seepage compared to scour.

Macroinvertebrates

Patterns and trends in benthic macroinvertebrate metric values for 2012–13 were broadly similar to those observed pre-Basslink with the following substantial exceptions:

- Community compositional similarity between Gordon River and reference sites were again higher than pre-Basslink means;
- The absolute and proportional abundance of EPT species was substantially raised in zone 1;

Trigger values were generally compliant in 2012–13, with the exception of:

- The total and proportional abundance of EPT species and Bray Curtis similarity to reference sites being raised, especially in zone 1, due to high densities of the caddis *Asmicridea* and the insect families Gripopterygidae and Hydrobiosidae. This is believed to be driven by the maintenance of the minimum environmental flow.

The combination of an increased level of peaking in 2010–11 and high flows in 2012–13 led to partial declines in biological condition in zone 1 compared to its peak in 2009–10.

Overall, for benthic macroinvertebrates, there continues to be a general compliance with, or positive exceedance of, established triggers and evidence of lagged improvement in benthic biological condition.

Conclusions

Geomorphic field observations were consistent with the conceptual models for low levels of power station usage in spring and high power station discharge and high levels of bank saturation in autumn.

Macroinvertebrate results were also consistent with the conceptual model with a partial decline in some metrics due to high discharges in 2013.

The results suggest that the revised ramp-down rule is reducing the risk of seepage erosion and the environmental flow remains effective.

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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
$m^3 s^{-1}$	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

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1 Introduction and background

The purpose of this Gordon River Basslink Annual Report is to present the results of the monitoring undertaken pursuant to the Gordon River Interim Basslink Monitoring Program during 2012–13. This is the seventh year of post-Basslink operation and the first of two years of interim Basslink monitoring. The monitoring area is shown on Figure 1-1.

1.1 Context

The Gordon River Basslink Interim Monitoring Program was put in place after the completion of the Basslink Monitoring Program. The aim of the Gordon River Interim Basslink Monitoring Program is to obtain additional data to assess the continued effectiveness of the mitigation measures; the minimum environmental flow and the revised ramp-down rule as required by Hydro Tasmania’s Special Water Licence Agreement.

The aims of the preceding 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 prevailing 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. Six years of data were collected post-Basslink.

The Gordon River Interim Basslink Monitoring Program comprises a monitoring regime for two years from May 2012 to April 2014 to assess the effectiveness of the mitigation measures. The monitoring focusses on most of the monitoring elements of the Basslink Program for hydrology, fluvial geomorphology and macroinvertebrate disciplines.

1.2 Basslink Baseline and Review Reports

One of the requirements of Hydro Tasmania’s Special Licence was to produce a Basslink Baseline Report (BBR) (Hydro Tasmania 2005a, 2005b) prior to Basslink commencement to provide a comprehensive assessment of pre-Basslink conditions in the Gordon River below the power station. The BBR described how post-Basslink conditions would be compared with the pre-Basslink ranges of variability and trends.

Basslink Review Reports were produced in 2010 and 2013 (Hydro Tasmania 2010, 2013) and assessed the full datasets in greater detail than presented in the annual reports. The review reports included the assessment of the effectiveness of mitigation measures. The Basslink Baseline and Review Reports are available on Hydro Tasmania's website: (www.hydro.com.au/environment/basslink-studies).

1.3 Logistical considerations and monitoring in 2012–13

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.

To complete the required monitoring work, the monitoring program has a schedule of at least two visits per year, each requiring the power station to be turned off for one or two consecutive days.

The 2012–13 monitoring trips were conducted on 6–7 October 2012, 3 December 2012 (reference rivers) and 17 March 2013.

1.4 Geographic datum

Map coordinates given in this document use the 1966 Australian Geodetic Datum (AGD) as this corresponds with the topographic maps currently available for the area. A later datum, the Geocentric Datum for Australia (GDA), has recently been 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.

1.5 Document structure

This document is the first of two Gordon River Basslink Monitoring Annual Reports reporting on the **i**nterim monitoring data. The report is organised into four chapters and four appendices.

This first chapter discusses the requirements, context, operational considerations and constraints of the program. Chapters 2–4 report on the monitoring work that was undertaken during 2012–13, 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 1);

- Erosion pin graphs (Appendix 2);
- Fluvial geomorphology photo-monitoring and site descriptions (Appendix 3); and
- Macroinvertebrate data (Appendix 4).

1.6 Authorship of chapters

The information presented in chapters 2–4 is based on field reports produced by scientists employed 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 Marie Egerrup with review from Malcolm McCausland (Entura), Alison Howman, Gerard Flack 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 2–10 was extracted.

Chapter	Chapter title	Lead Author(s)
2	Hydrology	Malcolm McCausland (Entura)
3	Fluvial geomorphology	Lois Koehnken (Technical Advice on Water)
3	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 Basslink monitoring area.

2 Hydrology and water management

This chapter provides an overview of the hydrological data from the Gordon River downstream of the Gordon Power Station for the July 2012 to June 2013 period. Conformance with the two mitigation measures, the environmental flow and the revised ramp-down rule, are presented.

2.1 Factors affecting Gordon Power Station discharge

The Gordon Power Station running regime has always been heavily influenced by a number of factors. A timeline of some of the major factors is presented in Figure 2-1.

The normal factors include:

- inflows to Hydro Tasmania catchments (volume, distribution and sequence);
- 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
- power station outages.

In all but four of the last 18 years, Tasmanian electricity demand was higher than the annual yield in the hydro scheme (Figure 2-2). The post-Basslink years (2006–2012) began with a continuation of a downward trend in overall storage position until 2007–08 (Figure 2-3). Implementation of the storage rebuild strategy in June 2008, an opportunity made possible by the commissioning of Basslink, resulted in increasing storage levels as Hydro Tasmania provided less hydro-generated electricity to the market. Consequently there was significant net import of power in 2007–08 and 2008–09. In 2009–10 there was lower net import and in 2010–11, a small net export of power as a result of an increase in the system-wide hydro generation in response to higher inflows and greater thermal generation. In 2011–12, hydro generation was reduced from the previous year, while demand was very similar. The difference was met by generation from the Aurora Energy Tamar Valley (AETV), wind and a small net import of power.

In 2012–13, the highest overall hydro generation of the past 18 years was produced in Tasmania (10,500 GWh) which contrasted with the relatively low hydro generation of recent years. The high hydro generation was primarily due to increased generation at Poatina Power Station and Gordon Power Station to capture additional revenue during the fixed carbon price period. Basslink net export was the highest since its commissioning (2,034 GWh).

Gordon Power Station generation in 2012–13 (1,821GWh) was one of the highest annual generation values since 1996, and exceeded the long-term average annual generation (1,299 GWh). The higher generation relative to yield has resulted in a rapid decline in water levels in Lake Gordon and Great Lake and a significant reduction in the overall system storage (Figure 2-3).

Based on modelling undertaken prior to Basslink commissioning it was expected that the Gordon Power Station running regime would become extremely ‘peaky’, increasing the number and severity of high to low flow reductions, as Hydro Tasmania responded to market opportunities. After seven years of Basslink operation, there have been some changes to the operation of Gordon Power Station, but the anticipated degree or pattern of peaking operation was not observed. A number of factors over the seven years of Basslink operation have played differing roles in the power station discharge, and include:

- drought conditions and associated low water storages;

- conversion of Bell Bay Power Station to gas-fired generators, and the commissioning of the AETV gas fired power station;
- market conditions that do not match assumptions used in the initial modelling; and
- the desire to hold water in storage until the carbon price was finalised.

The number and potential influence of factors on Gordon Power Station operation is vast, and the identification and quantification of the influence of these remains difficult to determine.

Some more specific month by month details of factors influencing the generation at Gordon Power Station in 2012-13 is provided in Table 2-3.

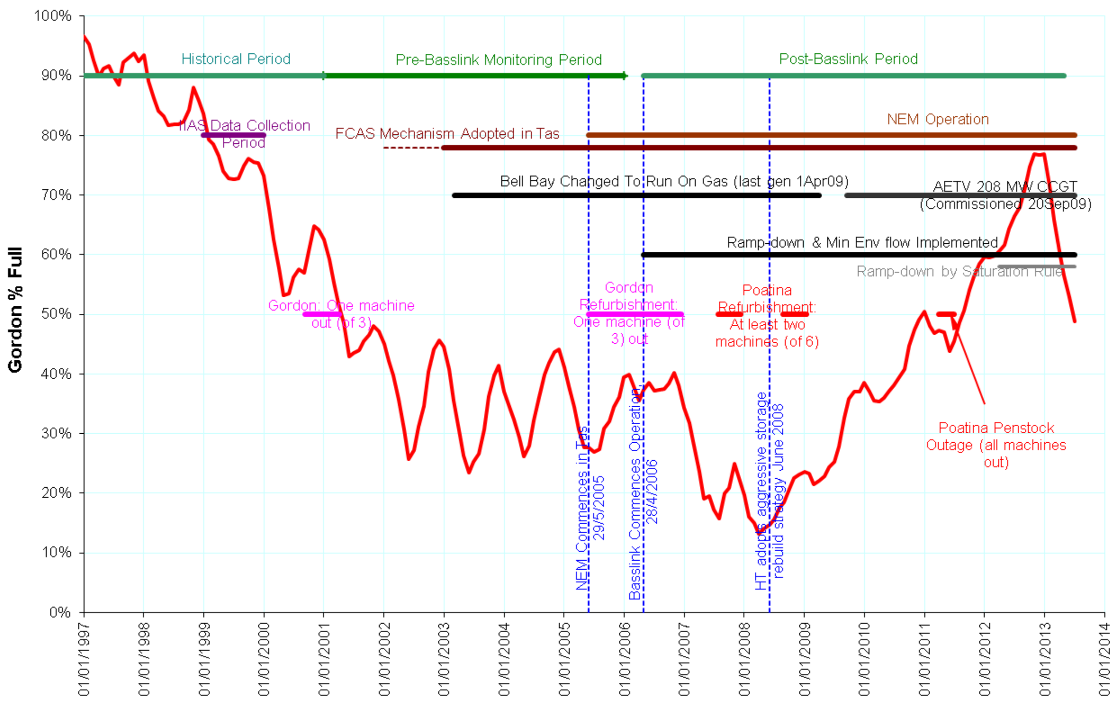

Figure 2-1: Timeline of significant factors affecting Gordon Power Station operation (including storage levels) relative to Basslink monitoring periods.

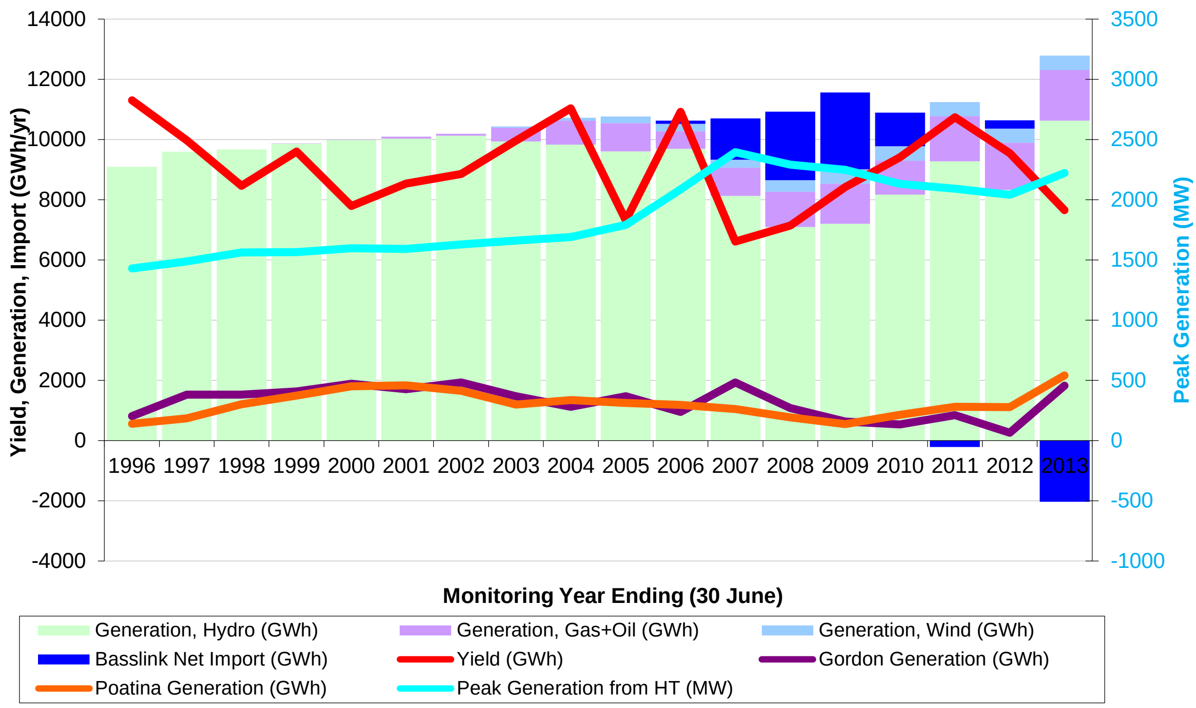

Figure 2-2: Annual hydro generation and yield, Basslink import, wind and gas generation, Gordon and Poatina generation in GWh and peak demand in MW for financial years from 1995–96 to 2012–13. Yield presents system inflows converted to GWh.

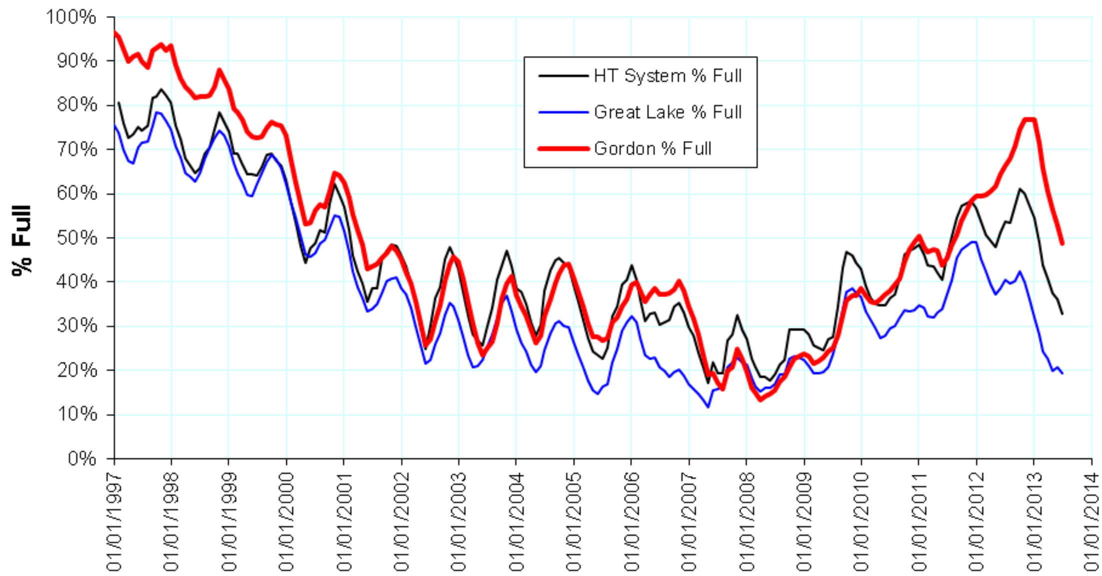

Figure 2-3: System, Lake Gordon and Great Lake water level presented as percent full for 1997–2013.

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 application (FLOCAP) used by the operators for the measurement 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:

- Machine 1 power output;
- Machine 2 power output;
- Machine 3 power 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 gauging stations used to record river levels during 2012–13 were sites 44, 62, 65, 69, 71 and 75. Power station discharge derived from the three-dimensional rating is used to estimate the flow in the tailrace (site 77). The sites reported in this chapter (and those for which data were collected but not reported here) are shown in Figure 2-4. The sites reported in this chapter are Gordon above Franklin (site 44), Gordon above Denison (site 65; also known as the flow compliance site) and the Gordon Power Station tailrace (site 77).

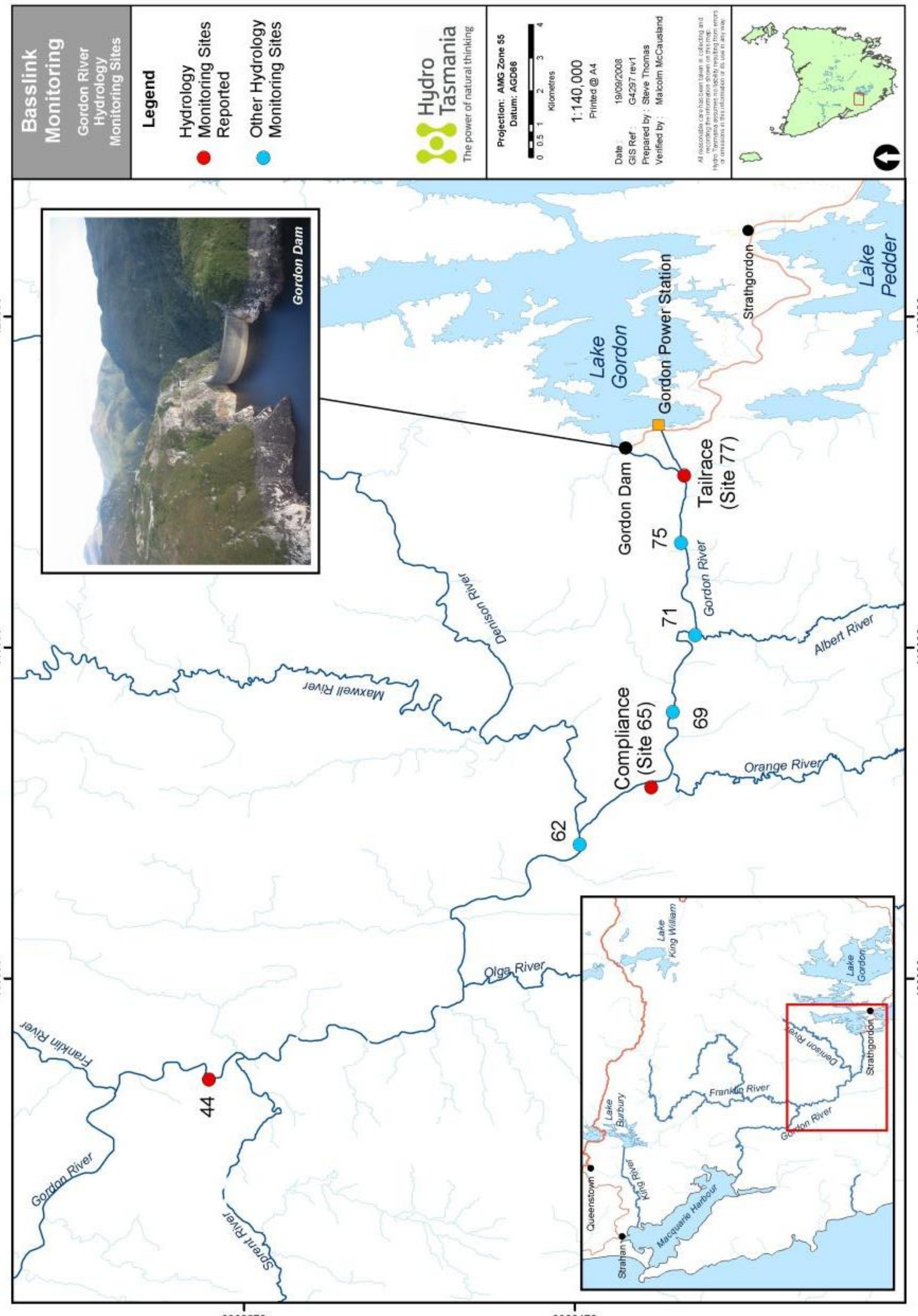

Figure 2-4: Gordon River hydrology monitoring sites

2.4 Data analysis

2.4.1 General flow analysis

For 2012–13, 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. These three sites are considered representative of the various river sections below the power station. Data from sites 75, 71, 69, 62 were recorded hourly but are not presented in this report. These are a resource available to assist researchers in the interpretation of their data. 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.

Analyses at sites 77, 65 and 44 have provided the comparison of data from the 2012–13 year to the long-term average at that site. It could be argued that only data from the pre-Basslink period (2001–05) should be used to ensure a strict comparison with the baseline period, however longer datasets are considered a more representative comparison. 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.

2.4.2 High flow change frequency analysis

Analysis of changes in flow in the 2–3 turbine operation are presented. This information shows how individual periods vary with regard to flow changes above 180 $m^3 s^{-1}$. The information assists with the interpretation of data in the discipline sections, in particular chapter 3 Fluvial geomorphology. Flow change frequency analysis was conducted on the data to determine the frequency with which different flow changes occurred, i.e. between one hour's average and the next hour's average[1].

The calculation of the one-hour lag difference was conducted applying the following rules:

- missing data was eliminated;
- only data where the start flow was above 180 $m^3 s^{-1}$ was selected; and
- data was ranked and plotted.

2.4.3 Low range rapid flow increase analysis

An analysis of the frequency of rapid flow increases was undertaken for low range discharges for the Gordon Power Station discharge and for the Gordon above Denison site. This was undertaken with specific relevance to understanding the influence of a variable flow regime on the macroinvertebrates at the lower flow ranges. This examined the number of occasions when:

- flow was below 25 $m^3 s^{-1}$; and
- subsequently increased to greater than 100 $m^3 s^{-1}$ within a two-hour period.

The number of instances where this flow pattern was observed is presented for each year for which hourly data is available for the Gordon Power Station and Gordon below Denison site, and for each month in 2012–13.

[1] This method cannot be used to determine conformance with ramp-down rule.

2.4.4 Ramp-down rule

2.4.4.1 Background

A ramp-down rule mitigation measure has been in place since the commissioning of Basslink in April 2006, under the terms of Hydro Tasmania's Special Water Licence Agreement. A revised and improved ramp-down rule has been developed following significant modelling and field investigations.

This work to develop a new rule began in response to the finding that the original ramp-down rule did not fully achieve its aim of reducing seepage erosion (Koehnken 2008, Rutherfurd 2009). Work was undertaken to investigate the most environmentally and operationally appropriate rule to be implemented. This work included:

- the development of a newly calibrated SEEP-W model, which was used to investigate the possible impacts of varying operations and ramping scenarios on bank stability (Entura 2010)
- the undertaking of field monitoring trials to test selected results of the modelling under a range of operational scenarios including peaking operation, and ramping at different rates. This work also identified the critical bank saturation level of 2.75 m at which seepage erosion would occur (Koehnken 2011); and
- the development of a regression model that accurately predicts the saturation level of the banks by utilising available real-time discharge data from Gordon Power Station (Hydro Tasmania 2012, Appendix 2).

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 bank saturation prediction is based on a robust relationship that was established through above modelling work undertaken during 2011–12 and the field confirmation that the critical level of bank saturation is 2.75 m (Koehnken 2011). This field work also showed that only minimal seepage erosion was apparent at flow reductions of 45 $m^3 s^{-1}$ per hour. This average flow reduction can be achieved through the reduction in power station generation of 1 MW per minute.

The revised rule was implemented from 1 April 2012 and 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 $m^3 s^{-1}$, 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 $m^3 s^{-1}$.

2.4.4.2 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 $m^3 s^{-1}$.

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 (Section 2.4.4.3) with the -1.0 MW/minute target.

2.4.4.3 Evaluation of rate of change in generation

The evaluation of the rate of change of power generation utilised a 60-minute moving average (MA). The change in generation is taken to be this MA minus a similar MA taken 5-minutes previously. This results in a 5-minute interval time-series of generation change-rate:

$$Generation\ Change\ Rate\ (MW/min)\ at\ time\ t\ = \frac{\Delta Power}{\Delta T} = \frac{MA_t - MA_{t-5min}}{5\ minutes}$$

Where:

$$MA_t = \ Average\ of\ the\ 5\ minutely\ Power\ (MW)\ for\ the\ 60\ minutes\ up\ to\ time\ t$$

2.4.4.4 Performance of Bank Saturation Model

The integral component for the implementation of the ramp-down rule is the Bank Saturation Model. Its continued good performance is important to ensure that un-ramped flow reductions do not occur while saturation in the banks is high. The performance of the model was assessed in a comparison of observed and modelled water level. In addition, the percentage of false positives (modelled values higher than actual level of 2.75 m) and false negatives (modelled values lower than actual level of 2.75 m) is reported.

2.5 Results

2.5.1 Data availability

Data was collected at all the water level (flow measurement) sites. There were no periods of missing data at any of the sites (Table 2-1). Site 75 was manually downloaded on 13 July 2013, while site 62 was last able to be accessed on 17 March 2013, when data was manually downloaded.

Table 2-1: Data availability for water level sites on the Gordon River 2012–13.

Site no.	Site name	Periods of missing data	Reason	Comment
75	Gordon River at G4	none	---	Data manually downloaded. Currently available to 13/07/13
71	Gordon River below Albert (G5A)	none	---	Nil.
69	Gordon River above 2nd Split (G6)	none	---	Nil
65	Gordon above Denison (compliance site)	none	---	Nil
62	Gordon River below Denison	none to last download	---	Data manually downloaded. Currently available to 17/03/13
44	Gordon River above Franklin	none	---	Nil

2.5.2 General analysis

2.5.2.1 System yield

The inflows to Hydro Tasmania's state-wide system during 2012–13 were the lowest since 2007–08. The total system inflows (system yield) of 7,653 GWh were 80% of the long-term mean (1976–2012). The inflows in 2012–13 were significantly less (by the equivalent of 2,847 GWh) than the hydro generation which resulted in the significant reduction of storage in Lake Gordon and the state-wide system.

Figure 2-5 shows the monthly total system yield during 2012–13 compared with the long-term (1976–2012) median, 20th and 80th percentile inflows. The most pronounced below average inflows were observed in November and December 2012 and January, February and June 2013.

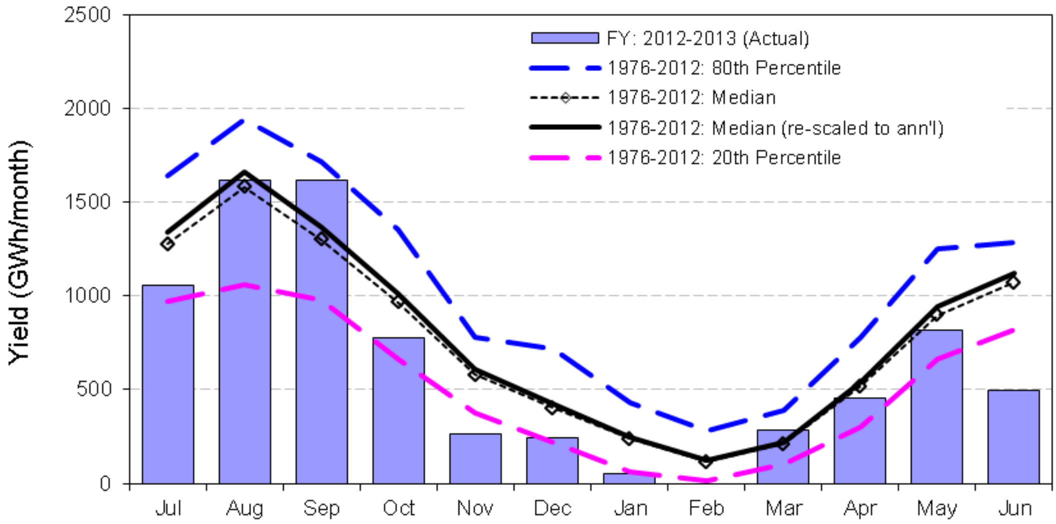

Figure 2-5: Monthly total system yield for 2012–13 compared to the long-term median, 20th and 80th percentiles for 1976–2012.

2.5.2.2 Strathgordon rainfall

The Strathgordon meteorological station has rainfall records dating back to 1970. These allow the calculation of long-term mean monthly values and comparisons with the monthly rainfall totals recorded for 2012–13.

Figure 2-6 shows the total monthly and long-term average monthly rainfall values. In 2012–13 it was a dry year in Strathgordon which received 2,056 mm. This annual rainfall was appreciably less than the long-term average of 2,442 mm. The 2012–13 annual pattern of rainfall in Strathgordon was similar to the pattern of system inflows. In October and November 2012 and February and May 2013 rainfall was less than the monthly 20th percentiles. In all, nine months of the year had rainfall lower than the average. In September 2012 rainfall exceeded the long-term 80th percentile.

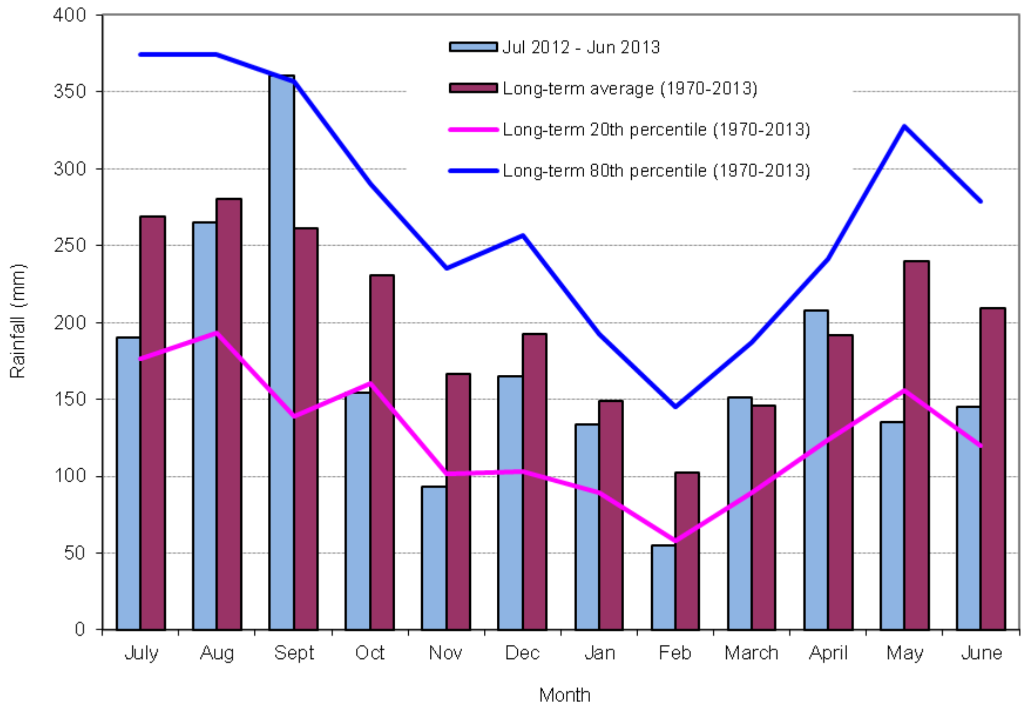

Figure 2-6: Total monthly rainfall values recorded at Strathgordon for 2012–13 compared with the long-term average (1970–2013).

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 2-7 shows the discharge from the power station for 2012–13. For a more detailed view of the graph month by month, please refer to Appendix 1. A summary of significant points of interest in the 2012–13 discharge data is as follows:

- the discharge from Gordon Power Station was bi-modal, having generally low discharge from July to December 2012 and very high discharge from January to June 2013;
- in July and August 2012, the operation was typified by a regular peaking pattern between low (20–30 $m^3 s^{-1}$) and mid-high (100–200 $m^3 s^{-1}$) discharges;
- in the period from late August 2012 to early October 2012, the discharge pattern was characterised by maintenance of the environmental flow of 20 $m^3 s^{-1}$. This was occasionally interspersed with modest increases in flow to less than 50 $m^3 s^{-1}$;
- for the remainder of 2012, the regular peaking flow pattern between low (10–30 $m^3 s^{-1}$) and mid-high (100–200 $m^3 s^{-1}$) discharges was resumed;
- high discharge commenced in January 2013 and was initially very high (generally >220 $m^3 s^{-1}$) with some minor fluctuations in discharge; and
- in early March, the flow pattern altered to daily fluctuations in the very high flow range (i.e. daily hydro-peaking in the efficient load to full gate level), with a minimum discharge of 205 and a peak of 260 $m^3 s^{-1}$. This flow pattern continued to the end of the monitoring period in June 2013.

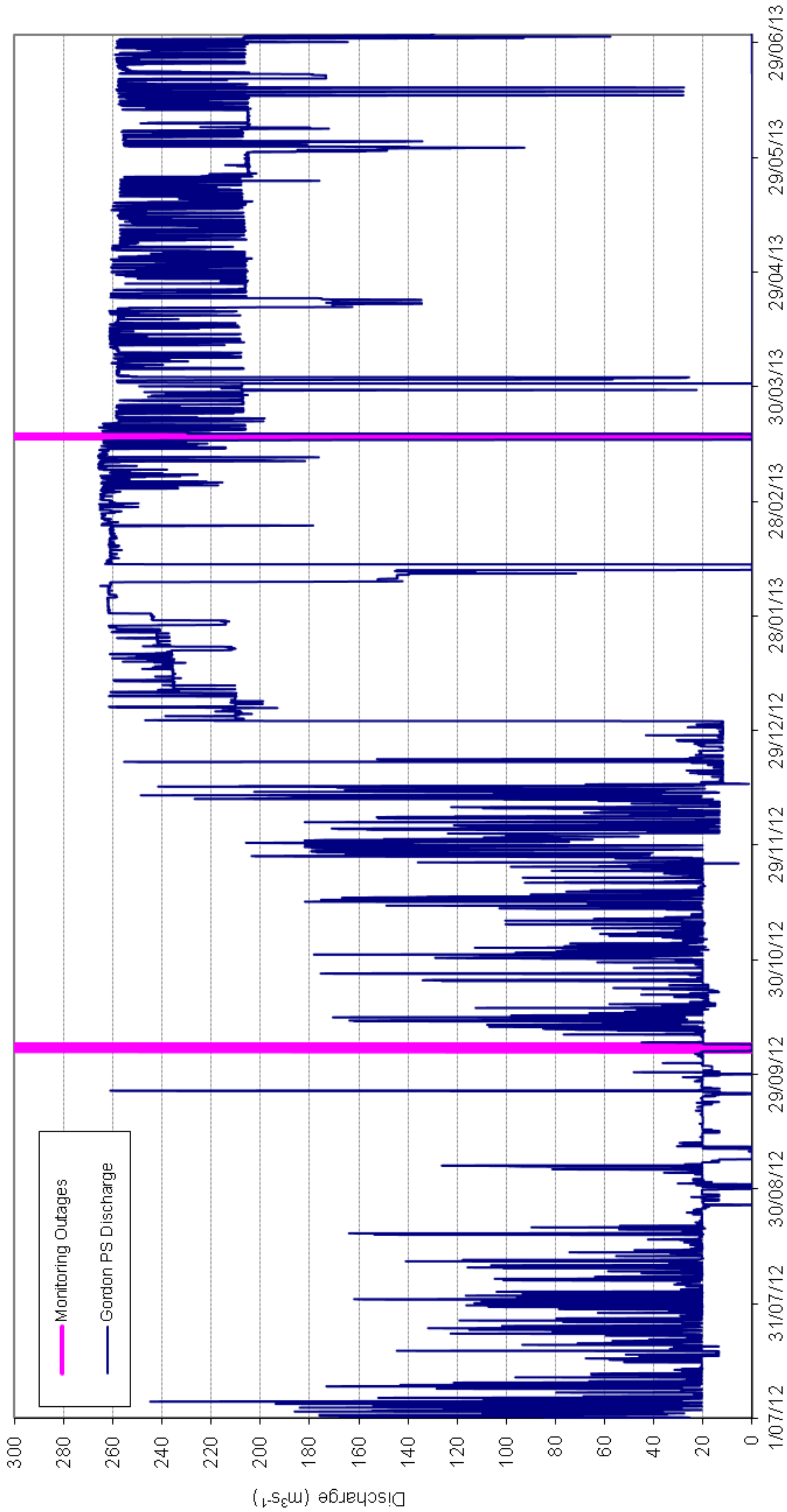

Figure 2-7: Gordon Power Station discharge (hourly data) from July 2012 to June 2013. Vertical lines indicate monitoring events.

Table 2-2 and Table 2-3 show the percentage of time zero, one, two and three turbines were running annually and on a monthly basis, respectively, along with a description of shorter term influencing factors (Table 2-3). The monthly breakdown of power station operating pattern throughout the year provides an indication of the downstream hydrological regime, as efficient discharge for operating one, two or three turbines is approximately 70, 140 and 210 $m^3 s^{-1}$, respectively. The use of the third turbine is generally related to higher discharge, however since joining the National Electricity Market, there has been greater use of three turbines at low to moderate discharge. This data indicates that in 2012–13 there was high use of the third turbine compared to previous operations. The most recent use of the third turbine to similar levels occurred in 2006–07, when generation was high as a result of the drought conditions. The use of just one turbine had the next greatest percentage of running time. The high use of one and three turbines (and consequently low use of two turbines) is reflective of the two major operating patterns in 2012–13 typifying lower generation from July to December 2012 and high generation from January to June 2013.

Table 2-2: Percentage of time that each configuration of turbines was in operation during 2012–13, in each of the financial years post-Basslink and in all previous records.

Configuration	Percentage of time operating							
	Jul 12– Jun 13	Jul 11– Jun 12	Jul 10 – Jun 11	Jul 09 – Jun 10	Jul 08 – Jun 09	Jul 07 – Jun 08	Jul 06 – Jun 07	Sep 96 – Jun 12
0 turbines running	2.6	2.8	6.9	2.6	3.1	7.5	3.6	12.7
1 turbine running	34.9	74.8	42.0	33.1	34.3	22.7	9.0	25.7
2 turbines running	13.4	17.3	24.5	49.9	38.1	30.8	40.1	32.4
3 turbines running	49.2	5.1	26.6	14.4	24.5	39.1	47.3	29.2

Table 2-3: Summary information on discharge, weather conditions, market volatility and outages for 2012–13. 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	Market volatility, inflows and outages	Basslink Net Import (GWh) (negative = export, positive = import)
July 2012	0.0	58.1	33.9	8.1	< average	Gordon used for peaking, low market volatility, below average yield for the month	-262.7
August 2012	2.8	80.8	15.6	0.8	< average	Some market volatility, Gordon used for peaking, a number of single machine outages occurred in this month, above average yield received	-272.8
September 2012	11.4	83.6	2.8	2.2	wet	Very low Gordon usage with above average yield and low market volatility. Outage for intake gate work.	-300.5
October 2012	5.9	74.3	19.8	0.0	dry	Some market volatility, a below average yield month, two day station outage occurred and only two machines were available for the month. Monitoring outage.	-229.8
November 2012	0.3	60.7	33.6	5.4	dry	Some market volatility at end of month, below average yield, a number of single machine outages in this month	-9.7
December 2012	0.4	57.8	35.8	6.0	< average	Low market volatility, below average yield, a number of single machine outages	0.3
January 2013	0.0	0.0	0.0	100.0	< average	Some early market volatility, below average yield, west coast followed by Rowallan dam works and the fixed carbon price result in solid running on major storages including Gordon	-150.3
February 2013	5.2	0.0	3.0	91.8	dry	Below average yield continued, outages on west coast and Rowallan Dam works and the fixed carbon price result in solid running of major storages including Gordon, Bush fires in the Collinsvale area makes transmission lines to Gordon unavailable for a number of days, some market volatility	-159.8
March 2013	5.0	0.1	0.5	94.4	> average	Some market volatility early in month, above average yield, Rowallan Dam work and the fixed carbon price result in continued high running of major storages including Gordon, Gordon station monitoring outage mid-month	-92.0
April 2013	0.0	0.0	9.4	90.6	dry	Below average yield, high market volatility and continuing low yield and the fixed carbon price result in high running on major storages including Gordon	-191.4

Period	0-turbine operation % time	1-turbine operation % time	2-turbine operation % time	3-turbine operation % time	Strathgordon rainfall	Market volatility, inflows and outages	Basslink Net Import (GWh) (negative = export, positive = import)
May 2013	0.0	0.0	0.1	99.9	> average	Below average yield continues, moderate market volatility, the fixed carbon price result in high running on major storages, and a Basslink outage from 24/05/13 to 01/06/13	-190.8
June 2013	0.0	0.0	5.0	95.0	< average	Below average yield, 1 in 20 years dry for June with some market volatility and the fixed carbon price result in continued high running on major storages some reduction to environmental flow overnight.	-174.3

Table 2-3 continued

2.5.3.2 Power station outages

There were five power station maintenance outages in 2012–13. All of these were only a few hours' duration, and these were all done in accordance with the Licence requirements.

Basslink monitoring power station outages took place on:

- 5–7 October 2012; and
- 16–17 March 2013;

2.5.3.3 Median monthly discharge

Figure 2-8 shows the median monthly discharge from the power station for 2012–13 compared with long-term values (since January 1997) and the previous six years of the post-Basslink period. This figure illustrates the pronounced bi-modal flow pattern observed in 2012–13. This pattern is a return to flow patterns more similar to those in the pre-Basslink and historic periods. July through to October 2012 had similar low median values to the post-Basslink period to those in the long-term and post-Basslink periods. November and December 2012 also had very low median values. The consistently very high discharge from January to June 2013 ensured that median values were higher than long-term median values while departing to an even greater extent from the low median values of previous post-Basslink years.

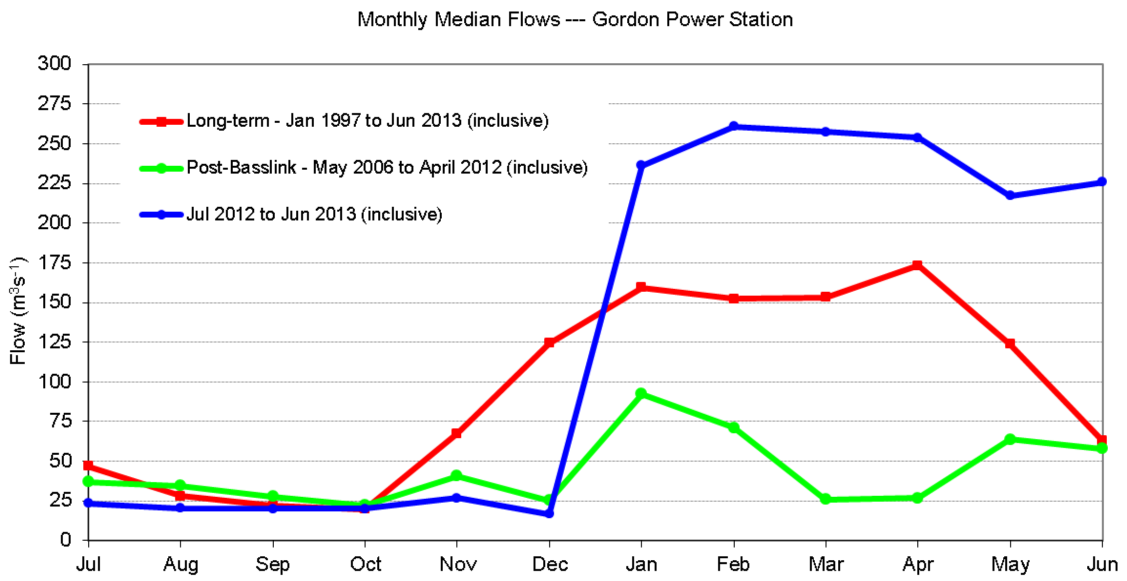

Figure 2-8: Median monthly discharge from the Gordon Power Station (site 77) for 2012–13 compared with long-term median values and previous post-Basslink years.

2.5.3.4 Flow duration curves

Figure 2-9 to Figure 2-12 show the duration (percentage exceedance) curve for the power station discharge for:

- Whole of year;
- winter period (May–October);

- summer period (November–April); and
- years one to seven of post-Basslink annual data.

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 2013);
- 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 2012) prior to the current year ; and
- 2012–13 financial year (1 July 2012–30 June 2013).

The annual 2012–13 discharge (Figure 2-9) is defined by the distinct periods of very high and very low flow, and the relative lack of flow in the ranges in between. The annual discharge in 2012–13 had greater periods of very high flow, relative to long-term, historical and all previous post-Basslink years. In 2012–13 flow discharges greater than 200 $m^3 s^{-1}$ accounted for 45% of flows which was much greater than long-term (18%), historical (15%), pre-Basslink (26%) and previous post-Basslink (9%) periods. Discharges less than 30 $m^3 s^{-1}$ were observed for 39% of the time in 2012–13. This was similar to the long-term record which had 35% of discharges less than 30 $m^3 s^{-1}$. The median discharge in 2012–13 was 138 $m^3 s^{-1}$ compared to the historic, pre-Basslink (2001–05), long-term and post-Basslink median discharges of 120 $m^3 s^{-1}$, 119 $m^3 s^{-1}$, 79 $m^3 s^{-1}$ and 35 $m^3 s^{-1}$, respectively.

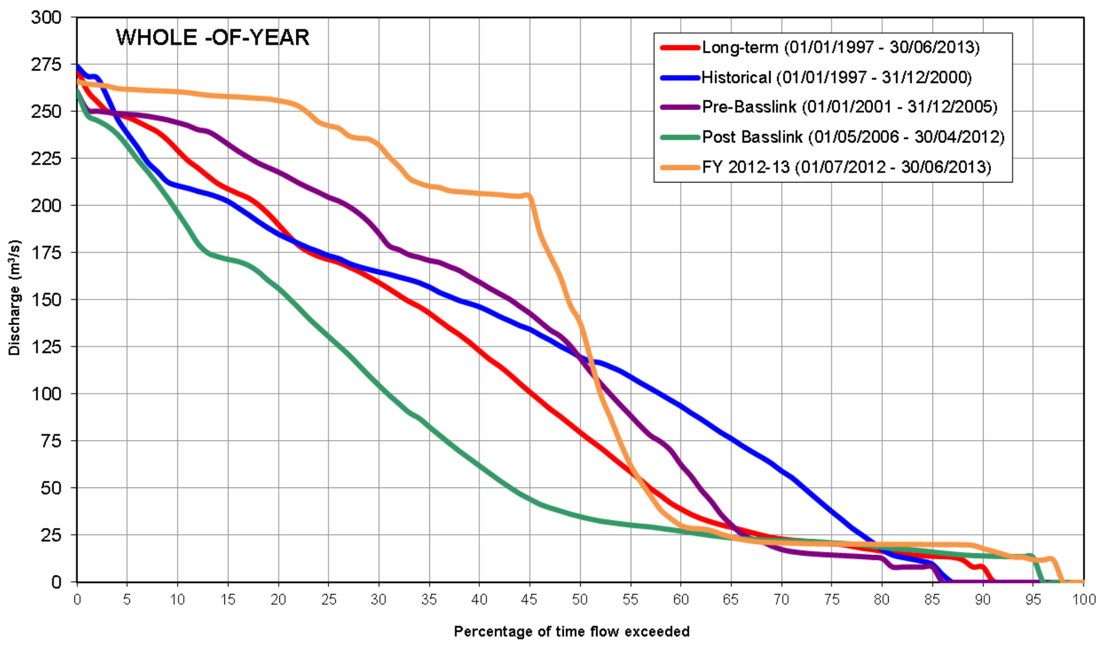

Figure 2-9: Duration curves for discharge from the power station tailrace using annual data for selected periods.

The 2012–13 winter discharge flow duration curve (Figure 2-10) was a similar shape to that of the annual duration curve. It had a distinctive bi-modal appearance, with few periods of flow in the mid-ranges. Similar to flows for the whole year, the winter flows had a high proportion of discharges > 200 $^3 s^{-1}$ (31%), which was well in excess of the proportion of flows >200 $m^3 s^{-1}$ for all other periods for comparison (e.g. 10% of all long term flow >200 $m^3 s^{-1}$). The winter curve in 2012–13 had a higher period of lower flows compared to the annual curve, as a result of the low flows in July to October 2012. Flows <30 $m^3 s^{-1}$ accounted for 55% of all winter flows in 2012–13 and 45% of all long-term winter flows.

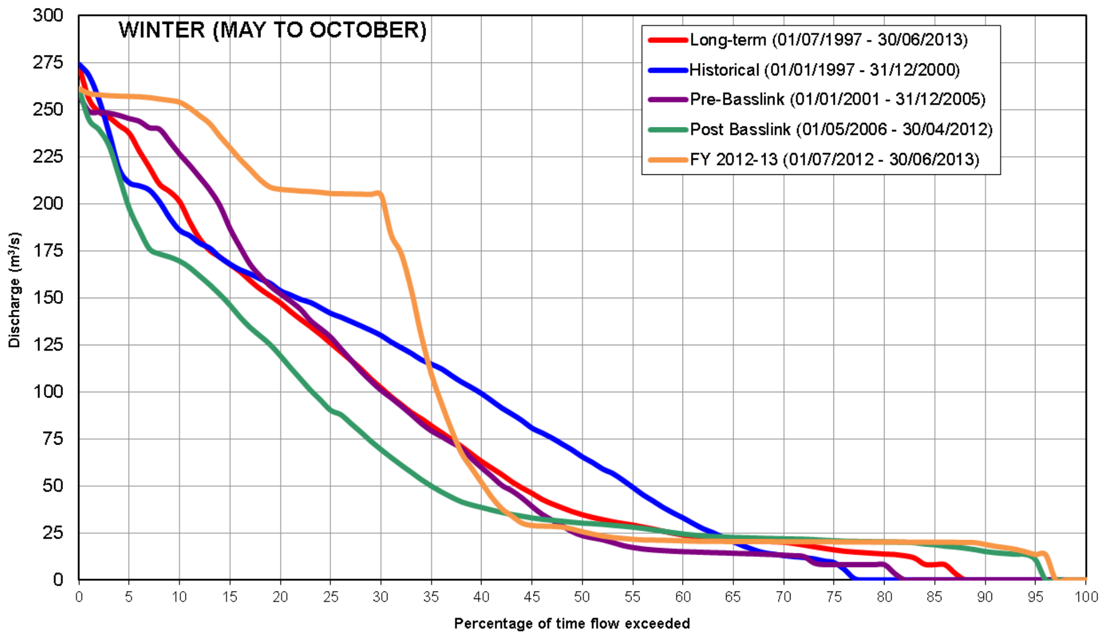

Figure 2-10: Annual duration curves for discharge from the Gordon Power Station using winter data (for the months of May to October inclusive) for selected periods.

The 2012–13 summer discharge flow duration curve (Figure 2-11) was also a similar shape to that of the annual duration curve. It had a distinctive bi-modal appearance, with few periods of flow in the mid-ranges. The periods of high flow were greater than the annual curve, and were indicative of the very high flow in the six months of January to June 2013. Summer 2012–13 had a very high proportion of flows >200 $m^3 s^{-1}$ (60%) which far exceeded any of the comparison periods (long-term: 26%; historical: 23%; pre-Basslink: 40%; previous post-Basslink years: 13%) and June 2013. The small proportion of flows <30 $m^3 s^{-1}$ in summer 2012–13 (23%) was similar to long term summer period (25%), but much greater than in the historical (6%) or pre-Basslink (17%) summer period. The high proportion of very high flows is reflected in the median flow for 2012–13 (212 $m^3 s^{-1}$), which was higher than all periods for comparison (long-term: 139 $m^3 s^{-1}$; historical: 160 $m^3 s^{-1}$; pre-Basslink: 174 $m^3 s^{-1}$; previous post-Basslink years: 39 $m^3 s^{-1}$).

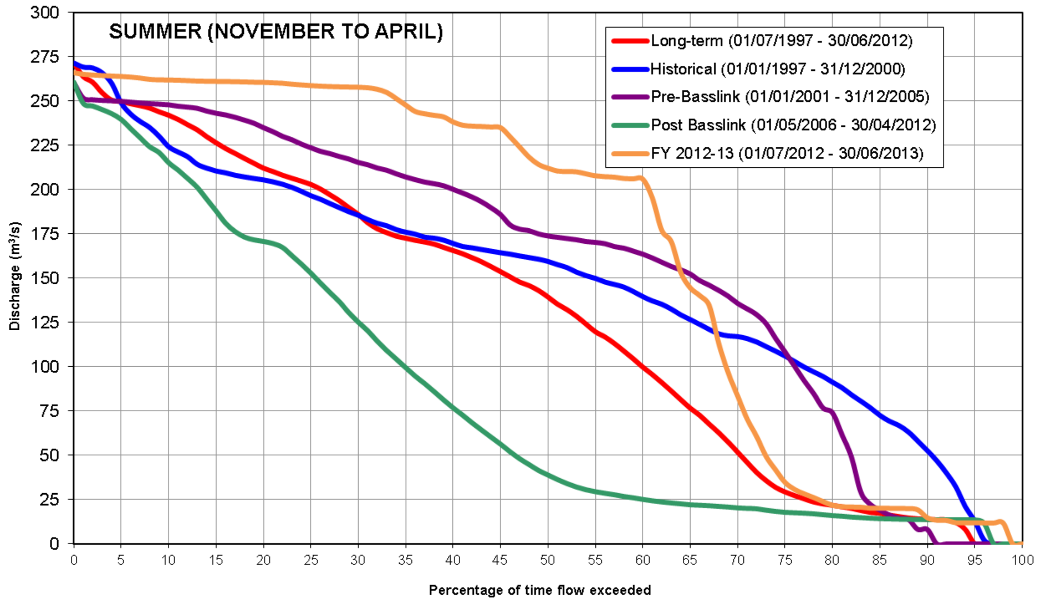

Figure 2-11: Annual duration curves for discharge from the Gordon Power Station using summer data (for the months of November to April inclusive) for selected periods.

Annual flow duration curves for each post-Basslink year are represented in Figure 2-12 to compare the current 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 2012–13 differs from the annual curve in Figure 2-9 as it represents a 12-month period that is offset by two months. In comparison to each of the post-Basslink years, year seven (May 2012–April 2013) had much different flow characteristics to all previous post-Basslink years. While years three to six had similar low flow characteristics to that found in part of 2012–13, this is reflected in the similarity of the duration curves in the lower flow region, representing the low flow period in May to December 2012. The stark difference in 2012–13 is in the high range of the duration curve. This shows that in 2012–13 there have been the highest and longest periods of very high flows (>200 $m^3 s^{-1}$) in the post-Basslink period. Similarities are seen between 2006–07 and 2012–13 in the upper flow portion of the duration curve, but 2006-07 had a greater prevalence of high flows in the region of 175 $m^3 s^{-1}$.

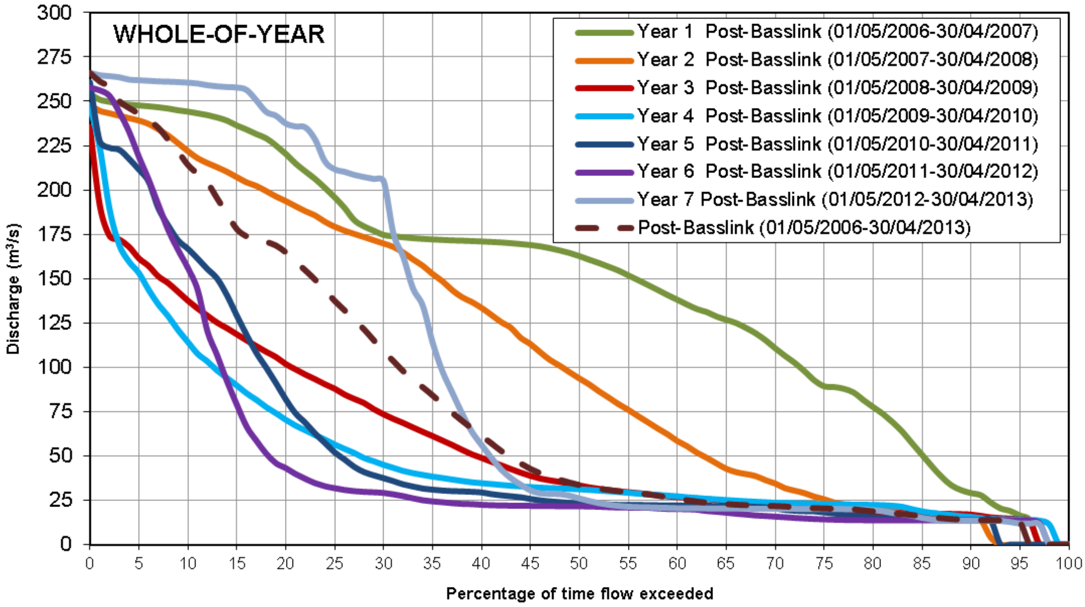

Figure 2-12: Annual duration curves for discharge from the Gordon Power Station for the seven years post-Basslink.

2.5.3.5 Flow change frequency analysis

The results of the flow change frequency analysis are shown in Figure 2-13 to Figure 2-16. The data for 2012–13 indicate that six months up to 1 October 2012 had fewer hours (6 hours) of flow reduction in excess of 30 m^3 s^{-1} per hour while discharge was > 180 m^3 s^{-1} than the six months up to April 2013 (28 hours) (Figure 2-15). The April to October 2012 period had one of the lowest occurrences on record, and is indicative of the very low power station operation at this time, where 180 m^3 s^{-1} was rarely exceeded. The 28 hours of reductions >30 m^3 s^{-1} per hour from 1 October 2012 to 1 April 2013 was at a similar level to the pre-Basslink period and occurred primarily during March 2013.

Bank saturation conditions during 2013 were high, leading to the requirement to implement the ramp-down rule. The influence of the revised ramp-down rule was evident in the fewer number of rapid reductions in flow compared to similar periods of power station operation in April to October 2007 when banks also were saturated (Figure 2-13). Decreases in flow under saturated conditions in April to October 2007 were often substantially greater than 30 m^3 s^{-1} per hour, as the previous ramp-down rule allowed for uncontrolled ramping if flows remained >150 m^3 s^{-1}, regardless of the saturation conditions of the bank.

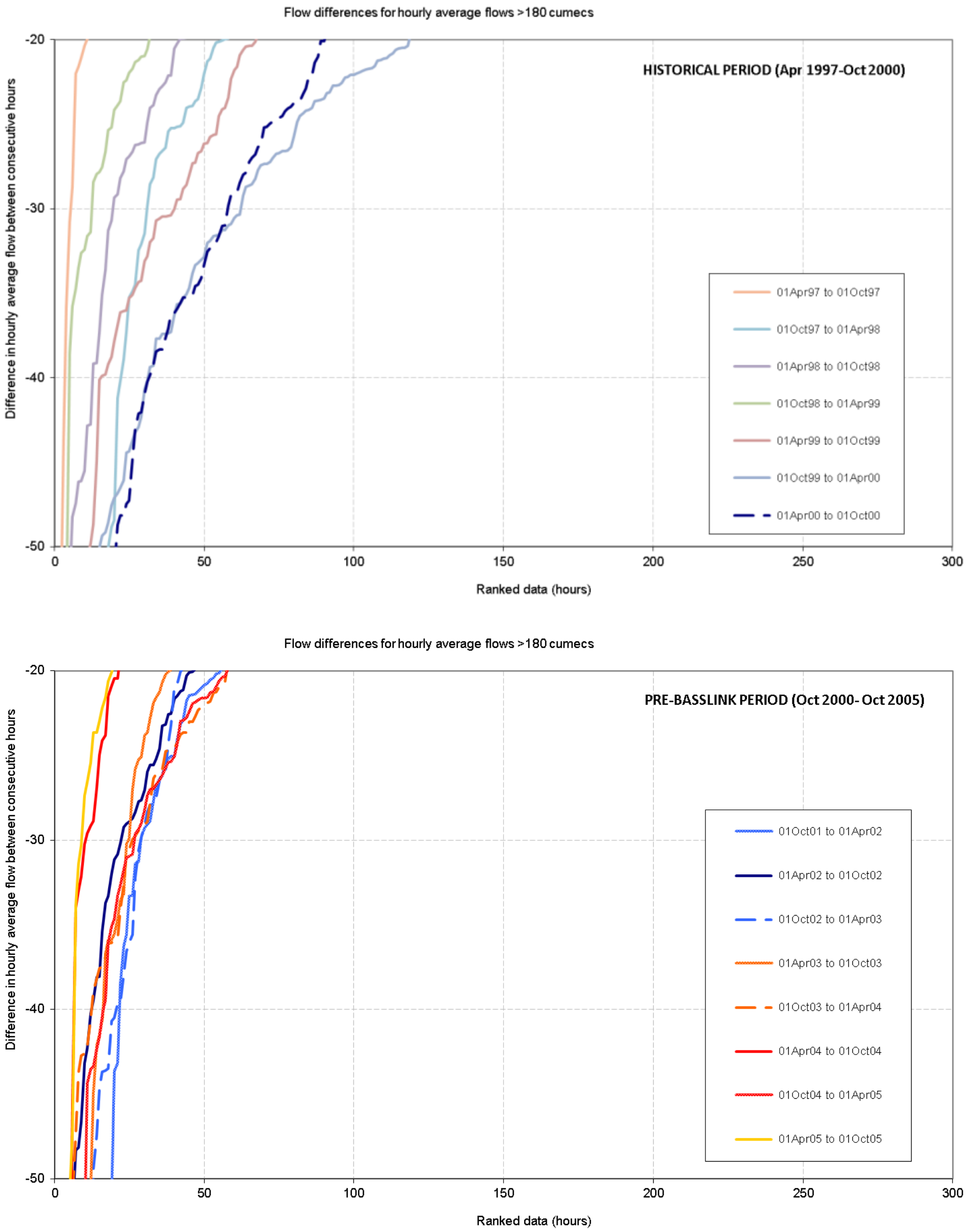

Figure 2-13: Flow change frequency plot showing the ranked rate of flow reductions data for six month periods occurring while power station discharge was greater than 180 $m^3 s^{-1}$ for 1997–2005.

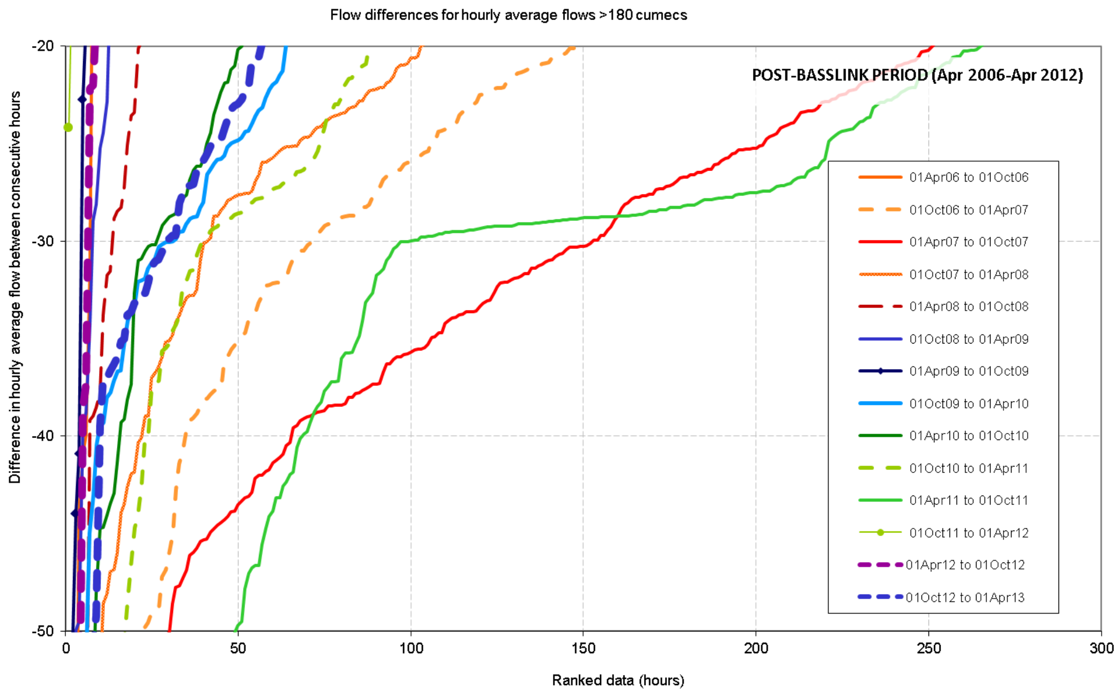

Figure 2-14: Flow change frequency plot showing the ranked rate of flow reductions data for six month periods occurring while power station discharge was greater than 180 $m^3 s^{-1}$ for 2006–13.

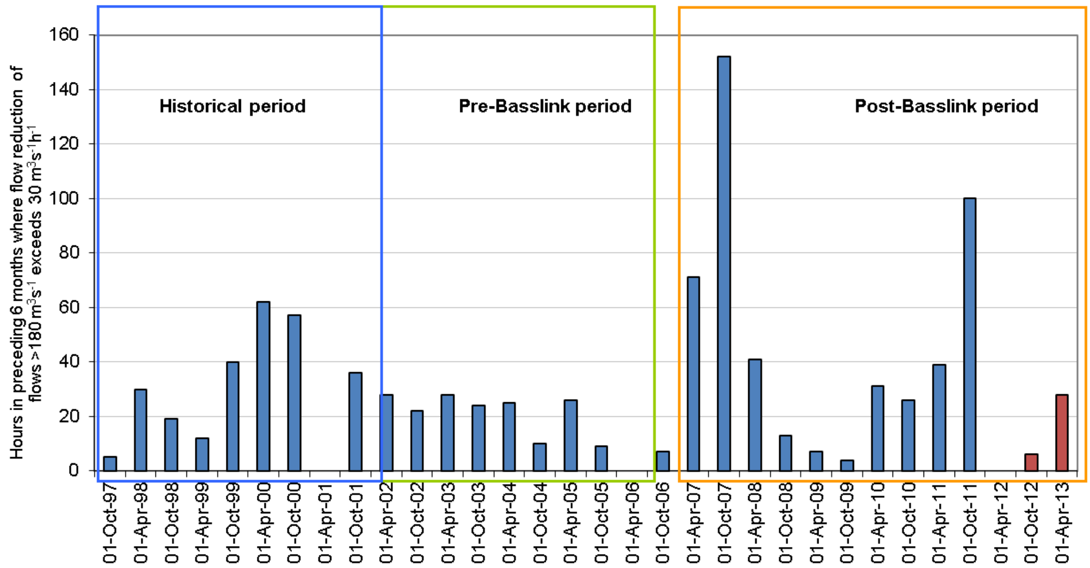

Figure 2-15: Number of hours for each prior six-month period where flow reductions from >180 $m^3 s^{-1}$ exceed 30 $m^3 s^{-1}$ per hour.

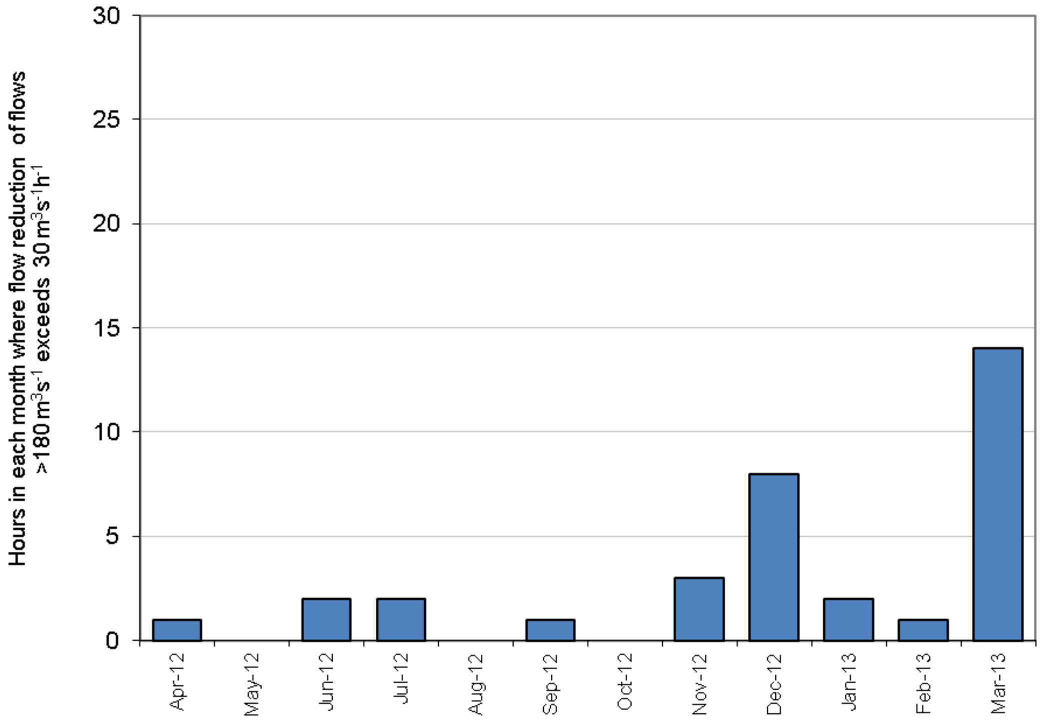

Figure 2-16: Number of hours for each month between April 2012 and March 2013 where flow reductions from >180 m^3s^{-1} exceed 30 m^3s^{-1} per hour.

2.5.3.6 Low to mid-range flow variability analysis at the power station

Figure 2-17 presents analysis of rapid increases between low and mid-range flows, and provides a measure of flow variability that is at a scale of relevance to macroinvertebrates and fish. The rapid increases are not indicative of full-range hydro-peaking, just rapid low-mid range variations in flow. This analysis presents data for the number of occasions when flows have increased rapidly (within two hours) from low flows in the vicinity of the environmental flow (<25 m^3 s^{-1}) to greater than 100 m^3 s^{-1}. Since 1997, when hourly data became available, 2012–13 had a similar number of such events (44 instances) to many previous pre- and post-Basslink years. This was significantly lower than 2010–11 which had the highest number of such rapid increases in flow (100 instances).

Rapid flow increases were most common in July and December 2012 (Figure 2-18).

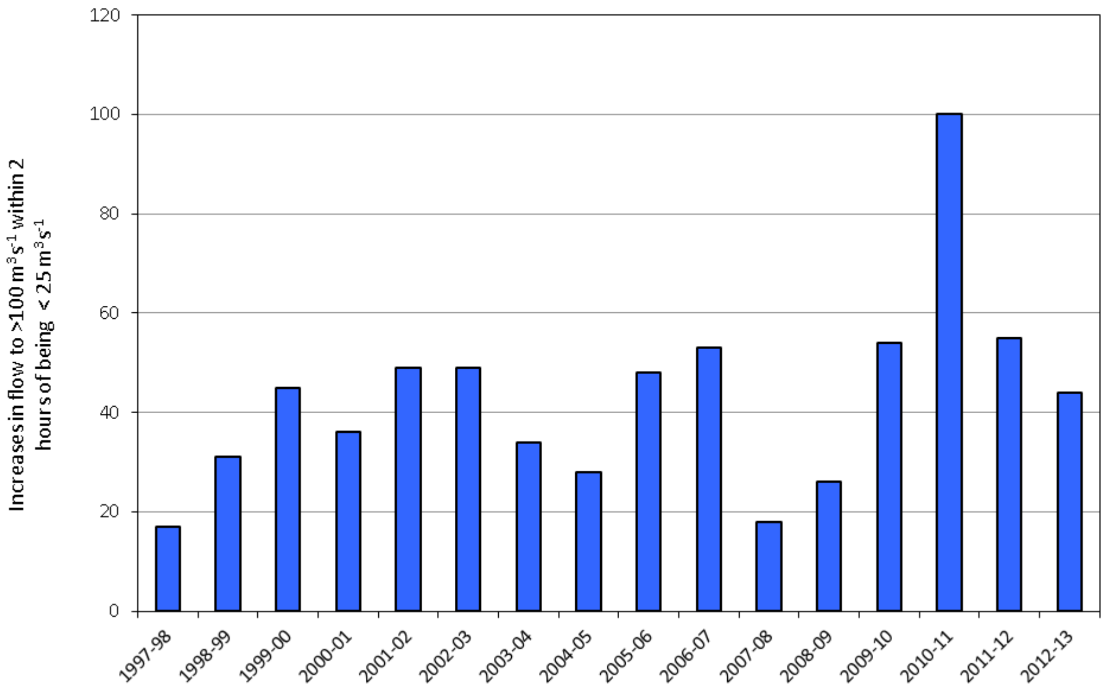

Figure 2-17: Rapid flow increases (<25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon Power Station discharge for each year where hourly data are available.

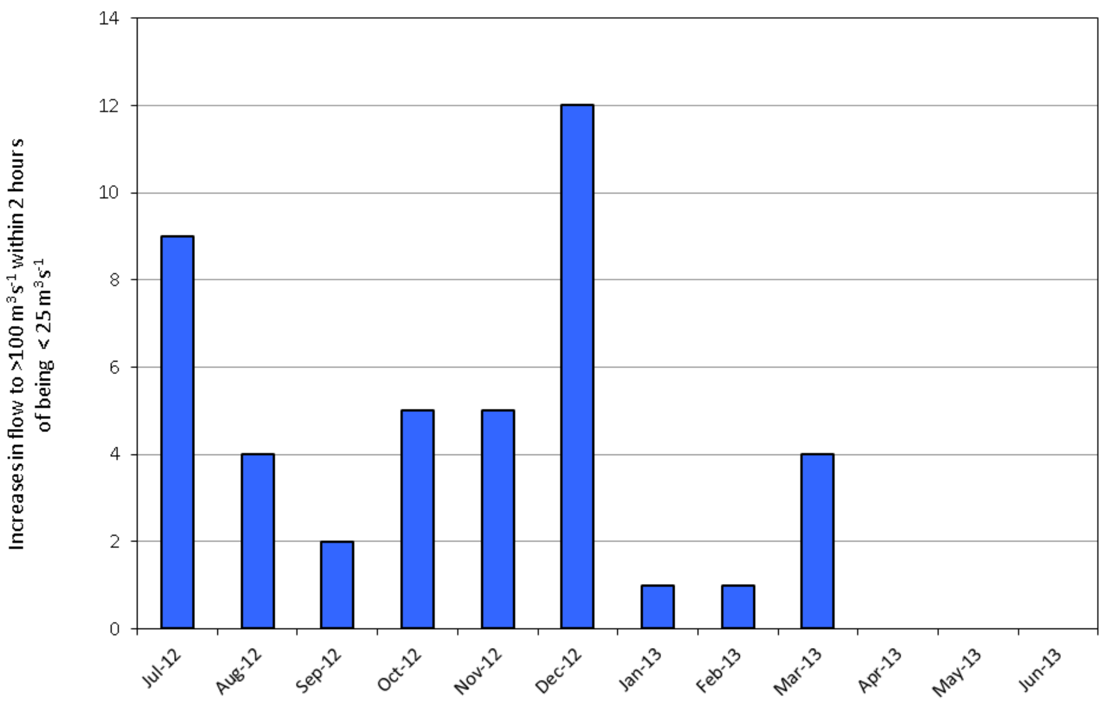

Figure 2-18: Rapid flow increases (<25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon Power Station discharge for each month during 2012–13.

2.5.3.7 Compliance with ramp-down rule

Since the changes to the ramp-down rule were implemented, there have been no non-compliances. During the audit period (April 2012–June 2013) the ramp down rule was required to be applied for 4039 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 (automatically) set for all of those periods and so it follows that there were no ramp-down rule non-conformances.

2.5.3.8 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 4039 hours where ramping was required during flow reductions, those that exceeded 1 MW per minute occurred on 21 separate events (Table 2.4), and totalled a little less than 5 hours (0.12% of time that the ramp-down rule was applied). 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 exceedences 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 is 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.

The longest exceedances of the 1 MW per minute reduction target were seen during events 10 and 19 (Table 2.4). These exceedences occurred as a result of a machine trip at machine 2 triggered by power system network event (24 May 2013 – event 10) and an electrical fault trip at machine 3 that resulted in automatic shutdown (19 June – event 19). Both of these events were beyond the control of operators.

Table 2.4: Ramping events that exceed 1 MW per minute between 1 April 2012 and 30 June 2013. The longest events are indicated in bold.

Event no.	Date	Duration (minutes)	Average Generation reduction rate (MW/min)	Maximum Generation reduction rate (MW/min)
1	7 Jan 2013	15	1.07	1.16
2	13 Mar 2013	10	1.13	1.21
3	16 Mar 2013	5	1.39	1.39
4	18 Mar 2013	5	1.01	1.01
5	19 Mar 2013	10	1.02	1.03
6	11 Apr 2013	10	1.01	1.01
7	24 Apr 2013	5	1.01	1.01
8	3 May 2013	5	1.03	1.03
9	23 May 2013	20	1.07	1.11
10	**24 May 2013**	**60**	**1.37**	**2.44**
11	31 May 2013	5	1.01	1.01
12	31 May 2013	5	1.02	1.02
13	2 Jun 2013	5	1.02	1.02
14	4 Jun 2013	10	1.01	1.01
15	11 Jun 2013	10	1.04	1.05
16	12 Jun 2013	5	1.01	1.01
17	15 Jun 2013	10	1.01	1.02
18	18 Jun 2013	10	1.02	1.03
19	**19 Jun 2013**	**65**	**1.92**	**2.14**
20	25 Jun 2013	10	1.03	1.05
21	29 Jun 2013	15	1.04	1.07

2.5.3.9 Performance of Bank Saturation Model

The bank saturation model performed well in providing accurate estimates of the water level in the river banks in the vicinity of the trigger level of 2.75 m (Figure 2-19). The analysis of 30 minute aggregated data indicated that for the operation undertaken over the audit period (1 April 2012 to 30 June 2013) the modelled data provided very few false negative results. There were only 33 false negatives (0.4% of compared values) in the period, where water levels were greater than the trigger level of 2.75 m, while the model indicated that they were less than this level. The maximum observed level where a false negative was recorded was 2.94 m. There were only 75 false positives (0.9% of compared values) for the period, however these are of little concern.

This low percentage of false negative and positive values is likely to be related to the two types of operation undertaken at Gordon Power Station during the audit period. The very low or very high discharges generally resulted in water levels being held well above or well below the 2.75 m level.

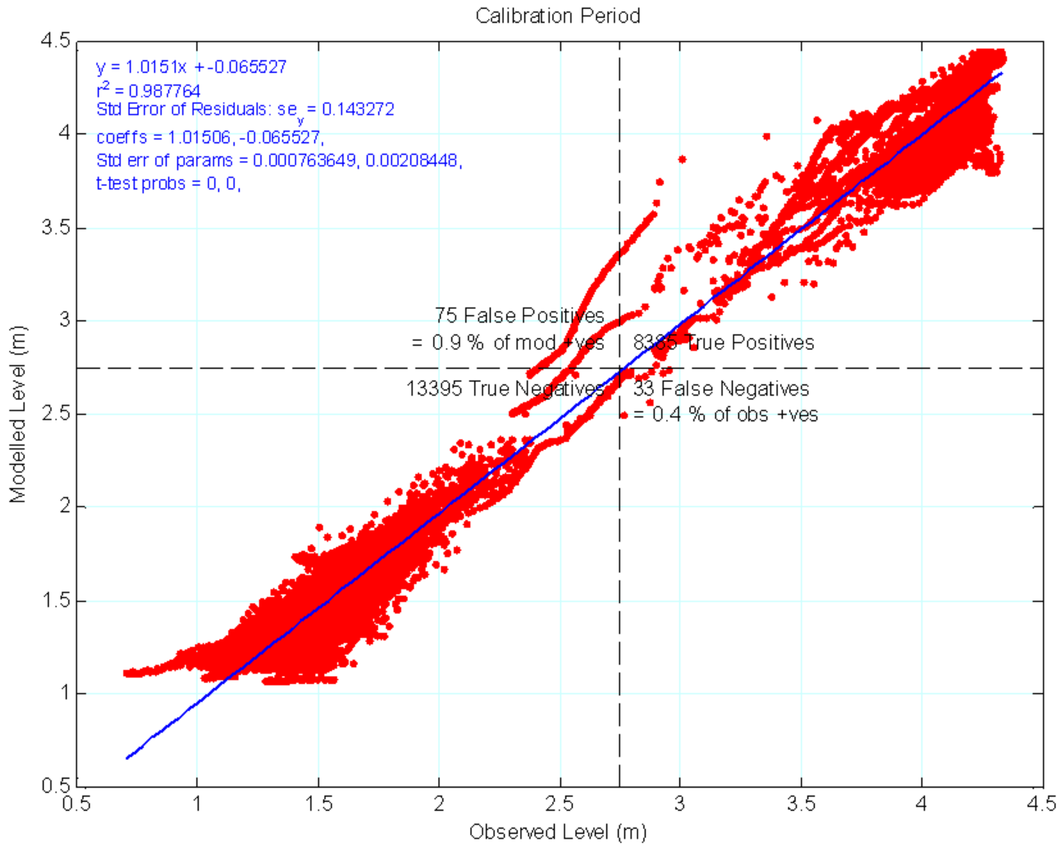

Figure 2-19: Observed versus modelled water levels for period 1 April 2012 to 30 June 2013 based on 30 minute aggregated data.

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 2-20 shows the flow recorded at site 65 for 2012–13 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. It should be noted that in some cases, when there is little natural inflow, peaks in flow at site 65 are lower than those from the power station. It is considered that the flow attenuation that occurs between the discharge point at the power station and the 12 km distance to the compliance site is responsible for causing a reduction in the height of flow peaks.

Notable high tributary inflows were seen from a number of events in late August to early October 2012 and late March to early May 2013. The departure of the hydrograph from that of the Gordon Power Station discharge is indicative of these tributary inflows from such rainfall events.

A backwater effect has been observed at this site. When the Denison River floods and Gordon discharge is low, Denison River water may backflow up past site 65. The result of this effect at site 65 would be an over-estimation of the flows during the period of Denison River flooding. The primary function of this site is to monitor the minimum environmental flow, so the backwater effect will not interfere with this function as it only occurs during periods of high tributary flow (i.e. when the minimum environmental flow is met by tributary inputs).

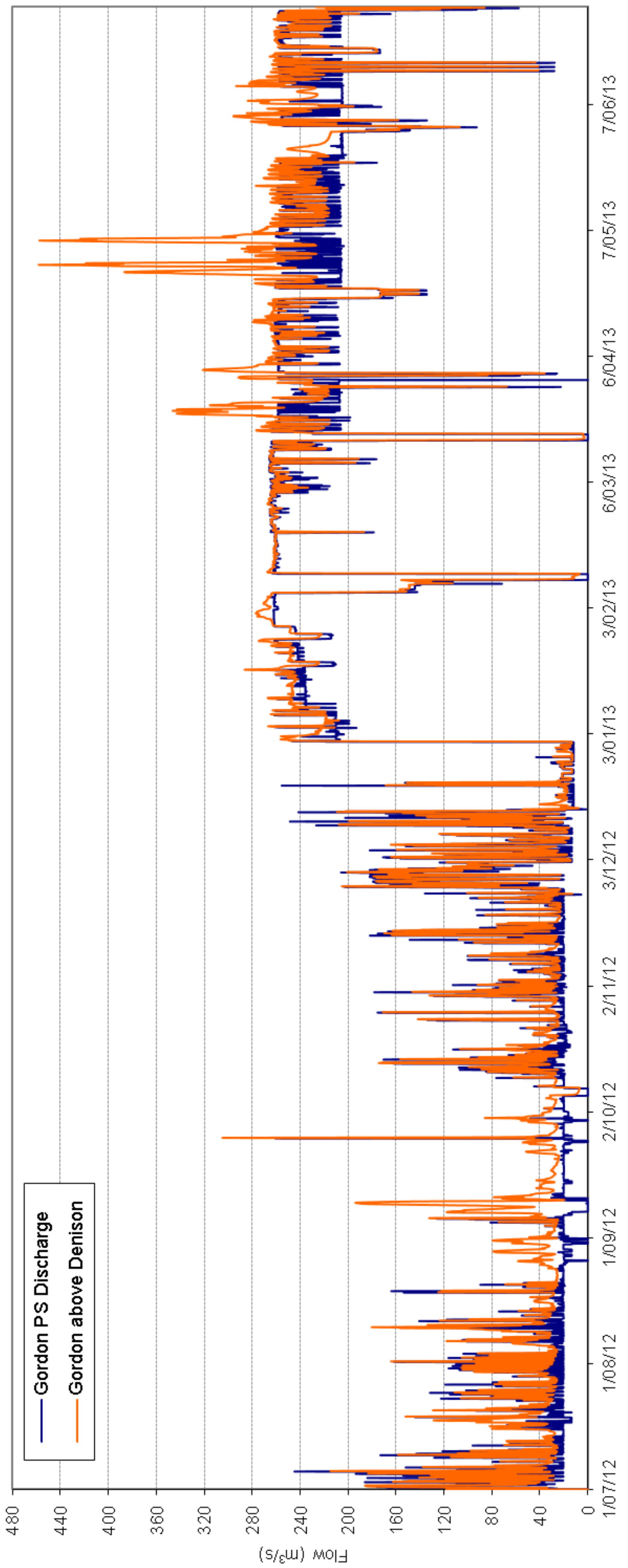

Figure 2-20: Flow recorded (hourly data) at site 65 (Gordon above Denison) showing full scale of flows, from July 2012 to June 2013.

2.5.4.2 Median monthly flows

The median monthly flow for site 65 (Gordon above Denison) is shown in Figure 2-21. Comparison with historic average (2003–13) patterns shows monthly median flows from July to December 2012 tended to be lower than average. In contrast, as indicated by the Gordon Power Station discharge, the median flow for January to June 2013 far exceeded long-term and previous post-Basslink years.

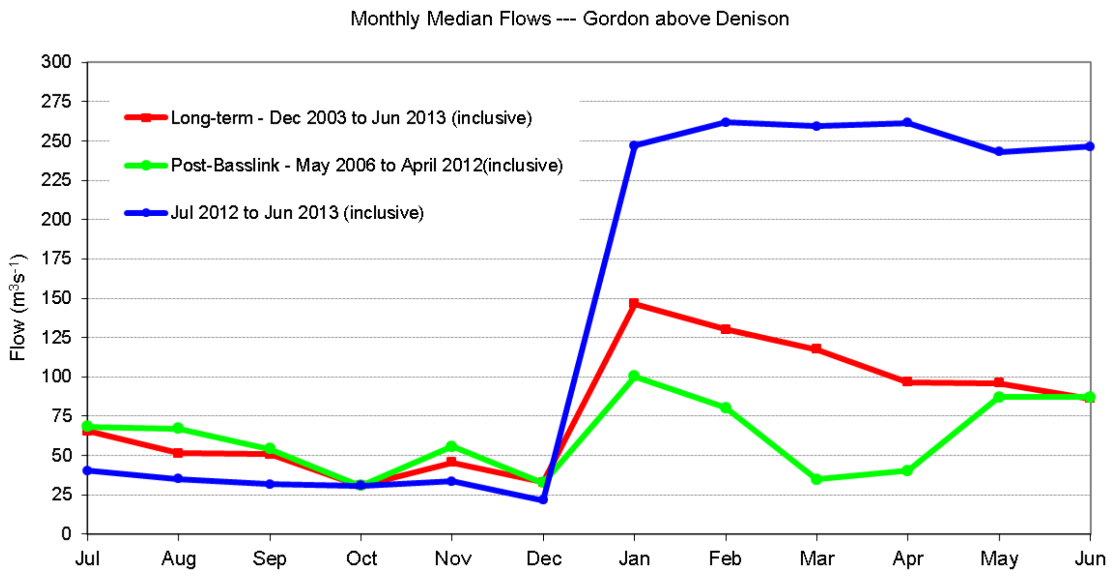

Figure 2-21: Median monthly flow at site 65 (Gordon above Denison) for 2012–13 compared with long-term median values and previous post-Basslink years.

2.5.4.3 Duration curves

The duration curve for site 65 is shown in Figure 2-22. Comparison with the long-term curve shows a bi-modal flow for the 2012–13 year, as seem on the power station discharge flow duration curve (Figure 2-12). Similar flow durations for long-term and 2012–13 are seen for flows less than 80 m^3s^{-1}. At flows in excess of 80 $m^3\ s^{-1}$, 2012–13 had a greater prevalence of very high flows from power station discharges, but small and relatively few flood flows in excess of 260 $m^3\ s^{-1}$.

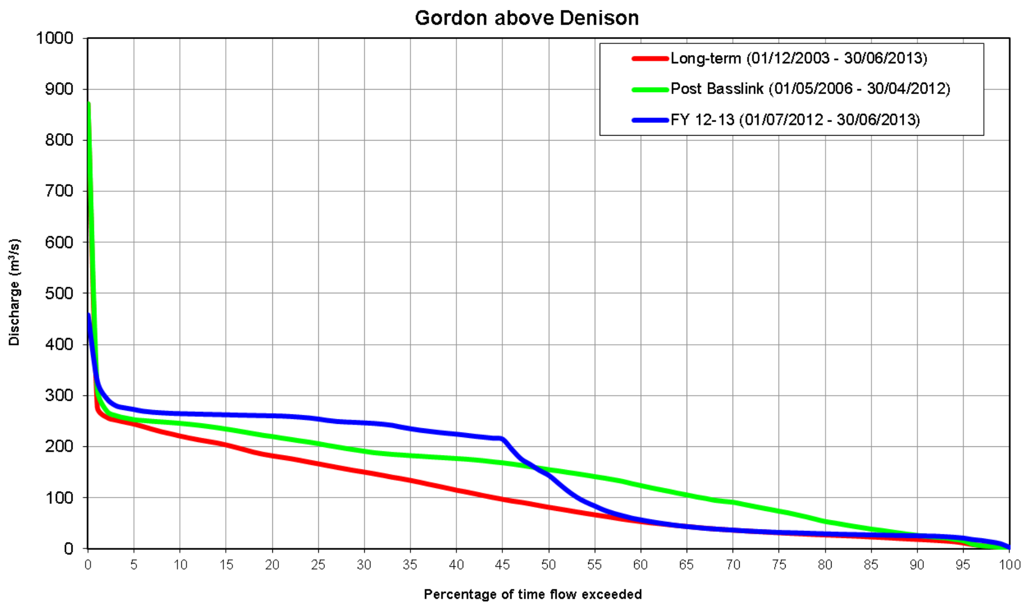

Figure 2-22: Flow duration curve for Gordon above Denison for 2012–13 compared with long-term and previous post-Basslink years.

2.5.4.4 Environmental flow compliance

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

An analysis of hourly flows at site 65 (Figure 2-23) shows that for the winter periods (July–November 2012 and June 2013), the minimum flow requirement of 20 $m^3 s^{-1}$ was met 99.93% of the time. The minimum summer (December 2011–May 2012) flow requirement of 10 $m^3 s^{-1}$ was met 99.75% of the time (Table 2-5). Note that times of shutdown of the Gordon Power Station due to maintenance, AEMO conformance testing, and/or monitoring have been excluded from the analysis, as per the licence conditions.

There were two instances where flows were non-compliant:

- The first of these on 10 September 2012 (when environmental flow was 20 $m^3 s^{-1}$) lasted for a period of three hours, declining to a minimum of 18.7 $m^3 s^{-1}$. This occurred because Gordon Power Station was shut down following high catchment pick-up from the tributaries below the power station. The tributary flows dropped off rapidly, and the generation controller restarted the environmental flow in response. However the transit time from the power station to the compliance site was too long, and this small, short non-compliant period resulted.
- The second instance on 11 February 2013 (when environmental flow was 10 $m^3 s^{-1}$) lasted for a period of 11 hours and declined to a minimum of 6.9 $m^3 s^{-1}$. The cause for the non-compliance was that Gordon Power Station was shut down at request of Transend and the Tasmanian Fire Service to safely manage a fire under the Gordon-Chapel St transmission lines in the Collinsvale area. The power station was shut down for nearly 37 hours, resulting in the non-compliance in the latter part of the shutdown.

Table 2-5: Environmental low flow non-conformance events at site 65 for 2012–13.

Period	Minimum environmental flow	Non-compliant events	Non-compliant hours	Compliance rate
Winter (July–Nov 2012)	20	1	3	99.92%
Summer (Dec 2012–May 2013)	10	1	11	99.75%
Winter (June 2013)	20	0	0	100%

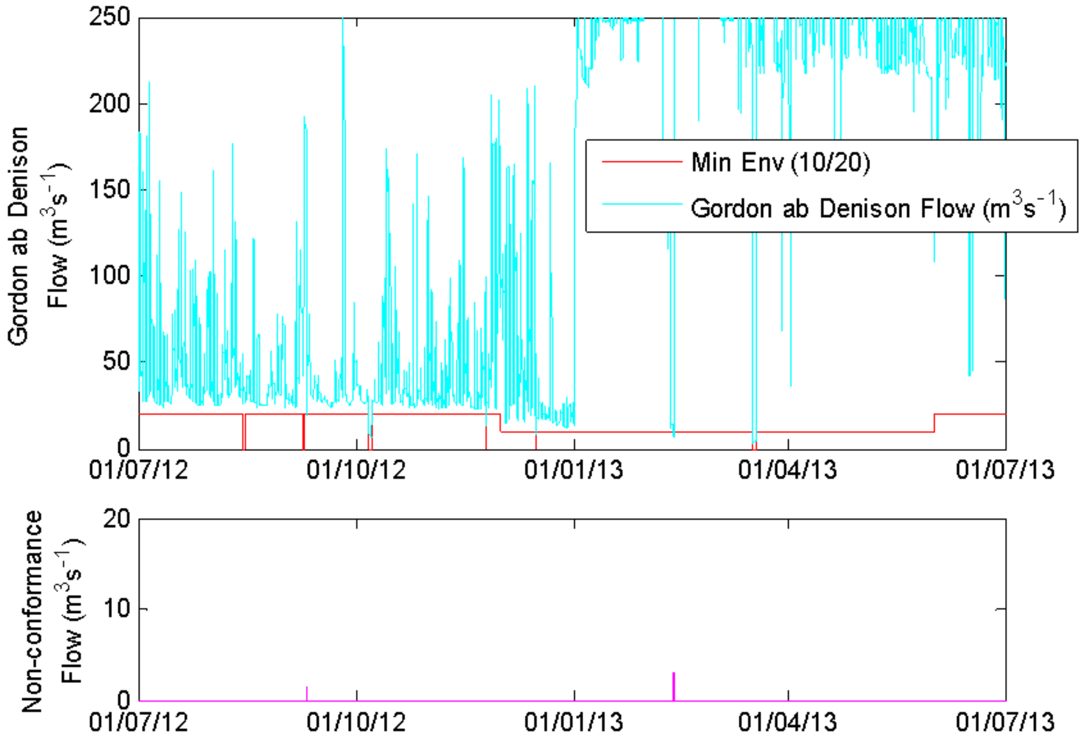

Figure 2-23: Flow recorded (hourly data) at site 65 (Gordon above Denison), from July 2012 to June 2013, and analysis of non-conforming flows.

2.5.4.5 *Low to mid-range flow variability analysis at Gordon above Denison*

Figure 2-24 presents analysis of rapid increases between low and mid-range flows at the Gordon above Denison site, and provides a measure of flow variability that is at a scale of relevance to macroinvertebrates and fish. This measure is not indicative of full-range hydro-peaking, but rapid low-mid range variations in flow. This analysis presents data for the number of occasions when flows have increased rapidly in the post-Basslink period (within two hours) from low flows in the vicinity of the environmental flow (<25 $m^3 s^{-1}$) to greater than 100 $m^3 s^{-1}$. In 2012–13 there were 14 instances, which was similar to the previous year (12 instances), and substantially lower than 2010–11 which had the highest occurrence for the available record (39 instances). The annual number of events for most years is less than half of that recorded for the Gordon Power Station discharge (Figure 2-17) and is due to the downstream attenuation of flows and tributary inputs. In 2012–13 the number of instances were three times lower than those experienced at Gordon Power Station as a result of the attenuation.

In 2012–13, rapid flow increases were most common in December 2012 (Figure 2-25).

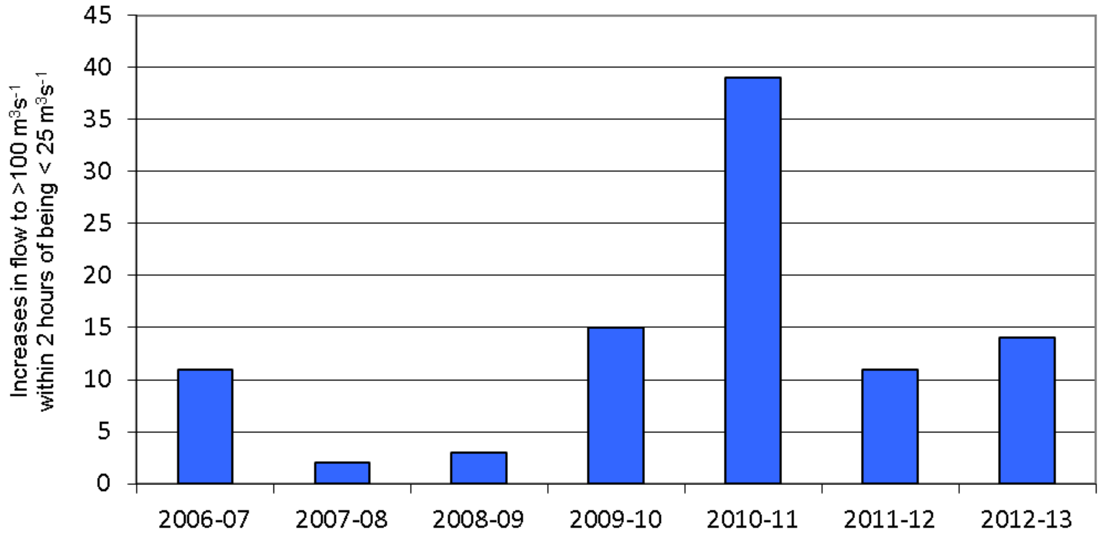

Figure 2-24: Rapid flow increases (<25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon above Denison for each post-Basslink year.

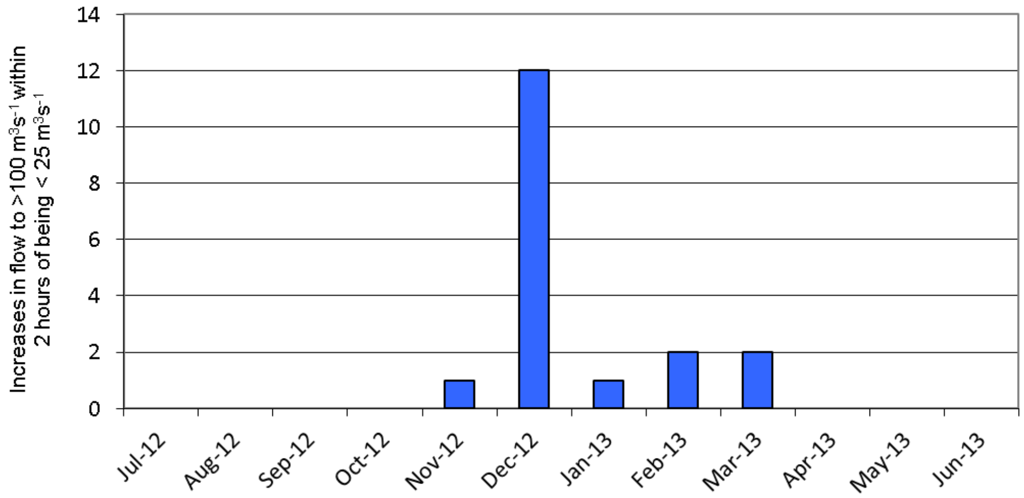

Figure 2-25: Rapid flow increases (<25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon above Denison for each month during 2012–13.

2.5.5 Gordon above Franklin (site 44)

The Gordon above Franklin site (site 44) is the furthest remaining downstream monitoring site on the Gordon River. Power station releases 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.

2.5.5.1 Flow

Figure 2-26 shows the hourly flows at site 44 for 2012–13 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, is an under-estimate. In 2012–13, power station discharge was the dominant flow component at site 44. However, there were 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 were most common in July-September 2012 and April-May 2013. The maximum flow of 758 $m^3 s^{-1}$ for the year occurred on 4 May 2013.

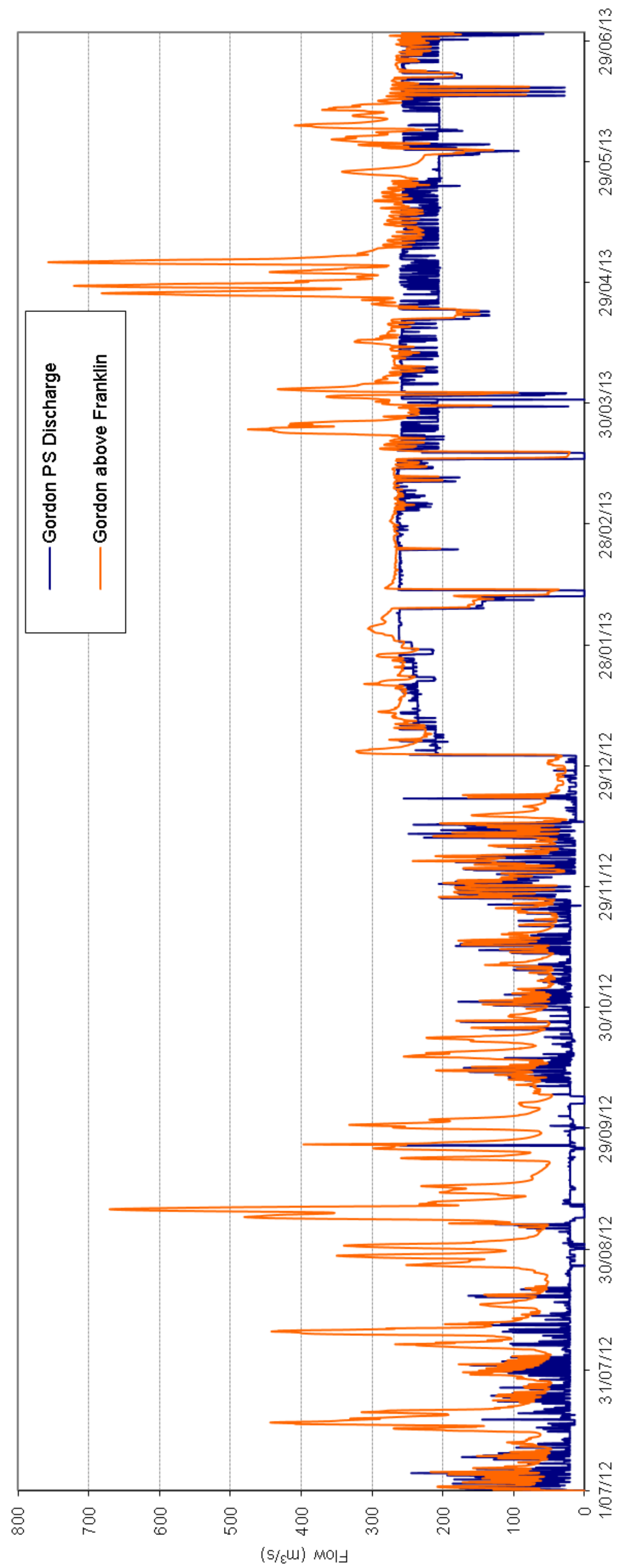

Figure 2-26: Flow recorded (hourly data) at site 44 (Gordon above Franklin) and Gordon Power Station discharge derived from the simplified three-dimensional rating during 2012–13.

2.5.5.2 Median monthly flows

Figure 2-27 shows the median monthly flow for the data at site 44 over the 2012–13 year, compared with the long-term post-dam (since January 1978) patterns. With the exception of October, all months from July to December 2012 were less than the long-term median. Notably, all median flow values for January to July 2013 were substantially higher than long-term and previous post-Basslink years' median flows. The high power station discharge was the main influence of the flow patterns at site 44 from January to June 2013.

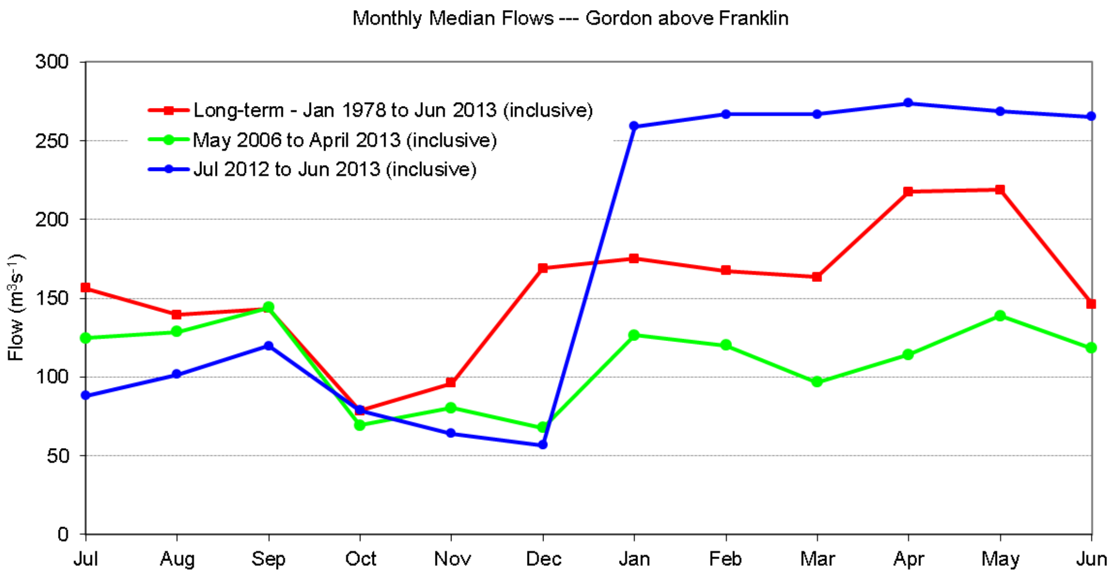

Figure 2-27: Median monthly flow at site 44 (Gordon above Franklin) for 2012–13 and the long-term monthly median values.

2.5.5.3 Duration curves

The duration curve for site 44 is shown in Figure 2-28. Comparison with the long-term curve is indicative of the significantly higher flows for part of the year as a result of the high power station discharge. The higher proportion of lower flow ranges in 2012–13 compared with the long-term is due to the generally low flows resulting from low power station discharge in July to December 2012.

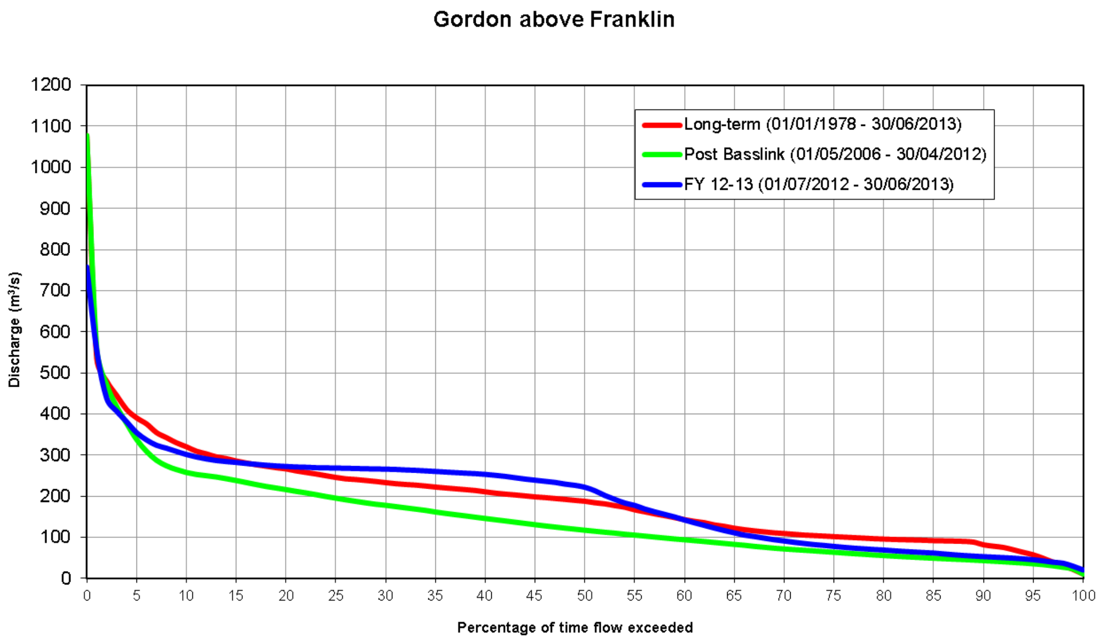

Figure 2-28: Flow duration curve for Gordon above Franklin (Site 44) for 2012–13 compared with long-term and previous post-Basslink years.

2.6 Conclusions

The flow in the Gordon River in 2012–13 was influenced by low power station discharge in the first six months of the year and high discharges in the second half of the year. High discharges were maintained to take advantage of the capacity to raise additional generating income following the implementation of the fixed carbon price.

Under the conditions of regular peaking while the banks were saturated, the operation of the newly implemented ramp-down rule was applied successfully, with indications of lower ramping rates compared to previous operations under condition of highly saturated banks. All ramping was compliant, as the system for controlling the rate of generation reduction was automatically activated under all trigger conditions (>2.75 m modelled bank level, >150 $m^3 s^{-1}$ discharge).

The minimum environmental flow was achieved 99.75% of the time in summer and 99.93% in winter.

3 Fluvial geomorphology

3.1 Introduction

This section summarises fluvial geomorphology monitoring results obtained in October 2012 and March 2013. Geomorphology monitoring in the middle Gordon River is being completed to assess the efficacy of a revised ramp-down rule, and follows the 6-years of post-Basslink monitoring associated with the Gordon River Basslink Monitoring Program.

3.1.1 Aims of monitoring program

The aims of geomorphology monitoring in the Gordon River include:

- to document fluvial geomorphological processes and changes in the Gordon River between the power station tailrace and the mouth of the Franklin River (defined as the middle Gordon River);
- to relate these changes to power station operations, including the revised 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.

3.2 Methods

Basslink geomorphology monitoring is described in detail in the first pre-Basslink fluvial geomorphology monitoring report (Koehnken and Locher, 2002) and the Basslink Baseline Report (Hydro Tasmania, 2005) 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, 2005). The following is a brief summary of the monitoring components.

The monitoring includes field observations and measurements of ~250 erosion pins located at 47 monitoring sites in the middle Gordon River (Table 3-1). The monitoring sites are distributed over five geomorphic zones in the river, which have been identified based on hydrologic and hydraulic attributes and are shown in Figure 3-1 to Figure 3-6. Erosion pins are located in sandy alluvial banks along the middle Gordon within the height affected by power station operation. The location of pins at each site has also been classified according to the turbine discharge required for inundation (<1 turbine indicates that the operation of 1-turbine is likely to inundate the pin, 1-2 turbine bank level requires the operation of 2 turbines for inundation and 2-3 turbine bank is inundated when all 3-turbines are in operation). These levels are approximate and based on field observations under low-flow conditions only as no hydraulic model is available for the river and observations during periods of power station discharge have not been completed. A history of monitoring in the middle Gordon associated with the Basslink Monitoring Program is shown in Table 3-2.

All sites are visited and measurements collected in late summer or autumn of each year. During the summer / autumn monitoring trip, photos are taken at each of the Basslink photo-monitoring sites. In addition to the annual monitoring trip, erosion pins in Zones 2 through 4 are also measured in the spring, with measurements completed in zone 1 and 5 if time permits. This monitoring strategy allows results to be compared to historical results on an annual basis, with the spring results providing an indication of changes over the winter period.

The observations, erosion pin measurements and photo-monitoring are completed by boat based teams. In addition to the field monitoring results, ground water levels are continuously recorded by a piezometer array in zone 2 at site 71 (Figure 2-4).

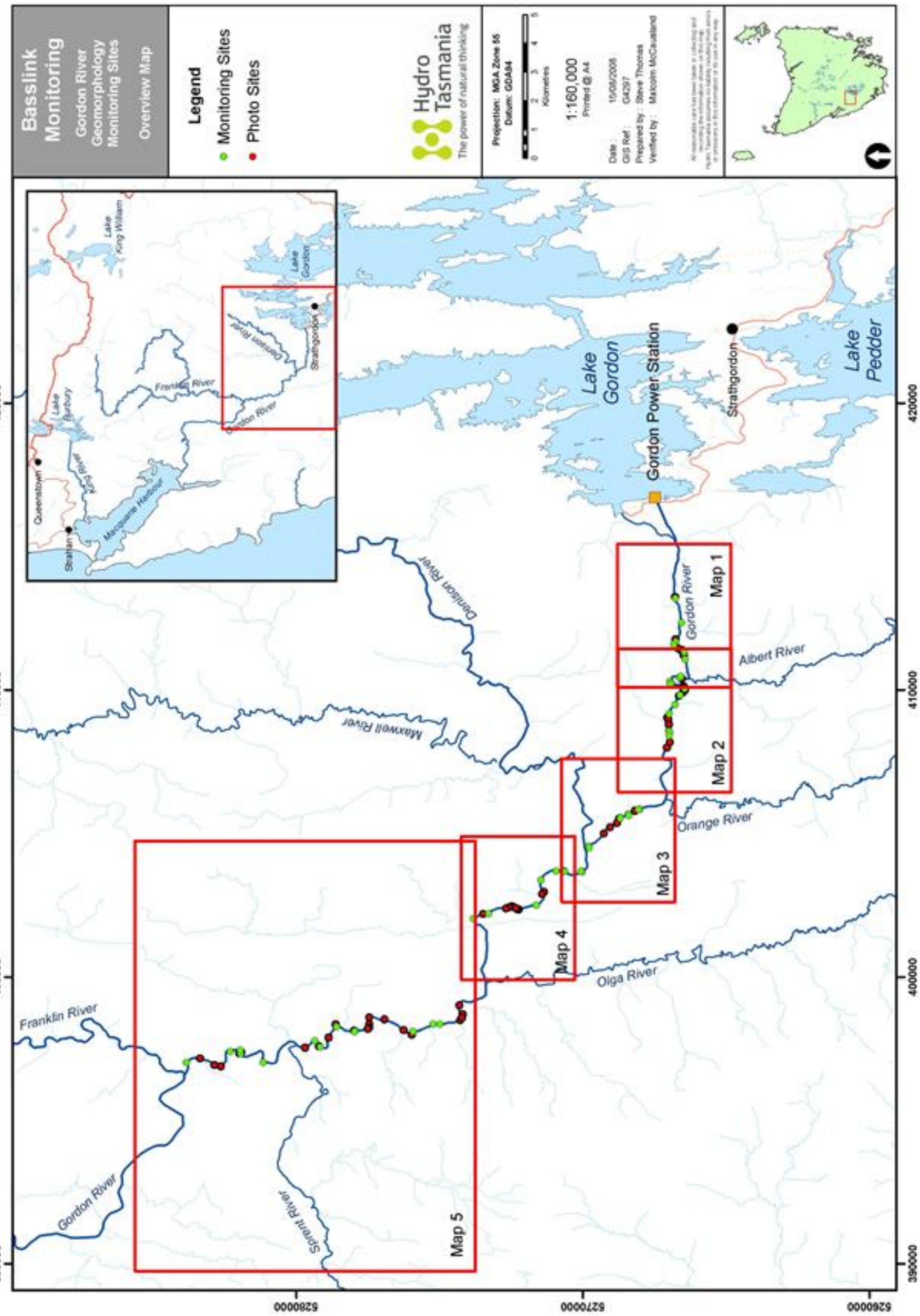

Figure 3-1: Overview of Gordon River Geomorphology monitoring sites.

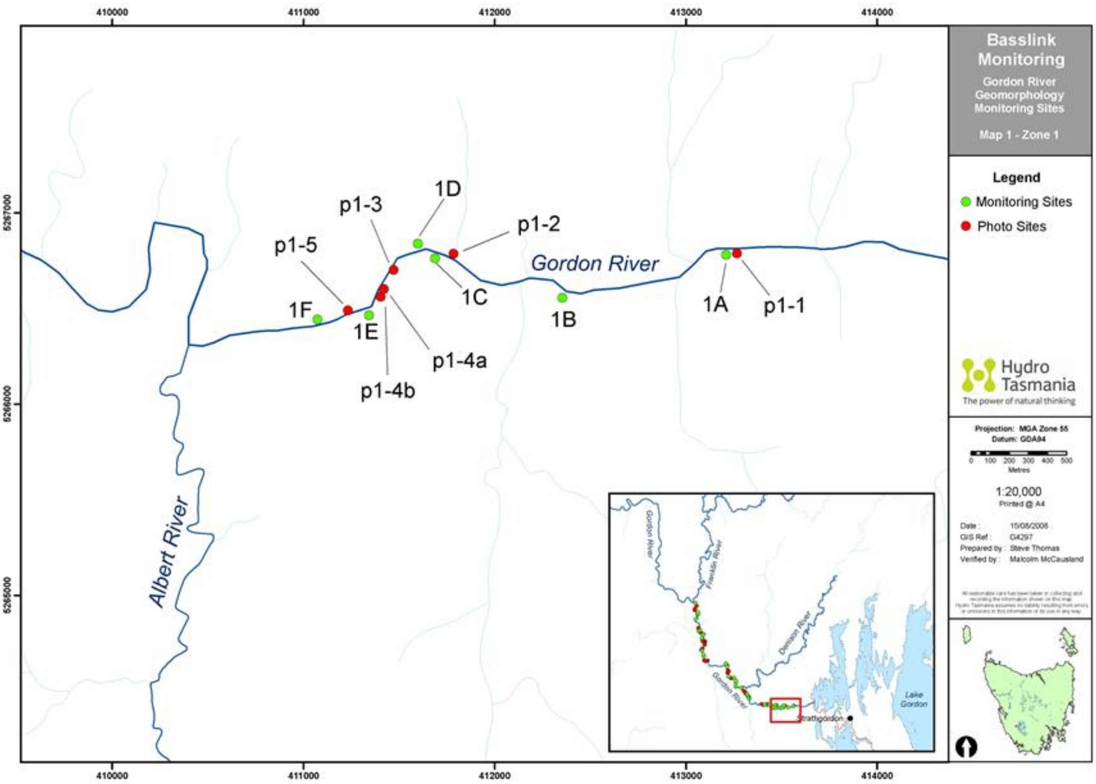

Figure 3-2: Gordon River geomorphology monitoring sites, zone 1.

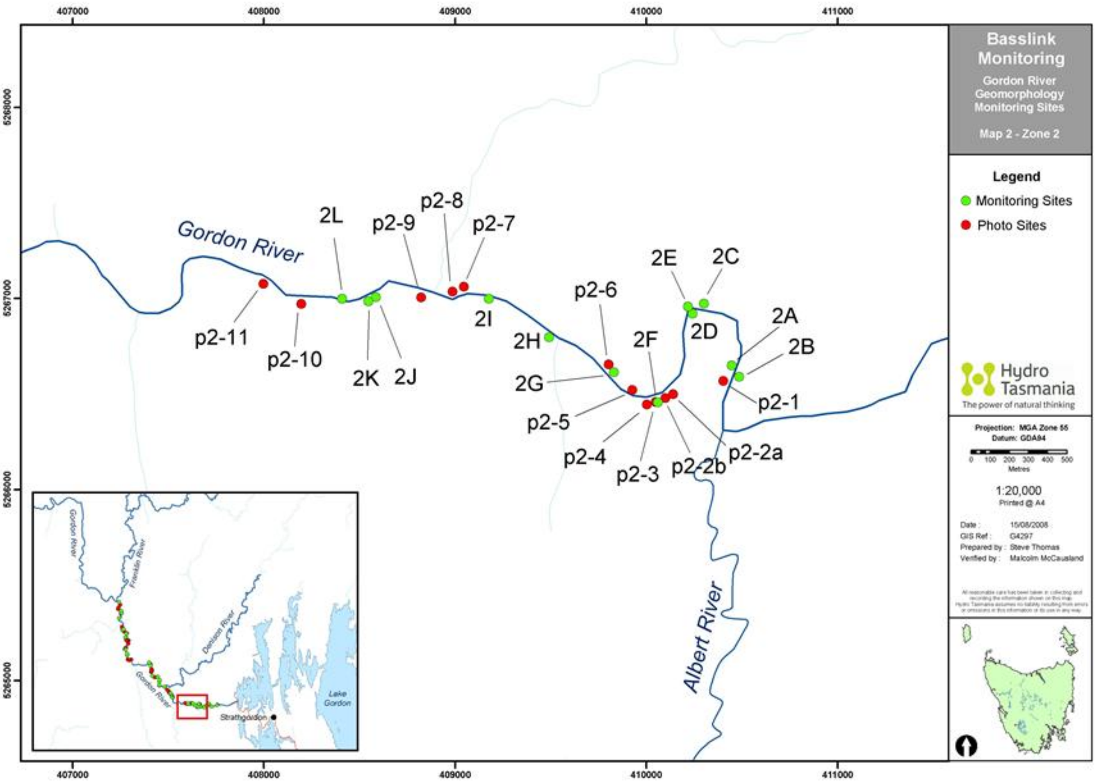

Figure 3-3: Gordon River geomorphology monitoring sites, zone 2.

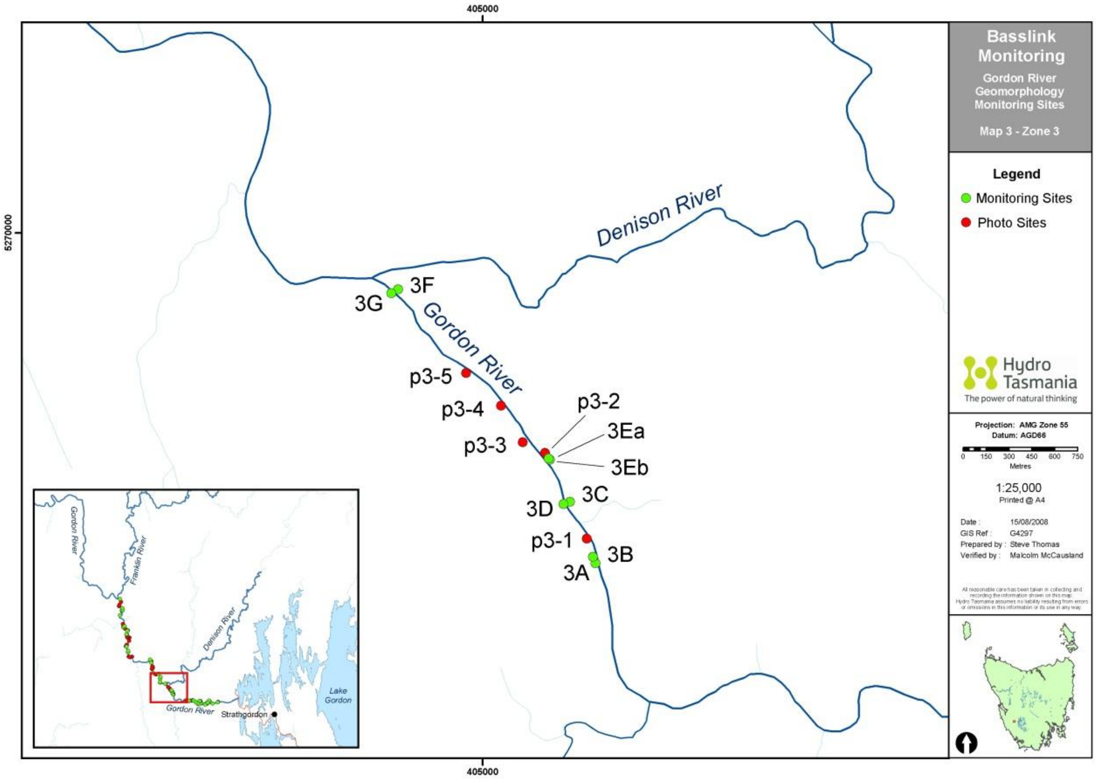

Figure 3-4: Gordon River geomorphology monitoring sites, zone 3.

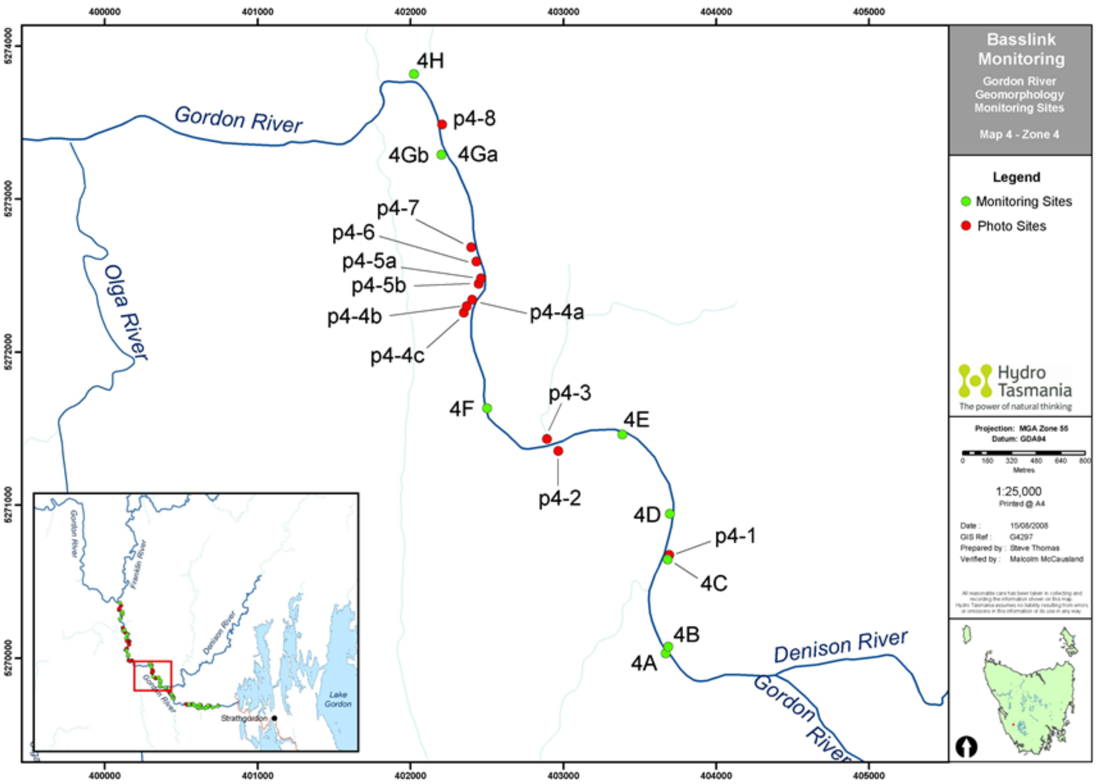

Figure 3-5: Gordon River geomorphology monitoring sites, zone 4.

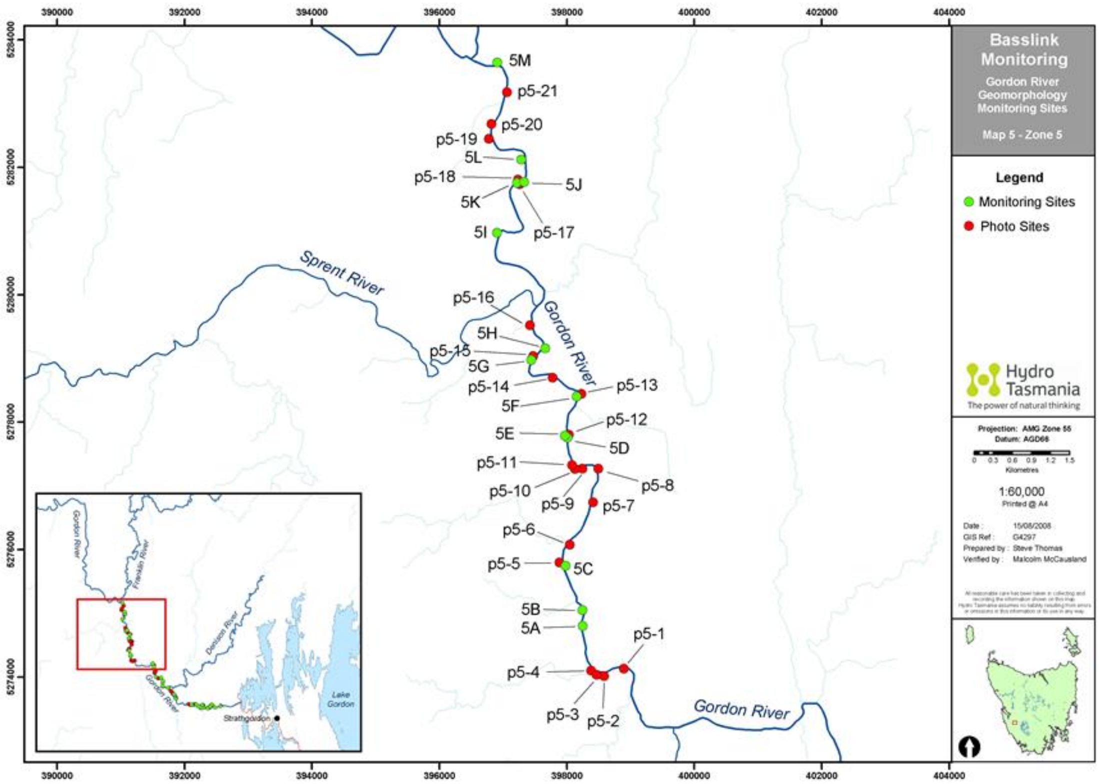

Figure 3-6 : Gordon River geomorphology monitoring sites, zone 5.

Table 3-1: Number of monitoring sites and erosion pins in each geomorphology zone.

Zone	#Sites	#Erosion Pins
Zone 1	6	35
Zone 2	12	63
Zone 3	8	47
Zone 4	8	39
Zone 5	13	63
Total	**47**	**247**

Table 3-2: Summary of geomorphology monitoring activities in the middle Gordon River between 1999 and present. Derivation indicates that the data was used in the formulation of trigger values, 'test' indicates that the erosion pin results from that monitoring period have been compared with the trigger values.

Monitoring Type	Triggers: Derivation or Test	Season	Dates	Monitoring completed
Pre-Basslink	Initial investigations		11 Dec 99 18 Dec 99 4 Mar 00 25 Mar 00 22 Jul 00 2 Sep 00 4 Aug 01	Investigations for IIAS: Field observations Erosion pin measurements Photo-monitoring Scour chains Painted cobbles
Pre-Basslink	Derivation	Spring 2001	23 Nov 01 9 Dec 01	Field observations Erosion pin measurements
Pre-Basslink	Derivation	Autumn 2002	10 Feb 02 9 Mar 02	Field observations Erosion pin measurements Photo-monitoring
Pre-Basslink	Derivation	Spring 2002	5 Oct 02 16 Dec 02	Field observations Erosion pin measurements
Pre-Basslink	Derivation	Autumn 2003	29 Mar 03	Field observations Erosion pin measurements Photo-monitoring
Pre-Basslink	Derivation	Spring 2003	18 Oct 03	Field observations Erosion pin measurements
Pre-Basslink	Derivation	Autumn 2004	6 Mar 04	Field observations Erosion pin measurements Photo-monitoring
Pre-Basslink	Derivation	Spring 2004	9 Oct 04	Field observations Erosion pin measurements Bank profiling
Pre-Basslink	Derivation	Autumn 2005	2 Apr 05	Field observations Erosion pin measurements Photo-monitoring
Pre-Basslink	Derivation	Spring 2005	15 Oct 05	Field observations Erosion pin measurements
Transition	Test	Autumn 2006	11 Mar 06	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2006	17 Oct 06	Field observations Erosion pin measurements
Post-Basslink	Test	Autumn 2007	17 Mar 07	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2007	20 Oct 07	Field observations Erosion pin measurements
Post-Basslink	No	Spring 2007	1 Dec 07	Field observations
Post-Basslink	Test	Autumn 2008	1 Mar 08	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2008	17-19 Oct 08	Field observations Erosion pin measurements
Post-Basslink	Test	Autumn 2009	21–22 Mar 09	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2009	17 Oct 09 (zones 3&4) 31 Oct 09 (zones 1,2,5)	Field observations Erosion pin measurements

Monitoring Type	Triggers: Derivation or Test	Season	Dates	Monitoring completed
Post Basslink	Test	Autumn 2010	12–14 Mar 10	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2010	19-20 Oct 10	Field observations Erosion pin measurements Establishment of vegetation transects at subset of geomorphology monitoring sites in zones 2 – 4.
Ramp-down rule investigations	No	Summer 2011	7-days in Jan – Mar 11	Observations of ramp-downs and drawdowns at varying levels of bank saturation associated with investigations to revise ramp-down rule.
Post-Basslink	Test	Autumn 2011	26–27 Feb 11	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2011	5–6 Nov 11	Field observations Erosion pin measurements Combined geomorph & vegetation monitoring
Post-Basslink	Test	Autumn 2012	25–26 Feb 12	Field observations Erosion pin measurements Photo-monitoring
Interim monitoring	Test	Spring 2013	6-Oct 12	Field observations zones (1-4, limited in zone 5) Erosion pin measurements (zones 1-4 only)
Interim monitoring	Test	Autumn 13	17 Mar 13	Field observations Erosion pin measurements Photo- monitoring (zones 1-5)

Table 3-2 continued.

3.2.1 Monitoring in October 2012 and March 2013

Geomorphology monitoring was completed twice in the 2012–13 year. The spring monitoring was completed on 6 October 2012, and the autumn monitoring on 17 March 2013.

The spring monitoring was immediately preceded by and coincided with high tributary inflows to the Gordon River, so that many erosion pins located on bank toes were partially or completely submerged. Although only zones 2 to 4 were scheduled for monitoring, there was sufficient time to obtain erosion pin measurements from zone 1. A few measurements were also completed in zone 5, however as not all pins were measured, the results from this zone were not included in the statistical analysis of the data.

The autumn monitoring included the measurement of erosion pins, and photo-monitoring in all five geomorphic zones.

The pins which were not found or not measured in zones 1–4 in October 2012 but which were located in March 2013, and pins which were located in October 2012 but not located in March 2013, are listed in Table 3-3.

At site 2K, located at the downstream end of zone 2, a metal detector was used to locate pin 2K/1 which was buried almost 200 mm under a degraded root-mat (Figure 3-7 to Figure 3-9). This pin was located and measured in February 2012 indicating that bank slumping occurred between the monitoring periods. Site 2K is a very active site just upstream from the Splits, with numerous pins lost over the history of the Basslink monitoring program. The metal detector did not locate any other pins suggesting they are either buried very deeply, or have been lost to the river.

Table 3-3: List of erosion pins not located in October 2012 and March 2013.

Pin	Monitoring period	Change(s) to site (eg. treefall, et)	Comment
2G/6	October 2012	No measurement	Monitoring error– photo of site shows pin is present, but no measurement was recorded in field notes.
2K/1	October 2012	Pin buried	Found with metal detector
4A/3	October 2012	Pin buried	Duplicate pin measured
3Eb/2	March 2013	Pin buried	Flagging tape showing – duplicate pin measured
4D/7	March 2013	None indicated	Pin associated with combined vegetation geomorph monitoring and not long term erosion pin
5F/2	March 2013	Tree fall observed in October 2012 at site	Pin not found
5F/3	March 2013	Tree fall observed in October 2012 at site	Pin not found
5H/2	March 2013	Pin buried	Pin not found
5M/3	March 2013	Evidence of scour	Pin not found

Figure 3-7: Use of metal detector at erosion pin site 2K.

Figure 3-8: Unearthing of erosion pin 2K/1.

Figure 3-9. Erosion pin 2K/1 buried by slumping root mat.

3.3 Overview of hydrology, March 2012 – March 2013

A detailed discussion of the hydrology of the Gordon River during the 2012–2013 monitoring year is presented in Chapter 2 Hydrology and water management. The following short discussion highlights hydrologic characteristics of the monitoring year relevant to the geomorphology monitoring results.
Discharge from the Gordon Power Station between March 2012 and April 2013 is shown in

Figure 3-10Figure 3-10, and discharge from the station is compared to flow at the Gordon above Denison compliance site and Gordon above Franklin gauging site in Figure 3-11. The hydrograph for the power station shows that between March 2012 and January 2013, discharge from the station was characterised by short-duration events, with magnitudes generally less than 150 m^3s^{-1}. This operating pattern is consistent with the previous several years of power station operations. During winter 2012, there were numerous natural high flow events recorded at the Gordon below Denison and Gordon above Franklin gauging sites, with maximum daily flows of 347 m^3s^{-1} and 670 m^3s^{-1} recorded during winter at these downstream sites, respectively.

Beginning in January 2013, the operating mode of the power station substantially changed, with the discharge pattern characterised by long-duration high magnitude events. Since January 2013, the station has only reduced discharge on three occasions, one of which was associated with the monitoring trip in March 2013. Each of these flow reductions coincided with periods of high bank saturation based on the bank saturation model, and flow reductions were ramped as required by the ramp-down rule (Figure 3-12).

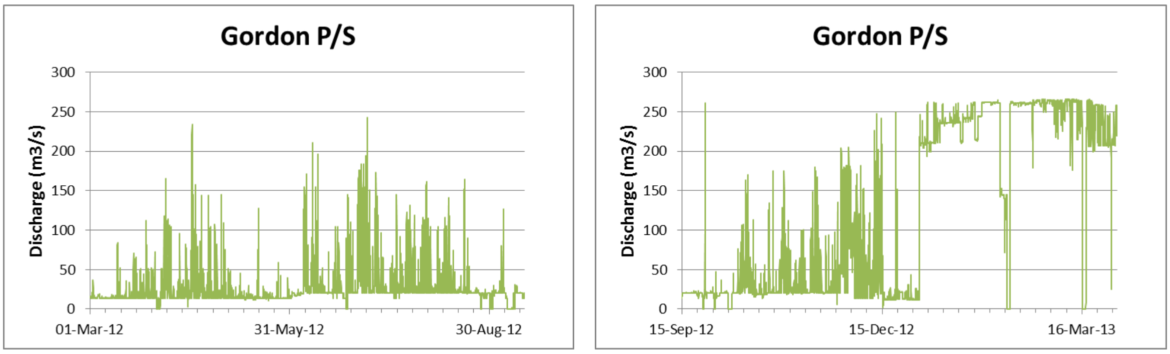

Figure 3-10: Hydrograph of discharge from the Gordon Power Station between 1 March 2012 and 1 April 2013.

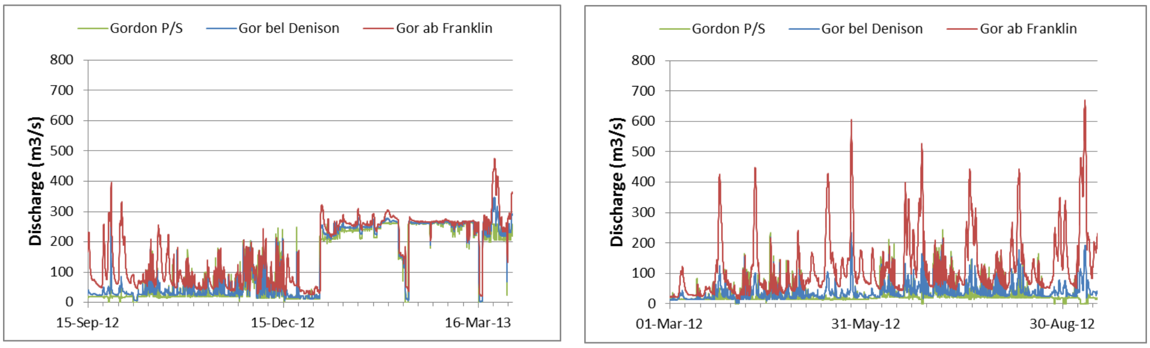

Figure 3-11: Hydrographs from the Gordon Power Station, the Gordon above Denison (Compliance site) and the Gordon above Franklin gauging station for the period 1 March 2012 to 1 April 2013.

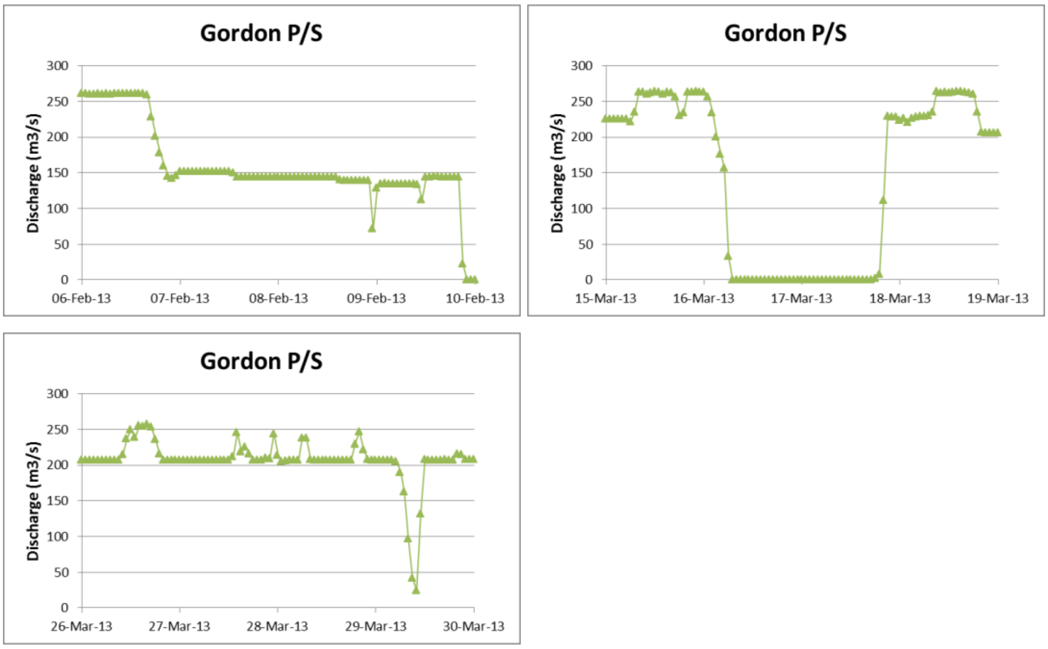

Figure 3-12. Hydrograph of hourly discharge from the Gordon Power Station for the three shut-downs between January 2013 and March 2013 showing ramp-down of flows >180 $m^3s^{-1}$and 150 m^3s^{-1}.

3.4 Sediment transport capacity modelling

A theoretical sediment transport model for zone 1 in the Gordon River was developed by S. Wilkinson and I. Rutherfurd during the IIAS investigations (Koehnken *et al,* 2001). Actual results from the model are not particularly meaningful, but changes between years provide a relative indication of how the potential for scour in the river varies as a function of power station discharge. Figure 3-13 compares the model results for the 2012–2013 monitoring year with previous years and the unregulated (natural) flow regime, and Figure 3-14 breaks the sediment transport results for the 2012–2013 year into pre- and post- January 1, 2013.

The results show that total sediment transport increased considerably in 2012–2013 relative to the previous four monitoring years, but remained lower than most pre-Basslink years. It is also evident that a larger proportion of the sediment transport capacity is attributable to high flows (>185 m^3s^{-1}) related to the operation of all three turbines at the power station. The breakdown of the 2012–2013 monitoring year clearly shows that the majority of the sediment transport capacity is related to power station operations after 1 January 2013, as would be expected given the long-duration high flow discharge from the power station after this date.

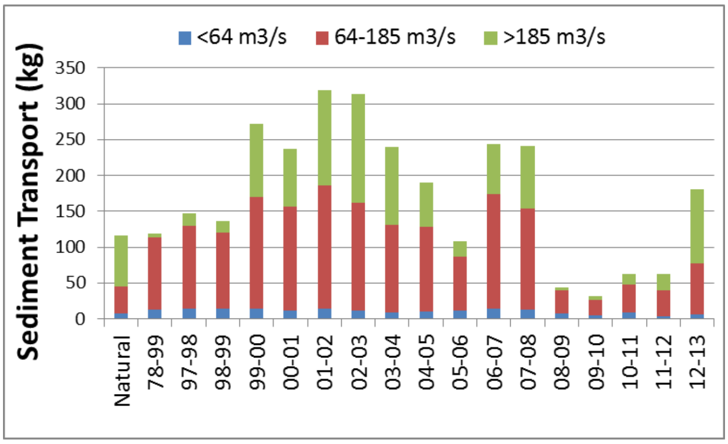

Figure 3-13: Theoretical sediment transport in zone 1 of the Gordon River. Total calculated sediment transport is divided into flow levels approximately equivalent to 1, 2 and 3-turbine power station operation. Model developed by Wilkinson and Rutherfurd during Basslink IIAS.

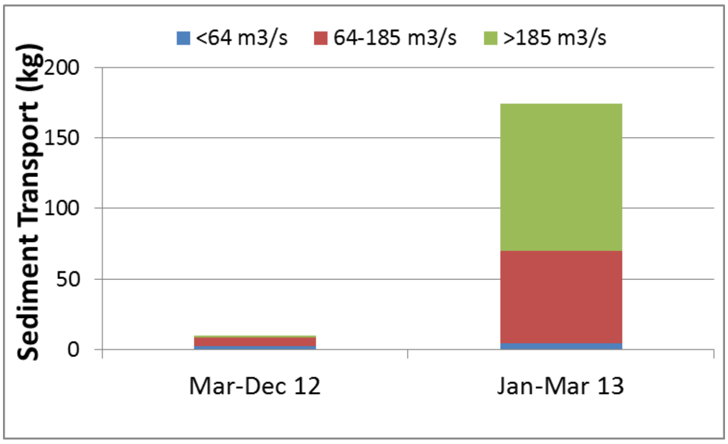

Figure 3-14: Theoretical sediment transport in zone 1 of the Gordon River during March to December 2012, and January to March 2013.

3.5 Monitoring results

3.5.1 Field observations: October 2012

Field observations in October 2012 were consistent with low levels of power station operation combined with numerous natural high flow events during the previous several months. Observations relevant to the geomorphic investigations in October included:

- Evidence of extended periods of low flow, including the presence of algal growth on bank toes with distinct upslope boundaries, and increased terrestrial vegetation upslope of the algae (Figure 3-15);
- Mud veneers on bank toes with distinct upslope boundaries similar to the algae indicative of natural inflow events in the absence of high power station discharge (Figure 3-16);
- The continued growth of vegetation on bank faces within the power station operating level (Figure 3-17);
- Larger deposits than has previously been observed of sand as shadow deposits on cobble bars in zones 3–5, suggesting higher rates of deposition associated with the

low power station discharge combined with the unregulated, sediment bearing winter inflows (Figure 3-18); and

- The removal of a deposited tree which was first observed in November 2011 at erosion pin site 3H (Figure 3-19, Figure 3-20).

Figure 3-15: Algae on bank toe in erosion pin site 2C (zone 2), with increased vegetation upslope.

Figure 3-16: Mud veneers, ripple marks and recent scour on bank toe at erosion pin site 3C (zone 3).

Figure 3-17: Vegetation at piezometer site in zone 2 downstream of erosion pin site 2G.

Figure 3-18: Sandy shadow deposits on cobble bar near erosion pin sites 3A and 3B.

Figure 3-19: Dead tree washed up on erosion pin site 2H located just upstream of Sunshine Gorge in February 2012.

Figure 3-20: Erosion pin site 2H showing removal of tree compared to February 2012. Tree was present in October 2012. Red circle indicates position of erosion pin which was knocked down when tree was deposited on the bank.

3.5.2 Field observations: March 2013

Field observations in March 2013 reflected the prolonged, high flow discharge from the Gordon Power Station since January 2013, and the recent shutdown. Field evidence and piezometer results clearly indicates that the banks were highly saturated prior to the power station shutdown associated with the monitoring. Field observations included the following:

- seepage related sediment deposits including:
  - seepage deposits associated with the rilling of the bank toe (Figure 3-21). The rilling was most pronounced on bank toes below the environmental flow level, suggesting it was related to the power station shutdown required for monitoring and would be unlikely to occur if flows were reduced to the environmental flow level;
  - seepage deposits downslope of historically active seepage 'vents' (Figure 3-22), but no new large seepage sites were identified;
  - seepage induced sediment slumping on banks exposed due to landslips (Figure 3-23)
  - sand deposits derived from the washing out of sands from under degraded tea tree root mats (Figure 3-24);
  - bank rilling above the environmental flow level (Figure 3-25 and Figure 3-26); and

  - tension cracks (Figure 3-27).

- fluvial deposition of sands on banks in zones 3–5 (Figure 3-28). Some of this sand deposition may be related to the inflow of tributaries following power station shutdown. It is likely that sands were temporarily stored at the mouths of tributaries due to high flows in the Gordon River 'damming' the tributary inflows. As flow in the Gordon River decreased, these backwater areas would have drained, transporting the stored sands. The deposition was widespread in zones 3–5 suggesting a tributary source for the material.
- ripple marks and other indications of strong flows (flattened vegetation) were common throughout the middle Gordon (Figure 3-29 and Figure 3-30); and
- the filamentous algae present in October 2012 had decreased in extent as seen by comparing photos of site 2C (Figure 3-15, Figure 3-26). In other areas, vegetation cover remains similar, although the health of the plants appears to be declining (e.g. comparison of 2A back channel in February 2012 in Figure 3-31 and in March 2013 in Figure 3-32).

Figure 3-21: Localised seepage deposits derived from rilling on the bank toe in zone 1 in March 2013.

Figure 3-22: Seepage deposit from historically active seepage 'vent' in zone 2, March 2013. Site is on right bank just downstream of the zone 2 piezometer array.

Figure 3-23: Seepage slumping at landslip site in zone 2. Site is located on the left bank, d/s of erosion pin site 2A.

Figure 3-24: Seepage deposits derived from the transport of sand from beneath the degraded tea tree root-mat.

Figure 3-25: Rilling of bank toe at erosion pin site 4A.

Figure 3-26: Saturated bank toe at site 2C.

Figure 3-27: Tension cracks in bank at erosion pin site 5A.

Figure 3-28: Fluvial sand deposition at erosion pin site 3Ea.


Figure 3-29: Ripple marks at erosion pin site 3Gb.


Figure 3-30: Ripple marks and flattened vegetation at erosion pin site 2D.


Figure 3-31: Back channel area behind erosion pin site 2A in February 2012.


Figure 3-32: Back channel area behind erosion pin site 2A in March 2013.

3.5.3 Zone 2 piezometer results

The zone 2 piezometers are located adjacent to erosion pin site 2G, and installed in an array with probe 1 (P1) at the edge of the river at low flow (power station off) with 5 additional probes installed at 10 m intervals extended back from the bank. The probes were serviced and calibrated in July 2013 and the water level results recorded by the probes are shown in Figure 3-33 through Figure 3-36.

Figure 3-33 to Figure 3-35 show that during the period of low power station usage, water levels in the banks were low, generally <1.5 m except for a period towards the end of November when the groundwater level increased to almost 2.5 m for a short period of time, but rapidly decreased when peaking operations at the station ceased. Minimum levels were recorded during the end of December following a fortnight of infrequent power station usage (Figure 3-35 and Figure 3-37).

Figure 3-36 shows that following the initiation of prolonged high discharge from the power station, ground water levels steadily increased, with groundwater levels being similar to river level by the end of January. The two shutdowns, and other minor reductions in power station discharge during the first quarter of 2013 were insufficient to drain the bank, and ground water levels remained high until the end of the monitoring year (1 April 2013).

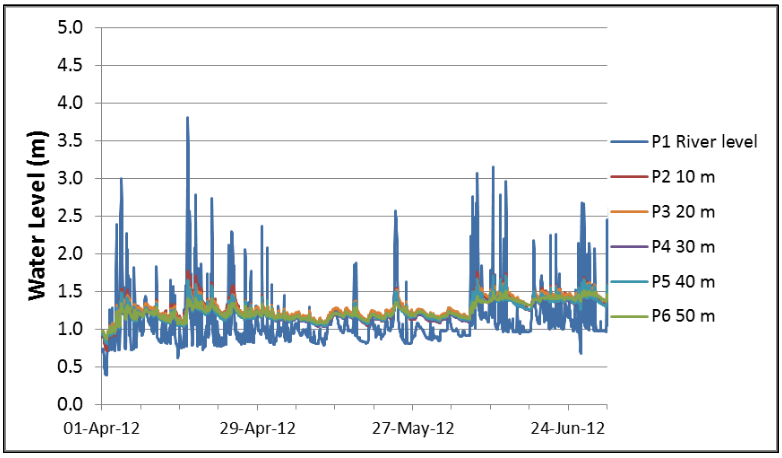

Figure 3-33: Zone 2 piezometer results for 1 April 2012 to 30 June 2012.

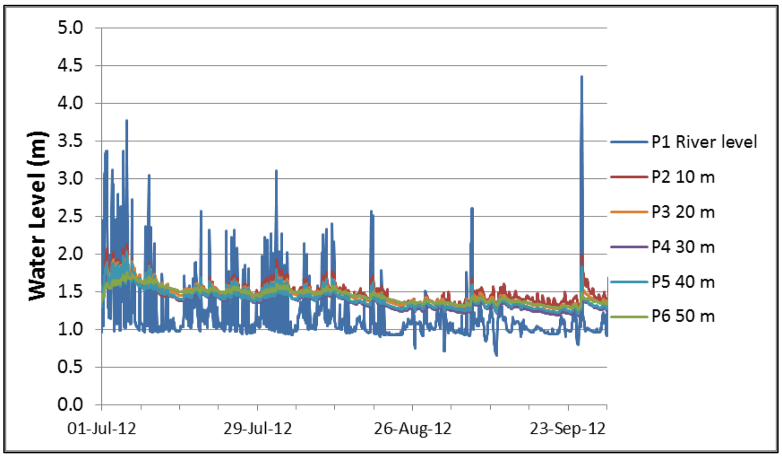

Figure 3-34: Zone 2 piezometer results for 1 July 2012 to 30 September 2012.

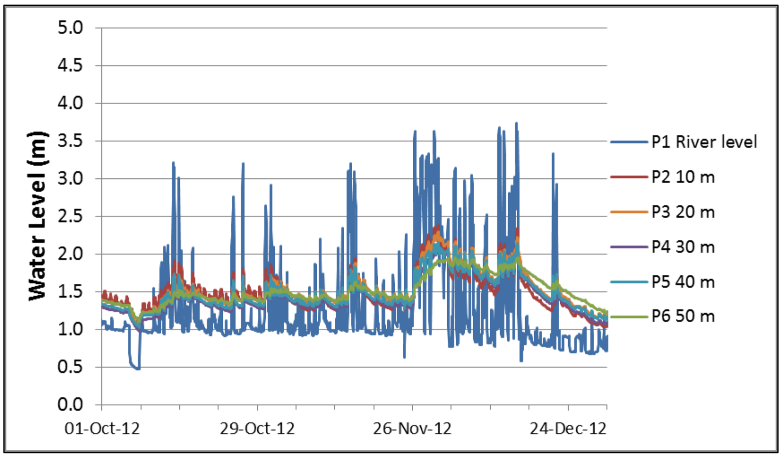

Figure 3-35: Zone 2 piezometer results from 1 October 2012 to 31 December 2012.

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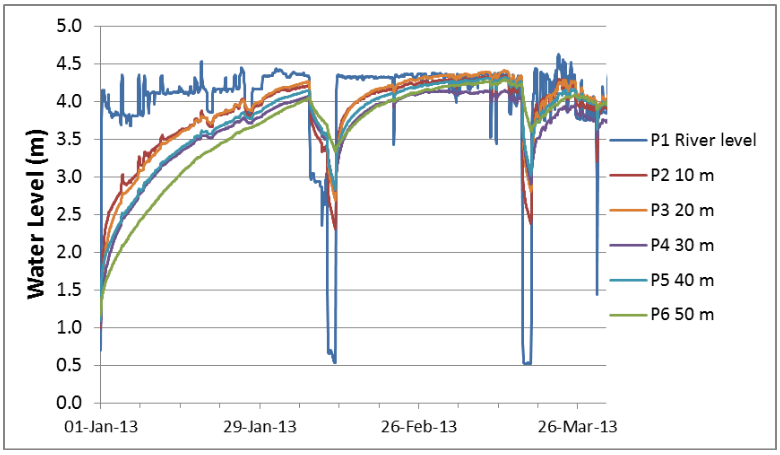

Figure 3-36: Zone 2 piezometer results from January 2013 to 31 March 2013.

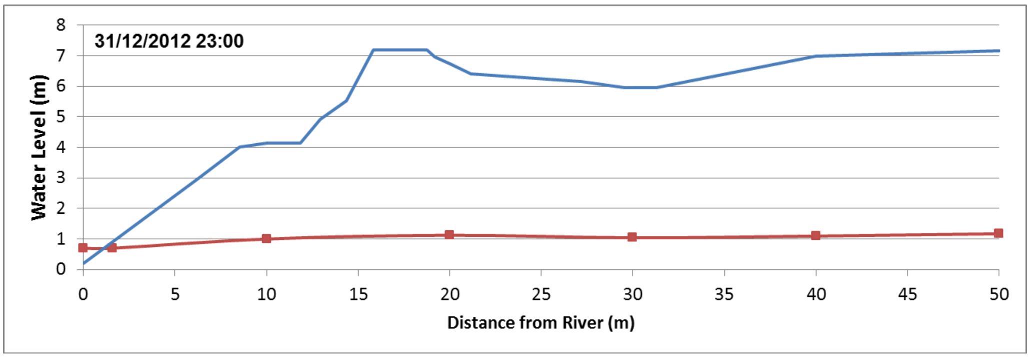

Figure 3-37: Profile of bank where zone 2 piezometers are installed showing ground water level on 31 December 2012.

The piezometer results were used to calculate the slope of the groundwater based on river level, and probe 2 (P2), located 10 m inland. The results are shown in Figure 3-38 (grey) with a positive slope indicating water flow out of the bank. Periods when conditions were considered to pose high risks of seepage erosion are overprinted in black, and are based on the water slope exceeding 0.1, and the water level at P2 exceeding 2.75 m. These criteria identify when seepage processes may be active in the bank in the 2–3 turbine bank level.

The results in Figure 3-38 show there were high risk periods during each of the two power station shutdowns in 2013, and during a short period when flows were reduced in late March 2013. The piezometer results during the power station shutdown in March 2013 (Figure 3-39) show the slower rate of water level decrease at probes 2–6 relative to river level.
The numerical piezometer results for the beginning of the shutdown are contained in

Table 3-4, and show that water level in the river decreased by about 0.20 to 0.30 m hour^{-1} over the first 5 hours, reflecting the ramp-down at the power station. Over this period, water level in the river decreased by 1 m, and the water level at P2 decrease by 0.28 m, and at probe 3 (P3) by 0.17 m. Following the ramping period, river levels decreased markedly, and because the water levels in the bank remained elevated, the periods of high seepage risk occurred. The results show that the ramp-down rule promoted drainage of the bank under low groundwater slopes, but the ramping period was insufficient to allow drainage of the bank to the point where water levels at P2 were below 2.75 m, or groundwater slopes were maintained below 0.1. This is attributable to the very high level of bank saturation related to the prolonged high discharge from the Gordon Power Station.

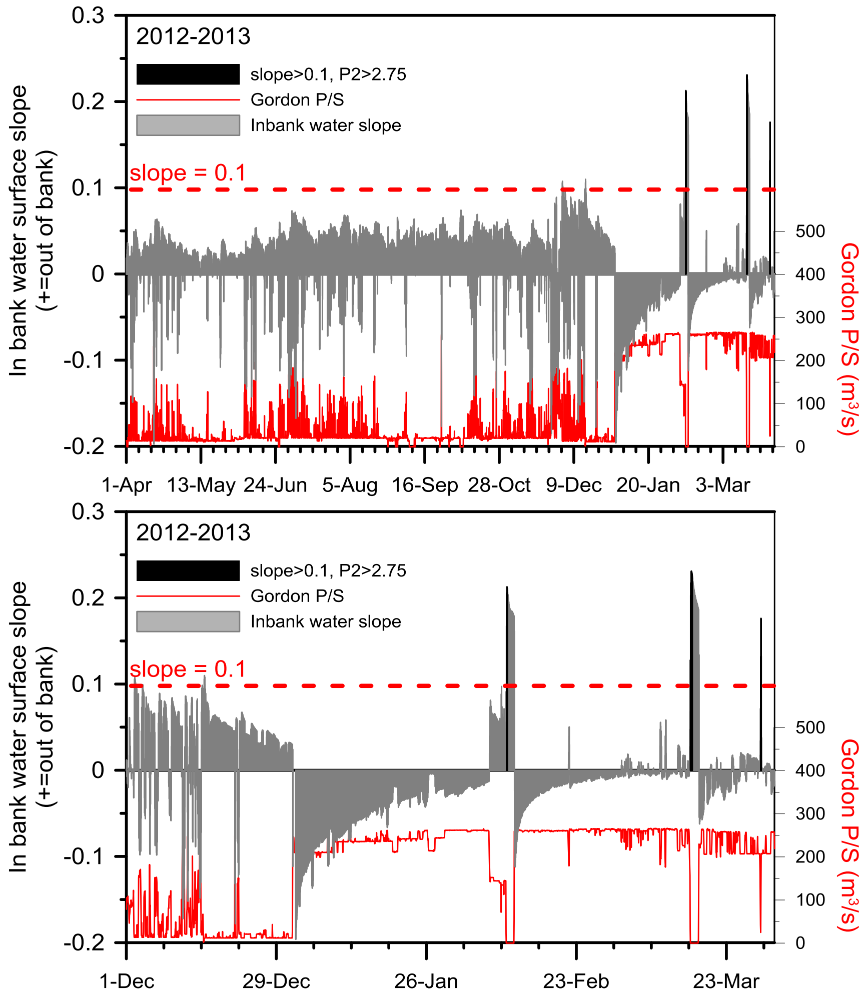

Figure 3-38: Zone 2 piezometer results shown as groundwater slopes based on the difference in water level between the river and probe 2, 10 m inland (grey), and the periods when seepage risks are considered high (black lines). Power station discharge shown in red for comparison. Slopes are calculated using hourly results. Top graph shows 2012–13 monitoring year, bottom graph is enlargement of 1 January 2013 to 1 April 2013.

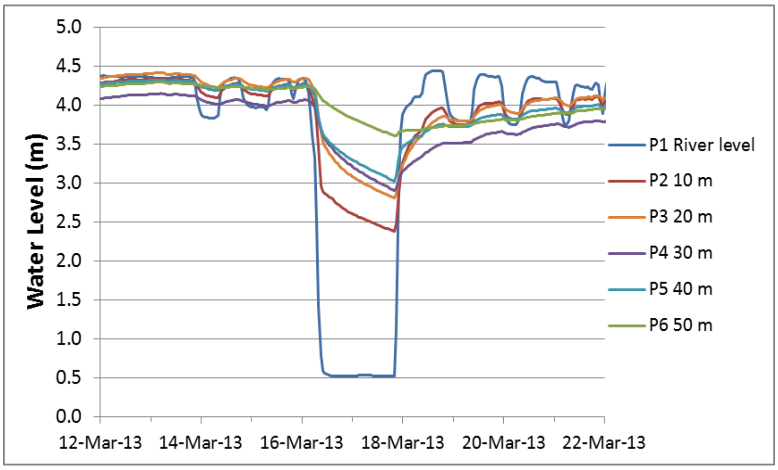

Figure 3-39: Piezometer results for power station shutdown in March 2013.

Table 3-4 Piezometer results for probes P1-P3 and ground water slopes during beginning of power station shutdown in Mach 2013. Blue cells show period of power station ramp, red cells show periods of high seepage risk based on water slopes and water level at probe 2.

Date Time	P1	P2	P3	Slope
16/03/2013 1:00	4.341	4.277	4.342	-0.0064
16/03/2013 2:00	4.301	4.272	4.342	-0.0029
16/03/2013 3:00	4.167	4.246	4.33	0.0079
16/03/2013 4:00	3.904	4.179	4.294	0.0275
16/03/2013 5:00	3.619	4.095	4.241	0.0476
16/03/2013 6:00	3.317	3.998	4.177	0.0681
16/03/2013 7:00	2.507	3.787	4.051	0.128
16/03/2013 8:00	1.43	3.458	3.857	0.2028
16/03/2013 9:00	0.783	2.959	3.65	0.2176
16/03/2013 10:00	0.594	2.892	3.536	0.2298
16/03/2013 11:00	0.557	2.868	3.472	0.2311
16/03/2013 12:00	0.54	2.845	3.421	0.2305
16/03/2013 13:00	0.528	2.822	3.379	0.2294
16/03/2013 14:00	0.524	2.801	3.337	0.2277
16/03/2013 15:00	0.518	2.776	3.304	0.2258
16/03/2013 16:00	0.515	2.749	3.271	0.2234
16/03/2013 17:00	0.515	2.726	3.241	0.2211
16/03/2013 18:00	0.514	2.704	3.213	0.219

The groundwater levels in the bank for the following stages are shown in Figure 3-40:

- March 16, 2013 at 01:00: Prior to the initiation of the power station shutdown (red) showing water levels in the bank are equivalent to river level for a distance of at least 50 m;
- March 16 at 07:00: End of the ramping period (blue) showing 1 m decrease in river level with decreasing reductions in levels at successive probes;
- March 16 2013 at 11:00: Point of maximum groundwater slope (green) while water level at Probe 2 exceeds 2.75 m;
- March 17, 2013 at 20:00, maximum bank draining (purple) prior to re-initiation of water level rise associated with power station discharge.

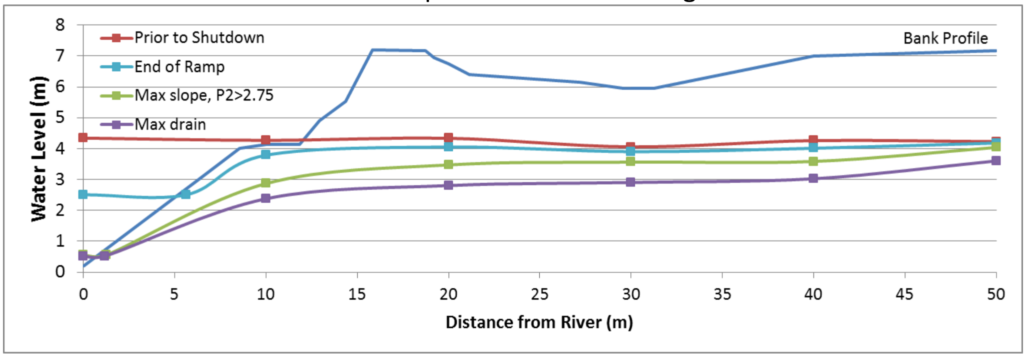

Figure 3-40: Bank profile showing groundwater levels, at piezometer probes 1 to 6 (P1 to P6), prior to initiation of shutdown on 16 March 2013 at 00:00 (red), at the end of the ramping period on 16 March 2013 at 07:00 (blue), at the point where water slopes were highest when the water level at P2 exceeded 2.75m (green) (16 March 2013 at 11:00), and at the maximum extent of draining 44 hours after initiation of shutdown on 17 March 2013 at 20:00 (purple). Note vertical exaggeration. Water level extrapolated to bank face based on P1 (river level probe).

The bank profiles demonstrate that water levels decreased substantially at P1 during the 4 hours following the end of the ramp down, which led to the high groundwater slopes. The profiles also show that over the 44 hour period of the power station shutdown, water levels at P3 decreased by 1.9 m, the level at P6 only reduced by 0.63 m, suggesting a prolonged shutdown or period of low power station discharge would be required to allow full drainage of the bank. The high level of bank saturation led to rapid re-saturation of the banks once power station operations resumed, as shown in Figure 3-39.

The occurrence of high seepage risks following the ramping period is attributable to the prolonged duration of high discharge from the power station resulting in high levels of bank saturation extending back over 50 m from the river. Extended periods of high power station discharge also result in the storage of large volumes of water in the lower reaches of tributaries which drain as water levels recede during the ramp-down period. This additional flow from the tributaries, combined with water draining from the banks, will reduce the rate at which the river recedes during the first few hours of the ramp down, and limit the rate of bank draining compared to periods of lower power station usage (e.g. lower bank saturation, less water stored in tributaries).

Field teams working in zone 2 on 17 March 2013 observed saturated bank faces up to levels of ~1.0 m above the low water level, and evidence of recent sediment flows at some of the sites where seepage erosion had previously been active. Seepage processes were not as widespread as observed in 2000 – 2001 when the power station operating patterns also included high flow long duration events, suggesting the ramp-down rule is reducing the risk of seepage processes.

3.5.4 Erosion pin results

3.5.4.1 Results grouped by zones

Graphs showing the erosion pin results for each site are contained in Appendix 2. The erosion pin results for each zone are plotted in Figure 3-41 through Figure 3-45, with the omission of October 2012 results in the graph for zone 5.

For each zone, several data sets are presented on the graphs. For all data sets, a positive value indicates erosion and a negative value denotes deposition. The central dataset (crosses and dots) shows the average change of all pins in the grouping using spring 2001 as the baseline (value indicates net change since 2001). The difference between data points on the graphs indicates the relative difference in erosion or deposition between the two dates.

The ‘net erosion’ dataset is further divided into pre- and post-Basslink periods. The pre-Basslink results (spring 2001 to spring 2005, crosses on graph) were used to predict a trend into the future, as shown by the line in each graph. The 95th percentile confidence interval for each projected trend was also calculated and is shown on the graphs in dashed lines. The dots indicate post-Basslink monitoring results and include the October 2012 (where available) and March 2013 results.

Two additional datasets on each graph show the average change for pins recording erosion (compared to spring 2001) during the monitoring period in the grouping, and the average change for pins showing deposition (compared to spring 2001) during the monitoring period. The relative changes between data points shows whether erosion or deposition has increased or decreased between monitoring periods. The positioning of the data sets relative to the mean values provides an indication of the relative number of pins recording erosion or deposition (e.g. if the trend for all results is closer to the erosion trend, more pins are showing erosion than deposition).

In October 2012, zones 1–4 showed a decrease in net erosion relative to February 2012, and the results for each of these zones fell below the 'predicted' erosion rate based on pre-Basslink measurements. This is the first sampling period where the zone 1 results were outside of the predicted envelope. The relatively low erosion relative to pre-Basslink condition in zones 1–4 is likely attributable to the much lower flow rates in the river during the post-Basslink period as compared to the pre-Basslink period, and possibly the effects of the ramp-down rule mitigation measure as discussed in the Basslink Review Report 2006-12 (Hydro Tasmania, 2013).

The March 2013 results showed different trends. In zones 1 and 3, net erosion (or reduction in deposition) increased relative to October 2012, whereas in zones 2 and 4, net erosion decreased. Zone 5 showed a relative decrease in erosion relative to the February 2012 results, as did zones 1, 2 and 4. In zones 2, 4 and 5, the erosion pin results followed similar trends as the past few monitoring periods. In zone 3, the seasonal trend of deposition in spring, and erosion in autumn continued.

The net erosion pin results for all zones are compared in Figure 3-46 and Figure 3-47. Zones 1 and 5 continue to show the lowest net changes, with zone 3 having the largest change. At a 'zone' level, the increase in power station operation post 1 January 2013 has resulted in an increase in net erosion through scour in zone 3, with increased deposition in zones 2–4. The low net change in zone 1 is consistent with this zone being 'adjusted' to the power station flow regime.

In October 2012, the deposition had progressively increased in zones 1–3 (Figure 3-47), which may reflect increased winter inflows and sediment deposition with distance from the power station. Deposition in zone 3 may also be aided by the backwater effects which occur in the zone when high flows occur in the Denison River during periods of no or low power station discharge, which occurred several times over the winter months. In March 2013, the greater proportion of power station derived flow led to a decrease in deposition / increase in erosion in zones 1–3, a small increase in deposition in zone 4, and a large increase in deposition in zone 5.

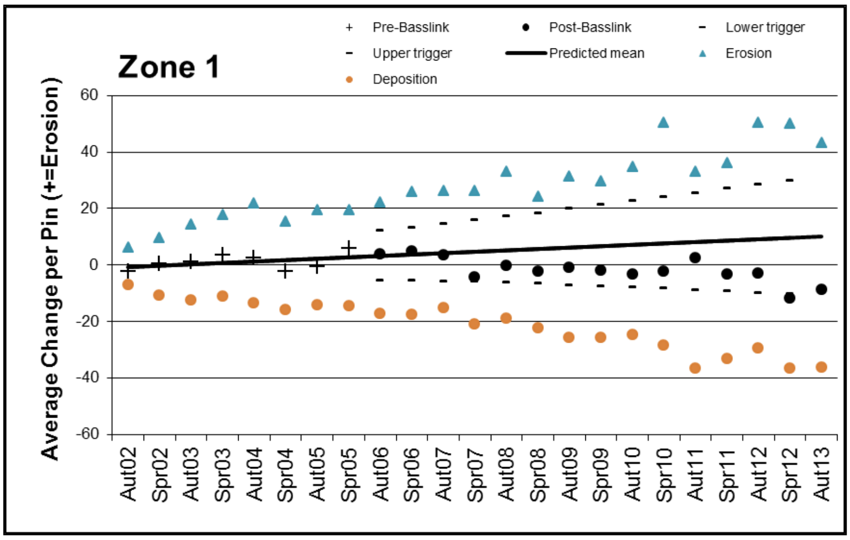

Figure 3-41: Erosion pin results grouped by zones for zone 1. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period.

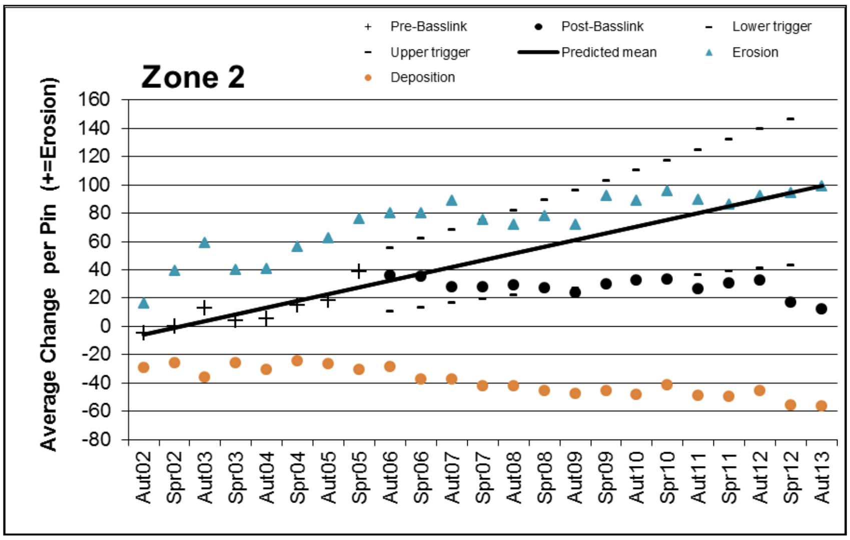

Figure 3-42. Erosion pin results grouped by zones for zone 2. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period.

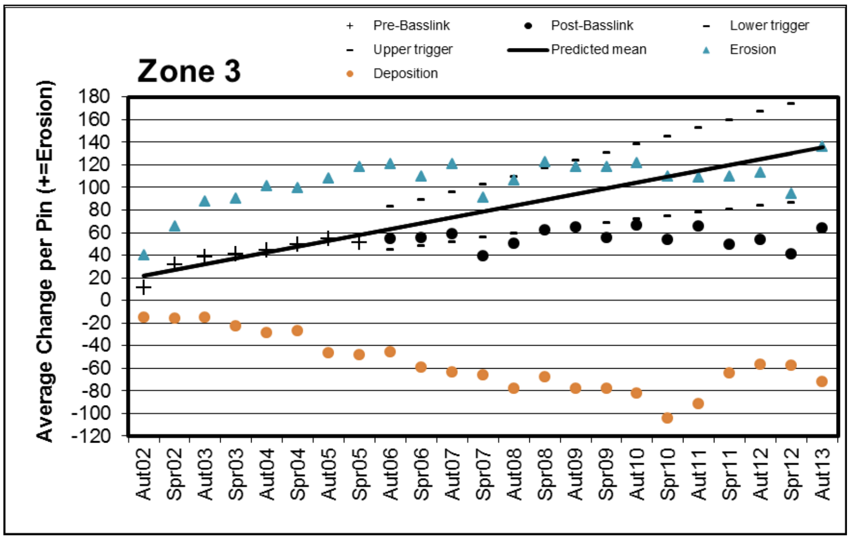

Figure 3-43: Erosion pin results grouped by zones for zone 3. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period.

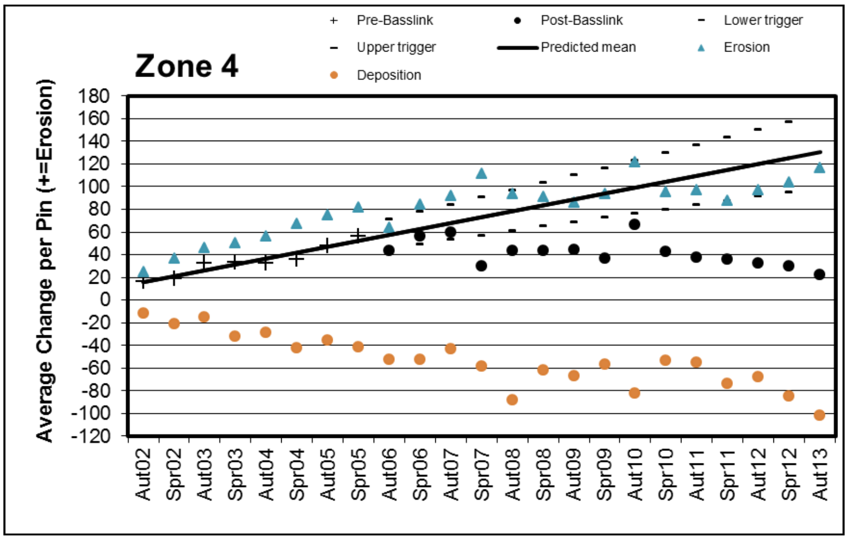

Figure 3-44: Erosion pin results grouped by zones for zone 4. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoirng period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period.

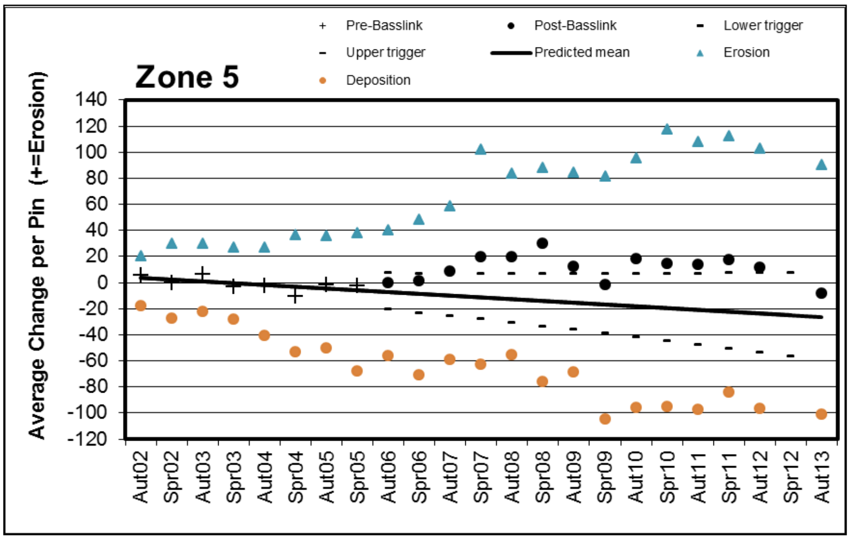

Figure 3-45: Erosion pin results grouped by zones for zone 5. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period.

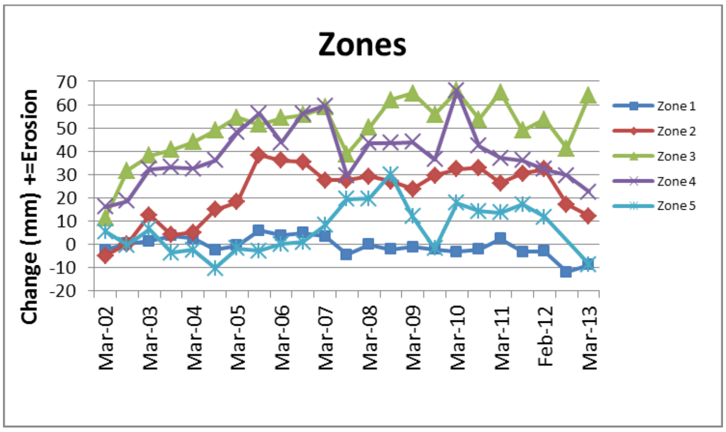

Figure 3-46: Comparison of net erosion pin results for all zones. No results available for zone 5 for October 2012. Graph shows net change since spring 2001.

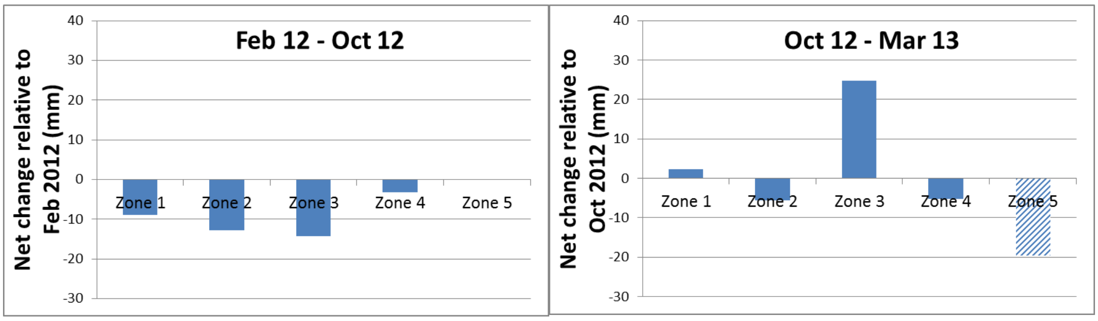

Figure 3-47: Net erosion results by zones compared to previous monitoring period for October 2012 and March 2013. A positive result indicates net erosion, a negative result indicates net deposition. No results are available for February 2012 to October 2012 period for zone 5 as zone was not monitored in October 2012. Result for zone 5 in March 2013 indicates change since February 2012 rather than October 2012.

The erosion pin results grouped by zones are shown as annualised erosion rates in Figure 3-48 for the complete monitoring period and for the past three years. Over the past 3 years, zone 3 has shown consistent fluctuations with erosion recorded in autumn and deposition in spring. This is likely reflecting seasonal deposition from tributary inflows over the wet winter when power station discharge was low, alternating with the loss of sediment during summer months when power station operations control a higher proportion of flows, and deposition from inflows is reduced. The annualised erosion rate for zone 3 for the October 2012 to March 2013 period is the highest recorded in the zone since monitoring began. The other zones do not show strong seasonality, with rates of change generally varying between -10 and +20 mm yr^{-1} on an annualised basis, which is within the range of previous results.

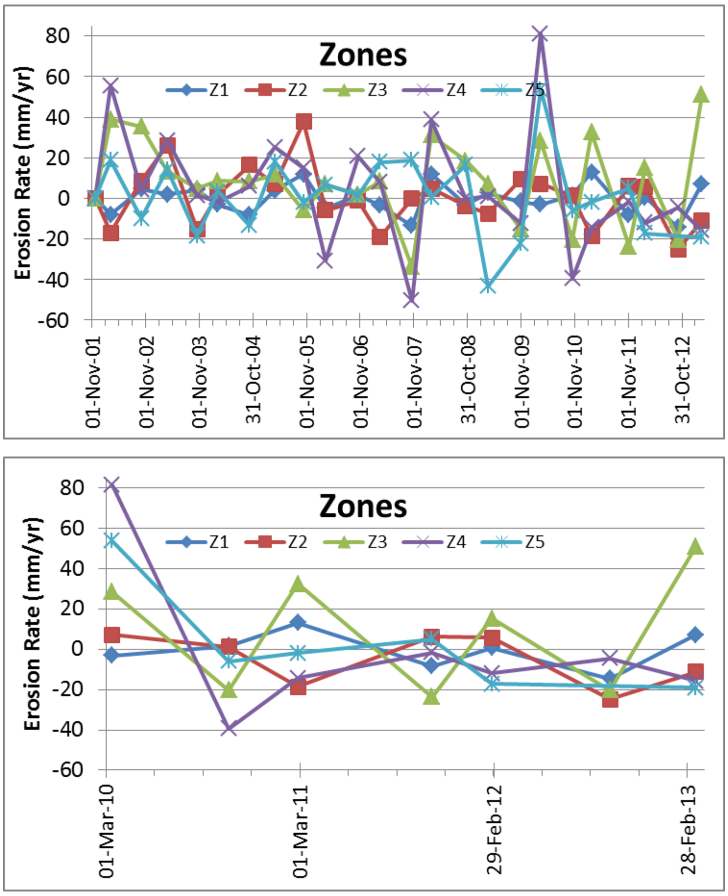

Figure 3-48: Annualised erosion rate for zones based on change since previous monitoring period. Top: All results since November 2001. Bottom: Enlargement of results since March 2010.

3.5.4.2 Comparison of zones and turbine levels

Net erosion pin results grouped by turbine level for all zones (Figure 3-49) show that there has been little change in the <1 turbine level in 2012–13, and a reduction in erosion (increase in deposition) in the 1-2 and 2-3 turbine levels. This is consistent with the upper banks being affected by fluvial deposition and seepage processes under conditions of high river flow. Results are not included for October 2012 due to the lack of zone 5 erosion pin results.

The erosion pin results for zones 2 and 3 are shown in Figure 3-50, and indicate that under the low flow conditions leading up to October 2012, all three turbine levels recorded a reduction in erosion / increase in deposition. In March 2013, the results were reversed with all three turbine levels recording an increase in erosion (decrease in deposition), consistent with the higher shear stress associated with high power station discharge. The results for zones 4 and 5 (Figure 3-51) show a decline in net erosion in the 1-2 and 2-3 turbine levels (relative to February 2012), and an increase in erosion on the bank toe.

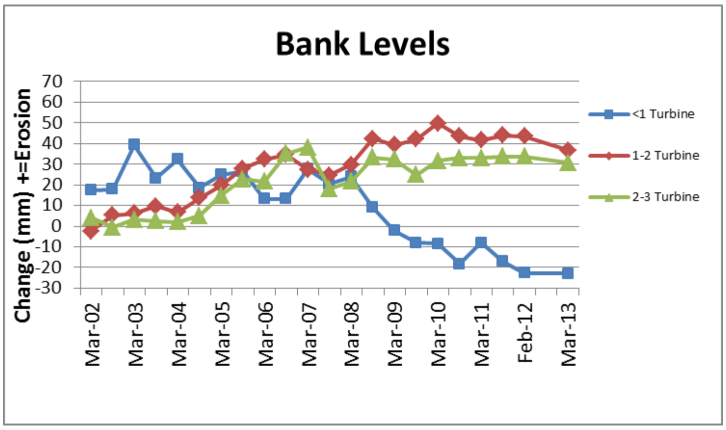

Figure 3-49: Erosion pin results by bank levels for all zones. Results from October 2012 are excluded as no results from zone 5 are available.

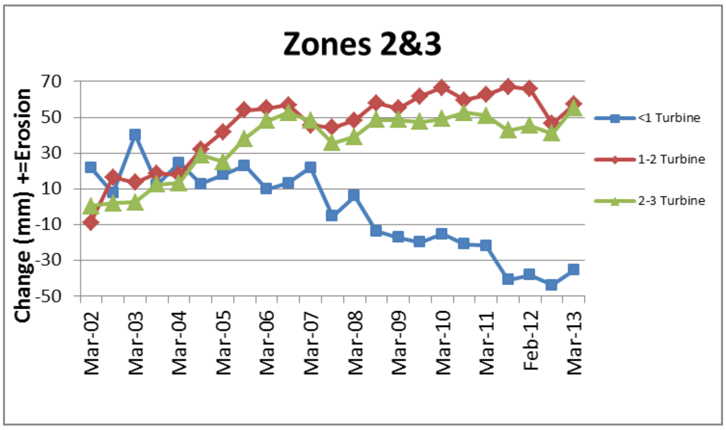

Figure 3-50: Erosion pin results grouped by turbine levels for zones 2 and 3. Results are shown relative to October 2001.

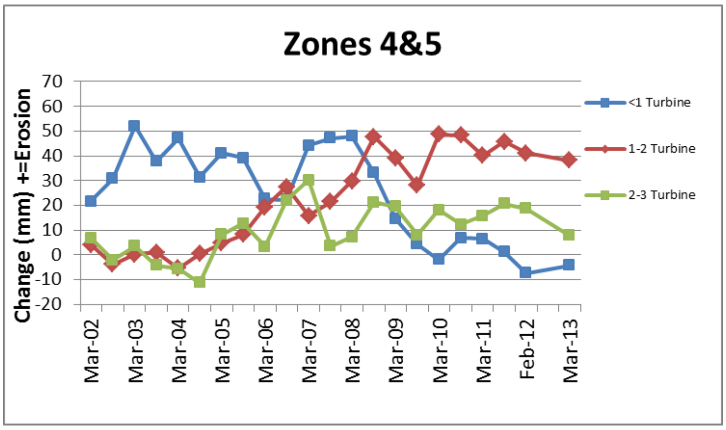

Figure 3-51. Erosion pin results grouped by turbine levels for zones 4 & 5. Results from October 2012 are excluded as no results are available from zone 5. Results are shown relative to October 2001.

The annualised erosion pin results for the zones and turbine levels are shown in Figure 3-52 to Figure 3-54. The results show that the annualised rates of change for all zones, and for zones 4 and 5 are within the range of previous erosion rates. The results from zones 2 and 3 show an increase in erosion rates for all three turbine levels, with the rate for the 2-3 turbine level being higher than previously recorded.

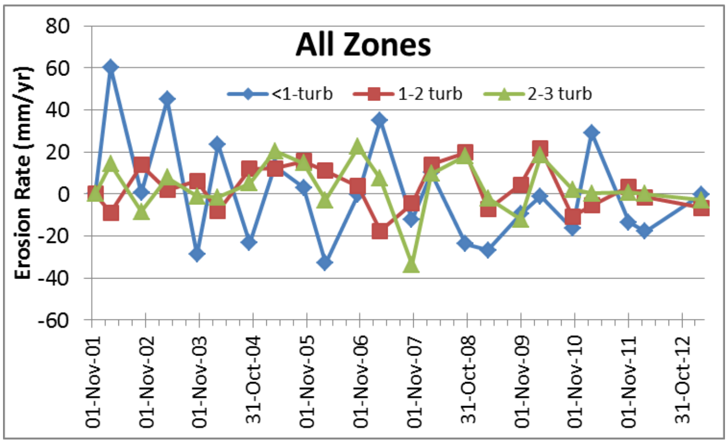

Figure 3-52: Annualised erosion pin results grouped by turbine levels for all zones based on erosion pin results compared to previous monitoring period.

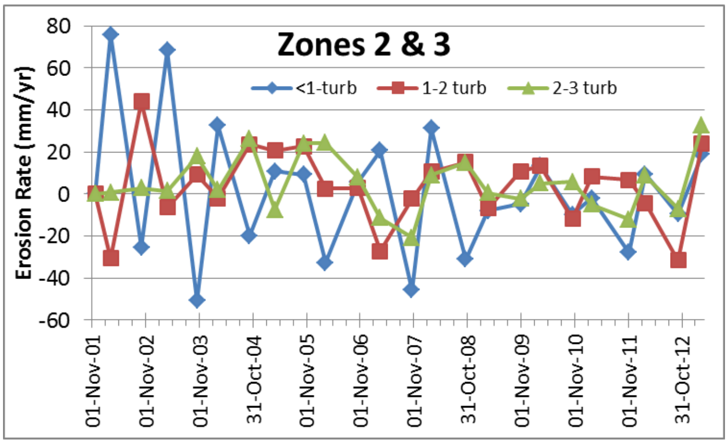

Figure 3-53: Annualised erosion pin results grouped by turbine levels for zones 2 and 3 based on erosion pin results compared to previous monitoring period.

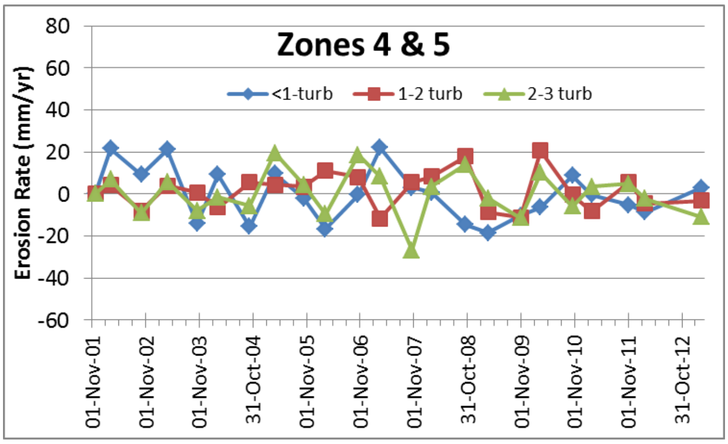

Figure 3-54: Annualised erosion rates for turbine levels in zones 4 and 5 based on erosion pin results compared to previous monitoring period.

The October 2012 and March 2013 zone and turbine level erosion rate results are compared to the pre- and post- Basslink results in Figure 3-55. In zones 2 and 3, the October 2012 and March 2013 erosion rates for the <1 turbine level were within the post-Basslink range, the 1-2 turbine bank level were outside of the post-Basslink erosion rates, but within the range recorded during the pre-Basslink phase of monitoring, and the 2-3 turbine level erosion rates were within the range of previous results for October 2012, but outside of all previous results for March 2013. The zone results indicate that a large component of this erosion was detected in zone 3, which is subjected to a combination of power station flows, natural inflows, and backwater effects from the Denison River.

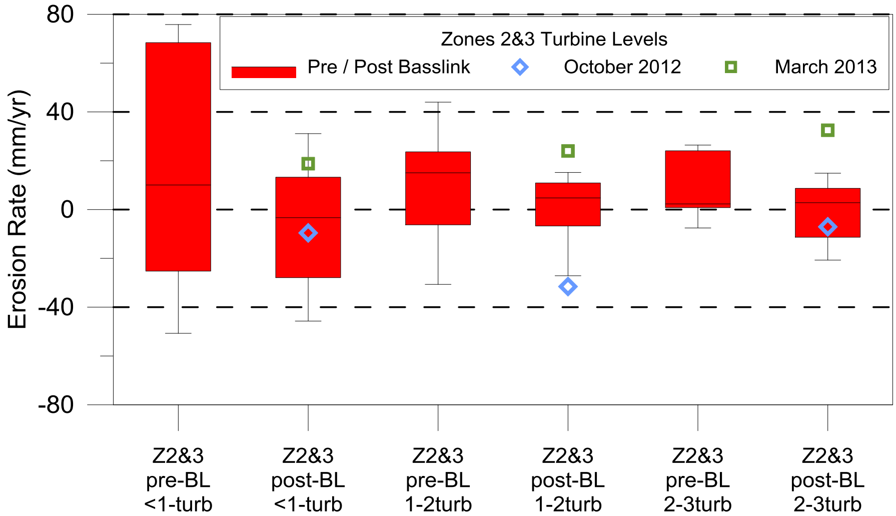

Figure 3-55: Box and whisker plot of pre and post-Basslink annualised erosion rates for turbine levels in zones 2 and 3. The boxes encompass the 25th to 75th percentile values with the median shown by a horizontal line in each box. Minimum and maximum values are shown by the 'whiskers'. The annualised erosion rates for October 2012 and March 2013 are shown by the blue diamonds and green squares, respectively. The rate is based on comparison with the previous monitoring period (e.g. February 2012, October 2012).

A comparison of annualised erosion rate results for March 2013 relative to February 2012 for zones 4 and 5 (Figure 3-56) were within the pre- and post-Basslink range of results.

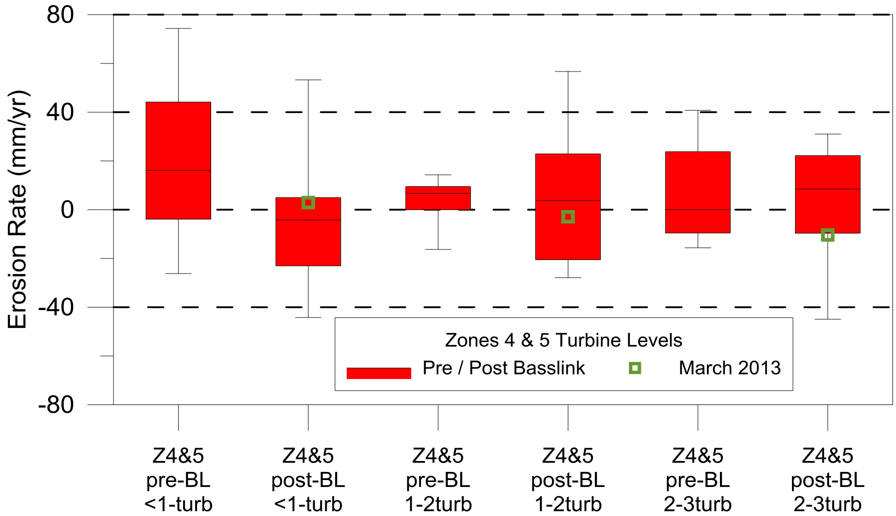

Figure 3-56: Box and whisker plot of pre and post-Basslink annualised erosion rates for turbine levels in zones 4 and 5. The boxes encompass the 25th to 75th percentile values with the median shown by a horizontal line in each box. Minimum and maximum values are shown by the 'whiskers'. The annualised erosion rates for March 2013 are shown by the green squares. The rate is based on comparison with February 2012 as zone 5 was not monitored in October 2012.

3.5.5 Photo-monitoring results

Photo-monitoring was completed at 60 sites in March 2013. The photos are provided in Appendix 3, along with a table summarising changes observed in 2013. The results are summarised in Figure 3-58 which also contains results from previous monitoring years for comparison. Poor weather conditions combined with several of the sites being difficult to identify, due to increased vegetation or other changes over the years, resulted in 7 sites not being photographed in March 2013.

Similar to past years, the majority of sites (50%) showed no change (Figure 3-57). This percentage is lower than in any year since the implementation of Basslink, but similar to pre-Basslink values. The categories of change shown in Figure 3-58 were not commonly observed in the 2013 results. Changes were identified in 36% of the sites, with the most common change being the removal, movement or addition of woody debris on bank toes. This is consistent with the high flow velocities in the river since January 2013 resulting in increased shear stress on bank toes relative to the past few years.

Four sites showed evidence of recent bank movement; one site in zone 2 (site 2new1), two sites in zone 4 (sites-new2 and 2), and one in zone 5 (site 17). At site zone 2 site 2new1 the movement was attributable to seepage processes and sediment flows, while at the other sites, small rotational and block slumps were evident.

The deposition of sand near tributary confluences was observed within the backwater area of the Splits at the downstream end of zone 2. Deposition was also observed in the upstream end of zone 3 which can also be a backwater during periods of high flow in the Denison River, but more likely reflects the deposition of sand from the Orange River following shutdown of the power station.

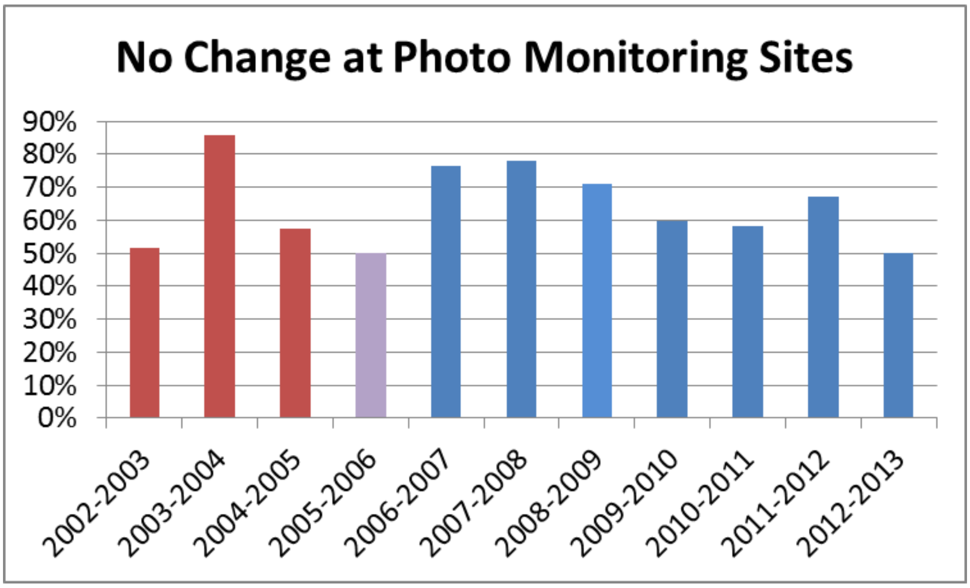

Figure 3-57: Summary of photo-monitoring results for 2012–2013. Comparison of photo-monitoring sites showing no change compared with the previous year, with pre-Basslink results shown in red, and post-Basslink in blue (2005 –2006 was a transitional year).

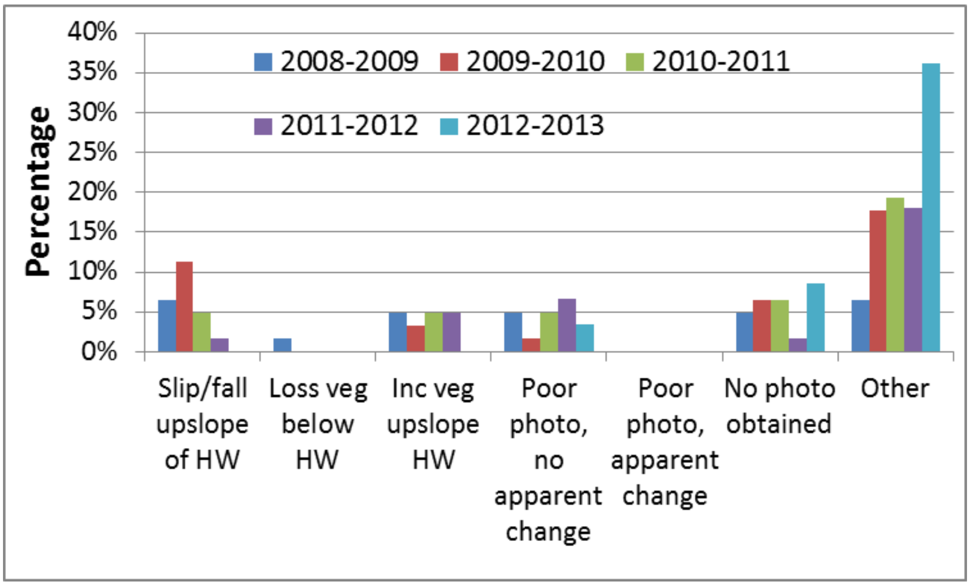

Figure 3-58: Summary of photo-monitoring results for 2012–2013. Distribution of changes by category.

3.5.6 Conclusion

The following can be concluded from the field observations, erosion pin results and photo-monitoring results:

- Between February 2012 and October 2012, power station discharge was low, and unregulated tributary inflows resulted in net deposition of sands and muds on banks. Several large winter flow events which coincided with low or no power station discharge likely contributed to the increase in deposition observed downstream from the power station in October 2012.
- The results in March 2013 reflected an increase in power station usage, leading to conditions of high bank saturation. Seepage processes were observed in areas previously identified as being prone to seepage, suggesting the existing ramp-down rule does not eliminate all seepage activity. However, given the prolonged high discharge from the power station and the lack of new seepage areas in the river suggests the rule is achieving its aim of reducing risks.
- Combined with the seepage processes in March 2013, was a large increase in the potential sediment transport capacity (e.g. scour potential) of the river. Zones 1 through 4 and all three turbine levels in zones 2 and 3 showed an increase in scour in March 2013 relative to October 2012, suggesting that scour rather than seepage was the dominant process associated with the high flows.
- The March 2013 results from zones 4 and 5, which can only be compared to the February 2012 results due to zone 5 not being monitored in October 2012, show increased erosion on the bank toe, with deposition on the remaining bank. This is consistent with both increased deposition during the winter from unregulated high flow events, and increased shear stress associated with the extended high magnitude discharge from the power station.

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4 Macroinvertebrates

4.1 Introduction

Gordon River macroinvertebrate sampling was conducted in spring (6 October 2012) and autumn (17 March 2013), and reference sites sampled in spring (7 December) consistent with the requirements of the Basslink Interim Monitoring Program for the Gordon River. Both quantitative (surber) and rapid bioassessment (RBA) sampling was conducted at nine 'monitoring' sites in the Gordon River between the power station and the Franklin River confluence. This sampling was also conducted at six 'reference' sites located in rivers within the Gordon catchment.

This sampling completes seven years of post-Basslink macroinvertebrate monitoring being conducted in the Gordon River catchment.

This document reports on the results of field sampling for macroinvertebrates in spring and autumn 2012–13, provides a comparison of these results with those for the pre-Basslink period and describes trends over the entire monitoring program to date.

Results were also compared with triggers derived from pre-Basslink period data, as described in the Basslink baseline report (Hydro Tasmania, 2005a).

4.2 Methods

4.2.1 Sample sites

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

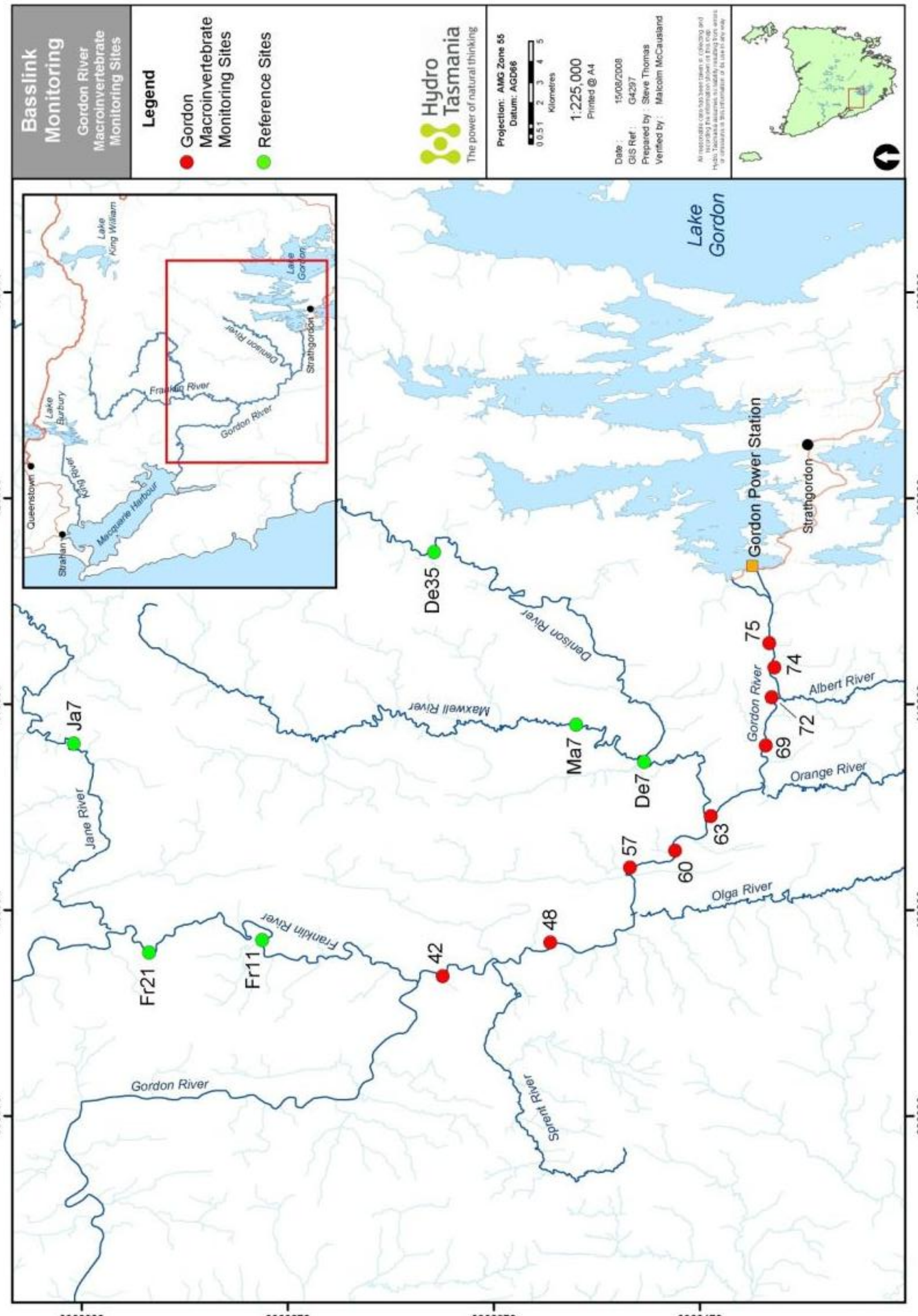

Figure 4-1: Map of locations of macroinvertebrate monitoring sites in the Gordon, Denison and Franklin rivers.

Table 4-1: Sites sampled in 2012–13 for macroinvertebrates.

River	Site Name	Site code	Zone	Distance from power station (km)	Easting	Northing
Gordon	Gordon R ds Albert Gorge (G4)	75	1	2	412980	5266630
	Gordon R ds Piguenit R (G4A)	74	1	3	412311	5266383
	Gordon R in Albert Gorge (G5)	72	1	5	410355	5266524
	Gordon R us Second Split (G6)	69	1	8	408005	5266815
	Gordon R us Denison R (G7)	63	-	14	404584	5269469
	Gordon R ds Denison R (G9)	60	2	17	402896	5271211
	Gordon R us Smith R (G10)	57	2	20	402083	5273405
	Gordon R ds Olga R (G11A)	48	2	29	398178	5278476
	Gordon R @ Devil's Teapot (G15)	42	2	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
Jane	Jane R (J1)	Ja7	-	-	408100	5300400
Maxwell	Maxwell R (M1)	Ma7	-	-	409011	5276009

4.2.2 Macroinvertebrate sampling

Quantitative sampling (surber sampling) and rapid bioassessment kick sampling (RBA) methods were conducted at all sites with one exception. One reference site, site D1 (De35) could not be sampled due to weather and time constraints. Thus, at each sampled 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 10 cm 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 10 m (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 a Marchant box subsampler, and random cell selection. 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 was recorded at each site and a number of variables were recorded from 1:25,000 maps. The habitat variables recorded were:

- percent cover of substrate types (boulder, cobble, pebble, gravel, sand, silt and clay);
- percent 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
- percent 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, representing the condition where no expected taxa are found in the sample, to 1, 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 Monitoring Program as detailed in the Basslink Baseline Report (Hydro Tasmania, 2005a), and subsequently expanded to include the full six year post-Basslink program (Hydro Tasmania 2012). Mean values of each indicator derived from the 2012–13 data were compared against the relevant one-year trigger values (shown graphically in this report).

Plots of trends in indicator values and abundances of selected families are presented.

4.3 Results

4.3.1 Spring 2012

4.3.1.1 Quantitative data

Data from spring 2012 season quantitative surber samples are shown in Appendix 4.1 to 4.3 at the family level of identification and for EPT species.

Diversity and total abundance at both family and species level, as well as the number and abundance of EPT species, fell generally within or close to the range observed in previous years across most sites (Figure 4-2 and Figure 4-3). Total abundance, the number of families and the abundance of EPT species were at the higher end of the range observed pre-Basslink at several sites (notably sites 69 and 48) in spring 2012. Several such exceedances were also noted for some reference sites, suggesting that diversity was naturally transiently high across the larger Gordon-Franklin catchment.

The relative (proportional) abundance of EPT species was equal to or higher than the pre-Basslink means for all zone 1 sites (Figure 4-4) in spring 2012, especially sites 69 and 74. The zone 1 sites had relatively high abundances of stoneflies (family Gripopterygidae) and of the *Asmicridea* caddisfly larvae (family Hydropsychidae). Sites downstream of the Denison River confluence (except site 48) had more variable *Asmicridea* caddisfly larval densities, falling at or below the pre-Basslink means, except for site 48 where densities were just higher than the pre-Basslink range. It should also be noted that this variable was high for all reference sites.

The community compositional similarity of all zone 1 Gordon River sites relative to the reference sites was greater than the pre-Basslink means, as measured by the mean Bray Curtis similarity measure based on either abundance or presence/absence data (Figure 4-5).

4.3.1.2 RBA data

Spring season RBA data is shown in Appendix 4, Table 3. O/Epa and O/Erk values and their impairment bands are shown in Table 4-2.

O/Epa values in spring 2012 fell generally close to pre-Basslink means for six of the eight Gordon River sites, as it did for all reference sites except site Ja7 (Figure 4-6). Gordon sites 74 and 75 showed raised O/Epa values relative to pre-Basslink means and ranges, indicating a higher number of expected families. Values for 2012 were not significantly different from pre-Basslink means (by paired t-test of spring pre-Basslink means with 2012 values, $p > 0.3$).

O/Erk values in spring 2012 were generally close to pre-Basslink mean values in the Gordon River (Figure 4-6) and not significantly different (by paired t-test of spring pre-Basslink means with 2012 values, $p > 0.5$), though values in zone 1 were higher than pre-Basslink means with the exception of site 75. Reference site O/Epa values were again not statistically significantly different from pre-Basslink means (by paired t-test of spring pre-Basslink means with 2012 values, $p > 0.25$).

4.3.1.3 Conclusions

Both diversity at family level and the relative abundance and diversity of EPT species were greater overall in zone 1 Gordon River sites than pre-Basslink values. These changes, while also partially observed at reference sites, are likely a result of post-Basslink within-Gordon effects, most likely driven by the presence of minimum environmental flows (Hydro Tasmania

2010). This conclusion is supported by the observation of an increase in overall community compositional similarity of zone 1 sites to reference sites.

Table 4-2. O/Epa and O/Erk values for all sites sampled in spring and autumn 2012–13, for individual replicate samples, and averages. Impairment bands also indicated.

			Spring 2012				Autumn 2013			
River	**Site**	**Replicate**	**O/Epa**	**Band**	**O/Erk**	**Band**	**O/Epa**	**Band**	**O/Erk**	**Band**
Gordon R	75	1	0.60	B	0.45	B	0.49	C	0.50	B
		2	0.90	A	0.77	B	0.39	C	0.50	B
		Mean	**0.75**	**B**	**0.61**	**B**	**0.44**	**C**	**0.50**	**B**
	74	1	0.88	A	0.94	A	0.39	C	0.30	C
		2	0.88	A	0.87	A	0.78	B	0.66	B
		Mean	**0.88**	**A**	**0.90**	**A**	**0.59**	**B**	**0.48**	**B**
	72	1	0.80	A	0.87	A	0.88	A	0.71	B
		2	0.94	A	0.97	A	1.08	A	0.81	B
		Mean	**0.87**	**A**	**0.92**	**A**	**0.98**	**A**	**0.76**	**B**
	69	1	0.68	B	0.80	A	0.78	B	0.68	B
		2	0.98	A	1.07	A	0.98	A	0.78	B
		Mean	**0.83**	**A**	**0.93**	**A**	**0.88**	**A**	**0.73**	**B**
	60	1	0.90	A	0.93	A	1.17	A	0.81	B
		2	0.90	A	1.00	A	1.27	X	0.91	A
		Mean	**0.90**	**A**	**0.96**	**A**	**1.22**	**X**	**0.86**	**A**
	57	1	0.97	A	1.12	A	0.88	A	0.60	B
		2	0.82	A	0.82	A	1.17	A	0.71	B
		Mean	**0.90**	**A**	**0.97**	**A**	**1.03**	**A**	**0.66**	**B**
	48	1	1.12	A	1.29	X	1.17	A	0.95	A
		2	1.12	A	1.04	A	1.08	A	0.85	A
		Mean	**1.12**	**A**	**1.16**	**A**	**1.12**	**A**	**0.90**	**A**
	42	1	1.05	A	1.04	A	1.27	X	1.01	A
		2	0.97	A	1.00	A	1.17	A	0.86	A
		Mean	**1.01**	**A**	**1.02**	**A**	**1.22**	**X**	**0.93**	**A**
Franklin R	Fr11	1	1.20	X	1.29	X	1.37	X	1.01	A
		2	1.20	X	1.23	X	1.47	X	1.06	A
		Mean	**1.20**	**X**	**1.26**	**X**	**1.42**	**X**	**1.03**	**A**
	Fr21	1	1.35	X	1.23	X	1.47	X	0.96	A
		2	1.20	X	1.12	A	1.57	X	1.11	A
		Mean	**1.27**	**X**	**1.17**	**X**	**1.52**	**X**	**1.03**	**A**
Denison R	De7	1	1.37	X	1.12	A	1.08	A	0.76	B
		2	1.21	X	1.11	A	1.57	X	1.21	X
		Mean	**1.29**	**X**	**1.11**	**A**	**1.32**	**X**	**0.98**	**A**
	De35	1	NA	NA	NA	NA	1.47	X	1.11	A
		2	NA	NA	NA	NA	1.56	X	1.11	A
		Mean	**NA**	**NA**	**NA**	**NA**	**1.52**	**X**	**1.11**	**A**
Maxwell R	Ma7	1	1.28	X	1.03	A	1.47	X	1.11	A
		2	1.28	X	1.23	X	1.57	X	1.21	X
		Mean	**1.28**	**X**	**1.13**	**A**	**1.52**	**X**	**1.16**	**A**
Jane R	Ja7	1	0.87	A	1.00	A	1.56	X	1.21	X
		2	1.03	A	0.91	A	1.47	X	1.06	A
		Mean	**0.95**	**A**	**0.95**	**A**	**1.52**	**X**	**1.13**	**A**

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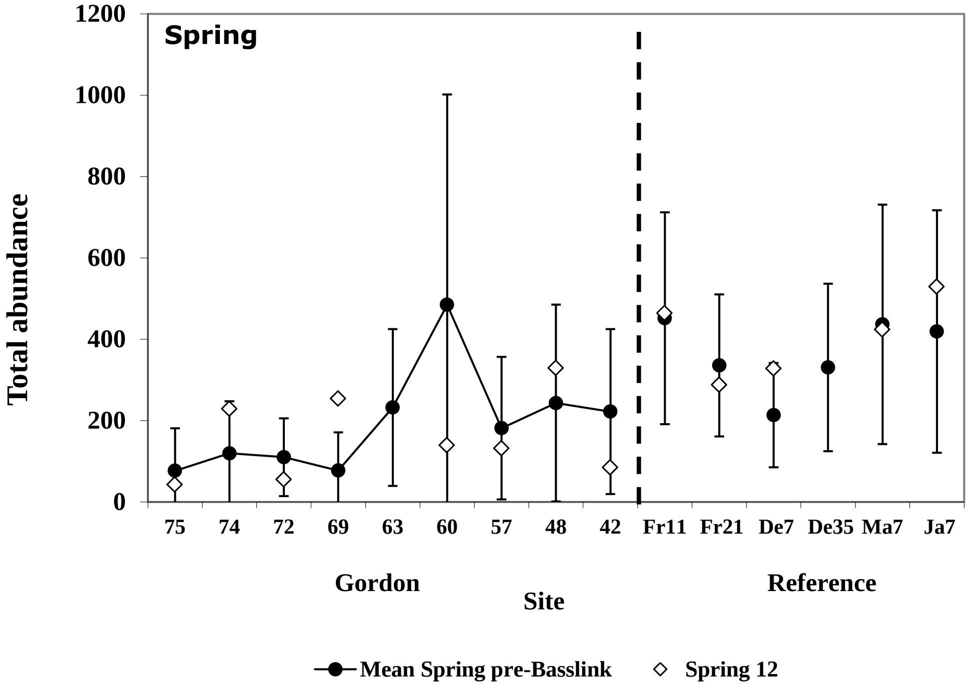


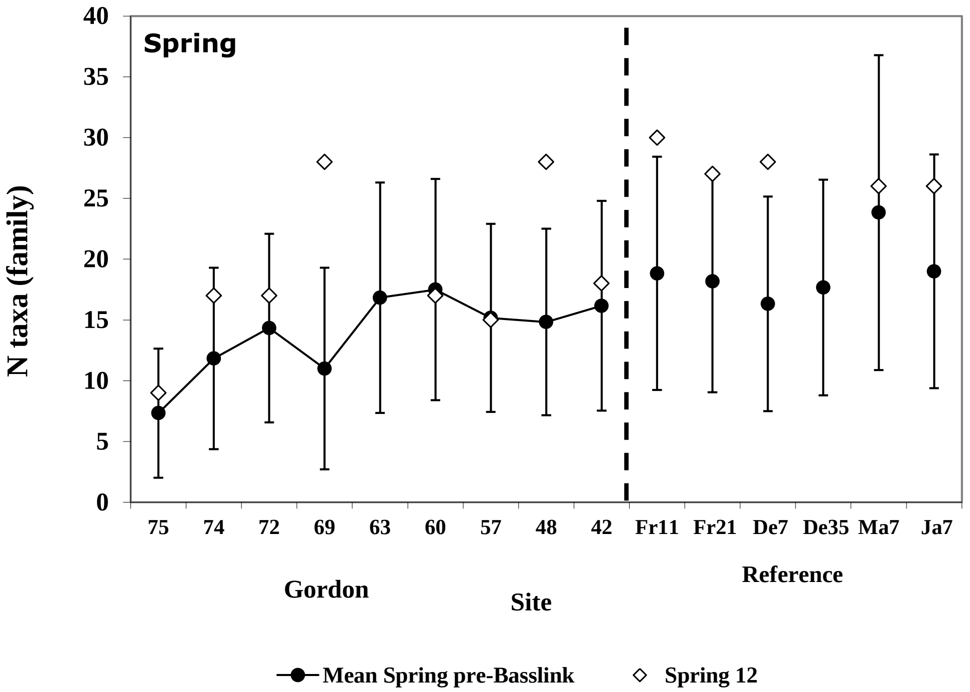
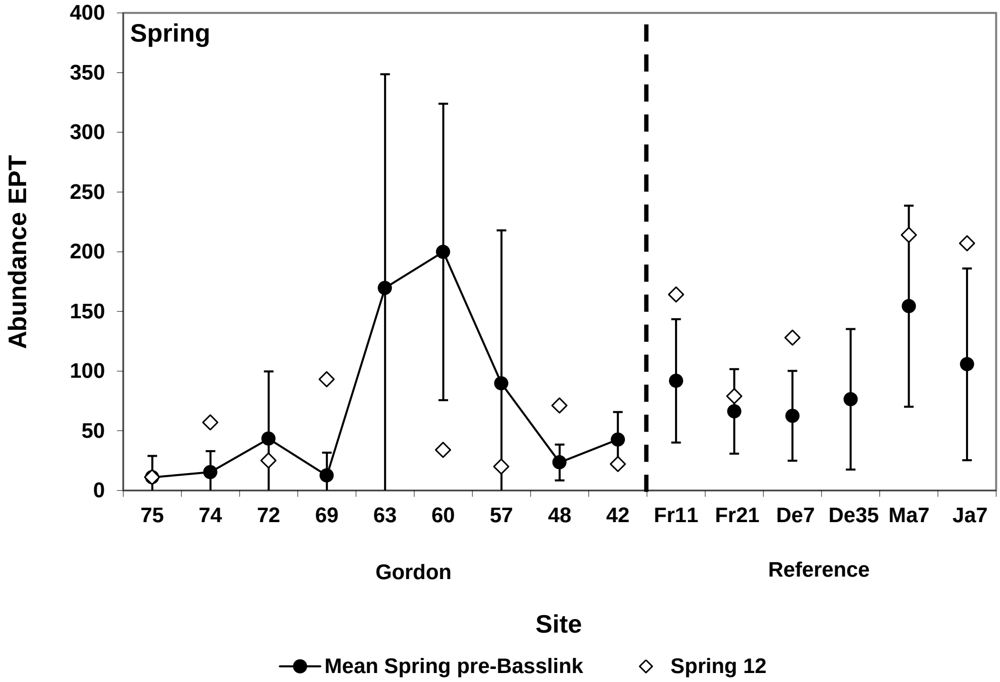


Figure 4-2: Comparison of total abundance of all benthic macroinvertebrates and diversity (number of taxa at family level) for spring 2012 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean. Note that the pre-Basslink values for site 63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



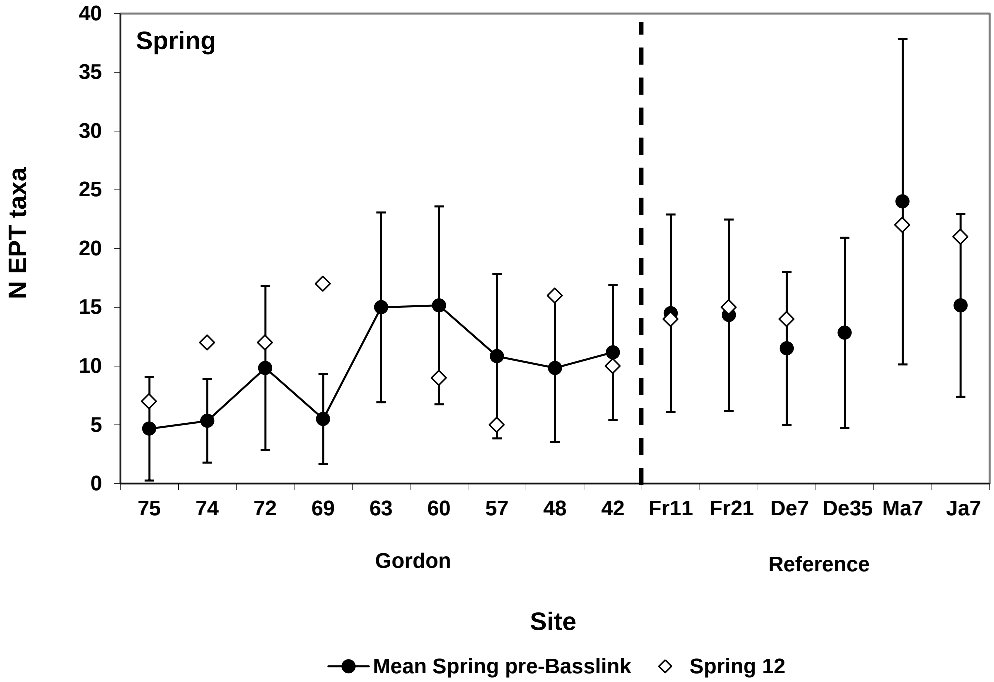


Figure 4-3: Comparison of total abundance and number of benthic EPT taxa (genus and species) for spring 2012 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean. Note that the pre-Basslink values for site 63 are shown for interest, though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

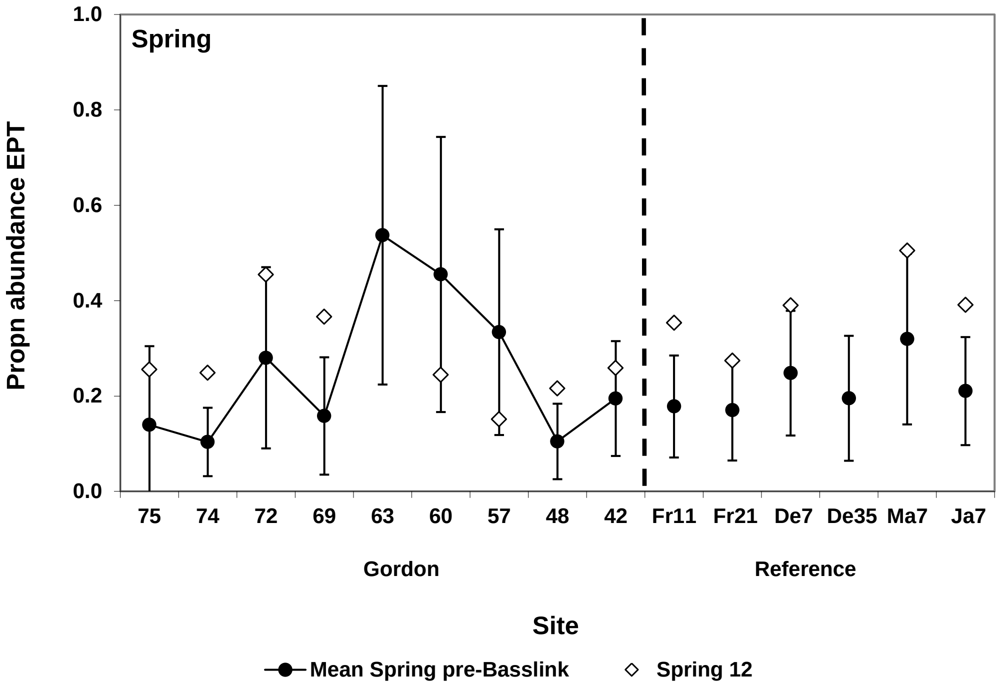
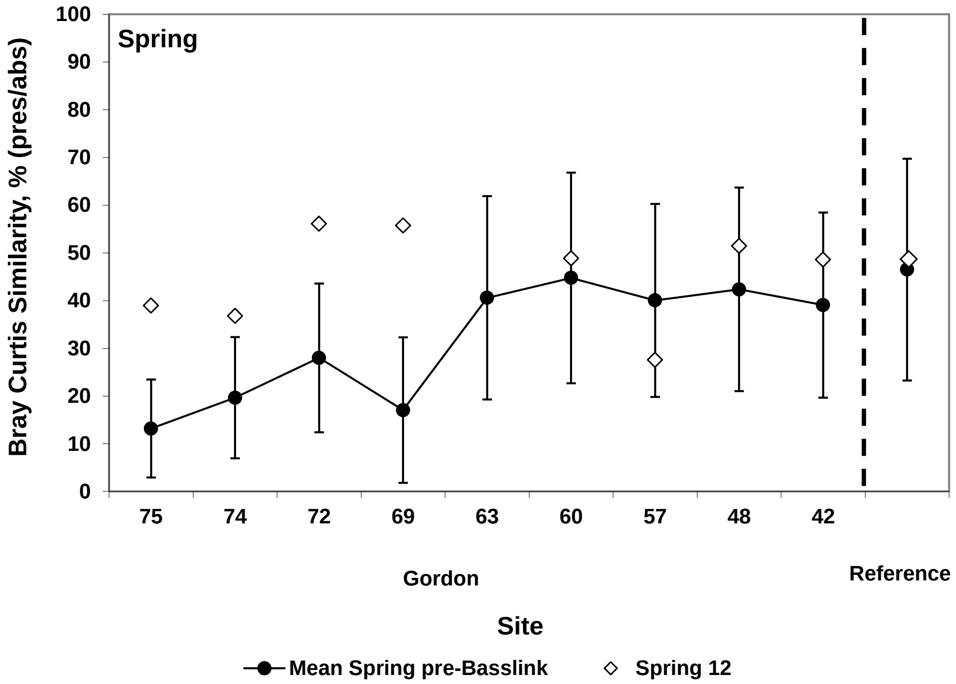


Figure 4-4: Comparison of proportion of total benthic macroinvertebrate abundance represented by EPT species for spring 2012 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean. Note that the pre-Basslink values for site 63 are shown for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



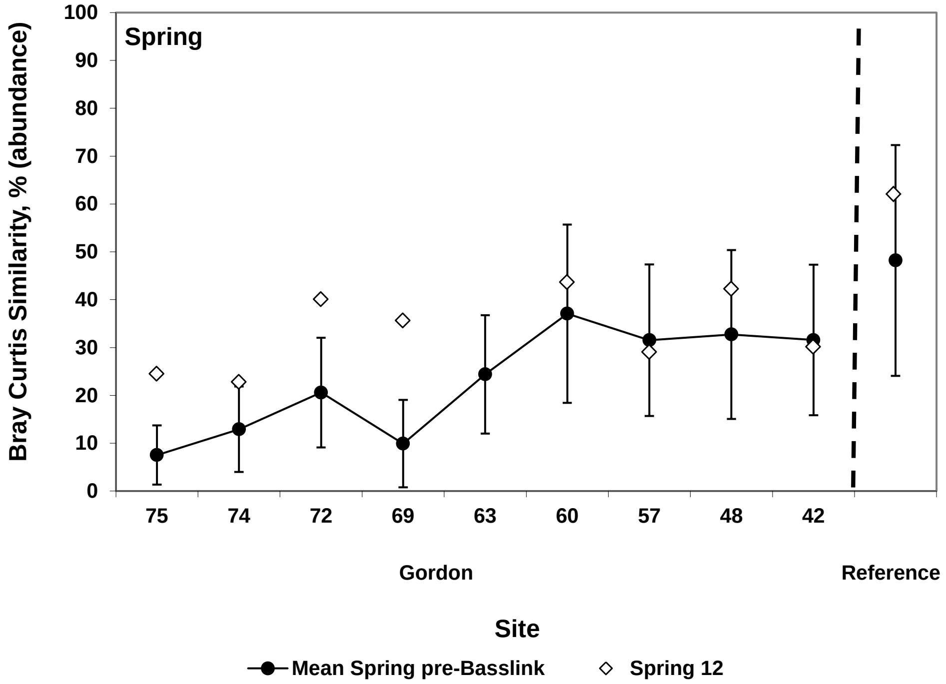


Figure 4-5: Comparison of values for the mean Bray Curtis Similarity between each sampled site and the reference sites for spring 2012 with spring values from previous years. Similarities are calculated with either abundance data or presence/absence data. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean. The value for reference sites represents the mean of similarities between each reference site and the other reference sites sampled at the same time. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.

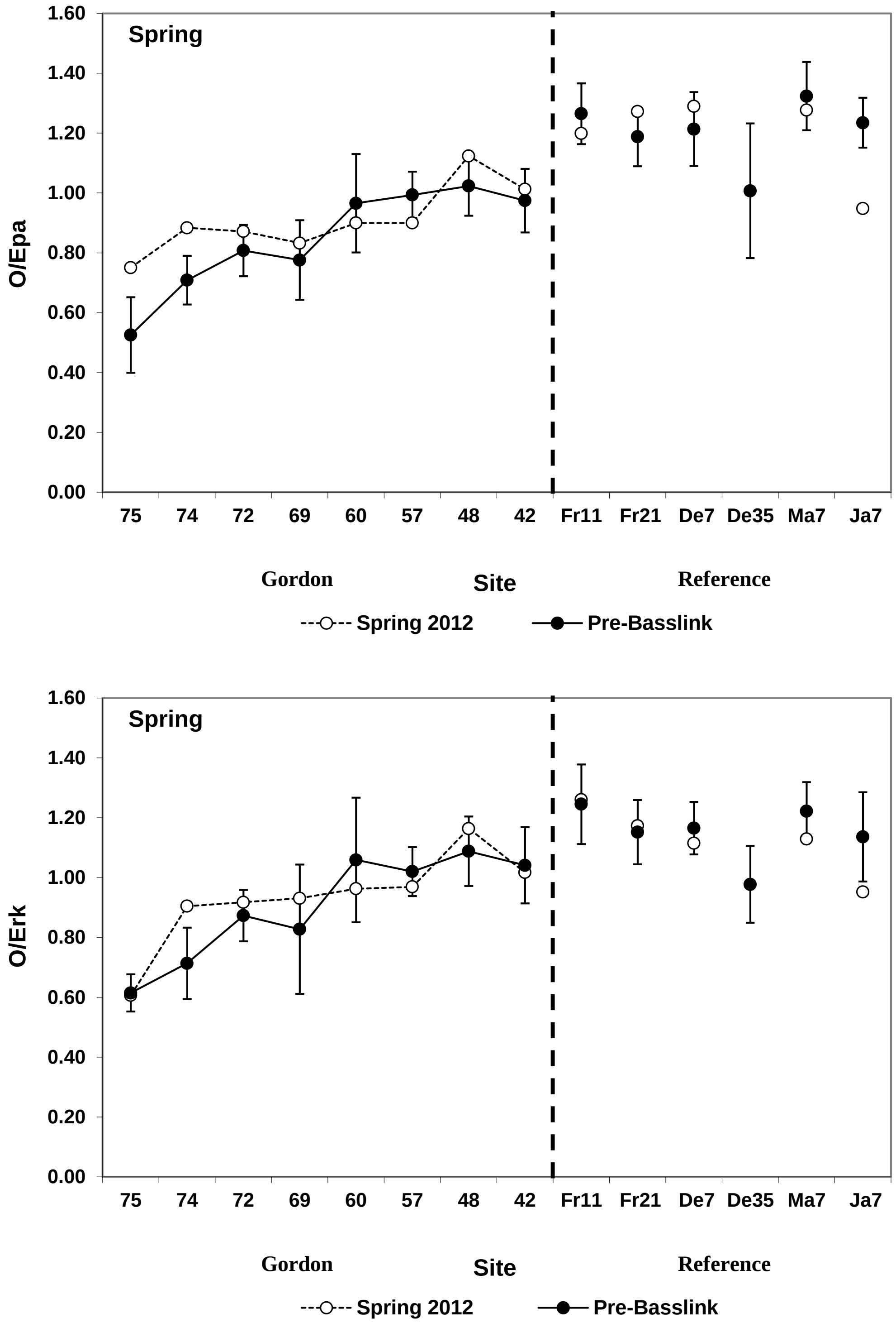


Figure 4-6: Comparison of O/Epa and O/Erk values for spring 2012 with values from previous years. Note consistently high O/Epa values at sites 69–75 upstream of Denison. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.

4.3.2 Autumn 2013

4.3.2.1 Quantitative data

Data from the autumn 2013 season quantitative surber samples are shown in Appendix 4.3 and 4.4 at family level and for EPT species.

Total abundance and number of taxa at both family and species level for the Gordon River sites generally were at or higher than pre-Basslink means (Figure 4-7 and Figure 4-8), with total abundance well above pre-Basslink ranges at four of the eight Gordon River sites (Figure 4-7). The number of families was also above pre-Basslink means for six of the eight Gordon River sites. Total abundance was generally reduced relative to the pre-Basslink means across the six reference sites (Figure 4-7).

The abundance of EPT species was variable among Gordon sites, with most sites being close to their pre-Basslink means (Figure 4-8). Two of the six reference sites had abundances of EPT species above the pre-Basslink means, especially site De7 (Figure 4-8). The number of EPT species was quite variable relative to pre-Basslink means for the Gordon sites with no consistent pattern (Figure 4-8), while values were below pre-Basslink means for four of the six reference sites.

The proportional abundance of EPT species was generally lower in the Gordon River than pre-Basslink means, but substantially exceeded pre-Basslink means and ranges at site 75 (Figure 4-9). Four of the six reference site values were well above their pre-Basslink means. The low proportional abundance of EPT species in most Gordon River sites is primarily due to the presence of relatively high abundances of blackfly (Simuliidae) larvae at these sites in autumn 2013 (Appendix 4.4), an event not observed at reference sites. This family therefore contributes to total abundance but is not part of the EPT taxonomic grouping.

The autumn 2013 community compositional similarity of the Gordon River sites relative to reference sites was greater than pre-Basslink means at three of the four zone 1 sites, for both similarity measures (Figure 4-10). All remaining Gordon River sites had similar Bray Curtis indicator values to pre-Basslink means, as did the reference sites.

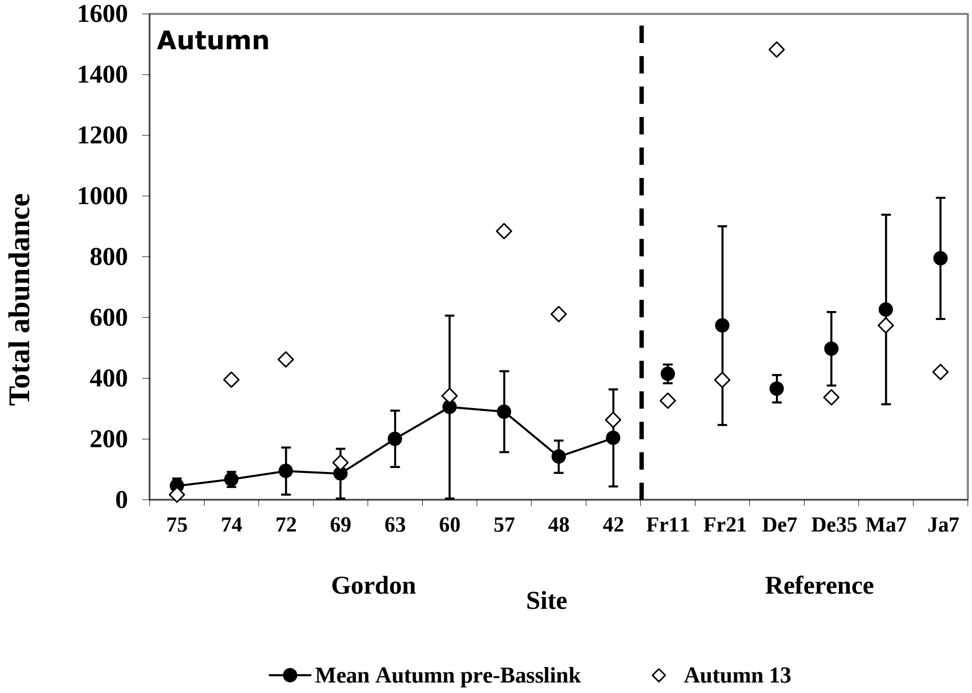
4.3.2.2 RBA data

Autumn season RBA data is shown in Appendix 4.6. O/Epa and O/Erk values and their impairment bands are shown in Table 4-2, and are plotted alongside pre-Basslink values in Figure 4-11.

O/Epa and O/Erk values in autumn 2013 did not show a consistent pattern relative to their pre-Basslink means for all Gordon sites, though sites 74 and 75 had reduced O/Epa values (Figure 4-11). There was also no consistent pattern across the reference sites. The differences between autumn 2013 and pre-Basslink mean values were not statistically significant over all sites (by paired t-test, all $p > 0.5$) for Gordon River sites or for reference sites.

4.3.2.3 Conclusions

Diversity at family level and total abundance were both variable in the Gordon River sites while tending to be higher relative to their mean pre-Basslink values, and is most likely driven by the presence of minimum environmental flows (Hydro Tasmania 2010). This pattern was not observed at reference sites. There was also an increase in overall community compositional similarity to reference sites at three of the four zone 1 sites.



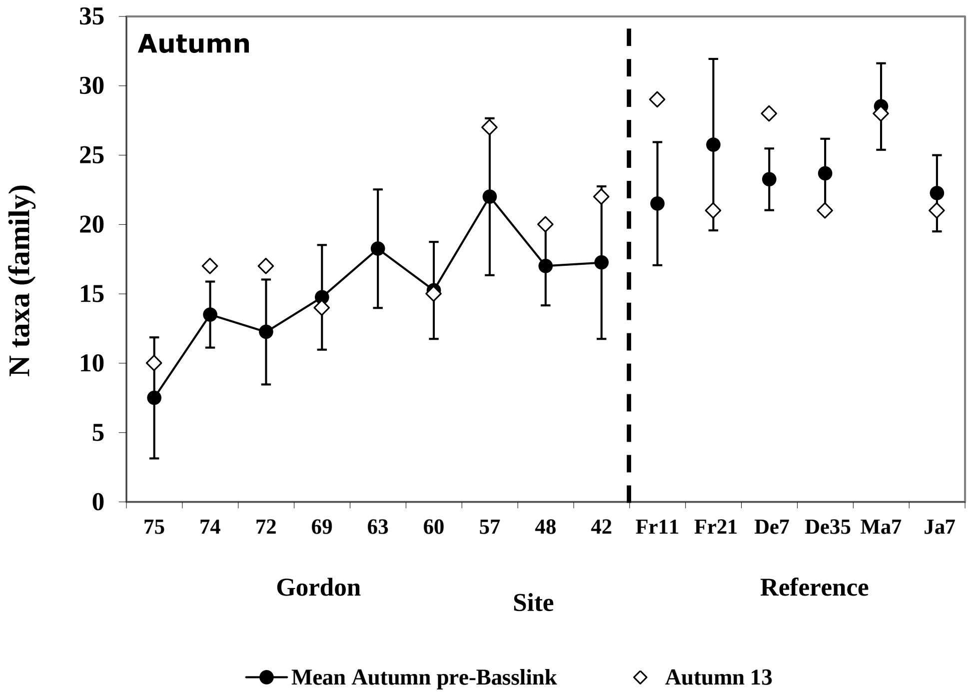
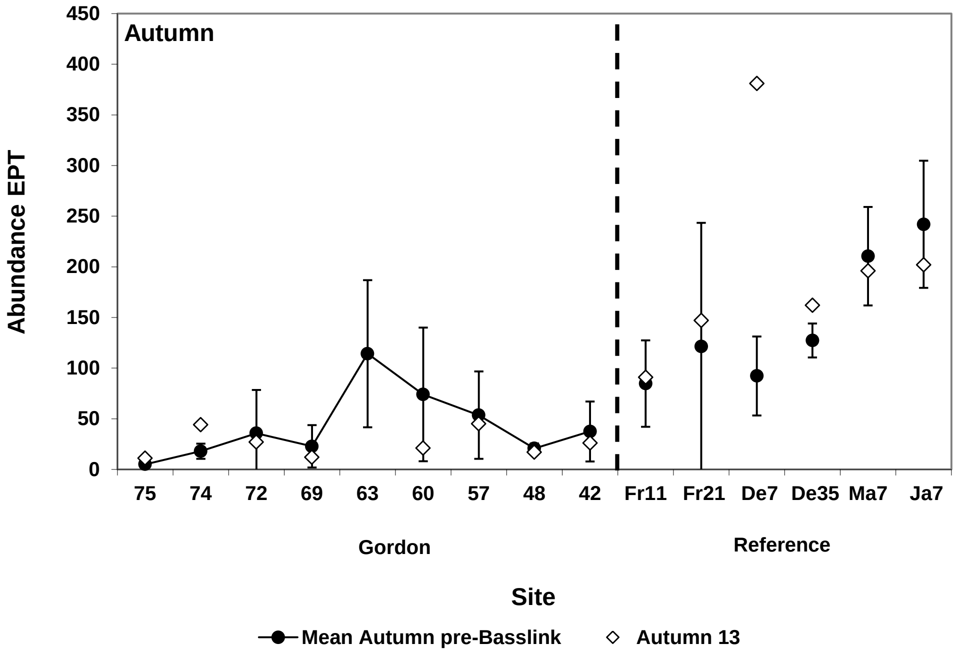


Figure 4-7: Comparison of total abundance and diversity (number of taxa at family level) for autumn 2013 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.



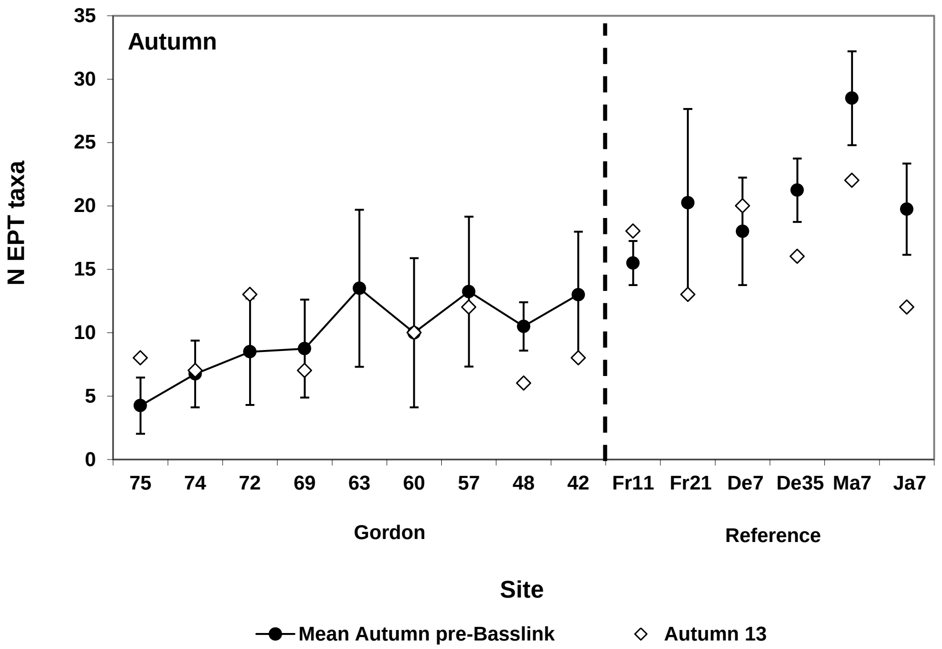


Figure 4-8: Comparison of total abundance and number of benthic EPT species for autumn 2013 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.

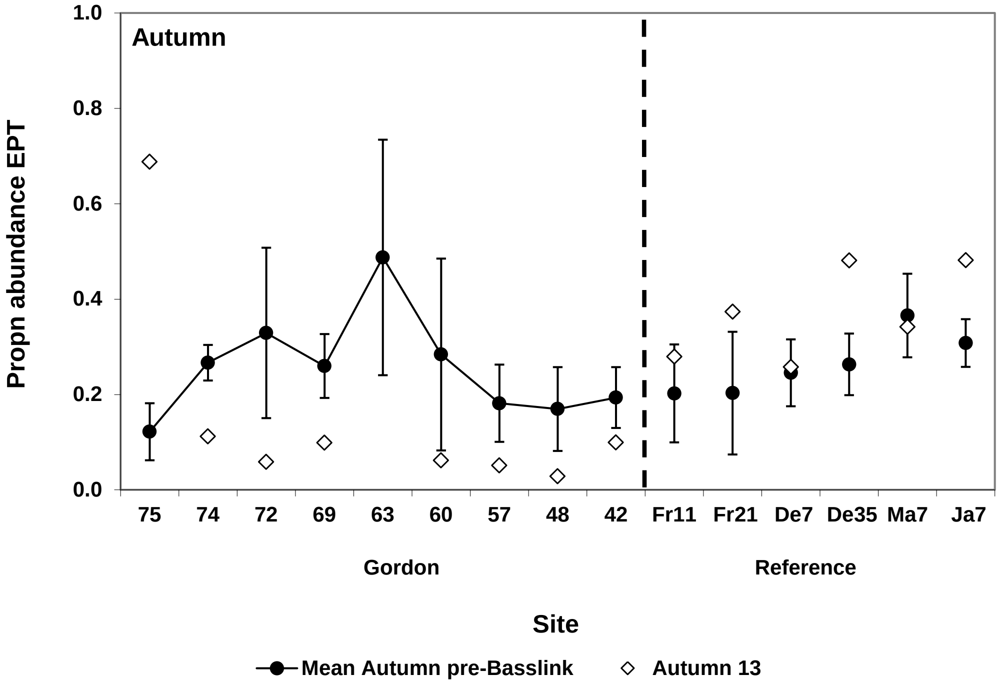
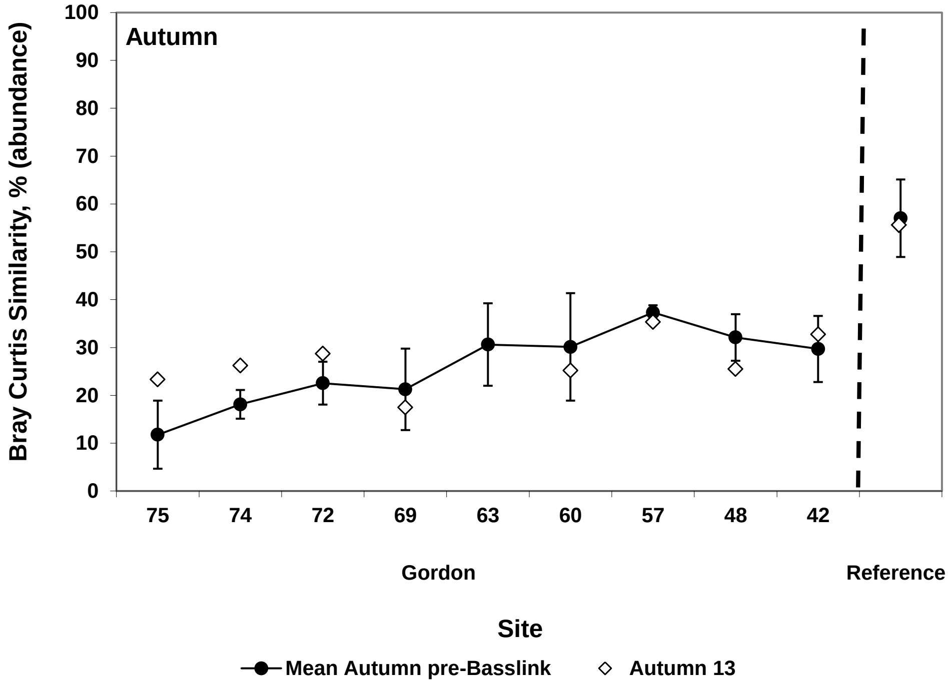


Figure 4-9: Comparison of proportion of total benthic macroinvertebrate abundance represented by EPT species for autumn 2013 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.



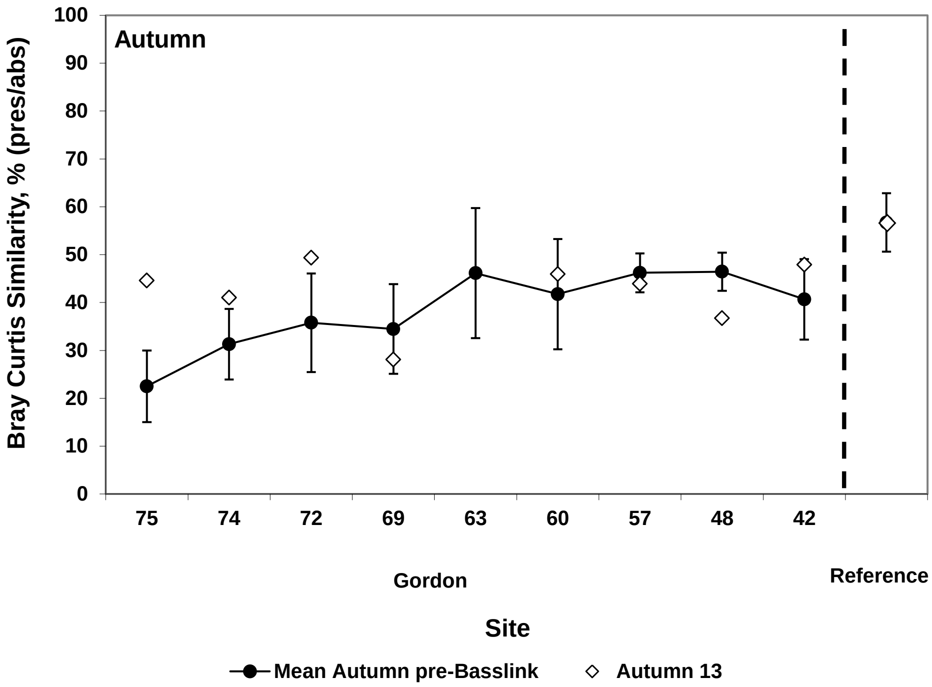
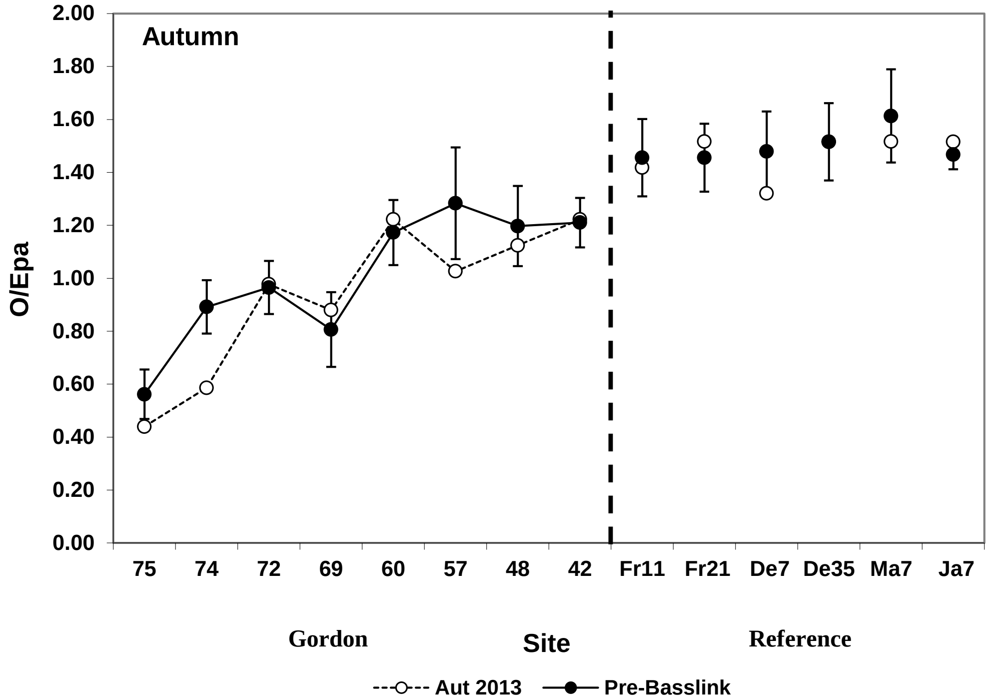


Figure 4-10: Comparison of values for the mean Bray Curtis Similarity between each sampled site and the reference sites for autumn 2013 with autumn values from previous years. Similarities are calculated with either abundance data (square root transformed) or with presence/absence data. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean. The value for reference sites represents the mean of similarities between each reference site and the other reference sites sampled at the same time. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.



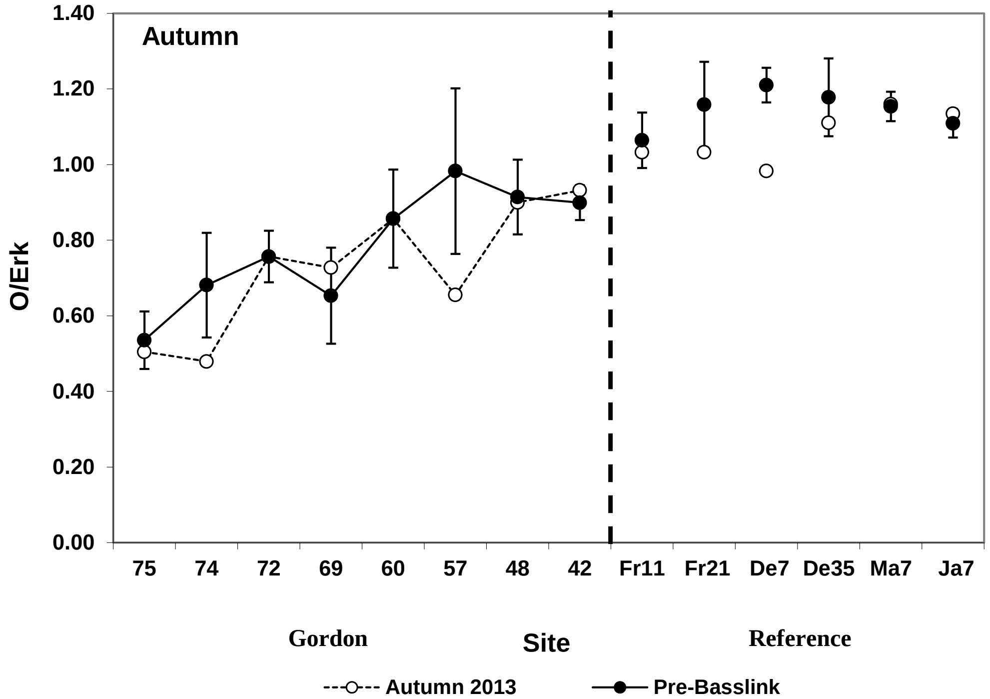


Figure 4-11: Comparison of O/Epa and O/Erk values for autumn 2013 with values from previous years. Note consistently high O/Epa values at sites 69 – 75 upstream of Denison. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean.

4.4 Comparisons with triggers

4.4.1 Results

Nine metrics have been identified 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 metrics have been 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 in the post-Basslink period. Triggers have been developed for each individual site in the Gordon, as well as for the entire river ('whole of river', WOR) and zones within the river. Seasonal differences are also taken into account for the WOR case. Two zones have been described for benthic macroinvertebrates – zone 1 upstream of the Denison junction (incorporating sites 69 to 75) and zone 2 downstream of the Denison junction (incorporating sites 42 to 60).

Values of all metrics for 2012–13 are shown in Table 4-4. It was not possible to calculate metric values for site De35 (D1) in spring 2012 as this site could not be visited.

Plots of the trigger levels for each metric are shown below along with the value for the metric recorded in 2012–13 at whole of river and zone levels (Figure 4-12 to Figure 4-16).

Table 4-4: Values of all metrics for each site sampled in spring 2012 and autumn 2013.

			Spring 2012									Autumn 2013								
			Community Structure		Community Composition		Taxonomic richness		Ecologically significant species		Biomass / productivity	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	Bray Curtis (abundance)	O/Erk	Bray Curtis (pres/abs data)	O/Epa	N Taxa (fam)	N EPT Species	Propn Abundance EPT	Abundance EPT	Density (Total abundance)
Gordon																				
	75	**G4**	24.51	0.61	38.97	0.75	9	7	0.256	11	43	23.35	0.50	44.55	0.44	10	8	0.688	11	16
	74	**G4a**	22.83	0.90	36.80	0.88	17	12	0.249	57	229	26.24	0.48	40.98	0.59	17	7	0.111	44	395
	72	**G5**	40.07	0.92	56.10	0.87	17	12	0.455	25	55	28.71	0.76	49.32	0.98	17	13	0.058	27	462
	69	**G6**	35.64	0.93	55.74	0.83	28	17	0.366	93	254	17.46	0.73	28.06	0.88	14	7	0.098	12	122
	60	**G9**	43.64	0.96	48.87	0.90	17	9	0.245	34	139	25.20	0.86	45.86	1.22	15	10	0.061	21	342
	57	**G10**	29.10	0.97	27.59	0.90	15	5	0.152	20	132	35.33	0.66	43.89	1.03	27	12	0.051	45	884
	48	**G11B**	42.26	1.16	51.42	1.12	28	16	0.216	71	329	25.52	0.90	36.68	1.12	20	6	0.028	17	611
	42	**G15**	30.18	1.02	48.57	1.01	18	10	0.259	22	85	32.77	0.93	47.88	1.22	22	8	0.099	26	263
Reference																				
Franklin	**Fr11**	**G19**	62.30	1.26	54.80	1.20	30	14	0.353	164	464	56.15	1.03	62.64	1.42	29	18	0.279	91	326
	Fr21	**G20**	59.44	1.17	60.80	1.27	27	15	0.274	79	288	59.01	1.03	63.26	1.52	21	13	0.373	147	394
Denison	**De7**	**G21**	61.74	1.11	55.90	1.29	28	14	0.390	128	328	55.66	0.98	61.12	1.32	28	20	0.257	381	1482
	De35	**D1**	na	na	na	na	na	na	na	na	na	50.00	1.11	51.62	1.52	21	16	0.481	162	337
Maxwell	**Ma7**	**M1**	62.88	1.13	60.05	1.28	26	22	0.505	214	424	47.70	1.16	50.78	1.52	28	22	0.341	196	574
Jane	**Ja7**	**J1**	64.81	0.95	62.72	0.95	26	21	0.391	207	529	55.98	1.13	58.07	1.52	21	12	0.481	202	420

4.4.2 Trigger status

The following section summarises and comments on the observations for 2012–13 in comparison with the trigger values.

4.4.2.1 Community Structure

Bray Curtis (abundance): A substantial exceedance was observed for zone 1 (all year). Whole of River (WOR) and zone 2 values were within trigger bounds (Figure 4-12).

Comment – Overall compliant, with a positive post-Basslink change due to increased compositional similarity to reference sites in zone 1.

O/Erk: Compliant at WOR and zone levels (Figure 4-12), with zone 1 (all year) value was at the upper trigger bound.

Comment – Consistent with pre-Basslink conditions.

4.4.2.2 Community Composition

Bray Curtis (pres/abs data): Exceeded upper trigger for the whole of river case for all year and the spring season, and for zone 1 (all year) (Figure 4-13).

Comment – Minor improvement in community composition at whole of river scale, and particularly in zone 1.

O/Epa: WOR compliant (Figure 4-13).

Comment – Consistent with pre-Basslink conditions.

4.4.2.3 Taxonomic richness

N Taxa (fam): A minor exceedance for the whole of river case both for all year and for the autumn season, and in zone 2 (Figure 4-14).

Comment – Consistent with pre-Basslink conditions with improvement overall and in autumn.

N EPT Species: All values within trigger bounds (Figure 4-14).

Comment – Consistent with pre-Basslink conditions.

4.4.2.4 Ecologically significant species

Proportion of total abundance as EPT: Compliant, lying inside triggers for Whole of River and zone 2. Was at upper trigger bound value for zone 1 (Figure 4-15).

Comment – Consistent with pre-Basslink conditions; minor improvement for zone 1.

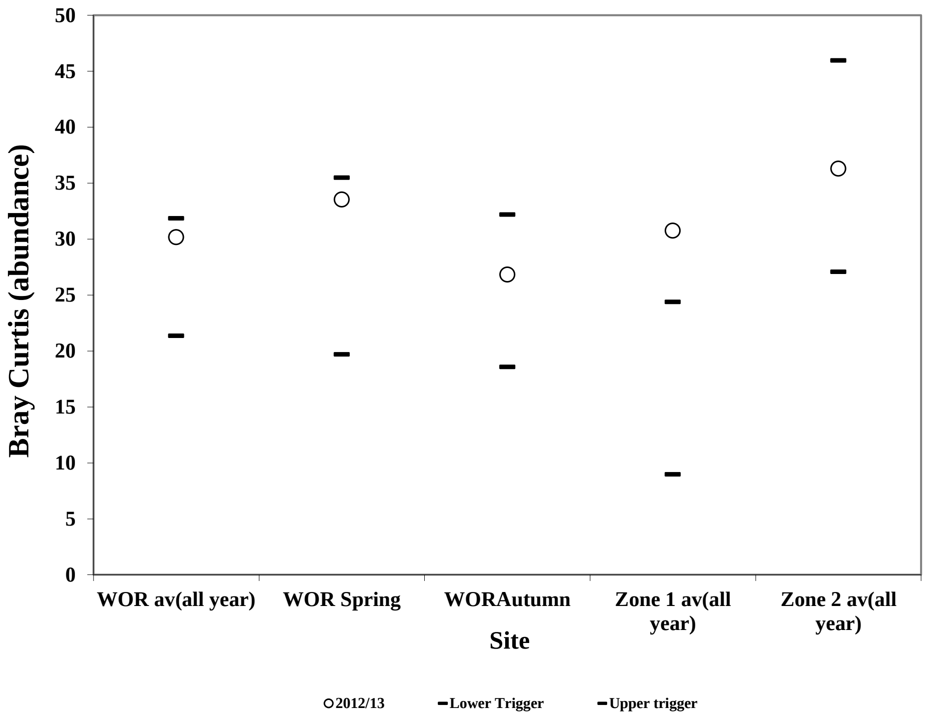
Abundance EPT: Exceeds for whole of river (all year and in spring) and both zones (Figure 4-15) especially zone 1.

Comment – High densities of *Asmicridea* caddis and a range other taxa (e.g. Grypopterygidae, Hydrobiidae, Hydrobiosidae) now contribute to this metric. Enhanced densities are believed to be a product of consistent application of the post-Basslink environmental flow rules, interacting with food inputs from the tributary streams.

4.4.2.5 Biomass / productivity

Total abundance: Values above upper bound for WOR (all year and in autumn) and compliant at zone scale (Figure 4-16).

Comment – Compliant and improved at whole of river scale.



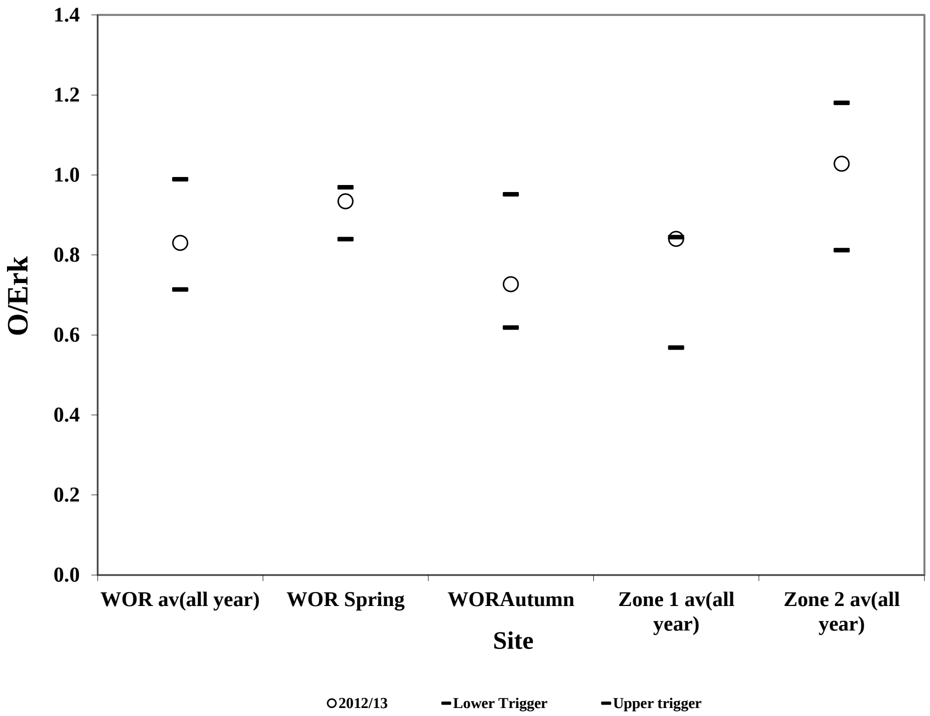
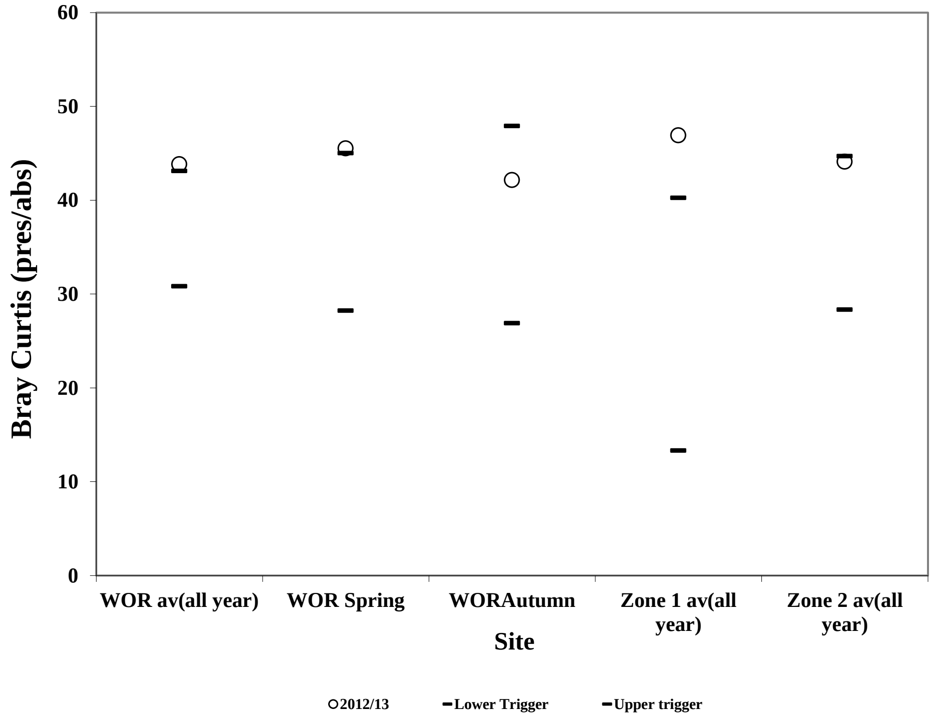


Figure 4-12: Community structure metric values for 2012–13 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = whole of river (by year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data.



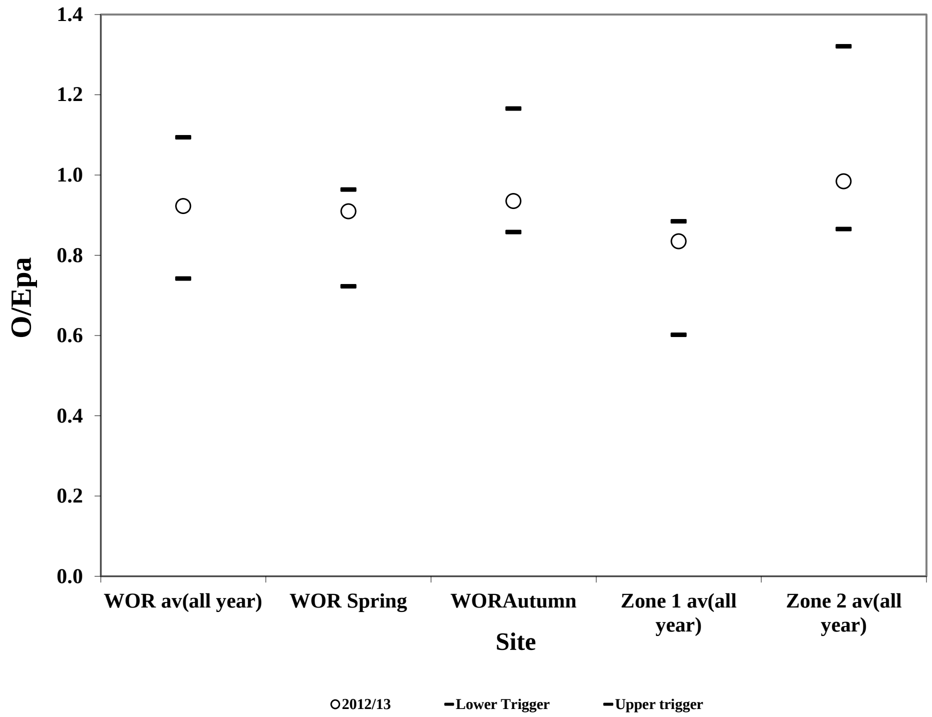
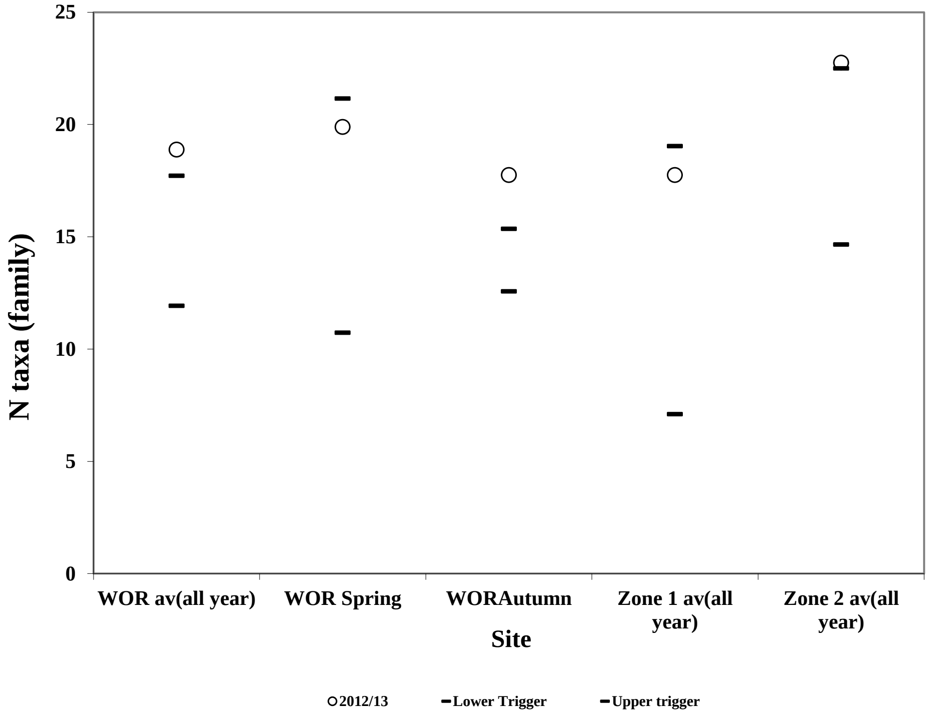


Figure 4-13: Community Composition metric values for 2012–13 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: whole of river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data.



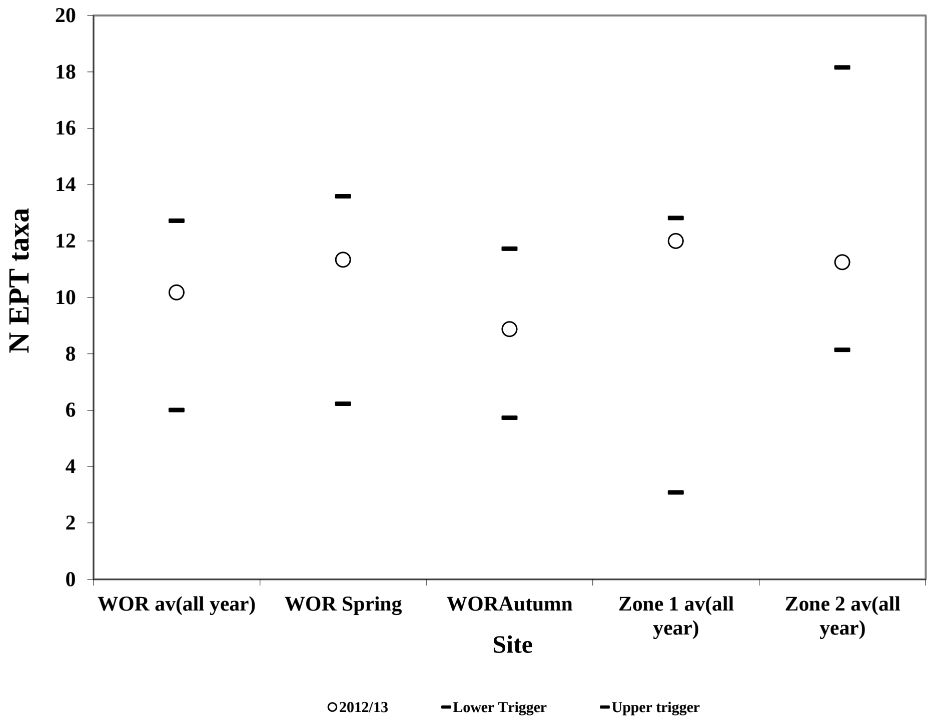
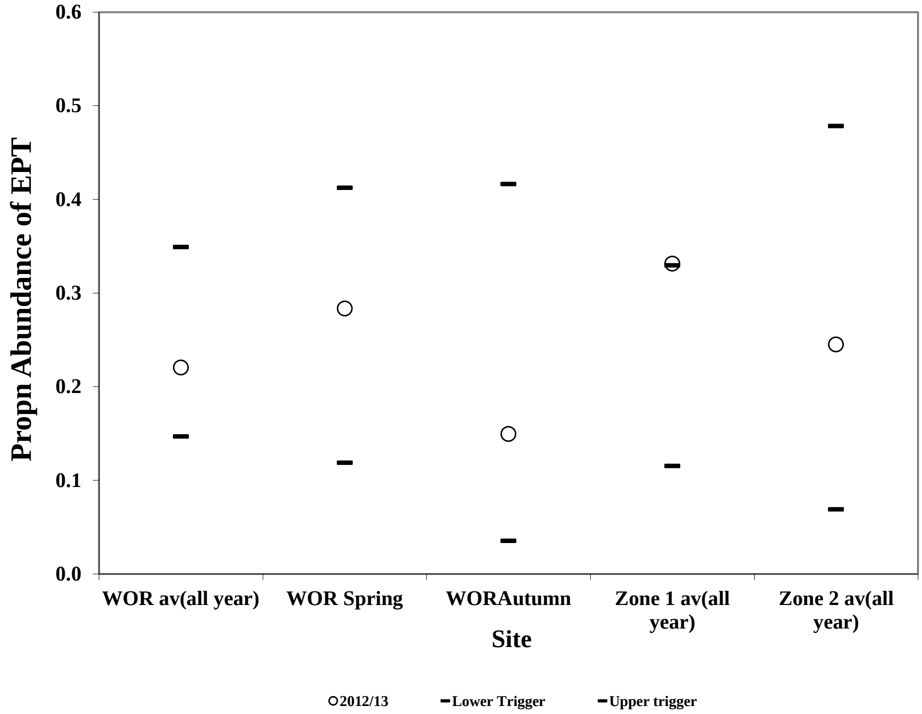


Figure 4-14: Taxonomic Richness metric values for 2012–13 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: whole of river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data.



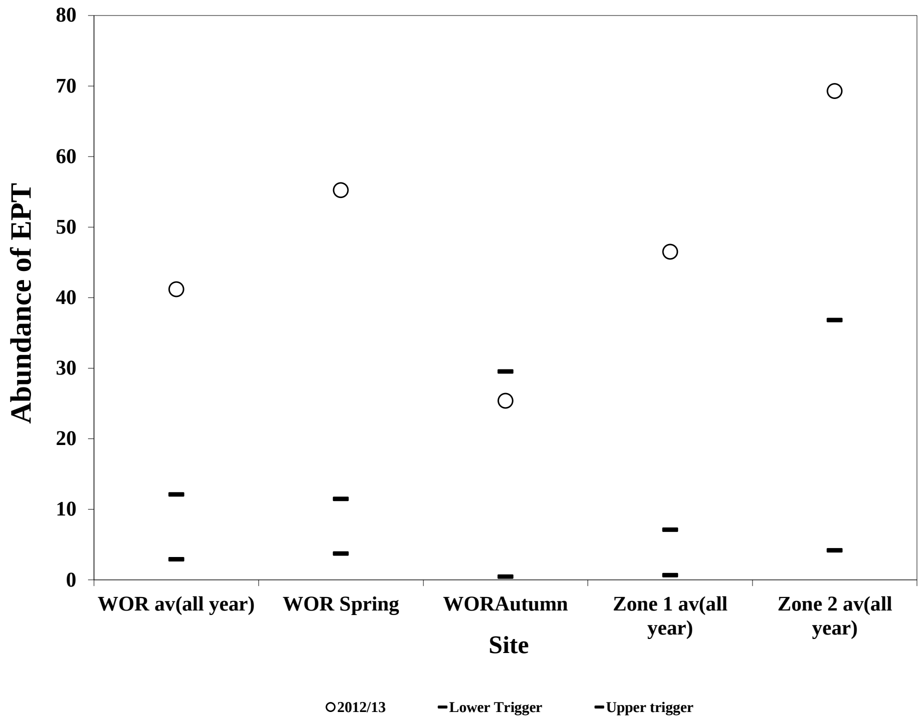


Figure 4-15: Ecologically Significant Species metric values for 2012–13 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: whole of river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data.

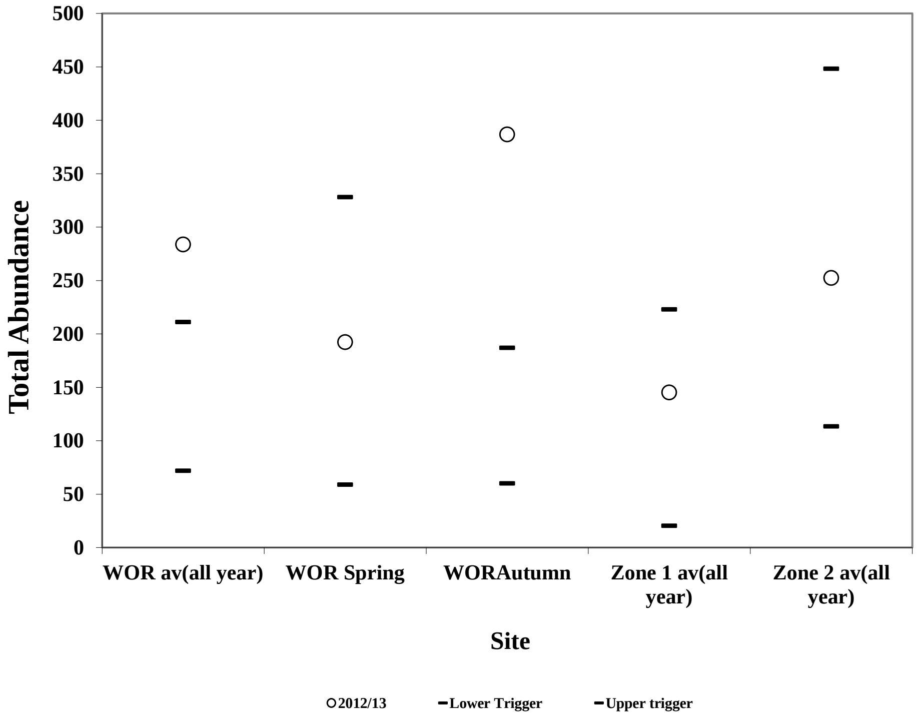


Figure 4-16: Biomass/Productivity metric values for 2012–13 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: whole of river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data.

4.5 Long-term trends

4.5.1 Univariate indicators

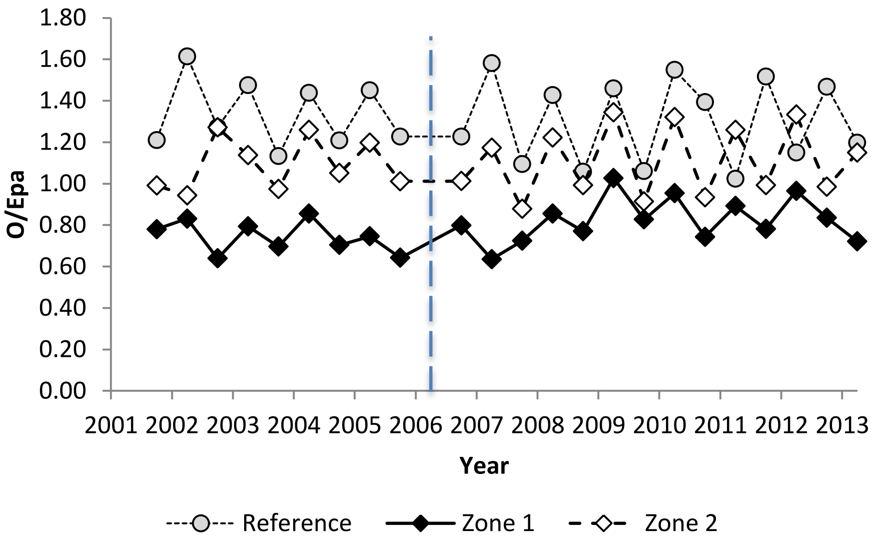
Trends in all metrics are shown in Figure 4-17 to Figure 4-21. As expected, the value of all metrics is predominantly highest in reference sites, lowest in zone 1 and intermediate in zone 2. Most metrics show no monotonic trend over the entire sampling period in the Gordon River, and are generally consistent in values with time. Some post-Basslink trends are apparent.

Some metrics have however shown a post-Basslink rise in value for zone 1 over the period 2007–08 to 2012–13. These include O/Epa, the proportional and total abundance of EPT species, the number of EPT species, the number of macroinvertebrate families and the Bray Curtis similarity to reference (based on both abundance and presence/absence data) (Figure 4-17 to Figure 4-19).

Several zone 1 metrics (Bray Curtis similarity, number of taxa and EPT species and abundance) declined in 2010–11. Most of these metrics recovered or continued to increase in 2011–12. In 2012–13 the same metrics declined again, with the exception of total abundance which increased slightly.

No substantive overall post-Basslink increases in metric values have been observed in zone 2. A general, though variable, increase in total abundance in zone 2 has been observed post-Basslink relative to pre-Basslink values (Figure 4-21). Overall in zone 2, both the trends in metric values and the temporal variation in abundance of several dominant taxa (see section 4.5.2) have tended to follow those of the reference rivers. 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 4-18). It is also worth noting that the Bray Curtis similarity abundance-based value sustained higher values than for the pre-Basslink period between autumn 2009 and autumn 2012 (Figure 4-18) though a decline was observed in 2012–13.

Indicator values for reference rivers have generally been more stable over the entire monitoring period than those for the Gordon River. However, reference rivers experienced a decline over the monitoring period between 2001 and 2012 in the number of EPT species and to a lesser extent in total macroinvertebrate abundance (Figure 4-19 to Figure 4-21). This decline is believed to be related to the dry conditions experienced during much of the program which led to lower than normal flows in reference rivers. Several metrics rose substantially in spring 2011–12, and a subsequent rise in the number of EPT species and the absolute and proportional abundance of EPT species was observed in 2012–13 associated with wetter periods (Figure 4-19 and Figure 4-20).



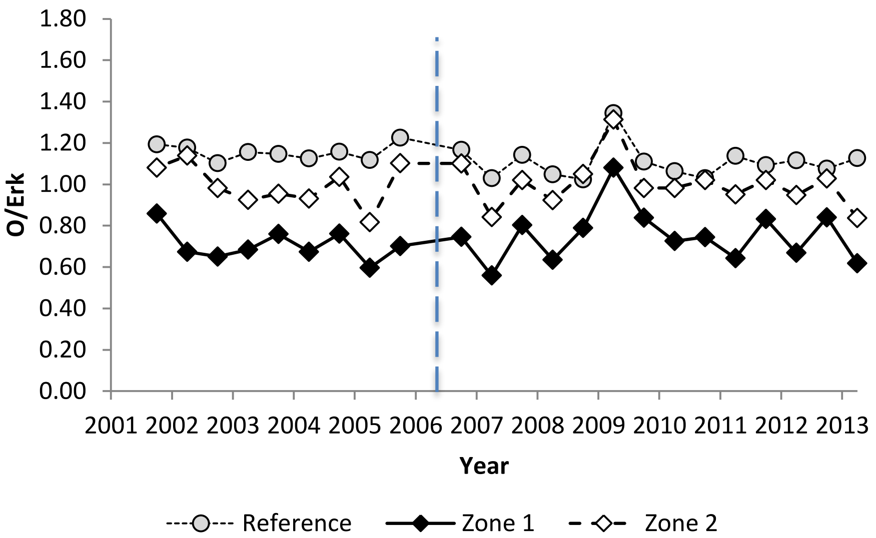
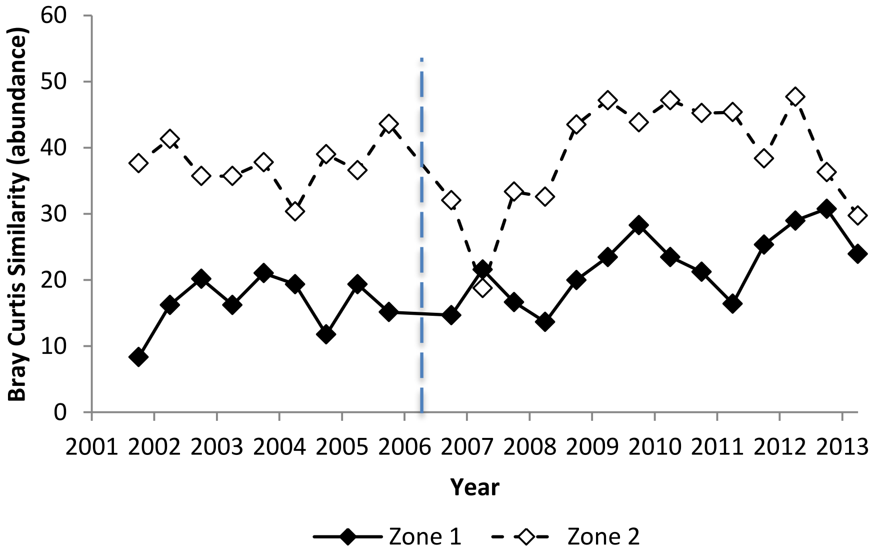


Figure 4-17: Mean O/Epa and O/Erk indicator values for each zone in the Gordon and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations.



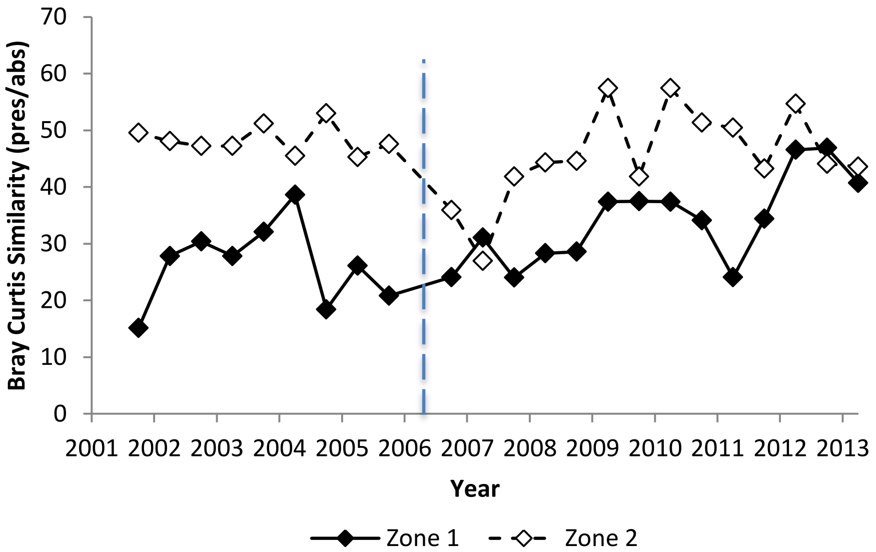
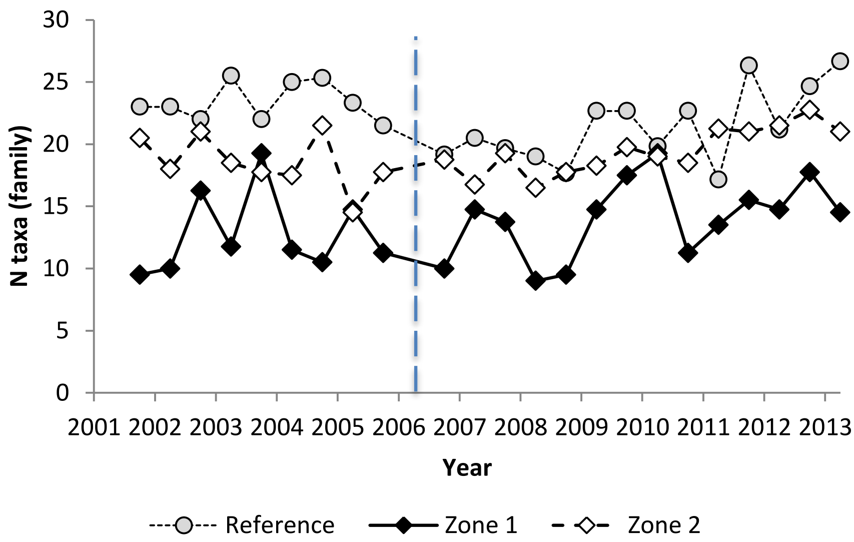


Figure 4-18: Mean Bray Curtis Similarity indicator values between each zone in the Gordon and the reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations.



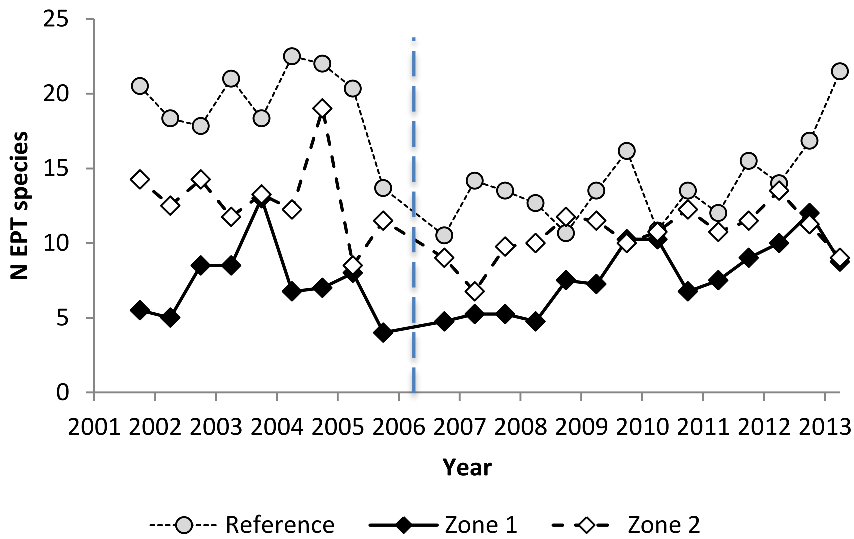
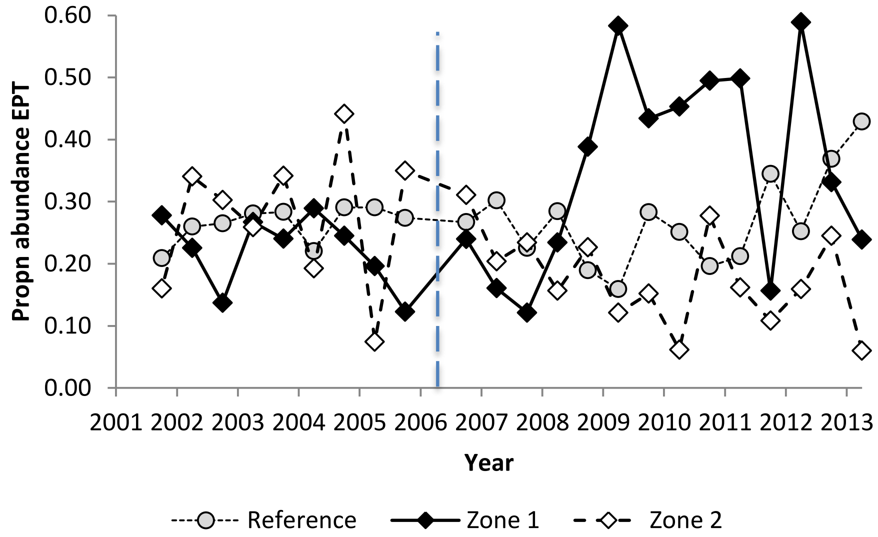


Figure 4-19: Mean N taxa (family) and N EPT species indicator values for each zone in the Gordon and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations.



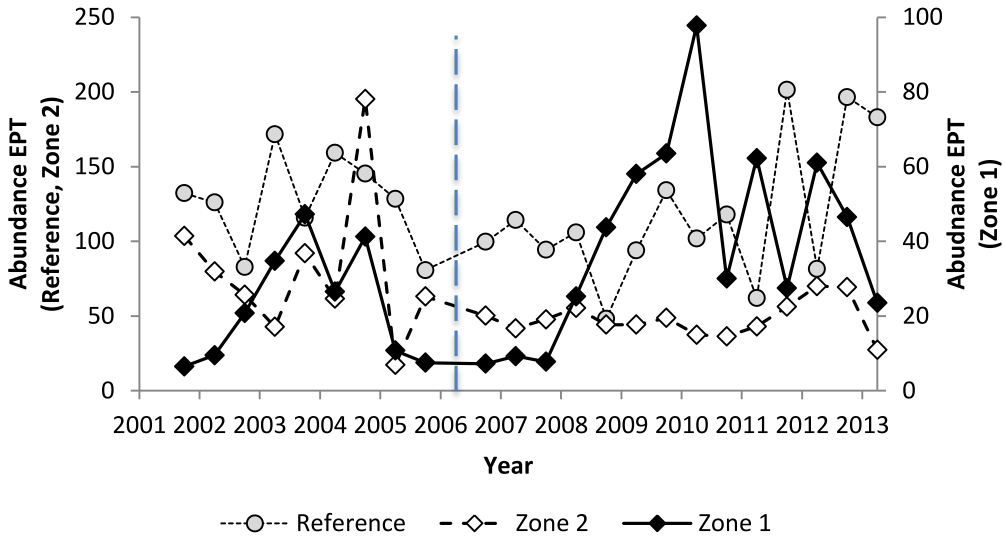


Figure 4-20: Mean Proportional abundance and absolute abundance of EPT taxa indicator values for each zone in the Gordon and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations.

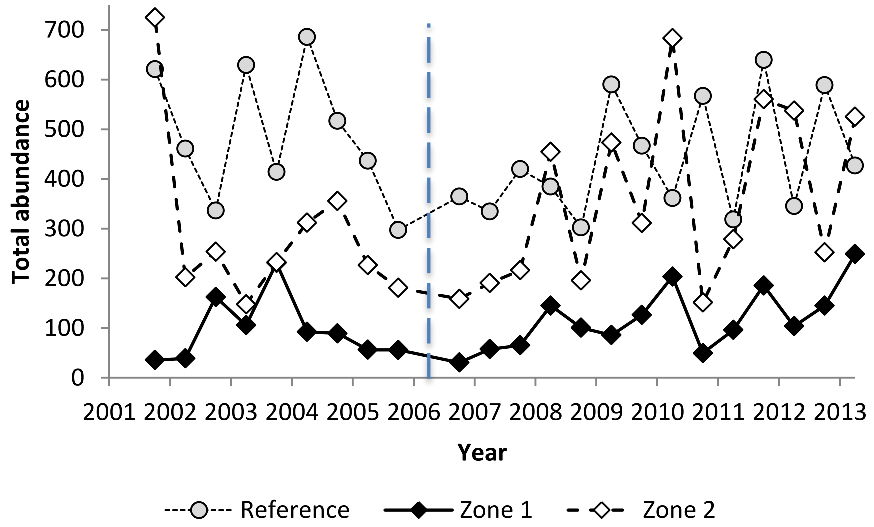


Figure 4-21: Mean Total benthic macroinvertebrate abundance indicator values for each zone in the Gordon and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations.

4.5.2 Individual taxon abundances

Both marked variation and long term trends have been evident over the monitoring period in several of the numerically dominant macroinvertebrate taxa in the Gordon River (Figure 4-22 to Figure 4-24).

The taxon primarily responsible for the change in the absolute and proportional abundance of EPT taxa indicators in zone 1 until 2013 was the caddis family Hydropsychidae (especially *Asmicridea*, the snowflake caddis), for which an increased abundance was observed between spring 2008 and autumn 2011 in zone 1 (Figure 4-22). Numbers have reduced since 2010-11 but still remain higher than observed during the pre-Basslink period.

Both Gripopterygidae and Hydrobiosidae also increased in abundance in zone 1 (though with considerable inter-annual variation) and continue to contribute to the observed increase in proportional EPT representation and to community compositional similarity to reference sites (Figure 4-22 and Figure 4-23). Gripopterygidae and Hydrobiosidae are favoured by uninterrupted, steady flow conditions combined with abundant food resources in the form of particulate organic material, especially the net-building filter feeder *Asmicridea*. After Basslink operations commenced, uninterrupted steady flow conditions were increasingly being met upstream of the Denison junction in zone 1 due to the presence of the environmental flow, especially between sites 63 and 74 downstream of the tributaries of the Orange, Albert and Piguenit rivers. The timing and rate of these abundance increases were consistent with a lagged response to post-Basslink environmental flows controlled by recruitment and responses to food availability.

Abundances of Gripopterygidae and Hydrobiosidae declined in 2010–11 in zone 1, particularly for the Hydrobiosidae (Figure 4-22 and Figure 4-23). The declines were related to higher frequencies of peaking events, to which these flow-sensitive taxa are sensitive. Abundances recovered in 2011–12 but then have decreased again in 2012–13. This is likely due to the relatively constant high flows experienced in 2013, resulting from sustained high volume power station releases. By contrast, numbers have been more stable in zone 2.

A seasonal (generally autumn) increase in simuliid (blackfly) larval densities post-Basslink has been evident for zone 2 (Figure 4-23). A decline in autumn 2011 reversed in the 2012 and 2013 autumn monitoring trips.

It is also noteworthy that Hydrobiid snails (which generally consist of the species *Beddomeia franklinensis*) increased in abundance in zone 1 during the post-Basslink period (Figure 4-24). A substantial spike in abundance was also observed in zone 2 and in reference rivers in autumn 2013.

Overall, there was a post-Basslink increase in abundance of the aquatic insect families Hydropsychidae, Gripopterygidae and Hydrobiosidae in zone 1, with indications of other longer generation taxa (e.g. Hydrobiid snails) showing a lagged increase in both zones. General declines observed for flow-sensitive taxa in 2010–11, due to increased peaking, were partially reversed in 2011–12, and then repeated in 2012–13 following constant high flows.

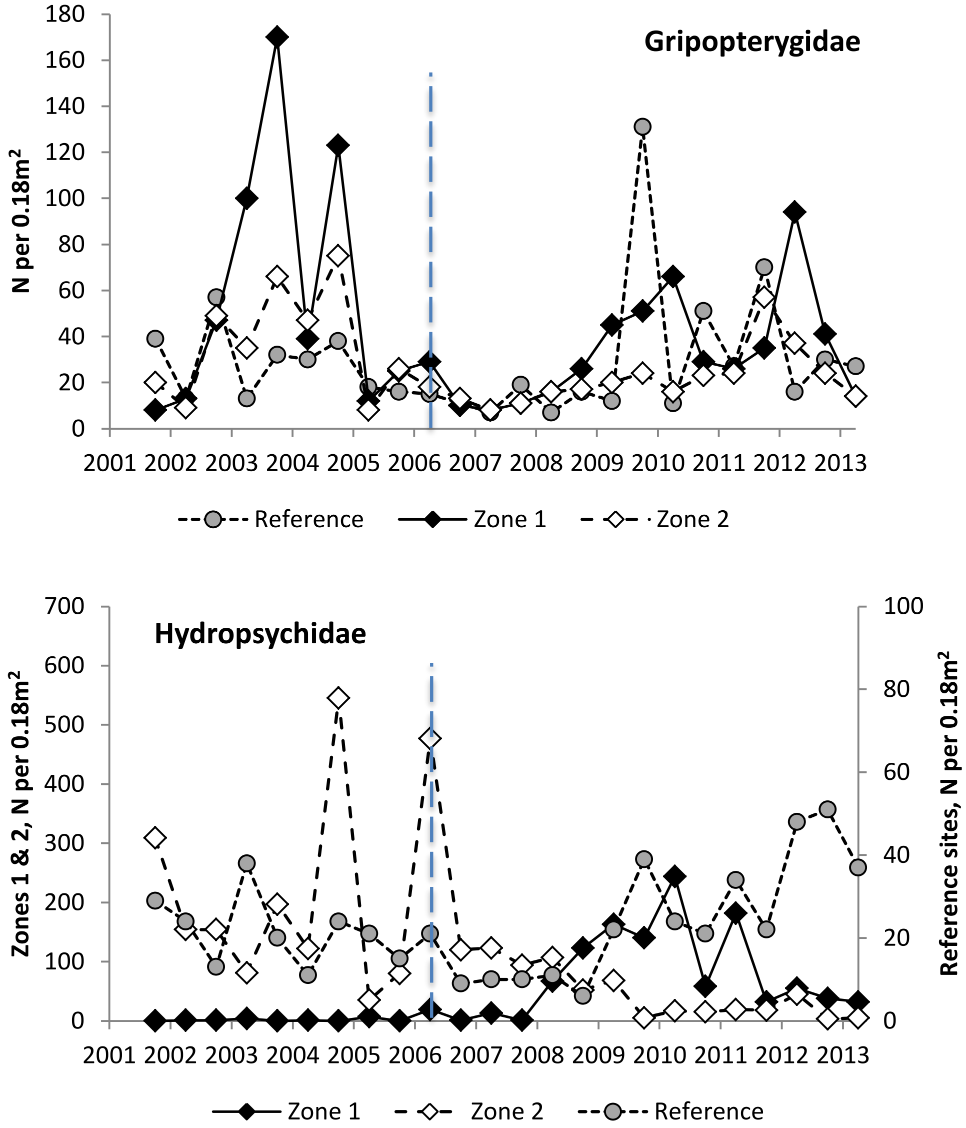


Figure 4-22: Mean abundance (n per 0.18 m^2) of two key taxa for zones 1 and 2 in the Gordon River and for the reference river sites against time. Dashed vertical line indicates initiation of Basslink operations.

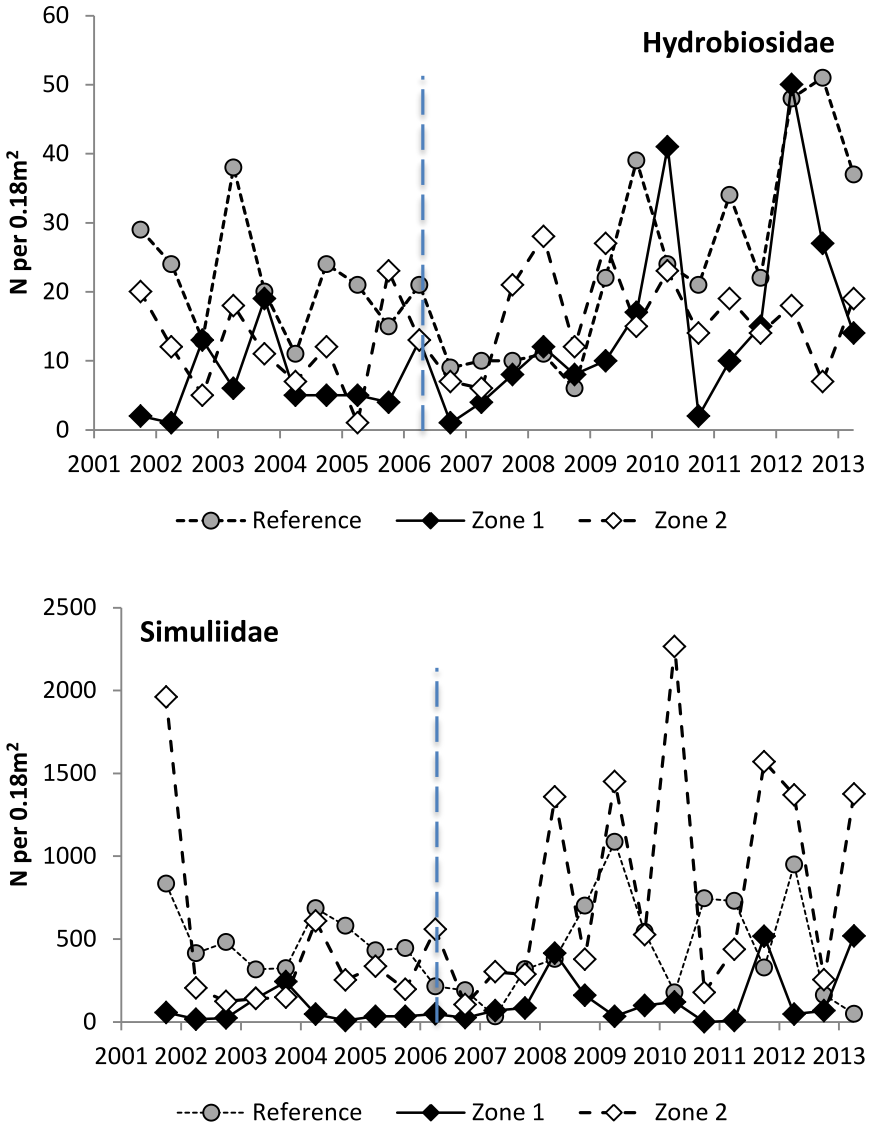


Figure 4-23: Mean abundance (n per 0.18 m^2) of two key taxa for zones 1 and 2 in the Gordon River and for the reference river sites against time. Dashed vertical line indicates initiation of Basslink operations.

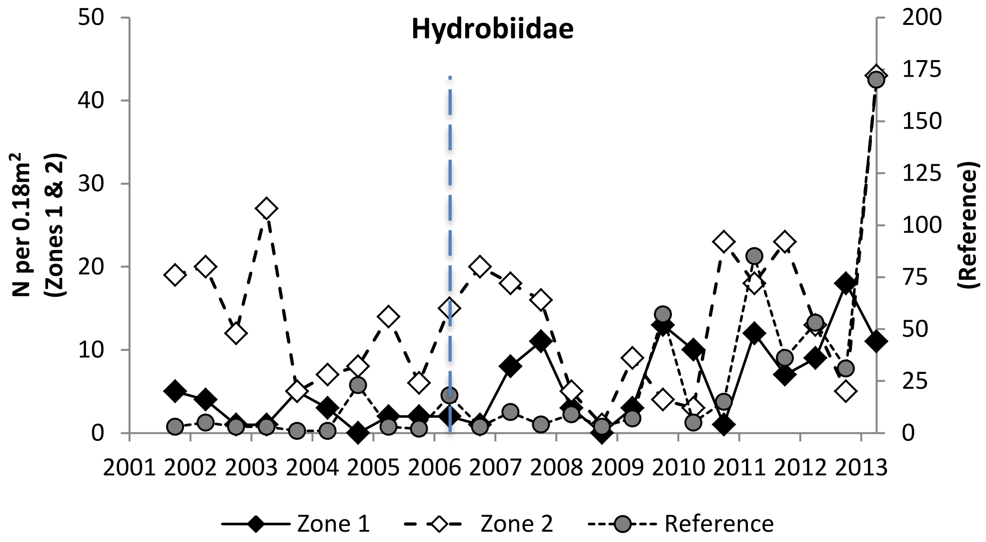


Figure 4-24: Mean abundance (n per 0.18 m^2) of Hydrobiid snails for zones 1 and 2 in the Gordon River and for the reference river sites against time. Dashed vertical line indicates initiation of Basslink operations.

4.6 Conclusions

Spring 2012 and autumn 2013 constitute the seventh full year of the post-Basslink monitoring period.

Sampling was conducted consistent with the requirements of the Gordon River Basslink Monitoring program. All sites were sampled, with the exception of reference site D35 in spring 2012 which was not sampled due to poor weather conditions.

Overall, trigger compliance was high. Some upper trigger exceedances reflect substantive, ongoing post-Basslink increases in abundance and diversity of aquatic insects. These increases in abundance and diversity have been particularly strong in zone 1, and increasingly extended upstream with time from 2007–08, accompanied by a substantive increase in macroinvertebrate community compositional similarity to reference sites. Changed flow conditions in 2010-11 reversed these trends, with partial restoration due to an environmental flow dominated flow regime during 2011-12, followed by a second decline in 2012–13 possibly related to sustained high discharges from the power station.

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

- trigger exceedances for the total and proportional abundance of EPT species and Bray Curtis similarity to reference sites, especially in zone 1;
- general trigger compliance for all other metrics.

The exceedances represent improvement in biological condition relative to pre-Basslink conditions. Most of this improvement occurred prior to 2010–11, followed by large, short-term swings since then. The environmental flow continues to mitigate post-Basslink operation effects on instream biota for zone 1, though inter-annual variations in power station release patterns, particularly the incidence of peaking and high flows, drive swings in indicator values.

5 References

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Appendix 1: Power station discharges graphed per month

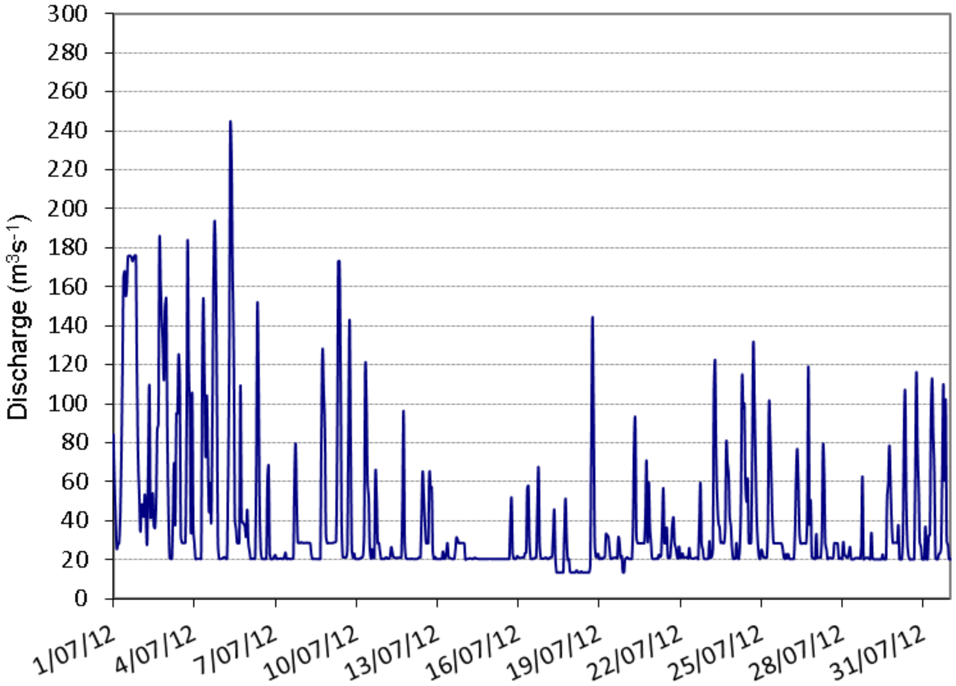

Figure A1.1: Gordon Power Station discharge (hourly data) for July 2012

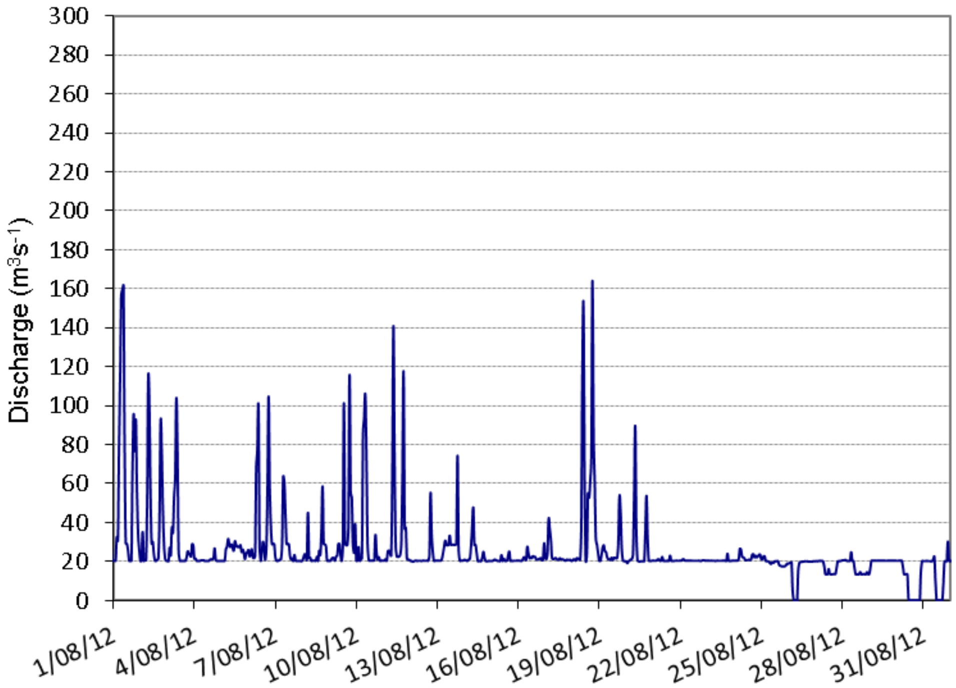

Figure A1.2: Gordon Power Station discharge (hourly data) for August 2012

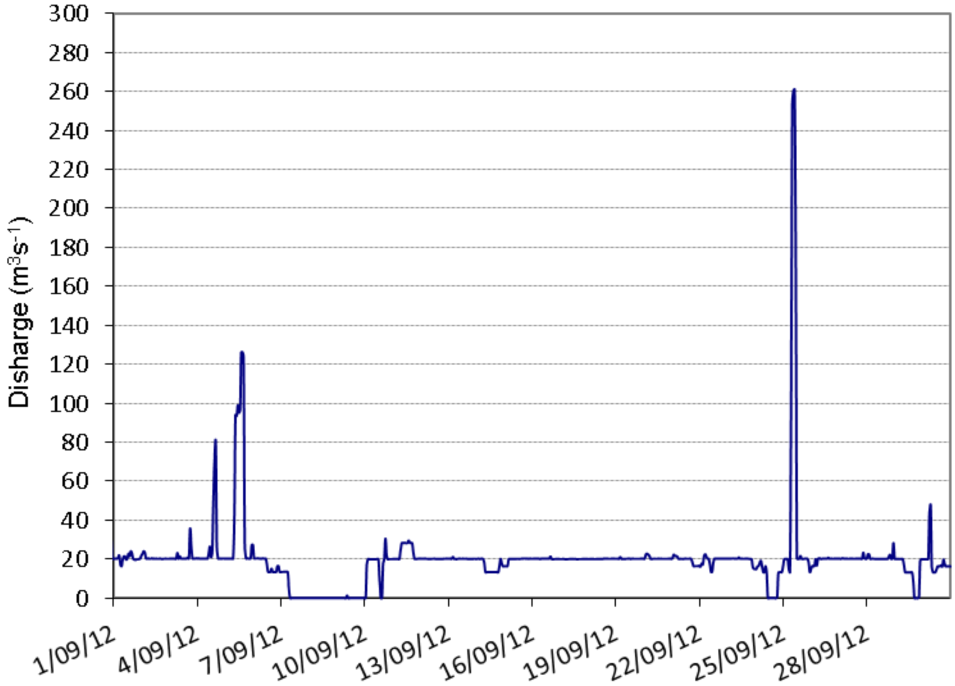

Figure A1.2: Gordon Power Station discharge (hourly data) for September 2012

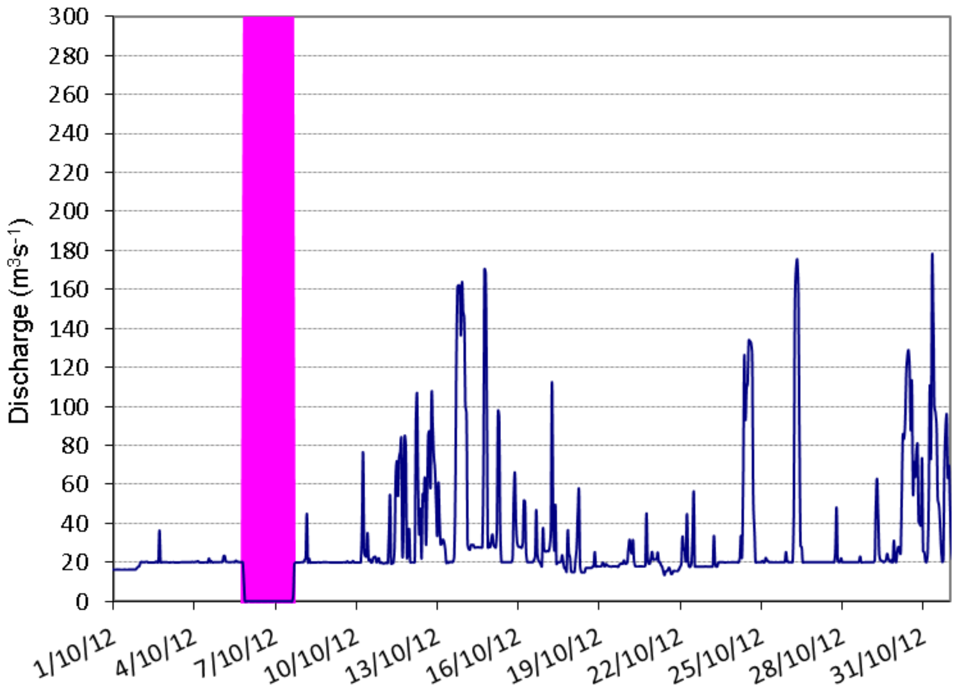

Figure A1.3: Gordon Power Station discharge (hourly data) for October 2012. Pink block indicates a monitoring shutdown

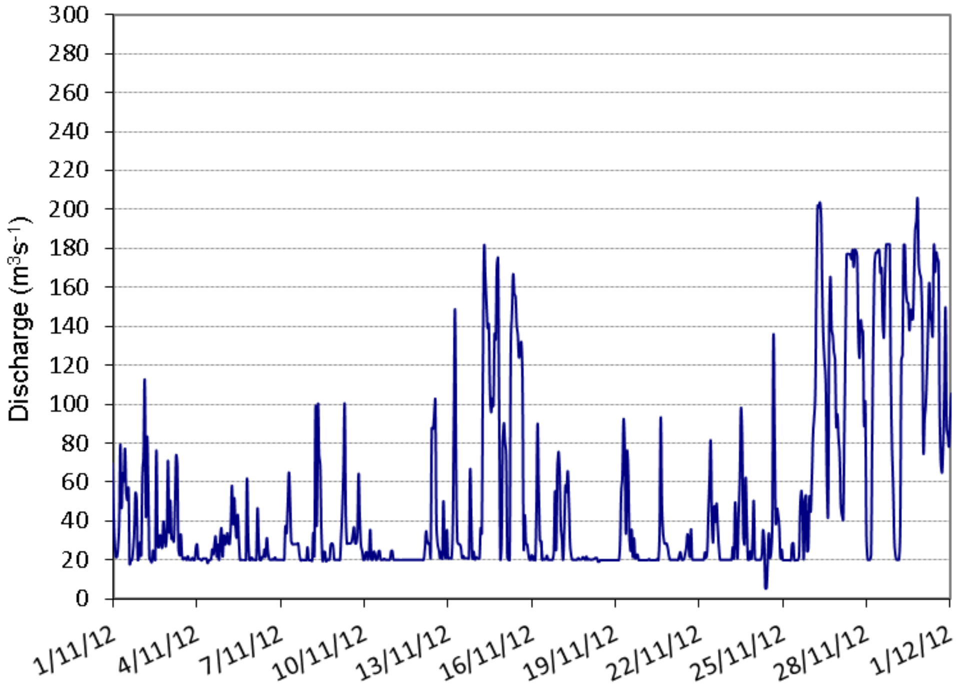

Figure A1.4: Gordon Power Station discharge (hourly data) for November 2012

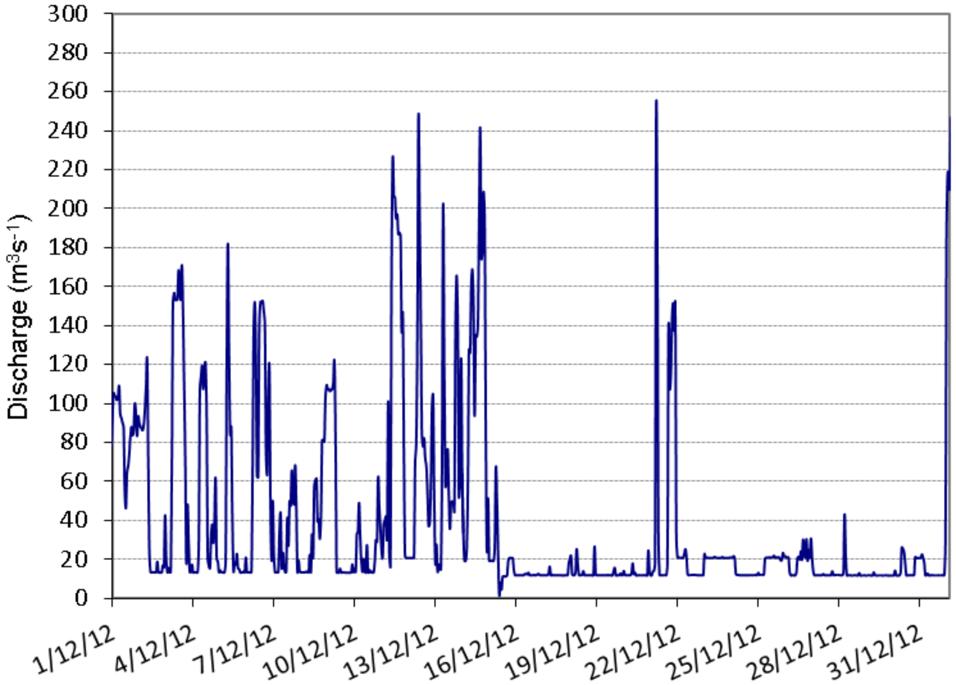

Figure A1.5: Gordon Power Station discharge (hourly data) for December 2012

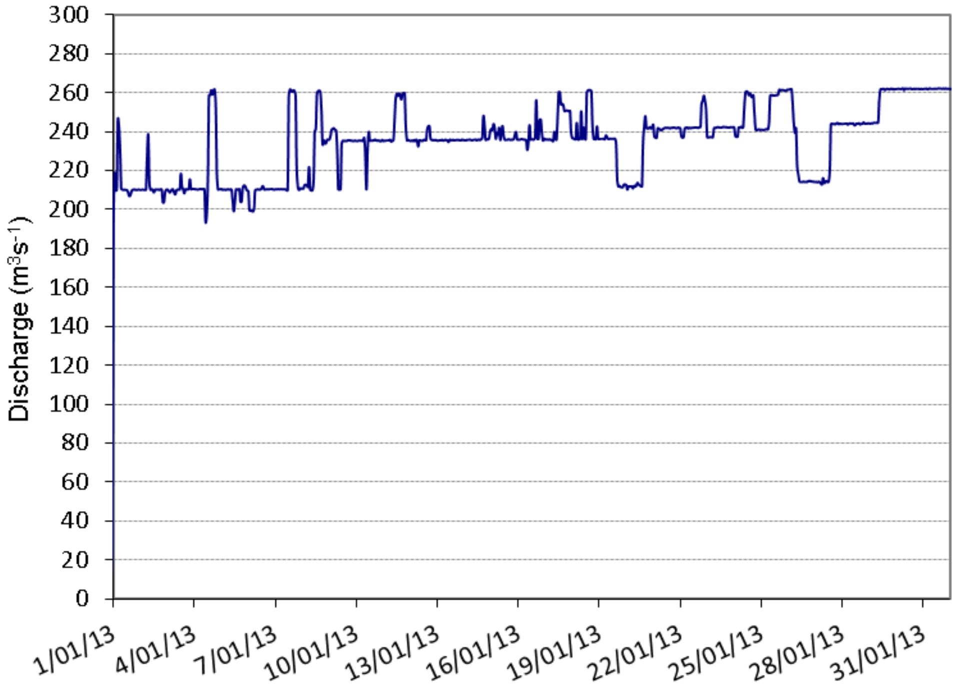

Figure A1.6: Gordon Power Station discharge (hourly data) for January 2013

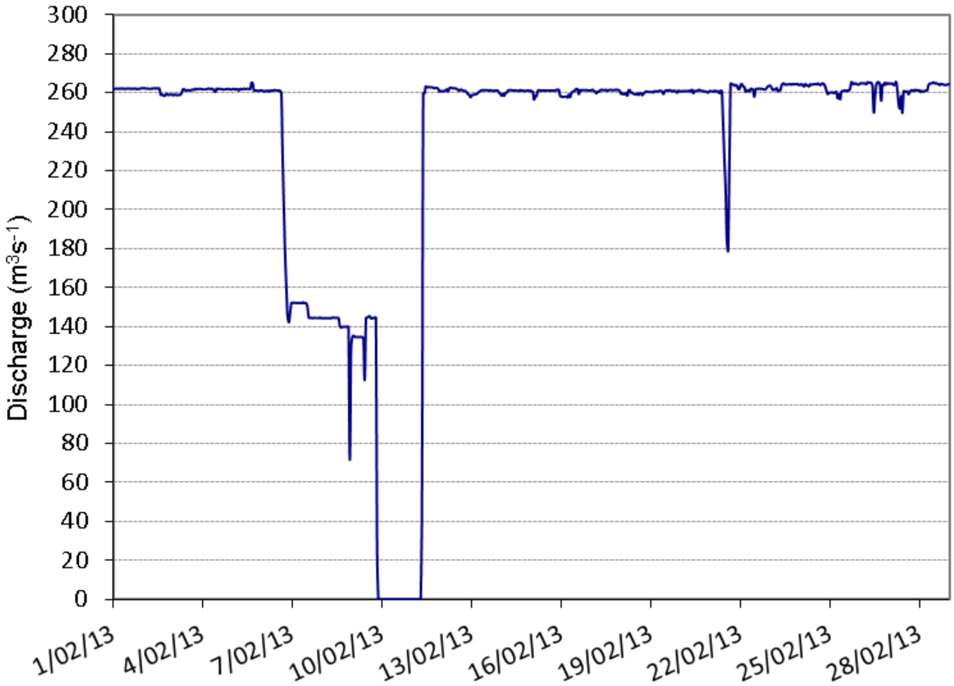

Figure A1.7: Gordon Power Station discharge (hourly data) for February 2013

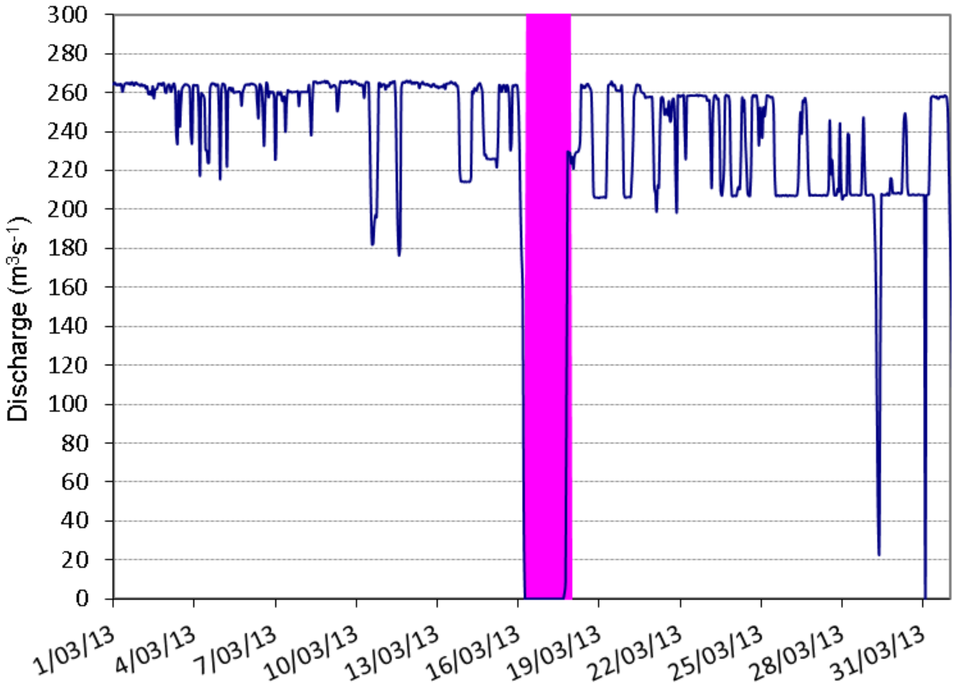

Figure A1.8: Gordon Power Station discharge (hourly data) for March 2013. Pink block indicates a monitoring shutdown

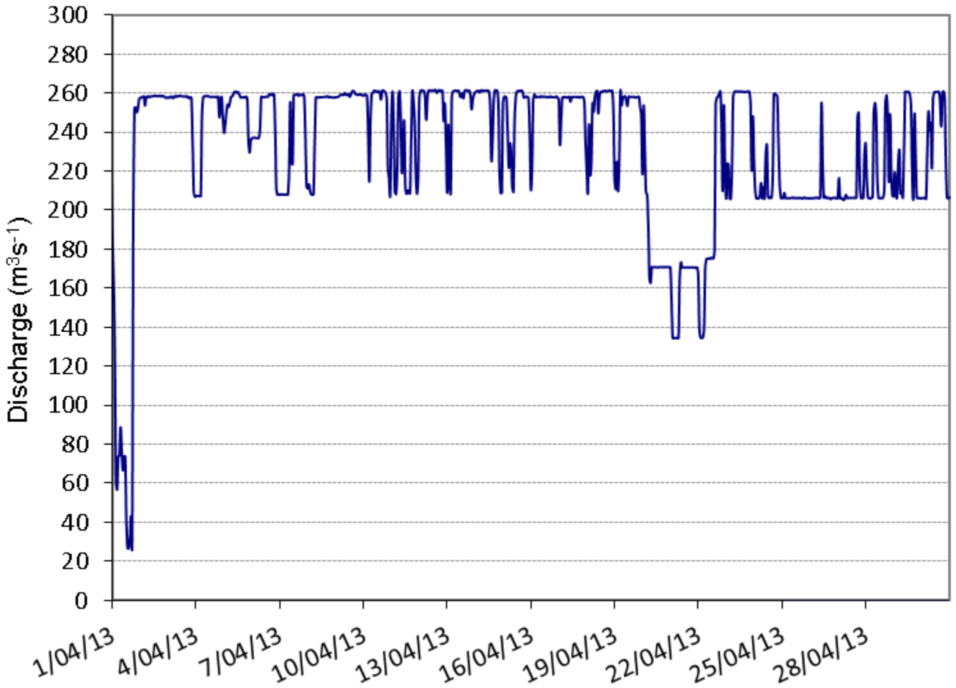

Figure A1.9: Gordon Power Station discharge (hourly data) for April 2013

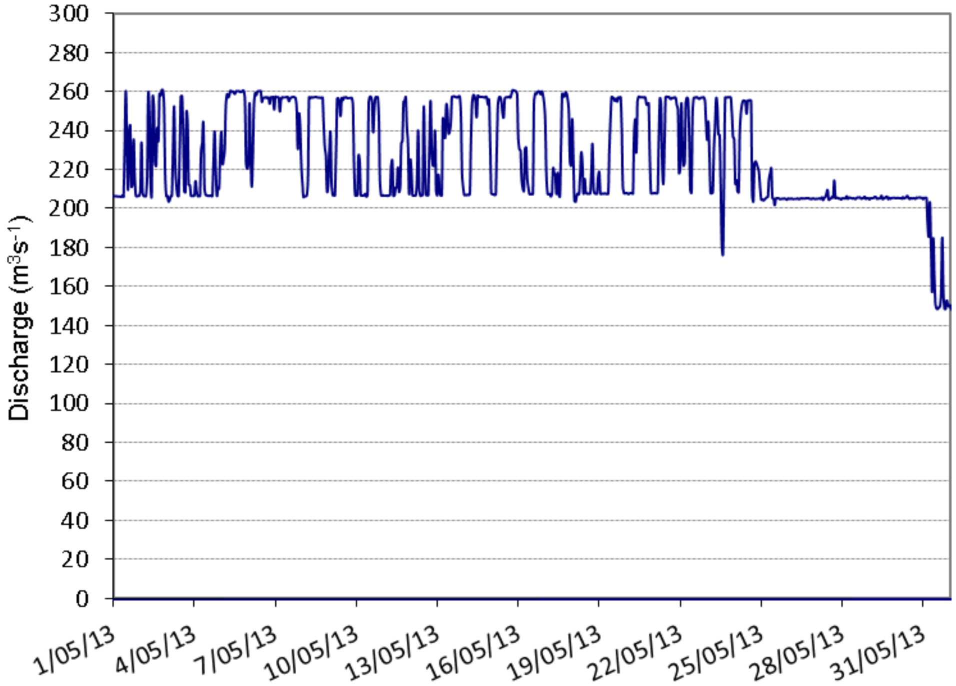

Figure A1.10: Gordon Power Station discharge (hourly data) for May 2013

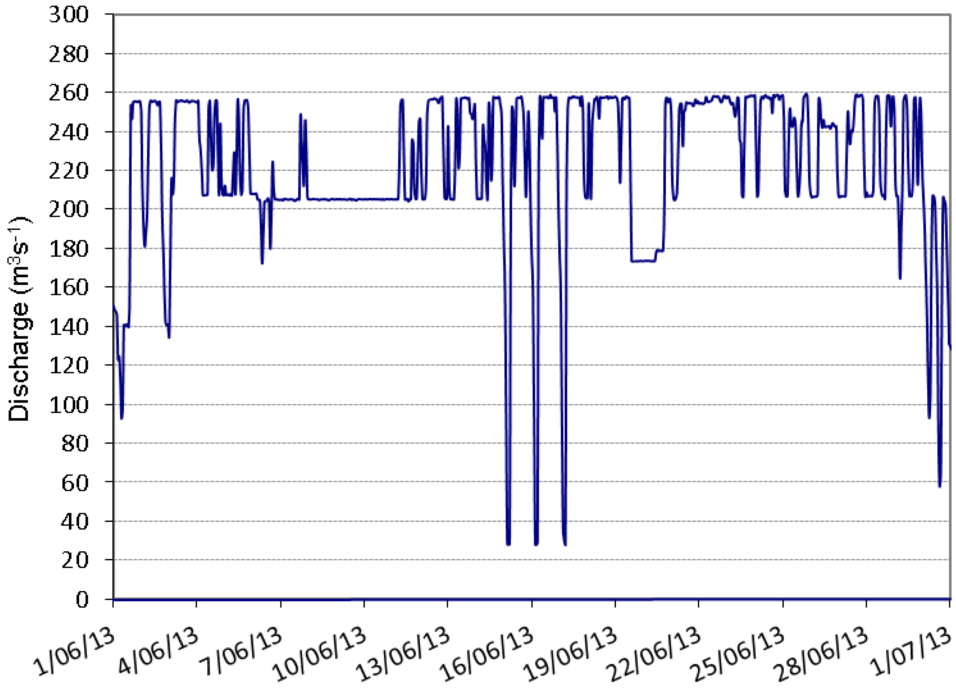

Figure A1.11: Gordon Power Station discharge (hourly data) for June 2013

Appendix 2: Erosion pin graphs

Abbreviations used in graphs

b/slope – back slope; slope behind crest of bank
b/water – back water
cave – bank cavity
cob – vertical cobble bank
col – vertical colluvial bank
crest – crest of bank
flow – sediment flow
HW – power station controlled high water marker
pipe – casing for piezometer measured as erosion pin
slope – sandy bank slope
toe – sandy bank toe
top – top of bank

Appendix 2.1. Description of erosion pin monitoring sites

Zone	Turbine Level	Bank Material-Colluvial	Bank Material - Alluvial	Bank Material – Alluvial over cobbles or bedrock	Location -Inside bend	Location-Outside bend	Location- Straight reach	Turbine level Totals
Zone 1	<1		1C/1-4, 1E/4, 1E/5		1C/1-4, 1E/4, 1E/5			6
	1-2	1A/1-7,1A/9	1E/2, 1E/3	1B/1, 1B/3, 1B/4, 1D/2, 1D/3	1B/1, 1B/3, 1B/4,	1D/2, 1D/3, 1E/2, 1E/3	1A/1-7,1A/9	15
	2-3	1A/8C	1E/1, 1E/6, 1E/7	1B/2, 1B/5, 1D/1, 1D/4	1B/2, 1B/5,	1D/1, 1D/4, 1E/1, 1E/6, 1E/7	1A/8C	8
	>3	1A/8a, 1A/8b		1F/1-4			1A/8a, 1A/8b, 1F/1-4	6
Bank type, location totals		11	11	13	9	9	15	
Zone 2	<1		2B/8, 2C/4, 2D/4, 2E/5, 2H/3, 2H/6, 2J/3, 2K/5, 2L/4	2G/6	2D/4, 2J/3, 2K/5	2C/4, 2E/5	2B/8, 2G/6, 2H/3, 2H/6, 2L/4	10
	1-2		2B/1, 2B,3, 2B/5, 2B/7, 2C/3, 2D/3, 2E/3, 2E/4, 2H/2, 2H/5, 2I/1, 2I/2, 2J/2, 2K/4, 2K/3, 2L/2, 2L/3	2A/1, 2A/2, 2G/2	2D/3, 2E/3, 2I/1, 2I/2, 2J/2, 2K/4, 2K/3	2C/3, 2E/4	2A/1, 2A/2, 2B/1, 2B,3, 2B/5, 2B/7, 2G/2, 2H/2, 2H/5, 2L/2, 2L/3	20
	2-3		2B/2, 2B/4, 2B/6, 2C/1, 2C/2, 2D/1, 2D/2, 2E/1, 2E/2, 2H/1, 2H/4, 2J/1, 2K/1, 2K/2, 2L/1, 2L/5, 2L/6	2A/3, 2A/5, 2A/6, 2A/7, 2G/1, 2G/3, 2G/4, 2G/5	2D/1, 2D/2, 2J/1, 2K/1, 2K/2	2C/1, 2C/2, 2E/1, 2E/2	2A/3, 2A/5, 2A/6, 2A/7, 2B/2, 2B/4, 2B/6, 2G/1, 2G/3, 2G/4, 2G/5, 2H/1, 2H/4, 2L/1, 2L/5, 2L/6	25
	>3			2A/4			2A/4	1
Bank type, location totals		0	43	13	15	8	33	
Zone 3	<1		32A/1, 3A/4, 3A/5, 3C/5, 3D/3, 3Ea/3, 3Eb/5, 3F/4, 3G/5	3B/5	3C/5	3D/3	32A/1, 3A/4, 3A/5, 3B/5, 3Ea/3, 3Eb/5, 3F/4, 3G/5	10
	1-2		3A/2, 3A/3, 3C/2, 3C/3, 3C/4, 3D/2, 3Ea/4, 3Eb/3, 3Eb/4, 3G/2, 3G/3, 3G/4	3B/1, 3B/4, 3F/2, 3F/3,	3C/2, 3C/3, 3C/4	3D/2	3A/2, 3A/3, 3B/1, 3B/4, 3Ea/4, 3Eb/3, 3Eb/4, 3F/2, 3F/3, 3G/2, 3G/3, 3G/4	16
	2-3		3A/5, 3A/6, 3C/1, 3D/1, 3D/4, 3Ea/2, 3Ea/5, 3Eb/2, 3Eb/6, 3G/1	3B/2, 3B/3, 3F/1	3C/1	3D/1, 3D/4	3A/5, 3A/6, 3B/2, 3B/3, 3Ea/2 3Ea/5, 3Eb/2, 3Eb/6, 3F/1, 3G/1	13
	>3		3Ea/1, 3Ea/6, 3Eb/1				3Ea/1, 3Ea/6, 3Eb/1	3
Bank type, location totals			34	8	5	4	33	

Zone	Turbine Level	Bank Material-Colluvial	Bank Material - Alluvial	Bank Material – Alluvial over cobbles or bedrock	Location -Inside bend	Location-Outside bend	Location- Straight reach	Turbine level Totals
Zone 4	<1		4A/3, 4B/3, 4E/4, 4Ga/3, 4Ga/4, 4Gb/3, 4Gb/4, 4Gb/5, 4H/4, 4H/5		4E/4	4H/4, 4H/5	4A/3, 4B/3, 4Ga/3, 4Ga/4, 4Gb/3, 4Gb/4, 4Gb/5	10
	1-2		4A/2, 4B/2, 4E/3, 4Ga/2, 4Gb/2, 4H/3	4D/2, 4D/3, 4F/3, 4F/4, 4F/5	4E/3, 4F/3, 4F/4, 4F/5	4D/2, 4D/3, 4H/3	4A/2, 4B/2, 4Ga/2, 4Gb/2	11
	2-3		4A/1, 4A/4, 4B/1, 4/B/4, 4E/1, 4E/2, 4Ga/1, 4Gb/1, 4H/1, 4H/2	4D/1, 4D/4, 4F/1, 4F/2,	4E/1, 4E/2, 4F/1, 4F/2,	4D/1, 4D/4, 4H/1, 4H/2	4A/1, 4A/4, 4B/1, 4/B/4, 4Ga/1, 4Gb/1	14
	>3			4F/HW	4F/HW			1
Bank type, location totals			26	10	10	9	17	
Zone 5	<1		5A/4, 5B/4, 5C/3, 5D/3, 5E/3, 5E/4, 5F/3, 5G/6, 5H/4, 5I/4, 5J/4, 5K/3, 5L/4, 5M/3		5B/4, 5C/3, 5F/3, 5J/4, 5K/3	5H/4, 5I/4, 5M/3	5A/4, 5D/3, 5E/3, 5E/4, 5G/6, 5L/4	14
	1-2		5A/3, 5B/2, 5B/3, 5B/5, 5B/6, 5C/2, 5D/2, 5E/2, 5F/2, 5G/2, 5G/3, 5G/4, 5G/5, 5H/2, 5H/3, 5I/2, 5I/3, 5I/6, 5J/3, 5J/2, 5K/2, 5L/2, 5L/3, 5M/2		5B/2, 5B/3, 5B/5, 5B/6, 5C/2, 5F/, 5J/3, 5J/2, 5K/2	5H/2, 5H/3, 5I/2, 5I/3, 5I/6	5A/3, 5D/2, 5E/2, 5G/2, 5G/3, 5G/4, 5G/5, 5L/2, 5L/3, 5M/2	24
	2-3		5A/1, 5A/2, 5B/1, 5C/1, 5C/4, 5D/1, 5E/1, 5F/1, 5G/1, 5H/1, 5I/1, 5I/5, 5J/1, 5J/5, 5J/6, 5K/0, 5K/1, 5L/1, 5M/1		5B/1, 5C/1, 5C/4, 5F/1, 5J/1, 5J/5, 5J/6, 5K/0, 5K/1	5H/1, 5I/1, 5I/5	5A/1, 5A/2, 5D/1, 5E/1, 5G/1, 5L/1, 5M/1	19
	>3							
Bank type, location totals			57	0	23	11	23	

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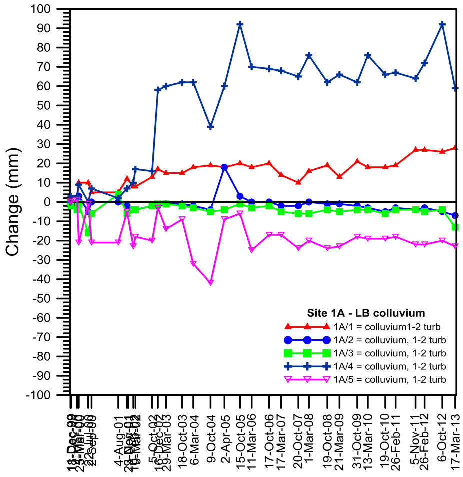
Appendix 2.2. Graphs of erosion pin results at each site

Zone 1



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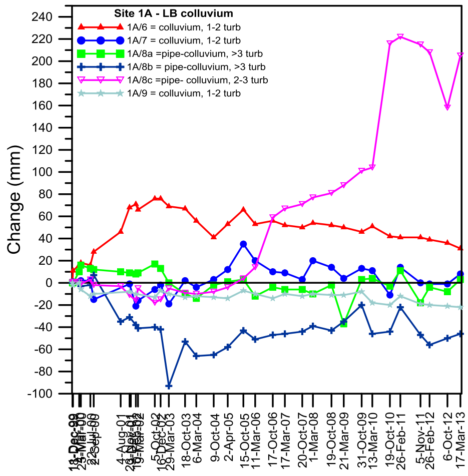

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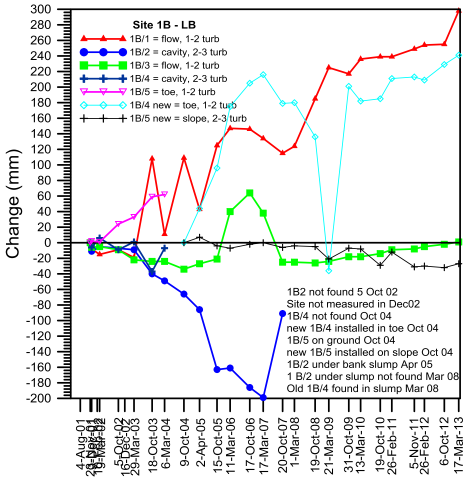

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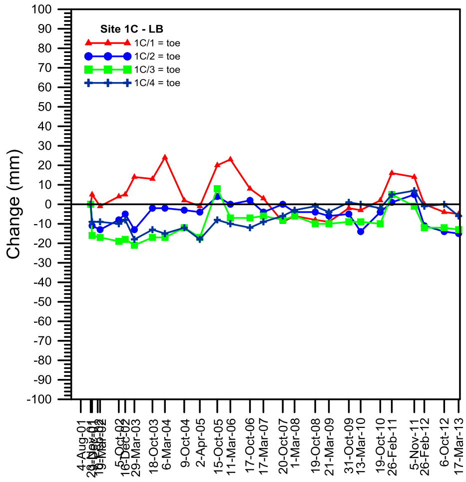

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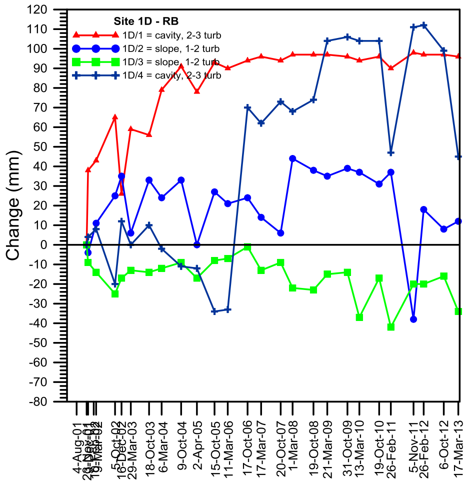

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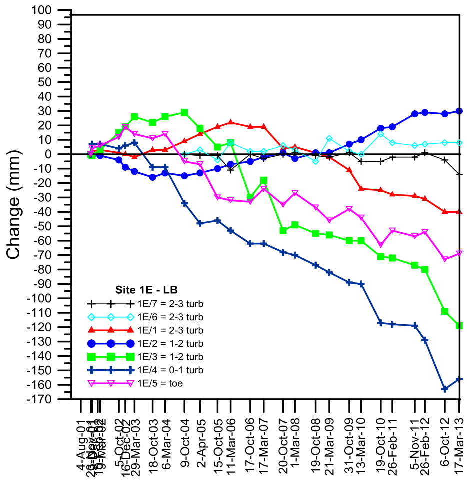

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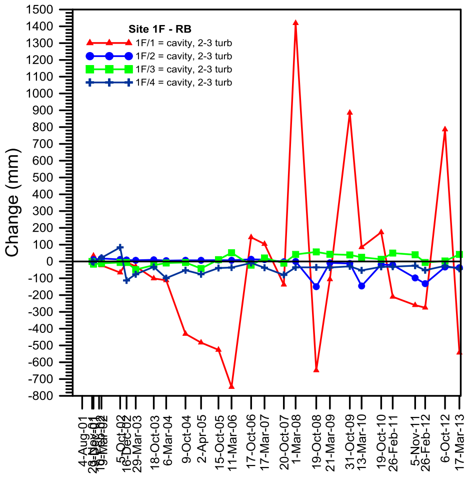

Site 1/F

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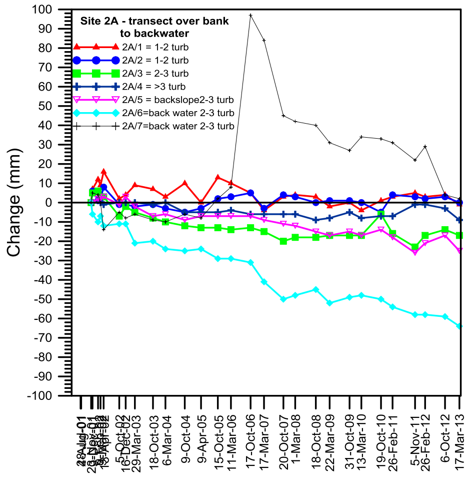

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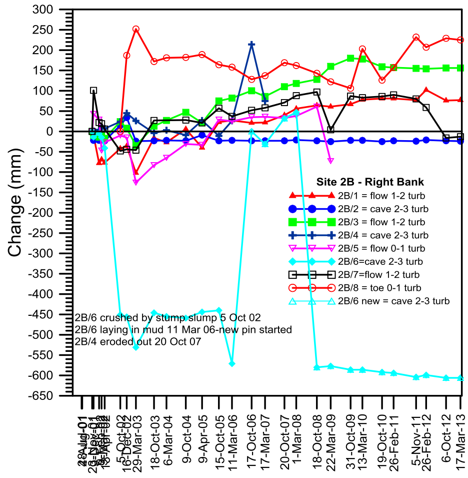

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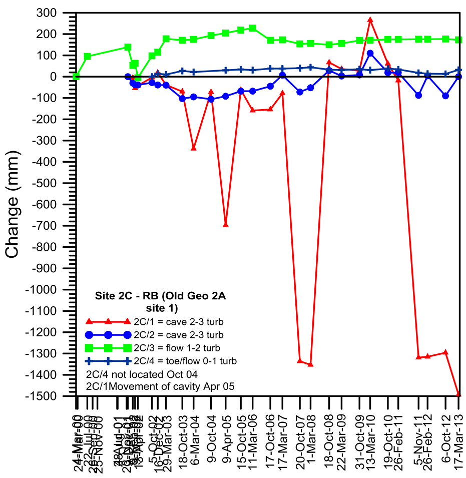

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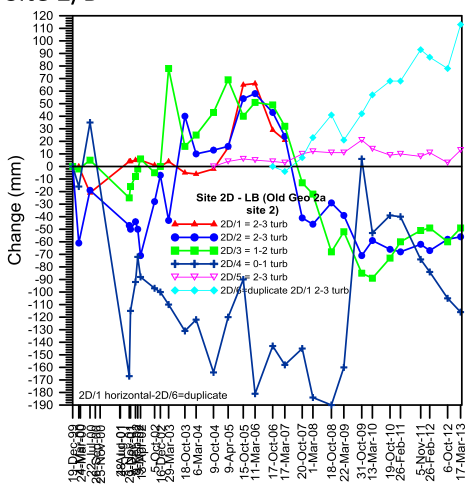
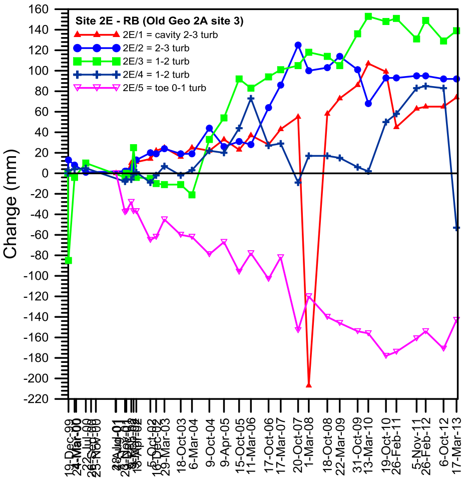


Site 2D

Hydro Tasmania
The power of natural thinking



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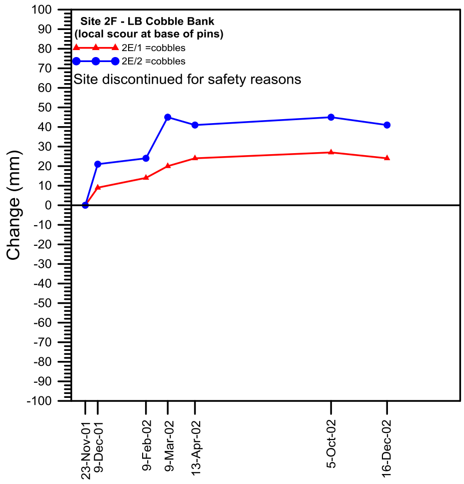

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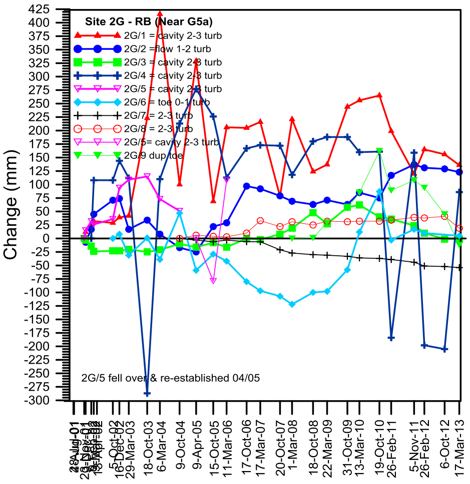

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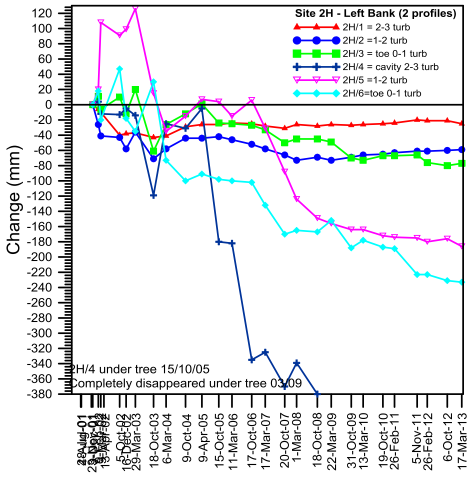
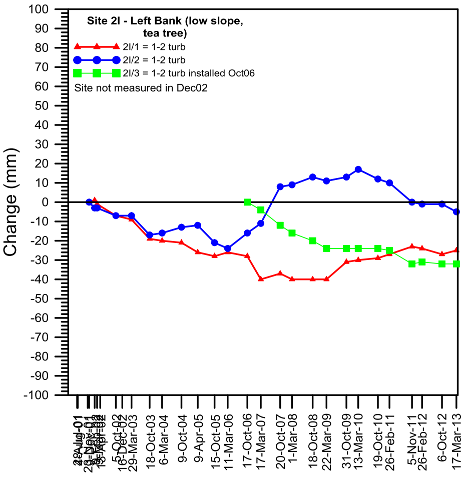
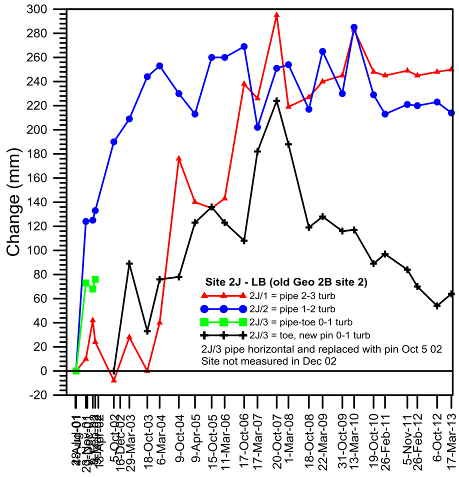


Site 2H

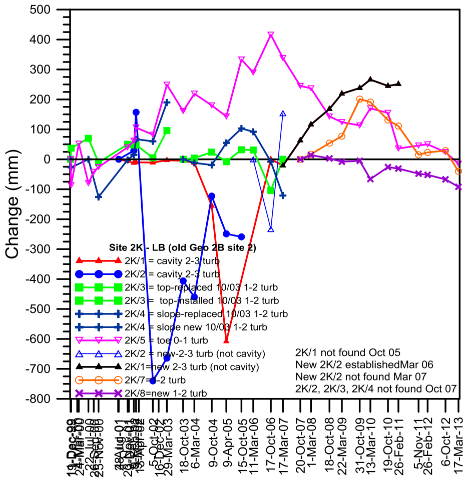


Site 2I



Site 2J

Hydro Tasmania
The power of natural thinking



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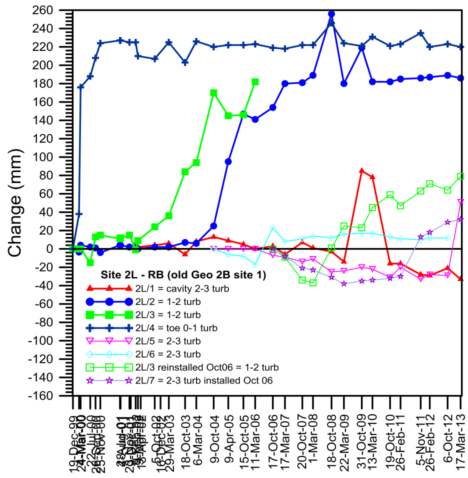
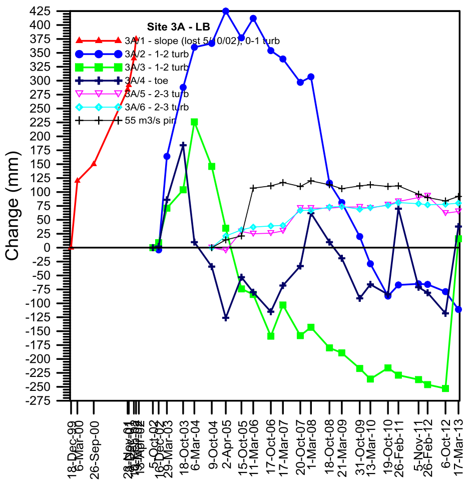


Site 2L

Zone 3



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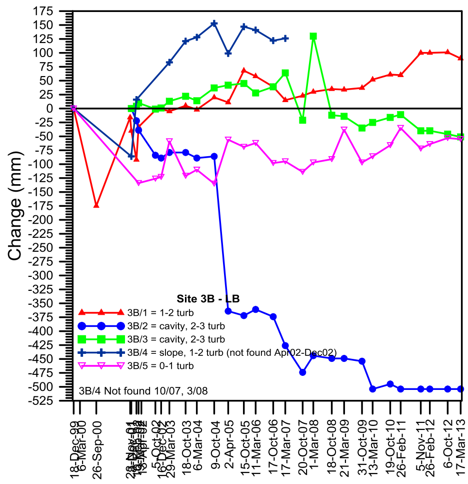

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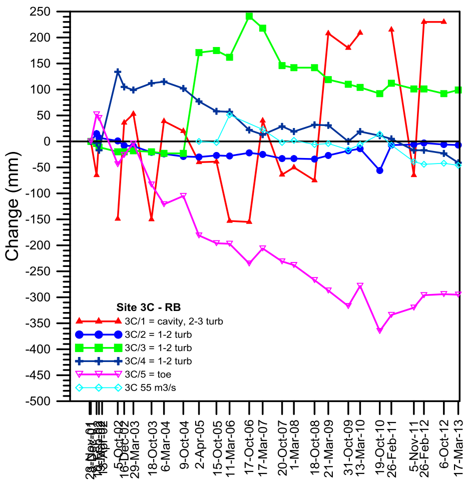

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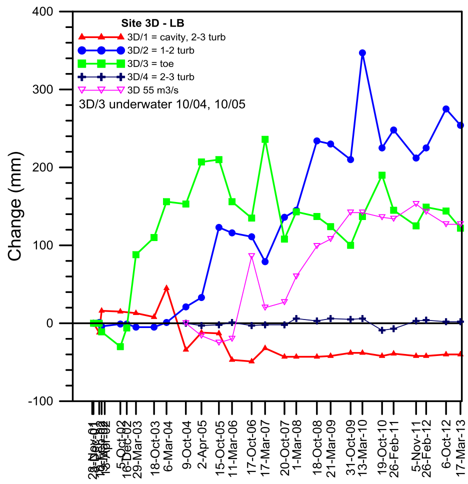

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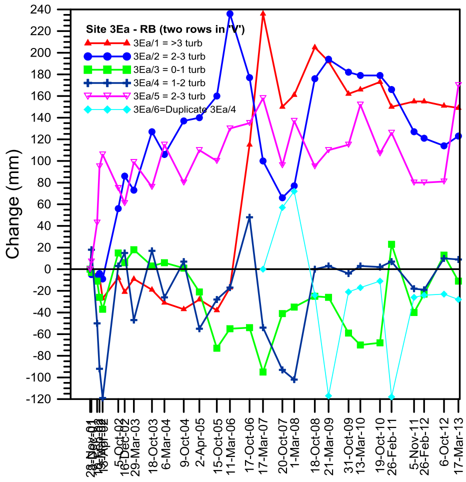

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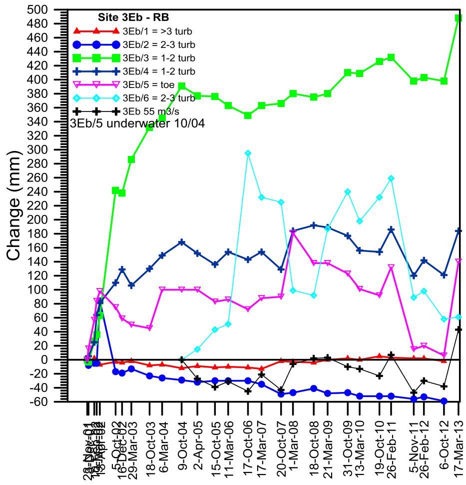

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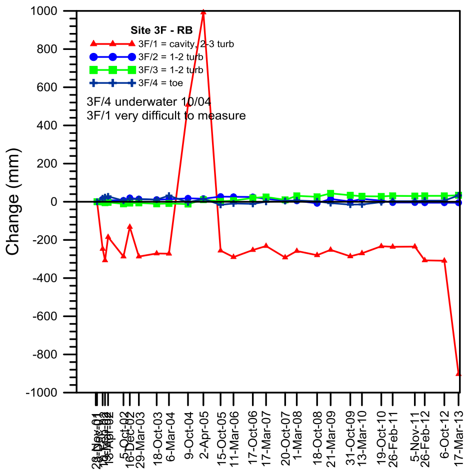

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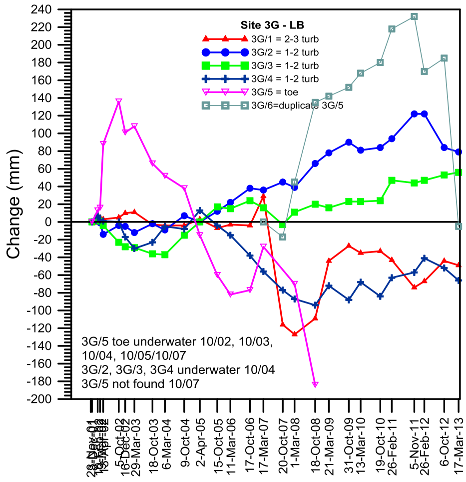
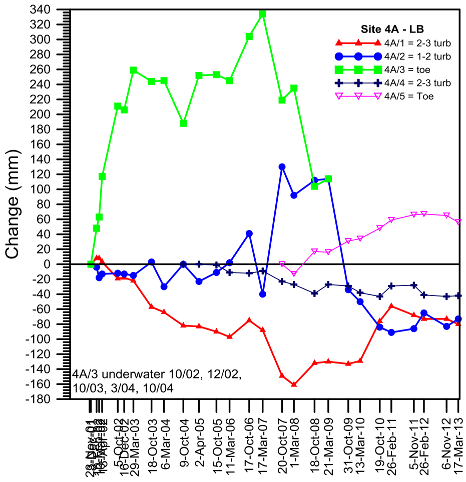
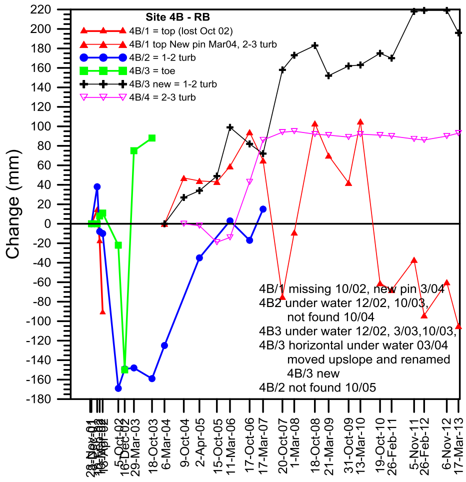


Site 3G

Zone 4



Site 4A



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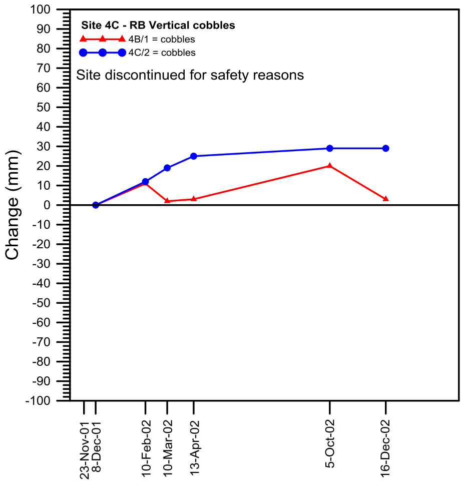

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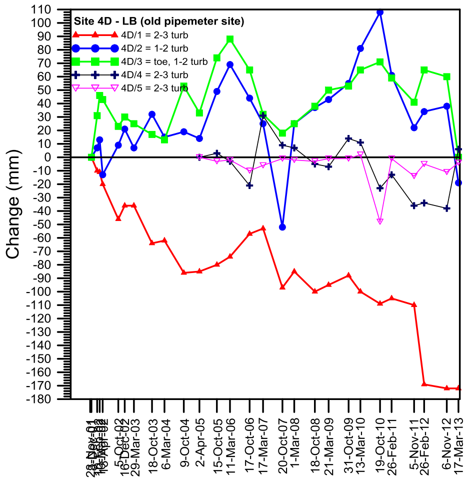

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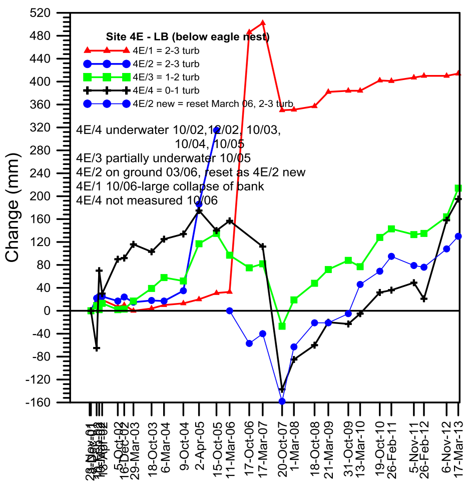

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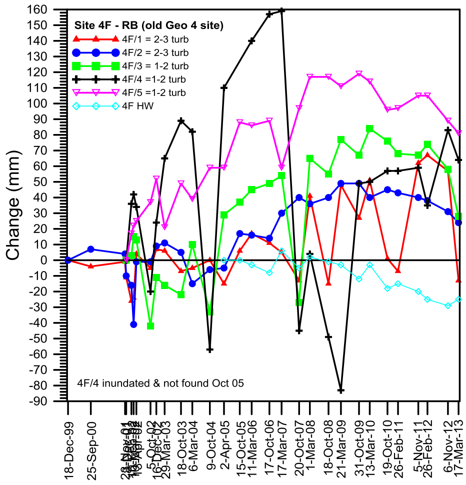

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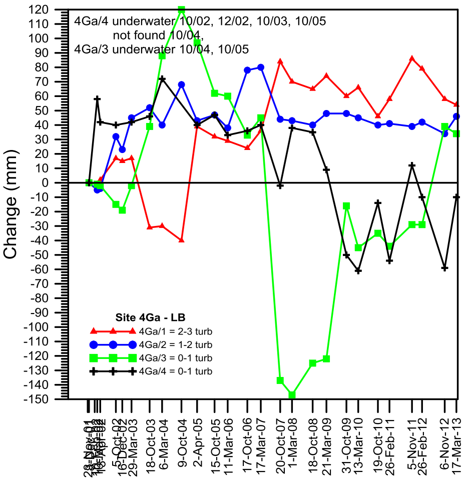

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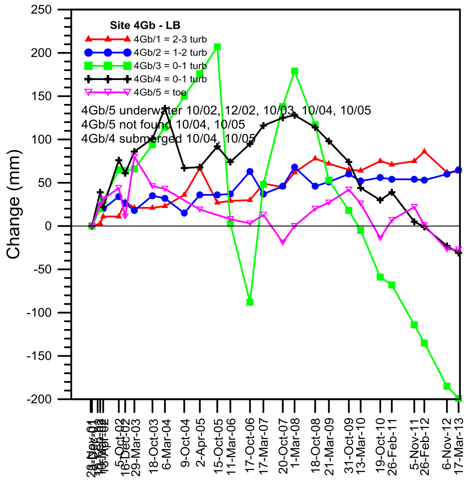

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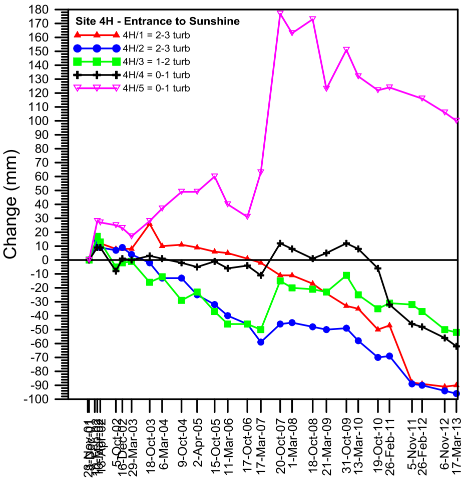
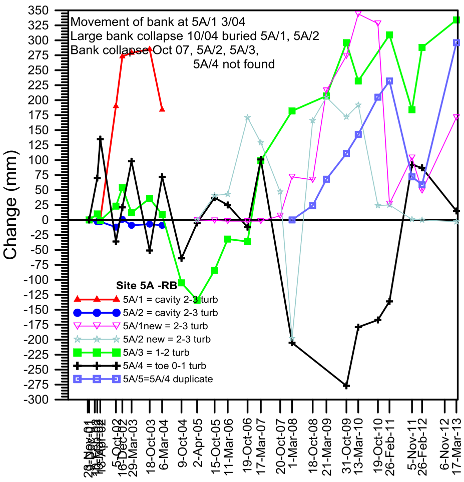
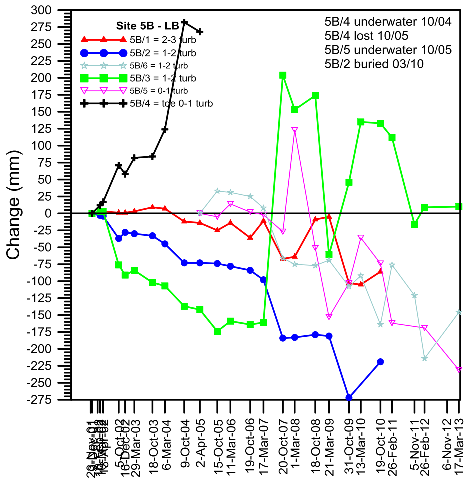


Site 4H

Zone 5

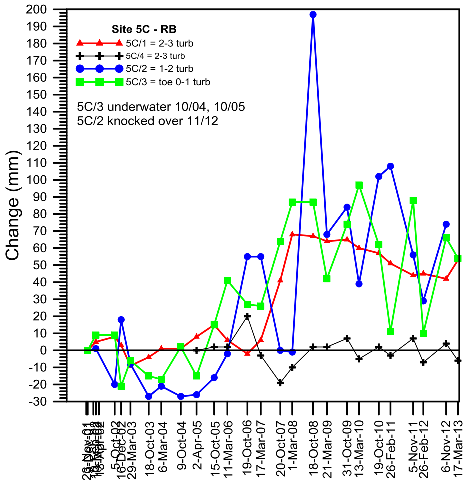


Site 5A

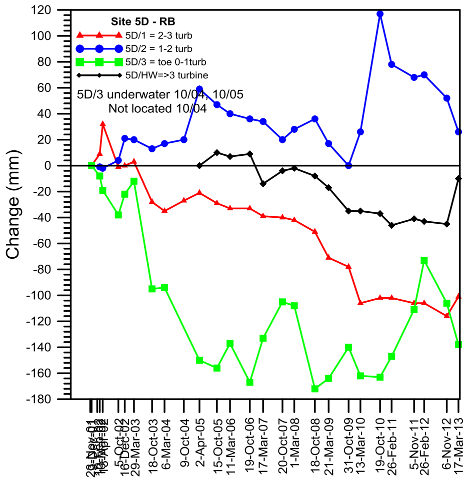


Site 5B

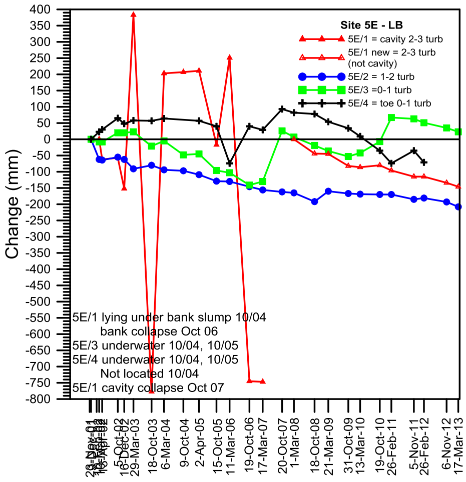
Hydro Tasmania
The power of natural thinking



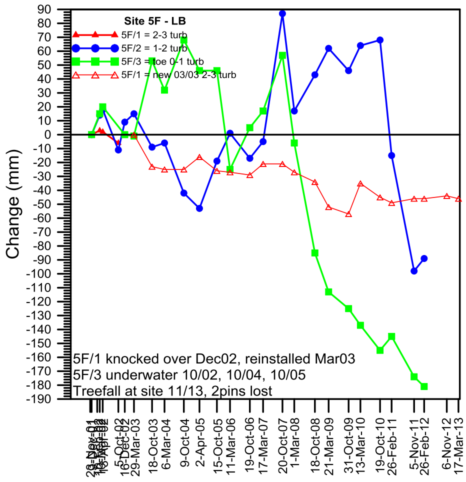
Site 5C



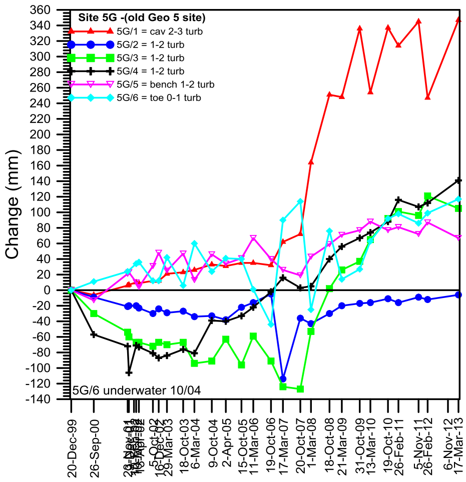
Site 5D



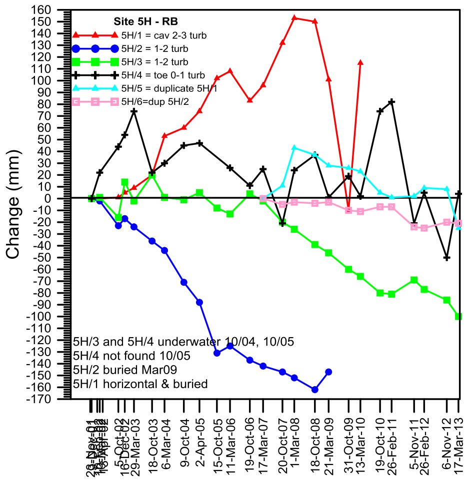
Site 5E



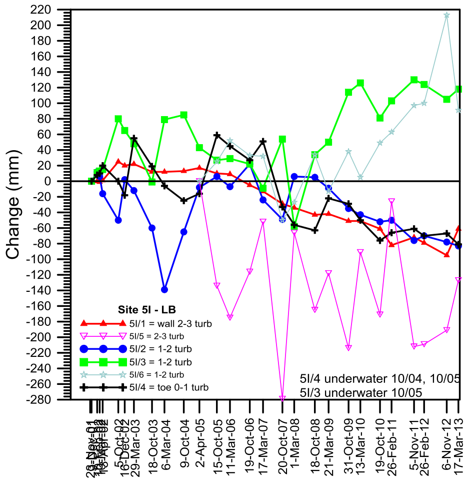
Site 5F



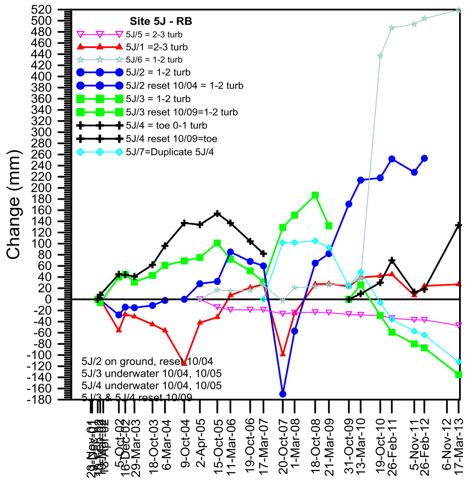
Site 5G



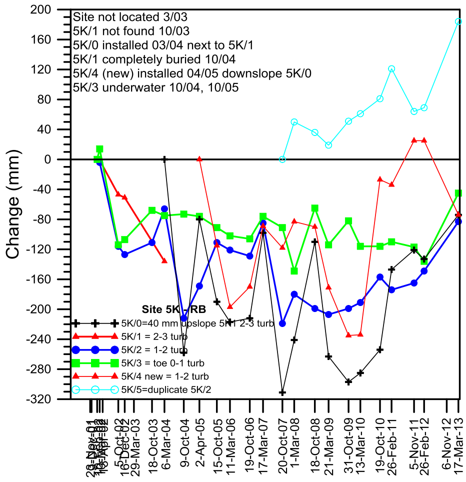
Site 5H



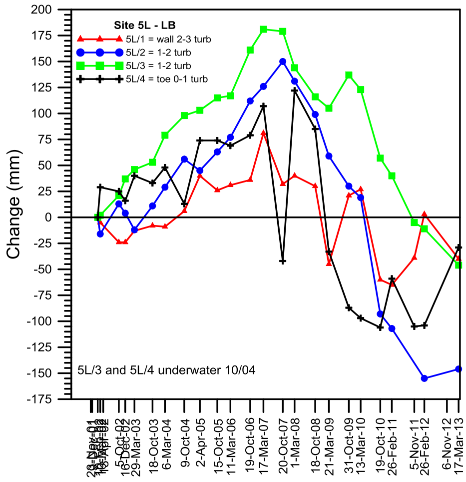
Site 5I



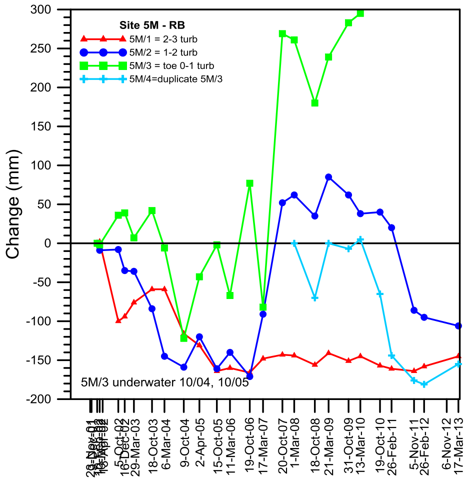
Site 5J



Site 5K



Site 5L



Site 5M

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Appendix 3: Fluvial geomorphology photo-monitoring and site descriptions

Appendix 3.1. Summary of photo-monitoring, March 2013.

Evaluation of changes based on comparison of photos taken in March 2012. P = zone, FI = Flood impact, Mvmt = movement, WD = woody debris, WL = water level, Turb = turbine level

Site	No apparent change	Slip/ tree fall upslope of HW level	Removal of veg at base of slip	Increased veg on slip upslope of HW level	Poor photo-no apparent change	Poor photo-apparent change	No photo obtained	Other
P1-1	03, 04, 05, 06, 07, 08, 09, 10, 11, 12, 13							
P1-2	03, 04, 06, 07, 08, 09, 10, 11, 12, 13				05			
P1-3	03, 04, 05, 06, 07, 08, 09, 10, 11, 12, 13							
P1-4a	03, 04, 05, 07, 08, 10, 11, 12, 13		06				09	
P1-4b	0, 05, 07, 08, 09, 10, 11, 12, 13	03	03, 06					
P1-5	03, 04, 06, 07, 08, 09, 10, 11, 13				05			12 (new log in river)
P2-1a	03, 04, 05, 07, 08, 09, 10, 11, 12, 13							06 Inc in veg bel HW level
P2-1b	03, 04, 05, 09, 12						08	06 Inc in veg bel HW level, 07 less sand on bank toe, 11 sand dep on toe, 13 sand dep on toe
P2-2 new1	08	09						10 eros. Of slumped root mat, 11 Inc veg, mvmt of WD on toe, 12 mvmt WD on toe & sed flows, 13 additional slumping, mvmt WD on toe
P2-2 new2	06, 07, 08, 10, 12	09	05					11 mvmt of WD on toe, 13 mvmt WD on toe
P2-2a	07, 09, 10	04, 08		03, 05	06, 12			13 mvmt WD on toe
P2-2b	03, 04, 07, 13	08, 10, 11		06, 09, 11, 12			05	06, Inc in veg bel HW level,

Site	No apparent change	Slip/ tree fall upslope of HW level	Removal of veg at base of slip	Increased veg on slip upslope of HW level	Poor photo-no apparent change	Poor photo- apparent change	No photo obtained	Other
P2-3	07, 11, 13	04, 08	05	03	06, 10			12 Inc WD on toe
P2-4	11, 12, 13	03		03, 04, 05, 06, 08, 09, 10				07 loss of leaves from tree fall on bank crest; 09 shifting of wd on toe
P2-5	04, 07, 08, 12	03, 11	06			03, 04		04 inc tree fall?, 05 small tree fall or accum of debris on toe; 07 inc sand dep on bank?, 09 mvmt of wd on toe, 10 mvmt of wd on toe, 13 slumping, mvmt WD on toe
P2-6	04, 05, 08							03 inc. coating on cobbles; 06 loss of cobbles, 09 loss of cobbles, 10 scour of cobbles, 11 scour of cobbles, 12 loss of tea tree, 13 mvmt cobble blocks on toe
P2-new3	07, 08, 09, 10, 11, 12							13 mvmt small WD on toe
P2-7	03, 04, 05, 06, 07, 08, 09, 10, 11, 12							13 dep of sands on bank and debris in tea tree, collapse of tea tree
P2-8	03, 04, 05, 06, 07, 08, 09, 10, 11, 12							13 dep sands, collapse of tea tree
P2-9	04, 05, 08, 09,			03, 06, 07, 10, 11, 12		03		07 maybe inc erosion on face, 10 & 11 mvmt wd on toe, 13 mvmt WE on toe
P2-10	03, 04, 05, 06, 07, 08, 09, 11, 12					13		
P2-11	04, 05, 06, 07, 08				09, 11		03, 10 poor light	Discontinued 2011
P3-1	04, 05, 06, 07, 08, 09, 10, 12, 13		03					11 change to WD on toe
P3-2	03, 04, 05, 07, 08, 09, 11, 12, 13						06	10 mvmt wd on toe
P3-3	03, 04, 05, 09, 11			07				06 flood debris 08 loss of small veg in 2-3 turb, 10 mvmt wd on toe, 12 mvmt to WD on toe, 13 mvmt WE on toe

Site	No apparent change	Slip/ tree fall upslope of HW level	Removal of veg at base of slip	Increased veg on slip upslope of HW level	Poor photo-no apparent change	Poor photo-apparent change	No photo obtained	Other
P3-4	04, 05, 06, 07, 08, 09	10, 11				03	13	03 may not be same site, 12 mvmt to WD on toe
P3-5	03, 04, 05, 06, 07, 10, 11, 12, 13	09						08 removal of WD & veg (FI)
P4-new1	07, 11, 12	09, 10						08 new wd on toe (FI), 13 mvmt WD on toe, new slump
P4-new2	07				09, 12			08 new wd on toe (FI);09 poor light conditions, 10, 11 mvmt wd on toe
P4-1	03, 04, 05, 06, 07, 08, 09, 10, 12, 13						11	
P4-new3	07, 09, 10, 11, 12						13	08 loss of WD from toe (FI)
P4-2	04, 08, 09, 11, 12	07			03			06 inc veg 2-3 turb level, 10 mvmt WD on toe, 13 mvmt WD and slumping
P4-3	05, 06, 12	10	03, 04, 09					07 overhanging veg may be lower 08 inc WD on toe (FI); 09 loss of fine branches on toe wd, 11 mvmt of WD on toe, 13 mvmt WE and pebbles/cobbles on toe
P4-4a	03, 04, 05, 07, 08, 09, 10, 11, 12		06				13	
P4-4b	03, 04, 05, 09, 10, 11, 12		06					07 movmt of WD 08change to WD (FI)
P4-4c	07, 08, 09, 10, 11, 12							04, change to dist'n of sand on cobble bar; 06 loss of flood debris
P4-5	03, 04, 05, 06, 07, 08, 09, 10,11, 12				13			
P4-6	03, 04, 07, 08, 09, 11, 12, 13				05, 06		10	
P4-7	04, 06, 08, 09			05	03		10 (bad light), 11, 13	07 movmt of submerged wd, 12 mvmt of WD

Site	No apparent change	Slip/ tree fall upslope of HW level	Removal of veg at base of slip	Increased veg on slip upslope of HW level	Poor photo-no apparent change	Poor photo-apparent change	No photo obtained	Other
P4-8	04, 05, 06, 07, 09, 10, 13				03			08 movmt of WD (FI), 11 mvmt of WD on toe, 12 mvmt of WD on toe
P5-1	04, 05, 06, 07, 08, 09, 10, 11, 12, 13					03		03 extra slip?
P5-2	03, 04, 06, 07, 08, 09, 10, 11, 12		05					13 mvmt WE on toe
P5-3	04, 06, 08, 09, 11, 12, 13			05	03, 07		10	
P5-4	03, 04, 05, 06, 07, 09, 10, 11, 13	12					08	
P5-5	05, 08, 09, 12					04	11	04, additional small tree fell, 06 movement of veg d/slope, 07 loss of branches, 10 mvmt wd on toe, 13 mvmt WD on oe
P5-6	04, 07, 09, 10, 11, 12, 13			05, 06	03,			06 inc veg 2-3 turb 08 movmt of WD on toe (FI)
P5-7	04, 07, 08, 09, 10		05	06	03			06 inc veg 2-3 turb, 11 mvmt WD on toe, 12 mvmt WD on toe, 13, mvmt WD on toe
P5-8	04, 06, 07, 08, 09, 10, 11, 12, 13			05	03			
P5-9	03, 04, 05, 06, 07						11	08 inc WD on toe (FI), 09 mvmt wd on toe, 12 mvmt WD on toe, mvmt WD on toe
P5-10	04, 05, 07, 08, 09, 10, 11, 12, 13		03					06 inc WD at base
P5-11	03, 04, 07, 08, 09, 10, 11, 12, 13		06	05				05 inc veg below high WL
P5-12	04, 05, 07, 09, 10, 11, 12, 13		03					06 inc WD at base 08inc SWD on toe
P5-13	03, 04, 05, 06, 07, 08, 11, 12, 13	10					09	
P5-14	03, 04, 07	10		06	11		09	08 inc WD on toe (FI), 12 mvmt WD on toe (dif angle), 13 mvmt WD on toe

Site	No apparent change	Slip/ tree fall upslope of HW level	Removal of veg at base of slip	Increased veg on slip upslope of HW level	Poor photo-no apparent change	Poor photo-apparent change	No photo obtained	Other
P5-15	04, 05, 06, 07, 08, 09, 10, 11, 12, 13			03 inc. in veg on bar		03		
P5-16	06, 07, 08, 09, 10, 11, 12, 13		03	04, 05				03 movement of branch downslope
P5-17	03, 04, 06, 08, 09		05	07	12			06 maybe inc veg in 2-3 turb, 10&11 mvmt wd on bank
P5-18	04, 05, 06, 08, 09, 10, 12							03 may not be same site;07 new dead tree fall, 11 mvmt WD on toe, 13 bank slump
P5-19	06, 07, 09, 13			04, 05, 10, 11, 12	03			08 Erosion of slip face-major change
P5-20	04, 05, 06, 07, 08, 09, 10, 11, 13				03, 12			
P5-21	04, 07, 10, 12			09	11		03, 05	06 inc veg 2-3 turb 08 loss of veg 2-3 turb (may not be same site), 13 mbmt to WD
2013Total	30	0	0	0	2	0	5	21

Appendix 3.2. Photo monitoring photos

Zone 1

Zone 1, site 1


(L-R) 9 March 2002, 29 March 2003

No data available for 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 1, site 2

(L-R) 9 March 2002, 29 March 2003

(L-R) 6 March 2004, 3 April 2005, 11 March 2006

(L-R) 17 March 2007, 1 March 2008, 21 March 2009

(L-R) 13 March 2010, 26 February 2011, 25 February 2012

17 March 2013

Zone 1, site 3



(L-R) 9 March 2002, 29 March 2003, 6 March 2004



(L-R) 3 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

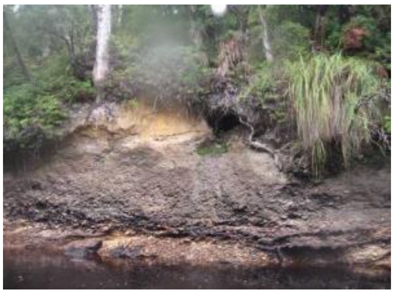
Zone1 site 4


(L-R) 9 March 2002, 29 March 2003



(L-R) 6 March 2004, 3 April 2005, 11 March 2006





(L-R) 17 March 2007, 1 March 2008, 21 March 2009 (wrong site, slightly upstream)



(L-R) 13 March 2010, 26 February 2011, 25 February 2012, 17 March 2013

Zone 1 site 4b

(L-R) 9 March 2002, October 2002, 29 March 2003.

Note vegetation at base in 2002 which is absent in 2003

(L-R) 6 March 2004, 3 April 2005, 11 March 2006

(L-R) 17 March 2007, 1 March 2008, 21 March 2009

(L-R) 13 March 2010, 26 February 2011, 25 February 2012

17 March 2013

Zone 1, site 5



(L-R) 9 March 2002, 29 March 2003, 6 March 2004



(L-R) 3 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 2

Zone 2 site 1a

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 3 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 2, site 1b

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 3 April 2005, 11 March 2006, 17 March 2007

Photo not taken 1 March 2008 (field error)—no changes noted in field notes.

(L-R) 21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013

Zone 2, site new 1

(L-R) 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009

(L-R) 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013

Zone 2, site new 2

(L-R) 6 March 2004, 9 April 2005, 11 March 2006

(L-R) 17 March 2007, 1 March 2008, 21 March 2009

(L-R) 13 March 2010, 26 February 2011, 25 February 2012

17 March 2013

Zone 2, site 2a

(L-R) 9 March 2002, 29 March 2003, 6 March 2004 (d/s end)

(L-R) 9 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

Photo not taken in 2011

(L-R) 25 February 2012, 17 March 2013

Zone 2, site 2b

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

Photo not taken April 2005

(L-R) 11 March 2006, 17 March 2007, 1 March 2008

(L-R) 21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013

Zone 2, site 3

(L-R) 9 March 2002, 29 March 2003, 11 March 2006

(L-R) 17 March 2007, 1 March 2008, 21 March 2009

(L-R) 13 March 2010, 26 February 2011, 25 February 2012

17 March 2013

Zone 2, site 4

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 9 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 2, site 5

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 9 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 2, site 6

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 9 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 25 February 2012 (loss of tea tree)

17 March 2013

Zone 2, site new 3


(L-R) 17 October 2006, 17 March 2007


(L-R) 1 March 2008, 21 March 2009


(L-R) 13 March 2010, 26 February 2011


(L-R) 25 February 2012, 17 March 2013

Zone 2, site 7



(L-R) 9 March 2002, 29 March 2003, 6 March 2004



(L-R) 9 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 2, site 8

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 9 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 2 site 9



(L-R) 9 March 2002, 29 March 2003, 6 March 2004



(L-R) 9 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 2, site 10



(L-R) 9 March 2002, 29 March 2003, 9 April 2005

Photo not obtained in March 2004


(L-R) 11 March 2006, 17 March 2007, 1 March 2008



(L-R) 21 March 2009, 13 March 2010, 26 February 2011


(L-R) 25 February 2012, 17 March 2013

Zone 2, site 11

(L-R) 9 March 2002, 9 April 2005

No suitable photo obtained March 2003 or March 2004

(L-R) 11 March 2006, 17 March 2007, 1 March 2008

(L-R) 21 March 2009, 26 February 2011

No photo obtained March 2010
Site discontinued in 2012 as difficult to obtain similar photos from chopper

Zone 3

Zone 3, site 1



(L-R) 9 March 2002, 29 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 3 site 2


(L-R) 9 March 2002, 29 March 2003


(L-R) 6 March 2004, 2 April 2005

Photo not taken 11 March 2006



(L-R) 17 March 2007, 1 March 2008, 21 March 2009



(L-R) 13 March 2010, 26 February 2011, 25 February 2012

17 March 2013

Zone 3, site 3

(L-R) 9 March 2002, 29 March 2003

(L-R) 6 March 2004, 2 April 2005

Wrong site photographed in 2006

(L-R) 17 March 2007, 1 March 2008, 21 March 2009

(L-R) 13 March 2010, 26 February 2011, 25 February 2012

17 March 2013

Zone 3 site 4

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012

No photo taken in 2013

Zone 3 site 5

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009 (different site), 13 March 2010 (different site)

(L-R) 26 February 201, 25 February 2012, 17 March 2013 –correct site

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Zone 4

Zone 4, site new 1


(L-R) October 2006, 17 March 2007


(L-R) 1 March 2008, 21 March 2009


(L-R) 13 March 2010, 26 February 2011


(L-R) 25 February 2012, 17 March 2013

Zone 4, site new 2


(L-R) October 2006, 17 March 2007


(L-R) 1 March 2008, 21 March 2009


(L-R) 13 March 2010, 26 February 2011

25 February 2012 (taken from different angle)

No photo taken in 2013

Zone 4, site 1



(L-R) 10 March 2002, 29 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010

Site not photographed in February 2011


(L-R) 25 February 2012, 17 March 2013

Zone 4, site new 3


(L-R) October 2006, 17 March 2007


(L-R) 1 March 2008, 21 March 2009


(L-R) 13 March 2010, 26 February 2011

25 February 2012

Not photographed in March 2013

Zone 4, site 2

(L-R) 10 March 2002, 29 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 4, site 3

(L-R) 10 March 2002, 29 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 4, site 4a

(L-R) 10 March 2002, 29 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012

No photo taken in 2013 March

Zone 4, site 4b

(L-R) 10 March 2002, 29 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 4, site 4c

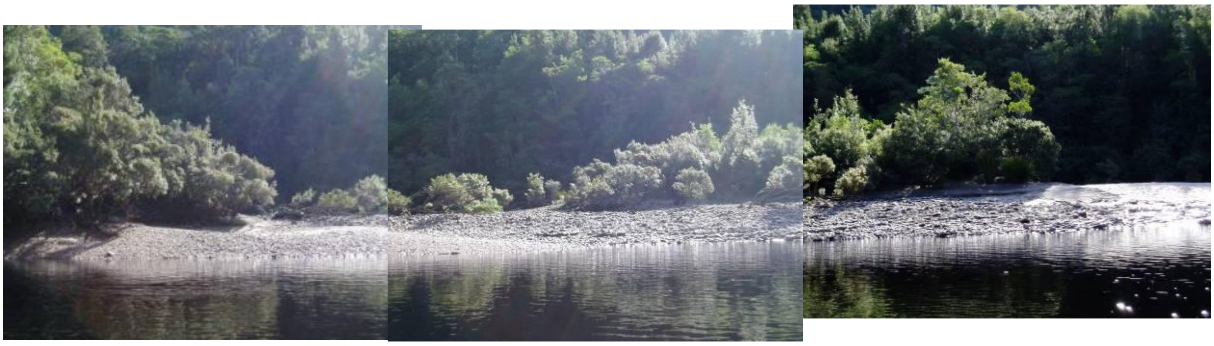
10 March 2002

29 March 2003

6 March 2004

2 April 2005

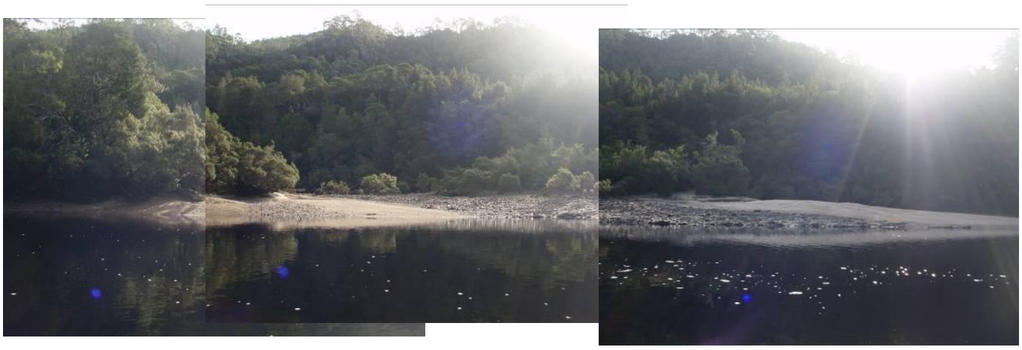
Zone 4, site 4c continued



11 March 2006

17 March 2007

1 March 2008



21 March 2009

Zone 4, site 4c continued

13 March 2010

26 February 2011

26 February 2012

No photo taken in March 2013

Zone 4, site 5

(L-R) 10 March 2002, 29 March 2003

(L-R) 29 6 March 2004, 2 April 2005, 11 March 2006

(L-R) 17 March 2007, 1 March 2008

(L-R) 21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013 (upstream end)

Zone 4, site 6

(L-R) 10 March 2002, 29 March 2003, 6 March 2004, 2 April 2005

(L-R) 11 March 2006, 17 March 2007, 1 March 2008, 21 March 2009

Photo not obtained March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 4, site 7



(L-R) 10 March 2002, 29 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007


(L-R) 1 March 2008, 21 March 2009

Photo not obtained in March 2010 or February 2011

25 February 2012

No photo taken in March 2013

Zone 4, site 8

(L-R) 10 March 2002, 29 March 2003, 6 March 2004, 2 April 2005

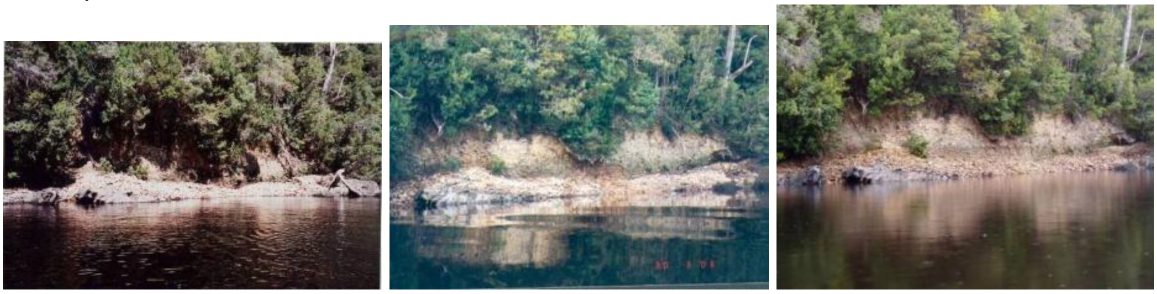
(L-R) 11 March 2006, 17 March 2007, 1 March 2008

(L-R) 21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013

Zone 5

Zone 5, site 1



(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 5, site 2



(L-R) 10 March 2002, 30 March 2003, 6 March 2004




(L-R) 2 April 2005, 11 March 2006, 17 March 2007, 1 March 2008



(L-R) 21 March 2009, 13 March 2010, 26 February 2011

Photo not obtained February 2012

17 March 2013

Zone 5, site3

(L-R) 10 March 2002, 30 March 2003, 6 March 2004, 2 April 2005

(L-R) 11 March 2006, 17 March 2007, 1 March 2008, 21 March 2009

Photo not obtained March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 5, site 4

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

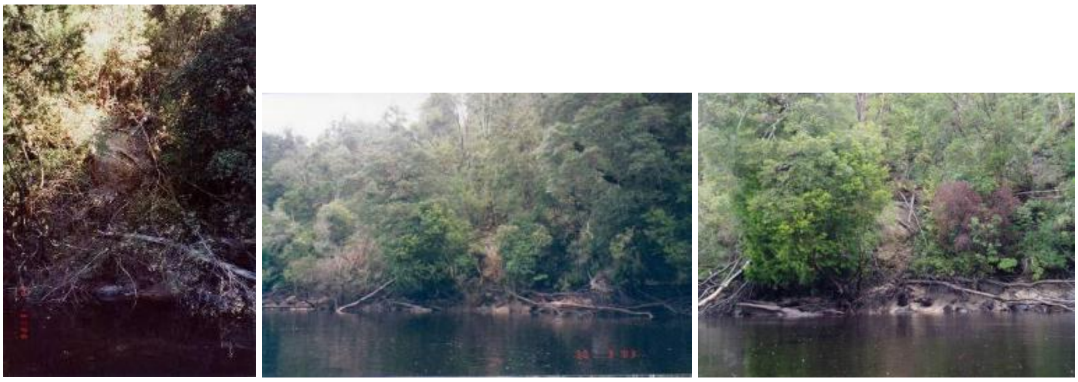
(L-R) 2 April 2005, 11 March 2006, 17 March 2007

Photo not taken in March 2008

(L-R) 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 5, site 5



(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

Not photographed in February 2011

(L-R) 25 February 2012, 17 March 2013

Zone 5, site 6

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 5, site 7




(L-R) 10 March 2002, 30 March 2003, 10 March 2004, 2 April 2005



(L-R) 11 March 2006, 17 March 2007, 1 March 2008



(L-R) 21 March 2009, 13 March 2010, 26 February 2011


(L-R) 25 February 2012, 17 March 2013

Zone 5, site 8

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 5, site 9



(L-R) 10 March 2002, 30 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010

Not photographed in February 2011


(L-R) 25 February 2012, 17 March 2013

Zone 5, site 10

(L-R) 10 March 2002, 30 March 2003, 6 March 2004, 2 April 2005

(L-R) 11 March 2006, 17 March 2007, 1 March 2008

(L-R) 21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013

Zone 5, site 11

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 5, site 12

(L-R) 10 March 2002, 30 March 2003, 6 March 2004, 2 April 2005

(L-R) 11March 2006, 17 March 2007, 1 March 2008

21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013

Zone 5, site 13

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 13 March 2010 (wrong site), 26 February 2011

Photo not taken March 2009

(L-R) 25 February 2012, 17 March 2013

Zone 5, site 14

(L-R) 10 March 2002, and March 2003

Photo not taken in 2004 and 2005.

(L-R) 11 March 2006, 17 March 2007, 1 March 2008

Photo not taken in March 2009

(L-R) 13 March 2010, 26 February 2011, 25 February 2012

17 March 2013

Zone 5, site 15

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 11 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 5, site 16



(L-R) 10 March 2002, 30 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 5, site 17

(L-R) 9 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012 (taken on different angle), 17 March 2013

Zone 5, site 18

(L-R) 9 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 5, site 19

(L-R) 9 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 5, site 20



L-R) 9 March 2002, 30 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

Zone 5, site 21

(L-R) 30 March 2003, 6 March 2004, 11 March 2006, 17 March 2007

Photo not obtained in March 2002, or in April 2005

(L-R) 1 March 2008 (may not be same site), 21 March 2009 (correct site), 21 March 2009

(L-R) 13 March 2010, 26 February 2011, 25 February 2012, 13 March 2013

Appendix 4: Macroinvertebrate data

Appendix 4.1. Quantitative macroinvertebrate ‘family level’ data

Abundances as n per 0.18 m^2 for Gordon and reference sites sampled in spring 2012. Gordon River sampled on 6 October 2012 and reference rivers samples on 3 December 2012.

			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**														
Platyhelminthes	Turbellaria						1			2	2	10	2	4		1	5
Nematoda					2			1	1	1	2	6		1			3
Mollusca	Bivalvia	Sphaeriidae				1											
	Gastropoda	Hydrobiidae			3		15			4	1	22	1	4		4	
		Ancylidae										1					
		Gastr. Unid.			1												
Annelida	Oligochaeta				45	12	30	33	25	49	10	99	42	18		38	120
Arachnida	Acarina						1					1	1	1			
Crustacea	Amphipoda	Paramelitidae						1		1			1	1			
		Eusiridae										1					
		Paracalliopidae									1						
		Neoniphargidae		3		2	2										
	Isopoda	Janiridae			6	1	1				3	9	8	1			1
		Phreatoicidea					1										
Insecta	Plecoptera	Eustheniidae			2		3					1	1			1	3
		Gripopterygidae		3	5	6	27	4		9	11	5	1	7		10	7
		Notonemouridae				2	2		1	1							
	Ephemeroptera	Leptophlebiidae			1	11	24	23	13	30	4	121	56	81		143	113
		Baetidae						3	3	1	1	4	2	20		19	24
	Diptera	Chironomidae:	*Chironominae*			4	47	1		34	4	1	3	18			
		Chironomidae:	*Orthocladiinae*	15	64	1	30	3	1	8	20	4	4	4		24	10
		Chironomidae:	*Podonominae*				1	2		7	3	2	1	2		3	3
		Chironomidae:	*Diamesinae*	3	5					3	2					1	
		Chironomidae:	*Aphroteniinae*				1		1			3	1	1		1	
		Simuliidae		9	40	2	16	49	71	125	10	38	93			7	24

Class	Order	Family	Sub family														
			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
		Tipulidae					1			2		1					
		Blephariceridae							6	4		10	19	1		1	
		Ceratopogonidae			1		1		1		2	4					
		Empididae					1						1			3	1
		Tanyderidae															1
		Dip. Unid. Pup.		2	4	2	1	4	1	7	3	9	8	4		5	3
	Trichoptera	Calocidae								1				1			4
		Conoesucidae			13	2	13	1	2	17	2		2	5		1	2
		Ecnomidae															
		Glossosomatidae						1		2		1	1				9
		Hydrobiosidae		4	7	2	14	2		1	4	7	5	4		18	17
		Hydropsychidae		3	29	1	5		1	2			1	2		4	7
		Hydroptilidae														3	
		Leptoceridae		1		1	4			3		20	7	5		12	18
		Philopotamidae												1		2	1
		Philorheithridae					1			3		2		1			
		Trich. Unid. Pup.								1		3	3	1		1	2
	Coleoptera	ElmidaeA				3	2	3	3	4		7	5	52		51	72
		ElmidaeL			1		4	7	2	6		66	17	86		68	77
		ScirtidaeL				2	5	1				3		1		1	1
		PsepheniidaeL								1		3	2	1		2	1
			Total abundance	**43**	**229**	**55**	**254**	**139**	**132**	**329**	**85**	**464**	**288**	**328**	**NA**	**424**	**529**
			N Taxa (families)	**9**	**17**	**17**	**28**	**17**	**15**	**28**	**18**	**30**	**27**	**28**	**NA**	**26**	**26**

Appendix 4.1 continued

Appendix 4.2. Quantiative ‘species level’ data for EPT taxa

Ephemeroptera, Plecoptera and Trichoptera for Gordon and reference sites sampled in spring 2012 (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
		Old site code:	G4	G4a	G5	G6	G9	G10	G11B	G15	G19	G20	G21	D1	M1	J1
x = formerly Baetid Genus 2 MV sp3		**Date:**	06/10/2012	06/10/2012	06/10/2012	06/10/2012	06/10/2012	06/10/2012	07/10/2012	06/10/2012	03/12/2012	03/12/2012	03/12/2012		03/12/2012	03/12/2012
Order	**Family**	**Genus/Species**														
Ephemeroptera	Baetidae	x Offadens hickmani					3	3	1	1	4	2	20		19	24
	Leptophlebiidae	Nousia sp. AV5/6			7	2	20	13	24	2	120	52	79		131	110
		Nousia sp. AV7		1	3	19			6	2	1	1	1		2	
		Nousia sp. AV9				1						1	1		8	
		Tillyardophlebia sp AV2			1	2	3					2			2	3
Plecoptera	Eustheniidae	Eusthenia costalis										1			1	1
		Eusthenia spectabilis		2		3					1					2
	Gripopterygidae	Cardioperla incerta			3	4			8	6			2		4	1
		Cardioperla media/lobata	1	1	2	17	3			4					2	2
		Dinotoperla serricauda								1	1	1			1	
		Leptoperla varia		1		5									1	
		Trinotoperla inopinata		1		1										
		Trinotoperla tasmanica													2	
		Trinotoperla zwicki	2	2	1		1		1		4		5			4
	Notonemouridae	Austrocercoides sp						1	1							
Trichoptera	Calocidae	Caenota plicata							1							
		Tamasia variegata											1			4
	Conoesucidae	Conoesucus nepotulus		7	1	12		2	2	1		1				
		Conoesucus norelus		1	1	1	1		15	1		1	5			2
		Conoesucus sp. AV6		5												
		Matasia satana													1	
	Glossosomatidae	Agapetus sp. AV1					1		2		1	1				9
	Hydrobiosidae	Apsilochorema obliquum													1	2
		Moruya opora	1	2		2	1		1	3			1		1	1
		# Taschorema apobamum	1		1						2				5	5
		# Taschorema asmanum			1	1	1				3	2	3		6	5
	Includes all#	Taschorema ferulum grp	2	5		11				1	1	2			4	3
		Ulmerochorema rubiconum									1	1			1	1
	Hydropsychidae	Asmicridea sp. AV1	3	29	1	5		1	2			1	2		4	7
	Hydroptilidae	Maydenoptila cuneola													3	
	Leptoceridae	Notalina sp.AV1							2		1					
		Notalina sp.	1		1	4			1		19	7	5		12	17
		Triplectides proximus														1
	Philopotamidae	Hydrobiosella waddama											1		2	1
	Philorheithridae	Tasmanthrus angustipennis							1							
		Tasmanthrus galbinomaculatus				1										
		Tasmanthrus sp.							2		2		1			
		Abundance EPT	**11**	**57**	**23**	**91**	**34**	**20**	**70**	**22**	**161**	**76**	**127**	**NA**	**213**	**205**
		N EPT Taxa	**7**	**12**	**12**	**17**	**9**	**5**	**16**	**10**	**14**	**15**	**14**	**NA**	**22**	**21**

Appendix 4.3. RBA macroinvertebrate data

Abundances per live picked sample for Gordon River and reference sites sampled in spring 2012.

			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			1	1													1		1			1		1						
Nematoda																															1
Nematomorpha		Gordiidae																				1		1							
	Gastropoda	Hydrobiidae										1						1												11	2
Annelida	Oligochaeta				2	8	7	3	4	10	10	1	9	11	9	10	12	5	4	19	10	4	10	9	5			27	17	6	6
Arachnida	Acarina																	1	1	1		2		3						6	
Crustacea	Amphipoda	Paramelitidae						1	1		2	1	1			4	3	1						2	2					1	
		Ceinidae														1		2													
		Paracalliopidae																	1												
		Neoniphargidae		3	3	4	2			2	4	1	1				1		1												
	Isopoda	Janiridae		3	1																									1	
		Phreatoicidea				1																								1	1
Insecta	Plecoptera	Eustheniidae		1	4	2	1	1			1			1	2	2	4			1	1	2	2	7	3			1		1	2
		Austroperlidae			1	2	1																								
		Gripopterygidae		13	17	21	28	44	38	22	21	8	6	8	9	31	27	21	12	15	12	7		1	2				5	10	14
		Notonemouridae			1	1	1	4			1					1		2	1												
	Ephemeroptera	Leptophlebiidae		6	6	4	7	54	31	22	22	61	38	40	87	69	59	28	18	59	48	106	61	124	107			99	78	47	62
		Baetidae										5	3	3	9	3	5	3	6	13	10	8	2	6	1			8	9	8	4
	Diptera	Chironomidae:	*Chironominae*	1				1	1	3					1	5	7	10	1	2	2		5	5	1						
		Chironomidae:	*Orthocladiinae*	15	15	3	15	8	5	1			1			5	4	10	11			3	3		1					1	13
		Chironomidae:	*Podonominae*					3	1	2	2	22	14	12	20	10	29	15	26	4	1	2			1			2			1
		Chironomidae:	*Tanypodinae*																			1			1						
		Chironomidae:	*Diamesinae*	1	1		5											1	1												
		Chironomidae:	*Aphroteniinae*										1																		
		Simuliidae		12	12	7	7	1	2	3	5	23	23	28	25	13	14	2	8	12	10	15	9	2	8			1	6		2
		Tipulidae			2				2		2						1		1	1			1	1	1						2
		Athericidae																												1	
		Blephariceridae																		3	6	1	4	1					1		
		Ceratopogonidae																					4								
		Empididae																													1
		Dip. Unid. Pup.							1						1	1	1	1	1												
	Trichoptera	Calocidae																				1		2	1					2	1
		Conoesucidae					5	12	9			1		1		1		2	3		2	1	1						4	4	2
		Glossosomatidae														1															
		Helicophidae																													1
		Helicopsychidae																													1
		Hydrobiosidae		84	117	25	42	34	18	12	17	11	10	17	11	19	25	8	13	43	47	43	27	16	33			33	23	17	35
		Hydropsychidae		2	3	21	30						1			1	1			2	1	1	2								1
		Leptoceridae				2			1	1	2	1	1			1	2			13	2	8	4	6	13			3	1	2	12
		Philopotamidae																		3		3		1					1		1
		Philorheithridae						1	1	2	5	5	1	3	2		5	1		4	3	4	2	4	1			2	2	4	2
		Trich. Unid. Pup.				1	1				1	1		1		2				4	3	3	1	2							2
	Coleoptera	ElmidaeA		2		1	4		3			1	5	3		4	2	5	1	38	38	21	10	13	14			30	22	36	65
		ElmidaeL												2		1				8	4	1		1	1			2	3	4	2
		ScirtidaeL						3	1	5	2			1	4								1	2					1		
		PsepheniidaeL			1																2	2			3			1	3	10	
			N Taxa	**13**	**16**	**15**	**15**	**14**	**16**	**12**	**15**	**15**	**15**	**14**	**12**	**21**	**18**	**20**	**18**	**20**	**18**	**23**	**19**	**21**	**20**	**NA**	**NA**	**12**	**15**	**20**	**25**

Appendix 4.4. Quantitative macroinvertebrate ‘family level’ data

Abundances as n per 0.18 m^2 for Gordon and reference sites sampled in autumn 2013.

			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
			Date:	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013
			Sampler	JG	PD	PD	RM	JG	PD	LC	JJ	JJ	LC	PD	JG	RM	LC
			Picker:	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
			Identifier:	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
Class	**Order**	**Family**	**Sub family**														
Platyhelminthes	Turbellaria				4	1	1	7	5	2		2	13	6		1	3
Nematoda					3			1	8	1	3	5		1		15	
Mollusca	Bivalvia	Sphaeriidae							3								
	Gastropoda	Hydrobiidae		2	3		6	9	21	8	5	13	4	3	2	147	1
		Ancylidae									1	10	16				
		Glacidorbidae			1	1											
Annelida	Oligochaeta				56	89	9	96	118	99	78	76	58	147	21	57	37
Arachnida	Acarina								1	1			1	4	1	2	1
Crustacea	Amphipoda	Paramelitidae							6	1	1	1		1		1	
		Neoniphargidae		1	1				1								
	Isopoda	Janiridae			90	3	2			1	9	6	46	24		11	
		Phreatoicidea					2		1								
Insecta	Plecoptera	Eustheniidae							1		1	1	2	8	6	2	
		Gripopterygidae		2	6	6		7	5	1	1	3	5	2	3	7	7
		Notonemouridae										1		2			
	Ephemeroptera	Leptophlebiidae			5	5	6	5	24	8	13	47	67	194	78	87	51
		Baetidae										6	6	53	27	11	28
	Diptera	Chironomidae:	*Chironominae*		3	4	7	10	4	3		23	8	436	14	6	2
		Chironomidae:	*Orthocladiinae*		9	62	1		3	1		7	1	20		9	3
		Chironomidae:	*Podonominae*						1		2	1					
		Chironomidae:	*Aphroteniinae*						1			3		5			
		Simuliidae		1	183	255	80	174	638	449	114	9		28	8	2	2
		Tipulidae				2			4		1	2		8	1	1	
		Blephariceridae							2	1	4						
		Ceratopogonidae							1							1	
		Empididae			1			1	2	1	2	1	3	1	1	1	1
		Dip. Unid. Pup.			1	5		7	1	14	1			3	1		
	Trichoptera	Calocidae		1								1		1		8	10
		Conoesucidae		5		2	1	1	4		2	4	3	5	1	40	28
		Glossosomatidae										10	4	5			20
		Helicophidae					1									1	
		Hydrobiosidae		1	3	9	1	4	8	3	4	4		18	7	3	5
		Hydropsychidae		1	27	2	2		2	1	2	1	1	42	12	1	34
		Hydroptilidae					1									1	
		Leptoceridae						1		3	1	10	51	40	14	20	14
		Philopotamidae													1		
		Philorheithridae		1		1		1				1	8	11	13	14	5
		Trich. Unid. Pup.			3	2		2	1	1	2	2				1	
	Coleoptera	ElmidaeA			2			10	10	9	11	4	11	43	31	20	46
		ElmidaeL		1	1	5	3	14	17	5	7	26	53	217	52	87	92
		ScirtidaeL				9			4	1	1	52	45	157	43	32	32
		PsepheniidaeL										1	1	4		1	1
			Total abundance	**16**	**395**	**462**	**122**	**342**	**884**	**611**	**263**	**326**	**394**	**1482**	**337**	**574**	**420**
			N Taxa (families)	**10**	**17**	**17**	**14**	**15**	**27**	**20**	**22**	**29**	**21**	**28**	**21**	**28**	**21**

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Appendix 4.5. Quantitative 'species level' data for EPT taxa

Ephemeroptera, Plecoptera and Trichoptera for Gordon and reference sites sampled in autumn 2013 (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
		Old site code:	G4	G4a	G5	G6	G9	G10	G11B	G15	G19	G20	G21	D1	M1	J1
		Date:	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	17/03/2013	18/03/2013
		Sampler	RM	PD	PD	RM	JG	PD	LC	JJ	JJ	LC	PD	JG	RM	LC
		Picker:	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
x = formerly Baetid Genus 2 MV sp3		Identifier:	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
Order	**Family**	**Genus/Species**														
Ephemeroptera	Baetidae	x Offadens hickmani									6	6	53	27	11	28
	Leptophlebiidae	Austrophlebioides sp. AV7												1		
		Nousia sp. AV5/6		3	4	2	4	16	8	13	37	49	152	71	34	51
		Nousia sp. AV7		2		4	1	7			5	2	26	3	14	
		Nousia sp. AV9			1			1			1				39	
		Tillyardophlebia sp AV2									4	16	16	3		
Plecoptera	Eustheniidae	Eusthenia costalis								1	1	2	1	6	2	
		Eusthenia spectabilis						1					7			
	Gripopterygidae	Cardioperla incerta	1												5	
		Cardioperla media/lobata		1	2			3						1	2	1
		Dinotoperla serricauda									2	3				6
		Leptoperla varia										1				
		Trinotoperla hardyi									1					
		Trinotoperla tasmanica					1						1			
		Trinotoperla zwicki	1	5	4		6	2	1	1		1	1	2		
	Notonemouridae	Austrocercoides sp									1		2			
Trichoptera	Calocidae	Tamasia variegata	1								1		1		8	10
	Conoesucidae	Conoesucus digitiferus			1	1									3	1
		Conoesucus nepotulus	4		1		1	3		2	3	3	5	1	14	27
		Costora delora									1				4	
		Costora ramosa/krene						1								
		Costora rotosca	1												17	
		Lingora aurata													2	
	Glossosomatidae	Agapetus sp. AV1									10	4	5			20
	Helicophidae	Allocoella grisea													1	
		Allocoella longispina				1										
	Hydrobiosidae	Apsilochorema obliquum			1						1			2		
		Apsilochorema gisbum			1						3		3			
		Moruya opora			1	1	2	1		2						
		# Taschorema apobamum					1		1						1	
		# Taschorema asmanum		1	1			2		2			6	4		5
		# Taschorema ferulum													1	
	Includes all#	Taschorema ferulum grp		2	5		1	5	2				8	1	1	
		Taschorema sp. AV1											1			
	Hydropsychidae	Asmicridea sp. AV1	1	27	2	2		2	1	2	1	1	42	12	1	34
	Hydroptilidae	Oxyethira mienica				1									1	
	Leptoceridae	Notalina bifaria													1	
		Notalina sp.AV1	1				1		3	1	10	51	40	14	19	14
	Philopotamidae	Hydrobiosella waddama												1		
	Philorheithridae	Kosrheithrus remulus											2			
		Tasmanthrus sp.	1		1		1				1	8	9	13	14	5
		Abundance EPT	**11**	**41**	**25**	**12**	**19**	**44**	**16**	**24**	**89**	**147**	**381**	**162**	**195**	**202**
		N EPT Taxa	**8**	**7**	**13**	**7**	**10**	**12**	**6**	**8**	**18**	**13**	**20**	**16**	**22**	**12**

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Appendix 4.6. RBA macroinvertebrate data

Abundances per live picked sample for Gordon River and reference sites sampled in autumn 2013.

			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					1		1		5				2				1			3			1			
Nematoda						2									1						1								1		
Mollusca	Gastropoda	Hydrobiidae											1	1			1														
Annelida	Oligochaeta					12	12	10	10	2	3	7	12	51	31	26	32	61	28	3	9	4	1	8	25	6	11	32	15	2	1
Arachnida	Acarina			1																3	2	5	5		1	2				2	1
Crustacea	Amphipoda	Paramelitidae							1	1		1	4	4	10	8	5			3											1
		Ceinidae					1								1																
		Neoniphargidae		4		3	5	4			2	1												8							
	Isopoda	Janiridae		5	1								1						1		1		1								
		Phreatoicidea							1						1	1															
Insecta	Plecoptera	Eustheniidae					7	1	1		3	4	1	3	2	1		2	5			4	6	2	5	15	17	6		11	1
		Austroperlidae					1				2					1															
		Gripopterygidae				2	12	5	2	4	2	7	10	1	2	1	1	8	11		3		2	1	1	16	12	1	1	1	9
	Ephemeroptera	Leptophlebiidae		14	4			14	10	38	30	9	25	1	3	31	22	49	30	49	64	60	66	13	48	38	57	62	50	67	35
		Baetidae										1				1	1		1	24	28	7	19	2	9	18	25	36	11	33	20
	Odonata	Telephlebiidae																	1												
	Mecoptera	Nannochoristidae																				1									
	Diptera	Chironomidae:	*Chironominae*						1				1	1		1			3	1		1	2		3	3	14		1		1
		Chironomidae:	*Orthocladiinae*	1			1					1	1							6	6	1	3		1	2					9
		Chironomidae:	*Podonominae*									7				6	3	1							1	4	2				1
		Chironomidae:	*Tanypodinae*					1														1									
		Simuliidae					5	35	4	38	17	46	41	1	5	53	63	68	65		1		2	1	6	2	4			2	8
		Tipulidae						2	1					3	3			2		1		2	1	1	6	2	2	3	2	1	
		Athericidae					1							1																	
		Blephariceridae																1													
		Ceratopogonidae																				1			2						
		Empididae												2		1		1													
		Dip. Unid. Pup.				1							1					1													
	Trichoptera	Calocidae																			1							6		1	
		Conoesucidae							1		2	1						1		2		1	1		1			4	3	2	4
		Glossosomatidae										1	1							3	1	1						8			
		Helicophidae				1																									
		Hydrobiosidae		17	4	3	12	9	11	4	1	18	4	2	2	20	16	24	37	13	19	9	21	5	20	17	27	48	42	18	9
		Hydropsychidae				18	24		1	1	1							1	1		4		1		1		2	1	2		1
		Leptoceridae		1			1								2				1	26	30	69	40		14	8	13	12	9	25	11
		Philorheithridae									1		1		8	1	5	2		2	4	16	11		1	1	3	3	3	9	2
		Trich. Unid. Pup.				6	7		2		1		1	2				3	6	4		3	6		2			5			3
	Coleoptera	ElmidaeA			1			1		7	10	18	13		10	5	1	1	12	25	23	8	25	2	23	16	18	44	31	23	26
		ElmidaeL											1		1	2	2		1	6	1	9		1	5	4	10	12	1	2	
		ScirtidaeL		2	1								1							26	13	9	10	3	6	9	10	20	15	9	3
		PsepheniidaeL																			1	3	3			1	1	4	2	4	4
		DytiscidaeA												1	1		1							1	3	1					
			N Taxa	**9**	**6**	**9**	**13**	**10**	**13**	**9**	**13**	**15**	**18**	**15**	**16**	**16**	**13**	**17**	**15**	**17**	**19**	**22**	**20**	**13**	**23**	**NA**	**NA**	**19**	**16**	**17**	**20**

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