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the renewable energy business

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Basslink Monitoring Program

Gordon River Basslink Monitoring Annual Report

2006-07

Volume I: The Report

Prepared by

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Executive summary

The Gordon River Basslink Monitoring Annual Report is the primary output from Hydro Tasmania's Gordon River Basslink Monitoring Program. This monitoring program is required under Hydro Tasmania's Special Licence and seeks to document changes in the Gordon River environment in response to Basslink operation. The program will extend the knowledge gained during the 1999-2000 investigative years and the 2001-06 monitoring on the pre-Basslink condition, trends, and spatial and temporal variability of the middle Gordon River environment. The 2006-07 monitoring year was the sixth year of Basslink monitoring and the first year of monitoring completed since the start of Basslink operation in April 2006. The program will monitor the post-Basslink condition of the river for six years.

The principal objective of this report is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program during the 2006-07 reporting year. The results from the 2006-07 monitoring are reported in eight sections corresponding to each of the disciplines being monitored. As this is the first of the post–Basslink annual reports, there are a further two components included which has not been included in previous annual reports:

- each discipline chapter contains a section on comparisons with trigger values; and
- chapter 10 - Discussion of trigger value results, provides a discussion on the integration of trigger value exceedances during 2006-07. This chapter also provides a summary of how unusual flow characteristics have affected the results during 2006-07.

All monitoring was conducted successfully across a wide range of scientific disciplines for the sixth consecutive year.

Hydrology

Total rainfall at Strathgordon in 2006–07 was lower than usual, with approx. 82% of the annual long-term average. Gordon Power Station was used more extensively during the year compared to previous years, however only two of the three turbines were available for June-December 2006.

On a monthly basis, all months except May 2007 exceeded the long–term median power station discharge values. This is also represented by figures that indicate there were 75% less shutdowns than in 2005–06. However, one long–duration maintenance shutdown occurred in October 2006. The longest continuous operating period was greater than 90 days.

Two mitigation measures, a ramp-down rule and a minimum environmental flow, have been incorporated into the Hydro Tasmania water licence. The minimum flow requirement of 20 m^3 s^{-1} from July to November 2006 outside of maintenance and monitoring shutdowns was achieved

100% of the time. The minimum flow target 10 $m^3 s^{-1}$ for the months of December to May was also achieved 100% of the time as per licence requirements.

The ramp-down rule, ensures that power station discharge may not be reduced by more than 30 $m^3 s^{-1} h^{-1}$. This only applies when discharge from the power station is intended to be reduced to below 150 $m^3 s^{-1}$ and the power station has been discharging at greater than 180 $m^3 s^{-1}$ for at least one hour. Twenty-six events were identified as not conforming with the ramp-down rule. Another 13 events were identified but, in these instances discharge was reduced to a level just below 150 $m^3 s^{-1}$ for only a brief period. As a result, these 13 events should not be included as non-conformances.

The Gordon above Franklin site (44) incurred instrument problems during the recording year and as such, a large percentage of the data are missing. For the data that do exist, the flow pattern closely mirrors the power station discharge but includes some peak flow events produced by rainfall and tributary inflow.

Due to the current system low inflow conditions and requirement for a higher than average energy contribution from the Gordon Power Station, flows at all sites in the Gordon River were greater than average for the year.

Water quality

Water quality surveys of Lake Gordon, Lake Pedder and the collection of water quality data for the Gordon River were undertaken successfully in compliance with the conditions of the water licence.

As in previous years, Lakes Gordon and Pedder continued to have good water quality in 2006-07. The thermal structure of Lakes Gordon and Pedder were similar to previous years. Lake Pedder showed little sign of stratification, while significant thermal stratification was evident at all three sampled sites in Lake Gordon (Boyes Basin, Calder Reach and Intake Site). The intake site maintained its stratification for the entire year, with the hypolimnion being below the level of the intake on three of the four sampling occasions, posing no problem for intake of water with low dissolved oxygen. In April 2007, the thermocline was at the same level as the intake, and provided the possibility of the drawing of water of low dissolved oxygen into the power station. Despite this, there was no evidence of any impact at site 65, 12 km downstream from tailrace.

Dissolved oxygen in the Gordon River at the compliance site (site 65) is reported on for the first full year as part of the Basslink monitoring. Dissolved oxygen levels were indicative of good water quality at this site. There was no seasonal variation or relationship to the dissolved oxygen levels in Lake Gordon at the power station intake. Variation in the dissolved oxygen levels at site 65 was clearly related to variations in discharge from the power station. Higher dissolved oxygen levels were present while discharge was high, indicating that water receives significant aeration on its way downstream from the tailrace.

The temperature of the Gordon River followed expected patterns, being influenced by the thermal structure of Lake Gordon at the intake on a seasonal basis, and by the discharge from the power station. Greater variation in temperature occurred downstream from the tailrace when there was lower power station discharge and greater relative contribution to flows in the Gordon River from tributaries, the temperature of which are influenced by variation in air temperature.

Fluvial geomorphology

Geomorphology monitoring in the middle Gordon River was completed successfully on 17-18 October 2006 and 17-18 March 2007 by boat-based teams in accordance with licence requirements.

During October 2006, deposition of organic matter and establishment of seedlings in the 2-3 turbine level upstream of the Denison River was observed. This bank level also showed rilling due to rainfall on the exposed bank presumably due to winter rainfall, but there was little evidence of seepage erosion. Downstream of the Denison, collapse of the 2-3 turbine zone and associated deposition on the bank toe was widespread. These observations were consistent with discharge from the power station being limited to two turbines. The March 2007 monitoring period followed an extended period of 3-turbine power station operation. Field observations documented muds and sands deposited on bank toes downstream of tributaries, a lack of organic matter on the bank below the 3-turbine power station level and saturated bank toes and seepage erosion in areas prone to seepage processes.

A new piezometer array was installed at site 2G between June and October 2006. The new array extends monitoring to 50m inland, and includes a probe downstream to provide information about longitudinal ground water movements. The new array shows that water levels at least 50m inland are affected by power station operation.

Using a combination of new and old piezometer records, only one period of high seepage erosion risk was identified to coincide with 2-turbine power station operation between June and December 2006. Following resumption of 3-turbine operation in December 2006, several periods of high seepage erosion risk were identified. However, seepage erosion risks were no higher relative to pre-Basslink conditions. The constant 3-turbine operation of the power station, rather than the expected post-Basslink peaking, is likely to have limited the occurence of high risk seepage erosion. The link between seepage erosion and net erosion rates is not well understood, and requires additional analysis.

The October 2006 pin results were consistent with field observations, and showed an increase in erosion in the 1-2 and 2-3 turbine levels in zones 4 and 5, and a decrease in bank toe erosion.

Whether these changes were in response to winter inflows, the short-term changes in power station operation, or the anticipated progression of bank erosion in the 2-3 turbine level due to over steepening of bank faces is unknown. March 2007 erosion pin results showed erosion rates of bank toes returned to previous rates downstream of the Denison, and erosion of the 2-3 turbine zone continued.

For the erosion pins, zones 1-4 remained within the pre-Basslink trigger limits, with results from zones 2-4 falling below the predicted mean erosion rate. The result for zone 5, the only zone where net deposition is predicted, exceeded the trigger value as the actual rate of deposition (10.7 mm) was less than the trigger (95th percentile) minimum rate (15.1 mm) for the year. This result may be due to reduced erosion rates upstream which have led to a decrease in deposition downstream, increased erosion in zone 5 due to re-adjustment of the over steepened banks, or variability not captured by the trigger values.

Karst geomorphology

The karst monitoring data was collected successfully from both the Gordon–Albert and Nicholls Range karst areas on 17 October 2006 and 17 March 2007 in accordance with licence requirements. The karst section of this report includes a brief discussion of results and a comparison with the informal trigger values determined as part of the Basslink Baseline Report (Hydro Tasmania, 2005).

The three indicator variables being used to assess likely post-Basslink effect in the karst areas of the Gordon River are:

- inundation of the dry sediment bank in Bill Neilson Cave;
- sediment changes at erosion pins in the caves; and
- structural change in the dolines.

There were four peak flow events this year that would have inundated the pins in the dry sediment bank in Bill Neilson Cave; twice in winter and twice in summer. The pins were inundated less than 1% of the time which is within the accepted informal trigger value. The maximum peak event was also 0.6m less than the highest pre-Basslink event. The inundation have resulted in negligible sediment movement. The results from the lowest pin in the wet sediment bank indicate that the relatively strong trend of summer deposition has changed this year to very slight erosion (1 mm). These results suggest that there has been no significant change to the inundation trends and little change in sediment erosion and deposition since Basslink commenced.

The pins in Kayak Kavern have indicated the occurrence of winter erosion and summer deposition on the sediment mound. This resulted in a net gain of sediment on the mid and high active slopes, and a net loss of sediment on the eddy slope and the top flat. The winter erosion is probably due to the fluctuating one-turbine operations in the three weeks prior to the field visit which would have actively worked the sediment on the bank. The summer deposition probably occurred in the relatively stable backwater environment while the station was operating at the three-turbine output level.

The pins in the GA-X1 cave indicate that there was generally more deposition than usual over the 12 month period. The deposition pattern showed a minor net increase in sediment at the lowest of the pins, and deposition over summer at the mid-level pin. This contrasted to the expected pattern of summer erosion at the mid-level. The water level and power station impacts on these changes is not clear but they are probably related to operations immediately prior to the field visit rather than the overall seasonal activity. There has been little change at the higher erosion pin levels due to the lack of inundation.

In Channel Cam, the pins experienced little change over winter in contrast to the significant deposition over the previous two years. This is probably due to the low winter rainfall and consequent lack of sediment introduced from surrounding areas. Over summer, the trend was also slightly different to previous years with more deposition than erosion taking place.

In the dolines, the sums of the distances between the erosion pins were within the range experienced pre-Basslink and no significant change in morphology is considered to have occurred.

All the available evidence suggests that there have been no significant Basslink changes in the caves and karst features this period.

Riparian vegetation

Summer monitoring, incorporating seedling and photo-monitoring studies was undertaken successfully on 7-10 December. Autumn monitoring for tributaries was undertaken on 14 and 15 April and in the Gordon River a month later on 12 and 13 May. The data from both these monitoring periods and the ‘intermediate’ Basslink monitoring in March 2006 are presented in this report and assessed against trigger values where appropriate.

Environmental conditions over this period were characterised by a period of prolonged drought affecting both the region of study but also the State, and hence power station operations. The top of the banks in the areas above regulated flow levels were relatively dry in the December monitoring period compared with other monitoring events. It is likely that this has resulted in localised successful recruitment of seedlings of species which require drier conditions for establishment and are not tolerant to water logging.

Comparison of photo-monitoring of riparian vegetation at 35 sites along the river indicated little discernable change. Where evidence of change occurred, this was generally continued expansion and contraction of canopy or ground layers in sites which have shown those patterns over the past four years. Overall, there was no discernable Basslink effect.

The measures of community integrity, including similarity indices of composition, species richness and evenness also showed few significant changes between this first post-Basslink year and the trigger values calculated from the pre-Basslink baseline. Increased species richness confirmed the increase in successful recruitment of seedlings in the areas above regulated flow levels in zone 2. Reduced species richness in the low quadrats in zone 3, and similarly the high quadrats in zone 5 may be related to the increased duration of inundation at this level from the prolonged 2-turbine operation. The evenness of species composition index did not show any results outside the trigger values.

There were numerous values outside the trigger range for the abundance of the three identified species of ecological significance *Acradenia franklinii* (whitey wood), *Lagarostrobos franklinii* (huon pine) and *Leptospermum riparium* (tea tree). However, these measures all showed an increase in abundance above the previously recorded values and are not cause for concern.

The status of the vegetation cover for most plant life forms was stable over time and was within the trigger values. These triggers have been set based upon the ratio of cover for different vegetation life forms between the different positions on the bank. That is, vegetation cover in the area above regulated flow ('above' quadrats) is compared with that in the area coinciding with 3-turbine flow ('high' quadrats); a second measure is the area above regulated flow ('above') compared with the area of 2-turbine flow ('low' quadrats). The ratio of fern cover exceeded the trigger values, reflecting a substantial reduction in fern cover in the areas below 2-turbine flow in zones 2 and 3, those zones which show the strongest influence of power station operation. This is very likely to be the result of the prolonged 2-turbine operation which would have led to inundation of both the roots and fronds.

Many measures of seedling numbers (ratio of 'above' to 'high' quadrats) were outside the trigger range in autumn 2007. These results indicated a decrease in seedlings in the areas affected by regulated flows. This result can be attributed to the prolonged 2 and 3-turbine flow preceding the later-than-usual May monitoring event. The results were also influenced by an extreme result in zone 5 where one site showed a very high ratio due to high numbers in the 'above' quadrat compared with the 'low' quadrat.

The numerous riparian vegetation measures (seedling numbers, fern cover, species richness, ecologically significant species) outside the trigger range indicate there are some changes occurring along the river which may be related to changes in hydrology. It is possible that the changes to water dynamics have provided the mechanism for sufficient increases in stress to vegetation to cause such changes. However, many of these changes were relatively small and some such as the increase in species richness and ecologically significant species, are positive. Therefore, these results should lead to level one response (note and explain).

Macroinvertebrates

Macroinvertebrate sampling was conducted successfully in spring (17-19 October) 2006 and autumn (17 March) 2007 at nine sites in the Gordon River between the Gordon Power Station and the Franklin confluence. Six reference sites were sampled in the Franklin, Denison, Maxwell and Jane Rivers. Sampling was conducted as required under the Basslink Monitoring Program, with all sites sampled using quantitative surber samplers and rapid bioassessment (RBA) kick sampling, with live-picking on-site.

The quantitative surber samples were used to generate data on key metrics of abundance of taxa, total abundances and diversity (as number of taxa), both at family level and at species level for the aquatic insect orders Ephemeroptera, Plecoptera and Trichoptera (EPT). RBA samples were used to derive O/E values for each site, using the single season models developed by Davies (unpub. rep.) for Hydro Tasmania catchments.

The results for 2006-07 were within the pre-Basslink trigger ranges with the exception of:

- density of EPT species being elevated and high in the vicinity of the Denison junction. This is due to high densities of the caddis *Asmicridea*, which may be enhanced by the maintenance of environmental baseflows; and
- Community compositional similarity between Gordon and reference sites was reduced in autumn 2007 compared with pre-Basslink period, mainly due to poor sample quality following heavy rains and rising river levels.

Other patterns and trends in benthic macroinvertebrate metric values were broadly similar to those observed in the five years pre-Basslink. However, total abundance and diversity of EPT species were frequently lower than pre-Basslink means, but within trigger ranges. The lower abundance and diversity values were sometimes accompanied by similar low values in reference sites. More observations are required to assess whether the low EPT abundance and diversity trend is consistent in years two and three post-Basslink.

Overall, for benthic macroinvertebrates, no major changes in communities of the Gordon were observed that could be attributed to Basslink operations, and post-Basslink conditions were broadly associated with compliance with established triggers.

Benthic algae and moss

Benthic algae were surveyed in spring (16-19 October) 2006 and autumn (17 March) 2007 at nine sites in the Gordon River between the Gordon Power Station and the Franklin confluence, and three reference sites. The survey was conducted as required under the Basslink Monitoring

Program. However, autumn 2007 sampling was slightly impaired by sampling scheduling restrictions which gave insufficient time for algal and moss cover to be measured at reference sites.

As in the pre-Basslink period, aquatic plant cover was low in the Gordon River.

Moss cover was very low downstream of the Denison confluence, as observed previously. Values fell within trigger level ranges. Filamentous algal levels were low and, as usual, were higher in spring than in autumn, and broadly consistent in magnitudes and trends of cover with pre-Basslink years.

Particularly low algal levels were observed downstream of site 74, falling at or close to the lower trigger levels. This is believed to be due to the period of sustained two-turbine flows and the resulting low benthic light levels.

There has been no change in aquatic flora that could be ascribed to the operations of Basslink at this stage.

Fish

Fish surveys were conducted successfully on 7-10 December 2006, 17-18 April and 12-13 May 2007. The autumn trip was split over two months due to logistical and system operation constraints restricting power station outage availability. This departure from the normal autumn monitoring schedule was discussed with, and approved by, the regulator. Sampling was conducted in accordance with Hydro Tasmania's Water Licence.

The main feature of note from the monitoring program was the low relative abundance of brown trout in the Gordon River. As a result of this low abundance, three out of ten triggers were exceeded. Declines in the relative abundance of exotic species may be ecologically beneficial due to reduced predation on and competition with native species. Though lower abundance of brown trout may be of ecological benefit, this fish population provide the most sensitive measure of possible impacts from environmental change due to Basslink. As a result, this trigger exceedence may provide an early warning of impacts upon native fish populations.

The abundance of the exotic species, redfin perch, appears to be decreasing in the upper zones. A single live stranded redfin was collected in zone 2, and this was the only verifiable stranding of any species recorded for the year. One rainbow trout was collected from a small tributary in Abel Gorge, which is the first time that this species has been collected during the monitoring program. The presence of this species is not unexpected as rainbow trout occur in Lake Gordon and Macquarie Harbour. Four species of exotic fish have now been collected from the Gordon River or tributaries during the monitoring program.

The relative abundance of native fish in the Gordon River was similar to previous years, and triggers associated with galaxiid and native fish relative abundance were not exceeded during 2006-07.

Discussion on trigger value results

The first year of post-Basslink monitoring has coincided with power station operations which differed from the pre-Basslink operating regime, but did not contain several of the flow elements predicted to occur under Basslink. This was due to extended maintenance at the power station, limiting discharge to two turbines for approximately half of the monitoring year combined with an extended drought necessitating prolonged use of the Gordon Power Station throughout the year, as well as a very high natural flow event in May 2007.

A total of 34 trigger values (13%) were exceeded during the monitoring year. Trigger values were exceeded in all disciplines except algae cover and karst, however, in no discipline were the exceedances considered to be of immediate concern. In fact, of the 35 trigger value exceedances, 18 may potentially be considered beneficial. The potentially favourable exceedences relate to increasing seedling species diversity, number of ecologically important plants, high abundance of EPT macroinvertebrates and reductions in exotic fish.

The trigger exceedances detected during this first monitoring year can be largely accounted for by unusual flow components and logistical issues not related to Basslink. The Basslink researchers collectively suggest that one monitoring year consisting of an atypical flow regime with respect to pre- or post-Basslink conditions is insufficient to identify Basslink-related changes. Hence for all disciplines at this point, all on-going work is at level 1, or the “note and explain” response.

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Acronyms

ANOVA	analysis of variation
AUSRIVAS	Australian River Assessment System
ASL	above sea level
BBR	Basslink Baseline Report
BMP	Gordon River Basslink Monitoring Program
CPUE	catch per unit effort
IIAS	Basslink Integrated Impact Assessment Statement: Potential Effects of Changes to Hydro Power Generation
mASL	metres above sea level
NTU	Nephelometric turbidity units
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
SRC	Scientific Reference Committee
TKN	total Kjeldahl nitrogen
TWWHA	Tasmanian Wilderness World Heritage Area

Glossary

Ambient	background or baseline conditions
Ammocoete(s)	juvenile lamprey(s)
Anoxic	absence of oxygen (concentrations below about 2 mg L^{-1})
Benthic	the bottom of a lake
Bray Curtis index	a measure of assemblage similarity between sites/samples
Bryophyte(s)	division of photosynthetic, nonvascular plants, including the mosses, liverworts, and hornworts
Catch per unit effort (CPUE)	the catch related to a standardised measure of effort. In this case, the number of fish collected by electrofishing at a site, standardised to a shocking time of 1200 seconds
Coleoptera	the largest order of insects comprising the beetles and weevils
Confluence	the location when two rivers or tributaries flow together
Copepoda	a subclass of Crustaceae comprising minute aquatic forms which are important as fish food
Depauperate	a community of organisms is diminished or impoverished of certain species
Diurnal	relating to or occurring in a 24-hour period
Dolines	are karst features which present as depressions or collapses of the land surface. Dolines are formed when a solution cavity in the underlying rock becomes enlarged enough for overlying sediment to collapse into it.
Environmental flow	water which has been provided or released for the benefit of the downstream aquatic ecosystem and broader environment
Ephemeroptera	is an order of fragile winged insects commonly known as mayflies which develop from aquatic nymphs and live in the adult stage no longer than a few days

Exotic	introduced organisms or species
Full-gate	is the discharge which produces the maximum amount of energy by the turbine
Geomorphic	the study of the earths shape or configuration
Histograms	a bar graph of a frequency distribution in which the widths of the bars are proportional to the classes into which the variable has been divided and the heights of the bars are proportional to the class frequencies
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
Inundation	an area of vegetation or bank which becomes covered by water associated with flows from either an upstream dam or tributary input
Karst	an area of irregular limestone in which erosion has produced fissures, sinkholes, underground streams and caverns
Macrophyte	aquatic vascular plant
$m^3 s^{-1}$	cubic metres per second, units for the measure of flow rate
$mg L^{-1}$	milligrams per litre, units for the concentration of a substance dissolved in a solution
Morphology	the consideration of the form and structure of organisms
MW	megawatts (10^6 watts)
Oligochaetes	various annelid worms of the class Oligochaeta, including the earthworms and a few small freshwater forms
Oxycline	level at which dissolved oxygen decreases rapidly
pH	a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity (scale of 0-14)

Piezometer	an instrument for measuring pressure
Plecoptera	order containing weak-flying insects known as stoneflies, whose nymphs live under stones along the banks of streams. Adult and larval stoneflies are used as fishing bait. Also called plecopteran.
Plimsoll line	lines which show the level the water should reach when a ship is properly loaded. In this case used to describe the distinct line created on the river bank by the riparian vegetation in response to flow regulation by the power station.
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
Tardigrada	microscopic arachnid-like invertebrates living in water or damp moss having four pairs of legs and instead of a mouth they have a pair needle-like piercing organs connected with the pharynx
Taxon	a taxonomic category or group, such as a phylum, order, family, genus, or species
Temporal trend	change or pattern over time
Thermal stratification	change in temperature profiles over the depth of a water column
Trichoptera	an order of insects consisting of caddis flies
Turbellaria	an extensive group of worms which have the body covered externally with vibrating ilia
Zooplankton	animal constituent of plankton which are mainly small crustaceans and fish larvae

1 Introduction and background

The purpose of the Gordon River Basslink Monitoring Annual Report (GRBMAR) is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program (BMP) during 2006–07. As 2006-07 is the first full year of post-Basslink operation, monitoring results have been assessed against the trigger levels set out in the 2005-06 Gordon River Basslink Monitoring Annual Report.

1.1 Context

The Gordon River Basslink Monitoring Program (BMP) was established as a requirement of the Basslink approvals process. The aims of the Gordon River Basslink Monitoring Program are:

- to undertake pre–Basslink monitoring 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;
- to undertake six years of post–Basslink monitoring in order to determine the effects of Basslink operations in the Gordon River below the power station and to assess the effectiveness of mitigation measures; and
- to obtain long–term datasets for potentially Basslink–affected aspects of the middle Gordon River ecosystem, which 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 has been to measure conditions under the existing operating regime, rather than attempting to relate them to 'natural' or 'pristine' conditions. This approach is an essential element of the monitoring program given the highly modified conditions which presently exist due to the presence of, and the flow regulation resulting from, the Gordon Power Scheme.

The independent investigative studies produced for the Basslink Integrated Impact Assessment Statement (IIAS) (see Locher 2001) led to the formulation of the BMP and its requirements. These were included in the Special Licence which Hydro Tasmania holds under the *Water Management Act* 1999.

The focus of the post–Basslink monitoring program is to compare post-Basslink data with trigger values derived from pre-Basslink data. It must be recognised that only one year of data is currently available post-Basslink. A more detailed analysis of post-Basslink data will be conducted after three and six years of post-Basslink monitoring.

The operation of the Gordon Power Station differed from predicted post-Basslink operation in 2006-07 due to:

- low system inflows which meant high utilisation of Gordon Power Station to compensate for the lack of water elsewhere in the system;
- the unavailability of one of the three Gordon machines between May 2006 and December 2006 due to a major upgrade; and
- low lake levels in Great Lake with the result that Gordon was elevated to first priority in terms of generation production, resulting in a greater than normal utilisation for the power station.

1.2 Basslink Baseline Report

One of the requirements of Hydro Tasmania's Special Licence is to produce a Basslink Baseline Report (BBR) prior to Basslink commencement. The BBR was submitted to the Minister in December 2005 and provided a comprehensive assessment of pre–Basslink conditions in the Gordon River below the power station. This involved the analysis of the BMP data collected to date and the application of the results of these analyses to the consideration of how post–Basslink conditions will be compared with the pre–Basslink ranges of variability and trends. The Basslink Baseline Report is a public document and is available on Hydro Tasmania's website.

1.3 2005–06 monitoring and reporting

The Gordon River Basslink Monitoring Program for 2005–06 completed the fifth and final year of pre–Basslink monitoring. However, Basslink began transmission trials in early December 2005, and was commissioned and went into service on 28 April 2006. Changes in flow regimes were evident in the Gordon River during some of the pre–commissioning period, and as a result the autumn sampling in March and April 2006 is considered somewhat transitional between the pre– and post–Basslink periods.

The 2005-06 Basslink Annual report had updated trigger value reports specifying the values post-Basslink monitoring will be assessed against.

1.4 Logistical considerations

As indicated in the 2001–02 GRBMAR, 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 infrastructure and extent of the study area.

Power station outages are needed because the majority of viable helicopter landing sites are on cobble bars in the river bed which are exposed only when there is little or no discharge from the power station. Shutdowns are also required 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 Gordon River Basslink Monitoring Program has a schedule of four visits per year, each involving two consecutive days of power station outage.

The 2006-07 monitoring surveys were conducted on 17-18 October and 7-10 December 2006, 17-18 March, 17-18 April and 12-13 May 2007. The 2007 autumn fish and riparian vegetation surveys were spread over two months. The unregulated reference sites were sampled in April and the Gordon River sites were sampled in May. However, one of the riparian vegetation sites (located in zone 4) was unable to be sampled due to time and logistical constraints.

Extremely low inflows and lake levels throughout the Tasmania hydro generation system resulted in increased reliance on Gordon Power Station for energy production. This delayed the monitoring outage until May, when rainfall and inflows across several catchments enabled other stations to produce sufficient power to compensate for the shutdown required to undetake the monitoring. The implications of this are discussed in the individual discipline chapters of this report.

1.5 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. Site references using the AGD will be approximately 200m different (-112m east and -183m north) from those using the GDA. These will be updated as updated maps are made available.

1.6 Document structure

This document is the sixth of the Gordon River Basslink Monitoring Annual Reports to be produced, and is organised into ten sections plus an executive summary.

This first section discusses the requirements, context, operational considerations and constraints of the program. Sections 2–9 report on the monitoring work which was undertaken during 2005-06, and present the consolidated results of each of the individual monitoring elements. These include:

- Hydrology (section 2);
- Water quality (section 3);
- Fluvial geomorphology (section 4);
- Karst geomorphology (section 5);
- Riparian vegetation (section 6);

- Benthic macroinvertebrates (section 7);
- Benthic algae and moss (section 8); and
- Fish (section 9).

The results from the 2006–07 monitoring are reported in each of these sections. Some between-year analyses were undertaken, where sufficient data were available to make such analyses meaningful.

As this is the first of the post–Basslink annual reports, there are a further two components included that have not previously been included in the annual report:

- each discipline chapter also contain a section on comparisons with trigger values; and
- discussion of trigger value results (section 10).

When a result fell outside the trigger levels, the terminology 'a trigger has been exceeded' has been used in this report. However, it should be noted that an 'exceedance' can both be above or below the acceptable levels. It should also be noted that a trigger exceedance can be considered an ecological benefit, for example lower levels of exotic fish. Interpretation of the trigger exceedances will be discussed in the individual chapters and in section 10.

A series of ten appendices is included as follows:

- Changes to monitoring regime (Appendix 1);
- Installation of new piezometer array (Appendix 2);
- Erosion pin and scour chain results (Appendix 3);
- Erosion pin graphs (Appendix 4);
- Photo-monitoring sites (Appendix 5);
- Riparian vegetation photo-monitoring (Appendix 6);
- Fish – relative abundance from test and reference zones (2001-07) (Appendix 7); and
- Formal trigger levels (Appendix 8).

1.7 Authorship of sections

The information presented in sections 2-10 was extracted from field reports produced by the various scientists employed to conduct the monitoring, as shown in Table 1-1. Section 10 was prepared by Lois Koehnken. The efforts and original contributions of these researchers are duly acknowledged.

This document was collated by Marie Egerrup, with considerable assistance from the researchers and internal reviewers. Donna Porter assisted with editing and production.

Table 1-1. Section numbers, section titles and original authors from whose reports the information in sections 2 – 11 was extracted.

Section	Section title	Author(s)
2	Hydrology	Kirsten Adams (Hydro Tasmania)
3	Water quality	Malcolm McCausland (Hydro Tasmania)
4	Fluvial geomorphology	Lois Koehnken (Technical Advice on Water)
5	Karst geomorphology	Jenny Deakin and Rolan Eberhard (consultants)
6	Riparian vegetation	Anita Wild (Hydro Tasmania)
7	Macroinvertebrates	Peter Davies and Laurie Cook (Freshwater Systems)
8	Benthic algae and moss	Peter Davies and Laurie Cook (Freshwater Systems)
9	Fish	David Ikedife (Hydro Tasmania)
10	Discussion of trigger value results	Lois Koehnken (Technical Advice on Water)

1.8 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 39 (immediately downstream of the Franklin confluence, at the upstream tidal limit) and site 77 (the power station tailrace).

Some disciplines, such as fluvial geomorphology and riparian vegetation, use zones rather than the standard site numbering system. This is because their work is associated with longer reaches of river bank than are suitable for the 'site' nomenclature. The fish monitoring uses both systems. Site numbers define the specific monitoring location and fish zones define the river reach to which the sites belong.

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2 Hydrology

This section of the Gordon River Basslink Monitoring Annual Report provides an overview of the hydrological data from the Gordon River downstream of the Gordon Power Station for the July 2006 to June 2007 period.

2.1 Long-term data

In this report, most of the analyses have been carried out by the comparison of data from the 2006-07 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, however longer datasets will provide more representative figures for long-term statistics when available. 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.

2.2 Low system inflows

The 2006-07 monitoring year was an extreme year in terms of inflows to Hydro Tasmania's system. The total system inflows received were some 30% down on expectations necessitating:

- higher levels of import over Basslink;
- increased operation of the Bell Bay gas power station; and
- increased power generation using the major storages of Lake Gordon and Great Lake.

In times of low inflow, the major storages of Great Lake and Lake Gordon are utilised more to compensate for the lack of water in the shorter-term storages (annual or run-of river storages) of the system. Figure 2-1 shows the total system yield received over 2006-07 compared with the long-term medians (1976-2006).

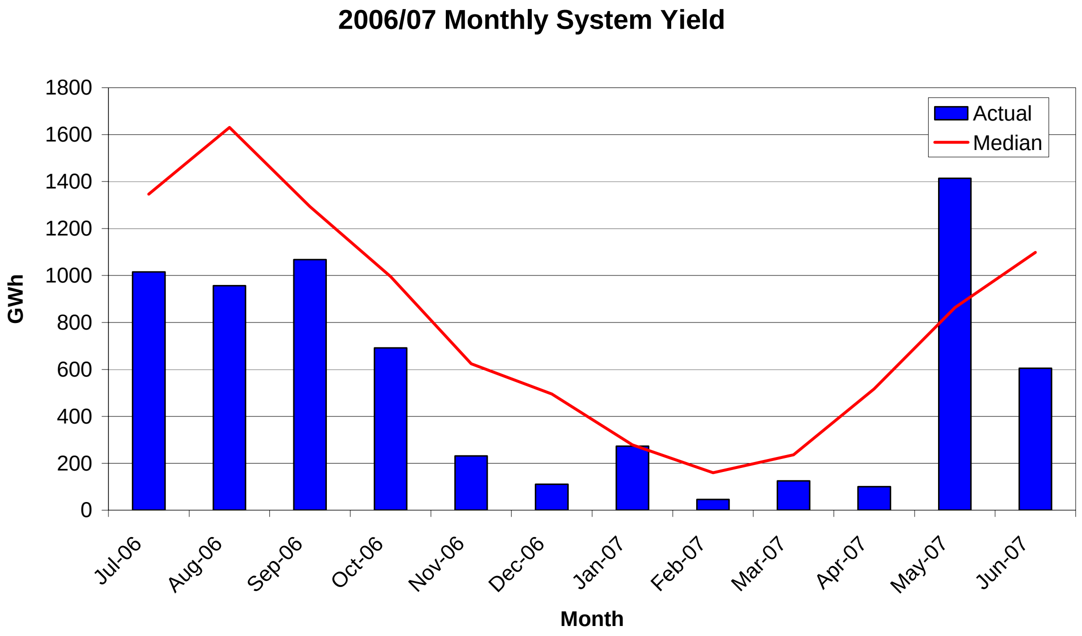
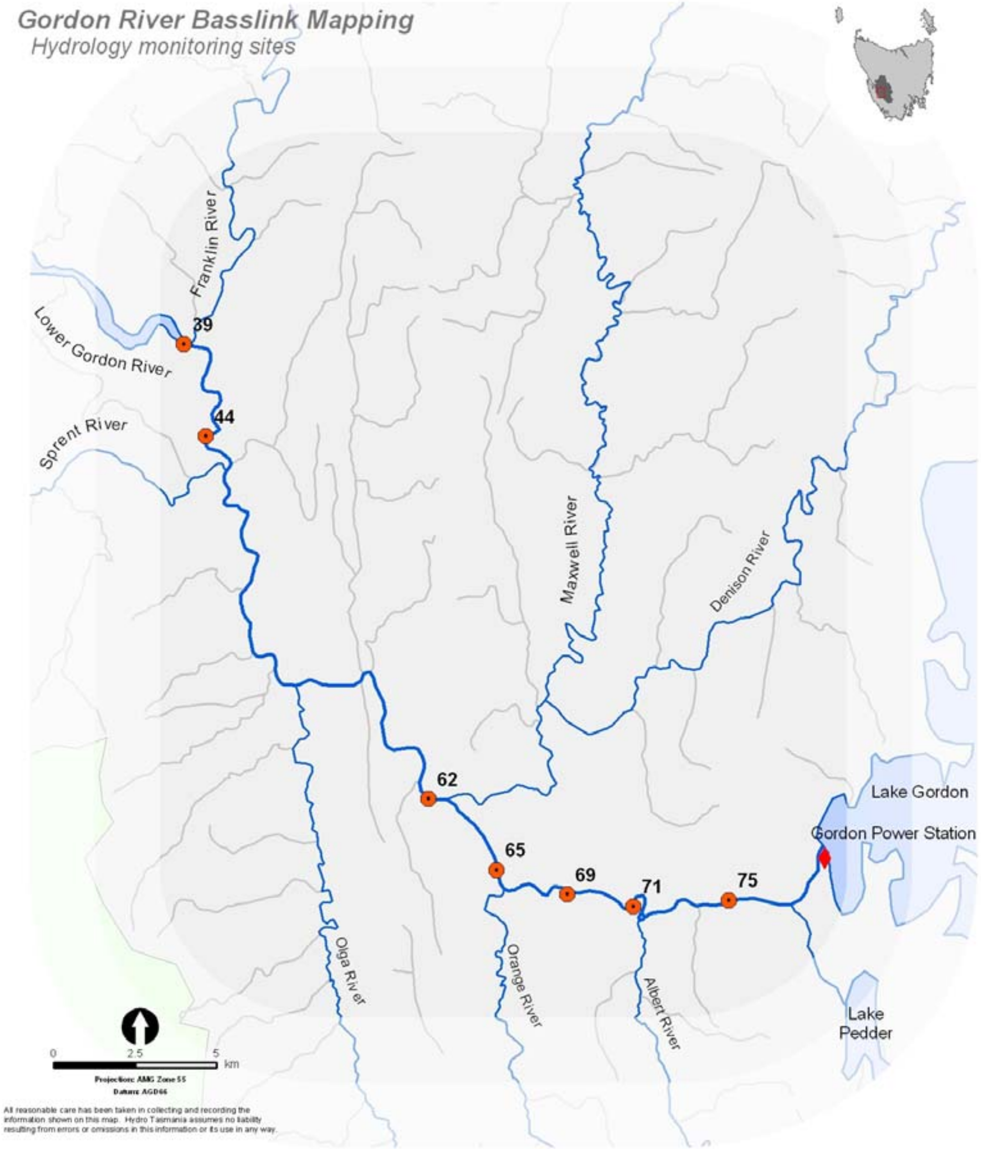


Figure 2-1. Monthly system yield for 2006-07 compared to the long-term median (1976-2006)

2.3 Site locations

The gauging stations used to record river levels during 2006–07 are shown in Map 2-1. These were sites 39, 44, 62, 65, 69, 71, 75 and the Gordon Power Station tailrace (site 77).



Map 2-1. Location of the water level recorders in the Gordon River

2.4 Strathgordon rainfall

The Strathgordon meteorological station has rainfall records dating back to 1970. These allow the development of long-term mean monthly values and comparisons with the monthly rainfall totals recorded for 2006-07. Figure 2-2 shows the total monthly and long-term average rainfall values. These indicate that 2006-07 received below average annual rainfall (2005 mm compared to a long-term average of 2458 mm). 2006-07 was the third driest year on record at Strathgordon.

During 2006-07, five months were classified as dry (with values lower than the 20th percentile of the long-term values); these being August 2006, November 2006, February 2007, April 2007 and June 2007. However January and May 2007 were wet months. Wet months are defined as those with values greater than the 80th percentile of the long-term values.

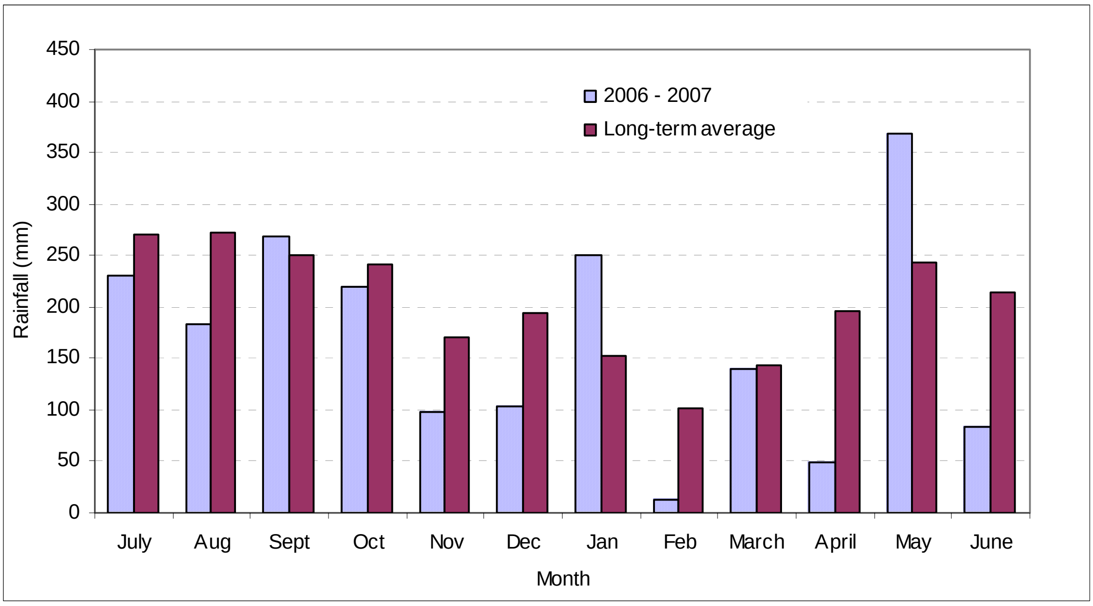


Figure 2-2. Total monthly rainfall values recorded at Strathgordon for 2006–07 compared with the long-term average (1970–2007)

2.5 Gordon Power Station discharge

The discharge pattern for the Gordon Power Station is driven by factors other than local rainfall. For the year 2006-07, the following factors influenced the operation of the Gordon Power Station:

- low system inflows;
    - Gordon Power Station was utilised more than usual to compensate for the low water levels elsewhere in the system.
    - Historically, Gordon Power Station was generally shutdown during high inflow events elsewhere in the system, however due to overall low system inflows, Gordon was required to supply a large proportion of base load and these shutdowns did not occur in 2006-07.
- major machine upgrade;
    - A major upgrade to one of the three Gordon machines took place between May 2006 and December 2006 meaning that this machine was out of service for this period.
- Great Lake environmental risk;
    - Prioritisation of Gordon and Poatina Power Station operation is influenced by the balance between Lake Gordon and Great Lake levels.
    - For much of the year Great Lake had less water than Lake Gordon.

Figure 2-3 shows the discharge from the power station for 2006–07.

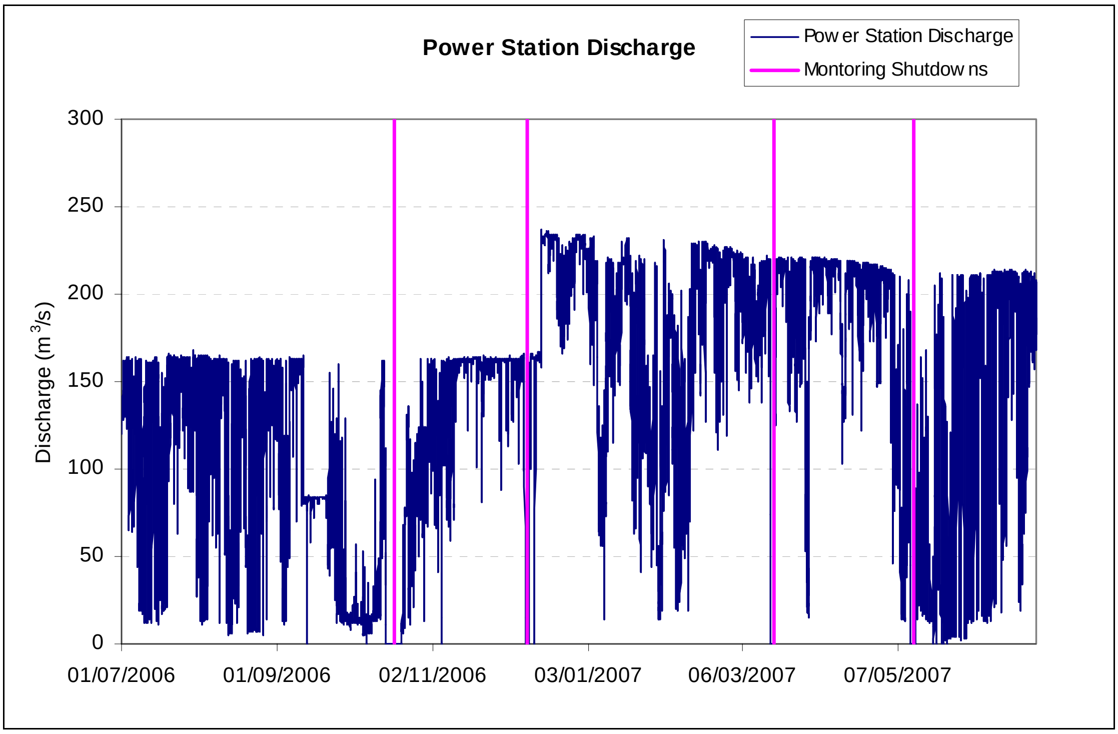


Figure 2-3. Gordon Power Station discharge (hourly data) from July 2006 to June 2007. Vertical lines indicate monitoring shutdowns.

During 2006–07, the power station operated three turbines almost 50% of the time (Table 2-1). This is a significant increase over historical operations and was due to drought conditions elsewhere in Tasmania. The third turbine was only returned to service in December 2006.

Historically, Gordon Power Station is not used during high flow times in Hydro Tasmania catchments in the winter months. However, due to the ongoing low system inflows, a greater proportion of water was released from the power station during the winter months (even though operation was limited to two turbines) as compared to pre-Basslink, as shown by the low number of shutdowns and one machine running times when compared to both the previous year and historical operations.

Table 2-1 Percentage of time that each configuration of turbines was in operation during 2006–07 and historically

Configuration	Percentage of time operating 06-07	Percentage of time operating 05-06	Percentage of time operating 96 to 06	Approximate tailrace discharge (m³/s)
0 machines running	3.6%	14.8%	18.3%	0–10
1 machine running	9.0%	31.0%	18.2%	70–80
2 machines running	40.1%	53.2%	29.5%	140–150
3 machines running	47.3%	1.0%	34.0%	>210

The power station operating pattern throughout the year, and hence the downstream hydrological regime can be summarised as follows:

2.5.1 July–December 2006

The power station was only able to run two of the three turbines due to the outage for maintenance on the third machine. However, these two turbines were run consistently with only one long shutdown period due to maintenance occurring in October. Higher than average discharges (except for October) occurred in this period.

2.5.2 January–March 2007

There was significant discharge from the power station during this period as the third turbine was reinstated and the water level at Great Lake was very low, causing Gordon to be run at 3-turbines for a prolonged period. Some peaking generation occurred during this period.

2.5.3 March–May 2007

During this period there were two monitoring events where the power station was shutdown, however these were both of short duration (<48 hours) and for the remaining time, the power station was run using either 2 or 3-turbine operation.

2.5.4 May-June 2007

Due to an increase in system inflows in May, power station operation was able to be reduced to allow for some recovery of Lake Gordon levels, however operation increased again in June due to low rainfalls.

Basslink Monitoring power station outages took place on:

- 17 and 18 October 2006;
- 9 and 10 December 2006;
- 17 and 18 March 2007; and
- 12 and 13 May 2007.

2.5.5 Median monthly discharge

Figure 2-4 shows the median monthly discharge from the power station for 2006–07 compared with long–term values (since August 1996). This figure illustrates that median discharge was higher than usual for the majority of the year, with only one month (May) being below the long-term median. During May high rainfall was observed in other catchments allowing run of river power stations to provide a substantial contribution to overall generation.

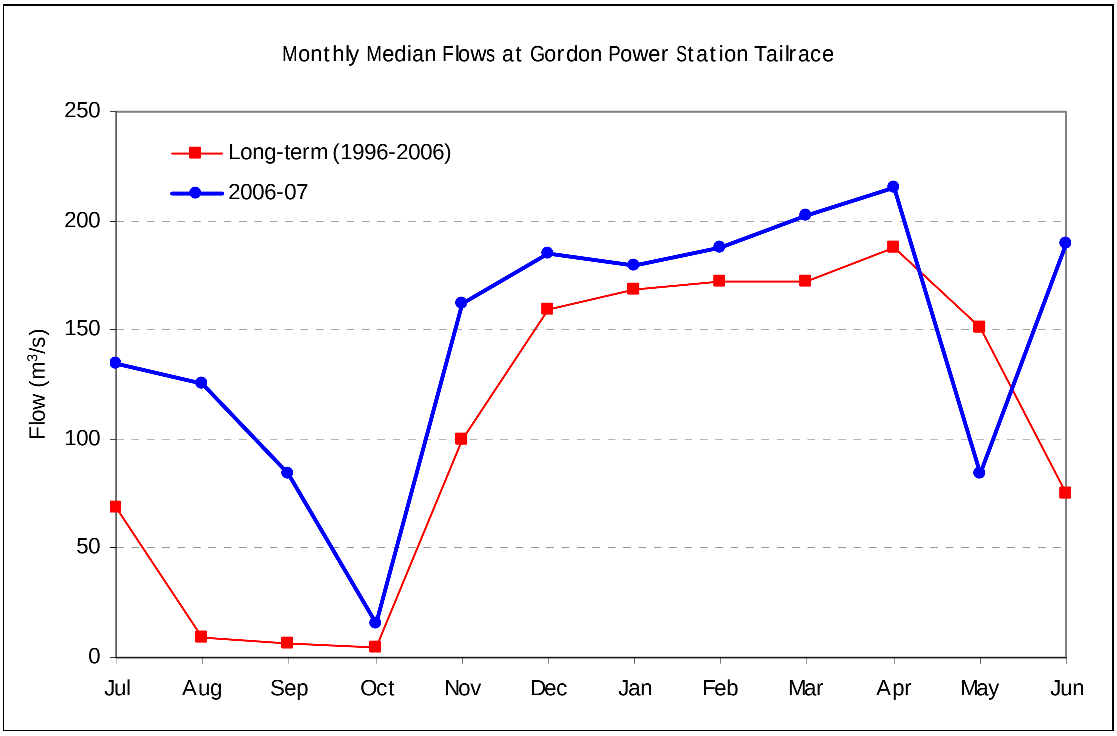


Figure 2-4. Median monthly discharge from the Gordon Power Station for 2006–07 compared with long–term median values

2.5.6 Duration curves

Figure 2-5 shows the duration (% exceedance) curve for the power station discharge for 2006–07, as well as the long–term (since 1996) duration curve. The 2006–07 curve shows that there was more discharge than usual for 85% of the time, with the greatest variance to the long-term curve occurring around the 75th percentile. The long–term median value is 127 $m^3 s^{-1}$, while the 2006–07 median value was 158 $m^3 s^{-1}$.

As described in section 2.5, the Gordon Power Station operated at or close to full capacity for nearly 50% of the 2006–07 year, which resulted in the higher than normal flows seen in Figure 2-5.

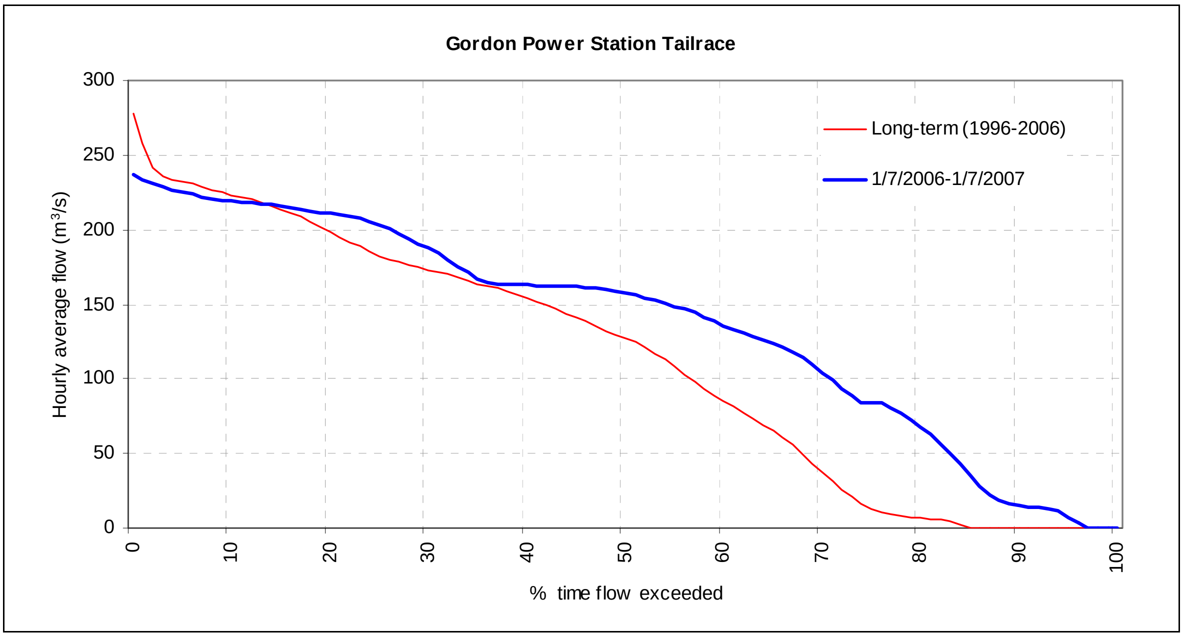


Figure 2-5. Duration curve for discharge from the power station tailrace for 2006–07

2.5.7 Event analyses

One of the methods for analysing power station operations and their effect on discharge into the Gordon River is to examine the number and duration of shutdown (zero discharge) and operating (>zero discharge) events.

In 2006-07 the pattern of both shutdown and operating events was substantially different to previous years. There were fewer times when the power station was turned off and on through the year, with the power station running for longer periods between shutdowns. This is primarily due to the low system inflows requiring the prolonged use of Gordon Power Station.

Figure 2-6 shows the frequency and duration of the shutdown events. In total 21 shutdown events were recorded during the year, which is a substantial decrease from an average of 76 events between 2001 and 2005 (Figure 2-7). The shutdown events that occurred during the year were in general shorter in duration than for previous years with the average length being approximately five hours in comparison to 2005-2006 where the average length was 21 hours. Most shutdowns were less than four hours long. However, one long-term outage (>168 hours) occurred in October 2006, whilst Gordon intake gate inspections were carried out.

The overall low system inflows as discussed above explains the majority of this change, as Gordon Power Station was utilised much more than in previous years.

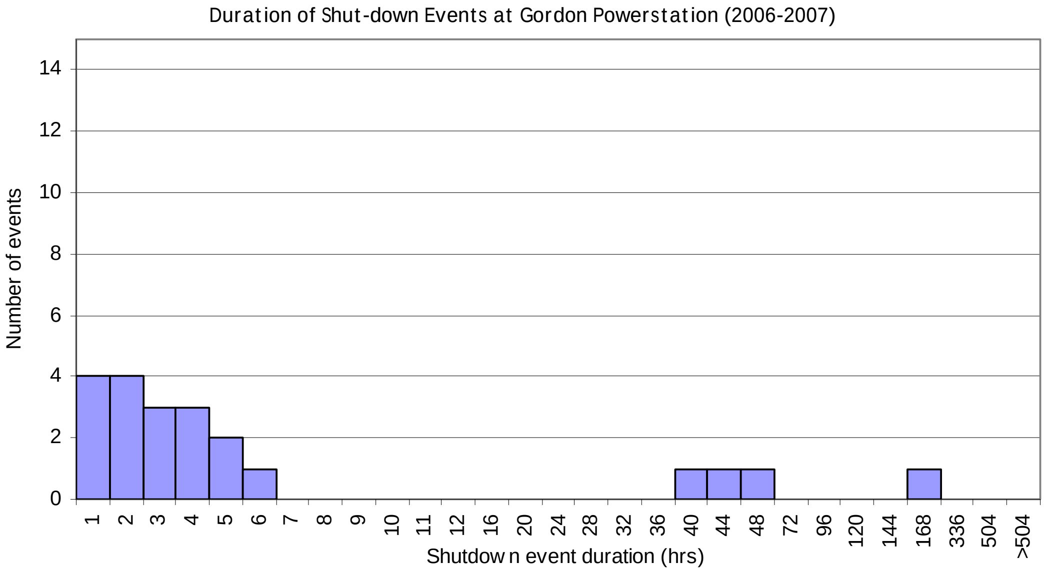


Figure 2-6. Frequency and duration of zero discharge (shutdown) events recorded for the Gordon Power Station during 2006–07

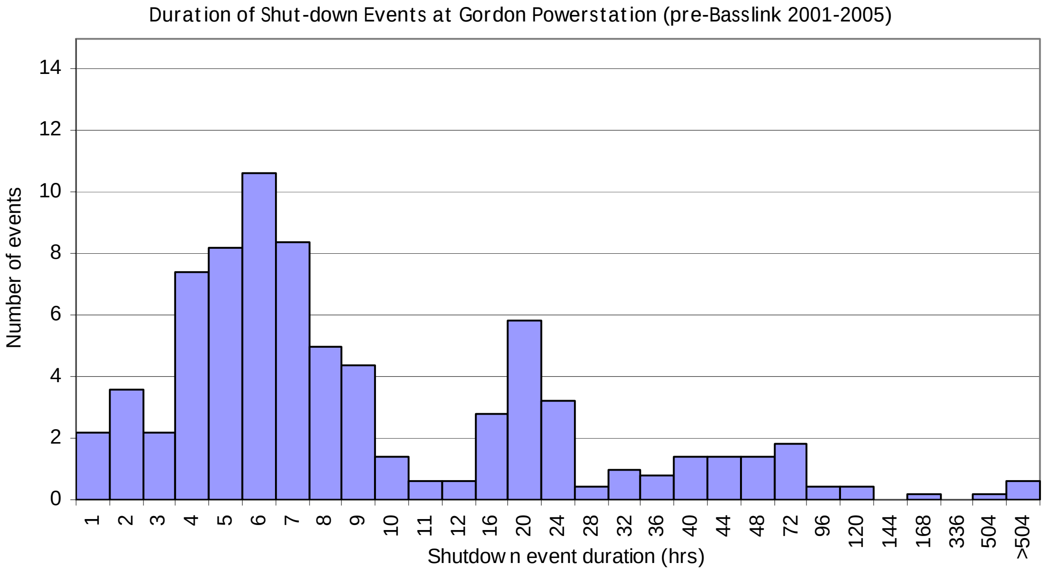


Figure 2-7. Frequency and duration of zero discharge (shutdown) events recorded for the Gordon Power Station during pre-basslink years (2001-05)

The number of operating events, indicated by discharges greater than 3 m^3 s^{-1}, is shown in Figure 2-8. This figure shows that there were five long-duration operating events (>504 hours) in 2006-07. This is substantially different to previous years where the mode of the observations was around the 16-24 hour mark (Figure 2-9).

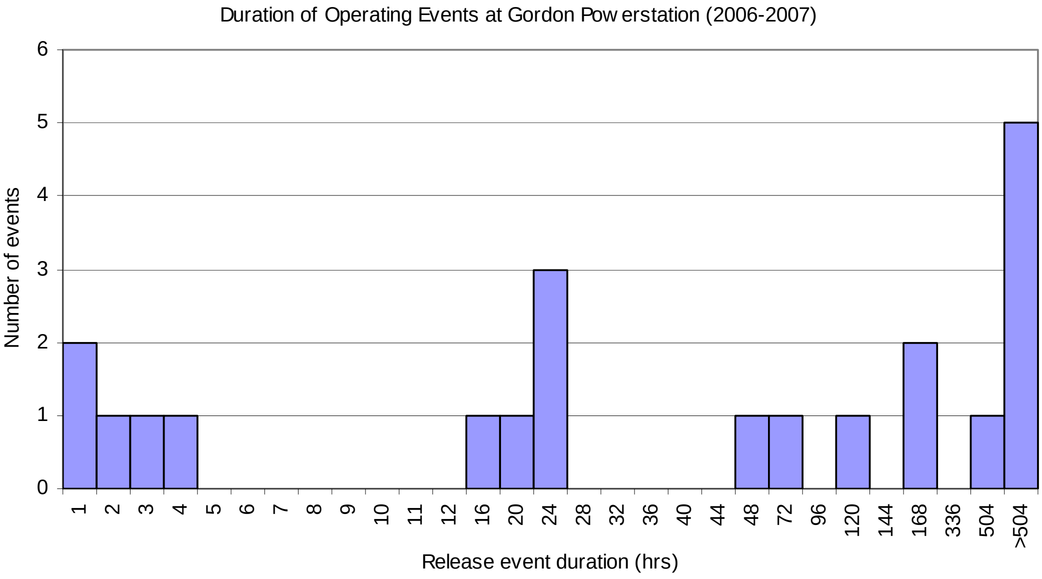


Figure 2-8. Frequency and duration of operating events (discharge > 3 $m^3 s^{-1}$) recorded for the Gordon Power Station during 2006–07

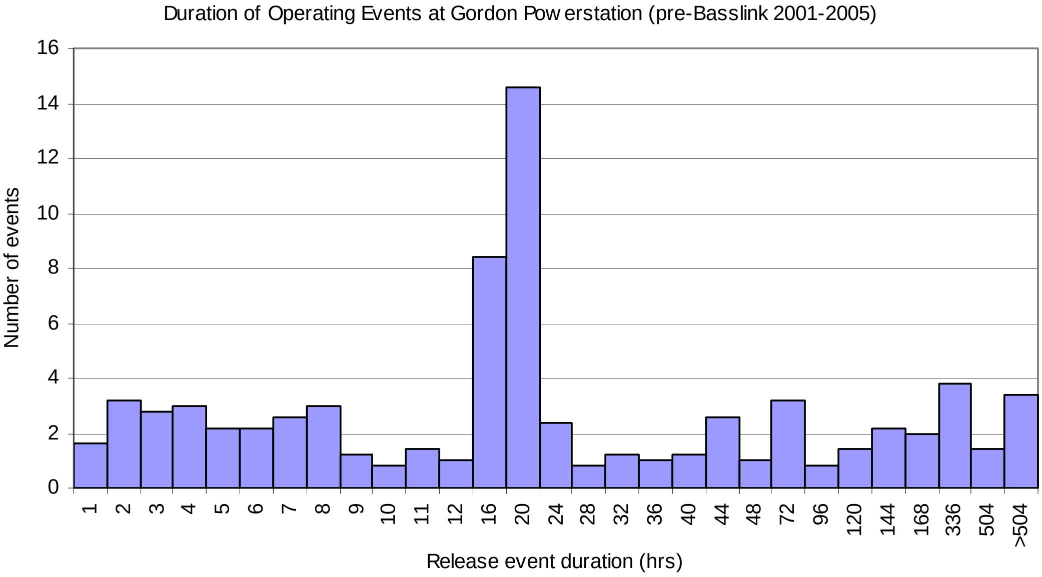


Figure 2-9 Frequency and duration of operating events (discharge > 3 $m^3 s^{-1}$) recorded for the Gordon Power Station during pre-basslink years (2001-05)

2.5.8 Ramp-down rule

An analysis of the discharge from the Gordon Power Station was undertaken to determine if the ramp-down rule had been adhered to. In general, the terms of the ramp-down rule can be described as;

- after discharging at 180 $m^3 s^{-1}$ or more, for longer than 60 minutes, the discharge cannot fall from above 180 $m^{3\ s-1}$ to below 150 $m^3 s^{-1}$ in less than 60 minutes; and

- the power station discharge may fluctuate between 180 and 240 $m^3 s^{-1}$ without having to invoke the ramping rate, unless it is intended to reduce the discharge to less than 150 $m^3 s^{-1}$.

2.5.8.1 Method

In order to determine a non-conforming event, one-minute power station MegaWatt (MW) data stored on the TimeStudio database was converted to discharge in $m^3 s^{-1}$ using a simple conversion equation. The data was checked for events where discharge remained above 180 m^3s^{-1} for more than one hour, and for each time this occurred the time taken to reduce discharge from 180 $m^3 s^{-1}$ to below 150 $m^3 s^{-1}$ was recorded. If this time was less than 60 minutes, the event was considered a non-conformance.

2.5.8.2 Results

Thirty-nine events were identified through this process. Of these events, 11 have been excluded as being non-intentional as these were event swhere the discharge dropped to no lower than 145 $m^3 s^{-1}$ for a maximum of five minutes and then returned and remained above the 150 $m^3 s^{-1}$ level.

Two of the 39 events are considered as borderline non-conformance as the discharge dropped from above 180 $m^3 s^{-1}$ and hovered around the 150 $m^3 s^{-1}$ mark for at least an hour, which infers the intention of the operator was not to reduce below 150 $m^3 s^{-1}$, but to remain slightly above to conform with the ramp-down rule.

This leaves 26 non-conformance events during the 2006-07 reporting period.

A further seven non-conformances had system events relating to their occurrence, such as NEMMCO issues affecting power station operation.

To minimise the incidents of non conformance in future Hydro Tasmania is implementing the following improvements to our processes:

- instructing the Generation Controllers to bid the Gordon Power Station out of the ancillary service market once the 30 $m^3 s^{-1}$ per hour ramp has been initiated; and
- introducing a scada alarm which is triggered if Gordon Power Station is enabled for ancillary service with the ramp rate set to 30 $m^3 s^{-1}$ per hour.

2.6 Gordon above Denison (site 65)

Site 65 is located in the Gordon River downstream of the power station and about 2km upstream of the Denison confluence. This site was installed in late 2003 in preparation for Basslink commencement. This site monitors the minimum environmental flow required post–Basslink commencement.

2.6.1 Flow

Figure 2-10 shows the flow recorded at site 65 for 2006–07. This data indicates a close concordance with power station discharge (Figure 2-3), to which peak values, the result of high flows from tributary streams, such as the Albert and Orange Rivers are added.

A backwater effect has been observed at this site. When the Denison floods and Gordon discharge is low, the Denison water may backflow up past site 65. The result of this effect would be an overestimation of the flows during the period of Denison flooding, at site 65. 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).

In February 2006, ministerial approval was obtained to alter the minimum environmental flow targets at site 65. Two levels of minimum environmental flow were approved on a three–year trial basis for different periods of the year. For the period December through May, the minimum flows required are 10 m^3 s^{-1}, for the period June through November the minimum flow required is 20 m^3 s^{-1}.

A duration analysis of hourly flows at site 65 shows that for the winter period (July-Nov 2006 and June 2007), the minimum flow target of 20 m^3 s^{-1} was achieved 100% of the time. The minimum flow target of 10m^3 s^{-1} for the months of December to May was also achieved 100% of the time. Note that times of shutdown of Gordon Power Station due to maintenance and/or monitoring have been excluded from the analysis, as per the licence conditions. The times, where flow was recorded as less than the required minimum environmental flow, are documented in Table 2-2. For each of these events, Gordon Power Station was shut down and the reason for the shutdown in each case is included in the table. No non-conformances with the minimum environmental flow rule were recorded during 2006-07.

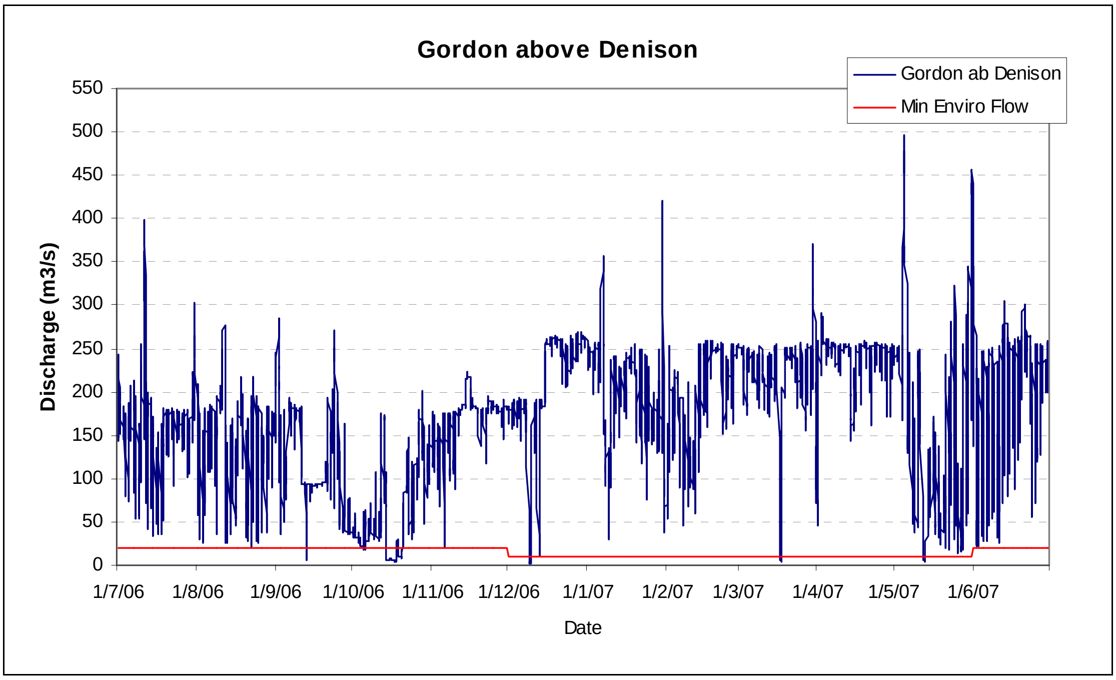


Figure 2-10. Flow recorded (hourly data) at site 65 (Gordon above Denison), from July 2006 to June 2007

Table 2-2. Low flow events at site 65

Date	Reason for Gordon PS shutdown
12/09/06 - 13/09/06	#1 machine stator check
06/10/06	Black start testing
15/10/06 – 20/10/06	Gordon intake gate inspection (includes monitoring shutdown)
09/12/06 – 10/12/06	Monitoring shutdown
17/03/07 – 18/03/07	Monitoring shutdown
12/05/07 – 13/05/07	Monitoring shutdown

2.6.2 Median monthly flows

The median monthly flow for site 65 is shown in Figure 2-11. Comparison with historic average (2003-06) patterns shows all median flows for the year were higher than usual.

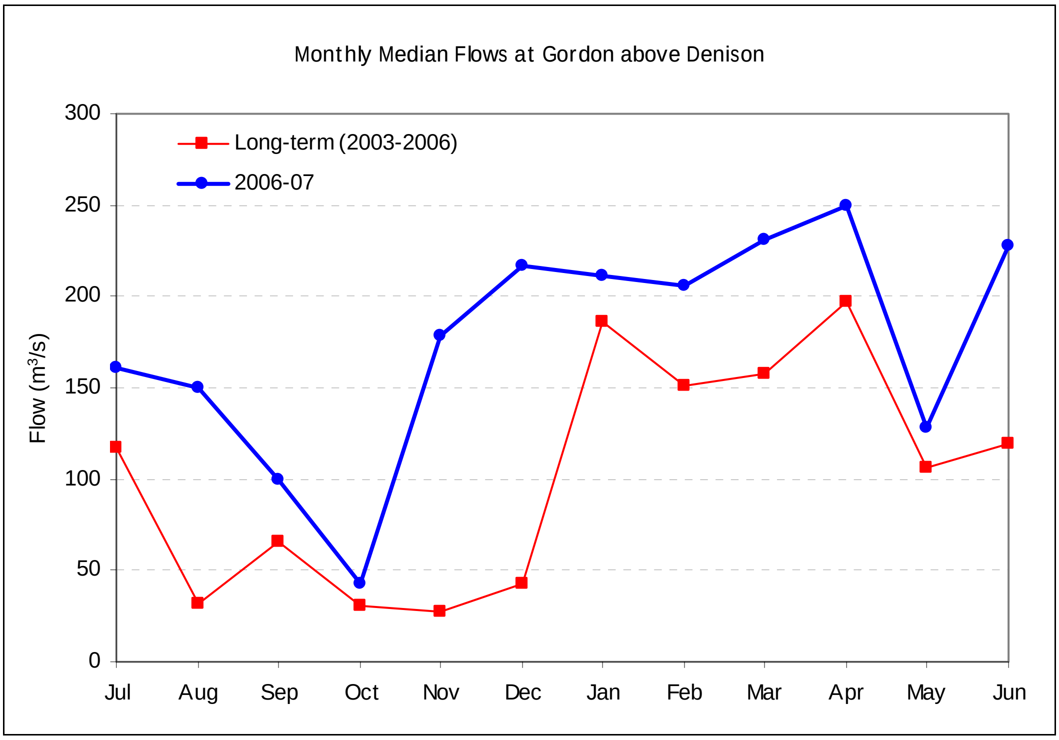


Figure 2-11. Median monthly flow at Gordon above Denison for 2006–07 compared with long–term median values

2.6.3 Duration curves

The duration curve for site 65 is shown in Figure 2-12. Comparison with the long-term curve shows an increase in flow during for the 2006-07 year for flow in all percentiles.

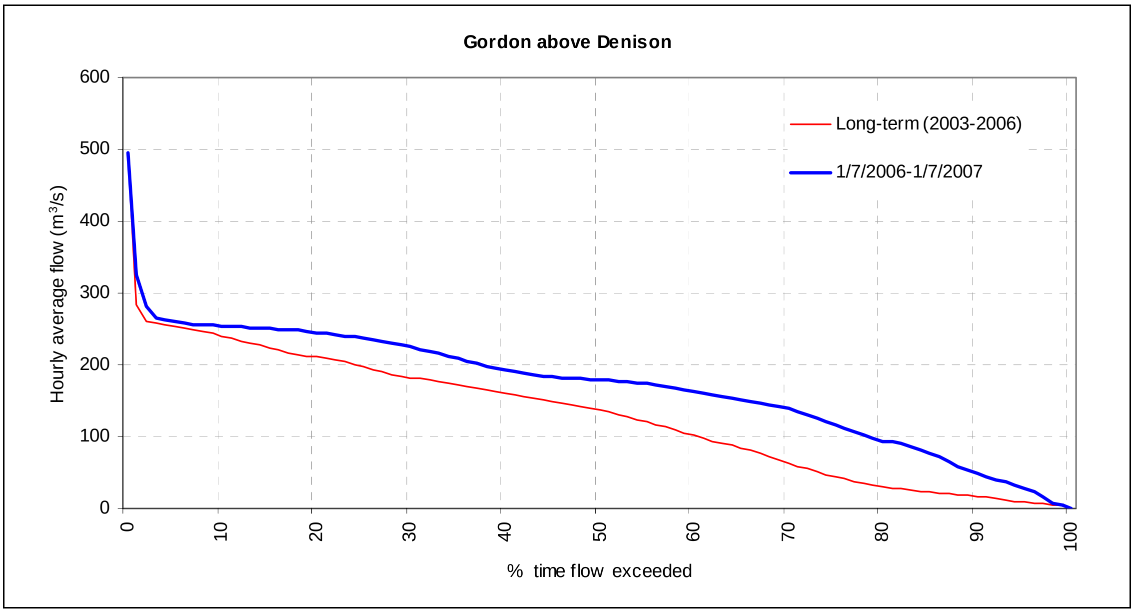


Figure 2-12. Duration curve for flow at Gordon above Denison

2.7 Gordon above Franklin (site 44)

The Gordon above Franklin site (site 44) is the furthest downstream site unaffected by tidal influences. Power station releases travel 33 km down the Gordon River before passing the site 44 gauge. 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 and indication of the influence of tributary streams and flow attenuation of the power station discharge on hydrology of the lower reaches of the river.

2.7.1 Flow

Figure 2-13 shows the hourly flows at site 44 for 2006–07, note that data are missing for the period 29 September 2006 to 30 January 2007 and from 5 May to 30 June 2007 due to equipment failure. Power station discharge is superimposed on to this plot for comparison. Power station discharge forms the major component of the flow at site 44, with the high peak discharges resulting from flow from tributary streams, such as the Denison River.

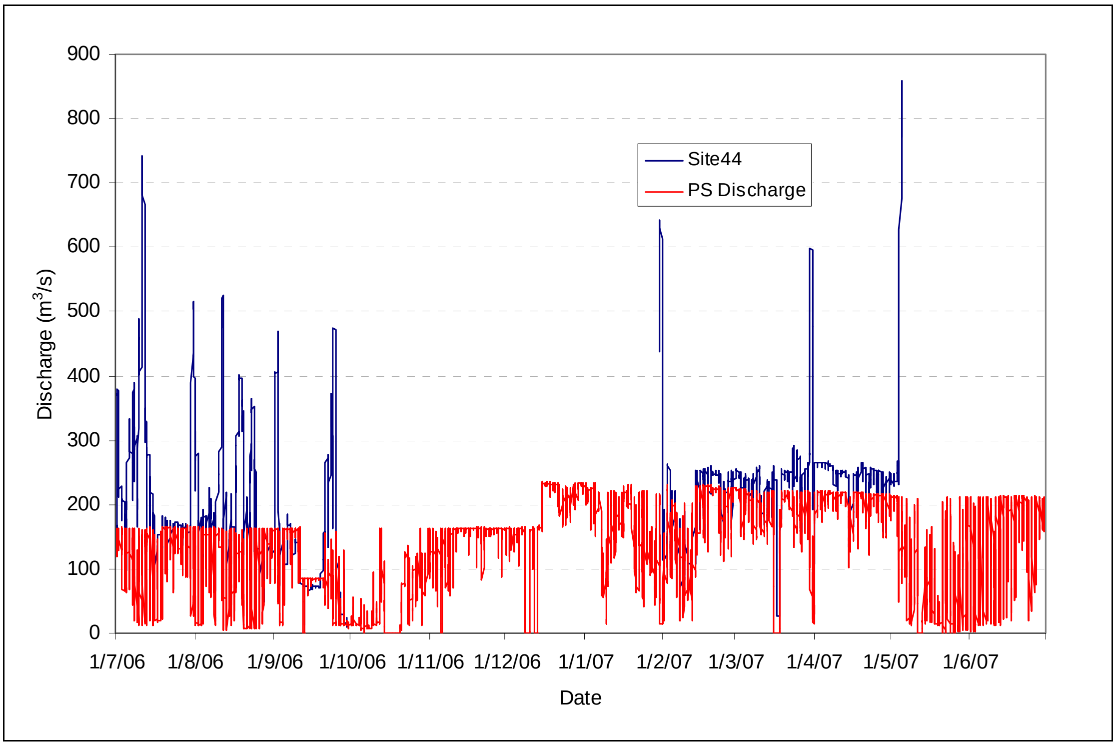


Figure 2-13. Flow recorded (hourly data) at site 44 (Gordon above Franklin) and Gordon Power Station discharge during 2006–07

2.7.2 Median monthly flows

Figure 2-14 shows the median monthly discharge for the data which are available for site 44 over the 2006–07 year, compared with the long-term (since December 1999) pattern. For the period data is available the monthly medians are higher than the long-term average with February and April 2007 being very close to average.

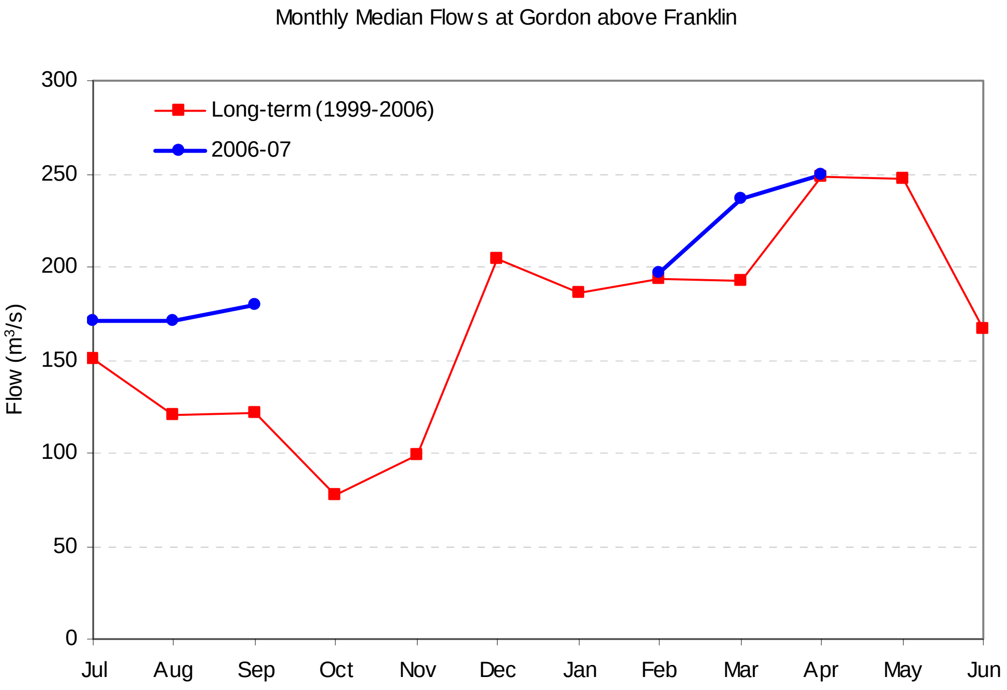


Figure 2-14. Median monthly flow at site 44 (Gordon above Franklin) for 2006–07 and the long–term monthly median values

2.7.3 Duration curves

Given the quantity of data missing, no meaningful comparison via the plotting of duration curves is possible.

2.8 Conclusion

Rainfall at Strathgordon in 2006–07 was lower than usual, with an annual total that was less than 82% of the annual long-term average. However, Gordon Power Station was used more extensively during the year even though only two turbines were available for June-December.

On a monthly basis, all months except May 2007 exceeded the long–term median power station discharge values. In addition, power station discharge events have been of a higher magnitude than usual except at the higher flow range where maximum output is somewhat reduced at lower lake levels.

There were 75% less shutdowns than in 2005–06. One long–duration shutdown was recorded in October 2006 for maintenance purposes. In terms of operating events, the power station recorded fewer start–ups than in 2005–06, with one event being greater than 90 days.

Flow pattern at the compliance monitoring site (site 65) and median monthly flow values were similar to those of the tailrace, with additional flow from upstream tributaries. The duration curve for this site was similar to that of the tailrace, but with increased flows for the entire flow range. At least some of this difference may be attributable to backwater from high Denison River flows which would lead to exaggeration of the apparent discharge at this point.

The duration analysis of hourly flows at site 65 shows that for the winter period (July-Nov 2006 and June 2007), the minimum environmental flow target of 20 $m^3 s^{-1}$ was achieved 100% of the time. The minimum environmental flow target of 10$m^3 s^{-1}$ for the months of December to May was also achieved 100% of the time. Some lower flows were experienced during permitted outages.

The ramp-down rule was not adhered to on 26 occasions. Improvements to the alert processes are being put in place to minimise non-conformance in future.

The Gordon above Franklin site (44) was plagued by instrument problems during the recording year and as such a large percentage of the data is missing. For the data that does exist, the flow pattern closely mirrors the power station discharge but includes some peak flow events produced by rainfall and tributary runoff.

Due to the current system low inflow conditions and requirement for a higher than average energy contribution from the Gordon Power Station flows for all sites in the Gordon River were greater than average for the year. Site 65 is most affected by the power station operation while site 44 has more natural inflow and is less influenced by power station operations. The median flow rates at the tailrace, site 65 and site 44 for 2006–07 were almost twice as high as in 2005-06 year.

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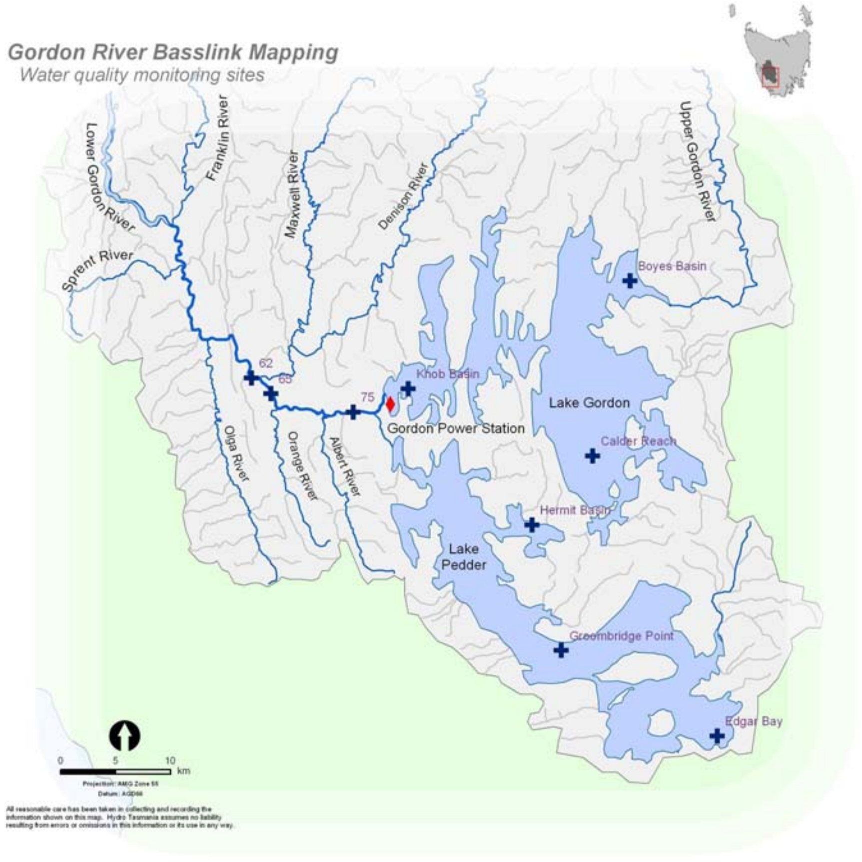
3 Water quality

Water quality parameters were measured in Lake Gordon and Lake Pedder July and October 2006 and January and April 2007, and in the Gordon River downstream of the power station, in compliance with the requirements of the water licence. The water quality monitoring sites are shown in Map 3-1.

Lake Gordon is a major source of water in the middle Gordon River, and the quality of water in the river is influenced by the conditions at the power station intake and the flow regime in the river. There are no specific trigger values for water quality. However, water quality is collected and reported as a possible input variable that may relate to the biological monitoring in the Gordon River. Therefore it is the aim of the Basslink Water Quality Monitoring Program to document the water quality in both the storages (Lake Gordon and Lake Pedder) and downstream in the Gordon River to assist in the interpretation of biological monitoring data in the middle Gordon River.



Map 3-1. Map of the locations of water quality monitoring sites in Lakes Pedder and Gordon, and the Gordon River

3.1 Methods

In the lakes, chemical analyses were carried out on surface water samples. The following parameters were analysed for each water sample:by Analytical Services Tasmania to NATA approved standards:

- total phosphorus and filterable reactive phosphorus (FRP);
- nitrite, nitrate, total Kjeldahl nitrogen (TKN) and ammonia;
- chlorophyll-*a*;
- metals (Fe, Mn, Zn, Cd, Cu, Al, Co, Cr, Ni and Pb);
- sulphate;
- alkalinity; and
- dissolved organic carbon.

Additionally, *in situ* depth profiles of basic physico-chemical parameters (water temperature, dissolved oxygen, conductivity and pH) were taken at approximately 2m vertical intervals at each of the sampling sites in Lakes Gordon and Pedder.

3.1.1 Lake Gordon

During 2006-07, quarterly water quality monitoring was conducted in Lake Gordon at Knob Basin near the power station intake, Calder Reach and Boyes Basin adjacent to the upper Gordon River inflow. This sampling was undertaken on 18-19 July 2006, 13 October 2006, 15-16 January 2007 and 12-13 April 2007. Depth profiles of water temperature, dissolved oxygen, pH, and conductivity were taken to monitor the status of the water column at these sites. Surface water chlorophyll-*a*, water temperature, pH, conductivity, turbidity and dissolved oxygen concentrations were also recorded at these locations and surface samples for laboratory measurement of nutrients and metals were collected.

3.1.2 Lake Pedder

Depth profiles were measured off Groombridge Point in Lake Pedder, which is the deepest part of the main body of the lake on 18 July 2006, 15 January 2007 and 12 April 2007. It was not possible to collect the October profile, due to poor weather conditions. Surface water samples were taken for the measurement of chlorophyll-*a*, nutrients and metals at Groombridge Point. The *in situ* measurement of surface water temperature, pH, conductivity, turbidity and dissolved oxygen was undertaken on 18 July 2006, 15 January 2007 and 12 April 2007 at Groombridge Point, Hermit Basin and Edgar Bay.

3.1.3 Gordon River

Water quality monitoring data were collected from four sites on the Gordon River, downstream from the Gordon Power Station. These sites are:

- Gordon Power Station tailrace (site 77);
- Gordon River at site 75 (G4 –Albert Rapids);
- Gordon River at site 62 (downstream of the Denison confluence); and
- Gordon River at site 65 (upstream of the Denison confluence – compliance site).

Water temperature was logged at all sites for the full year, with dissolved oxygen also being recorded at sites 65 (compliance site) and 77 (tailrace). Dissolved oxygen data at the tailrace are not presented here, as there have been difficulties in obtaining good quality data, suitable for analysis. Sites 65 and 77 have their data retrieved by telemetry, while sites 62 and 75 must be downloaded manually during field visits. For this reason, the data from sites 62 and 75 is analysed outside the normal financial year cycle from April 2006–April 2007. This corresponds with field visits when data retrieval occurred.

3.2 Results

3.2.1 Lake Gordon water quality

Changes in water temperature, pH and dissolved oxygen for Boyes Basin, Calder Basin and at the Intake site are shown in Figure 3-1, Figure 3-2 and Figure 3-3. Depth profiles of each of the parameters varied with location, inflows and season.

3.2.1.1 Boyes Basin

Boyes Basin is the shallowest of the three sampling sites, with water depths ranging between 20 to 30m during the year (Figure 3-1). It is also located closest to the upper Gordon River which is one of the major inflows to the lake. In July, temperatures through the water column ranged between 7.8 °C at the surface to 5.9 °C at 29m. A thermocline was evident at around 15m indicating that there was persistent stratification into winter. In October, a similar pattern of stratification was evident; the thermocline was at a depth of around 15m, however with higher temperatures of 11 °C at the surface and 8 °C in the hypolimnion. This stratification may be the result of inflows of cool water from the upper Gordon River. In January, stratification was significantly more pronounced, with a temperatures range of 21 °C at the surface to 11 °C in the hypolimnion. The April 2007 water temperature was appreciably lower than January, with temperatures approximating 15 °C in the surface and 12 °C in the hypolimnion.

The pH values were lower at greater depth in October 2006 and January 2007, with values ranging between 6.0 and 6.7 for these two sampling profiles. In January, the difference between surface and bottom was most pronounced, with the higher pH at the surface probably attributable to increased algal production. A different vertical pattern in pH was evident for the July 2006 and April 2007 profiles, with higher pH values near the bottom. The higher pH in deeper waters may be indicative of inflows of water from the upper Gordon, with different chemical characteristics to that of the lake.

Dissolved oxygen levels were highest in October 2006 ranging between 10.2–11.2 mg L^{-1} (90–95% saturation). July dissolved oxygen levels were also high, and ranged from 9.7–11.3 mg L^{-1} (81-89% saturation) throughout the depth of the water column. In January, levels were above 7.7 mg L^{-1} (75% saturation), in the upper 15m but decreased between 15 and 23m to a minimum of 3.1 mg L^{-1} (28% saturation) as a result of thermal stratification. Dissolved oxygen levels had decreased by April ranging from 6.3-8.3 mg L^{-1} (62-83% saturation) in the upper 14m, while the lower 6m had increasing concentration of dissolved oxygen, up to 8.7 mg L^{-1} (83% saturation).

Conductivity at Boyes Basin was low, and ranged between 25–63 µS cm^{-1} over the full depth range for each of the sampling days, while turbidity was low within the range of 1.5–4.3 NTU (Table 3-1). Chlorophyll *a* was generally low with a range of 0.32–3.56 µg L^{-1} (Table 3-1).

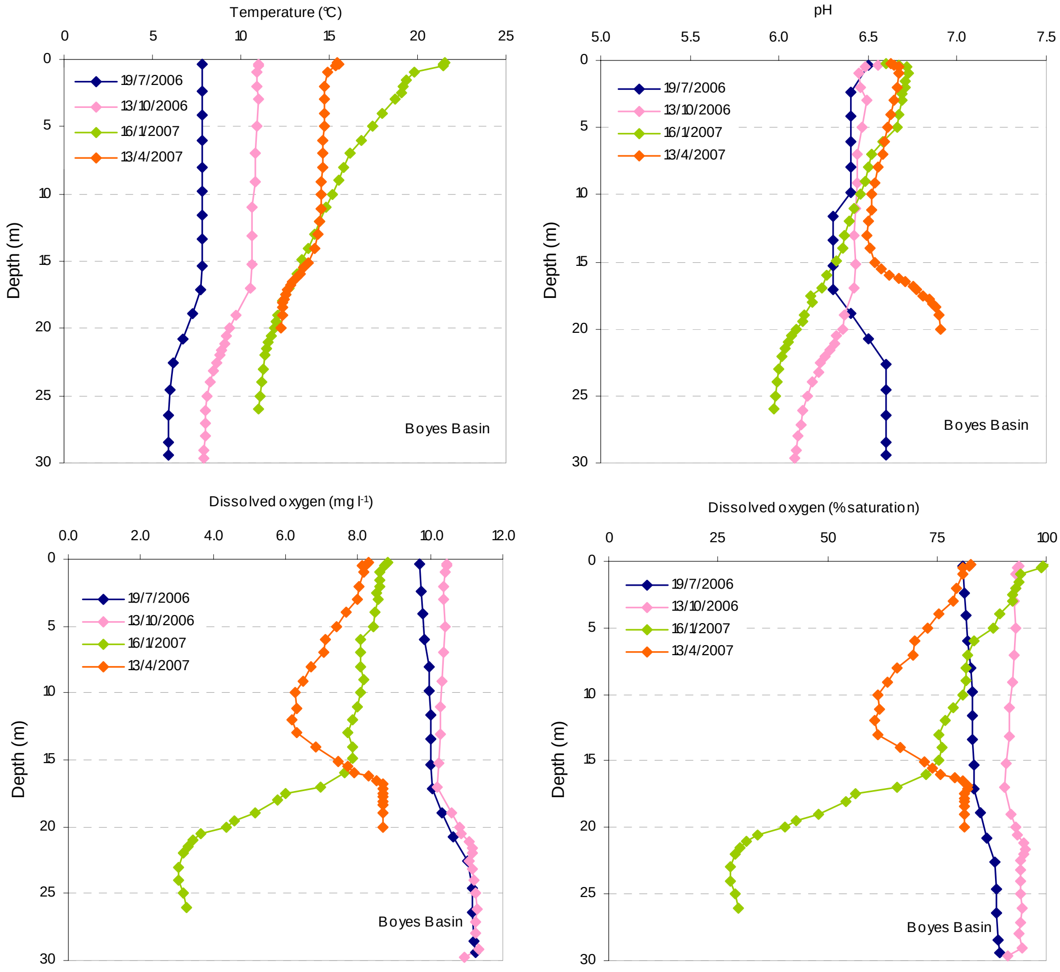


Figure 3-1. Depth profiles temperature, pH and dissolved oxygen at Boyes Basin in Lake Gordon

3.2.1.2 Calder Reach

Calder Reach had a gradual heating of the water column from isothermal conditions in July to stratification in January. The depth profile in April indicated isothermal conditions for the first 20m indicating a deepening of surface mixing following the decline in surface temperatures. In January, surface and hypolimentic (40m depth) temperatures approximated 19 and 10 °C, respectively. In April, water temperatures approximated 14 °C in the upper 20m, and decreased to 11 °C at a depth of 30m.

The pH profiles at Calder Reach ranged from 5.8–6.9 Dissolved oxygen levels were high in July and October ranging between 10-11 mg L^{-1} (82-98% saturation) (Figure 3-2). In January, levels were above 9.0 mg L^{-1} (91% saturation), in the upper 14m but decreased between 20 and 42m as a result of thermal stratification to a minimum of 7.0 mg L^{-1} (62% saturation). In April, dissolved oxygen between the surface and 14m depth was high at around 8.8 mg L^{-1} (85% saturation), however there was a strong oxycline at 20m, The lowest dissolved oxygen levels in the hypolimnion of all sampling periods, of 2.7 mg L^{-1} (24% saturation) was measured in the hypolimnion in April. Conductivity, turbidity and chlorophyll *a* were all low ranging between 36–42 µS cm^{-1}, 2.4–3.5 NTU and 0.12–1.53 µg L^{-1}, respectively (Table 3-1).

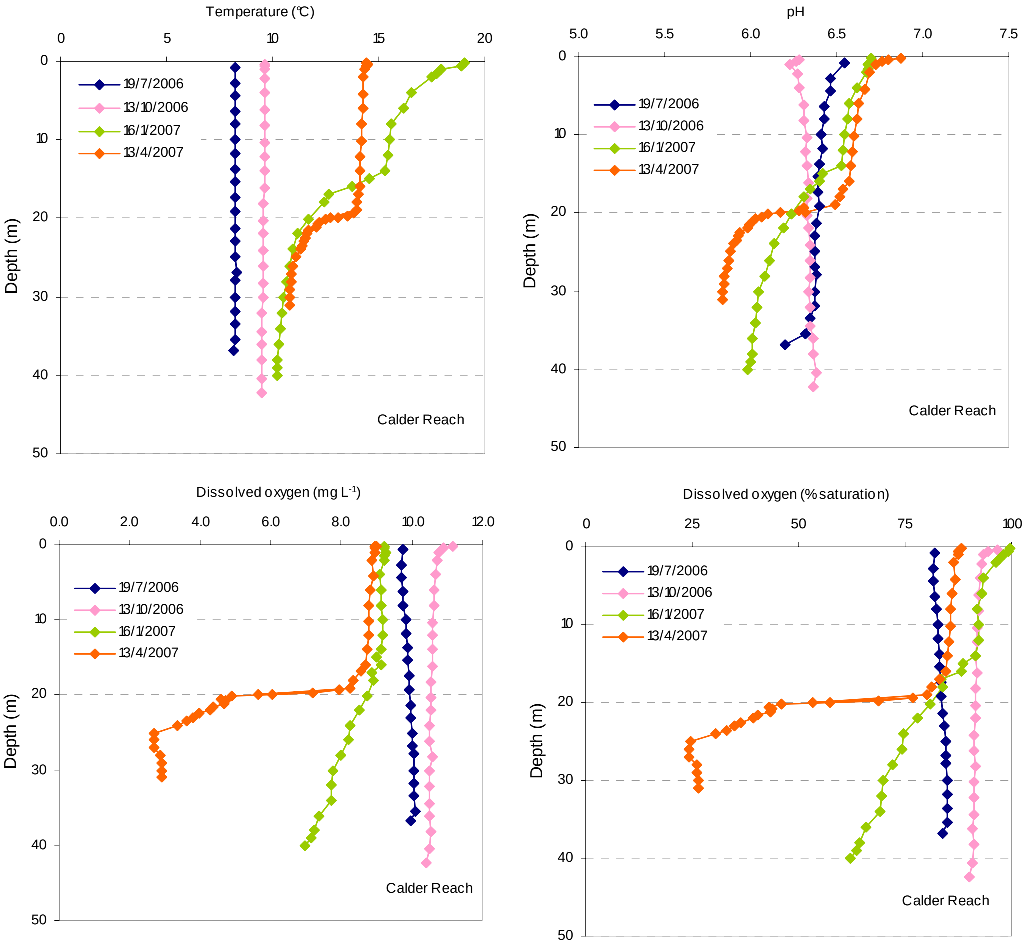


Figure 3-2. Depth profiles of for temperature, pH and dissolved oxygen at Calder Reach in Lake Gordon.

3.2.1.3 Intake site

The temperature profiles at the power station intake displayed near isothermal conditions in July, and October and strong stratification in January. In April there was a deepening of the surface mixed layer as the seasonal stratification began to decline (Figure 3-3).

In July, temperatures approximated 8.5 °C to a depth of around 50m (233 mASL), at which point the temperature slowly declined with depth to an approximate minimum of 8 °C on the bottom at 79m depth (204 mASL). Also in July, the dissolved oxygen >7.6 mg L^{-1} (65% saturation) to a depth of 44m (239 mASL). An oxycline was evident at this depth with anoxia evident over the depth range of 51 to 79m (232 to 204 mASL). A strong oxycline, with anoxia in bottom waters was also evident on all other sampling days (Figure 3-3).

In October, the water temperature remained cool and ranged between 8 and 9.3 °C, while dissolved oxygen ranged between 0 and 9.8 mg L^{-1}; anoxic conditions only occurred on the very bottom sampling point in October.

In January, the temperature ranged from 8 °C at 76m depth (204 mASL) to 19 °C at the surface (280 mASL), and displaying a shallow mixed layer on the day of sampling. Dissolved oxygen was >8.4 mg L^{-1} in the upper 24m, and then declined at a relatively constant rate with depth with anoxic conditions first seen at a depth of 65m (215 mASL), and persisting to the lake bottom at a depth of 76m (204 mASL). The pattern of decline with depth differed in the% saturation profile due to the influence of temperature on the capacity for water to hold dissolved oxygen.

In April, water temperature ranged from 14.8 °C at the surface (273 mASL) to 8 °C at 66m depth (207 mASL). Dissolved oxygen was 8.9 mg L^{-1} at the surface, with an oxycline located between the depth of 14 and 45m (259 and 228 mASL). Water was anoxic between the depths of 45 and 66m (228 and 207 mASL). It was clear at this time that there was a significant chance of water of low dissolved oxygen being drawn into the power station from Lake Gordon, as the intake level was located just below the oxicline.

The pH values at the intake displayed variability with time and depth (Figure 3-3). Values were higher at the surface ranging from 6.1 to 6.6, and 5.5 to 5.8 in the hypolimnion between July 2006 and April 2007. Surface conductivity at the intake location was low and ranged from 34 to 49 µS cm^{-1} over depth for each of the sampling days, while turbidity was low within the range of 1.0-1.5 NTU (Table 3-1). Chlorophyll *a* was also very low with a range of 0.05–2.38 µg L^{-1} and is typical for oligotrophic lakes (Table 3-1).

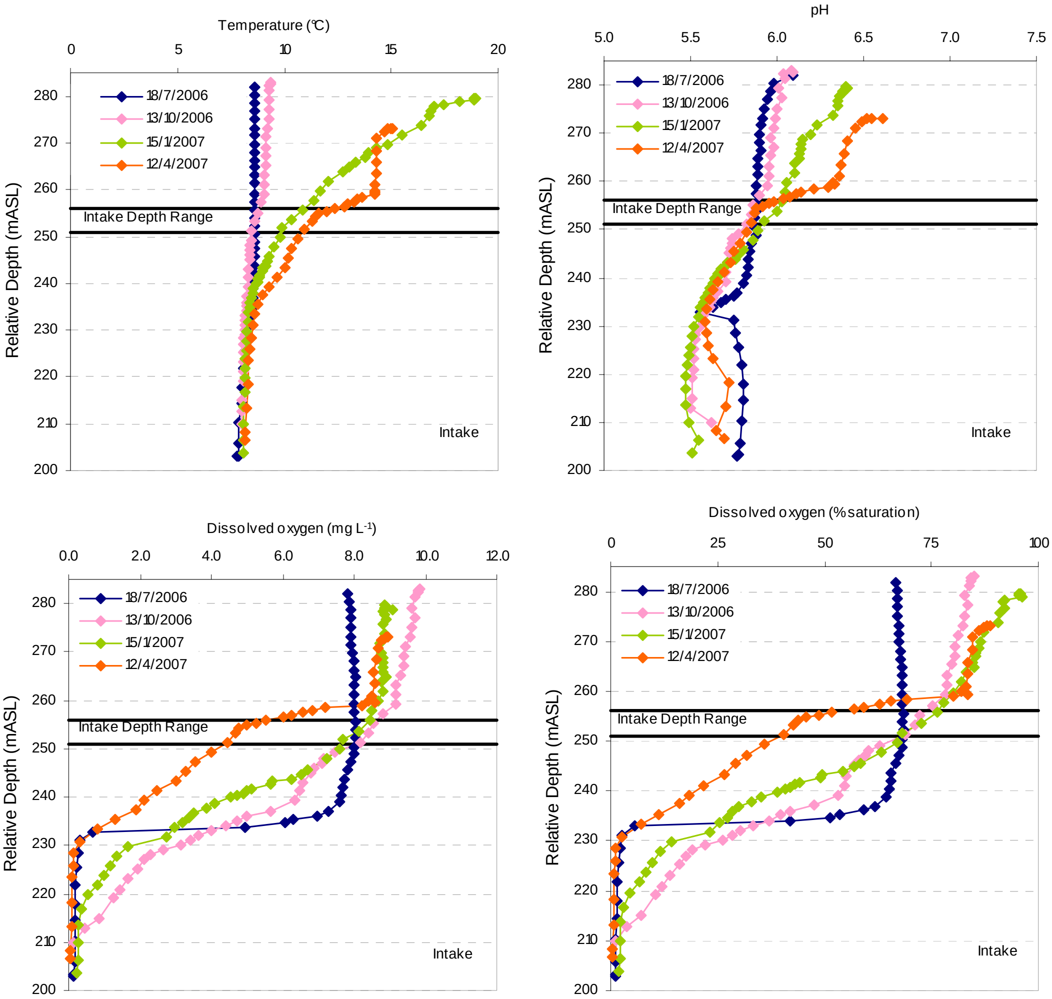


Figure 3-3. Depth profiles for the intake site located at Knob Basin in Lake Gordon for temperature, pH and dissolved oxygen. Depths are represented as relative depth in mASL to demonstrate the potential fluctuations in water quality at the power station intake. The depth range of the power station intake is indicated by two heavy black lines.

3.2.1.4 Lake surface water quality

The surface water quality data are presented in Table 3-1. The results are typical of Tasmanian fresh waters in the Tasmania's south-western region with low nutrient and metal concentrations, relatively high dissolved organic carbon and slightly acidic pH values. Chlorophyll *a* levels were slightly elevated at Boyes Basin compared to the other two sites in summer. Sulphate concentrations were within the range reported last year, while the low alkalinity measures continue to indicate that the water in Lake Gordon is "soft" (i.e. low in carbonates).

Table 3-1. The range of nutrients, metals, sulphate, alkalinity, dissolved organic carbon and chlorophyll–a levels recorded from three monitoring sites in Lake Gordon during 2006–07 during sampling trips on 18 July 2006, 13 October 2006, 15 January 2007 and 12 April 2007.

Parameter	Boyes Basin	Calder Basin	Intake
Specific conductivity (µS cm^{-1})	25-63	36-42	34-49
Turbidity (NTU)	1.5–4.3	2.4–3.5	1.0–1.5
Chlorophyll–*a* (µg l^{-1})	0.32–3.56	0.12–1.53	0.05–2.38
Dissolved organic carbon (mg L^{-1})	5.6–8.3	6.1–7.5	6.0–7.4
Sulphate (mg L^{-1})	1.1–1.2	1.2–1.3	1.1–1.2
Alkalinity (mg L^{-1})	2–5	2–3	2–3
Total phosphorus (mg L^{-1})	<0.005–0.008	<0.005–0.007	<0.005–0.006
Filterable reactive phosphorus (mg L^{-1})	<0.002–0.002	<0.002–0.003	<0.002–0.002
Nitrite (mg L^{-1})	0.003–0.004	0.002–0.004	<0.002–0.003
Nitrate (mg L^{-1})	0.038–0.056	0.044–0.064	0.041–0.062
Total Kjeldahl nitrogen (mg L^{-1})	0.179–0.234	0.181–0.216	0.189–0.261
Ammonia (mg L^{-1})	0.012–0.029	0.014–0.030	0.013–0.043
Iron (µg L^{-1})	236–495	448–535	404–602
Manganese (µg L^{-1})	4.2–8.4	5.0–9.5	6.5–33.6
Zinc (µg L^{-1})	<0.1–2	<1–11	<0.5–2
Cadmium (µg L^{-1})	<0.1	<0.1	<0.1
Copper (µg L^{-1})	<1	<1	<1
Aluminium (µg L^{-1})	92–236	137–197	128–164
Cobalt (µg L^{-1})	<0.5	<0.5	<0.5
Chromium (µg L^{-1})	<1–1	<1–1	<1–1
Nickel (µg L^{-1})	<0.5–0.8	<0.5–0.5	<0.5–0.6
Lead (µg L^{-1})	<0.5	<0.5	<0.5

3.2.2 Lake Pedder water quality

Lake Pedder is relatively shallow (15–16m depth) and well mixed with depth profiles of temperature displaying isothermal conditions in July and April with some surface heating in January (Figure 3-4). The temperature profiles also demonstrate a gradual heating of the water body from winter at 7 °C to 16 °C in summer. The resulting effect was that water quality parameters did not change with depth (Figure 3-4, Table 3-2) which is consistent with previous monitoring results. Water samples from the surface were analysed for a range of parameters as outlined in section 3.1. As in previous years, water quality was high in Lake Pedder. Conductivity, turbidity, chlorophyll, nutrient and metal concentrations were all low, while dissolved oxygen was high in surface waters and pH was slightly acidic. Dissolved organic carbon concentrations were high and similar to those measured in Lake Gordon (Table 3-3).

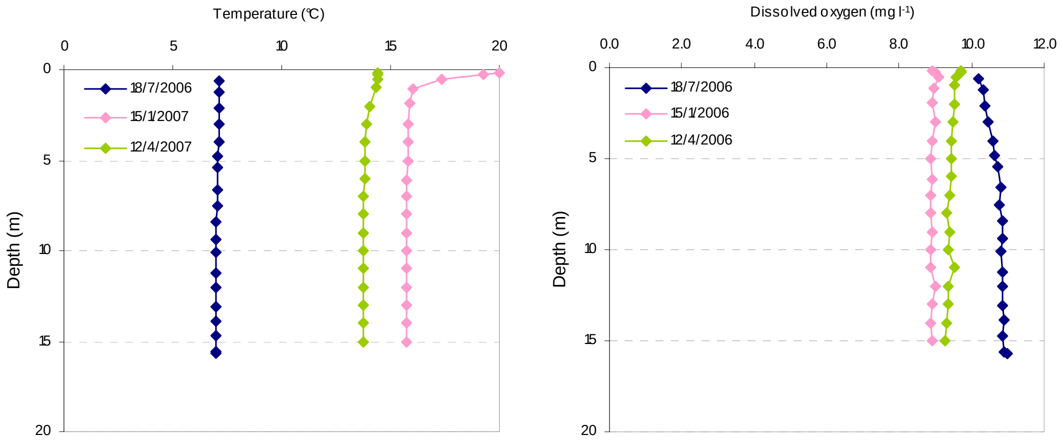


Figure 3-4. Depth profiles of water temperature and dissolved oxygen at Groombridge in Lake Pedder for 2006–07

Table 3-2. Water quality parameter ranges measured at the three monitoring sites in Lake Pedder during 2006–07. Sampling trips were undertaken on 18 July 2006, 15 January 2007 and 12 April 2007.

Parameter	**Edgar Bay (surface)**	**Hermit Basin (surface)**	**Groombridge Point (surface)**	**Groombridge Point (15m)**
Chlorophyll–*a* (μg l^{-1})	0.55–1.41	0.46–1.330	0.57-1.24	–
Dissolved oxygen (mg L^{-1})	8.5–11.1	8.6–10.8	9.0-10.2	8.9-11.0
Dissolved oxygen (% saturation)	85-96	82-97	83-98	89
pH	6.2–6.6	5.7-6.5	6.3-6.5	6.2-6.4
Turbidity (NTU)	0.69-1.10	0.61-0.95	0.7-1.1	–
Conductivity (μS cm^{-1})	37–43	34-42	41	41-42
Water temperature (°C)	7.0–21.0	7.1-18.1	7.1-20.0	7.0-15.7

Table 3-3. Nutrients, metals, sulphate, alkalinity, and dissolved organic carbon levels at Groombridge Point, Lake Pedder during 2006–07. Sampling trips were undertaken on 18 July 2006, 15 January 2007 and 12 April 2007.

Parameter	Range
Sulphate (mg L^{-1})	1.1-1.5
Alkalinity (mg L^{-1} as $CaCO_3$)	<2-7
Dissolved organic carbon (mg L^{-1})	5.8-6.4
Total phosphorus (mg L^{-1})	<0.005–0.008
Filterable reactive phosphorus (mg L^{-1})	<0.002
Nitrite (mg L^{-1})	0.003–0.013
Nitrate (mg L^{-1})	0.036-0.048
Total Kjeldahl nitrogen (mg L^{-1})	0.195-0.223
Ammonia (mg L^{-1})	0.020–0.028
Iron (µg L^{-1})	211-536
Manganese (µg L^{-1})	3-9.1
Zinc (µg L^{-1})	2-8
Cadmium (µg L^{-1})	<0.1
Copper (µg L^{-1})	<1.0
Aluminium (µg L^{-1})	102-126
Cobalt (µg L^{-1})	<0.5
Chromium (µg L^{-1})	<1-1
Nickel (µg L^{-1})	<0.5-0.5
Lead (µg L^{-1})	<0.5

3.2.3 Water quality in the Gordon River

The Gordon River water temperatures were measured at the tailrace (site 77), site 75 (Gordon @ G4) and site 62 (Gordon @ Denison confluence), while dissolved oxygen was measured at the tailrace. More recent installation of water quality monitoring equipment at site 65 (Gordon upstream of the Denison confluence) is presented since its installation in April 2006.

3.2.3.1 Data quality and duration

Temperature (Figure 3-5) data is missing for short periods during the 2006–07 monitoring period at the tailrace, and for a significant period between April and October 2006 at site 75. These records are not available due to equipment failures. There is a degree of uncertainty in the dissolved oxygen readings taken at the tailrace (site 77) . This uncertainty has arisen since the instrument used to measure the dissolved oxygen was moved in September 2006 to a new location. This cause of the unreliable data is currently unknown and is being investigated. Due to the uncertainties in the dissolved oxygen data at site 77, they will not be presented or discussed in this report.

3.2.3.2 Water temperature

The hydrological regime and conditions in Lake Gordon tend to govern water temperature in the Gordon River at and immediately below the power station (Figure 3-5 and Figure 3-6). The temperature of water released was influenced by lake level, degree of thermal stratification and power station discharge.

Water temperature was monitored at the tailrace (site 77), site 75 (G4), site 65 (compliance site) and site 62 (Figure 3-5). Site 75 is located 2 km downstream of the power station tailrace and is below the Albert River but above the Orange River confluence, site 65 is above the confluence with the Denison River (a further 10 km downstream) while site 62 is a further 3 km downstream below the Denison and Maxwell river confluences.

A similar seasonal pattern at sites 77, 75, 65 and 62 was observed, which ranged from approximate mean seasonal maximum temperature of 14 °C in March 2007 to a mean minimum of around 7–8 °C in August 2006. The actual maximum value was recorded in December 2006, and corresponded to the shutdown of the power station to undertake monitoring for the Basslink Gordon Monitoring Program. With the exception of this one occasion, the temperature regime was primarily influenced by the temperature of water at the Lake Gordon intake to the power station which can be seen to correspond very closely on most occasions when lake water quality profiles were undertaken (Figure 3-5). A large difference was seen on 12 April between the temperature of water in the river and in Lake Gordon at the level of the intake. The cause for this discrepancy is most likely the result of the intake being at the level of the thermocline.

Differences between the water temperatures at the different sites on the river are related to their distance downstream from the power station. For most of the year the coolest water was found in the tailrace, while the warmest was found below the confluence with the Denison at site 62 (Figure 3-5, Figure 3-6). The increase in temperature downstream is related to a combination of the influence of ambient air temperature and the greater proportion of water sourced from tributaries. In addition to the higher temperature at site 62, there was a significant degree of diurnal water temperature variation (Figure 3-6), which was increased by a combination of low power station discharge and high ambient air temperature. In addition, at lower power station discharge, there is greater relative contribution of water from tributaries that is more responsive to daily temperature fluctuations. During the cooler months (May and June) the temperature trend along the river was reversed so that water was generally cooler further downstream due to the cooling effect of ambient air temperature (i.e. when air temperature was lower than water temperature), and the greater influence downstream of cooler water sourced from tributaries (Figure 3-6).

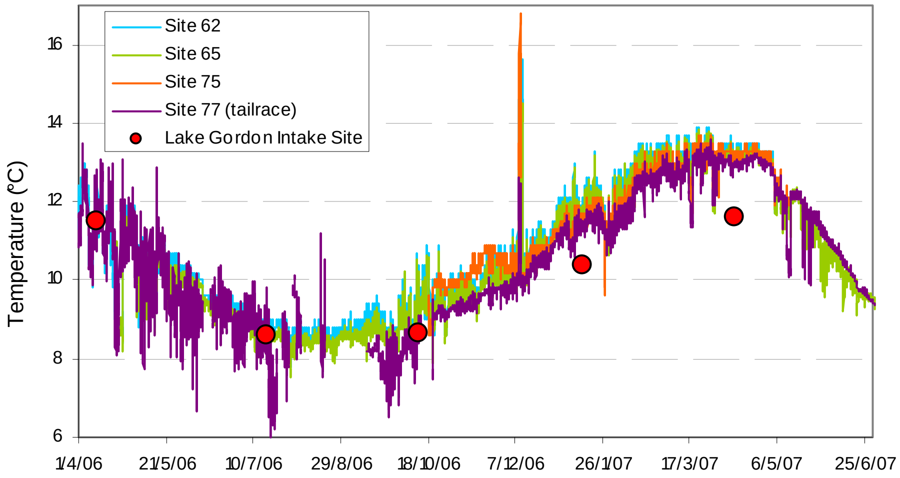


Figure 3-5. Water temperature data recorded for sites 75 (2km downstream of the tailrace), 65 (12km downstream of the tailrace) and 62 (15km downstream of the tailrace) from April 2006 to June 2007. Note that data from sites 65 and 77 was retrieved by telemetry, while sites 62 and 75 were downloaded manually from the data logger and due to logistical constraints were only available until early May.

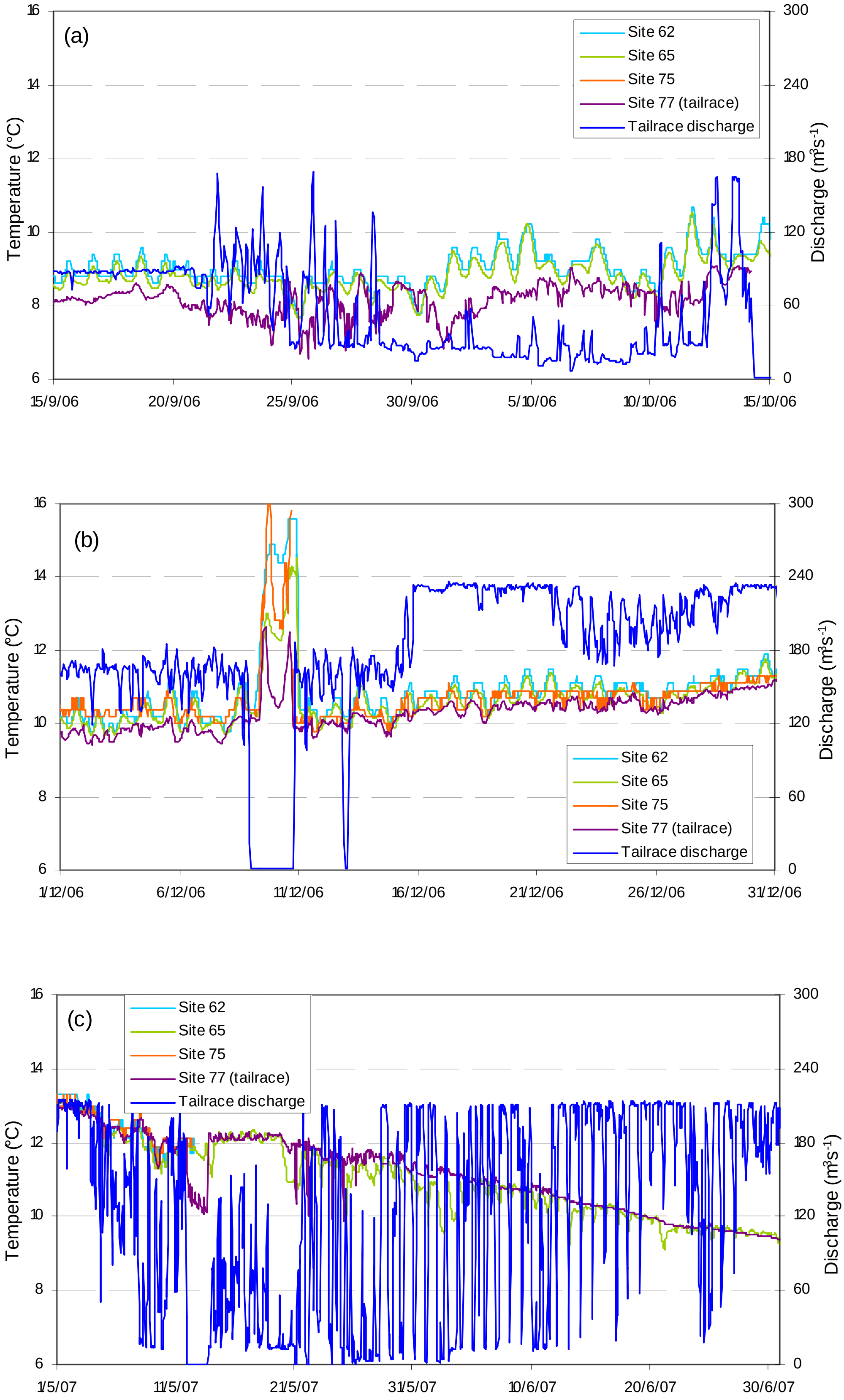


Figure 3-6. Water temperatures at sites 77 (tailrace), 75, (2 km downstream), 65 (12 km downstream) and 62 (15 km downstream) and corresponding tailrace discharge for (a) September-October 2006, (b) December 2006 and (c) May-June 2007.

3.2.3.3 Dissolved oxygen

Dissolved oxygen levels at the compliance site (site 65) for the period of July 2006 to June 2007 are shown relative to the dissolved oxygen measurements at the intake level in Figure 3-7.

It appears from the Lake Gordon sampling that the intake level corresponded to the thermocline in April 2007, and that there was the possibility that water of low dissolved oxygen was drawn into the power station. However, temperature data presented here suggest that water drawn into the intake from Lake Gordon comes predominantly from a shallower depth above the level of the thermocline, therefore reducing the possibility of drawing in water of low dissolved oxygen concentration.

There was no evidence of low dissolved oxygen at the compliance site. In fact dissolved oxygen levels were generally high with a median of 12.5 mg L^{-1} and a range between 10.1 mg L^{-1} on 10 December 2006 to 13.3 mg L^{-1} on 11 September 2006. Concentrations of oxygen therefore were higher than those in Lake Gordon at the level of the intake (Figure 3-7) and more likely reflect the levels of aeration with the river between the tailrace and site 65. There were no specific seasonal trends in the dissolved oxygen at the compliance site (site 65).

This is the first year of recording dissolved oxygen data from the compliance site. The levels of dissolved oxygen at this site were similar to those presented previously (Koehnken 2001). Dissolved oxygen levels were highest under high power station discharge conditions, with greater turbulence and aeration at high flow appearing to be responsible for this (Figure 3-8). Though dissolved oxygen data is unreliable from the tailrace site, data collected in 2005-06 (Hydro Tasmania 2006) indicated that the water at this location generally reflected the dissolved oxygen concentrations at the intake level in Lake Gordon. In addition, spikes in dissolved oxygen in the tailrace at this time reflected the use of air injection in the power station. Air injection is used when turbines are operated at 25 to 70% of full load (Koehnken 2001), to ensure their smooth operation. While low dissolved oxygen levels are not seen downstream, it also appears that variation in dissolved oxygen levels at the power station tailrace are also not evident at site 65.

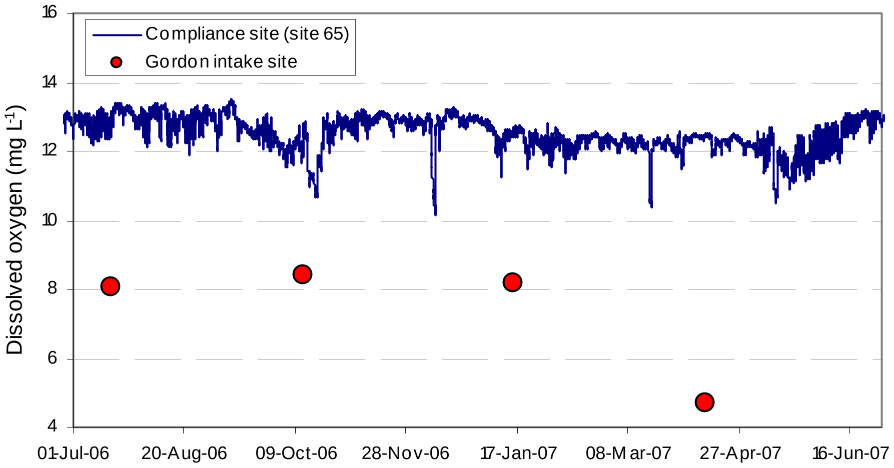


Figure 3-7. Dissolved oxygen levels at site 65 (compliance site) for 2006-7 in comparison to dissolved oxygen levels at the same depth of the intake (254 mASL) in Lake Gordon.

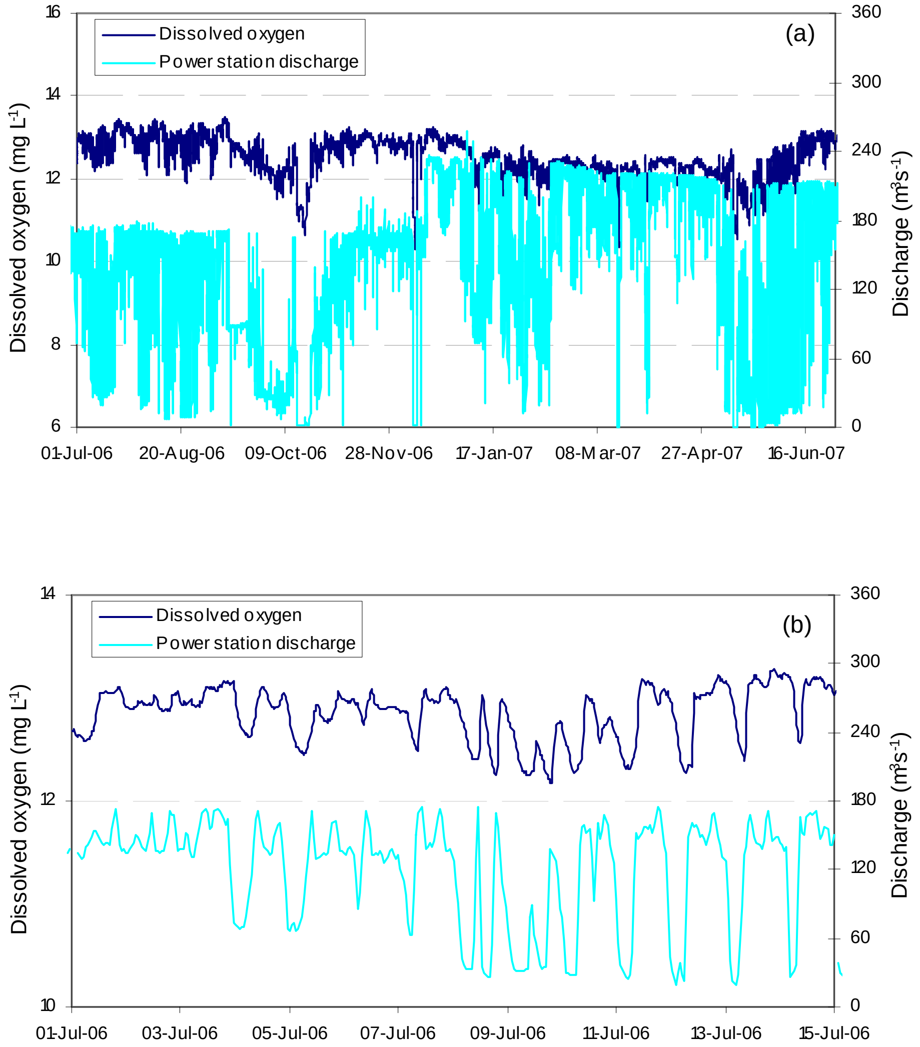


Figure 3-8. Dissolved oxygen concentrations at site 65 (compliance site) in 2006-07 relative to power station discharge for (a) July 2006-June 2007 and (b) 1-15 July 2007.

3.3 Conclusions

Water quality surveys were undertaken on Lake Gordon and Lake Pedder in July and October 2006 and January and April 2007 in compliance with the requirements of the water licence. The physico-chemical conditions for both lakes were considered typical for lakes in the region with seasonal effects. Surface water quality was good in both lakes and was characterised by low nutrient, turbidity, dissolved metal and chlorophyll-*a* levels. There was one exception when chlorophyll *a* levels were slightly higher than expected in summer at Boyes Basin in Lake Gordon.

The thermal structure of Lakes Gordon and Pedder were also similar to previous years. Depth profiles varied with location and between monitoring trips. Dissolved oxygen showed declines at depth at all sites in Lake Gordon. Boyes Basin and Calder Reach had significantly reduced dissolved oxygen in the hypolimnion of 2.6-3 mg L^{-1}. At the intake site, anoxia was evident at and near the bottom on all occasions it was sampled. The intake was above the hypolimnion on three of the four sampling occasions in Lake Gordon, however in April the intake level was the same as that of the thermocline thermocline. This provided the potential for water of low dissolved oxygen to be drawn into the power station, however, temperature data suggest that water entering the intake was being drawn from above the thermocline.

Lake Pedder remained evenly mixed during 2006–07.

In the Gordon River, all water quality monitoring was undertaken compliant with the conditions of the water licence. However, the questionable quality of the dissolved oxygen data from the tailrace, has meant that this has not been reported for 2006-07. In the river, dissolved oxygen and water temperatures displayed a broad seasonal pattern related to the thermal pattern of Lake Gordon.

Water temperatures along the river differed between sites due to the effects of tributary inputs that are subject to the influences of ambient air temperature. Water temperatures were generally higher at sites further downstream due to the opportunity for greater inputs from tributaries as well as from some degree of warming in the Gordon River itself. However during cooler periods of the year, the trend was reversed, so that water temperatures were cooler downstream.

Water temperature in the Gordon River was also sensitive to fluctuations in power station discharge. All sites were sensitive to reductions in discharge, with significant increases or decreases in temperature observed under the influence of ambient air temperatures and greater relative volume of water from tributaries at low power station discharge.

Dissolved oxygen concentrations at the compliance site were generally high and did not reflect the concentration of dissolved oxygen in Lake Gordon at the depth of the power station intake. Changes in dissolved oxygen concentration appear to be influenced by the rate of discharge from the power station as higher dissolved oxygen levels coinciding with higher discharges. It is probable that the high dissolved oxygen is due to the significant aeration that the water receives as it travels the 12 km from the tailrace to the compliance site.

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4 Fluvial geomorphology

4.1 Introduction

This chapter summarises the Basslink fluvial geomorphology monitoring results for the period March 2006 – March 2007. Monitoring is being completed as part of Hydro Tasmania's Basslink commitments with the objective to detect and document geomorphic changes in the middle Gordon River between the power station tailrace and the mouth of the Franklin River. In undertaking this analysis, this report seeks to determine the linkages between the operation of the Gordon Power Station and fluvial geomorphic processes within the Gordon River and compare the current status of the river to 'trigger values' derived from erosion rates documented during the pre-Basslink monitoring period. This monitoring year (2006-07) is the first complete post-Basslink year, and is the first dataset to be compared against the trigger values. This report also provides the preliminary opportunity to evaluate the effectiveness of the ramp-down rule which was implemented to reduce seepage related erosion due to Basslink.

Details of the monitoring approach, monitoring program and its relationship with the initial Basslink geomorphology investigations are presented in the first pre-Basslink fluvial geomorphology monitoring report (Koehnken and Locher, 2002) and should be consulted for 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 Integrated Impact Assessment Statement (IIAS) report (Koehnken *et al.,* 2000) and the Basslink Baseline Report (BBR) (Hydro Tasmania, 2005).

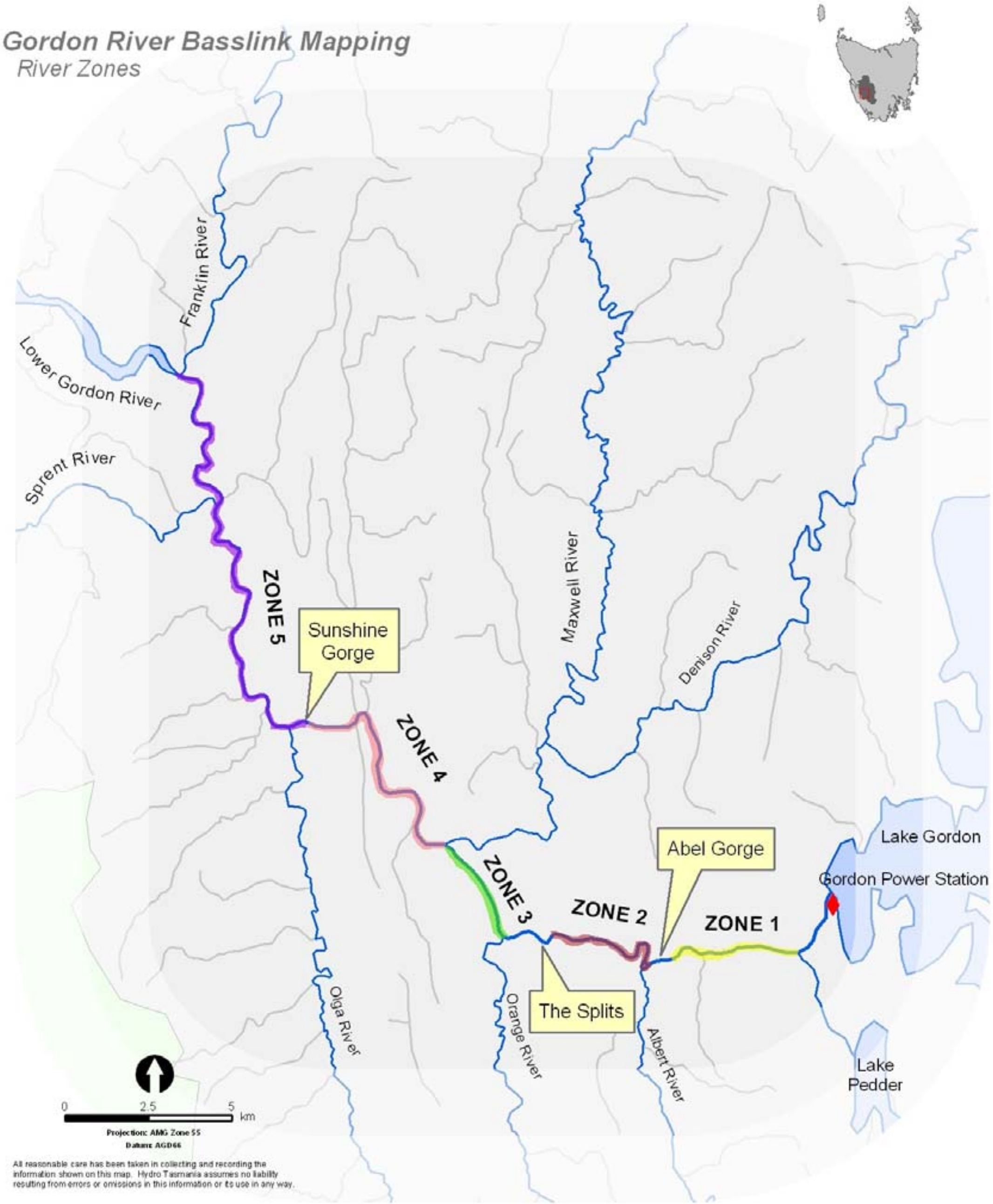
4.2 Methodology

Geomorphology monitoring includes the measurement of 200 erosion pins and 25 scour chains located at 48 monitoring sites in the middle Gordon River twice a year (October and March), photo-monitoring of an additional 54 sites on an annual basis in March each year, and analysis of piezometer results. The geomorphology monitoring zones are shown in Map 4-1. Site locations and site descriptions are contained in the November 2001– March 2002 field report (Koehnken and Locher, 2002).

4.2.1 October 2006

Monitoring was completed on 17-18 October 2006. Monitoring occurred midway through a two-week shutdown of the power station. Rainfall was low during the two weeks prior to monitoring.

All erosion pins were located during the October 2006 monitoring run, however the pins listed in Table 4-1 were not measured for the reasons shown in the table. Pins 2B/6 and 2L/3 were lying on the bank and were re-installed in the same location allowing the continuation of the erosion pin records.



Map 4-1. Map of middle the Gordon River showing the location of the five geomorphology monitoring zones.

Table 4-1. List of erosion pins not measured in October 2006

Pin	Change(s) to site	Reason
2B/6	eroded out of cavity	Re-installed lower in same bank
2L/3	eroded out of bank	Re-installed in same location
4E/4	none	not measured due to human error

4.2.2 March 2007

During the sampling run, only one erosion pin was not located as shown in Table 4-2. Site 2K is an active seepage erosion site, and the missing pin had been situated within a large seepage flow. It is most likely that this pin was lost through the down-slope mass-movement of the bank, rather than buried or removed through scour. A new one was established at approximately the same elevation (turbine level) in the bank.

Table 4-2. Erosion pins not located in March 2007

Pin	Reason not found	Action
2K/3	Knocked over	New pin re-installed in same location

A description of additional erosion pins installed during March 2007 is contained in Appendix 1.

4.3 Overview of hydrology, March 2006 – March 2007

For a complete discussion of hydrology during the study year, refer to chapter 2 (Hydrology) of this report. The following aspects of the hydrology are relevant to the geomorphology monitoring results:

- for most of the monitoring year, March 2006 – December 2006, only two turbines were in operation at the Gordon Power Station. This limited the range of power station controlled water levels within the river during this time period;
- following re-commissioning of the third turbine in the Gordon Power Station, there was prolonged use of all three turbines for the remainder of the monitoring year (December 2006 – March 2007);
- throughout the monitoring year, the power station was used extensively. This operation differs compared to pre-Basslink power station operation when the Gordon Power Station was generally shutdown during storm events. This led to a greater proportion of water released from the power station occurring during the winter months (even though operation was limited to two turbines) as compared to pre-Basslink;
- there was only one flood event in excess of >700 $m^3 s^{-1}$ recorded at the Gordon above Franklin (site 44) gauging site during the monitoring year and no very high flow events recorded during the period of missing record at the Gordon below Franklin site. There were numerous moderate flood events in the 400-600 $m^3 s^{-1}$ range. Most of these events occurred during power station operation;

- the Gordon Power Station was not operated in 'peaking' mode very often during the monitoring year as compared to the predictions for Basslink operations; and

4.4 Monitoring results

4.4.1 Field observations

4.4.1.1 October 2006

Monitoring in October 2006 was completed during an extended power station shutdown, with low tributary inflows. Discharge at the compliance site (site 65) ranged from 4 - 6 $m^3 s^{-1}$ throughout the weekend, and flow was also low at the Gordon above Franklin site (site 44), but not recorded due to a problem with the level recorder. These conditions resulted in dry bank toes, and little evidence of seepage erosion.

Discharge from the power station was limited to 2-turbines during the monitoring period (March–October 2006) which led to increased deposition of organic debris on the bank faces in the 2-3 turbine level and colonisation by grasses and other seedlings (Photo 4-1). There was also evidence of rilling on the upper banks, presumably due to rainfall on the exposed banks. A distinct plimsoll line was evident in zones 3 and 4 where sand deposition occurred, presumably during the final power station shutdown prior to the outage (Photo 4-2).

Depositional activity was widespread in zones 3-5, where recent sand deposits on bank toes were common, and scour chains were buried by up to 200 mm.

Photo 4-1. 2-3 turbine zone at site 3B showing deposition of organic matter and colonisation

Photo 4-2. Sand deposition in zone 3 showing 2-turbine water level

In spite of the lack of 3-turbine power station operation, a high level of erosional activity through bank slumping was evident in the 2-3 turbine bank level, especially downstream of the Denison River in zones 4 and 5. This erosion may be the result of undercutting due to prolonged 2-turbine power station operation, or possibly indicate that a threshold in bank steepening has been surpassed in zones 4 and 5. Previous monitoring results have indicated a steepening of bank faces through bank toe erosion in these zones, and it was highlighted in the Basslink Baseline Report that this steepening could not continue indefinitely, and would eventually lead to erosion of the upslope bank.

4.4.1.2 March 2007

Monitoring in March 2007 was completed immediately following a 3-turbine-to-off shutdown during the previous night. The station had been operating for prolonged durations at three turbines due to the continuing drought in Tasmania. The observations noted below were compiled from the notes of the three teams, and are similar to previous field observations following 3-turbine to off power station shutdowns.

Consistent with previous observations of rapid power station shutdown following high flow conditions, bank toes were saturated, and seepage erosion was present at sites where it has been previously observed (e.g. sites 2C, 2G, 4B). Photo 4-3 shows site 4B where a new pin has been installed next to an existing pin which has moved due to mass movement of the bank associated with seepage. The photo shows that the root mat has been removed from the bank face, active seepage flows and tension cracks. This mass-movement is highlighted by Photo 4-4 showing a completely submerged erosion pin which was initially installed in 2001 the 1-2 turbine bank level. The pin was first observed to be partially submerged in 2003, rotated downslope by October 2005 and since 2005 has moved downslope to the point where it is now completely submerged at low flows.

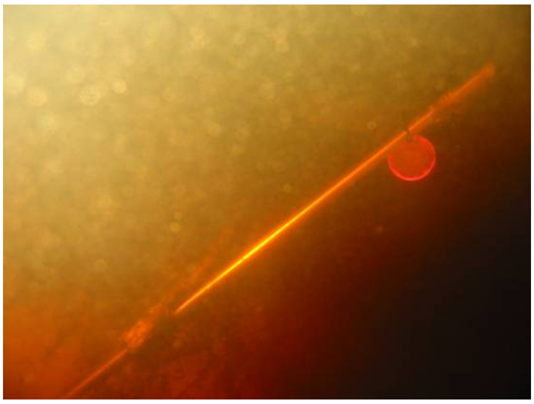


Photo 4-3 (left) Seepage erosion at erosion pin site 4B on March 17, 2007

Photo 4-4 (right) Underwater photo of submerged erosion pin 4B/2 showing angle of pin

A new seepage flow was observed at erosion pin site 3A (Photo 4-5). The flow may be associated with bank disturbance which also lead to the loss of several small trees from the upslope bank (Photo 4-6).

Rilling was observed in zones 1 and 2 below the 3-turbine power station level as bank toes drained.

Photo 4-5 (left) New seepage flow at erosion pin site 3A. Seepage is likely associated with bank disturbance due to tree falls shown in following photo.

Photo 4-6 (right) Tree fall at erosion pin site 3A. Trees are located approximately 10m downstream of new seepage flow shown in previous photo.

Near the mouths of tributaries, deposition of mud and fine sands was observed below the 3-turbine power station operating level, the result of deposition of suspended material during the power station shutdown (Photo 4-7, Photo 4-8). Deposition decreased with distance downstream.

Photo 4-7 (left) Mud deposition on bank toes in Albert River zone 2 (left) and zone 5 associated with power station shutdown. Photo also shows two dead redfin perch, see discussion in section 9.3.1.3.

Photo 4-8 (right) Mud deposition in zone 5 downstream of the mouth of the Olga River (erosion pin site 5A).

In zone 2, downstream of erosion pin site 2G near photo-monitoring site P2-6, a block of cobbles has eroded from the bank, and been transported approximately five metres downstream (Photo 4-9).

Photo 4-9. Recently eroded cobble block upstream in zone 2, from photo-monitoring site P2-6

4.4.1.3 Albert River observations

The Albert River was visited in October 2006 and March 2007. Over the year, the progression of a landslip on the spur separating the Gordon and Albert River first noted in March 2006 was documented. Between October and March, the root mat failed, and a large block of the bank has fallen into the river (Photo 4-10 - Photo 4-12).

Along the steep left bank upstream of the mouth of the Albert, additional bank failure occurred over the year, with recently slumped material present in the centre of the October 2006 photo. Erosion of this newly deposited material occurred between October 2006 and March 2007 as shown in Photo 4-13 through Photo 4-15.

Photo 4-10 (left) View of bank slumping near the mouth of the Albert River from the top of the bank in October 2006. Tape measure length is 1m. The Albert River is towards the right side of the photo.

Photo 4-11 (right) Active bank slumping in the Albert River, view from Albert river looking upslope (October 2006).

Photo 4-12. Bank slump near mouth of Albert River from top of bank in March 2007. Root mat has been severed, exposing underlying fine-sands. Tape measure extends ~1m into photo.

Photo 4-13. Lower Albert River, left bank, March 2006

Photo 4-14. Lower Albert River, left bank, October 2006

Photo 4-15. Lower Albert River, left bank, March 2007

4.4.2 Zone 2 piezometer results

A new piezometer array was installed between March and October 2006 and a comparison of results from old and new array is contained in Appendix 2.

4.4.2.1 Ground water behaviour based on new piezometer array results

Results from the new piezometer array for the two periods of record, 19 October 2006 – 8 February 2007 and 30 March - 15 May 2007 are presented in Figure 4-1 as time series plots. The initiation of record coincides with the end of a week long power station shutdown. The return to 3-turbine power station operation is apparent in mid-December (plot 'B'), with water levels increasing from ~3.5m to ~4.5m.

The time-series captures the end of the power station shutdown in October, when water levels in the bank are relatively low and sloping towards the river (Figure 4-2). With the resumption of power station operations, water levels in the bank steadily increase, but remain below the maximum river level height as operation of the power station fluctuates. In-bank water levels reach river level heights following a prolonged period of 2-turbine power station operation in November. Following a power station shutdown in December 2006, there was prolonged use of three turbines until mid-January 2007. During this time, the ground water levels increased, equilibrating with river levels. Ground water levels remained elevated through February 8, when the record stops.

The results show that the in-bank water levels reflect river level changes, but have a lower range of amplitudes. Probes 1 and 2 show the greatest range of water levels, with probes 3, 4 and 5 returning similar levels. The new piezometer array extends monitoring of ground water levels to 50m inland (probe 6). This probe generally returned higher water levels as compared to the other probes, probably due to the inflow of regional ground water. The graphs in Appendix 2, Figure 1 and Figure 4-5 show that probe 6 is recording water levels consistent with power station-controlled river levels during extended periods of 3-turbine power station operation, indicating the operation of the power station affects groundwater levels for distances of at least 50m inland.

The records in Graph ‘C’ in Figure 4-1 show data beyond March 2007, and is presented to show ground water behaviour during a power station shutdown. Water level profiles during the shutdown are also shown in Appendix 2, at hourly or 20-minute intervals. Figure 3 in Appendix 2 shows that during this shutdown, river levels decreased about 1m between the times of 2200 and 2300. Ground water levels rapidly decreased in the toe of the bank, with the more distal probes recording a slower reduction in water levels. Water surface slopes are discussed in section 4.4.3.

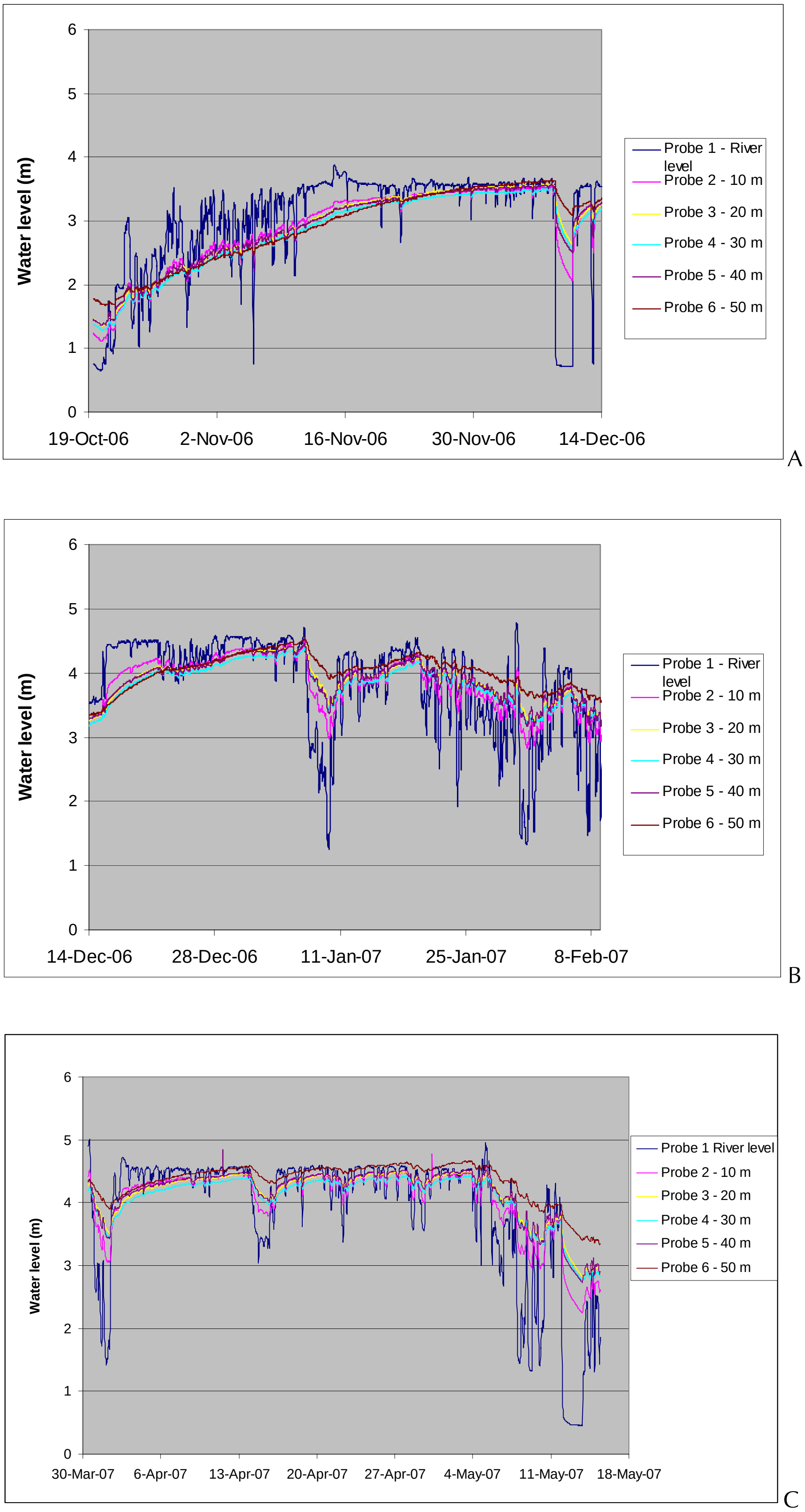


Figure 4-1. Water level results from new piezometer array 9 October 2007 - 15 May 2007, with the period 9 February–30 March missing

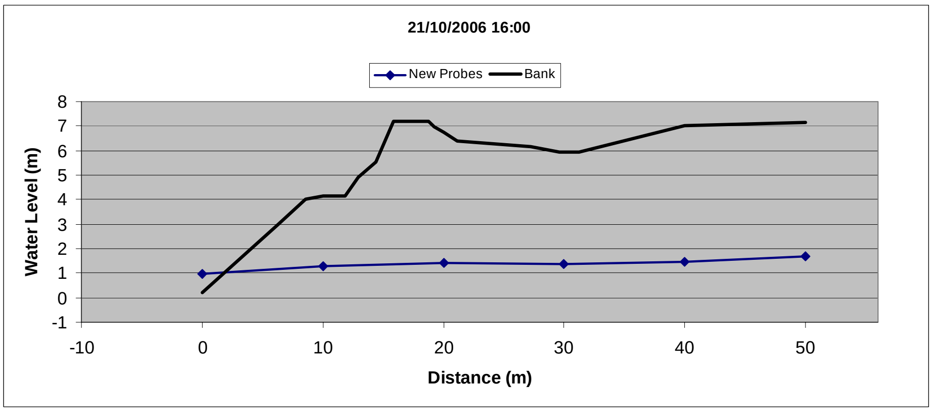


Figure 4-2. In-bank water levels at end of power station shutdown, 21 October 2006

The new piezometer array also provides information about the longitudinal behaviour of ground water within the bank. The results from probe 7, located ~25m downstream of the main piezometer array between probes 3 and 4, are plotted in Figure 4-3 along with the results from probes 3 and 4. The resulting profile provides an indication of longitudinal water levels. The time period shown in the two graphs corresponds to 3-turbine power station 'on' water levels, and minimum water levels recorded during the power station shutdown on 11-12 May 2007.

The results show that there is a constant downstream gradient between the piezometer array and probe 7 suggesting there is a downstream movement of ground water in the bank. The site is located at the head of a rapid, with the gradient probably reflecting the river gradient.

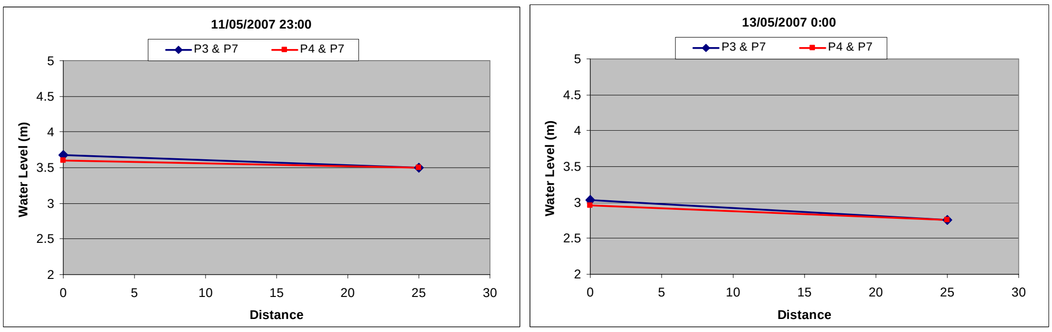


Figure 4-3. Longitudinal profile of In-bank water levels during 3-turbine power station operation (left) and during power station shutdown (right). Graphs show water level at probes 3, 4 and 7. Probes 3 and 4 are located at '0' on the graph, with probe 7 located ~25m downstream. Lines depict water surface slope between probe 3 and 7, and between probe 4 and 7. Date and time shown in each graph.

4.4.3 Ground water slopes

Figure 4-4 shows the ground water slopes recorded by the old piezometer array during the monitoring year. The in-bank slope is based on the difference in water level between old probes 3 (13.3m inland) and probe 1 (river level). The grey lines indicate the in-bank water surface slope, with positive values indicating the bank is draining towards the river. The red dashed line delineates the slope value of 0.1, which has been identified as promoting seepage erosion in the 2-3 turbine bank level when the water level in the bank exceeds 2.75m. The red lines show events where the water level exceeded 2.75 m, and the in-bank water surface slope exceeded 0.1, indicating a high risk of seepage erosion. The same information, where available, is shown for the new probes in Figure 4-5. This method of groundwater analysis has been completed each year since 2002, and previous reports should be referred to for comparison.

Because the spacing of the new piezometers is at 10m intervals, the in-bank water surface slope cannot be determined using the same interval as used in the past. An analysis was completed which compared the water slopes obtained using new probe 2 (10m inland) and river level, and new probe 3 (20m inland) and river level with the slopes obtained using the old piezometer array. It was found that using the results from probe 2 (10m inland) and the river level identified all periods of high seepage risk as initially defined (slope >0.1, water level at 13.3m distance from the river >2.75 m), and overestimated the duration of the high seepage risk period as compared to the old piezometer array results. The increased duration of the high risk event is due to the higher water levels being recorded by the new array as compared to the old array (so there are more periods when water levels exceed 2.75 m), and due to the shorter distance inland (10 m) as compared to 13.3m for the old array. It was found that using a water surface slope based on water levels at probe 3 (20 m) and river level consistently overestimated or underestimated the actual water level due to the non-linear shape of the water level profile in the bank. Based on these findings, water surface slopes for the new array have been based on the difference between probe 2 (10 m) and probe 1 (river level).

The results in Figure 4-4 show there were three periods of high seepage erosion risk during the period when only 2-turbines were in use at the power station. These periods were short in duration, and corresponded to a decrease in discharge at the power station. The event leading to the highest in-bank water slopes was associated with the December 2006 monitoring shutdown. Following re-commissioning of the third turbine, seven periods of high seepage risk were identified. Most of these high risk events did not coincide with power station shutdowns, but with reductions in power station discharge.

The results from the new piezometer array (Figure 4-5) show the same high risk periods as identified by the old piezometer array, and identified several additional events.

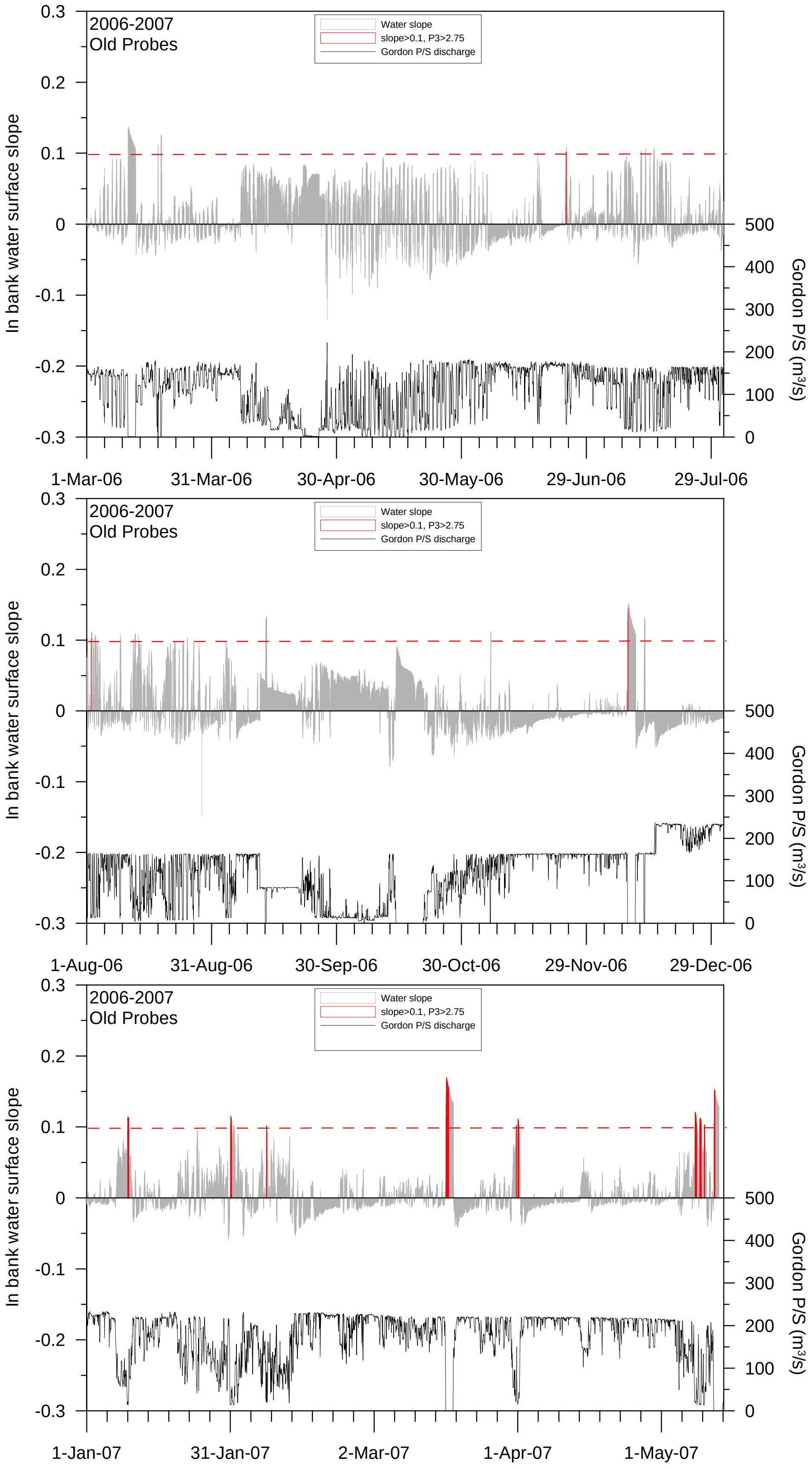


Figure 4-4. In-bank water surface slopes (upper) and discharge from Gordon Power Station (lower). Periods when water slopes exceed 0.1 and water level at probe 3 exceeds 2.75m are highlighted in red.

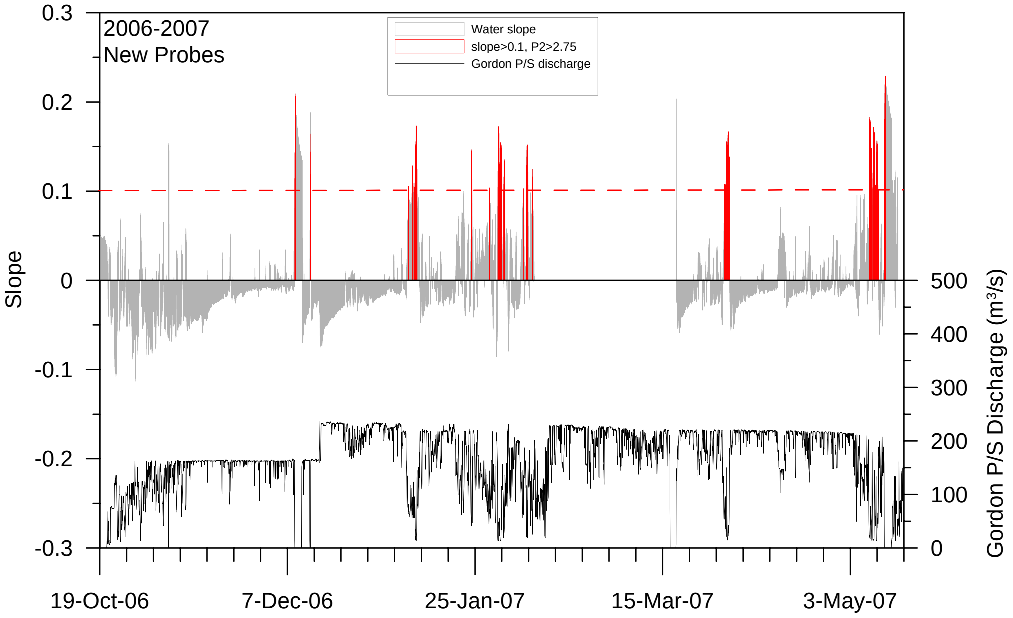


Figure 4-5. In-bank water surface slopes from new piezometer array. Slopes based on water level difference between probe 2 (10m inland) and probe 1 (river level). Periods when slopes exceed 0.1 and water level at probe 2 exceeds 2.75m are highlighted in red.

4.4.4 Implementation of ramp-down rule

The frame work for a ramp-down rule for the Gordon Power Station was developed during the IIAS investigations. The intention of the ramp-down rule is to reduce ground water slopes in the 2-3 turbine bank level gradually following 3-turbine power station operation such that seepage erosion is limited. Based on field observations, piezometer data and modelling results, it was suggested that a 30 m^3s^{-1} per hour continuous ramp-down between discharges >180 m^3s^{-1} and approximately 150 m^3s^{-1} would reduce the water surface slopes in alluvial banks in the Gordon. It was also shown that maintaining flows at 150 m^3s^{-1} for one-hour prior to power station shutdown would increase the effectiveness of the ramp-down by allowing maximum drainage of the upper bank at a low ground water gradient.

Hydro Tasmania committed to the implementation of a ramp-down rule, and has implemented the following rule-set:

- Once discharge at the power station has exceeded 180 m^3s^{-1} for 1-hour, if the intent is to reduce discharge to <150 m^3s^{-1}, then the station is to be ramped down at 30 m^3s^{-1} per hour.

Under this rule, if there is no intention to reduce discharges to less than 150 m^3s^{-1}, no ramping is required. Reductions of up to 100 m^3s^{-1} per hour are permissible under this rule if the station is reduced from full-gate to 155 m^3s^{-1}.

The hourly discharge records from the Gordon Power Station for the period 1 July 2006– 17 March 2007 were analysed to identify events which did not comply with the aim of the ramp-down rule as developed during the IIAS process. The hourly discharge records from the Gordon Power Station were analysed for the following requirements:

- Discharge from the power station decreased greater than 30 m^3s^{-1} in one-hour; and
- Discharge prior to the decrease exceeded 180 m^3s^{-1}.

It should be noted that this review differs from that reported in Chapter 2 (Hydrology) which analysed data in line with the requirements of the Water Licence. The difference in methodology is reflected in the outputs of analysis e.g. the analysis implemented in Chapter 2 did not include events above180 m^3s^{-1} where flow did not go below 150 m^3s^{-1}.

The analysis of hourly discharge data identified 48 events which matched the abovementioned criteria (Figure 4-6). All of the events occurred following the resumption of 3-turbine power station operation in December 2007. This is not surprising as 3-turbine operation is required to achieve 180 m^3s^{-1} discharge. Half of the events had rates of change of discharge between 30 and 42 m^3s^{-1} per hour. Four events had rates of change of discharge greater than 90 m^3s^{-1} per hour, with the largest rate of change 110.5 m^3s^{-1} per hour. Only one of these events was associated with a power station shut-down, with the remainder occurring during periods when discharge was reduced, and subsequently increased within a few hours.

Periods of high risk of seepage erosion, shown by high ground water slopes, (Figure 4-4 and Figure 4-5) correlate well with the rapid decrease in water level that occur when power station discharge is rapidly decreased (i.e. when ramp-down rates are high). A notable exception was seen immediately following the resumption of 3-turbine power station operation in January 2007. Several rapid decreases in discharge occurred at this time, but there was not a high risk of seepage erosion as water levels in the bank were low compared to river levels.

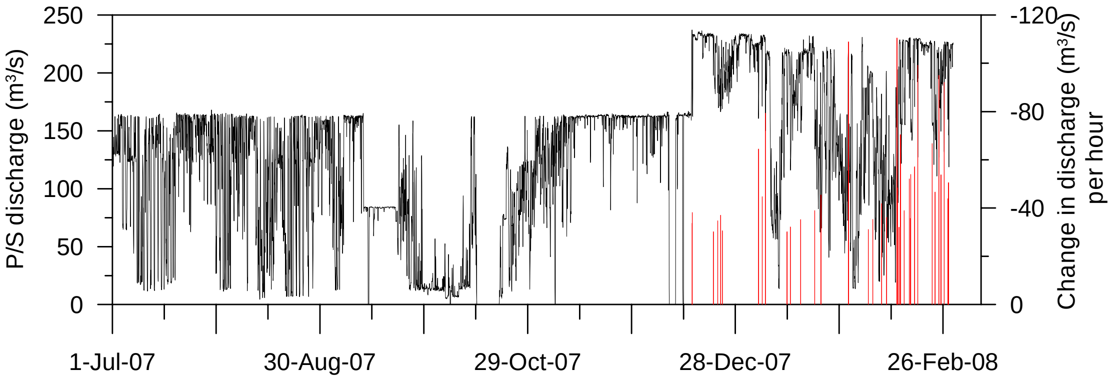


Figure 4-6 Power station discharge (black line) and events which exceed conditions of intended ramp-down rule (red bars). The rate of change in discharge (m^3 s^{-1} per hour) associated with each event is shown on the second y-axis.

4.4.4.1 Discussion of ramping

The contribution of seepage erosion to net erosion rates in the middle Gordon River is an unresolved question. It has been demonstrated through both modelling and field assessment that reducing in-bank water surface slopes decreases seepage erosion processes. However it has yet to be clearly demonstrated that a reduction in seepage processes reduces overall erosion rates of the 2-3 turbine bank level. The ramp-down rule was developed when it was hypothesized that seepage erosion was the predominant process controlling erosion rates in the 2-3 turbine bank level. The monitoring completed since the IIAS process has raised questions about this hypothesis, as erosion rates in the 2-3 turbine zone in the river have remained relatively constant, even during periods when seepage erosion was absent. An example of this is the March 2006 – October 2006 period when power station discharge was limited to 2-turbines. Erosion rates in the 2-3 turbine level did not decrease during this period, with the continued erosion caused by bank collapse due to undercutting of the 1-2 turbine bank level, and erosion from incident rainfall on the denuded banks.

It also needs to be recognised that the number of high risk periods of seepage erosion has not increased substantially since the implementation of Basslink because the power station has not operated in peaking mode due to the extended drought conditions. It is quite possible that even though present monitoring results do not show a clear link between high seepage risk and net bank erosion, substantially increasing the number of high seepage risk periods will increase overall erosion rates.

A more detailed analysis of how the short-term fluctuations in water levels occurring under Hydro Tasmania's ramp-down rule are affecting in-bank water surface slopes is warranted. If ongoing monitoring shows that seepage erosion is not being adequately addressed by the existing ramp-down rule, then as required by the adaptive management sections of the Water Licence, Hydro Tasmania will, in consultation, look to develop a more appropriate rule to address the erosion issue.

4.4.5 Erosion pins

4.4.5.1 Results grouped by zones and turbine levels

Erosion pin and scour chain results for the March 2006 – March 2007 monitoring year are contained in Appendix 3 (tables) and Appendix 4 (graphs).

Erosion pin results are plotted in Figure 4-7 through Figure 4-10 based on different groupings of the results. In Figure 4-7, results are grouped by zones (zones 1-5) see Map 4-1, in Figure 4-8 results are grouped by turbine level (<1-turbine, 1-2 turbine, 2-3 turbine), and in Figure 4-9. and Figure 4-10 results are grouped by turbine levels for zones 2 and 3, and zones 4 and 5, respectively. These groupings are the same as those presented and discussed in the Basslink Baseline Report. For each grouping, three graphs are presented. The large first graph ("A") depicts average erosion pin results for pins showing erosion during each monitoring period, and pins showing deposition over the monitoring period, with the results plotted separately. The second graph ("B") shows the average results for all erosion pins in the grouping, and the third graph ("C") shows the ratio of the number of pins which recorded erosion to the number of pins which recorded deposition.

Results grouped by zones

The erosion pin results grouped by zone (Figure 4-7) show similar trends as in previous years. Zone 1 continues to show similar magnitudes of erosion and deposition ('A'), and a similar number of pins recording erosion and deposition ('C'), resulting in a low net erosion rate for the monitoring year ('B'). Zone 2 shows similar trends as in the past for pins showing erosion, and pins showing deposition ('A'), but because fewer pins recorded deposition between October and March 2007 ('C'), there was a net decrease in the erosion rate for the zone ('B'). Zone 3 recorded increased rates of erosion in pins showing erosion and increased rates of deposition in pins showing deposition, but there was little change to the net erosion rate due to similar numbers of pins showing erosion as deposition ('C'). Zone 4 continued to have the highest ratio of pins showing erosion to pins showing deposition, even though the ratio decreased over both monitoring periods. Erosion, deposition and net erosion in this zone remained consistent with previous trends. Zone 5 continues to show net deposition, although the rate has decreased between October 2006 and March 2007. The decrease in net erosion is due to an increase in the erosion rate of pins showing erosion.

The similarity of results between the 2006-07 monitoring year and previous years is notable because of the difference in power station operation during the March 2006 – March 2007, which was characterised by 2-turbine power station operation for over half-of the year. The lack of 3-turbine power station operation did not lead to large changes in the erosion pin results when grouped by zones.

Results grouped by turbine level

When grouped by turbine level, the results show greater variability over the monitoring year as compared to the zones. The <1 turbine level recorded a sharp decrease in erosion and increase in deposition during the March 2006 - October 2006 period ('A'), corresponding to the initiation of 2-turbine power station operation, followed by a sharp increase in erosion and decrease in deposition during the second half of the monitoring year when 3-turbine operation resumed. The higher number of pins recording erosion during the October 2006 – March 2007 monitoring year ('B') lead to an increase in net erosion rates for this turbine level ('C'), returning rates to levels documented during spring 2005.

There was little change to the erosion or deposition recorded by pins in the 1-2 turbine level ('A'), but due to the fewer number of pins recording erosion ('C'), net erosion rates decreased over the monitoring year in this turbine level (‘B’). The decrease in net erosion rates is the largest recorded for this turbine level since monitoring was initiated.

The 2-3 turbine level showed an increase in erosion in pins showing erosion and small decrease in pins showing deposition over the monitoring year relative to previous results (‘A’). Although there was a decrease in the ratio of pins showing erosion to deposition (‘C’), net erosion rates remained consistent with previous trends. This is a somewhat surprising result because there was no 3-turbine power station operation during the March 2006 – October 2007 monitoring period, indicating that releases from the power station were not responsible for the direct erosion of this turbine level. The continued erosion of the banks at this level is likely attributable to the impact of natural inflows from the tributaries on the banks, bank collapse due to under-cutting of the lower bank, and erosion of the exposed denuded banks by rainfall. Tributary inflows would have the greatest impact downstream of the Denison in zones 4 and 5 where inflows constitute a substantial proportion of total flow, especially during the winter months. These differences are discussed in the following sections where pin results are grouped by zone and turbine level.

Results grouped by zone and turbine level

In the grouping of results for zones 2 and 3 by turbine level (Figure 4-9.), the <1 turbine level continues to record the highest rates of erosion in pins showing erosion, and deposition in pins showing deposition of the three turbine levels, but overall low net erosion rates due to fewer pins recording erosion. In contrast, the 1-2 and 2-3 turbine levels show lower rates of erosion and deposition (‘A’), but higher net erosion rates due to a higher ratio of pins recording erosion. The 1-2 turbine bank level showed a decrease in net erosion rates over the monitoring year (‘B’) due to a sharp decrease in the ratio of pins recording erosion. In contrast, results from the 2-3 turbine level were consistent with previous results, in spite of the lack of 3-turbine power station operation. These results are consistent with field observations of rilling due to rainfall and bank slumping in the 2-3 turbine level, especially in zones 3-5.

The grouping of erosion pin results from zones 4 and 5 by turbine level (Figure 4-10) shows that erosion rates in pins showing erosion have remained relatively constant in the <1 and 1-2 turbine level, but the 2-3 turbine level has recorded a sharp increase in erosion over the monitoring year (‘A’), especially between March 2006 and October 2006. This increase is consistent with field observations of bank slumping in the 2-3 turbine bank level during this period. This increase in erosion in the 2-3 turbine level is accompanied by a decrease in deposition for monitoring year (‘A’, 2-3 turbine level), which may be attributable to a reduction in seepage related deposition.

The ratio of pins in the <1 turbine level recording erosion has increased over the monitoring year (‘B’), doubling between October 2006 and March 2007, resulting in an increase in measured net erosion rates. Net erosion in the 2-3 turbine level is consistent with the increasing trend first recorded in spring 04. These results suggest a re-adjustment of the bank toe in zones 4 and 5 following the resumption of 3-turbine power station operation, and continued erosion of the 2-3 turbine level possibly due to over-steepening of the bank.

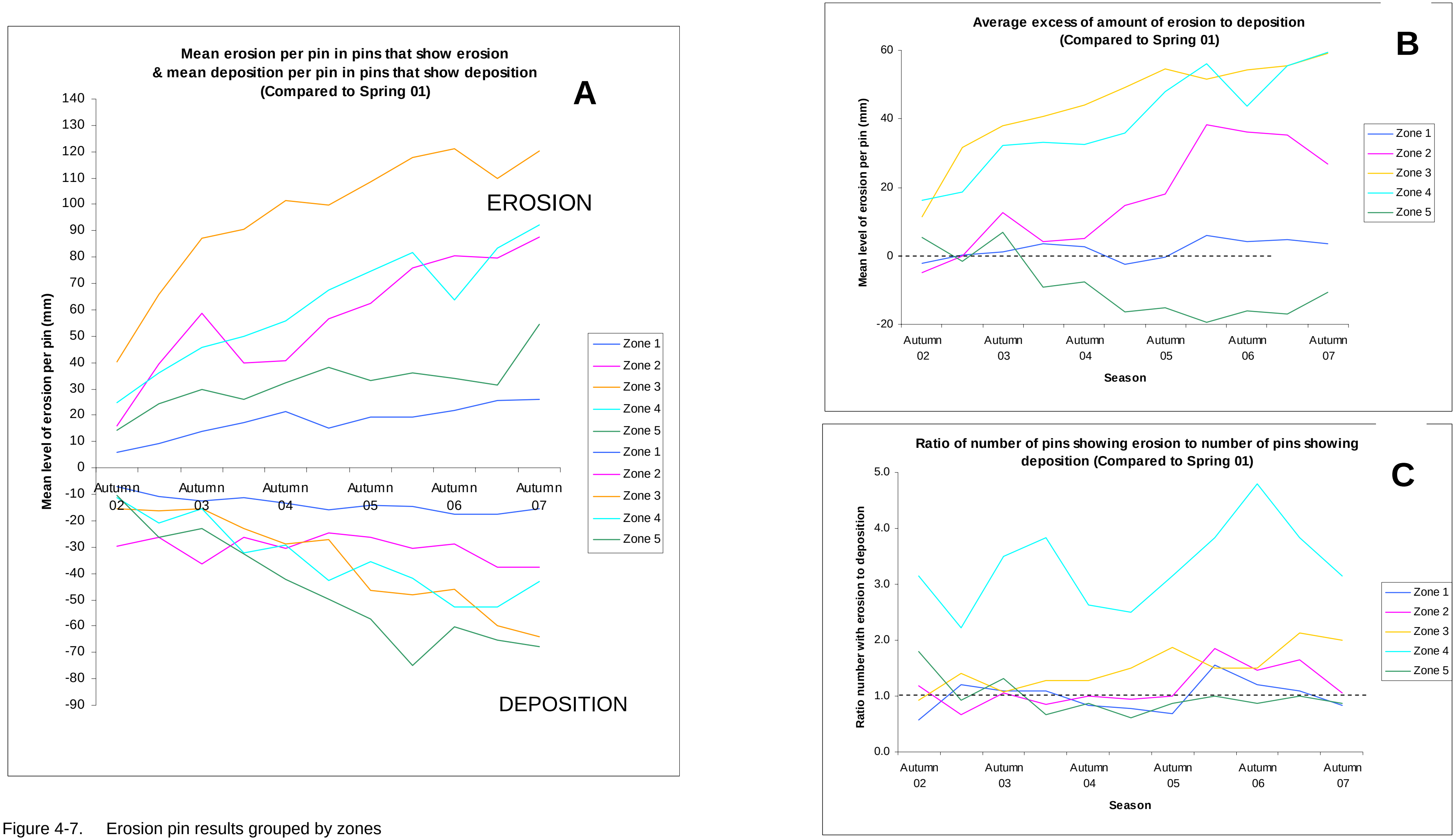


Figure 4-7. Erosion pin results grouped by zones

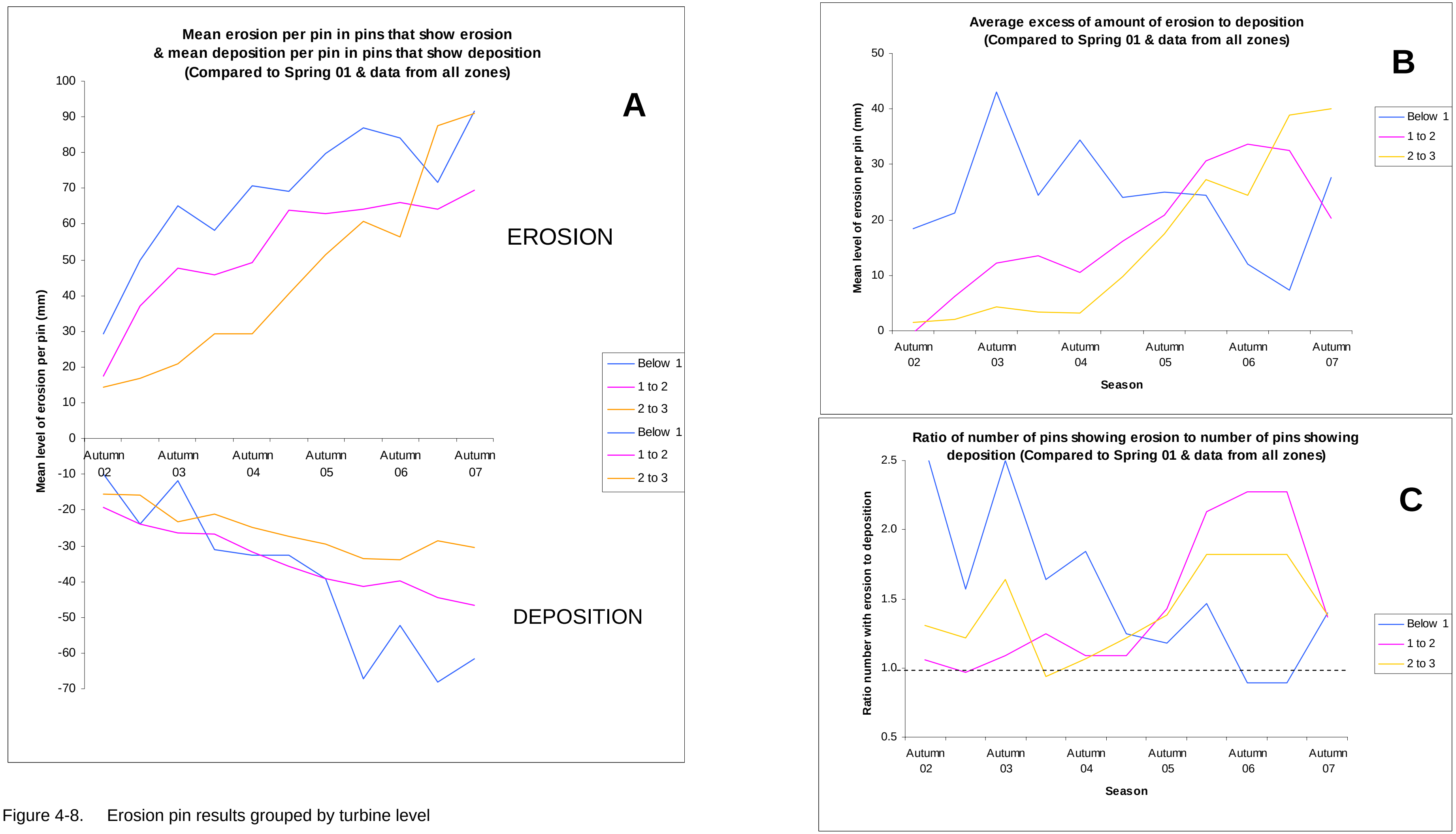


Figure 4-8. Erosion pin results grouped by turbine level

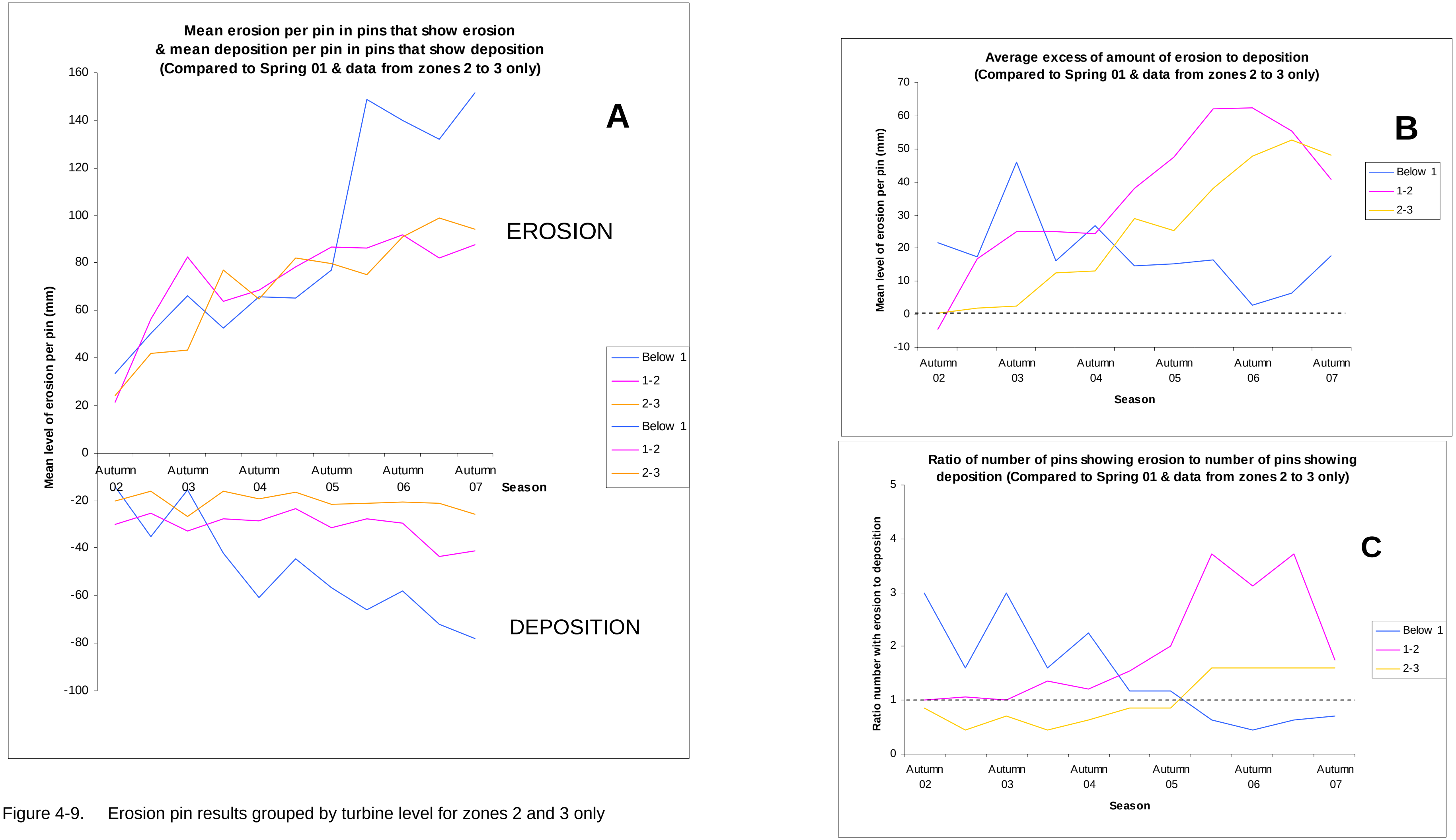


Figure 4-9. Erosion pin results grouped by turbine level for zones 2 and 3 only

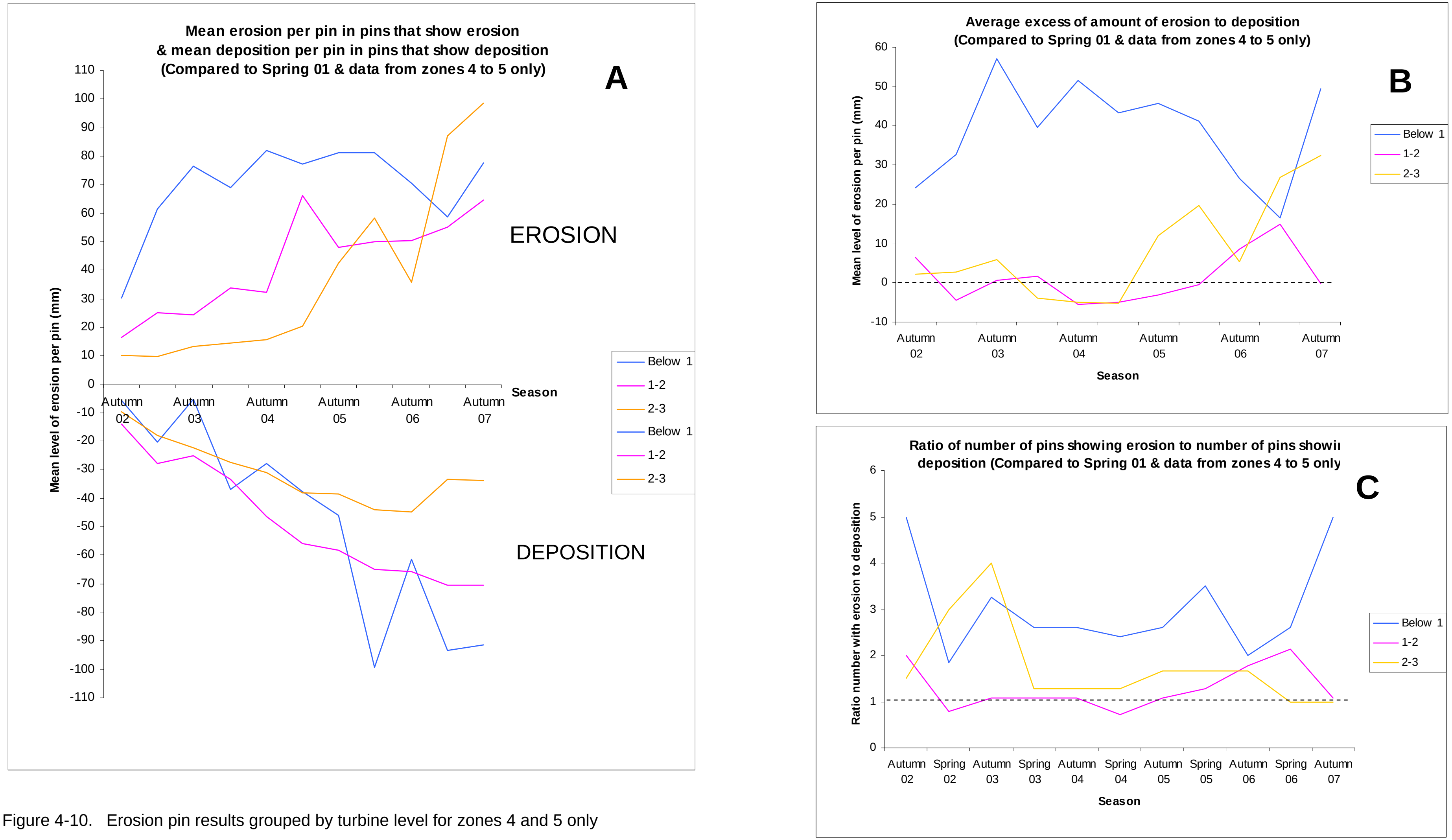


Figure 4-10. Erosion pin results grouped by turbine level for zones 4 and 5 only

4.4.6 Photo-monitoring

Photo-monitoring was completed in March 2007. Photos obtained in March 2007 along with previous photos are contained in Appendix 5. During the 2006-07 monitoring year, new photo sites were added to the monitoring program based on the findings of the aerial photo analysis completed for the Basslink Baseline Report. These sites were photographed in October 2006 and in March 2007. The sites include two landslips in zone 2, two landslips at the confluence of the Denison and Gordon Rivers, and a large landslip in zone 4. Photos of the steep left bank of the Albert River upstream of the confluence are also being routinely taken.

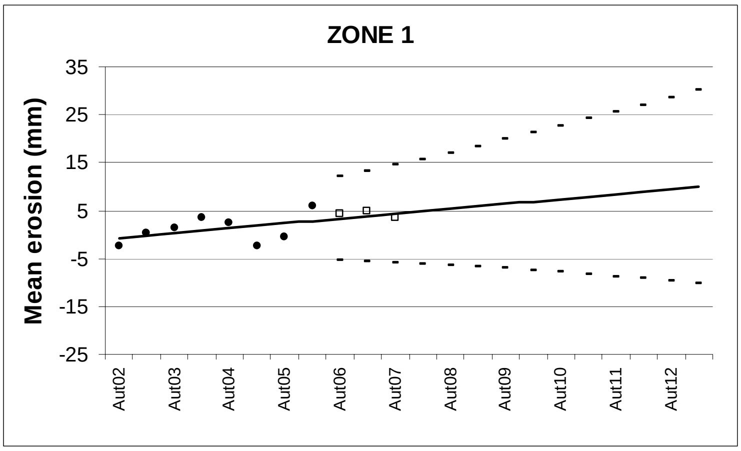
The results from comparing the March 2007 photos with the March 2006 photos are summarized in Appendix 5. The majority of the sites (45 of 59) showed no changes at the scale of the photos. Changes which were discernible included the movement of woody debris on bank toes, the loss of small branches from existing tree falls, and changes to the volume of deposited sands. There were no changes noted for any of the newly added photo-monitoring sites.

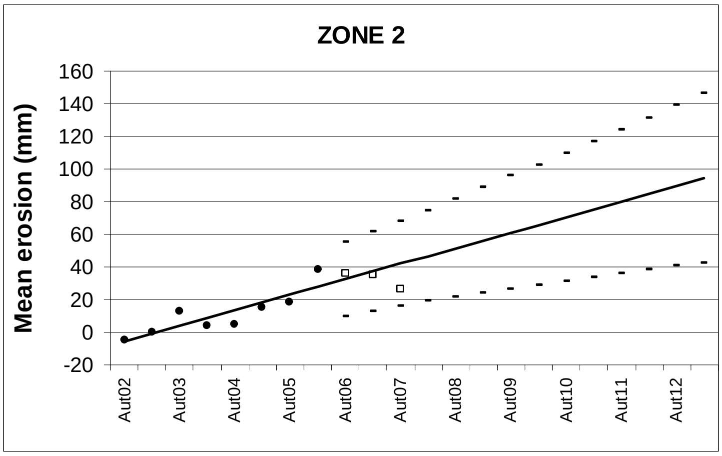
4.4.7 Trigger values

Trigger values based on the erosion pin results grouped by zones were developed for the Basslink Baseline Report (2006). The trigger values are based on the projected net erosion rate for each of the geomorphology zones, and defined by the 95th percentile confidence limit of the projected median value, as shown by the envelope in Figure 4-11. The autumn result (March) for each zone (Figure 4-7, graph 'B') is used as the basis for comparison.

The results from March 2007 are plotted in Figure 4-11, along with the projected rates of erosion. The results from zones 1-4 fall within the trigger envelopes, with the results for zone 1 falling on the predicted median, and results for zones 2, 3 and 4 falling below the predicted median. The result for zone 5, the only zone which is predicted to have net deposition, falls above the trigger value, indicating that deposition was lower during the period than predicted based on the pre-Basslink results. The erosion pin results in Figure 4-7 ('A') show that this decrease of net erosion in zone 5 is associated with an increase in erosion in pins showing erosion, and the increased erosion is occurring in the <1 and 2-3 turbine level of the bank (Figure 4-10).

It is considered unlikely that this result is solely due to Basslink operation of the power station, as zone 5 is located furthest from the power station, and power station-derived flows constitute a smaller portion of total flow as compared to the other zones. It is plausible that the result is related to the relatively low erosion rates recorded in zones 2-4 as compared to the historic median, which may have reduced the material available for deposition downstream. It may also reflect bank re-adjustment in response to over-steepening which has been documented during pre-Basslink monitoring, or lack of sediment availability from tributary due to low inflows during the drought. There are insufficient results to establish the cause for this result, and a level one response ('note and explain') will be maintained on the zone 5 results.





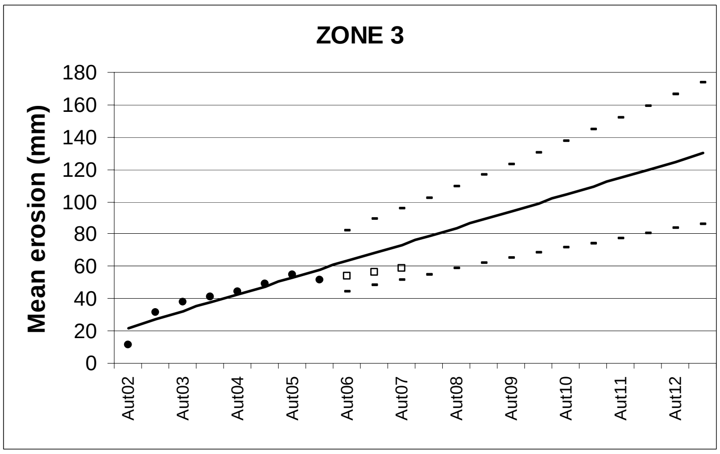
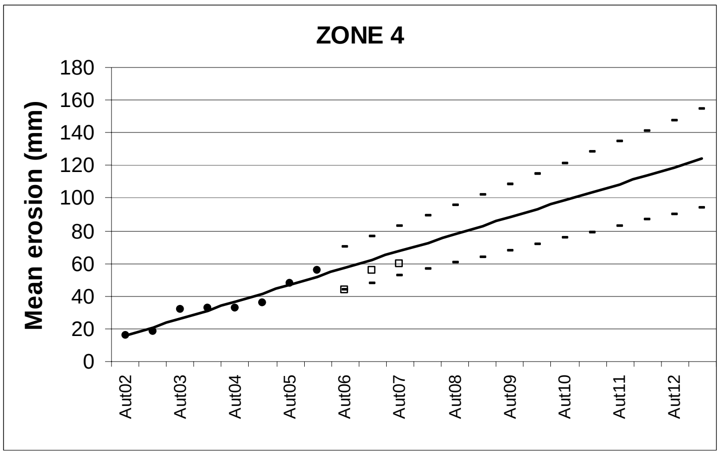


Figure 4-11. Mean erosion results plotted against predicted values based on the pre-Basslink monitoring results. The line indicates the predicted mean, with the dashed envelope enclosing the 95th percentile confidence limits.



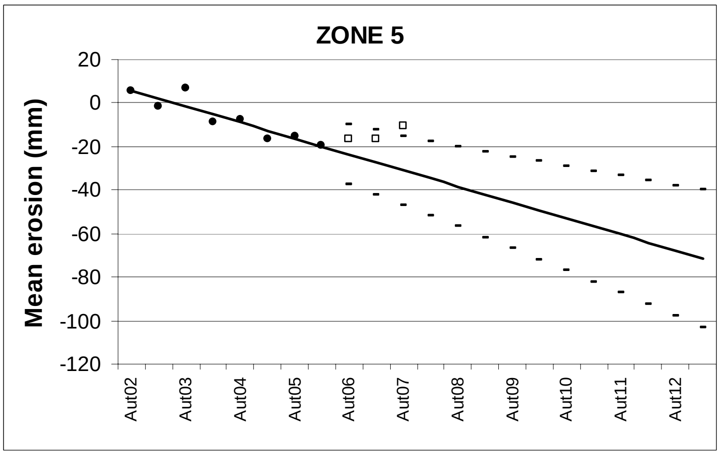


Figure 4-11 continued

4.5 Geomorphology summary

Monitoring was successfully completed as required under the licence.

Net erosion rates are within pre-Basslink trigger range for zones 1-4. Scour erosion in response to sustained 2-turbine flows is suggested as the predominant erosion process during the monitoring year.

The rate of deposition in zone 5 has slowed and is outside of the trigger range – may be in response to reduced upstream erosion and sediment supply.

A number of events deemed to present high seepage erosion risk were identified, with most associated with a lack of power station ramping following discharges in excess of 180 $m^3 s^{-1}$. Despite this, seepage erosion was not considered to be a major contributor to erosion rates for the year.

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5 Karst geomorphology

5.1 Introduction

The objectives of monitoring the karst caves are to:

- improve the understanding of the sediment transfer processes occurring in the caves, and to see how they may relate to sediment flux in the Gordon River;
- monitor dolines to provide evidence for whether they may be affected by repeated draw down in the river channel under Basslink operation; and
- water level monitoring in Bill Neilson Cave to give a good indication of natural water level conditions in the immediate area.

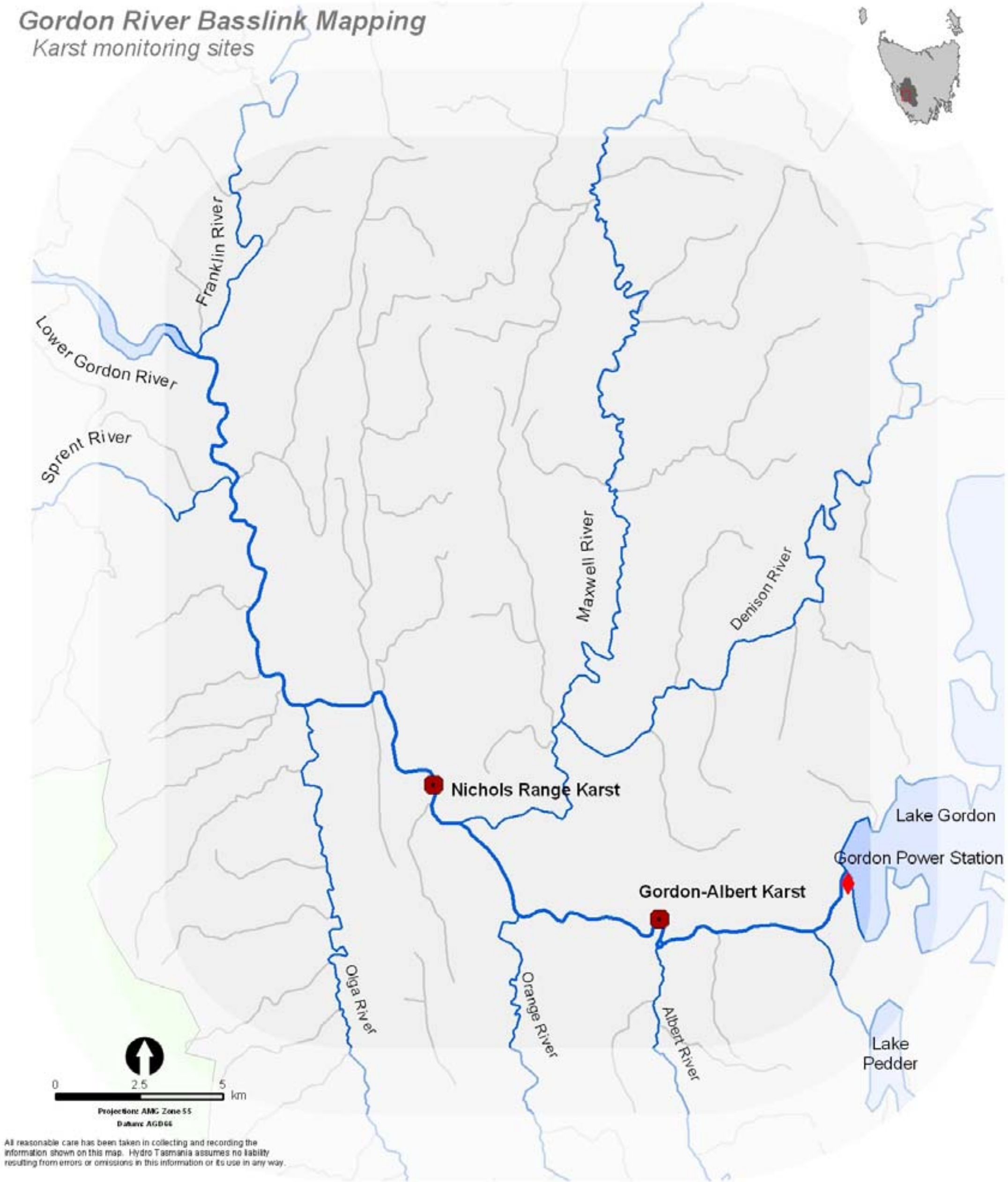
Background information can be found in the Basslink Baseline Report (Hydro Tasmania, 2005) and the Integrated Impact Assessment Statement (Hydro Tasmania, 2001).

This chapter provides a summary of:

- the monitoring data (erosion pin and water level data from Bill Neilson Cave, Kayak Kavern, GA-X1 and dolines) obtained on 17 October 2006 and 17March 2007 field trips, including a brief discussion of the results; and
- analysis and discussion of the monitoring results against the informal trigger values determined as part of the baseline review.

5.1.1 Karst areas

Key karst features are monitored in both the Gordon–Albert and Nicholls Range karst areas twice per year. Map 5-1. shows the location of the two karst areas investigated by the monitoring program.



Map 5-1. Map of the karst monitoring sites in the Gordon River

5.2 Methods

5.2.1.1 Gordon-Albert karst area

There are four karst monitoring sites in the Gordon-Albert karst area. Site 1 is a backwater channel known as Channel Cam, site 2 is the GA-X1 cave with a doline at the entrance and sites 3 and 4 are dolines. Each site has a number of stainless steel erosion pins installed and a photo-monitoring site marked with a red metal peg. A water level recorder is installed in GA-X1.

The GA-X1 cave is 28m long (including the large entrance area), 10m deep and is located approximately 10-20m from the Gordon River. There are two entrances to the cave: the smaller entrance lies on the western (river) side of the feature and is a short, near–vertical shaft leading down into the main chamber; the second entrance is much larger and is effectively the base of a second large doline. The cave has a sump at its lowest level, which is at approximately the same elevation as the Gordon River.

All erosion pins were measured to the nearest mm using a steel tape measure placed to the right side of the pin, on the contour level.

Photos were taken at all photo-monitoring sites as required.

5.2.1.2 Nicholls Range karst area

There are two karst monitoring sites in the Nicholls Range karst area, site 5 in Kayak Kavern and site 6 in Bill Neilson Cave. Bill Neilson Cave contains a cave stream. Both sites were accessed by boat. Kayak Kavern has five erosion pins installed and a photo–monitoring site. Bill Neilson Cave site has three sub–sites within the cave which are designated 6A–C and comprise various arrays of erosion pins. There are also three lightweight capacitive water level probes deployed in the cave which are occasionally moved around for different monitoring purposes. Water levels are recorded every 10 minutes over a range of 1–2m.

All erosion pins were measured to the nearest mm using a steel tape measure placed to the right side of the pin, on the contour level.

Photos were taken at all photo-monitoring sites as required.

5.3 Results and discussion

5.3.1 Water level recorders

There were some difficulties with data retrieval from the data loggers in Bill Neilson Cave this year. The winter data from the upstream recorder and the middle recorder in the cave could not be recovered as both the loggers were dislodged during a flood event and spent a proportion of the period under water. The summer data from the middle recorder in Bill Neilson Cave were also lost due to logger malfunction.

Hydrographs for the available data from the water level recorders in Bill Neilson Cave, together with the Gordon below Denison (site 62) data between 24 April 2006 and 17 March 2007 are shown in Figure 5-4 in separate winter (a) and summer (b) graphs. The water level data for GA-X1 for the same period is shown in Figure 5-5 (a,b) with the corresponding water levels at site 72.

5.3.2 Photo-monitoring

No specific issues or changes were highlighted from this year's photos.

5.3.3 Erosion pin data

Data for all sites are summarised in Table 5-2and illustrated in Figure 5-1, Figure 5-2, and Figure 5-3. The distances between the tops of the pins located in the dolines at sites 3 and 4 were also measured to assess whether any major structural change had occurred. Measurements are summarised in Table 5-1.

Table 5-1. Erosion pin survey data for sites 3 and 4 from spring 2002 to autumn 2007. S=spring and A=autumn

Site No.	Pins measured	Distance between pins (m)									
		S02	A03	S03	A04	S04	A05	S05	A06	S06	A07
3	PMP* to pin 5	3.280	3.295	3.295	3.295	3.298	3.300	3.290	3.290	3.293	3.305
	Pin 5 to pin 6	1.055	1.055	1.050	1.055	1.050	1.050	1.049	1.053	1.049	1.044
	Pin 6 to pin 7	1.350	1.345	1.345	1.355	1.359	1.356	1.359	1.355	1.357	1.354
	Pin 7 to pin 8	1.850	1.850	1.850	1.845	1.852	1.850	1.854	1.851	1.850	1.849
	Sum pins 5 to 8	**4.255**	**4.250**	**4.245**	**4.255**	**4.261**	**4.256**	**4.262**	**4.259**	**4.256**	**4.247**
4	PMP* to pin 12	2.620	2.620	2.630	2.625	2.628	2.630	2.626	2.630	2.629	2.628
	Pin 12 to pin 13	1.515	1.515	1.515	1.515	1.522	1.517	1.517	1.520	1.519	1.518
	Pin 13 to pin 14	1.435	1.435	1.435	1.435	1.440	1.435	1.438	1.435	1.436	1.436
	Pin 13 to stick (pin 31)	n/a	n/a	n/a	1.505	n/a	n/a	n/a	n/a	n/a	n/a
	Pin 12 to pin 31	n/a	n/a	n/a	n/a	0.530	0.530	0.524	0.525	0.520	n/a
	Pin 12 to pin 32	n/a	n/a	n/a	n/a	0.722	0.720	0.720	0.720	0.720	n/a
	Sum pins 12-14	**2.950**	**2.950**	**2.950**	**2.950**	**2.962**	**2.952**	**2.955**	**2.955**	**2.955**	**2.954**

*PMP is photo-monitoring peg

Table 5-2. Erosion pin data at all sites from spring 2001 to autumn 2007. S=spring and A= autumn

Site description and site no.	Pin no.	Erosion pin lengths (mm)												Comments and interpretation
		S01	**A02**	**S02**	**A03**	**S03**	**A04**	**S04**	**A05**	**S05**	**A06**	**S06**	**A07**	**Spring 2006 and Autumn 2007 data**
Channel Cam (S1)	1	322	318	318	316	318	322	314	323	320	322	322	316	Negligible change at either pin over winter, in contrast to winter deposition in recent years. 6 mm deposition at pin 1 over summer, in contrast to more typical summer erosion. Net change since the beginning still relatively small at -1 and +6 mm.
	28	n/a	n/a	245	245	248	248	243	256	245	248	247	246	
GA-X1 cave (S2)	2	250	239	238	244	242	245	248	251	250	251	253	251	5 mm deposition over winter at the lowest level (pin 4) in the cave this period, similar to the winter period of 2003. 2 mm deposition at the mid level (pin 2) over summer, in contrast to more typical summer erosion, but obstruction may be influencing the result. All other changes consistent with previous years.
	3	190	189	193	195	196	194	194	194	195	193	194	194	
	4	154	161	160	163	159	165	168	168	176	178	173	177	
Doline at cave entrance	9	214	213	220	217	219	224	201	215	213	215	181	182	Significant apparent increase in debris at pin 9 over winter but pin was strongly tilted and is likely to have been knocked by falling debris. Minor changes otherwise.
	10	278	278	293	290	291	290	283	286	286	288	284	283	
Doline adjacent to GA-X1 (S3)	5	259	287	294	297	284	283	291	290	292	290	283	290	No significant seasonal changes. Zero net change over 12 months at pin 5 at the base, slight net decrease in debris at pin 6 and slight net increase in debris at the higher levels (pins 7 and 8).
	6	300	300	294	306	297	290	296	296	295	297	300	301	
	7	254	252	258	261	257	252	250	248	261	260	261	254	
	8	195	196	192	200	194	192	195	194	192	189	188	186	
Small doline (S4)	12	192	171	170	172	152	155	156	145	151	150	131	147	Winter increases and summer decreases in debris across all pins. Relatively large increase in debris [12–19 mm] at the three pins in the base of the feature during the winter period. Over a 12 month period there were slight net decreases in debris in the base of the feature (pins 14, 31 and 32), and slight net increases on the slopes (pins 13 and 14).
	13	234	238	231	231	245	241	240	225	236	232	230	235	
	14	253	256	244	262	257	257	250	257	249	255	253	260	
	31	n/a	n/a	n/a	n/a	n/a	n/a	570	564	568	568	556	561	
	32	n/a	n/a	n/a	n/a	n/a	n/a	776	770	750	768	750	765	
Kayak Kavern (S5)	16	309	308	319	359	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Consistent changes across many of the pins with winter erosion (9-13 mm) and summer deposition (19-37 mm). Over the 12 month period, the pins on the mid and high active slopes have demonstrated net sediment gains of 13 to 27 mm, while the pins on the eddy slope and the top flat have recorded net sediment losses of -10 to -12 mm.
	17	293	291	284	288	339	384	349	320	366	302	315	287	
	18	267	266	255	263	258	252	256	271	269	272	281	284	
	19	249	245	271	267	225	220	222	232	215	115	95	125	
	29	n/a	n/a	n/a	n/a	n/a	273	?	272	?	233	216	220	
	30	n/a	n/a	n/a	n/a	n/a	259	?	241	243	245	243	224	
	33	n/a	n/a	n/a	n/a	n/a	n/a	n/a	275	266	283	293	256	
Bill Neilson (S6): 6A at entrance	20	483	480	499	495	501	493	502	497	497	495	498	499	Erosion (3-4 mm) at the lower and mid levels over winter, with slight 3 mm increase at the higher level at pin 22. Minor summer erosion (1 mm) at the lower and higher levels with no change at the mid level. Seasonal trend change at the lowest pin.
	21	300	299	302	301	304	305	301	300	304	306	310	310	
	22	272	272	269	272	271	271	270	271	270	270	267	268	

Site description and site no.	**Pin no.**	**Erosion pin lengths (mm)**												**Comments and interpretation**
		S01	**A02**	**S02**	**A03**	**S03**	**A04**	**S04**	**A05**	**S05**	**A06**	**S06**	**A07**	**Spring 2006 and Autumn 2007 data**
Bill Neilson: 6B Sed bank II	25	194	195	195	195	198	198	205	203	204	204	207	208	Consistent 12 month changes at the lower level as that in the first wet sediment bank. Zero changes at the mid levels. 3 mm net erosion at the highest level.
	26	203	203	202	202	202	204	206	204	204	205	205	205	
	27	215	216	214	213	212	208	210	210	209	210	210	213	
Bill Neilson: 6C Dry sed bank	23	297	297	295	298	298	297	297	297	296	297	297	297	No significant change. Consistent trends.
	24	227	226	202	203	203	203	203	203	203	203	202	202	

Table 5-2 continued

5.3.4 Bill Neilson Cave

5.3.4.1 Sediment transfer

There are three sets of erosion pin data in Bill Neilson Cave, the wet sediment bank in the entrance chamber (pins 20–22), the wet sediment bank 5–10m further into the cave (pins 25–27), and the dry sediment bank 175m into the cave (pins 23–24).

Erosion pin results from the winter period at the first wet sediment bank indicates that there has been 4 mm of sediment erosion at the lowest level closest to the cave stream (pin 20), 3 mm of erosion at the mid level (pin 21) and 3 mm of deposition at the higher level at pin 22. At the second wet sediment bank, a similar level of erosion has occurred at the lowest level (3 mm at pin 25), while there has been zero change at the mid and higher levels. These are the same patterns of sediment movement as occurred during the 2003 winter period. It is interesting to note however, that the power station operations during winter 2003 were very different to 2006, comprising more full gate and one turbine operations.

During the summer period, the trends were very similar at both the wet sediment banks with 1 mm of erosion at the lower levels, zero change at the mid levels and 1 to 3 mm of erosion at the higher levels. This is the first summer season when erosion (albeit just 1 mm) has occurred at pin 20 rather than deposition.

Over the 12 month period the net result at the wet sediment banks is 3 to 4 mm of erosion at pins 20 (low), 21 (mid), 25 (low) and 27 (high); zero change at pin 26 (mid) and 2 mm of deposition at pin 22 (high).

At the dry sediment bank, there was just 1 mm of deposition recorded at the higher of the two pins (pin 24) during the winter period but zero change during summer. There were no changes all year at the lower of the two pins (pin 23).

5.3.4.2 Water level monitoring

The winter season's water level data show that the Gordon Power Station operated relatively consistently at the mid level range, with a number of discrete, significantly larger peak flow events occurring. The largest flood event this period was in mid July and reached 5.5m on the Gordon below Denison gauge. There are no cave stream data available for this period but it is likely based on the Denison flows that, with the exception of the peak flow events, the cave stream flows were relatively low. This general lack of consistent inundation and strong recession flows following peak flow events can account for the patterns of erosion occurring at the lower levels. The pins in the dry sediment bank would have been inundated at least twice this winter, once in mid June and once in mid July which may account for the very small change recorded at the higher of the pins.

The summer water level data show that power station operated fairly consistently at two turbines during November and half of December before switching to predominantly 3-turbine flow. The power station discharge during January and the first half of February, were relatively variable across the full range of operations. This variable pattern of inundation is reflected in the erosion pin data. There was erosion at both the higher pin levels and the lower pin levels in the wet sediment banks this period. The lowest of the three pins in the first wet sediment bank (pin 20) has recorded a very minor decrease in sediment (1 mm) which has effectively reversed the strongest previous trend of all the pins being measured, that of summer deposition and winter erosion. While this change is likely to be attributable to the reduction in higher level power station flows, this interpretation is treated with caution as the erosion was just 1 mm and the approximate level of accuracy of the measurement method is ±1 mm.

Two peak flow events which would have inundated the dry sediment bank occurred in the river in early and late January, although neither superceded the highest winter event.

Interestingly, the peak flow event in the cave stream during the summer period did not coincide with peak flows in the Denison which demonstrates that the cave catchment may have slightly different or localized rainfall patterns. Despite this, the Denison flow events had a much more significant impact on the inundation regime in the cave than did the cave stream.

5.3.4.3 Conclusion

The Gordon Power Station generally operated relatively consistently at the mid level range this winter and spring, before increasing to 3- turbine operations in mid December. There were four peak flow events this year that would have inundated the pins in the dry sediment bank, although between them they have resulted in negligible sediment change.

There was moderate net erosion measured at four of the six pins in the wet sediment banks, across all three levels being monitored, and moderate net deposition at the higher level in the second bank. The results from the lowest pin in the wet sediment bank indicate that the relatively strong trend of summer deposition may have been changed this year to very slight erosion (1 mm). This is tentatively attributed to the reduction in higher level power station flows this period.

5.3.5 Kayak Kavern

5.3.5.1 General observations

The active slope of the sediment bank is being impacted by the monitoring team continually accessing the bank from the boat. A new access route to the pins in Kayak Kavern has been located over the large boulders between the cave and the river instead of up the active slope of the silt bank to reduce the impact.

5.3.5.2 *Sediment transfer*

During the winter period, four of the erosion pins in Kayak Kavern (pins 17, 18, 29 and 33) recorded similar losses in sediment of between 9 and 13 mm. These pins include the high active slope pin, two of the three mid active slope pins, and the pin on the top flat. The other two pins, pin 30 on the mid active slope and pin 19 on the eddy slope, recorded a 2 and 20 mm sediment gain respectively.

During the summer period, four of the pins (pins 17, 29, 30 and 33) recorded similar net increases in sediment from 19 to 37 mm. These pins represent the high and mid active slope areas. pin 19 in the eddy again showed a slightly different pattern to the other pins with 30 mm of erosion occurring, while pin 18 on the top flat indicated that slight erosion (-3 mm) has taken place in that area.

Over the 12 month period, the pins on the mid and high active slopes have demonstrated net sediment gains of 13 to 27 mm, while the pins on the eddy slope and the top flat have recorded net sediment losses of -10 to -12 mm.

While pins 29, 30 and 33 were not installed prior to Basslink as they replaced original pins that had fallen out and therefore direct comparisons with pre-Basslink data cannot be made, it is considered that they can be used to aid the interpretation of the data for the other pins. These pins have consistently recorded relatively large winter erosion and summer deposition events on the active slope of the sediment mound. These events have been consistent with the scale of changes at the other pins located in the same parts of the sediment bank prior to Basslink.

The majority of the active slope in Kayak Kavern is inundated when the station is operating at the one-turbine level. Once the station moves to two-turbine operations, the inundation level increases and pin 18 on the top flat becomes submerged. The relatively consistent and strong decreases in sediment across the pins during the winter months may be attributable to the three weeks of fluctuating one-turbine operations just prior to the field visit. The deposition during the summer months is likely a result of the relatively stable extent of inundation with the station at the three-turbine output level.

5.3.5.3 *Conclusion*

The pins in Kayak Kavern have demonstrated that there has generally been winter erosion and summer deposition on the sediment mound, resulting in a net gain of 13 to 27 mm of sediment on the mid and high active slopes, and a net loss of 10 to 12 mm of sediment on the eddy slope and the top flat, over the 12 month period. The winter erosion is likely to be a consequence of the fluctuating 1-turbine operations in the three weeks prior to the field visit which would have actively worked the sediment on the bank. The summer deposition is likely to have taken place in the relatively stable backwater environment while the station was operating at the 3-turbine output level.

5.3.6 GA-X1

5.3.6.1 General observations

There is significant sediment build up occurring up-gradient of pin 2 due to the presence of a stick which has lodged against the pin. Small local currents occurring around the pin when the water in the cave rises and falls may be influencing apparent sediment changes. An additional pin will be installed on the next trip adjacent to pin 2 but away from the stick to corroborate the results.

It was observed during the spring field trip that pin 9, located in the debris in the doline at the cave entrance, has been tilted off the vertical to approximately 75-80 degrees. During the autumn trip, leaf litter, which appears to have been floated into position, was found in the higher parts of the cave adjacent to the photo-monitoring site. This may suggest relatively high inundation levels in the cave coupled with a significant rainfall event that delivered fresh debris into the cave.

5.3.6.2 Sediment transfer

The two pins in the entrance doline (pins 9 and 10) showed little significant change during the year, with the exception of pin 9 which registered an apparent 32 mm increase in leaf litter over winter. This occurred during the same period as the pin was tilted off the vertical however, and may be more likely a result of the pin being knocked by falling debris.

Inside the cave, 5 mm of sediment was deposited at the lowest of the pins (pin 4) over winter, which was in contrast to the previous two winters when sediment was eroded, but similar to the trends during the 2002 and 2003 winters. There was slight winter erosion (-2 mm) at the mid level pin (pin 2), and little change at pin 3 which was typically outside the zone of inundation.

During the summer period, the trends at the lowest pin (pin 4) and highest pin (pin 3) were similar to previous years, with 4 mm of erosion and no change, respectively. The middle pin recorded 2 mm of deposition, in contrast to the more typical summer erosion. Given the obstruction caused by the stick behind the pin however, this may not be an accurate reflection of sediment transport conditions in this area of the cave.

Pin 4 has demonstrated for the first time, that a net increase in sediment has occurred over the 12 month period, rather than a net decrease which is more typically the case. The net change however is relatively small at just 1 mm and may not be significant given the accuracy of the method of assessment with the ruler. The net changes at the other pins were negligible and were consistent with other years.

5.3.6.3 Water level monitoring

The water level data from GA-X1 this season, together with the corresponding data from site 72, are shown in Figure 5-5. Water levels in the cave have correlated well with the site 72 water level data once again this period.

The data show that the cave was relatively dry for much of the winter period, as would be expected from the low flows in the river and the relatively low power station output. Peak flows were not even high enough to reach the top of the recorder as they have done in previous years. During the summer period, the cave was regularly inundated with the 3-turbine flows, for the most part consistently.

The pattern of relatively strong sediment deposition at the lowest pin (pin 4) over winter may have been caused by the extensive fluctuations in water levels early in the season bringing sediment into the water column, followed by a period of deposition during relatively stable low flow conditions immediately prior to the field visit. A similar process may have occurred during the 2003 winter when the same trend emerged. Minor changes at the mid and higher level pins reflect the general overall lack of inundation in the cave.

5.3.6.4 Conclusion

It appears there may have been generally more deposition than usual in the cave over the 12 month period with a very slight net increase in sediment at the lowest of the pins, and deposition over summer at the mid level pin in contrast to the more usual erosion. The water level and power station impacts on these changes are not clear but it may be that they are more directly related to operations immediately prior to the field visit than the overall seasonal activity. There has been little change at the higher levels due principally to the lack of inundation.

5.3.7 Dolines

The erosion pins at site 3 adjacent to GA-X1 are arranged with pin 5 in the base of the depression with a succession of pins arrayed in a line up the side of the feature at 1–2m distance apart up to pin 8. None of the pins showed any significant changes this season. There was zero net change in the base of the feature (pin 5), a slight increase in debris of 3-6 mm at the higher levels (pins 8 and 7 respectively) and a slight decrease at pin 6.

There are now five erosion pins at site 4 adjacent to Channel Cam. Pins 12–14 are positioned in an array up the side of the feature, with pins 31 and 32 supporting pin 12 at the base. Unusually, all pins showed a consistent increase in debris over the winter months (range 2-19 mm), and a decrease (range 5-16 mm) during summer. These changes have lead to slight net increases in debris over 12 months on the slope (pins 13 and 14) and slight net decreases in the base of the feature.

As noted in previous trip reports, the changes in the lengths of the erosion pins are not determined by the inundation regime of the Gordon River and are of less consequence than any changes in the distances between the tops of the pins. Consistent with previous trips, there were no significant changes between the pins within the precision of the measuring method. This suggests that the morphology of the dolines has remained stable since the program commenced.

5.3.8 Channel Cam

The trends in erosion pins at Channel Cam over the winter and summer this year are different to that which has occurred in recent years, and are more consistent with the earlier years of the monitoring program, i.e. 2001-03. The net change since the program began however, is still relatively small at –1 mm at pin 28 and +6 mm at pin 1.

The two erosion pins at Channel Cam recorded negligible change in sediment (0 and +1 mm respectively) over the winter period. This is in contrast to the previous two winters which were periods of significant deposition – as much as 11 mm of deposition took place at pin 28 in October 2005. It is likely that the lack of any change this period is due to no inundation by the Gordon River combined with relatively low rainfall.

The changes recorded over the summer months were also slightly different to the trends over the last three years. This summer was a period of deposition (6 mm at pin 1 and 1 mm at pin 28), in contrast to the more typical summer erosion (up to 13 mm during the 2004-05 summer). The Channel was inundated this period for approximately 30 days over December, January and February. There were also two significant, discrete, rainfall events in January which may have contributed additional sediment from the surrounding area.

5.4 Comparison with the informal trigger values

The primary indicator variables for assessing potential Basslink changes to the karst features, as discribed in the Basslink Baseline Report and in the subsequent review of trigger values report in the 2005-06 Gordon River Basslink Monitoring Annual Report, can be divided into three main groups:

1. sediment changes at erosion pins;
2. inundation of the dry sediment bank in Bill Neilson Cave; and
3. structural change in the dolines.

Within each group, the indicators are used to assess whether there is significant change occurring.

The Basslink Baseline Report identified that it was not feasible to determine formal trigger values for these karst indicator variables, as have been developed for the other disciplines. This is because averaging across karst sites and zones is not possible and there is no reasonable alternative consistent with the methodology being used by other disciplines. Nonetheless it was accepted that consideration of possible changes in pattern at the erosion pins should take place and an informal basis for alerting to possible changes was proposed.

A series of informal trigger values have been determined for the indicator variables which are being used to detect if potentially significant change is occurring. Should change be detected, the next step will then be to determine whether the cause of the change is Basslink related or due to one of the other potential drivers of change in the system.

5.4.1 Sediment change at erosion pins

Sediment change at erosion pins is being assessed and monitored in three ways:

1. current maximum range of change in erosion or deposition between sampling periods and since sampling began (Table 5-3);
2. average rates of change between sampling periods and since sampling began; and
3. changes in seasonal or long-term trends.

Changes identified through all three methods of analysis are required in order to trigger the need for further investigation and/or analysis of the data.

Analysis of the erosion pin data for the 2006-07 monitoring season shows that while some relatively minor changes to some of the sub-components of this indicator variable have occurred at some pins, none of the changes has occurred across all methods of analysis and are therefore not considered to be significant. Pin 4 in GA-X1 and pin 20 in Bill Neilson Cave appear to be exhibiting the most noteworthy changes, as the direction of change has changed from deposition to slight erosion at pin 20 and from erosion to deposition at pin 4. The changes may not be a preliminary indicator of any significant trend changes. These changes will be further monitored over the coming season.

Table 5-3 highlights the minor changes that have been detected in the minimum, maximum and average rates of change. Blue squares identify those changes that have occurred outside the pre-Basslink maximum range of change, or that have been greater than ±100% of the average rate of change, both since the pins have been installed and relative to the previous trips. These blue squares therefore highlight where the informal trigger values have been exceeded. Note however that all five sub-components of the sediment change indicator variable need to be triggered at an erosion pin before any change at that pin is considered potentially significant.

Just two pins have registered changes to more than 2 of the possible five sub-component triggers: Pin 19 in Kayak Kavern and pin 4 in GA-X1. Changes to seasonal trends have also been noted at pin 4 in GA-X1 and pin 20 in Bill Neilson Cave.

Pin 19 in Kayak Kavern has recorded the greatest extent of change of all pins, registering changes outside the maximum and minimum ranges of change since the pins were installed and between trips respectively, and recording relatively large changes to the average rate of change. The changes are also evident on the seasonal trend graph of all pin data (Figure 5-2a). However, this pin was knocked by floating debris and tilted off the vertical during the 2005-06 summer period and therefore the relatively major changes, particularly the results against the change since the pin was installed, are not considered to be Basslink changes.

Pin 4 in GA-X1, which is the lowest of the pins in the cave, has consistently demonstrated that there is a progressive but gradual removal of sediment at that level. If this trend is to continue, it means that an increased minimum value since the pin was installed is to be expected. The maximum change between sampling trips was greater this period than the pre-Basslink range of change, by just 1 mm. The graph of all pin 4 data (Figure 5-2b) shows that over the 12 month period there was a slight net increase in sediment (also 1 mm), in contrast to the more typical net decrease. Given the method of measurement of the pins by eye using a ruler held against the pin, these changes may not be significant but if they are they may be attributable to the nature of the power station operations immediately prior to the field visit rather than the overall seasonal activity. Further discussion is presented in section 5.3.3.

Table 5-3. Summary of erosion pin changes and exceedences of the informal trigger values relative to the pre-Basslink benchmarks

Location	Pin no	Changes between sampling trips						Changes since pins were installed (mm)					
		Post-Basslink changes (mm)			Pre-Basslink changes or informal triggers (mm)			Post-Basslink changes (mm)			Pre-Basslink changes or informal triggers		
		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Channel Cam	1	0	6	3.0	-9	8	-0.1	-1	8	2.8	-1	8	3.1
	28	1	1	1.0	-13	11	0.0	-11	2	-2.1	-11	2	-2.0
GA-X1 cave	2	-2	2	0.0	-6	11	-0.1	-3	12	3.2	-1	12	5.4
	3	-1	0	-0.5	-4	2	-0.6	-6	1	-3.4	-6	1	-3.1
	4	-4	5	0.5	-8	4	-3.0	-24	0	-12.8	-14	0	-10.0
Kayak Kavern	16	n/a	n/a	n/a	-40	1	-16.7	n/a	n/a	n/a	-50	1	-14.8
	17	-13	28	7.5	-51	35	-9.0	-91	9	-25.2	-91	9	-31.0
	18	-9	-3	-6.0	-15	11	-0.3	-17	15	0.8	-4	15	5.0
	19	-30	20	-5.0	-26	42	4.0	-22	154	42.3	-22	4	11.0
	29	-13	26	6.5	n/a	n/a	n/a	0	53	24.2	n/a	n/a	n/a
	30	2	19	10.5	n/a	n/a	n/a	0	35	16.5	n/a	n/a	n/a
	33	-10	37	13.5	n/a	n/a	n/a	-18	19	0.4	n/a	n/a	n/a
Bill Neilson Cave	6A at entrance												
	20	-3	-1	-2.0	-19	8	-2.0	-19	3	-11.9	-19	3	-10.8
	21	-4	0	-2.0	-4	4	-1.0	-10	1	-3.5	-5	1	-1.5
	22	-1	3	1.0	-3	3	0.1	0	5	1.8	0	3	1.0
	6B sed bank II												
	25	-3	-1	-2.0	-7	2	-1.3	-14	0	-6.5	-11	0	-5.0
	26	0	0	0.0	-2	2	-0.1	-3	1	-0.8	-3	1	-0.3
	27	-3	0	-1.5	-2	4	0.7	-1	7	3.3	-1	7	2.8
	6C dry sed bank												
	23	0	0	0.0	-3	2	0.1	-1	2	0.1	-1	2	0.1
	24	0	1	0.5	-1	24	3.4	0	25	20.3	0	25	19.0

Pin 20, which is located at the lowest level of the first wet sediment bank in Bill Neilson Cave, has indicated that minor erosion (1 mm) occurred at that level in the cave this summer period, in contrast to the relatively strong previous trend of summer deposition. This change may be attributable to the overall reduced frequency of three turbine operations in the system compared to pre-Basslink data. The ranges of change and the average rates of change were consistent with pre-Basslink data however.

5.4.2 Inundation of the dry sediment bank in Bill Neilson Cave

It has been estimated that the pins in the dry sediment bank in Bill Neilson Cave are inundated when the river level at the Gordon below Denison gauge is greater than 4.4m. During the pre-Basslink period, the pins were inundated just over 1% of the time, with the majority of peak flow events occurring during the winter months. The maximum peak flow measured during the monitoring program was 6.1m on 12 June 2002.

Over the 2006-07 period there were four flow events that inundated the pins in the dry sediment bank, two during the winter on 15 June and 11 July 2006, and two during the summer on 7 and 30 January 2007. The duration of the events was approximately 2.5 days in total which is less than 1% of the time. The peak flow event was 5.5m on 11 July which is also less than the previous maximum.

No significant change to the pre-Basslink inundation regime is considered to have occurred.

5.4.3 Structural change in the dolines

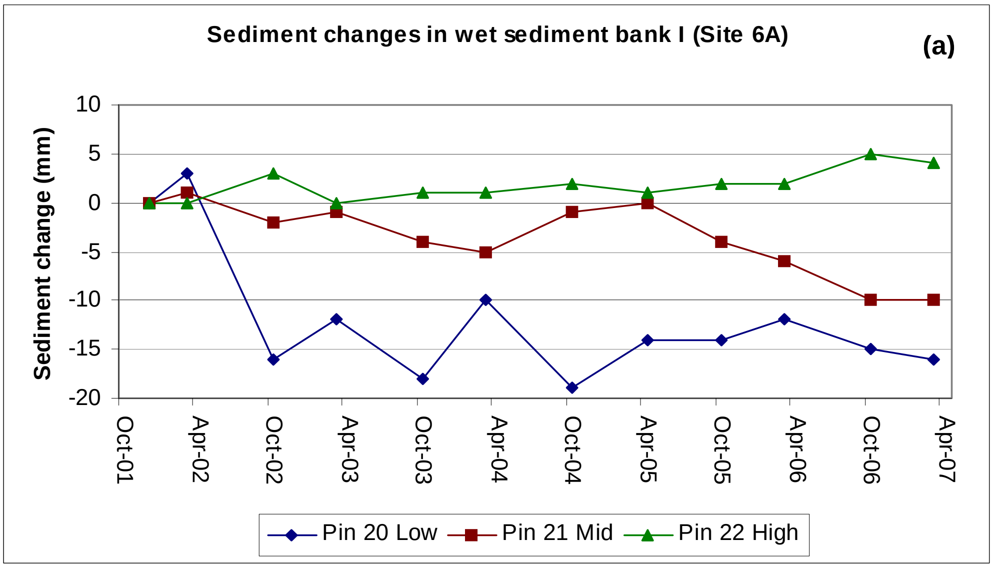
Structural change in the dolines is assessed by measuring the distances between the tops of a number of erosion pins installed in a line up the sides of the dolines. The average sum of the distances between the pins at site 3 was 4.25m during the pre-Basslink sampling period and the informal trigger value was therefore determined in the Basslink Baseline Report to be 4.25 ± 0.02m to allow for the level of accuracy inherent in the measurement technique. The average sum of the distances between the pins at site 4 was 2.95m and the informal trigger value was 2.95 ± 0.02m. In carrying out the assessment, consideration needs to be given to whether pins could have been interfered with by wildlife or falling debris.

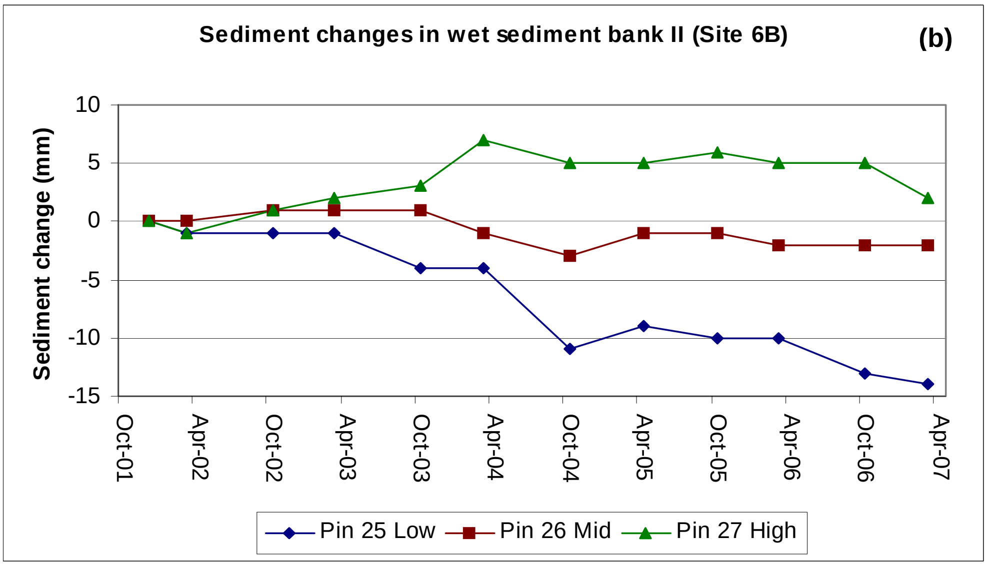
Table 5-3 shows the distances measured between the erosion pins since the program began, including this period. At site 3, the sums of the distances were 4.256m and 4.247m during the spring and autumn sampling periods respectively, while at site 4, the equivalent results were 2.955m and 2.954m.

None of the measurements therefore exceeded the informal trigger values.

5.5 Conclusions

The karst monitoring was undertaken as required by the licence in 2006-07. Some minor changes in sediments were observed in the caves but no departures from informal trigger levels were found during the monitoring year.





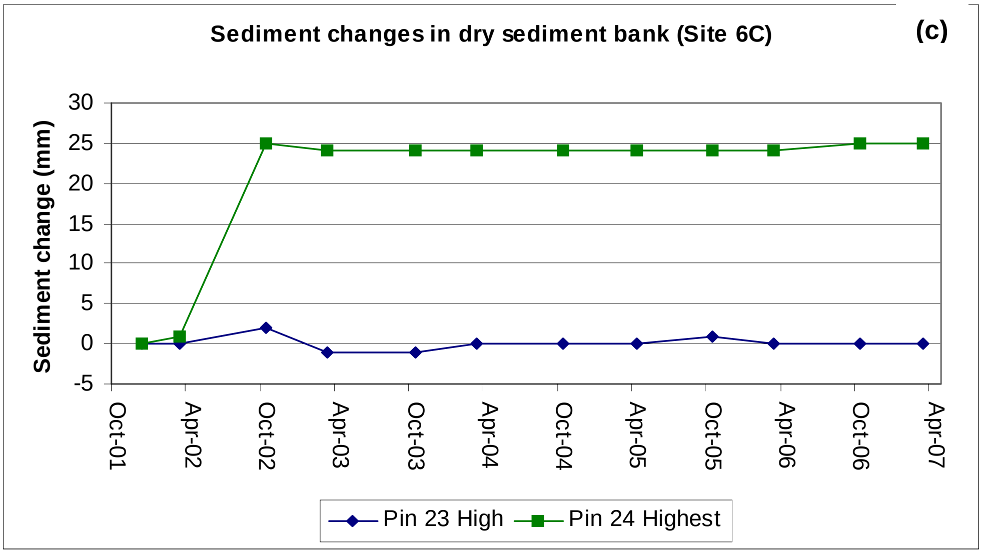


Figure 5-1 (a,b,c) Changes in erosion pin lengths at the three sites in Bill Neilson Cave over time

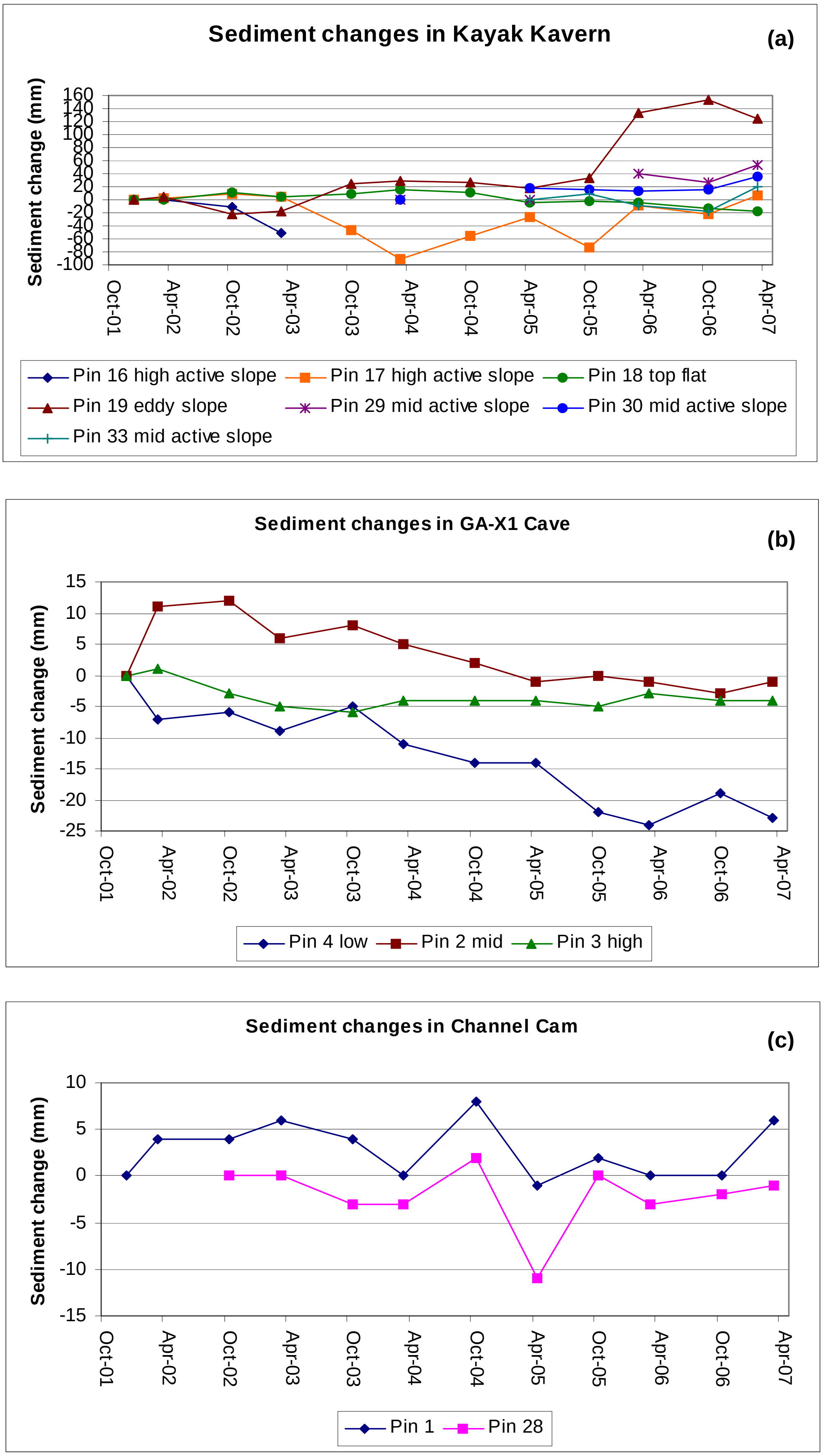


Figure 5-2 (a,b,c) Changes in erosion pin lengths at Kayak Kavern, GA-X1 and Channel Cam over time

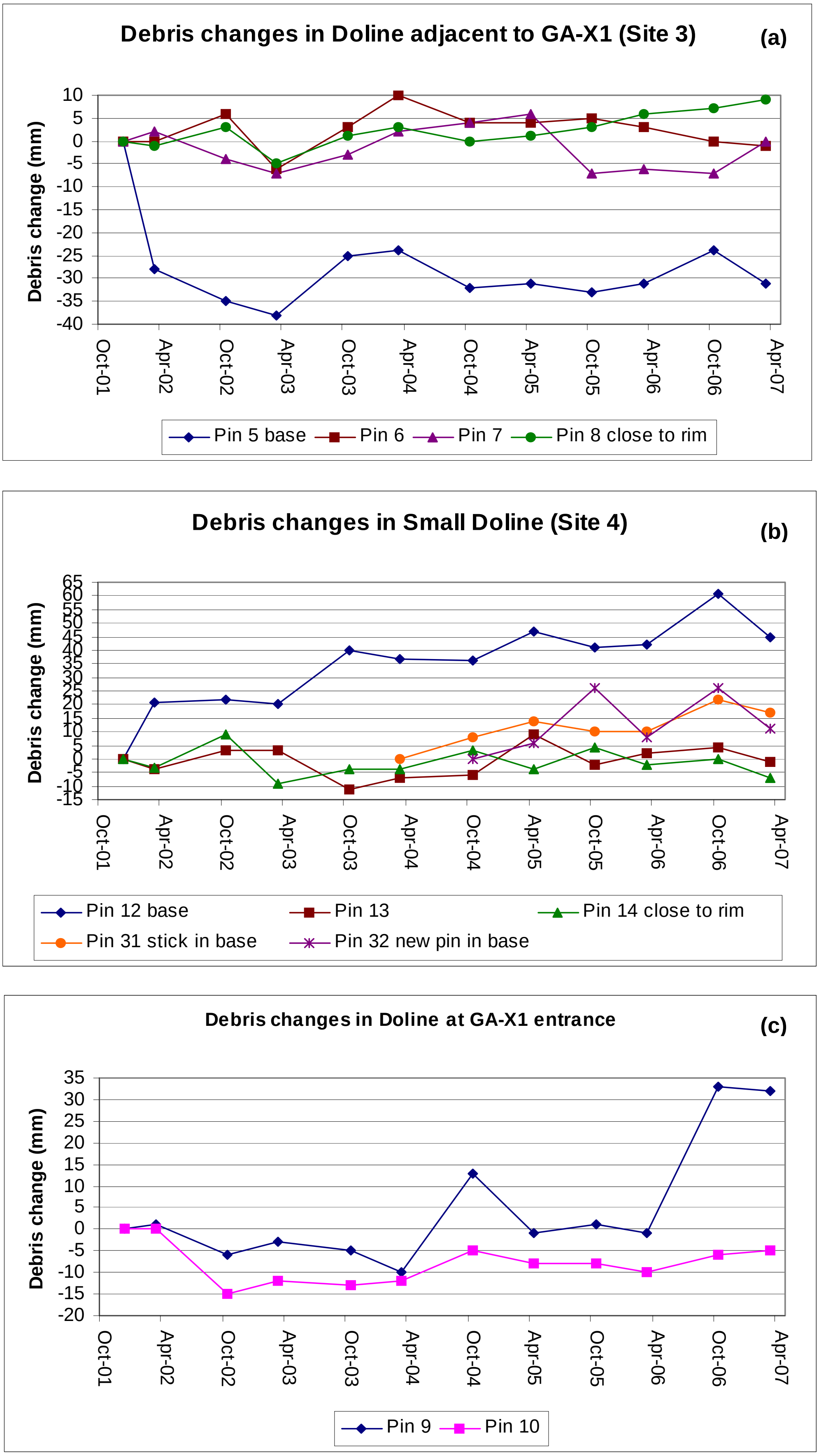
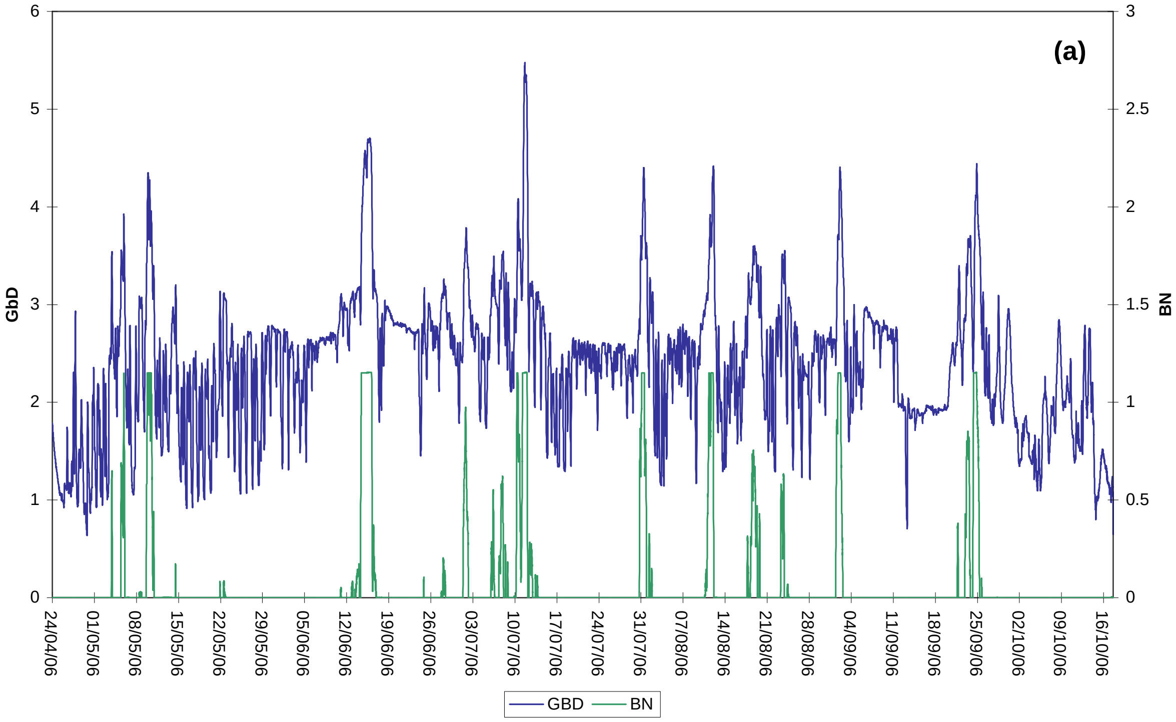


Figure 5-3 (a,b,c) Changes in erosion pin lengths in the three dolines over time



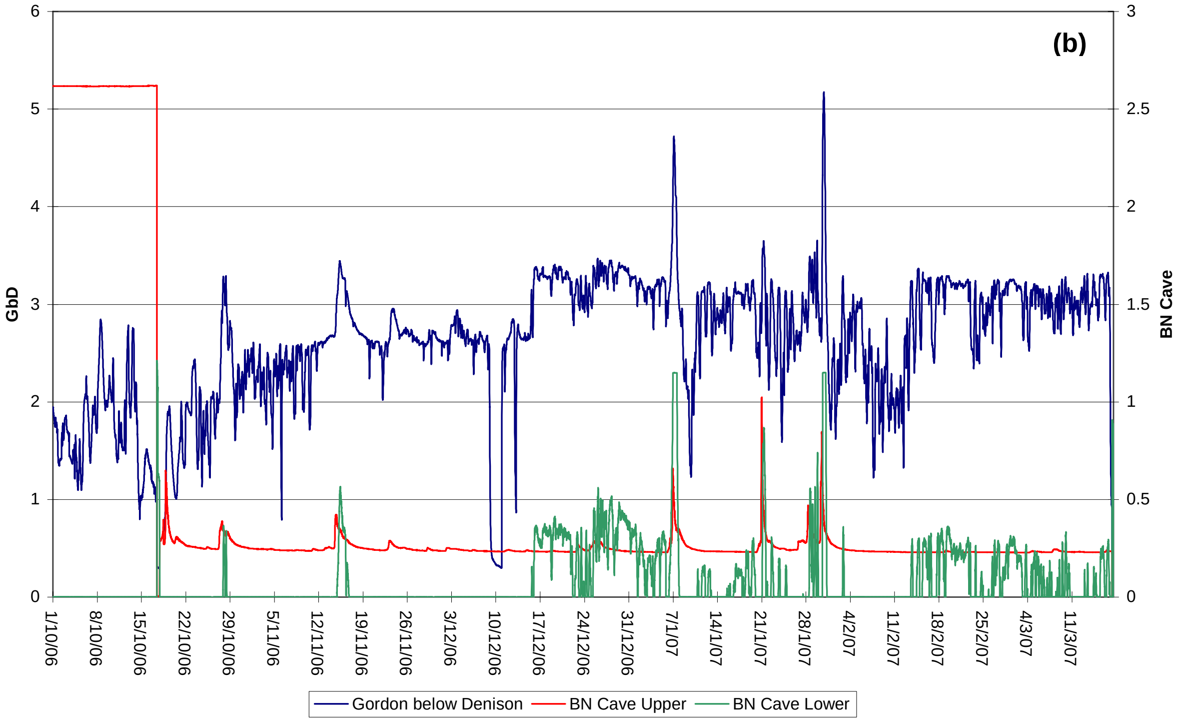


Figure 5-4 (a,b) Bill Neilson Cave water level recorder data together with Gordon below Dension (site 62) river data. Winter data is depicted in (a) followed by summer data in (b).

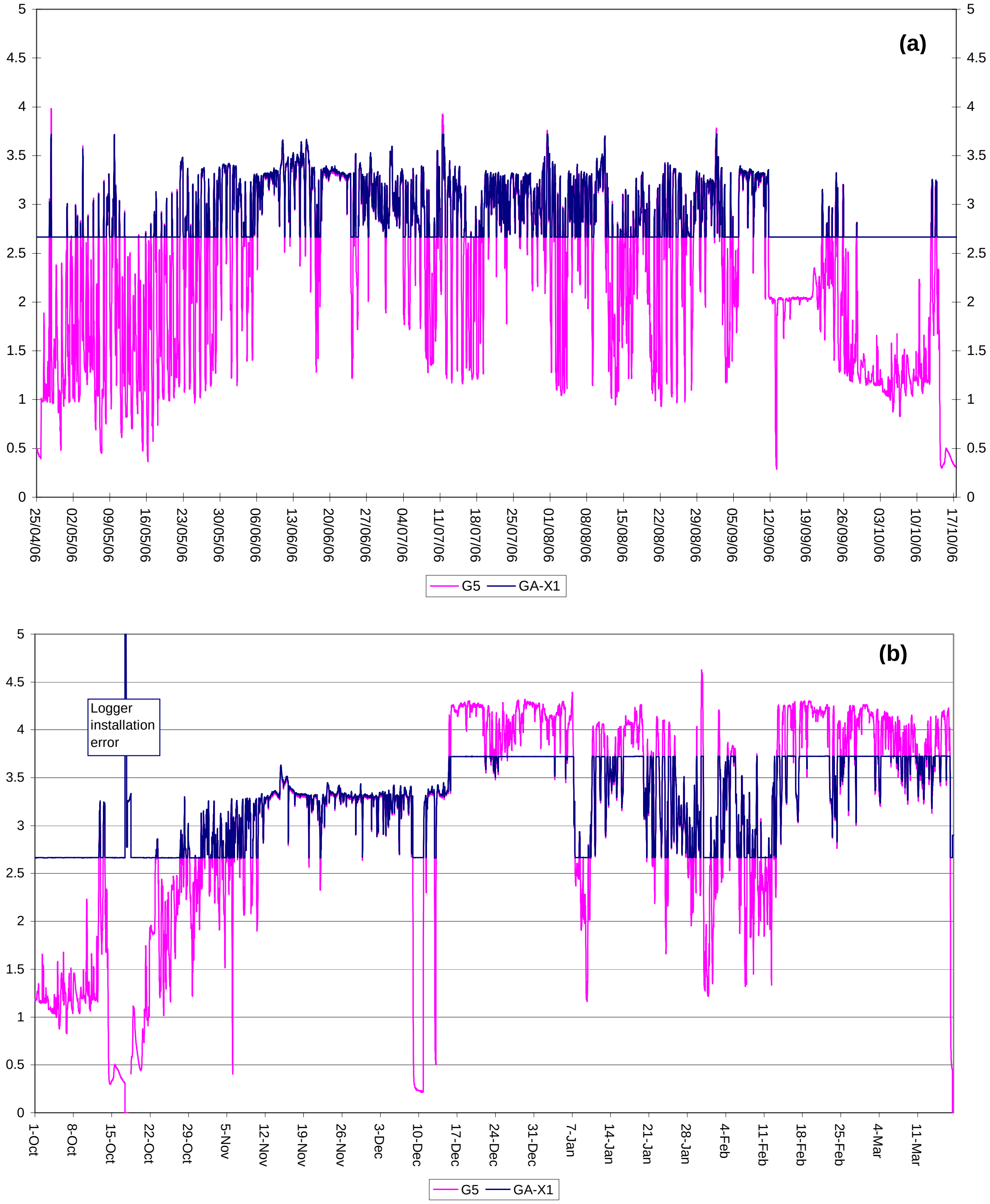


Figure 5-5 (a&b) GA-X1 water level recorder with water levels from site 72. Data in metres above arbitrary zero levels. Winter data is depicted in (a) followed by summer data in (b).

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6 Riparian vegetation

6.1 Introduction

Riparian vegetation monitoring is being undertaken along the Gordon River to fulfil requirements of Hydro Tasmania's Special Licence. This program aims to characterise the riparian vegetation processes and relate these to power station operation or other variables. These data have been gathered for four years prior to the operation of Basslink (known as pre-Basslink) to determine a baseline for the system which have been summarised into a set of quantitative and qualitative trigger values (see Hydro Tasmania, 2006). A fifth year of transitional data has been discounted in developing the trigger values; these data have been included in some assessments requiring continuous data in the riparian vegetation section. The monitoring program is in the first post-Basslink year and these data represent the first results to be compared with the trigger values.

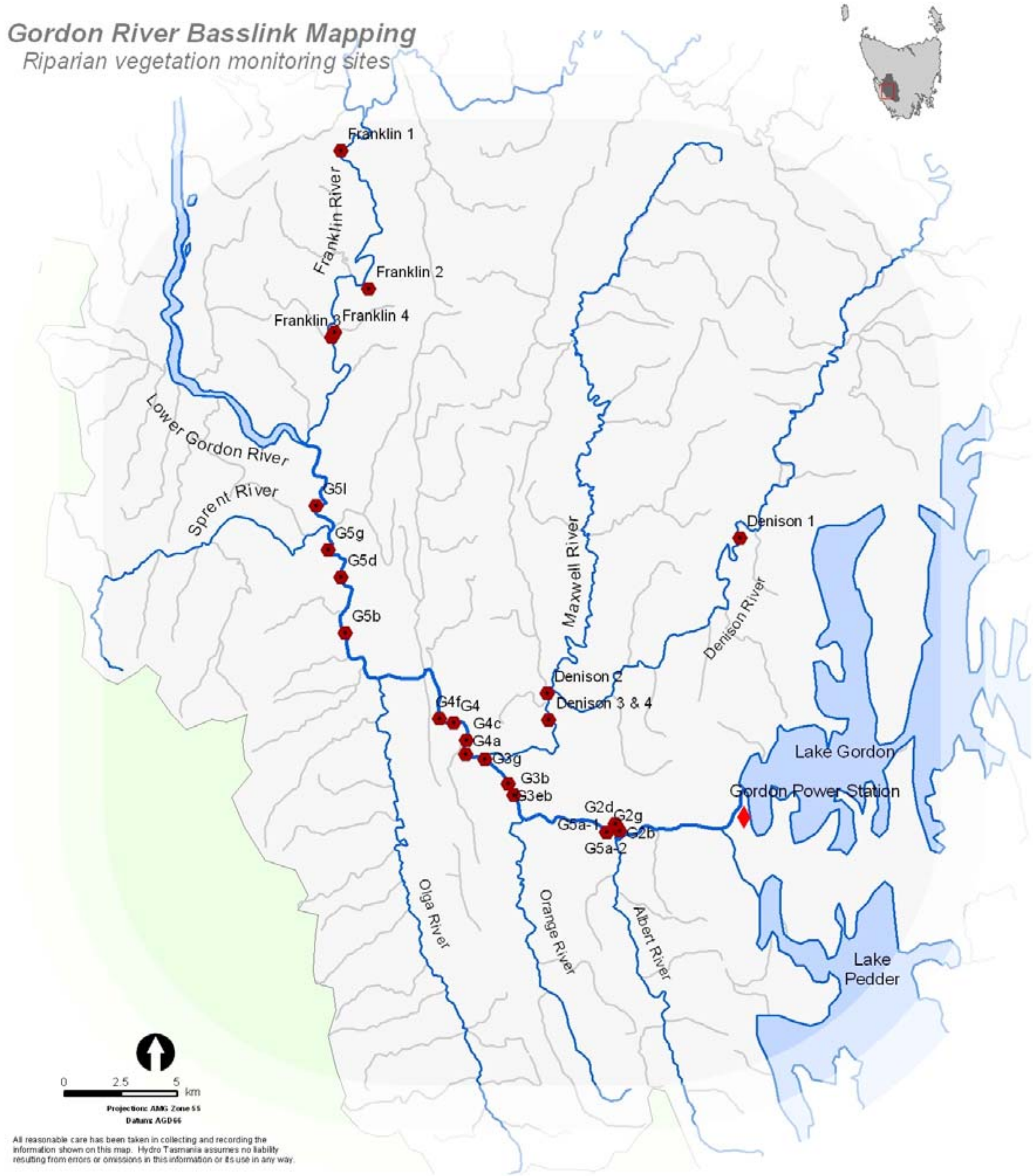
This report presents the Basslink riparian vegetation monitoring program results for the post-Basslink monitoring sessions in December 2006 and May 2007. The data for April 2006, a data-set not previously reported on and considered intermediate (that is, neither pre-or post-Basslink) is presented but not included in analyses or comparisons with trigger values unless otherwise noted.

Details of the monitoring and experimental design have been presented in previous reports (Davidson and Gibbons, 2001) and in detail in the Basslink Baseline Report (BBR) (Hydro Tasmania, 2005). The Basslink Baseline Report also presents material on general vegetation descriptions and vegetation responses to regulated rivers and should be consulted for further information or explanation as required.

6.2 Methods

Vegetation monitoring in the Gordon River includes assessments of vegetation metrics at 16 permanent plots in geomorphic zones 2, 3, 4 and 5, which comprise quadrat and belt transect-based methods (see Map 6-1 and Figure 6-1). At each of these permanent sites, six 1 m^2 quadrats are monitored, corresponding with the operation of two turbines, three turbines and above the level of 3-turbine operation. The bank location has been used to label the quadrats; 'low', 'high' and 'above' respectively.

The monitoring for seedling recruitment is undertaken twice-yearly in summer and autumn, whilst ground cover and vegetation abundance measures are undertaken in autumn only. Photo-monitoring is undertaken at 35 sites along the river to compare coarse-scale changes in ground cover and canopy cover. For further details of the monitoring program please refer to the BBR (Hydro Tasmania, 2005).



Map 6-1. Riparian vegetation monitoring sites on the Gordon River and tributaries. Monitoring zones are indicated in the Gordon River site labels: e.g. site G2d is in zone 2; site G5g is in zone 5, etc.

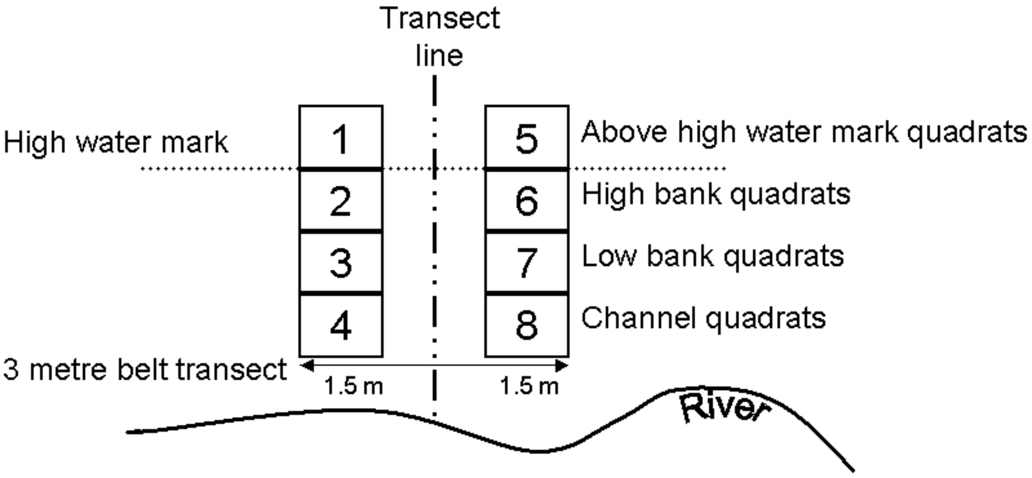


Figure 6-1. Diagrammatic representation (plan view) of quadrat positions along transects in Gordon, Franklin and Denison Rivers

All permanent sites were monitored in December 2006; including seedling monitoring and photo-monitoring. All permanent sites in zones 2, 3 and 5 were monitored in May 2007. However, one of the permanent sites in zone 4 was not monitored in May 2007 due to time and logistical constraints. Where feasible, values to compare within the trigger ranges are calculated and the data presented. However, due to the reduction in sites, some values outside trigger ranges have been found and reflect this variation in calculation. However, these values are still presented and the implications of these results are considered in the individual analyses.

6.3 Results

6.3.1 Photo-monitoring

Photo-monitoring was undertaken at thirty-five sites during the post-Basslink monitoring in May 2007 and compared with the transition monitoring period of April 2006. The comparison between the two concurrent years is used to show trends between the years. These trends are then compared with the patterns of trends found pre-Basslink. The last year of pre-Basslink comparisons are also presented in Figure 6-2 because they have not been presented in previous reporting. The photographs used for the assessment are presented in appendix 6 Riparian vegetation photo-monitoring.

Most comparisons showed no discernable change (defined as a change of 10% or more) over the monitoring period. Where changes did occur, the dominant patterns of vegetation change were ongoing contractions in ground cover or canopy vegetation; much of this happened in zone 2 over both years. In most cases the contraction of the ground layer was a reduction in ferns (*Blechnum nudum*), grasses (*Ehrharta* spp.) and also the root mat due to scouring and continued erosion. Contraction of the canopy vegetation was also prevalent in zone 2.

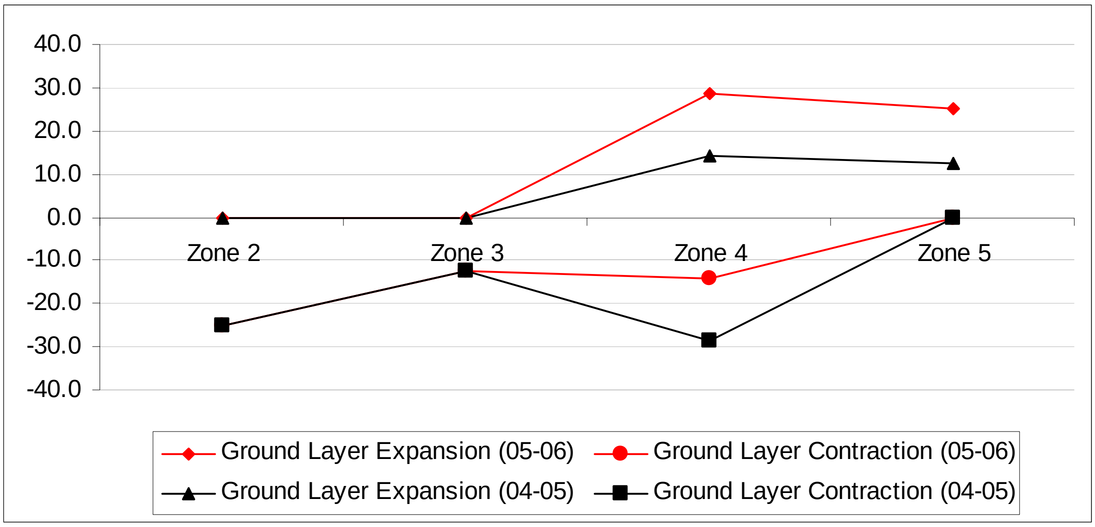


Figure 6-2. Summary of photo-monitoring results for ground layers in zones 2-5 for the Gordon River; December 2004-December 2005 and December 2005-December 2006 comparisons

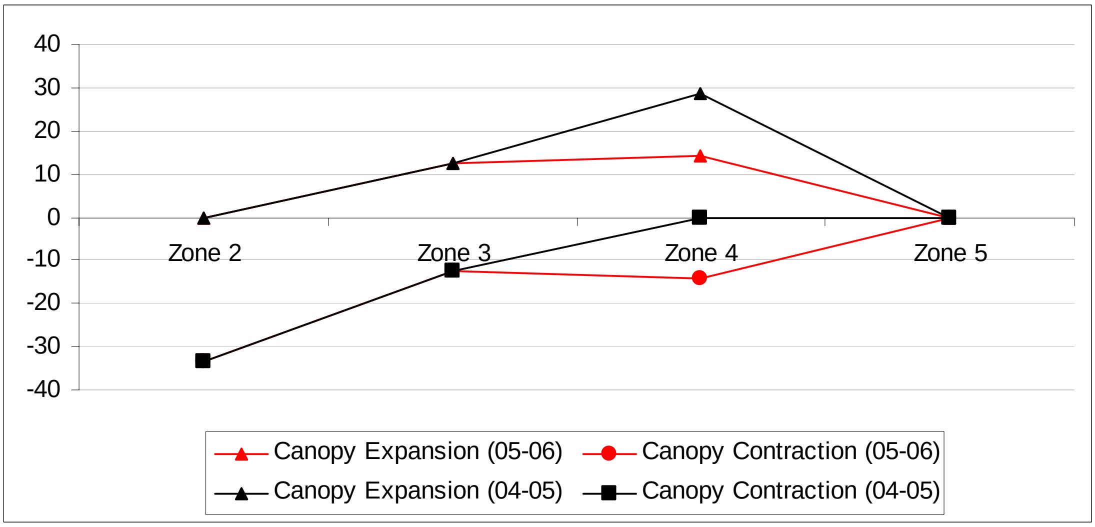


Figure 6-3. Summary of photo-monitoring results for canopy layers in zones 2-5 for the Gordon River; December 2004-December 2005 and December 2005-December 2006 comparisons

Much of this was due to thinning of the bottom layer of *Leptospermum riparium*, a trend noticed in pre-Basslink photo analysis in zones 2 to 4. However, zone 4 is now exhibiting different patterns with expansion of canopy and ground layer vegetation in many of the photographs. The expansion of the ground cover was the result of increases in bryophyte, fern (*Blechnum nudum*) and filamentous algae cover. Whereas, the expansion of the canopy vegetation was largely the result of thickening of foliage of existing trees and shrubs, particularly *Leptospermum riparium*; *Anopterus glandulosus* also showed an increase in canopy density. Zone 5 showed little change over both comparison periods.

6.3.2 Presence of Phytophthora cinnamomi in the Gordon River

The presence of the soil-borne plant pathogen *Phytophthora cinnamomi* was recorded in 2005 in the middle Gordon River in all monitored zones and at the helipad. This pathogen has resulted in dieback of the highly susceptible and conspicuous species *Richea pandanifolia* (a map of sites where soil sample analyses were taken is presented in the Basslink Baseline Report).

No additional soil samples have been taken as part of the post-Basslink monitoring period. Visual assessment of susceptible species is undertaken in the course of monitoring and was also undertaken when assessing the photo-monitoring. No dieback of *Richea pandanifolia* was recorded in new photos or noted as part of field studies. However, there is additional dieback of another species, potentially *Acradenia franklinii* in photo site 6 in zone 3.

6.3.3 Species richness and evenness

Species richness is a count of the number of different species recorded in a quadrat excluding seedlings. Over the first four monitoring periods species richness has fluctuated to a small degree but has been considered relatively stable (Hydro Tasmania, 2005). The significant differences in species richness were found to be between the zones, rather than the monitoring periods.

Data grouped for the whole river (Figure 6-4) showed species richness values to be within the range of previously-recorded measures although they were at the higher-end of these values; statistical testing showed that these were not significantly different (Repeated measures ANOVA $p>0.05$).

As found in the pre-Basslink data, the major patterns of differences in the May 2006 and May 2007 in species richness were between the quadrat types and the zones (data not presented). These patterns showed the continued stratification between quadrats due to the ongoing influence of the regulated flow reducing the number of species being able to cope with the disturbance levels, particularly within those zones closer to the power station.

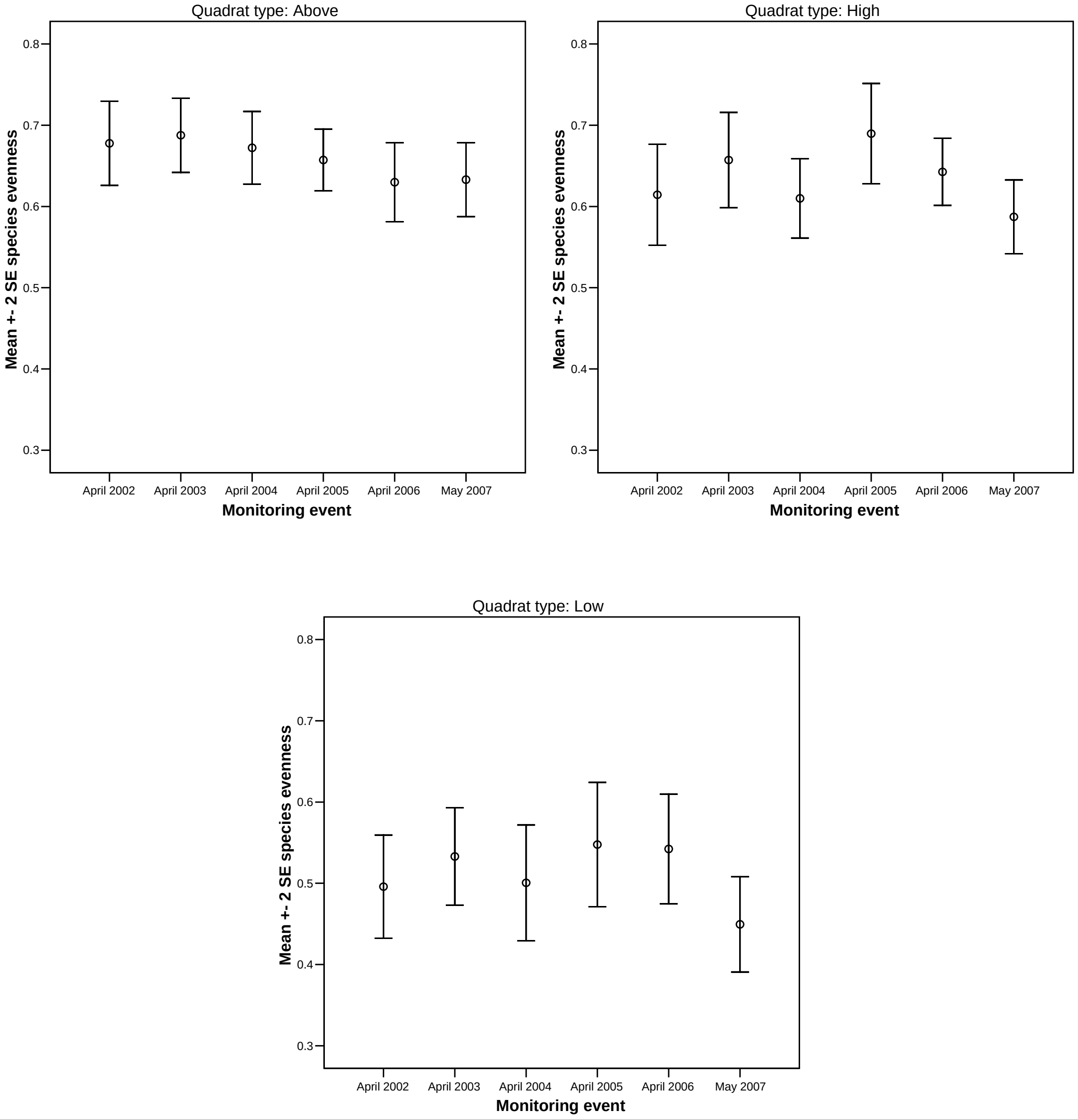


Figure 6-4. Mean species richness in all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

Species or taxa evenness is a measure of the degree to which the abundance of the quadrat is equitably spread or if one or two species may be dominating the vegetation cover in a plot. Higher values indicate that the spread of abundance is high, whilst lower values indicate that a few species or taxa may be dominating abundance and other species are just small components.

Data grouped for the whole river (Figure 6-5) showed species evenness values to be within the range of previously-recorded measures although they were at the lower-end of these values; statistical testing showed that these were not significantly different (repeated measures ANOVA p>0.05). Exploration of the current data at the life form (not species) level shows that there may be an increasing predominance of bryophytes in zones 4 and 5 where they are replacing some ferns.

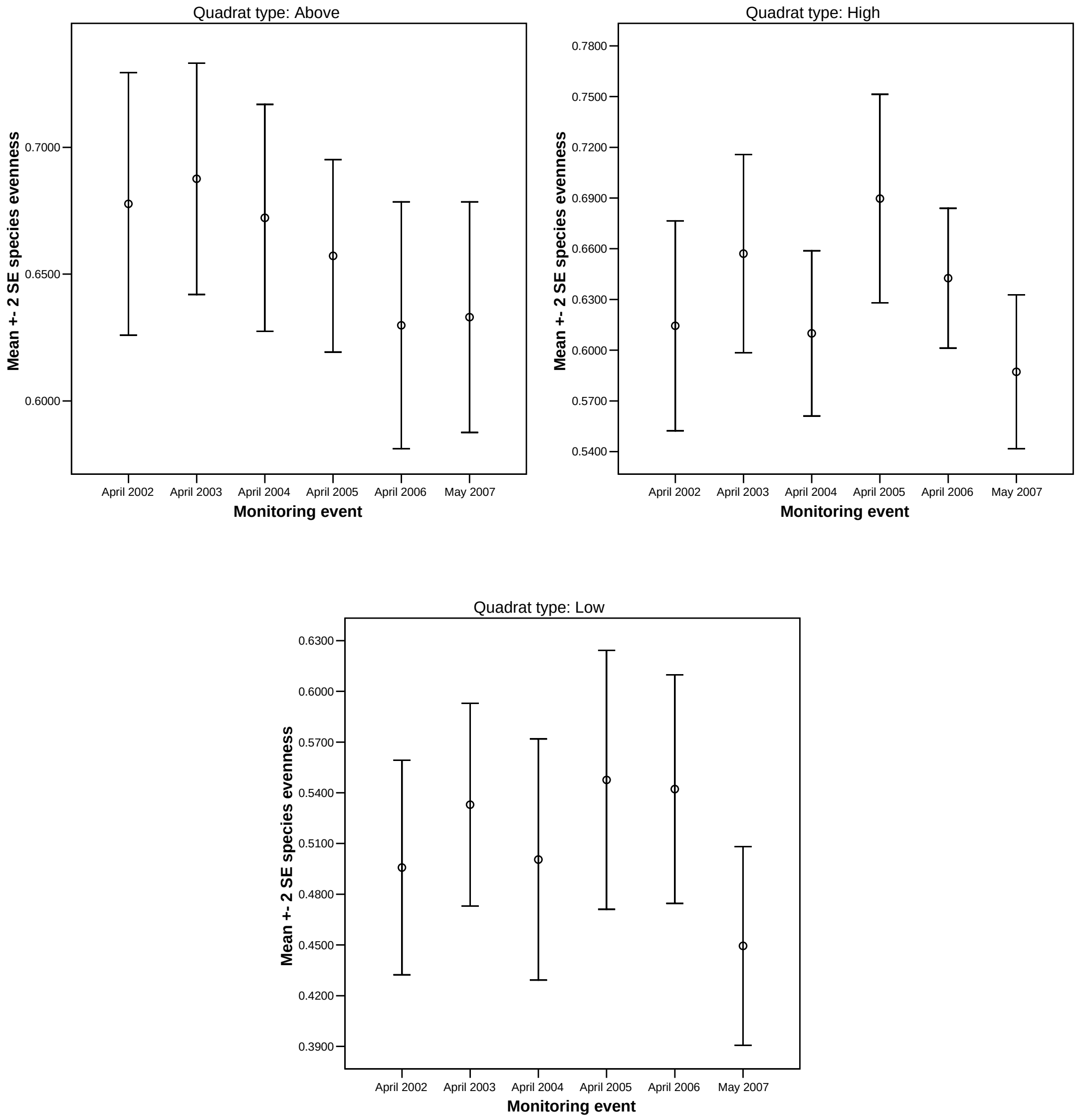


Figure 6-5. Mean species evenness (±SE) in all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

6.3.4 Vegetation and bare ground

6.3.4.1 Total vegetation cover and ground cover

Data grouped for the whole river (Figure 6-6) showed total vegetation cover values to be within the range of previously-recorded measures; statistical testing showed that these were not significantly different (Repeated measures ANOVA p>0.05).

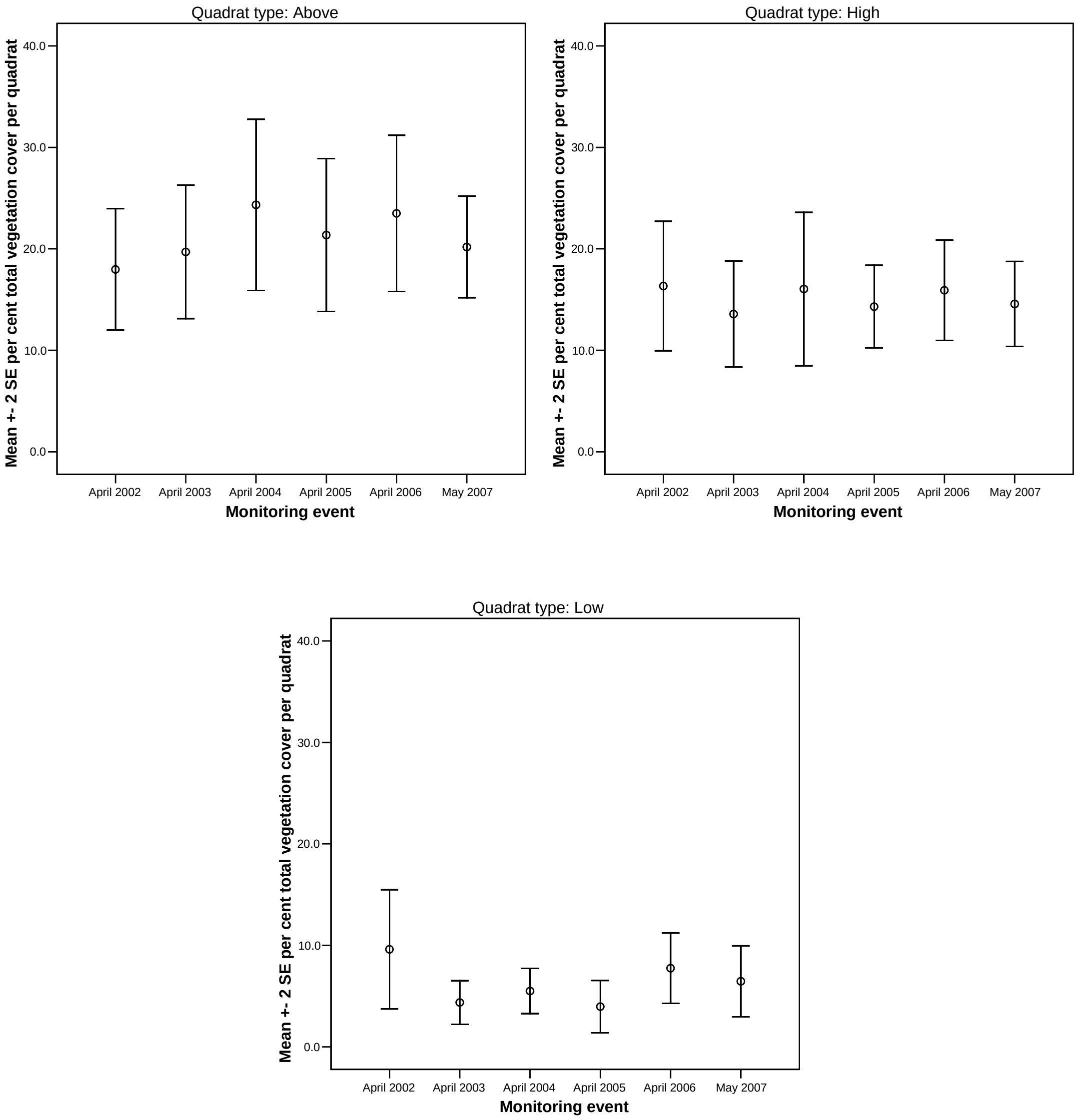


Figure 6-6. Mean per cent cover (±SE) of total vegetation cover in all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

Once again, differences were most apparent between quadrat types due to the stratification of disturbance and inundation along the river. The total vegetation cover decreases a moderate amount between the 'undisturbed by regulated flow' above quadrats and the high quadrats which are inundated around 3-turbine operation levels. The differences between the high and low quadrats are much more substantial over all monitoring periods. It is these differences, or ratios of these differences, which provide the trigger levels for detecting changes in the total vegetation cover. These analyses are presented in the Comparisons with trigger values section below.

Total bare substrate is a composite measure including bare ground and exposed roots within the one metre square quadrats at different heights on the river bank. Data grouped for the whole river (Figure 6-7) showed total bare substrate cover values to be within the range of previously-recorded measures; statistical testing showed that these were not significantly different (Repeated measures ANOVA $p>0.05$).

As expected, these data showed a directly inverse relationship with the total vegetation cover values presented above. Bare ground and exposed roots comprised much of the 'cover' not occupied by vegetation cover (see discussion below on litter, root exposure and coarse woody debris cover).

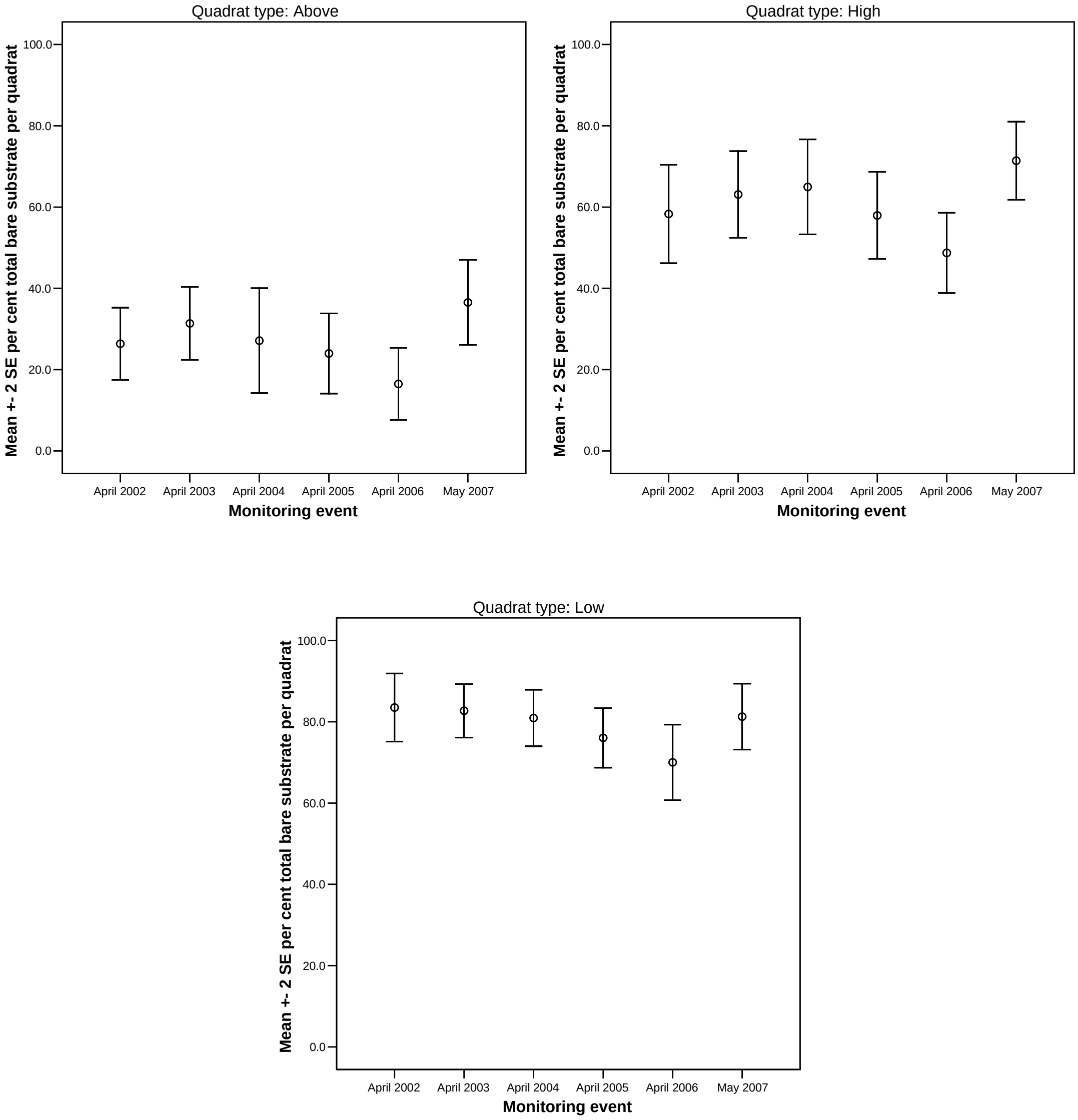


Figure 6-7. Mean per cent cover (±SE) of total bare substrate cover in all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

Of those areas not vegetated in the quadrats, in areas above regulated flows (above quadrats), the majority of the ground surface was covered by litter including organic matter such as fallen leaves, shredded bark and small twigs and branches less than 5cm in width (material larger than this is included in the coarse woody debris category) (refer Figure 6-8). Within rainforest systems such as this, organic material plays an important role in seed capture, protection of seedlings and insulation of soil from rain splash impacts and subsequent erosion. The levels of recorded bare ground are largely the result of occasional inundation and disturbance of these areas, particularly those which receive flood flows downstream of the Denison. In this context, bare ground is a natural feature which provides germination opportunities. The stable nature of these areas above the regulated water flow level is also demonstrated by the low levels of root exposure.

In contrast, the high relative levels of bare ground around the level of 3-turbine operation reflects the removal of litter during high flows and, often, subsequent erosion. Following this removal of litter and ongoing erosion at a site, continued disturbance leads to moderate levels of root exposure. Root exposure increased in relative importance at this level in the period leading up to May 2007. This is largely due to a substantial increase in the amount of root exposure in zone 2 where alluvial material is continuing to be eroded and large mats of roots hang from the banks. These observations are supported by the results of the geomorphology studies which have found that ongoing erosion in zone 2 at this level. It is likely that these impacts were even more pronounced in the vegetation monitoring due to the field monitoring occurring around two months after the geomorphology monitoring after periods of continued, extensive 3-turbine discharge. Concomitantly, there was a reduction in the proportion of litter at this level.

At the low quadrats which are inundated at 2-turbine discharge, the patterns of relative composition between litter, bare ground and root exposure were more consistent with those found in the previous monitoring event. Bare ground continued to dominate with smaller areas of root exposure and very little litter.

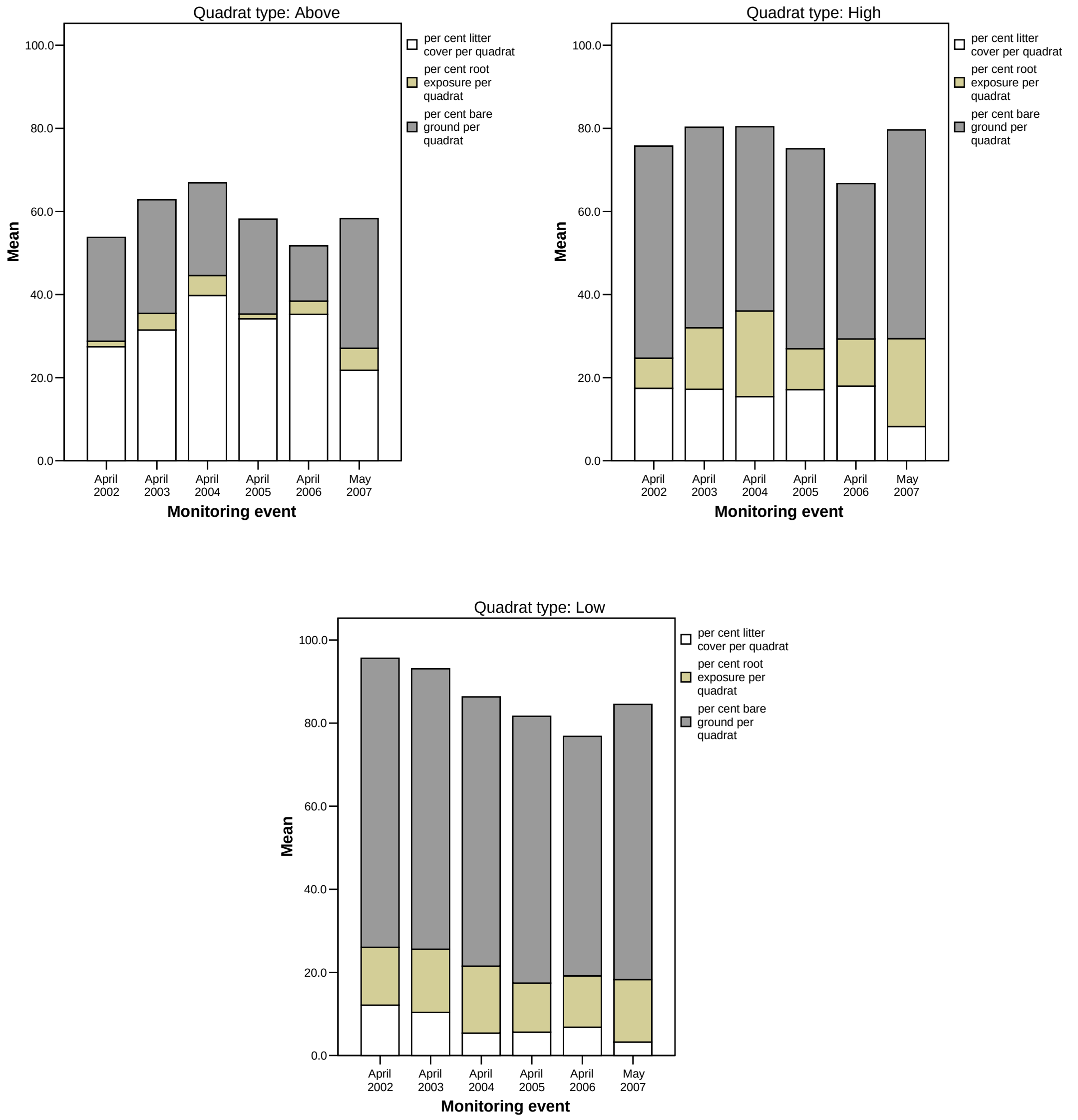


Figure 6-8. Mean per cent cover of bare ground, root exposure and litter for all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

6.3.4.2 Bryophytes, ferns, small shrubs, graminoids, grasses, herbs, shrubs and trees

Data grouped for the whole river (refer Figure 6-9 to Figure 6-15 inclusive) showed the per cent cover values for all life forms to be within the range of pre-Basslink measures; statistical testing showed that these were not significantly different (Repeated measures ANOVA p>0.05). The relative abundance between life forms was generally stable in all zones and for the whole of river although varying between the quadrat types.

Bryophyte (comprising moss, algae, fungi and liverworts) cover continued to be the highest proportion of cover in region above regulated flow (above quadrats), particularly in zones 2 and 3 which do not receive significant flood flows. Fern cover was the second most abundant life form and this appeared to reduce in relative abundance in zone 4 but this is an artefact of one fern-rich site being missed in the monitoring (see discussion of triggers below).

Areas of inundation at the three turbine level (high quadrats) also displayed bryophyte dominance but to a lesser extent than those areas above regulated flows. Ferns were more relatively abundant in zones 2, 3 and 4 whereas grasses were the second most abundant life form in zone 5.

Cover of all life forms in the area inundated at the two turbine level (low quadrats) was low. Where present, again bryophytes were dominant followed by ferns and grasses.

Graminoids (grass-like plants including sedges and lilies but excluding grasses) were of low cover in all quadrat types for all monitoring events.

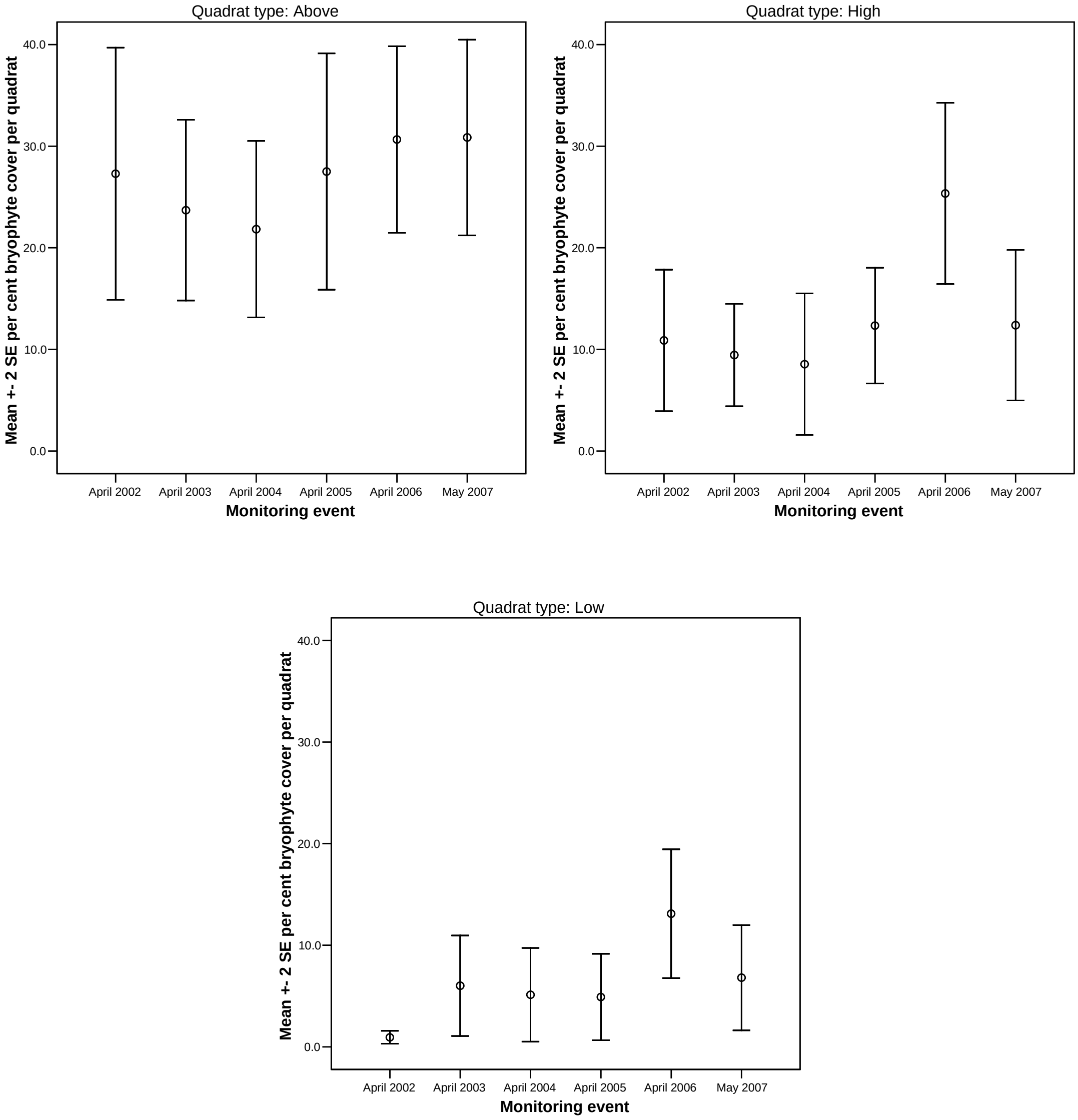


Figure 6-9. Mean per cent cover (±SE) of bryophytes in all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

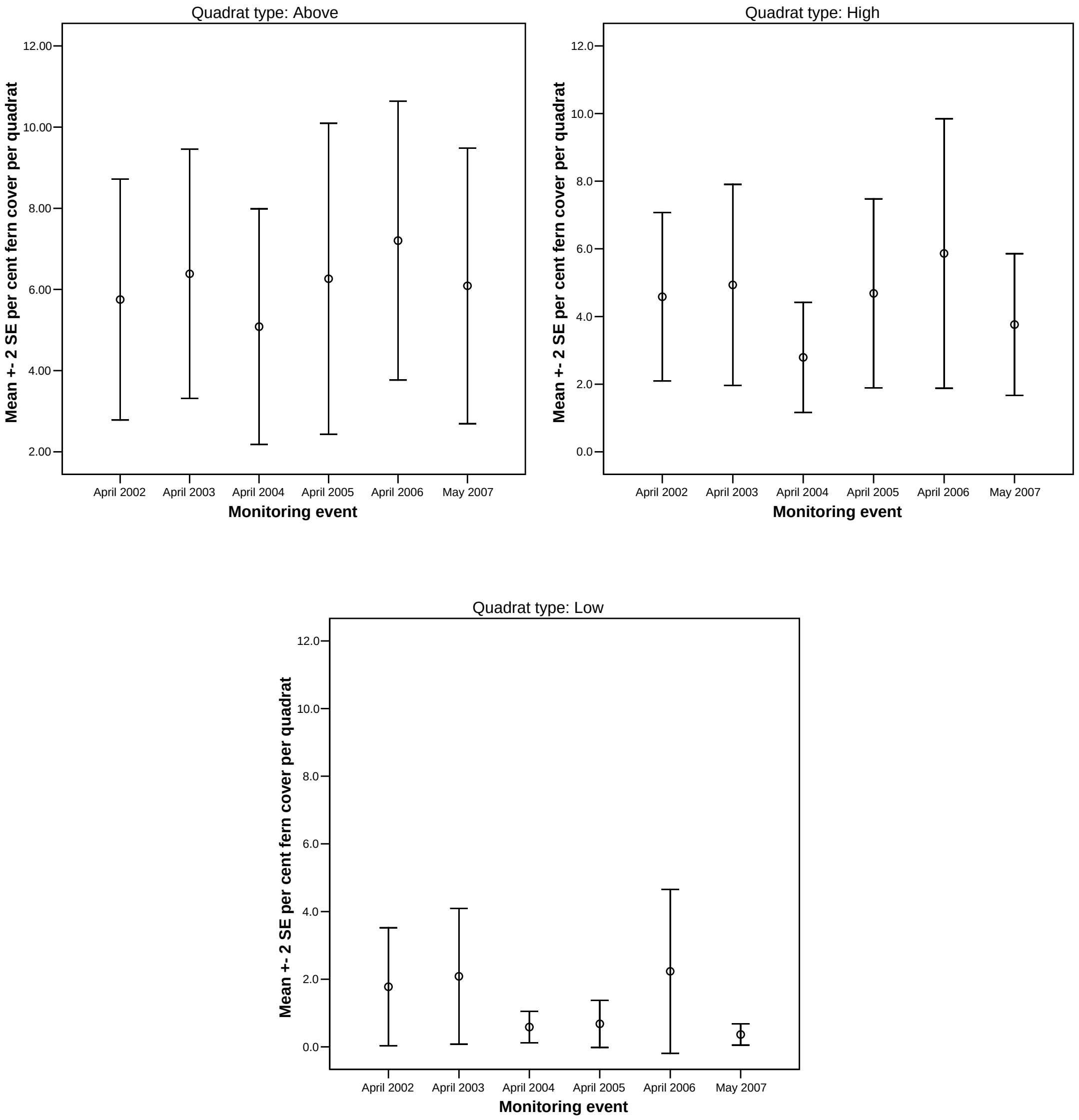


Figure 6-10. Mean per cent cover (±SE) of fern cover in all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

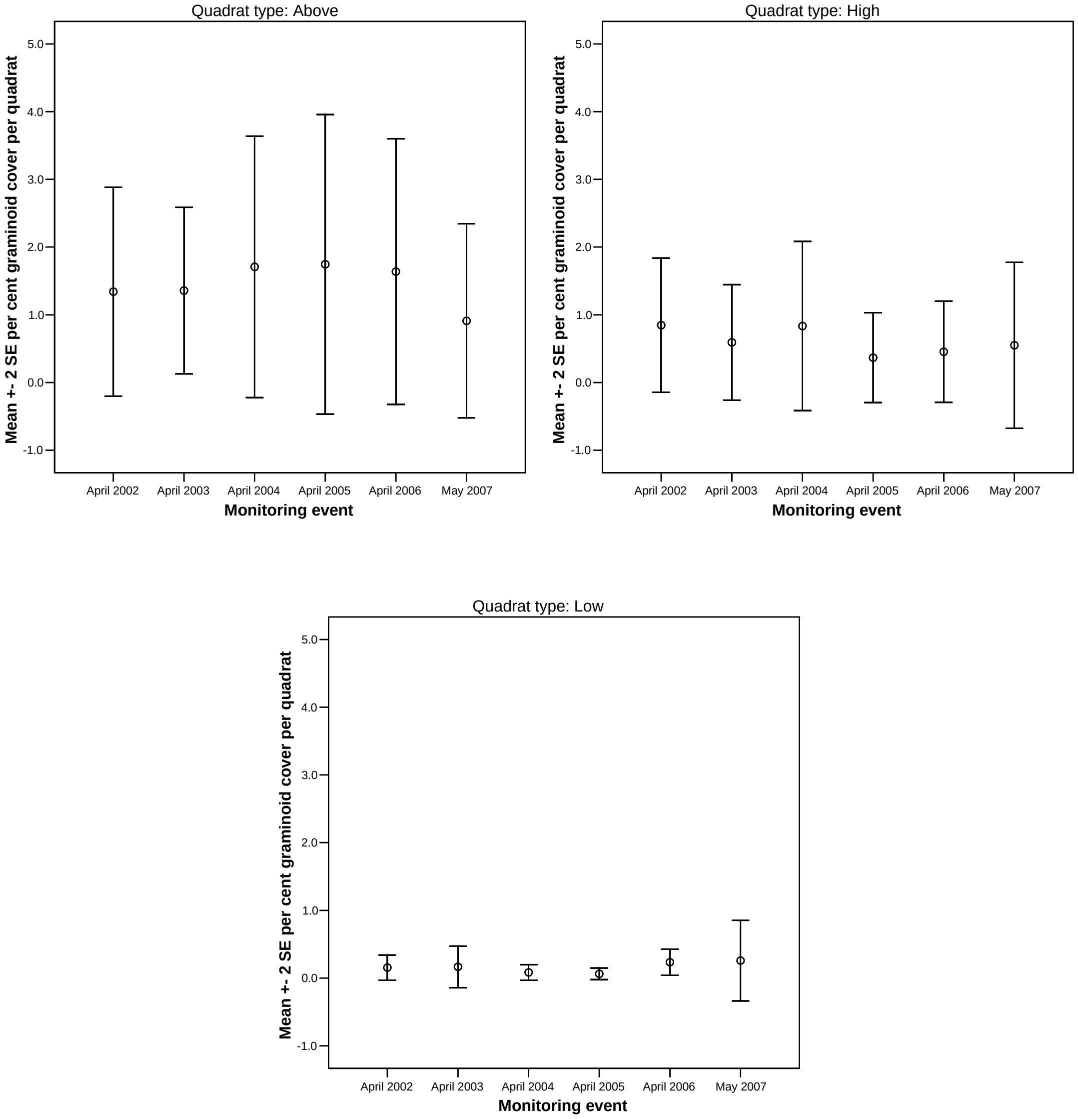


Figure 6-11. Mean per cent cover (±SE) of graminoid cover in all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

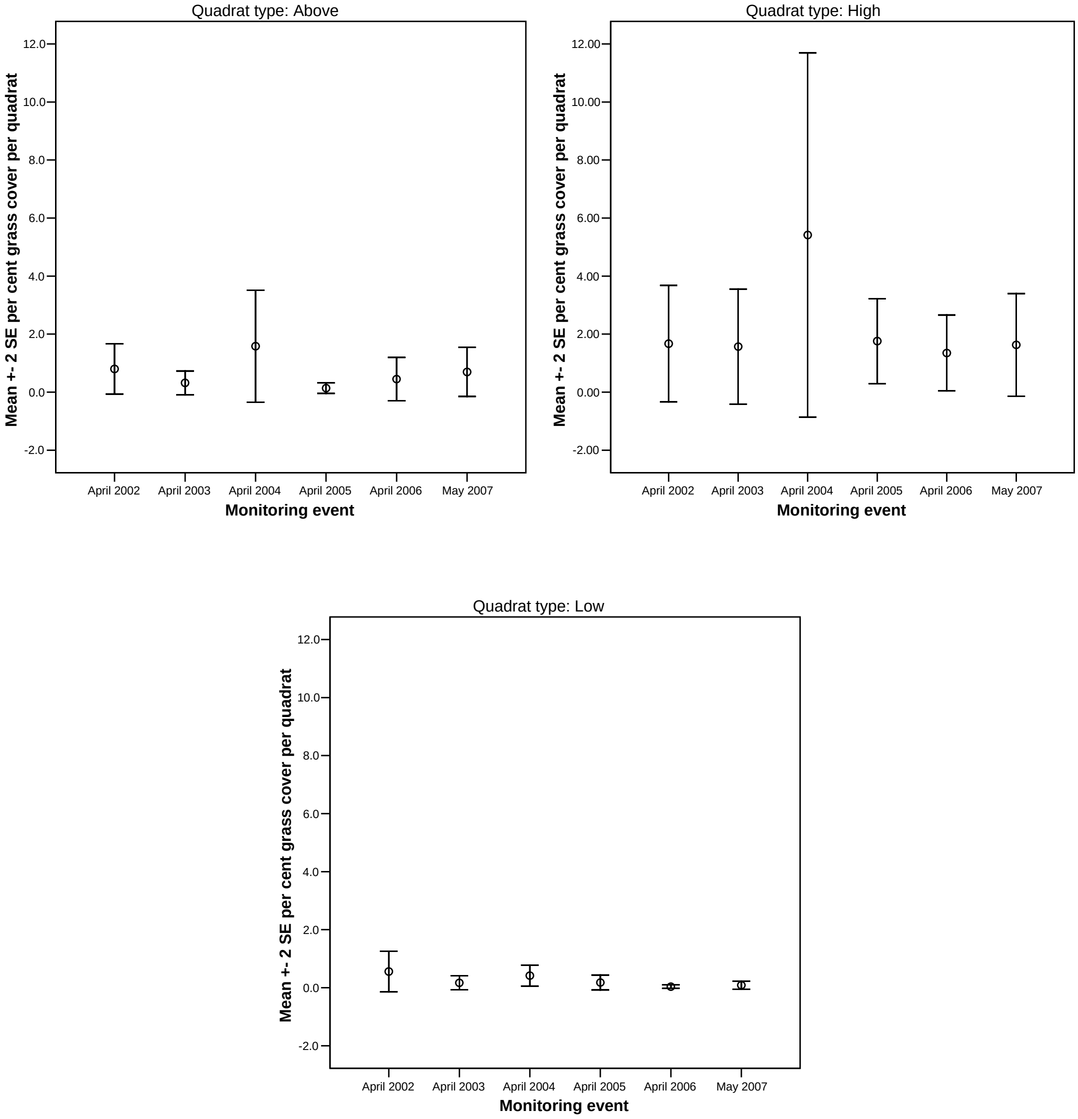


Figure 6-12. Mean per cent cover (±SE) of grass cover in all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

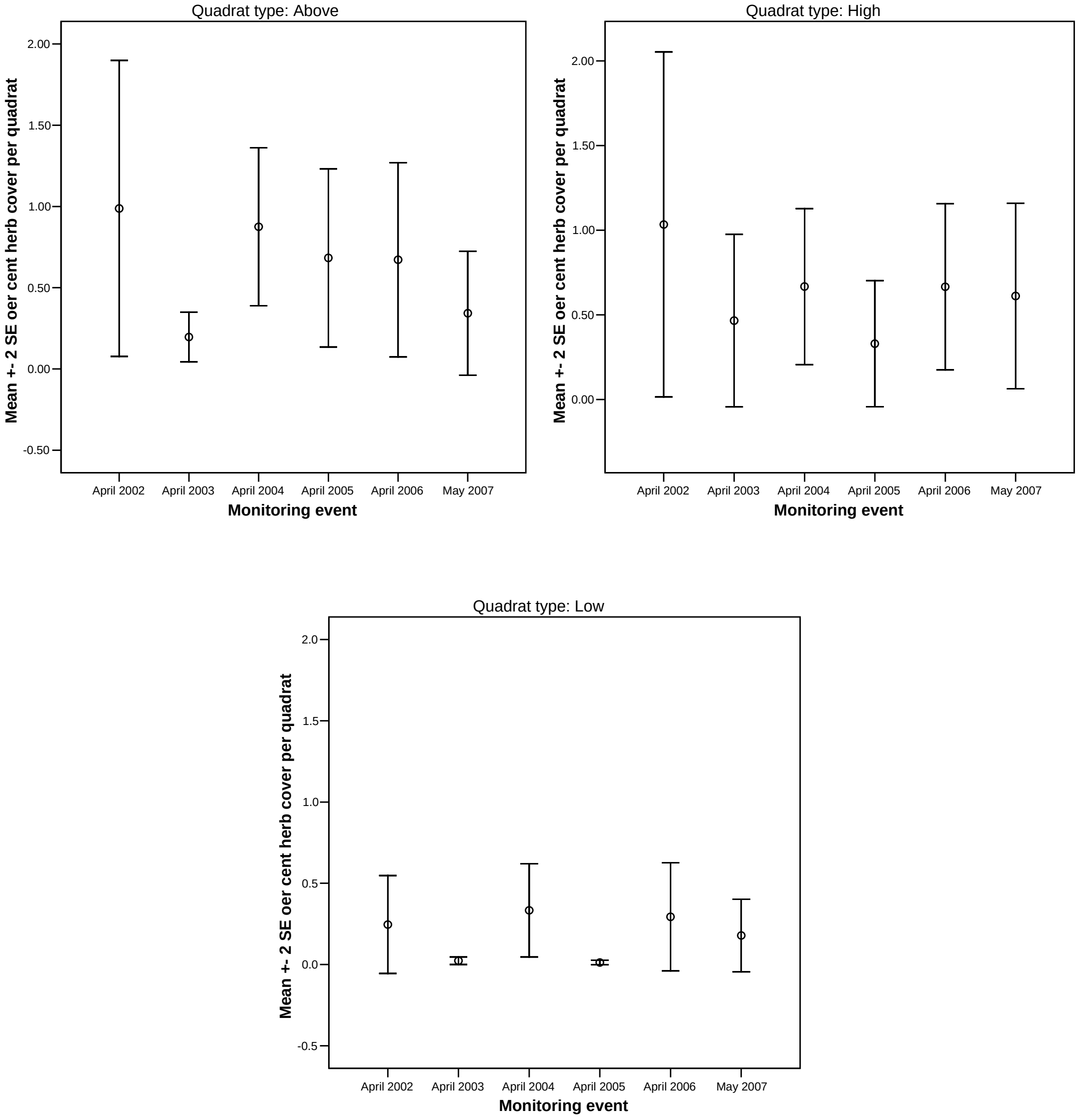


Figure 6-13. Mean per cent cover (±SE) of herb cover in all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

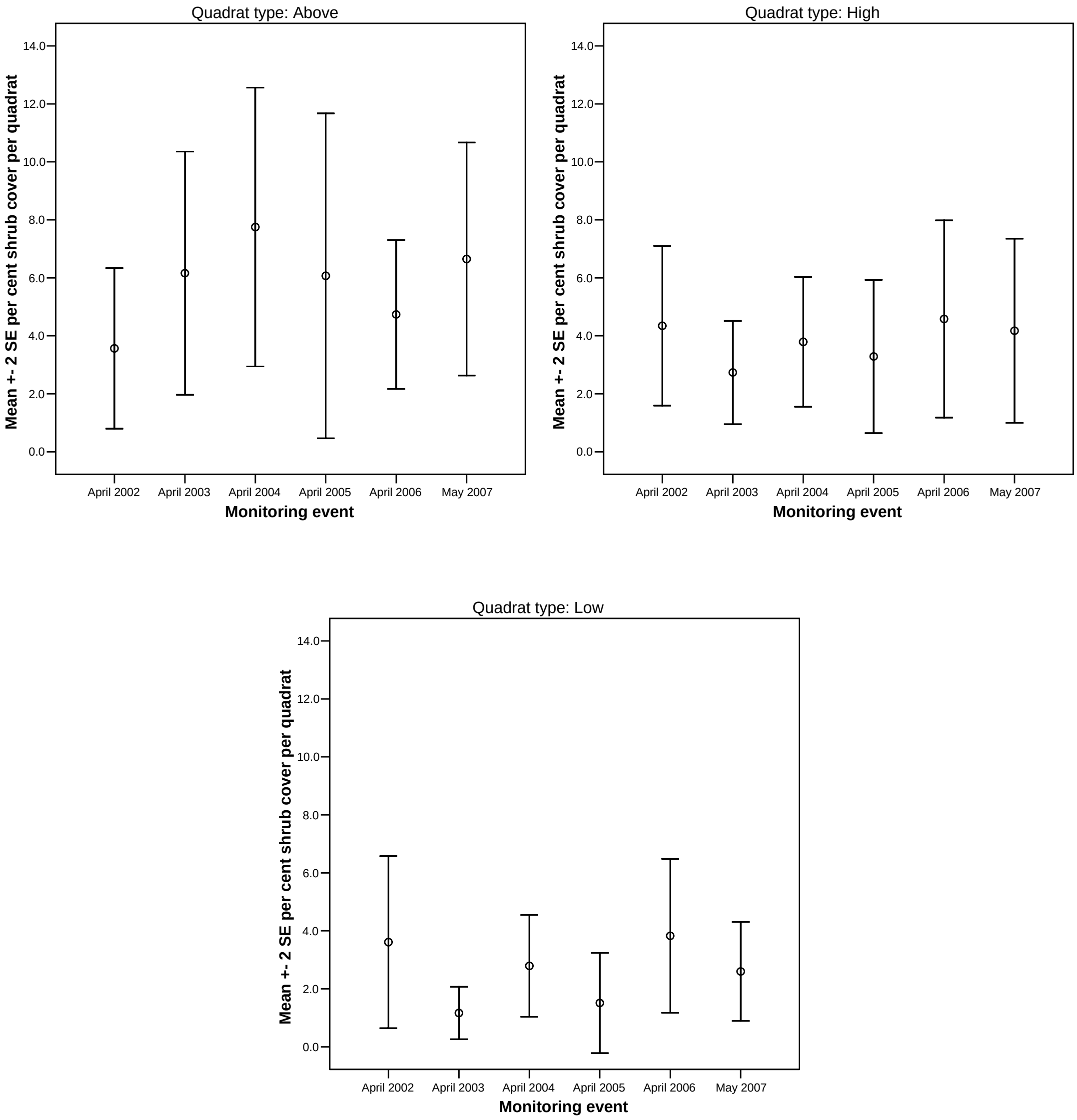


Figure 6-14. Mean per cent cover (±SE) of shrub cover in all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

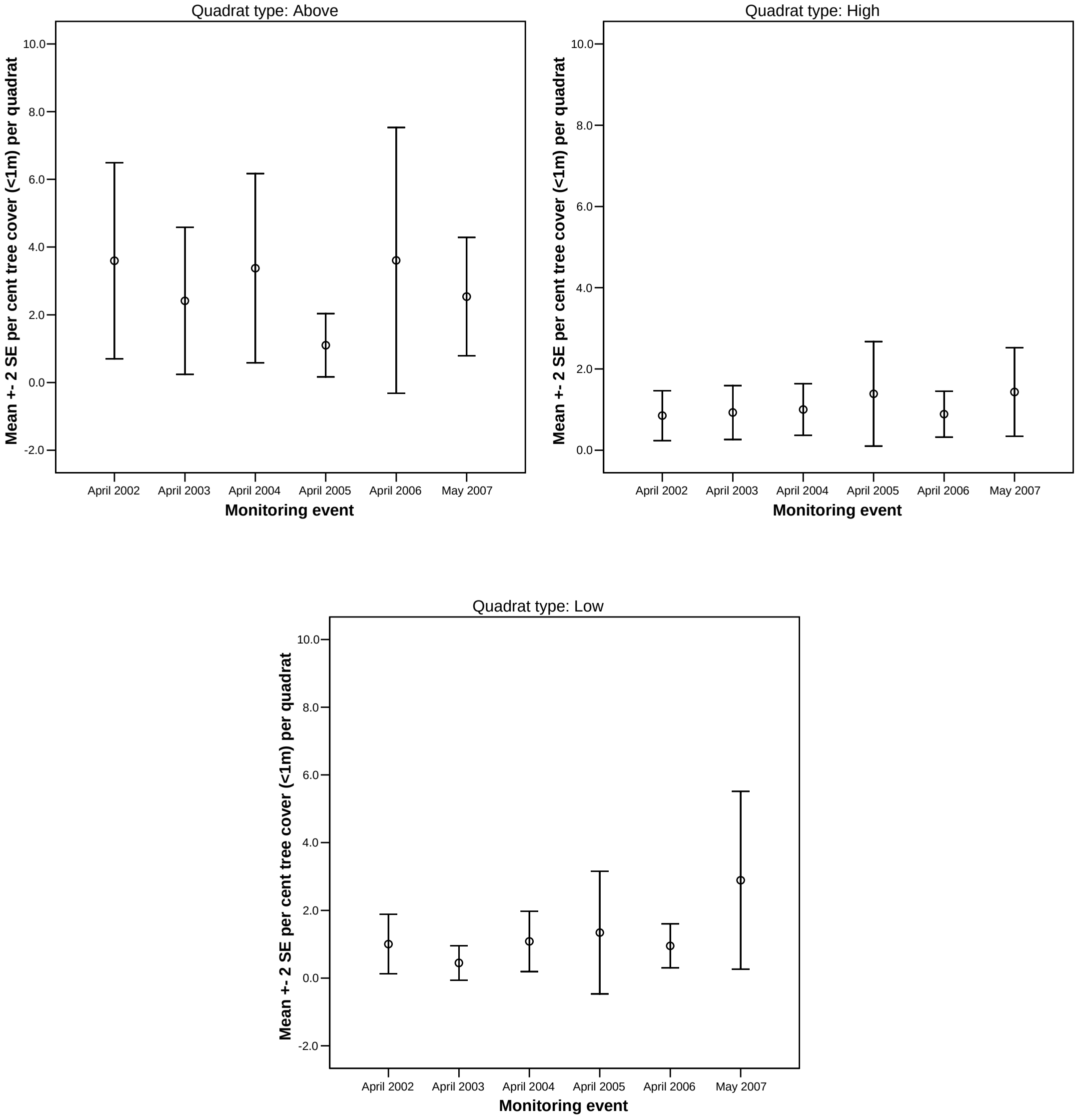


Figure 6-15. Mean per cent cover (±SE) of tree (<1m) cover in all zones and sites by monitoring event for 'above', 'high' and 'low' quadrats in the Gordon River

6.3.5 Seedling recruitment

Mean numbers of seedlings, both those <5cm and the combined total of all size classes, continued to show the myriad of patterns present in the pre-Basslink data up to December 2005. A seasonal effect was apparent in most zones and in most quadrats reflecting the peak in seedling densities in summer and a subsequent decline in autumn. This continues to reflect the generally unfavourable conditions for long-term seedling survival along the banks of the river irrespective of quadrat type or the periods of exposure to regulated flow levels. The seasonal decline in May 2007 is more-pronounced in zones two and three compared with those of the previous cohorts (if it is assumed that the same seedlings are monitored over the summer and autumn events). This is likely to reflect the later timing of the monitoring for the autumn sampling when seedlings at all levels have been exposed to unfavourable conditions for a longer period of time.

These data are considered in the context of the pre-Basslink data in the discussion of triggers below.

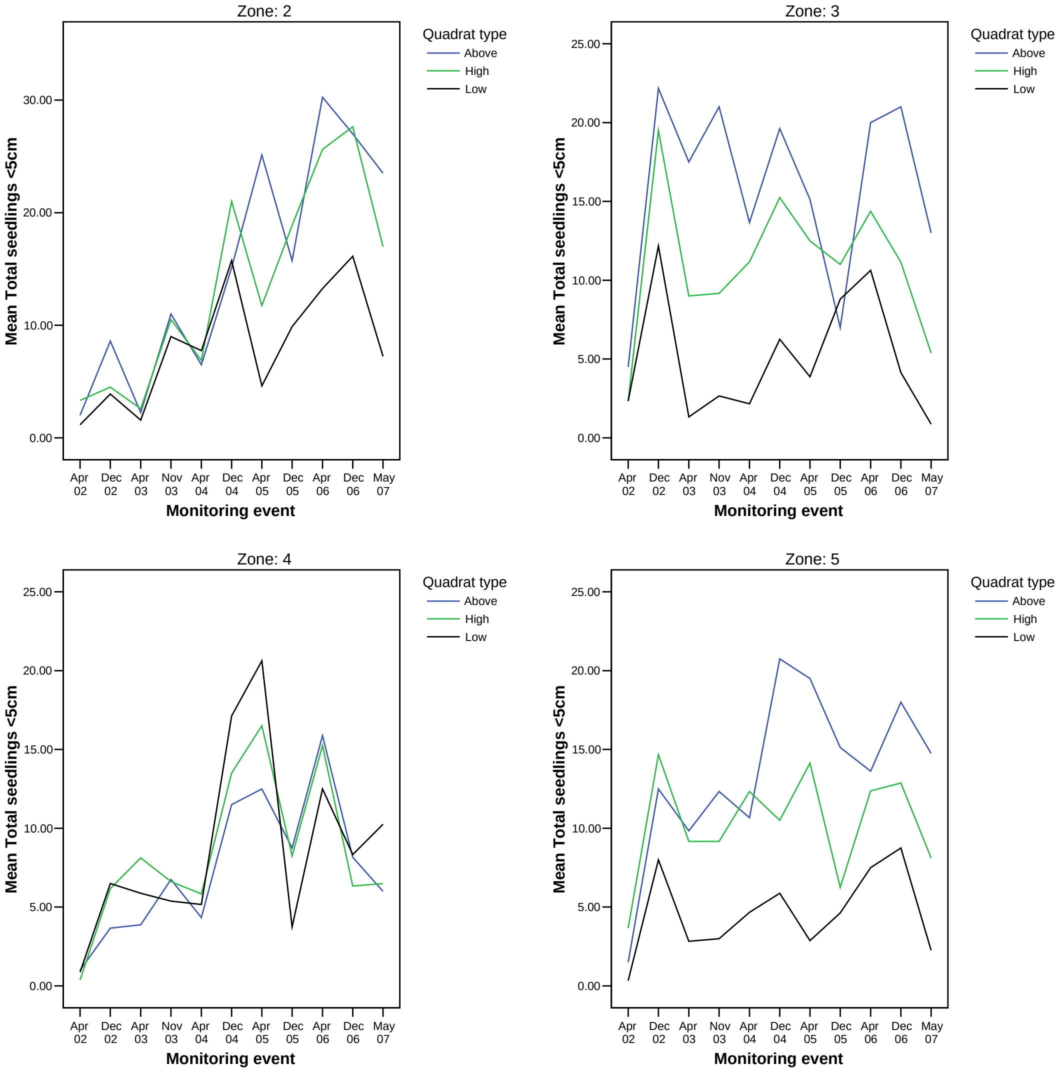


Figure 6-16. Mean number of seedlings <5cm per quadrat by quadrat type for each zone over the eleven seasonal monitoring events including pre- and post-Basslink periods

6.4 Comparisons with trigger values

6.4.1 Community integrity variables

6.4.1.1 Community composition

This trigger provides a comparison of presence-absence data for pairs of years at zone level. This measure is intended to provide an indication of changing community composition over time. The trigger has been developed from the average similarity of pre-Basslink sites compared between the monitoring events. That is, the average similarity of the 2002-03 comparison, the 2003-04 comparison and the 2004-05 comparison. This average similarity for the pre-Basslink period then provides the baseline for annual changes between the quadrats. Therefore, if the average similarity of the sites has changed more than the pre-Basslink average, this can be further investigated.

The post-Basslink assessment has compared the 'intermediate' 2006 year with the 2007 post-Basslink data. There were no values outside triggers of the determined trigger values. However, some sites were near the upper levels of the confidence intervals for the similarity index. Interestingly, these sites have shown values outside triggers of other, more specific trigger values which relate to the presence or absence of species such as species richness and species evenness (see below).

Table 6-1. Mean values and 95% confidence interval range for Bray Curtis Similarity index for all zones based on annual similarity values calculated on presence-absence data.

Zone	Quadrat	Mean	Confidence interval range	2006-07 result
2	Above	73.89	64.39 - 80.08	65.15
	High	66.04	57.43 - 74.79	65.34
	Low	65.11	61.79 - 68.76	67.25
3	Above	53.94	51.95 - 55.17	53.24
	High	59.05	56.42 - 62.45	59.12
	Low	59.99	52.43 - 66.41	53.48
4	Above	41.37	37.86 - 45.52	*
	High	35.98	35.59 - 36.39	*
	Low	38.01	36.13 - 40.32	*
5	Above	59.10	53.31 - 66.35	62.35
	High	59.40	57.18 - 61.08	57.95
	Low	61.55	57.33 - 65.51	60.08
* Analysis was not undertaken for zone 4 due to an omission of some sites in monitoring which would not allow a comparison between zone groups.				

6.4.1.2 Species/taxa richness

Species/taxa richness is an indicator of the number of species/taxa present per site. This measure is intended to show changes in species diversity at the sites. Monitoring in May 2007 showed a decrease in species richness outside the trigger values at low quadrats in zone 3, high quadrats in zone 4 and zone 5. This reduction in species richness in the low quadrats in zone 3 is due to the loss of many fern species due to the longer periods of continuous inundation at the two turbine level. This effect is also likely to be responsible for the reductions in species richness further away from the power station in zones 4 and 5.

Table 6-2. 95% confidence intervals for species richness values for each zone and quadrat type calculated from pre-Basslink data and the results of monitoring for the first year (2006-07) in the post-Basslink period. + Indicates a value outside the range of pre-Basslink trigger values.

Zone	Quadrat type	Pre-Basslink mean	Confidence interval range	2006-07 result
2	Above	3.50	3.06 - 3.94	4.75+
	High	3.33	2.72 – 3.94	3.62
	Low	2.88	1.92 – 3.83	3.00
3	Above	5.92	4.94 – 6.89	5.13
	High	4.63	3.84 – 5.41	4.13
	Low	2.50	1.70 – 3.30	1.33+
4	Above	8.15	6.48 - 9.83	7.50*
	High	5.58	4.56 - 6.59	4.25+*
	Low	4.54	3.47 - 5.61	4.5*
5	Above	5.38	3.89 - 6.86	5.62
	High	6.46	4.68 - 8.24	4.5+
	Low	2.42	1.69 - 3.14	2.13
* Zone 4 values are the mean value of two sites only				

Conversely, the predominance of operation at 2-turbines is likely to have resulted in an increase in species richness in zone 2 in the quadrats above high-water mark due to the impacts on ground water levels. Ground water levels (as described in section 4, Fluvial geomorphology) have shown reduced in duration at higher levels due to the operating regimes over the summer period. This may have resulted in relatively drier conditions more suitable for seedling establishment.

The vegetation data show that the additional vegetation species recorded in the above quadrats to include *Pomaderris apetala* and *Pimelea drupaceae* seedlings, a tree and small shrub species respectively. These seedlings have survived long enough to now be included in the cover measurements, a factor not often recorded in these quadrats in the pre-Basslink period. Survival of seedlings into larger size classes has always been low (Hydro Tasmania 2005 and Figure 6-17), and whilst numbers remain relatively low, this may indicate a change in conditions which allow more successful recruitment, albeit that myriad other factors may also be the cause.

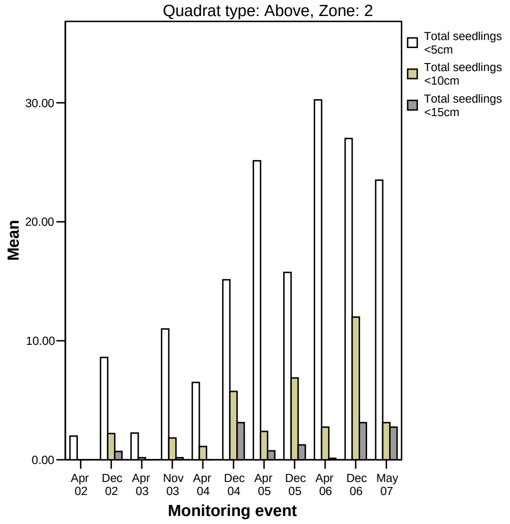


Figure 6-17. Mean number of total seedlings per quadrat in three size classes within zone 2 for the above quadrats for all monitoring events

The altered conditions which allowed continued growth of *Pomaderris apetala* are likely to be related to the prevailing soil moisture which is in turn affected by the duration of bank inundation. Adult specimens of *Pomaderris apetala* are predominantly found in the areas above inundation and are found frequently in zone 5 (Hydro Tasmania, 2005). This species was found to be a good indicator species that delineates between the areas affected by regulated flows and those not affected. It therefore follows that this species is unlikely to be tolerant of waterlogging and inundation. Although not specifically investigated, the reduction in ground water levels, coupled with a reduction in capillary action through the organic surface layers from near 2-turbine outflows, may have led to more favourable conditions for persistence of seedlings.

Whilst no such data on waterlogging response are known for *Pimelea drupaceae*, the other species also found to be surviving into larger seedlings, it is probable that similar factors are driving the additional recruitment of this species.

6.4.1.3 Species/taxa evenness

Species/taxa evenness is an indication of the relative equity or dominance in species abundance. Values can range from 0 to 1 with 1 being perfect evenness in distribution of species abundance. This measure will show if the relative abundance of the composite species are changing (Table 6-3).

All the values recorded, with the exception of two, in May 2007 were within the band for the trigger values. Despite the two exceedances, it is generally concluded that there are no substantial changes in the relative abundance of species or bare ground at the sites.

Table 6-3. 95% confidence intervals for species evenness values for each zone and quadrat type calculated from pre-Basslink data and the results of monitoring for the first year (2006-07) in the post-Basslink period. + indicates a value recorded outside the range of pre-Basslink trigger values.

Zone	Quadrat type	Pre-Basslink mean	Confidence interval range	2006-07 result
2	Above	0.69	0.58 - 0.79	0.71
	Low	0.53	0.35 - 0.70	0.41
	High	0.62	0.49 - 0.76	0.54
3	Above	0.70	0.61 - 0.78	0.61
	Low	0.36	0.19 - 0.53	0.43
	High	0.62	0.50 - 0.74	0.63
4	Above	0.62	0.51 - 0.73	0.48+
	Low	0.57	0.42 - 0.71	0.58
	High	0.58	0.47 - 0.70	0.59
5	Above	0.43	0.30 - 0.56	0.65+
	Low	0.31	0.15 - 0.47	0.44
	High	0.52	0.38 - 0.65	0.59
* Zone 4 values are the mean value of two sites only				

6.4.2 Ecologically significant species

A biogeographical study of Tasmanian flora distribution and subsequent community classification has shown that the south-western rivers have distinct flora assemblages to other rivers. This classification showed that four species present on the middle Gordon River are considered to be indicator species that characterise the southwest river systems. Three species were selected for consideration as trigger species and values were calculated for their mean abundance pre-Basslink.

Comparisons of the May 2007 data with the pre-Basslink trigger values showed recorded values to be above trigger values in six instances (Table 6-4). Of these values outside triggers, four were in zone 4. These are the result of fewer sites being averaged, and hence the cover values being divided only by two sites, not three; this resulted in a different mean value being calculated. This was checked by calculating the mean of the sites monitored in 2007 and comparing them only with means from these two sites in the past. They were found to be within the mean values for those sites. The values outside triggers in zones 2 and 5 were both from increases in the abundance of these species and therefore, not a cause for concern.

Table 6-4. Confidence intervals for per cent cover values for ecologically significant species for each zone and quadrat type calculated from pre-Basslink data and the results of monitoring for the first year (2006-07) in the post-Basslink period. + indicates a value outside the range of pre-Basslink trigger values.

Zone	Quadrat	Species	Pre-Basslink mean	Confidence interval range			2006-07 result
2	Above	*Acradenia franklinii*	4.13	1.79	-	6.46	1.86
		Lagarostrobos franklinii	0.00	0.00	-	0.00	.00
		Leptospermum riparium	0.00	0.00	-	0.00	.00
	Low	*Acradenia franklinii*	0.08	0.00	-	0.25	.00
		Lagarostrobos franklinii	0.63	0.10	-	1.15	3.33+
		Leptospermum riparium	0.00	0.00	-	0.00	.00
	High	*Acradenia franklinii*	0.58	0.02	-	1.15	.02
		Lagarostrobos franklinii	0.00	0.00	-	0.00	.00
		Leptospermum riparium	0.00	0.00	-	0.00	.00
3	Above	*Acradenia franklinii*	0.58	0.16	-	1.01	.70
		Lagarostrobos franklinii	0.08	0.00	-	0.20	.00
		Leptospermum riparium	0.00	0.00	-	0.00	.00
	Low	*Acradenia franklinii*	0.67	0.00	-	1.89	1.00
		Lagarostrobos franklinii	0.67	0.03	-	1.30	.50
		Leptospermum riparium	0.00	0.00	-	0.00	.00
	High	*Acradenia franklinii*	0.71	0.00	-	1.59	1.33
		Lagarostrobos franklinii	0.50	0.03	-	0.97	.33
		Leptospermum riparium	0.00	0.00	-	0.00	.00
4	Above	*Acradenia franklinii*	0.12	0.00	-	0.28	.05
		Lagarostrobos franklinii	0.00	0.00	-	0.00	.00
		Leptospermum riparium	2.50	0.85	-	4.15	7.50+
	Low	*Acradenia franklinii*	0.00	0.00	-	0.01	.00
		Lagarostrobos franklinii	0.00	0.00	-	0.00	.02
		Leptospermum riparium	3.81	1.00	-	6.62	8.00+
	High	*Acradenia franklinii*	0.35	0.00	-	0.77	2.00+
		Lagarostrobos franklinii	0.00	0.00	-	0.00	.00
		Leptospermum riparium	3.96	1.13	-	6.79	13.75+
5	Above	*Acradenia franklinii*	2.50	0.00	-	5.21	3.66
		Lagarostrobos franklinii	0.00	0.00	-	0.00	.00
		Leptospermum riparium	0.04	0.00	-	0.12	.00
	Low	*Acradenia franklinii*	0.17	0.00	-	0.49	.00
		Lagarostrobos franklinii	0.00	0.00	-	0.00	.00
		Leptospermum riparium	0.25	0.00	-	0.54	.00
	High	*Acradenia franklinii*	0.00	0.00	-	0.01	1.33+
		Lagarostrobos franklinii	0.00	0.00	-	0.00	.00
		Leptospermum riparium	0.67	0.00	-	1.67	.33

The density of extant trees and shrubs of these significant species as recorded in the belt transect studies showed no difference from the pre-Basslink data (Table 6-5). Therefore, there were no values outside the trigger values, or any changes in density of the different size classes (diameter at ground height).

Table 6-5. Indicator of a 20% change in the density of ecologically significant species in diameter at ground height age classes recorded in transects on the Gordon River. + indicates a recorded value outside pre-Basslink trigger values.

Species	Confidence interval range	2006-07 result
Acradenia frankliniae <5 cm	13.6 - 20.4	17
Acradenia frankliniae <10 cm	2.4 - 3.6	3
Lagarostrobos franklinii <5 cm	4.0 - 6.0	5
Lagarostrobos franklinii <20 cm	0.8 - 1.2	1
Lagarostrobos franklinii >20 cm	1.6 - 2.4	2
Leptospermum riparium <5 cm	16.8 - 25.2	21
Leptospermum riparium <10 cm	2.4 - 3.6	3
Leptospermum riparium <20 cm	3.2 - 4.8	4
Leptospermum riparium >20 cm	1.6 - 2.4	2

6.4.3 Community structure

6.4.3.1 Ground cover and vegetation cover data

Ground cover and vegetation cover triggers are calculated at the 'whole of river' scale, not differentiating between the zones. Due to the variability in the data over the pre-Basslink period, the triggers were calculated as changes in the ratio of vegetation cover between the above quadrats and the high quadrats and the above quadrats and the low quadrats.

The results for the measured life forms were all within the trigger values except for the ferns (Table 6-6). The ratio of ferns above the influence of the power station was above the highest tolerance trigger calculated from pre-Basslink data. This reflects a reduction of *Blechnum nudum* in the low quadrats in zones 2 and 3 which is likely to be a result of the prolonged 2-turbine operation and the unlikely, although possible influence of increased moisture in toe slopes as a result of the implementation of the environmental flow.

Artefacts of monitoring and the omission of a site in zone 4 in May 2007 also contributed to the reduction in the ratio. The absence of the cover data from this site has resulted in a large reduction of fern cover for the zone as this site is a well-illuminated sandy site with a dense cover of *Blechnum nudum* and *Blechnum wattsii*.

Table 6-6. The range within which 95% of values are likely to lie for means of ratios for selected ground cover variables based on pre-Basslink data and the results of monitoring for the first year (2006-07) in the post-Basslink period. + indicates a recorded value outside the range of pre-Basslink trigger values.

Post-Basslink, year 1	**Ratio (% above+1) to (% high+1)**		
	Lower	**Upper**	**2006-07 result**
% bare ground:	0.2	0.9	0.65
% bryophyte	1.1	6.1	3.46
% fern	0.5	3.1	1.47
% shrub	0.6	2.0	0.98
% total vegetation*	1.0	3.2	1.32
Post-Basslink, year 1	**Ratio (% above+1) to (% low+1)**		
	Lower	**Upper**	**2006-07 result**
% bare ground:	0.1	0.7	0.52
% bryophyte	3.3	9.9	5.38
% fern	1.1	7.8	9.83+
% shrub	0.6	4.5	1.82
% total vegetation*	3.0	11.6	3.94
*Total vegetation is a composite measure of the abundance of all life forms and species			

6.4.4 Ecological processes

6.4.4.1 *Seedling trigger values*

Seedling numbers were predominantly within the calculated ranges for trigger values set pre-Basslink. However, values for seedlings <5cm were outside the trigger value range in autumn data for the whole of river, zone 2 and zone 5 (Table 6-7). On all occasions the trigger value was exceeded meaning that there were reduced seedling numbers in the high quadrats compared with the above quadrats. In zone 5 this statistic reflected the influence of one site (5d) where only one seedling was recorded in the high quadrat whereas over 20 were recorded in the above quadrat, comprising *Nothofagus cunninghamii* and *Anopterus glandulosus*. There is no clear link to a variable which may explain this lack of seedling abundance. No stochastic or environmental anomalies such as major deposition or erosion were recorded within this quadrat. Similarly, in zone 2, a mix of seven species, predominantly ferns, were much more abundant in the above quadrats than the high quadrats. This site is a sandy site which is prone to erosion as found at the nearby, co-located erosion pin monitoring site (see appendix 3 Erosion pin and scour chain results). Following the frequent use of two and three turbines proceeding the monitoring period, it is possible that the physical disturbance in the high quadrats resulted in very low seedling numbers.

The impacts of the zone 2 and zone 5 data resulted in a value outside the trigger range for the 'whole of river' for the seedlings <5cm which is the total of values for zones 2, 3, 4 and 5. The impact of the changes in seedling ratios in the seedlings <5cm (again in zones 2 and 5) was also reflected in trigger analyses of the total number of seedlings (

Table 6-8). This measure is the sum of seedlings in the <5cm, <10cm and <15cm size classes. Because of the predominance of seedlings in the <5cm size class (see also Figure 6-16), the same patterns of ratios occurred with values outside the trigger range in the same zones and seasons.

Table 6-7. The range within which 95% of values are likely to lie for means of ratios for seedlings <5cm based on monitoring in the pre-Basslink period including data collected in December 2005. + indicates a recorded value outside the range of pre-Basslink trigger values

Number of seedlings less than 5 cm: Ratio of ABOVE quadrats to HIGH quadrats			
Post-Basslink	1 year		2006-07 result
Whole of River	Lower	Upper	
Autumn	0.76	1.80	2.82+
Summer	0.72	2.35	2.17
Zone 2	Lower	Upper	
Autumn	0.45	3.08	4.31+
Summer	0.25	6.80	1.28
Zone 3	Lower	Upper	
Autumn	0.56	4.32	2.81
Summer	0.27	6.24	2.24
Zone 4	Lower	Upper	
Autumn	0.10	6.94	1.54
Summer	0.40	2.62	2.01
Zone 5	Lower	Upper	
Autumn	0.42	2.86	4.36+
Summer	0.31	7.40	3.14

Table 6-8. The range within which 95% of values are likely to lie for means of ratios for total number of seedlings in all size classes based on monitoring for pre-Basslink period including data collected in December 2005. + indicates a recorded value outside the range of pre-Basslink trigger values

Total Number of seedlings: Ratio of ABOVE quadrats to HIGH quadrats			
Post-Basslink	1 year		2006-07 result
Whole of River	Lower	Upper	
Autumn	0.69	2.08	2.66+
Summer	0.36	6.87	2.05
Zone 2	Lower	Upper	
Autumn	0.34	4.12	4.64+
Summer	0.13	13.06	1.18
Zone 3	Lower	Upper	
Autumn	0.61	4.31	2.67
Summer	0.23	6.57	1.92
Zone 4	Lower	Upper	
Autumn	0.11	6.02	1.53
Summer	0.39	2.58	2.13
Zone 5	Lower	Upper	
Autumn	0.57	2.36	4.20+
Summer	0.31	9.23	2.96

6.5 Conclusion

The riparian vegetation of the Gordon River continues to display the impacts of regulated flows and stratification up the bank as found in the pre-Basslink investigations. In general, the density and abundance of the vegetation and other quantitative measures are within the range of variation predicted from the pre-Basslink period.

The photo-monitoring recorded increased dieback in a localised area due to the active *Phytophthora* infection in zone 3. This infection may continue to kill susceptible species in the immediate region. However, many of the adjacent species are known to be resistant therefore it is unlikely large-scale dieback will occur in the area.

Fifteen per cent (17 of 111) of the riparian vegetation triggers were found to require further investigation in the first post-Basslink monitoring period. Some of these values outside triggers represented positive changes in the vegetation including increased abundance of ecologically significant species. Whilst it is of note to see such changes, the upward limit on the trigger value band should be removed to preclude unnecessary reporting on such occurrences.

A further anomaly of trigger reporting included the reduced number of sites monitored in zone 4. This lead to other values outside triggers due to the reduced number of sites to calculate average values. Where these occurred, they have been included in reporting for the purposes of transparency but they have not been included when considering the implications of results.

Other values outside triggers, including the increase and decrease in species richness and the altered ratio of ferns between the high and low quadrats, to some extent may have been influenced by the extended 2-turbine operation of the power station and subsequent changes in bank saturation levels, ground water levels and the impact of prolonged, sustained inundation.

It is possible that these changes to water dynamics have provided the mechanism for sufficient increases in stress to vegetation to cause such changes. However, due to the limited number of sites for monitoring and the potential for individual sites to influence triggers and measures at the scale of the whole river, the myriad other factors which may result in changes in vegetation cover, and the lack of corroborating evidence for a widespread waterlogging response, these results should lead to a level one response (‘note and explain’).

The six remaining values outside triggers were related to seedling measures which have been considered to be useful as corroborating evidence only.

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7 Macroinvertebrates

7.1 Introduction

Macroinvertebrate sampling was conducted in spring (17-19 October) 2006 and autumn (17 March) 2007 in accordance with the requirements of the Basslink Monitoring Program for the Gordon River. This macroinvertebrate monitoring in the middle Gordon River has three primary objectives to:

1. document biological changes resulting from changes to flow management;
2. assess compliance with biological management targets or objectives; and
3. provide core data for adaptive environmental management, along with other environmental data.

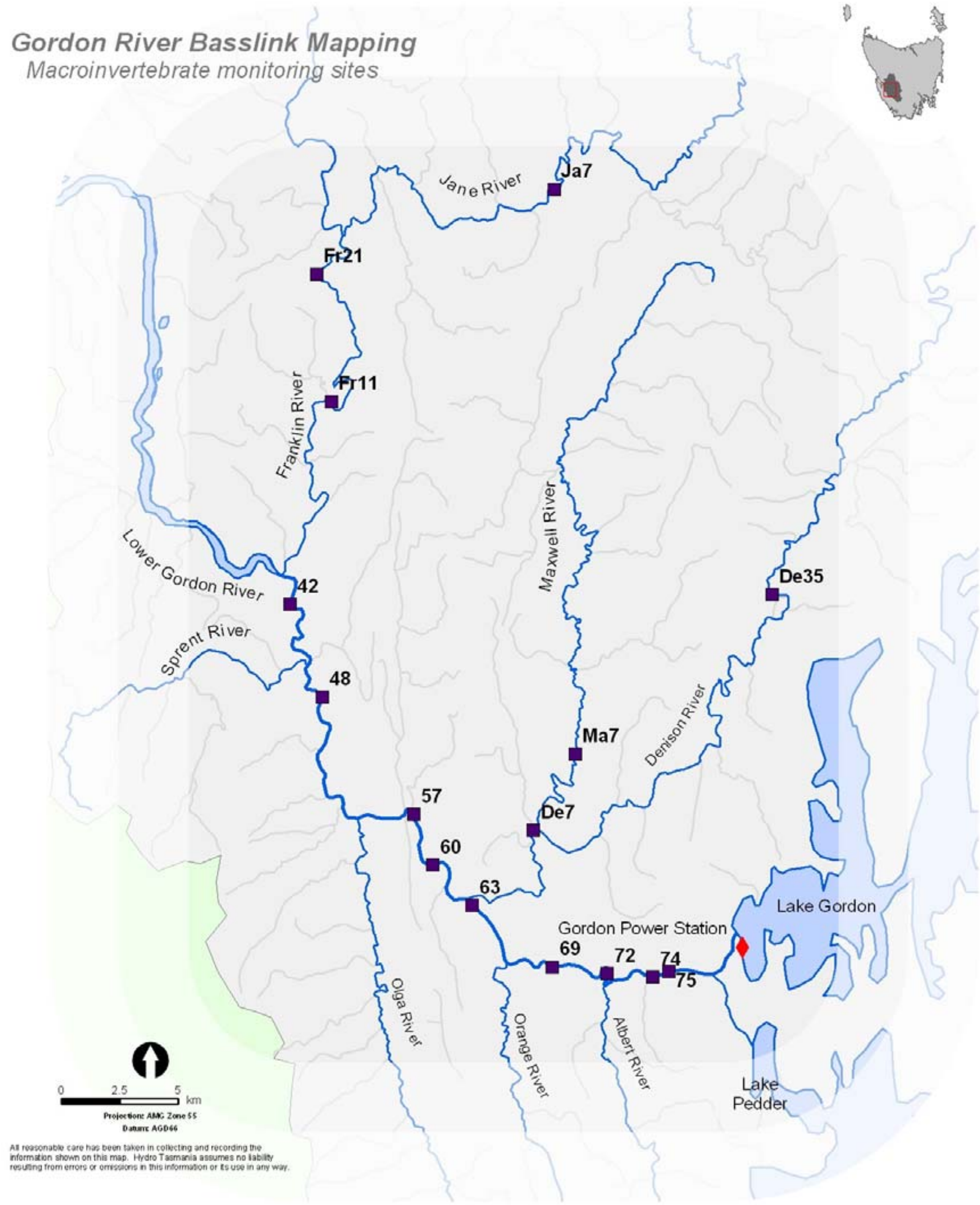
The sampling for 2006-07 comprises the first full year of the post-Basslink macroinvertebrate monitoring conducted in the Gordon River catchment. Both quantitative (surber) and rapid bioassessment (RBA) sampling was conducted at nine 'monitoring' sites in the Gordon River between the power station and the Franklin confluence. Sampling was also conducted at six 'reference' sites located in rivers within the Gordon catchment and in pristine condition.

The results of field sampling for macroinvertebrates in spring and autumn 2006-07 are presented, and these are compared with pre-Basslink results - years 1 to 4 of the monitoring program - through the analysis of triggers derived from pre-Basslink period data, as detailed in the Basslink Baseline Report and the 2005-06 Annual Report (Hydro Tasmania 2005, Hydro Tasmania 2006).

7.2 Methods

7.2.1 Sample sites

The locations of the monitoring and reference sites are shown in Map 7-1. All sites sampled in 2006-07 are listed in Table 7-1.



Map 7-1. Map of the locations of macroinvertebrate monitoring sites in the Gordon, Denison and Franklin Rivers.

Table 7-1. Sites sampled in 2006-07 for macroinvertebrates

River	Site Name	Site code	Distance from power station (km)	Easting (GDA94)	Northing (GDA94)
Gordon	Gordon R d/s Albert Gorge (G4)	75	2	412980	5266630
	Gordon R d/s Piguenit R (G4A)	74	3	412311	5266383
	Gordon R in Albert Gorge (G5)	72	5	410355	5266524
	Gordon R u/s Second Split (G6)	69	8	408005	5266815
	Gordon R u/s Denison R (G7)	63	14	404584	5269469
	Gordon R d/s Denison R (G9)	60	17	402896	5271211
	Gordon R u/s Smith R (G10)	57	20	402083	5273405
	Gordon R d/s Olga R (G11A)	48	29	398178	5278476
	Gordon R @ Devil's Teapot (G15)	42	35	396804	5282486
Franklin	Franklin R d/s Blackman's bend (G19)	Fr11	-	398562	5291239
	Franklin R @ Flat Is (G20)	Fr21	-	397939	5296733
Denison	Denison d/s Maxwell R (G21)	De7	-	407206	5272718
	Denison R u/s Truchanas Reserve (D1)	De35	-	417400	5282900
Jane	Jane R (J1)	Ja7	-	408100	5300400
Maxwell	Maxwell R (M1)	Ma7	-	409011	5276009

7.2.2 Macroinvertebrate sampling

The same sampling method was used at all sites. Thus, at each site at low flows, riffle habitat was selected and sampled by:

- collecting 10 surber samples (30 x 30 cm area, 500 micron mesh) by hand disturbance of substrate to a depth of 10 cm and washing 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.

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 Ephemeroptera, Plecoptera, Trichoptera - the 'EPT' fauna, using the most current keys.

Two rapid biological assessment (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.

7.2.3 Habitat variables

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

7.2.4 Analysis

All relevant indicators (including O/E scores, numbers of taxa and total abundance) were derived from the raw quantitative and RBA data, tabulated and summary trends were plotted. All RBA data were analysed using the autumn season Hydro Tasmania 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. More details on the derivation of these ratios can be found in Davies and Cook 2001.

O/Epa and O/Erk scores range between 0, representing the condition where no expected taxa are found in the sample, to around 1, where all expected taxa are found. This range is divided into *Impairment bands* for reporting purposes, as follows:

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

All indicators were assessed against triggers by direct comparison of relevant individual values at site scale and mean values at whole of river and zone scales, as appropriate. Derived values for spring and autumn seasons were also presented in plots along with the relevant trigger values.

7.3 Results

7.3.1 Spring 2006

7.3.1.1 Quantitative data

Data from spring 2006 season surber samples are shown for family level identification and for EPT species in Table 7-2 and Table 7-3.

Diversity and total abundance at both family and species level fell generally within or close to the range observed in previous years (Figure 7-1). Total family and EPT species abundance (density) was lower than the pre-Basslink mean for 7 out of the 9 Gordon sites, but still within pre-Basslink ranges (Figure 7-1 and Figure 7-2). The number of EPT species was lower than the pre-Basslink mean for all Gordon and reference sites except site 48; though not beyond one standard deviation from the pre-Basslink mean (Figure 7-2).

The relative abundance of EPT species was slightly higher than the pre-Basslink mean, especially at site 63 (Figure 7-3). This site had unusually high abundance of *Asmicridea* caddisfly larvae. This observation is not unusual for this reach of the Gordon, as this species' abundance frequently peaks adjacent to the Denison confluence, somewhere between sites 63 and 60, depending on antecedent flow conditions (See Hydro Tasmania 2005; conceptual model).

The community compositional similarity of the Gordon sites relative to the reference sites was similar to that observed pre-Basslink as measured by the mean Bray Curtis Similarity measure, based on either abundance or presence/absence data (Figure 7-4).

7.3.1.2 RBA data

Spring season RBA data is shown in Table 7-4. O/Epa and O/Erk values and their impairment bands are shown in Table 7-5.

O/Epa values in spring 2006 fell within or close to pre-Basslink values in the Gordon, with slight elevation downstream of the Denison junction (Figure 7-5). While three sites had results that fell outside one standard deviation of the pre-Basslink mean, they did not fall outside the 95% confidence ranges. Reference site O/Epa values were all substantially higher than pre-Basslink means (statistically significant by paired t-test of pre-Basslink means with 2006 values, $p < 0.01$).

O/Erk values, however, were consistently lower than observed in previous years in spring at all Gordon and reference sites (Figure 7-5, Table 7-5). These differences were statistically significant (by paired t-test of pre-Basslink means with 2006 values, $p < 0.02$) for both Gordon and reference sites, though individual sites did not fall outside the historically observed ranges.

7.3.1.3 Conclusions

In spring 2006, trends and magnitudes of all variables generally fell within historical ranges pre-Basslink. Reference sites O/Epa values were higher than pre-Basslink means. Consistently low EPT diversity and O/Erk was observed across most sites, including reference sites. It is suggested that low flow conditions preceding sampling may have contributed to enhanced overall diversity in the RBA samples, combined with reduced EPT diversity and relative abundance. These changes did not result in any substantial changes in community composition or overall density.

7.3.2 Autumn 2007

7.3.2.1 Quantitative data

Data from autumn 2007 season surber samples are shown at the family level of identification in Table 7-6 and for EPT species in Table 7-7.

Diversity and total abundance at both family and species level fell generally at or close to the pre-Basslink values in the Gordon, with some variation downstream of the Denison confluence (Figure 7-6). Abundance was substantially lower than pre-Basslink means for site 57 and for three of the six reference sites, several of which also had significantly reduced numbers of taxa.

The total andrelative abundance of EPT species were generally lower in the Gordon than the pre-Basslink mean, with the exception of sites 63 and 60 where *Asmicridea* again dominated (Figure 7-3, Figure 7-8). These values generally fell within pre-Basslink ranges. Reference site values generally fell close to pre-Basslink values.

The community compositional similarity of the Gordon sites relative to the reference sites was similar to that observed pre-Basslink for Gordon sites 60 to 75 as measured by the mean Bray Curtis Similarity measure, based on either abundance or presence/absence data (Figure 7-9). However, all sites in the lower Gordon, especially sites 42 to 57, had lower similarities than experienced pre-Basslink, suggesting some consistent factor affecting this metric downstream of the Denison confluence.

7.3.2.2 RBA data

Autumn season RBA data are shown in Table 7-8. O/Epa and O/Erk values and their impairment bands are shown in Table 7-5.

O/Epa values in autumn 2006 were generally lower than pre-Basslink means for both Gordon and reference sites (Figure 7-10). These differences were statistically significant (by paired t-test of pre-Basslink means with 2006 values, both $p < 0.01$) for both Gordon and reference sites, a number of individual sites fell just below or at the lower margins of historically observed ranges.

By contrast, O/Erk values were generally close to or somewhat higher than pre-Basslink means in the Gordon, and generally close to pre-Basslink means for reference sites (Figure 7-10).

7.3.2.3 Conclusions

In autumn 2007, trends and magnitudes of most variables generally fell within pre-Basslink historical ranges. Exceptions were: reduced O/Epa values (for both Gordon and reference sites); and reduced diversity, abundance and community compositional similarity (for lower Gordon and reference sites).

Flow conditions had been exceptionally low prior to sampling, especially at reference sites and the lower Gordon. Intensive rainfall immediately prior to the sampling event in autumn raised river levels, restricting sampling to areas of river bed marginal to the previously wetted river bed. Marginal channel areas are frequently depauperate for a time after rapid level rises, as colonisation from the channel centre and upstream may take several days to weeks.

This is likely to have caused the observations of particularly low abundance and/or diversity in reference sites and sites downstream of the Denison. It is highly unlikely to have any relationship with the operations of the Gordon Power Station post-Basslink. This is confirmed by the absence of similar observations, especially in community composition (as measured by Bray Curtis Similarity) upstream of the Denison confluence - a river section with flows much more controlled by power station releases than catchment input.

Generally reduced values of EPT species diversity, EPT abundance and relative abundance of EPT species were however observed in the Gordon in autumn 2007. The reference sites at the same time of year had indications of either the absence and presence of such an effect. This was also observed, though to a lesser degree, in the spring sampling. These variables are early warning of changes and indicate a need for a level one response (‘note and explain’) and further analysis in years two and three to evaluate the likelihood of this being a post-Basslink effect.

Table 7-2. Quantitative macroinvertebrate ‘family level’ data (abundances as n per 0.18 m^2) for Gordon and reference sites sampled in spring 2006

Class	Order	Family	Gordon									Franklin		Denison		Maxwell	Jane
			75	**74**	**72**	**69**	**63**	**60**	**57**	**48**	**42**	**Fr11**	**Fr21**	**De7**	**De35**	**Ma7**	**Ja7**
Platyhelminthes	Turbellaria		3	4		1	2	7	3	6	2	11	6	2		15	3
Nematoda				12			2	2		13	3	28					2
Mollusca	Bivalvia	Sphaeriidae					1	1				2	1			3	5
	Gastropoda	Hydobiidae		1		8		2	7	3	8	3	1	4	1	198	19
		Ancylidae										1	5				
		Glacidorbidae		1		1		1									
Annelida	Oligochaeta			115	161	75	63	159	124	466	340	314	11	53	96	337	107
Arachnida	Acarina			1						1		3	2	2		8	1
Crustacea	Amphipoda	Paramalitidae						1	9	18	2	1				12	
		Neoniphargidae	22	6	1	5		3		1	2					2	
	Isopoda	Phreatoicidea				6										1	1
		Janiridae	97	59	9	11	9	3	5	9	5	97	20	3		3	
Insecta	Plecoptera	Eustheniidae	2	3	1		1	6	4	11	4		7	3	25	1	
		Austroperlidae			1		1			1					1		
		Gripopterygidae	3	16	61	13	97	48	43	29	33	8	26	12	36	104	23
		Notonemouridae				2	2				1						
	Ephemeroptera	Leptophlebiidae	5	2	27	4	16	135	77	85	101	313	198	245	233	305	134
		Baetidae					1	14	2	3	4	12	12	11	78	123	47
	Odonata	Telephlebiidae												1			1
	Diptera	Chironomidae: Chironominae		2	4	3	9	7	4	6	21	3	5	21	10	5	13
		Chironomidae: Orthocladiinae	10	10	27	2	9	11	7	16	10	1	27	1	6	18	12
		Chironomidae: Podonominae		1	3		8	16	19	22	9	7	7	12	19	8	7
		Chironomidae: Tanypodinae										1					
		Chironomidae: Diamesinae	10	11	4								2			1	
		Chironomidae: Aphroteniinae								1		4	1			2	2
		Simuliidae	1	82	58	17	15	268	281	349	87	526	1000	91	515	100	120
		Tipulidae			9			6	3	5	2	4		3	1	2	1
		Athericidae											1				
		Blephariceridae		1	3			3	2	11	3	53	169	2	17		1
		Ceratopogonidae										9	4		1	1	1
		Chaoboridae	2														
		Empididae		1	1	1	1			1	2	1		1	1	4	3
		Tanyderidae															1
		Dip. Unid. Pup.	2	2	3	2	2	3	12	13	35	5	9	8	28	2	3
	Trichoptera	Calocidae		4						1		1		1	2	26	53
		Conoesucidae		1	19		10	6	1	1	4		7			50	20
		Glossosomatidae					1	1						1		6	29
		Helicophidae									1						1
		Helicopsychidae														2	
		Hydrobiosidae	1	6	4	4	11	31	19	31	14	24	27	14	17	23	14
		Hydropsychidae				1	78	313	67	29	9	1	3	5	4	18	5
		Hydroptilidae			1		2	2									
		Leptoceridae	1	2		3		10	8	10	5	17	36	7	32	2	29
		Philopotamidae						6					1			4	
		Philorheithridae						2	1		2	4	4		9	22	26
		Polycentropodidae													1		
		Trich. Unid. Pup.					1	5	2	9	1	2			1		8
	Coleoptera	ElmidaeA			1		5	10	16	2	3	69	67	99	70	456	144
		ElmidaeL	1	3	27		12	37	14	13	1	147	92	143	118	178	298
		ScirtidaeL			2	1	2	5		4		69		9	30	2	13
		PsephenidaeL			4						1	3	4	9		23	8
Nematomorpha		Gordiidae											1			1	
Total Abundance			**160**	**346**	**431**	**160**	**361**	**1124**	**730**	**1170**	**720**	**1744**	**1756**	**763**	**1352**	**2068**	**1155**
N Taxa			**14**	**24**	**23**	**19**	**26**	**32**	**24**	**31**	**30**	**33**	**31**	**27**	**26**	**37**	**35**

Table 7-3. Quantiative ‘species level’ data for EPT taxa (Ephemeroptera, Plecoptera and Trichoptera) for Gordon and reference sites sampled in spring 2006 abundances as n per 0.18 m^2).

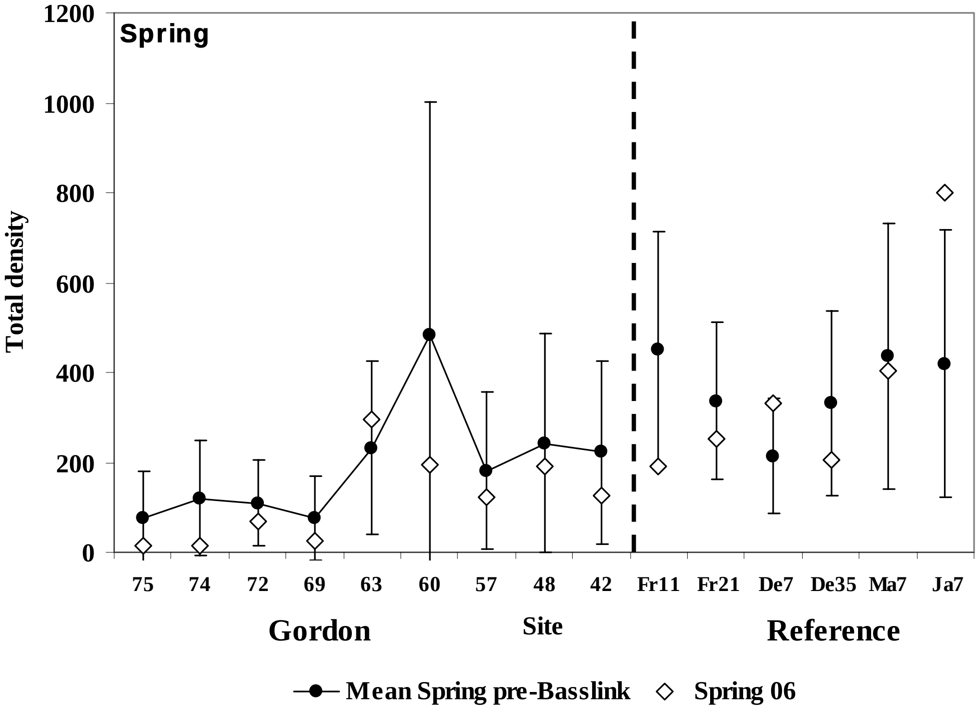
		River :	**Gordon R**									**Franklin R**		**Denison R**		**Maxwell R**	**Jane R**
		Site code:	75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
		Old site code:	G4	G4a	G5	G6	G7	G9	G10	G11B	G15	G19	G20	G21	D1	M1	J1
		Date:	18-Oct-06	18-Oct-06	19-Oct-06	10-Dec-06	17-Oct-06	18-Oct-06	18-Oct-06	17-Oct-06	17-Oct-06	19-Nov-06	19-Nov-06	18-Oct-06	17-Oct-06	17-Oct-06	17-Oct-06
		Sampler	WE	LC	LC	LC	JG	JG	BS	JG	JG	TS	RM	JG	JG	JG	JG
		Picker:	JG	LC	LC	WE	JG	JG	JG	JG	JG	TS	LC	JG	JG	JG	JG
		Identifier:	TS	LC	LC	WE	TS	TS	TS	TS	TS	TS	LC	TS	LC	TS	LC
Order	**Family**	**Genus/Species**															
Ephemeroptera	Baetidae	Baetid Genus 2 MV sp. 3	0	0	0	0	0	0	0	1	1	1	2	1	1	35	43
	Leptophlebiidae	Austrophlebioides sp. AV7	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
		Nousia sp. AV5/6	1	1	1	0	1	13	7	14	9	27	23	88	51	88	122
		Nousia sp. AV7	0	1	1	1	3	1	0	1	1	1	0	0	0	0	0
		Nousia sp. AV8	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
		Tillyardophlebia sp AV2	0	0	0	0	0	0	0	1	0	1	2	1	0	1	2
Plecoptera	Eustheniidae	Eusthenia costalis	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0
		Eusthenia spectabilis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Austroperlidae	Tasmanoperla thalia	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	Gripopterygidae	Cardioperla incerta	0	0	0	0	7	1	0	2	2	0	0	0	1	7	2
		Cardioperla media/lobata	0	0	3	0	0	0	0	0	0	0	0	1	0	11	5
		Cardioperla spinosa	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Cardioperla nigrifrons	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Dinotoperla marmorata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
		Dinotoperla serricauda	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0
		Leptoperla varia	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0
		Trinotoperla zwicki	1	1	4	0	2	4	0	1	1	0	2	1	1	6	3
	Notonemouridae	Austrocercoides sp	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Trichoptera		Tamasia variegata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Conoesucidae	Conoesucus brontensis	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
		Conoesucus digitiferus	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
		Conoesucus fromus	0	0	2	0	0	0	0	0	0	0	0	0	0	5	0
		Conoesucus nepotulus	0	0	0	0	7	0	1	3	2	0	0	0	0	0	0
		Conoesucus norelus	0	0	0	0	4	0	0	0	0	0	0	0	0	0	2
		Costora delora	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Matasia satana	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Glossosomatidae	Agapetus sp. AV1	0	0	0	0	1	0	0	0	0	0	0	0	0	2	7
	Hydrobiosidae	Apsilochorema obliquum	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
		Moruya opora	0	0	0	0	2	1	1	3	1	0	0	0	0	3	0
		# Taschorema apobamum	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1
		# Taschorema asmanum	0	0	0	0	0	0	0	0	0	0	1	3	2	1	4
		# Taschorema ferulum	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
	Includes all#	Taschorema ferulum grp	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Hydropsychidae	Asmicridea sp. AV1	0	0	0	1	223	77	33	3	7	1	0	0	0	1	0
		Smicrophylax sp. AV3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	Notalina sp.AV1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
		Notalina sp.	0	0	0	0	0	1	0	0	0	3	0	0	0	0	0
		Triplectides proximus	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Philorheithridae	Tasmanthrus galbinomaculatus	0	0	0	0	0	0	1	1	0	2	0	0	0	2	0
		Tasmanthrus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		Total abundance	**4**	**4**	**17**	**4**	**256**	**99**	**47**	**31**	**24**	**42**	**32**	**99**	**62**	**166**	**197**
		N Taxa	**4**	**4**	**7**	**4**	**13**	**8**	**9**	**11**	**8**	**10**	**7**	**9**	**7**	**16**	**14**

Table 7-4. RBA macroinvertebrate data (abundances per live picked sample) for Gordon River and reference sites sampled in spring 2006.

			River :	Gordon R																		Franklin R				Denison R				Jane R		Maxwell R	
			Site :	75		74		72		69		63		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	1	2
Platyhelminthes	Turbellaria								1			1																					
Nematoda																				1													
Mollusca	Bivalvia	Sphaeriidae									1																						
	Gastropoda	Hydrobiidae															1																1
Annelida	Hirudinea																								36								
	Oligochaeta					4	3	7	23	8	1	12	35	28	15	15	9	22	18	37	38	17	21	16		12	19	4	2	23	12	2	9
Arachnida	Acarina										1					1		1						1							1	4	1
Crustacea	Amphipoda	Paramelitidae			1					2	4			1	2	15	14	5	5	2		1	3			2	1					2	
		Ceinidae			1																												
		Neoniphargidae		15	3	1								1				1															
	Isopoda	Phreatoicidea			1											1																	
		Janiridae			8																												
Insecta	Plecoptera	Eustheniidae		2	5	1	2	3	2	2	2	1		2	2	4	1	7	3	1	6	2	1	4	6	1	2	3	10		1		
		Austroperlidae		1			1								1								1										
		Gripopterygidae		11	3	11	4	14	5	7	4	5	25	7	13	13	9	2	4		7	1		8	2	1	2	5	8	8	4	28	28
		Notonemouridae							1		1								1														
	Ephemeroptera	Leptophlebiidae		9	9			25	13	8	2	8	8	53	31	26	50	42	46	45	53	84	64	85	103	85	137	52	89	64	102	65	69
		Baetidae															1					1	1	1	6	5	4	1	1	11	6	9	4
	Odonata	Telephlebiidae																							1					1			
	Diptera	Chironomidae:	Chironominae						1	1		1		2	5			2	4	1	9	2	1	4					1	1	1		
		Chironomidae:	Orthocladiinae	6	3	1				2		3	6	1	1			1	1			1		8	2			1			1		6
		Chironomidae:	Podonominae	1	1			16	3			8	25	13	17	7	10	18	12	13	31	9	10	13	14	22	28	11	10	5	5	12	3
		Chironomidae:	Tanypodinae								1																						
		Chironomidae:	Diamesinae																					3	1				1				
		Simuliidae			1	12	22	5	8	41	38	2	2	15	8	13	16	22	33	6	12	8	27	20	13	14	2	44	16	20	14	5	2
		Tipulidae		3	2		1	2	1	1	1			2		2	3	1			1	3	1	3	1	1	4	1	2		2		1
		Athericidae																									1					1	
		Blephariceridae			1		1						1	1				3	5		1	2	7	3				2			1		
		Ceratopogonidae																				20	1	5	12	1							
		Dip. Unid. Pup.													1		1					1	2	1									
	Trichoptera	Calocidae																						1							1		
		Conoesucidae				3		10	1			1	9					1											1	5	1	8	11
		Glossosomatidae																					1			1				9	1	1	1
		Helicophidae				1																											
		Hydrobiosidae		211	91	13	14	1	3	7	7	6	10	8	21	5	21	19	11	15	11	25	31	36	36	25	16	21	26	31	32	10	8
		Hydropsychidae				1						49	76	41	42	8	4	4	2	3	2	1							1	1			
		Leptoceridae		4	1				1							2	1					2	2	1	1		1		1		1	1	
		Philopotamidae																					1		1								
		Philorheithridae		1							3				1	3		1	3	1		9	2		4	1	1	4	2	6	1	5	4
		Trich. Unid. Pup.								1			2		1	2				2	1		5	1									
	Coleoptera	ElmidaeA		1					2		1			7	10	17	20	1	1	2	1	16	30	19	2	25	13	13	5	28	18	45	23
		ElmidaeL												4		1	3					6	9	4	2	3	16		2	1	12	1	
		ScirtidaeL		3	3			1		3	2				1	1						63	2	8	20	3	1				6	1	1
		PsephenidaeL				1		2															2		1	2						2	7
			N Taxa	**13**	**16**	**11**	**8**	**11**	**14**	**12**	**15**	**12**	**11**	**16**	**17**	**18**	**16**	**18**	**15**	**13**	**13**	**21**	**23**	**22**	**20**	**17**	**16**	**13**	**17**	**15**	**21**	**18**	**17**

Table 7-5. O/Epa and O/Erk values for all sites sampled in spring and autumn 2006-07, for individual replicate samples, and averages. Impairment bands also indicated.

River	**Site**	**Replicate**	**Spring 2006**				**Autumn 2007**			
			O/Epa	**Band**	**O/Erk**	**Band**	**O/Epa**	**Band**	**O/Erk**	**Band**
Gordon	75	1	0.83	A	0.62	B	0.59	B	0.45	B
		2	0.75	A	0.65	B	0.49	C	0.40	C
		Mean	**0.79**	**A**	**0.63**	**B**	**0.54**	**B**	**0.43**	**C**
	74	1	0.74	A	0.88	A	0.68	B	0.50	B
		2	0.59	B	0.64	B	0.88	A	0.76	B
		Mean	**0.66**	**B**	**0.76**	**B**	**0.78**	**A**	**0.63**	**B**
	72	1	0.80	A	0.87	A	0.68	B	0.61	B
		2	0.87	A	0.80	A	0.78	B	0.76	B
		Mean	**0.84**	**A**	**0.83**	**A**	**0.73**	**B**	**0.68**	**B**
	69	1	0.76	A	0.63	B	0.29	C	0.26	C
		2	1.06	A	0.89	A	0.68	B	0.73	B
		Mean	**0.91**	**A**	**0.76**	**A**	**0.49**	**B**	**0.49**	**B**
	63	1	0.67	B	0.59	B	0.98	A	0.61	B
		2	0.67	B	0.75	B	1.08	A	0.76	B
		Mean	**0.67**	**B**	**0.67**	**B**	**1.03**	**A**	**0.68**	**B**
	60	1	0.97	A	1.10	A	1.47	X	1.16	A
		2	0.97	A	1.12	A	1.37	X	0.91	A
		Mean	**0.97**	**A**	**1.11**	**A**	**1.42**	**X**	**1.03**	**A**
	57	1	1.20	X	1.35	X	1.08	A	0.71	B
		2	1.12	A	1.17	A	1.17	A	0.81	B
		Mean	**1.16**	**A**	**1.26**	**X**	**1.12**	**A**	**0.76**	**B**
	48	1	1.20	X	1.23	X	0.98	A	0.79	B
		2	1.04	A	1.04	A	1.27	X	0.85	A
		Mean	**1.12**	**A**	**1.13**	**A**	**1.12**	**A**	**0.82**	**B**
	42	1	0.75	A	0.91	A	1.08	A	0.71	B
		2	0.82	A	0.88	A	0.98	A	0.81	B
		Mean	**0.79**	**A**	**0.90**	**A**	**1.03**	**A**	**0.76**	**B**
Franklin	Fr11	1	1.42	X	1.29	X	1.76	X	1.06	A
		2	1.50	X	1.52	X	1.57	X	0.96	A
		Mean	**1.46**	**X**	**1.41**	**X**	**1.66**	**X**	**1.01**	**A**
	Fr21	1	1.35	X	1.29	X	1.76	X	1.16	A
		2	1.12	A	1.06	A	1.76	X	1.01	A
		Mean	**1.23**	**X**	**1.17**	**A**	**1.76**	**X**	**1.08**	**A**
Denison	De7	1	1.29	X	1.23	X	1.56	X	1.11	A
		2	1.21	X	1.05	A	1.56	X	0.96	A
		Mean	**1.25**	**X**	**1.14**	**A**	**1.56**	**X**	**1.03**	**A**
	De35	1	0.95	A	1.00	A	1.47	X	1.06	A
		2	1.11	A	0.97	A	1.37	X	0.96	A
		Mean	**1.03**	**A**	**0.98**	**A**	**1.42**	**X**	**1.01**	**A**
Maxwell	Ma7	1	1.35	X	1.21	X	1.27	X	0.86	A
		2	1.13	A	1.11	A	1.76	X	1.16	A
		Mean	**1.24**	**X**	**1.16**	**A**	**1.52**	**X**	**1.01**	**A**
Jane	Ja7	1	0.95	A	1.11	A	1.57	X	1.01	A
		2	1.34	X	1.15	A	1.57	X	1.06	A
		Mean	**1.15**	**A**	**1.13**	**A**	**1.57**	**X**	**1.03**	**A**



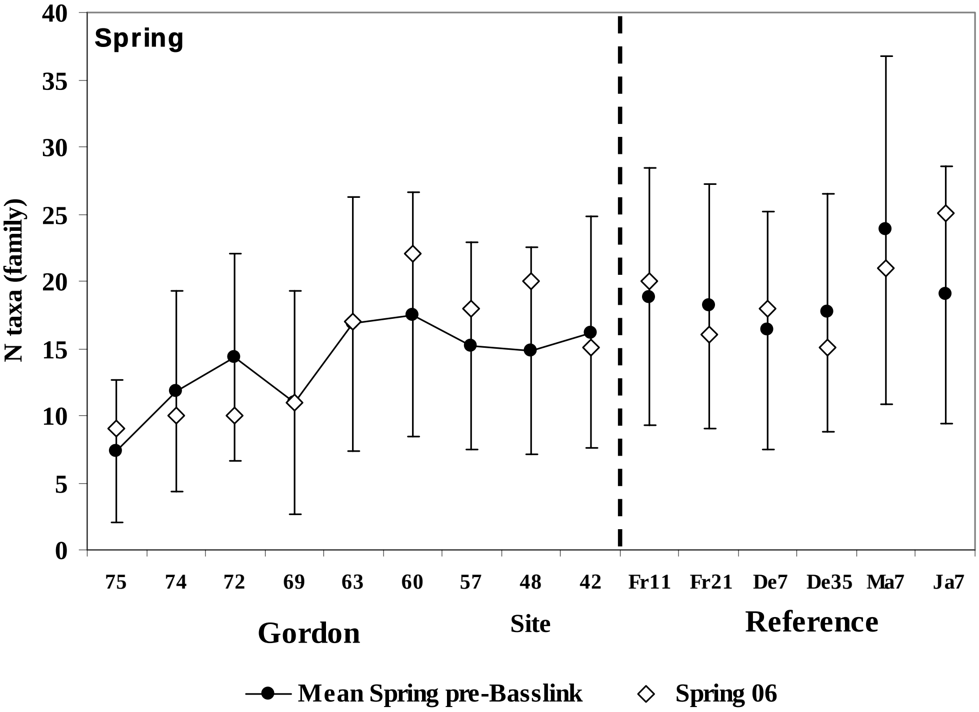
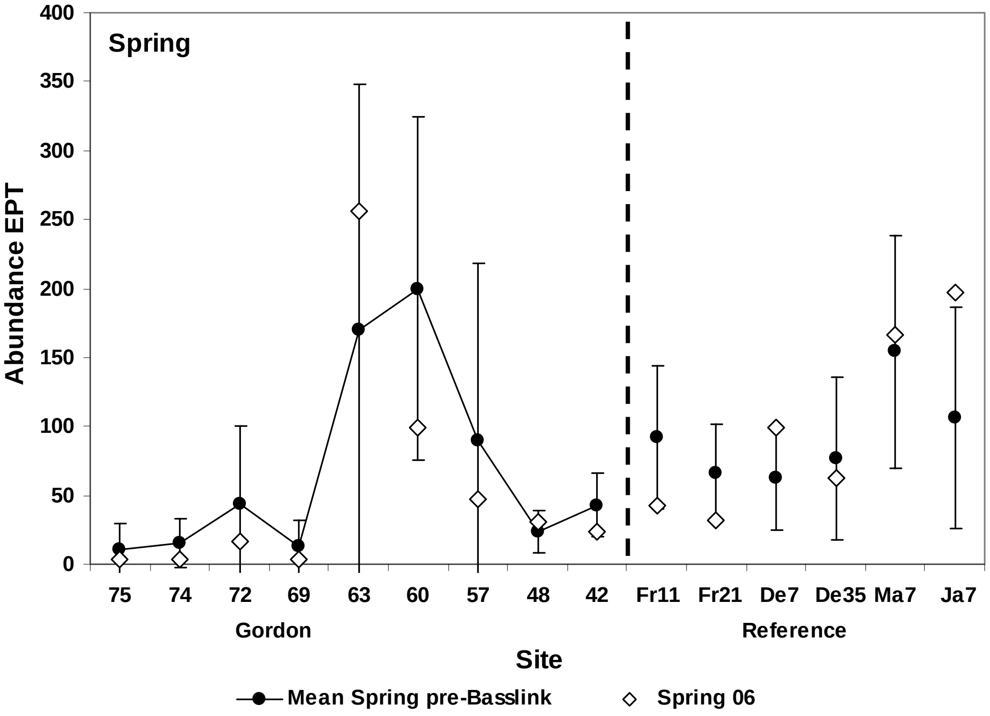


Figure 7-1. Comparison of total abundance and diversity (number of taxa at family level) for spring 2006 with spring values from previous years, derived from quantitaive Surber samples. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean.



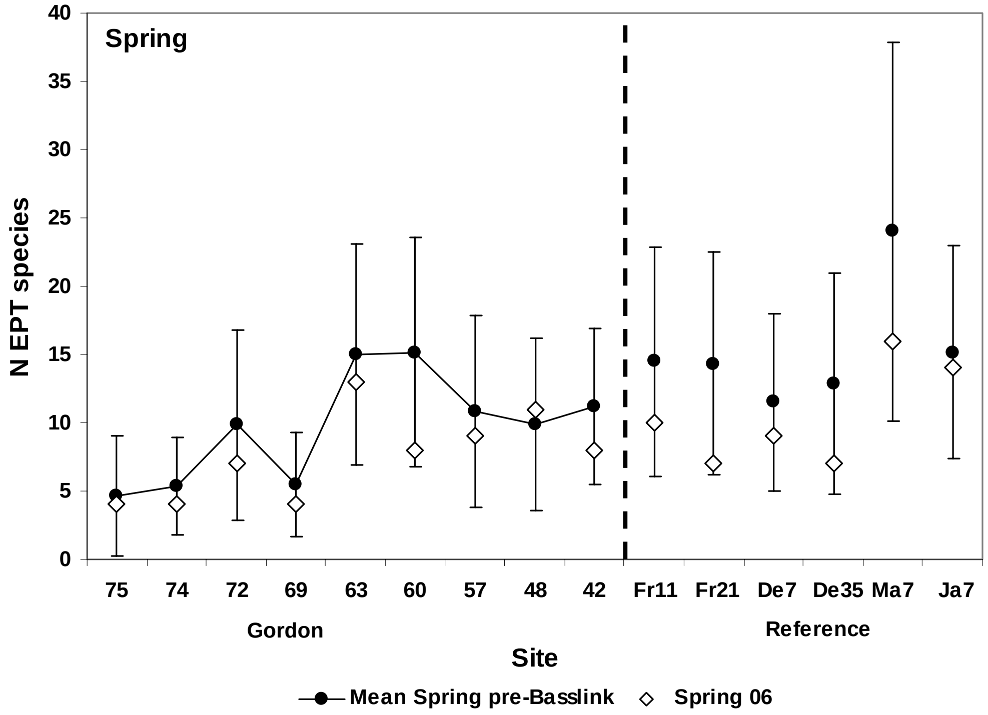


Figure 7-2. Comparison of total abundance and number of EPT species for spring 2006 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean.

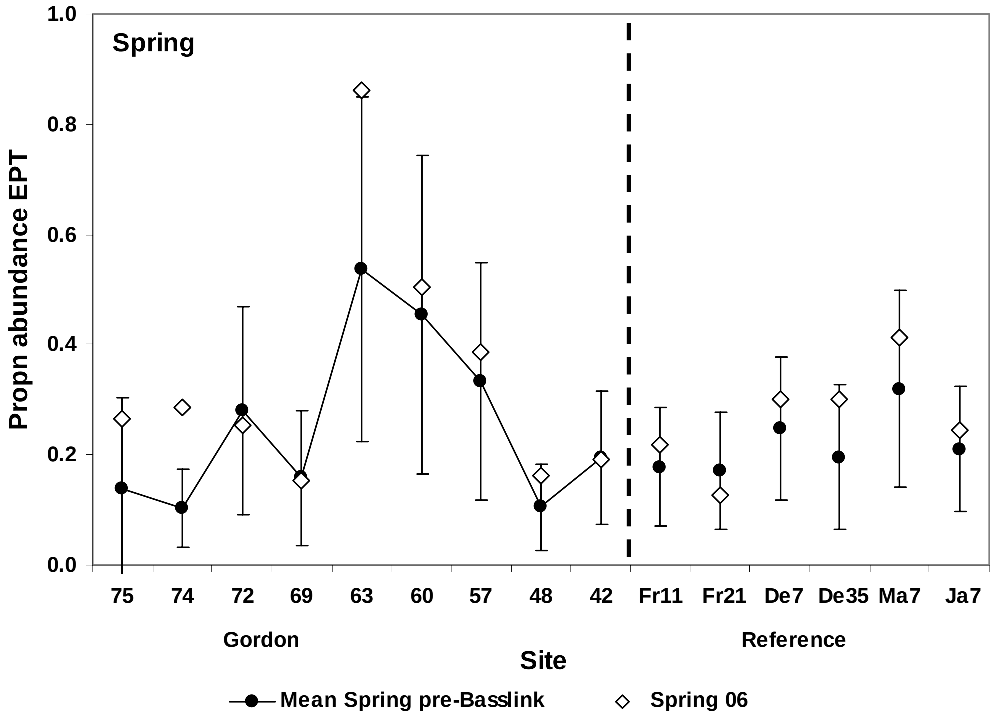
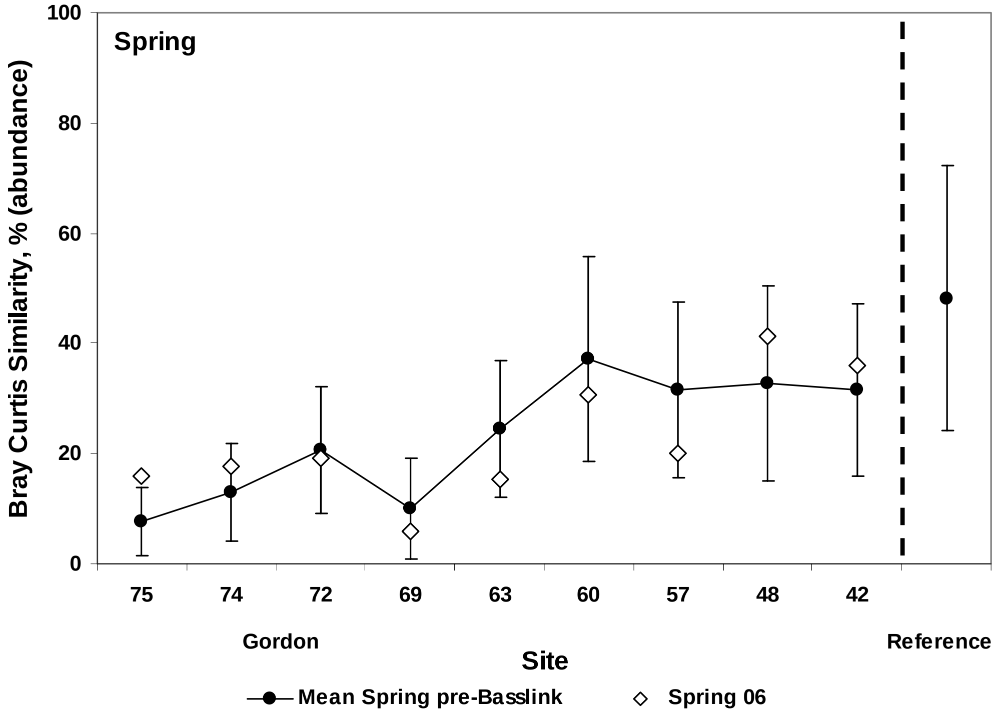


Figure 7-3. Comparison of proportion of total abundance represented by EPT species for spring 2006 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean.



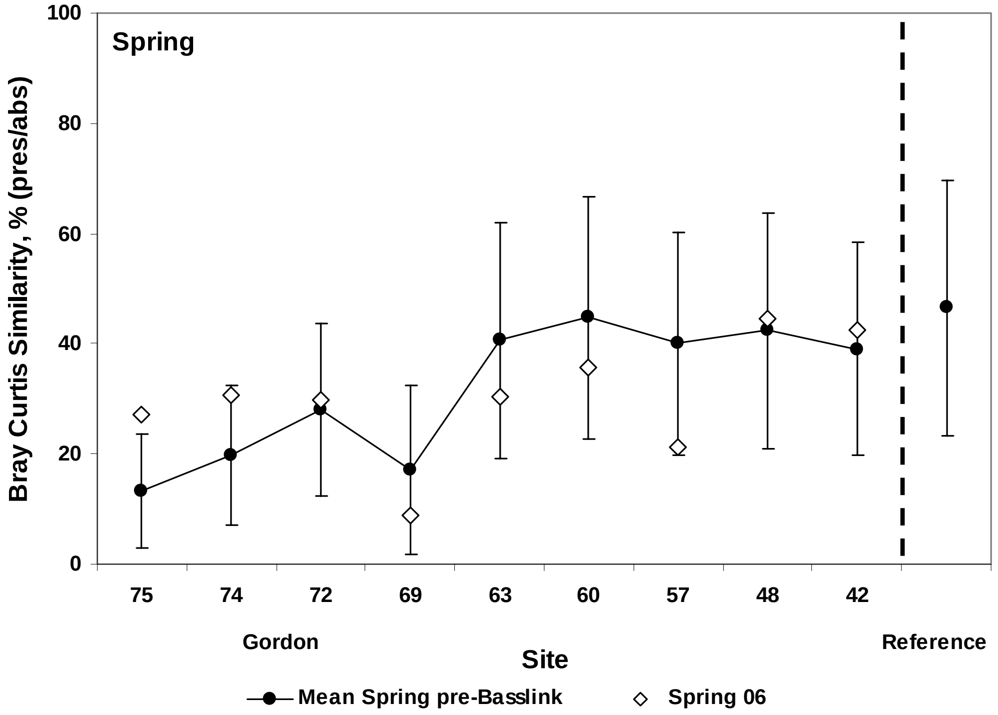
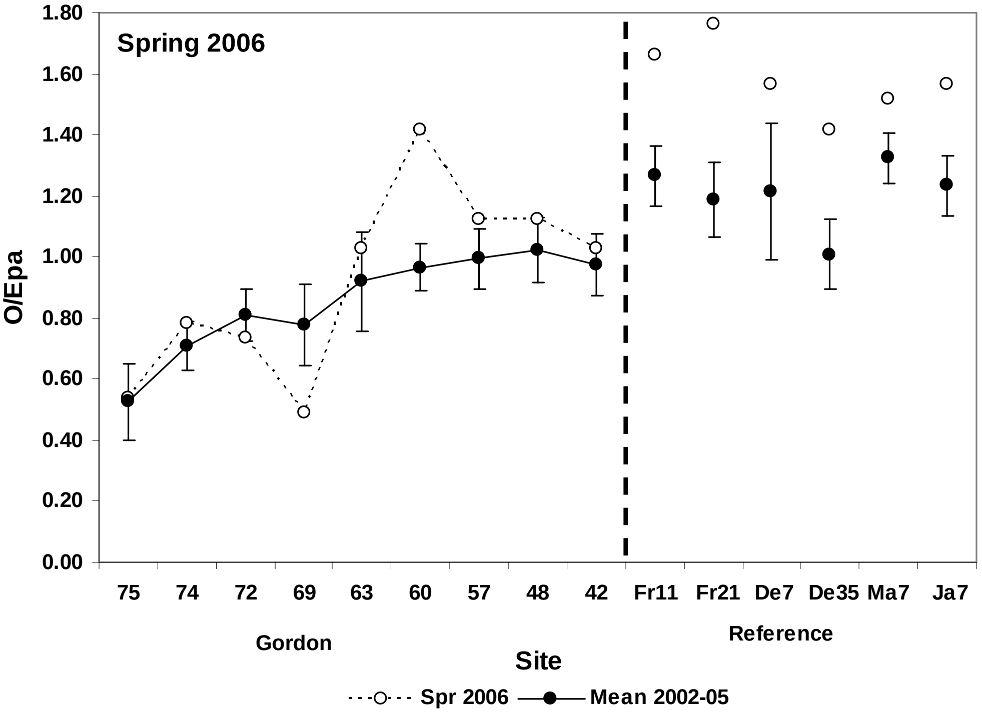


Figure 7-4. Comparison of values for the mean Bray Curtis Similarity between each sampled site and the reference sites for spring 2006 with spring values from previous years.Similarities were calcuated with either abundance data (square root transformed) or presence/absence data. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the value for reference sites represents the mean of Similarities between each reference site and the other reference sites.



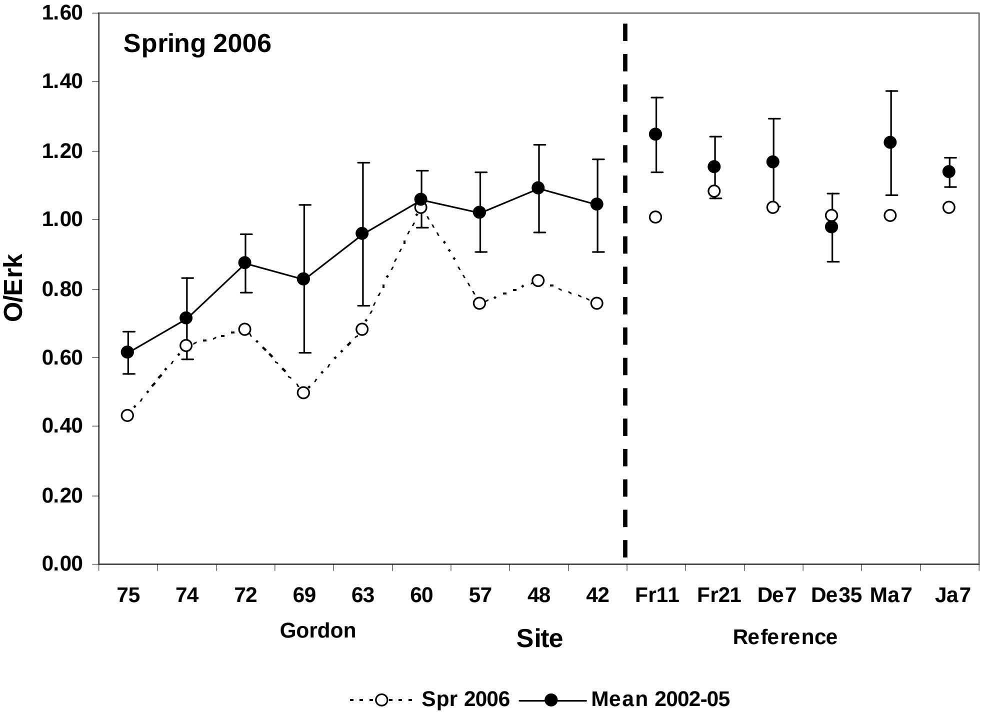


Figure 7-5 Comparison of OEpa and OErk values for spring 2006 with values from previous years. Note consistently high O/Epa values at sites 69 – 75 upstream of Denison. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean.

Table 7-6. Quantitative macroinvertebrate ‘family level’ data (abundances as n per 0.18 m^2) for Gordon and reference sites sampled in autumn 2007

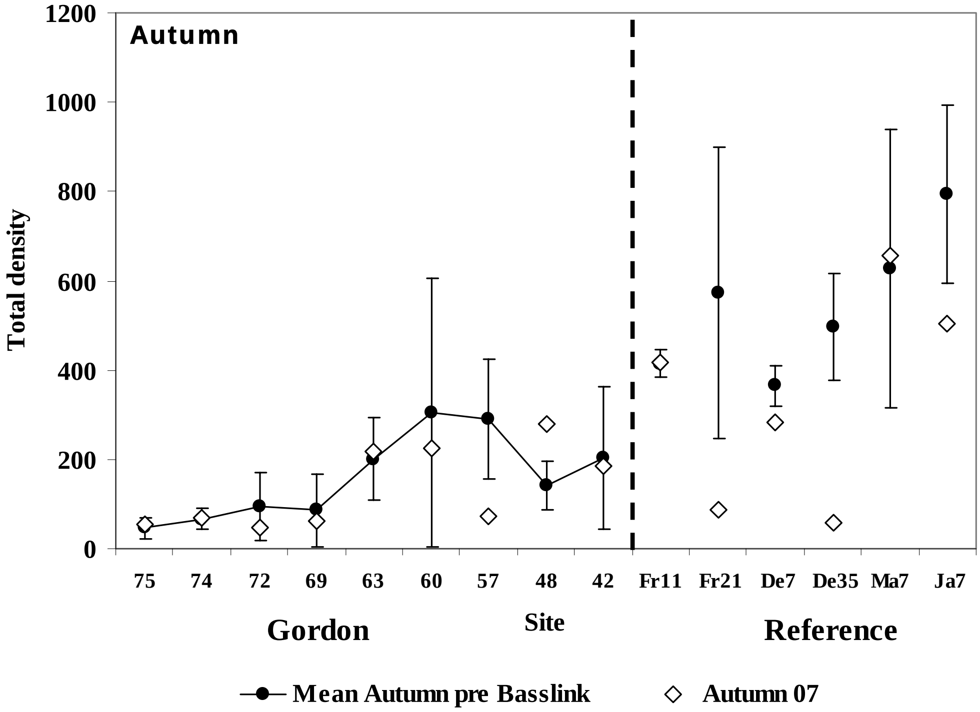
			River :	**Gordon R**									**Franklin R**		**Denison R**		**Maxwell R**	**Jane R**
			Site code:	75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
			Old site code:	G4	G4a	G5	G6	G7	G9	G10	G11B	G15	G19	G20	G21	D1	M1	J1
			Date:												16-Mar-03			
			Sampler	RM	RM	RM	WE	LC	LC	TS	TS	TS	JJ	JJ	JJ	LC	JG	JJ
			Picker:	WE/TS	RM	RM	WE	TS	TS	TS	JJ	JJ	TS	TS	JJ	TS	TS	JJ
			Identifier:	TS	LC	LC	LC	TS	TS	TS	JJ	JJ	TS/JJ	TS	LC	TS	TS	JJ
Order	**Family**	**Sub family**	**Taxon name**															
Hydrozoa			Hydrozoa				1											
Turbellaria			Turbellaria	1				1	2		1	1	2		2		2	2
			Nematoda						2		7	3	2	2	2		41	3
Bivalvia	Sphaeriidae		Sphaeriidae				1	1							1			
Gastropoda	Hydrobiidae		Hydrobiidae		1	1	6	1	7	4	4	3	2	3	5		60	
	Ancylidae		Ancylidae											1				
	Glacidorbidae		Glacidorbidae	1			1		1									
Oligochaeta			Oligochaeta	3	11	14	5	46	31	27	81	55	35	18	19	10	115	63
Acarina			Acarina				1											
Amphipoda	Paramelitidae		Paramelitidae						6	3	3				2		2	
	Neoniphargidae		Neoniphargidae	2		2	2				1							
Isopoda	Phreatoicidea		Phreatoicidea				1						2					
	Janiridae		Janiridae	40	6	1	3	2	3	1			86	1	1		18	
Plecoptera	Eustheniidae		Eustheniidae			1	1		1			1	1		3			1
	Austroperlidae		Austroperlidae		1													
	Gripopterygidae		Gripopterygidae		6	1	1	8		3	4	1	3	2		2	5	
Ephemeroptera	Leptophlebiidae		Leptophlebiidae	1	1	3	2	3	3	1	6	10	42	6	33	6	54	52
	Baetidae		Baetidae										3	3	11		33	22
Diptera	Chironomidae:	Chironominae	Chironominae			1	2	1	6	1			2	5	27	13	10	2
	Chironomidae:	Orthocladiinae	Orthocladiinae	1	1	5	2	2	2	8	3						4	2
	Chironomidae:	Aphroteniinae	Aphroteniinae											1				
	Simuliidae		Simuliidae	2	38	11	17	32	40	17	148	97	23	3		6	1	29
	Tipulidae		Tipulidae			1									1			
	Blephariceridae		Blephariceridae		1				1		4	2						
	Chaoboridae		Chaoboridae	1														
	Empididae		Empididae				1	1	1	1			2			2	5	
	Dip. Unid. Pup.		Dip. Unid. Pup.		1						3	4			1			1
Trichoptera	Calocidae		Calocidae									1	1		3		4	13
	Conoesucidae		Conoesucidae	1				1	1				32				29	16
	Glossosomatidae		Glossosomatidae										74		3	1	1	40
	Hydrobiosidae		Hydrobiosidae	1	1	1	1	1	1		4	1	6	1	2	1	7	11
	Hydropsychidae		Hydropsychidae		1	1	11	115	107	5	9	2	9		4	1	36	36
	Leptoceridae		Leptoceridae			1			1	1		1	9		26	1	8	3
	Philopotamidae		Philopotamidae									1						
	Philorheithridae		Philorheithridae										4	2	7		10	3
	Trich. Unid. Pup.		Trich. Unid. Pup.						1				1					2
Coleoptera	ElmidaeA		ElmidaeA						2		1		12	2	26	7	65	81
	ElmidaeL		ElmidaeL	1		1	1	3	4	1	1	2	48	27	95	7	122	100
	ScirtidaeL		ScirtidaeL			1							16	11	4	1	22	21
	PsephenidaeL		PsephenidaeL						1				1		3	1	4	
			Total abundance	**55**	**69**	**46**	**60**	**218**	**224**	**73**	**280**	**185**	**418**	**88**	**281**	**59**	**658**	**503**
			N Taxa	**12**	**12**	**16**	**19**	**15**	**22**	**13**	**16**	**16**	**25**	**16**	**23**	**14**	**24**	**21**

Table 7-7. Quantiative ‘species level’ data for EPT taxa (Ephemeroptera, Plecoptera and Trichoptera) for Gordon and reference sites sampled in autumn 2007 (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	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
		Old site code:	G4	G4a	G5	G6	G7	G9	G10	G11B	G15	G19	G20	G21	D1	M1	J1
		Date:					16-Mar-03							16-Mar-03			
		Sampler	RM	RM	RM	WE	LC	LC	TS	TS	TS	JJ	JJ	JJ	LC	JG	JJ
		Picker:	WE/TS	RM	RM	WE	TS	TS	TS	JJ	JJ	TS	TS	JJ	TS	TS	JJ
		Identifier:	TS	LC	LC	LC	TS	TS	TS	JJ	JJ	TS/JJ	TS	LC	TS	TS	JJ
Order	**Family**	**Genus/Species**															
Ephemeroptera	Baetidae	Baetid Genus 2 MV sp. 3										3	3	11		33	22
	Leptophlebiidae	Nousia sp. AV5/6	1	1	2	2	2	2				41	2	27	1	26	12
		Nousia sp. AV7			1	1	1	1	1				2	1	3	3	
		Nousia sp. AV8	1													25	
		Nousia sp. AV10															1
		Tillyardophlebia sp AV2										1	3	5	2		4
		Unidentified Leptophlebiidae								6	10						35
	Eustheniidae	Eusthenia costalis						1			1	1					1
Plecoptera		Eusthenia spectabilis			1	1								3			
	Gripopterygidae	Cardioperla incerta						2								1	
		Cardioperla media/lobata													1	1	
		Dinotoperla serricauda											2			1	
		Dinotoperla sp.										1					
		Leptoperla varia		1												1	
		Trinotoperla hardyi					3										
		Trinotoperla inopinata					1										
		Trinotoperla zwicki	1	5	1	1	4	2	1						1	1	
		Trinotoperla sp.								4	1	2					
Trichoptera	Calocidae	Tamasia variegata									1	1		3		4	13
	Conoesucidae	Conoesucus brontensis														3	
		Conoesucus nepotulus					1	1								10	
		Conoesucus sp.										28					15
		Costora delora														1	1
		Costora luxata														15	
		Lingora aurata										4					
	Glossosomatidae	Agapetus sp. AV1										74		3	1	1	40
	Hydrobiosidae	* Ethochorema nesydrion												1	1		1
		Moruya opora								1	1		1				
		Moruya sp AV1						1									
	includes all *	Taschorema complex			1												
		#* Taschorema apobamum														1	1
		#* Taschorema asmanum		1						1				1			9
		#* Taschorema ferulum														2	
	Includes all#	* Taschorema ferulum grp				1						5				4	
		Ulmerochorema rubiconum					1			2		1					
	Hydropsychidae	Asmicridea sp. AV1		1	1	11	115	107	5	9	2	9		4	1	28	34
		Smicrophylax sp. AV3														8	2
	Leptoceridae	Notalina bifaria														2	
		Notalina sp.AV1			1			1	1					25	1	6	
		Notalina sp.										7					3
		Triplectides proximus												1			
		Unidentified Leptoceridae									1						
	Philopotamidae	Hydrobiosella sp AV10									1						
	Philorheithridae	Austreithrus sp.														2	
		Tasmanthrus angustipennis												7			
		Tasmanthrus sp.										4	2			8	3
		Total abundance	**3**	**9**	**8**	**17**	**128**	**118**	**8**	**23**	**18**	**182**	**15**	**92**	**12**	**187**	**197**
		N Taxa	**3**	**5**	**7**	**6**	**8**	**9**	**4**	**6**	**8**	**15**	**7**	**13**	**9**	**24**	**17**

Table 7-8. RBA macroinvertebrate data (abundances per live picked sample) for Gordon River and reference sites sampled in autumn 2007.

			River :	**Gordon R**																		**Franklin R**				**Denison R**				**Jane R**		**Maxwell R**	
			Site :	**75**		**74**		**72**		**69**		**63**		**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**	**1**	**2**
Platyhelminthes	Turbellaria			2													2				1			1									
Nematoda																					2					1				1			
Mollusca	Gastropoda	Hydrobiidae														5					1		2	2			1					2	
Annelida	Oligochaeta				2	8	7	9	2		3	5	6	10	26	12	24	25	30	45	37	12	4	15	10	11	8	14	10	5	13	10	7
Arachnida	Acarina													1				9			1	3		5		5	1	1	1	1	1	7	5
Crustacea	Amphipoda	Paramelitidae			1							1		12	2	31	10		7	1		1	2		3	5		1					1
		Ceinidae					1																										
		Paracalliopidae																					1										
		Neoniphargidae		1	6		2		2			1		1				1															
	Copepoda			2			1																										
	Isopoda	Janiridae		12	19	2	4										1					1		1									
Insecta	Plecoptera	Eustheniidae				1	2		8			2		13	2	1		5	5	3	1	3	4	6	10	13	8	7	14	2	3		3
		Austroperlidae						1																					1				
		Gripopterygidae		1		13	27	3	9			8	6	21	17	4	1	7	19	8	9	1		1	2	1	1		2	9		2	3
		Notonemouridae							1					1																			
	Ephemeroptera	Leptophlebiidae		8	6		1	21	11		2	10	12	27	12	9	10	21	27	28	40	60	63	54	73	44	59	75	63	88	73	15	22
		Baetidae													1				1			8	5	29	33	32	17	29	18	7	14	21	23
	Odonata	Telephlebiidae																										2					
	Diptera	Chironomidae:	Chironominae							1	1		1		1		1		1					1	1	3	1	4	9	1	4	1	3
		Chironomidae:	Orthocladiinae	1									1			1				1				2	1		2	2	2			1	1
		Chironomidae:	Podonominae											1		1		2	2									3	3	2	1		
		Chironomidae:	Tanypodinae																														1
		Chironomidae:	Diamesinae									1																					
		Simuliidae		3	6	63	26	18	15	2	4	22	38	18	21	11	17	47	111	18	67	9	1	7	1	7		1	2	9	4		1
		Tipulidae												2	2		1					2	1	3	2	2	1	8	4	3	3		
		Blephariceridae				1							1						2	1	3												
		Ceratopogonidae																							10								
		Empididae																	1												2		
		Dip. Unid. Pup.							2		2																	4					
	Trichoptera	Calocidae																					1					1		4	7		
		Conoesucidae					2					1	1									5	8	4	4			1		4	2	6	5
		Glossosomatidae																				26	25	5	2	1	1			5	3		2
		Helicopsychidae																								1							
		Hydrobiosidae		23	18	18	18	33	8		3	8	13	11	4	4	1	9	14	8	4	22	23	26	14	12	6	16	8	19	24	6	12
		Hydropsychidae		1		1	3	2	3	3	4	40	17	14	20	11	1	1	4		1	1		1			1			3	2	9	1
		Leptoceridae											1	1		4	1	1	2	2		30	61	18	33	21	13	16	14	9	8	7	3
		Philopotamidae												1																			
		Philorheithridae							1				1	1			5				1	14	20	22	15	5	7	26	5	2	10	9	6
		Trich. Unid. Pup.										1	1		1			1	3	2	1					1					1	1	1
	Coleoptera	ElmidaeA					2							1	4	1	2	3	1	1	1	27	25	10	6	23	22	13	9	23	26	52	12
		ElmidaeL													1							1	4	2	3	1	3	4	2		3	7	1
		ScirtidaeL						1			1			1								5	3	2	2	3	1	15	10	2	6	3	2
		PsephenidaeL												1	1							1	7	2	5		3						2
		N Taxa		**10**	**7**	**8**	**13**	**8**	**11**	**3**	**8**	**12**	**13**	**19**	**15**	**13**	**14**	**13**	**16**	**12**	**15**	**20**	**19**	**23**	**20**	**20**	**19**	**21**	**18**	**20**	**21**	**17**	**22**



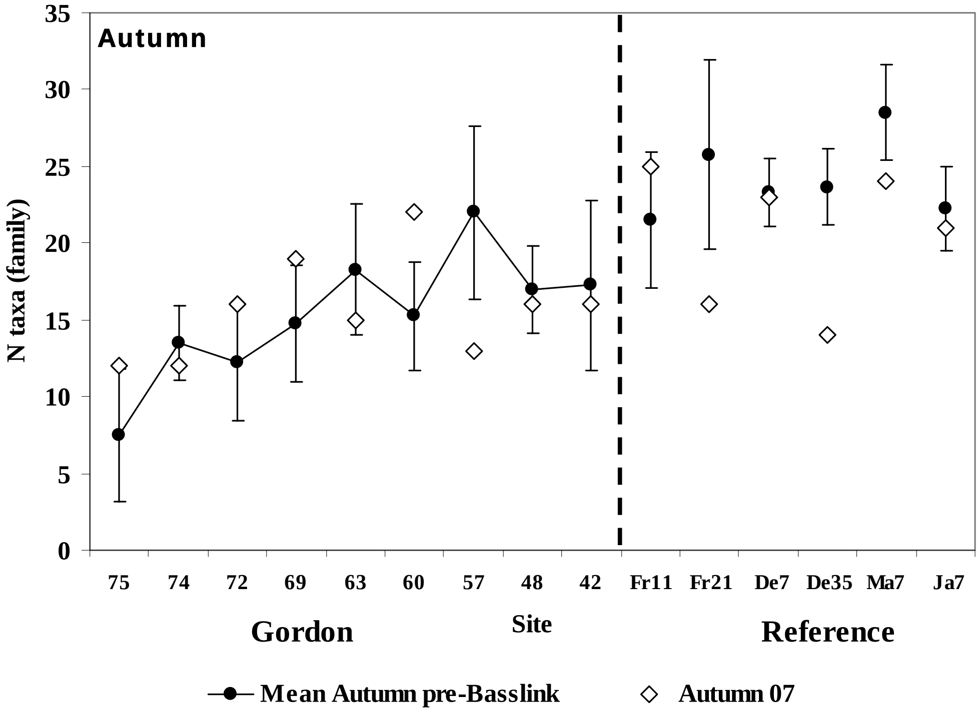
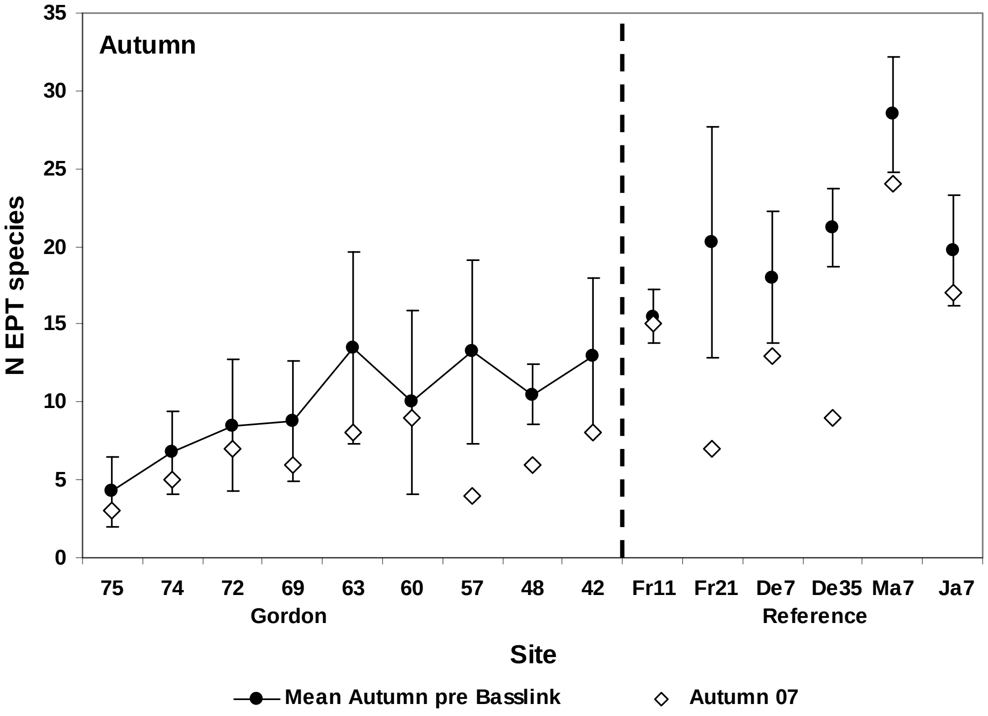


Figure 7-6. Comparison of total abundance and diversity (number of taxa at family level) for autumn 2007 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean.



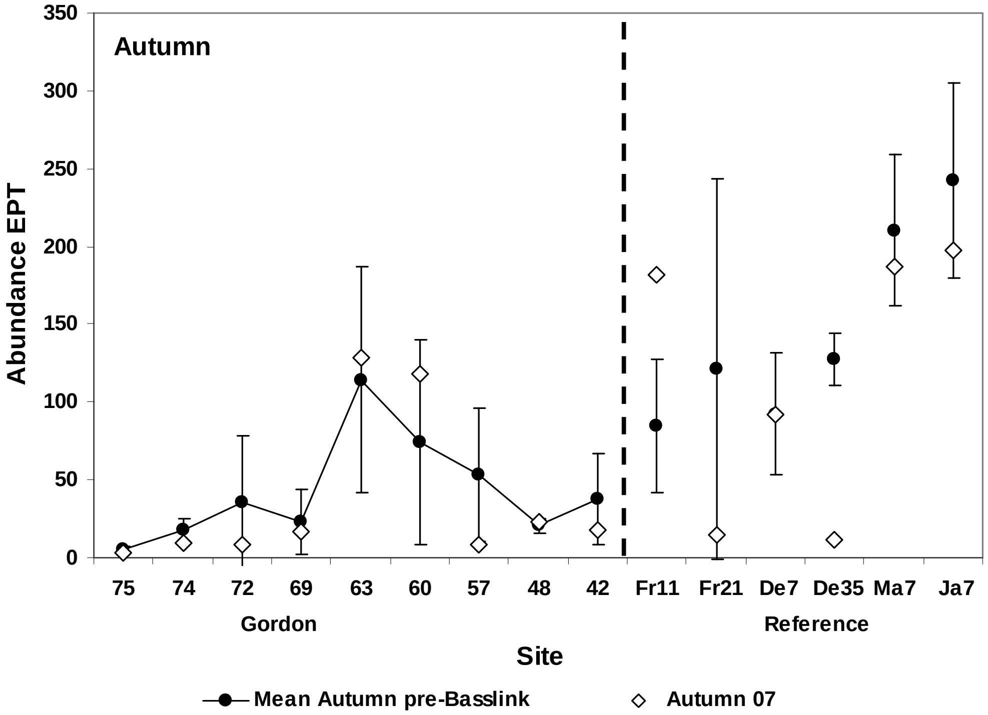


Figure 7-7. Comparison of total EPT number of species and abundance of EPT species for autumn 2007 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean.

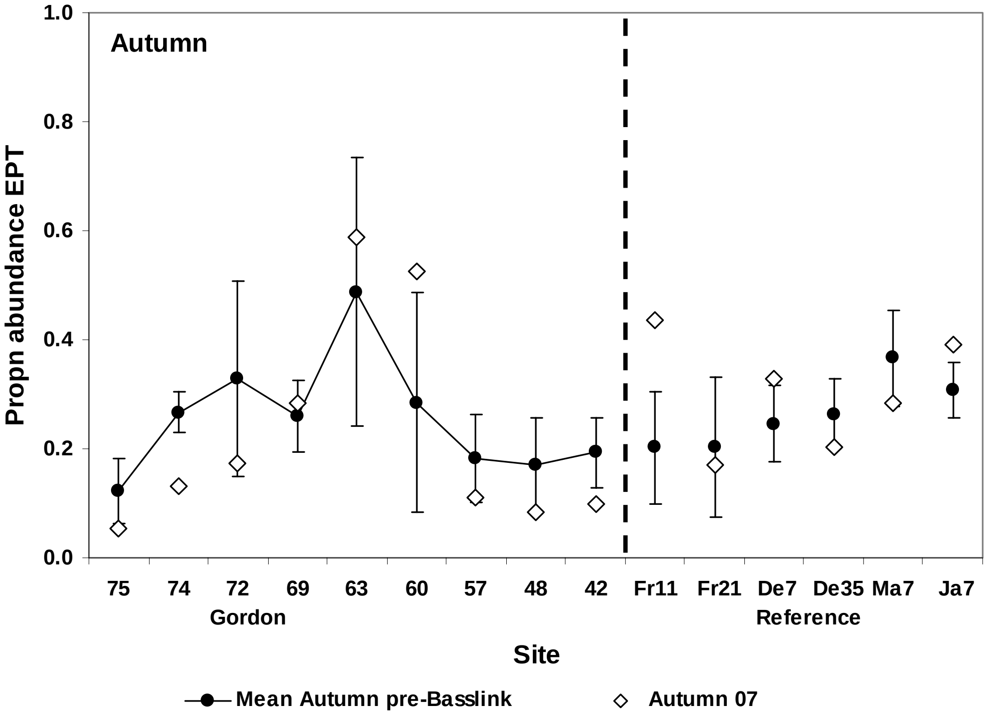
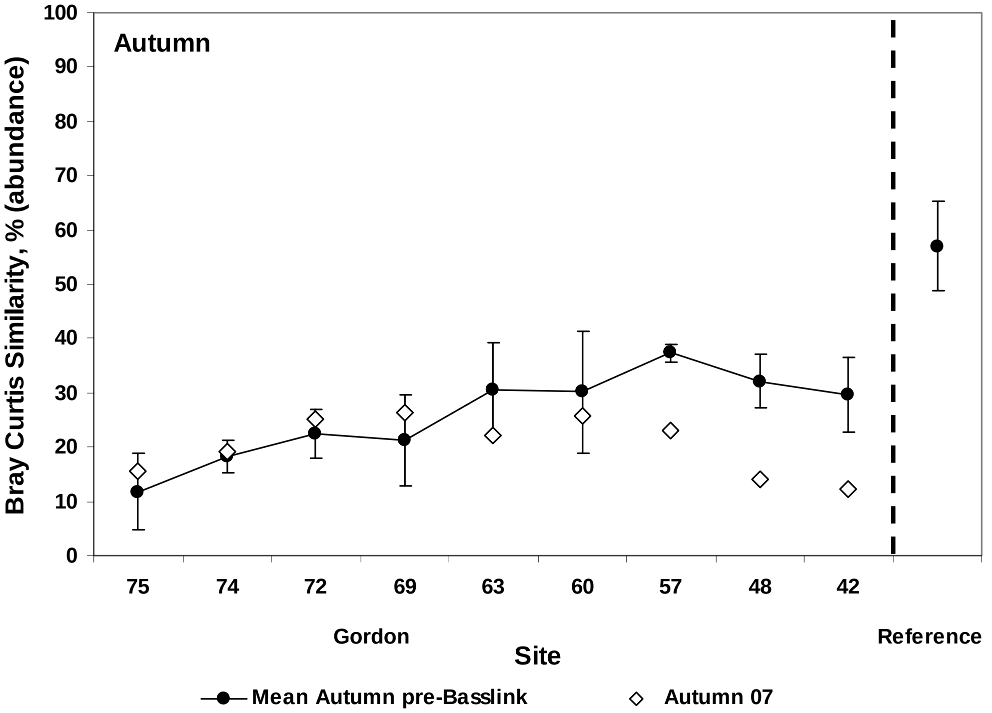


Figure 7-8. Comparison of proportion of total abudance represented by EPT species for autumn 2007 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean.



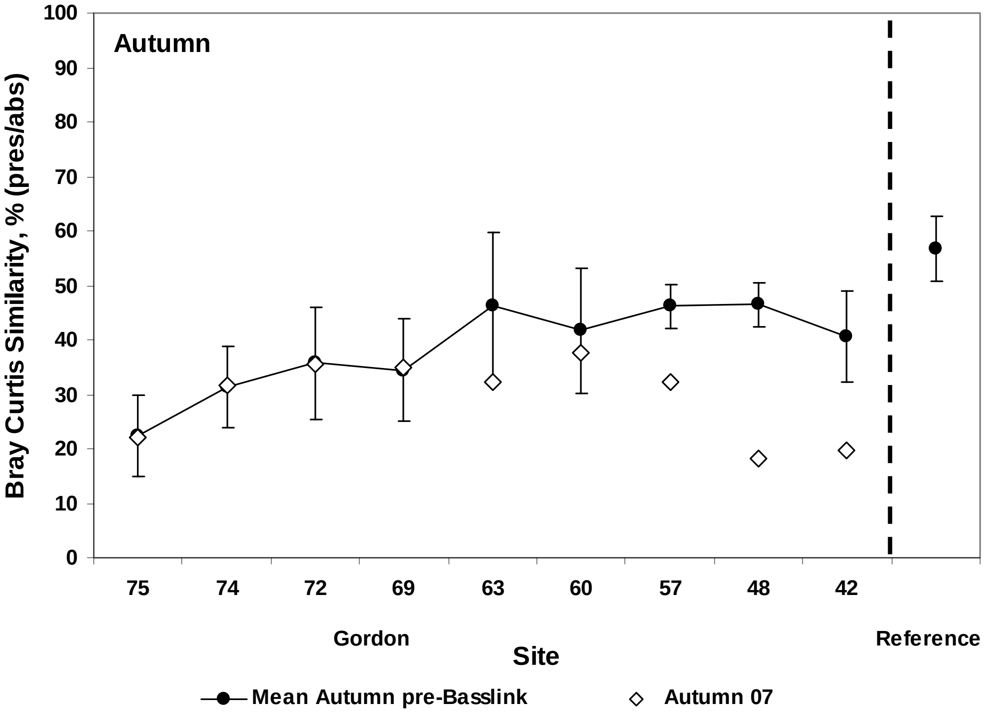
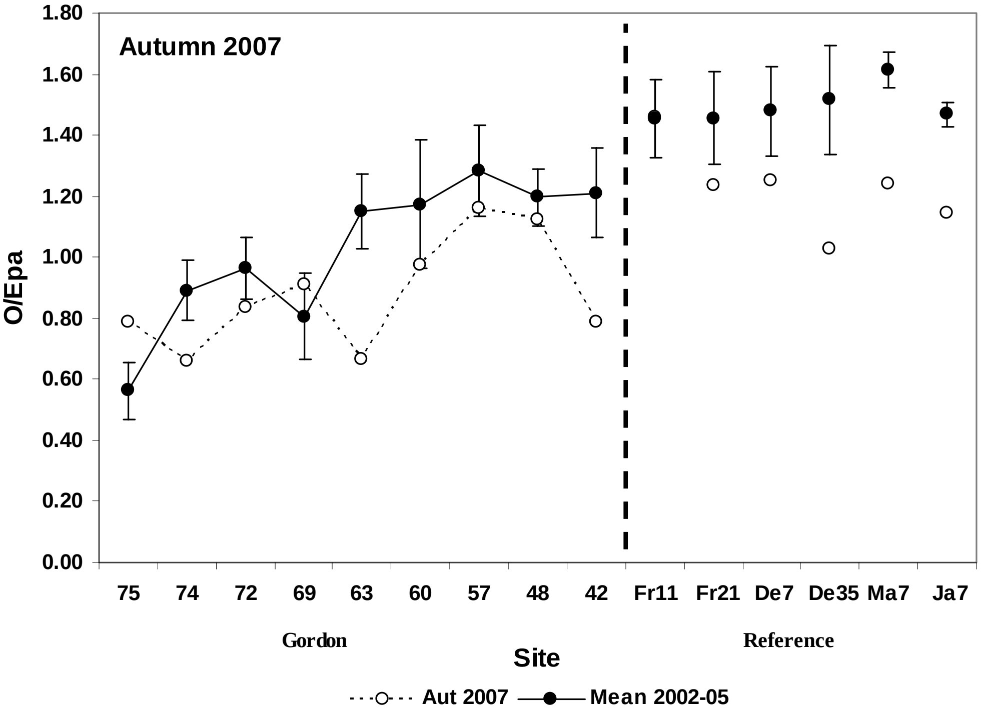


Figure 7-9. Comparison of values fo the mean Bray Curtis Similarity between each sampled site and the reference sites for autumn 2007 with autumn values from previous years. Similarities are calculated with either abundance data (square root transformed) or presence/absence data. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the value for reference sites represents the mean of Similarities between each reference site and the other reference sites.



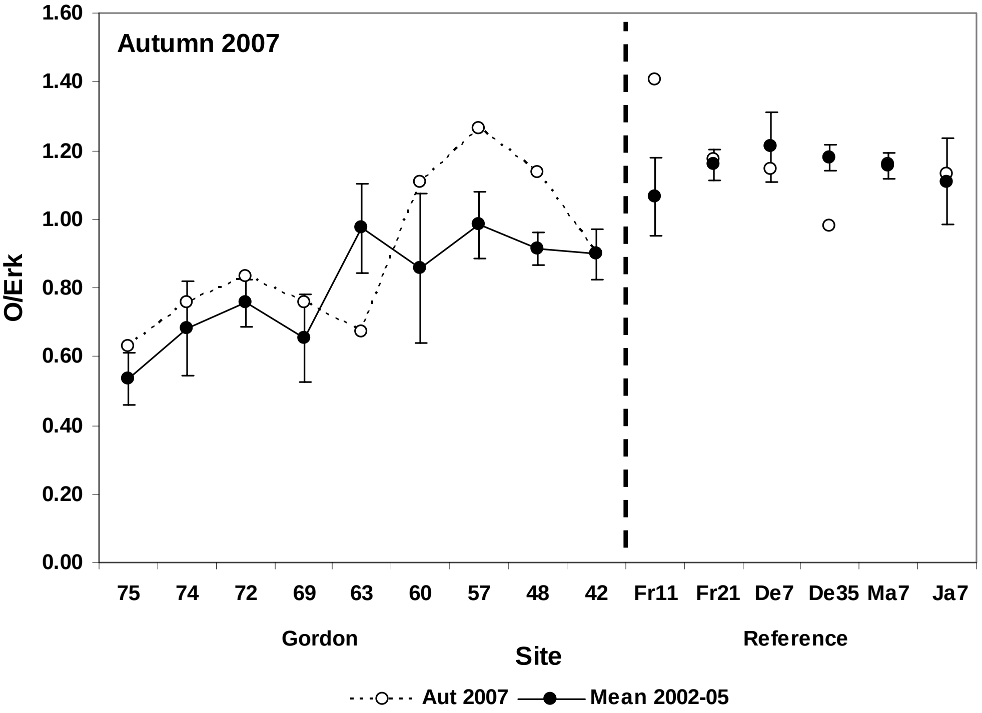


Figure 7-10 Comparison of OEpa and OErk values for autumn 2007 with values from previous years. Note consistently high OEpa values at sites 69 – 75 upstream of Denison. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean.

7.4 Comparisons with triggers

7.4.1 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 follows:

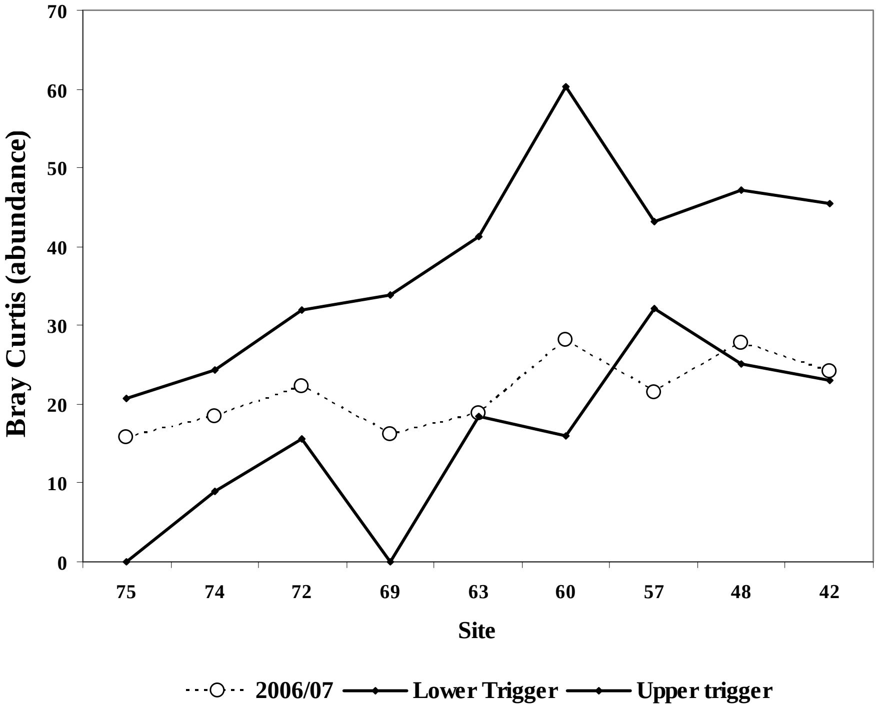
Components	Metrics
Community Structure	Bray Curtis (abundance)
	O/Erk
Community Composition	Bray Curtis (pres/abs data)
	O/Epa
Taxonomic richness	N Taxa (fam)
	N EPT Species
Ecologically significant species	Proportion of total Abundance as EPT
	Abundance EPT
Biomass / productivity	Total abundance

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 or not Limits of Acceptable Change (LOAC) have been exceeded, post-Basslink. Upper and lower triggers have been determined. The values of the lower level triggers are shown in Appendix 7. 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 whole of river case. Two zones have been described for benthic macroinvertebrates – zone 1 (upstream of the Denison confluence (incorporating sites 69 to 75) and zone 2 downstream of the Denison confluence (incorporating sites 42 to 60).

Values of all metrics for 2006-07 are shown in Table 7-9. Plots of the trigger levels for each metric are shown below compared with the value for the metric recorded in 2006-07, at individual site level (Figure 7-11 to Figure 7-15) and at whole of river (WOR) and zone level (Figure 7-16 to Figure 7-20).

Table 7-9. Values of all metrics for each site sampled in spring 2006 and autumn 2007

			Spring 2006									**Autumn 2007**								
			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**	15.81	0.63	27.26	0.79	9	4	0.267	4	15	15.65	0.43	22.07	0.54	12	3	0.055	3	55
	74	**G4a**	17.74	0.76	30.61	0.66	10	4	0.286	4	14	19.24	0.63	31.68	0.78	12	5	0.130	9	69
	72	**G5**	19.29	0.83	29.72	0.84	10	7	0.254	17	67	25.13	0.68	35.60	0.73	16	7	0.174	8	46
	69	**G6**	5.86	0.76	8.89	0.91	11	4	0.154	4	26	26.35	0.49	34.92	0.49	19	6	0.283	17	60
	63	**G7**	15.30	0.67	30.36	0.67	17	13	0.862	256	297	22.22	0.68	32.25	1.03	15	8	0.587	128	218
	60	**G9**	30.80	1.11	35.59	0.97	22	8	0.505	99	196	25.64	1.03	37.73	1.42	22	9	0.527	118	224
	57	**G10**	20.10	1.26	21.10	1.16	18	9	0.385	47	122	23.01	0.76	32.19	1.12	13	4	0.110	8	73
	48	**G11B**	41.30	1.13	44.66	1.12	20	11	0.162	31	191	14.19	0.82	18.35	1.12	16	6	0.082	23	280
	42	**G15**	35.92	0.90	42.43	0.79	15	8	0.190	24	126	12.24	0.76	19.57	1.03	16	8	0.097	18	185
Reference																				
Franklin	**Fr11**	**G19**	37.64	1.41	30.45	1.46	20	10	0.219	42	192	30.53	1.01	42.11	1.66	25	15	0.435	182	418
	Fr21	**G20**	47.82	1.17	47.99	1.23	16	7	0.126	32	254	26.40	1.08	37.21	1.76	16	7	0.170	15	88
Denison	**De7**	**G21**	54.31	1.14	50.30	1.25	18	9	0.300	99	330	36.18	1.03	47.89	1.56	23	13	0.327	92	281
	De35	**D1**	50.33	0.98	45.83	1.03	15	7	0.300	62	207	24.85	1.01	40.57	1.42	14	9	0.203	12	59
Maxwell	**Ma7**	**M1**	47.72	1.16	47.52	1.24	21	16	0.412	166	403	31.78	1.01	39.65	1.52	24	24	0.284	187	658
Jane	**Ja7**	**J1**	47.98	1.13	47.67	1.15	25	14	0.246	197	801	33.79	1.03	44.23	1.57	21	17	0.392	197	503



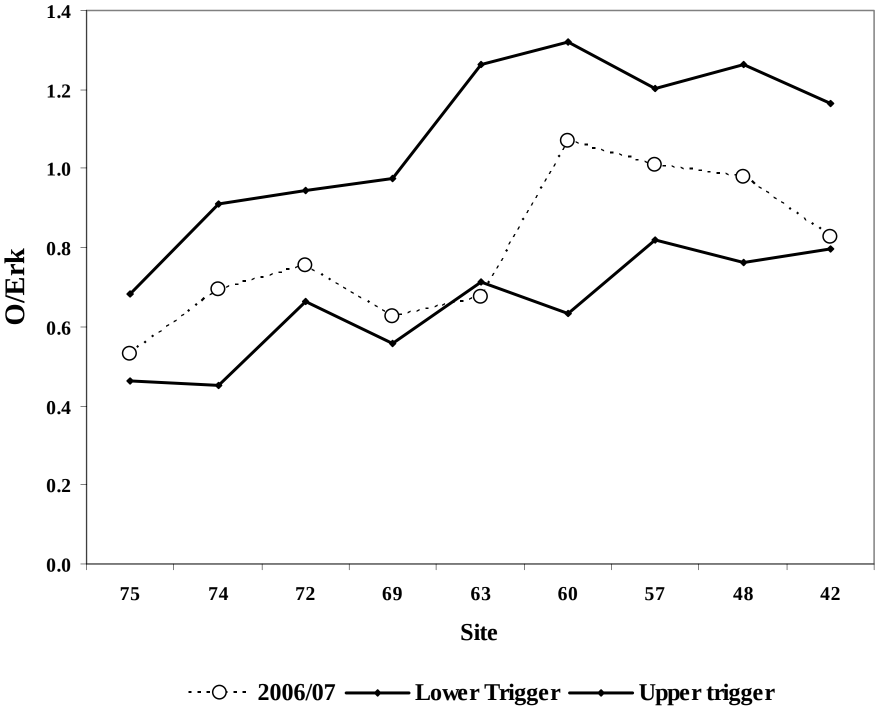
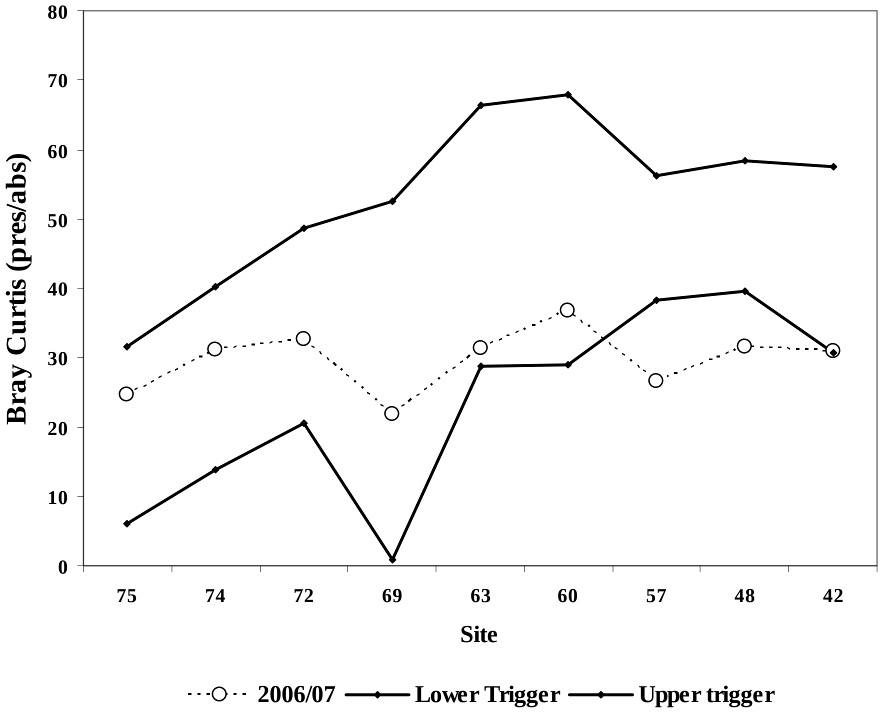


Figure 7-11. Community structure metric values for 2006-07 compared with upper and lower LOAC Trigger values for each site in the Gordon River. Trigger values based on the 95 percentile of pre-Basslink data.



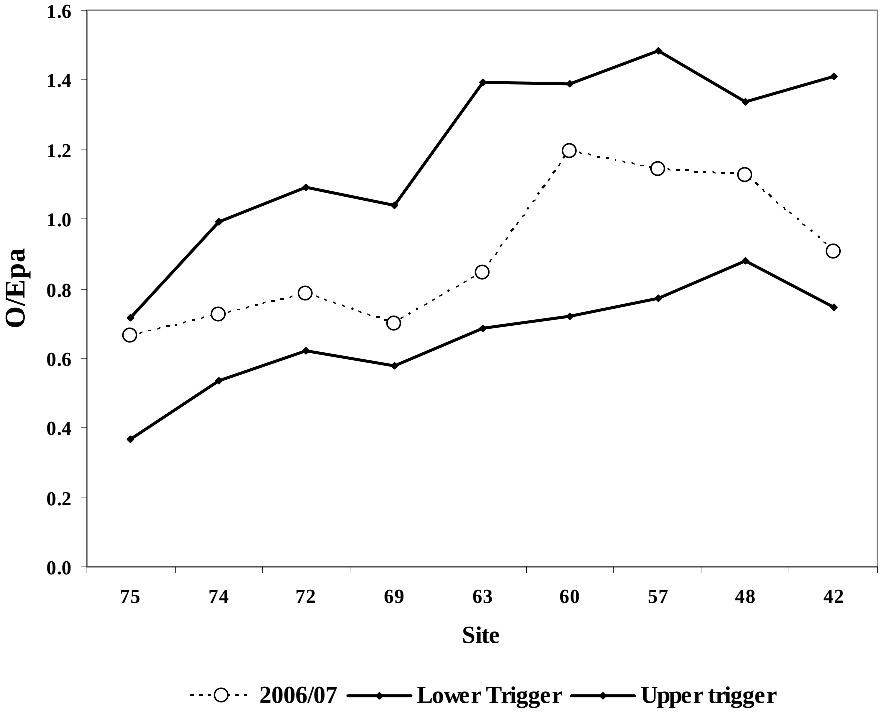
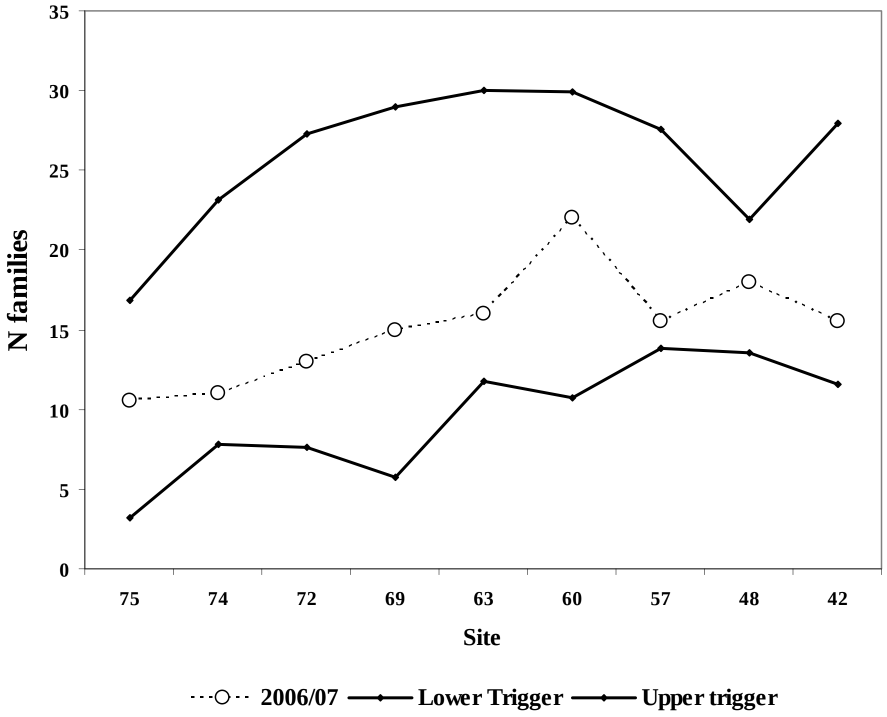


Figure 7-12. Community Composition metric values for 2006-07 compared with upper and lower LOAC Trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data.



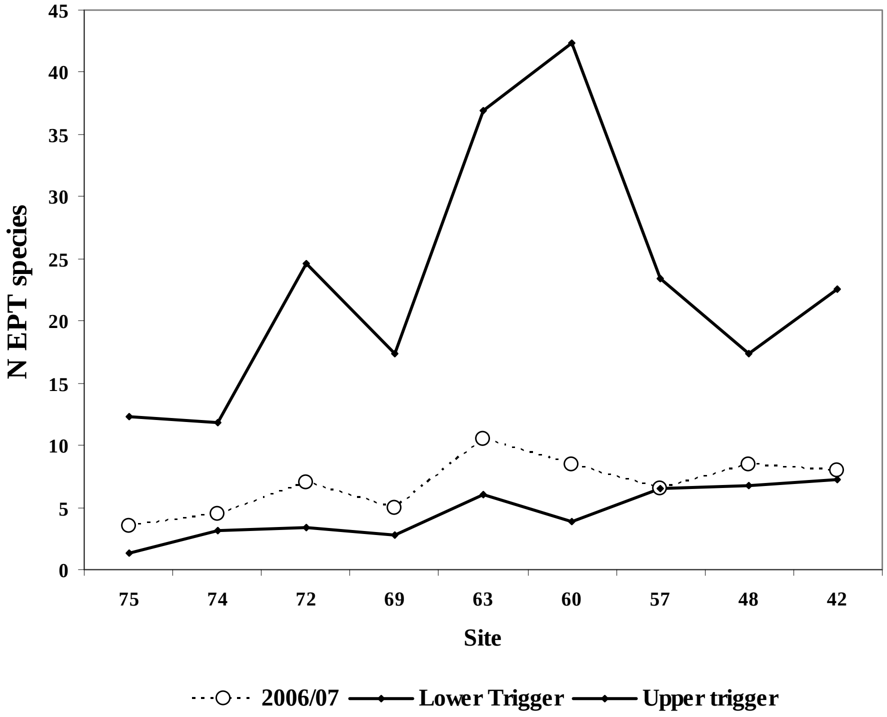
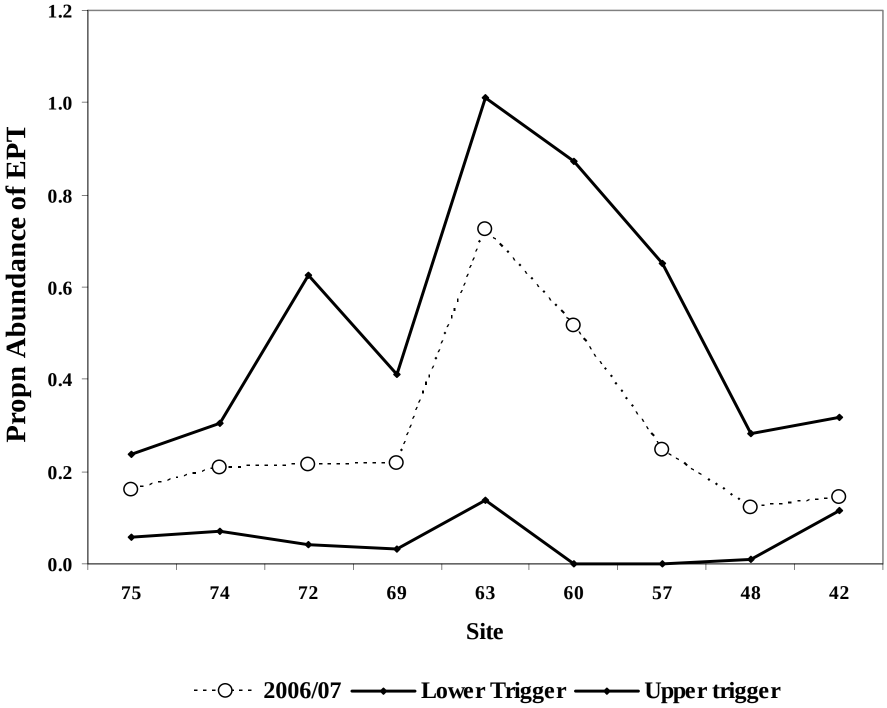


Figure 7-13. Taxonomic Richness (N Taxa (fam)) metric values for 2006-07 compared with upper and lower LOAC Trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data.



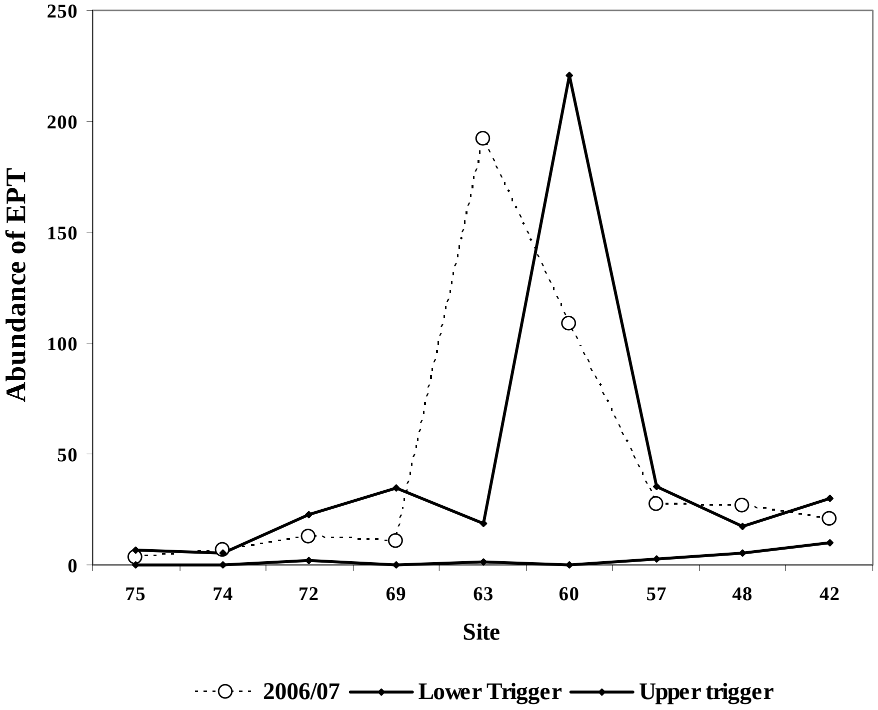


Figure 7-14. Ecologically Signicant Species metric values for 2006-07 compared with upper and lower LOAC Trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data.

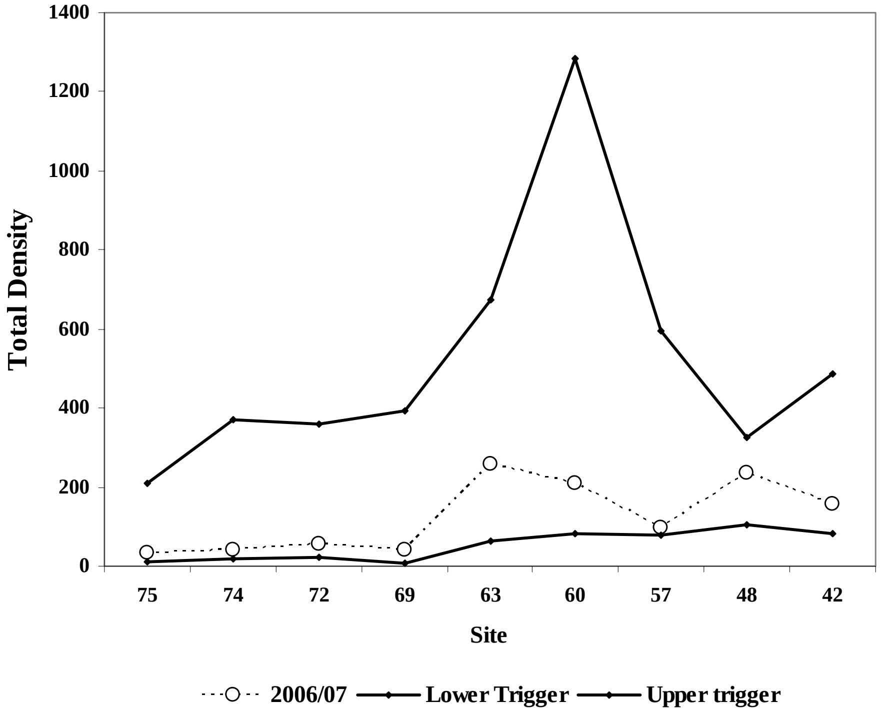
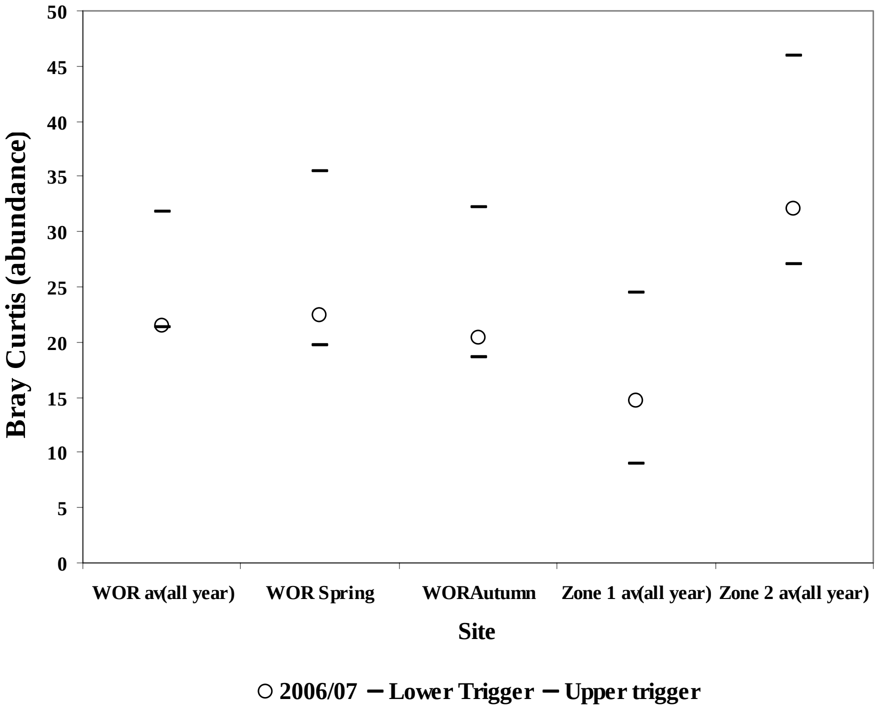


Figure 7-15. Biomass/Productivity metric values for 2006-07 compared with upper and lower LOAC Trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data.



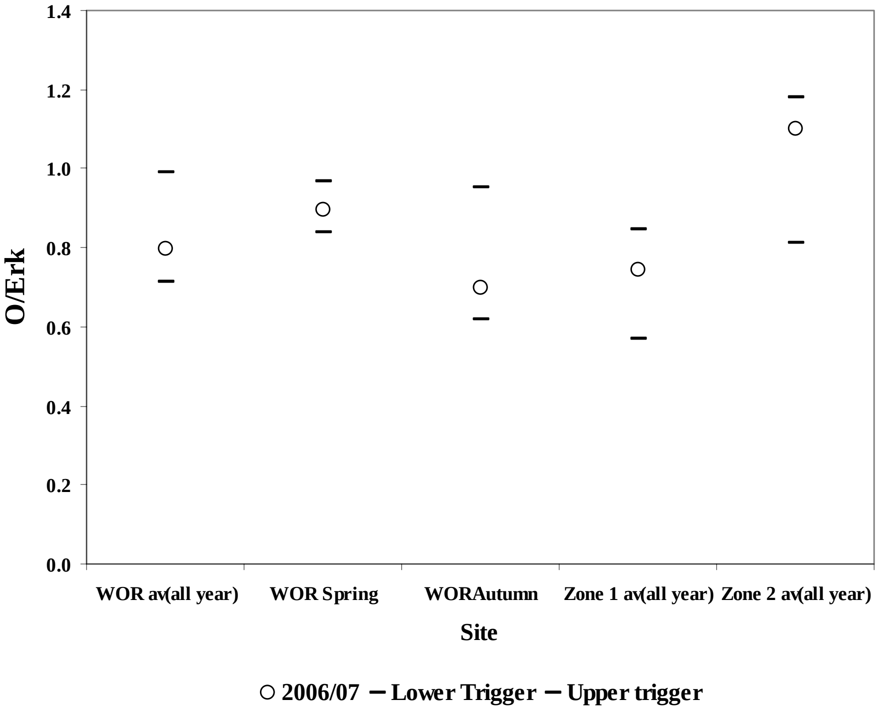
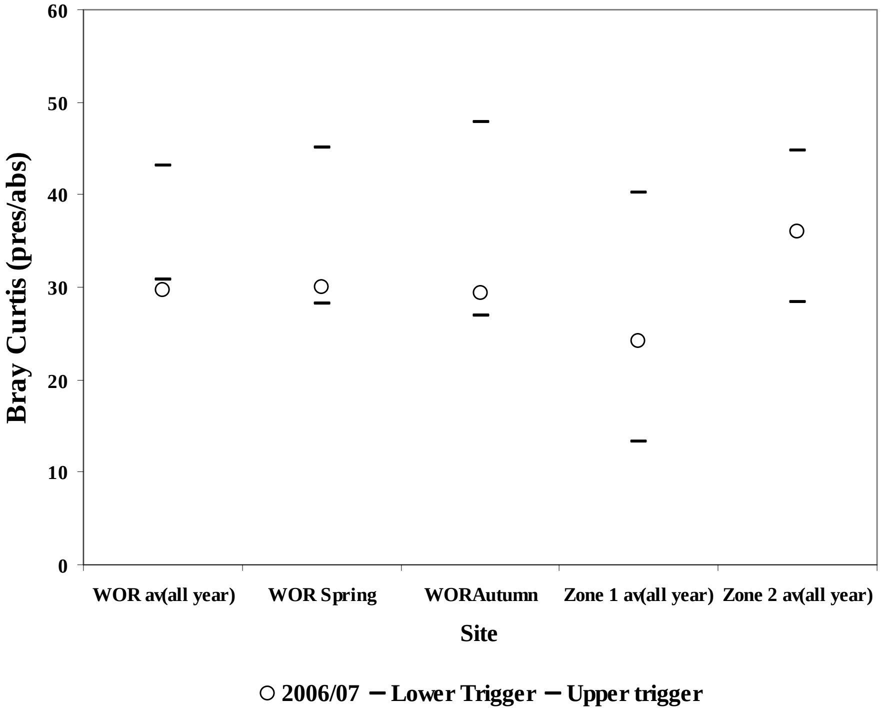


Figure 7-16. Community structure metric values for 2006-07 compared with upper and lower LOAC Trigger values in the Gordon River for the folllowing cases: WOR = Whole of River (by year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data.



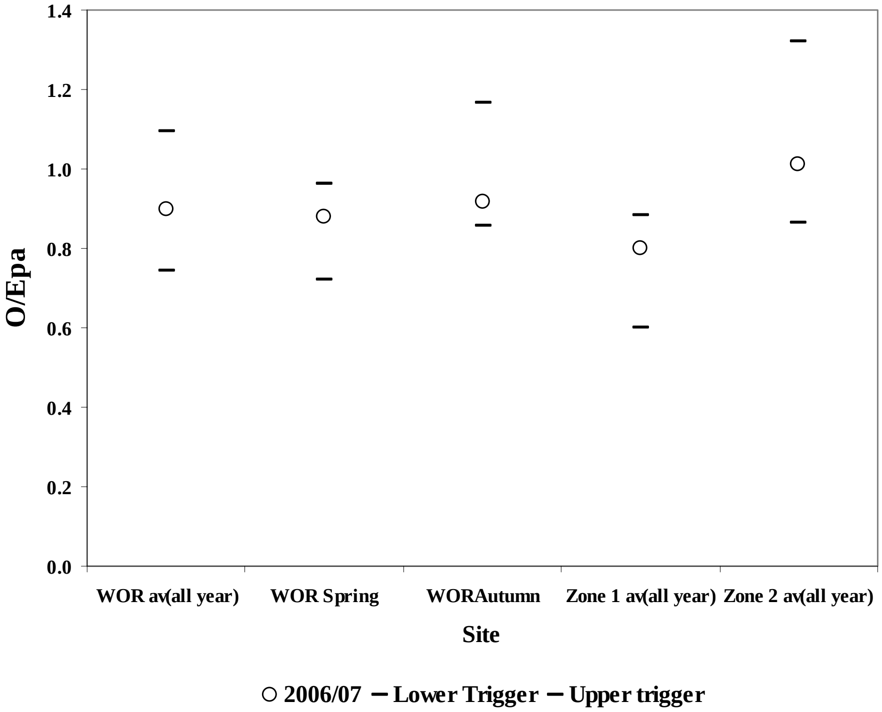
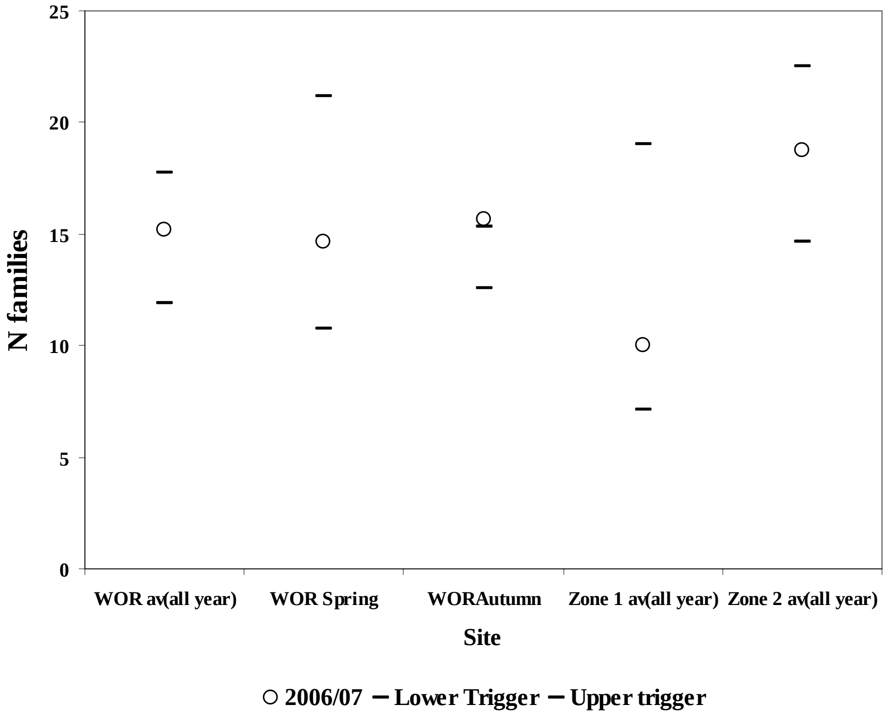


Figure 7-17. Community Composition metric values for 2006-07 compared with upper and lower LOAC Trigger values in the Gordon River for the folllowing cases: Whole of River (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data.



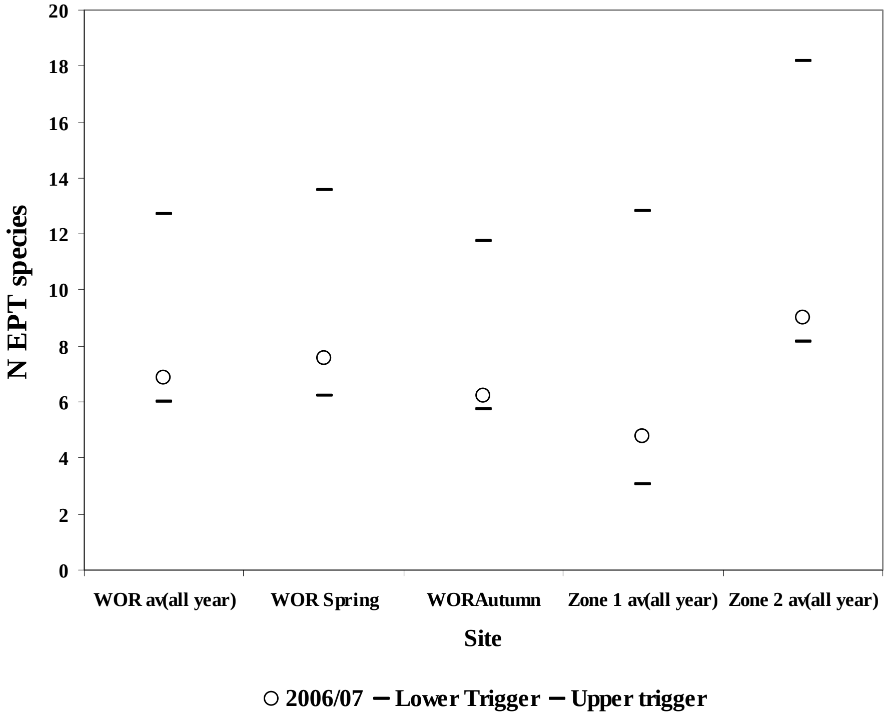
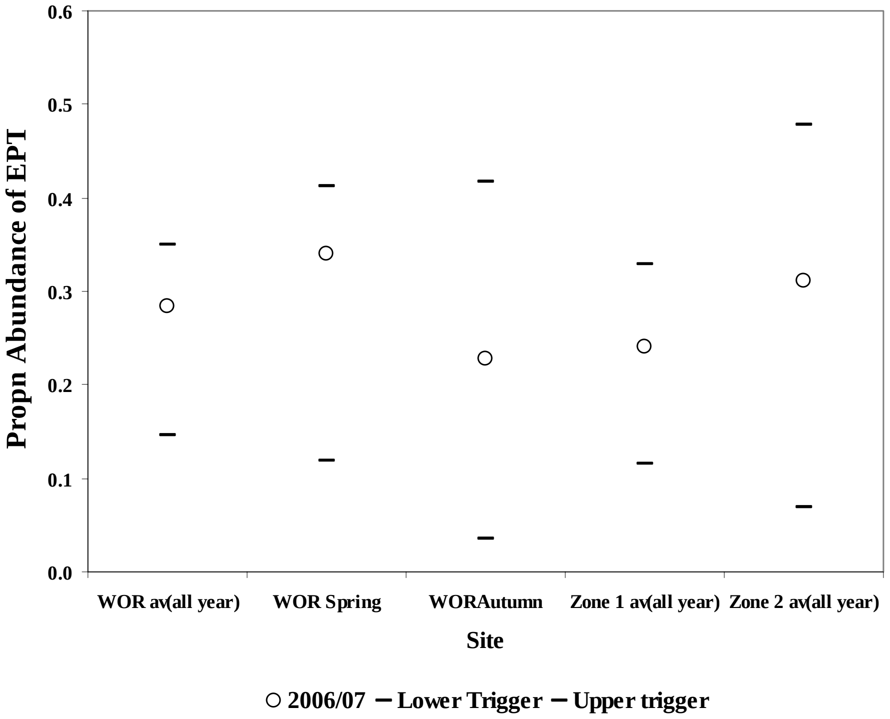


Figure 7-18. Taxonomic Richness metric values for 2006-07 compared with upper and lower LOAC Trigger values in the Gordon River for the folllowing cases: Whole of River (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data.



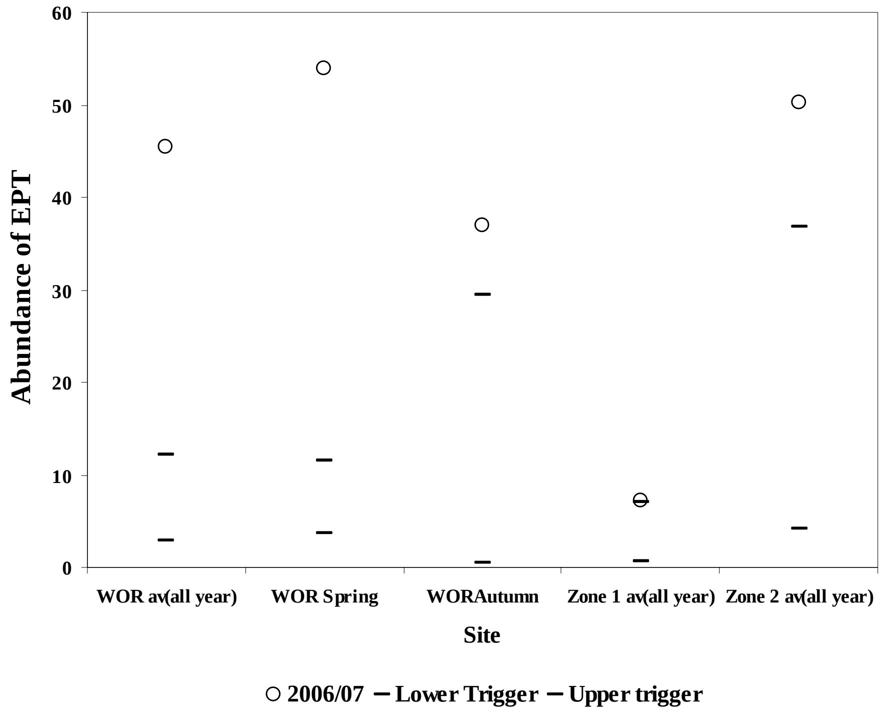


Figure 7-19. Ecologically Signicant Species metric values for 2006-07 compared with upper and lower LOAC Trigger values in the Gordon River for the folllowing cases: Whole of River (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data.

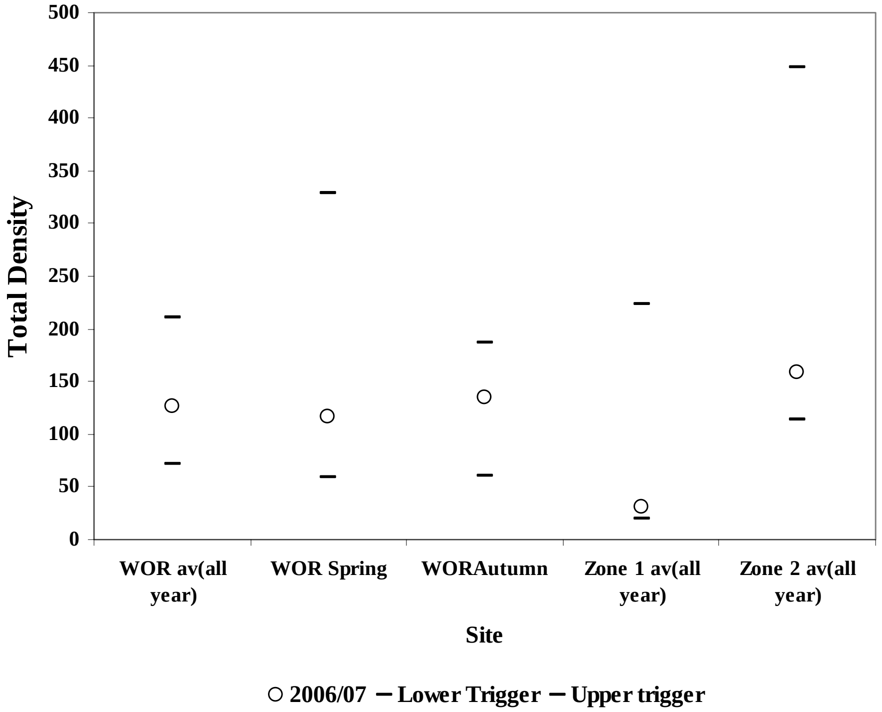


Figure 7-20. Biomass/Productivity metric values for 2006-07 compared with upper and lower LOAC Trigger values in the Gordon River for the folllowing cases: Whole of River (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data.

7.4.2 Trigger status

The following section summarises and comments on the monitoring data collected for 2006-2007 in comparison with the trigger values.

7.4.2.1 Community structure

Bray Curtis (abundance) metric (Figure 7-11) indicates that site 57 is below the trigger bound and sites 63, 48 and 42 are near the lower bound. The whole of river (WOR) comparisons for 2006-07 (all year and both seasons) (Figure 7-16) are all near the lower trigger bound. Observations at reference sites also have reduced similarities to pre-Basslink observations, and indicate that the lower abundance is not related to Basslink operations.

Comment –A level one response ('note and explain') is recommended. The low abundance is likely to be a sampling artefact due to changed river levels just prior to sampling.

O/Erk are within triggers for all sites, except one (site 63) which exhibits a minor excursion of 0.01 units (1.4%) below the trigger value for this site (Figure 7-11). This is not considered to be an ecologically significant excursion.

Comment – This metric was broadly consistent with pre-Basslink conditions.

7.4.2.2 Community composition

Bray Curtis (pres/abs data) metric (Figure 7-12, Figure 7-17) was similar to the Bray Curtis (abundance) metric both for the individual site and WOR comparisons. Specific sites that went below the lower trigger bound were sites 48 and 57.

Comment – A level one response ('note and explain') is recommended. The low values for this measure were likely to be a sampling artefact due to changed river levels just prior to sampling.

O/Epa values were within the triggers at all sites.

Comment – This measure is consistent with pre-Basslink conditions.

7.4.2.3 Taxonomic richness

N Taxa (fam): All sites were within the trigger levels for this metric (Figure 7-13). The N Taxa value for the WOR in autumn fell just above the upper trigger bound (Figure 7-18). This single exceedance is not regarded as a substantial ecological effect, and is likely to be a result of normal variability.

Comment – This metric is broadly consistent with pre-Basslink conditions at this stage.

N EPT Species: All sites were very close to lower trigger bounds, though within the bounds of the trigger levels. This was also the case for the WOR and river zones 1 and 2 (Figure 7-13, Figure 7-18).

Comment – This metric requires a level one response ('note and explain'). It is yet to be determined if post-Basslink operations are influential in the lower NPT species .The lower number of EPT species may be natural, as most reference site values also had relatively low values relative to pre-Basslink conditions (see Figure 3-7). .

7.4.2.4 Ecologically significant species

Proportion of total abundance as EPT: This metric fell well within the trigger levels at all sites, for the whole of river and both river zones (Figure 7-14, Figure 7-19).

Comment – This metric is consistent with pre-Basslink conditions.

Abundance EPT: This metric exceeds triggers for all site and zone combinations, especially zone 2.

Comment – High densities of *Asmicridea* caddis, especially at sites 60 and 63, contribute to this metric. Enhanced densities adjacent to the Denison are a product of high flow constancy combined with food input from the Denison River. This is considered to be a result of sustained two-turbine releases during the summer of 2006-07. It is not considered to be specifically related to Basslink operations.

7.4.2.5 Biomass/productivity

Total abundance: For this metric, the upper sites (75-69), in particular, are close to the lower trigger values (Figure 7-15).

Comment – This may or may not be post-Basslink effect, as the majority of reference sites also have reduced total densities of macroinvertebrates (Figure 3-6), suggesting a degree of natural variation, probably caused by low summer-autumn natural catchment yield. Reductions in values in the Gordon relative to the pre-Basslink period are on average less than that observed in reference sites. A level one response ('note and explain') is required.

7.5 Effectiveness of the minimum environmental flow

The hydrological regime for 2006-07 was characterised by a prolonged period of two-turbine operations characterised by sustained high flows and much lower flow variability than would be anticipated under expected post-Basslink operations. This was largely dictated by the drought conditions state-wide. Flow conditions changed to the expected Basslink operational peaking pattern after macroinvertebrate sampling had been conducted in autumn 2007. The data available for this year therefore do not allow an assessment of the efficacy of the environmental flows to mitigate typical post-Basslink conditions.

7.6 Conclusions

Sampling was conducted successfully according to the requirements of the Gordon River Basslink monitoring program, for all sites. Autumn 2007 sampling was slightly impaired by rapid changes in river level immediately prior to sampling, which is likely to have influenced the value of some derived metric values in reference sites and at Gordon sites downstream of the Denison. Declines in community similarity, diversity and abundance at some of these sites are likely to be artefacts of this event. Otherwise, macroinvertebrate data collected during 2006/07 were consistent with the pattern described in the Gordon river conceptual model.

Overall, trigger compliance was high. Two metrics (number of EPT species, and total abundance) may be showing signs of change associated with post-Basslink operations: However this could also be due to the prevailing drought conditions as these metrics also were low at reference sites. These require a level one response ('note and explain').

High trigger exceedance by elevated densities of EPT species are related to enhanced caddis densities in the Gordon near the Denison confluence, a phenomenon caused primarily by sustained two-turbine flow releases. This is consistent with the known response of the river system to flow regulation caused by Hydro operations, and is not a Basslink related outcome.

Overall patterns of diversity, community composition and abundance derived from quantitative data are similar to those observed previously. Some measures are reduced compared to pre-

Basslink values, lying close to but not below the trigger values. There is no evidence of any significant change due to Basslink operations at this stage.

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8 Benthic algae and moss

8.1 Introduction

Benthic algae, mosses and macrophytes were surveyed in spring (October) 2006 and autumn (March) 2007 in accordance with the requirements of the Basslink Monitoring Program for the Gordon River. Quantitative (quadrat-based) assessment of algal cover was conducted at nine 'monitoring' sites in the Gordon River (see Map 8-1) between the power station and the Franklin confluence. Three reference sites are also routinely sampled.

This constitutes year one (2006-07) of the post-Basslink phase of algal monitoring being conducted in the Gordon River catchment.

Benthic algae and moss are a key aquatic ecological component of the Gordon River, providing habitat for macroinvertebrate taxa, interacting with food resources for macroinvertebrates, and showing marked responses to changes in flow conditions.

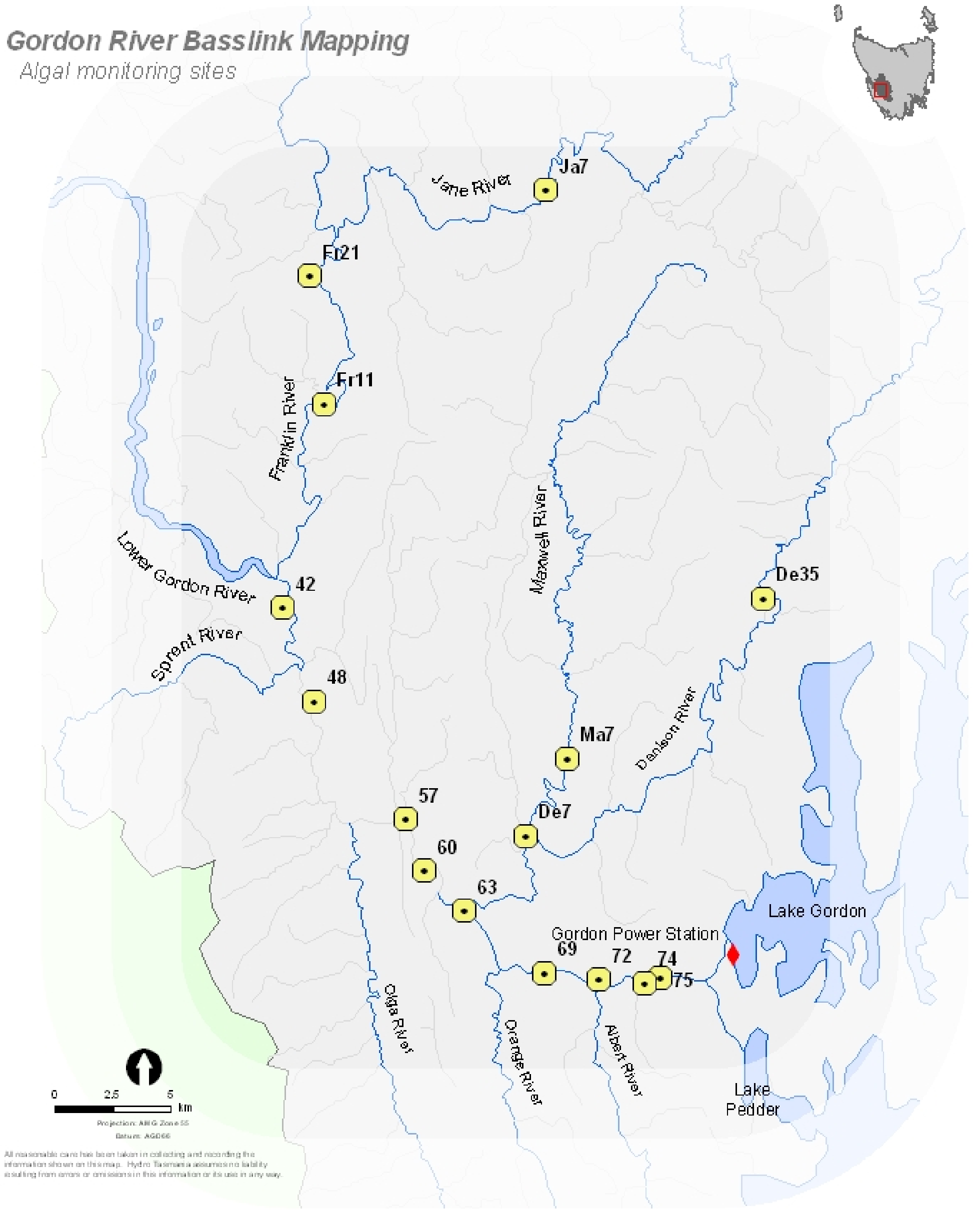
This algal and moss monitoring in the middle Gordon River has three primary objectives:

1. documenting biological changes resulting from changes to flow management;
2. assessing compliance with biological management targets or objectives; and
3. along with other environmental data, providing core data for adaptive environmental management.

8.2 Methods

8.2.1 Sample sites

Survey sites were the same as for the Basslink benthic macroinvertebrate monitoring, as shown in Table 8-1 and Map 8-1. None of the reference sites could not be sampled due to logistical and time constraints imposed on sampling in autumn 2007.



Map 8-1. Map of the algal monitoring sites in the Gordon River and reference sites

8.2.2 Benthic algal survey

8.2.2.1 Gordon River

All algal assessments at Gordon river sites was conducted by measuring percentage area of cover at fixed distances along existing transects across the river, with one transect assessed at each site.

All Gordon River monitoring data were collected as follows:

- transects were re-established, perpendicular to the direction of river flow, by running a measuring tape across the river from the existing transect head-peg (which was designated as the zero distance offset) to a fixed peg on the opposite bank;
- algal density, as % cover, was recorded using a 30cm x 30cm quadrat at 2.5m intervals in three locations – 1m upstream of the transect line, on the transect line, and 1m downstream of the transect lines; and
- within each quadrat, density was reported for four broad floristic groups – filamentous algae, characeous algae, moss and macrophytes.

The transect was also divided into broadly similar ‘zones’, characterised by consistency of benthic substrate composition. Zones were defined following visual inspection of the channel substrate, and defined in terms of their dominant substrate composition, eg: cobble/gravel, sand/silt, sand/snags, bedrock, etc.

Scrapes of filamentous algae/moss were taken from the upper surface of boulder/cobbles in the centre of each zone at each site on all sampling occasions. All scrapes were pooled, resulting in a single, composite and representative sample of the dominant benthic species present within each zone. These samples were preserved in 10% formalin for later identification.

8.2.2.2 Reference sites

At each of the three reference sites (Fr11, Fr21, De7), plant cover was assessed at 30 randomly chosen locations across the channel on the dominant substrate (typically cobbles and boulders) using the same quadrat procedure described above. Data comparability between these sample sets and those for the Gordon River is therefore restricted to filamentous algae only.

Table 8-1. Sites sampled in 2006-07 for algae, moss and macrophytes

River	Site code	Site name (old code)	Easting (GDA 94)	Northing (GDA 94)
Gordon	75	Gordon R d/s Albert Gorge (G4)	412980	5266630
	74	Gordon R d/s Piguenit R (G4A)	412311	5266383
	72	Gordon R in Albert Gorge (G5)	410355	5266524
	69	Gordon R u/s Second Split (G6)	408005	5266815
	63	Gordon R u/s Denison R (G7)	404584	5269469
	60	Gordon R d/s Denison R (G9)	402896	5271211
	57	Gordon R u/s Smith R (G10)	402083	5273405
	48	Gordon R d/s Olga R (G11b)	398450	5277275
	42	Gordon R @ Devil's Teapot (G15)	396804	5282486
Reference sites:				
Franklin	Fr11	Franklin R d/s Blackman's bend (G19)	398562	5291239
	Fr21	Franklin R @ Flat Is (G20)	397939	5296733
Denison	De7	Denison d/s Maxwell R (G21)	407206	5272718

8.2.3 Analysis

Plant cover scores were derived, and presented in tabular and graphical formats. The indicators were assessed against triggers by direct comparison of relevant individual values at site scale and mean values at whole of river and zone scales, as appropriate. Derived values for spring and autumn seasons were also presented in plots along with the relevant trigger values.

8.3 Results

8.3.1 Spring 2006 results

Surveys were successfully completed across the entire river channel for sites 75, 74, 72, 69 and 63. The presence of deep, fast water prevented survey across the entire channel for sites 60, 57, 48 and 42. An average 59m of river bed was surveyed across all sites, ranging between 39.5 and 82.5m.

Data from surveys are summarised in Table 8-2. Aquatic flora in the Gordon River had a consistently low to moderate cover across all sites, as in previous years. Moss and filamentous algae were again the dominant forms, and had low to moderate overall mean percentage cover across all sites (0 - 21% of benthic area combined). Macrophytes only occurred at site 72, with both *Callitriche* sp. (starworts) and *Isolepis fluitans* observed at low density.

Filamentous algal cover in the reference river samples was very low (less than the detection limit of 0.1%) for all sites.

Table 8-2. Summary cover data for algae, moss and macrophytes surveyed in spring 2006 for Gordon, Franklin and Denison River sites.

Site		**Mean % cover**				**Width surveyed (m)**
		Moss	**Filamentous algae**	**Nitella/Chara**	**Macrophytes**	
Gordon						
75	G4	3.81	2.56	0	0	67.5
74	G4A	10.97	21.01	0	0	65
72	G5	0.78	0.09	0.55	1.37	82.5
69	G6	0.17	0.74	0	0	39.5
63	G7	3.41	0	0	0	72.5
60*	G9	1.37	0	0	0	67.5
57*	G10	0.56	0	0	0	40
48*	G11B	1.70	0.05	0	0	55
42*	G15	0.38	0.42	0	0	37.5
Reference						
Fr11	G19	0	0	0	0	
Fr21	G20	0	0	0	0	
De7	G21	0	0	0	0	

** indicates transects for which only part of the channel could be surveyed. Total distances surveyed from the transect head pegs are indicated.*

8.3.2 Autumn 2007 results

Surveys were successfully completed across the entire river channel for sites 75, 74, 72, 69 and 63. The presence of deep, fast water prevented survey across the entire channel for sites 60, 57, 48 and 42, and references sites could not be sampled. An average 65m of river bed was surveyed across all sites, ranging between 37.5 and 87.5m.

Data from surveys are summarised in Table 8-3. Aquatic flora in the Gordon River had a consistently low to moderate cover across all sites, consistently lower than in spring (as in pre-Basslink years). Moss and filamentous algae were again the dominant forms, and had low to moderate overall mean % cover across all sites (0 - 5% of benthic area combined). Macrophytes only occurred at site 72, with both *Callitriche* sp. (starworts) and *Isolepis fluitans* observed at low density.

Table 8-3. Summary cover data for algae, moss and macrophytes surveyed in autumn 2007 for Gordon River sites.

Site		Mean % cover				Width surveyed (m)
		Moss	Filamentous algae	Nitella/Chara	Macrophytes	
Gordon						
75	G4	1.64	5.35	0	0	67.5
74	G4A	5.17	1.85	0	0	62.5
72	G5	0.04	0.68	0.03	0.14	80
69	G6	5.47	0.26	0	0	80
63	G7	2.06	0	0	0.12	72.5
60*	G9	0.86	0	0	0	87.5
57*	G10	0.00	0	0	0	47.5
48*	G11B	1.20	0.17	0	0	50
42*	G15	0.90	0.31	0	0	37.5
Reference						
Fr11	G19	No data available				
Fr21	G20					
De7	G21					
* indicates transects for which only part of the channel could be surveyed. Total distances surveyed from the transect head pegs are indicated.						

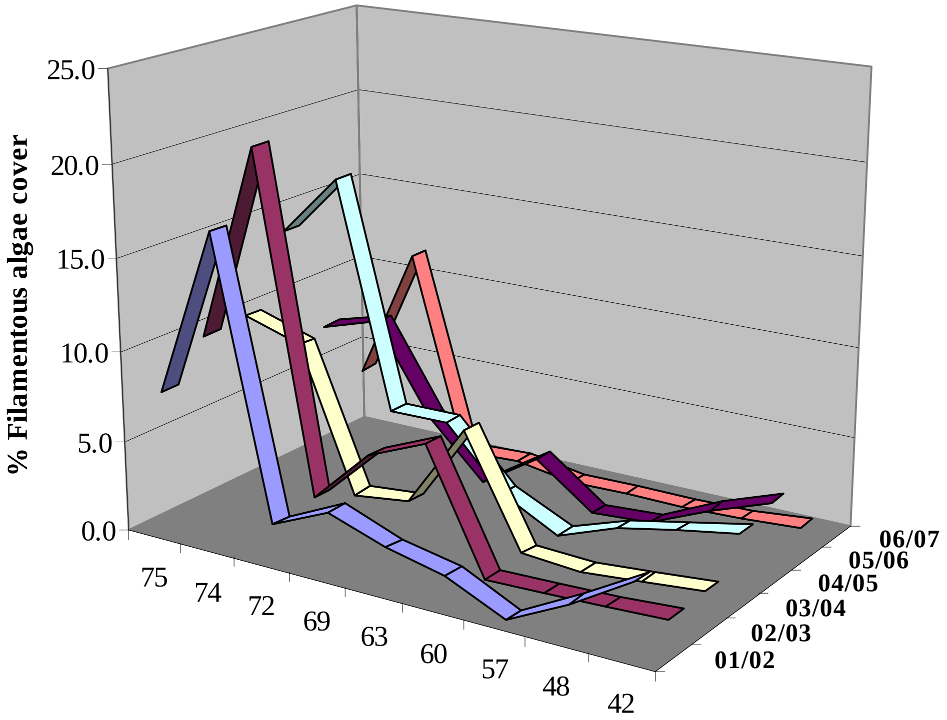
8.3.3 Comparison with previous years

Overall mean percent cover for moss and filamentous algae are shown for all sites for each year (as means across each transect over the two seasonal sampling occasions), in Table 8-4. There was no significant difference in percentage cover of either moss or filamentous algae, between 2006-07 and pre-Basslink years. Plots of the downstream trends in annual mean of moss and filamentous algae for all five years 2001-02 to 2006-07 are shown in Figure 8-1.

The pattern and mean percent cover for both moss and filamentous algae in 2006-07 were broadly similar to previous years. Filamentous algal levels were particularly low downstream of the Denison confluence (see sites 42 – 63, Figure 8-1). Reduced algal levels are an anticipated effect of sustained minimum environmental flows post-Basslink (see Basslink Baseline Report conceptual model). There were however, no statistically significant differences between 2006-07 data and the mean of previous years (by paired t-test, with pairing by site, $p > 0.1$).

Table 8-4. Annual mean % cover for moss and filamentous algae at all transects in 2001-02 to 2006-07 in the lower Gordon River

Site	01-02 mean		02-03 mean		03-04 mean		04-05 mean		05-06 mean		06-07 mean	
	Moss	**Filamentous**	**Moss**	**Filamentous**	**Moss**	**Filamentous**	**Moss**	**Filamentous**	**Moss**	**Filamentous**	**Moss**	**Filamentous**
75	6.09	7.79	2.07	9.88	21.09	10.10	4.91	13.99	1.94	7.61	2.73	3.96
74	10.63	17.00	8.16	20.73	6.18	9.08	12.62	17.43	8.63	8.49	8.07	11.43
72	0.14	1.86	1.06	2.18	0.07	1.18	0.54	4.87	0.06	3.52	0.41	0.38
69	8.50	3.35	3.42	5.28	1.64	1.56	0.76	4.95	1.54	0.33	2.82	0.50
63	1.05	2.19	2.46	6.59	2.15	6.31	2.14	1.55	0.50	2.48	2.73	0.00
60	0.33	1.51	0.13	0.03	0.98	0.18	1.98	0.00	1.63	0.09	1.12	0.00
57	0.80	0.01	0.25	0.09	0.75	0.00	0.25	1.20	0.64	0.26	0.28	0.00
48	2.84	1.72	0.54	0.26	0.87	0.32	1.59	1.84	0.25	1.76	1.45	0.11
42	3.10	3.72	0.06	0.44	0.62	0.67	0.41	2.50	2.08	2.96	0.64	0.37
Grand Mean	3.72	4.35	2.01	5.05	1.71	3.27	2.80	5.37	1.92	3.06	2.25	1.86
Mean u/s Denison	5.28	6.44	3.43	8.93	2.43	5.65	4.19	8.56	2.53	4.49	3.35	3.25
Mean d/s Denison	1.77	1.74	0.24	0.21	0.81	0.29	1.06	1.38	1.15	1.27	0.87	0.12



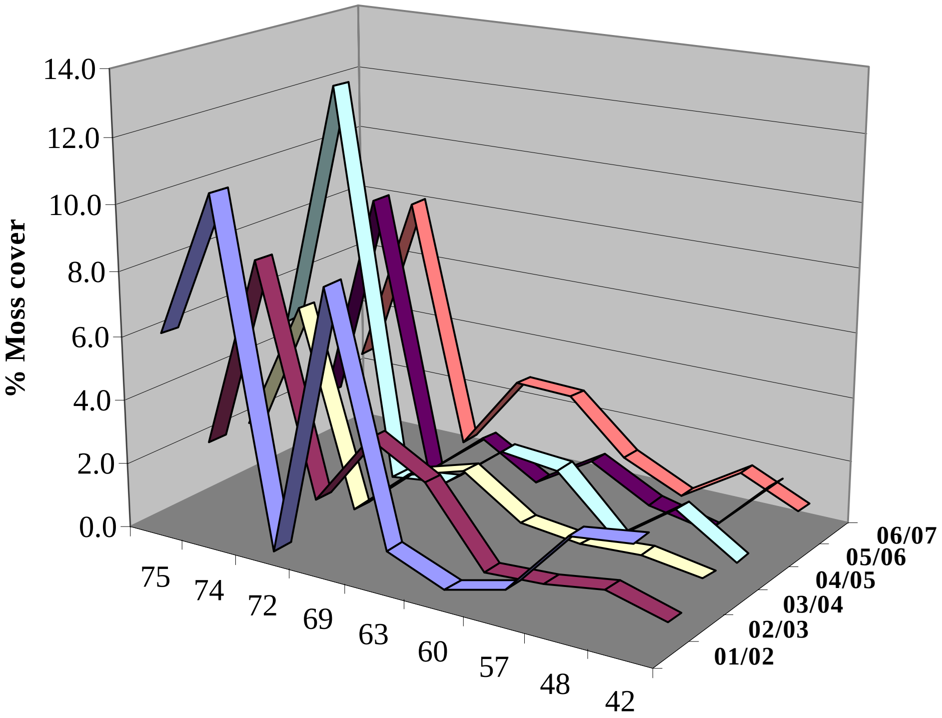


Figure 8-1. Downstream trends in mean % moss cover and mean % filamentous algal cover in the Gordon during the pre-Basslink period (2001-02, 02-03, 03-04, 04-05), the transitional period (2005-06) and the first year of the post-Basslink period (2006-07).

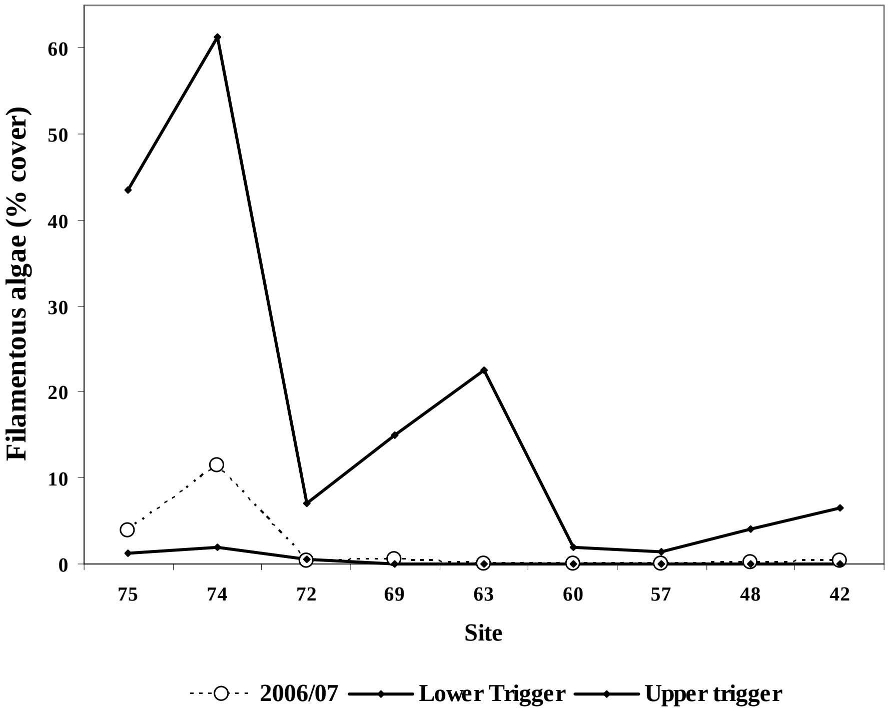
8.4 Comparisons with triggers

8.4.1 Results

Two metrics have been identified for assessing the degree of any changes in benthic plants in the Gordon River due to Basslink operations - percentage cover of filamentous algae and percentage cover of moss.

Trigger values for these metrics have been established based on the 95th percentile of pre-Basslink values (Hydro Tasmania, 2006). These trigger values are used in reporting on whether Limits of Acceptable Change (LOAC) have been exceeded or not post-Basslink. Values are shown in Appendix 8. 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 whole of river case. Two zones have been described for algae and moss – 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 these metrics for 2006-07 are shown in Table 8-2 and Table 8-3. Plots of the trigger levels for each metric are shown below compared with the value for the metric recorded in 2006-07, at individual site level (Figure 8-2) and at whole of river (WOR) and zone level (Figure 8-3).



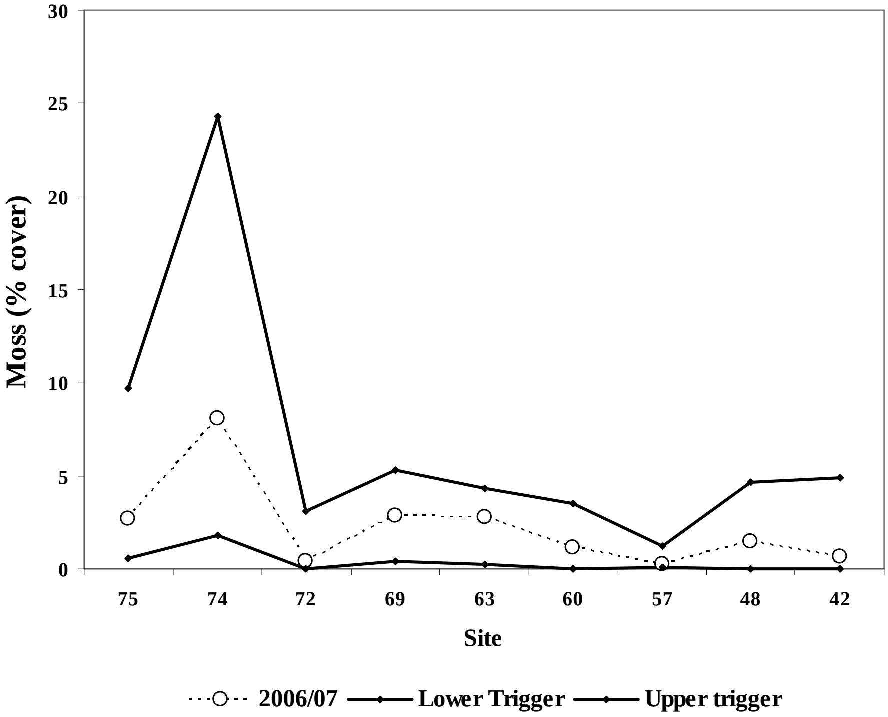
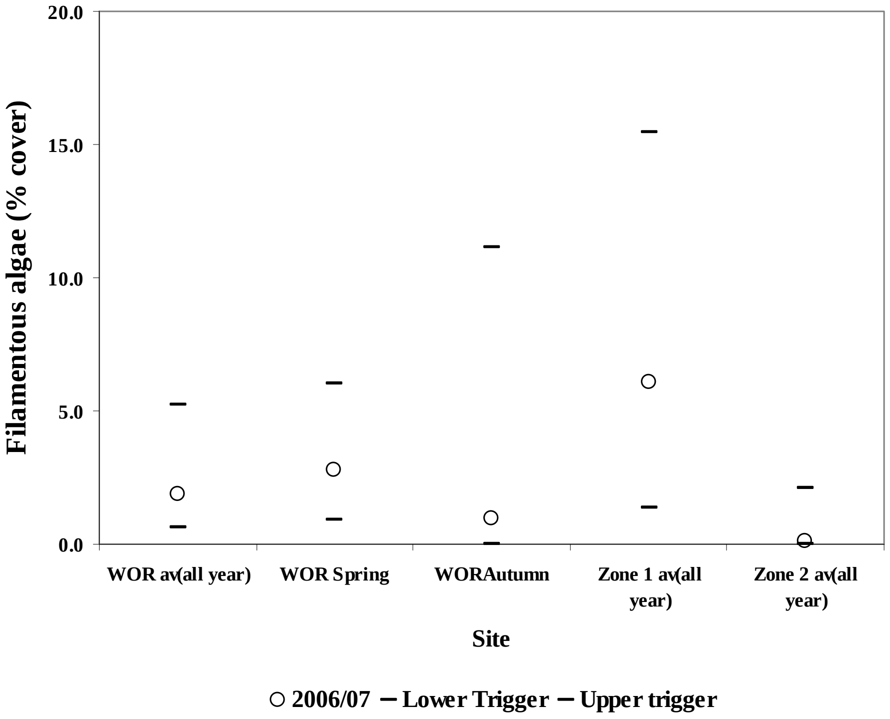


Figure 8-2. Percent cover of benthic filamentous algae and moss for 2006-07 compared with upper and lower Trigger value bound for each site in the Gordon River. Trigger values are based on the 95th percentile of pre-Basslink data.



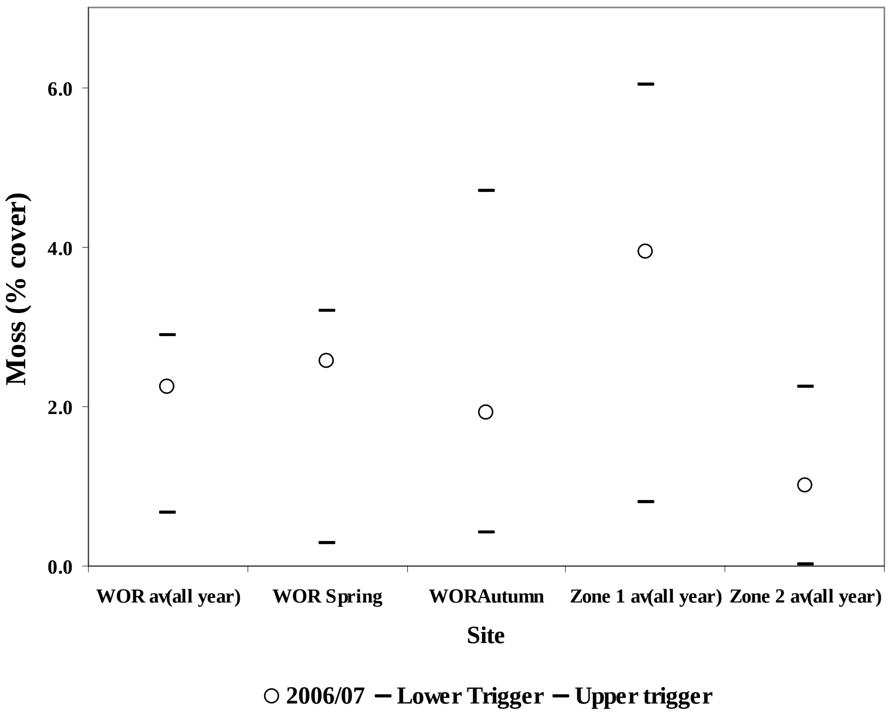


Figure 8-3. Percent cover of benthic filamentous algae and moss for 2006-07 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: Whole of River (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data.

8.4.2 Trigger status

The following section summarises and comments on the observations for 2006-07 in comparison with the trigger values.

8.4.2.1 Filamentous algal cover

Percent cover values in 2006-07 at all sites downstream of site 72 in zone 1 and for all zone sites 2 (downstream of Denison) fall at or close to the lower trigger bound. This is the expected response to the sustained period of two-turbine flows (around 160 cumec) which occurred for approximately four months prior to sampling being completed in autumn 2007. Sustained high flows are associated with low light levels on the river bed, which is the primary cause of low benthic algal cover.

Comment – these results are consistent with pre-Basslink conditions, though sustained two-turbine releases led to low values.

8.4.2.2 Moss cover

All cover values fall within trigger bounds.

Comment – these results are consistent with pre-Basslink conditions.

8.5 Effectiveness of the minimum environmental flow

The hydrological regime for 2006-07 was characterised by a prolonged period of two-turbine operations characterised by sustained high flows and much lower flow variability than would be anticipated under expected post-Basslink operations. This was largely dictated by the drought conditions state-wide. Flow conditions changed to the expected Basslink operational peaking pattern after algal sampling had been conducted in autumn 2007. The data available for this year therefore do not allow an assessment of the efficacy of the environmental flows to mitigate typical post-Basslink conditions. Low levels of benthic filamentous algae are typical of the reference streams, and the occurrence of low levels in 2006-07 from site 72 downstream, in response to sustained two-turbine flows, is consistent with behaviour described in the Gordon River conceptual model.

8.6 Conclusions

Spring 2006 and autumn 2007 constitute the first full year of the post-Basslink monitoring period.

Sampling was conducted successfully according to the requirements of the Gordon River Basslink monitoring program, for all sites. Autumn 2007 sampling was slightly impaired by sampling scheduling restrictions which gave insufficient time for algal and moss cover to be measured at reference sites.

As in the pre-Basslink period, aquatic plant cover was low in the Gordon River.

Moss cover was very low downstream of the Denison River confluence, as observed previously. Values fell within trigger level bounds. Filamentous algal levels were low, as usual higher in spring than in autumn, broadly consistent in magnitudes and trends of cover with pre-Basslink years.

Particularly low algal levels were observed downstream of site 74, falling at or close to the lower trigger levels. This is believed to be due to the period of sustained two-turbine flows and the resulting low benthic light levels.

There has been no change in aquatic flora that could be ascribed to the operations of Basslink at this stage.

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9 Fish

9.1 Introduction

The aims of the fish monitoring program are to:

- monitor relative abundance of fish in the middle Gordon River and assess whether there is a significant change due to altered hydrological conditions under Basslink operations.
- assess potential changes in the longitudinal fish community structure of the Gordon River with the aim of identifying any changes in the zone of influence;
- determine any changes to the fish populations of affected tributaries, in particular, if recruitment success for juvenile galaxiids is changed under Basslink.

This report summarises the results of the first year of the post-Basslink fish monitoring surveys, which were undertaken in December 2006 and April-May 2007.

9.2 Methods

The 2006-07 monitoring surveys were conducted on 7-10 December 2006, and the autumn surveys took place on 17-18 April and 12-13 May 2007. The autumn surveys could not be completed over the usual consecutive four day trip in April due to extremely low inflows and lake levels throughout the Hydro Tasmania generation system resulting in increased reliance on the Gordon Power Station. The monitoring outage for Gordon Power Station was delayed until rainfall and inflows across several catchments enabled other stations to produce sufficient power to compensate for the Gordon outage.

Ten previous monitoring surveys have been completed prior to the 2006-07 sampling round. These were conducted in December 2001, April 2002, December 2002, March 2003, November 2003, April 2004, December 2004, April 2005, December 2005 and April 2006.

As per previous surveys, 31 Gordon catchment monitoring sites were scheduled for sampling on each occasion. Map 9-1 shows the location the Gordon catchment monitoring zones, and these sites are listed in Table 9-1. The rationale behind the zone allocations is discussed in Howland *et. al* (2001). Seven river and four tributary reference sites were scheduled for sampling in conjunction with the monitoring sites, and these reference sites are listed in Table 9-2.

The Fish monitoring zones are defined a follows:

- Zone 1: Gordon River and tributaries from Gordon Dam downstream to, and inclusive of, Abel Gorge;

- Zone 2: Gordon River and tributaries from Albert River downstream to, and inclusive of, the First Split;
- Zone 3: Gordon River and tributaries from Orange River downstream to Sunshine Falls;
- Zone 4: Gordon River and tributaries from Sunshine Falls to the Sprent River;
- Zone 5: Gordon River from Angel Cliffs downstream to Big Eddy;
- Zone 7: Franklin River between Pyramid Island and Big Fall;
- Zone 8: Franklin River and tributaries upstream of Big Fall;
- Zone 9: Birches Inlet catchment;
- Zone 13 Henty River at or downstream of the Yolande River; and
- Zone 14 Henty River upstream of the Yolande River.

Map 9-1. Fish monitoring sites and zones in the Gordon River (1-5), Franklin River (7-8), Birches Inlet (9) and Henty River (13-14)

Table 9-1. Gordon catchment monitoring sites. Alternative site names are shown in parenthesis. * indicates a change to the original site list, see text for explanation.

Zone	River Sites	Tributary Sites
1	75 (G4), 74 (G4a), 73 (G3 u/s and d/s)	Left bank Creek @ site 75*, Indigo Creek, Piguenit Rivulet
2	72 (G5 upper and lower), 71 (G5a pipe and water meter) and 69 (G6)	Albert River, Splits Creek and Mudback Creek
3	68 (G6a), 63 (G7) and 57 (G16)	Smith River and Harrison Creek, Denison River u/s Gorge, Denison River @ Maxwell, Orange River*
4	54 (Howards Creek), 51 (Platypus Creek), 46 (Gordon u/s Sprent)	Howards Creek, Olga River, Platypus Creek and Sprent River
5	45 (Gordon d/s Sprent), 44 (G14), 42 (G15)	Franklin @ Pyramid Island

Table 9-2. Reference monitoring sites

Zone (catchment)	River sites	Tributary sites
7 (Franklin)	Franklin d/s Big Fall	none
8 (Franklin)	Franklin u/s Big Fall Franklin @ Canoe Bar	Forester Creek, Ari Creek, Wattle Camp Creek
9 (Birches Inlet)	Sorell River	Pocacker River
13 (Henty)	Henty u/s Bottle Creek Henty @ Yolande River	None recommended
14 (Henty)	Henty @ Sisters	None recommended

‘Optional’ sites, listed in Table 9-3, were included in the monitoring regime and consisted of 11 monitoring and three reference sites that were located in both Gordon River tributaries and out of catchment rivers. These sites were included to provide additional data for the monitoring program in the event of failure to sample some of the core sites. ‘Optional’ sites were sampled if time and logistics permitted it, however core sites took priority in the sampling regime.

All of the essential sites and ten optional sites were monitored during summer 2006, and eleven optional sites were fished in autumn.

Several changes have been made to the monitoring site classifications. The Orange River monitoring site was originally classified as optional, but was reclassified as essential to replace the Denison u/s Maxwell site, which had to be abandoned due to ongoing access difficulties. The Serpentine River site was removed from the sampling program and replaced by Left bank Creek @ G4 due to ongoing safety concerns due to the risk of slip or fall related injuries at this site.

Table 9-3. Optional sites surveyed during the monitoring program. Alternative site names are shown in parenthesis.

Zone	River Sites	Tributary Sites
1	76 (G2)	none
2	Gordon @ Grotto Creek	Grotto Creek
3	Site 60 (G9), Gordon @ G8, Gordon @ Fluffies	Denison @ Denison Camp
4	none	Howards Creek inundation, Olga @ riffles
5	Gordon @ Angel Cliffs	none
8 (Franklin)	Franklin @ Forester Creek, Franklin @ Wattle Camp Creek	none
14 (Henty)	Henty @ West Sister	none

Fish surveys were undertaken by backpack electrofishing, following the methods detailed in Howland *et al.* (2001). Surveys of the Gordon monitoring sites were conducted by three, two-person teams, with a target electrofishing effort of 1200 seconds shocking time for each site. Gordon catchment tributary sites situated outside the power station zone of influence were sampled by two teams, and a single team sampled the out of catchment reference sites.

Fish teams sampled a range of representative habitats at each site. Fish were identified, counted and fork lengths were recorded to the nearest mm. Qualitative assessments of general aquatic habitat descriptors were recorded for each site.

9.3 Results and discussion

9.3.1 Exotic species

9.3.1.1 Trout (Salmoniidae)

Figure 9-1 shows brown trout catches in the Gordon River and tributaries between the start of the monitoring program in December 2001 and the last survey which was completed in May 2007. As per previous surveys, the summer catch per unit effort (CPUE) results tend to be higher and more variable than autumn catches. Autumn catches in zones 2-4 were significantly below previous autumn means for these zones, resulting in an exceedance of trigger levels associated with changes in exotic fish relative abundance in the Gordon River monitoring zones (see section 9.4). Length frequency histograms of size structure in the Gordon River during 2006-07 showed evidence of an autumn decline in numbers across the majority of size classes. Possible factors contributing to the observed decline in brown trout relative abundance are discussed in section 9.4.

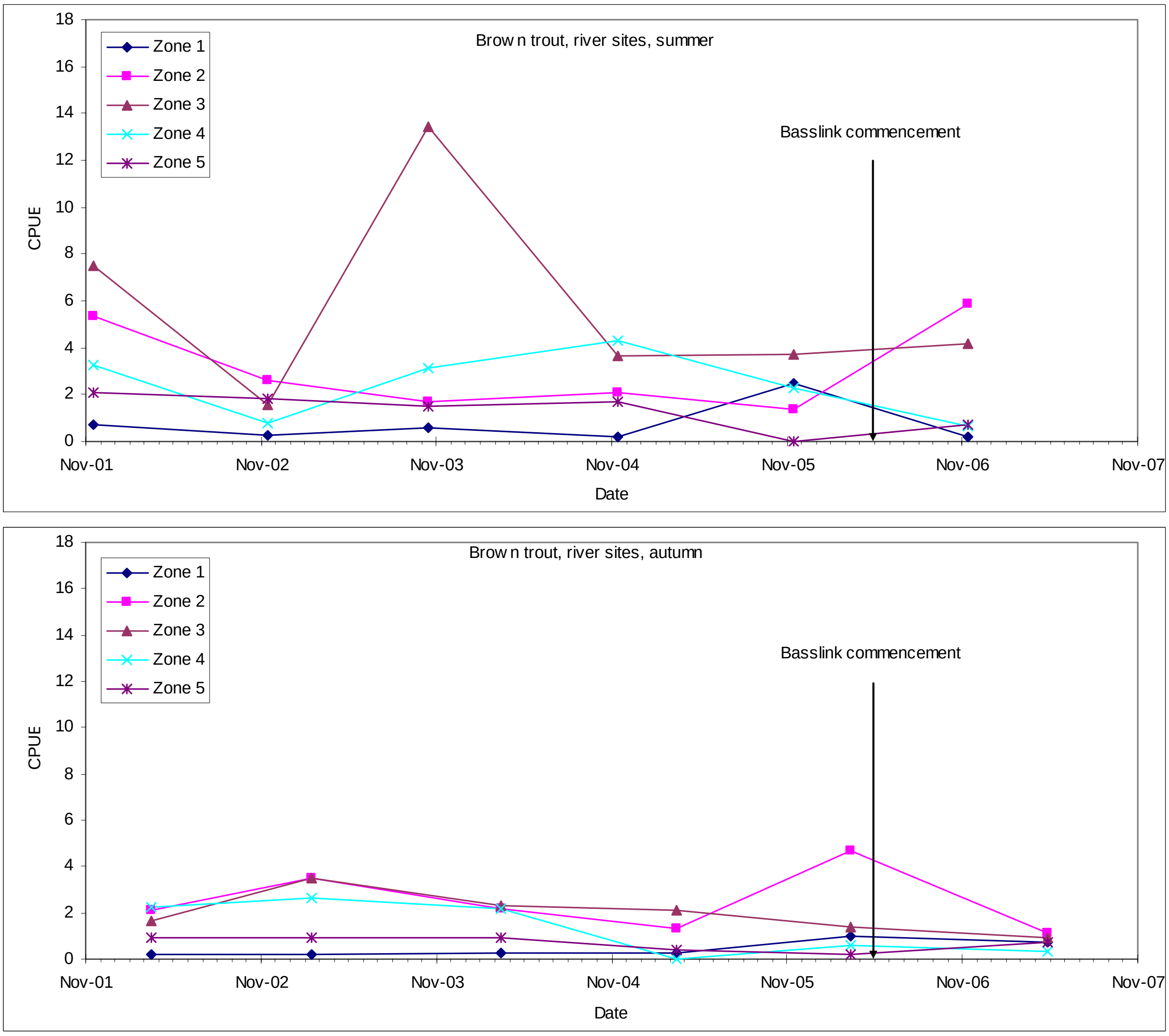


Figure 9-1. Seasonal (summer and autumn) CPUE for brown trout caught in the Gordon River zones between December 2001 and May 2007

Higher summer catch rates are probably attributable to warmer water temperatures resulting in increased trout activity, movement and vulnerability to electrofishing capture around shallow river margins. Heggenes and Dokk (2001) reported distinct seasonal behaviours and habitat selection in brown trout and Atlantic salmon, with feeding the dominant behaviour at high water temperatures in summer.

Juvenile galaxiids are also more prevalent around the river margins of the downstream zones in summer which has been observed to affect trout behaviour in the downstream zones (zones 4 and 5). It is likely that such factors increase trout abundances around the margins of the river during warmer months, increasing their vulnerability to electrofishing.

Figure 9-2 shows that there does not appear to be a seasonal differentiation in relative abundance in the Gordon tributary sites, as summer and autumn relative abundances show inter-sample variability through a similar range of relative abundance. The tributary sites are typically shallower and narrower than the Gordon River sites allowing sampling across a wider range of habitats and a higher proportion of the river bed. It is likely that this reduces the effect of trout behaviour and habitat selection on catch rates between seasons.

Previous surveys have reported that the tributary sites show higher relative abundance when compared to the main river sites, and the 2006-07 results continue to support this observation. The tributary sites are shallower and narrower than the Gordon River sites allowing sampling across a wider range of habitats and a higher proportion of the river bed, and the tributaries are not directly affected by flow regulation.

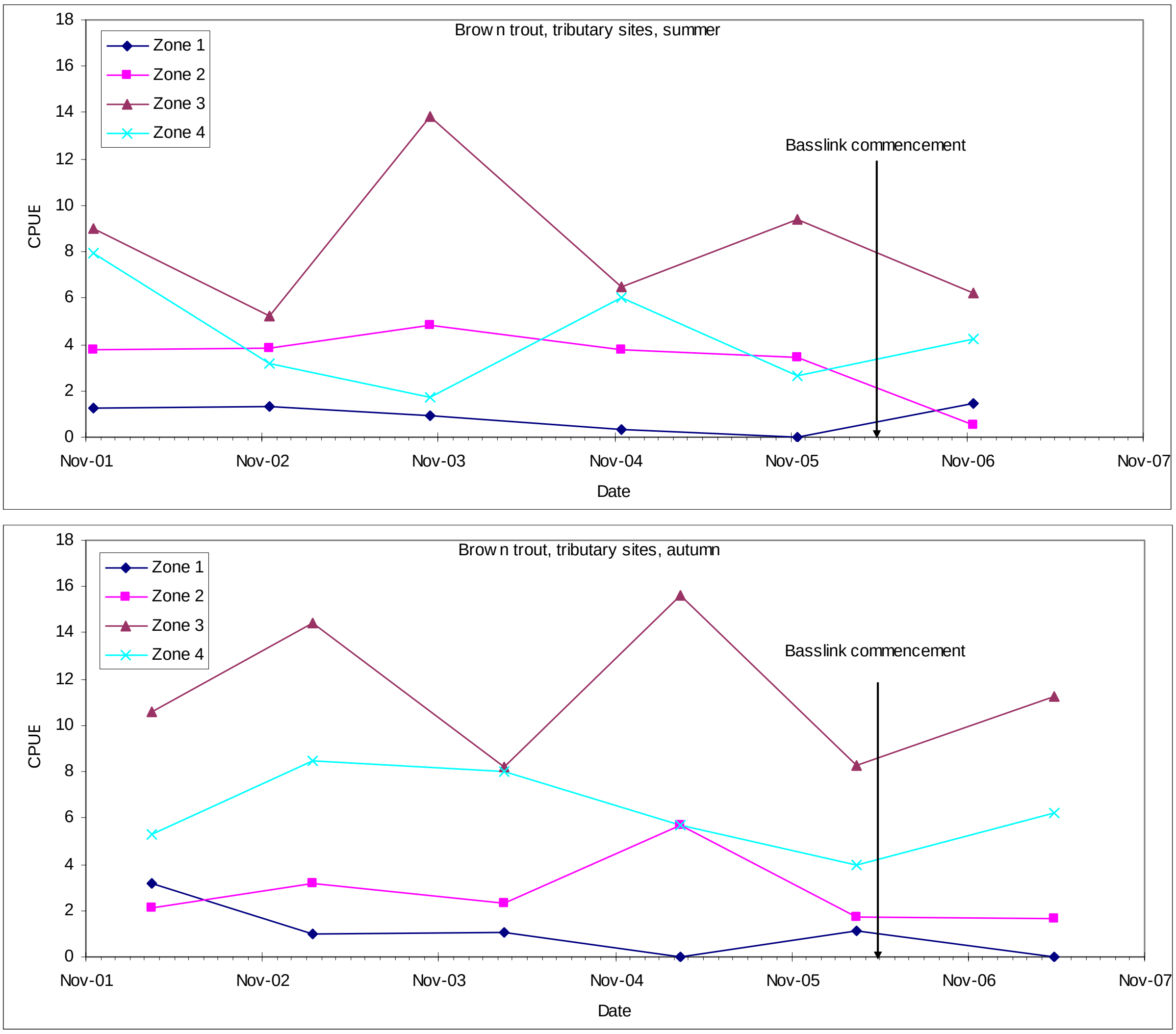


Figure 9-2. Seasonal (summer and autumn) CPUE for brown trout caught in the Gordon tributary zones between December 2001 and May 2007

9.3.1.2 *Rainbow trout (Salmoniidae)*

A single juvenile rainbow trout was electrofished in the Piguenit River, a small zone 1 tributary, during the May 2007 survey. This is the first recorded occurrence of a rainbow trout in the river since the start of the Gordon River Basslink investigative studies in 1999. The catch is not surprising, as rainbow trout occur in Lake Gordon, the lower reaches of the Gordon River and are farmed in Macquarie Harbour. The lake stocks were initially derived from stocking for recreational angling and have been sustained by natural recruitment, but this species only accounts for a small percentage of the trout harvest in Lake Gordon (French 2002, Phil Boxall pers. comm.). Rainbow trout occur in the lower Gordon River and Macquarie Harbour, and it is likely that these stocks are supplemented by accidental releases from fish farm sea cages in the harbour.

The ecological significance of this species in the TWWHA is relatively low, as competition by brown trout has probably restricted the establishment of self sustaining populations in the Gordon River and its tributaries.

9.3.1.3 Perch (Percidae)

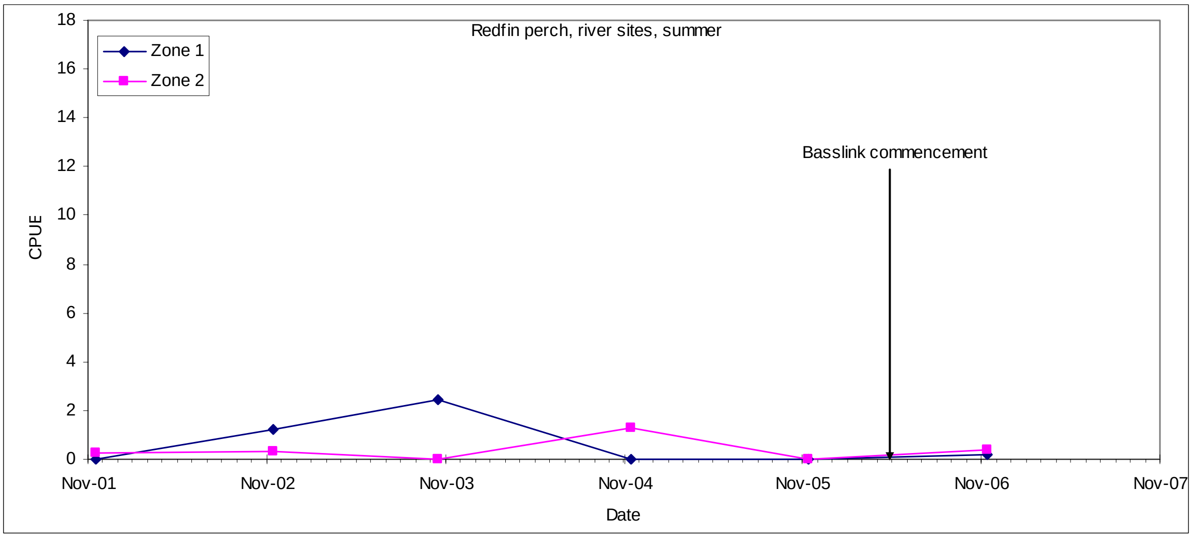
Figure 9-3 shows the relative abundance of redfin perch in the Gordon River between the start of the monitoring program and the latest monitoring trip in May 2007. To date, redfin catches have been restricted to zones 1 and 2, and their 2006-07 distribution was within their historical range. The relative abundance of this species appears to have declined over the monitoring program. Summer catches have shown a higher degree of variability, whereas autumn catches, particularly those from zone 2 have shown a trend in decreasing abundance.

Two dead redfin were noted during the December 2006 monitoring trip. These fish were collected from the upper reaches of zone 2 beside the large pool at G5, and appeared to have been dead for several days.

Three dead redfin perch were discovered by a geomorphological monitoring team on 17 March 2007 monitoring trip. The fish were also found on a bank in the upper reaches of zone 2 near G5 in a backwater area formed where the Gordon River backs up into the Albert River when the power station is operating. These fish also appeared to have been dead for several days.

In both these instances, the power station had been operating at a consistently high discharge in the weeks preceding the monitoring shutdown, and the deteriorated condition of these fish was not consistent with death due to a recent shutdown linked stranding. While the cause of the demise of these fish is unclear, it is accepted that a proportion of fish that move downstream through Gordon power station suffer turbine mortality, some of which would probably settle out in the low energy depositional areas around the G5 pool.

A live, stranded redfin was collected from G5 during the May 2007 survey. This was obviously a recent stranding linked to the monitoring shutdown.



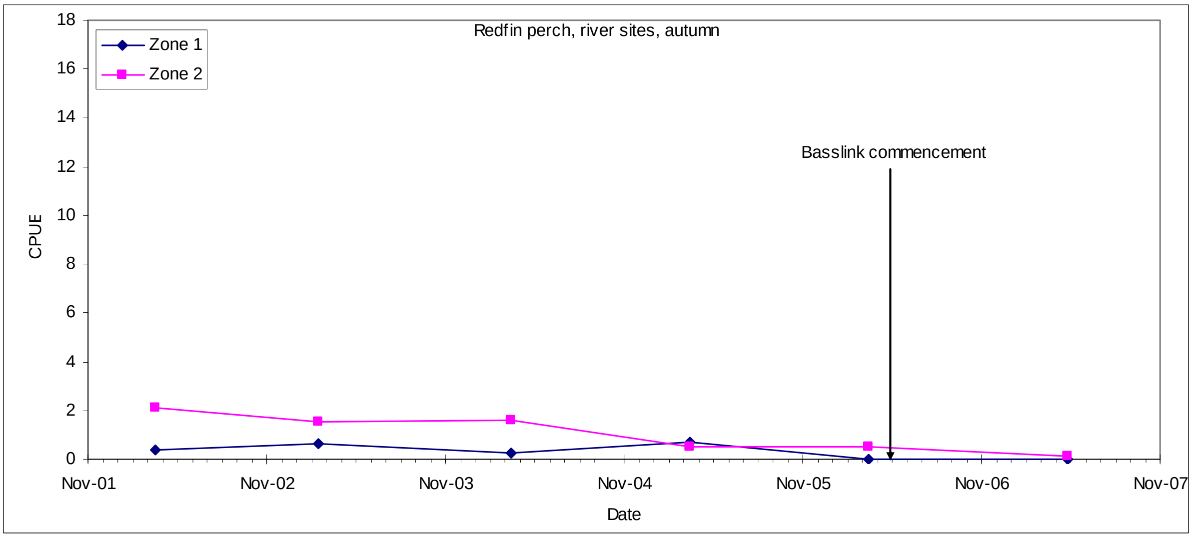


Figure 9-3. Seasonal (summer and autumn) CPUE for redfin perch caught in the Gordon River zones 1 and 2 between December 2001 and May 2007.

Redfin have been absent from tributary catches, however two redfin were electrofished from the lower reaches of the Albert River in December 2006. It is interesting to note that these tributary fish were notably smaller (89 and 108mm) than the fish caught from the river over the duration of monitoring program (142-190mm). Redfin were not caught from this site in May 2007, but this tributary will be closely monitored for evidence of redfin recruitment in future surveys.

9.3.2 Native species

9.3.2.1 Lampreys (Mordaciidae and Geotriidae)

Short headed lamprey (*Mordacia mordax*)

Short headed lampreys comprised less than 20% of the lamprey catch. Their exact representation in catches is difficult to calculate, as a significant proportion of ammocoetes are difficult to identify in the field due to their small size. Data from previous surveys has also shown that short headed lampreys consistently represent a minority of the lamprey catch. No adults were captured in either the summer or autumn surveys. The majority of short headed lampreys were captured in autumn 2007. Their distribution ranged from the upper reaches of zone 2 to the lower reaches of zone 5, and throughout the reference rivers, which was similar to historical data.

Pouched lamprey (*Geotria australis*)

Figure 9-4 shows the relative abundance of pouched lampreys in the Gordon River zones. Pouched lampreys were caught from most river zones, but were absent from zone 1 in both summer and autumn surveys, which is consistent with data from previous years. Pouched lampreys have been absent from Denison River catches throughout the pre-Basslink period, however they were caught during the “transitional period” (December 2005 April 2006) and again in April 2007 from the Denison u/s George site in zone 3. This is indicative of a successful spawning event in this tributary catchment in recent seasons.

Summer and autumn pouched lamprey catches were high relative to previous years, with summer means in zones 4 and 5 and autumn means in zones 2, 4 and 5 above the 95% confidence interval about the historical mean. These results are indicative of good juvenile recruitment from suitable areas of habitat within these zones. Relative abundance in the reference zones was similar to other years, except for above average catches in zone 8.

Catches were comprised solely of ammocoetes and macrophthalmia. No adults were observed or captured. It is interesting to note that the Inland Fisheries Service lamprey trapping program also recorded very low yield of adult migrating lampreys in the Derwent River during spring 2006-07.

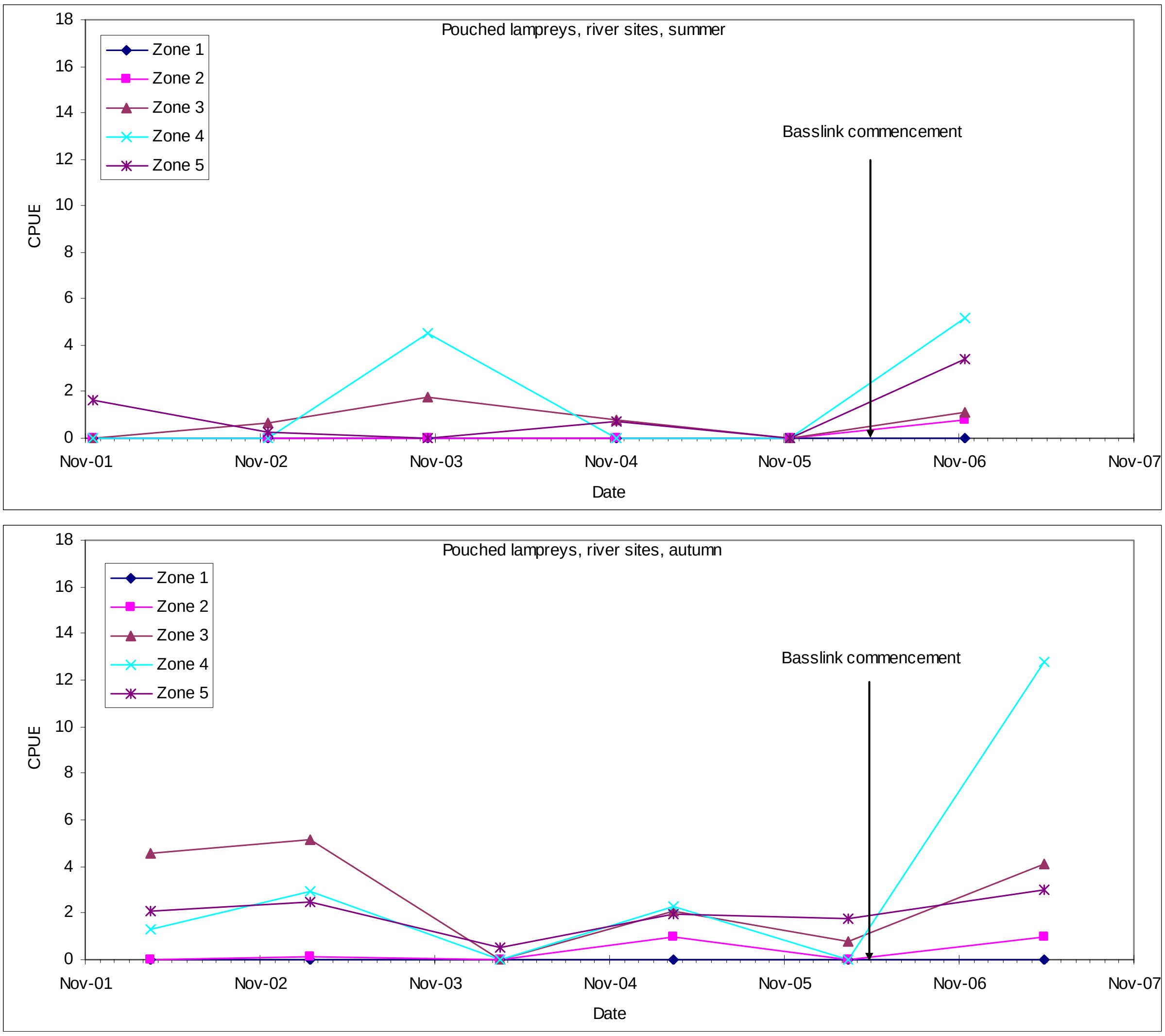


Figure 9-4. Seasonal (summer and autumn) CPUE for pouched lampreys caught in the Gordon River zones 1 and 2 between December 2001 and May 2007

9.3.2.2 *Eels (Anguillidae)*

Short-finned eels (*Anguilla australis*)

The relative abundance of short-finned eels over the duration of the monitoring survey is shown in Figure 9-5. No consistent seasonal trend is evident across all zones. Historical mean catches from zones 1-4 are higher in summer, while mean catches from zone 5 are higher in autumn. The 2006-07 results showed that relative abundance in zones 3 and 4 was higher than the 95% confidence interval around the historical summer and autumn means. No eels were captured from zones 1 and 2 during 2006-07, which is below average for zone 1 in autumn. However, relative abundance in the two most upstream river zones has been low throughout the monitoring program. The longitudinal distribution of this species throughout the monitoring sites was within the range of pre-Basslink data.

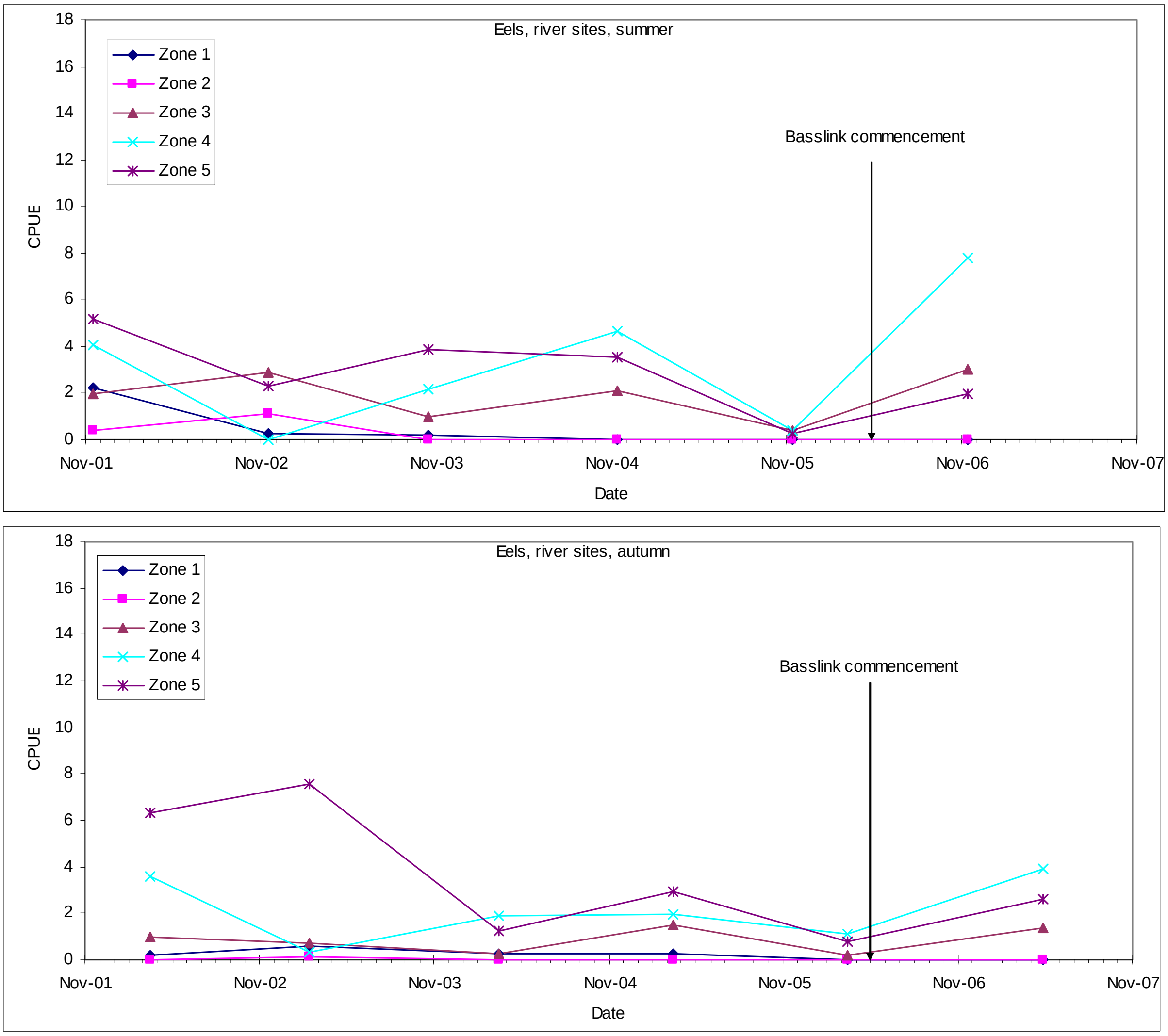


Figure 9-5. Seasonal (summer and autumn) CPUE for short finned eels caught in the Gordon River zones 1 and 2 between December 2001 and May 2007

Population structure was similar between seasons. Length frequency analysis of the data showed that size ranged between 90mm and 660mm, with a summer mode of 140mm and an autumn mode of 120mm.

A dead eel was observed by one of the Gordon River Basslink geomorphological monitoring teams on 17 March 2007. The eel was found tangled in a tree in the upper reaches of zone 2. The adult eel appears to have suffered turbine mortality when passing through the power station as there was evidence of bruising along its body. The size and colour of the eel indicate that it was probably a downstream migrating or "silver eel". Tasmanian silver eels generally migrate between October and March, and the timing of migration peaks appears to be influenced by rainfall and flows.

9.3.2.3 Galaxiids (Galaxiidae)

Figure 9-6 and Figure 9-7 show the relative abundance of galaxiids in the Gordon River and tributary sites during summer and autumn. Relative abundance data for *G. truttaceus*, *G. brevipinnis* and *G. maculatus* have been used to derive these plots, and these species comprised 72%, 21% and 7% of the annual galaxiid catch respectively (refer to Appendix 8). Summer galaxiid abundance in the Gordon River is clearly higher in the lower zones in comparison to the upper zones, and this is driven by the combined effects of annual juvenile migration runs, decreasing galaxiid species diversity with increasing distance from the sea, and the effects of flow regulation. This phenomenon has been discussed in previous Basslink Monitoring Program annual reports.

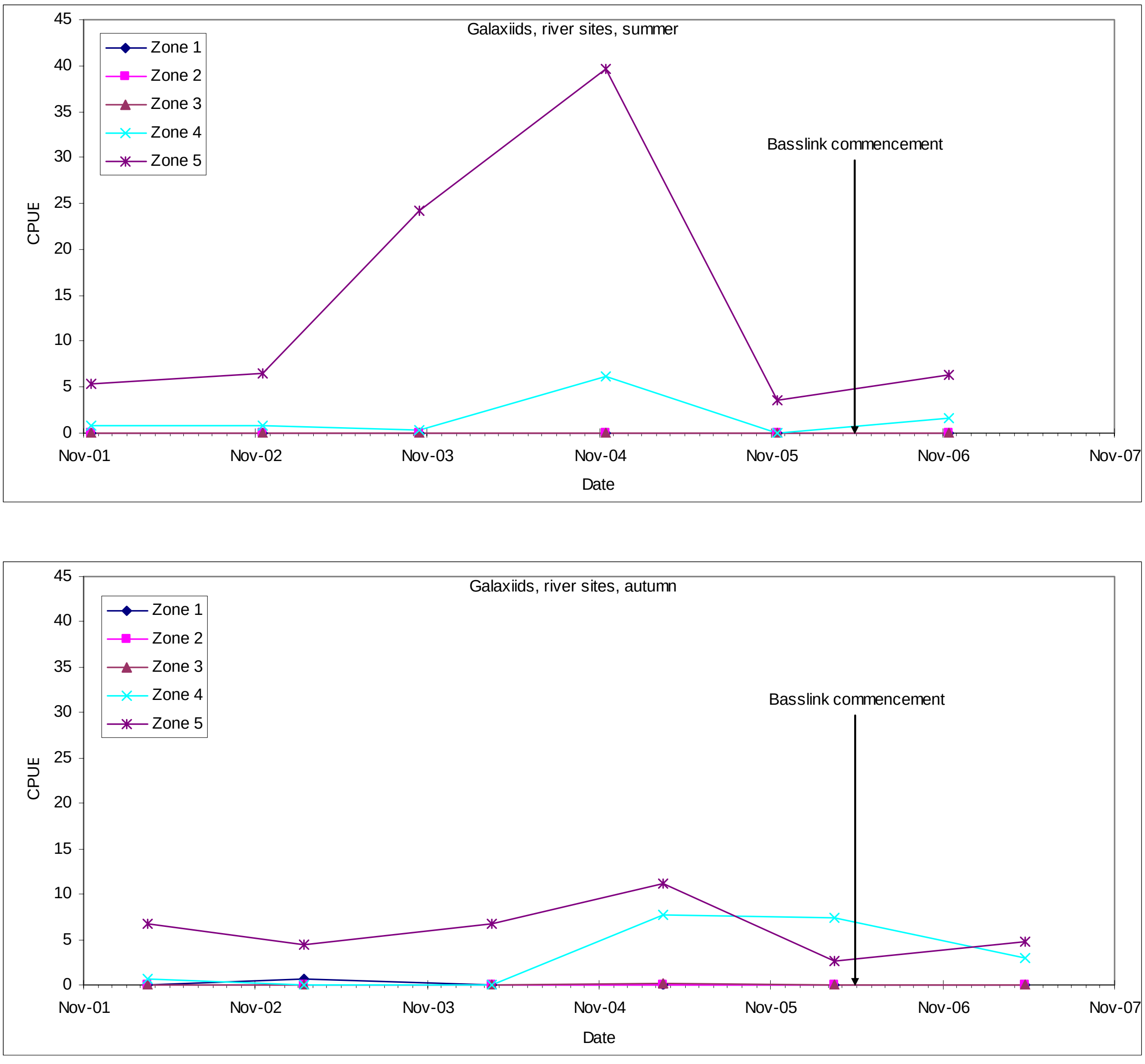


Figure 9-6. Seasonal (summer and autumn) CPUE for galaxiids caught in the Gordon River zones between December 2001 and May 2007

The longitudinal distribution of galaxiids throughout the monitoring sites was within the range of pre-Basslink data. The isolated tributary population of *G. brevipinnis* continues to persist in Ari

Creek, a small tributary located in zone 1, and shown no obvious signs of recent recruitment of juveniles. Galaxiids were not collected from river or tributary sites in zones 2 and 3 during the autumn survey, which is consistent with previous surveys. A single adult *G. truttaceus* was collected from Harrison Creek, a zone 3 tributary, in December 2006. With the exception of the Ari Creek climbing galaxias population, it is unusual to collect galaxiids upstream of zone 4.

G. truttaceus recorded by far the highest relative abundance of the three galaxiid species caught in the Gordon River and tributary sites. Summer and autumn CPUE's were similar at river and tributary sites. Comparisons between the population structure of summer and autumn river samples is shown in Figure 9-8. The histograms show the presence of a small number of 60-70mm juveniles in the summer catches, which have recruited to the 70-80mm size classes in autumn. A series of moderate flow events occurred in the catchment in the weeks prior to sampling, and it is likely that these flows temporarily inhibited galaxiid migration in the lower Gordon River coincident with the monitoring program.

Summer and autumn abundances for all galaxiid species collected from the river and tributaries zones fell within the 95% confidence interval about the historical mean.

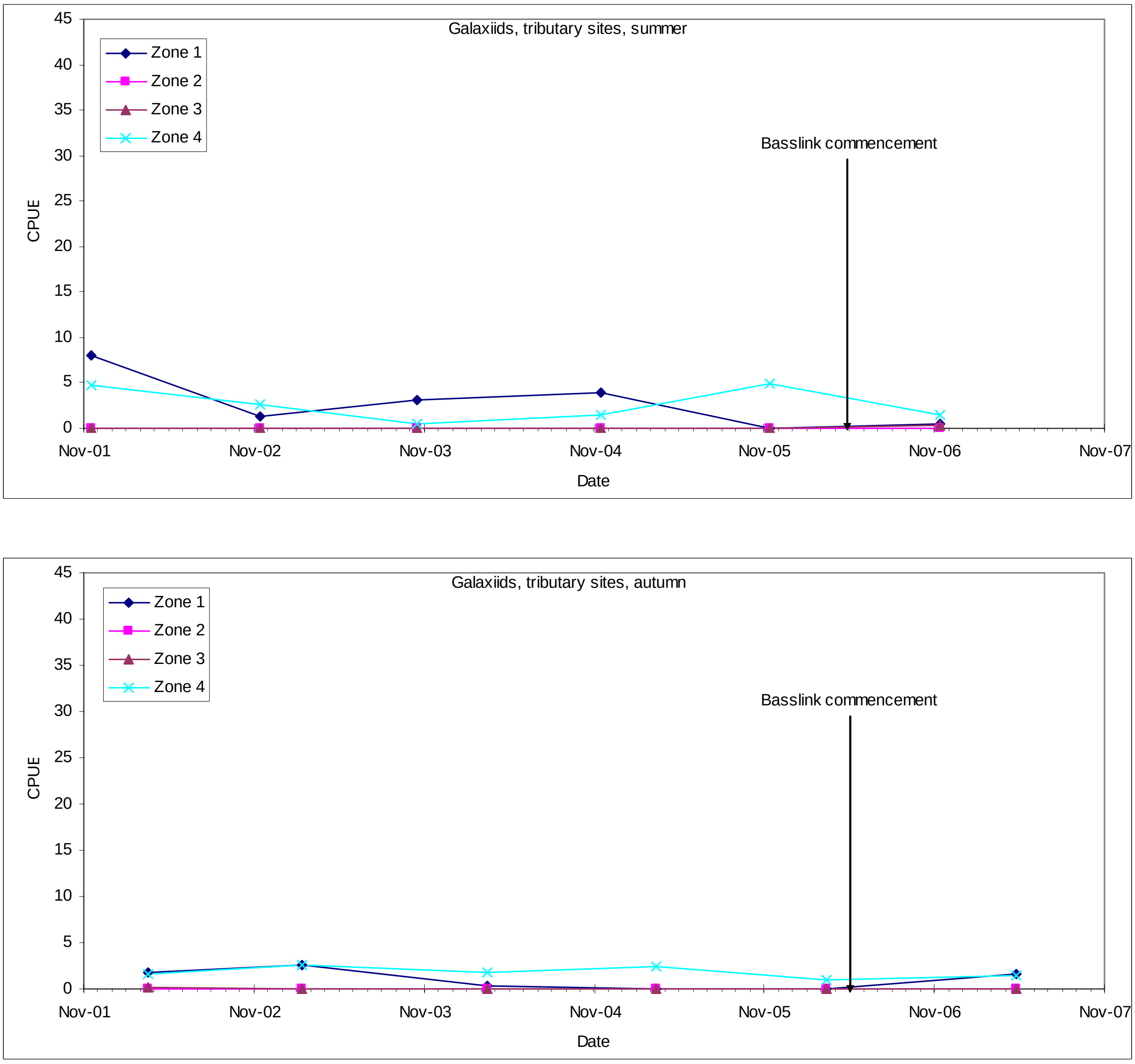


Figure 9-7. Seasonal (summer and autumn) CPUE for galaxiids caught in the Gordon tributary zones between December 2001 and May 2007

Neochanna cleaveri or Tasmanian mudfish have not been caught from the Gordon River sites, but they have been caught infrequently and in relatively small numbers from the Henty River. Catches for this species were higher than usual in 2006-07, recording a mean CPUE of 12.73 for the Henty River zones. The size of these fish ranged between 39 mm and 42 mm, which is indicative of juvenile fish recruiting to the catchment. A small number of slightly larger *N. cleaveri* were present in the autumn catches from the Henty River.

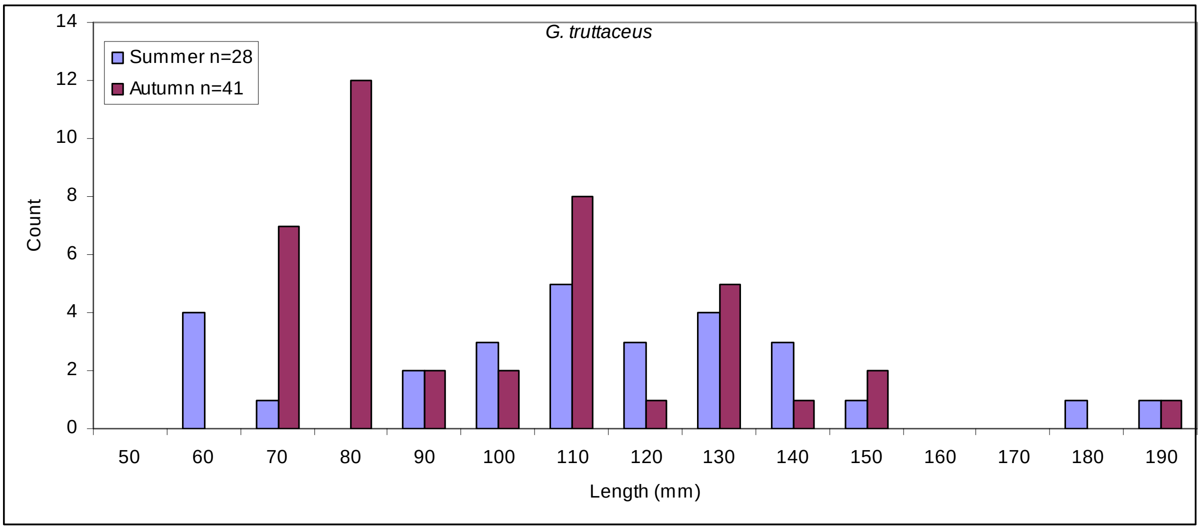


Figure 9-8. *G. truttaceus* length frequency histograms for December 2006 and May 2007.

9.3.2.4 Bovichthyidae

Sandys (*Pseudaphritis urvillii*)

The pre-Basslink distribution of *P. urvillii* in the Gordon River was restricted to the lower monitoring zones, and the 2006-07 data shows that their longitudinal distribution is similar to pre-Basslink data.

Figure 9-9 shows the relative abundance of sandys in zones 3-5. Summer catches in zone 5 were marginally above average. Sandys have occasionally been collected from zone 3 in previous surveys; however catches were restricted to zones 4 and 5 during 2006-07. It is anticipated that sandys and spotted galaxias may be potential qualitative indicators capable of indicating improved post-Basslink upstream passage conditions, indicated by an increased frequency of occurrence in zone 3.

9.3.2.5 Prototroctidae

Australian grayling (*Prototroctes maraena*)

Australian grayling were not caught from Gordon River, tributary or reference sites during the 2006-07 surveys. Grayling have previously only been caught on one occasion during the monitoring program. A single fish was caught at the Henty u/s Bottle Creek reference site in December 2004.

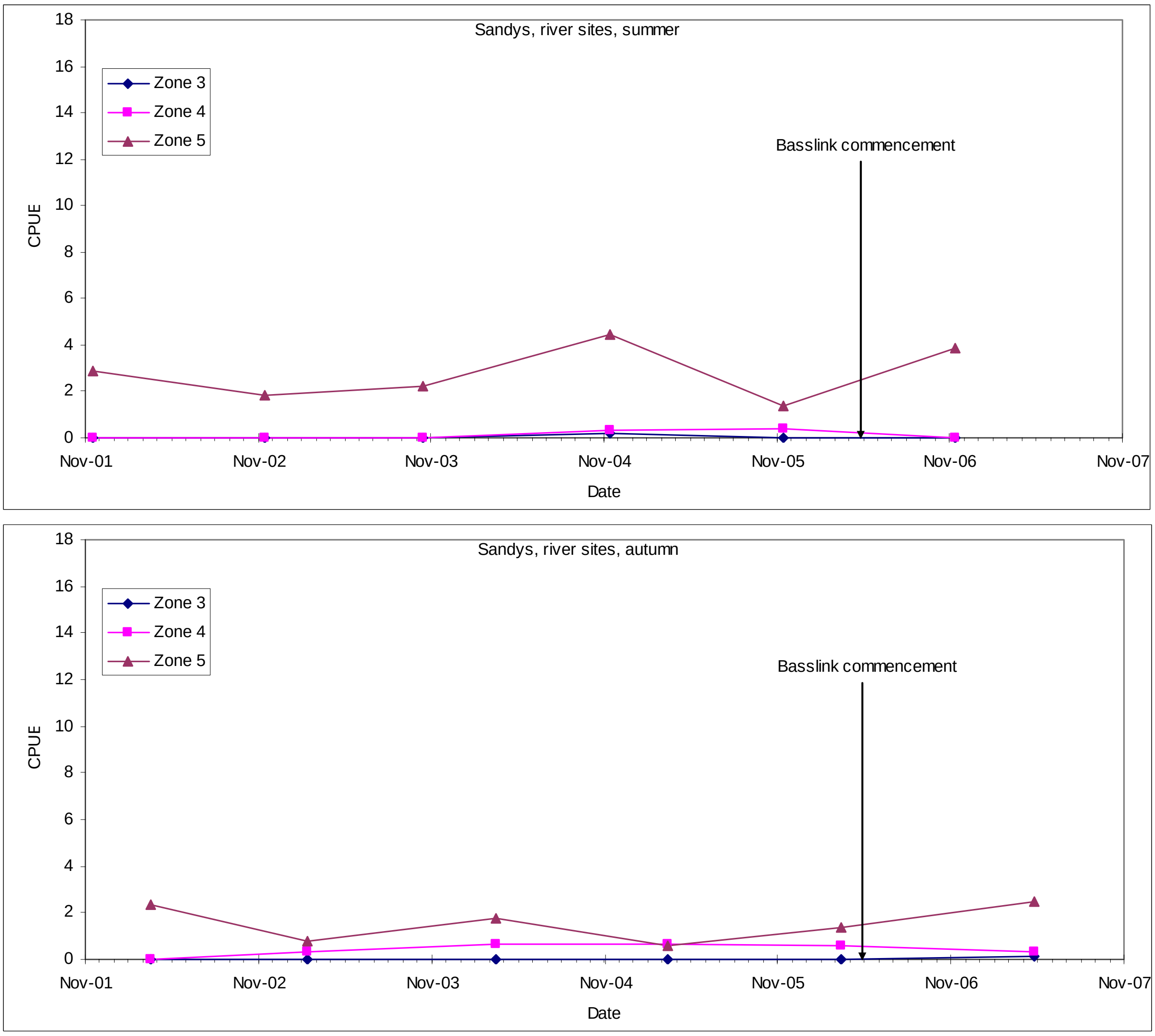


Figure 9-9. Seasonal (summer and autumn) CPUE for sandys caught in the Gordon river zones between December 2001 and May 2007.

9.4 Trigger values

Ten trigger levels have been developed for the Basslink fish monitoring program. Data was pooled from sites and zones for the assessment against trigger levels. Five triggers were derived using autumn data and the remaining five triggers were derived using annual data. Hydro Tasmania (2006) gives further details on the derivation of these triggers. Performance against these triggers during the 2006-07 monitoring year is shown in Figure 9-10 and Figure 9-11 and discussed in the following paragraphs.

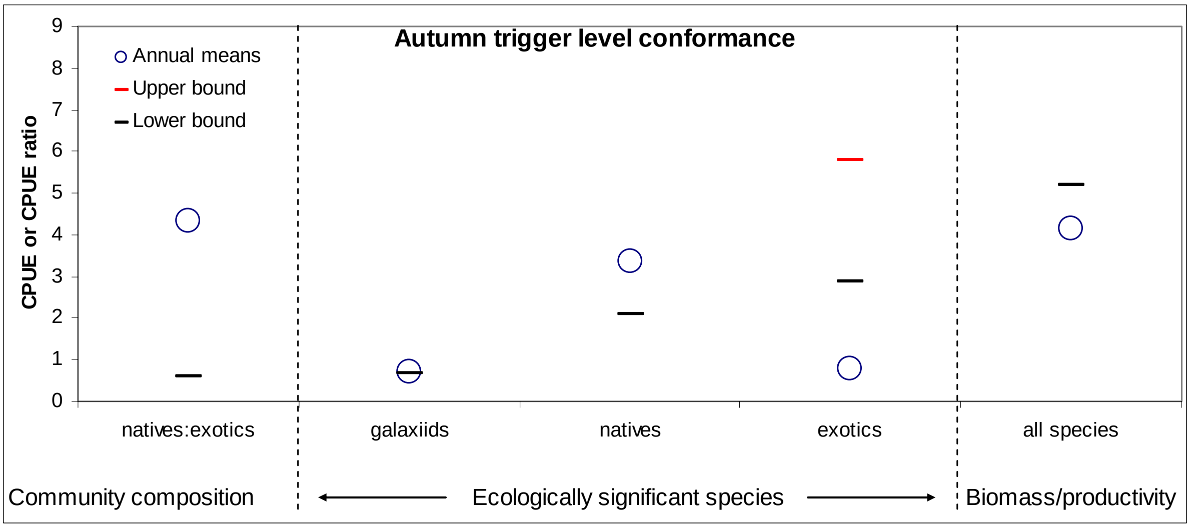


Figure 9-10. Summary of autumn trigger level conformance. Note that exotics is the only category with an upper bound.

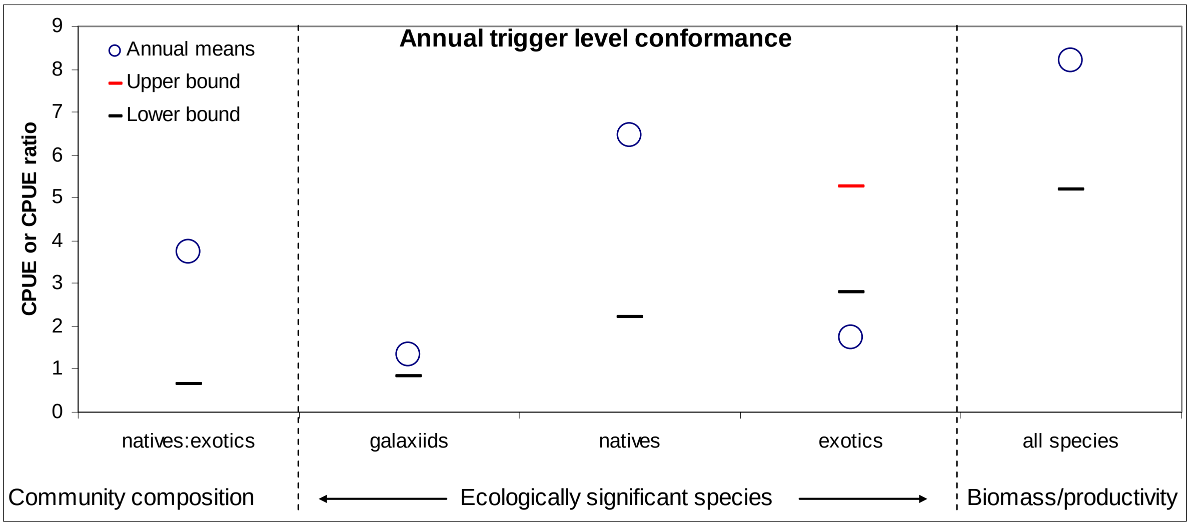


Figure 9-11. Summary of annual 2006-2007 trigger level conformance. Note that exotics is the only category with an upper bound.

9.4.1 Community composition

Two trigger levels, derived from the ratio of native to exotic fish, have been developed to assess potential changes to community composition following the commencement of Basslink operations. Single season (autumn) and annual trigger values are shown in appendix 10 –Table 10-1. Figure 9-10 and Figure 9-11 show a graphical representation of autumn and annual means in comparison to their respective triggers levels. The community composition indicators were well above their triggers due to low trout relative abundance, and no exceedances were recorded.

There is no upper bound for this trigger as a change in ratio in favour of native fish relative abundance is considered an ecologically beneficial change.

9.4.2 Ecologically significant species

Six trigger levels have been developed to assess the potential impact of Basslink operations on ecologically significant species. Seasonal trigger levels derived for native fish relative abundance, exotic species relative abundance and galaxiid relative abundance are shown in Appendix 10 – Table 10-2 and Table 10-4, while Figure 9-10 and Figure 9-11 show performance against these triggers during 2006-2007.

Exceedances for the exotic fish category were recorded during 2006-07 both for the autumn data and for the annual data. Figure 9-10 and Figure 9-11 show that exotic fish relative abundances were below both autumn and annual trigger levels. Brown trout comprised 95% of the summer and 96% of the autumn exotic species catch in the Gordon River zones, and are currently the primary influence on the exotic species indicator performance. Annual relative abundance data are used in the derivation of the annual trigger, and low autumn trout relative abundance strongly influenced annual exotic species CPUE, and so it is not unexpected that both autumn and annual triggers were exceeded simultaneously.

The factors driving the trigger exceedances are speculative at this early stage in the post-Basslink monitoring program. Persistence of this phenomenon over several monitoring cycles will result in more rigorous examination of potential causal factors. Preliminary discussion of several potential factors that may have contributed to the declines in relative abundance are summarised in the following paragraphs.

High rainfall in the week prior to sampling the Gordon River monitoring sites resulted in a flow of 860 $m^3 s^{-1}$ at the Gordon above Franklin gauge (site 44) respectively. Historical data (from September 1996) shows that flows of this magnitude have been exceeded less than 1% of the time at this site, and was the highest flow recorded during 2006-07. Short-term flow increases such as freshes or flow events have been shown to affect fish behaviour. Jowett and Richardson (1994) reported that brown trout show lateral movement in response to changing hydraulic conditions, and speculated that lateral movements may be a response to hydraulic stress avoidance and altered feeding behaviour, while Bunt *et. al.* (1999) reported that brown trout appeared to use cover and pools as discharge increased. It is likely that there were residual effects of the high flow event that affected trout habitat selection and relative abundance during the May monitoring trip, as data from fish monitoring trips conducted on the falling hydrographic limb of an event generally show decreased catch rates.

Sampling was also conducted later in autumn than is normally the case, coincident with the start of annual brown trout spawning period. Spawning runs are catalysed by flow events and so it is likely that spawning migration runs into tributaries were underway during May, which may have decreased catch rates in the Gordon River to due to temporary emigration into tributaries. Brown trout relative abundance in the tributaries during May was similar to historical levels; however tributary sites are only sampled for a distance of several hundred metres above their confluence with the main channel. It is arguable that a significant proportion of spawning trout moving into the tributaries would be transient at the survey sites on their way to spawning areas (redds), and may not be represented in the May CPUE statistics for tributary sites.

The reference rivers were monitored approximately four weeks prior to the monitoring sites due to logistical constraints (inability to secure a power station shutdown) and unfortunately are of limited value in providing an assessment of whether a decrease in exotic fish relative abundance in the Gordon River reflected a broader spatial trend across the region.

Low yields throughout Tasmania's hydropower generation catchments resulted in heavy reliance of Gordon Power Station to provide base load power. Discharge for the majority of the year reflected this, with long periods of two or three turbine operation major features of the tailrace hydrograph, particularly from mid February to early May 2007. Power station discharge variability increased significantly following the flow event on 5 May, seven days prior to the sampling trip. It is unlikely that such a short period of hydro-peaked operation would be a major factor accountable for permanent declines in brown trout relative abundance. It is possible, but highly speculative, that the period of variable flows superimposed over the tail of the flow event may have contributed to modified habitat use behaviour during the May sampling, namely avoidance of shallow channel margins prone to dewatering on the falling limb of the hydrograph.

The explanations for triggering of the exotic species trigger are, at this time, speculative. Further explanations will be sought if this trigger is exceeded over successive monitoring periods. It is important to recognise that, in the absence of exceedances of the remaining ecologically significant triggers, a decline in exotic fish relative abundance in the Gordon River may be ecologically beneficial to the ecology of the catchment due to decreased likelihood of competition and predation on native species.

The autumn and to a lesser extent, annual trigger levels for galaxiids were close to but did not exceed the limit, and the autumn and annual native fish trigger levels were above their respective limits. The flow event that occurred immediately prior to the autumn sample would have reduced catches for these indicator groups.

9.4.3 Biomass/productivity

Two trigger levels have been developed to assess potential changes to biomass or productivity due to changed hydrological conditions due to Basslink operation. Trigger levels for this category are derived from autumn and annual relative abundance for all species present in the pooled Gordon River monitoring zones.

Figure 9-10 shows that CPUE for the 'all species' category exceeded the autumn trigger level. Historically, brown trout have comprised a major component of the fauna in the Gordon River monitoring zones. Representation in catches fell from 29% in December 2006 to 12% in May 2007 and a decline in brown trout relative abundance is the primary factor driving an exceedance of this trigger. The annual CPUE for this indicator is well above the trigger level, reflecting the strong contribution of native species CPUE to this category. The discussions included in Section 9.4.2 are relevant to this trigger.

Both the 'all species' and 'exotic species' indicator variables are ranked as having the lowest ecological significance and highest response sensitivity, and as such are considered early warning indicator variables (Hydro Tasmania, 2006). The fish trigger values have adopted levels of alpha (0.1 to 0.2) which will increase the probability of detecting a meaningful environmental effect; and so it is important to recognise that this approach also increases the risk of falsely declaring that significant environmental change has occurred (increased Type 1 error level).

9.5 Conclusions

This report summarises the results of the first year of post-Basslink operation fish monitoring surveys. Summer monitoring was conducted in December 2006 and autumn monitoring was conducted in April and May 2007. Low rainfall resulted in the inability to secure a shutdown of Gordon Power Station in April and resulted in monitoring zone sampling being conducted approximately one month later than the reference sites.

The first occurrence of rainbow trout was reported from a small zone 1 tributary during the autumn 2007 monitoring trip. Populations of rainbow trout exist in Lake Gordon and Macquarie Harbour, and so it is likely that this species will occasionally be collected during the monitoring program. The ecological significance of this species in the TWWHA is relatively low, as competition by brown trout has probably restricted the establishment of self sustaining populations in the Gordon River and its tributaries.

Redfin perch continue to persist in the upstream zones of the Gordon River, but relative abundance appears to be declining, particularly in autumn catches. The capture of two redfin from the Albert River marks the first recorded occurrence of this species in a Gordon River tributary. This tributary will be monitored for evidence of recruitment in further surveys. The large pool situated at G5 continues to be a focal point for redfin. Live, live stranded and dead redfin were collected from this site during 2006-07. The hydraulic characteristics of this site and its proximity to the tailrace probably contribute to the regular occurrence of this species at this site. The single live, stranded redfin at G5 was the only clear evidence of fish stranding in the monitoring zones.

Catches of pouched lampreys were consistently high during the 2006-07 monitoring period. The majority of specimens were ammocoetes and a small number of macrophthalmia which is indicative of successful spawning in the river in previous years, as lamprey ammocoetes remain in the sediments for several years prior to metamorphosis.

Galaxias truttaceus dominated galaxiid catches during 2006-07. Summer and autumn abundances for all galaxiid species collected from the Gordon River and tributary sites were similar to historical means.

The longitudinal distribution of most species in the monitoring zones was similar to previous years. The Albert River redfin capture does not constitute a significant range extension due to its close proximity to the Gordon River. Pouched lamprey ammocoetes are now a regular occurrence in Denison River catches.

Three trigger level exceedances were recorded in the first year of post-Basslink operation. Both autumn and annual exotic species indicator variables were triggered by low relative abundances, and the trigger was exceeded for the autumn 'all species' indicator variable. Declines in autumn brown trout CPUE were the primary factor accountable for these exceedances. It is speculated that a flow event in the week prior to sampling, sampling coincident with the brown trout spawning season, and the resumption of variable discharges following a prolonged period of base load operation are factors that may have contributed to changes in habitat use leading to a reduction in brown trout catch rates in the Gordon River. Further sampling is required to assess whether this apparent decline is real and persists over several monitoring events.

The 'exotic' and 'all species' indicator variables will be monitored closely to assess whether a consistent trend is evident, and if so, assess the ecological implications (positive or negative) of these trends.

10 Discussion of trigger value results

10.1 Introduction

Trigger values were derived from pre-Basslink monitoring results and incorporate the range of variability expected in the system based on pre-Basslink conditions. Trigger values are being used as a tool to identify changes in the river system associated with the implementation of the Basslink operating regime at the Gordon Power Station. The parameters used to establish trigger values are considered by the researchers to represent characteristics of the Gordon affected by or driven by the flow regime, although it must be stressed that quantitative links between the flow regime and response of the selected 'triggers' have not been established for any discipline. Trigger values were derived for all disciplines except karst, water quality and hydrology. Informal indicator variables have been identified for karst, whereas water quality is recognised as an explanatory variable, rather than a result of flow change at the power station.

Trigger values were derived using similar but slightly varying approaches for each discipline. The confidence levels adopted in the derivation of trigger values were 90% or 95%, indicating that exceedances are to be expected by chance 1-in-10 or 1-in-20 times. Trigger exceedances must therefore be accompanied by expert interpretation regarding the ecological significance of the exceedance, with an assessment of changes observed at reference sites included where applicable. A discussion of how exceedances are assessed for each discipline is contained in the Basslink Baseline Report (Hydro Tasmania, 2005).

Following discussions with the SRC and Regulator it was decided that exceedance of variables is likely to lead to responses of a different scale which is determined by the perceived seriousness of the response. Therefore, three categories outlining the response were determined for all disciplines as listed below:

1. Note and explain
2. Investigate
3. Management response required

A detailed discussion of the specific actions for the various disciplines is found in the trigger value reports in the Gordon River Basslink Monitoring Annual Report 2005-06 (Hydro Tasmania, 2006).

This annual report summarises the first year of post-Basslink monitoring, and a detailed discussion of trigger values is contained within each discipline chapter. The aim of this chapter is to provide an overview of trigger value results across disciplines, and discuss underlying factors which may be influencing or driving trigger results.

10.2 Comparison of monitoring results with trigger values

Table 10-1 lists the monitoring results in the 2006-07 monitoring year which were outside the trigger limits. A total of 34 triggers (13%) were found to have been exceeded during the 2006-07 monitoring. Of these, 18 exceedances show some potentially favourable trends for environmental health and include increasing seedling species diversity, number of ecologically important plants, high abundance of EPT macroinvertebrates and reductions in exotic fish abundance. A full list of trigger value limits evaluated for each discipline is located in Appendix 8 (Formal trigger levels). Disciplines in which there is high variability in the seasonal and annual monitoring results, namely geomorphology and fish, have few trigger values compared to other disciplines because site or zone results need to be grouped to provide trigger values which are statistically suitable. The higher number of trigger values associated with macroinvertebrates and vegetation are due to trigger values being derived for individual sites, as well as zones, 'whole of river' and/or seasons. See the Basslink Baseline Report (Hydro Tasmania, 2005) for a full discussion.

Of the disciplines in which formal or informal trigger values have been established, all but algae and karst recorded exceedances of trigger values in 2006-07. To try and identify potential underlying causes of the trigger value exceedances, and establish whether there were similarities or distinct differences between disciplines, a workshop was conducted by Hydro Tasmania on 20 July 2007 with each researcher presenting an overview of monitoring results and trigger exceedances. Discussions focussed on the ecological significance of the trigger value exceedances and potential links between the 2006-07 flow regime and monitoring results and other factors, such the timing and conditions preceding and during sampling, and logistical issues which may have contributed to the monitoring results. Overall, the researchers agreed that:

- monitoring results were consistent with past findings with respect to the pre-Basslink understanding of the river (i.e. no changes to the conceptual model of the river);
- one monitoring year with an unusual flow pattern was an insufficient period to confidently link trigger exceedances with Basslink flow changes;
- the trigger exceedances could be attributed to the unusual flow characteristics and logistical issues associated with the monitoring year; and
- none of the trigger value exceedances were of concern at this stage, and that a 'note and explain' level one response was appropriate to all exceedances.

The rationale behind these conclusions is outlined.

Table 10-1. Summary of monitoring results falling outside trigger values

Discipline	Trigger	Zone/Site/Season	Trigger exceeded	No. and proportion of triggers exceeded	No. triggers indicative of potentially of favourable changes	Trigger response
Geomorphology 5 trigger values	Erosion pins	Zone 5	Deposition 4.4 mm less than trigger	*1 trigger exceeded out of 5 (20%)*	-	Note and explain
Macroinvertebrates 126 trigger values	*13 Triggers exceeded out of 126 (10%)*					
	Bray Curtis (abundance)	Site 57	Below trigger band	1 out of 9	-	Note and explain
	O/Erk	Site 63	Below trigger band	1 out of 9	-	Note and explain
	Bray Curtis (pres/abs)	Sites 57 and 48	Below trigger band	2 out of 9	-	Note and explain
	Abundance of EPT	Site 63 and 48	Above trigger band	2 out of 9	2	Note and explain
	Bray Curtis (pres/abs)	WOR av (all year)	Below trigger band	1 out of 5	-	Note and explain
	N families	WOR autumn	Above trigger band	1 out of 5	1	Note and explain
	Abundance of EPT	WOR all Year, WOR spring and autumn, zone 1 and zone 2	Above trigger band	5 out of 5	5	Note and explain
Algae cover 2 trigger values	*0 triggers exceeded out of 2 (0%)*					
Riparian vegetation 111 trigger values	*17 triggers exceeded out of 111 (15%)*					
	Species/taxa richness	Zone 2, above zone 3, low zone 4, high zone 5, high	One above trigger band, 3 below trigger band	4 out of 12	1	Note and explain
	Ecologically significant species	Zone 2, low zone 4, above, low, high, high zone 5, high	Above trigger band – greater abundance	6 out of 36	6	Note and explain
	Table 10-1 continued next page					

Discipline	Trigger	Zone/Site/Season	Trigger exceeded	No. and proportion of triggers exceeded	No. triggers indicative of potentially of favourable changes	Trigger response
Riparian vegetation 111 trigger values	% cover. Ratio (% above 3-turbines+1) to (% between 1- and 2-turbines+1)	% fern cover	Above trigger	1 out of 5	-	Note and explain
	Number of seedlings less than 5 cm: Ratio of ABOVE quadrats to HIGH quadrats	autumn whole of river, zone 2, zone 5	Above trigger	3 out of 10	-	Note and explain
	Total Number of seedlings: Ratio of ABOVE quadrats to HIGH quadrats	autumn whole of river, zone 2, zone 5	Above trigger	3 out of 10	-	Note and explain
Fish 10 trigger values						
	Ecologically significant species (exotics)	Autumn, Annual	Below trigger band	2 out of 2	2	Note and explain
	Biomass/productivity	Autumn	Below trigger band	1 out of 2	1	Note and explain
Karst 3 Informal Indicator groups	*No group showed change across all indicators*					
			TOTAL	**34**	**18**	

Table 10-1 continued

10.3 Effects related to 2006-07 flow characteristics

The flow regime during the 2006-07 monitoring year has been suggested as the major driver of trigger value exceedances. Flow characteristics of the 2006-07 monitoring year are discussed in detail in chapter 2 (Hydrology).

The hydrology in the 2006–07 monitoring year was not consistent with expected changes under Basslink. The drought resulted in the power station being run similarly to pre-Basslink conditions (extended base flow), but the restriction of discharge to two turbines for half of the monitoring year was dissimilar to any pre-Basslink or anticipated post-Basslink conditions. These flow characteristics, which are not directly related to Basslink operation, have been potentially linked to the exceedances of trigger values as discussed in the following sections.

10.3.1 Extended 2-turbine power station operation

Of the 2006-07 flow characteristics, the extended period of 2-turbine operation differs most from pre-Basslink conditions as well as predicted post-Basslink conditions. There are two components of this which have affected the river, firstly the limit of maximum discharge from the power station for half of the monitoring year, and secondly, the extended duration of 2-turbine operation through the winter due to the drought conditions in the State.

The increase in riparian flora species and taxa richness in zone 2 in the ‘above’ quadrat is possibly related to a decrease in ground water levels and continued growth of seedlings into larger size classes where in the past they have not survived. Increased seedling survival was also noted in the ‘above’ quadrats in zone 3 showing an effect in the two zones where vegetation is most highly stratified by flow disturbance. The impact of reduced ground water levels is likely to have been amplified by the general drought conditions which led to a relatively dry organic layer in many of the areas above the water level.

Conversely, prolonged periods of inundation may have contributed to a reduction in species richness in low quadrats in zone 3. This was largely due to a reduction in fern species. As a result of the prolonged 2-turbine discharge, many plants may not have had sufficient opportunity for gaseous exchange through the leaves or the roots may have remained inundated for too long during prolonged release events. This mechanism may also be driving the reduction in high quadrats in zone 5.

The extended duration of 2-turbine power station discharge is also potentially driving the relatively low erosion rates recorded in zones 2 and 3 due to the reduction in shear stress on the bank. Lower erosion was also noted in the doline in zone 2, and attributed to the water level being too low to inundate or erode the pin.

Extended 2-turbine power station discharge, may also be partially responsible for peaks in abundance of the macroinvertebrate caddisfly *Asmicridea* at several sites and hence exceedances in three macroinvertebrate triggers: the proportion and abundance EPT (Ephemeroptera, Plecoptera and Trichoptera) species and O/Erk. In addition sustained deep water during 2 turbine operations may be responsible for the consistent reduction in benthic algal cover.

10.3.2 Local low inflow conditions

The low tributary inflows associated with the extended drought has been suggested as a contributing factor to the lower than predicted deposition rates in zone 5, due to less tributary derived sediment being delivered to the banks. This effect may be exacerbated by lower erosion rates in zones 2 and 3 associated with reduced 3-turbine power station operation which may also have reduced sediment availability for deposition downstream.

Low inflows may be partially responsible for some macroinvertebrate trigger exceedances in the Gordon River. Evidence for this is suggested by the observation of similar patterns of decline in most macroinvertebrate measures at reference sites, which were also subject to low inflows over the year.

10.3.3 High flow event in May 2007

One week prior to the autumn fish and vegetation monitoring trips, there was a flow event measuring 850 $m^3 s^{-1}$ at the Gordon above Franklin site, which places it in the top 1% of flows recorded at this site since December 1999. This large flow has been suggested as potentially affecting the sampling of brown trout in the Gordon, in that the species is known to alter feeding habits and habitat use in response to hydraulic stress. This large flow event may also have contributed to the reduction in species richness in high quadrats in zone 5 (downstream of the Denison) through erosion of vegetation which established during the prolonged period of 2-turbine power station operation.

10.3.4 Minimum environmental flow

The implementation of the minimum environmental flow has been suggested as a possible cause for eight of the trigger exceedances. A reduction in vegetation richness in low quadrants in zone 3 may be associated with increased inundation or increased ground water levels, increased residence time and a subsequent reduction in gaseous exchange ability for plant roots. The presence of the minimum environmental flow may also have contributed to the peak in *Asmicridea* caddisfly abundance and hence to the changes in EPT indicator values.

10.3.5 Hydro-peaking prior to monitoring

Following the high flow event in May 2007, power station operations increased in variability due to the greater availability of water in other Hydro Tasmania catchments. This resulted in more ‘peaking’ operations during the week before the vegetation and fish monitoring as compared to the year as a whole. These fluctuating water levels may have contributed to the hydraulic stress already experienced by trout in the system, resulting in a decrease in margin feeding and movement to deeper pools.

Sampling for macroinvertebrate and geomorphology had already been completed prior to this period of changed discharge conditions, thus trigger values for these disciplines were not affected by peaking flows.

10.3.6 Discussion of flow – trigger links

When considered collectively, the potential links between the flow regime during the monitoring year and trigger value exceedances are interesting because with the exception of hydro-peaking and the environmental flow, the flow characteristics identified as probable drivers of trigger exceedances are not consistent with pre- or post- Basslink power station operations. The extended 2-turbine power station operation was related to routine power station maintenance, and the extended drought and very high flow in May are part of the natural variability of the catchment. Several triggers appeared to respond to these events. This suggests that the 'triggers' are good indicators of change in the system, but also highlights the need to examine the underlying drivers of change in the system before attributing these changes to Basslink and considering management responses.

10.4 Logistical aspects of monitoring affecting results

A number of logistical aspects of monitoring during the 2006-07 monitoring year were identified by the researchers as probable contributors to trigger value exceedances. These include:

- slightly impaired macroinvertebrate samples in autumn due to high inflows and rising water levels during sampling;
- the one-month delay in sampling fish and vegetation resulting in data being collected later than during the pre-Basslink period. This is especially relevant to fish monitoring, as the delay forced sampling to coincide with the known period of fish spawning which could have reduced fish numbers in the Gordon;
- the reference sites for the fish monitoring were sampled four weeks earlier than the Gordon monitoring, before the large flow event, commencement of spawning season and increased variability of power station operation. These differences eliminated the possibility of comparing the two datasets; and
- the omission of one riparian vegetation site in zone 4 lead to trigger values being exceeded due to a different number of sites being used in the averaging of vegetation results.

10.5 Summary

The first year of post-Basslink monitoring has coincided with power station operations which differed from the pre-Basslink operating regime, and did not contain several of the flow elements predicted to occur under Basslink. This was due to extended maintenance at the power station limiting discharge to two turbines for much of the monitoring year combined with an extended drought and a very high flow event in May 2007.

A total of 34 trigger values (13%) were exceeded during the monitoring year. Trigger values were exceeded in all disciplines except algae cover and karst, however, in no discipline were the exceedances considered to be of concern. A level one response ('note and explain') is required for all exceedances, and has been addressed in this report, with most likely explanations provided for the exceedances. The trigger exceedances detected during this first monitoring year can be largely accounted for by flow components and logistical issues not related to Basslink, and the Basslink researchers collectively suggest that one monitoring year consisting of an atypical flow regime with respect to pre- or post-Basslink conditions is insufficient to identify Basslink related changes.

The results from 2006-2007 highlight the variability of flow in the Gordon, and show the necessity of assessing trigger exceedances in the context of the hydrology of the monitoring year. It is likely that many years will be atypical compared to the 'expected' Basslink flow regime, and interpretation of trigger exceedances will be complex. As additional data is collected over longer time periods, trends will emerge which will provide a more indicative picture of changes in the Gordon compared to any one monitoring period.

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