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Basslink Monitoring Program

Gordon River Basslink Monitoring Annual Report

2003-04

Prepared by

Hydro Tasmania

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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. The principal objective of the report is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program during the 2003-04 reporting year.

2003-04 was the third year of pre-Basslink monitoring. The program will extend the knowledge gained during the 1999-2000 investigative years and the 2001-03 monitoring on the present condition, trends, and spatial and temporal variability of the middle Gordon River environment. This information will assist in the future management of the river.

The results from the 2003-04 monitoring are reported in eight sections. Where appropriate, comparisons have been made with the data from earlier years. The information presented in this document is extracted from field reports produced by the various scientists employed to conduct the monitoring. The efforts of these researchers are duly acknowledged.

Hydrology

The 2003-04 year was notable for being somewhat wetter than average, recording 3.11 m of rainfall at nearby Strathgordon. August-September 2003 and May-June 2004 were the wettest months, while November 2003 recorded substantially lower than normal rainfall.

The power station operations tended to reflect the rainfall pattern inversely. Discharge was relatively low and intermittent during the wet months and became high and more consistent during the drier months of January to April 2004. There was also a substantial maintenance outage in October-November 2003, during which time the power station discharge was zero. In general, the power station operated at a much lower rate than usual, with a median discharge value of around 20 $m^3 s^{-1}$ as opposed to the long-term median of around 132 $m^3 s^{-1}$. Throughout the year, the power station operated at full capacity 31% of the time and was not operating 24% of the time.

The majority of shutdown events were of less than 10 hours duration, with a modal value of 5-7 hours. Seventy-one shutdown events were recorded during 2003-04. Power station operating events were clustered around 16-24 hours, with very few short-duration events (<10 hours) compared to 2002-03.

A new gauging site (site 65) was established upstream of the Denison-Gordon confluence, which commenced operating in January 2004. The purpose of this site is to measure compliance of the post-Basslink environmental flow. The first six months of record indicated a flow pattern governed by power station discharge, with the addition of tributary inflows during the wetter months.

The flow pattern at site 44 (Gordon above Franklin, 33 km downstream of the power station) indicated that natural flood events originating in tributary streams were relatively common and corresponded broadly with the rainfall pattern recorded at Strathgordon. During the drier months, the downstream river flow matched the power station tailrace discharge pattern closely.

The duration curve for site 44 showed the contributory effect of the natural inflows. Whereas the median discharge value at the tailrace for 2003-04 was around 20 $m^3 s^{-1}$, the median at site 44 was a substantial 160 $m^3 s^{-1}$. This is only slightly less than the long-term median of 191 $m^3 s^{-1}$ for this site.

Water Quality

Surveys of water quality were undertaken on Lake Gordon and Lake Pedder during July and October 2003, as well as February and May 2004. The physico-chemical conditions of surface waters Lakes Gordon and Pedder were considered normal for lakes in the region. One incidence of high chlorophyll-a values was recorded at Boyes Basin during the summer (February) monitoring. Such levels have not previously been recorded in Lake Gordon and no similar elevation in chlorophyll-a was recorded at other sites or other monitoring times.

The stratification characteristics of Lakes Gordon and Pedder were similar to those recorded in previous years.

Monitoring in the Gordon River included water temperature at three sites (tailrace, 75, 62) and dissolved oxygen at the tailrace site. Water temperatures in the river showed a broad seasonal pattern related to the water temperature of Lake Gordon. Diurnal and weather-related temperature patterns were eliminated during times of power station discharge, with even small discharge volumes (<10 $m^3 s^{-1}$) constraining temperatures at the closest site (site 75). This effect was less marked at site 62, but larger power station discharges still dominated water temperatures at this site.

Dissolved oxygen concentrations were monitored at the tailrace site and did not fall significantly below 6 mg l^{-1} during 2003-04. High dissolved oxygen values were associated with variable power station output. A study of oxygen and total gas saturation showed that, although oxygen levels were supersaturated during the test operating regime, the total gas saturation levels did not exceed 99%.

Fluvial Geomorphology

During 2003-04, geomorphic monitoring in the middle Gordon River was conducted in October 2003 and March 2004. Erosion pins and scour chains were measured on all trips, with photo-monitoring completed in March. The October monitoring followed a period of extended power station shutdown. The March monitoring following a period of high power station discharge. Field conditions during the March trip limited the ability to obtain useful comparative photographs.

Field observations reflected the preceding power station operating patterns. In October the deposition of fine muds and organic debris on banks in all zones was common, due to deposition associated with natural flow events during the power station shutdown. In March this deposition was absent in zones 1 or 2, and seepage erosion processes were active. Piezometer results show that in-bank water surface slopes exceeded 0.1 during this period, consistent with previous results and the present understanding of seepage processes.

Comparative photo monitoring has shown little activity at most sites. Vegetation density and size has increased above high water level at some landslip sites, but many slip faces remain vegetation free.

Erosion pin changes in zones 1 & 2 were consistent with previous results and reflected power station operation, with the influence of natural inflows limited to the deposition of fine-material on bank toes during power station shutdowns. Seepage erosion was widespread following 3-turbine to 'off' power station operation in March 2004 in these zones, with calculated annual rates of change frequently exceeding 100 mm yr^{1}. Erosion pin data also suggest that the 1- and 2- turbine peaking operation of the power station during the winter combined with high rainfall resulted in repeated saturation of the lower banks and toes, promoting the mass movement of material down slope.

High winter flows occurred during the monitoring year, with river levels in excess of 8 m recorded at the Gordon above Franklin gauge site (site 44). In zones 3 - 5, the winter events deposited material on the upper banks and toes, with mid-banks commonly showing erosion due to scour associated with fluctuating water levels. Toe scour was recorded at many sites in March 2004 following prolonged 3-turbine power station operation, and this reflects the re-adjustment of the banks from winter flow events to power station flow conditions.

Piezometer results showed that in-bank water levels reflected river levels as previously documented. There were several periods during the monitoring year when in-bank water surface slopes would have posed a high risk of seepage erosion. These corresponded to power station shutdowns immediately following prolonged 3-turbine operation. When this type of shutdown was accompanied by high rainfall and followed by 1- or 2-turbine peaking operation of the power station, the high risk period for seepage erosion was prolonged, due to the inability of the banks to drain, and continued inflow to the bank from rainfall. Inconsistencies and off-sets within the piezometer records suggest that the probes may not be providing an accurate record of in-bank water surface slopes, and should be investigated.

Karst Geomorphology

Karst monitoring was conducted in October 2003 and March 2004. There were few significant natural flow events in the Bill Neilson Cave stream. Sediment transfer processes in the wet sediment banks at the cave entrance were generally similar to previous years. There was no evidence of any major sediment shift at any of the monitoring sites within Bill Neilson cave from this year's photos.

In Kayak Kavern, over the 2003 winter, erosion occurred at the northern end of the silt mound and deposition at the southern side in the eddy. The 2003-04 summer was a period of deposition on the top of the silt mound and in the eddy, although erosion has continued on the front slope of the mound. There may be similar flux processes occurring here as in Bill Neilson Cave with relatively stable conditions at high and low levels and fluctuations primarily affecting the middle levels of the slope.

In cave GA-X1, similar sediment deposition trends were evident as in the previous summer period. The water level data from GA-X1 correlate well with those of the Gordon River at site 72 (G5), suggesting a relatively good connection between the river and the cave. The inundation regime this period was relatively stable due to the extended shutdown period and the extended period at full gate. This was a relatively significant period of erosion at the lowest pin in the cave.

There was no significant change in the distances between the erosion pins at the doline site, indicating no appreciable change in the structure of the feature, either over the last sampling period, or since the pins have been installed. There were no changes observed from the photo-monitoring pictures. In October 2003, a small depression was observed. A new photo-monitoring site was installed to monitor any changes to the morphology of the base of the depression.

There were no significant changes evident from the photo-monitoring of Channel Cam.

Riparian Vegetation

Riparian vegetation monitoring took place in November 2003 and April 2004. Poor weather and high flows during the autumn trip prevented access to some reference sites. These were monitored in May 2004.

Seasonal influence continued to dominate seedling recruitment patterns in the upstream zones in the Gordon River. Stratification of quadrat types was also greatest in the upstream zones: those subject to the greatest flow regulation influence.

Size class analysis of seedling recruitment showed that while germination occurred in most areas, including the highly impacted areas below the Plimsoll line, seedlings did not persist. This pattern is less severe but still apparent at the furthest downstream site, which is 32 km from the tailrace.

Species richness data showed few significant differences over the monitoring period. Patterns between zones and between quadrat types were present, as expected, with increasing richness corresponding to distance downstream of the power station, and higher bank position.

Macroinvertebrates

Macroinvertebrates were monitored in spring (October) 2003 and autumn (April and May) 2004.

Overall patterns of diversity, community composition and abundance were similar to those observed in previous years. For the quantitative monitoring, all Gordon River sites fell below reference sites in total abundance.

O/E values followed the same trends as observed in previous years. Combined season O/Epa and O/Erk values upstream of the Denison fell into the significantly impaired band (B), while sites downstream of the Denison fell around the lower margin of band A. These values were statistically significantly lower than those for reference sites. The trend in single season O/E values was similar for all seasons and for O/Epa and O/Erk, with lower values in the reaches immediately downstream of the power station. O/E values increased with distance downstream, but did not usually reach the values attained by the reference sites.

Paired t-tests of O/Epa and O/Erk values for all sites did not suggest a significant change between this survey and those of previous years. This indicates that no consistent or substantial change in O/E values has occurred across all sites between any of these dates.

Algae

Benthic algae were sampled in spring (October) 2003 and autumn (March) 2004. As in previous monitoring, plant cover was low (typically 10% or less, with an overall mean of 2.9% cover across all transects), and decreased downstream from the Gordon power station to the Franklin River junction. Moss cover in 2003-04 was not significantly different from that in 2002-03.

Fish

The November 2003 fish survey was conducted at the end of an extended power station maintenance shutdown. Water flows and temperatures had varied naturally in the two months prior to monitoring. The April 2004 monitoring took place during the recession of a significant natural flow event and followed several weeks of high-discharge power station operations.

Brown trout catch rates were similar to previous years. The fish dominated catches in the middle Gordon River and tributary streams. The redfin perch distribution appears stable at present and there is a developing pattern of seasonal movements between zones 1 and 2.

Short headed lamprey were a small component of the lamprey catch, which was dominated by pouched lampreys in both November and April surveys. In November, a number of dead and dying adult lampreys were observed. This was attributed to the high mortality associated with the seasonal spawning migrations.

The majority of eels were collected in the lower Gordon and Franklin Rivers. Catches from the April 2004 survey were relatively small in comparison to historical results, and may be an artefact of high flows in the catchment immediately prior to sampling.

The distribution of galaxiids in the Gordon and reference rivers was similar to previous surveys, although the catch rates in the April survey were generally low. This is a consistent pattern for these species due to the high numbers captured during the summer in association with the annual whitebait run. Remnant populations of climbing galaxias persisted in the zone 1 tributaries, whilst galaxiids were absent from catches in the middle zones of the Gordon catchment. In November, schools of whitebait were observed in zone 5 and zone 7 of the Gordon and Franklin Rivers respectively. Juvenile galaxiids were strongly represented in catches from these zones in both rivers.

Sandys were captured from a single zone 4 tributary, zone 5 of the Gordon River and zones 7 and zone 8 in the Franklin River. Catches of this species were high in the Birches Inlet sites and low in the Henty River.

Catch rates were generally low in the April 2004 survey. The majority of sites were sampled on receding flows, which may have affected fish behaviour and had negative implications for catch rates.

Interdisciplinary linkages

It is evident that interactions between disciplines are important for investigating underlying processes and for a better understanding of the monitoring results. Hydrology and water quality affect all sites downstream of the power station to varying degrees. The regulated hydrological regime drives significant downstream geomorphic processes and the combination of these interactions affects riparian vegetation, benthic algae, macroinvertebrates and fish.

The regulated hydrological regime combined with topography and physical barriers may impede fish movement, an important factor in the Gordon River given that most native species are migratory.

Impoundment and flow regulation have the effect of damping or eliminating diurnal and weather-driven water temperature signals, although a fundamental seasonal signal remains. This reduction in temperature range and variability is likely to impact directly on macroinvertebrates and fish. It possibly has an impact on benthic algae, although this is likely to be less than the hydrological effect.

The interaction between the Lake Gordon water quality, water level and the intake to the power station may be creating opportunities for downstream translocation of lacustrine organisms under certain conditions. The largest and most obvious of these apparently translocated biota is the redfin perch.

The Basslink Baseline Report, which is due to be produced in 2005, will include a discussion and examination of interdisciplinary linkages and interaction effects.

Contents

1 Introduction and background

The Gordon River Basslink Monitoring Annual Report (GRBMAR) is the primary output from the Gordon River Basslink Monitoring Program, which is being conducted by Hydro Tasmania. The objective of this report is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program during 2003-04. The report is to be submitted to the Minister administering the *Water Management Act 1999* (Tasmania) and the Commonwealth Environment Minister.

The Gordon River Basslink Monitoring Program was incorporated into Hydro Tasmania's Special Licence by a Deed of Amendment in 2002. The work carried out in 2003-04 fulfilled the requirements of the specified monitoring program.

1.1 Context

The fundamentals of the Basslink Monitoring Program (BMP) were established as outcomes of the Basslink approvals process via an Integrated Impact Assessment Statement (IIAS) presented to the Basslink Joint Advisory Panel.

The IIAS researchers concluded in Blühdorn (2001) that Basslink-induced changes to the operating regime of the Gordon Power Station were predicted to affect:

- Fluvial geomorphology, by changing the geomorphic processes controlling stability of the Gordon River banks relative to the present processes. This is predicted to increase the probability of scour and modify seepage erosion processes;
- Riparian vegetation, by accelerating present rates of loss of communities, in part by causing a migration of existing vertical zonation up the banks;
- Benthic macroinvertebrates, by altering the community composition and further reducing diversity and abundance; and
- Fish populations, by a reduction in habitat and food (macroinvertebrate) availability.

These conclusions resulted in the development of a set of mitigation measures to be introduced following Basslink implementation. The aim of the mitigation package is for no net Basslink impact, and this is defined in Locher (2001b) as, 'impact that remains within the present boundaries, recognising inherent variability in the environmental indicators as well as long-term presently occurring trends'.

1.1.1 BMP aims

The Basslink Monitoring Program has been designed to provide the information needed to assess Basslink-related impacts. The aims of the Basslink Monitoring Program are:

- To undertake three years of 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 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.

1.1.2 Existing conditions

The focus of the pre-Basslink monitoring program has been to measure conditions under the presently existing operating regime, rather than attempting to relate them to 'natural' or 'pristine' conditions. This approach is implicit in the first aim of the monitoring program, above, and 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 middle Gordon Power Scheme.

In terms of World Heritage values, the highly modified conditions in the Gordon River have been explicitly recognised throughout the World Heritage nomination and management activities and the Basslink approvals process. Kriwoken (2001) documented the specific points that:

- the production of hydro-electricity significantly and extensively impacted South-west Tasmania, and in particular the Gordon River, four years before the region was first nominated as a World Heritage Area. The Gordon River was therefore a regulated, highly modified river environment and not representative of a pristine ecosystem when listed under the World Heritage Convention;
- the 1982 and 1989 World Heritage Area nominations expressly acknowledge existing hydro-electric schemes and the direct impact those schemes have on natural waterways in the Tasmanian Wilderness World Heritage Area (TWWHA). Implicit in this acknowledgement is that downstream ecosystems are modified by flow regulation; and
- Lake Gordon, the Gordon River Power Station and the tailrace were not included in the TWWHA.

1.1.3 Previous decisions and other investigations

There has been some feedback from stakeholders associated with the Basslink Monitoring Program suggesting that a much broader, whole-of-catchment approach would be a more appropriate resource management paradigm for the BMP to adopt.

The raft of independent investigative studies produced for the Basslink IIAS (see Locher 2001a) led, via the comprehensive approvals process, to the formulation of the BMP and its requirements. These were, by agreement, enshrined in the Special Licence which Hydro Tasmania holds under the *Water Management Act* 1999. The constraints on the BMP are appropriate for the task at hand (as defined in the Special Licence) given the physical limitations of the area and climate and the resource constraints of the Basslink project.

The broader investigative remit of the IIAS studies allowed a comprehensive range of issues to be studied. These included the likely effects on Macquarie Harbour and on the Gordon River meromictic lakes. Management actions independent of the BMP have been taken to address issues identified by these studies.

1.1.4 Basslink Baseline Report

The next step in the Gordon River Basslink Monitoring Program is the production of a comprehensive statement of pre-Basslink conditions in the middle Gordon River. This will involve the analysis of all 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.

This work is due for completion in late 2005. The Basslink Baseline Report will be a public document.

1.2 The 2003-04 monitoring program

The Gordon River Basslink Monitoring Program for 2003-04 completed the third year of pre-Basslink monitoring.

As well as completing the two required monitoring trips for this year for each discipline, supplementary monitoring was carried out for riparian vegetation, benthic macroinvertebrates and fish in May 2004 due to the effects of poor weather and high water levels which occurred during the scheduled autumn monitoring.

1.3 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 and the absence of access infrastructure.

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. They 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 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.

1.4 Geographic datum

Map coordinates given in this document use the 1966 Australian Geodetic Datum (AGD) as this corresponds with the topographic maps currently available for the area. A later datum, the Geocentric Datum for Australia (GDA), has recently been adopted. Site references using the AGD will be approximately 200 m different from those using the GDA. These will be updated as new maps become available.

1.5 Document structure

This document is the third of the Gordon River Basslink Monitoring Annual Reports to be produced, and is organised into eleven 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 2003-04, 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);
- Macroinvertebrates (section 7);
- Algae (section 8); and
- Fish (section 9).

The results from the 2003-04 monitoring are reported in each of these sections. Some between-year analyses were undertaken, where sufficient data were available to make such analyses meaningful. A more complete analysis of variability and time-related trends within the Gordon River ecosystems under study will be reported in the Draft Basslink Baseline Report, which is due to be submitted four months prior to the commencement of Basslink.

Section 10 briefly discusses the interdisciplinary linkages which are likely to be in operation in the middle Gordon River, while section 11 lists the reference material used in this report.

1.6 Authorship of Field Reports

The information presented in sections 2 - 9 was extracted from field reports produced by the various scientists employed to conduct the monitoring, as shown in Table 1.1. The efforts, and original contributions, of these researchers are duly acknowledged.

This document was prepared by David Blühdorn, with considerable assistance from the researchers and internal reviewers, including Helen Locher and Greg Carson.

Table 1.1. Section numbers, section titles and original authors from whose field reports the information in sections 2 – 9 was extracted.

Section	Section title	Author(s)
2	Hydrology	David Blühdorn and Wes Jeffries (Hydro Tasmania)
3	Water quality	David Blühdorn and David Andrews (Hydro Tasmania)
4	Fluvial geomorphology	Lois Koehnken (Technical Advice on Water)
5	Karst geomorphology	Jenny Deakin and Jeff Butt (consultants)
6	Riparian vegetation	Anita Wild (Hydro Tasmania)
7	Macroinvertebrates	Peter Davies and Laurie Cook (Freshwater Systems)
8	Algae	Peter Davies and Laurie Cook (Freshwater Systems)
9	Fish	David Andrews (Hydro Tasmania)

1.6.1 Vale Jeff Butt

It is with sadness that we note the death of Jeff Butt in April 2004 from natural causes. Jeff was one of the karst consultants who had worked on the BMP since its inception, as well as the antecedent IIAS. He made a significant contribution to the program and to our understanding of the karst processes in operation in the Gordon River area.

Jeff will be missed.

1.7 Site numbers

Throughout this report, monitoring locations are identified by site number. These represent the approximate distance upstream from the Gordon River mouth at the south-eastern end of Macquarie Harbour. The monitoring work is conducted between sites 39 (immediately downstream of the Franklin River junction, 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 riverbank 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.

In the macroinvertebrate section (Section 7), some figures use 'distance from the power station' to better illustrate the point being made. Site numbers can be determined, if necessary, by subtracting 'distance from power station' from 77.

2 Hydrology

The hydrological conditions in the Gordon River are important, both in direct water volume terms and with regard to the effects on the physical and biotic systems of the river. A changed hydrological regime is the major impact that Basslink might have on the Gordon River, and hence the variability of the current hydrological regime is of prime importance in the analysis of other aspects of the environment of the Gordon River.

This part of the Gordon River Basslink Monitoring Annual Report summarises the hydrological data from the Gordon River downstream of the Gordon Power Station for the 2003-04 period.

2.1 Site Locations

The seven gauging stations used to record river levels during 2003-04 are shown in Figure 2.1. These were sites 39, 44, 62, 69, 71, 75 and the Gordon Power Station tailrace (site 77). Figure 2.1 also indicates a monitoring location at site 65. This site was installed late in 2003 and commenced operation in January 2004.

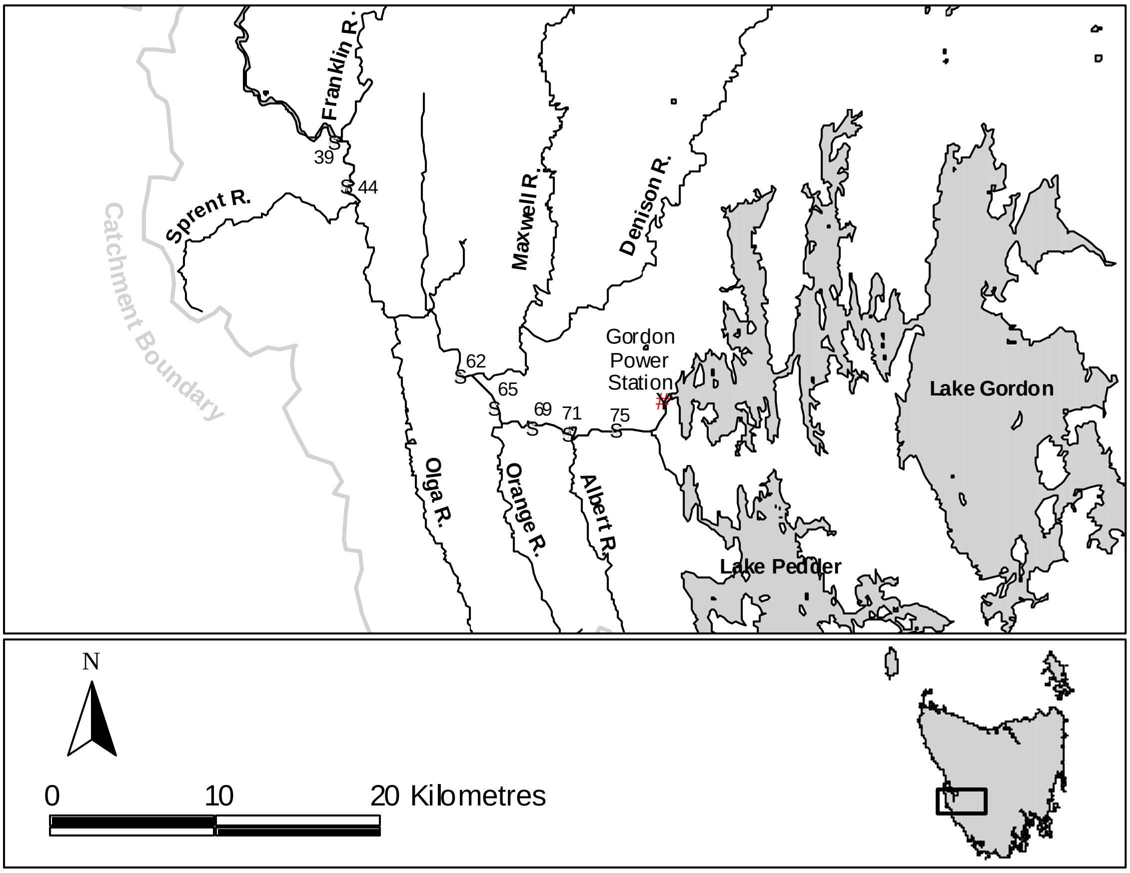


Figure 2.1. Location of the water level recorders in the middle Gordon River.

2.2 Strathgordon rainfall

The Strathgordon meteorological station is located approximately 5 km east of the Gordon Power Station. It has rainfall records dating back to 1970, which allow the development of long-term mean monthly values and comparisons with the monthly rainfall totals recorded for 2003-04. Figure 2.2 shows the total monthly, and long-term mean, rainfall values. These indicate that the rainfall for the 2003-04 year was about 26% greater than the long-term average (3,110 mm vs. 2,466 mm). August-September 2003, January 2004 and May-June 2004 exceeded the 80th percentile of the long-term values for those months. November 2003 and March-April 2004 recorded at or below the 20th percentile of the long-term record for those months.

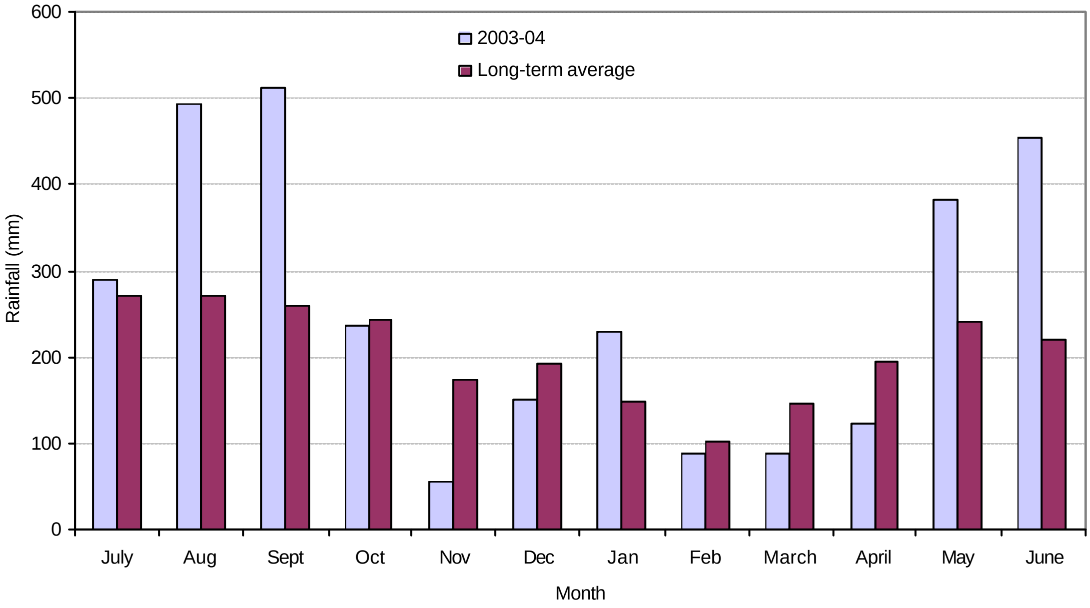


Figure 2.2. Total monthly rainfall values recorded at Strathgordon for 2003-04 compared with mean monthly values from 1970-2004.

2.3 Gordon Power Station discharge

The discharge pattern for the Gordon Power Station is driven by factors other than local rainfall. These include rainfall over the rest of Tasmania's hydropower catchments, state-wide power demand, local maintenance activities, and system constraints.

2.3.1 Discharge

Figure 2.3 shows the discharge from the power station for 2003-04. It indicates a period of intermittent power station operation from mid-July to late September 2003. This was followed by an extended shutdown which lasted until late November. Full discharge conditions ensued until late January 2004 after which a period of very low discharge lasted until mid-February, when full discharge conditions resumed. This lasted until late April, when a more-intermittent operating pattern began which lasted until the end of June.

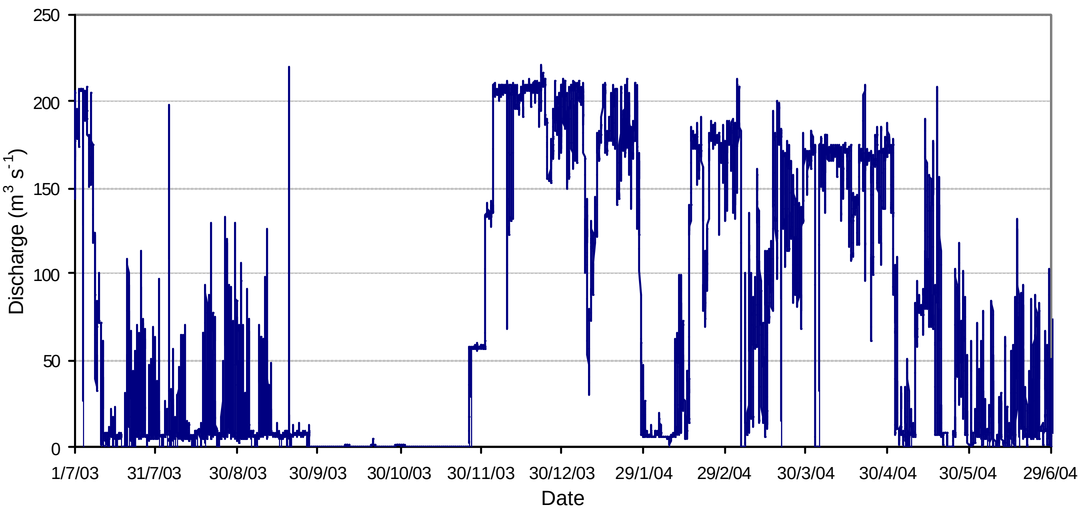


Figure 2.3. Gordon Power Station discharge (hourly data) from July 2003 to June 2004.

During 2003-04, power station operations were geared toward 1 or 3 turbine operations (Table 2.1). The high percentage of time with no machines operating is partially attributable to the October - November power station shutdown. The time at 3 turbine operations was greatly reduced from previous years (31% compared with 60 – 80%).

Table 2.1. Percent of time that each configuration of turbines was in operation during 2003-04.

Operational configuration	Percentage of time operating	Approximate tailrace discharge ($m^3 s^{-1}$)
0 machines running	24%	0-10
1 machine running	33%	70-80
2 machines running	12%	140-150
3 machines running	31%	>210

2.3.2 Median monthly discharge

Figure 2.4 shows the median monthly discharge from the power station for 2003-04 compared with long-term values (since August 1996). This figure illustrates that discharge was lower than usual for July, August and November 2003, and from February to June 2004. It was higher than usual only in January 2004. The low November discharge was the result of an extended outage. This pattern reinforces the general picture of the power station running at lower production levels than in previous years.

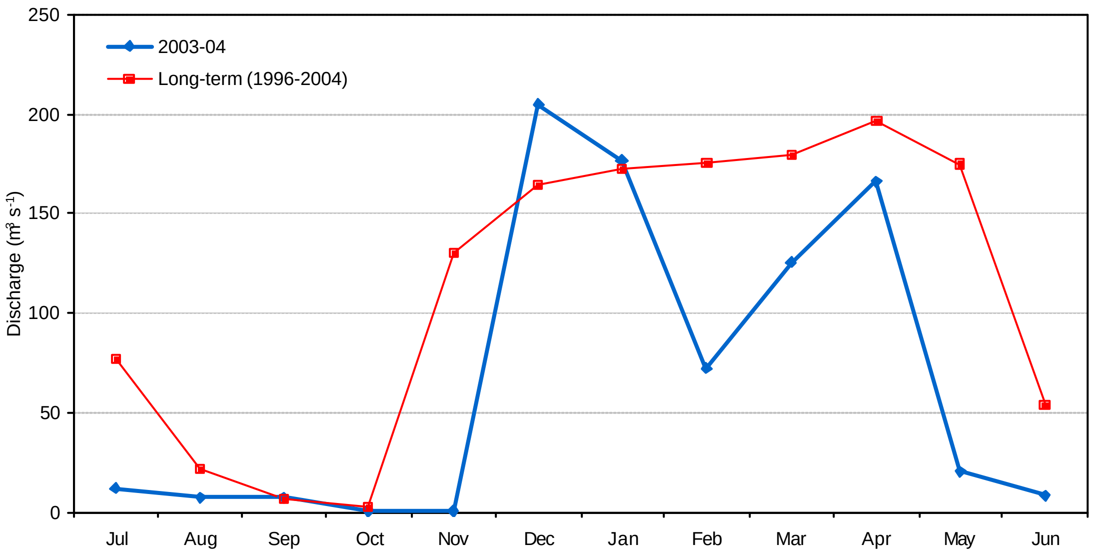


Figure 2.4. Median monthly discharge from the tailrace of the Gordon Power Station for 2003-04 compared with long-term median values.

2.3.3 Duration curves

Figure 2.5 shows the duration curve for the power station tailrace discharge for 2003-04, as well as the long-term (since 1996) duration curve. The 2003-04 curve shows that there was considerably less discharge than usual across the whole curve, with the greatest difference occurring around the median value. The long-term median value was around 132 $m^3 s^{-1}$, while the 2003-04 median value was 20 $m^3 s^{-1}$. In previous years, the duration curves have matched the long-term curves more closely.

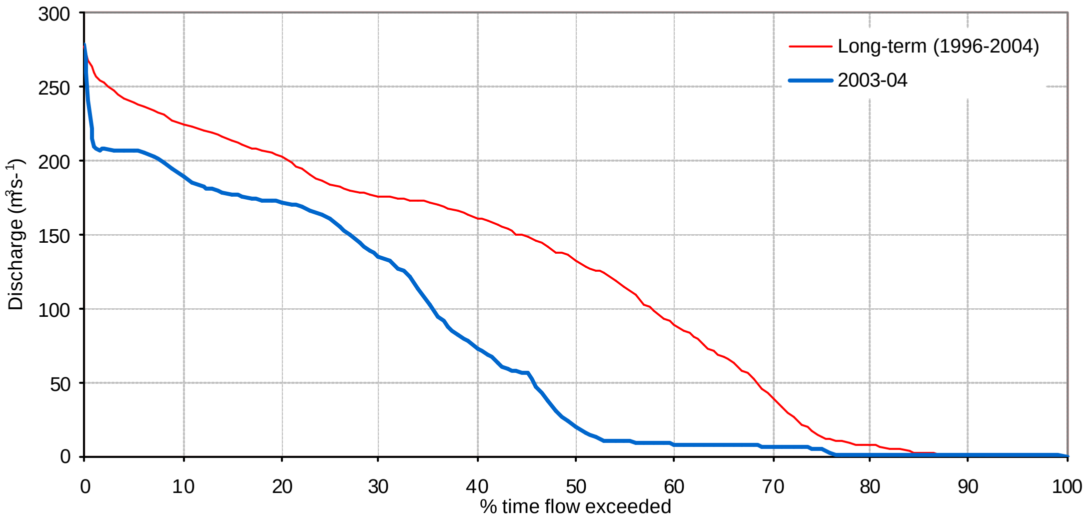


Figure 2.5. Duration curve for discharge from the power station tailrace for 2003-04.

2.3.4 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 2003-04, the shutdown events were clustered around 4-8 hour durations, a similar modal range to previous years. Figure 2.6 shows the frequency and duration of these events. In total, 71 shutdown events were recorded during the year, a small reduction on 2002-03. The 36 to 48 hour events were attributable to the power station outages required for the Basslink monitoring program, while the long-duration shutdown was associated with the maintenance outage in October-November 2003.

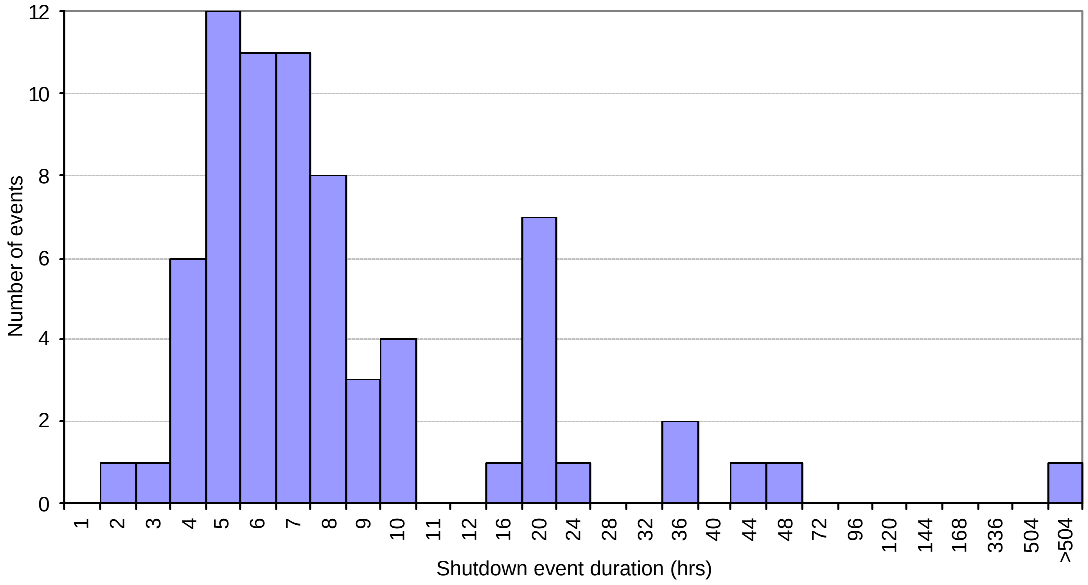


Figure 2.6. Frequency and duration of zero discharge (shutdown) events recorded for the Gordon Power Station during 2003-04.

The number of operating events, indicated by discharges greater than 3 $m^3 s^{-1}$, is shown in Figure 2.7. This figure indicates that there were a comparatively large number of 16-20 hour operating events, a similar modal value to previous years. The number of short-duration start-up events was much lower than in previous years, with few 1-2 hour duration events recorded.

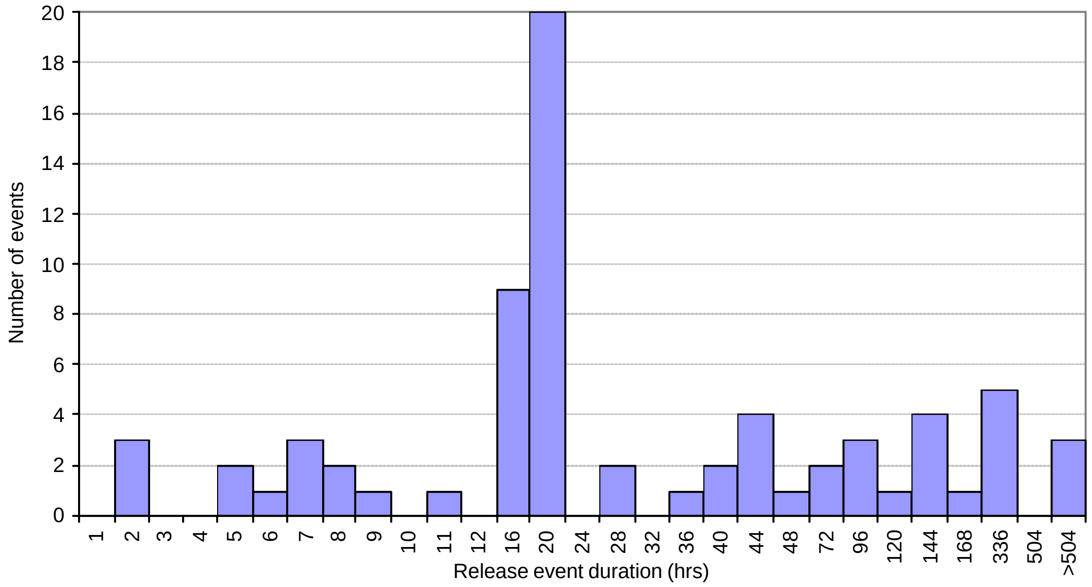


Figure 2.7. Frequency and duration of operating (discharge > 3 m^3 s^{-1}) events recorded for the Gordon Power Station during 2003-04.

2.4 Gordon above Denison (Site 65)

A new stream gauging site was established on the Gordon River at site 65, about 2 km upstream of the Denison confluence, to monitor post-Basslink compliance. This site began recording flow data in January 2004 and Figure 2.8 shows the flow data recorded to the end of June 2004. These data indicate the expected close concordance with power station discharge (Figure 2.3), over which is superimposed the natural discharge pattern from small tributary streams, such as the Albert and Orange Rivers. Note that the rating curve for high discharges at this site is still under development and the upper values shown in Figure 2.8 should be considered indicative only.

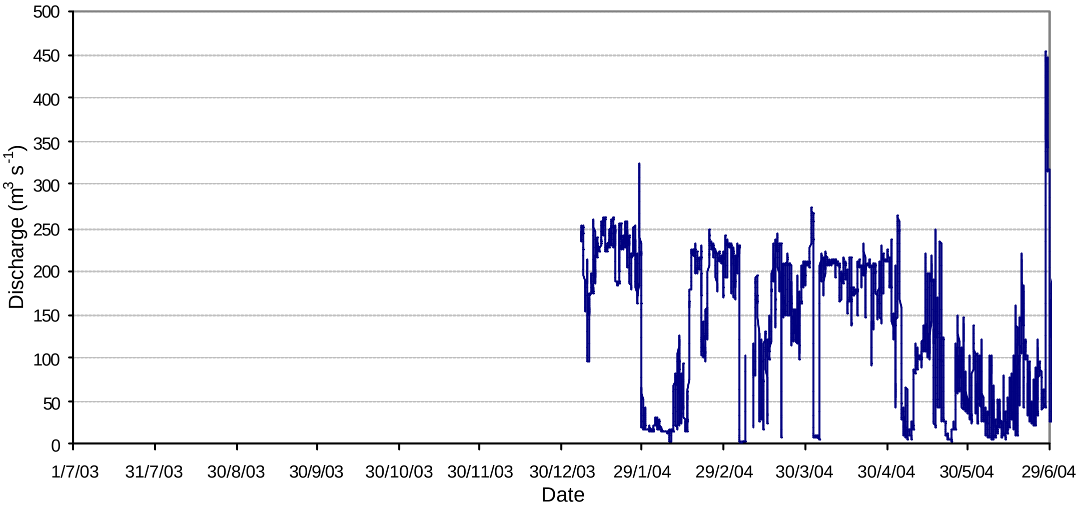


Figure 2.8. Flow recorded (hourly data) at site 65 (Gordon above Denison), from commencement of the site in January 2004.

2.5 Gordon above Franklin (Site 44)

The Gordon above Franklin site (site 44) is the furthest downstream site unaffected by tidal influences. Site 44 records the power station discharge after 33 km of flow in the existing river bed. This is mixed with the discharge from a number of significant tributaries, including the Albert, Orange, Denison, Maxwell, Olga and Sprent Rivers. It does not include flows in the Franklin River. Data from site 44 were used to indicate the effects of tributary streams on the discharge pattern from the power station.

2.5.1 Flow

Figure 2.9 shows the time series plot for flow at site 44 for 2003-04. The power station discharge pattern (see Figure 2.3) remains discernable, especially during the period from December through to the end of April. Over this is superimposed the discharge pattern from tributary streams, such as the Denison River, giving the high peak discharges evident in Figure 2.9. Peak flows occurred regularly from July to September 2003, and in May and June 2004.

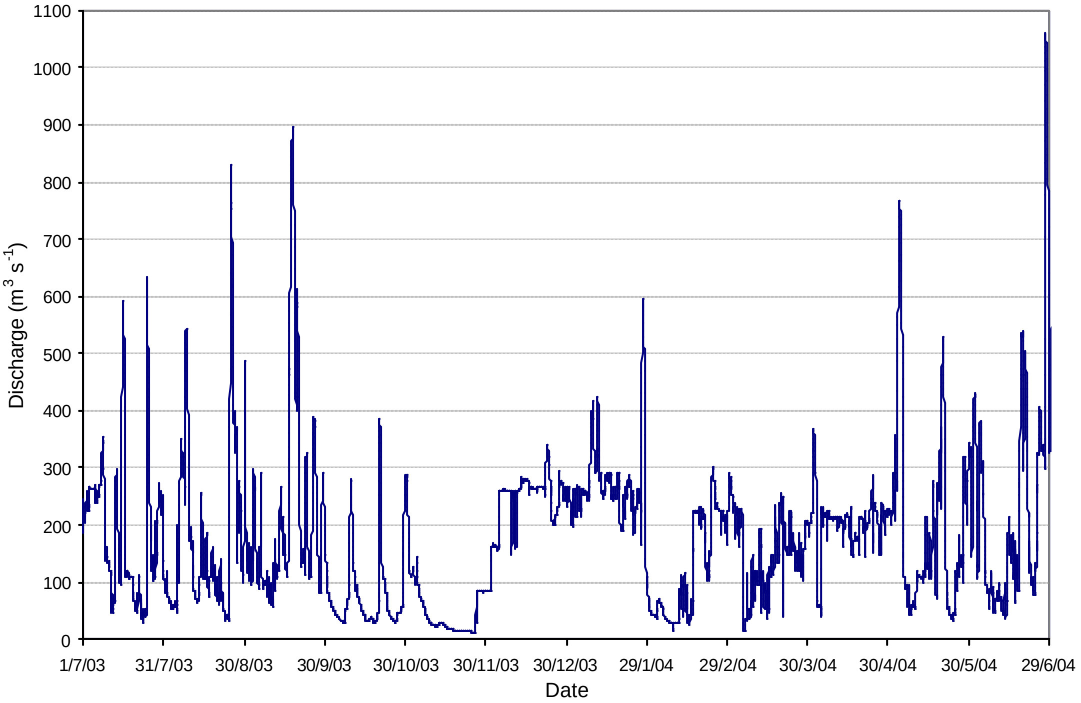


Figure 2.9. Flow recorded (hourly data) at site 44 (Gordon above Franklin) during 2003-04.

The high flow events raised water levels in the lower river considerably above those associated with power station discharge. Whereas power station discharge increased water levels to approximately 3 m, there were about 20 rainfall events that increased river levels to greater than 4 m, and 7 events which increased levels to greater than 6 m. During the large flood in late June 2004 (see Figure 2.9) the river level exceeded 10 m at this site.

2.5.2 Median monthly flows

The peaks in the discharge data for site 44 (Figure 2.9) are also reflected in the median monthly discharge values. Figure 2.10 shows the median monthly discharge for this site over 2003-04, compared with the long-term (since December 1999) pattern. It indicates that discharge at the downstream end of the study area was quite different from previous years. The pattern tended to mirror that of the Gordon Power Station discharge (Figure 2.4) over the spring-summer months, while showing the additional contribution of natural inflows in the autumn-winter months. The main points of difference from previous years was produced by the extended power station outage in November 2003 and the less-than-usual running of the power station from February to May 2004.

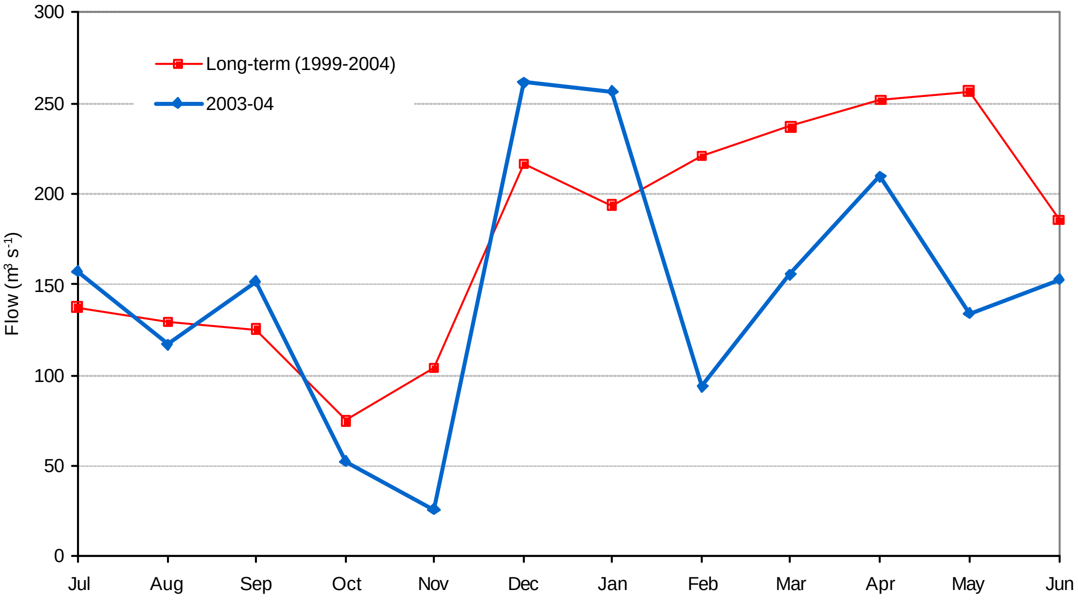


Figure 2.10. Median monthly flow at site 44 (Gordon above Franklin) for 2003-04 and the long-term monthly median values.

2.5.3 Duration curves

Figure 2.11 shows the duration curve for Gordon River site 44 (upstream of the Franklin River) for 2003-04 and compares it with the historic (since December 1999) record. It shows that, for this year, site 44 recorded slightly lower discharge than usual, from the 30th percentile to the 90th percentile.

Figure 2.12 shows the same duration curves with the Y axis scaled to match that of the tailrace duration curves (Figure 2.5). This allows a more accurate comparison between the two sites, and shows that the pattern of low discharges evident at the tailrace was not apparent at site 44, indicating that the tributary streams were making a substantial contribution throughout the year at this site.

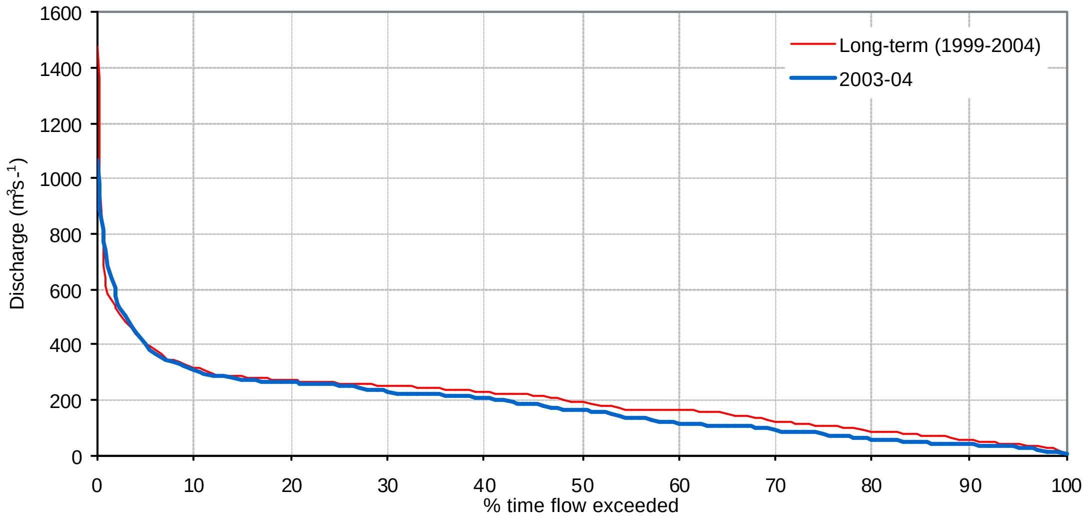


Figure 2.11. Duration curves for the Gordon above Franklin site (site 44) for 2002-03 and historic (since 2000).

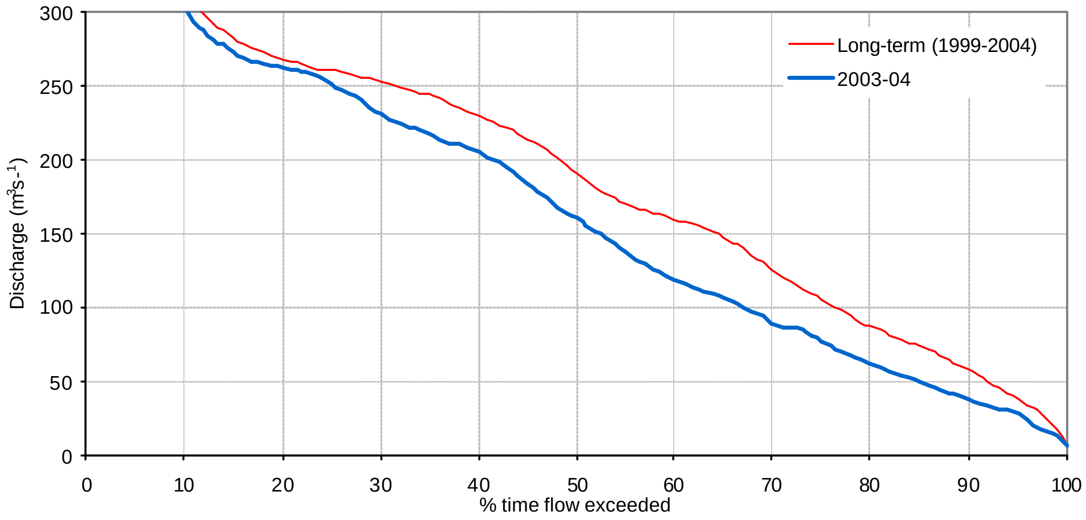


Figure 2.12. Duration curves for long-term and 2003-04 records for site 44 (Gordon above Franklin). The Y axis has been converted to the same scale as that for the tailrace (site 77) duration curves (Figure 2.5).

2.6 Conclusion

The 2003-04 year was wetter than usual, with much of the additional rainfall occurring in August-September 2003 and May-June 2004. Partly in reaction to these rainfall events, the power station did not operate at full capacity during 2003-04, which resulted in less three-turbine operation and more intermittent 1-2 turbine operation than in previous years.

As in other years, the power station operation, and hence the downstream hydrological regime, fell into four categories:

- zero discharge (the power station was not operating), from late-September to late-November 2003; plus a number of shorter periods throughout the year;
- operation at intermediate discharges (indicative of two-three turbine operations), from mid-February to late April 2004;
- operation essentially at full gate in early July 2003, and from late November to late January 2004; and
- operating more intermittently and usually at lower discharges, for the remainder of the year.

On a monthly basis, only December 2003 substantially exceeded the long-term median discharge values. This was a direct consequence of an extended maintenance outage in October-November.

Overall, the power station discharge pattern was much lower than usual, with a median value of 20 $m^3 s^{-1}$ compared with the long-term median value of around 132 $m^3 s^{-1}$.

Analysis of the duration and frequency of shutdown events indicated that there were fewer than 2002-03, but with a similar modal range. In terms of operating events, the power station recorded fewer short-duration start-ups than in 2002-03. The modal range was 16-20 hours, similar to previous years.

A new monitoring site (site 65) was established in January 2004 on the Gordon River, upstream of the Denison confluence, to monitor discharge associated with the mitigation measures to be introduced post-Basslink.

The Gordon above Franklin (site 44) recorded a flow pattern which included the power station discharge plus several peak flow events produced by rainfall and tributary runoff. The data from this site showed that the flow pattern matched the power station tailrace discharge pattern closely from late November to late April. Natural high volume flow events originating in tributary streams were relatively common from July to September 2003 as well as May-June 2004.

The duration curve for site 44 showed the overall effect of the natural inflows. Whereas the median discharge value at the tailrace for 2003-04 was around 20 $m^3 s^{-1}$, the median at site 44 was a substantial 160 $m^3 s^{-1}$. This is only slightly less than the long-term median of 191 $m^3 s^{-1}$ for site 44.

The power station discharge was predominant during periods of low natural flow, from the power station tailrace to the junction with the Franklin River. In 2003-04, tributary streams contributed substantial, seasonally variable volumes to this, as well as peak flows during major runoff events.

3 Water Quality

Water quality parameters were measured in Lakes Gordon and Pedder, and in the Gordon River downstream of the power station during 2003-04. The water quality monitoring sites are shown in Figure 3.1.

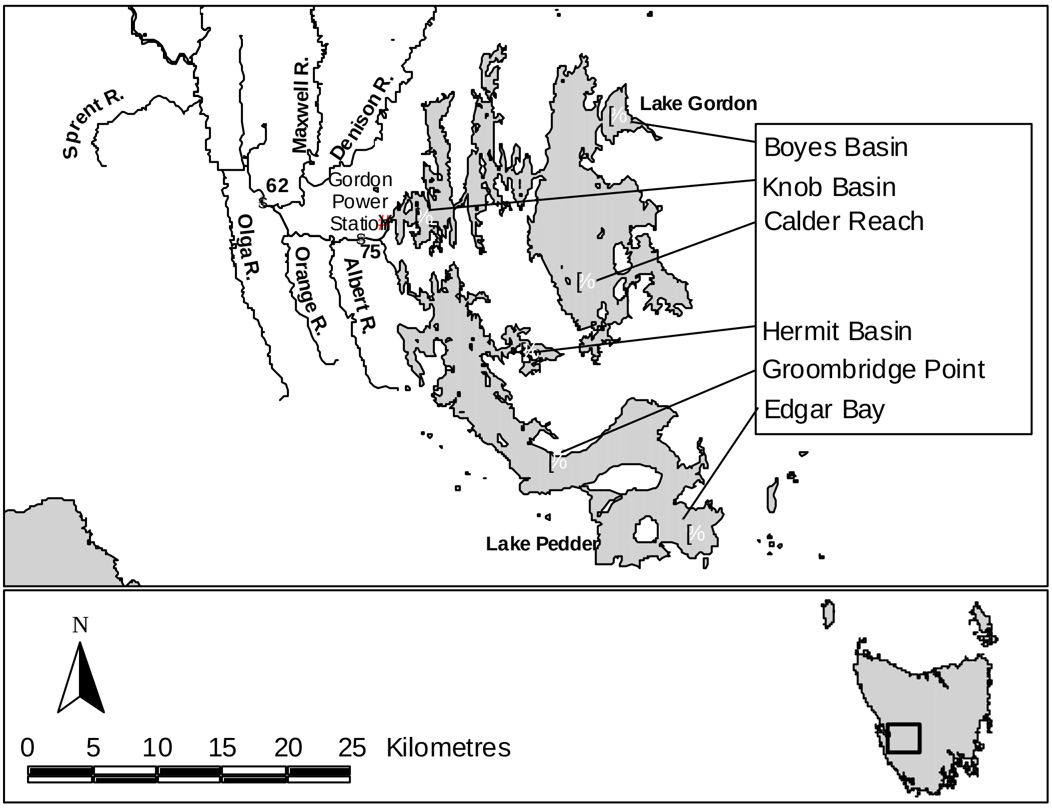


Figure 3.1. Map of the locations of water quality monitoring sites in Lakes Pedder and Gordon, and the Gordon River.

3.1 Field methods

In the lakes, water samples for nutrient analysis were taken from the surface waters. For each water sample, the following parameters were measured by laboratory analysis:

- total phosphorus and dissolved reactive phosphorus (DRP);
- 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, depth profiles of basic physico-chemical parameters (water temperature, dissolved oxygen, conductivity, pH and turbidity) were taken at approximately 2 m vertical intervals at each of the sites in Lakes Gordon and Pedder.

3.1.1 Lake Gordon

During 2003-04, quarterly water quality monitoring was conducted in Lake Gordon at the power station intake, at Calder Basin and at Boyes Basin adjacent to the upper Gordon River inflow. 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 concentration was also recorded at these locations. Surface samples for laboratory measurement of nutrients and metals were collected at the power station Intake, at Calder Basin, and at Boyes Basin.

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. Surface water samples measuring chlorophyll-a, water temperature, pH, conductivity, turbidity and dissolved oxygen were collected at Groombridge Point, Hermit Basin and Edgar Bay, while surface nutrient, metals, DOC and general ions samples were collected from Groombridge Point.

3.1.3 Gordon River

Water quality monitoring was carried out at three sites on the Gordon River downstream from the Gordon Power Station. These were:

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

Water temperature was logged at all three sites, and dissolved oxygen was recorded at the tailrace site.

3.2 Lake Gordon water quality

Figure 3.2 and Figure 3.3 show changes in stratification status at Boyes Basin, Calder Basin and at the Intake site during 2003-04. Depth profiles varied with location, inflows and season.

3.2.1 Boyes Basin

Boyes Basin is the shallowest of the three sampling sites, and closest to one of the major inflows into the Lake, the upper Gordon River. The temperature profiles showed seasonal changes (Figure 3.3). There was little indication of thermal stratification, with only the May sample showing any inflection (at about 13 m depth).

All of the dissolved oxygen profiles for this site showed an increase at around 15 m, peaking at about 20 m (Figure 3.2). This pattern was most pronounced in the February profile and is different from the other Lake Gordon sites. It suggests the effect of inflowing Gordon River water at this site.

pH values remained relatively uniform with depth (Figure 3.3).

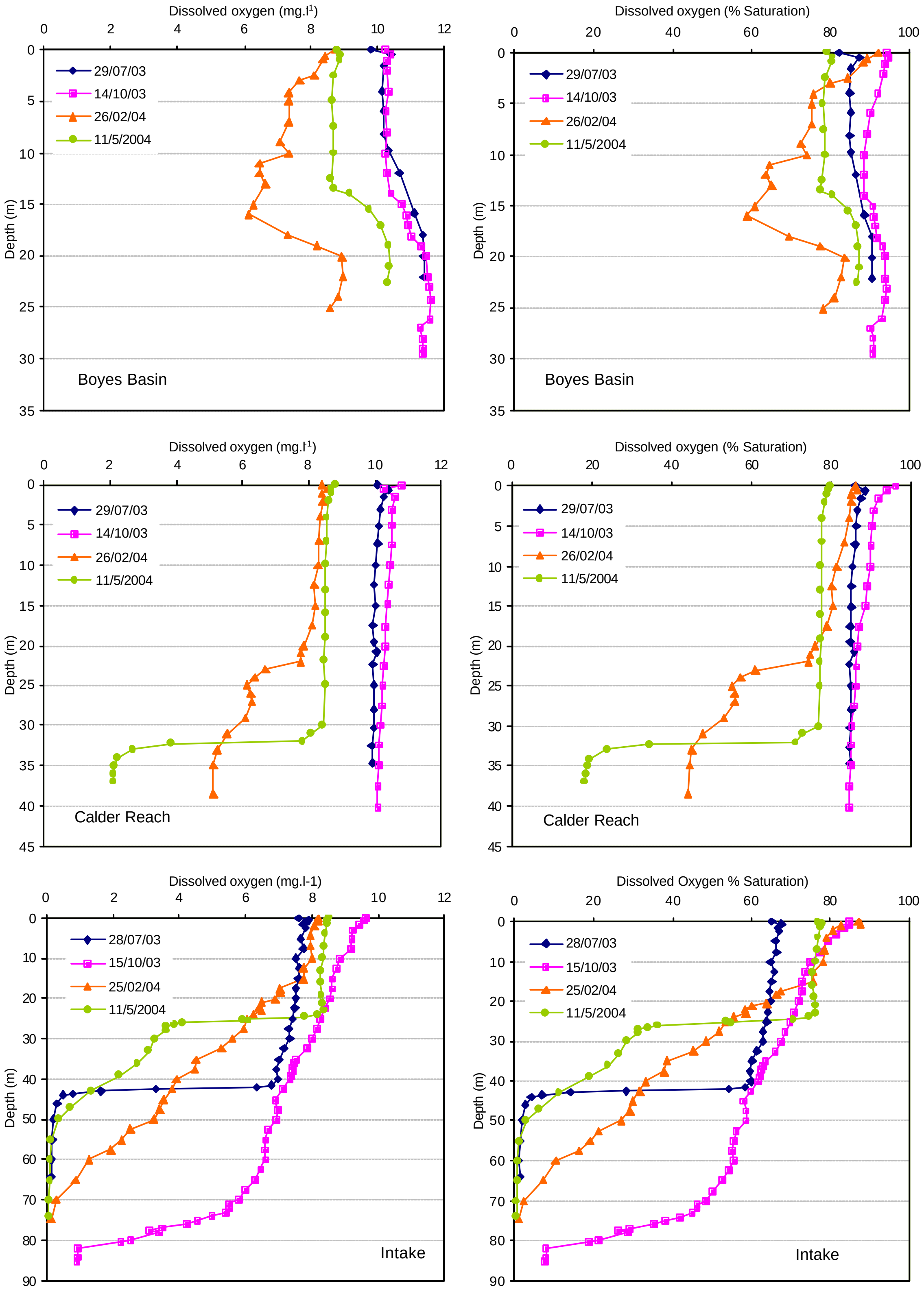


Figure 3.2. Depth profiles of dissolved oxygen concentration (left) and percent saturation (right) in Lake Gordon at Boyes Basin (top), Calder Reach (middle) and the power station intake (bottom) for 2003-04.

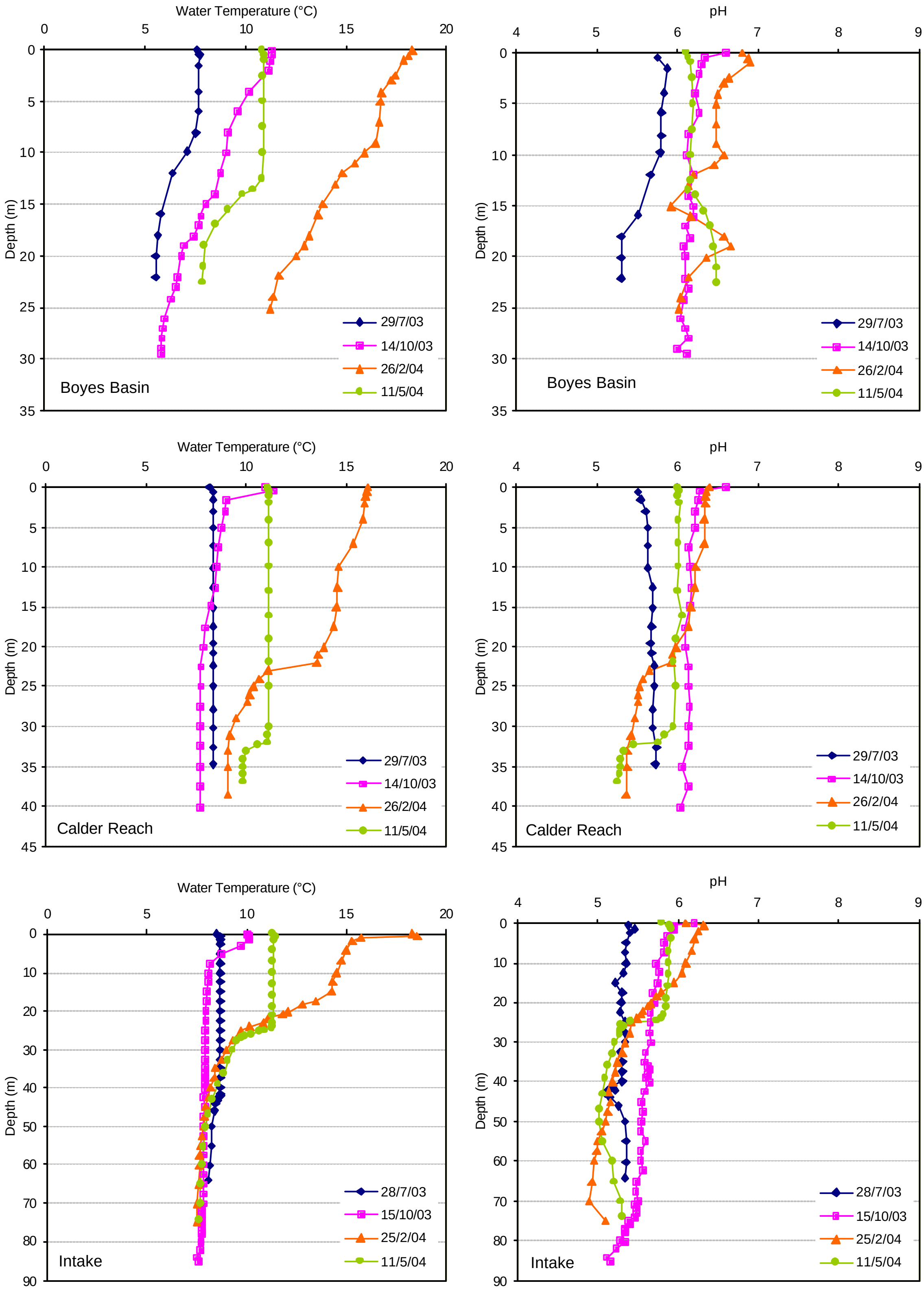


Figure 3.3. Depth profiles of water temperature (left) and pH (right) in Lake Gordon at Boyes Basin (top), Calder Reach (middle) and the power station intake (bottom) for 2003-04.

The Boyes Basin conductivity profiles were fairly typical, with surface values ranging from 40 - 47 µS cm^{-1} and an erratic summer (February) profile which peaked at 64 µS cm^{-1} at 18 m. This again suggests the impact of inflowing Gordon River water.

Surface turbidities were low, ranging from 2.6 to 4.2 NTU.

The Boyes Basin site recorded a very high level of chlorophyll-a during the February monitoring. Usual values for this parameter throughout the lake range from 1-2 µg l^{-1} (see Table 3.1). The February value was 15.14 µg l^{-1}, and this was supported by a duplicate sample which returned a value of 18.19 µg l^{-1}. Both total phosphorus and total Kjeldahl nitrogen values for this sample were also slightly elevated (see Table 3.1). No other site recorded any unusual values.

3.2.2 Calder Basin

The dissolved oxygen (Figure 3.2) and water temperature (Figure 3.3) profiles collected from Calder Reach indicated that stratification was beginning in February 2004 and had become fully established by May. Thermocline and oxycline formation was evident at 23 m in February and 33 m in May. This pattern is also suggested in the pH profile (Figure 3.3). The July and October 2003 profiles showed no indication of stratification.

Surface conductivity values ranged from 38 – 44 µS cm^{-1} and conductivity values were fairly uniform with depth. Surface turbidity values were low and ranged from 2.8 to 6 NTU. Surface chlorophyll-a values were low (all <1.1 µg l^{-1}, see Table 3.1).

3.2.3 Intake site

The deeper profiles at the power station intake showed some measure of stratification year round, during 2003-04. The July profile showed no thermocline, but an oxycline was evident at about 41 m (Figure 3.2). By October the stratification was breaking down, with no evident thermocline (Figure 3.3), and a relatively even decrease in dissolved oxygen with depth. In February 2004, both a thermocline and an oxycline were becoming established at around 15 m and by May the stratification was firmly established with sharp thermo- and oxyclines established at 24 m.

Because of low lake water levels, the power station intake depth ranged from 20 – 26 m throughout the year and was located above the oxycline during all sampling events except February, when it was slightly below the forming cline.

Surface conductivity values ranged from 37 - 43 µS cm^{-1}. In October 2003 and February 2004, the profiles were even through all depths, while the profiles in both July 2003 and May 2004 showed a sharp increase of 5 - 6 µS cm^{-1} at the anoxic depth of 43 m and 50 m, respectively.

The surface turbidity values were very low and ranged from 1.6 to 1.85 NTU. The turbidity profiles were even at around 2 NTU.

The surface chlorophyll-a values were low, ranging from 0.22 to 1.44 µg l^{-1} (Table 3.1).

3.2.4 Surface water sample results

Surface water samples were analysed in the laboratory for the parameters listed in section 3.1. The results of these analyses are given in Table 3.1.

Table 3.1. Value rangess of nutrients, metals, sulphate, alkalinity, dissolved organic carbon and chlorophyll-a taken from three monitoring sites in Lake Gordon during 2003-04.

Parameter	Boyes Basin	Calder Basin	Intake
Total phosphorus (mg l^{-1})	<.005 - 0.055	<0.005 - 0.008	<0.005 - 0.006
Dissolved reactive phosphorus (mg l^{-1})	<0.002 - 0.004	<0.002 - 0.004	0.002 - 0.005
Nitrite (mg l^{-1})	0.003 - 0.004	0.002 - 0.003	0.003
Nitrate (mg l^{-1})	0.037 - 0.062	0.059 - 0.071	0.06 - 0.074
Total Kjeldahl nitrogen (mg l^{-1})	0.209 - 0.334	0.205 - 0.212	0.189 - 0.287
Ammonia (mg l^{-1})	0.007 - 0.027	0.015 - 0.031	0.011 - 0.021
Iron (mg l^{-1})	0.401- 0.692	0.479 - 0.704	0.43 - 0.827
Manganese (mg l^{-1})	<0.005 - 0.015	<0.005 - 0.015	0.005 - 0.012
Zinc (mg l^{-1})	<0.001 - 0.011	<0.001 - 0.008	<0.001 - 0.016
Cadmium (mg l^{-1})	<0.001	<0.001	<0.001
Copper (mg l^{-1})	<0.001 - 0.002	<0.001	<0.001 - 0.001
Aluminium (mg l^{-1})	0.119 - 0.187	0.174 - 0.203	0.13 - 0.16
Cobalt (mg l^{-1})	<0.001	<0.001	<0.001
Chromium (mg l^{-1})	<0.001	<0.001 - 0.001	<0.001
Nickel (mg l^{-1})	<0.001 - 0.001	<0.001	<0.001 - 0.001
Lead (mg l^{-1})	<0.005	<0.005	<0.005
Sulphate (mg l^{-1})	0.9 - 1.3	1 - 1.3	0.96 - 1.2
Alkalinity (mg l^{-1})	7 - 10	5 - 10	5 - 10
Dissolved organic carbon (mg l^{-1})	6.8 - 8	6.1 - 7.2	6.3 - 7
Turbidity (NTU)	2.66 - 4.14	3.24 - 6.04	1.61 - 1.85
Chlorophyll-a (µg l^{-1})	1.02 - 15.14	0.22 - 1.07	0.22 - 1.44

The results shown in Table 3.1 indicate that surface water quality in Lake Gordon was within the expected range for Tasmanian fresh waters in the state's south western region, with reasonably low nutrient and metal levels, relatively high dissolved organic carbon, and slightly acidic pH values. The single notable elevated value was for chlorophyll-a recorded in Boyes Basin in February 2004.

The concentrations of the remaining parameters were similar to, or lower than, those reported in the previous Gordon River Basslink Monitoring Annual Report, and were consistent with concentrations found in other Tasmanian organic-rich west coast waterways.

3.3 Lake Pedder water quality

Lake Pedder is relatively shallow and did not show any indication of stratification in any of the parameters measured. This is consistent with previous monitoring results. Table 3.2 shows the results of water quality monitoring at the three sites in Lake Pedder during 2003-04.

Water samples were analysed in the laboratory for the range of parameters listed in section 3.1. The results of these analyses are given in Table 3.3. As in previous years, these data indicate that Lake Pedder had high water quality. None of these values is outside the normal range for this lake.

Table 3.2. Water quality parameter ranges measured at the three monitoring sites in Lake Pedder during 2003-04.

Parameter	**Edgar Bay (surface)**	**Hermit Basin (surface)**	**Groombridge Point (surface)**	**Groombridge Point (15 m)**
Chlorophyll-a (µg l^{-1})	0.28 – 1.41	0.48 – 1.63	0.5 – 1.25	
Dissolved oxygen (mg l^{-1})	8.4 – 12.1	8.4 – 10.8	8.6 – 10.7	8.3 – 10.6
Dissolved oxygen (% saturation)	84 – 100	86 – 96	86 – 95	82 – 89
pH	6.3 – 6.5	5.5 – 6	6.1 – 6.4	5.9 – 6.3
Turbidity (NTU)	0.95 – 1.29	0.63 – 1.24	0.58 – 1.34	1.54
Conductivity (µS cm^{-1})			39.5 – 45	39.5 – 43
Water temperature (°C)			7 – 17.4	7 – 14.6

Table 3.3. Value ranges of nutrients, metals, sulphate, alkalinity, and dissolved organic carbon at Groombridge Point, Lake Pedder during 2003-04.

Parameter	**Range (mg l^{-1})**
Total phosphorus	<0.005
Dissolved reactive phosphorus	0.002 - 0.003
nitrite	0.003
nitrate	0.05 - 0.061
Total Kjeldahl nitrogen	0.186 - 0.214
ammonia	0.016 - 0.033
Iron	0.202 - 0.252
Manganese	<0.005
Zinc	<0.001 - 0.006
Cadmium	<0.001
Copper	<0.001 - 0.003
Aluminium	0.093 - 0.121
Cobalt	<0.001
Chromium	<0.001
Nickel	<0.001
Lead	<0.005
Sulphate	1 - 1.3
alkalinity	4 - 10
Dissolved organic carbon	5.6 - 6.3

3.4 Water Quality in the Gordon River

The hydrologic regime tends to drive the two water quality parameters measured in the Gordon River at, or downstream of, the power station. Release water from the power station is drawn from a deep intake in Lake Gordon and so has a generally stable temperature which varies seasonally, but not diurnally. The dissolved oxygen concentration of outflow water is a function of the lake level, stratification of the water column, and power station operating conditions: in some cases oxygen is lost and the outflow has low dissolved oxygen; and in other cases oxygen is added and may reach very high values.

The Gordon River water temperatures were measured at the tailrace (site 77), site 75 (Gordon @ G4) and site 62 (Gordon @ Denison junction), while dissolved oxygen is measured at the tailrace.

3.4.1 Missing or unavailable data

As in previous years, the tailrace dataset suffered from a number of equipment failures during the year. Continuing technical problems have beset this site, associated with the difficulty of powering the probes in their isolated position and with physical damage to the probes caused by the high current velocities in the tailrace. In September 2003 a new arrangement was trialled, which pumped tailrace water up to a monitoring tank in a shed on the top of the bank. This allowed the probes to be powered more reliably while also decreasing the incidence of damage. Data delivery has been much more reliable since this installation took place. Initial problems with the new arrangement meant that some erroneous data were recorded due to premature draining of the sample tank in the shed. Figure 3.4 shows the available record of water temperature at the tailrace site from March 2003 to March 2004.

Apart from the missing data, this figure also indicated some artefacts of the monitoring conditions. Prior to the installation of the remote sampling chamber in September 2003, there was little diurnal variation in the signal as the probes were immersed in the tailrace water. Occasional divergences from this pattern were the result of power station shutdowns which allowed the water temperature at the tailrace to regain ambient levels. Following the installation of the remote sampling chamber there is much more diurnal variation evident. Initially, this variability was the result of an extended power station shutdown which continued until November 25th. Around the 7th November, the diurnal variability increased again, to reach extraordinary levels late in November. This was the result of the sampling tank draining prematurely, leaving the probes exposed to record the ambient air temperature. This was corrected on 24th December and the diurnal variation returned to the more moderate pattern produced by the sampling chamber.

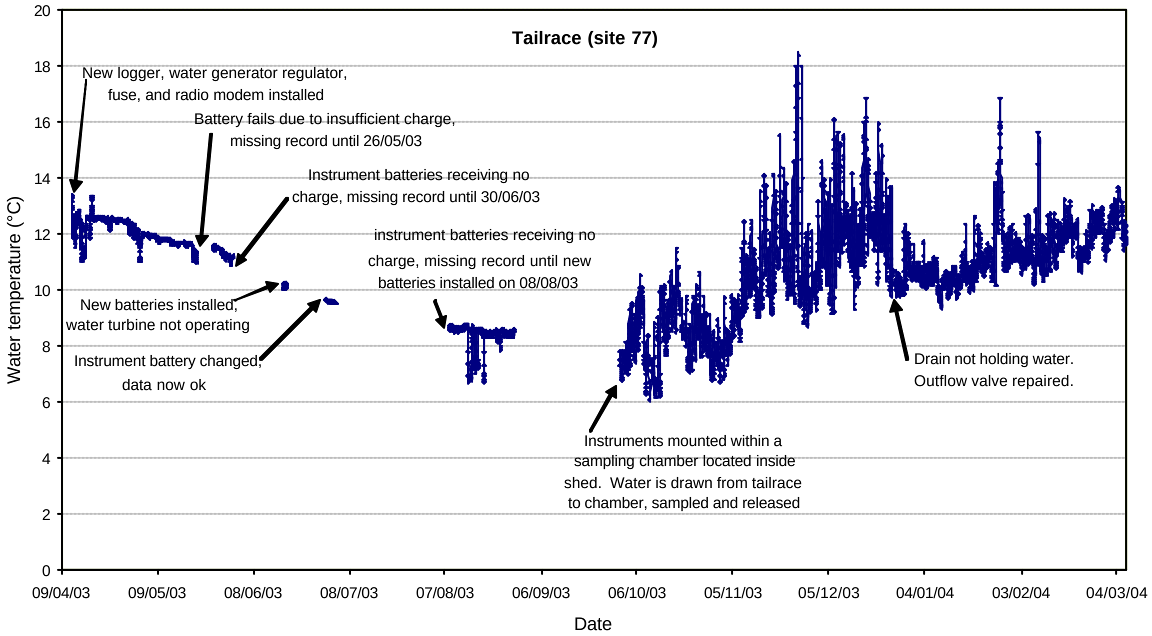


Figure 3.4. Water temperature values in the Gordon River at the power station tailrace.

3.4.2 Water Temperature

The tailrace (site 77) and site 75 (G4) are approximately 2 km apart, while site 62 is a further 13 km downstream. The river has no significant inflows between the tailrace and site 75. At site 62, the Gordon River has received inflows from the Albert and Denison Rivers.

Whilst the tailrace data are telemetered, this is not the case for the other two temperature monitoring sites. The dataloggers at these sites must be downloaded manually. For both sites 75 and 62 the latest available data finish in early March 2004 (corresponding to the last maintenance field trip). This is a consistent time lag each year, rather than missing data. Consequently, the temperature relationships between sites will be discussed in relation to the 12 month period from March 2003-March 2004. While this is outside the usual July-June reporting period, it continues the analysis timeline from the 2002-03 report for these sites. Figure 3.5 shows the water temperature values recorded for sites 75 and 62 for this period.

The tailrace water temperature values are shown in Figure 3.4. These data indicate that the tailrace site showed an annual pattern, with temperatures ranging from about 13°C in March and about 8°C in August. A similar annual pattern is evident at the downstream sites 75 and 62 (Figure 3.5) Lower temperatures were recorded in October, but these were associated with a power station shutdown. This annual pattern reflects the temperature of the inflowing water from Lake Gordon. Figure 3.5 also indicates that, when there was no power station outflow (September – November 2003 and February 2004), the water temperatures at site 62 tended to be higher than those at site 75.

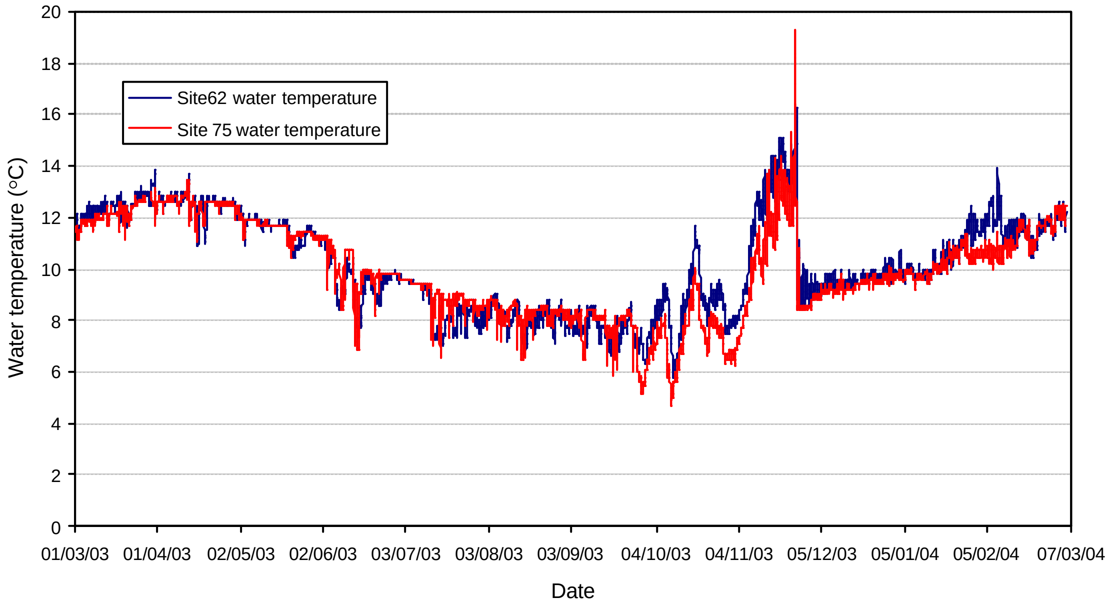


Figure 3.5. Water temperature data recorded for sites 75 (2 km downstream of the tailrace) and 62 (15 km downstream of the tailrace) over the period from March 2003 to March 2004.

Other temperature signals were evident during the period of extended shutdown from September to late November 2003. These included diurnal cycles and apparently weather-driven temperature variability with an 8 – 15 day period. These patterns were also evident at the downstream sites and the extended shutdown period represents the best time to examine the relationships between the sites, independent of power station releases. Figure 3.6 shows the diurnal pattern and weather-driven variability for sites 75 and 62 for October and November 2003 as well at the thermal relationship between the two sites at this time, with site 62 being 0.5 to 1.0°C warmer than site 75 on average.

Initially, both sites displayed a diurnal variation of about 1°C, which increased to about 2°C as the average temperature rose from 7°C to about 15°C later in November. As the temperature rose, the diurnal variability at site 75 increased to almost 5°C, while that of site 62 remained less than 2°C.

The variability in average temperatures occurred in a periodic fashion, with temperatures falling during rainfall events and increasing during apparently clear days.

Figure 3.6 also illustrates the effect on both the diurnal pattern and weather-driven variability after the power station outflow re-commenced on November 25th. The temperature at site 75 was immediately constrained to around 9°C, with little diurnal pattern, and the temperature at site 62 was similarly constrained but with a diurnal variability of around 1°C.

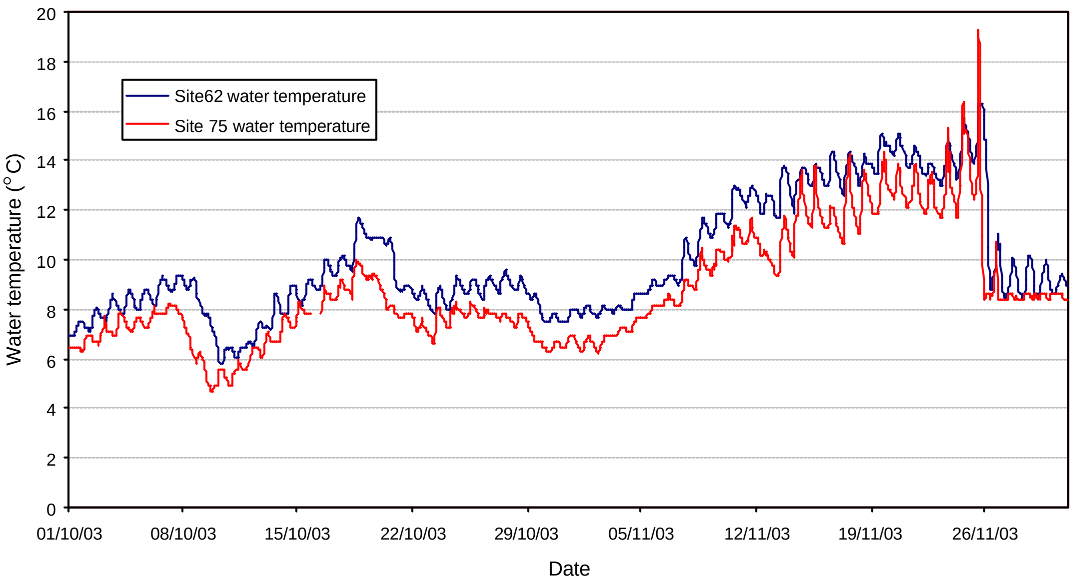


Figure 3.6. Water temperatures recorded at sites 75 and 62 over the period of October and November 2003, during an extended power station shutdown. The shutdown ended on November 25th.

The effect of power station outflows varied seasonally, depressing temperatures in the warmer months and raising temperatures in the colder periods. Figure 3.7 illustrates the effect in August 2003, with power station discharge constraining temperatures at both downstream sites to around 8.5°C. When the discharge ceased, temperatures dropped by as much as 2°C. However, even a small outflow (~10 m^3 s^{-1}) tended to maintain the temperature constraint at site 75. At this time of year, there would have been some natural discharge contributing to the temperature regime at site 62, so small power station discharges had a decreased effect.

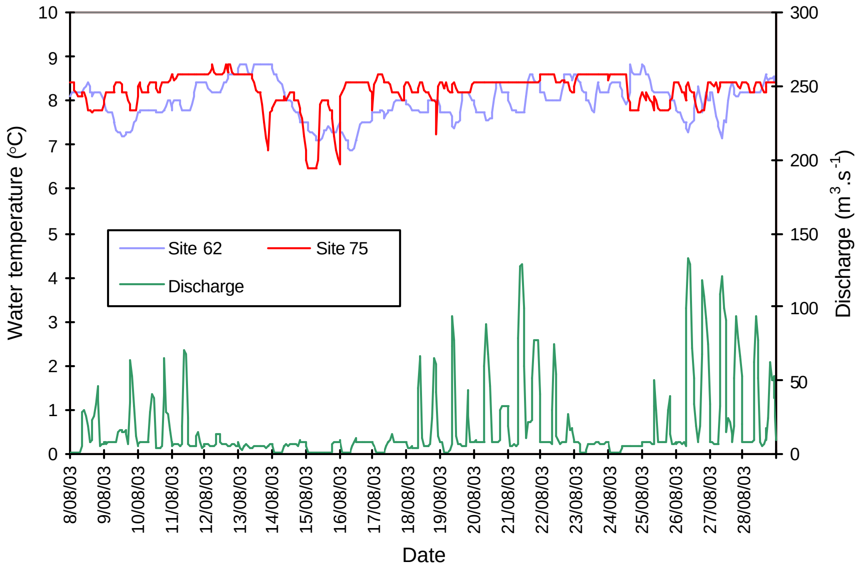


Figure 3.7. Water temperatures at sites 75 (2 km downstream of the tailrace) and 62 (15 km downstream) and corresponding power station discharge for August 2003.

The inverse of this pattern is illustrated in Figure 3.8, which shows the temperatures at sites 75 and 62 during February 2004. Initially, with a small power station discharge, site 62 temperatures were about 2°C higher than those of site 75 and both sites had around 1.5°C diurnal variation. As sporadic power station discharge occurred, the thermal differences between sites decreased as did diurnal variation. When continuous discharge occurred, both sites were constrained to around 11°C, with little diurnal pattern.

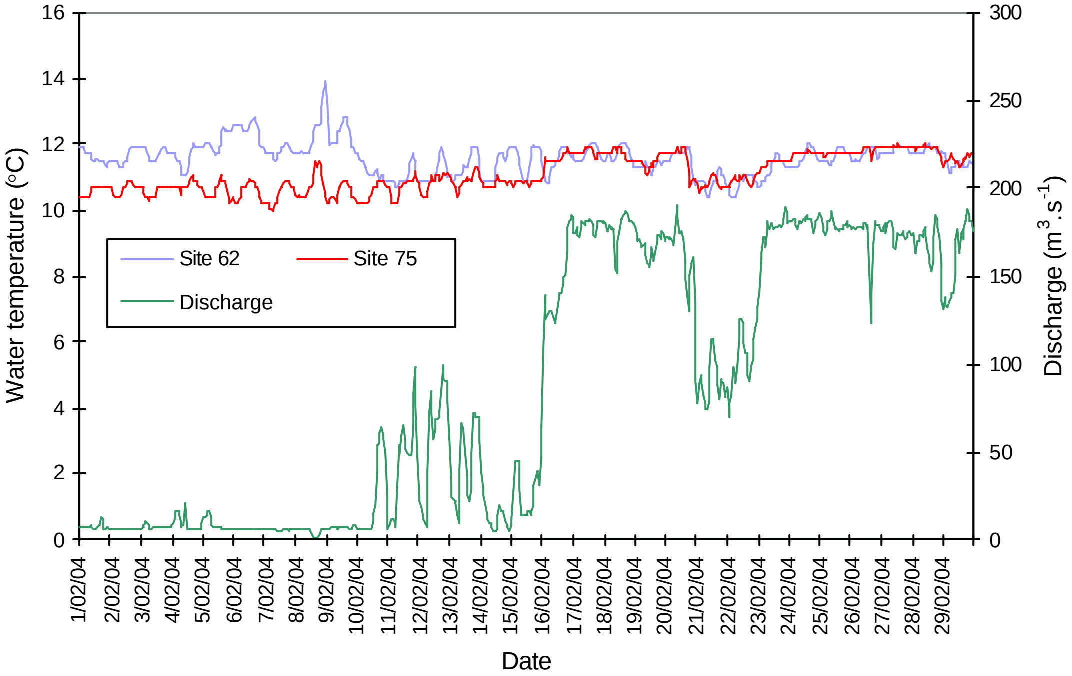


Figure 3.8. Water temperatures at sites 75 (2 km downstream of the tailrace) and 62 (15 km downstream) and corresponding power station discharge for February 2004.

In the absence of power station discharge, water temperatures at both site 75 and 62 demonstrated a diurnal pattern and apparently weather-driven variability. It is assumed that an annual cycle of similar frequency and phase as that demonstrated in the power station outflow (Figure 3.4) would also occur naturally, but with greater amplitude.

The effect of the power station discharge was to largely eliminate the weather-driven variability and greatly reduce the diurnal pattern. In colder times, the power station discharge constrains downstream temperatures to be warmer than they would normally be and in warmer months it keeps water temperatures colder than normal. The extent of these effects would vary depending on the relative volumes of discharge from the power station and unregulated tributary streams. With the power station run almost continually in the summer-autumn and less frequently in the winter-spring, and a natural pattern of winter rainfall, the result was that the power station discharge tended to dominate water temperatures during the summer-autumn, while natural inflows provided some mitigation of this impact during the winter-spring period.

3.4.3 Dissolved Oxygen

Figure 3.9 shows dissolved oxygen levels at the power station tailrace between July 2003 and June 2004. As discussed in section 3.4.1, data are missing due to equipment malfunctions.

Spot dissolved oxygen levels in Lake Gordon at intake depth are also included in Figure 3.9 to facilitate comparison between the oxygen content of water being drawn into the power station and that discharged into the Gordon River following passage through the turbines. These showed little difference between the inflow and outflow values.

The data do not indicate any unusual conditions with respect to dissolved oxygen for the period covered. Values below 6 mg l^{-1} were recorded twice in late November 2003. During this period, the power station was shut down, so the values reflect only the conditions in the tailrace pool rather than power station discharge.

High values of dissolved oxygen were recorded during May-June 2004. These were associated with a period of variable power station output. The relationship between elevated dissolved oxygen levels and total gas saturation is discussed in section 3.5, below.

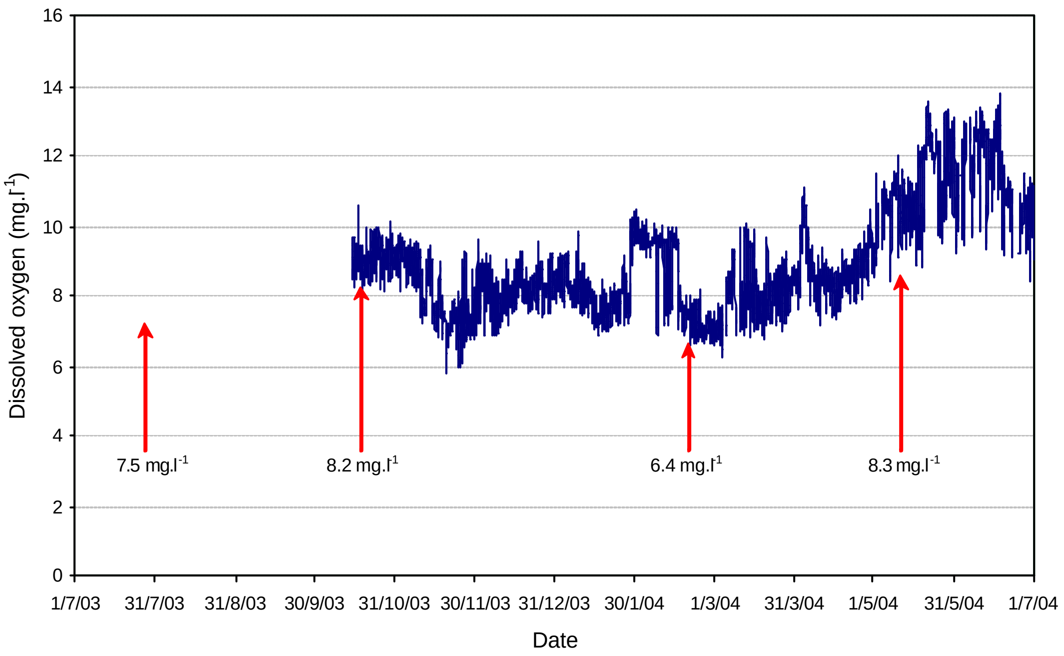


Figure 3.9. Dissolved oxygen values recorded at the power station tailrace from July 2003 to June 2004. Arrows indicate the dissolved oxygen value recorded at the intake to the power station.

3.5 Total Dissolved Gas

Water quality monitoring in the Gordon River downstream of the power station has shown that dissolved oxygen levels exhibit a high degree of variability, which is related to water levels and stratification status of the impoundment and the operating regime of the power station (Hydro

Tasmania 2002, Hydro Tasmania 2003, Koehnken 2001). High power load variability appears to result in elevated dissolved oxygen concentrations in the outflowing water due to increased jet pump operation, which is used to smooth the start-up of the turbines, and which normally occurs during periods of partial machine load.

Dissolved oxygen levels recorded at the Gordon River tailrace since 1999 have shown periods of elevated oxygen concentrations. Oxygen is not the major component of total dissolved gasses in water, which include nitrogen and trace gasses, and dissolved oxygen values may not accurately reflect the total dissolved gas level. It is widely recognised that total dissolved gas (TDG) supersaturation poses a risk to aquatic biota. Although supersaturated dissolved oxygen levels have been recorded at the tailrace, total dissolved gas levels were not monitored, and so it was not known whether total gas supersaturation occurred downstream the power station and, if so, its extent, magnitude and duration.

3.5.1 Gas saturation study

The mechanisms that may lead to total gas supersaturation downstream of the Gordon Power Station have been discussed in previous Gordon River Basslink Monitoring Annual Reports. In August 2003 a gas saturation study was undertaken to determine if the high dissolved oxygen values occasionally recorded at the tailrace were likely to be problematic for downstream biota.

The aims of this study were to:

- monitor the saturation levels of total dissolved gas (TDG) and dissolved oxygen (DO) in water discharged from the Gordon Power Station tailrace under varying load scenarios;
- determine whether significant volumes of TDG supersaturated water were generated;
- determine whether it is possible to define a strong relationship between dissolved oxygen and total dissolved gas levels; and
- contingent upon the results of the preceding aims, assess the distance that supersaturated water can be detected downstream of the tailrace under worst-case scenario conditions using dissolved oxygen as a surrogate measure for TDG.

3.5.2 Methods

The investigations were scheduled for early August 2003 to target a period when the power station was drawing water from well above the oxycline in Lake Gordon, and dissolved oxygen levels adjacent to the intake were relatively high. These conditions were selected to maximise the potential for discharge of high levels of total dissolved gases during periods of jet-pump operation at the power station.

The study consisted of two components. Initially, a variety of power station operating scenarios were run in order to vary levels of dissolved oxygen and total dissolved gas in tailrace water, and determine whether significant levels of supersaturated water were discharged under partial load conditions. Following the completion of this trial the data were analysed to determine if a strong relationship existed between total dissolved gas and dissolved oxygen.

The second phase of the study aimed to map the extent of TDG-saturated water in the Gordon River using a helicopter. The TDG Tensiometer took approximately 20 minutes to equalise, and so it was not suitable for measuring spot TDG levels. Each measurement would require considerable hovering time to allow equilibration and it would be prohibitively expensive to conduct a comprehensive survey. Therefore dissolved oxygen was to be used as a surrogate TDG measure. The response time for this parameter is much shorter than that of TDG. The implementation of phase two was contingent upon the results of the initial trial, particularly the strength of the correlation between dissolved oxygen and total dissolved gas.

Details of the methods for each experimental phase are provided below.

3.5.2.1 Phase 1

The relationship between dissolved oxygen and total dissolved gas was determined by simultaneously measuring DO and TDG at the tailrace under a variety of operating conditions, as listed in Table 3.4. DO was measured by a Hydrolab Datasonde and Surveyor logger. Total dissolved gas was measured using a Novatech 300C TDG tensiometer. This instrument was calibrated and tested prior to deployment in the field. Both probes were mounted at the base of the tailrace water quality monitoring rack so that they were submerged during all flow conditions.

Calculation of TDG percentage saturation required the measurement of ambient atmospheric pressure and water temperature in addition to total dissolved gas pressure. Atmospheric pressure was measured using a calibrated barometer, and temperature was logged by the Hydrolab Datasonde. Percentage total dissolved gas saturation represents total gas pressure as a percentage of local barometric pressure, and was calculated using the following equation (Novatech Designs, 1983):

$$\% \text{ TDG saturation} = (P_{atm} + P_t - P_{H2O} \;/\; P_{atm} - P_{H2O}) *100$$

where:

P_{atm} = local barometric pressure (mm Hg)

P_t = depth corrected tensiometer pressure differential (mm Hg)

P_{H20} = water vapour partial pressure corrected for temperature (mm Hg)

The tensiometer pressure differential was corrected for depth using the following formula:

$$\text{Depth corrected } P_t = P - (D * 0.0914)$$

where:

P = tensiometer reading (mm Hg)

D = probe depth (m)

The tensiometer required approximately 10 to 20 minutes to equilibrate to changes in pressure, and so it was planned that each power station load scenario would run for around of 60 minutes in order to allow ample setup and equilibration time. Switching times remained flexible however, allowing a faster switching of scenarios if necessary. The need for jet-pump operation was discussed with the power station operators, so that partial loads could be adjusted to maximise jet pump operation during the trial. It was estimated that 6 hours would be required to run the full suite of tests for the first phase of the trial.

Table 3.4. Summary of proposed power station operating scenarios to be run during tailrace DO and TDG monitoring. Partial load = 45-70% load, full gate = >80% load.

Test	Machine 1	Machine 2	Machine 3
Ambient river conditions	off	off	Sync load
1	Partial load	Partial load	Partial load
2	Partial load	Partial load	Full gate
3	Partial load	Full gate	Full gate
4	Full gate	Full gate	Full gate

3.5.2.2 Phase 2

Implementation of phase 2 was dependent upon the results of phase 1, and aimed to track the downstream distribution or zone of influence of supersaturated water in the middle Gordon River. A series of spot measurement were to be collected downstream of the tailrace at approximately 1 km intervals until TDG saturation fell to around 100%. If levels showed an unexpectedly rapid, or conversely, slow decline, the spacing between spot measurements was to be adjusted accordingly to obtain the optimum resolution of dissolved gas/atmosphere equalisation rates with distance downstream.

3.5.3 Results

Figure 3.10 shows the dissolved oxygen, total dissolved gas and probe depth during the phase 1 trials. Dissolved oxygen levels spiked up to approximately 150% saturation during the initial power station start up at the beginning of the trial, but this occurred briefly and prior to the start of the Hydrolab logging run, and passed too rapidly to be picked up by the TDG meter. The data shown in Figure 3.10 are based on stable running conditions and do not include initial fluctuations following start up.

The record shows that dissolved oxygen levels decreased with increasing power station discharge, and levels were highest at partial machine loads.

Total dissolved gas levels showed little variation, and remained below full saturation for the duration of the trial, peaking at 98.64% saturation. Fine scale peaks in TDG saturation did loosely corresponded to variations in dissolved oxygen levels, but Figure 3.11 shows that there was not a strong correlation between these parameters.

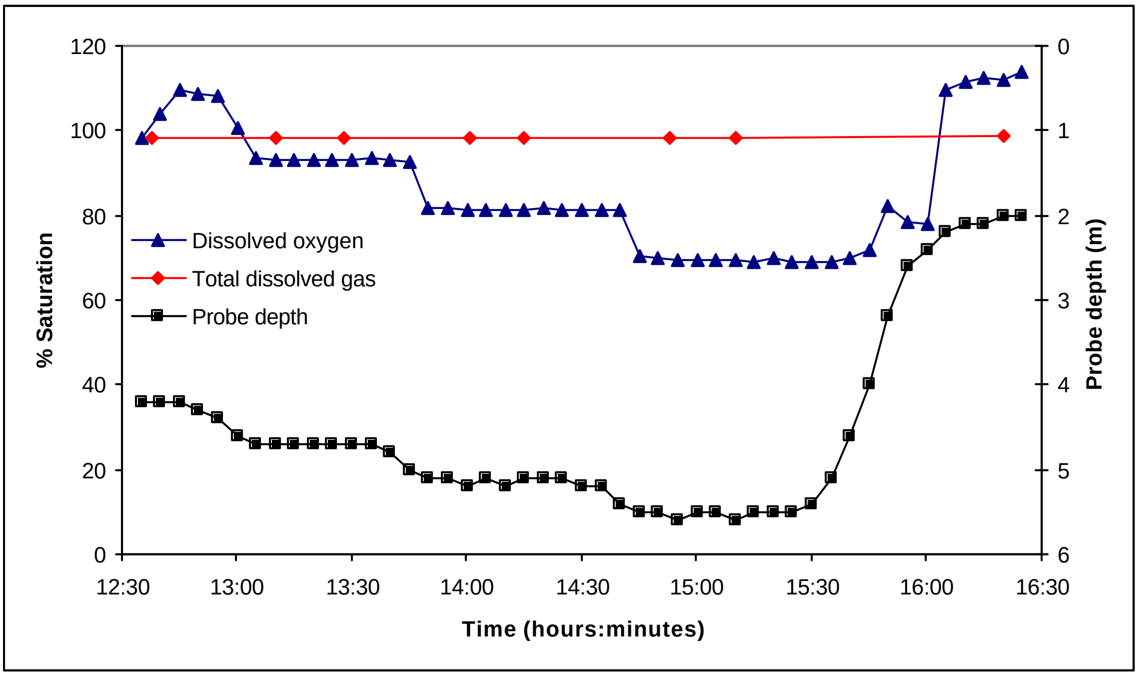


Figure 3.10. Dissolved oxygen, total dissolved gas saturation and tailrace probe depth during the tailrace trial. DO and TDG levels are shown as percent saturation.

Following the analysis of the results from phase 1 of the study, the phase 2 downstream aerial monitoring survey was cancelled for two principal reasons. Total dissolved gas data indicated that, although environmental and operational conditions predisposed tailrace waters to oxygen supersaturation, total dissolved gas levels approached but did not exceed 100% saturation. Moreover, the weak relationship between TDG and DO (Figure 3.11) meant that it was not feasible to use dissolved oxygen levels as a fast responding surrogate to track downstream TDG saturation.

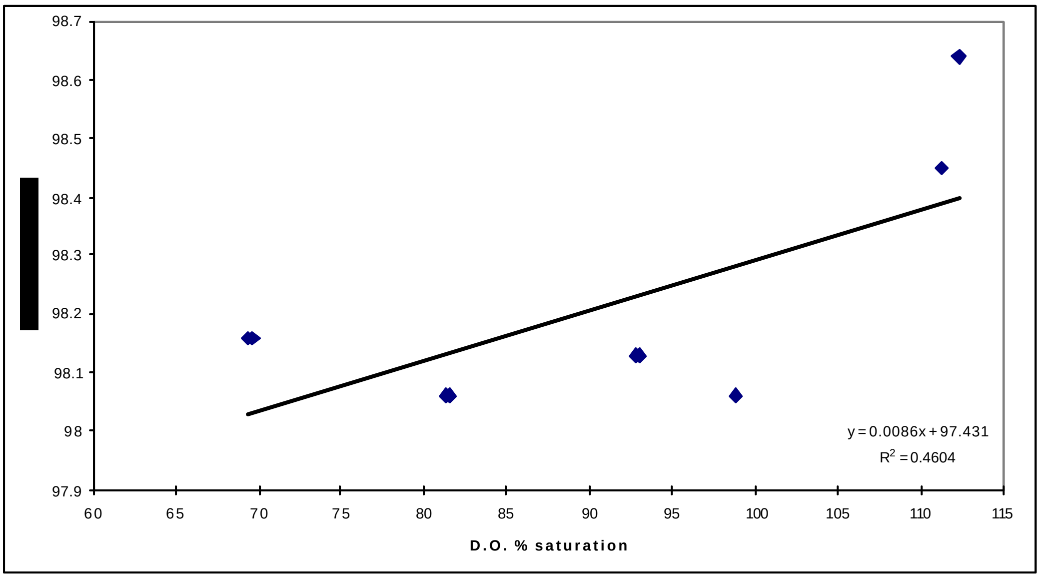


Figure 3.11. Regression of dissolved oxygen versus total dissolved gas percent saturation.

3.5.4 Discussion

The test scenarios were selected to maximise the probability of air entrainment via jet-pump operation at partial loads, and were also chosen to reflect extreme (but possible) load scenarios. Under normal power station operation it would be unusual and inefficient to operate all machines on partial load, when operating at least one machine at efficient load would be a more economical approach to produce an equivalent power output.

Dissolved oxygen levels spiked up to approximately 150% saturation during the initial power station start-up at the beginning of the trial. Spikes in dissolved oxygen levels during load changes have been reported in previous Basslink monitoring reports and so this observation was not unexpected. The spike was transient, lasting for less than two minutes, and as such was not reflected in TDG readings.

Prior to the initiation of the trials, the TDG and DO probes were given sufficient time to equilibrate to ambient river conditions. The dissolved oxygen probe recorded a reading of 111% saturation in the tailrace pool, while calculations from the TDG meter indicated 98.45% total gas saturation (Figure 3.10).

The results of the survey indicated that Gordon Power Station did not discharge water with supersaturated levels of TDG, despite the artificial congruence of predisposing limnological and power station operating conditions. Given that the timing of the survey was selected to correspond to conditions that should maximise the probability of tailrace gas supersaturation, it is unlikely that discharge of supersaturated water occurs for extended periods below the tailrace under normal operating conditions.

While it is possible that the power station may discharge spikes of TDG supersaturated water during start-up or during large, rapid increases in load, it appears as though these events are short-lived and present a limited risk to downstream aquatic fauna. The potential downstream extent of these transient events was not determined as part this study due to the inability to rapidly detect and track spikes in total dissolved gas.

If future system requirement call for significant periods of partial load running of one or more machines, additional tailrace monitoring of total dissolved gas should be considered. If technically possible, monitoring would be conducted with equipment with a faster response time to changes in TDG to in order to measure the magnitude of transient peaks.

3.6 Conclusion

Surveys of water quality were undertaken on Lake Gordon and Lake Pedder during July and October 2003, as well as February and May 2004.

The physico-chemical conditions of surface waters Lakes Gordon and Pedder were considered normal for lakes in the region, with moderately increased in turbidity at some sites. Metals concentrations were similar to those recorded in previous monitoring. One incidence of high chlorophyll-a values was recorded at Boyes Basin during the summer (February) monitoring.

The stratification characteristics of Lakes Gordon and Pedder were similar to those recorded in previous years. Parameter values recorded in the depth profiles varied with location and season. The deepest profile (intake site) showed virtual anoxia in the bottom waters of each quarterly profile. Lake Pedder remained evenly mixed during the 2003-04 surveys, with no indication of stratification in any of the parameters measured.

Monitoring in the Gordon River included recording water temperature at three sites (tailrace, 75, 62) and dissolved oxygen monitoring at the tailrace site. Water temperatures in the river showed a broad seasonal pattern related to the water temperature of Lake Gordon. Diurnal patterns and weather-related temperature variability were eliminated during times of power station discharge, with even small discharge volumes (<10 $m^3 s^{-1}$) constraining temperatures at the closest site (site 75). This effect was less marked at site 62, but larger power station discharges still dominated water temperatures at this site.

Dissolved oxygen concentrations were monitored at the tailrace site and did not fall significantly below 6 mg l^{-1} during 2003-04. High values were associated with variable power station output. A study of oxygen and total gas saturation showed that, although oxygen levels were supersaturated during the test operating regime, the total dissolved gas did not exceed 99% saturation.

4 Fluvial Geomorphology

Geomorphology monitoring aims to document fluvial geomorphic processes and changes in the Gordon River between the power station tailrace and the confluence of the Franklin River (defined as the middle Gordon River), and relate these changes to power station operations or other factors wherever possible. The information will be used as a baseline against which post-Basslink monitoring results may be compared.

In 2003-04, Basslink geomorphology monitoring in the middle Gordon River was completed on 18-19 October 2003 and 6 March 2004. Erosion pins and scour chains were measured at all sites by two boat based teams on each occasion, and repeat photo monitoring was completed during the March trip. Flow patterns during the 2003-04 monitoring year were similar to the 2002–03 monitoring year, with high power station discharge during the summer months, intermittent 1-2 turbine operation during the winter, and an extended power station shutdown in autumn.

4.1 Methodology

Geomorphology monitoring included measuring 200 erosion pins and 25 scour chains located at 48 sites in the Gordon River on a 6-monthly basis, and photo monitoring of an additional 54 sites on an annual basis in March each year. Site locations and site descriptions are listed in the Gordon River Basslink Monitoring Annual Report 2002-03. The Gordon River was divided into five zones, as shown in Figure 4.1, and the sites were numbered according to their position in each zone.

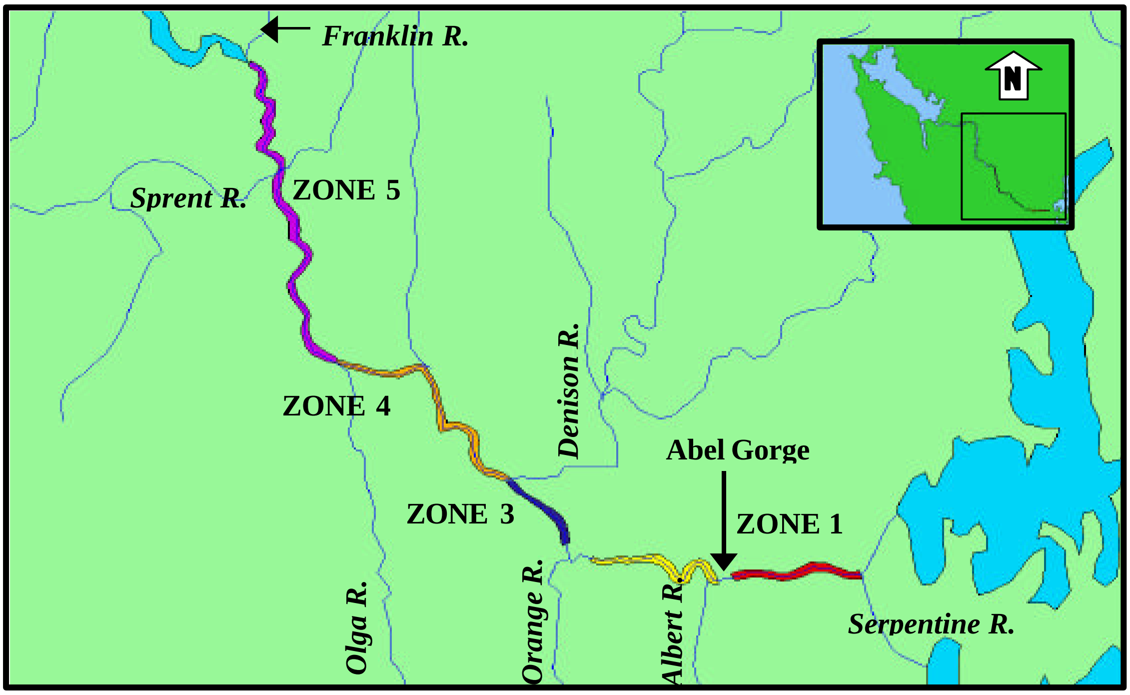


Figure 4.1.Geomorphology monitoring zones in the Gordon River.

During the October 2003 - March 2004 monitoring period, no new sites were established, although several pins were replaced or reset. Table 4.1 lists the sites and changes to erosion pins recorded during the October 2003 field trip and Table 4.2 contains a summary of changes to erosion pins recorded during the March 2004 fieldtrip.

Table 4.1. Summary of erosion pins changes between April 2003 and October 2003.

Site	Change(s) to site	Reason
2K	Pins 2K/3 & 2K/4 replaced	Old pins had become rotated towards downstream to high angles and buried
5E	Pin 1 not measured	Cavity collapse obscured pin
5K	Site located, pin 5K/1 not found	Suspected buried

Table 4.2. Summary of erosion pins changes between October 2003 and March 2004.

Site	Change(s) to site	Reason
2G	Pin 5 reset in cavity	Pin was almost buried
2H	Pins 5 and 6 reset	Pins unstable due to movement in bank
3A	Scour chain reset	Scour had removed chain from bank
4B	Pin 1 replaced Pin 3 moved upslope of Pin 2	Pin 1 missing since 10/02 Pin 3 consistently underwater, pin 2 near toe due to bank movement
5K	New pin installed near Pin 1	Pin 1 almost buried

4.2 Overview of hydrology

Hourly discharge from the power station is shown in Figure 4.2 for the period March 2003 –March 2004 along with flow duration curves for the same period, and for the previous two years. Similar to the 2002-03 monitoring year, near-continuous three turbine power station operation dominated during the summer months, intermittent variable power station usage was more common in the winter, and there was an extended power station shutdown in October and November. October monitoring was completed 3 weeks after the start of the power station shut down, and the March monitoring was completed during a shutdown following 3-turbine power station usage.

The flow duration curve for March 2003 – March 2004 shows that discharge from the power station exceeded 200 $m^3 s^{-1}$ (cumecs) about 35% of the time, with low flows (<20 $m^3 s^{-1}$) occurring about 45% of the time. This bimodal distribution of flow is similar to that predicted for Basslink.

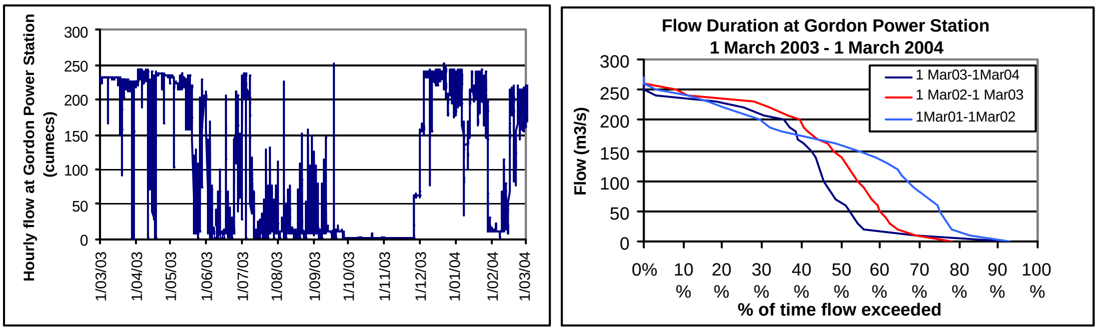


Figure 4.2. Power station discharge, 1 March 2003 – 1 March 2004 (left) and flow duration curves for past 3 years.

The flow duration curves demonstrate that the 2003-04 monitoring year was similar to the 2002-03 monitoring year for high flows, but had lower duration medium flows (25 – 150 $m^3 s^{-1}$) by about 10%.

Water levels in zones 2, 4 and 5 over the past year are shown in Figure 4.3, with daily rainfall at Strathgordon shown in Figure 4.4. This figure shows that water level in zones 1 and 2 is controlled by power station operation, with winter storm events increasing the variability of flows downstream of the Denison River. Water level heights in zone 2 varied from 0.2 to 4.6 m (at the G5a piezometer site), whereas in zone 5, levels varied between 0.3 m and 8.7 m (at the Gordon above Franklin gauge). The plots demonstrate that the power station-controlled high water levels in zone 2 (up to 4.5 m) exceed the power station-controlled water levels in zone 5 (up to 3 m) at the gauging site.

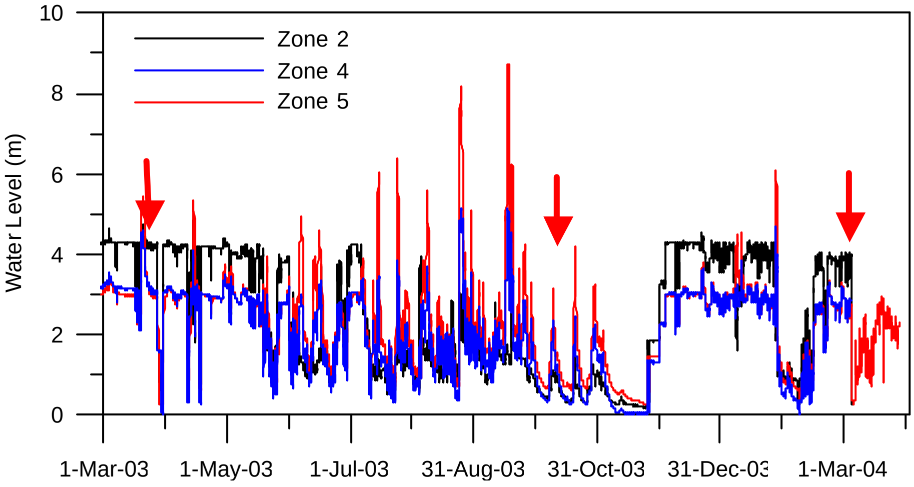


Figure 4.3. Water level in zones 2, 4 and 5 from 1 March 2003 to 1 March 2004. Zone 2 data are for site 71 (G5a), zone 4 data are for the Gordon below Denison site (site 62), and zone 5 data are for the Gordon above Franklin site (site 48). Sampling dates are indicated by red arrows.

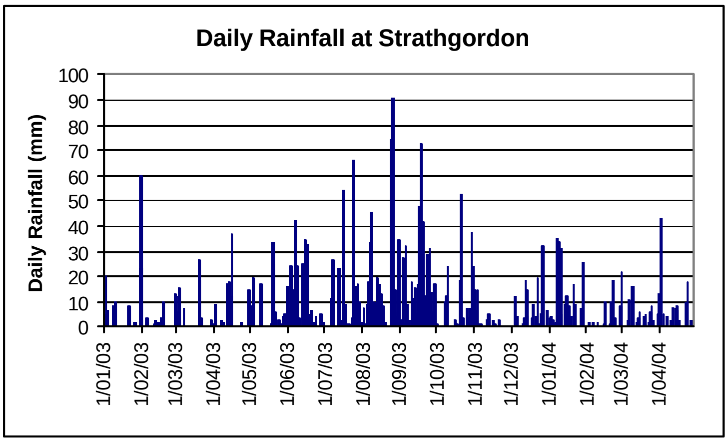


Figure 4.4. Rainfall at Strathgordon, 1 March 2003 – 27 April 2004.

Between the October 2003 and March 2004 monitoring runs, a series of storm events occurred which increased water levels downstream of the Denison River to above power station-controlled levels (3 – 6 m). The last major storm event prior to monitoring occurred at the end of January 2004. Similar to other March monitoring trips, power station operation was characterised by 3-turbine operation for two weeks prior to the monitoring shutdown.

4.3 Monitoring Results

The October 2003 monitoring run was completed over 2-days during an extended shutdown of the power station. The March 2004 monitoring run was completed during a 1-day power station shutdown. Field conditions during March 2004 were less than optimal, with constant, heavy rain hampering helicopter transport and limiting the ability to obtain useful comparative photographs.

4.3.1 Field Observations

4.3.1.1 March 2003 – October 2003

Field conditions during October 2003 were similar to those observed during October 2002, when monitoring was also completed during an extended power station shutdown. Organic material and fine sand and mud deposits were common on bank toes and slopes, reflecting deposition from natural inflows during the shut down. Mud deposits were restricted to the lower bank face in zones 1 – 3 (upstream of the Denison confluence), due to relatively smaller fluctuations in water level compared to the downstream zones 4 and 5. In the downstream zones, there were sand, mud and organic deposits on the banks and above the power station-controlled water level, presumably deposited during the high winter flow events.

In zone 2, sediment flows below cavities were rarely present, and where they occurred appeared to be eroded. This is possibly due to the very short duration power station 'on' events that occurred infrequently during July and August. These higher flows were probably sufficient to erode the previously deposited sediment flows, but insufficient in duration (and frequently magnitude) to saturate the banks to the point of initiating new sediment flows. Some bank toes in zones 2 and 3 showed signs of deposition, with the material derived from upslope, rather than upstream. This down slope deposition was limited to banks where cavities and sediment flows were present upslope. The downslope angle of erosion pins at several of the same sites supports the observation of downslope mass movement of saturated materials. The downslope transport of sediment from surface runoff was also observed.

New bank failures were observed in zone 2 and in the Albert River. In zone 2, two new slips occurred on the left bank outside bend downstream of erosion pin site 2F. These slips occurred in vertical cobble banks, and are in the same area as the slips photographed as photo monitoring sites P2/2 – P2/4. Photo 4.1 shows the fresh slips observed in October 2003 in zone 2.

Photo 4.1 Two new bank failures observed in October 2003 in zone 2.

In the Albert River, a new slip occurred approximately 150 m upstream of the confluence with the Gordon River, on the left bank, downstream of the large vertical cobble bank in sands. This failure has altered the flow of a portion of the river, with water being directed behind the fallen material. This redirected flow has undercut the bank downstream of the initial failure, with additional tree fall resulting. Also in the Albert, large blocks of consolidated orange sandy sediment, derived from the sandy sedimentary unit overlying the cobbles, have been transported across the channel and downstream. Photo 4.2 shows two views of this slip.

Photo 4.2. New slip in the lower Albert River, observed in October 2003: (left) Left bank, and (right) lower Albert River looking upstream. Large sediment blocks have been transported by flow.

4.3.1.2 October 2003 – March 2004

Field observations in March 2004 were consistent with the 3-turbine operation of the power station prior to monitoring shutdown. Several of the monitoring sites were saturated, and there was evidence of recent seepage erosion, including active sediment flows, rilling, and tilting of erosion pins due to the mass movement of the banks.

Deposition of muds or organic debris on bank toes was lacking in zones 1-2, but was present in zones 3 – 5. In these downstream zones there were also freshly deposited sands on the middle banks (below power station operating levels), suggesting there was a sizeable sediment load in the river when the power station was shut down on 5 March 2004. In the week prior to the shutdown, ~33 mm of rain fell in Strathgordon. Some of this deposition could be attributable to tributaries being 'undammed' by a reduction in Gordon River flows when power station operations ceased.

No new slips were observed in March 2004, but there was some additional loss of overhanging vegetation at the zone 2 slips sites first observed in October 2003.

4.3.2 Zone 2 piezometer results

In-bank water levels for the period 1 March 2003 to 6 March 2004 as recorded by the array of piezometers located in zone 2 are shown in Figure 4.5. The traces reflect the power station operating pattern and winter rain events as discussed in section 4.2, and which are covered in detail in section 4.4.1.

In the dataset illustrated in Figure 4.5, probe 2 shows consistently lower water levels under high flows relative to probe 1 (river level). During flows higher than 3.3 m, the locations of both probes are submerged and they should record the same water level. The discrepancy is of the order of 2-4 cm and has been a characteristic of the probe since installation. The slow rate at which probe 2 responds also raises questions about the condition of the probes. The casings of the piezometers have been infiltrated with very fine-grained materials which make extraction of the probes for checking impossible. This material could alter the filling and draining rates of the probes relative to the surrounding bank.

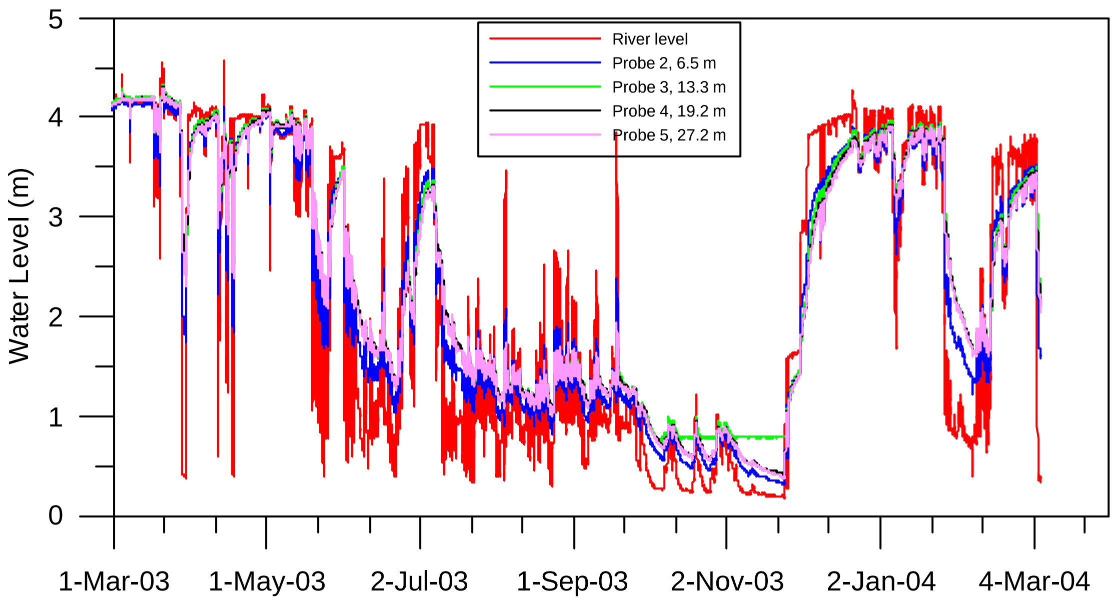


Figure 4.5. Piezometer data from zone 2 between 1 March 2003 and 6 March 2004. Data interval is 15 minutes.

4.3.3 Erosion pins & scour chains

Erosion pins and scour chains were measured in October 2003 and March 2004 by two boat-based teams. The erosion pin and scour chain data are summarised in tables and discussed on a zone-by-zone basis in section 4.4.2.

4.3.4 Photo Monitoring

Photo monitoring of the 54 sites was completed in March 2004. Unfortunately, bad weather resulted in poor light conditions. There were few discernable changes to the photo monitoring sites, although the poor picture quality hampered interpretation at some sites. The most common change was an increase in the size of vegetation on slip faces above power station-controlled high water levels. Notable changes or comments about specific photos are summarised in Table 4.3.

Overall, these features have been found to be stable since photo monitoring began in 2002 (and even earlier for some sites). Given the stability of the features, it is surprising that more of the slip faces remain unvegetated. It is unknown if this is due to bank desiccation, lack of seed source, or both. A qualitative observation is that once vegetation is established, it increases in size and extent quite rapidly. However, in some locations there appears to be a sizeable time delay between disturbance and the initiation of revegetation (at least 2 years).

Table 4.3. Summary of changes to photo monitoring sites in March 2004.

Site	Change / Comment
P1-4b	Slip in sandy alluvium overlying cobbles. First observed in Oct. 2002. No change since March 2003
P2-1	Distribution of grasses on cobble bar very similar to March 2003
P2-2a	Collapse of overhanging vegetation over slip first observed in October 2003. No change to slip.
P2-3	Additional loss of overhanging vegetation. No change to slip
P2-4	Increase in size of vegetation on slip face.
P2-5	Possibly additional small tree fall – difficult to compare photos due to difference in angles and poor light.
P4-4c	Small changes to extent of sand deposit on cobble bar
P4-3	Loss of leaves from LWD at base of bank
P5-5	Possibly additional small tree fall
P5-16	Increase in vegetation, removal of fallen branches extending into river
P5-19	Increase in size of vegetation

4.4 Discussion

4.4.1 Piezometer

The piezometer results for March 2003 to March 2004 are consistent with previous observations obtained during extended power station usage, and power station shutdowns. During the summer, water levels in the banks equalise with river levels following several days of continuous power station discharge (Figure 4.6, left). During the winter period, in-bank water levels are typically higher than river base levels, with short duration power station usage reversing the slope into the bank. These frequent river level fluctuations are insufficient to increase the water level in the banks to river levels, as shown in Figure 4.6, right).

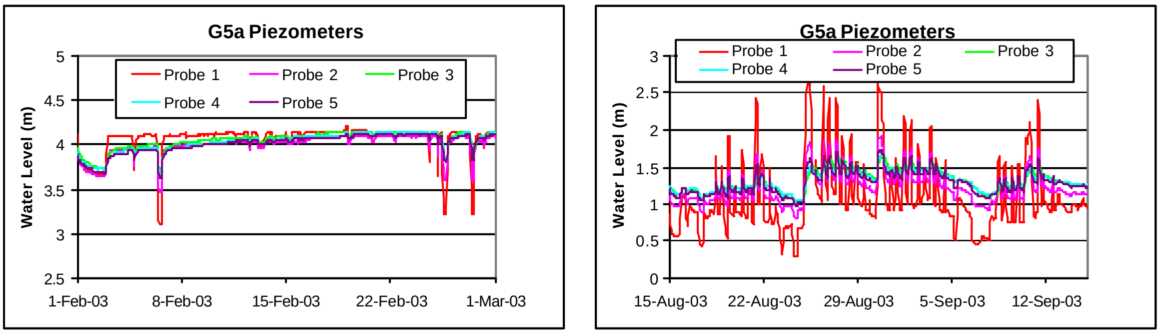


Figure 4.6. Piezometer data from zone 2 for a summer (left) and winter (right) period.

Past investigations have shown that the highest risk of seepage erosion occurs when in-bank water slopes (as described by water height differences between Probe 3 and Probe 1) exceed 0.10 m and river levels are ~2 m (at Probe 1) or greater. Water surface slopes and power station discharge for the period 1 January 03 to 31 March 04 are shown in Figure 4.7. The graph shows that high-risk periods for seepage erosion occurred following shutdowns preceded by 3-turbine power station operation, including the March 2003 and March 2004 Basslink monitoring shutdowns.

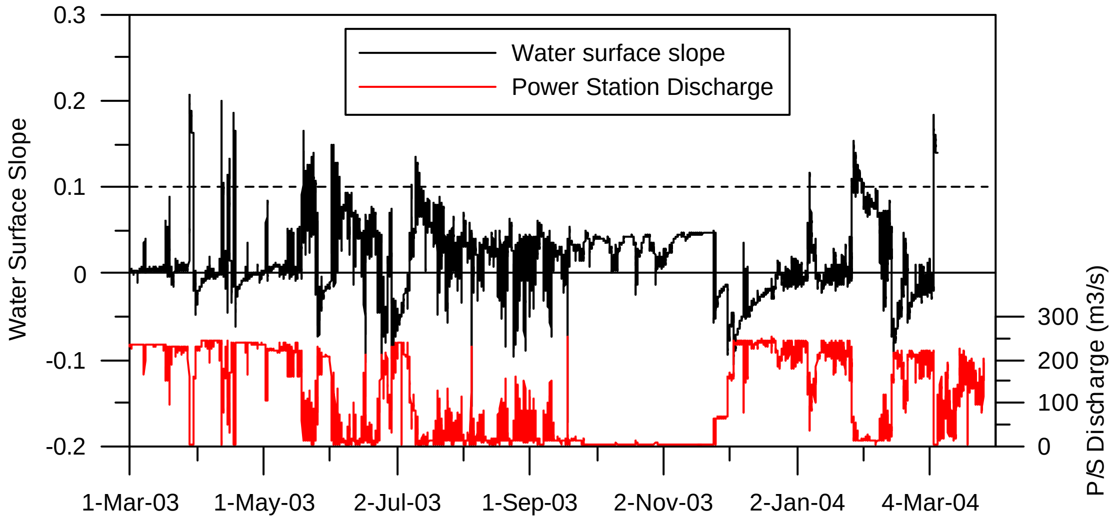


Figure 4.7. In-bank water surface slopes as determined by the difference in water level between Probe 3 and Probe 1, and power station discharge. A positive slope indicates the in-bank water surface is sloping towards the river. Slopes in excess of 0.1 are considered to pose a high risk of seepage erosion

A prolonged high-risk period occurred in late May 2003 when the power station was used intermittently to provide peak power following a 3-turbine to 'off' shutdown (Figure 4.8). Figure 4.9 shows power station operation, water level at Probe 3, and the in-bank water surface slope for this period. During this time, rainfall in excess of 30 mm fell over several days, and is likely to have contributed to the extended high water levels in the banks, with the fluctuating river levels impeding bank draining.

It is surprising that the water level at Probe 3 increased when river level increased, even though the resulting river level remained below the recorded water height at Probe 3. This could indicate that the groundwater inflow through the banks was very high, and the higher river level decreased the rate of bank draining such that the water level in the bank increased. Alternatively, it could suggest that there is an offset in the relative positioning of the probes which requires investigation.

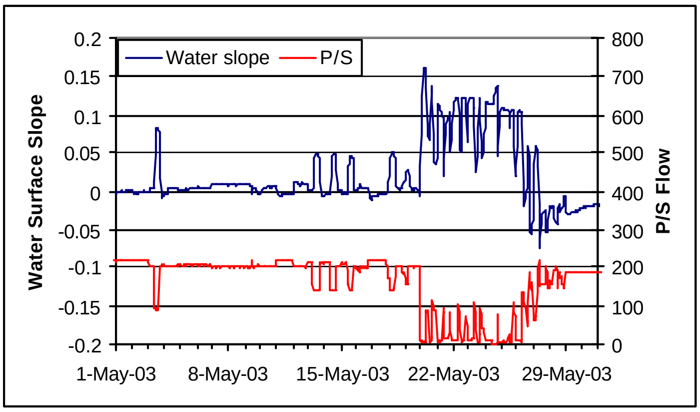


Figure 4.8. In bank water surface slopes and power station discharge for May 03.

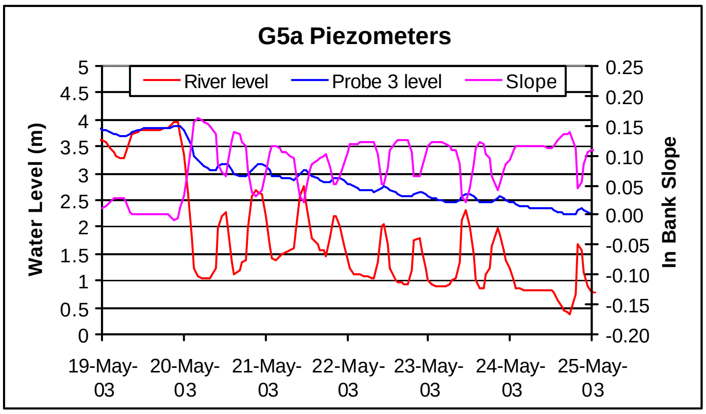


Figure 4.9. Power station discharge, Probe 3 water level, and in-bank water surface slopes for 20 –25 May 2003.

During August and September 2003, the power station was operated in a similar manner, but the in-bank water surface slopes remained low because the banks were not saturated by previous 3-turbine power station operation (Figure 4.7). These results again highlight the importance of power station operating patterns over timeframes of days to weeks on in-bank water levels.

In late January 04, another period of high in-bank water surface slopes occurred following the cessation of 3-turbine power station operation. This shutdown occurred during a moderate storm event (see Figure 4.4) where ~34 mm of rain fell between the January 25th and 30th (at Strathgordon). This event combined with the previous rains resulted in elevated groundwater levels which took a long time to diminish, leading to an extended period of apparently high in-bank water slopes. Alternatively, the probes did not accurately reflect bank saturation due to the infiltration of silt and mud into the probe casing. An investigation of the probes is required to verify the validity of the data.

4.4.2 Erosion pins

For each zone, a summary of erosion pin results for the past monitoring period, past year and past two years is presented in tabular form. All measurements in the tables are in millimetres and rates are expressed as millimetres per year (mm yr^{-1}). Positive numbers indicate erosion and negative numbers indicate deposition. In the case of the Gordon River, deposition can be caused by two different processes. The first is the deposition of material by fluvial processes, and the second is the downslope movement of sediment due to seepage erosion processes (bank collapse or sediment flows).

4.4.2.1 Zone 1

Table 4.4 contains a summary of erosion pin data for zone 1, with a histogram of erosion pin changes between October 2003 and March 2004 summarised in Figure 4.10.

In zone 1, greater than 98% of flow is derived from the power station, with natural inflows limited to very small events due to the small catchment area. Monitoring in October 2003 occurred ~3 weeks after the beginning of an extended power station shutdown. During these 3 weeks there were several rain events which led to the deposition of fine material and organic debris on bank toes. Based on the distribution of the mud, water level changes were restricted to ~20 cm in zone 1. In October there was no sign of recent seepage erosion, due to the extended power station shut down, although the erosion pin results showed the seepage features had been active since previous monitoring.

Erosion pin site 1A differs from the other sites in zone 1, in that the erosion pins are installed horizontally into a bank face composed of colluvium. Erosion pin results commonly show deposition at the site but this is the result of colluvium creeping over the pin, and not fluvial deposition.

Sites 1C (Figure 4.11) and 1E are affected by fluvial processes only and have recorded lower rates of erosion pin change compared to sites affected by seepage erosion. Bank toes at 1C showed erosion of up to 11 mm in October 2003 whereas site 1E recorded deposition of up to 17 mm. In March, these two sites showed no change or erosion of up to 11 mm, with only one pin showing deposition. Bank toes at these sites and 1B (Figure 4.12) generally show erosion over the last year (March 03 – March 04), and last two years (March 02 – March 04), with rates ranging from ~1 to 30 mm yr^{-1}.

Table 4.4. Summary of erosion pin results from zone 1. All measurements in mm and rates in mm yr^{-1}. Negative numbers indicate deposition, positive indicate erosion.

Site	Description	Pin #	Change Mar 03-Oct 03 (mm)	Change Oct 03-Mar 04 (mm)	Rate Oct 03-Mar 04 (mm yr^{-1})	Net Rate Mar 03 – Mar 04 (mm yr^{-1})	Net Rate Mar 02 – Mar 04 (mm yr^{-1})	Date installed	Comments
1A	**LB straight reach, series of pins along vertical colluvial bank behind cobble bar**								
1A	Collu, vertical wall	1	0	3	7.8	3.2	5.0	Dec-99	
1A	Collu, vertical wall	2	0	-1	-2.6	-1.1	1.0	Dec-99	
1A	Collu, vertical wall	3	-11	-1	-2.6	-2.1	0.5	Dec-99	
1A	Collu, vertical wall	4	2	0	0.0	2.1	22.6	Dec-99	
1A	Collu, vertical wall	5	5	-23	-60.0	-19.2	-7.0	Dec-99	
1A	Collu, vertical wall	6	-2	-11	-28.7	-13.8	-5.0	Dec-99	
1A	Collu, vertical wall	7	21	-6	-15.6	16.0	6.0	Dec-99	
1A	Collu, vertical wall	8a	-10	-4	-10.4	-14.9	-11.5	Dec-99	pipe casing
1A	Collu, vertical wall	8b	40	-13	-33.9	28.7	-12.5	Dec-99	pipe casing
1A	Collu, vertical wall	8c	-4	-1	-2.6	-5.3	-2.5	Dec-99	pipe casing
1A	Collu, vertical wall	9	-3	1	2.6	-2.1	-1.0	Dec-99	
1B	**LB, pool, sandy alluvium over bedrock**								
1B	Cavity	1	127	-97	-252.9	31.9	13.0	Nov-01	Long pin, bank collapse
1B	Cavity	2	-31	-9	-23.5	-42.6	-22.1	Nov-01	
1B	Sed. Flow	3	-2	0	0.0	-2.1	-9.5	Nov-01	
1B	Cavity	4	-38	30	78.2	-8.5	-6.5	Nov-01	
1B	Toe	5	26	3	7.8	30.9	30.6	Nov-01	
1C	**LB inside bend, series of pins along toe of sandy alluvium over cobbles**								
1C	Toe	1	-1	11	28.7	10.6	12.5	Nov-01	
1C	Toe	2	11	0	0.0	11.7	5.5	Nov-01	
1C	Toe	3	4	0	0.0	4.3	0.0	Nov-01	
1C	Toe	4	5	-2	-5.2	3.2	-3.0	Nov-01	
1D	**RB, outside bend, cobbles & sands with cavities**								
1D	Cavity	1	-3	23	60.0	21.3	18.0	Nov-01	
1D	Slope	2	27	-9	-23.5	19.2	6.5	Nov-01	
1D	Wall	3	-1	2	5.2	1.1	1.0	Nov-01	
1D	Cavity	4	10	-12	-31.3	-2.1	-5.0	Nov-01	
1E	**LB straight reach u/s Abel Gorge, sandy alluvium, transect down bank**								
1E	Wall	1	5	0	0.0	5.3	0.0	Nov-01	
1E	Wall	2	-4	3	7.8	-1.1	-6.0	Nov-01	
1E	Slope	3	-4	4	10.4	0.0	11.5	Nov-01	
1E	Slope	4	-17	0	0.0	-18.1	-8.0	Nov-01	
1E	Toe	5	-3	3	7.8	0.0	4.0	Nov-01	
1F	**RB straight reach u/s Abel gorge, alluvium & colluvium with cavities**								
1F	Cavity	1	-71	-11	-28.7	-87.3	-44.6	Nov-01	Long pin
1F	Cavity	2	3	-5	-13.0	-2.1	-6.5	Nov-01	
1F	Cavity	3	26	13	33.9	41.5	1.0	Nov-01	
1F	Cavity	4	44	-67	-174.7	-24.5	-60.7	Nov-01	

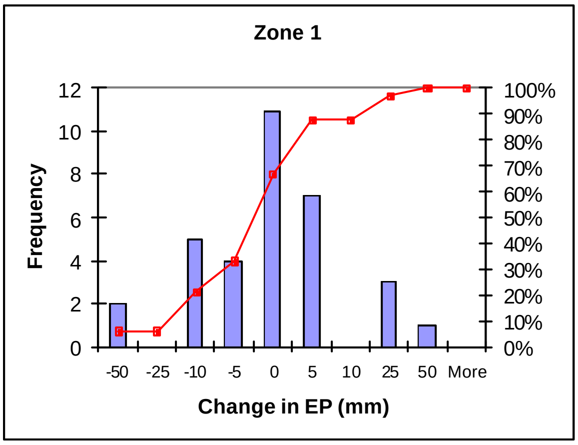


Figure 4.10. Changes to erosion pins (mm) between October 2003 and March 2004. Negative numbers indicate deposition, positive numbers indicate erosion.

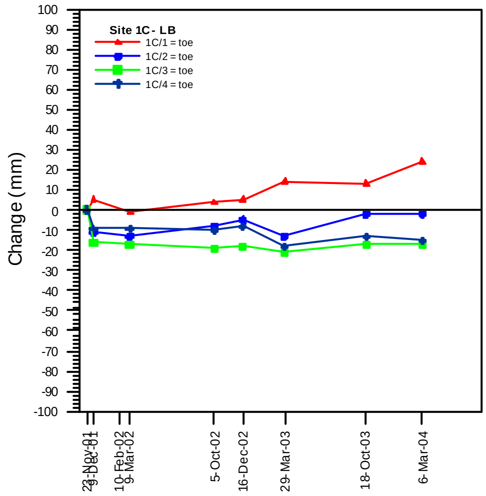


Figure 4.11. Erosion pin results from Site 1C. Graph shows change in exposure length of erosion pin with time. Positive changes indicate erosion, negative changes indicate deposition. Reference level (0 change) is length of erosion pin exposed at time of installation.

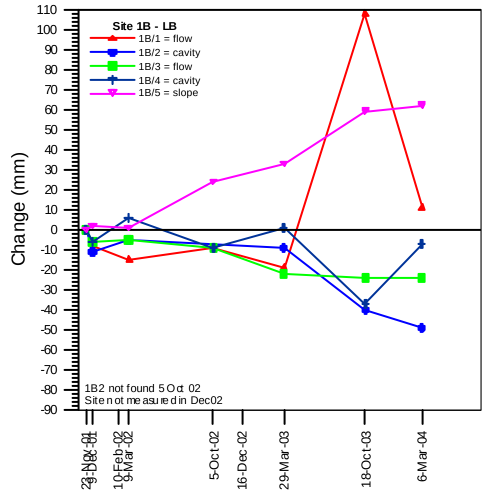


Figure 4.12. Erosion pin results from site 1B. Positive changes indicate erosion, negative changes indicate deposition.

At the other sites in zone 1, pins in cavities show the greatest magnitude of change, due to the mass movement of material within the cavities, and collapse of cavity walls. Large erosional and depositional changes are common at cavity and sediment flow sites, demonstrating the dynamic nature of the bank features (Figure 4.12).

The two scour chains at Site 1A in zone 1 did not show any scour, and showed minor deposition of sand on top of the chain (~6 mm). This is in contrast to the erosion pin results from site 1E which showed net erosion of 3 mm during the same period.

4.4.2.2 Zone 2

Zone 2 consistently exhibits the most active seepage erosion processes in the middle Gordon River due to the high range of water level fluctuations associated with power station operation, the lack of tributary inflows, and the abundance of silty/sandy alluvial banks.

Table 4.5 provides a summary of erosion pin results from zone 2. The histogram in Figure 4.13 summarises erosion pin changes between October 2003 and March 2004 for all pins in the zone. Examples of erosion pin results from sites dominated by fluvial processes and seepage processes are presented in Figure 4.14 and Figure 4.15, respectively.

Table 4.5. Summary of erosion pin results for zone 2. All measurements in mm and rates in mm yr^{-1}. Negative numbers indicate deposition, positive indicate erosion.

Site	Description	Pin #	Change Mar 03-Oct 03 (mm)	Change Oct 03-Mar 04 (mm)	Rate Oct 03-Mar 04 (mm yr^{-1})	Net Rate Mar 03 – Mar 04 (mm yr^{-1})	Net Rate Mar 02 – Mar 04 (mm yr^{-1})	Date installed	Comments
2A	**LB straight reach, transect from river side to backwater**								
2A	Toe (Gordon side)	1	-2	-4	-10.4	-6.4	-3.0	Nov-01	
2A	Slope	2	1	-2	-5.2	-1.1	-2.5	Nov-01	
2A	Slope	3	-3	-2	-5.2	-5.3	-6.5	Nov-01	
2A	Crest	4	-1	1	2.6	0.0	0.0	Dec-01	
2A	b/slope	5	-5	1	2.6	-4.3	-4.0	Dec-01	
2A	b/slope	6	1	-4	-10.4	-3.2	-8.5	Nov-01	
2A	b/water	7	-3	-1	-2.6	-4.3	-5.0	Nov-01	
2B	**RB straight reach, sands over bedrock, cavities**								
2B	Flow	1	86	-11	-28.7	79.8	21.1	Nov-01	
2B	Cav	2	1	1	2.6	2.1	-0.5	Nov-01	long pin
2B	Flow	3	48	14	36.5	66.0	17.0	Nov-01	
2B	Cav	4	-30	7	18.3	-24.5	-3.5	Nov-01	long pin
2B	Flow	5	43	18	46.9	64.9	-9.0	Nov-01	
2B	Cav	6	85	-9	-23.5	80.9	-220.6	Nov-01	
2B	Flow	7	73	-316	-823.9	-258.6	-154.4	Nov-01	
2B	Toe	8	-80	9	23.5	-75.6		Oct-02	affected by seepage
2C	**RB outside bend, sands over bedrock, cavities**								
2C	Cav	1	-31	-268	-698.7	-318.2	-142.4	Dec-01	long pin
2C	Cav	2	-63	8	20.9	-58.5	-28.6	Dec-01	long pin
2C	Slope/flow	3	-7	4	10.4	-3.2	56.2	Nov-01	
2C	Toe	4	17	-5	-13.0	12.8		Oct-02	
2D	**LB inside bend, sandy alluvium**								
2D	Top	1	-9	-1	-2.6	-10.6	-5.5	Nov-01	
2D	Slope	2	83	-30	-78.2	56.4	30.1	Nov-01	
2D	Slope	3	-62	9	23.5	-56.4	13.5	Nov-01	
2D	Toe	4	-21	9	23.5	-12.8	-25.1	Nov-01	
2E	**RB outside bend, alluvium, cavities**								
2E	Cav	1	-9	9	23.5	0.0	7.5	Nov-01	
2E	Top	2	-5	0	0.0	-5.3	6.0	Nov-01	
2E	Slope	3	86	-96	-250.3	-10.6	-23.1	Nov-01	affected by seepage
2E	Slope	4	-9	5	13.0	-4.3	2.0	Nov-01	
2E	Toe	5	-15	-2	-5.2	-18.1	-12.5	Nov-01	Site 2F not monitored. In vertical cobble bank
2G	**RB, beg of straight reach, sands over cobbles, cavities**								
2G	Cav	1	181	193	503.2	398.0	192.5	Nov-01	long pin
2G	Flow	2	17	-26	-67.8	-9.6	-18.6	Nov-01	
2G	Cav	3	-5	4	10.4	-1.1	1.5	Nov-01	
2G	Cav	4	-399	397	1035.0	-2.1	1.0		long pin/measure error?
2G	Cav	5	6	-42	-109.5	-38.3	23.6	Nov-01	long pin
2G	Toe	6	32	-40	-104.3	-8.5		Oct 02	affected by seepage
2H	**LB straight reach, sands, 2 transects of 3 pins.**								
2H	Slope	1	-6	2	5.2	-4.3	-15.5	Nov-01	
2H	Slope	2	-35	13	33.9	-23.4	-8.5	Nov-01	
2H	Toe	3	-81	35	91.3	-49.0	-10.0	Nov-01	
2H	Cav	4	-105	94	245.1	-11.7	-6.5	Nov-01	
2H	Slope	5	-111	-50	-130.4	-171.3	-71.7	Nov-01	affected by seepage
2H	Toe	6	65	-103	-268.5	-40.4	-26.6	Nov-01	
2I	**LB straight reach, low slope alluvium w/ Ti Tree**								
2I	Slope	1	-10	-1	-2.6	-11.7	-9.5	Nov-01	
2I	Toe	2	-10	1	2.6	-9.6	-6.5	Nov-01	
2J	**LB outside bend, alluvium**								
2J	Top	1	-28	40	104.3	12.8	8.0	Dec-99	
2J	Slope	2	35	9	23.5	46.8	60.2	Dec-99	

Site	Description	Pin #	Change Mar 03-Oct 03 (mm)	Change Oct 03-Mar 04 (mm)	Rate Oct 03-Mar 04 (mm yr^{-1})	Net Rate Mar 03 – Mar 04 (mm yr^{-1})	Net Rate Mar 02 – Mar 04 (mm yr^{-1})	Date installed	Comments
2J	Toe	3	-56	43	112.1	-13.8		Dec-99	New pin Oct 02, 77.5=rate between Dec 99 and Oct 02
2K	**LB outside bend, alluvium**								
2K	Cavity	1	-2	-7	-18.3	-9.6	-1.0	Nov-01	long pin
2K	Flow	2	258	-54	-140.8	217.1	-309.3	Nov-01	
2K	Top	3	198	4	10.4			Dec-99	pin horizontal on bank, new pin Oct 03, 94.2= rate between Nov 00 to Mar 03
2K	Slope	4	-73	-12	-31.3			Dec-99	pin horizontal on bank, new pin Oct 03, 94.2= rate between Nov 00 to Mar 03
2K	Toe	5	-88	58	151.2	-31.9	56.7	Dec-99	affected by seepage
2L	**RB inside bend, sands, cavity**								
2L	Cav	1	-12	14	36.5	2.1	3.0	Nov-01	
2L	Top	2	5	-1	-2.6	4.3	3.0	Dec-99	
2L	Slope	3	48	10	26.1	61.7	42.6	Dec-99	
2L	Toe	4	-22	23	60.0	1.1	8.0	Dec-99	

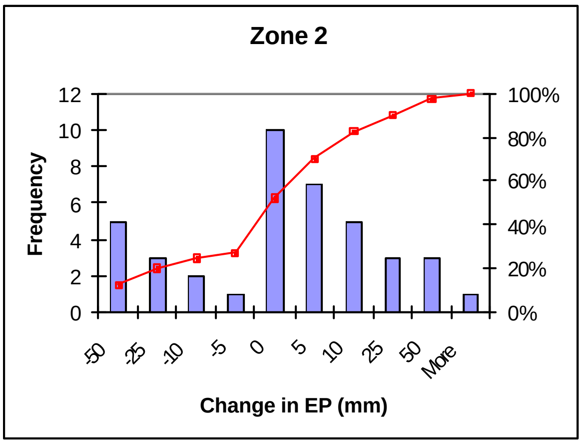


Figure 4.13. Histogram of erosion pin results from zone 2 between October 2003 and March 2004. Negative values indicate deposition, positive values indicate erosion.

In October 2003 widespread deposition was recorded by the erosion pins on toes and bank slopes. Some of this deposition was attributable to a recent natural high flow event which increased water levels in zone 2 to ~2 m without power station input, resulting in the widespread presence of a shallow deposit of white sands on the banks. However, field evidence indicated that most of the deposition recorded in October was related to the down slope movement of saturated bank material. The lack of 3-turbine power station operation for months prior to monitoring suggests that the bank movement was the result of either the power station 1-2 turbine peaking operations during the winter months combined with winter rains, or seepage erosion events following 3-turbine power station operations in May, June and July. Due to the lack of monitoring frequency it is not possible to conclusively establish which mechanism is responsible for the seepage induced deposition.

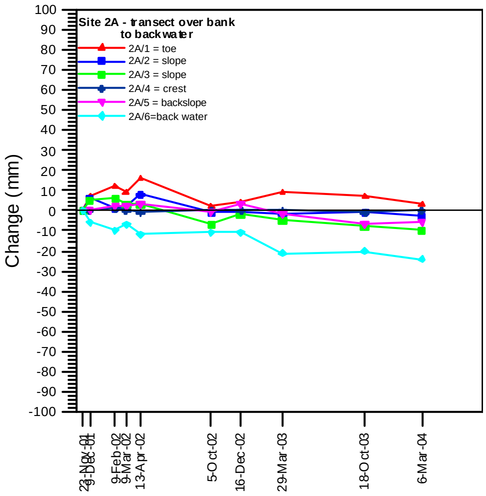


Figure 4.14. Erosion pin results from site 2A, a transect of six pins up the river bank and into a backwater. Positive values indicate erosion, negative values indicate deposition.

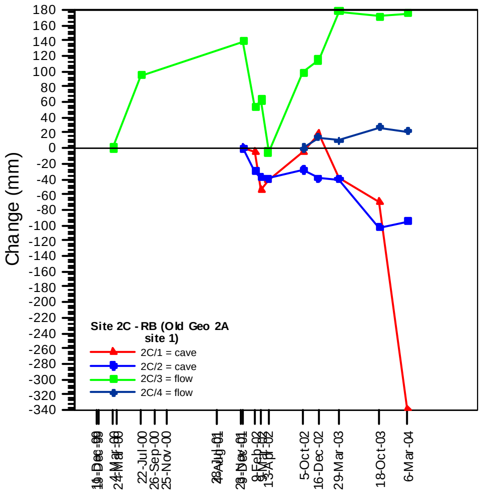


Figure 4.15. Erosion in results from site 2C, which is affected by seepage erosion. Positive values indicate erosion, negative values indicate deposition.

Sites located on alluvial banks with low slopes supporting tea-tree and showing no evidence of seepage features (2A [Figure 4.14], 2D, 2I) showed relatively low rates of deposition and erosion due to fluvial processes during both monitoring periods. The one year (March 03 – March 04) and two year rates (March 02 – March 04) at these sites indicate depositional environments.

Overall, rates of change at sites not dominated by seepage erosion processes varied between -78.2 mm yr^{-1} (deposition) and 112 mm yr^{1} (erosion) for the October 2003 to March 2004 period. Net changes were lower when considered over the March 03 to March 04 year (-56.4 to 61.7 mm yr^{-1}).

In March 2004, erosion pin results from sites located on banks containing seepage erosion features (2B, 2C [Figure 4.15], 2E, 2G, 2H, 2J and 2K) also showed greater variability due to the down slope movement of material, accounting for the dominance of depositional sites in Table 4.5 and the histogram in Figure 4.13. An unquantifiable portion of this deposition is attributable to the saturated bank conditions associated with the extended 3-turbine power station operation immediately preceding the monitoring shutdown, as indicated by the piezometers. Calculated erosion or deposition rates in excess of 100 mm yr^{-1} are common at these sites, and highlight the dynamic nature of seepage erosion as most if not all of this change appears to occur during short events.

Scour chain results in March 2004 were similar to the October 2003 results and consistent with the erosion pin results, with the chain at site 2A recording no deposition or scour, and at sites 2D and 2H recording no scour, but up to 10 mm deposition. At the other chain sites (2K and 2L), which are very active seepage erosion sites, deposition of up to 40 mm was recorded in March, which appeared to be due to the down slope movement of material. Scour of three links was also recorded at site 2K. In October 2003, this site also showed a high level of activity with 150 mm of sediment deposited on top of the chain from down slope movement.

4.4.2.3 Zone 3

Zone 3 has flow and sediment input from the Orange River. Natural inputs during the power station shutdown prior to monitoring in October resulted in the fluvial deposition of sands on banks in zone at about half of the erosion pin locations.

Table 4.6 summarises the erosion pin results for this zone. In March 2004, the erosion pins showed net erosion at more sites, as shown in Figure 4.16.

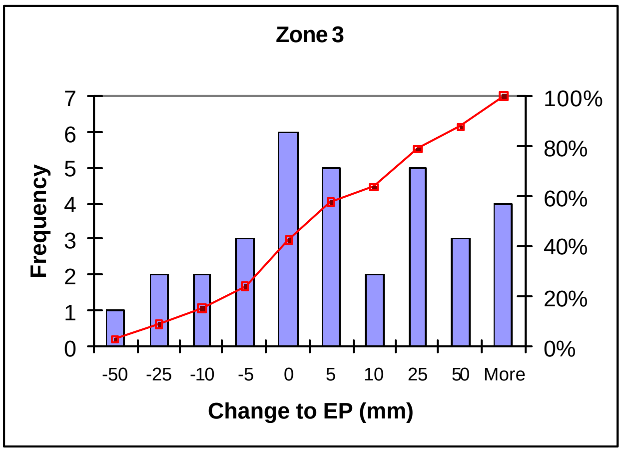


Figure 4.16. Histogram of erosion pin results from zone 3 between October 2003 and March 2004. Negative numbers indicate deposition, positive numbers indicate erosion.

Table 4.6. Summary of erosion pin results for zone 3. All measurements in mm and rates in mm yr^{-1}. Negative numbers indicate deposition, positive indicate erosion.

Site	Description	Pin #	Change Mar 03- Oct 03 (mm)	Change Oct 03- Mar 04 (mm)	Rate Oct 03- Mar 04 (mm /yr^{-1})	Net Rate Mar 03 – Mar 04 (mm /yr^{-1})	Net Rate Mar 02 – Mar 04 (mm /yr^{-1})	Date installed	Comments
3A	**LB straight reach, sands over cobbles**								
3A	Slope	1 (old)						Dec 99-Mar 02	replaced by #2 (new) Oct 02
3A	slope	1	124	72	187.7	208.6		Oct-02	
3A	slope	2	33	122	318.1	164.9		Oct-02	
3A	toe	3	98	-174	-453.6	-80.9		Oct-02	
3B	**LB, straight reach sands over cobbles, cavities**								
3B	slope	1	10	-7	-18.3	3.2	15.5	Dec-99	
3B	cavity	2	0	-10	-26.1	-10.6	-25.1	Dec-01	affected by tree fall
3B	cavity	3	9	-8	-20.9	1.1	2.0	Dec-01	
3B	slope	4	38	7	18.3	47.9	141.4	Dec-99	
3B	slope	5	-62	11	28.7	-54.3	12.0	Dec-99	
3C	**RB, straight reach, alluvium**								
3C	cavity	1	-203	189	492.8	-14.9	18.6	Dec 01	long pin/error in measurement?
3C	top	2	-12	-3	-7.8	-16.0	-15.5	Dec-01	
3C	slope	3	-2	-3	-7.8	-5.3	-6.0	Dec-01	
3C	slope	4	113	3	7.8	123.4	66.2	Dec-01	
3C	toe	5	-79	-38	-99.1	-124.5	-83.2	Dec-01	affected by seepage
3D	**LB, straight reach, alluvium sand over cobbles, cobbles in back wall of bank**								
3D	cavity	1	-5	37	96.5	34.1	14.5	Dec-01	
3D	slope	2	0	6	15.6	6.4	2.5	Dec-01	
3D	toe	3	22	46	119.9	72.4	83.7	Dec-01	
3Ea	**RB straight bank sands with 5 pins in V-shape in gully**								
3Ea	top	1	-10	-12	-31.3	-23.4	-12.0	Nov-01	
3Ea	slope	2	54	-21	-54.8	35.1	55.2	Nov-01	
3Ea	Toe (base of gully)	3	-15	3	7.8	-12.8	16.0	Nov-01	
3Ea	slope	4	64	-43	-112.1	22.3	33.1	Nov-01	
3Ea	top	5	-23	39	101.7	17.0	10.0	Nov-01	
3Eb	**RB straight reach, d/s 3Ea**								
3Eb	top	1	-6	1	2.6	-5.3	-2.5	Nov-01	
3Eb	slope	2	-10	-3	-7.8	-13.8	-10.5	Nov-01	
3Eb	slope	3	46	13	33.9	62.8	154.9	Nov-01	
3Eb	slope	4	24	19	49.5	45.8	42.6	Nov-01	
3Eb	toe	5	-5	55	143.4	53.2	8.0	Nov-01	
3F	**RB, straight reach, sands with cavity**								
3F	cavity	1	16	-1.0	-2.6	16.0	17.5	Dec-01	long pin
3F	top	2	-3	2	5.2	-1.1	2.5	Dec-01	
3F	slope	3	-5	2	5.2	-3.2	-2.0	Dec-01	
3F	toe	4	-3	21	54.8	19.2	4.0	Dec-01	
3G	**LB, straight reach, sands with cavity**								
3G	cavity	1	-14	-1	-2.6	-16.0	-4.5	Dec-01	
3G	top	2	10	-7	-18.3	3.2	-4.0	Dec-01	
3G	slope	3	-7	-1	-2.6	-8.5	-19.1	Dec-01	
3G	slope	4	7	18	46.9	26.6	-3.5	Dec-01	
3G	toe	5	-142	86	224.2	-59.6	18.0	Dec-01	pin freq underwater-difficult to measure

The most upstream site in zone 3 (3A) recorded very high erosion rates on the bank slope throughout the monitoring year. Between October 2003 and March 2004, this site recorded the highest erosion (318 mm yr^{-1}) and deposition rates (-454 mm yr^{-1}) of any site in the study area. The annual range of rates (March 03 – March 04) at the site was lower (208.6 to -80.9 mm yr^{-1}), showing the rates are not uniform throughout the year.

Total net erosion on the bank slope at site 3A exceeds 600 mm since monitoring began in 1999. This erosion has undermined the original star picket installed in the bank and completely exposed the scour chain installed in December 1999. The toe of this site is buttressed by a large log, and the erosion pin on the toe has shown deposition over the past year in contrast to the erosion of bank slope. It is likely these large rates of change are related to the placement of the site, immediately downstream of the steep, bedrock controlled Splits and Snake rapids, and inflows from the Orange River. Very turbulent flow was observed in this part of the Gordon River while the power station was operating on 5 March 2004.

The other erosion pins located on bank toes in zone 3 not experiencing seepage erosion generally show relatively high rates of erosion, with the upslope banks showing lower rates of change. Figure 4.17 shows results from site 3Eb which is a profile of 5 pins down an alluvial bank midway down zone 3. The results show a steepening of the bank since monitoring began, with erosion of 100 - 340 mm of the toe and lower bank and deposition of 1 – 25 mm of the upper bank. This deposition is likely associated with storm events. An exception is site 3B which shows deposition due to upslope seepage processes, and site 3G where deposition is most likely due to backwater effects from the Denison River.

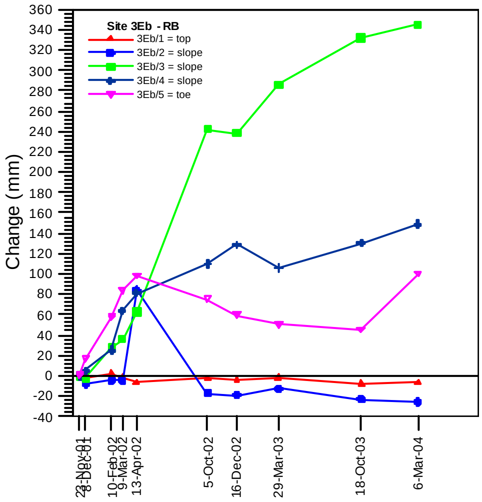


Figure 4.17. Erosion pin results from site 3Eb. Positive values indicate erosion, negative values indicate deposition

Seepage erosion is active at a number of monitoring sites in zone 3 (3B, 3C [Figure 4.18], 3D, 3F), and accounts for some of the material deposited on the bank faces. In general, the cavities are not as large as in zone 2, although they are very deep and require long pins for monitoring (2 m). Some of the variability in Figure 4.18 is likely attributable to measurement error, due to the presence of tree roots in the cavities which interferes with measuring the pins.

Maximum erosion rates for the zone (excluding site 3A) were 224 mm yr^{-1} for the October 03 to March 04 period and 123 mm yr^{-1} for the March 03 to March 04 year. Deposition rates of up to -112 mm yr^{-1} (October 2003 – March 2004) and -125 mm yr^{-1} (March 03 – March 04) were recorded in zone 3, which exceed the non-seepage deposition rates recorded in zone 2. The influx of sediment from the Orange, and possibly backwater effects from the Denison are the likely sources of this sediment. Erosion is more prevalent in zone 3 as compared to zone 2, but this may reflect a relative decrease in seepage erosion activity in zone 3 relative to zone 2. Sediment flows resulting from seepage erosion in zone 2 may be obscuring bank erosion caused by scour through the deposition of material on bank faces following power station shutdown.

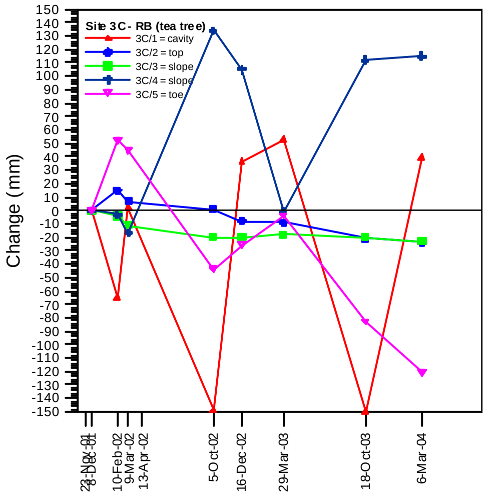


Figure 4.18. Erosion pin results for site 3C. Positive values indicate erosion, negative values indicate deposition.

4.4.2.4 Zone 4

Zone 4 begins at the confluence of the Denison and Gordon Rivers, and is the first zone in the study area to be subjected to high natural flow events, with water levels of up to 2 m above power station-controlled levels recorded during the winter of 2003. Erosion pin results are summarized in Table 4.7, and in Figure 4.19 for changes recorded between October 2003 and March 2004.

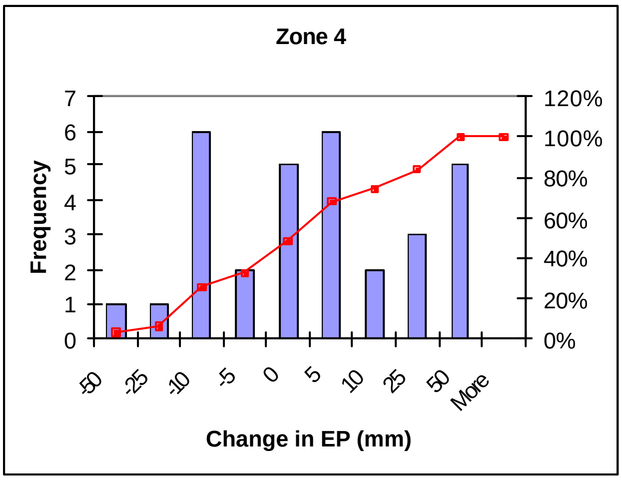


Figure 4.19. Erosion pin changes in zone 4 between October 2003 and March 2004.

Table 4.7. Summary of erosion pin results for zone 4. All measurements in mm and rates in mm yr^{-1}. Negative numbers indicate deposition, positive indicate erosion.

Site	Description	Pin #	Change Mar 03-Oct 03 (mm)	Change Oct 03-Mar 04 (mm)	Rate Oct 03-Mar 04 (mm yr^{-1})	Net Rate Mar 03 – Mar 04 (mm yr^{-1})	Net Rate Mar 02 – Mar 04 (mm yr^{-1})	Date installed	Comments
4A	**LB straight reach, sands**								
4A	top	1	-35	-7	-18.3	-44.7	-36.1	Dec-01	
4A	slope	2	18	-33	-86.0	-16.0	-6.0	Dec-01	
4A	toe	3	-15	1	2.6	-14.9	91.4	Dec-01	
4B	**RB sands, cavity**								
4B	top	1					-263.6	Dec-01	Net rate Dec 01-Apr 02; lost Apr 02, re-est. Mar 04
4B	slope	2	-11	34	88.6	24.5	-58.7	Dec-01	
4B	toe	3	13	-105	-273.8	-97.9	-12.6	Dec-01	Freq underwater, Lost Oct 02, re-estab Mar 04
4D	**LB, beg inside bend sands over cobbles,**								
4D	Top	1	-28	2	5.2	-27.7	-25.6	Dec-01	Lost Oct 02, re-est. Mar 04
4D	Slope	2	25	-17	-44.3	8.5	1.0	Dec-01	Freq underwater
4D	Toe	3	-8	-4	-10.4	-12.8	-16.6	Dec-01	
4E	**LB, inside bend, sands**								
4E	top	1	4	6	15.6	10.6	-0.5	Dec-01	
4E	slope	2	3	-1	-2.6	2.1	-4.0	Dec-01	
4E	slope	3	22	19	49.5	43.6	28.1	Dec-01	
4E	toe	4	-13	22	57.4	9.6	27.6	Dec-01	Freq underwater
4F	**RB, inside bend, sands over bedrock**								
4F	top	1	-13	2	5.2	-11.7	9.5	Dec-99	
4F	slope	2	-6	-20	-52.1	-27.7	13.1	Dec-99	
4F	slope	3	-6	32	83.4	27.7	-2.5	Dec-01	
4F	slope	4	24	-7	-18.3	18.1	20.1	Dec-01	
4F	slope	5	26	-10	-26.1	19.2	8.5	Dec-01	
4Ga	**LB straight reach, sands**								
4Ga	top	1	-48	1	2.6	-50.0	-14.6	Dec-01	
4Ga	slope	2	7	-12	-31.3	-5.3	22.6	Dec-01	
4Ga	slope	3	41	49	127.8	95.8	44.7	Dec-01	
4Ga	toe	4	4	26	67.8	31.9	7.0	Dec-01	
4Gb	**LB straight reach, sands; immed d/s 4Ga**								
4Gb	top	1	0	2	5.2	2.1	10.0	Dec-01	
4Gb	slope	2	17	-3	-7.8	14.9	4.5	Dec-01	
4Gb	slope	3	28	20	52.1	51.1	47.2	Dec-01	
4Gb	slope	4	15	35	91.3	53.2	48.7	Dec-01	
4Gb	toe	5	-34	-3	-7.8	-39.4	9.0	Dec-01	
4H	**RB, u/s gorge entrance, sand over cobbles**								
4H	top	1	18	-16	-41.7	2.1	-1.0	Dec-01	
4H	slope	2	-6	-11	-28.7	-18.1	-13.6	Dec-01	
4H	slope	3	-15	4	10.4	-11.7	-14.6	Dec-01	
4H	slope	4	3	-2	-5.2	1.1	-4.0	Dec-01	
4H	slope	5	11	9	23.5	21.3	54.7	Dec-01	

At sites 4A and 4 D [Figure 4.20] October 03 results show deposition on the upper bank slopes and toes, with erosion more common on the mid-banks. The deposition is consistent with fluvial deposition during the winter high flows. The mid-bank erosion is likely due to scour associated with fluctuating water levels. The other sites typically showed erosion of bank toes, with variable changes to bank slopes.

In March 2004 there were no clear trends, with 18 of the 31 sites showing opposite responses to the October results. At sites where the 'top' pin is above the power station-controlled high water level (4F, 4G), the March 2004 measurements show little change, but the March 2003 – March

2004 rates indicate deposition associated with storm events occurring between March 2003 and October 2003. The majority of sites show net erosion based on the 1-year and 2-year net change rates.

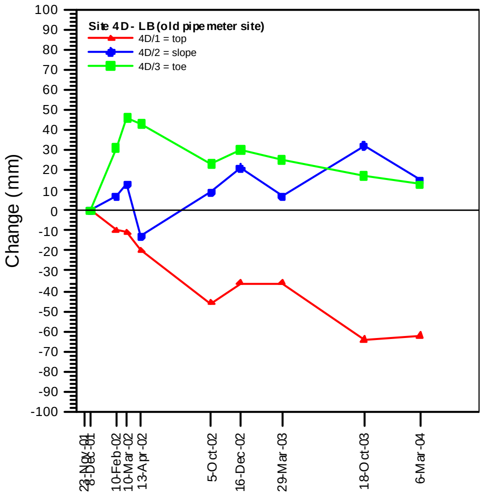


Figure 4.20. Erosion pin results from site 4D. Positive values indicate erosion, negative values indicate deposition

Site 4B is the only monitoring site in zone 4 subject to seepage processes, with the bank frequently saturated following power station shutdown. The loss of erosion pins and migration of pins down the bank is due to the mass movement of saturated bank material, as indicated by the high deposition rates recorded at the site and frequency of the pins being underwater. These pins have had to be replaced, and reset due to downslope migration.

Scour chains at Sites 4D and 4E showed scour of 1 link, with subsequent deposition of 50 – 80 mm (4D) and 5 – 25 mm (4E) indicating the banks are more dynamic than the net erosion recorded by the pins.

4.4.2.5 Zone 5

Zone 5 begins below the confluence of the Olga and Gordon Rivers and is subject to the largest water level changes (up to 8 m in 2003). Deposition in the zone is dominated by fluvial processes, with a low occurrence of seepage erosion. Erosion pin results are summarized in Table 4.8 and in Figure 4.21 for changes recorded between October 2003 and March 2004.

In October 2003, the pins located along straight reaches all showed deposition for the monitoring period, sites situated on inside bends showed erosion, and three of the four sites situated on outside bends recorded net deposition. Similar trends in the data were not present with respect to pin placement on bank (toe, slope, etc) and suggest that during the high winter flow events, channel location may play a major role in determining bank processes.

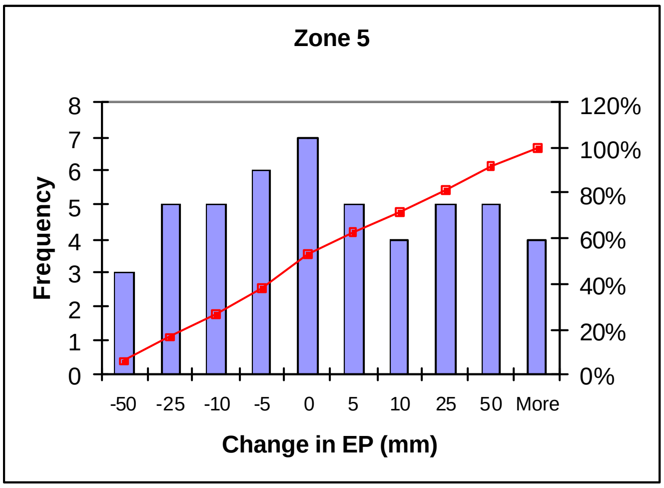


Figure 4.21. Changes in erosion pins between October 2003 and March 2004. Negative values indicate deposition, positive values indicate erosion.

Table 4.8. Summary of erosion pin results for zone 5. All measurements in mm and rates in mm yr^{-1}. Negative numbers indicate deposition, positive indicate erosion.

Site	Description	Pin #	Change Mar 03-Oct 03 (mm)	Change Oct 03-Mar 04 (mm)	Rate Oct 03-Mar 04 (mm yr^{-1})	Net Rate Mar 03 – Mar 04 (mm yr^{-1})	Net Rate Mar 02 – Mar 04 (mm yr^{-1})	Date of Installation	Comments
5A	**RB, straight reach, sands,**								
5A	Cavity	1	6	-101	-263.3	-101.1	92.4	Dec-01	root mat on pin
5A	cavity	2	2	-2	-5.2	0.0	-3.0	Dec-01	
5A	slope	3	24	-27	-70.4	-3.2	-0.5	Dec-01	
5A	toe	4	-139	123	320.7	-17.0	10.0	Dec-01	
5B	**LB, inside bend, sands**								
5B	top	1	6	-2	-5.2	4.3	4.0	Dec-01	
5B	slope	2	-3	-12	-31.3	-16.0	-21.1	Dec-01	
5B	slope	3	-18	-5	-13.0	-24.5	-55.2	Dec-01	
5B	toe	4	2	40	104.3	44.7	56.2	Dec-01	
5C	**RB, inside bend**								
5C	top	1	5	5	13.0	10.6	-2.0	Dec-01	
5C	slope	2	-19	6	15.6	-13.8	-11.0	Dec-01	
5C	toe	3	-9	-2	-5.2	-11.7	-13.1	Dec-01	
5D	**RB, straight reach, steep**								
5D	top	1	-31	-7	-18.3	-40.4	-22.1	Dec-01	
5D	slope	2	-7	4	10.4	-3.2	9.0	Dec-01	
5D	toe	3	-83	1	2.6	-87.3	-43.2	Dec-01	
5E	**LB, straight reach, alluvium with grass**								
5E	Cavity	1		203	539.0	826.8	63.8	Dec-01	collapse on pin 10/03
5E	Slope	2	11	-14	-36.5	-3.2	-16.1	Dec-01	
5E	Slope	3	-44	16	41.7	-29.8	1.5	Dec-01	
5E	toe	4	-1	7	18.3	6.4	20.6	Dec-01	
5F	**LB, straight reach, sands with grass**								
5F	Wall	1	-23	-2	-5.2			Dec-01	Reset Oct 03; 7.3=Dec 01-Oct 03
5F	Slope	2	-24	3	7.8	-22.3	-10.0	Dec-01	
5F	toe	3	54	-21	-54.8	35.1	8.5	Dec-01	
5G	**RB, straight reach, sands over cobbles behind cobble bar**								
5G	Cavity	1	2	3	7.8	5.3	8.0	Dec-99	
5G	slope	2	2	-7	-18.3	-5.3	-7.0	Dec-99	
5G	slope	3	3	-27	-70.4	-25.5	-13.6	Dec-99	
5G	slope	4	8	-5	-13.0	3.2	-5.0	Dec-99	
5G	bench	5	22	-34	-88.6	-12.8	1.5	Dec-99	
5G	toe	6	-36	54	140.8	19.2	13.1	Dec-99	
5H	**RB, outside bend, steep sandy alluvium**								
5H	top	1	11	33	86.0	46.8	26.6	Dec-01	
5H	slope	2	-12	-8	-20.9	-21.3	-21.1	Dec-01	
5H	slope	3	22	-19	-49.5	3.2	0.0	Dec-01	
5H	toe	4	-52	8	20.9	-46.8	4.0	Dec-01	

Site	Description	Pin #	Change Mar 03-Oct 03 (mm)	Change Oct 03-Mar 04 (mm)	Rate Oct 03-Mar 04 (mm yr^{-1})	Net Rate Mar 03 – Mar 04 (mm yr^{-1})	Net Rate Mar 02 – Mar 04 (mm yr^{-1})	Date of Installation	Comments
5I	**LB outside bend, sands**								
5I	wall	1	-10	0	0.0	-10.6	6.5	Dec-01	
5I	slope	2	-48	-79	-206.0	-135.1	-72.8	Dec-01	
5I	slope	3	-49	80	208.6	33.0	33.1	Dec-01	
5I	toe	4	-36	-25	-65.2	-64.9	-8.0	Dec-01	
5J	**RB, inside bend, sands**								
5J	Top	1	-14	-11	-28.7	-26.6	-28.1	Feb-02	
5J	slope	2	4	9	23.5	13.8	-0.5	Feb-02	
5J	slope	3	12	18	46.9	31.9	33.6	Feb-02	
5J	toe	4	21	34	88.6	58.5	44.2	Feb-02	
5K	**RB, outside bend, sands – not read March 03**								
5K	slope	1		-85 (since 12/02)				Feb-02	not read 3/03, 10/03
5K	slope	2		45	117.3		-31.1	Feb-02	not read 3/03
5K	toe	3		-7	-18.3		-44.7	Feb-02	not read 3/03
5L	**LB, straight reach**								
5L	Wall	1	5	-1	-2.6	4.3	-2.0	Feb-02	
5L	slope	2	23	18	46.9	43.6	22.6	Feb-02	
5L	slope	3	7	26	67.8	35.1	38.7	Feb-02	
5L	toe	4	-7	15	39.1	8.5	9.5	Feb-02	
5M	**RB, outside bend**								
5M	top	1	17	0	0.0	18.1	-30.6	Feb-02	
5M	slope	2	-48	-61	-159.0	-116.0	-68.3	Feb-02	
5M	toe	3	35	-48	-125.1	-13.8	-2.0	Feb-02	

In March, there were no trends associated with location of sites within the channel. Six sites (5B [Figure 4.22], 5G, 5H, 5J, 5L, 5M) showed bank steepening to various degrees, with erosion of bank toes accompanied by deposition on bank slopes, possibly reflecting a re-adjustment of the bank face to power station operation following the winter flows.

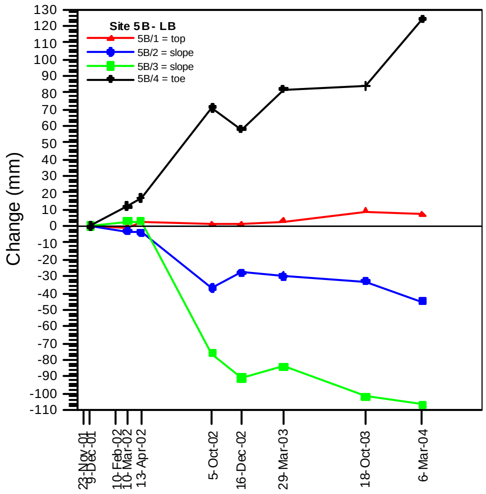


Figure 4.22. Erosion pin results from site 5B. Positive values indicate erosion, negative values indicate deposition

Between October 2003 and March 2004, the highest rates of erosion (321 mm yr^{-1}) and deposition (-206 mm yr^{-1}) recorded in the study area occurred in zone 5. For the year-long period between March 2003 and March 2004, net erosion rates were generally lower than the October 2003 to March 2004 interval, reflecting the deposition of sands during the winter high flow events. This behaviour is consistent with previous observations where deposition by winter storm events is scoured by continuous power station operation. Rates of change based on the 2 years of monitoring show that net erosion has occurred at 17 pins, deposition at 18 pins, with no change recorded by one pin. Average erosion rates for the two year period are 19 mm yr^{-1} (median = 13.1 mm yr^{-1}), and average deposition rates are -15 mm yr^{-1} (median = -10.5 mm yr^{-1}).

4.5 Synthesis of monitoring results

The following points summarise the March 2003 – March 2004 fluvial geomorphology monitoring results

4.5.1 Flow patterns

Flow patterns in the middle Gordon River were similar to the 2002-03 monitoring year, with high power station discharge during the summer months, intermittent 1-2 turbine operation during the winter, and an extended power station shutdown in autumn. Monitoring in October 2003 occurred during a prolonged shut down, and monitoring in March 2004 occurred during a 1-day shutdown preceded by 3-turbine power station operation. Field observations reflected the preceding power station operating patterns. In October the deposition of fine muds and organic debris on banks in all zones was common, due to deposition associated with natural flow events during the power station shutdown prior to monitoring. In March 2004 this deposition was absent in zones 1 or 2, and seepage erosion processes were active. Piezometer results show that in-bank water surface slopes exceeded 0.1 during this period, consistent with previous results and the present understanding of seepage processes.

4.5.2 Photo monitoring

Comparative photo monitoring showed little activity at most sites. Vegetation density and size has increased above high water level at some land slip sites, but many slip faces remain unvegetated. In zone 2, overhanging vegetation has collapsed above new slips first observed in October 2003.

4.5.3 Erosion pins

Erosion pin results in zones 1 & 2 were consistent with previous results and reflected power station operation, with the influence of natural inflows limited to the deposition of fine-material on bank toes during the power station shutdown prior to monitoring. Seepage erosion was widespread following 3-turbine to ‘off’ power station operation in March 2004 in these zones, with calculated annual rates of change frequently exceeding 100 mm yr^{1}. Erosion pin data also suggest that the 1- and 2-turbine peaking operation of the power station during the winter combined with high rainfall resulted in repeated saturation of the lower banks and toes, promoting the mass movement of material downslope.

4.5.4 Natural flows

High winter flows occurred in the Gordon catchment during the monitoring year, with river levels in excess of 8 m recorded at the Gordon above Franklin gauge site. The monitoring showed that in zones 3 - 5, the winter events deposited material on the upper banks and toes, with mid-banks commonly showing erosion due to scour associated with fluctuating water levels. Toe scour was recorded at many sites in these zones in March 2004 following prolonged 3-turbine power station usage, and reflects the re-adjustment of the banks from winter flow events to power station flow conditions.

4.5.5 Piezometer results

Piezometer results show in-bank water levels reflect river level as previously documented. There were several periods during the monitoring year when in-bank water surface slopes posed a high risk of seepage erosion. These corresponded to power station shutdowns immediately following prolonged 3-turbine power station usage, as previously documented. When this type of shutdown was accompanied by high rainfall and followed by 1- or 2-turbine peaking operation of the power station, the high risk period for seepage erosion was prolonged, due to the inability of the banks to drain, and continued inflow to the bank from rainfall.

4.5.6 Piezometer accuracy

Inconsistencies and off-sets within the piezometer records suggest that the probes may not be providing an accurate record of in-bank water surface slopes, and should be investigated.

5 Karst Geomorphology

5.1 Karst areas

Key karst features are monitored in both the Gordon-Albert and Nicholls Range karst areas twice per year. During 2003-04, monitoring trips occurred in October 2003 and March 2004.

Figure 5.1 shows the location of the two karst areas investigated by the monitoring program.

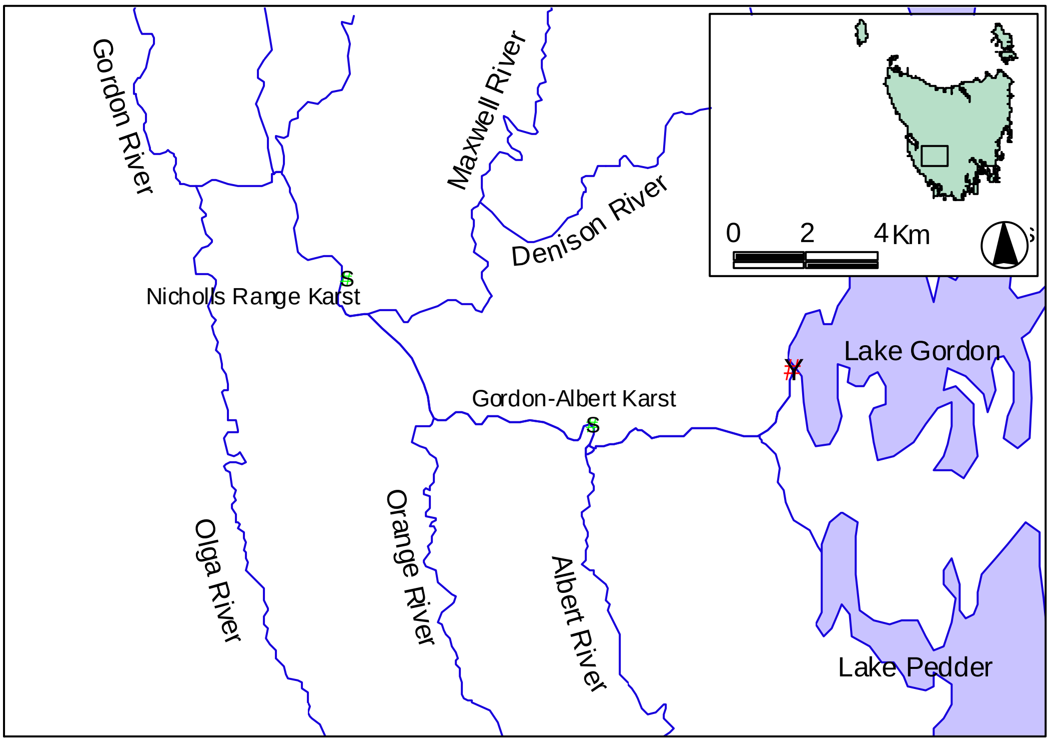


Figure 5.1. Map of the karst monitoring sites in the Gordon River.

5.1.1 Gordon-Albert karst area

There are 4 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 lightweight capacitive water level recorder is installed in GA-X1.

The GA-X1 cave is 28 m long (including the large entrance area), 10 m deep, and is located approximately 10–20 m 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 approximately at the same level as the Gordon River.

5.1.2 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 5 erosion pins installed and a photo-monitoring site. Bill Neilson Cave site has 3 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 20 minutes over a range of 1.0 – 1.5 m.

5.2 Methods and results

5.2.1 Erosion pin data

All erosion pins were measured using a steel 300 mm ruler placed to the right side of the pin, on the contour level. Data for all sites are summarised in Table 5.1. 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 5.2.

One of the pins in Kayak Kavern was washed out in October 2003 and two new pins were put in its place. An additional, makeshift, pin was also added to site 4, in the base of the doline.

5.2.2 Water level recorders

5.2.2.1 Bill Neilson Cave

The hydrograph from the water level recorder measuring the cave stream flow in Bill Neilson Cave, between 30 March 2003 and 15 October 2003, is shown in Figure 5.2. Figure 5.3 shows the hydrograph of water levels in Bill Neilson Cave, between 15 October 2003 and 6 March 2004, with the corresponding water levels from the Gordon below Denison recorder (site 62). Part of the same dataset, enlarged to show four high flow events in January 2004, is shown in Figure 5.4.

5.2.2.2 Cave GA-X1

The hydrograph from the water level recorder in GA-X1 between 16 October 2003 and 6 March 2004 is shown in Figure 5.5 with the corresponding water levels at site 71 (G5a) for comparison. Figure 5.6 shows an enlarged portion of the hydrograph for the period between 9 and 13 January 2004.

Table 5.1. Erosion pin data for karst sites from 2001 – 2004. Positive change values indicate erosion, negative values indicate deposition

Site no.	Site description	Pin no.	Length previous trips (mm)					Length 6/4/04 (mm)	Change this summer (mm)	Change in 12 months (mm)	Comments and interpretation
			23/11/01[a] or 8/12/01[b]	9/3/02	6/10/02	30/3/03	15/10/03				
1	Channel Cam	1	322[a]	318	318	316	318	322	+4	+6	Limited erosion during the summer period and overall loss over 12 months. Slight net deposition over same periods at Pin 1 last year.
		28	n/a	n/a	245	245	248	248	0	3	
2	GA-X1 cave	2	250[a]	239	238	244	242	245	+3	+1	Erosion at the lower levels and slight deposition at Pin 3. Similar trend as last year at the lower levels with erosion during summer and deposition in winter. No seasonal pattern at Pin 3.
		3	190[a]	189	193	195	196	194	-2	-1	
		4	154[a]	161	160	163	159	165	+6	+2	
	Doline at cave entrance	9	214[a]	213	220	217	219	224	+5	+7	Continued loss of sediment and debris this summer at Pin 9 since winter. Slight gain at Pin 10 but no change over 12 months
		10	278[a]	278	293	290	291	290	-1	0	
3	Doline adjacent to GA-X1	5	259[a]	287	294	297	284	283	-1	-14	Continued deposition of material at all pins this summer from last winter, in comparison to overall erosion of material during the previous summer. Probable movement of leaf and twig litter into the doline from surrounding areas with heavy summer rains. Little net change since Spring 01 at the highest levels.
		6	300[a]	300	294	306	297	290	-7	-16	
		7	254[a]	252	258	261	257	252	-5	-9	
		8	195[a]	196	192	200	194	192	-2	-8	
4	Small doline	12	192[a]	171	170	172	152	155	+3	-17	No change at top pin, and slight gain and slight loss at mid and lowest pins respectively. Opposite changes over 12 months with slight gain at top pin and net loss and net gain at mid and lowest pins respectively.
		13	234[a]	238	231	217–245	245	241	-4	+10	
		14	253[a]	256	244	262	257	257	0	-5	
5	Kayak Kavern	16	309[b]	308	319	359	n/a	n/a	n/a	n/a	Deposition in the eddy and top flat areas with significant erosion on the active slope at Pin 17. New pins installed on the active slope (Nos 28 and 29) to replace Pin 16. Net gain on top and in the eddy over 12 months with net loss on the active slope.
		17	293[b]	291	284	288	339	384	+45	+96	
		18	267[b]	266	255	263	258	252	-6	-11	
		19	249[b]	245	271	267	225	220	-5	-47	
		28	n/a	n/a	n/a	n/a	n/a	273	n/a	n/a	
		29	n/a	n/a	n/a	n/a	n/a	259	n/a	n/a	
6	Bill Neilson: 6A at entrance	20	483[b]	480	499	495	501	493	-8	-2	Deposition of material from the lowest level, slight decrease at the mid level and no change higher up. Little net change over 12 months at the higher level with slight net gain at the lower level and let loss in the middle.
		21	300[b]	299	302	301	304	305	+1	+4	
		22	272[b]	272	269	272	271	271	0	-1	
	Bill Neilson: 6B Sed bank II	25	194[b]	195	195	195	198	198	0	+3	No change at the lower level, slight erosion at the mid level and deposition higher up the bank. Continued net deposition at the highest level over 12 months, with net loss at the mid and lower pins.
		26	203[b]	203	202	202	202	204	+2	+2	
		27	215[b]	216	214	213	212	208	-4	-5	
	Bill Neilson: 6C Dry sed bank	23	297[b]	297	295	298	298	297	-1	-1	Little change this summer or over 12 months.
		24	227[b]	226	202	203	203	203	0	0	

Table 5.2. Erosion pin survey data, doline sites 3 and 4.

Site No.	Pins measured	Distance between pins (m)			
		6/10/02	30/3/03	15/10/03	6/3/04
3	Photo-monitoring peg to Pin 5	3.28	3.295	3.295	3.295
	Pin 5 to Pin 6	1.055	1.055	1.05	1.055
	Pin 6 to Pin 7	1.35	1.345	1.345	1.355
	Pin 7 to Pin 8	1.85	1.85	1.85	1.845
4	Photo-monitoring peg to Pin 12	2.62	2.62	2.63	2.625
	Pin 12 to Pin 13	1.515	1.515	1.515	1.515
	Pin 13 to Pin 14	1.435	1.435	1.435	1.435
	Pin 13 to new stick	n/a	n/a	n/a	1.505

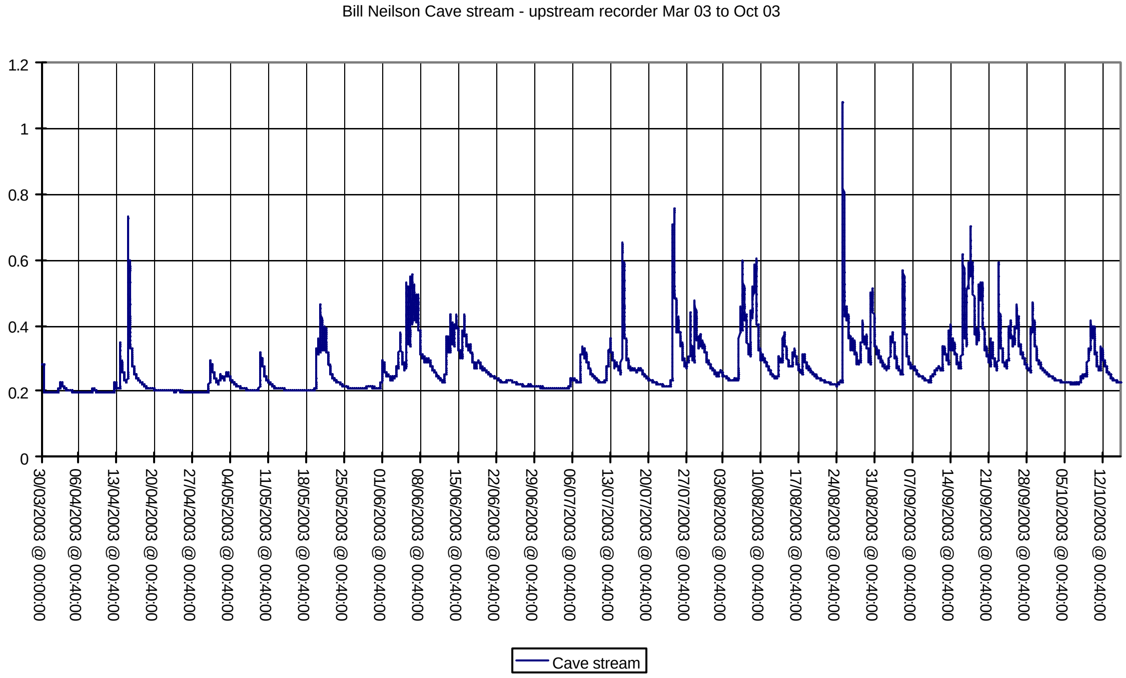


Figure 5.2. Water level at the upstream gauge in Bill Neilson Cave, March – October 2003 (relative to local zero datum).

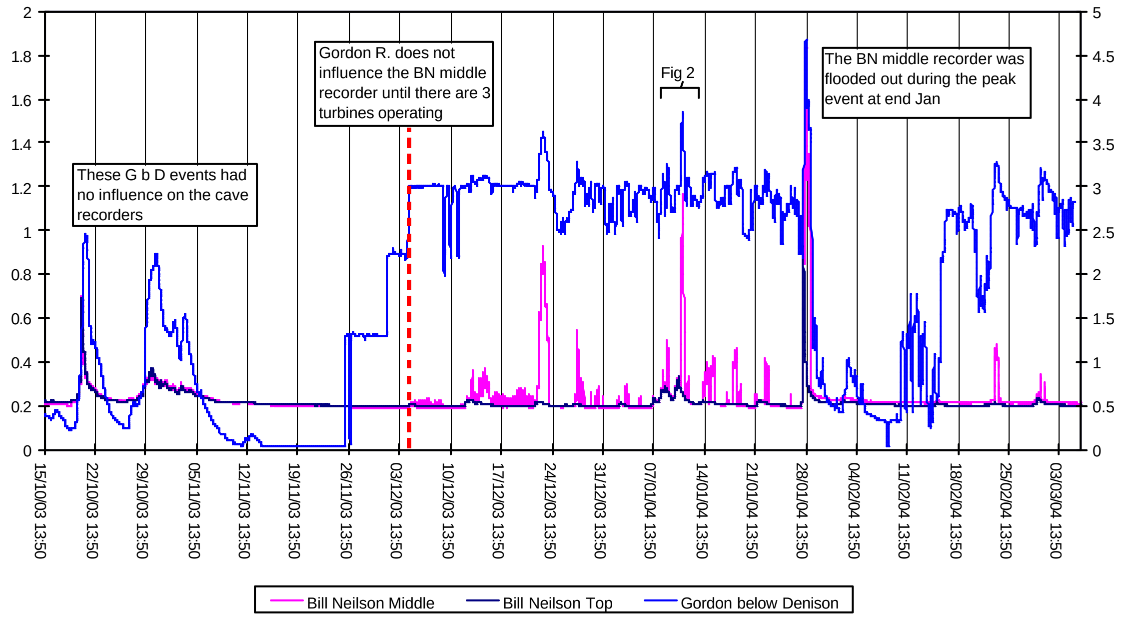


Figure 5.3. Bill Neilson cave water levels (October 03 – March 04) with Gordon below Denison water level data for comparison. Data in metres above arbitrary zero levels.

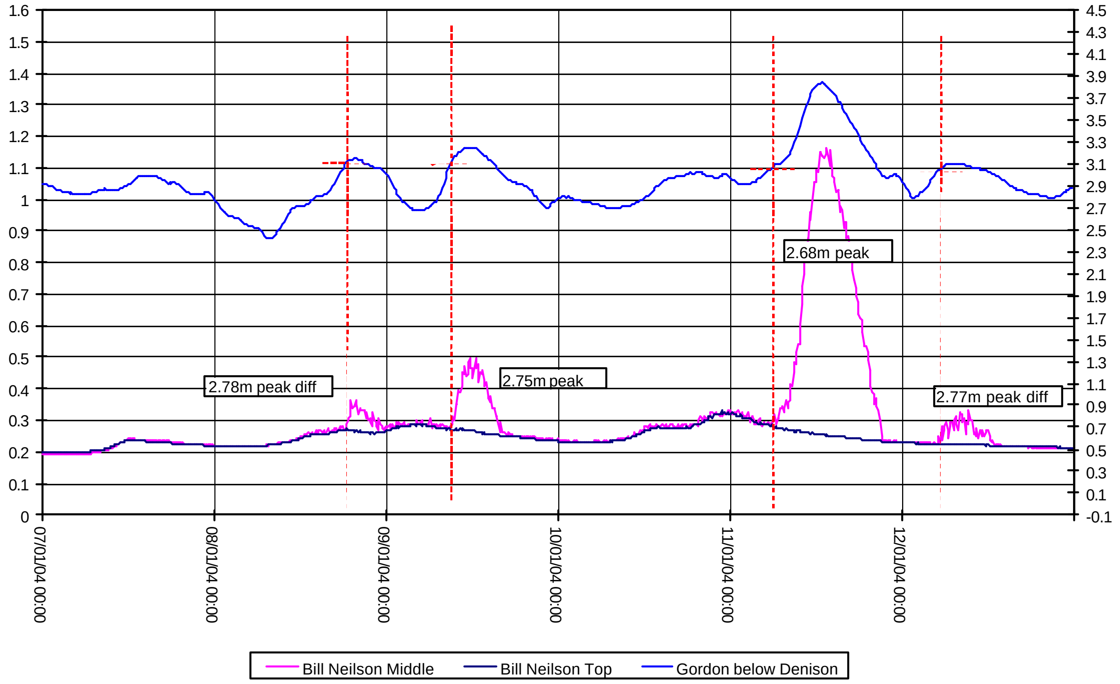


Figure 5.4. Bill Neilson Cave stream levels with Gordon below Denison for comparison, showing 4 high flow events in January 2004. Data in metres above arbitrary zero levels

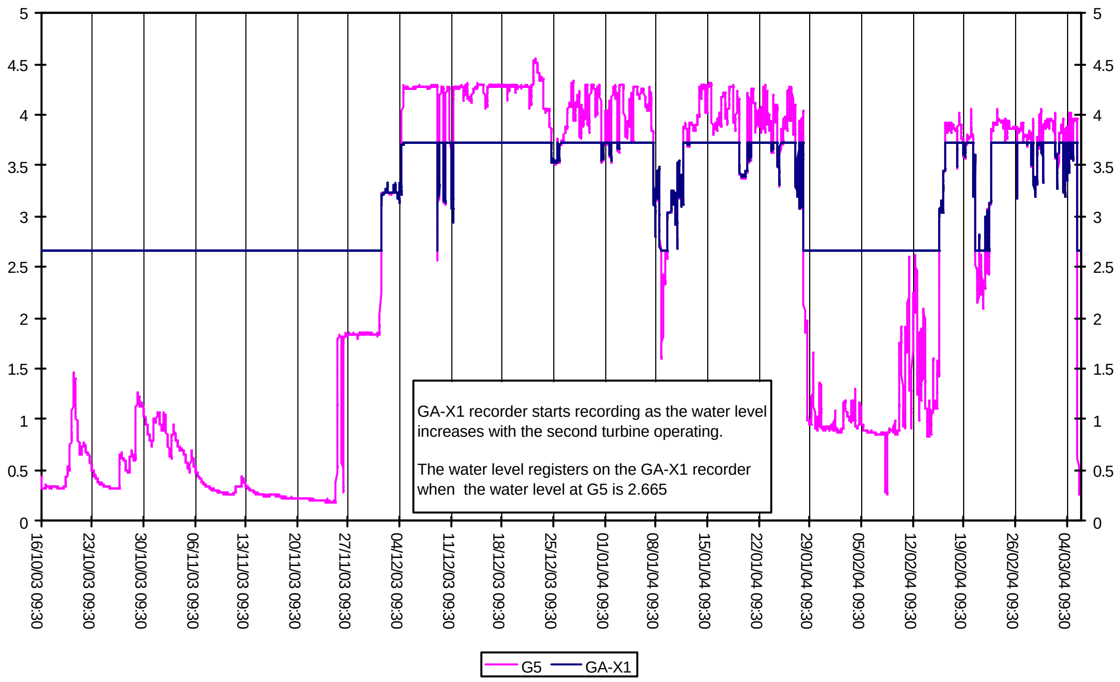


Figure 5.5. GA-X1 water level recorder with water levels from site 72 (G5) for comparison. Data in metres above arbitrary zero.

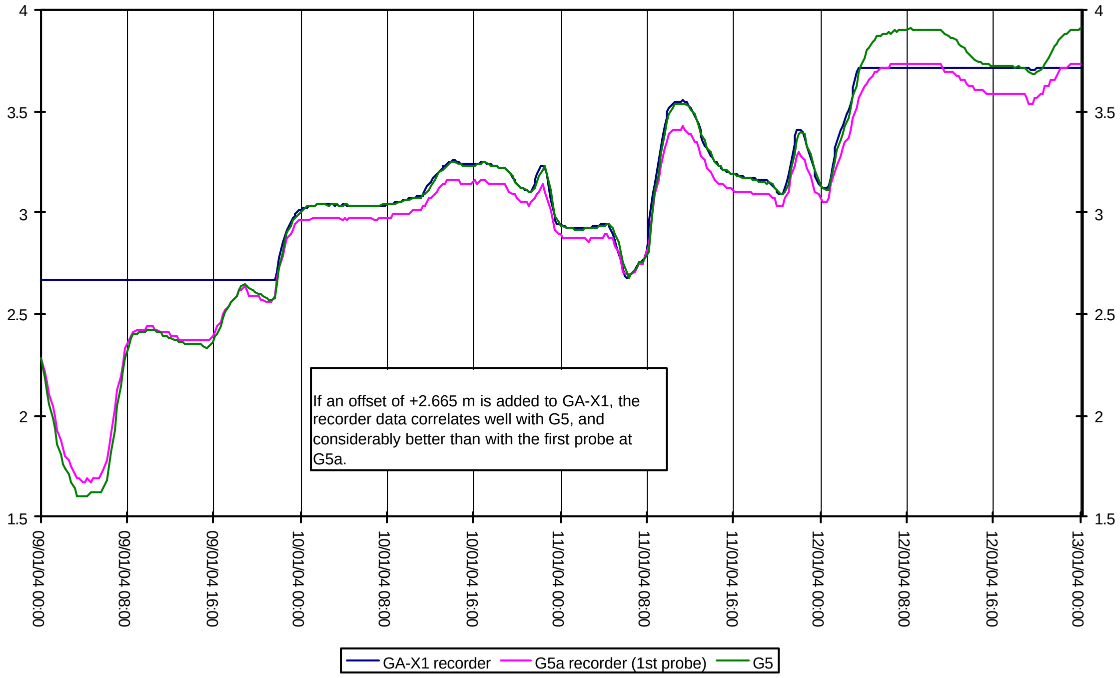


Figure 5.6. Water level recorder data from GA-X1 and site 71 (G5a) during the 5 days from 9/1/04 to 13/1/04.

5.2.3 Photo-monitoring

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

5.3 Discussion

5.3.1 Bill Neilson Cave

5.3.1.1 General observations

During the October monitoring it was observed that a tree, located in the soft sediment at the upper entrance to the main chamber of the cave, had fallen back into the cave and lay across the main chamber. The tree was located at or close to the top of the range of influence of power station operations, so it may have fallen during one of the previous winter's natural flood peak events.

The water level marks at Site 6a and the fine grained mud observed after the 2002-03 summer period have not returned and there were no new high water level marks. Despite the relatively wet summer in the rest of the State, there were few significant natural flow events in the system. The biggest of these was at the end of January 2004, which completely flooded out the middle water level recorder (see Figure 5.3). The power station was operating at 3 turbines over an eight week period in December and January, and again briefly at the latter end of February.

5.3.1.2 Sediment transfer

There are three sets of erosion pin data in Bill Neilson cave, the wet sediment bank in the entrance chamber, the wet sediment bank 5–10 m further into the cave, and the dry sediment bank 175 m into the cave.

The data for the first wet sediment bank in the entrance chamber show that there was 8 mm of deposition at the lowest level close to the cave floor over the summer period with a net gain of just 2 mm over the last 12 months. Little change occurred at the middle pin, with a 12-month net loss of 4 mm. The pin at the upper level showed zero change over the summer period with a net gain of 1 mm over 12 months.

A relatively strong seasonal pattern is emerging at the lowest pin (Pin 20), of erosion during the winter and deposition over summer. Seasonal patterns are not as obvious at the other two pins although there is less sediment flux occurring overall at these upper levels.

At the second wet sediment bank, zero sediment change was recorded at the lowest level this summer although there has been a net loss of 3 mm over 12 months. A zero net change was also recorded over the 2002-03 summer. Slight erosion occurred at the middle level in contrast to the zero change recorded over the same period last year. The uppermost pin indicated that 4 mm of sediment deposition occurred over the summer which is relatively high in comparison to the 5 mm net change over 12 months.

Seasonal trends are not strong in the second wet sediment bank. The uppermost pin exhibited continued slow deposition throughout the sampling period, while the lowest pin showed that since installation there have been two periods of slight erosion separated by longer periods of zero change.

During the summer months, the majority of the more intense fluctuations in water level associated with power station discharge occurred when the water level in the cave was at or lower than the level of the base of Pin 26. At the higher (Pins 27 and 22) and lower (Pins 20 and 25) levels, the inundated water tended to be more stable. This may explain why the slight erosion occurred at the middle levels with deposition or zero change elsewhere.

There has been little change, over the 12 months, in the erosion pins in the dry sediment bank with just 1 mm of sediment deposition recorded at the lowermost pin (Pin 23).

5.3.1.3 Photo-monitoring

Photo-monitoring sites have been established in the cave to support the erosion pin data in determining sediment transfer in the cave. There is no evidence of any major sediment shift at any of the monitoring sites within the cave from this year’s photos. It was interesting to note that the deposition which has occurred at Pin 20 (+8 mm) was discernable from the comparison of the photos with those from last season.

5.3.1.4 Water level monitoring

The water level data retrieved during the October monitoring is shown in Figure 5.2. These data are from the upstream recorder. The data from the cave’s downstream recorder could not be recovered, so it is difficult to determine the inundation regime for this period.

In March 2004, water level data were retrieved from the upstream and middle recorders, although a technical error prevented data recovery from the new recorder at the cave entrance. A small change in the relative baseflow measurements between the upstream and middle recorders is likely to be due to a slight shift in the downstream recorder during the high flow event in January 2004.

The data show that the middle recorder is inundated by Gordon River water when the water at the Gordon below Denison recorder reaches a height of approximately 3 m or more. The point at which the cave recorder is inundated depends on the height of the cave stream: the higher the flow in the stream, the higher the Gordon River needs to be before the recorder is inundated. The range of the effect may be of the order of about 0.2–0.3 m at the Gordon below Denison site depending on the height of the cave stream.

The maximum level of Gordon River inundation in the cave this season was >2.07 m RL (estimated to be approximately 2.3–2.4 m RL) which is about the level of the base of Pin 23 in the dry sediment bank. This suggests that the lower part of the dry sediment bank was inundated during the flood event in January but would have been dry at all other times.

5.3.1.5 Conclusion

The dry sediment bank was inundated to the level of the lower pin (Pin 23) this season during the peak event at the end of January which may have resulted in some slight sediment deposition (1 mm).

Sediment transfer processes in the wet sediment banks at the cave entrance have been generally similar to previous years. A relatively strong seasonal pattern of winter erosion and summer deposition is emerging at the lowest pin in the first wet sediment bank (Pin 20).

Water level data this period suggests that the higher the flow in the cave stream, the higher the Gordon River needs to be before the recorder, and therefore the dry sediment bank, is inundated. The range may be of the order of about 0.2–0.3 m at the Gordon below Denison site, depending on the height of the cave stream.

5.3.2 Kayak Kavern

5.3.2.1 General observations

Sediment influx this summer appears to have been a finer grained material than that which was present during previous trip. Distinctive banding was apparent in the sediment in October 2003, and this was masked by a thin film of finer grained material in March 2004. Pin No. 17 on the active slope has been exposed by a total of almost 100 mm during the sampling period and may be close to being washed out, as has happened to Pin 16. Two new pins have been installed on the slope to support the data from the three remaining pins.

5.3.2.2 Sediment transfer

Deposition (11 mm) on top of the silt mound at Pin 18 and in the eddy at Pin 19 (47 mm) has continued from winter through the summer period. The active slope continues to experience significant sediment loss, with Pin No. 17 indicating that 96 mm of erosion has taken place at that point.

Similar to the wet sediment banks in Bill Neilson cave, the deposition occurring on the top of the mound and in the eddy, in comparison to the erosion on the slope at Pin 17, may be due to the more stable inundation water at higher levels and the more fluctuating water regimes at the level of Pin 17 during the summer period.

5.3.2.3 Photo-monitoring

The photos from the photo-monitoring indicate the masking effect of the finer grained sediments over the banded sediment that was apparent after the winter period.

5.3.2.4 Conclusion

Over the 2003 winter, erosion occurred at the northern end of the silt mound and deposition at the southern side in the eddy. This is likely to have been a result of a relatively high frequency of fluctuations at the low flow levels. The 2003-04 summer has been a period of deposition on the top of the silt mound and in the eddy in Kayak Kavern although erosion has continued on the front slope of the mound. There may be similar flux processes occurring here as in Bill Neilson Cave with relatively stable conditions at high and low levels and fluctuations affecting primarily the middle levels of the slope.

5.3.3 GA-X1

5.3.3.1 General observations

No significant changes were observed in GA-X1 this year, with the exception of a minor sediment fall on the eastern wall of the entrance doline.

5.3.3.2 Sediment transfer

Pin 9 in the doline at the cave entrance has shown continued loss of debris this summer with a slightly larger net loss over 12 months, while there has been little or no change at Pin 10. Inside the cave, there has been minimal change over the 12 months at the higher level at Pins 2 and 3, and a slight loss of material at the lower pin closest to the sump (Pin 4).

5.3.3.3 Water level monitoring

The water level data from GA-X1 this summer, with the corresponding data from Gordon River site 72 (G5), and site 72 and the first probe at site 71, are shown in Figure 5.5 and Figure 5.6, respectively. The GA-X1 data correlate better with the site 72 data than with the site 71 data, notwithstanding the lag time because of the extra distance downstream. This would suggest that the connection between GA-X1 and the river is fairly good and that there is less of a sediment buffer between the river and the probe than is found at site 71.

The water level in the cave reaches the zero level on the recorder when the second turbine is ramping up to full capacity and when the water level at site 72 (G5) is 2.665 m. Full gate power station operations appear to flood the cave to a level approximately 0.55 m higher than the top of the current recorder when there is no additional natural pickup.

The cave has been inundated with relatively stable water levels this season, with fewer on-off sequences and an extended period of power station shutdown occurring when the cave would have been mostly dry. Despite this, this has been a relatively significant period of erosion at the pin closest to the sump.

The paint on the top water level recording stake (No. 3) in the cave has remained at the same level of 45.27 m, which is equivalent to a level of 0.56 m on the probe. Comparison of cave water level recorder data with site 72 (G5) data shows that this level marks the level at which the station is operating at two turbines with little to no additional catchment pickup. The river level has clearly been higher than this point on a regular basis since the stakes were painted, so it is probable that this level was established relatively soon after the paint was applied. No changes in the cave were evident from the photo-monitoring.

5.3.3.4 Conclusion

The two lower pins demonstrate that erosion typically occurs in the cave during the summer months followed by deposition during the winter, with a slight overall net loss over 12 months. Slight deposition has occurred at the higher pin this summer, in contrast to three previous periods of erosion. This may have been due to an influx of material through the second entrance during a heavy rainfall period. There has been a steady net loss of material at this pin since autumn 2002.

The water level data from the recorder in GA-X1 correlate well with those from site 72 (G5) and better than with the first probe at site 71 which suggests a relatively good connection between the river and the cave. The cave appears to flood to a level approximately 0.55 m higher than the top of the recorder at full gate operations without any additional natural pickup. The inundation regime this period has been relatively stable due to the extended shutdown period and the extended period at full gate. Despite this, this has been a relatively significant period of erosion at the lowest pin in the cave.

5.3.4 Dolines

There are two doline sites being monitored in zone 2, Site 3 adjacent to GA-X1 and Site 4 adjacent to Channel Cam.

The erosion pins in Site 3 are arranged with Pin 5 in the base of the depression with a succession of pins arrayed in a line at 1–2 m distance apart up to Pin 8. All the pins are demonstrating accumulation of material over the 12 month period. The distances between the tops of the pins were comparable to previous monitoring trips and indicate that there has been no appreciable movement or change in the structure of the feature since the pins were installed (see Table 5.2). The top of Pin 7 appears to have shifted upslope by approximately 1 cm but the distance between the pins on either side of it has remained the same indicating no net change. This pin may have been moved by animals or larger debris. The photo-monitoring shows that another large log has fallen into the base of the feature although it is not interfering with the pins.

There are three erosion pins installed in the doline at Site 4 which are: Pin 12 at the base of the depression and Pins 13 and 14 up the side. There was little change in material at Pin 14 with a slight increase at the base and a slight loss at Pin 13 over 12 months (see Table 5.2). There has been no significant change in the distances between the pins indicating no appreciable change in the structure of the feature, either over the last sampling period, or since the pins were installed. There were no changes observed from the photo-monitoring pictures.

In October 2003, a small depression, approximately 5 cm deeper than Pin 12, was observed 40 cm to the west of the pin. A new photo-monitoring site has been located, opposite the original peg, to monitor any changes to the morphology of the base of the depression. In March 2004, the depression did not appear to have changed. A thin but strong green stick was pushed into the base of the feature to act as an erosion pin until a proper pin can be installed. This new ‘pin’ measured 578 mm in height with a distance of 1.505 m from the top of Pin 13.

5.3.5 Channel Cam

The erosion pins at Channel Cam recorded a slight net loss of sediments over 12 months. The losses only appear to occur when the river level back-floods into the feature. During the summer months, for instance, the water level at site 72 (G5) exceeded the 4.1 m trigger level for inundation of the channel for approximately 7 weeks. There were 3 weeks of relatively stable water levels in December with depths of 100–200 mm in the channel and a peak of 400 mm, followed by 4 weeks of fluctuations in January between depths of 150 mm and zero. These fluctuations are likely to have caused the loss of material.

There were no significant changes evident from the photo-monitoring.

6 Riparian Vegetation

6.1 Introduction

The riparian vegetation monitoring collected data on the cover and abundance of existing vascular riparian species at permanent plots located both in the middle Gordon River and in two reference rivers, the Franklin and Denison.

This report provides results of the November 2003 and April 2004 sampling trips and provides general conclusions of baseline data obtained from April 2002 to April 2004. The locations of the riparian vegetation monitoring sites are shown in Figure 6.1. The Gordon River sites are numbered with reference to the fluvial geomorphology zone system (see Figure 4.1). There are no riparian vegetation monitoring sites in zone 1.

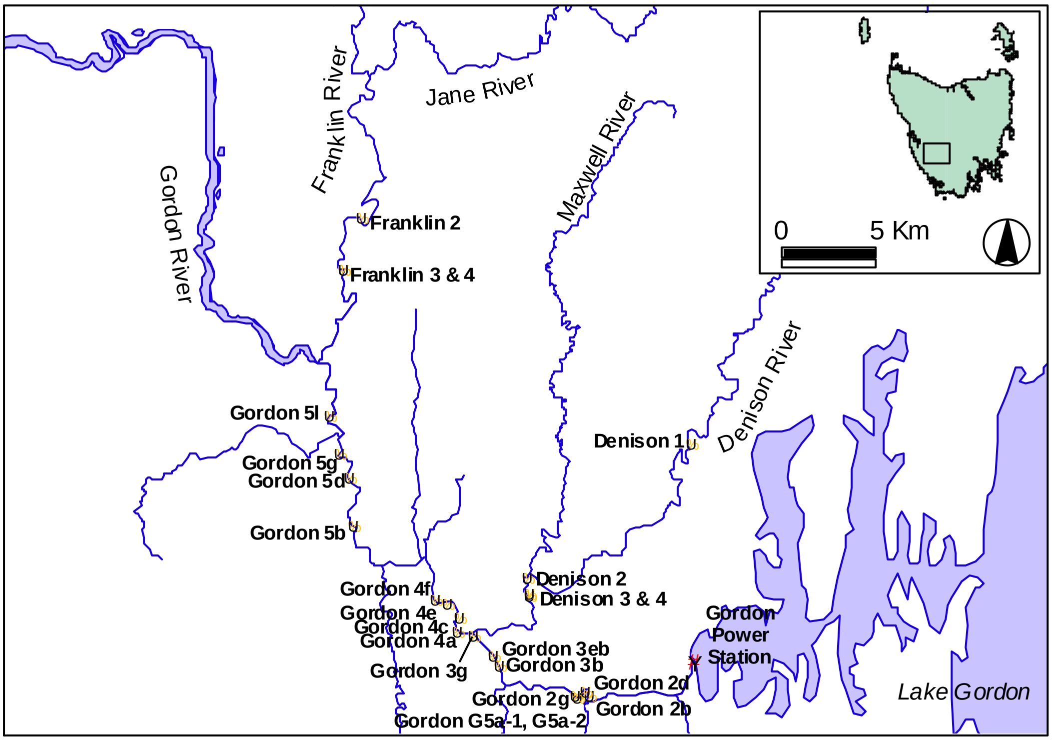


Figure 6.1. Map of the riparian vegetation monitoring sites in the Gordon, Denison and Franklin Rivers.

6.2 Methods

6.2.1 Summer 2003 field trip

Summer monitoring took place on 21-23 November 2003 and comprised seedling recruitment in permanent plots and photo-monitoring on the Gordon River. Seedling monitoring was completed successfully at all sites except the site downstream of 4e cobble bar. This site suffered substantial deposition of material that obscured all markers, making relocation impossible. This site will be relocated in a more stable location in zone 4 during the next monitoring visit.

6.2.2 Autumn 2004 field trip

The autumn monitoring collected data on the cover and abundance of all species in the quadrats, counted seedlings and obtained size class data for trees in a belt transect at all sites. The autumn field trip was undertaken as scheduled on 3-4 April 2004. Reference river monitoring was undertaken after this (5 April 2004). Due to high river flows and site relocation difficulties, two sites on the Denison River (Denison 1 & 2) could not be monitored. One of these sites (Denison 2) was located and monitored in a subsequent trip in May 2004.

6.3 Results

6.3.1 Seedling recruitment

6.3.1.1 Zone 2

Seedling numbers followed the previously recognised patterns of a peak during the summer monitoring events (December 2002 and November 2003) and reduction in the autumn in all quadrat types. Figure 6.2 shows the mean number of seedlings recorded at each quadrat type over five monitoring events from April 2002 to April 2004.

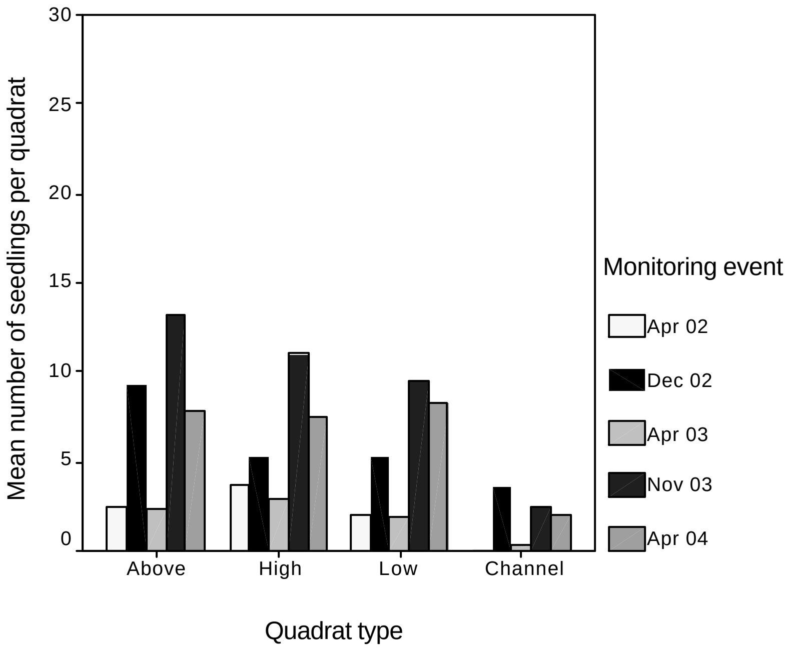


Figure 6.2. Mean number of seedlings per quadrat, by quadrat type for zone 2 over all monitoring events.

Mean values for all quadrat types in April 2004 were at least double those in previous autumn monitoring events. In the ‘Above’ quadrats this was due to large numbers of *Acacia* spp., *Nothofagus cunninghamii* and *Anopterus glandulosus* seedlings at one site (2g). The large numbers in the ‘High’ quadrats were also limited to one site (2b), again due to large numbers of Nothofagus seedlings in the <5 cm size class. High numbers in the ‘Low’ quadrats were represented by *Nothofagus cunninghamii*, *Anopterus glandulosus, Leptospermum riparium* and *Blechnum nudum* seedlings at two sites.

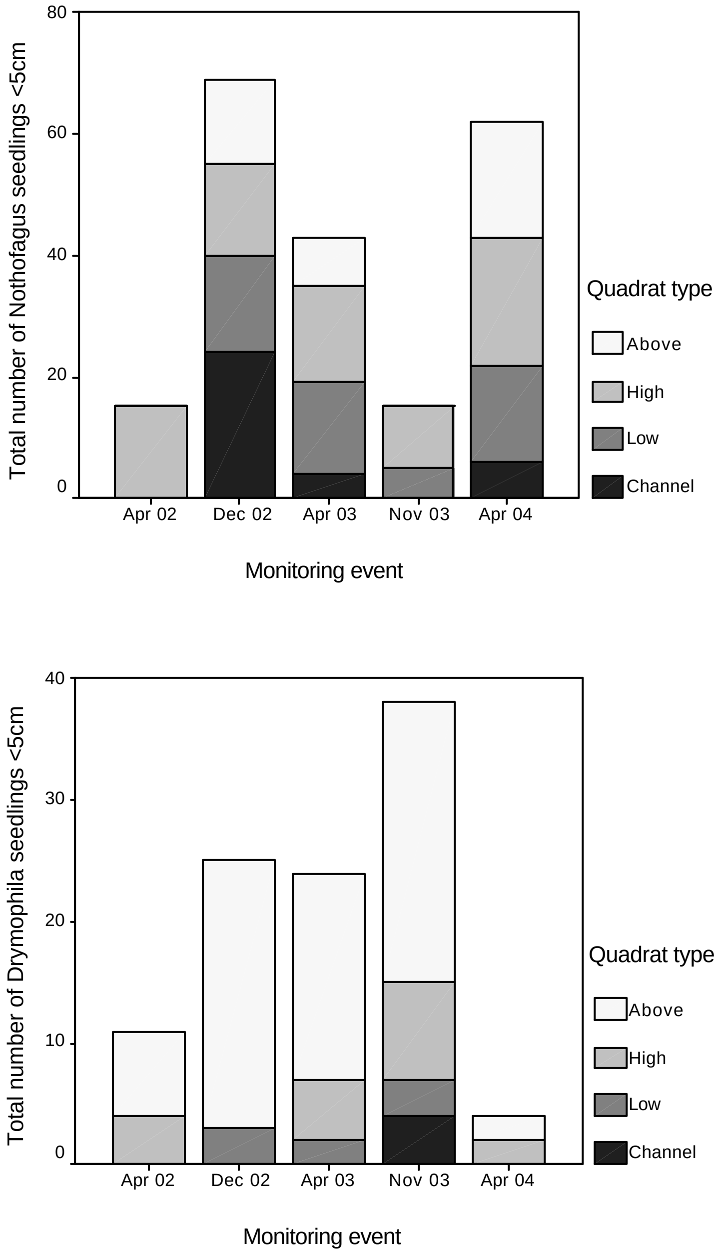


Figure 6.3 Total numbers of seedlings for major species in zone 2 showing abundance in each quadrat type for the five monitoring events.

The most abundant seedlings in zone 2 over the five monitoring events in descending order of total abundance were the tree *Nothofagus cunninghamii* (myrtle) (<5 cm), the small herb *Drymophila cyanocarpa* (Native Solomon's Seal) (<5 cm), and unknown dicotyledon and monocotyledon seedlings (<5 cm). These plants all had a mean occurrence greater than 1 for all quadrats (>1 m^{-2}).

Figure 6.3 shows that the distribution of the most abundant seedlings was not even between the different quadrat types or monitoring events. *Nothofagus* seedlings were most prominent colonisers of all quadrats, including the channel quadrats. The large increase in seedlings between November

2003 and April 2004 is likely to indicate that complete germination of the 2003-04 summer cohort had not occurred when monitoring was undertaken early in November 2003.

Drymophila cyanocarpa was substantially more abundant in the less disturbed 'Above' quadrats which are above the high water mark for three-turbine operation. This suggests that this species is not tolerant of high disturbance for germination and the period of shutdown provided conditions stable enough to allow for germination. This conclusion is supported by the dramatic decline in seedlings in the lower quadrats between November 2003 and April 2004, after resumption of 'normal' power station operation.

6.3.1.2 Zone 3

As indicated in Figure 6.4, data from zone 3 did not display the strong seasonal pattern of zone 2 (Figure 6.2). However, the stratification between the 'Above' quadrats and the quadrats below high water flows ('Low' and 'Channel') was more pronounced. Seedling numbers in the 'Above' quadrats were substantially higher indicating a more favourable environment for establishment. When compared with equivalent quadrats in other zones, the mean seedling numbers are generally much greater. The species composition of these seedlings is similar to other quadrats.

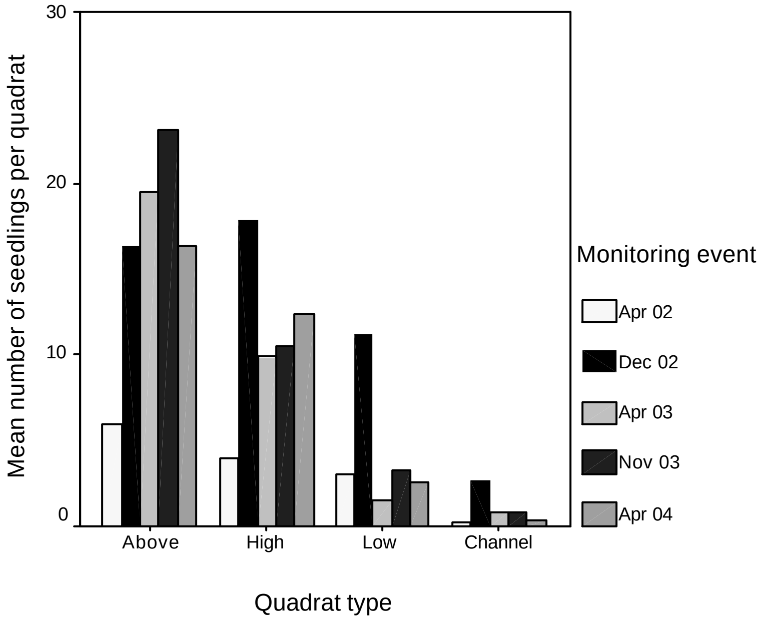


Figure 6.4 Mean number of seedlings per quadrat by quadrat type for zone 3 over all monitoring events.

The most abundant seedlings in zone 3 over the five monitoring events to date, in descending order of total abundance, were the trailing herb *Clematis aristata* (Clematis) < 5 cm, *Nothofagus cunninghamii* (myrtle) (<5 cm), unknown dicotyledons and monocotyledons <5 cm and the shrub *Anopterus glandulosus* (native laurel) <5 cm. These plants all had a mean occurrence greater than 1 for all quadrats. Figure 6.5 shows the total number of seedlings for *Clematis*, *Nothofagus*, and *Anopterus* seedlings for each quadrat over five monitoring events.

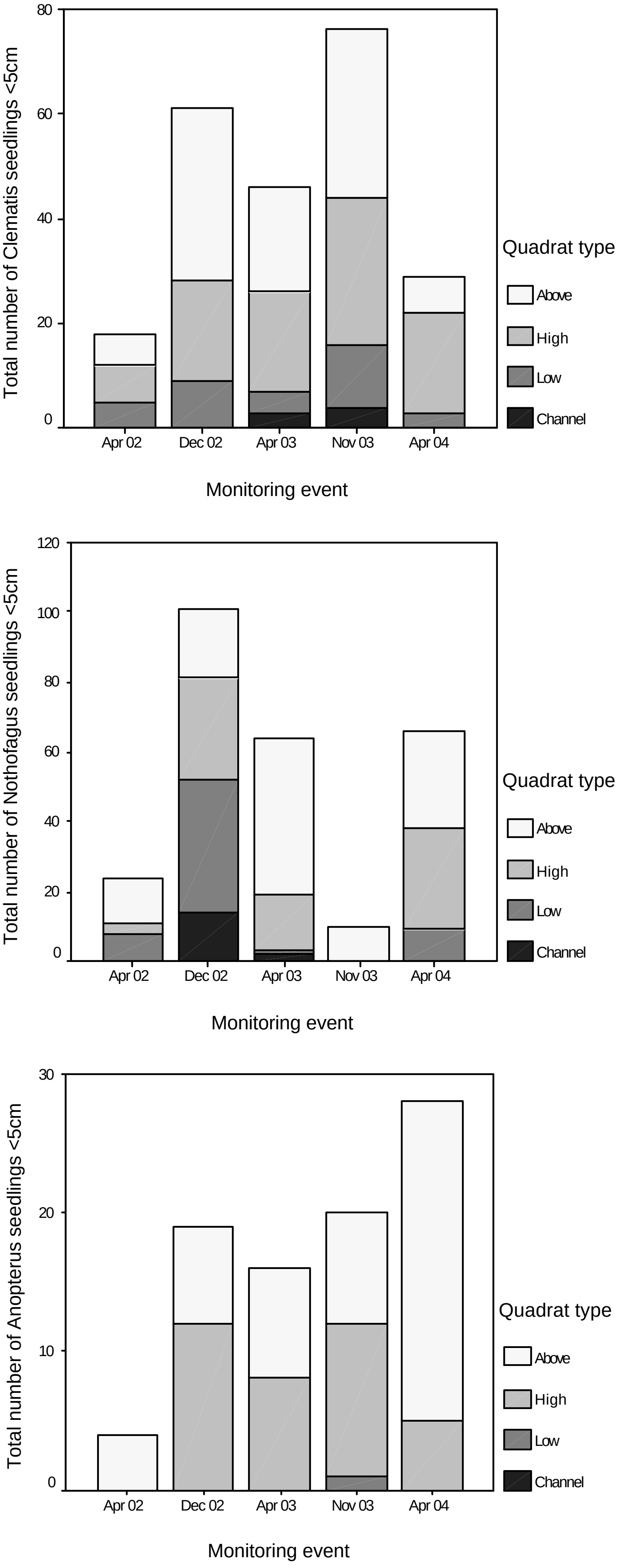


Figure 6.5 Total numbers of seedlings for major species in zone 3 showing abundance in each quadrat type for the five monitoring events.

Clematis is a trailing herb that often has high numbers of seedlings, and few adult plants, present. Seedlings were most abundant in the upper, less-disturbed quadrats with few individuals in the lower quadrats. The presence of some individuals on vertical faces in the lower channel quadrats in April 2003 after a summer of relatively high power station operation indicates that this species is a high tolerator of inundation and mechanical stress.

Nothofagus seedlings followed a similar pattern of quadrat stratification to that displayed in zone 2 (Figure 6.3), and the same substantial reduction in seedlings in November 2003, likewise the increase in abundance in April 2004.

Anopterus is a small, often straggly shrub that is commonly found in all life stages on the banks of the middle Gordon River. The seedlings often form dense clusters on bare mineral soils. The seedlings present in zone 3 also showed stratification by quadrat type with few or no seedlings present in the 'Low' or 'Channel' quadrats.

6.3.1.3 Zone 4

Seedling abundance in zone 4 displayed no consistent pattern over the five monitoring events (Figure 6.6). Clearly this zone was more highly variable and the patterns between the quadrat types were not as profound. This is supported in all data collected from this zone, including the cover data for all species. The absence of discernable pattern is likely to reflect the more natural flows in this zone, which includes significant winter inflows from the Denison River. Figure 6.7 shows the abundance of the major species found in each quadrat type.

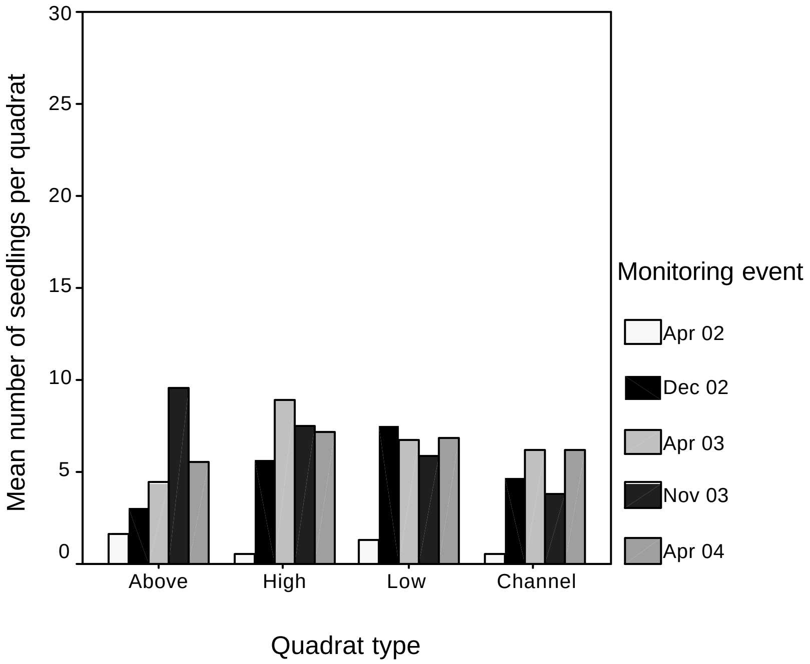


Figure 6.6 Mean number of seedlings per quadrat by quadrat type for zone 4 over all monitoring events.

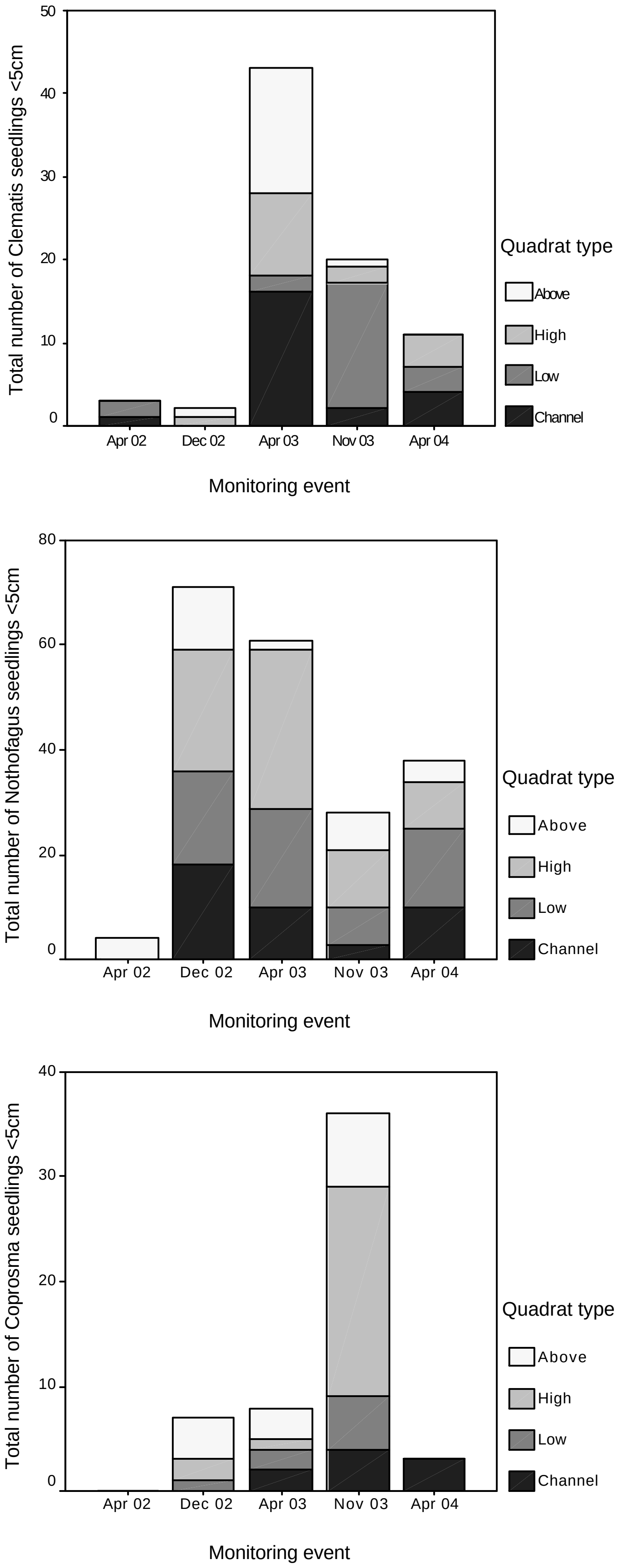


Figure 6.7 Total numbers of seedlings for major species in zone 4 showing abundance in each quadrat type for the five monitoring events.

The most abundant seedlings in zone 4 over the five monitoring events, in descending order of total abundance, were *Nothofagus cunninghamii* (<5 cm), unknown dicotyledon and monocotyledon seedlings (<5 cm), *Clematis aristata* (<5 cm) and the shrub *Coprosma quadrifida* (native currant) (<5 cm). These plants had a mean occurrence greater than 1 for all quadrats.

All the major seedling species in zone 4 showed less stratification by quadrat types than in other zones, with higher numbers recorded in the 'Channel' quadrats (Figure 6.7). Again, *Nothofagus* seedlings were well represented in all monitoring events and showed an increase between the November 2003 and April 2004 monitoring events. The distribution and density of *Coprosma* seedlings was reduced in April 2004, with only a few seedlings being present in the 'Channel' quadrats only.

6.3.1.4 Zone 5

Zone 5 seedling data (Figure 6.8) displayed little seasonal pattern and some stratification of higher and lower quadrats, similar to those of zones 2 and 3. This zone receives natural inflows from the Denison and Olga Rivers with power station inflows having a moderate, seasonal influence.

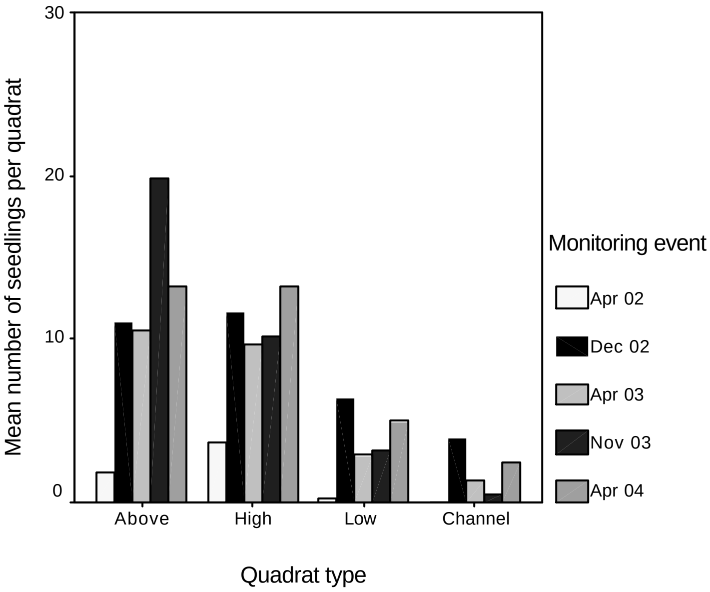


Figure 6.8 Mean number of seedlings per quadrat by quadrat type for zone 5 over all monitoring events.

The most abundant seedlings in zone 5 over the five monitoring events, in descending order of total abundance, were unknown dicotyledon and monocotyledon seedlings (<5 cm), *Nothofagus* <5 cm, *Clematis aristata* (<5 cm), *Coprosma quadrifida* (<5 cm) (Figure 6.9). These plants each had a mean occurrence greater than 1 for all quadrats. The significant bank stabilising species *Leptospermum riparium* (tea tree) had a mean occurrence of 0.8, the highest result for this species in all zones.

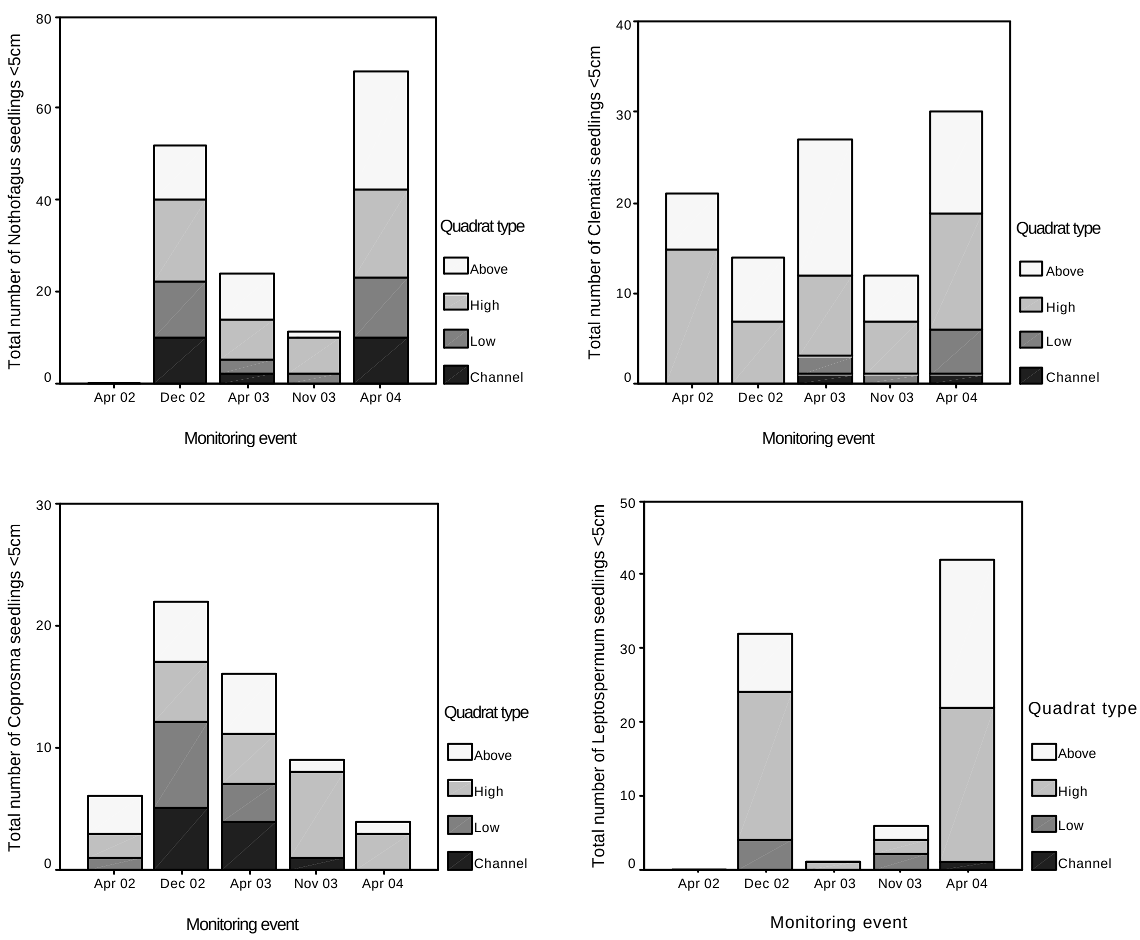


Figure 6.9 Total numbers of seedlings for major species in zone 5 showing abundance in each quadrat type for the five monitoring events.

As in zones 2 and 4, *Nothofagus* seedlings were present in all quadrat types for most monitoring events as was *Coprosma.* Interestingly, this zone is the only one with moderate numbers of *Leptospermum riparium.* There was a major increase in the abundance of this species in April 2004 in the 'Above' and 'High' quadrats. Future monitoring will determine if large seeding events like this lead to major increases in populations, that is, whether these individuals survive and move into the next size class (see discussion below).

6.3.2 Population structure and seedling persistence

Seedlings in all zones continue to be limited to high numbers of individuals in the smaller size classes, reducing substantially in the larger size classes (Figure 6.10). This pattern is a similar, although more extreme, example of the reverse 'j-curve' that generally characterises population structure (see Kirkpatrick *et al.* for description of methods).

The lack of older size classes (and therefore older individuals) supports the conclusion that while conditions are suitable for germination of many species in the higher quadrats, conditions are not suitable for persistence of these seedlings. The factors most likely to be responsible are the frequent disturbance of substrate and the inundation of leaf and stem material precluding photosynthesis. In the 'Above' quadrats, shading by established plants and ground litter may be a limiting factor.

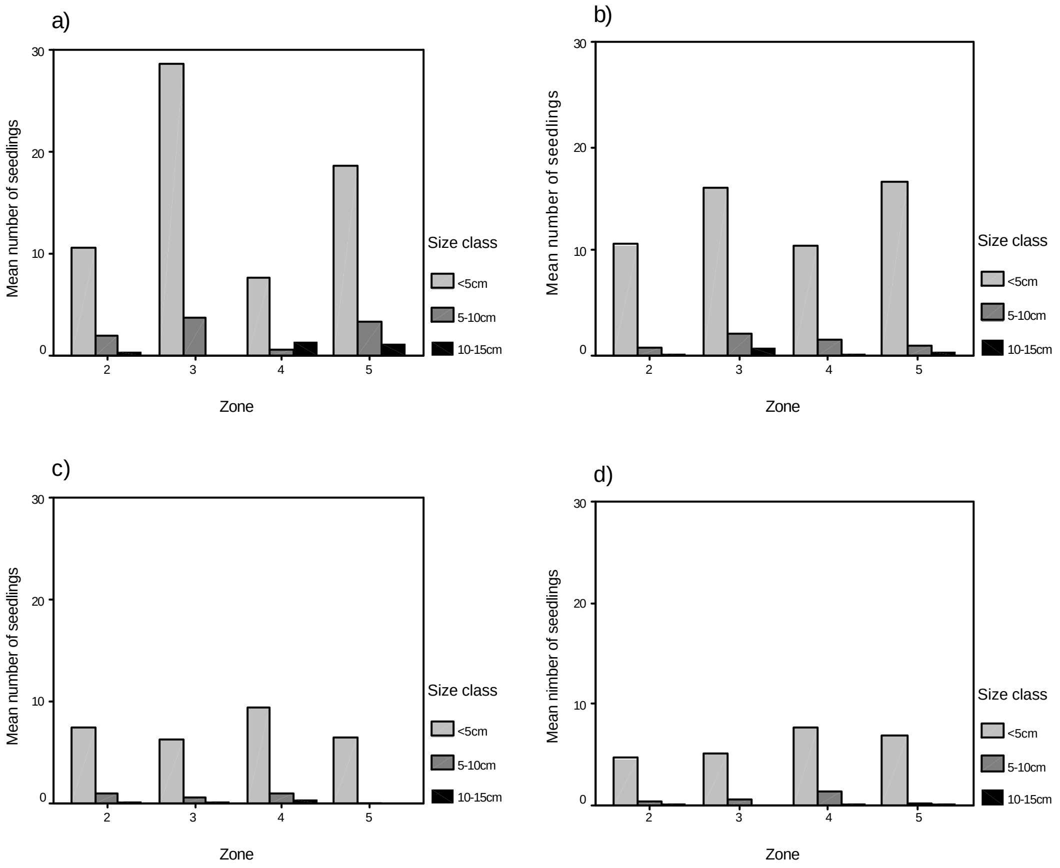


Figure 6.10 Mean number of seedlings in three size classes for all monitoring events in all zones of the Gordon River, by quadrat type: a) Above; b) High; c) Low; d) Channel.

Few species had seedlings in the 5-10 or 10-15 cm size classes. The most abundant included *Acacia* spp. (5-10 cm), *Clematis* (5-10 cm), *Acacia* spp. (>10 cm), *Leptospermum riparium* (5-10 cm), *L. riparium* (>10 cm), *Coprosma* (5-10 cm) and the snow berry *Gaultheria hispida (5-10 cm).* The Acacia seedlings generally had greater survival than most others. Figure 6.11 shows the mean number of Acacia and Leptospermum seedlings in three size classes for each zone.

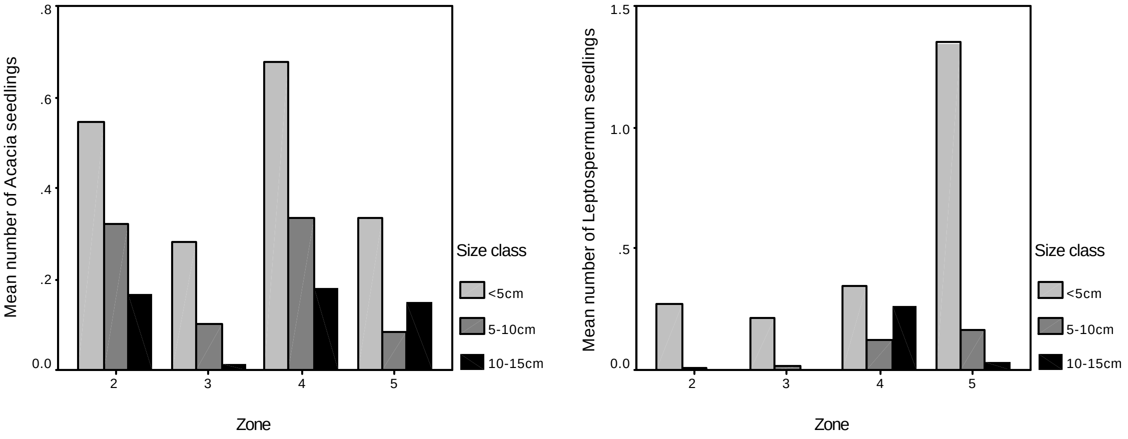


Figure 6.11 Mean number of *Acacia* spp. and *Leptospermum riparium* seedlings for three size classes by zone in the Gordon River – grouped data for all monitoring events.

6.3.3 Photo-monitoring

Thirty-five photo-monitoring sites were established in the Gordon River in zones 2-5 in December 2002. General observations of the photo-monitoring sites and comparisons between 2002 and 2003 are outlined in Table 6.1.

Table 6.1: General observations comparing 2002 and 2003 photo-monitoring data.

Zone	N*	Reduction+	Expansion+	No change+
2	12	1, 4, 5, 12		2, 3, 6, 7, 8, 9, 10, 11
3	8	1, 2, 3, 4, 8		5, 6, 7
4	7	4, 5		1, 2, 3, 6, 7
5	8	2, 6		1, 3, 4, 5, 7, 8

*Total number of sites per zone.

+Site numbers

In general, no expansion of the vegetation was observed since the December 2002 photo-monitoring. Several sites, however, were noted to have distinct dieback, or senescence. Most of these sites were located within zones 2 and 3, that is, those zones most influenced by power station operations. The majority of sites within the downstream zones (zones 4 and 5) remained unchanged.

6.3.4 Species diversity and cover

Fern and shrub species consistently provided greater mean cover in the ‘Above’ and ‘High’ quadrats in grouped data (Figure 6.12a & b) and in zones 2 to 4. Ferns were of reduced relative importance in zone 5 for all monitoring events, with tree species and graminoids providing greater mean cover. The peak of grasses in April 2004 was the result of one quadrat in zone 5 having >50% cover provided by *Poa* spp. and *Ehrharta* spp.

In the ‘Low’ bank sites (Figure 6.12c) shrub species recorded the greatest mean percent cover followed by fern species, although mean cover was generally low. ‘Channel’ sites (Figure 6.12d) recorded a low mean percentage cover for all species and life forms. Graminoid species, such as sedges and lilies were almost absent from these lower quadrats. Tree cover in these quadrats was largely the result of low (<1m) overhanging branches rather than tree species rooted in the quadrats.

Overall there were no significant or distinct patterns in life form (ferns, graminoids, grasses, herbs, trees) percentage cover over the monitoring period within the Gordon River (Figure 6.12).

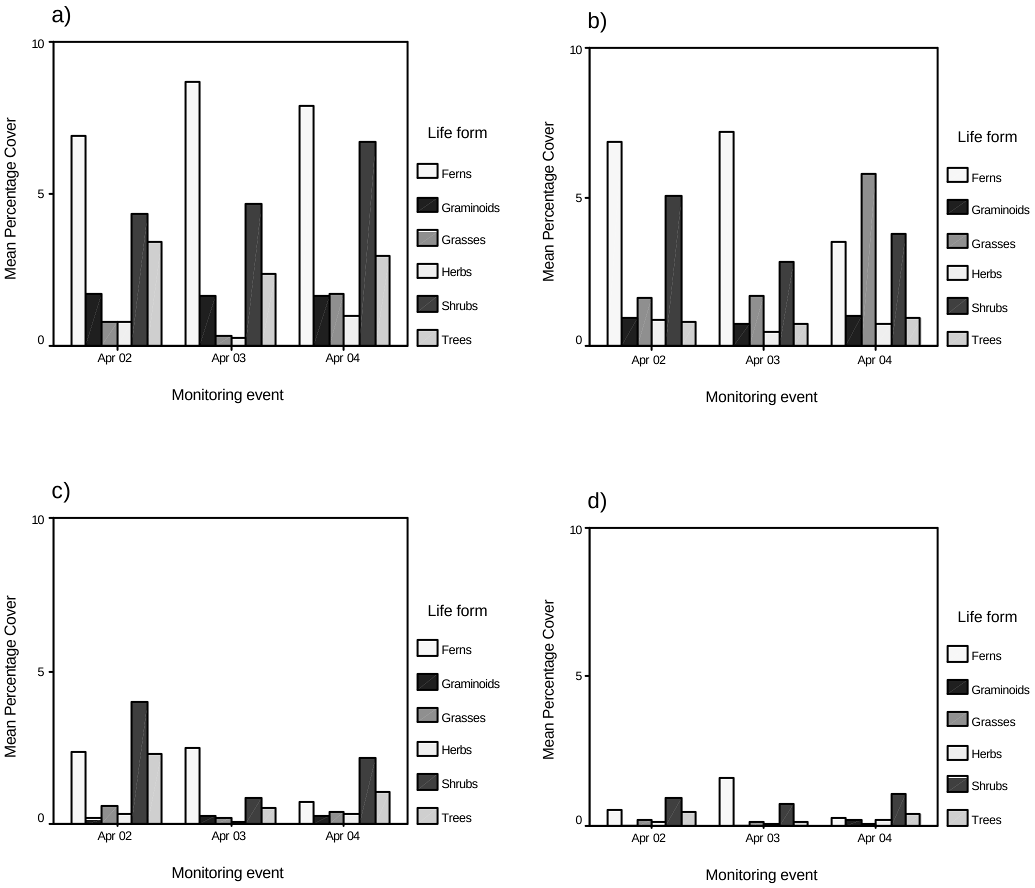


Figure 6.12 Mean percentage cover of vegetation life forms at all sites by monitoring event for each quadrat type: (a) Above, (b) High, (c) Low and (d) Channel.

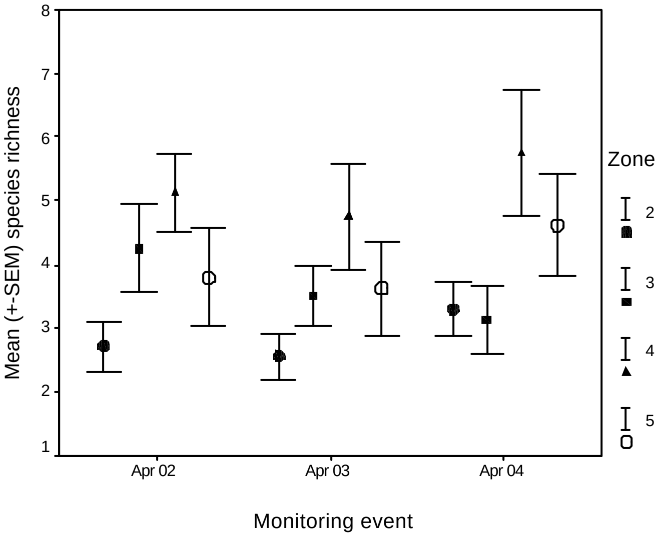


Figure 6.13 Mean (±S.E.M.) species richness for all quadrat types for each monitoring event and each zone.

Species richness was also relatively stable over the monitoring period and, within zones, did not show significant differences ($p<0.05$ ANOVA; post-hoc Tukey's HSD test) between monitoring events. Tests between zones within the monitoring events showed species richness in zone 4 to be significantly higher ($p<0.05$ ANOVA; post-hoc Tukey's HSD test) than zone 2 in April 2002 and zones 2 and 3 in April 2004 (Figure 6.13).

Stratification of channel heights, and not zones, continued to show the most significant differences at all monitoring events (Table 6.2). Zones 2 and 3 continued to show the strong influence of proximity to the tailrace, as increased inundation and waterlogging, altered flows and the predominantly alluvial nature of the banks led to significantly lower species richness in the 'Low' and 'Channel' quadrats.

Table 6.2 Significant differences in species richness between quadrat types (that is, at least one quadrat recorded significantly different values from at least one other) within zones for each monitoring event. Significance ratings: NS not significant; * = $0.01<P<0.05$; **=$0.001<P<0.005$; ***=$P<0.001$

	Monitoring event		
Zone	**April 2002**	**April 2003**	**April 2004**
2	*	*	*
3	*	***	***
4	NS	NS	NS
5	NS	*	NS

Although distinct stratification in terms of vegetation cover is apparent in zones 4 and 5, there are no significant differences in species richness in zone 4 and only in April 2003 for zone 5. This indicates that although the disturbance regime in the lower quadrats continues to limit vegetation cover over 17 km from the tailrace, species richness is not as dramatically affected.

Species richness is highly variable as indicated by the large standard error of the mean values in Figure 6.14. The absence of significant differences between quadrats in the downstream zones is likely to reflect the growth of disturbance-tolerating species in the lower quadrats, many of which may have originated from propagules introduced to the Gordon River from the tributary flows.

6.4 Discussion

Seasonal influence continued to dominate seedling recruitment patterns in the upstream zones in the Gordon River. Stratification of quadrat types was greatest in the upstream zones: those subject to the greatest flow regulation influence. Differences between the monitoring events are unlikely to be significant over time (Repeated Measures ANOVA).

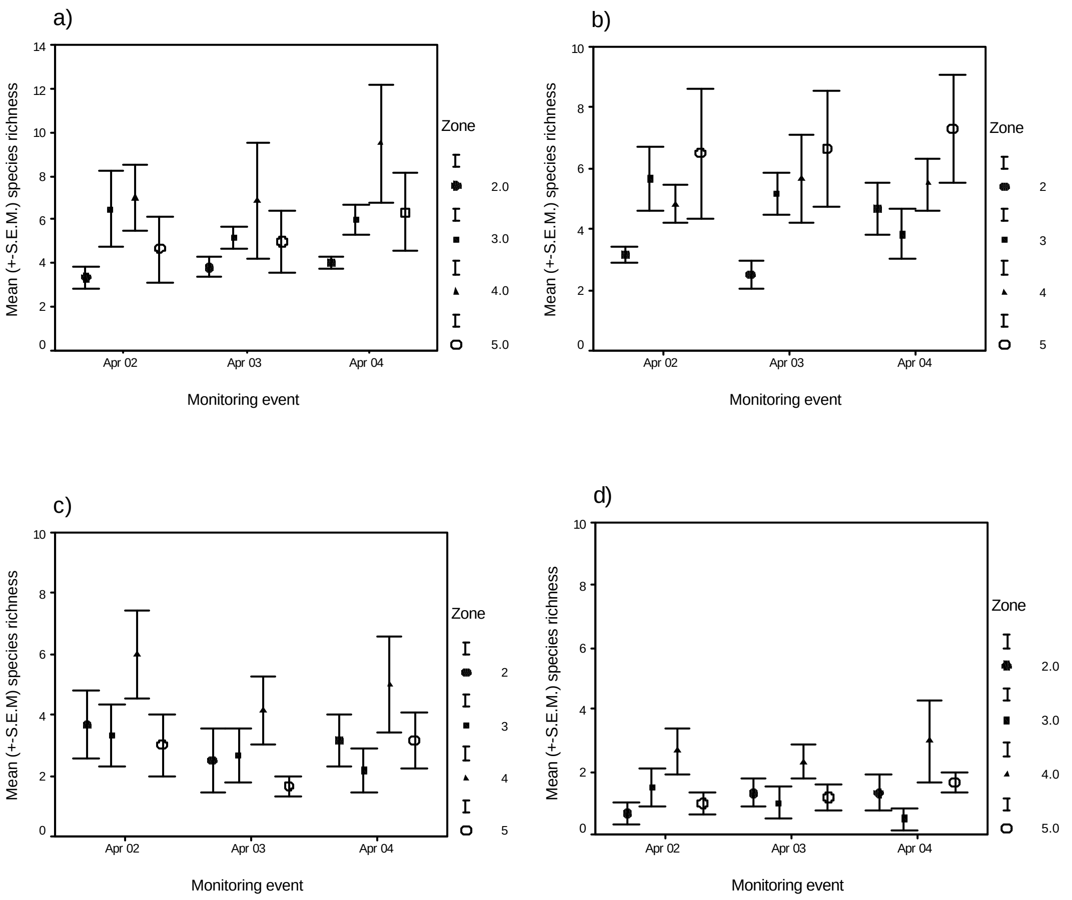


Figure 6.14 Mean species richness (+S.E.M.) at all sites by monitoring event for each quadrat type: (a) Above, (b) High, (c) Low and (d) Channel.

Size class analysis of seedling recruitment showed that while germination does occur in most areas, including the highly impacted areas below the Plimsoll line, seedlings do not persist. Periodic waterlogging, inundation and localised disturbance prove too frequent or intense to allow continued growth. This pattern is less severe but still apparent at the furthest downstream site which is 32 km from the tailrace.

Species richness data also showed few significant differences over the monitoring period. Patterns between zones and between quadrat types were present, as expected, with increasing richness corresponding to distance downstream of the power station (less dominance of regulated flows) and higher bank position. Future time series and repeated measures analysis of these data are likely to indicate that vegetation patterns on the Gordon River have been relatively stable over the past 3 years.

7 Macroinvertebrates

7.1 Introduction

Macroinvertebrate monitoring was conducted in spring (October-November) 2003 and autumn (March) 2004. Both quantitative (surber) and rapid bioassessment (RBA) sampling was conducted at nine ‘monitoring’ sites in the Gordon River between the power station and the Franklin River junction. The spring monitoring was conducted at six reference sites located in rivers within the Gordon catchment and in pristine condition, while poor weather restricted monitoring to five of the six ‘reference’ sites during autumn.

The locations of the monitoring and reference sites are shown in Figure 7.1.

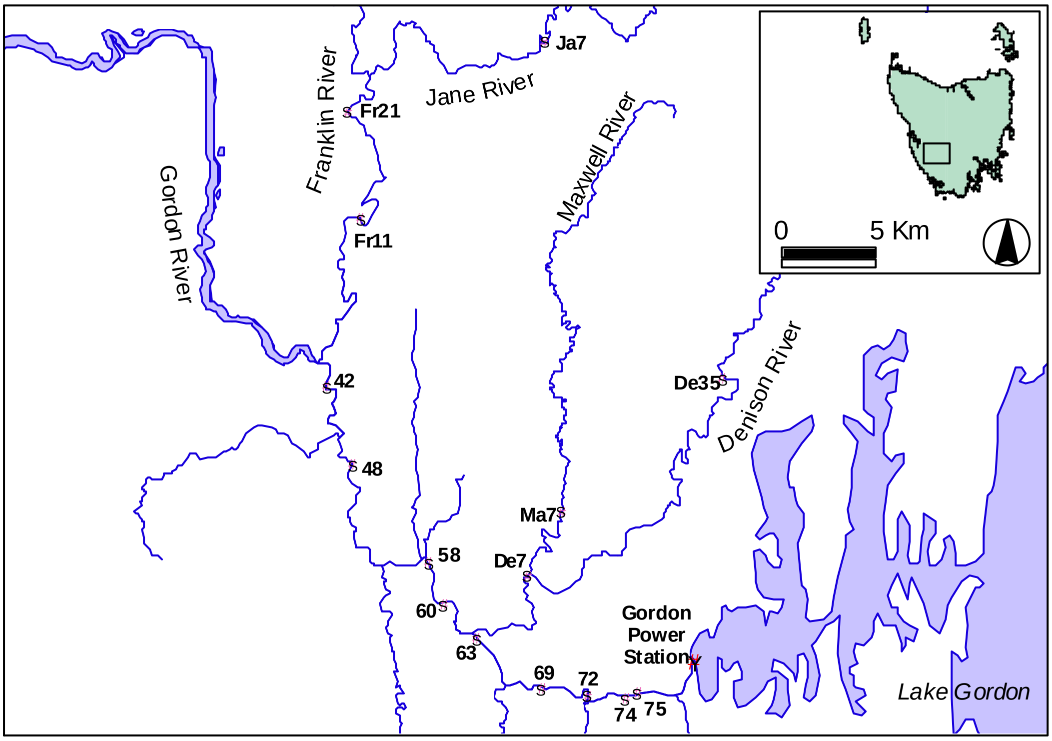


Figure 7.1. Map of the locations of macroinvertebrate monitoring sites in the Gordon, Denison and Franklin Rivers.

7.2 Methods

7.2.1 Sample sites

All sites were sampled in spring 2003 and again, bar one reference site, in autumn 2004. Four reference sites could not be sampled in March 2004 due to high water levels and poor weather. Three of these (sites Fr11, Fr21 and Ja7) were successfully sampled on a follow-up trip in May 2004, and site De35 was not able to be sampled in autumn. Table 7.1 indicates the locations of the sampling sites

Table 7.1. Sites sampled in October 2003 and March 2004 for macroinvertebrates. Sites marked with a strike-through could not be sampled in autumn 2004.

River	Site Name	Site code	Distance from power station (km)	Easting	Northing
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	Franklin R @ Flat Is (G20)	Fr21	-	397939	5296733
Denison	Denison d/s Maxwell R (G21)	De7	-	407206	5272718
~~Denison~~	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 conducted 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 10m.

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.

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

7.2.4 Analysis

O/E scores and summary trends were derived from the RBA data using the combined-season Hydro RIVPACS models developed by Davies *et al*. (1999).

O/Epa and O/Erk values were 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.

Data from the RBA samples was also analysed using the single-season (autumn and spring) Hydro RIVPACS models developed for this project from the original reference site data sets used to develop the combined season models (see Davies *et al*. 1999).

7.3 Results

7.3.1 Quantitative (surber) sampling

Data from surber samples are shown in Table 7.2 (spring 2003) and Table 7.3 (autumn 2004), below. Diversity was low at sites 75 to 72, and generally higher downstream of the Denison River (sites 60 to 42). The mean annual data showed no major trend downstream from site 75 (see Figure 7.2), with all sites collectively having significantly lower diversity than at reference sites ($p < 0.0018$, df = 12, t = 3.6, by t-test). Total abundance peaked at site 60, associated with a high local abundance of simuliids and hydrobiosid caddis. Mean values for reference sites are also shown in Figure 7.2. Even including site 60, all Gordon River sites fell below reference site in total abundance ($p <0.002$ by t-test, t = 3.538, df = 12).

7.3.2 RBA (kick) sampling

7.3.2.1 Combined season model analyses

Data from RBA kick-sampling and live picking are shown in Table 7.4 (spring 2003) and Table 7.5 (autumn 2004), below. These data were entered, along with values of predictor variables into the combined season RIVPACS models developed by Davies *et al*. (1999). O/E values derived from the presence-absence (pa) and rank abundance (rk) models are shown in Table 7.6. The trends in O/E values with distance downstream of the power station are shown in Figure 7.3, accompanied by values for reference sites sampled at the same time.

Table 7.2. Quantitative macroinvertebrate data (abundances as n per 0.18 m^2) for Gordon and reference sites sampled in spring 2003.

		River:	Gordon									Franklin		Denison		Maxwell	Jane
		Site:	75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Class	**Order**	**Family**															
Cnidaria	Hydrozoa						2										
Platyhelminthes	Turbellaria			1						3		3	4			4	
Nematoda			2	2	1		3			2	12	2	1			85	10
Mollusca	Bivalvia	Sphaeriidae					1										
	Gastropoda	Hydrobiidae		2		3	1		1	2	2		1			3	2
		Ancylidae											3				
		Glacidorbidae	5	3	2												
Annelida	Oligochaeta		3	30	11	2	20	22	29	137	41	45	13	6	16	118	94
Arachnida	Acarina			1		1							1	1	1	6	1
Crustacea	Amphipoda	Paramelitidae	8	1	1		1		1	1	2			1		1	
		Janiridae	148	39	4		2	4		4	1	31	18		1	1	
Insecta	Collembola			1													
	Plecoptera	Eustheniidae	1		1	1	3				2		3	3	1	2	
		Austroperlidae		1	1		1										
		Gripopterygidae	35	63	32	40	85	21	11	4	30	13	5	12	2	19	10
		Notonemouridae	1		1	1	1										
	Ephemeroptera	Leptophlebiidae	3	7	7	4	5	35	20	8	21	106	84	59	81	118	58
		Baetidae							1		1	15	3	3	1	50	13
	Odonata	Telephlebiidae												1			
	Diptera																
		Chironomidae: Chironominae			1	3	9	4	1		53	1		6		6	3
		Chironomidae: Orthocladiinae	37	14	8	4	29	3	7	3	10		4		1	3	
		Chironomidae: Podonominae		1	10	15	3	6	6	4	1	3			2	4	1
		Chironomidae: Tanypodinae		1													
		Chironomidae: Diamesinae	21	12	1			2						1			
		Chironomidae: Aphroteniinae										1					
		Simuliidae		134	30	78	6	29	74	19	26	128	73	48	75	17	32
		Tipulidae												1	1		1
		Blephariceridae		9				2	1	2	1	16	38	1	1	1	2
		Ceratopogonidae						2					1				
		Empididae			2		1									2	
		Dip. Unid. Pup.	4	10	13		8		3		8	2	1	1	3	4	
	Trichoptera	Calocidae					1									3	3
		Conoesucidae	1	6	1	1	1	4	2		1		2	1		8	1
		Glossosomatidae														1	
		Helicophidae					1										
		Helicopsychidae											1				
		Hydrobiosidae	5	7	4	3	4	8	2	1		5	5	3	7	6	9
		Hydropsychidae					169	172	23		2					8	2
		Hydroptilidae			3		9										
		Leptoceridae	1								1	1	4	6	1	7	4
		Limnephilidae					1										
		Philopotamidae														3	
		Philorheithridae							1					2	3	1	
		Trich. Unid. Pup.		1		5		1	1							1	
	Coleoptera	ElmidaeA		1		1	2	6	2		1	29	19	30	32	67	31
		ElmidaeL			1		2	11	1	2		42	25	55	222	83	113
		ScirtidaeL			1	2			1		1	2		4		3	
		PsephenidaeL			1								3	1		2	2
		N Taxa	**15**	**23**	**23**	**16**	**27**	**17**	**20**	**14**	**20**	**18**	**23**	**22**	**18**	**31**	**20**
		Total abundance	**275**	**347**	**137**	**164**	**371**	**332**	**188**	**192**	**217**	**445**	**312**	**246**	**451**	**637**	**392**

Table 7.3. Quantitative macroinvertebrate data (abundances as n per 0.18 m^2) for Gordon and reference sites sampled in Autumn 2004.

		River:	Gordon									Franklin		Denison	Maxwell	Jane
		Site:	75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	Ma7	Ja7
Class	**Order**	**Family**														
Platyhelminthes	Turbellaria			1			3		2			7	9		1	3
Nematoda						1	1	2		2					41	
Mollusca	Bivalvia	Sphaeriidae				2										
	Gastropoda	Hydrobiidae			1	2			5	2				1	104	2
		Ancylidae										1	1		4	
		Glacidorbidae				1										
Annelida	Oligochaeta		1	2	11	5	23	24	31	63	72	32	110	23	121	72
Arachnida	Acarina												1	1	7	
Crustacea	Amphipoda	Paramelitidae				3			1				3	2	2	
		Ceinidae				1										
		Neoniphargidae	2				1		1							
	Isopoda	Phreatoicidea												1	1	
		Janiridae	21	1	2	11	3	2	5	1	1				14	1
	Ostracoda								1							
Insecta	Plecoptera	Eustheniidae	1				1				1		3	3	1	1
		Austroperlidae											1	1		
		Gripopterygidae		28	4	7	7	24	7	7	9	2	9	19	11	19
	Ephemeroptera	Leptophlebiidae	3	3	13	43	5	24	16	8	14	22	13	82	93	102
		Baetidae						1	1		2	1	5	18	61	29
	Diptera															
		Chironomidae: Chironominae				2		6	8	2	2			4	8	
		Chironomidae: Orthocladiinae	1	11	10	110	10	6	5	2	5	3	4	5	32	5
		Chironomidae: Podonominae					1			1	1	2	5	1	2	4
		Chironomidae: Aphroteniinae					1								1	
		Simuliidae		33	4	9	8	476	105	27		260	346	79	41	211
		Blephariceridae		2				13	3	3	7	4	22	5		3
		Empididae				2			1		1	1	1		6	1
		Dip. Unid. Pup.						40	24	6			3	1		1
	Trichoptera	Calocidae													4	8
		Conoesucidae		2		1							7	2	48	18
		Glossosomatidae								1		2		1	3	137
		Hydrobiosidae		1	2	2		4	2		1	2	2	7	9	8
		Hydropsychidae				1		100	16	2	4		2	9	37	3
		Hydroptilidae													1	
		Leptoceridae										2	1	2	3	
		Philorheithridae											2	5	11	4
		Trich. Unid. Pup.						2	2		1				2	
	Coleoptera	ElmidaeA				1		8	2		3	2	5	44	118	25
		DytiscidaeA													1	
		ElmidaeL		1	1	2		11	7	2	3	27	18	89	265	157
		ScirtidaeL				1		4	1			9	50	19	21	98
		PsephenidaeL											1	6	9	1
		N Taxa	**6**	**11**	**9**	**20**	**12**	**17**	**22**	**15**	**16**	**17**	**25**	**26**	**33**	**24**
		Total abundanc	**29**	**85**	**48**	**207**	**64**	**747**	**246**	**129**	**127**	**379**	**624**	**430**	**1083**	**913**

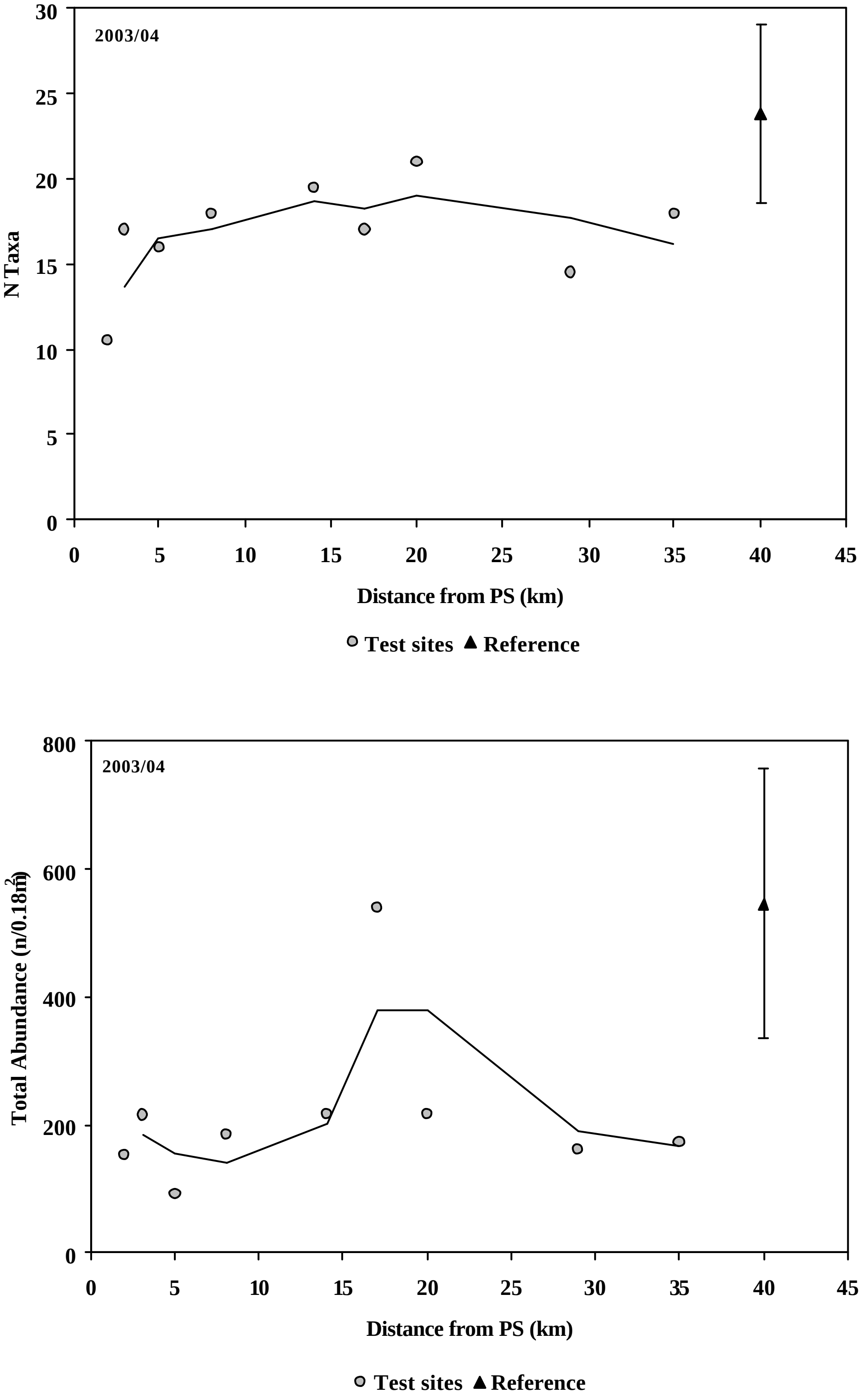


Figure 7.2. Trends in mean diversity (number of taxa) and total abundance of macroinvertebrates at sites in the Gordon River in 2003-04 with distance downstream of the Gordon power station. Mean values for the reference sites sampled at the same time are also shown, with error bars (+/- 1 SD).

Table 7.4. RBA macroinvertebrate data (abundances per live picked sample) for Gordon River and reference sites sampled in spring 2003.

Date	18/10/2003	River:	Gordon																		Franklin				Denison				Maxwell		Jane	
		Site:	75		74		72		69		63		60		57		48		42		Fr11		Fr21		De7		De35		Ma7		Ja7	
Class	**Order**	**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		1					1			1	1								1		
Nematoda						1													1	1												
Mollusca	Gastropoda	Hydrobiidae													3	1									1				7	1		
Annelida	Oligochaeta		1	9	6	5	4	4	5	1	5	12	1	4	10	6	15	12	10	28	6	9	12	5	6	5	18	11	2	4	60	23
Arachnida	Acarina															1							4		3	2			9	7	1	
Crustacea	Amphipoda	Paramelitidae	7	3		2	1			2			2		12	8	9			1					1	1		3		1		
	Isopoda	Phreatoicidea	1																									2				
		Janiridae		2	1	1					1	1																		1		
Insecta	Plecoptera	Eustheniidae		1		1			2	1	4		1	1	2	2		2	2	2		3	2		2	5		1	1			1
		Austroperlidae							1																							
		Gripopterygidae	2	5	41	40	20	19	6	4	22	14	17	13	7	13	13	3	15	6	15	19	3	8	2	7	3	7	28	23	13	14
		Notonemouridae	3	3				1		5	3	1					1															
	Ephemeroptera	Leptophlebiidae	12	7	2	7	10	18	6	1	13	8	72	61	43	52	27	26	36	23	32	66	121	46	89	45	61	35	55	28	87	39
		Baetidae															1		4		14	20	15	10	3	1			44	25	5	5
	Odonata	Telephlebiidae																								1						
	Diptera	Chironomidae: Chironominae						2							1	1			5	4			1		1				1			
		Chironomidae: Orthocladiinae	8	10	9	10	1	4			5	4				1			1		1		1	1			2		3	1		1
		Chironomidae: Podonominae		2	4	10	14	26	59	41	5	5	3	5		2	9	19	17	29	3	8	1	4	18	16	33	18	4		16	4
		Chironomidae: Diamesinae	44	11	2	18																							2	3		
		Simuliidae			31	52	54	39	30	24		3	26	27	9	8	40	40	13	7	14	28	10	26	7	12	57	38	1	7	37	8
		Tipulidae					1	1		1	1	1		1		3										2	1	1			1	1
		Athericidae															1		1							1						
		Blephariceridae						1				1	1	1		1	6	2	1	1	4	2	1	2	1							
		Empididae									1																				1	
		Dip. Unid. Pup.					1	6					1							4					1							
	Trichoptera	Calocidae																													2	4
		Conoesucidae			1		1						1				2				1		1	5				2	33	9	1	7
		Glossosomatidae																			1								1			11
		Hydrobiosidae	15	28	56	71	8	19	7	20	16	33	10	14	10	9	8	10	9	7	20	52	26	24	7	13	6	6	16	18	13	16
		Hydropsychidae									11	6	5	6	1	6	1	2	1						1	1				4		1
		Hydroptilidae						1			3																					
		Leptoceridae							3	1				1				1		1	2	9	3		6	6	1	1	1			
		Philopotamidae																	1		4	6	1							2		
		Philorheithridae								1	1		1	1	1		1	1			2	5		1	1	8	1		6	3	1	6
		Trich. Unid. Pup.				1							1	1								1	7	1					1	6		1
	Coleoptera	ElmidaeA			1	1				1	5	3	4	3	1	1	5		3		17	25	24	20	14	12	15	8	26	20	40	19
		DytiscidaeA																			1											
		ElmidaeL																			7		2	5	1	2	56	5	2	4	15	1
		ScirtidaeL				1	1	1	1				1	1					1			1			1		1		3		3	
		PsephenidaeL					1														5		6	3	2	1			2	1		1
		DytiscidaeL																				1										
Nematomorpha		Gordiidae																														1
		N Taxa	**9**	**11**	**11**	**15**	**13**	**14**	**10**	**13**	**16**	**13**	**17**	**15**	**12**	**16**	**15**	**12**	**17**	**13**	**19**	**17**	**19**	**15**	**21**	**19**	**13**	**14**	**22**	**21**	**16**	**20**
		Total Abundance	**93**	**81**	**154**	**221**	**117**	**142**	**120**	**103**	**98**	**92**	**148**	**140**	**100**	**115**	**139**	**119**	**121**	**114**	**150**	**256**	**241**	**161**	**168**	**141**	**255**	**138**	**248**	**169**	**296**	**164**

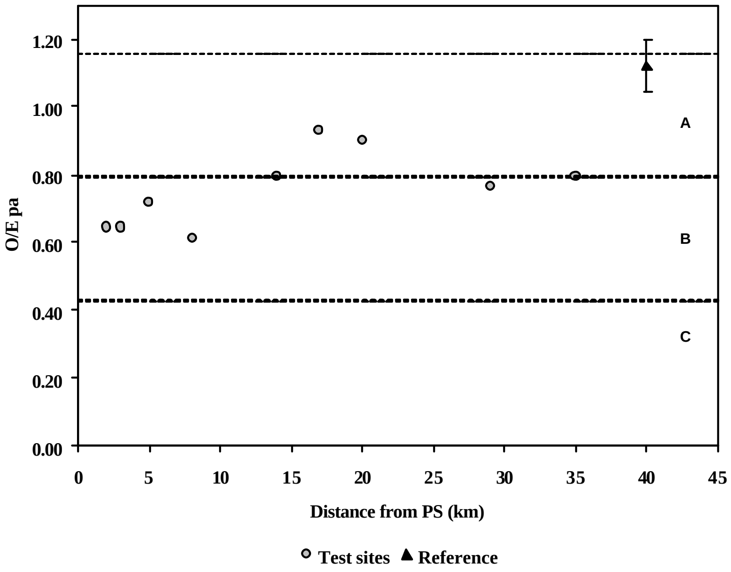
Table 7.5. RBA macroinvertebrate data (abundances per live picked sample) for Gordon River and reference sites sampled in autumn 2004.

		River:	**Gordon**																		**Franklin**				**Denison**		**Maxwell**		**Jane**	
		Site:	**75**		**74**		**72**		**69**		**63**		**60**		**57**		**48**		**42**		**Fr11**		**Fr21**		**De7**		**Ma7**		**Ja7**	
Class	**Order**	**Family**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Platyhelminthes	Turbellaria		2	1	2	1					4	4		1			1	1												
Mollusca	Bivalvia	Sphaeriidae									1																			
	Gastropoda	Hydrobiidae																									3	2		
Annelida	Oligochaeta		1		2	2	15	12		3	16	16	4		12	6	6	28	19	13	12	13	6		10	7	6	8	33	23
Arachnida	Acarina			5																		1			2		5	8		
Crustacea	Amphipoda	Paramelitidae		25		1				3				2	8	11	6				1	1				1	1		1	
		Neoniphargidae	18		2				3																					
	Copepoda		1																											
	Isopoda	Phreatoicidea	1										1																	
		Janiridae	21	88		2					1									1	1									
Insecta	Plecoptera	Eustheniidae	2		4			3	1	4	2		2	1	1	3			3	3			1	1	7	5	1			1
		Austroperlidae								1																				
		Gripopterygidae		1	201	162	97	42	11	6	24	24	20	13	20	18	36	23	37	35	12	10	50	16	32	18	2		23	19
		Notonemouridae	4	3	1	1			1			1																		
	Ephemeroptera	Leptophlebiidae	22	37	9	10	26	26	46	37	18	37	16	35	41	20	68	48	61	75	44	70	32	55	59	41	38	75	37	56
		Baetidae					1							4		1	11	9	4	9	15	11	16	46	16	13	27	44	39	36
	Odonata	Telephlebiidae																	1											2
	Diptera	Chironomidae:Chironominae				1	2		3	1	1	1					1	2		1			1		4	4		2		2
		Chironomidae:Orthocladiinae		3	3	4		2		1	3			1	2		2	4		1			3			2	1	2	1	
		Chironomidae:Podonominae		1							10			1			4	1		4	22	26	25	24	22	10	1	2	15	15
		Chironomidae:Tanypodinae																		1										
		Simuliidae	1	2	142	157	24	12	26	15	15	13	40	67	39	36	33	32	34	40	82	89	53	54	27	19	5	8	38	37
		Tipulidae					3	2	1		1	16		2	2						2				7	5	2	4		1
		Blephariceridae			1						1		2	2		1	3		7	3	2	3	6	6						
		Dip. Unid. Pup.																							4					
	Trichoptera	Calocidae																					1				1	2	2	
		Conoesucidae					1											1		1			3						2	
		Glossosomatidae					1	2													3		1		1	5		1	28	4
		Helicopsychidae																					2				1			
		Hydrobiosidae	2	2	22	17	56	43	27	23	12	28	16	32	13	25	26	12	20	5	45	48	29	36	45	18	21	40	31	33
		Hydropsychidae										16	16	34	1	8	1		2	4						1	4	1	8	1
		Leptoceridae		1	2	2						1	1	2	3	1	4	1									1	2		
		Philopotamidae											1	1		2	1									1				
		Philorheithridae										2		1	1		1	1		2	1		2	3		3	4	2	2	3
		Trich. Unid. Pup.												6	7				2	6								2		
	Coleoptera	ElmidaeA				1					1	4	1	10	8	8	4	1	3	2	2	8	11	1	28	15	20	23	8	7
		ElmidaeL										1		1	2	1					3		6	1	6	1	9	5	10	7
		ScirtidaeL	1	1			3	1	1	1			1		1						18	20	19	14	9	2	7	6	13	14
		PsephenidaeL									1	1			1				1						3	8	4	2		3
Nematomorpha		Gordiidae																								1				
		N Taxa	**12**	**13**	**12**	**13**	**11**	**10**	**10**	**11**	**16**	**15**	**13**	**19**	**17**	**14**	**17**	**14**	**13**	**18**	**16**	**12**	**19**	**12**	**17**	**21**	**22**	**21**	**17**	**18**
		Total abundance	**76**	**170**	**391**	**361**	**229**	**145**	**120**	**95**	**111**	**165**	**121**	**216**	**162**	**141**	**208**	**164**	**194**	**206**	**265**	**300**	**267**	**257**	**282**	**180**	**164**	**241**	**291**	**264**

Table 7.6. O/E values derived from combined season 2003-04 RBA macroinvertebrate data for Gordon and reference sites. O/Epa, O/Erk = derived using presence/absence and rand abundance data, respectively. Results shown for two replicate samples per site and their mean.

River	Site	Replicate	O/Epa	Band	O/Erk	Band
Gordon	75	1	0.57	B	0.43	C
		2	0.72	B	0.54	B
		Mean	**0.64**	**B**	**0.49**	**B**
	74	1	0.57	B	0.47	B
		2	0.71	B	0.58	B
		Mean	**0.64**	**B**	**0.52**	**B**
	72	1	0.72	B	0.60	B
		2	0.72	B	0.60	B
		Mean	**0.72**	**B**	**0.60**	**B**
	69	1	0.65	B	0.58	B
		2	0.57	B	0.50	B
		Mean	**0.61**	**B**	**0.54**	**B**
	63	1	0.73	B	0.76	B
		2	0.86	A	0.91	A
		Mean	**0.80**	**A**	**0.83**	**A**
	60	1	0.79	B	0.75	B
		2	1.07	A	1.00	A
		Mean	**0.93**	**A**	**0.87**	**A**
	57	1	0.97	A	0.90	A
		2	0.84	A	0.90	A
		Mean	**0.90**	**A**	**0.90**	**A**
	48	1	0.77	B	0.85	A
		2	0.77	B	0.75	B
		Mean	**0.77**	**B**	**0.80**	**B**
	42	1	0.83	A	0.87	A
		2	0.76	B	0.81	A
		Mean	**0.80**	**B**	**0.84**	**A**
Franklin	Fr11	1	1.47	X	0.96	A
		2	1.08	A	0.91	A
		Mean	**1.27**	**X**	**0.93**	**A**
Franklin	Fr21	1	1.47	X	1.21	X
		2	1.17	A	1.06	A
		Mean	**1.32**	**X**	**1.13**	**A**
Denison	De7	1	1.37	X	1.16	A
		2	1.66	X	1.21	X
		Mean	**1.52**	**X**	**1.19**	**A**
Maxwell	Ma7	1	1.66	X	1.21	X
		2	1.47	X	1.06	A
		Mean	**1.56**	**X**	**1.13**	**A**
Jane	Ja7	1	1.47	X	1.26	X
		2	1.57	X	1.21	X
		Mean	**1.52**	**X**	**1.24**	**X**

Overall, the values of O/E and the downstream trends are similar to those observed previously in 1995-96 and 1998-99 by Davies *et al*. (1999, 2001) and in the 1st and 2nd years of Basslink monitoring in 2001-02 and 2002-03. As in previous years, O/Epa and O/Erk values upstream of the Denison fall into the significantly impaired band (B), while sites downstream of the Denison fall around the lower margin of band A, and are statistically significantly lower than for reference sites (both $p < 0.05$ by t test). Thus, O/E values are low in the river reaches upstream of the Denison River junction, with values increasing downstream of the Denison, but still falling below those observed for reference sites.



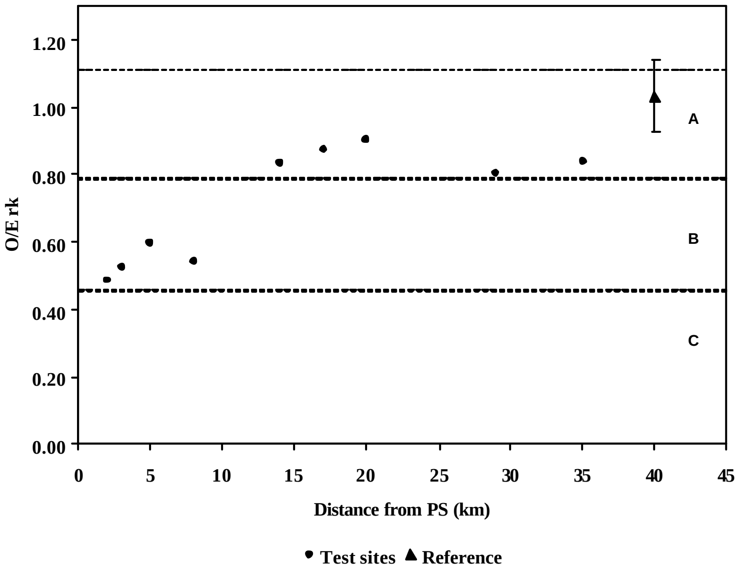


Figure 7.3. Trends in combined season O/Epa and O/Erk values for macroinvertebrates in the Gordon River with distance downstream of the Gordon power station in 2003-04. Mean values for the reference sites sampled at the same time are also shown, with error bars (+/- 1 SD). Horizontal lines indicate bounds of impairment bands A, B and C (see Davies *et al*. 2001).

7.3.2.2 Single season O/E values

All RBA samples from years 1 to 3 of pre-Basslink monitoring (2001-02, 2002-03 and 2003-04) were analysed using the relevant autumn or spring models, to generate O/Epa an O/Erk values for each sampling occasion. Results for 2002-03 and 2003-04 were generated for each duplicate sample, and the mean O/E values are reported in Table 7.7, and plotted in Figure 7.4.

The trend in O/E is similar for all seasons and for O/Epa and O/Erk, with lower values in the reaches below the power station, increasing with distance downstream, but not reaching the value attained by the reference sites.

There is little inter-annual variation in the trend, with some limited variation between seasons and years in actual O/E values for each site, as expected. O/Epa data for autumn 2004 fell at the lower end of the range experienced to date for both lower Gordon and reference sites (Figure 7.4). The overall level of variation is not great, however, indicating that the original power analyses conducted on the 1999-2000 survey results are likely to remain fairly valid for the overall analysis of pre-post Basslink changes in O/E.

Table 7.7. Single season O/E values for all sites monitored in the Gordon and Reference rivers from spring 2001 to autumn 2004.

	Year :	**2001**		**2002**		**2002**		**2003**		**2003**		**2004**	
	Season :	**Spring**		**Autumn**		**Spring**		**Autumn**		**Spring**		**Autumn**	
	O/E output :	**O/Epa**	**O/Erk**	**O/Epa**	**O/Erk**	**O/Epa**	**O/Erk**	**O/Epa**	**O/Erk**	**O/Epa**	**O/Erk**	**O/Epa**	**O/Erk**
River	**Site**												
Gordon	75	0.68	0.71	0.59	0.61	0.38	0.60	0.49	0.43	0.49	0.58	0.68	0.56
	74	0.66	0.64	0.88	0.66	0.81	0.61	1.03	0.83	0.63	0.73	0.88	0.73
	72	0.87	0.97	0.88	0.71	0.69	0.77	0.88	0.73	0.80	0.92	1.03	0.73
	69	0.91	1.12	0.98	0.73	0.68	0.61	0.78	0.74	0.87	0.81	0.83	0.68
	63	1.04	1.16	1.27	1.11	1.08	1.06	1.17	0.95	0.82	0.94	1.17	1.03
	60	0.90	1.12	1.37	1.11	0.90	1.14	1.17	0.83	1.05	1.02	1.27	0.91
	57	0.97	1.06	1.08	0.86	1.05	1.12	1.27	1.08	0.86	0.85	1.42	1.03
	48	0.96	0.98	1.27	0.95	0.92	1.17	1.08	0.93	1.04	0.98	1.17	0.93
	42	1.12	1.17	1.37	1.01	0.90	1.13	1.03	0.85	0.94	0.96	1.17	0.86
Reference													
Franklin	Fr11	1.35	1.40	1.57	1.01	1.31	1.17	1.52	1.16	1.12	1.20	1.27	0.93
	Fr21	1.20	1.18	1.66	1.21	1.35	1.17	1.47	1.18	1.05	1.03	1.32	1.13
Denison	De7	0.91	1.00	1.66	1.36	1.18	1.14	1.42	1.13	1.37	1.23	1.52	1.19
	De35	1.11	1.03	1.66	1.21	1.11	1.01	1.32	1.14	0.91	1.04		
Maxwell	Ma7	1.35	1.41	1.66	1.21	1.43	1.04	1.66	1.14	1.24	1.22	1.56	1.13
Jane	Ja7	1.34	1.15	1.47	1.06	1.26	1.07	1.47	1.19	1.11	1.16	1.52	1.24

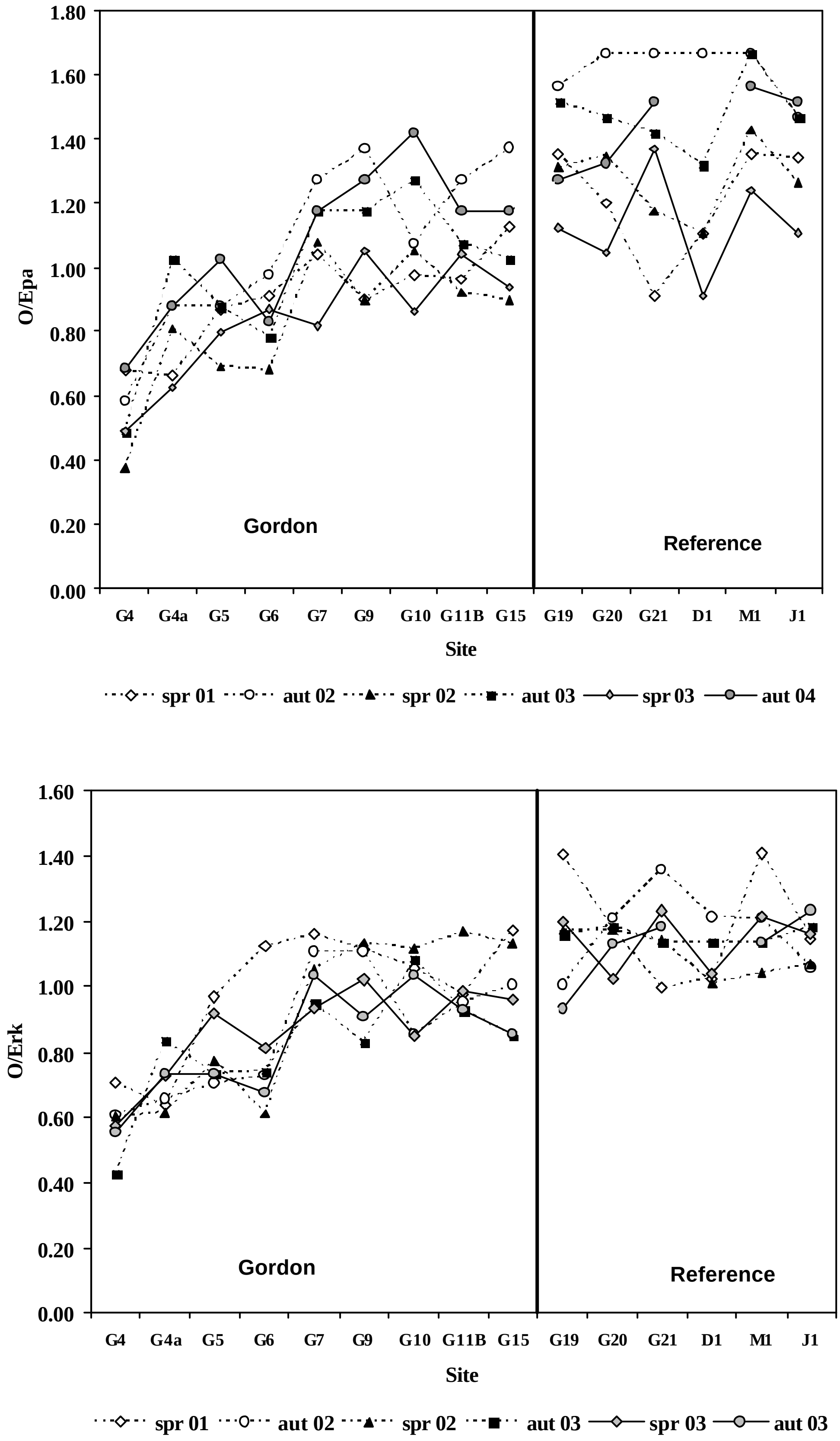


Figure 7.4. Values of O/Epa (top) and O/Erk (bottom) at all macroinvertebrate monitoring sites in the Gordon River downstream of the power sation, and at reference sites in all six seasons sampled to date (spring 2001 to autumn 2004). (Table 7.1 lists the site names against site numbers).

7.3.3 Changes between years

The overall pattern of O/E values, total macroinvertebrate abundance and number of taxa downstream of the power station in the Gordon River, and the higher values for all these variables in reference river sites is consistent for the three years of monitoring, and for six seasonal sampling occasions to date.

Paired t-tests were conducted to initially assess between-year differences in O/Epa, O/Erk, total abundance and number of taxa. There were no significant differences between years for any of these parameters (all $p > 0.05$). Values of O/Epa and O/Erk were significantly different, with O/Erk being smaller than O/Epa, in autumn 2002, autumn 2003 and autumn 2004. This is consistent with observations made by Davies et al. (1999) who described the impact of the Gordon River as being associated with both loss of taxa, resulting in reduced O/Epa values, and reductions in relative abundance of the remaining taxa, resulting in O/Erk being less than O/Epa. However, values of O/Epa and O/Erk in spring 2001, 2002 and 2003 were not significantly different for Gordon River sites. Significant differences were also observed between O/Epa and O/Erk values for reference sites in 2001-02, 2002-03 and 2003-04 making the interpretation of the differences for the Gordon River sites equivocal. These results suggest that analysis of variation in O/E results between years should be done using differences between Gordon River and reference sites for each year as a test statistic.

7.4 Conclusions

Monitoring was conducted successfully according to the requirements of the Gordon River Basslink monitoring program, for all sites with the exception of one reference sites in autumn 2004, due to high river levels. Overall patterns of diversity, community composition and abundance were similar to those observed previously in 1995-96 and 1998-99 by Davies *et al*. (1999, 2001), in 2001-02 and 2002-03. There is no evidence of any substantial changes over this period. There is a degree of background variability in abundance, which this project is designed to observe and incorporate into the assessment of pre- vs. post-Basslink changes.

O/E values follow the same trends as observed by Davies *et al*. (2001), in 2001-02 and 2002-03. Reference site values generally fell at the upper range or above the previously established bounds for the reference condition, as observed in previous years (see Figure 7.3). However, paired t-tests of O/Epa and O/Erk values for all sites did not suggest a significant change between this survey and those conducted in 1998-99, 2001-02 or 2002-03 (all with $p > 0.1$). This indicates that no consistent or substantial change in O/E values had occurred across all sites between any of these dates, and that reference sites are naturally highly diverse.

8 Algae

8.1 Introduction

Benthic algae were surveyed in spring 2003 and autumn 2004. Quantitative (quadrat-based) assessment of algal cover was conducted at nine 'monitoring' sites in the Gordon River between the power station and the Franklin River junction.

8.2 Methods

8.2.1 Monitoring sites

Monitoring sites were the same as for the Basslink macroinvertebrate monitoring being conducted in the Gordon River, as shown in Figure 8.1 and detailed in Table 8.1.

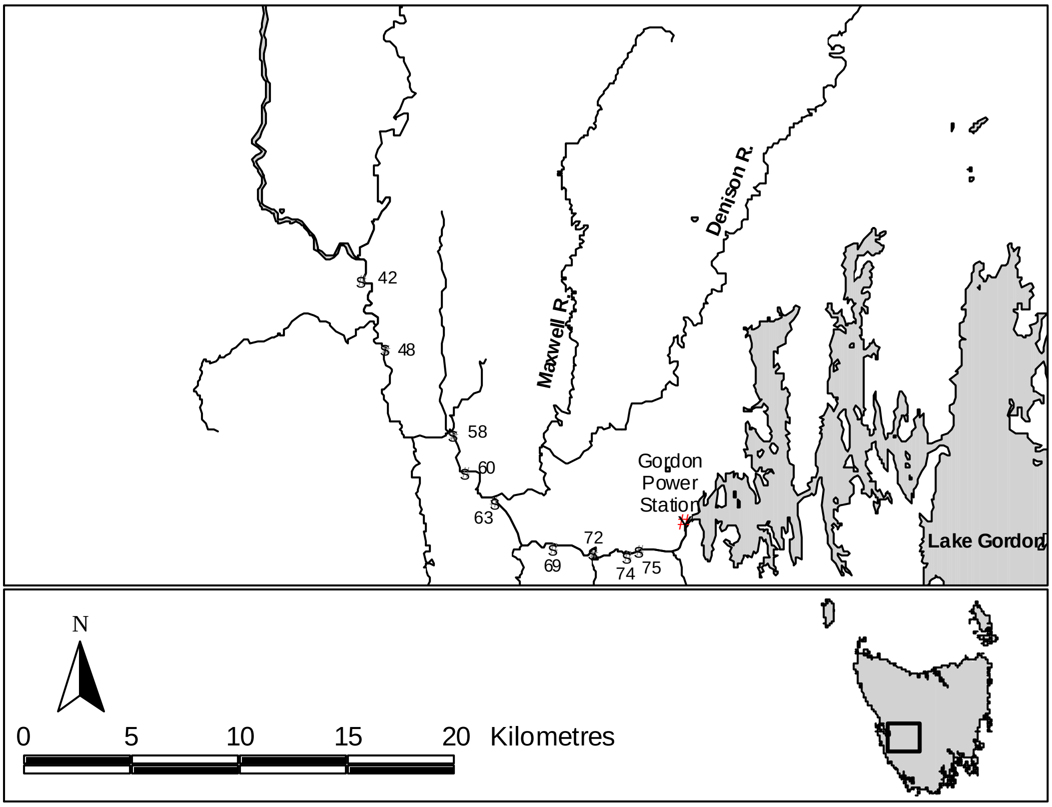


Figure 8.1. Map of the algal monitoring sites in the Gordon River.

Table 8.1. Sites sampled in March 2004 for macrophytes and macroinvertebrates.

River	Site name	Site code	Distance from power station (km)	Easting	Northing
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

8.2.2 Benthic algal survey

All algal assessment was conducted by measuring percent area of cover at fixed distances along existing transects across the Gordon River, with one transect assessed at each site.

All algal monitoring in 2003-04 was conducted 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 percent cover, was recorded using a 30 cm x 30 cm quadrat at 2.5 m intervals in three locations: 1 m upstream of the transect line; on the transect line; and 1 m downstream of the transect lines. Quadrat frames were fitted with a 100 cell wire grid to assist with areal cover estimates (as used for the first time in spring 2002); and
- within each quadrat, density was reported for four broad floristic groups: filamentous algae, characeous algae, moss and macrophytes.

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

Five scrapes of filamentous algae and moss were taken from the upper surface of boulders or cobbles in the centre of each zone at each site on all sampling occasions. The five 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.

8.2.3 Analysis

Mean plant cover was calculated for each transect for the 'channel bed' – i.e. that section of channel between the toe of each bank (for those transects for which the entire channel could be surveyed), or between the toe of the bank and the furthest point of observation across the channel). The locations of the channel bed relative to the transect head peg are shown in Table 8.2.

Table 8.2. Extent of 'channel bed' for which mean floristic cover is calculated.

Site	Channel bed (offset from peg, m)
75	5 - 60
74	7.5 - 60
72	5 - 92.5
69	10 - 75
63	7.5 - 70
60	9 - 87.5
57	7.5 - 55
48	7.5 - 72.5
42	7.5 - 47.5

8.3 Results

8.3.1 2003-04

Surveys were successfully completed across the entire river channel for sites 75, 74, 72, 69, 63 and 60. The presence of deep, fast water again prevented survey across the entire channel for sites 57, 48 and 42. An average 70 m of river bed was surveyed across all sites, ranging from 42.5 to 90 m in spring 2003 and 47.5 to 100 m in autumn 2004. Data from these surveys are summarised in Table 8.3. Aquatic flora have a consistently low to moderate cover across all sites. Moss and filamentous algae were the dominant forms, and had similar, low overall mean percent cover across all sites, with greatest cover of both forms at site 74. Characeous algae were again only observed at sites 74 and 72 (though not encountered on the transect at site 72 in autumn 2004), with both *Chara* and *Nitella* sp. evident. Macrophytes only occurred at site 72. Both *Callitriche* sp. (starworts) and *Isolepis fluitans* were observed at this site.

A trend of decreasing filamentous algae and moss cover with distance from the Gordon Power Station was again evident in autumn 2004 (Figure 8.2), with higher cover in several sites upstream of the Denison River junction. As in 2001-02 and 2002-03, low values were observed in both seasons at site 72.

Mean moss cover was highly variable, ranging from 0.14 to 10% in autumn 2004 (Table 8.3b). Also, in autumn 2004, moss and algal cover were significantly positively correlated (Pearson r = 0.746, n = 9, p = 0.02).

Table 8.3. Summary cover data for algae, moss and macrophytes surveyed in: a) spring 2003 and b) autumn 2004 for Gordon River sites. * indicates transects for which only part of the channel could be surveyed. Total distances surveyed from the transect head pegs are indicated.

a) – spring 2003

	Mean % cover				Width
Site	**Moss**	**Filamentous algae**	**Nitella/Chara**	**Macrophytes**	**surveyed (m)**
75	0.98	18.70	0	0	70
74	2.13	16.46	4.28	0	65
72	0.02	2.31	4.23	0.09	80
69	1.31	3.13	0	0	80
63	3.83	12.62	0	0	72.5
60	1.83	0.36	0	0	90
57*	0.89	0	0	0	55
48*	0.47	0.64	0.08	0	80
42*	0.67	1.07	0	0	42.5

b) – autumn 2004

	Mean % cover				Width
Site	**Moss**	**Filamentous algae**	**Nitella/Chara**	**Macrophytes**	**surveyed (m)**
75	3.19	1.50	0	0	67.6
74	10.23	1.70	0.09	0	65
72	0.81	0.59	0	2.54	100
69	1.98	0	0	0	52.5
63	0.47	0.003	0	0	72.5
60	0.14	0.01	0	0	95
57*	0.62	0	0	0	55
48*	1.27	0	0	0	72.5
42*	0.57	0.27	0	0	47.5

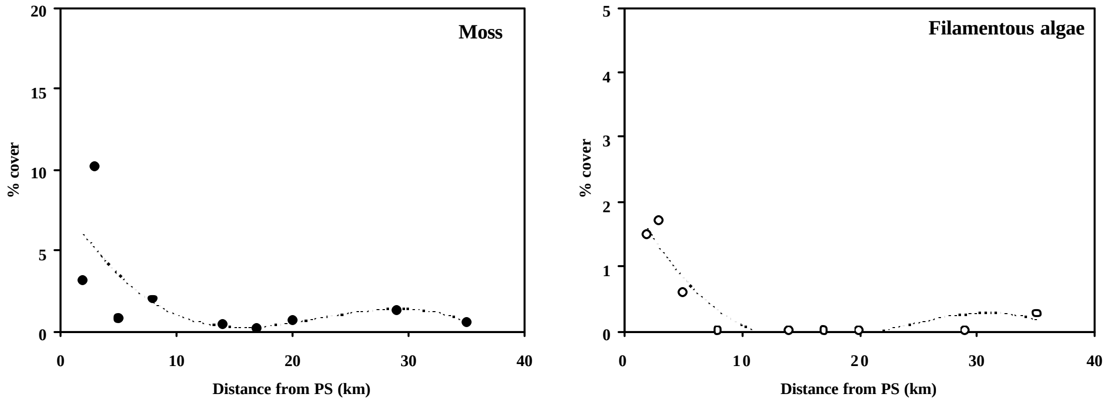


Figure 8.2. Summary trends in mean annual cross-channel percent cover of moss (left) and filamentous algae (right) in the Gordon River with distance downstream of the Gordon power station for autumn 2004.

8.3.2 Between-year comparisons

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 sampling occasions), in Table 8.4. Pairwise t-tests were conducted to assess changes in the mean annual cover in the Gordon below the power station between the 2002-03 and 2003-04 years. There was no significant difference in percent cover of either moss or filamentous algae, between these years.

Plots of the downstream trends in annual mean of moss and filamentous algæ for all three years, 2001-02 to 2003-04, are shown in Figure 8.3. Moss and filamentous algal cover were highly correlated between years (r = 0.961 with p = 0.00004, and r = 0.864 with p = 0.003, respectively, with n = 9).

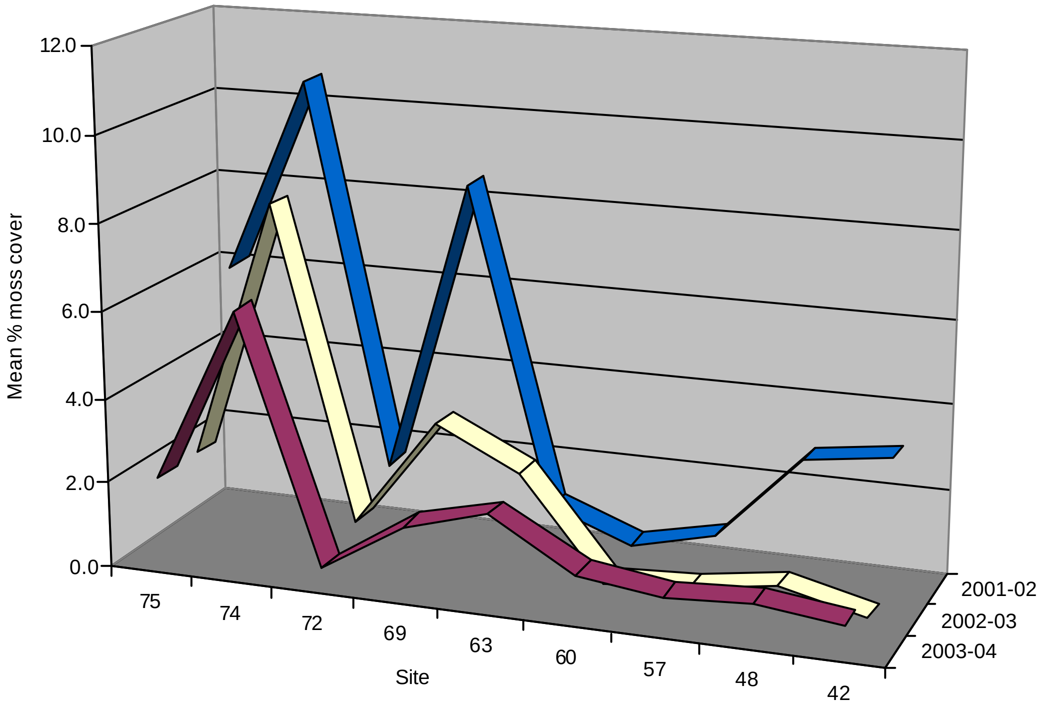
Table 8.4. Mean percent cover for moss and filamentous algae at all transects in 2001-02, 2002-03 and 2003-04 in the Gordon River.

	2001-02 mean		**2002-03 mean**		**2003-04 mean**	
Site	**Moss**	**Filamentous**	**Moss**	**Filamentous**	**Moss**	**Filamentous**
75	6.09	7.79	2.07	9.88	2.09	10.10
74	10.63	17.00	8.16	20.73	6.18	9.08
72	1.61	1.59	0.87	1.94	0.42	1.45
69	8.50	3.35	3.42	5.28	1.64	1.56
63	1.05	2.19	2.46	6.59	2.15	6.31
60	0.33	1.51	0.13	0.03	0.98	0.18
57	0.80	0.01	0.25	0.09	0.75	0.00
48	2.84	1.72	0.54	0.26	0.87	0.32
42	3.10	3.72	0.06	0.44	0.62	0.67
Grand mean	**3.88**	**4.32**	**1.99**	**5.03**	**1.74**	**3.30**
Mean upstream Denison	**5.57**	**6.39**	**3.39**	**8.88**	**2.49**	**5.70**
Mean downstream Denison	**1.77**	**1.74**	**0.24**	**0.21**	**0.81**	**0.29**

8.4 Conclusions

As in 2001-02 and 2002-03, and spring 2003, plant cover was low (typically 10% or less, with an overall mean of 2.9% cover across all transects), and decreased downstream from the Gordon power station to the Franklin River junction.

Though moss cover had been lower in 2002-03 than in 2001-02, cover in 2003-04 was not significantly different from that in 2002-03.



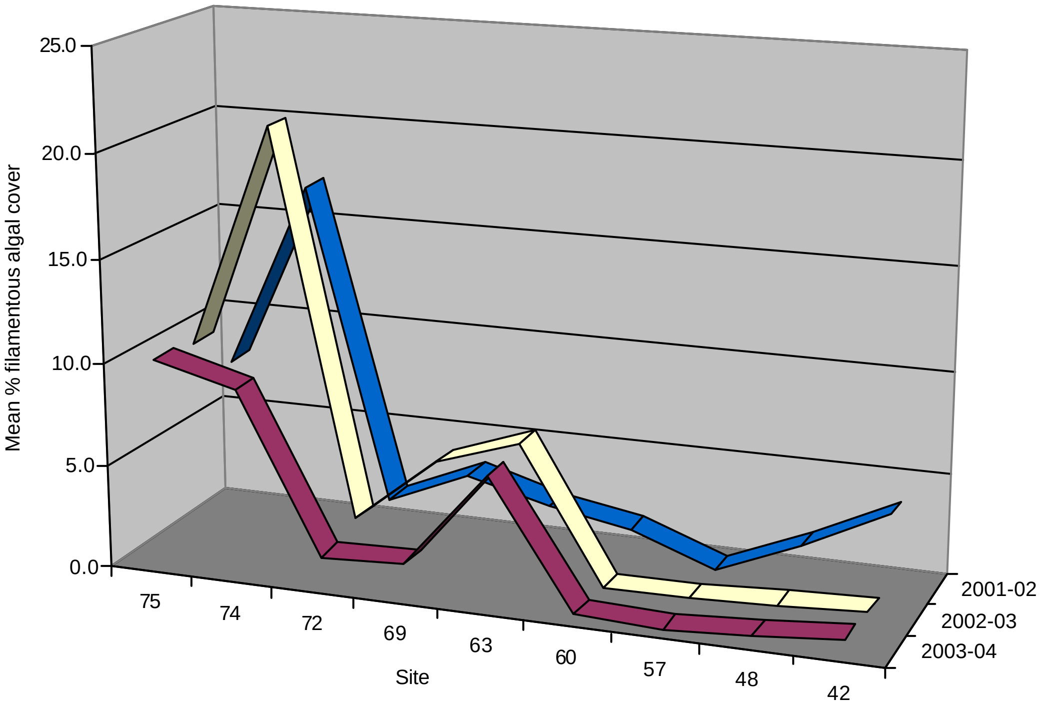


Figure 8.3. Downstream trend in mean percent moss cover (top) and mean percent filamentous algal cover (bottom) in the Gordon in 2001-02, 2002-03 and 2003-04.

9 Fish

9.1 Introduction

The aims of the Gordon River Fish Monitoring Program are to:

- quantify pre and post-Basslink variability in the relative abundance of fish populations to allow statistical comparison between these times and appropriate reference sites;
- 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;
- detect and assess potential changes in catch per unit effort which may result from Basslink operations;
- determine the incidence of fish stranding both pre- and post-Basslink; and
- determine any changes to the fish populations of affected tributaries, in particular, if recruitment success for juvenile galaxiids is changed under Basslink.

This section summarises the results of the 2003-04 fish monitoring survey.

9.2 Methods

The fish monitoring surveys were conducted in November 2003 and April-May 2004. Two reference sites could not be sampled during the April trip, due to high water levels and elevated flows. These sites were sampled in a follow-up trip on 14 May 2004.

Thirty one Gordon catchment test sites, divided amongst five zones, were scheduled for sampling on each occasion (Table 9.1). Figure 9.1 shows the location of the Gordon catchment monitoring zones. The rationale behind the zone allocations is discussed in Howland *et. al* (2001). Note that zones 3-5 differ in extent from the geomorphology zones as they are delineated by major barriers to fish passage rather than tributary confluences.

Seven river and four tributary reference sites were scheduled for sampling in conjunction with the test sites, and these are listed in Table 9.2. 'Optional' sites, listed in Table 9.3, were included in the monitoring regime and consisted of 11 test and 3 reference sites that were located in both tributaries and rivers. Optional sites were sampled if time and logistics permitted, however core sites took priority in the sampling regime. The Orange River test site (formerly classified as optional) has been reclassified as essential following ongoing access problems with the Denison u/s Maxwell site.

All core sites were monitored in both November 2003 and April-May 2004. Eight optional sites were sampled in November 2003 and five optional sites were sampled in April-May 2004.

Table 9.1. Gordon catchment (test) monitoring sites. Alternative site names are shown in parenthesis. *Orange River has replaced the Denison u/s Maxwell site (zone 3) due to ongoing access difficulties at the latter.

Zone	River Sites	Tributary Sites
1	75 (G4), 74 (G4a), 73 (G3 u/s and d/s)	Serpentine River, 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 & Pocacker Rivers	none
13 (Henty)	Henty u/s Bottle Creek Henty @ Yolande River	none
14 (Henty)	Henty @ Sisters	none

Table 9.3. Optional sites surveyed during the monitoring program. The Orange River site has been reclassified as essential due to ongoing access difficulties at the Denison u/s Maxwell site. Alternative site names are shown in parenthesis.

Zone	River Sites	Tributary Sites
1	76 (G2)	Left bank Creek @ site 75
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

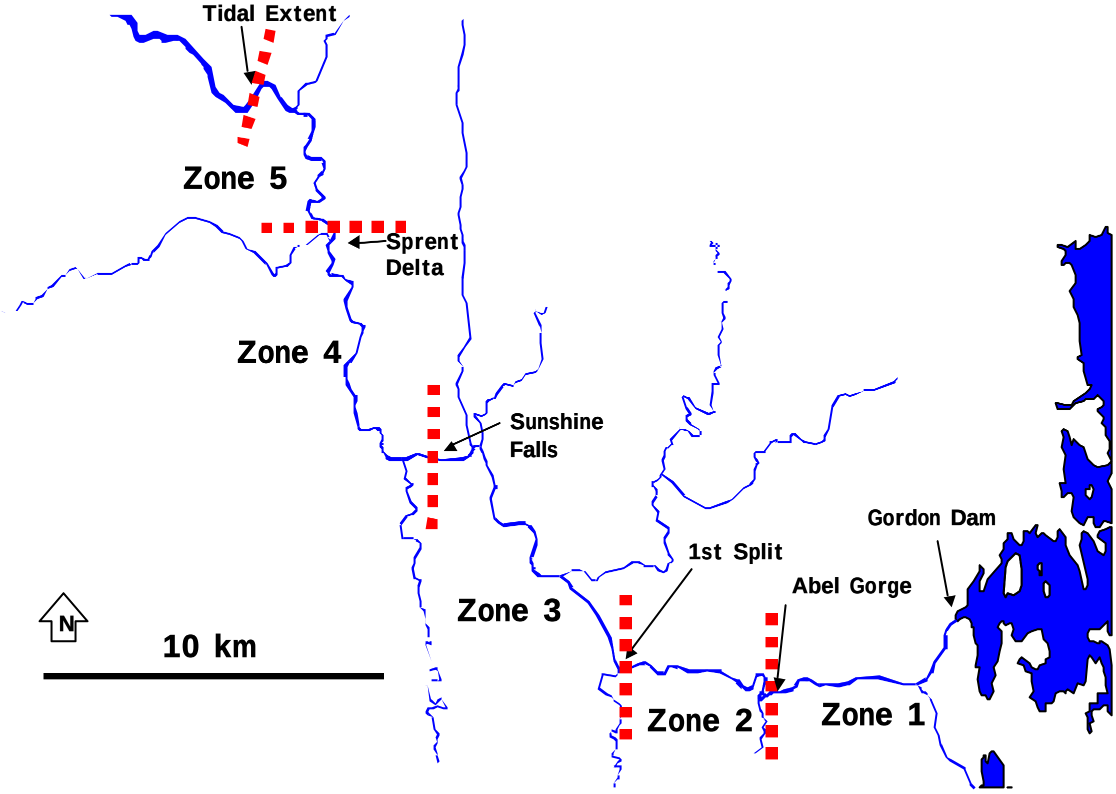


Figure 9.1. Fish monitoring zones in the Gordon River.

Fish surveys were undertaken by backpack electrofishing, and were conducted by two-person teams, with a target electrofishing effort of 1200 seconds shocking time for each site. Fish teams sampled a range of representative habitats at each site. Fish were identified, counted and fork lengths were recorded to the nearest millimetre. Qualitative assessments of general aquatic habitat descriptors were recorded for each site.

9.3 Results and Discussion

A total of 1019 fish (670 in November 2003 and 349 in April-May 2004) from ten species were captured during 2003-04. Two exotic species (*Salmo trutta,* and *Perca fluviatilis*), one eel species (*Anguilla australis*), two species of lamprey (*Mordacia mordax* and *Geotria australis*) and four galaxiids (*Galaxias brevipinnis*, *G. maculatus*, *G. truttaceus, and Neochanna cleaveri*) and the Sandy (*Pseudaphritis urvillii*) were collected during the survey.

No stranded fish were collected during either the November 2003 or the April 2004 surveys.

Table 9.4 and Table 9.5 give the mean CPUE for the fish caught during November 2003 and April-May 2004, respectively.

Table 9.4 Catch Per Unit Effort (CPUE) for each fish species caught during November 2003, summarised by site type and zone.

Zone	Type	*A. australis*	*G. australis*	*G. brevipinnis*	*N. cleaveri*	*G. maculatus*	*G. truttaceus*	*M. mordax*	*P. fluviatilis*	*P. urvilli*	*S. trutta*
1	River (Gordon)	0.19							2.42		0.56
2	River (Gordon)										1.70
3	River (Gordon)	0.97	1.75					0.39			13.45
4	River (Gordon)	2.18	4.52	0.31							3.12
5	River (Gordon)	3.89		4.26		12.77	7.22			2.23	1.48
7	River (Franklin)	12.93		5.96		0.99	4.96			3.97	4.96
8	River (Franklin)	1.29	1.69	2.25			0.32			0.32	6.43
1	Tributary (Gordon			3.12							0.94
2	Tributary (Gordon	0.24	0.24								4.85
3	Tributary (Gordon	0.19	0.76					0.19			13.82
4	Tributary (Gordon	1.43	0.52			0.17	0.35			0.17	1.74
8	Tributary (Franklin)	0.32	0.96	1.28			7.00				2.89
9	River (Birches)	4.81	1.31	0.44		2.19	7.44			9.19	
13-14	River (Henty)	0.28	5.84		0.28	0.28	6.12	0.28			1.67

Table 9.5. Catch per unit effort for each fish species caught during April 2004, summarised by site type and zone

Zone	Type	*A. australis*	*G. australis*	*G. brevipinnis*	*N. cleaveri*	*G. maculatus*	*G. truttaceus*	*M. mordax*	*P. fluviatilis*	*P. urvilli*	*S. trutta*
1	River (Gordon)	0.24							0.24		0.24
2	River (Gordon)							0.20	1.38		2.17
3	River (Gordon)	0.26									2.30
4	River (Gordon)	1.86								0.62	2.18
5	River (Gordon)	1.25	0.54			5.19	1.61	0.18		1.79	0.90
7	River (Franklin)									4.00	
8	River (Franklin)	0.72	1.20								3.60
1	Tributary (Gordon			0.35							1.05
2	Tributary (Gordon										2.34
3	Tributary (Gordon		0.71								8.21
4	Tributary (Gordon	0.19	0.19	0.19			1.53	0.19			8.02
8	Tributary (Franklin)			1.19			2.08				5.35
9	River (Birches)	0.45		0.45		0.45	4.96			5.86	0.45
13-14	River (Henty)	0.29	0.29	0.29	0.29	3.24	1.18			0.59	4.71

9.3.1 Exotic Species

9.3.1.1 Brown trout

A total of 426 brown trout (245 in November 2003 and 181 in April-May 2004) were captured during 2003-04. A mean total CPUE of 4.38 (fish per 1200 seconds) was returned for the November monitoring and 2.97 for the April-May monitoring.

Brown trout have dominated the mean total CPUE for each survey. This is unlikely to change under the current hydrological regime in the middle Gordon River, as trout readily recruit from local spawning areas throughout the catchment. With the exception of *P. urvillii*, the native species in the catchment are diadromous and recruitment success is affected by the modified flow regime in the river, as well as broad climatic and behavioural patterns.

Brown trout catch rates, shown in Table 9.6, were:

- similar to past levels for the Gordon river zones;
- in the higher range for the Franklin river and tributary zones; and
- fell within the mid-range of historical values for the Henty sites and Gordon tributary zones.

Within the tributary sites, catch rates appeared to be higher in zones 3 and 4 than in zones 1 and 2. The tributaries in the downstream zones include the Denison, Smith, Harrison, Orange and Olga Rivers, and provide a comparatively larger catchment area, spawning habitat and less volatile flows when compared to the smaller streams in the upstream zone. It is not surprising that this is reflected in the catch rates.

Table 9.6. Catch Per Unit Effort for *S. trutta* in all zones (river and tributary sites) between December 2001 and April 2004.

Site	**River**						**Tributary**					
Zone	**Dec-01**	**Apr-02**	**Dec-02**	**Mar-03**	**Nov-03**	**Apr-04**	**Dec-01**	**Apr-02**	**Dec 02**	**Mar-03**	**Nov-03**	**Apr-04**
1	0.74	0.20	0.25	0.20	0.56	0.24	1.29	3.15	1.30	0.97	0.94	1.05
2	5.34	2.11	2.58	3.48	1.70	2.17	3.77	2.15	3.87	3.17	4.85	2.34
3	7.50	1.62	1.59	3.47	13.45	2.30	8.98	10.58	5.22	14.44	13.82	8.21
4	3.24	2.26	0.77	2.62	3.12	2.18	7.93	5.30	3.20	8.47	1.74	8.02
5	2.08	0.94	1.81	0.95	1.48	0.90	-	-	-	-	-	-
7	1.91	2.51	0	0	4.96	0	-	-	-	-	-	-
8	6.12	8.05	3.73	5.46	6.43	3.60	5.62	5.43	2.38	2.42	2.89	5.35
9	0	0	0	0.45	0	0.45	-	-	-	-	-	-
13-14	11.26	4.36	1.99	5.67	1.67	4.71	-	-	-	-	-	-

9.3.1.2 Redfin perch

Thirteen redfin perch were caught during the November monitoring and nine during April. Table 9.7 shows the location and number of redfin perch captured in the Gordon River since the inception of the monitoring program, and Table 9.8 lists the catch rate in zones 1 and 2.

The thirteen redfin perch collected from zone 1 during the November 2003 survey produced a CPUE of 2.42. The species was not captured from any other zone in the river during this survey. Eleven fish were captured at site 75 (G4) and one from both sites 74 (G4a) and 73 (G3). Sizes varied from 118 mm to 178 mm. This range was similar to that recorded in previous surveys.

Only nine redfin were captured in the April 2004 survey, and 6 of these were electrofished at site 72(G5) in the upper reaches of zone 2. Unlike previous surveys, most of these fish were captured from the shallow isolated pools of site 72 (lower), and only a single redfin was electrofished in the large, normally productive pools of site 72 (upper). Sizes ranged between 83 and 184 mm.

Table 9.7. Capture locations and numbers caught for redfin perch (*Perca fluviatilis*) between December 2001 and April 2004. (*stranded on river bank, N/Sindicates site not sampled).

Site	**Dec-01**	**Apr-02**	**Dec 02**	**March-03**	**Nov-03**	**Apr-04**
Zone 1						
Gordon @ Serpentine	*2	N/S	N/S	N/S	N/S	N/S
Site 76 (Gordon @ G2)	N/S		N/S			N/S
Site 75 (Gordon @ G4)			3		11	
Site 74 (Gordon @ G4a)			2		1	
Site 73 (Gordon @ G3, d/s)		2		3	1	1
Site 73 Gordon @ G3, u/s)						
Zone 2						
Site 72 (Gordon @ G5, lower)		2		3		5
Site 72 (Gordon @ G5, upper)		7	2	13		1
Site 71 (Gordon @ G5a, pipe)						1
Site 71(Gordon @ G5a, water)		2		2		1
Site 69 (Gordon @ G6)	1	N/S				
Site 64 (Gordon @ Grotto Creek)	N/S		N/S			N/S
TOTALS	3	13	7	21	13	9

Table 9.8. Redfin CPUE in the Gordon River zones between December 2001 and April 2004. CPUE statistics were calculated on fish captured by electrofishing, and *excludes stranded or hand collected fish.

Zone	**Dec-01**	**Apr-02**	**Dec 02**	**Mar-03**	**Nov-03**	**Apr-04**
1	0*	0.40	1.23	0.61	2.42	0.24
2	0.25	2.11	0.32	1.55*	0.0	1.58
1 & 2 pooled	0.11	1.27	0.68	1.18	1.22	0.98

Table 9.7 indicates that catch rates appear to vary seasonally, with zone 1 CPUE higher in summer and zone 2 CPUE higher in autumn. This trend appears to have continued in 2003-04, indicating an interaction between zone and season. There does not appear to be any trend for increasing redfin numbers over time.

9.3.2 Eels and lampreys

9.3.2.1 Short headed lampreys

Short-headed lamprey (*Mordacia mordax)* were captured in low numbers during the November 2003 survey. One dead adult (600 mm) and two ammocoetes were captured from one tributary and two river sites in zone 3. Short headed lampreys were not captured from any of the reference sites.

Three *Mordacia mordax* were captured in the Gordon River and tributaries during the April 2004 survey. Single ammocoetes were captured at site 42 (G15) and Howards Creek. A single large adult was electrofished at site 71 (G5a), confirming that upstream migrating lampreys are able to negotiate the Splits.

9.3.2.2 Pouched lampreys

As in previous surveys, pouched lampreys (*Geotria australis*) were more numerous and showed a wider distribution in comparison to *Mordacia mordax*.

A total of 62 pouched lampreys were captured during the November 2003 survey, the vast majority (89%) of the catch were ammocoetes. No live adults were captured in the Gordon River, however dead specimens were collected from Gordon River zones 3, 4 and 5 and a single tributary in zone 3. Seven live adult fish were collected from the Denison, Henty and Sorell River sites. The adults appeared to be upstream migrating spawners, and a range of healthy, dying and dead specimens were observed in the reference sites.

Individuals that appeared to be dying were extremely sluggish and generally found attached to the substrate with their sucker or oral disc. Both dead and dying specimens had a light mottled appearance in contrast to the solid dark colouring of their more vigorous counterparts. It is common to find considerable numbers of dead lampreys that appear to be casualties of seasonal spawning migrations (Fulton, 1990).

In the April 2004 survey, fourteen ammocetes, ranging in size from 46-99 mm, were captured in Gordon River zone 5, Gordon tributary zones 3 and 4, Franklin River zone 8 and the Henty River. No adults were captured during the April survey.

Table 9.9 shows CPUE values for *G. australis* between December 2001 and April 2004 in the Gordon, Franklin and Henty river zones. Catch rates in 2003-04 were low in comparison to most of the previous surveys.

Table 9.9. CPUE (standardised to fish per 1200 seconds) for *G. australis* in all river zones between December 2001 and April 2004.

Zone	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04
Zone 1 river sites						
Zone 2 river sites				0.13		
Zone 3 river sites		4.55	0.64	5.12	1.75	
Zone 4 river sites		1.29		2.94	4.52	
Zone 5 river sites	1.66	2.11	0.23	2.46		0.54
Zone 7 river sites		2.74		1.90		
Zone 8 river sites				2.57	1.69	1.20
Zone 9 river sites		1.25		4.50	1.31	
Zone 13-14 sites		1.03	1.14	6.86	5.84	0.29

9.3.2.3 Short-finned eels

A total of 72 short-finned eels (*Anguilla australis*) were captured in November 2003 and 21 in April 2004, from most of the Gordon, Franklin, Henty River and Birches Inlet zones. Eels were not caught in zone 2 of the river nor the zone 1 tributaries. The majority of the eels were collected in the lower Gordon and Franklin River zones. *Anguilla australis* catch rates for all of the Basslink monitoring surveys are shown in Table 9.10. Catches from the April 2004 survey were relatively low in comparison to historical results, and may be an artefact of high flows in the catchment immediately prior to sampling.

Captured eels ranged in size between 90 and 730 mm, however most were in the 100-230 mm size range.

Table 9.10. CPUE (standardised to fish per 1200 seconds) for *A. australis* in all river zones between December 2001 and April 2004. (* denotes stranded)

Zone	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04
Zone 1	2.22	0.20*	0.25	0.61	0.19	0.24
Zone 2	0.38	0.00	1.13	0.13*		
Zone 3	1.99	0.97	2.86	0.73	0.97	0.26
Zone 4	4.05	3.56		0.33	2.18	1.86
Zone 5	5.19	6.32	2.26	7.57	3.89	1.25
Zone 7	0.38	4.52	1.92	0.95	12.93	
Zone 8	1.06	3.58	1.98	0.96	1.29	0.72
Zone 9	1.86	2.19	2.80	3.15	4.81	0.45
Zone 13-14	0.88	0.77	0.28	2.39	0.28	0.29

9.3.3 Galaxiids and Sandys

CPUE values for galaxiids and sandys captured between December 2001 and April 2004 are given in Table 9.11 for Gordon River zones, Table 9.12 for Gordon River tributaries, and Table 9.13 for the Franklin River and tributaries, Birches Inlet and Henty River.

In November 2003, moderate to high catches of *G. truttaceus*, *G. maculatus* and *G. brevipinnis* were recorded from zone 5 of the Gordon River, where large schools of juvenile galaxiids were observed in shallow cobble and sand areas. A single *G. brevipinnis* was captured in zone 4 of the river. Schools of juvenile galaxiids were also observed over shallow cobble areas below Big Fall on the Franklin River (zone 7). These schools are indicative of the annual whitebait run, which usually occurs in the late spring – early summer each year and represents the upstream migration of galaxiid juveniles. Catch rates were generally low in April 2004.

As in previous surveys, *Galaxias brevipinnis* was the only galaxiid species recorded upstream of zone 4 in the Gordon River.

9.3.3.1 Climbing galaxias (Galaxias brevipinnis)

A total of 52 climbing galaxias were captured during the November 2003 survey. The majority (71%) of these fish were juveniles less than 60 mm in length, and represented recruitment from the spring whitebait run. Juvenile fish were collected throughout river zones 5, 7 and 8 whilst mature fish were captured only from tributaries in zone 1 and zone 8. Length frequency distribution of the catch was strongly bimodal, reflecting the strong representation of adults and juveniles in the catch, with a distinct lack of intermediate-length fish.

Remnant populations of climbing galaxias reported in previous surveys were again sampled during the November 2003 survey. Ten mature climbing galaxiids were captured in the Serpentine River and Indigo Creek, ranging in size from 135 to 196 mm, and were predominant in catches from the zone 1 tributaries. Mature climbing galaxiids (122 to 155 mm) were also captured in the zone 8 tributaries of the Franklin River.

Catch rates of climbing galaxias in the downstream zones were moderate, in November 2003, with CPUE values of 4.26 and 5.96 recorded from zones 5 and 7 respectively. Catches were low in the Henty River, and no climbing galaxiids were recorded from the Birches Inlet sites, which was consistent with previous survey results.

A total of 8 climbing galaxias were captured during the April 2004 survey. Sizes ranged between 54 and 185 mm, with larger fish collected from tributaries in zone 1, zone 4 and zone 8. *G. brevipinnis* were not collected from river zones in the Gordon and Franklin. Catches were low in comparison to historical data, particularly in the zone 1 tributary and zone 5 river sites. Remnant populations of climbing galaxias reported in previous surveys were again sampled during the April 2004 survey, however only a single galaxiid was recorded, from Indigo Creek.

Table 9.11. CPUE for galaxiids (*G. brevipinnis*, *G. maculatus* , *G. truttaceus*) and sandys (*P. urvillii)* captured in the Gordon River between December 2001 and April 2004.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04
Zone 1 river	*G. brevipinnis*				0.61		
Zone 2 river	All (galaxiids and sandys)						
Zone 3 river	All (galaxiids and sandys)						
Zone 4 river	*G. truttaceus*	0.81	0.64	0.77			
	P. urvillii				0.33		0.62
	G. brevipinnis					0.31	
Zone 5 river	*G. brevipinnis*		0.47	2.71	0.76	4.26	
	G. maculatus	0.42	2.34	0.45	0.57	12.77	5.19
	G. truttaceus	4.98	3.98	3.39	3.03	7.22	1.61
	P. urvillii	2.91	2.34	1.81	0.76	2.23	1.79

Table 9.12. CPUE for galaxiids (*G. brevipinnis*, *G. maculatus* , *G. truttaceus*) and sandys (*P. urvillii*) captured in the Gordon River tributaries between December 2001 and April 2004.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04
Zone 1 tribs	*G. brevipinnis*	8.07	1.75	1.30	2.60	3.12	0.35
Zone 2 tribs	All (galaxiids and sandys)						
Zone 3 tribs	*G. truttaceus*		0.12				
	P. urvillii	0.18					
Zone 4 tribs	*G. brevipinnis*	0.28		0.38			0.19
	G. truttaceus	4.53	1.56	2.26	2.52	0.35	1.53
	P. urvillii	0.28	0.31		0.90	0.17	
	G. maculatus					0.17	

Table 9.13. CPUE for galaxiids (*G. brevipinnis, G. maculatus, G. truttaceus*) and sandys (*P. urvillii*) captured in the reference river and tributary zones between December 2001 and April 2004.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04
Zone 7 river	*G. brevipinnis*	3.43		3.83		5.96	
	G. maculatus		1.51	2.88		0.99	
	G. truttaceus	1.91	2.51	8.63	3.80	4.96	
	P. urvillii	1.91	3.01	0.96	2.85	3.97	4.00
Zone 8 river	*G. brevipinnis*	1.33		1.54		2.25	
	G. truttaceus	0.53	0.45	0.44		0.32	
	P. urvillii	0.27	0.45	0.44	1.29	0.32	
Zone 8 tributaries	*G. brevipinnis*	1.61	1.28	2.86	4.54	1.28	1.19
	G. truttaceus	4.02	2.87	1.43	0.60	7.00	2.08
Zone 9	*G. brevipinnis*		0.31	0.40		0.44	0.45
	G. maculatus	1.86		7.60	0.45	2.19	0.45
	G. truttaceus	1.24	3.12	7.60	5.41	7.44	4.96
	P. urvillii	9.31	12.49	6.80	12.16	9.19	5.86
Zone 13-14	*G. brevipinnis*	0.44		4.55	0.60		0.29
	G. maculatus	1.32	1.03		2.98	0.28	3.24
	G. truttaceus	3.31	5.9	7.68	6.27	6.12	1.18
	P. urvillii	1.55	1.28	0.28	1.19		0.59
	N. cleaveri					0.28	0.29

G. brevipinnis were absent from catches in river zones 7 and 8, which is consistent with results from previous surveys. The results from these zones show a significant seasonal trend, with moderate to high catches during summer surveys followed by an absence of climbing galaxias from autumn catches (see Table 9.13). The summer surveys coincide with juvenile galaxiid migratory runs into the lower catchment.

9.3.3.2 Spotted galaxias (Galaxias truttaceus)

A total of 105 spotted galaxias were captured during the November survey and 41 were captured during the April survey.

In November 2003, catches were restricted to the lower reaches of the Gordon and Franklin Rivers, with significant numbers of fish collected from zone 5 and zone 7, returning CPUE values of 7.22 and 4.96, respectively (see Table 9.4). Catches at the zone 8 river sites were restricted to a single fish, however 19 spotted galaxias were collected from zone 8 tributaries, returning a CPUE of 7.0. Both the Birches and Henty River sites returned strong catches of spotted galaxias, and catch rates were similar to those recorded in previous surveys.

Fish ranged in size from 38 to 180 mm, and analysis of the length frequency distribution of the catch showed strong juvenile recruitment from the spring whitebait run, which accounted for 29% of the catch during November 2003.

In April 2004, spotted galaxias were captured from zone 5 in the Gordon River, the zone 4 and zone 8 tributaries, and the Henty and Birches reference sites (see Table 9.5). Catch rates in the Birches Inlet zone were similar to those recorded in previous surveys, however CPUE values from the Henty River zones and Gordon River zone 5 were lower than in previous years.

Sizes ranged between 55 and 203 mm, and larger fish appeared to be more common in the zone 4 and zone 8 tributary sites, whilst fish collected from the downstream Gordon river zones tended to be smaller.

9.3.3.3 Jollytails (Galaxias maculatus)

A total of 77 *Galaxias maculatus* were captured during the November 2003 survey, and 41 during the April survey.

In November 2003, the vast majority of these fish were collected in zone 5, particularly from Pyramid Island and site 42. The CPUE of 12.77 was the highest of all fish species in zone 5 (see Table 9.4). It is interesting that catch rates in zone 7 were low, as the Franklin downstream of Big Fall site is only around 5 km upstream of Pyramid Island. Similarly, only three fish were collected from the Sprent River sites which are located approximately 3 km upstream of site 42. Current and previous Gordon River Basslink surveys have indicated that the distribution of *G. maculatus* is restricted to within less than 10 km of the Gordon River's tidal extent and an altitude of less than 10 m above sea level.

Zone 9 and zone 13-14 Jollytail catch rates were relatively low in November 2003. It is noteworthy that specimens collected from these sites ranged between 67 and 114 mm, and juveniles from the spring whitebait run were not represented in these catches. The zone 9 sites are approximately 25 m above sea level. The lowest Henty River site, Henty upstream of bottle Creek, lies at an altitude of approximately 5 m, while Henty at Yolande and Henty at East Sister are 35 m and 55 m above sea level, respectively. Only adult jollytails were collected from the lowest Henty site and from both sites in zone 9.

Analysis of the length frequency distribution of the data showed that juvenile fish in the 50-60 mm range comprised 88% of the total catch from all zones, with very few individual larger than 90 mm. Fish collected from the Gordon River sites were all juveniles whilst adults were only recorded from reference sites located in zones 9, 13 and 14.

In April 2004, most *Galaxias maculatus* were collected in zone 5, particularly from site 44 and, to a lesser extent, site 42, as well as the Henty River upstream of Bottle Creek (see Table 9.5). A single fish was collected from the Birches Inlet sites. Fish lengths ranged between 46 and 119 mm, however 97% of the catch were between 46 and 65 mm in length.

In the Henty River, the April catch comprised fish ranging in size between 51 and 65 mm, indicating that juvenile jollytails probably recruited to these zones from the whitebait run following the November survey.

9.3.3.4 Tasmanian mudfish (Neochanna cleaveri)

A single Mudfish (*Neochanna cleaveri*, formerly *Galaxias cleaveri*) was collected from the lowest site in zone 13 (Henty River) during the November 2003 survey. This was the first time this fish has been collected in the Basslink Monitoring surveys at either test or reference sites. The species normally inhabits swampy areas near the coast, although adult specimens are not often seen (Fulton, 1990), as it is possibly nocturnal (McDowall, 1996). The species grows to a maximum length of approximately 125 mm, and the Henty specimen was 103 mm. A single *Neochanna cleaveri* was again collected in zone 13 during the April 2004 survey. This specimen was 61 mm in length.

9.3.3.5 Sandys (Pseudaphritis urvillii)

A total of 39 sandys were recorded during the November 2003 survey and 31 during the April 2004 survey.

In November 2003, sandys were captured in river zones 5 and 7 and, to a lesser extent, zone 8. Catches in tributaries were restricted to zone 4, which was consistent with previous surveys. High catch rates were recorded from the Birches Inlet zones. Sandys are usually captured in low numbers at the Henty River sites but they were absent from the November 2003 catch.

Fish lengths ranged from 60 to 255 mm. Analysis of length frequency data showed that the average lengths of fish in each zone tended to increase with distance upstream. For example, the mean fish lengths (± standard error) in zones 5 and 7 were 106 ± 3.6 mm and 106 ± 5.3 mm, in comparison to 144 ± 16 mm in zone 4, 158 ± 14.6 mm in zone 8. Similarly, the mean fish length from zone 13 was 134 ± 8.6 mm compared to 169.5 ± 16.3 mm in zone 14. McDowall (1996) supports these observations, reporting that juveniles are most abundant in the downstream reaches during spring and summer, while larger specimens are generally more common further upstream.

Sandys collected during the April 2004 survey recorded lengths ranging from 46-152 mm. Fish were captured in river zones 4, 5 and 7, but no fish were captured in the tributaries. Relatively high catch rates were recorded from the Birches Inlet zone. This result is consistent with previous samples. The CPUE of 5.86 was the lowest for this species in the zone and probably reflects that the zone 9 sites were sampled immediately following a flow event in the catchment. Sandys were captured in low numbers at the Henty River sites, which is also consistent with previous surveys.

9.3.4 Hydrology and monitoring conditions

Prior to the November monitoring, the power station had been shut down, and releasing no water, since late September. Elsewhere in the catchment, in the month prior to monitoring, a period of rainfall, with subsequent tributary runoff, was recorded between 29th October and 4th November. Catchment streams had about 20 days to recede before monitoring commenced.

In summary, most of the Gordon catchment, and adjacent reference streams were about three weeks into the ‘dry’ season, with runoff and baseflows decreasing over time. Those sites on the Gordon River upstream of the Denison junction had had about 8 weeks of very low flows prior to monitoring.

Conditions prior to the April monitoring were quite different. The power station was operating at intermediate levels (1-3 turbines) for most of March, with only a short shutdown mid-March to facilitate other monitoring activities. The power station was operating on three turbines until the monitoring shutdown commenced. Natural discharge had been low, with small, infrequent rainfall events in February and March, which had not raised baseflow levels. On the day the April monitoring began, a significant rainfall event occurred, which raised water levels in the Gordon and other streams. This had the effect of preventing access to some of the reference streams due to high water levels and strong flows. It was a month before a return trip encountered water levels suitable for monitoring at these sites. Figure 9.2 shows discharge from the Gordon power station, at the Gordon River above Franklin site, the Franklin River at Mount Fincham site and the Collingwood River below Alma River site for the period March to May 2004.

In summary, the autumn fish monitoring commenced under conditions of high power station discharge superimposed on a low natural discharge pattern. This changed during the monitoring to become one of receding water levels following the first significant natural flow event of the 2004 'wet' season.

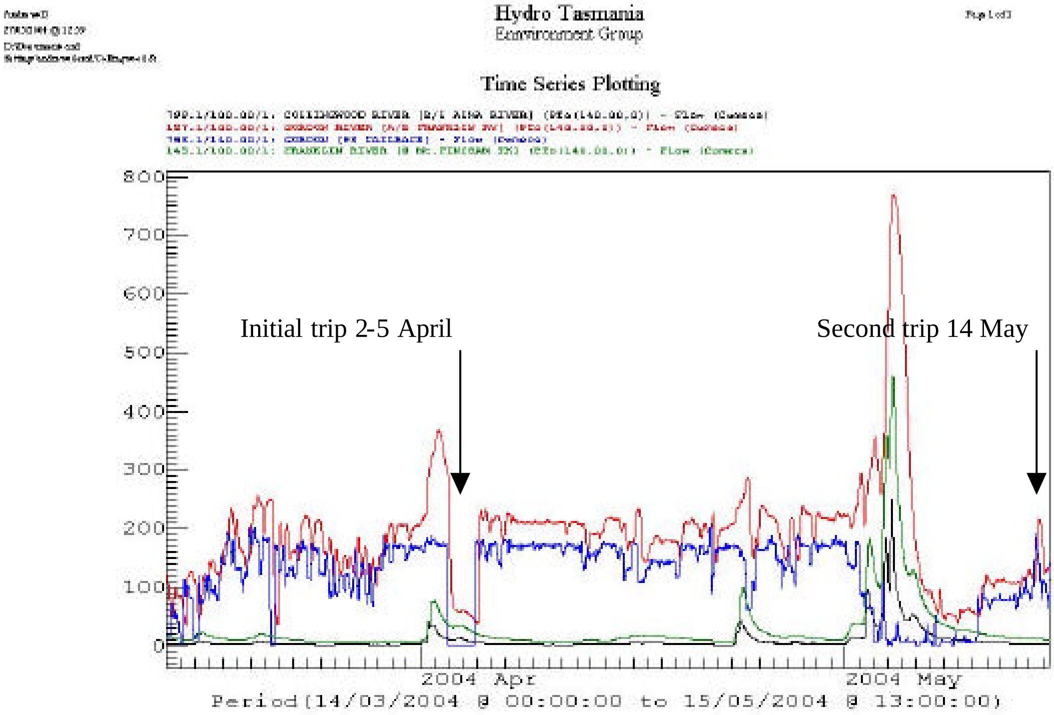


Figure 9.2. Discharge ($m^3 s^{-1}$) from the Collingwood River below Alma River, Gordon River above Franklin, Gordon power station and Franklin River at Mt Fincham between March and May 2004.

9.4 Conclusions

The November 2003 survey was conducted at the end of an extended power station maintenance shutdown. Water flows and temperatures would have varied naturally in the two months prior to monitoring. The April 2004 monitoring took place during the receding tail of a significant natural flow event and followed several weeks of high-discharge power station operations.

Brown trout catch rates were similar to previous years. The fish dominated catches in the middle Gordon River and tributary streams (zones 2-4) particularly zone three where, in November, juvenile trout comprised the majority of the catch.

The redfin perch distribution appears stable at present and there is a developing pattern of seasonal movements between zones 1 and 2. In the summer monitoring, numbers (and CPUE) tend to be highest in zone 1 sites and low in zone 2 sites, whereas the opposite pattern is evident in the autumn monitoring results.

Short headed lamprey were a small component of the lamprey catch, which was dominated by pouched lampreys in both November and April surveys. In November, a number of dead and dying adult lampreys were observed and this was attributed to the high mortality associated with the seasonal spawning migrations. Pouched lampreys were more numerous and showed a wider distribution in comparison to short-headed lampreys. A single adult specimen of the latter species was captured upstream of the Splits, which gives an indication of their climbing ability.

The majority of the eels were collected in the lower Gordon and Franklin River zones. Catches from the April 2004 survey were relatively low in comparison to historical results, and may be an artefact of high flows in the catchment immediately prior to sampling.

The distribution of galaxiids in the test and reference zones was similar to previous surveys, although the catch rates in the April survey were generally low. This is a consistent pattern for these species due to the high numbers captured during the summer in association with the annual whitebait run. Remnant populations of climbing galaxias persisted in the zone 1 tributaries, whilst galaxiids were absent from catches in the middle zones of the Gordon catchment. In November, schools of whitebait were observed in zone 5 and zone 7 of the Gordon and Franklin Rivers respectively, and juvenile galaxiids were strongly represented in catches from the downstream zones in both rivers.

A single Tasmanian Mudfish was captured in the Henty River in each survey of 2003-04.

Sandys were captured from a single zone 4 tributary, zone 5 of the Gordon River and zones 7 and zone 8 in the Franklin River. Catches of this species were high in the Birches Inlet sites and low in the Henty River.

Catch rates from the April 2004 survey were generally low. The majority of sites were sampled on receding flows, which may have affected fish behaviour and had negative implications for catch rates. Electrofishing efficiency is also affected by elevated flows, as electrical-field intensity is affected. Sighting and capture of stunned fish is also less efficient. Whilst every effort is made to conduct field sampling under suitable, repeatable conditions, the limitations of shutdown availability, logistics considerations and weather unpredictability can make sampling under suboptimal conditions unavoidable in some instances.

10 Interdisciplinary linkages

The Gordon River Basslink Monitoring Program is a comprehensive suite of monitoring activities aimed at determining the environmental variability and trends presently in evidence downstream of the Gordon Power Station, for a number of disciplines. By design, these activities take an individual-discipline approach. However, it is evident that interactions between disciplines are important for investigating underlying processes and for a better understanding of the monitoring results.

10.1 Hydrological interactions

The hydrological regime, the volume and pattern of river flows, is a consistent factor affecting all sites downstream of the power station. The flow regulation effects of the power station tend to dominate the flow regime of the downstream sites with a pattern which is largely determined by the requirements of Tasmania's electricity demand. As such, it is often substantially different from the natural flow regime. Seasonal tributary inflows mitigate this effect to an extent proportional to their flow volume and location in the catchment. In general, when there are major natural inflows, the Gordon Power Station operates less.

The hydrological regime is the primary driver of geomorphic processes and the linkages between hydrology and geomorphology are well described in chapters 4 and 5.

A synergy of hydrologic and geomorphic processes impacts on riparian vegetation through erosion (substrate stability), deposition (burying, light interception), inundation (for too long, or in the wrong season) and direct physical disturbance (shear, abrasion). Benthic algae would be subject to a similar range of impacts.

The hydrological regime directly impacts on benthic macroinvertebrates (habitat area, flow velocities, stranding) and, in combination with water temperature, on individual species' physiological responses.

The hydrological regime combined with topography and physical barriers may impede fish movement, an important factor in the Gordon River given that most native species are migratory. The extent of this effect is also driven by individual species' physiological and behavioural characteristics. Another significant factor is the predatory and competitive interaction with non-native fish species, especially brown trout. These interactions are as ubiquitous and pervasive as those of the hydrological regime. Water temperature has an impact on the physiology of individual fish species.

10.2 Water quality interactions

The predominant water quality parameter monitored downstream of the power station is water temperature. Impoundment and flow regulation have the effect of damping or eliminating diurnal and weather-driven temperature signals, although a fundamental seasonal signal remains (see chapter 3). This reduction in temperature range and variability is likely to impact directly on macroinvertebrates and fish. It possibly has an impact on benthic algae, although this is likely to be less than the hydrological impact.

The dominating effect of the power station discharge on downstream water temperatures is almost complete upstream of the Denison River, and even small discharges ($<10\ m^3\ s^{-1}$) constrain diurnal variation. Inflows from tributary streams add some variability to the thermal signal, but only when the power station is not operating.

In terms of large aquatic organisms, the present thermal regime and its interaction with the regulated hydrological regime, appear to favour brown trout (an exotic fish species) and *Astacopsis tricornis*, a native freshwater crayfish. Both of these species are ubiquitous and relatively numerous throughout the catchment. Although not specifically monitored, *A. tricornis* has been observed to be successfully reproducing and recruiting, even in the most impacted areas of the river.

The interaction between the Lake Gordon water quality, water level and the intake to the power station may be creating opportunities for the downstream translocation of lacustrine organisms under certain conditions. The power station intake is about 45 m below the lake’s full supply level. The impoundment also experiences thermal and chemical stratification at this location, which persists for most of the year. Consequently, the intake is usually below the oxycline (the point where dissolved oxygen values become too low for most organisms to survive). This is assumed to prevent, or minimise, the entrainment of living organisms into the power station inflow. Under present low lake level conditions, this chemical barrier is not in place and the intake is often above the oxycline.

The effect of this interaction appears to have been to allow the movement of lake-dwelling organisms into the downstream environment. The largest and most obvious of these apparently translocated biota is the redfin perch, which had not been recorded downstream of the power station prior to the commencement of the Basslink Monitoring Program. Lake-based macroinvertebrate species have also been anecdotally reported at downstream sites.

10.3 Other interactions

Adverse impacts on algae may reduce available food and habitat for macroinvertebrates. Similarly, reduced abundance of macroinvertebrates is likely to affect fish and aquatic mammals. To some extent, a reduction in riparian vegetation will reduce the amount of organic material entering the riverine habitat, again reducing food resources for macroinvertebrates. On the other hand, increased tree-fall has the potential to improve the quantity of habitat and resources for macroinvertebrates and larger aquatic biota.

On a broader scale, regional weather patterns (both seasonal and longer-term) will drive changes in most of the interactions already discussed.

10.4 Further interaction assessment

As indicated above and in section 1.1, the Basslink Monitoring Program has neither the resources nor the aim to pursue the investigative research that would be needed to address the full implications of the interactions identified. Nevertheless, a number of the interactions, especially those related to hydrology, water quality and geomorphology need further examination to enable a more-comprehensive statement of pre-Basslink conditions to be made.

Until the completion of the 2003-04 monitoring, there were insufficient data to allow a more in-depth examination of inter-disciplinary interactions. It is questionable whether, with even three years of record, there is a sufficient time series to allow definitive assessment of the interaction effects to be made.

The Basslink Baseline Report is due to be produced as a public document prior to the implementation of Basslink in late 2005. Its scope is to assess all of the information gathered by the Basslink Monitoring Program to date. Based on a minimum of three years of monitoring data, the Basslink Baseline Report will include a comprehensive discussion and examination of interdisciplinary linkages and measured interaction effects.

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