Hydro Tasmania
the renewable energy business

HYDRO ELECTRIC CORPORATION
ABN 048 072 377 158
4 Elizabeth St, Hobart
Tasmania, Australia

Basslink Monitoring Program

Gordon River Basslink Monitoring Annual Report

2002-03

Prepared by

Hydro Tasmania

September 2003

Executive Summary

The Gordon River Basslink Monitoring Annual Report is the primary output from Hydro Tasmania's Gordon River Basslink Monitoring Program. The objective of the report is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program during the 2002-03 reporting year.

2002-03 was the second year of pre-Basslink monitoring. The program will extend the knowledge gained during the 1999-2000 investigative years and the 2001-02 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 2002-03 monitoring are reported in eight sections. Where appropriate, comparisons have been made with the data from the 2001-02 program. Analyses of longer-term trends have not been undertaken because there are presently insufficient data to make such analyses meaningful.

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.

The requirements of the Gordon River Basslink Monitoring Program were successfully met in 2002-03. Additional monitoring was carried out for riparian vegetation, fluvial geomorphology and karst geomorphology.

Hydrology

For 2002-03, power station operation, and hence the downstream hydrological regime, fell into four categories:

- zero discharge (the power station was not operating), from mid-August to late-October 2002;
- operation at intermediate discharges (indicative of two-three turbine operations), from mid-November to December 2002;
- operation essentially at full gate (approximately 250 cumecs ($m^3 s^{-1}$), from January to mid-May 2003; and
- operation less regular and usually at lower discharges, for the remainder of the year.

Analysis of the duration and frequency of shutdown events indicated that these were clustered around 2-7 hour durations. In total, 89 shutdown events were recorded during the year, almost twice as many as 2001-02, but generally of shorter duration. Most of the 40 to 72 hour events were attributable to the power station outages required for this monitoring program.

There were a comparatively large number of short (1-2 hour) operating events, indicated by discharges greater than zero cumecs, as well as those of 16-20 hours duration. This pattern indicates that the power station was operated for relatively short-duration start-ups, day-long operations and, to a lesser degree than 2001-02, for lengthy periods between shutdowns.

Analysis of 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 in the latter half of 2002, and that the downstream river flow matched the power station tailrace discharge pattern closely in the first half of 2003.

The natural flood events raised water levels in the lower Gordon River considerably higher than levels associated with power station discharge. Whereas power station discharge increases water levels by up to 3 m, there were about 20 storm events that increased water level to greater than 4 m, and 5 events which increased level to greater than 6 m at site 44.

The hydrological data indicate that, when the power station was in operation, its discharge was predominant from the power station tailrace to the junction with the Franklin River during periods of low natural inflows,. Tributary streams contributed seasonally variable volumes to this, as well as peak flows during major runoff events.

Water Quality

Water quality parameters were measured in Lakes Gordon and Pedder, and in the Gordon River downstream of the power station.

Due to the complex morphology and bathymetry of Lake Gordon, stratification varied between basins. The deepest profile (intake site, 75-80 m) recorded anoxic conditions in the bottom waters of each quarterly profile. Analysis of stratification versus intake depth showed that the power station was drawing water of 6 - 8 mg l^{-1} dissolved oxygen content during each monitoring event. Lake Pedder remained well mixed during the 2002-03 surveys.

The physico-chemical conditions of Lake Gordon's surface waters were considered normal for lakes in the region, with occasional increased turbidity at some sites. Metals concentrations were similar to those recorded in previous monitoring, and were characterised by aluminium levels that exceeded ANZECC (1992) trigger levels. High levels of dissolved organic carbon, common in west coast lakes, are considered likely to reduce the bioavailability of heavy metals such as aluminium through complexation.

Lake Pedder exhibited natural seasonal variation in surface water quality and levels for all parameters were considered normal for lakes in the region. As in Lake Gordon, total aluminium levels exceeded ANZECC (1992) trigger levels.

In the Gordon River, water temperature was monitored at three sites and dissolved oxygen at a single site. Water temperatures in the river followed a natural seasonal pattern, but diurnal variability was reduced when the power station was operating, due to the effect of the relatively low-temperature tailrace discharge.

Dissolved oxygen concentrations were monitored at the tailrace site, however the record is fragmented due to equipment failure. Dissolved oxygen concentrations did not fall significantly below 6 mg l^{-1} in the available record. During periods of varying power station load, percent oxygen saturation values frequently exceeded 100%, raising the possibility that total gas may also be supersaturated, with possibly detrimental effects on downstream biota. Studies of total gas levels downstream of the power station are planned for 2003-04.

Fluvial Geomorphology

During 2002-03, geomorphic monitoring in the middle Gordon River was conducted on three occasions (October and December 2002, March 2003). Erosion pins and scour chains were measured on all trips, with photo-monitoring completed in March 2003. The October monitoring followed a period of extended power station shut-down, which had been preceded by extensive 3-turbine usage. The December results reflected the re-initiation of limited power station usage (frequent on/off operation of 1 or 2 turbines), with March 2003 following an extended period of high power station usage.

The 2002-03 monitoring year differed from previous years in that there were numerous large winter rain events which occurred during periods of power station shutdown. The natural events delivered sediment to the upper banks of the downstream zones, and eroded the mid-banks. Following the re-initiation of power station operation, erosion was more widespread, and erosion of bank toes was common in Zones 3 - 5, where banks are steepening.

The upstream zones, where unregulated inflows are minor, also experienced deposition during the natural winter flow events, although it was limited to mud and sand deposition near the toe of banks in Zone 1. Following the re-initiation of power station operations, there was no evidence of further mud deposition in Zones 1 or 2.

Consistent with previous monitoring results, the sandy alluvial banks in the middle Gordon were active, with erosion more common than deposition. Erosion pin results indicated that erosion was more prevalent following the re-initiation of power station operation than during the extended shut-down and large winter storm events. Most erosion pin changes were within ±25 mm of the results obtained in March 2002, although changes in excess of 50 mm were also recorded. Cavities in all zones were active, with erosion pin results showing both deposition and erosion.

Photo-monitoring of landslips and tree falls revealed that these features were stable over the year, in spite of high natural inflows and extended power station usage. The most common changes included the establishment or increase of vegetation on the slip face above high water level, and the loss of leaves and small branches from the large woody debris buttressing the bank toe. Photos of river reaches showed a new landslip in Zone 1, and new tree fall in Zone 2.

Mid-stream cobble bars included as photo-monitoring sites also showed no change. The black coating present on vertical cobble banks had increased in coverage between March 2002 and March 2003, suggesting the coating can form on time scales of about 1 year.

Karst Geomorphology

The 2002-03 summer period showed similar sediment transfer patterns in the wet sediment banks of Bill Nielson Cave to those of the previous summer. An additional element this year was the introduction of a layer of fine-grained mud which appears to have come from the Denison River catchment during natural high flow events.

Kayak Kavern recorded significant deposition on top of the silt mound in Kayak Kavern over the winter 2002 period, which coincided with high volume natural flows. In contrast, the summer 2002-03 period was primarily one of erosion. During this period, the power station was operating on irregular loads and, later, at full gate.

Sediment transfer in cave GA-X1 was most pronounced when power station flows were high and fluctuated widely. Erosion took place in GA-X1 over the period while the power station discharge fluctuated and there was limited catchment pickup. Water level monitoring as the power station started up suggests that there may be a significant sediment buffer through which the river water filters before reaching the cave. It is probable that the sediment is supported by surrounding rock, and that the cave may be relatively stable in terms of sediment flux.

Photo-monitoring showed that no major structural change in any of the Gordon-Albert dolines had occurred since the October 2002 monitoring.

Riparian Vegetation

Three riparian vegetation monitoring events were undertaken in 2002-03. These included a summer (December 2002) photo- and seedling monitoring, an autumn (March 2003) species cover and seedling monitoring and an additional trip in October 2002 to re-assess sites in Zone 5.

Previously described patterns of stratification within the sites on the Gordon River continued to be the dominant feature of the riparian vegetation. Generally, there was a decreasing area of bare ground with increasing distance up the bank, and an increase in overlapping vegetation cover. There was little variation in the species cover data between the summer and autumn sampling periods.

Seedling recruitment varied greatly between sampling periods, most noticeably between summer and autumn. In general, all zones within the Gordon River recorded an increase in the average number of seedlings in the December (summer) monitoring trip.

Macroinvertebrates

Macroinvertebrates were monitored in spring 2002 and autumn 2003 at nine sites in the Gordon River between the Gordon Power Station and the Franklin River confluence. Six reference sites were monitored in the Franklin, Denison, Maxwell and Jane Rivers at the same time.

Quantitative data from surber samples showed that the trend of increasing number of taxa and total abundance with distance downstream from the power station, that had been apparent in previous years, was not evident in 2002-03. For the Gordon River sites, the number of taxa were consistently low at site 75 (approximately 2 km downstream from the power station), while the remainder showed more variation between seasons than between sites. In the spring 2002 monitoring, sites 69 and 60 recorded similar numbers of taxa as the reference sites. In the autumn 2003 monitoring, after a prolonged period of high volume power station discharges, all Gordon River sites recorded lower abundance and number of taxa than did reference sites. For both number of taxa and total abundance, there was no apparent difference between sites upstream and downstream of the Denison junction.

Rapid bioassessment (RBA) data allow the calculation of a ratio of observed taxa and expected taxa (O/E) at a particular site. The O/E values, calculated using both combined season and individual season models followed similar trends to previous years. Reference site values generally fell at the upper bounds for the reference band (A) and above (X), while test sites recorded values in bands A and B. Site 75 recorded two single-season values in the C band.

Statistical analyses (paired t-tests) of O/Epa and O/Erk values for all sites did not suggest any significant changes between this survey and those conducted in 1998-99 or 2001-02.

Algae

Benthic algae were sampled in spring 2002 and autumn 2003 at nine sites in the Gordon River between the Gordon Power Station and the Franklin River confluence.

Overall aquatic algal and plant cover was low, and decreased with distance downstream from the Gordon Power Station, with a marked drop in percent cover downstream of the Denison River junction. Characeous algae were only observed at sites 74 and 72, while macrophytes were recorded only at site 72. There were no substantial differences in overall cover between years, although percent moss cover was lower, at most sites, in 2002-03 than in 2001-02.

Fish

Monitoring of the fish populations of the middle Gordon River, its tributaries, and out-of-catchment reference sites was conducted in December 2002 and March 2003.

Brown trout and short-finned eels remained the most widespread species in the Gordon River and tributary zones and at the reference sites. The March 2003 survey recorded the highest number of redfin perch captured since they first appeared in the Gordon River in December 2001. While catches appear to be increasing, the size range of redfin appears to be relatively stable with the majority of fish less than 200 mm in length.

The Gordon River appears to provide a significant recruitment opportunity for pouched lamprey, as captures of ammocetes and, to a lesser extent, macrophthalmia stages were significant during the 2002-03 monitoring. Reference streams in the Henty and Birches inlet catchment also returned moderate catches of this species.

Galaxiid catches in the Gordon River were similar to previous surveys, with little change in distribution.

The results of the monitoring to date indicate that fish stranding following power station shut-down was not common, and was most likely to occur at site 72 due to its network of backwaters and shallow channels and pools.

Contents

1 Gordon River Basslink Monitoring Annual Report

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 2002-03. The report is to be submitted to the Minister administering the *Water Management Act 1999* (Tasmania) and the Commonwealth Environment Minister. It will also be made available as a public document.

The Gordon River Basslink Monitoring Program was incorporated into Hydro Tasmania's Special Water Licence by a Deed of Amendment in 2002. The work carried out in 2002-03 fulfilled the requirements of the monitoring program, which are specified in Schedule 3, Part 2 of the Deed of Amendment.

1.1 The Monitoring Program

The Gordon River Basslink Monitoring Program for 2002-03 completed the second year of pre-Basslink monitoring. The program aims to extend the knowledge gained about the middle Gordon River environment during the 1999-2000 investigative years (see Locher 2001), and the 2001-02 Gordon River Basslink Monitoring Annual Report (Hydro Tasmania 2002).

As well as operating the two required monitoring trips per year for each discipline, additional monitoring was carried out for riparian vegetation (October 2002) and fluvial geomorphology (December 2002). The karst geomorphology team undertook additional monitoring in the Gordon-Albert karst area in order to observe conditions in cave GA-X1 following a power station start-up.

1.2 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 only 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. During 2002-03, poor weather and system constraints meant that the planned outages in December 2002, March and April 2003 needed to be rescheduled.

1.3 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 by Hydro Tasmania. 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.

1.4 Document structure

This document is the second of the Gordon River Basslink Monitoring Annual Reports to be produced, and is organised into ten sections plus an executive summary, as was the 2001-02 report.

This first section discusses the requirements and some of the operational considerations and constraints of the program. Sections 2 - 9 report on the monitoring work which was undertaken during 2002-03, 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 2002-03 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 lists the reference material used in this document.

1.5 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, Greg Carson and Greg Vinall.

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 Bryce Graham (Hydro Tasmania) and Lois Koehnken (Technical Advice on Water)
3	Water quality	David Andrews and Chris Bobbi (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 and Mel Ellis (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 Site numbers

Throughout this report, monitoring locations are identified by site number. These represent the approximate distance upstream from the Gordon River mouth at Macquarie Harbour. The monitoring work is conducted between sites 39 (immediately downstream of the Franklin River junction, and 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 their point. 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. The potential for changed hydrology 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 Gordon River environment.

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 2002-03 period.

2.1 Site Locations

The seven gauging stations used to record river levels during 2002-03 are shown in Figure 2.1. These were sites 39, 44, 62, 69, 71, 75 and the Gordon Power Station. Figure 2.1 also indicates a monitoring location at site 65. The gauging station has yet to be installed at this site.

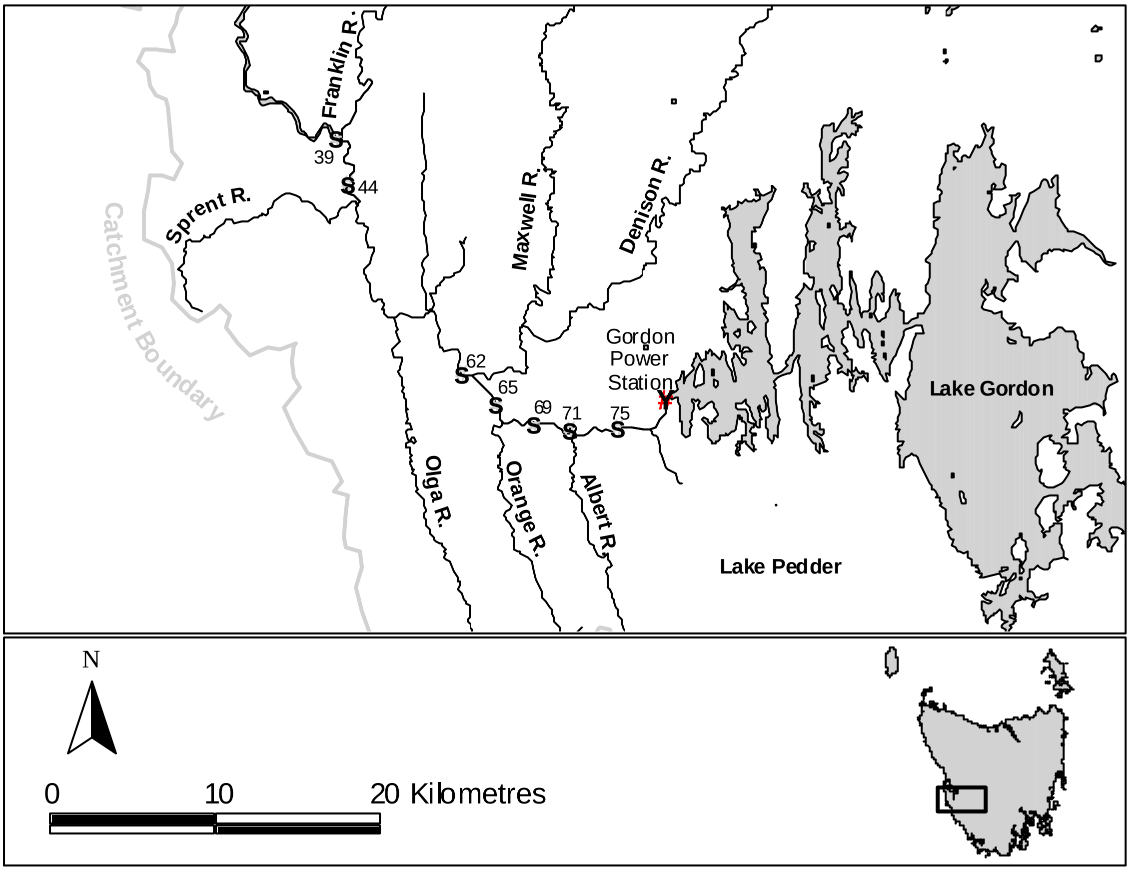


Figure 2.1 Location of the water level recorders in the middle Gordon River.

2.2 Gordon Power Station discharge

2.2.1 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 2002-03, the shutdown events were clustered around 2-7 hour durations. Figure 2.2 shows the frequency and duration of these event. In total, 89 shutdown events were recorded during the year, almost twice as many as 2001-02, but generally of shorter duration. Most of the 40 to 72 hour events were attributable to the power station outages required for the Basslink monitoring program.

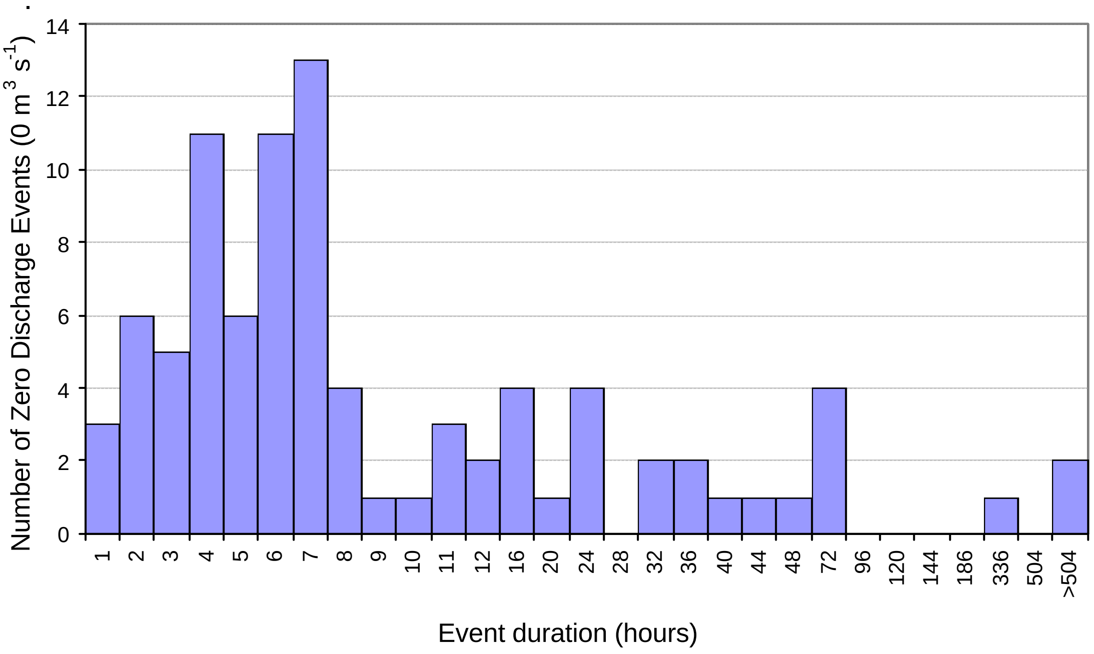


Figure 2.2. Frequency and duration of zero discharge (shutdown) events recorded for the Gordon Power Station during 2002-03.

The number of operating events, indicated by discharges greater than zero cumecs ($m^3 s^{-1}$), is shown in Figure 2.3. This figure indicates that there were a comparatively large number of short (1-2 hour) events, as well as those of 16-20 hours duration. This pattern tends to indicate that the power station was operated for relatively short-duration start-ups, day-long operations and, to a lesser degree than in 2001-02, for lengthy periods between shutdowns.

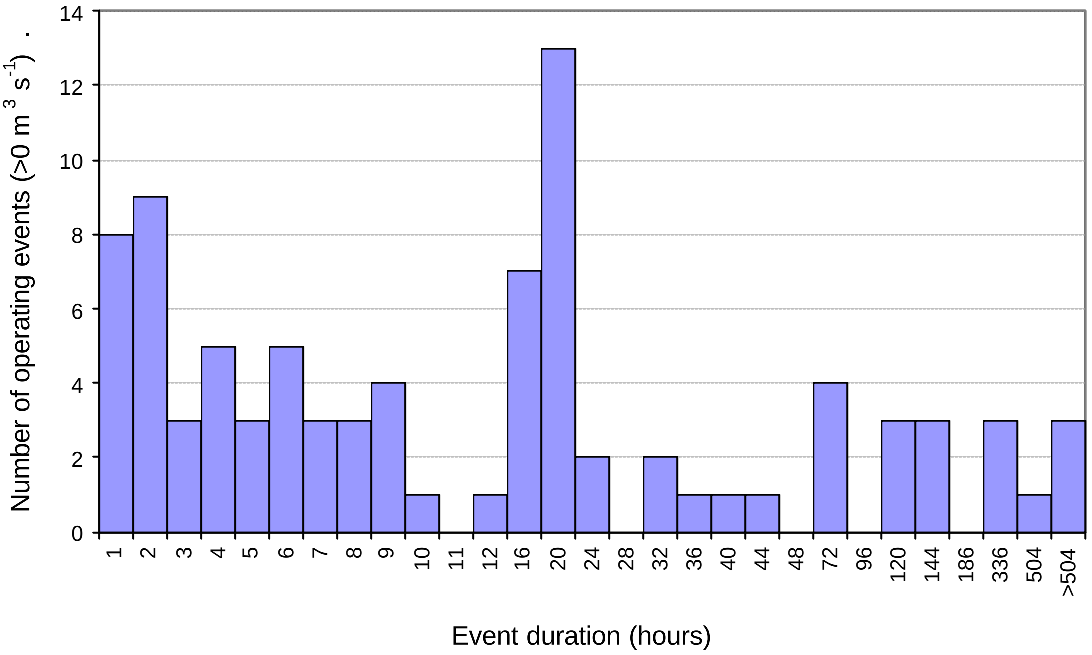


Figure 2.3. Frequency and duration of operating (discharge > zero) events recorded for the Gordon Power Station during 2002-03.

2.2.2 Discharge

Figure 2.4 shows the time series plot for discharge from the power station tailrace. It indicates that, from mid-August to late-October 2002, the power station was not operating (zero discharge). From January to mid-May 2003, it operated essentially at full gate (approximately 250 cumecs). From mid-November to December 2002, the power station operated at intermediate discharges, indicative of two-three turbine operations. For the remainder of the year, the power station operated more intermittently.

Compared with recent years (Table 2.1), discharge from the Gordon Power Station was more bi-modal, with the station either discharging <150 $m^3 s^{-1}$ or greater than 210 $m^3 s^{-1}$ for 89% of the time. The high percentage of low flow (<150 $m^3 s^{-1}$) is attributable to the August - October power station shut-down.

Table 2.1. Percent of time discharge at Gordon Power Station was less than 2 turbines (<150 $m^3 s^{-1}$), 3-turbines (>170 $m^3 s^{-1}$), and greater than 3-turbines efficient load (>210 $m^3 s^{-1}$), based on hourly flow records.

Year	<150 $m^3 s^{-1}$	>170 $m^3 s^{-1}$	>210 $m^3 s^{-1}$
2000	51	44	32
2001	39	49	20
2002	57	39	32

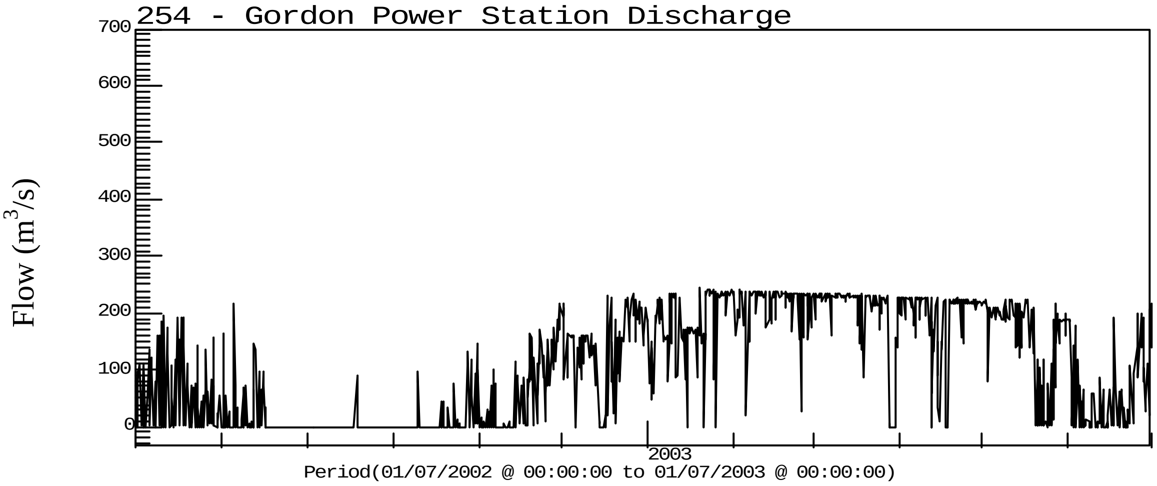


Figure 2.4. Tailrace discharge from the Gordon Power Station during 2002-03.

2.2.3 Median monthly discharge

Figure 2.5 shows the median monthly discharge from the power station for 2002-03 compared with long-term values (since August 1996). This figure illustrates that, for the last six months of 2002, the power station was run on lower loads than has been the historic norm. For 2003, the power station was run at similar loads to historic ones, with somewhat higher loads in February and March. These latter high loads were due to dry weather elsewhere in the state and other system constraints, which necessitated full-gate operation of the power station. In June 2003, heavy rainfall in the northern part of the state meant that the Gordon Power Station was less frequently used.

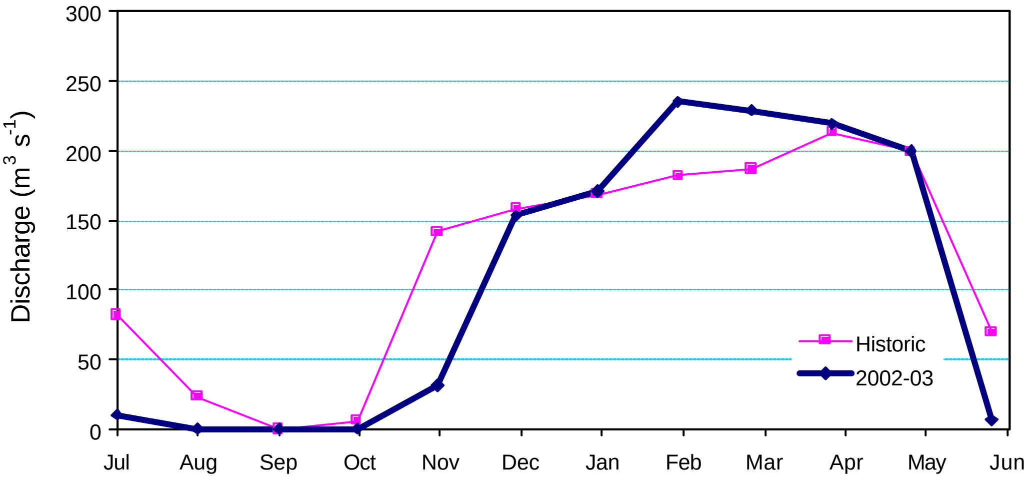


Figure 2.5. Median monthly discharge from the tailrace of the Gordon Power Station for 2002-03.

2.2.4 Duration curves

Figure 2.6 shows the duration curve for the power station tailrace discharge for 2002-03, as well as the historic (since 1996) duration curve. This year's curve shows the characteristic bulges and inflection points associated with the operation of two (160 $m^3 s^{-1}$), or three (240 $m^3 s^{-1}$) turbines, and of the standby mode of operation (about 10 $m^3 s^{-1}$).

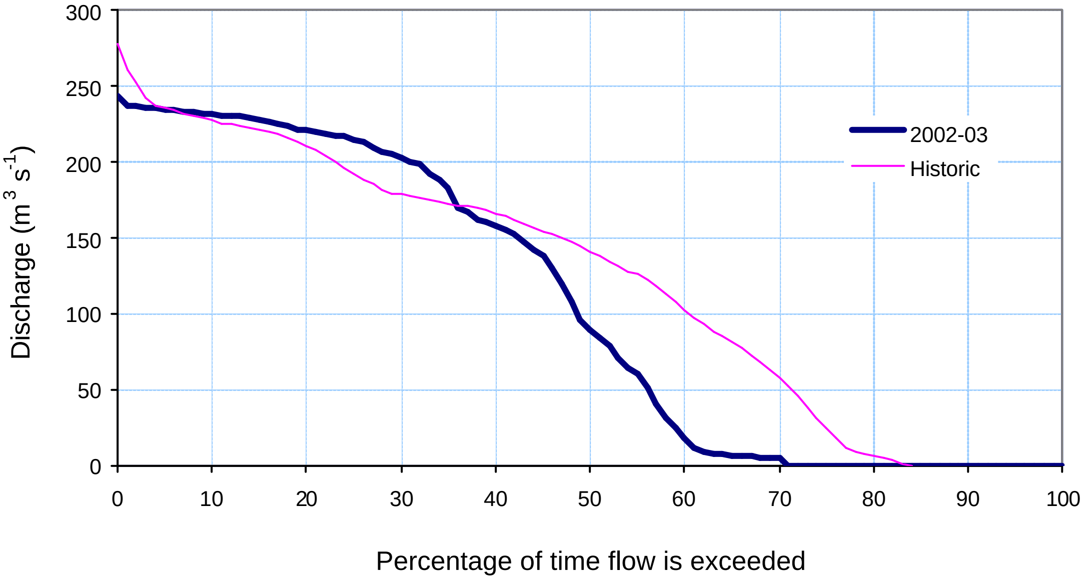


Figure 2.6. Duration curve for discharge from the power station tailrace for 2002-03.

2.3 Gordon River downstream of the power station

A number of stream gauging sites have been established on the Gordon River downstream of the power station (Figure 2.1). 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. It also captures the discharge from a number of significant tributaries, including the Albert, Orange, Denison, Maxwell, Olga and Sprent Rivers. It does not include information about 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.

2.3.1 Flow

Figure 2.7 shows the time series plot for flow at site 44 for 2002-03. The power station discharge pattern (see Figure 2.4) remains discernable, especially during the late summer - autumn 2003 period. Over this is superimposed the discharge pattern from tributary streams, such as the Denison River, giving the high peak discharges evident in Figure 2.7. Peak flows occurred regularly through the latter six months of 2002, and in March, April and June 2003.

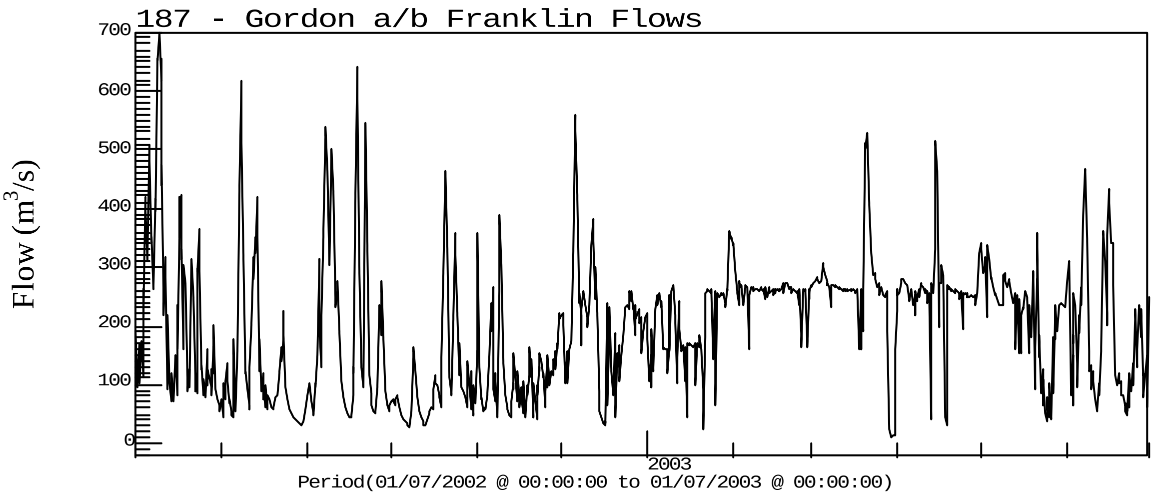


Figure 2.7. Flow recorded at site 44 (Gordon above Franklin) during 2002-03.

The winter high flow events raised water levels in the lower river considerably higher than levels associated with power station discharge, as shown in Figure 2.8. Whereas power station discharge increases water levels to approximately 3 m, there were about 20 storm events that increased water levels to greater than 4 m, and 5 events which increased levels to greater than 6 m.

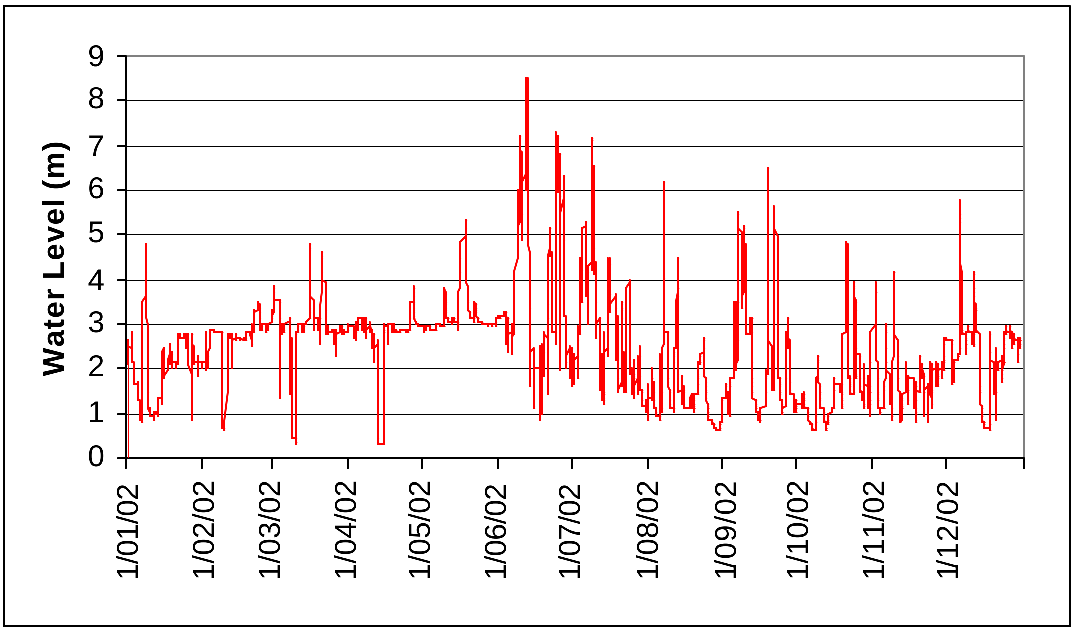


Figure 2.8. Water level (hourly) in the Gordon above Franklin site (site 44).

2.3.2 Median monthly flows

The peaks in the discharge data for site 44 (Figure 2.7) are also reflected in the median monthly discharge. Figure 2.9 shows the median monthly discharge for this site over 2002-03, compared with the historic (since 2000) pattern. It indicates that discharge at the downstream end of the study area was not greatly different from previous years. Comparison with the median values for the Gordon Power Station (Figure 2.5) show that natural discharge from tributary streams tended to dominate the pattern in the latter part of 2002, while the power station discharge has tended to dominate the pattern in the first half of 2003.

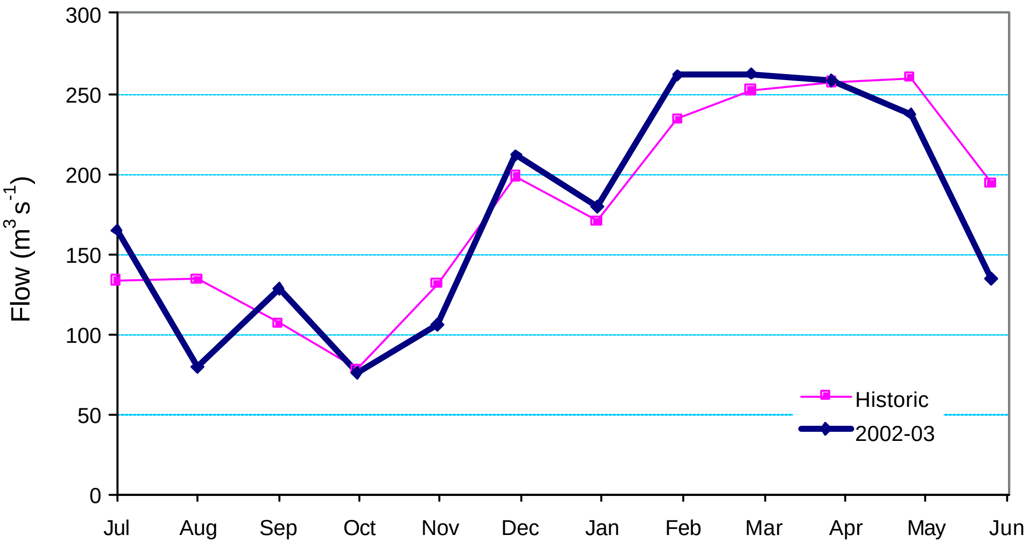


Figure 2.9. 2002-03 and historic median monthly discharges at site 44 (Gordon above Franklin).

2.3.3 Duration curves

Figure 2.10 illustrates the duration curve for Gordon River site 44 (upstream of the Franklin River) for 2002-03 and compares it with the historic (since 2000) record. It shows that, for this year, site 44 recorded slightly lower discharge from 0 to the 15th percentile, and from the 55th to the 80th percentile.

Comparison with the flow duration curve for the power station (Figure 2.6) shows the effect of the natural inflows (0-10th percentile) as well as the effect of the power station (20-70th percentiles, and natural baseflows (>70th percentile).

2.4 Conclusion

For 2002-03, power station operation, and hence the downstream hydrological regime, fell into four categories:

- zero discharge (the power station was not operating), from mid-August to late-October 2002;
- operation at intermediate discharges (indicative of two-three turbine operations), from mid-November to December 2002;
- operation essentially at full gate (approximately 250 cumecs ($m^3 s^{-1}$), from January to mid-May 2003; and
- operation less regular and usually at lower discharges, for the remainder of the year.

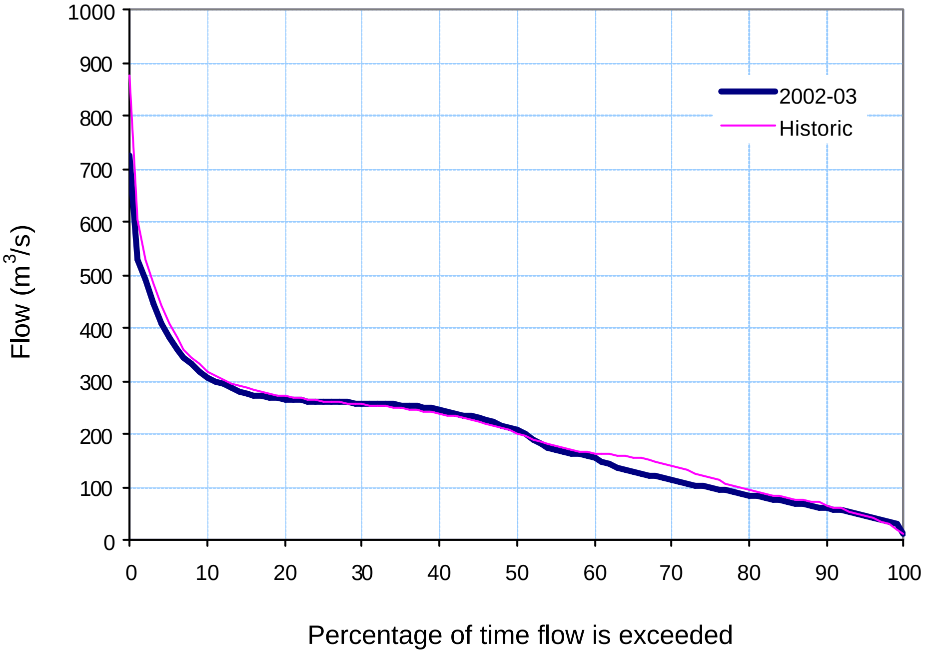


Figure 2.10. Duration curves for the Gordon above Franklin site (site 44) for 2002-03 and historic (since 2000).

Analysis of the duration and frequency of shut-down events indicated that there were almost twice as many as 2001-02, but generally they were of shorter duration. Most of the 40 to 72 hour events were attributable to the power station outages required for this monitoring program. In terms of operating events, the power station was operated for relatively short-duration start-ups, day-long operations and, to a lesser degree than 2001-02, for lengthy periods between shutdowns.

The furthest-downstream gauging site that is independent of tidal influences, the Gordon above Franklin (site 44), was used to compare discharge patterns. The data from this site showed that the flow pattern matched the power station tailrace discharge pattern closely in the first half of 2003, but that natural high volume flow events originating in tributary streams were relatively common in the latter half of 2002. This pattern was also evident in the median monthly flow pattern. The duration curve for site 44 mirrored the tailrace pattern from the 10th to the 70th percentiles, with the inclusion of flood flows forming the lower percentile values (0 - 10), and natural baseflow at the higher percentile values (70 - 100).

The hydrological data indicate that, when the power station was in operation, its discharge was predominant during periods of low natural flow, from the power station tailrace to the junction with the Franklin River. Tributary streams contributed 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.

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 intervals at each of the nominated depth profile sites in Lakes Gordon and Pedder. The water quality monitoring sites are shown in Figure 3.1.

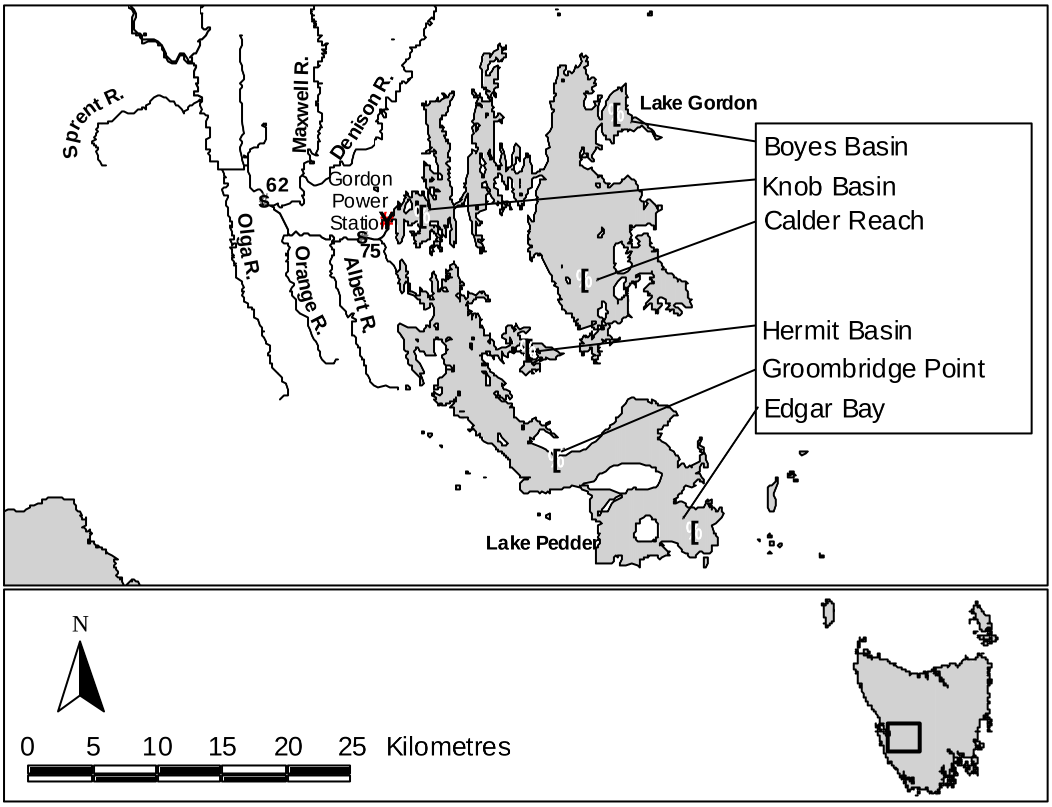


Figure 3.1. Map of the locations of water quality monitoring sites in Lakes Pedder and Gordon, and the Gordon River.

3.2 Water Quality of Lake Gordon

3.2.1 Site locations

During 2002-03, Lake Gordon water quality data were collected quarterly at the power station intake (Knob Basin), at Calder Reach and at Boyes Basin near the upper Gordon River inflow (see Figure 3.1). At these three locations, depth profiles of water temperature, dissolved oxygen, pH and conductivity were taken. Turbidity depth profiles were also collected. Surface samples for laboratory analysis of chlorophyll-a, nutrients, metals, sulphate, alkalinity and dissolved organic carbon were also collected at these locations.

3.2.2 Characteristics of stratification

Due to the complex morphology and bathymetry of Lake Gordon, stratification varied between basins. Figure 3.2 shows the dissolved oxygen profiles (absolute and percent saturation values) for Boyes Basin, Calder Reach and the power station intake. Figure 3.3 shows the profiles for water temperature and pH, while Figure 3.4 shows the profiles for conductivity and turbidity at each of the three sites. The complete suite of quarterly profile data were only available for the power station intake. The August 2002 profile data were not taken at Boyes Basin or Calder Reach due to operator error.

3.2.2.1 Boyes Basin

Boyes Basin is the shallowest of the three monitoring sites, and closest to one of the major inflows into the lake, the upper Gordon River. The profiles showed distinct seasonal changes in depth profiles.

Surface water temperatures were coolest in August 2002 at around 8°C, and by October the lake had warmed several degrees and was showing little difference in dissolved oxygen and temperature with depth. Temperatures peaked at approximately 22°C in the February 2003 sample, with profiles showing a gradual decline in temperature and dissolved oxygen with depth, but lacking a distinct thermocline. Dissolved oxygen levels fell to around 1 mg l^{-1} at the bottom of the February profile, the lowest for all surveys at this site during 2002-03. The February conductivity profile was unusual, showing a sharp increase between 5 m and 15 m depth. The cause of this is not known.

Profiles collected in May 2003 showed evidence of underflow activity at 15 m, which was reflected in a 2 mg l^{-1} increase in dissolved oxygen and to a lesser extent, pH, coincident with a sharp 4°C decrease in temperature at this depth. These signals may mark the occurrence of inflowing water from the upper Gordon River.

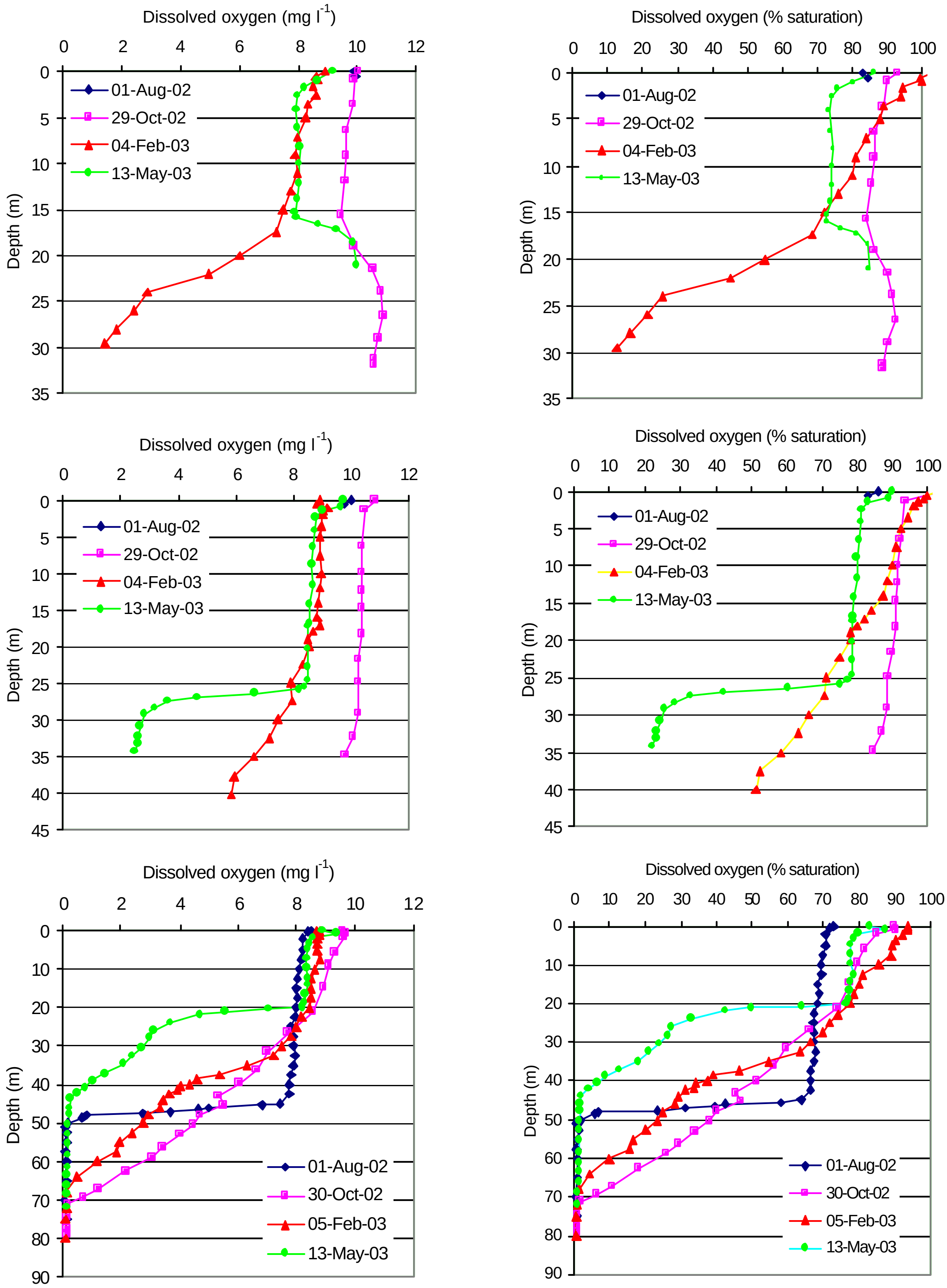


Figure 3.2. Depth profiles of dissolved oxygen at Boyes Basin (top plots), Calder Reach (middle plots) and at the power station intake (bottom plots) recorded between August 2002 and May 2003.

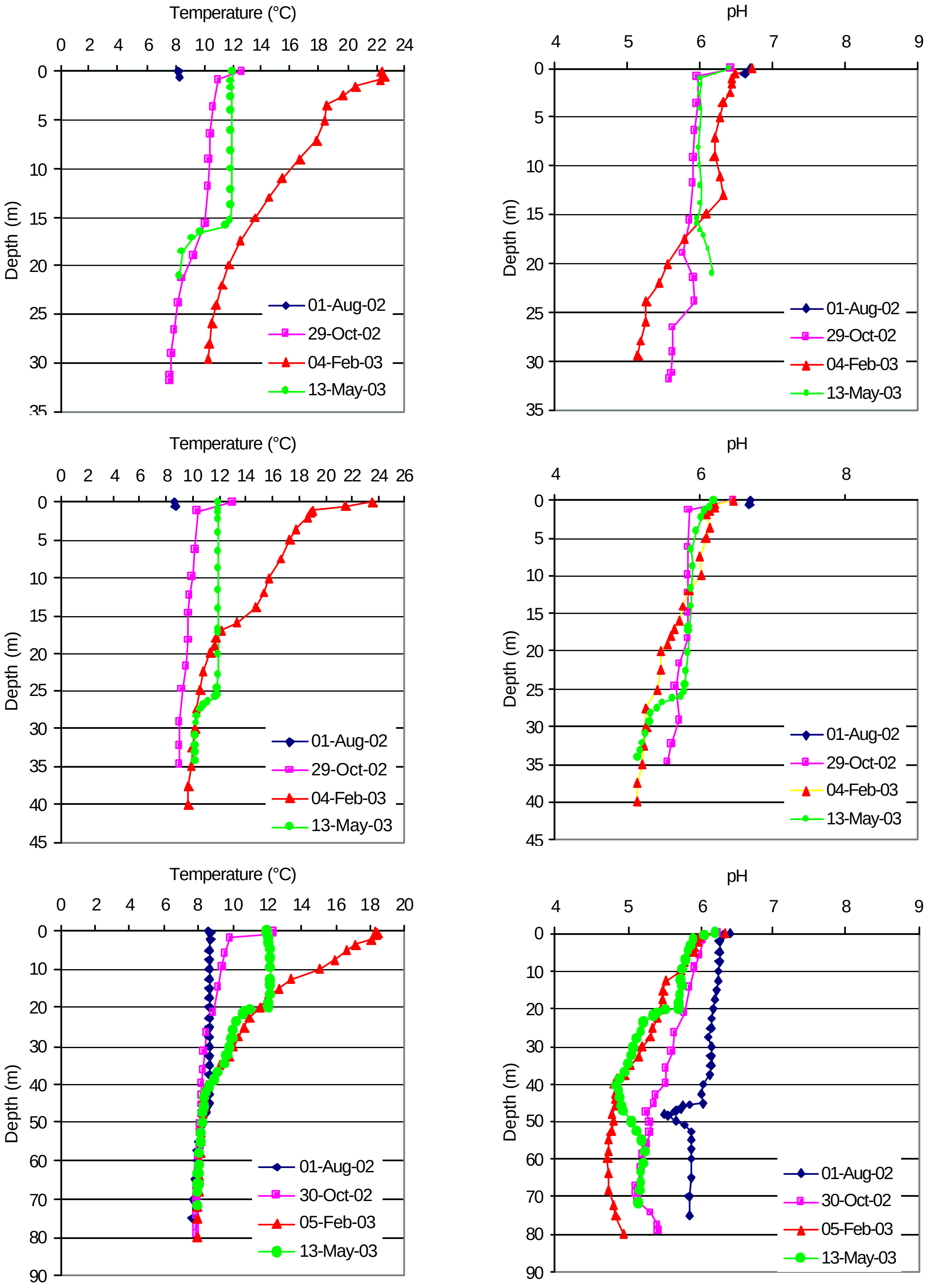


Figure 3.3. Depth profiles of temperature (left) and pH (right) at Boyes Basin (top plots), Calder Reach (middle plots) and at the power station intake (bottom plots) recorded between August 2002 and May 2003.

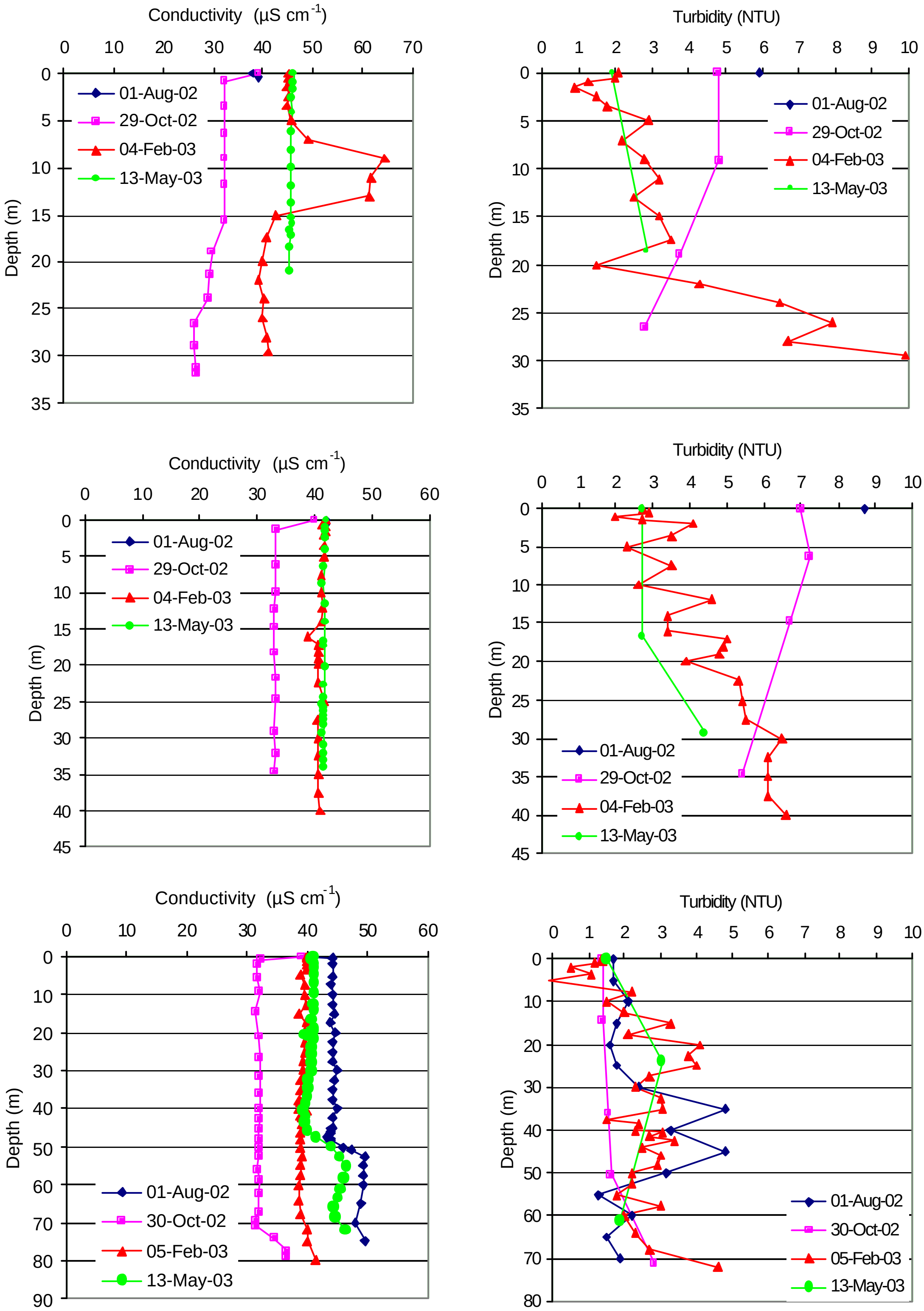


Figure 3.4. Depth profiles of conductivity (left) and turbidity (right) at Boyes Basin (top), Calder Reach (middle) and the power station intake (bottom) recorded between August 2002 and May 2003.

3.2.2.2 Calder Reach

Profiles taken at Calder Reach varied between approximately 35 m and 41 m in depth. The profile collected in late October 2002 showed little change in dissolved oxygen and temperature with increasing depth. Surface temperature was approximately 11°C, which decreased to a little below 10°C at the bottom of the profile.

The February 2003 profiles indicated the beginning of stratification at this site. Dissolved oxygen levels fell from 9 mg l^{-1} at the surface to around 6 mg l^{-1} at the base of the profile, while water temperature fell from 24°C at the surface to 9°C. pH also declined gradually with depth.

Profile data collected in May showed the occurrence of a small thermocline at approximately 26 m which corresponded with a distinct oxycline where dissolved oxygen levels fell from 8 mg l^{-1} to 2 mg l^{-1}. A small decrease in pH was also observed over the thermocline, however conductivity remained constant. Surface turbidity levels approached 9 NTU in August 2002, which is particularly high for Lake Gordon. Turbidity was lower in October 2002 and declined further in February and May 2003.

3.2.2.3 Power station intake (Knob Basin)

The intake is the deepest of the three Lake Gordon monitoring sites, and profiles collected from here were influenced by the steep-sided morphology of the basin. Profiles ranged between 75 m and 80 m in depth.

Profiles collected in August 2002 showed little temperature stratification but a distinct oxycline was apparent at around 50 m depth. At this depth, dissolved oxygen levels dropped from 8 mg l^{-1} to virtual anoxia within a few metres. The same depth was marked by a distinct undulation in pH and a 5 µS cm^{-1} increase in conductivity.

Profiles collected in October 2002 and February 2003 showed similar trends in dissolved oxygen, with levels gradually falling to anoxia at 70 m. The temperature profiles showed that February's water temperatures gradually declined with depth, falling from 18°C to 8°C over the profile, while the October temperature profiles showed a reduced range, varying between 12°C at the surface to 8°C at the bottom of the profile.

A distinct, 2°C thermocline was apparent at 20 m during May 2003. Dissolved oxygen levels were reduced below this depth, approaching anoxia at around 42 m. pH exhibited a small but sharp decrease adjacent to the thermocline, and both conductivity and, to a lesser extent, pH increased below 50 m. Such increases in conductivity are commonly associated with anoxia and increased concentrations of dissolved metals in the bottom of the profile.

The turbidity profile data showed that turbidity levels were low, particularly in comparison to the shallower survey sites, and reflected the sheltered, steep-sided position of this deep site.

Figure 3.5 shows dissolved oxygen concentrations adjacent to the power station intake between January 2001 and May 2003. The oxygen content of water being drawn into the power station was generally within the range of 6 - 8 mg l^{-1}, but dropped below 6 mg l^{-1} on several occasions, particularly at higher lake levels. These data suggest that the water being discharged from the power station during that period was likely to have contained sufficient oxygen to present no significant risk to in-stream biota in the Gordon River downstream. Low lake levels appear to reduce the risk of entrainment of anoxic water, while the converse applies at high lake levels.

Profile data collected in May 2003 show that the oxycline was adjacent to the intake, indicated by the convergence of the 6 mg l^{-1} and 8 mg l^{-1} strata at the intake level.

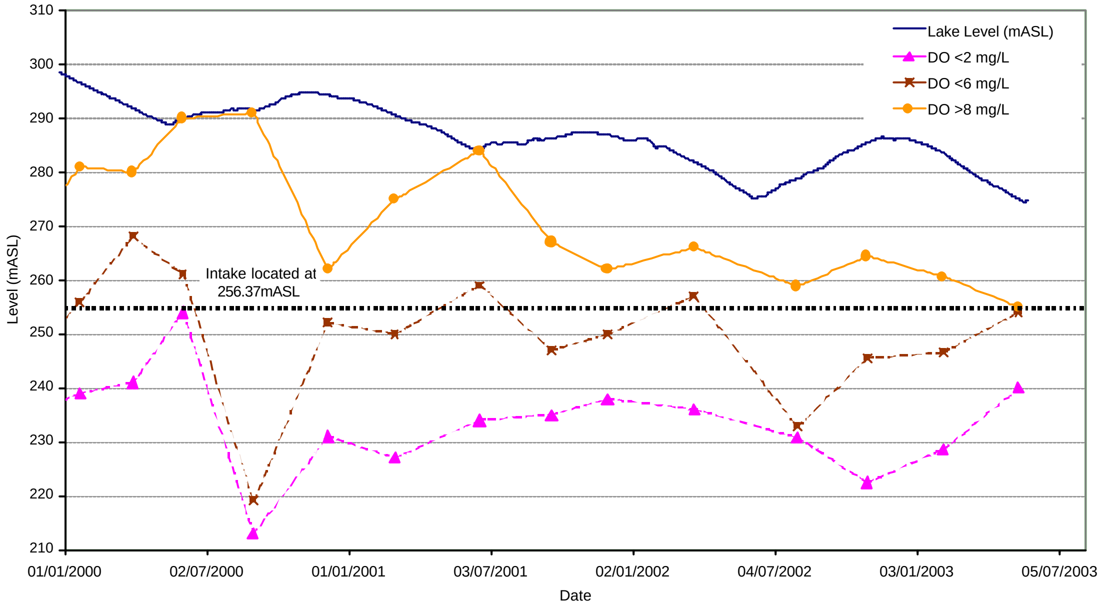


Figure 3.5. Dissolved oxygen profile characteristics in relation to lake levels meaured at the Lake Gordon power station intake site between January 2000 and May 2003.

3.2.3 Surface water characteristics

The surface water quality data from Lake Gordon are summarised graphically in Figure 3.6 and Figure 3.7. For the purposes of this report, all surface water data from the three sites on Lake Gordon have been pooled and plotted in the form of a box plot. In this graphical technique, the boxes represent the middle 50% of the data, with the horizontal line intersecting the box indicating the median (or 50th percentile) value. The vertical bars extend out to show the 95th and 5th percentile values and individual dots show outliers.

The summary plots show that surface water quality in Lake Gordon is within the expected range for Tasmanian fresh waters in the State’s western region, with good surface oxygen concentrations, reasonably low turbidity and nutrient levels, and slightly acidic pH. The turbidity summary statistics indicate that although the majority of the data were indicative of a low turbidity system, there were periods when turbidity approached 10 NTU. Calder Reach recorded incidents of turbidity >7 NTU during two of the four quarterly sampling events. Chlorophyll-a levels remained reasonably low and would have had only a minor influence on turbidity levels.

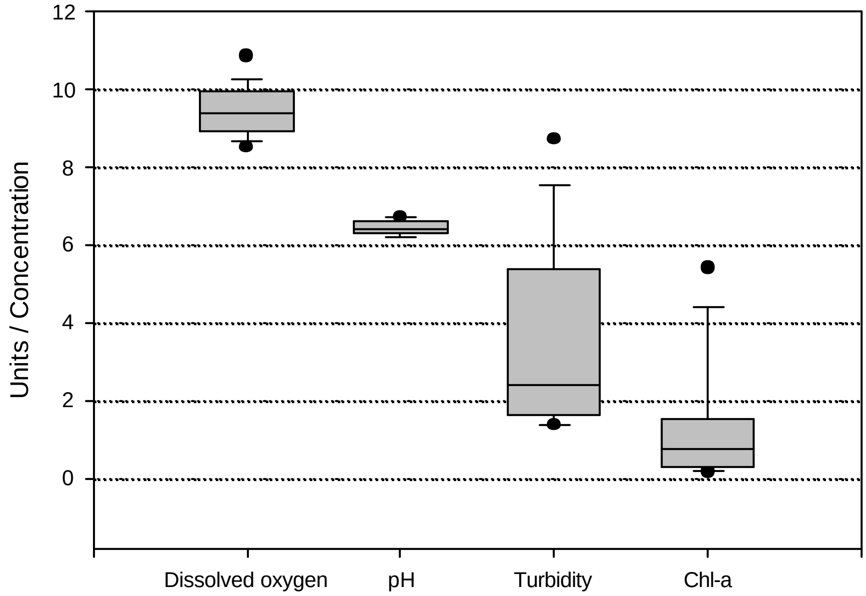


Figure 3.6. Boxplots summarizing the pooled data from the Lake Gordon surface water monitoring sites. Units for dissolved oxygen are mg l^{-1}; for turbidity, NTU and for chlorophyll-a, µg l^{-1}. pH is unitless.

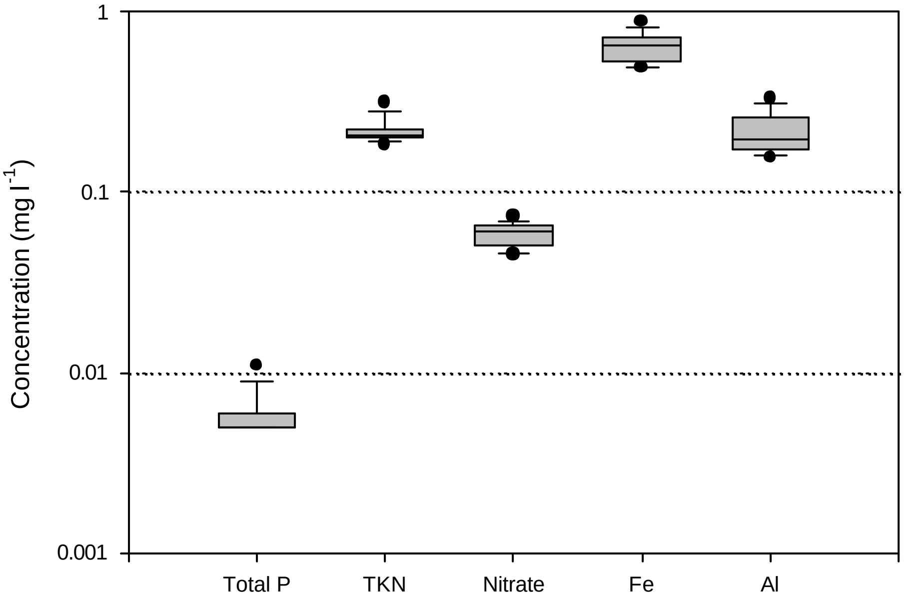


Figure 3.7. Boxplots summarizing the pooled nutrient and metals data from the Lake Gordon surface water monitoring sites. (Note: logarithmic scale).

Iron and aluminium were the only metals detected in concentrations that were significantly above laboratory detection limits (Figure 3.7). The concentrations of these two metals in Lake Gordon were similar to those reported in the 2001-02 Gordon River Basslink Monitoring Annual Report, and were consistent with concentrations found in other Tasmanian organic-rich west coast lakes. Total iron levels were below the ANZECC (1992) trigger level of 1 mg l^{-1}. Although the aluminium levels exceed the ANZECC (1992) guideline concentration for the protection of aquatic ecosystems (<0.1 mg l^{-1} for freshwater at pH <6.5), it is recognized that the presence of higher concentrations of dissolved organic carbon (DOC) in Lake Gordon is likely to complex with such metals and greatly reduce their bioavailability and toxicity (Koehnken 1992). Note that the ANZECC 1992 guidelines are used here because they list an empirical value as a guide. Later guidelines (ANZECC 2001) move beyond this approach and recommend the development of trigger levels based on local data. The development of local trigger values has not yet occurred for these lakes.

Analysis showed that most of the remaining heavy metals (Cu, Cd, Co, Cr, Ni and Pb) were present at or below the limit of detection (0.005 - 0.001 mg l^{-1}). Manganese levels peaked at 0.027 mg l^{-1} in Lake Gordon in the intake site in August 2002. Manganese levels in subsequent samples from the lake were well below this, and the reasons for this isolated spike are not clear. Zinc levels temporarily rose above the ANZECC (1992) guideline value of 0.005 mg l^{-1} in the August 2002 sample collected from Calder Reach (0.017 mg l^{-1}), but fell below the guideline value on all subsequent samples. The elevated zinc value corresponded to high turbidity levels at this site (9.4 NTU) and so it is possible that disturbed particulate matter may have caused a temporary increase in zinc levels.

Mean values and concentration ranges for alkalinity, sulphate and dissolved organic carbon in Lake Gordon are show in Table 3.1 below, and are within the normal range for waters on the west coast of Tasmania.

Table 3.1. Mean values and concentration ranges for alkalinity, sulphate and dissolved organic carbon in surface waters of Lake Gordon.

	Alkalinity (mg l^{-1})	**Sulphate (mg l^{-1})**	**Dissolved Organic Carbon (mg l^{-1})**
Lake Gordon	8.75 (8.0 – 11.0)	1.08 (0.7 - 2.3)	6.18 (5.2 - 8.0)

3.3 Water Quality of Lake Pedder

3.3.1 Lake Pedder

Quarterly depth profile data were taken off Groombridge Point (Figure 3.1). Surface water samples (chlorophyll-a, water temperature, pH, conductivity, turbidity and dissolved oxygen) were recorded at Groombridge Point, Hermit Basin and Edgar Bay, while samples for laboratory analysis (nutrient, metals, sulphate, dissolved organic carbon and alkalinity) were collected at Groombridge Point.

3.3.2 Characteristics of stratification

Quarterly profile data are shown in Figure 3.8, including dissolved oxygen, temperature, pH, conductivity and turbidity. These were collected between August 2002 and May 2003.

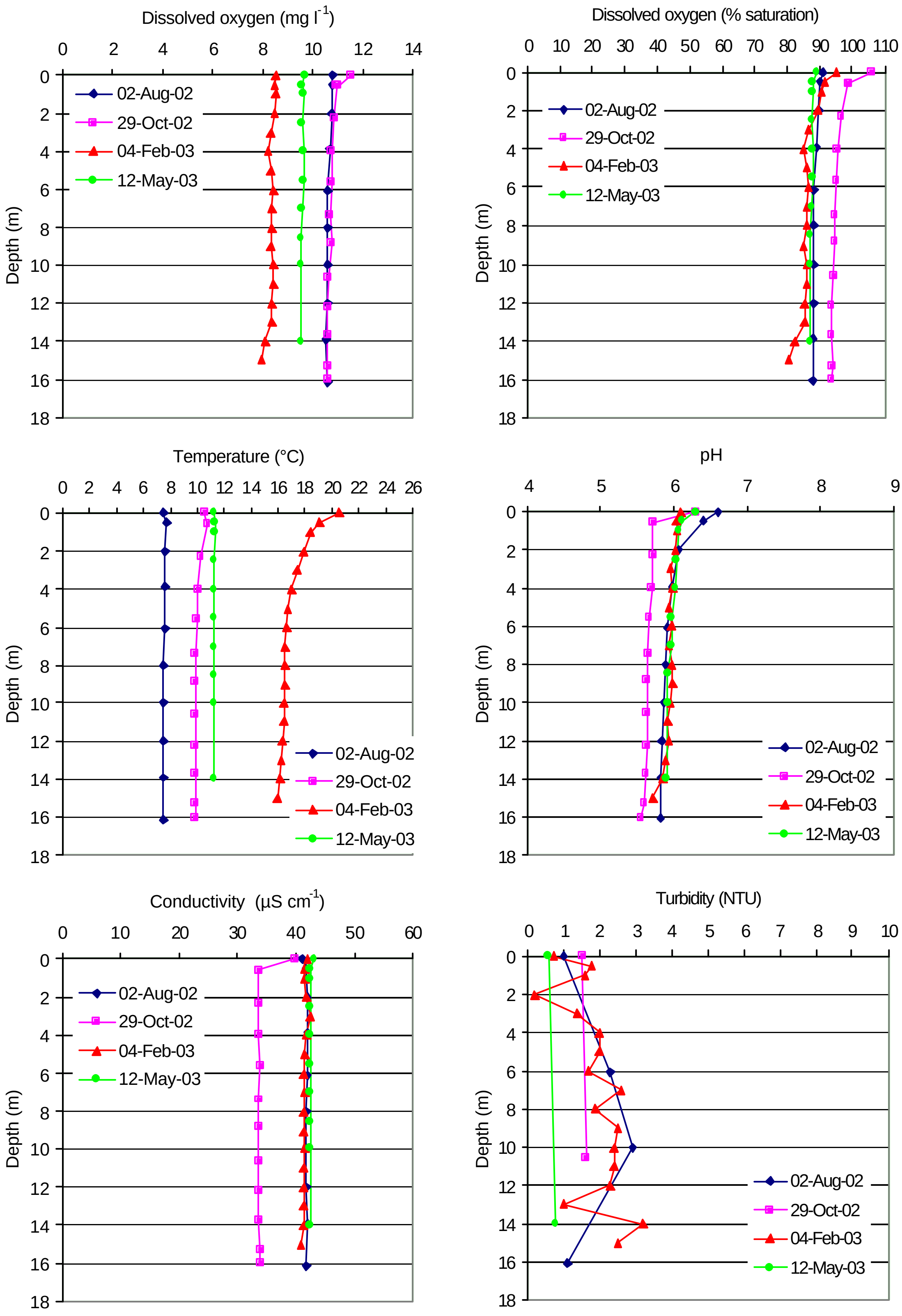


Figure 3.8. Depth profile characteristics in Lake Pedder off Groombridge Point recorded between August 2002 and May 2003.

The lake is relatively shallow, and profiles ranged between 14 m and 16 m in depth. The profiles were unremarkable, as the lake was well mixed due to its shallow depth, large exposed reaches and long fetch. Temperature and dissolved oxygen levels showed natural seasonal variation, but little change with depth. The turbidity profiles indicated that turbidity levels in the lake were low.

3.3.3 Surface water characteristics

The surface water quality data collected from sites in Lake Pedder are summarised graphically in Figure 3.9 and Figure 3.10.

Summary statistics for the data show that water quality in Lake Pedder was good, with natural seasonal variation in surface oxygen concentrations, and low turbidity and chlorophyll-a levels at all three monitoring sites. pH levels in the lake were slightly acidic, which is normal for lakes and rivers situated in the west coast region of Tasmania.

The nutrient and metal concentrations measured in Lake Pedder during 2002-03 were very similar to those recorded during the 2001-02 monitoring, and again total phosphorus and TKN levels were low. With the exception of total iron, total aluminium, and to a lesser extent, total zinc, metal concentrations were at or below laboratory detection limits. Total iron levels were above detection limits but well below the ANZECC (1992) guideline level of 1 mg l^{-1}. Total aluminium levels exceed the ANZECC (1992) guideline concentration. Zinc levels temporarily rose above the ANZECC (1992) trigger level of 0.005 mg l^{-1} in the August 2002 sample, but fell below this trigger on subsequent samples.

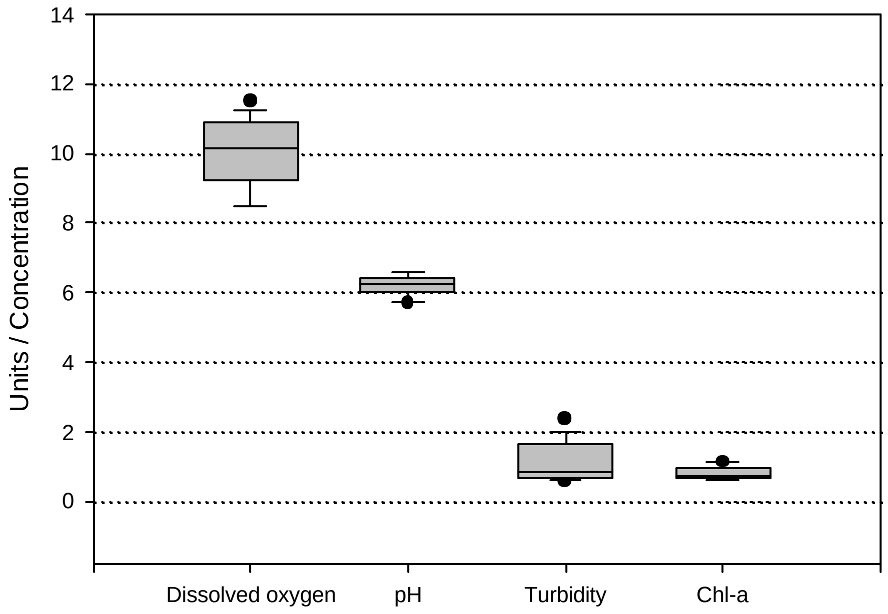


Figure 3.9. Boxplots showing the data from surface water sampling in Lake Pedder for 2002-03. Units for dissolved oxygen are mg l^{-1}; for turbidity, NTU and for chlorophyll-a, µg l^{-1}. pH is unitless.

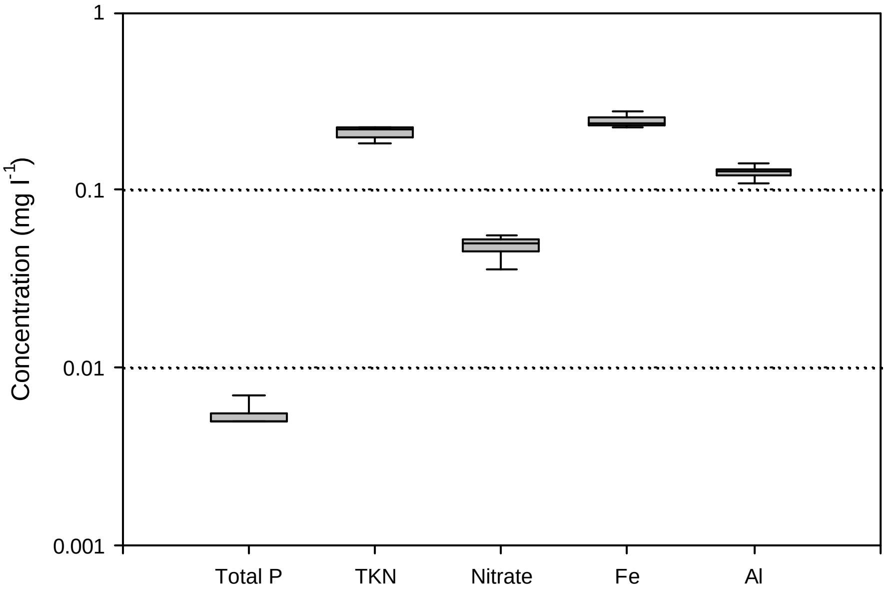


Figure 3.10. Boxplots summarizing the pooled nutrient and metals data from the Lake Pedder surface water monitoring sites assessed during 2002-03. (Note: logarithmic scale).

Analysis showed that all the other heavy metals (Zn, Cu, Cd, Co, Cr, Ni, Mn and Pb) were present at or below the laboratory detection limits (0.005 - 0.001 mg l^{-1}). Mean values and concentration ranges for alkalinity, sulphate and dissolved organic carbon in Lake Pedder are show in Table 3.2 below. They were similar to those recorded in Lake Gordon and within the normal range for waters on the west coast of Tasmania.

Table 3.2. Mean values and concentration ranges for alkalinity, sulphate and dissolved organic carbon in surface waters of Lake Pedder.

	Alkalinity (mg l^{-1})	**Sulphate (mg l^{-1})**	**Dissolved Organic Carbon (mg l^{-1})**
Lake Pedder	8.0 (6.0 – 13.0)	1.03 (0.8 - 1.2)	6.33 (4.4 - 6.5)

3.4 Water Quality in the Gordon River

3.4.1 Water Temperature

Water temperature values were recorded at the power station tailrace (site 77), at site 75 (Gordon @ G4) and at site 62 (Gordon @ Denison junction). Equipment failures caused some interruptions to the temperature and dissolved oxygen record at the tailrace site.

Figure 3.11 indicates that the temperature regimes at the tailrace and site 75 were almost identical, with marginally greater variability apparent at site 75. Essentially, water temperature at both sites was dictated by the temperature in Lake Gordon at the intake site when the power station was operating.

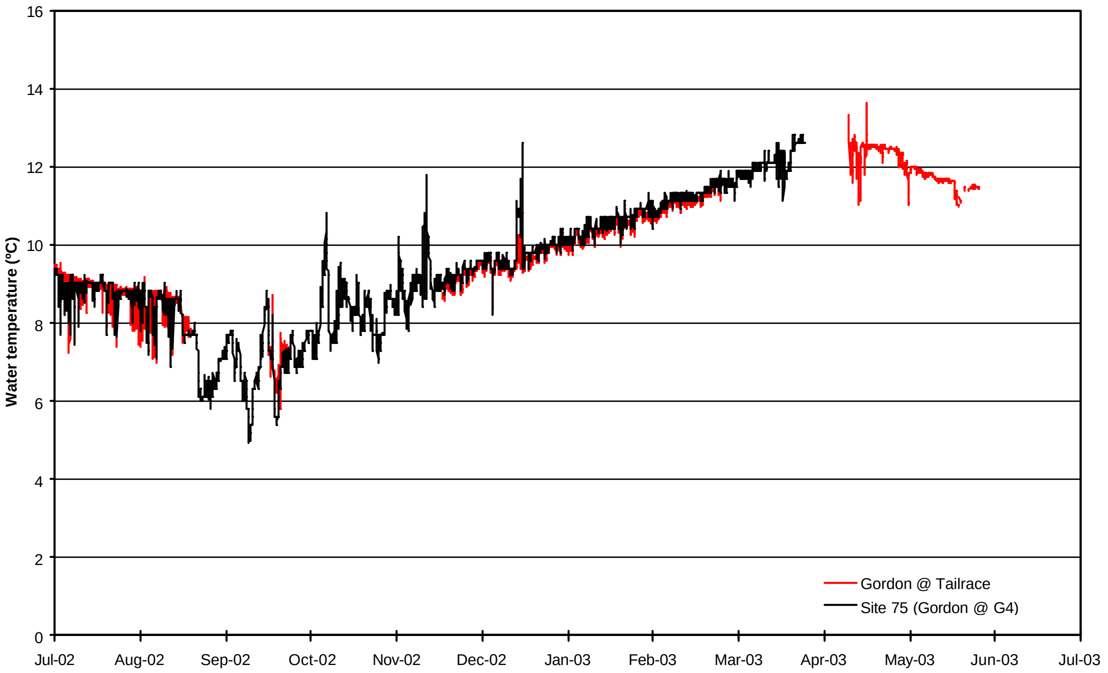


Figure 3.11. Water temperatures in the Gordon River at the power station tailrace and at site 75 (Gordon @ G4, approximately 2km downstream).

The period of increased water temperature variability between late August 2002 and mid November 2002 corresponded to a period of zero or low discharge from the power station. This allowed river temperatures to return to a variable regime influenced by local climate and weather conditions. Temperatures also showed increased variability with increasing fluctuations in power station discharge, particularly those between July and August 2002.

Water temperatures at site 75 and site 62 are shown in Figure 3.12. Data from site 62 indicated that downstream water temperatures were approximately 1°C higher than those at site 75 during this period. The plots show that temperature regimes at both sites were very similar between June 2002 and mid August 2002 and the greatest difference between sites occurred during the power station shutdown from mid-August to late October 2002.

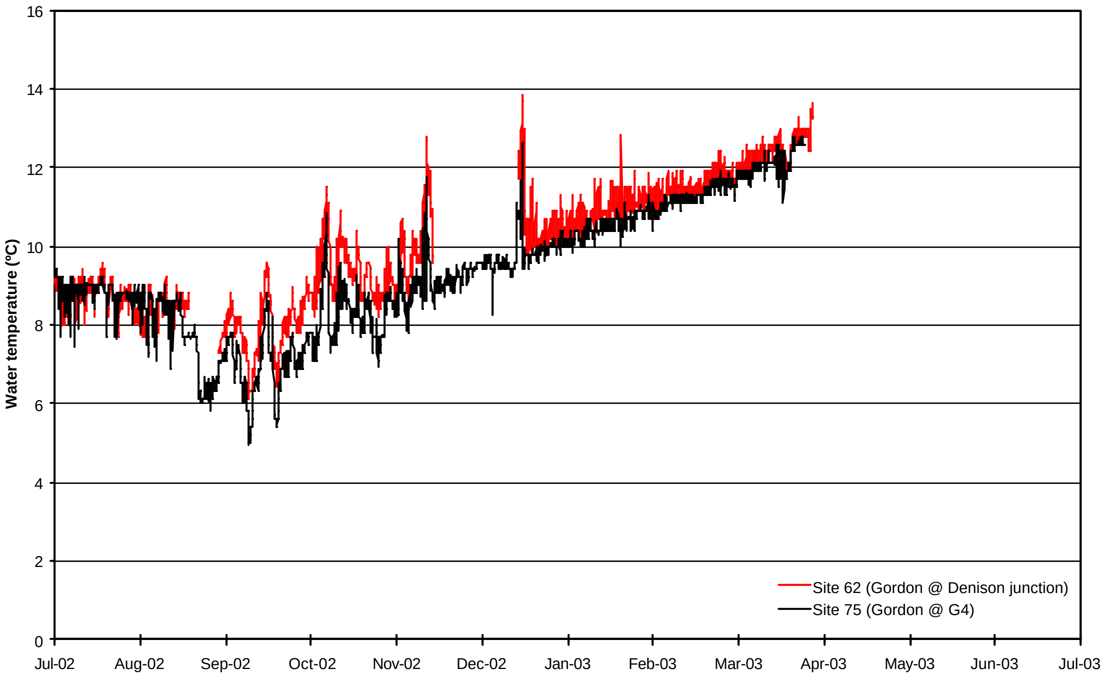


Figure 3.12. Water temperatures at sites 75 (Gordon @ G4) and 62 (Gordon @ Denison junction).

3.4.2 Dissolved Oxygen

Figure 3.13 shows dissolved oxygen levels at the tailrace (site 77) for 2002-03. Data are missing from three sections of the plot due to equipment failure (see section 3.4.1). Dissolved oxygen readings at the intake depth in Lake Gordon are also included in this figure. These data have been included to allow comparison between the quality of water being drawn into the power station with water discharged into the Gordon River from the power station's turbines.

The data support the observations made in the Water Quality section of the 2001-02 Gordon River Basslink Monitoring Annual Report (Hydro Tasmania 2002), which reported increased variability in tailrace dissolved oxygen levels under variable power station load conditions. Power station load was relatively consistent in early June 2002, and this is reflected in stable tailrace dissolved levels of around 6 mg l^{-1}.

Figure 3.13 shows that high dissolved oxygen levels occurred between July and mid-August 2002. The power station output was variable during this period (see Figure 2.4). The power station output variability decreased moderately between November 2002 and late January 2003, and the frequency of oxygen spiking was reduced as a result.

Power station output variability decreased further between late January 2003 and late March 2003, and this is reflected in the concurrence between tailrace dissolved oxygen levels and those measured in the impoundment at intake depth in early February 2003. The final section of the dissolved oxygen record shows relatively stable dissolved oxygen levels between mid-April and mid-

May 2003. During this period power station output was relatively constant and dissolved oxygen concentrations were similar to those at the intake.

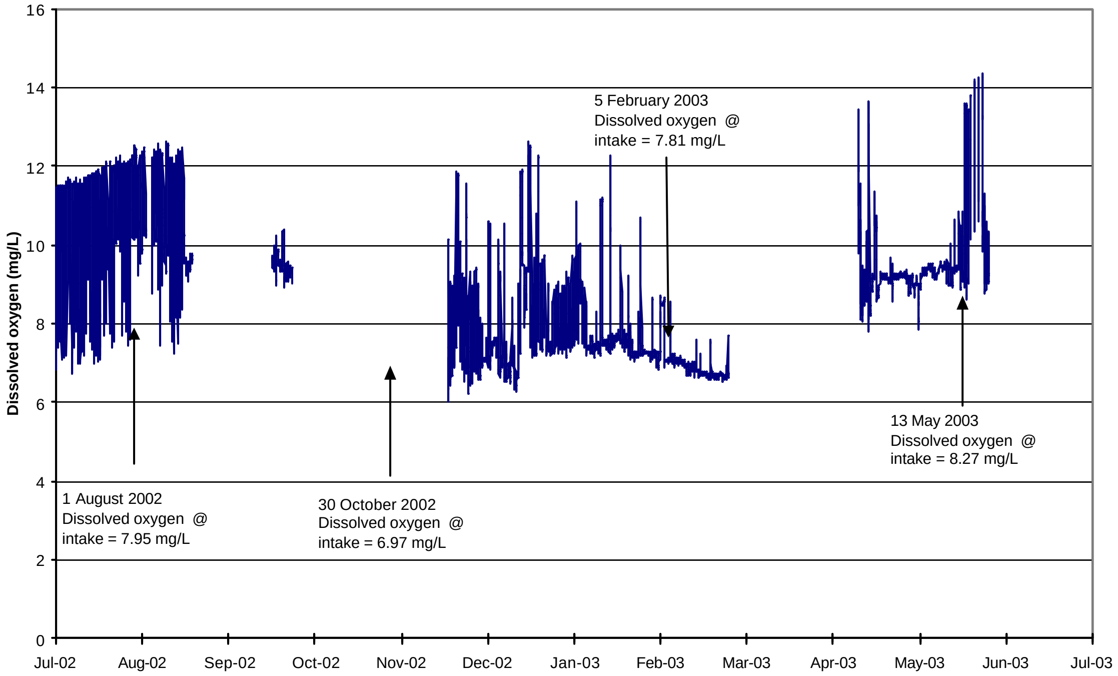


Figure 3.13. Dissolved oxygen concentration in the Gordon River at the power station tailrace. Arrows on the plot also show the measured concentration of oxygen in the water column at the level of the power station intake in Lake Gordon.

Figure 3.13 also shows that there was a significant elevation in dissolved oxygen values recorded at the tailrace compared to those at the intake. Air injection is generally used to smooth the start up of turbines, and to increase efficiency at partial operating loads, and it was frequently employed during periods of highly variable power station operation. Figure 3.13 indicates that the use of air injection added up to 5 mg l^{-1} to tailrace dissolved oxygen concentrations during the monitoring period.

3.4.3 Gas supersaturation

The Water Quality section in the 2001-02 Gordon River Basslink Monitoring Annual Report (Hydro Tasmania 2002) discussed the implications of, and mechanism that can lead to, total gas saturation below the Gordon Power Station. Total gas saturation values were not measured at the tailrace site, however dissolved oxygen concentrations were used as an indicator.

Dissolved oxygen concentrations recorded at the tailrace were converted to percent saturation using temperature corrected oxygen solubility tables published in Standard Methods (APHA 1995). The resulting percent saturation values are plotted in Figure 3.14.

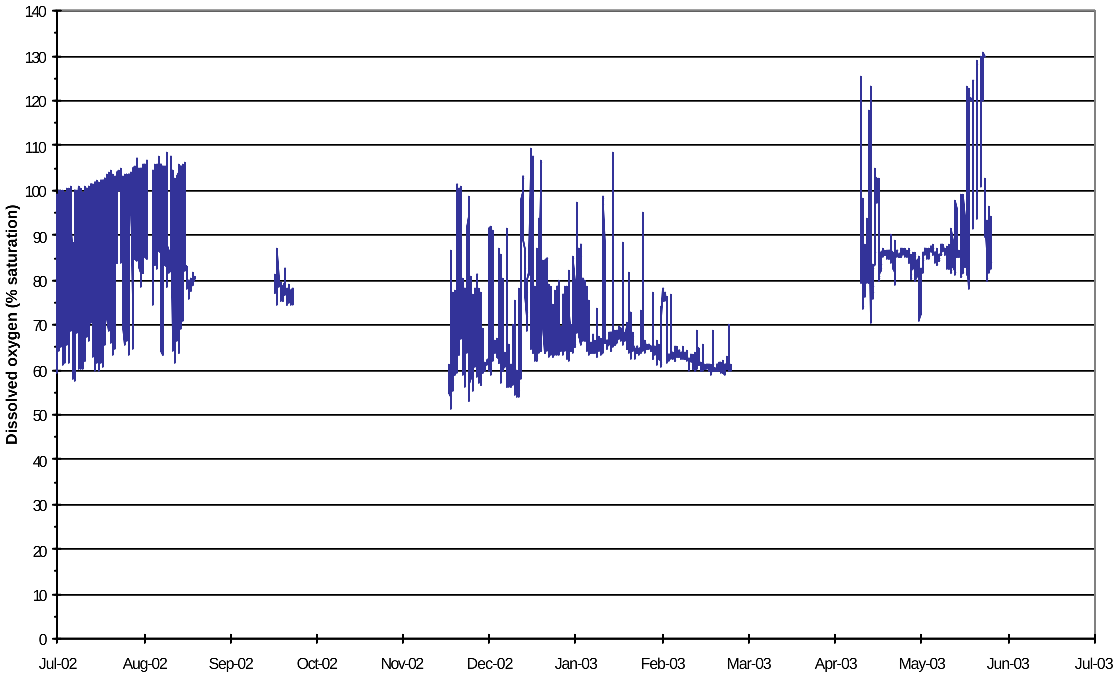


Figure 3.14. Percent saturation dissolved oxygen levels at the power station tailrace during 2002-03.

Figure 3.14 shows that dissolved oxygen levels at the tailrace frequently reached or exceeded 105% saturation during the study period, and that levels reached a maximum of approximately 130% in late May 2003. Examination of the data showed that dissolved oxygen levels were well in excess of 110% saturation on six occasions, for periods ranging from around one to eight hours. Total gas levels may also be saturated during these spikes. There is a risk that prolonged periods of supersaturated gas levels in the Gordon River downstream of the tailrace may have a detrimental impact on the in-stream biota. Presently, there are insufficient data to determine the magnitude of the risk, or how far downstream this impact may extend.

Further study of supersaturation in the Gordon River downstream of Gordon Power Station is planned for the 2003-04 year.

3.5 Conclusion

Surveys of water quality were undertaken on Lake Gordon and Lake Pedder during August and October 2002, as well as February and May 2003.

The physico-chemical conditions of Lake Gordon's surface waters 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, and were characterised by elevated aluminium levels that exceeded ANZECC (1992) trigger levels. Lake Pedder exhibited natural seasonal variation in surface water quality. Total aluminium levels also exceeded ANZECC (1992) trigger levels.

The stratification characteristics of Lake Gordon showed spatial and temporal variability related to the morphology of this impoundment. The deepest profile (intake site) showed virtual anoxia in the bottom waters of each quarterly profile. Lake Pedder remained evenly mixed during the 2002-03 surveys.

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 followed a general seasonal pattern, but short term variability was reduced due to the effect of tailrace discharge derived from the cool subsurface waters of Lake Gordon.

Dissolved oxygen concentrations were monitored at the tailrace site and did not fall significantly below 6 mg l^{-1} in the available record, but showed significant spiking which was linked to power station output variability. During periods of varying power station load, percent saturation levels frequently exceeded 100%, and peaked at 130% in May 2003. Although total gas levels were not measured at this site, they may have exceeded the ANZECC (2001) guideline of 105%. Specific studies on total gas saturation downstream of the Gordon power station tailrace are planned for 2003-04.

4 Fluvial Geomorphology

4.1 Introduction

The objective of the fluvial geomorphology monitoring program is to document geomorphic changes on the banks of the middle Gordon River between the power station tailrace and the junction with the Franklin River, and to relate these changes to power station operations or other factors wherever possible.

Scour and seepage erosion are the major focus of the monitoring program, as these have been identified as the dominant erosion processes presently affecting alluvial banks, and the ones most likely to be affected by alterations to discharge patterns resulting from Basslink operations.

The geomorphic monitoring focused on the same study area as the initial Basslink investigations (Koehnken *et al.* 2001). These investigations delineated five geomorphic zones in the study area, as shown in Figure 4.1. A major field component of the initial Basslink geomorphology investigations was the mapping of bank characteristics on both sides of the river over the length of the study area. The mapping identified the following bank characteristics on a reach by reach basis:

- underlying material (sandy alluvium or colluvium, cobbles, bedrock);
- height to green vegetation (indication of water level fluctuations);
- percent cover on bank of large woody debris (LWD);
- percent tea-tree on banks; and
- slope of bank, extent and nature of buttressing of bank toe, and level of recent activity (recent tree falls, active seepage erosion).

These characteristics were found to be important to overall bank stability in the middle Gordon River, and monitoring sites that reflect a range of these characteristics, as well as position in the river (inside bend, outside bend, above or below constrictions, etc.), have been incorporated into the monitoring program.

Erosion pin and scour chain sites that were established as part of the original Basslink investigations have been retained, providing a record of geomorphic activity since December 1999 at some sites.

4.2 Methods

Geomorphic monitoring included the measurement of 200 erosion pins and 25 scour chains located at 48 monitoring sites on a 6-monthly basis (spring and autumn), and photo-monitoring of an additional 54 sites on an annual (autumn) basis. Site locations and site descriptions are provided in the 2001-02 Gordon River Basslink Monitoring Annual Report (Hydro Tasmania 2002).

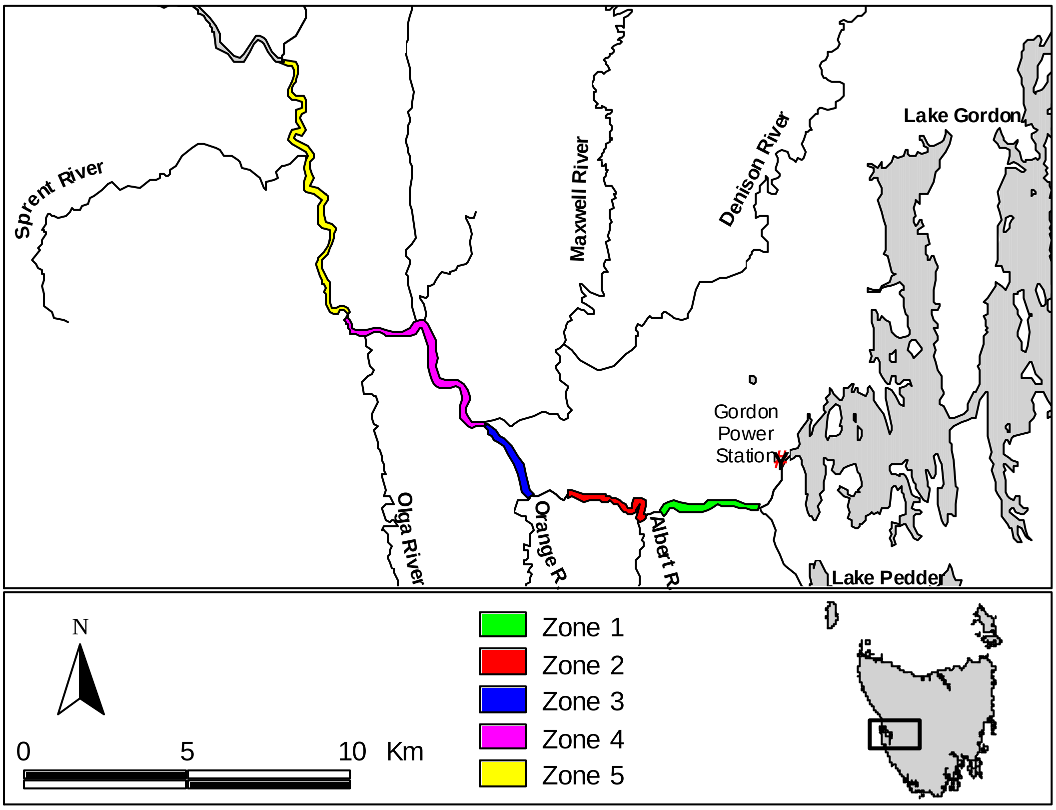


Figure 4.1. Geomorphology monitoring zones in the middle Gordon River.

Opportunistic monitoring occurred in December 2002, when erosion pins and scour chains were measured. Pins installed in vertical cobble banks (sites 2F and 4C) were not measured for safety reasons arising from over-hanging vegetation. These sites were included in the photo-monitoring.

Table 4.1 contains a summary of erosion pins not located during fieldwork. Site 5K, which was established on a bank with abundant large woody debris (LWD) and had shown a previous trend of rapid deposition, was not located. It is likely that fluvial deposition or bank slumping buried the site.

Table 4.1. Summary of erosion pins changes between October 2002 and April 2003

Site	Change(s) to site	Reason
3B/4	Pin not located 10/02; Located 4/03	Obscured under tree branch
4B/1	Not located	Consistent with 10/02
5K	Entire site not located	Probably due to deposition from bank slumping

4.2.1 Geomorphic monitoring sites

A total of 48 sites were monitored during 2002-03 over the five zones of the middle Gordon River (see Figure 4.1). The location and arrangement of monitoring sites and photo-monitoring sites are illustrated in the following figures:

- Figure 4.2 shows the locations of the six geomorphic monitoring sites and five photo-monitoring sites established in Zone 1 of the Gordon River;
- Figure 4.3 shows the locations of the 12 geomorphic monitoring sites and 11 photo-monitoring sites established in Zone 2;
- Figure 4.4 shows the locations of the seven geomorphic monitoring sites and five photo-monitoring sites established in Zone 3;
- Figure 4.5 shows the locations of the eight geomorphic monitoring sites and eight photo-monitoring sites established in Zone 4; and
- Figure 4.6 and Figure 4.7 show the locations of the 13 geomorphic monitoring sites and 21 photo-monitoring sites established in Zone 5.

4.3 Results

4.3.1 Field Observations

During the December 2002 opportunistic sampling and the scheduled March 2003 excursion, the banks of the Gordon had noticeably changed since the October 2002 monitoring, which coincided with an extended power station shutdown. Whereas in October, mud deposits and accumulations of organic matter on the banks were common, in December and March the bank faces and toes were clear of these deposits.

In Zones 3 – 5, sand and flood debris deposits on the upper banks (above the level of power station operation) were present. These deposits were observed in October 2002, and are associated with natural high volume winter flows.

Sediment flows in Zones 2 and 3 were largely inactive in December 2002, following 2-turbine operation of the power station, and were more active in March 2003, when monitoring followed extended 3-turbine discharge at the power station.

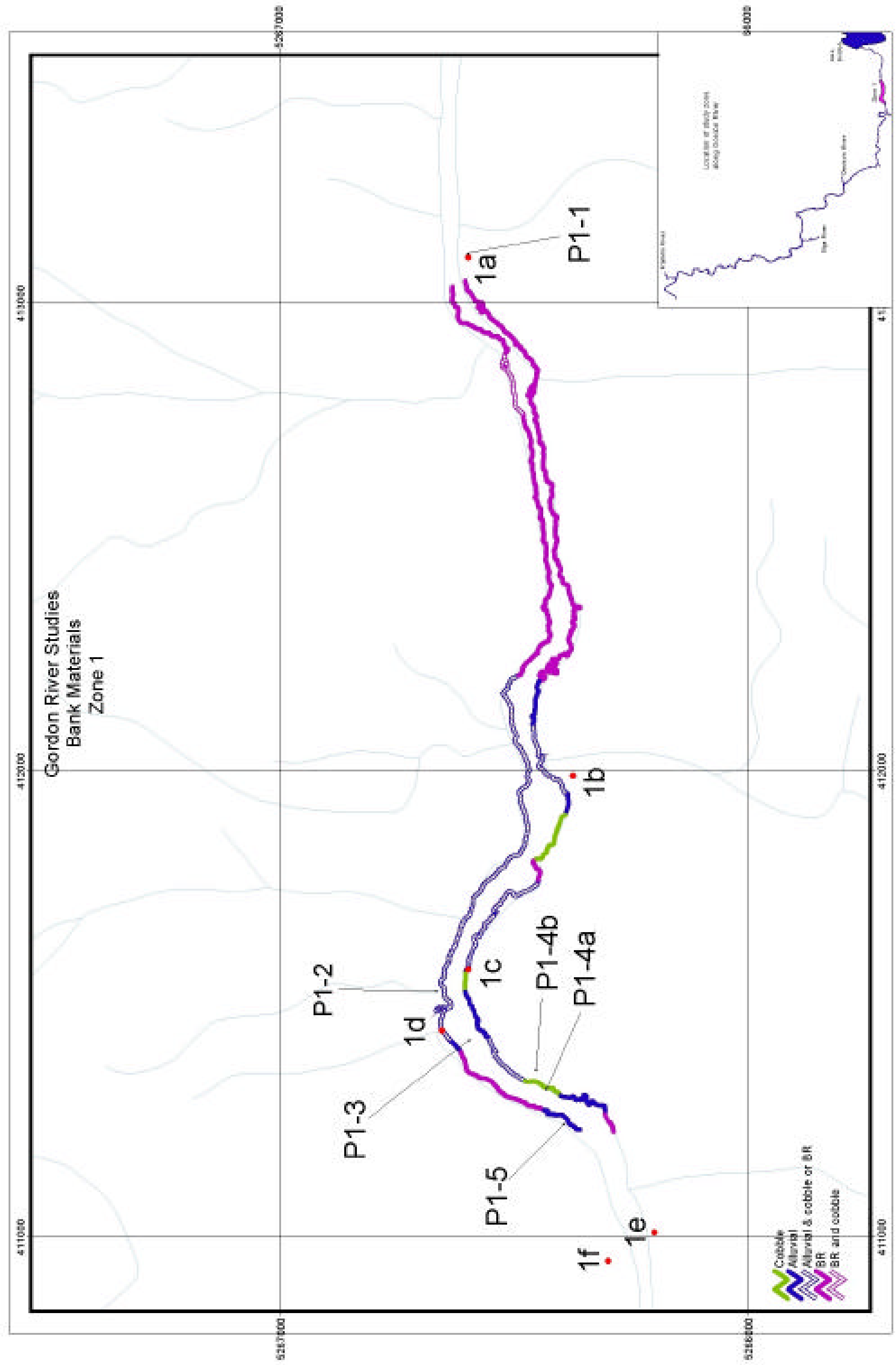


Figure 4.2. Map of the geomorphic monitoring sites (1a – 1f) and photo-monitoring sites (P1-1 to P1-5) in Zone 1 of the Gordon River.

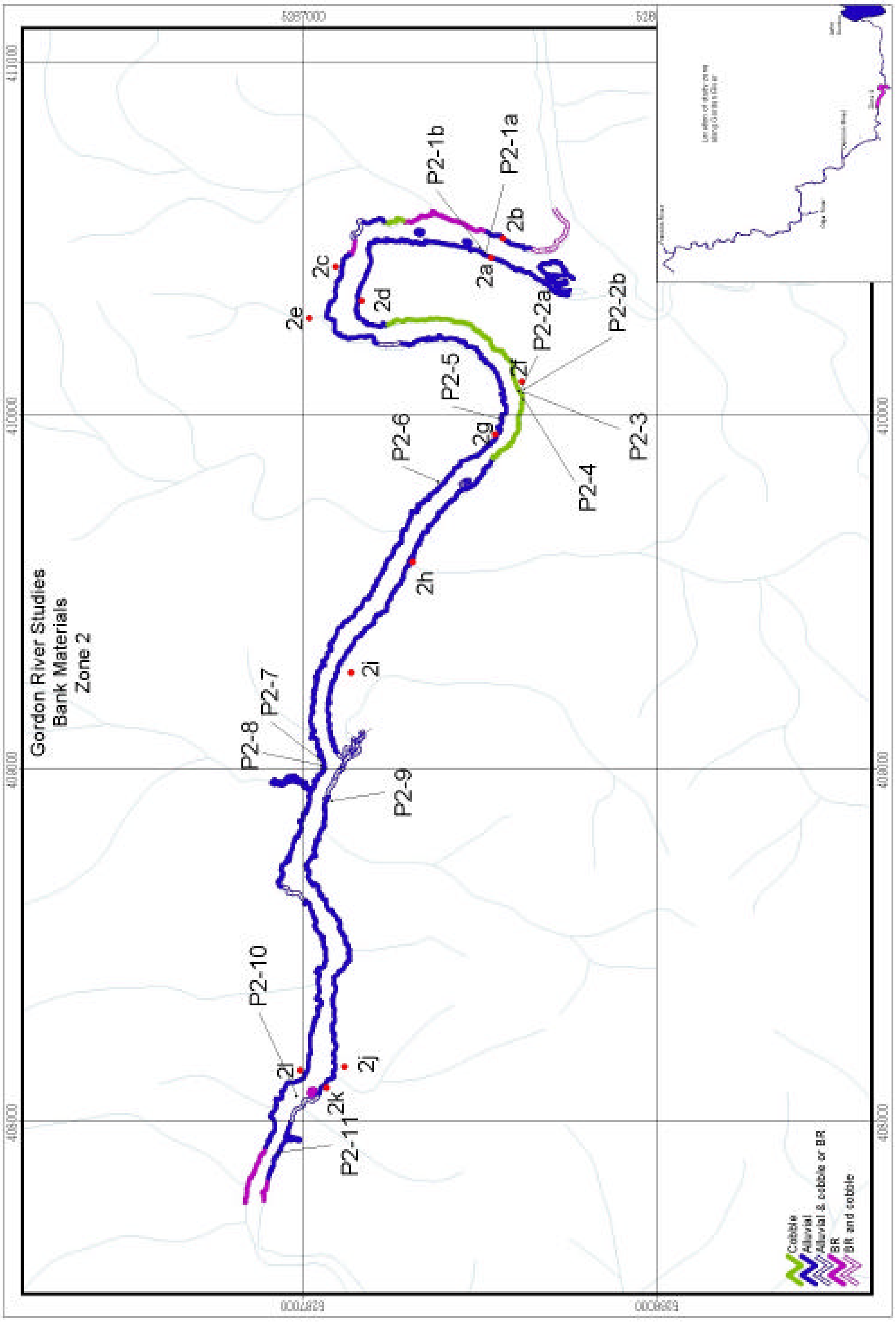


Figure 4.3. Map of the geomorphic monitoring sites (2a – 2L) and photo-monitoring sites (P2-1 to P2-11) in Zone 2 of the Gordon River.

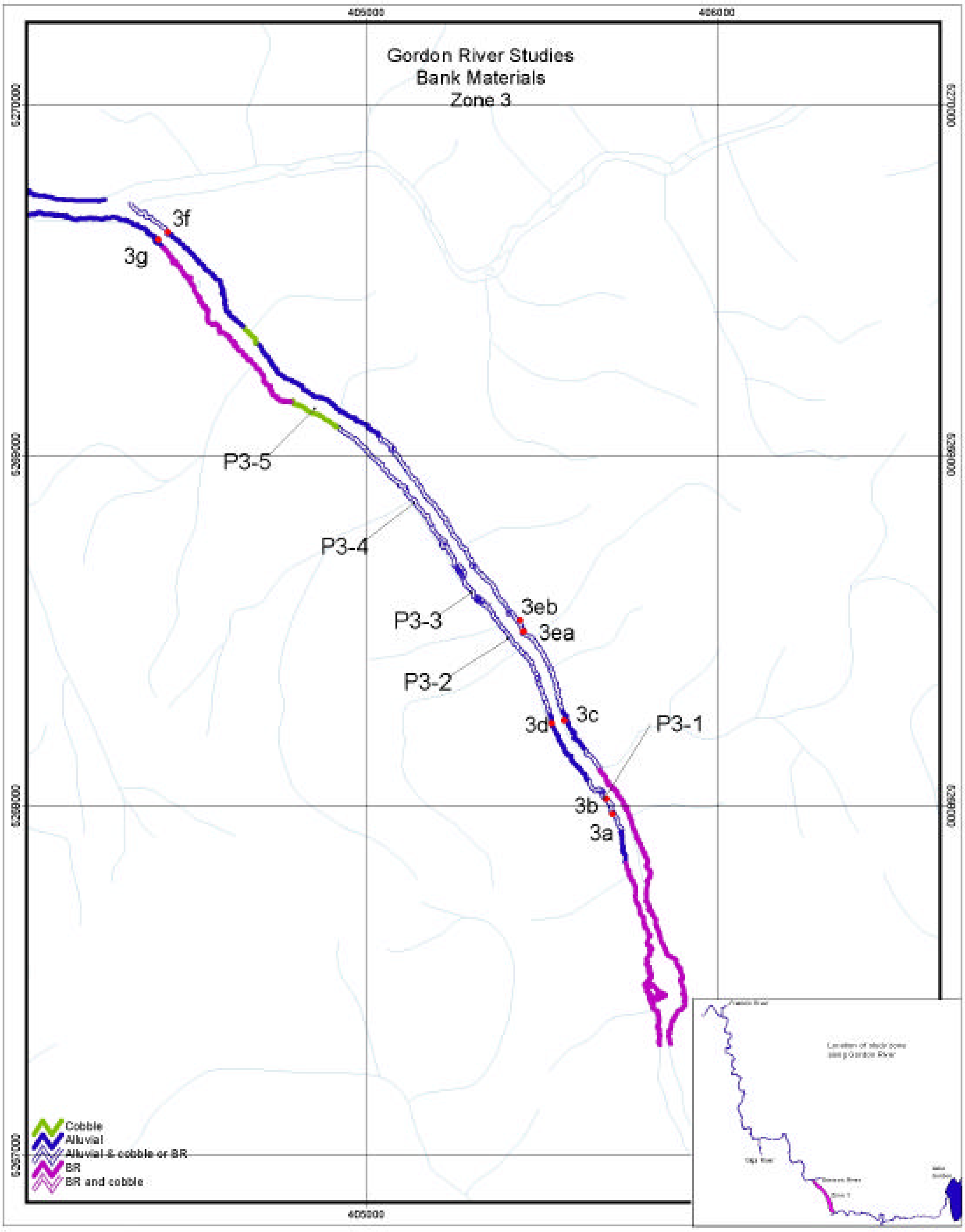


Figure 4.4. Map of the geomorphic monitoring sites (3a – 3g) and photo-monitoring sites (P3-1 to P3-5) in Zone 3 of the Gordon River.

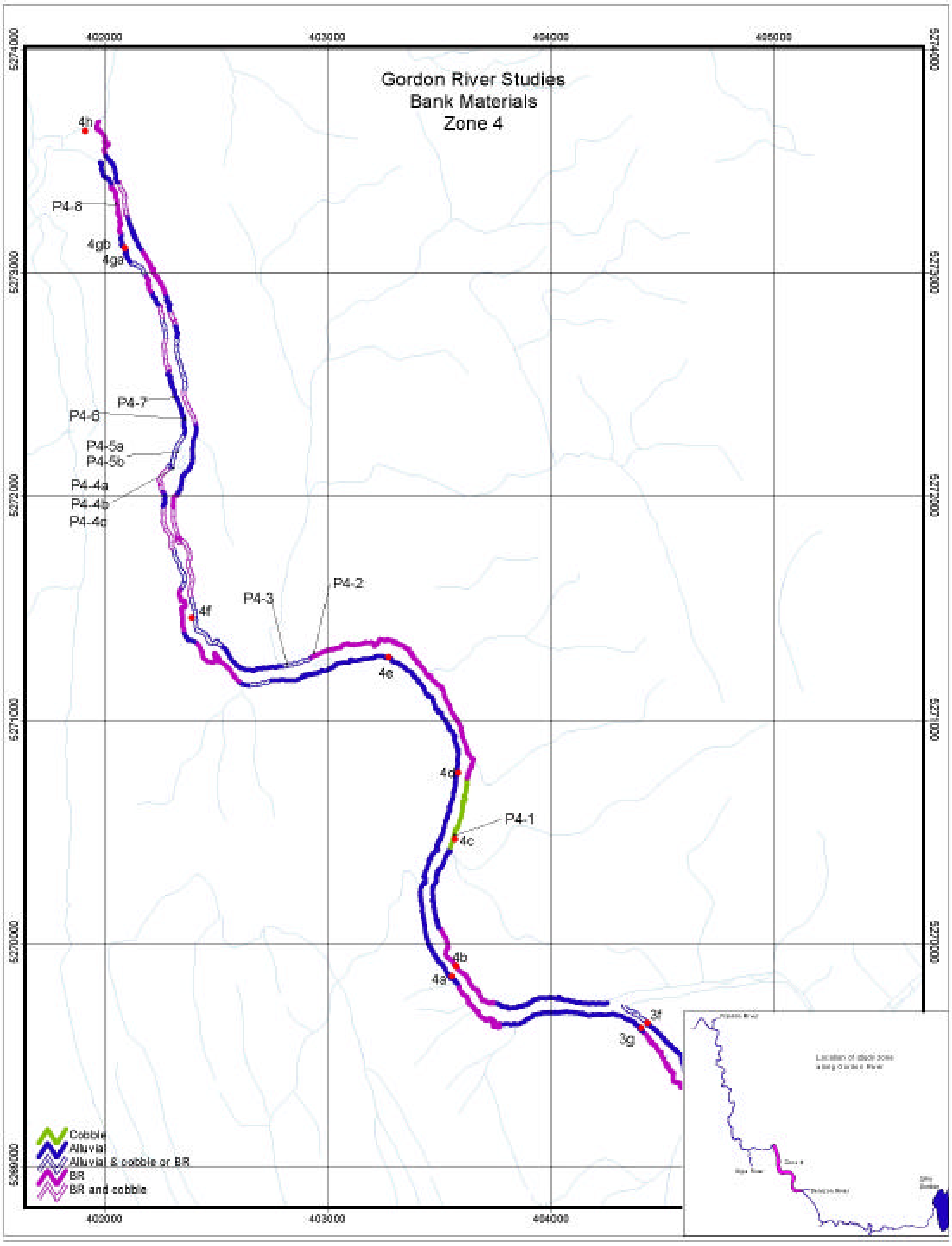


Figure 4.5. Map of the geomorphic monitoring sites (4a – 4h) and photo-monitoring sites (P4-1 to P4-8) in Zone 4 of the Gordon River.

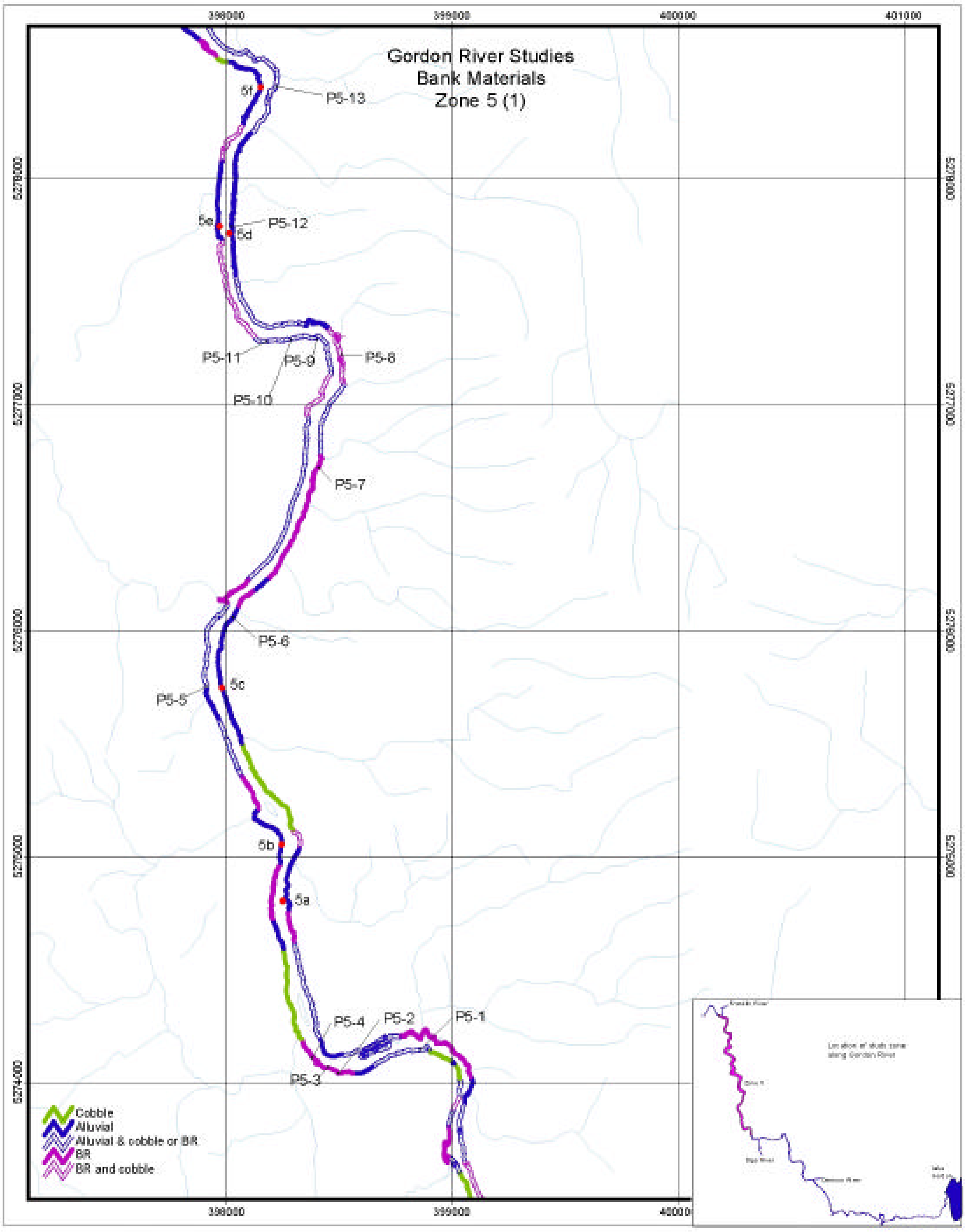


Figure 4.6. Map of geomorphic monitoring sites 5a – 5f and photo-monitoring sites P5-1 to P5-13 in Zone 5 of the Gordon River.

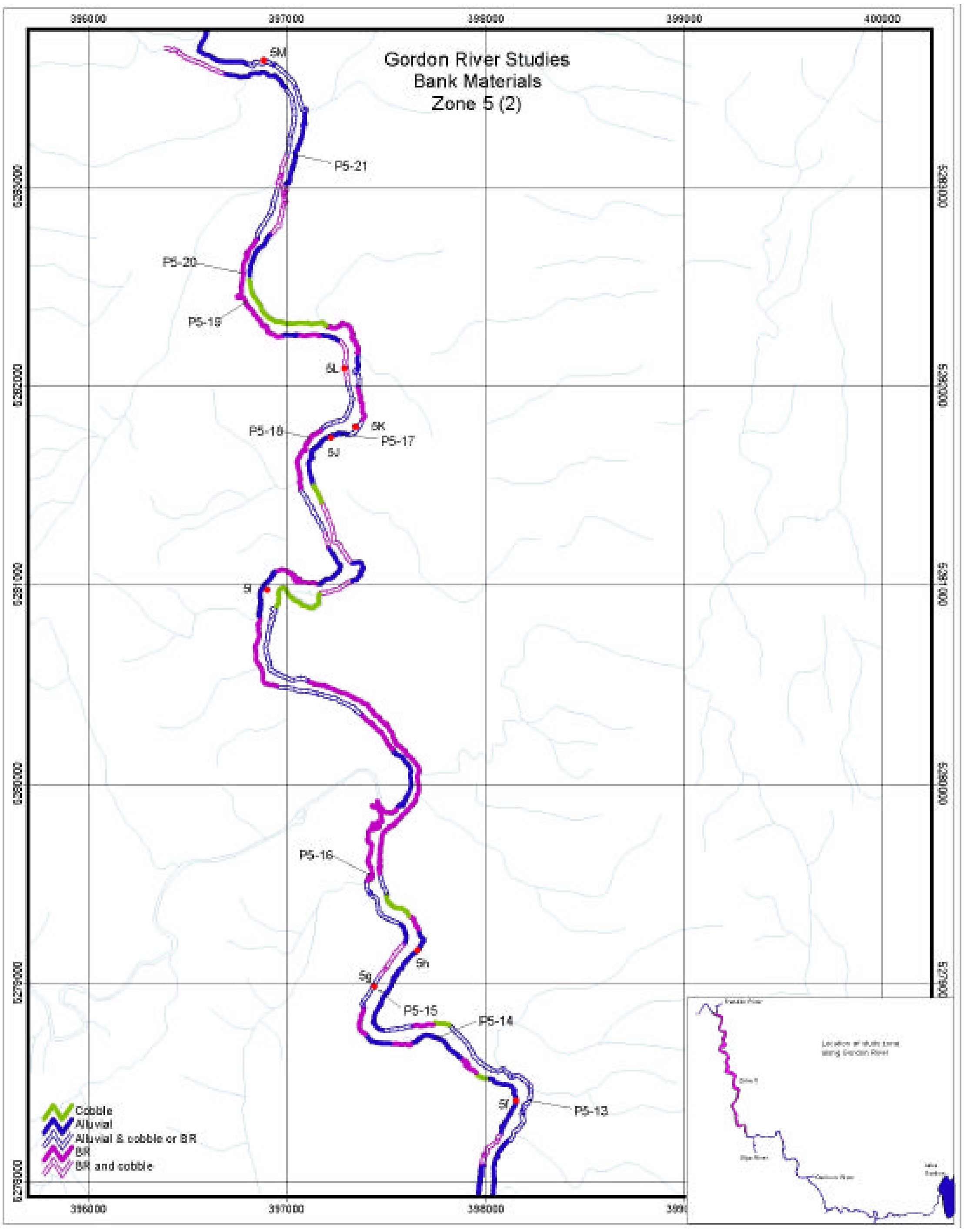


Figure 4.7. Map of geomorphic monitoring sites 5f – 5m and photo-monitoring sites P5-13 to P5-21 in Zone 5 of the Gordon River.

During March 2003, observations of sediment flows in Zone 2 gave the impression that there was comparatively less orange sand and more white sand in the fluxes than was observed during the initial Basslink investigations. The orange sands are derived from the less weathered lower portion of the bank, whereas the white sands are derived from the leached upper portion of the banks (Photo 4.1). This observation may indicate that cavities are collapsing, and seepage processes are transporting sand from higher in the bank.

Photo 4.1. White sands overlying orange sands in Zone 2.

This is consistent with related observations that, in Zone 2, bank slumping at sites of known cavities appeared to be common. Several erosion pins that were inserted into the back walls of established cavities had been squashed due to large-scale bank movement.

4.3.2 Zone 2 piezometer results

In-bank water levels, as recorded by the array of piezometers located in Zone 2, are shown in Figure 4.8. The discharge from the power station is superimposed on this figure. For the first 2 - 3 weeks of the record, the in-bank water level appears to be below the minimum recording level of Probe 3. The traces indicate that there were a number of natural runoff events which increased water levels in the river and banks during the power station shut-down and in 2003, when the power station was operating at 3-turbine capacity. These results are discussed in Section 4.4.1

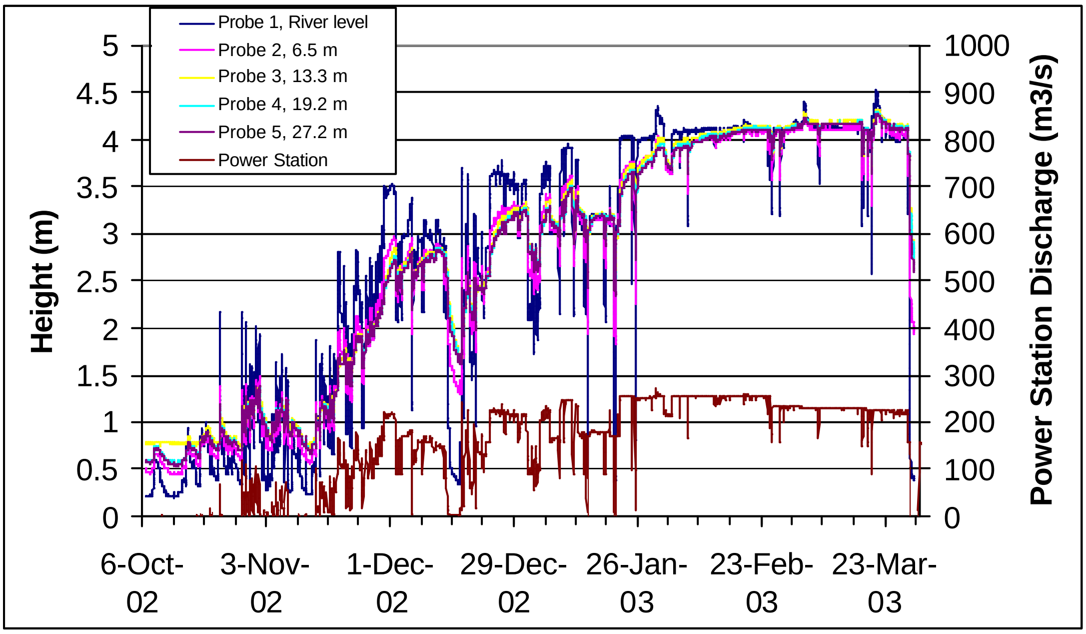


Figure 4.8. Piezometer data from Zone 2 between 6 October 2002 and 31 March 2003. Distance of probe from rivers edge (low water) is shown in the legend. Data interval is 15 minutes. Power station discharge is based on hourly data.

4.3.3 Erosion pins and scour chains

Erosion pins and scour chains were measured in December 2002 and March 2003. The December readings were obtained on an opportunistic basis while other field work was being completed. Sites 1B, and 2I – 2L were not visited in December due to logistical constraints.

The results are discussed on a zone-by-zone basis in Section 4.4.2.

4.3.4 Photo-monitoring

Photo-monitoring results from March 2002 and March 2003 are discussed in Section 4.4.3. A summary of apparent changes in the photos between March 2002 and March 2003 is contained in Table 4.2. Sites not listed in Table 4.2 showed no change between the monitoring dates. The table also lists which sites were difficult to compare due to varying light conditions or viewing angles.

Table 4.2. Summary of changes at photo-monitoring sites, March 2002 - March 2003

Site	**Change / Comment**
P1-4b	Slip in sandy alluvium overlying cobbles. First observed in Oct. 2002. Between Oct. 2002 and March 2003 fallen vegetation was removed from base of bank
P2-1	New tree fall on left bank upstream Site 2A
P2-2a	Vegetation has increased in size on the most downstream slip
P2-3	Increased vegetation on slip face
P2-4	New tree fall on top of bank (no change to slip); increase in size of vegetation on slip face above high water level
P2-5	Change in angle makes interpretation difficult; based on Oct. 2002 photo may have additional small tree falls upstream (right) of main slip
P2-6	Increase in black weathering coating on cobble face
P2-9	Possible increase in vegetation, light variations make interpretation difficult
P2-11	No photo obtained 2003
P3-1	Loss of leaves on tree fall
P3-4	May not be same site; if it is, tree has fallen over site
P4-2	Poor light, but no apparent change
P4-3	Loss of leaves from large woody debris (LWD) at base of bank
P4-7	Large differences in lighting, no apparent large scale changes
P4-8	Large differences in lighting, no apparent large scale changes
P5-1	Large differences in lighting, possibly additional slip in centre of photo
P5-3	Large differences in lighting, no apparent large scale changes
P5-6	Large differences in lighting, no apparent large scale changes
P6-7	Large differences in lighting, no apparent large scale changes
P5-8	Large differences in lighting, no apparent large scale changes
P5-10	Loss of small branches from LWD at base of bank
P5-12	Loss of small branches from LWD at base of bank
P5-14	May not be same site / large light differences
P5-15	Mid-bar vegetation appears fuller, variations in light
P5-16	Movement of branch on right side down slope
P5-18	Poor focus 2002, may not be same site
P5-19	Poor focus 2002, no apparent changes
P5-20	Poor focus 2002, no apparent changes
P5-21	No photo obtained in 2002

4.4 Discussion

4.4.1 Piezometer results

The piezometer results were consistent with previous observations obtained during extended power station operation, and power station shutdowns, and can be summarised as follows.

- Under power station ‘off’ conditions the in-bank water slope is predominantly from the bank towards the river except during peak storm flows when river levels increase for short time periods.
- During periods of intermittent power station usage or the initiation of extended power station usage, the in-bank water surface slope is from the river into the bank, with in-bank water levels increasing with time.
- Following extended power station usage, in-bank water levels up to 25 m (horizontal distance) from the rivers edge are equivalent to the river surface. Storm events under these conditions can increase in-bank water levels at a greater rate than the river level, and the in-bank water surface slopes temporarily dip back towards the river.
- The rate of in-bank water level increase or decrease associated with power station operations is much greater than rates recorded during natural flow events.

4.4.2 Erosion pins and scour chains

4.4.2.1 Introduction

Similar to October 2002, the December 2002 and March 2003 erosion pin results indicate a range of flow conditions. Whereas the October 2002 results reflected extended power station operation followed by a shut-down and limited power station usage, the March results reflect almost opposite conditions: an extended shutdown followed by extensive 3-turbine power station discharge. The December results provide additional detail as to changes between October and March, as the data were obtained following a period of frequent on/off at the power station, but infrequent 3-turbine usage (Figure 2.4). Therefore, comparing the erosion pin results from October 2002, December 2002 and March 2003 provides some insight into how the pattern of flows affects bank response. Comparing the March 2002 results with the March 2003 results gives an indication of what the nett change to the banks has been over the past 12-months.

For each zone, erosion pin results have been sorted by pin location on the bank (cavities, sediment flows, vertical banks (typically colluvium), upper slope, slope, and toe), and summarised in histograms. It must be stressed, however, that bank response is dependant on many factors in addition to location on the bank face (position in river, local hydraulics) and the site locations.

4.4.2.2 Zone 1

Zone 1 has only minor tributary inputs, with flow dominated by power station operation. In spite of this, in October 2002 during the extended power station shutdown, there were mud drapes on the toes of many banks reflecting sediment transport and deposition from tributaries. In December 2002 and March 2003, these mud deposits were absent. Erosion pin results are summarised in Figure 4.9, and show that between any two successive monitoring events, most changes were of the order of ±25 mm.

Pins in cavities showed erosion and deposition, with both responses indicating bank movement (either erosion of the back wall, or slumping of the bank onto the pin). Because of the long length of many of the cavity pins (>1000 mm) and difficulty in measuring due to the presence of roots in the cavities, the measurement error on these pins is large, and interpreting these relatively small-scale changes (±25 mm) is difficult. The nett change between March 2002 and March 2003 was predominantly deposition, suggesting that bank slumping was the dominant process affecting the cavities during the past year. The largest-scale changes were found at site 1F immediately upstream of Abel Gorge, which may reflect backwater effects from the gorge.

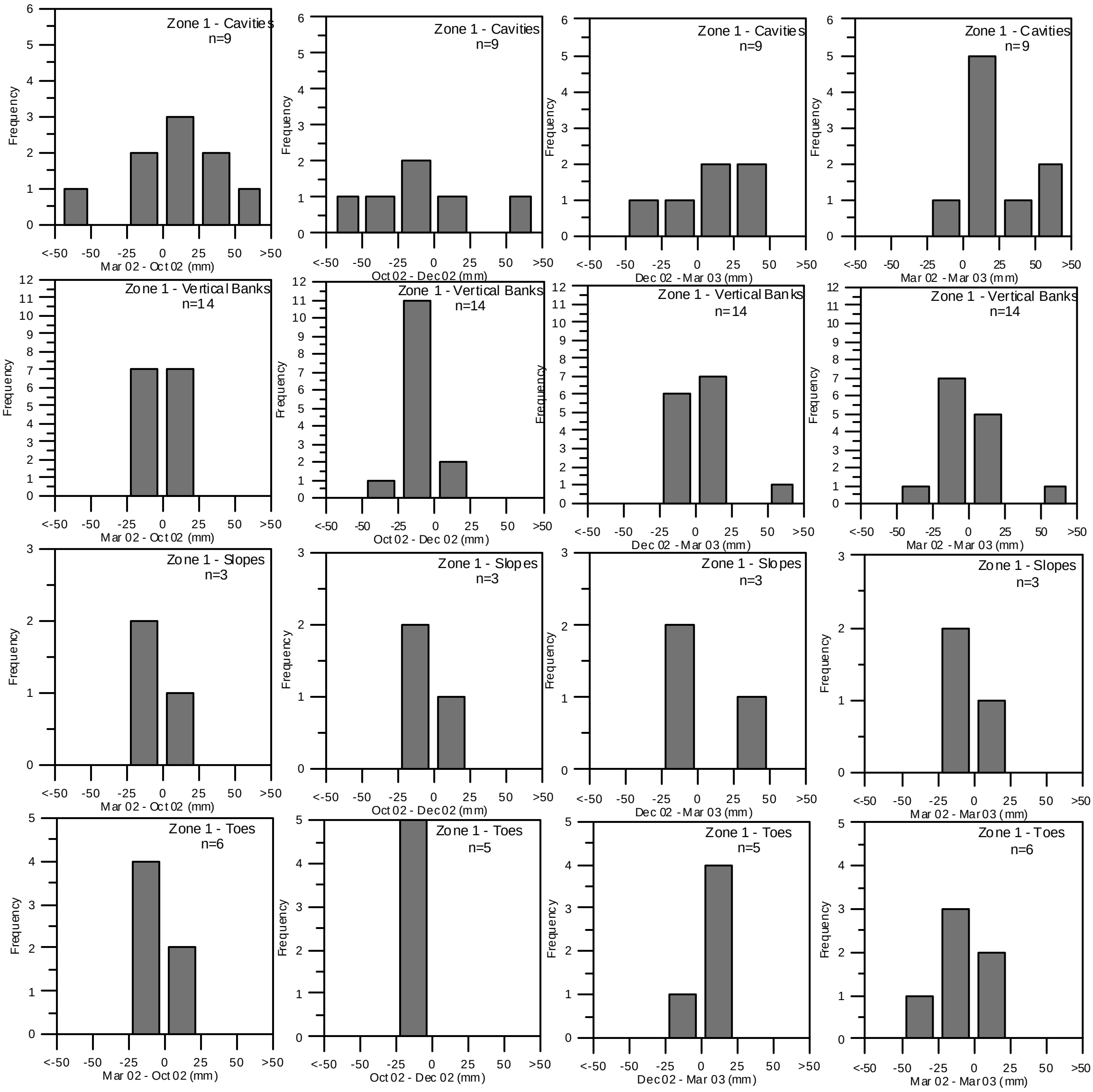


Figure 4.9. Summary of erosion pin results for Zone 1 between March 2002 and March 2003.

The ‘vertical bank’ results reflect pins placed in colluvium at site 1A or in the vertical banks behind sandy alluvial banks. ‘Depositional’ results generally reflect the movement of root mat and / or soil material from upslope onto the pin. These results suggest that erosion was more common between October and December, with deposition increasing between December and March 2003. This trend is also present in the ‘slopes’ and ‘toes’ results, and may suggest that frequent on/off operation of the power station promotes greater bank erosion compared with extended high power station discharges (December – March 2003). The erosion pin results from bank toes in Zone 1 are shown in Figure 4.10.

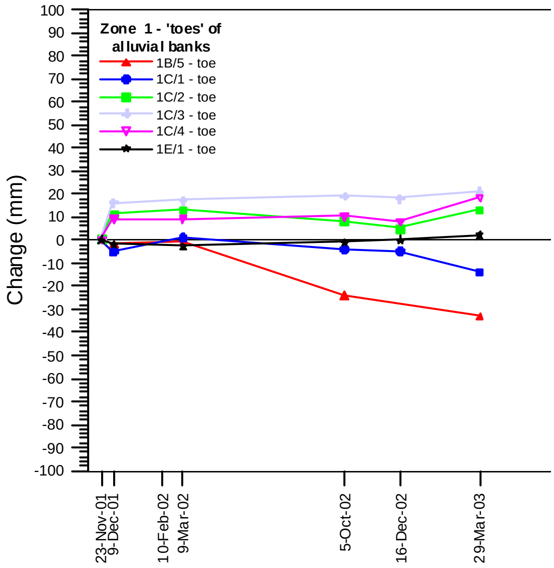


Figure 4.10. Erosion pin results from bank toes in Zone 1.

The nett changes between March 2002 and March 2003 on the vertical banks, slopes and toes show greater erosion than deposition, with changes generally within the ±25 mm range.

The scour chains in Zone 1 produced results consistent with those of erosion pins, showing scour of 0.5 - 1 link at the 2 chains located at Site 1A between December 2002 and March 2003, and no deposition. The chain at Site 1E indicated scour of 1 link between October and December, followed by deposition between December and March.

4.4.2.3 *Zone 2*

Erosion pin results for cavities and sediment flows monitored in Zone 2 are presented in Figure 4.11. The cavities showed activity between both October 2002 and December 2002, and December 2002 and March 2003. The cavity data suggest that erosion predominated in December 2002, with somewhat more deposition in March 2003. This may reflect erosion of the back walls during the power station shutdown, with deposition occurring due to seepage processes between December and March 2003 when water levels in the river were higher. The results from the ‘Flows’ show deposition, consistent with active upslope cavities. This differs from the October 2002 results when erosion, presumably due to winter storm events and power station operation, was common.

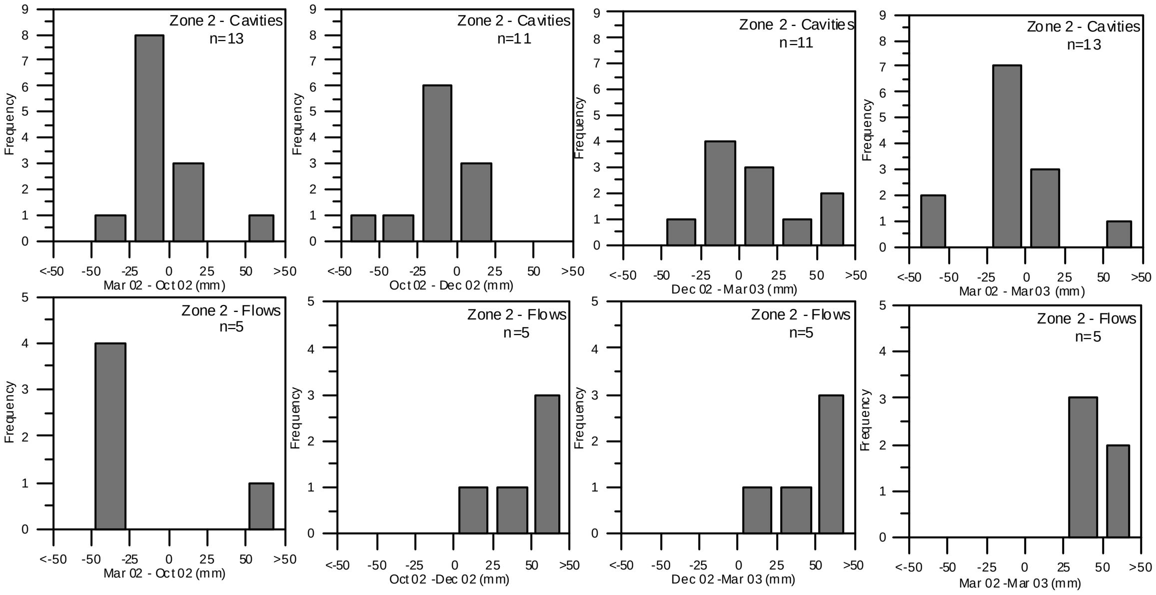


Figure 4.11. Erosion pin results from cavities and sediment flows in Zone 2.

Erosion pin results for upper bank slopes, mid-slopes and bank toes are presented in Figure 4.12. The plots for the upper slopes differ slightly from the previously presented results, as 4 out of the 5 sites where 'upper slope' pins are located were not measured in December 2002, so changes between October 2002 and March 2003 are shown.

Between March 2002 and October 2002, deposition was common on all parts of the bank, and this is attributed to the deposition of tributary-derived sediment during natural winter flow events while the power station was shut down. Erosion of the mid-slopes and toes was widespread in Zone 2 following the re-initiation of power station operations (October 2002 – March 2003), and continued during extended 3-turbine usage (December 2002 – March 2003). Figure 4.13 shows the erosion pin results from bank toes in Zone 2, showing either little change or deposition between March 2002 and October 2002, followed by erosion, especially at the sites in the lower part of the zone (J, K, and L).

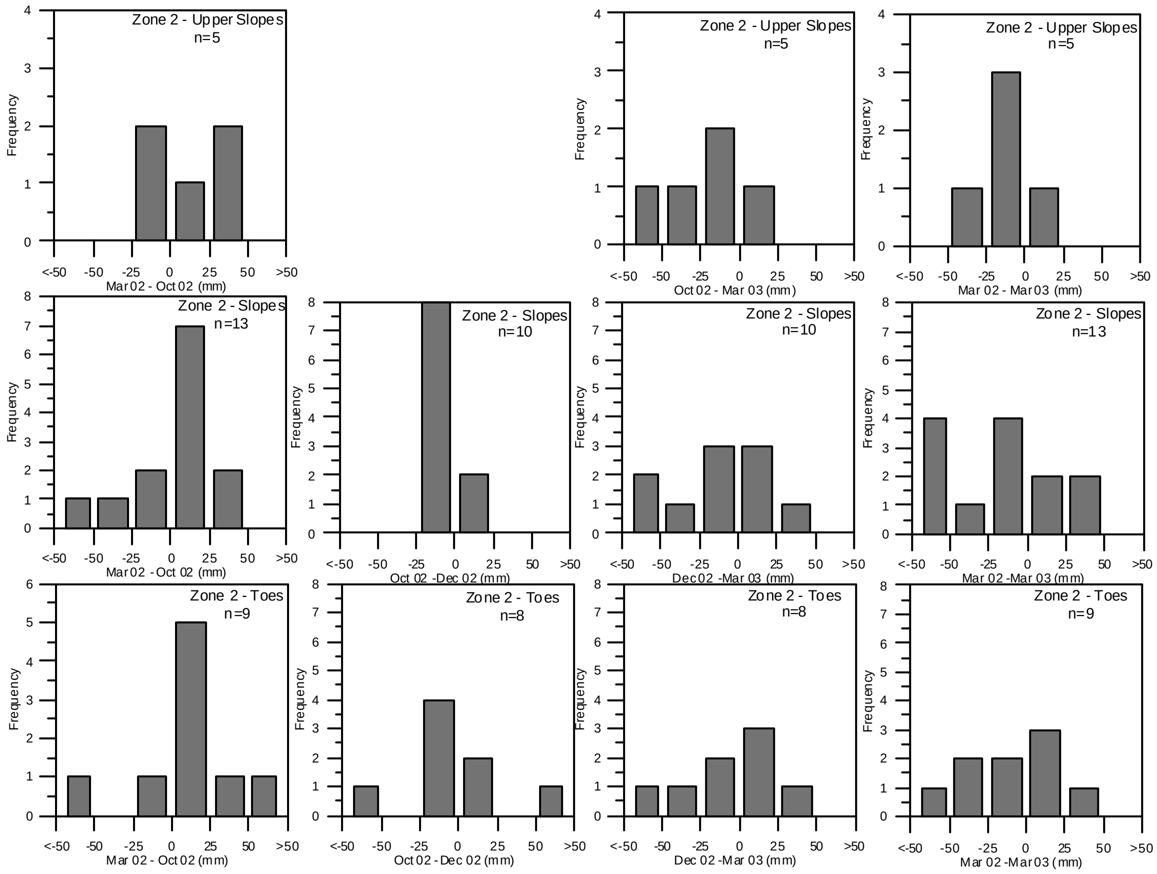


Figure 4.12. Zone 2 erosion pin results for upper slopes, mid-slopes and bank toes.

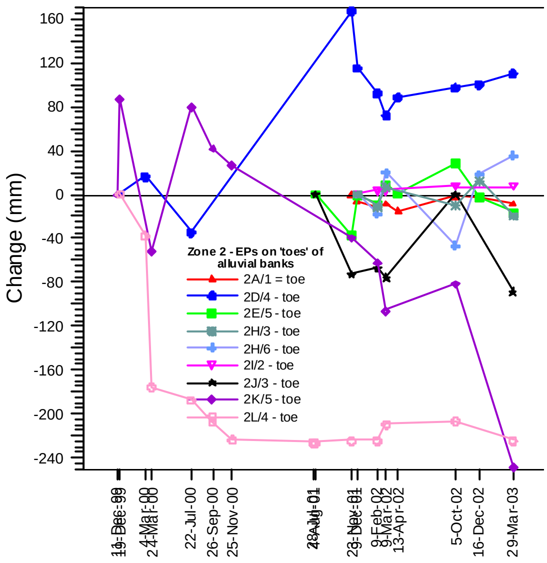


Figure 4.13. Erosion pin results for bank toes in Zone 2.

For the one-year period between March 2002 and March 2003, 18 sites out of a total of 27 showed nett erosion, with 5 sites exceeding 50 mm of erosive change. Sites having nett deposition were located on all parts of the bank, and showed increases of up to 50 mm.

The scour chain located at Site 2A showed no change between October and December 2002, and 1 link of erosion in March 2003. At the chain at Site 2D, both erosion and deposition occurred between October and December 2002, followed by deposition in March. Minor deposition, but no erosion was documented at Site 2H in both December and March. The chains in lower Zone 2, Sites K and L were monitored only in October 2002 and March 2003. Erosion equivalent to 6-links occurred at Site K, followed by up to 10 mm deposition. This is consistent with the erosion shown by the pin on the bank toe (Figure 4.13). At site L, one link was exposed by scour between October and March, accompanied by up to 45 mm deposition.

4.4.2.4 Zone 3

The natural inflows to Zone 3 are approximately double that of Zone 2, due to the increased size of the catchment below the dam. The water level fluctuations due to winter storm events were greater in Zone 3 than in Zone 2, and there was widespread evidence of freshly deposited sands on the upper banks of the zone in both October and December 2002. A summary of erosion pin results is presented in Figure 4.14.

Similar to the upstream zones, the cavities were active in Zone 3, with 3 out of the 4 cavities showing greater than 50 mm change between October 2002 and December 2002. This erosion was not reflected in the March 2002 and March 2003 results, and highlights the dynamic nature of the cavities.

The upper banks in Zone 3 showed deposition of up to 25 mm in October 2002, due to the winter storm events. This deposition continued through December 2002, reflecting the continued input of sediments during natural storm events. During the period of December 2002 to March 2003, when high power station discharge was more common, erosion increased.

The mid-slopes showed a different trend, with erosion common during the March – October 2002 period. This was possibly due to variable water levels associated with natural storm events attacking the mid-bank. The December 2002 and March 2003 results show both deposition and erosion on the slopes.

The only clear trend shown by bank toes in Zone 3 was widespread erosion between December 2002 and March 2003, as shown in Figure 4.15. The new erosion pin installed at Site 3A, following the loss of the original star-picket, showed little change between October and December 2002, and erosion of approximately 160 mm in March 2002, consistent with the original pin. In total, the bank toe at this site has eroded more than 500 mm since monitoring began in December 1999.

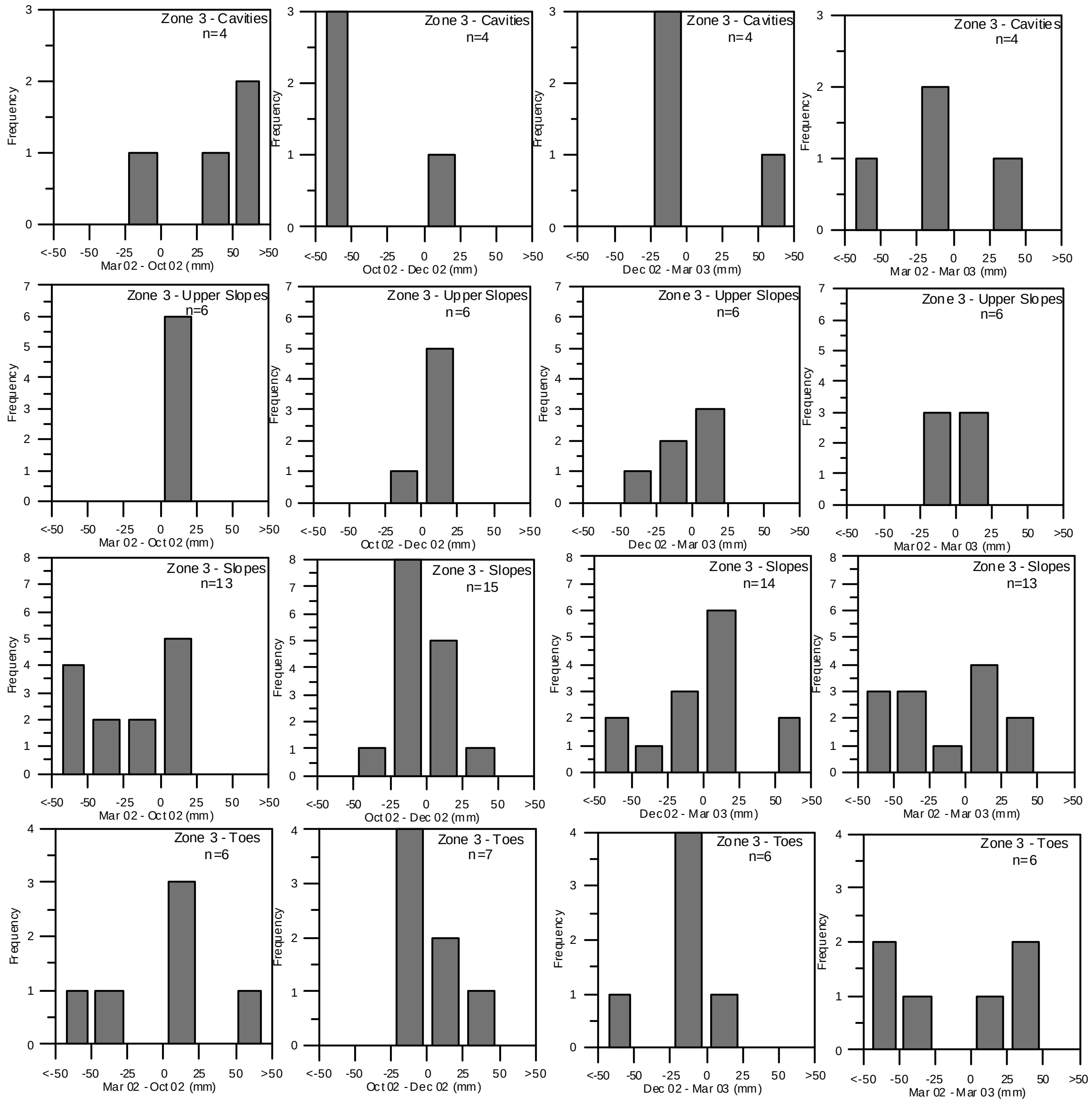


Figure 4.14. Summary of erosion pin results for Zone 3.

Scour chain results from Zone 3 were consistent with the erosion pin results. At Site 1, the scour was located in March 2003 for the first time since March 2002. A total of 7-links had been exposed in the intervening period, followed by 10 – 60 mm of deposition. Immediately downstream at Site 3B, one link was exposed between December 2002 and March 2003, with little change between October 2002 and December 2002. The two chains located at sites 3Eb and 3G showed no scour.

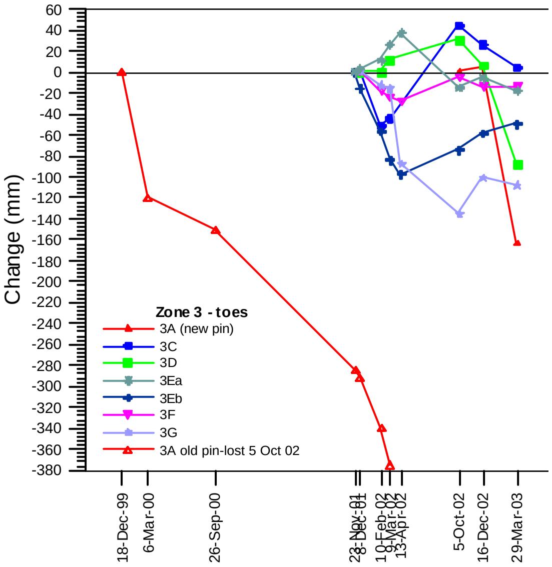


Figure 4.15. Erosion pin results from bank toes in Zone 3.

4.4.2.5 Zone 4

Zone 4, located downstream of the Denison River, was subjected to very large flood flows and fluctuations in river level between March 2002 and October 2002. These events resulted in deposition of up to 50 mm of sand on the upper slopes of alluvial banks, as shown in the histograms in Figure 4.16. Subsequent erosion of up to 25 mm was common between October and December 02, with nett deposition at 4 sites and nett erosion at 3 sites recorded for the year between March 2002 and March 2003.

Similar to Zone 3, the winter storm events contributed to erosion of mid slopes in Zone 4. The operation of the power station led to both erosion and deposition, generally within ±25 mm. For the year, more slopes experienced deposition than erosion, which is in contrast to Zones 1-3.

Bank toes in Zone 4 (Figure 4.17) generally showed a nett trend of erosion between March 2002 and March 2003, in spite of deposition at half the sites between March 2002 and October 2002. Some data are missing due to the toe pins being submerged and un-measurable at some sites.

Scour chains at Sites 4A, D and E all indicated that there was no change between October 2002 and December 2002. This was, followed by 1-link of scour, with deposition, between December 2002 and March 2003. Site 4F showed 2-links of scour in December 2002, but only deposition in March 2003. The remaining two scour chain sites (4Gb and 4H) showed little scour or deposition over the entire year.

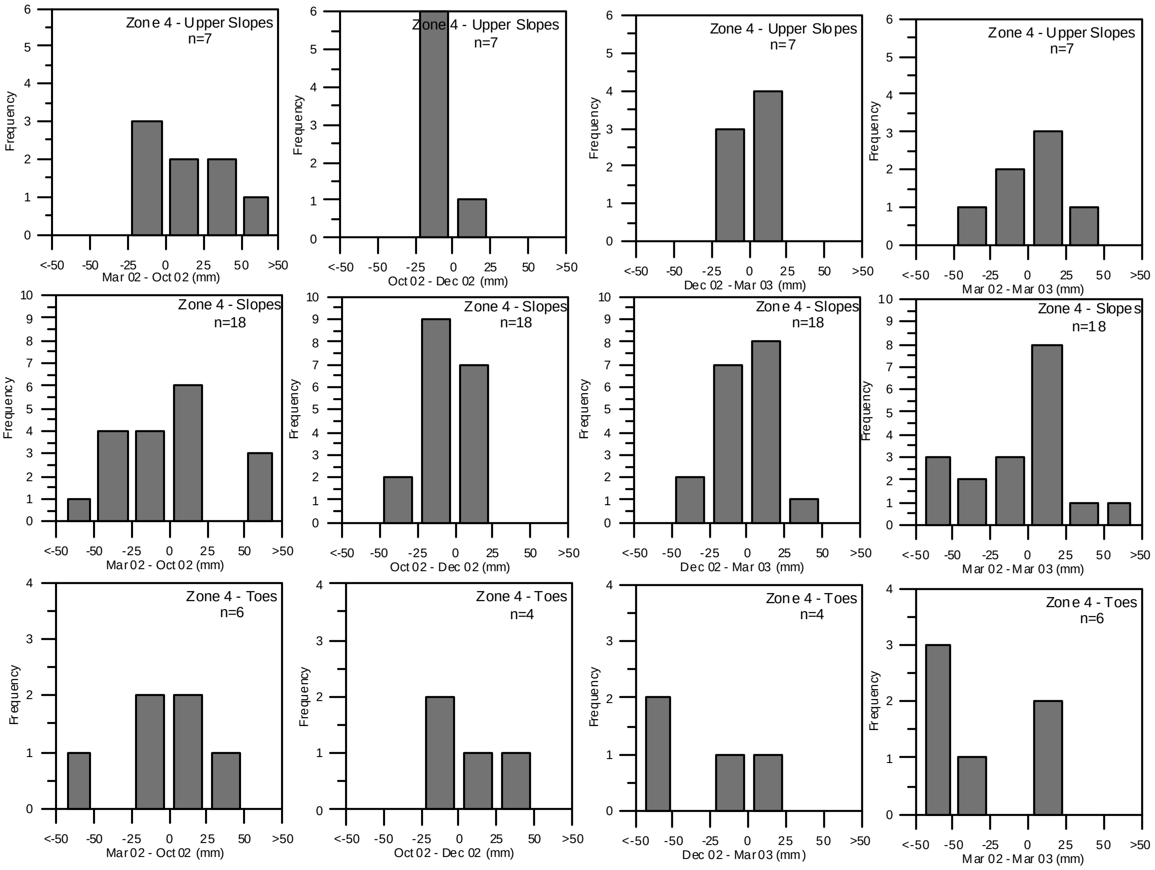


Figure 4.16. Summary of Zone 4 erosion pin results.

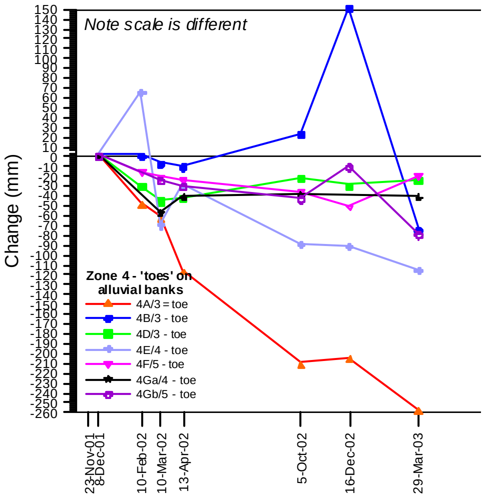


Figure 4.17. Erosion pin results from bank toes in Zone 4.

4.4.2.6 Zone 5

The cavities in Zone 5 showed similar results during all monitoring periods, indicating that both erosion and slumping of the cavity walls had occurred. Figure 4.18 summarises these changes.

Zone 5 erosion pin results were similar to Zone 4, in that there was nett deposition on the upper slopes and mid slopes between March 2002 and 2003. In general, the mid-slope results showed a more even distribution of erosion and deposition compared to the other zones, possibly reflecting the influence of a more natural flow regime and steady sediment supply from unregulated tributaries.

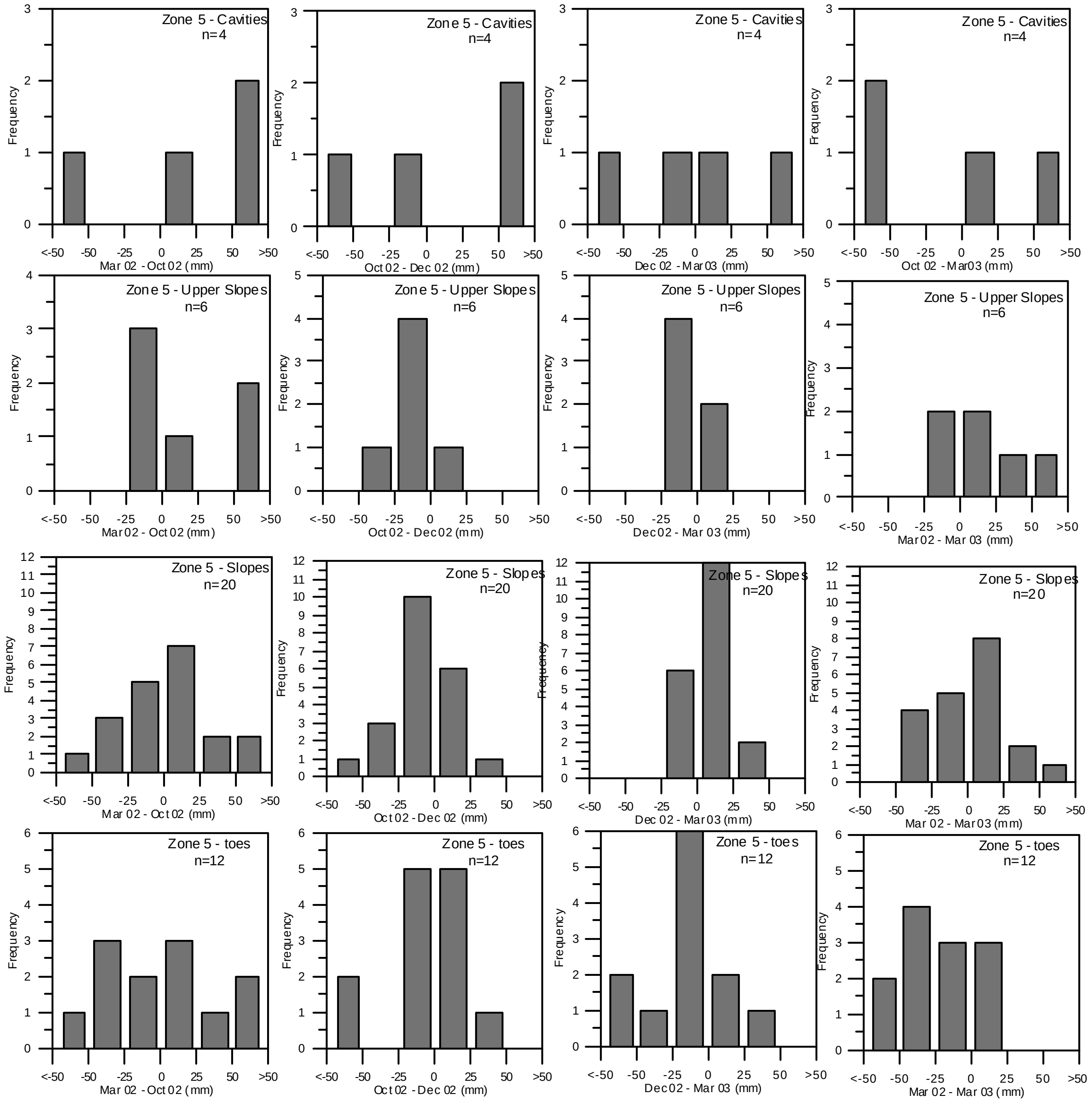


Figure 4.18. Summary of erosion pin results from Zone 5.

The majority of bank toes showed nett erosion in spite of deposition in the October and December 2002 results (Figure 4.19).

Scour chain results reflected the widespread deposition of sediments within the zone. The Site 5B chain had not been located since April 2002, and in the intervening year a total of 1 link of scour and 70 mm deposition occurred. At Sites 5C and 5G, no scour or deposition was recorded, whereas at Site 5D, deposition of up to 80 mm was recorded without any scour. Site I showed steady erosion, with 1-link exposed between October and December, and an additional link exposed between December and March. No deposition occurred on the chain. At the downstream site J, one-half a link of scour was recorded, accompanied by 30 – 40 mm of deposition. Site L showed no scour or erosion.

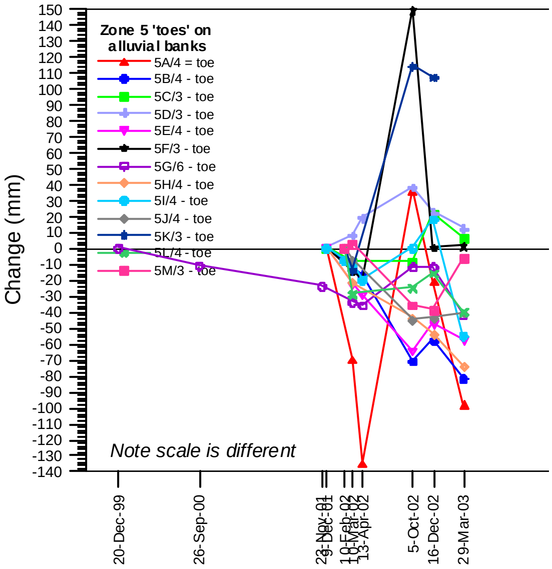


Figure 4.19. Erosion pin results from Zone 5 bank toes.

4.4.3 Photo-monitoring

The majority of photo-monitoring sites are tree falls and landslips, with the remainder comprising cobble bars, and general bank views. The tree falls and slips were selected because they are difficult to monitor using erosion pins, and provide information about the stability of banks following 'events', and long-term endpoints.

The majority of slips or trees falls showed no change between March 2002 and March 2003. Even sites that appeared to be very active, such as the series of three landslips in Zone 2 (Photo-monitoring sites P2-2 to P2-4) show very little change over the year. The most common change observed at slips and tree falls was an increase in vegetation on the slip face upslope of the power station controlled high water mark. Vegetation at many sites also appeared more 'lush' in 2003, but this may be due to differences in lighting conditions rather than actual increases in vegetation density. Other changes observed included the loss of leaves and small branches from LWD at the base of banks.

Site P2-5 was a notable exception to the above, with an initial tree fall in March 2000 leading to additional collapse of the steep sandy bank in an upstream direction. Large-scale changes were not apparent in the March 2003 photo, and may suggest the activity at the site is decreasing.

The cobble bar photo-monitoring sites showed no change over the monitoring period. In Zone 2, the black coating on cobbles at photo site P2-6 had increased, suggesting that the coating can develop on time-scales of 1-year.

The general bank photos showed a new slip in Zone 1 (Site 1-4b) and a new tree fall in Zone 2 (P2-1). A new tree fall may also have occurred at site P3-4, where obstruction by the tree fall made it difficult to ascertain whether it was the same monitoring site.

4.4.4 Interpretation of monitoring data

The interpretation of monitoring results between October 2002 and March 2003 was aided by the additional opportunistic monitoring completed in December 2002. The additional monitoring provided data about how the banks responded to the re-initiation of power station operation. The following points synthesise the year's results within the current understanding of fluvial geomorphic processes operating in the middle Gordon River.

- ➢ The March 2002 – March 2003 monitoring year differed from previous study years in that there were numerous large winter flood events, which occurred during periods of power station shutdown, and elevated water levels in zones downstream of the Denison River to heights in excess of power station controlled levels. The natural events delivered sediment to the upper banks of the lower zones, and eroded the mid-bank.
- ➢ The upstream zones, where natural flow inputs were minor, also experienced deposition during these winter flow events. This was limited to mud and sand deposition near the toe of banks in Zone 1 due to the restricted increase in river level during the flood events. Following the initiation of power station operation, there was no evidence of mud deposition in Zones 1 or 2.
- ➢ Erosion pin results were variable, with deposition and erosion occurring on all sections of banks. Erosion pin measurements most commonly varied within the range of ±25mm over the monitoring year, but changes of >±50 mm were also documented.
- ➢ Between March 2002 and March 2003 nett erosion was more common than nett deposition in the middle Gordon. Bank toes in Zones 3 – 5 consistently showed a loss of material in excess of 25 mm, whereas in Zones 1 and 2 the changes were smaller, in the range of ±25 mm. Typically, greater toe erosion was recorded in March 2003 than in December 2002, coinciding with increased usage of the Gordon Power Station prior to monitoring. The toe erosion caused a steepening of banks in the downstream zones.
- ➢ Erosion pin results indicated that erosion was more prevalent following the re-initiation of power station operation than during the extended shut-down and large winter storm events. In Zone 1, there was evidence that the frequent on / off sequence associated with

1 and 2-turbine usage between October and December resulted in greater erosion than the extended full-gate operation of the power station between December and March 2003.

- Cavities in all zones were active, and in Zones 1 and 2 were collapsing, as indicated by deposition on erosion pins located within cavities and field observations. The collapse of cavities is consistent with the working model of bank response in the middle Gordon developed during the initial Basslink investigations.
- Although cavities were active, landslips and tree falls remained stable over the monitoring year, in spite of large winter flows, and periods of extended power station operation. Vegetation increased above the power station-controlled high water level on the faces of several slips. This is also consistent with the working model of bank response, where large woody debris buttresses bank toes, and vegetation stabilises the upper bank.

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 2002-03, monitoring trips occurred in October 2002 and March 2003. An opportunistic overnight monitoring at GA-X1 (Gordon-Albert area) was undertaken on 30-31 March 2003.

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

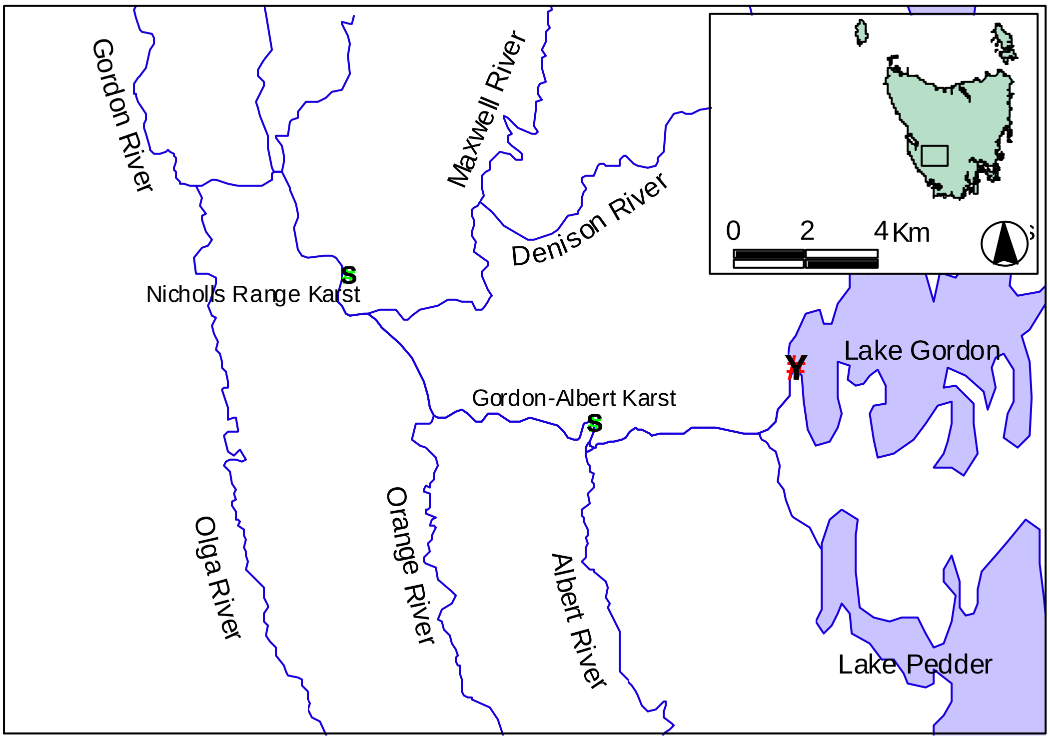


Figure 5.1. Map of the karst monitoring sites in the Gordon River.

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.

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 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 4 erosion pins installed and a photo-monitoring site. Bill Neilson Cave site has 5 sub-sites within the cave which are designated 6A–E. Sub-sites 6A–C comprise various arrays of erosion pins. Sub-sites 6D and 6E are two lightweight capacitive water level probes. Water levels were recorded every 20 minutes over a range of 1.0 m.

5.2 Methods and results

5.2.1 Erosion pin data

Erosion pins were measured using a steel 300 mm ruler placed to the right side of the pin, on the contour level. Pin length data for all sites are summarised in Table 5.1. Note that in the caves, smaller changes in erosion pin heights can be regarded as more significant than in the dolines as the substrate is fine sediment and measurements can be made reasonably accurately. The substrate in the dolines is leaf litter and twigs which is more unstable and therefore readings are less accurate.

For the Gordon-Albert karst area, 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. These measurements are summarised in Table 5.2. In October 2002, a second erosion pin (Pin No. 28) was added to Channel Cam to act as a back up for Pin No. 1 (see Table 5.1).

Table 5.1. Erosion pin data for karst geomorphology monitoring sites for 2002-03. Superscripts in the first Pin length column refer to the date of first monitoring: a = November, b = December 2001.

Site no.	Site description	. Pin no	Pin length (mm)				Change this summer (mm)	Change over 12 months (mm)	Comments and interpretation
			23/11/01[a] or 8/12/01[b]	9/3/02	6/10/02	30/3/03			
1	Channel Cam	1	322[a]	318	318	316	–2	–2	Little to no change during the summer period or over the previous 12 months. Pins have been inundated – mud on shaft of new pin.
		28	n/a	n/a	245	245	0	n/a	
2	GA-X1 cave	2	250[a]	239	238	244	+6	+5	Pins 2 and 3 on the middle and higher ground suggest that some erosion of material has occurred, in contrast to the deposition over the previous summer. Pin 4 at the lowest level shows a steady removal of material although there was little change over winter.
		3	190[a]	189	193	195	+2	+6	
		4	154[a]	161	160	163	+3	+2	
	Doline at cave entrance	9	214[a]	213	220	217	–3	+4	Some accumulation of leaf/twig litter material in the entrance to the cave, in comparison to greater general removal over the winter period.
		10	278[a]	278	293	290	–3	+12	
3	Doline adjacent to GA-X1	5	259[a]	287	294	297	+3	+10	All pins longer lengths suggesting a loss of material. Likely due to movement and breakdown of leaf and twig litter down slope. Less nett change at two of the pins over the previous 12 month period.
		6	300[a]	300	294	306	+12	+6	
		7	254[a]	252	258	261	+3	+9	
		8	195[a]	196	192	200	+8	+4	
4	Small doline	12	192[a]	171	170	172	+2	+1	All pins longer lengths suggesting a loss of material, probably due to movement of leaf and twig litter. Less nett change over the previous 12 months. Pin 13 ranged from 217 to 245 depending on how the measurement was taken in relation to the leaf and twig debris.
		13	234[a]	238	231	217–245	+14	+7	
		14	253[a]	256	244	262	+18	+6	
5	Kayak Kavern	16	309[b]	308	319	359	+40	+51	Sediment erosion on all pins except 19 on the slope. Nett deposition on the top flat area over 12 months and nett erosion from Pin 19. Pin 16 was affected by sediment slumping. Pin 17 is now just 60 mm from a slumped area and may be affected by slumping in the future.
		17	293[b]	291	284	288	+4	–3	
		18	267[b]	266	255	263	+8	–3	
		19	249[b]	245	271	267	–4	+17	
6	Bill Neilson: 6A at entrance	20	483[b]	480	499	495	–4	+15	Similar deposition at the lower levels to the 2001-02 summer period, in contrast to the significant erosion over the 2002 winter period. Minimal change at the mid and higher levels.
		21	300[b]	299	302	301	–1	+2	
		22	272[b]	272	269	272	+3	0	
	Bill Neilson: 6B Sed bank II	25	194[b]	195	195	195	0	0	No change at lower levels, limited deposition higher up the bank. Little change over 12 months, except at higher levels.
		26	203[b]	203	202	202	0	–1	
		27	215[b]	216	214	213	–1	–3	
	Bill Neilson: 6C Dry sed bank	23	297[b]	297	295	298	+3	+1	Minimal erosion appears to have taken place on the lower level. Significant change at the upper level relative to last year possibly due to slumping from above.
		24	227[b]	226	202	203	+1	–23	

Table 5.2. Surveyed distances between erosion pins at sites 3 and 4 in the Gordon-Albert karst area.

Site No.	Pins measured	Distance (m) 6/10/02	Distance (m) 30/3/03	Comments
3	Photo-monitoring peg to Pin 5	3.28	3.295	No structural change
	Pin 5 to Pin 6	1.055	1.055	No structural change
	Pin 6 to Pin 7	1.35	1.345	No structural change
	Pin 7 to Pin 8	1.85	1.85	No structural change
4	Photo-monitoring peg to Pin 12	2.62	2.62	No structural change
	Pin 12 to Pin 13	1.515	1.515	No structural change
	Pin 13 to Pin 14	1.435	1.435	No structural change

5.2.2 Automatic water level recorders

Automatic water level recorders are installed in Bill Nielsen Cave (downstream and upstream) in the Nicholls Range karst area, and at GA-X1 in the Gordon – Albert karst area. For comparison purposes, the discharge from the Gordon Power Station for 2002-03 is shown in Figure 2.4.

5.2.2.1 Cave GA-X1

The hydrographs from the water level recorder at GA-X1 are shown in Figure 5.2 for March to October 2002, and Figure 5.3 for the period from October 2002 to April 2003.

5.2.2.2 Bill Nielsen Cave

The hydrographs from the two water level recorders in Bill Neilson Cave, between March and August 2002, are shown in Figure 5.4. The hydrographs for the period August 2002 to March 2003 are shown in Figure 5.5.

The power station operated at full gate from the end of January to the end of March 2003, during which period there was almost no natural pickup within the cave catchment. The effects of the fluctuating power station flow on the water levels in the cave are most pronounced during this period between the 0.2 m and 0.4 m level on the recorder (RL 0.16 to 0.36).

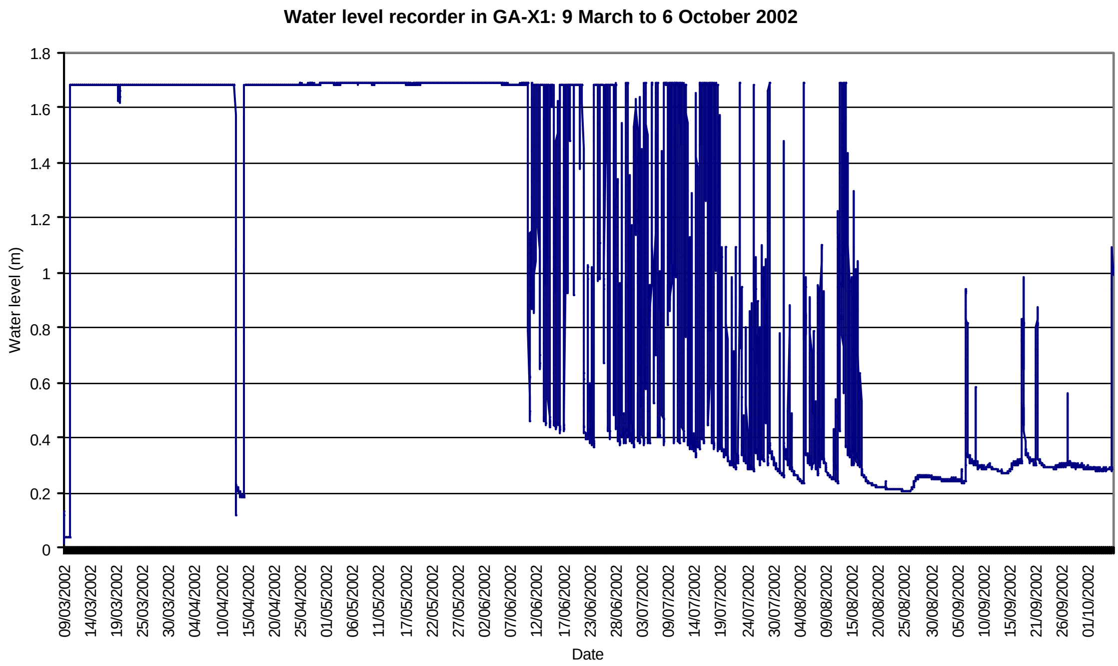


Figure 5.2. Water levels in cave GA-X1 from March to October 2002

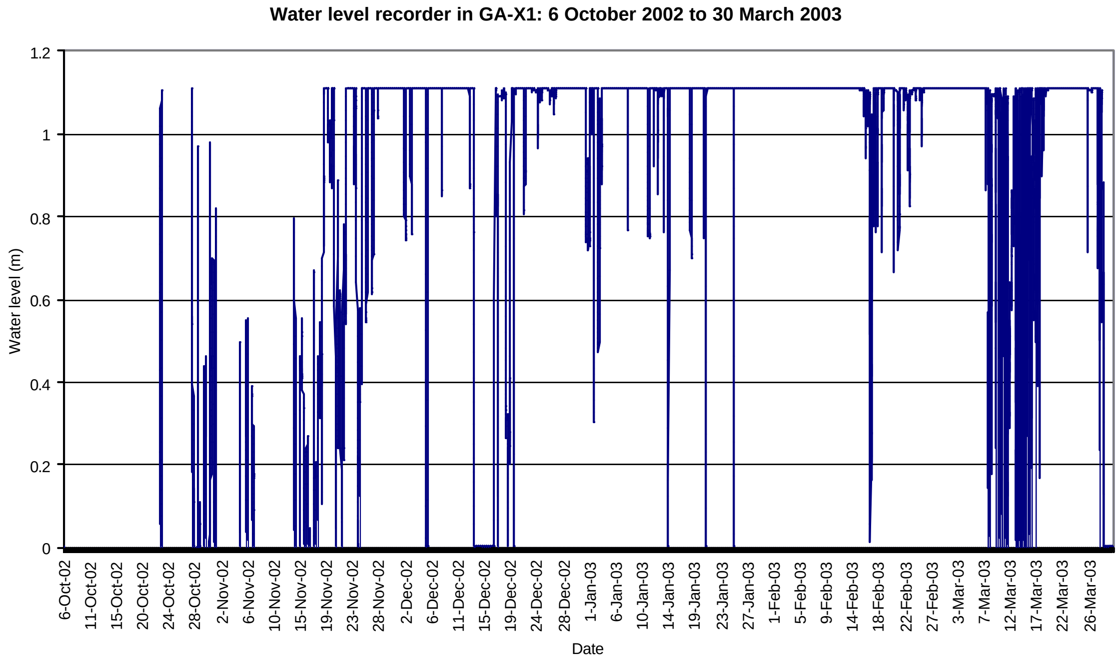


Figure 5.3. Water levels in cave GA-X1 from October 2002 to April 2003. Note that the recorder was changed after the October monitoring to one with a smaller height range.

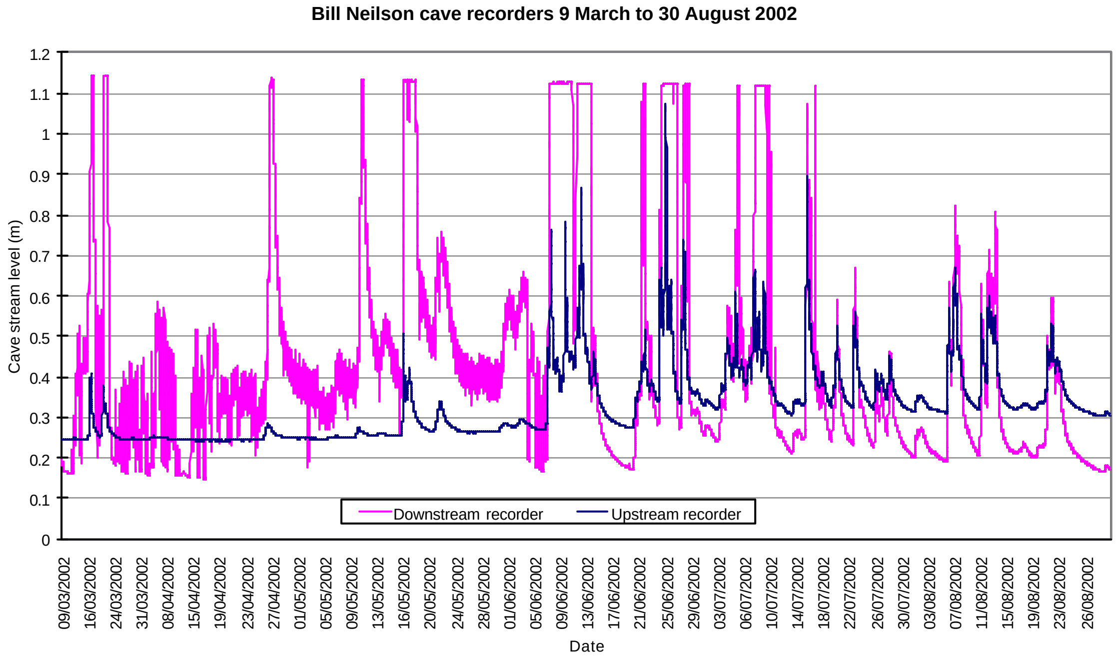


Figure 5.4. Water levels at the two recorder sites (downstream and upstream) in Bill Nielson Cave from March to August 2002.

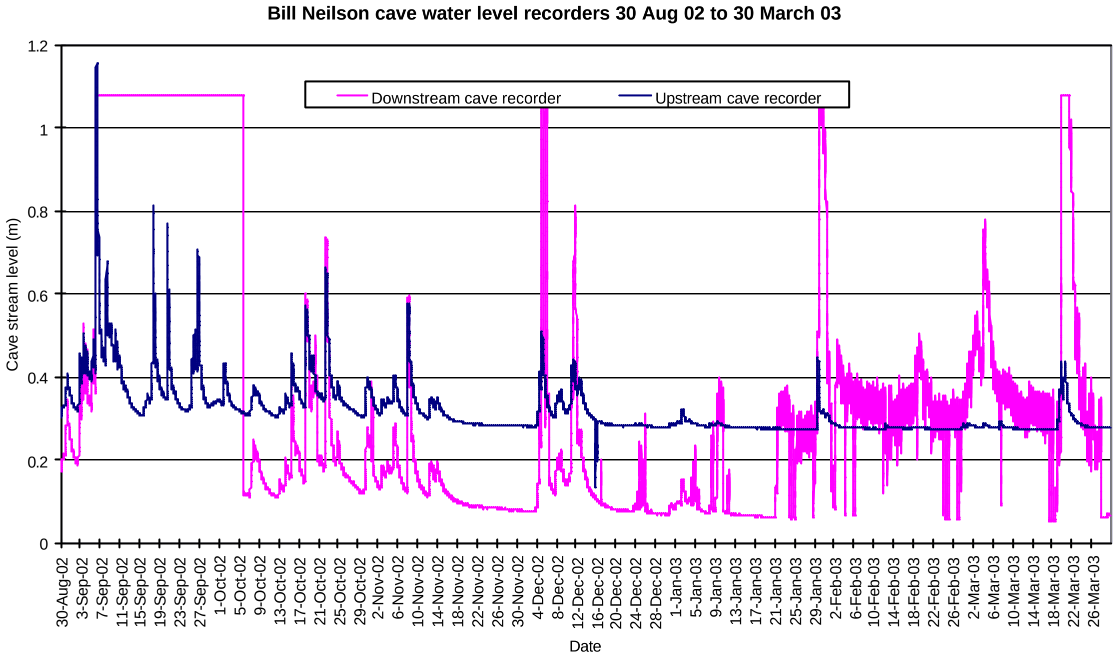


Figure 5.5. Water level data from the downstream (magenta line) and upstream (blue line) water level recorders in Bill Neilson Cave from August 2002 to March 2003. Note that the downstream recorder in Bill Neilson's Cave dislodged and lay in the water from 6 Sept 2002 to 6 Oct 2002.

5.2.3 Photo-monitoring

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

5.2.4 River and cave water levels, Gordon – Albert karst area

An opportunity was taken during a power station start-up event to monitor changes in water levels in GA-X1 relative to the rise in the Gordon River levels over the night of 30-31 March 2003. One set of temporary gauge boards was installed in GA-X1 (3 boards), and a second set in the main river channel adjacent to GA-X1 (4 boards). The boards were surveyed-in up the bank at each site such that relative levels could be taken at all river heights. The boards in the cave were also surveyed relative to the boards in the river so that both sets of data could be compared.

Water level data were collected from the river approximately every 20 minutes prior to the power station start-up. The power station was switched on at approximately 19:45 and was ramped up over 1 h 45 min to reach a constant flow by approximately 21:30. The first observation of the river rising in the river channel was made at 21:07 (approx. +1 h 22 min) and was easily identifiable by the noise of water moving through the cobble bars. The frequency of measurement was increased, at this time, to approximately one minute intervals and this was maintained until the rate of rise in the river had reduced. Readings were taken at appropriate intervals thereafter until 00:15, and again in the morning from approximately 07:00. The water level in the river tended to surge giving an accuracy of measurement of approximately ±0.75 cm (see Figure 5.6).

Immediately after the river had begun to rise, water level readings were commenced in GA-X1. The rate of rise in GA-X1 was less, and considerably more steady than in the river, resulting in readings accurate to approximately ±0.05 cm. Readings were taken when the water level reached specific identifiable levels and were recorded against time to the nearest quarter of a minute. The automatic recorder was also measuring in the cave during the monitoring period.

One reading was taken from a single additional reference board in Channel Cam on the morning of 31 March 2003.

5.3 Discussion

5.3.1 Bill Neilson cave

5.3.1.1 General observations

For the spring 2002 monitoring, indications throughout the cave were that there had been significant sediment movement and water inundation since the previous visit. The scum lines which had been present on all previous trips were gone, including the mark at Station 13 which was 2.1 m above the zero reference level (2.1 m RL) and was considered to be a relatively high-flow mark during the original investigations. There were new high water level marks on the vegetation in the entrance chamber, now surveyed to the reference point, which indicate that the inundation level reached RL 3.9 m during this period. This is supported by the fresh leaf debris located at Station 16, adjacent to the dry sediment bank, which was at RL 3.85 m. A relatively fresh water level mark above the erosion pins in the dry sediment bank (Pins 23/24) was surveyed in at RL 3.25 m.

For the autumn 2003 monitoring, the indications throughout the cave were that there had been little flow in the cave stream over the preceding few months. A coating of fine-grained mud was present over the boulders and gravels in the cave stream bed in the entrance chamber, suggesting that there had been little throughflow in the system. The mud was generally 1–2 mm thick, but reached as much as 35 mm thick at one point on top of the large boulder just inside the entrance to the cave. The mud was not evident in the cave beyond the downstream recorder, supporting the theory that it had come into the cave system via the Gordon River. It is probable that the mud originated in the Denison catchment (L. Koehnken, pers. comm.).

The high water marks on the vegetation in the entrance chamber, which were emplaced during the winter period at approximately RL 3.9 were still present, confirming that summer peak flows were smaller than those over the winter period.

5.3.1.2 Sediment transfer

There are three sets of erosion pins in Bill Neilson cave: the wet sediment bank in the entrance chamber (first set); the wet sediment bank 5–10 m further into the cave (second set); and the dry sediment bank 175 m into the cave.

For the spring 2002 monitoring, the data for the first wet sediment bank in the entrance chamber showed that there had been 19 mm of sediment loss at the lowest level close to the cave floor and 3 mm of sediment loss at the middle level, while there had been 3 mm of sediment deposition at the upper level. It is likely that the erosion at the lower levels was caused by the winter flows in the cave stream at times when the Gordon River level was low. At moderate rates of Gordon River flow, the river water back-floods into the cave reducing the erosive power of the cave stream. This is likely to have resulted in the much lower erosion rates at the middle levels in the sediment bank. At the uppermost level of the bank, there was a small nett gain in sediment, which is likely to have occurred when the Gordon River was at high levels and the effect of the cave stream was much reduced.

For the autumn 2003 monitoring, the data for the first wet sediment bank (in the entrance chamber) suggested that there had been limited sediment deposition at the lower and mid-levels. This is a similar result as the same period during the 2001–02 season, but is in contrast to the 2002 winter period (above) when erosion occurred. It is likely to be the result of the relatively low cave stream flows during this period, in conjunction with high power station discharges, bringing the Denison River sediments into the cave. The data suggest that limited erosion occurred at the higher level, which was likely to be due to the action of the power station fluctuations around the full-gate flow level.

Over 2002-03, the data for the second wet sediment bank (in the passageway) showed little evidence of nett sediment transfer. The pin closest to the cave floor had zero nett change since March 2002 and there was just 1–3 mm of deposition at the middle and upper levels. These pins consistently measure different sediment transfer trends to the first set of pins, the reason for which is still not clear. It is possible that there could be different sediment transfer dynamics occurring at the sites as a consequence of the different width and shape of the cave at each location. The first site is located in a much wider part of the chamber than the second site which is located more in the passageway where the cave begins to constrict.

For the spring 2002 monitoring, there was a significant change in the erosion pins in the dry sediment bank. The pin higher up the bank (Pin 24) recorded 24 mm of sediment gain while the lower pin closest to the cave floor (Pin 23) had an increase in sediment of just 2 mm. The differences between the pin results and the relatively large change at the upper level are interesting. There are several vertical and horizontal cracks in the sediment bank suggesting that there may have been some slumping of the sediment above the pins, which could have contributed to the increase at the upper pin.

For the autumn 2003 monitoring, the pins in the dry sediment bank indicated that limited erosion had taken place at the lower level. It is difficult to determine from the available data whether the cave stream flow event on 21-22 March 2003, which was coincidental with full-gate power station operations, could have inundated the lower pin. Based on the erosion pin data it is probable that it did. The water level recorder was subsequently moved to a higher level.

5.3.1.3 Photo-monitoring

There is no evidence of any major sediment shift at any of the monitoring sites within the cave from the 2002-03 season's photos.

5.3.1.4 Water level monitoring

The data from the water level recorders in Bill Neilson Cave, for the spring 2002 monitoring, are shown in Figure 5.4. During the relatively dry period in March and April 2002, when the power station was operating at more than 210 cumecs (m^3s^{-1}), the fluctuations in power station output were clearly reflected in the downstream cave recorder. Small catchment pickup events such as the one on 26 - 27 April 2002 had a very marked effect on the downstream recorder while the power station outflow was consistently high. This was in comparison to the larger catchment flow events in August 2002 when the tailrace discharge was low, which had a much lesser effect.

Isolating the effects of the Gordon flow from the effects of high cave stream flow during the June-July 2002 period was difficult as the downstream cave recorder flooded out regularly and appeared to be able to do so as a consequence of either high cave stream flow or high Gordon River flow. During the autumn monitoring, the downstream recorder was moved to a slightly higher level to try to isolate the effects of the Gordon River flow on the system when there is flow in the Denison

River. Initial indications are that, when the natural pickup in the catchment is high, the hydrological effects of the cave stream are more significant in the vicinity of the dry sediment bank, than the Gordon River water. While the flow peaks appeared to be higher than if the power station were not operating, the flow patterns were consistent with natural pickup flows and the effects of the fluctuating power station outputs were less significant.

During the period from October 2002 to March 2003, there were four broad blocks of different power station operation patterns, which are summarised in Table 5.3. This table shows the corresponding natural catchment pickup and the consequent effects on the downstream recorder.

Table 5.3. Summary of power station operations and river flow from October 2002 to March 2003.

Time period	Station operation	Natural pickup	Effect on downstream cave recorder
First three weeks in October	off	Regular small peaks, small baseflow	None
Last week of October to mid November	Infrequent use of one or two turbines	Similar to the first three weeks in October	None
Mid November to end January	More frequent use of two or three turbines. Three peak station events	Less baseflow, infrequent larger peak flow events.	Recorder trace reflects natural pickup unless station >210 cumecs. e.g. 10/1/03, small natural pickup peak in conjunction with peak station event gave larger peak in cave.
End January to end March	Consistently full gate	Little to no baseflow, minor flow events	Fluctuating power station output strongly reflected in recorder levels 0.2–0.4 m

There was no effect on the downstream cave recorder from October 2002 to January 2003 inclusive while the power station was operating at less than full gate. During the very dry period in February and March 2003, while the power station was operating at full gate and there was very little catchment pickup, the fluctuations in power station output were clearly reflected in the downstream cave recorder. The fluctuations were relatively intense in the cave between 0.2 and 0.4 m on the recorder, which is equivalent to RL 0.16 to 0.36. At these levels, the dry sediment bank located 175 m into the cave was not affected by the Gordon River.

5.3.1.5 Conclusion

The 2002-03 summer period showed similar sediment transfer patterns in the wet sediment banks to those of the previous summer. In general there was more activity during the winter period than during the summer months. An additional element this year however, was the introduction of a layer of fine grained mud which appears to have come from the Denison River catchment. It is anticipated that the winter flows in the cave stream will flush this mud coating out before the next visit.

The dry sediment bank may have been inundated to its lower levels, with full gate flow and a relatively small cave stream flow event. The downstream water level recorder was moved to a higher level to try to assess the relative contributions of the cave stream and the Gordon River water at this point in the system.

5.3.2 Kayak Kavern

5.3.2.1 General observations

The sediment mound in Kayak Kavern showed evidence of erosion during the winter 2002 period. Sediment cracking on the upper levels of the mound in March 2003 suggested that it had not been fully saturated for much of the 2002-03 summer.

5.3.2.2 Sediment transfer

The erosion pins in Kayak Kavern showed that, over the 2002 winter, deposition occurred on top of the silt mound (Pin 17: 7 mm and Pin 18: 11 mm), consistent with trends in previous results. Pin 19, on the active slope of the mound, recorded 16 mm of erosion, in contrast to the 4 mm of deposition recorded over the preceding period. Pin No. 16 also recorded 11 mm of erosion although slumping displaced it.

Over the 2002-03 summer, the data indicated that erosion had taken place at all but Pin 19. Pin 16 recorded a change of 40 mm but was further affected by slumping. This season also appears to have produced slightly higher sediment transport activity than during the 2001-02 summer period.

The sediment dynamics in Kayak Kavern are quite different to those in Bill Neilson cave. Kayak Kavern is more influenced by Gordon River dynamics, including the tributary inputs, than Bill Neilson Cave, in which processes appear to be more controlled by the cave stream.

5.3.2.3 Photo-monitoring

Photo-monitoring sites were established in the cave to support the erosion pin data and the general observations of debris movement in the cave. Over the 2002 winter, the photos supported the erosion pin data. A loss of sediment was evident where the buried branches were more exposed and the slope of the silt mound had become steeper. One of the larger branches positioned on the slope appeared to have moved closer to the water.

No significant changes to the sediment bank were evident from the photo-monitoring carried out in March 2003.

5.3.2.4 Conclusion

Significant deposition occurred on top of the silt mound in Kayak Kavern over the winter 2002 period, which coincided with high volume natural flows. Significant erosion also occurred at the active silt interface which was probably a consequence of the relatively high frequency of change in power station output.

The summer 2002-03 period was primarily one of erosion. This is likely to be a consequence of the high, but fluctuating, power station output combined with little natural catchment pickup.

5.3.3 GA-X1

5.3.3.1 General observations

GA-X1 is regularly inundated by Gordon River water although it is not completely submerged. The lower Pins 2 and 4, the photo-monitoring peg and the water level recorder were all coated in a fine white mud during the spring monitoring, while Pin 3 remained clean. There was also evidence of fresh leaf and twig debris on the walls of the cave approximately 1 m above the sandy floor. Disturbance of the white sand on the floor of the cave suggested that there had been some animal activity in the cave.

5.3.3.2 Sediment transfer

Over the 2002 winter, the pin array in GA-X1 recorded a range of results. Pins 2 and 4, those closest to the lower sump level, recorded 1 mm of deposition. The higher pin in the cave, Pin 3, had 4 mm of erosion.

Over the 2002-03 summer, there was a loss of sediment recorded at all erosion pins in the cave, ranging from 2 to 6 mm. Pin 3 on the higher ground registered the smallest loss while Pin 2 located in the middle ground on the main part of the cave floor indicated the loss of 6 mm of sediment. Pin 4 at the lowest level closest to the cave sump showed a slow, steady removal of material.

The pins in the entrance doline recorded 7 and 15 mm of erosion over the 2002 winter and less over the summer. These pins were placed amongst leaf and twig debris, and it is likely that the erosion was the movement of the organic debris down into the cave with rainfall events.

5.3.3.3 Photo-monitoring

There was no evidence of any major change at any of the monitoring sites within the cave.

5.3.3.4 Water level monitoring

The winter 2002 period recorded three distinct periods in the water level data. From March to June 2002 the power station output was high and the cave was constantly inundated. From June to August the water levels varied with a lower but fluctuating power station output. From August to early October the water level trace resembled a natural hydrograph and the power station was off. It must be noted that the water level recorder was installed at an angle of 43 degrees from horizontal in the sump (due to space constraints) so the actual level of inundation was less than the data indicated.

Despite the considerable water inundation in the cave during the winter period, there was only 1 mm of deposition recorded in the submerged part of the cave on both pins. In the previous (2001-02) summer, 11 mm of deposition was recorded on the sandy floor (Pin 2) and 7 mm of erosion at Pin 4, closer to the sump. The flow conditions in the river were quite different over the two periods, and it is considered likely that the different flow regimes were responsible for the different sediment transfer patterns.

The water level recorder in the cave was inundated for much of the three months prior to the March 2003 monitoring trip, as a result of full-gate operations at the power station. The relatively small reductions in station operations between 12 - 17 March 2003, which occurred during a period of little natural baseflow, resulted in relatively large water level changes in the cave. This was in contrast to a similar-sized reduction in power station output, around 18 May 2002, which occurred in conjunction with a natural flow event and appeared to have less impact on the water levels in the cave. Fluctuations in power station discharge appear to have been accentuated in the cave as a consequence of the very low natural baseflow, which would normally act as a buffer. This may account for the erosion in the cave.

The changes in water level in the cave and in the river as the power station started up on 30 March 2003 are shown in Figure 5.6. The river rose from the zero relative level at a rapid rate within the first half hour, after which the rate of rise decreased for the remainder of the observations. The lowest point in the cave from where water level readings could be taken was 1.425 m above the zero level in the river, and it took approximately 34 minutes for the water to reach this point. Analysis of the data showed that the lag time between the cave and the river was a maximum of 17 minutes in the early stages, reducing to approximately 8 minutes after an hour.

The head difference between the river and the cave when the water in the cave was first visible was 0.35 m, although this had reduced to 0.01 m within the next half hour. The river and cave levels had equalised by the following morning, i.e. within 10 hours, but by extrapolation on the graph it is probable that the actual equalisation time was of the order of 5 hours. The head differences between the river and the cave are shown in Figure 5.7. The total height change was 3.045 m.

The steady water level rise in the cave relative to the river (Figure 5.6), and the lag time and sustained head difference between the river and the cave (Figure 5.7), indicate that there is a sediment buffer through which the river water seeps before reaching the cave. This would suggest that the potential for continued rapid sediment transfer through the bottom of the cave into the river may be relatively low. This hypothesis is supported by the erosion pin data from the cave. It is probable that there is some rock present in order for the cave to have developed in the first instance, but that it is choked with sediment.

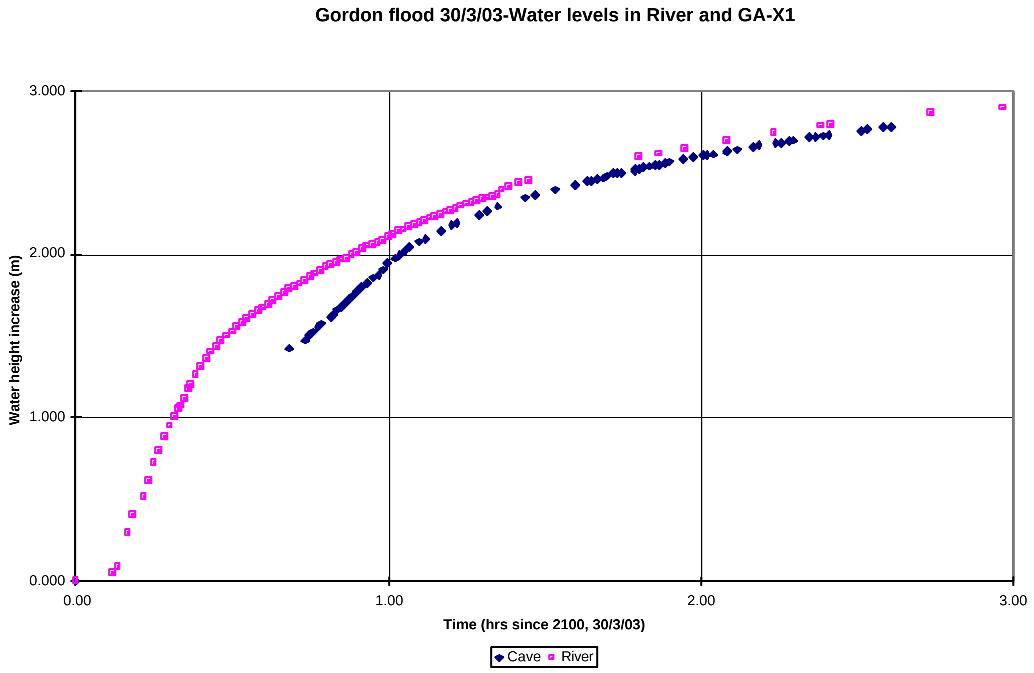


Figure 5.6. Water level changes in GA-X1 with time as the power station came back on. The station was switched on at 19:45 and was first noticeable in the river channel at GA-X1 at 21:07.

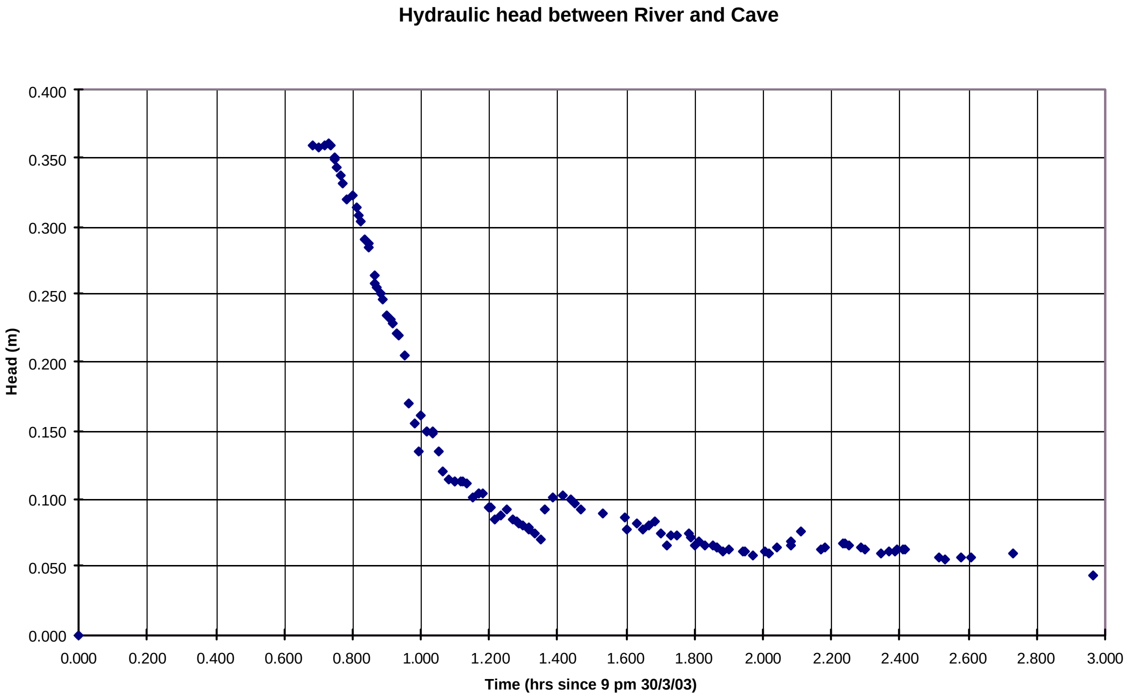


Figure 5.7. Head difference (m) between the Gordon River and cave GA-X1 during a power station start-up event, 30-31 March 2003.

5.3.3.5 Conclusion

Sediment transfer in GA-X1 appeared to be most pronounced when power station discharges were high and fluctuated widely. Consistent high discharge, or fluctuating low discharge, appears to have less nett effect than highly variable discharge. Erosion was recorded in GA-X1 during the period when the power station discharge varied and there was little catchment inflow.

Water level monitoring, carried out as the power station started up, indicated the presence of a sediment buffer through which the river water filters before reaching the cave. It is probable that the sediment is supported by surrounding rock, and that the cave may be relatively stable in terms of sediment flux.

5.3.4 Dolines

There are two doline sites being monitored in the Gordon-Albert karst area, 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 and a succession of pins arrayed in a line 1–2 m apart, up to Pin 8. The pins showed a variety of results but as the slope of the doline is relatively steep and leaf and twig debris has collected behind the pins, it is probable that the results have been affected by moving debris. The distances between the tops of the pins were comparable to when they were installed in November 2001.

There are three erosion pins installed in the doline at Site 4: Pin 12 at the base of the depression and Pins 13 and 14 up the side. There was negligible change to Pin 12, while Pins 13 and 14 recorded some deposition. The increase in material was principally leaf and twig litter. The distances between the tops of the pins were comparable to when they were installed in November 2001.

Changes to the height of all the erosion pins in the dolines suggested an overall loss of material. This was probably due to movement of leaf and twig litter downslope into the doline and to decay of material at the bottom. Significant accumulation of debris was recorded behind the pins at some locations, particularly Pin 13 at Site 4. This further emphasizes the limitations of individual pin changes and the importance of considering all the pin results together.

Photo-monitoring showed that there was no major structural change in any of the dolines.

5.3.5 Channel Cam

There was little change to the erosion pins at Channel Cam over the past 12 months. It has been estimated previously that Channel Cam is inundated when the Gordon River is higher than 4.1 m at site 71. While the water level exceeded this value for a major portion of the time between March and June 2002, there was little fluctuation above and below this level which would assist sediment transfer. The channel was dry from mid-June 2002.

Photo comparison showed that some of the moss present in the vicinity of the Pin 1 had died off by October 2002 and the channel was noticeably drier than in the past. In March 2003, the moss was still absent and the channel remained relatively dry. The adjacent sediment erosion feature on the bank of the Gordon River also looked as though it has been relatively inactive. In conclusion there has been little to no change in Channel Cam during 2002-03, due mainly to the lack of inundation and fluctuating water levels.

6 Riparian Vegetation

6.1 Introduction

The riparian vegetation monitoring aims to collect 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 summarises the results of the second year of vegetation monitoring. Scheduled monitoring took place in December 2002 and April 2003. An additional trip was undertaken in October 2002.

The locations of the riparian vegetation monitoring sites are shown in Figure 6.1.

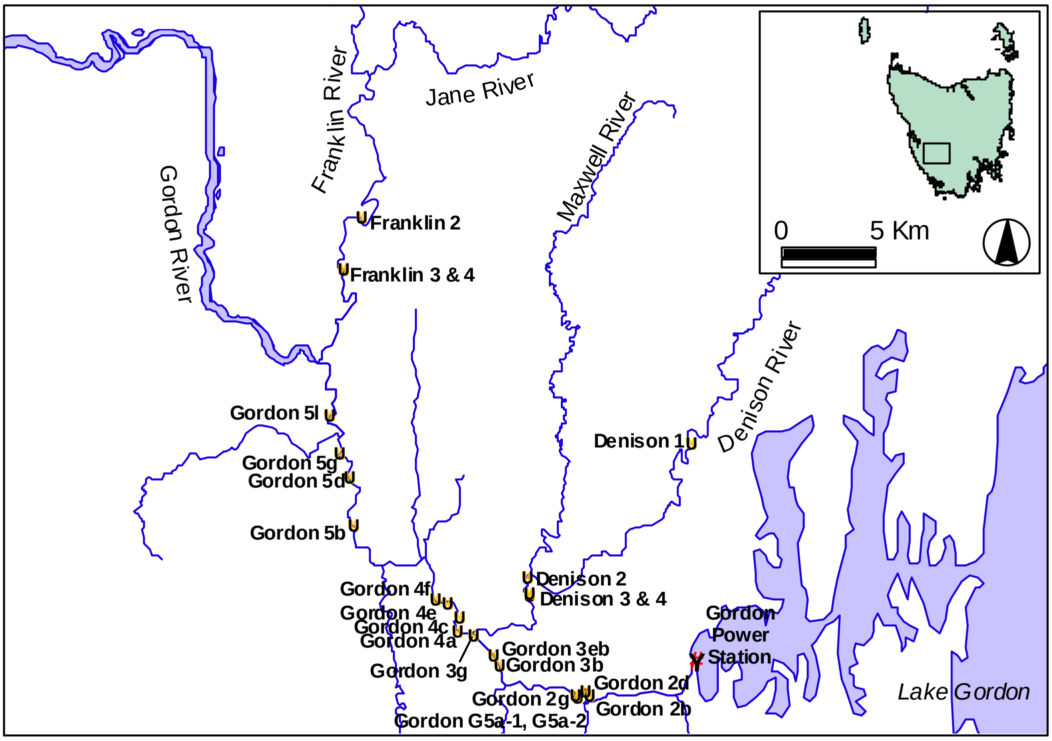


Figure 6.1. Map of the riparian vegetation monitoring sites in the Gordon, Denison and Franklin Rivers.

The data collected provide baseline information covering two sampling periods for species cover assessment. While some interpretation of the data is possible, the conclusions should be viewed as preliminary, due to the short time-frame of the data set. The following discussion presents general trends in the riparian vegetation within the middle Gordon River and the two reference rivers.

6.2 Methods

The riparian vegetation monitoring uses three methods of assessment: permanent quadrats, seedling recruitment, and photo-monitoring. Permanent quadrat monitoring includes assessment of species' ground cover, root exposure, and shrub- and tree-stem density. Seedling recruitment monitoring is undertaken twice yearly, in summer and autumn, in the Gordon River to record seasonal recruitment patterns. Photo-monitoring and all quadrat studies are undertaken concurrently in the Franklin and Denison Rivers. The monitoring schedule, covering both seasons, is presented in Table 6.1. Full details of the methods and rationale were presented in the Gordon River Basslink Monitoring Annual Report 2001-02 (Hydro Tasmania 2002).

Table 6.1 Scheduled variable monitoring for riparian vegetation monitoring program

	Season		**Method of assessment**		
Sites	Summer	Autumn	Quadrat studies [1]	Seedling recruitment	Photo-monitoring
Gordon Zones 2-5	*			✓	✓
Gordon Zones 2-5		*	✓	✓	
Denison Sites 1-3		*	✓	✓	✓
Franklin Sites 1-3		*	✓	✓	✓

[1] Quadrat studies include species cover, root exposure and tree- and shrub-stem counts.

6.2.1 October 2002 Field Trip

Zone 5 sites were re-installed or reassessed during October 2002. All variables monitored as part of the quadrat studies were included for each site in Zone 5.

6.2.2 December 2002 Field Trip

The December 2002 monitoring trip was a scheduled trip aiming to establish photo-monitoring sites on the Gordon River and to assess seedling recruitment at all Gordon River sites. During this monitoring, large pins were inserted in all quadrat corners to ensure accurate quadrat relocation.

6.2.3 April 2003 Field Trip

The April 2003 field trip was undertaken to obtain the second year of quadrat data and seedling data for all the Gordon River sites. Quadrat data, seedling data and photo-monitoring were completed for all the reference river sites (as per Table 6.1).

6.3 Results and Discussion

6.3.1 October 2002 Field Trip

The reassessment of Zone 5 for all variables was completed successfully in October 2002. Site 5d was considered to be sufficient for the purposes of the study and only species cover was re-monitored. Sites 5b and 5g were relocated in order to obtain a more representative sample of the riparian vegetation within that zone. All variables (including species cover, seedling recruitment, tree species and ground cover conditions) were monitored. The data presented below represent the first rigorous monitoring of permanent sites for Zone 5.

A total of twenty-eight species were recorded in the quadrat surveys in Zone 5, with over 70% of these found only in Site 5d. Akin with Zones 2-4, the species diversity and cover is vertically stratified on the Gordon River banks of Zone 5. The lower banks (represented by the channel quadrats) had sparse vegetation cover with limited species diversity and cover. Species recorded were limited to the overhanging and trailing shrub *Bauera rubioides*, filmy ferns (*Hymenophyllum* spp.), and the graminoids *Ehrharta* spp. and *Juncus* sp. The mean number of species recorded in these quadrats was less than one for all Zone 5 quadrats, as shown in Figure 6.2.

Vegetation cover within the 'channel' quadrats was often negligible, averaging less than 1%, which was inversely proportional to the bare ground cover, as indicated in Figure 6.3.

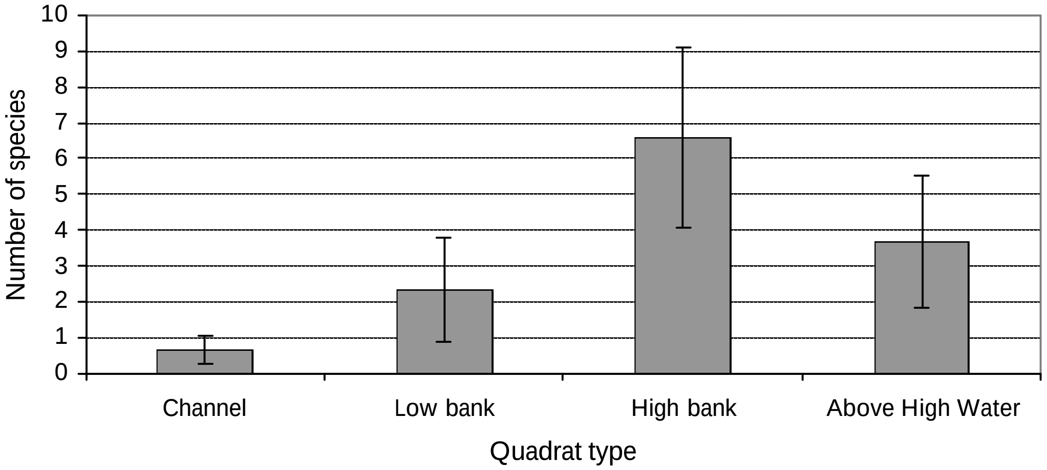


Figure 6.2. Number of ground species by quadrat type for Zone 5 bank sites in the Gordon River in October 2002. Error bars represent ± Standard Error of the mean (S.E.M.).

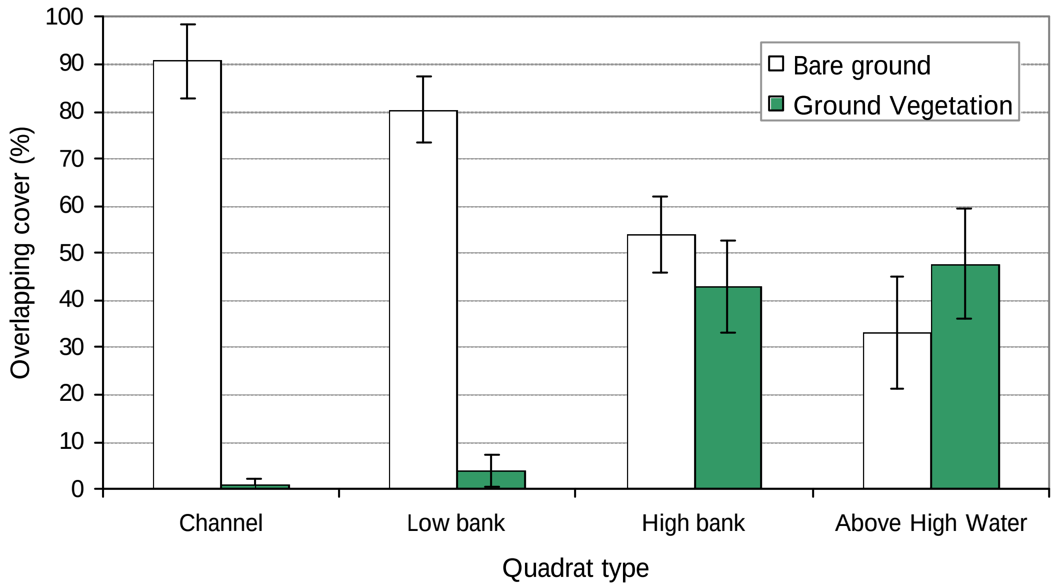


Figure 6.3. Percentage overlapping cover (± S.E.M.) for bare ground and ground vegetation by quadrat type for Zone 5 bank sites in the Gordon River in October 2002.

In the 'low bank' and 'high bank' quadrats (those associated with 2-3 turbine-related inundation) the species diversity increased. Fern species such as *Gleichenia microphylla, Blechnum nudum* and *B. wattsii* become more frequent in these areas, along with shrub species such as *Bauera rubioides*, *Tasmannia lanceolata* and *Pimelea drupaceae.* The most common species in this area was the grass species *Ehrharta stipoides*.

As expected with areas of lowest disturbance, the 'above high water' quadrats displayed higher mean total vegetation cover and lower mean bare ground cover than the lower bank and channel quadrats. However, the mean number of species in these quadrats was lower than the high bank quadrats. This result can be attributed to a wide variation in the counts within both groups of quadrats, as shown by the relatively large standard error of the mean in Figure 6.2.

Other variables measured in the quadrat studies, such as seedling recruitment, litter cover and tree species followed patterns similar to those reported for the other zones.

6.3.2 December 2002 Field Trip

Riparian vegetation monitoring in December 2002 comprised seedling recruitment and photo-monitoring along the Gordon River banks. All sites, excluding Site 4c, were monitored successfully on this field trip. Site 4c was not included in the monitoring due to substantial slipping of a near vertical cobble bank and reference markers could not be relocated. No monitoring of the reference rivers was undertaken during this trip (see Table 6.1 above).

6.3.2.1 Seedling recruitment

Discussion of the seedling recruitment results is included in Section 6.3.4 below.

6.3.2.2 Photo-monitoring

Thirty-five photo-monitoring sites were installed in the Gordon River in Zones 2-5.

The photo-monitoring trial (undertaken in April 2002) identified potential difficulties in identifying species and health indicators on the photographs, therefore species lists and notes on the current health of the vegetation were included for each site.

General observations as part of the photo-monitoring included:

- an overall increase in litter on the lower bank areas (this is likely to be the result of the more variable flow regime that prevailed during the extended power station shutdown from July to October 2002);
- a reduction in the debris generally apparent at high water mark (concomitant with the increase in litter over the whole bank); and
- reductions in cover of moss and root mats on cobble bars.

6.3.3 April 2003 Field Trip

Riparian vegetation monitoring in April 2003 included quadrat sampling and seedling recruitment in the Gordon River and quadrat sampling, seedling recruitment and photo-monitoring in the reference rivers (refer to Table 6.1).

All sites, excluding Site 4c in the Gordon River and Franklin 1 in the Franklin River, were successfully monitored on this trip. Bank slippage at Site 4c resulted in the loss of reference markers and the site's removal from the monitoring schedule. The Franklin 1 site at Flat Island had been tampered with, and was not able to be monitored. Both sites have been replaced.

Site 4e was monitored in April 2003 to replace Site 4c. In the Franklin River, an additional site was installed downstream of Canoe Bar to replace the Franklin 1 site. It is thought that this site is less frequently used as a camping spot, therefore it is hoped that the chance of future tampering has been reduced.

General trends of species stratification within the sites continued to follow the patterns described in the Gordon River Basslink Monitoring Annual Report 2001-02 and will not be repeated here.

6.3.4 Overall seedling recruitment

With only three recruitment monitoring events (two in the case of zone 5 sites), only the broadest trends will be evident in these data. The results of these analyses should be viewed with this limitation in mind.

6.3.4.1 Gordon river sites

In general, all zones within the Gordon River recorded an increase in the average number of seedlings in the summer (December 2002) monitoring trip (refer to Figure 6.4 - Figure 6.7). This increase occurred across quadrat types including the low bank and channel quadrats. There was, however, a large variation in seedling numbers within the quadrat types, as shown by the large standard error of the mean (S.E.M) indicated on the graphs. The reasons for this apparent pattern in seedling numbers are likely to be seasonal, in conjunction with flow regulation effects.

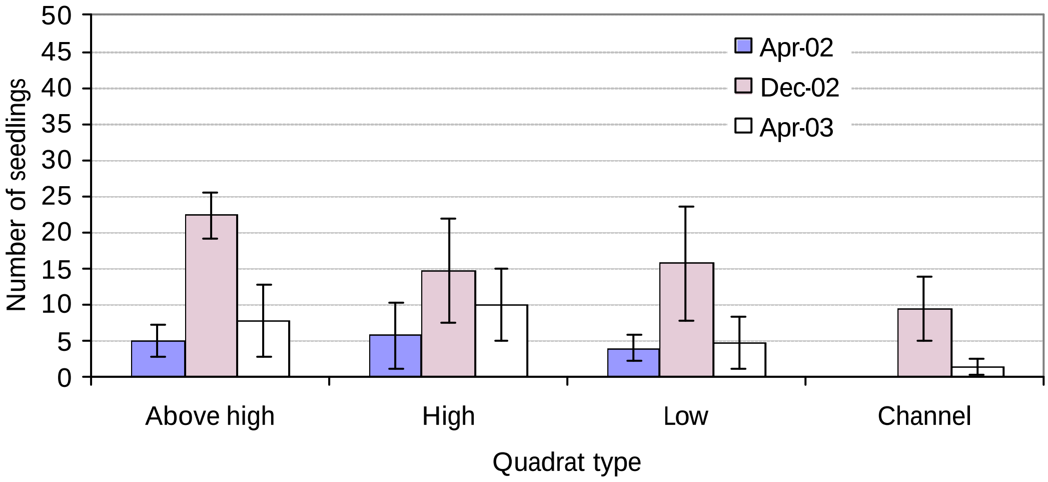


Figure 6.4 Average seedling count (±S.E.M.) by quadrat type for Zone 2 bank sites in the Gordon River for April 2002, December 2002 and April 2003 monitoring sessions. Note that counts of >10 have been included as 15 individuals for average seedling counts.

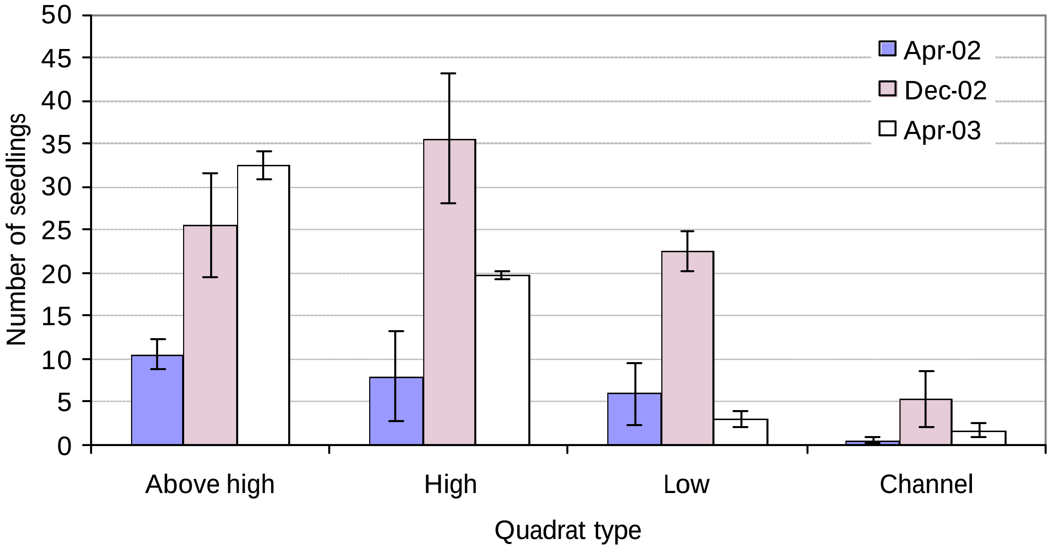


Figure 6.5 Average seedling count (±S.E.M.) by quadrat type for Zone 3 bank sites in the Gordon River for April 2002, December 2002 and April 2003 monitoring sessions.

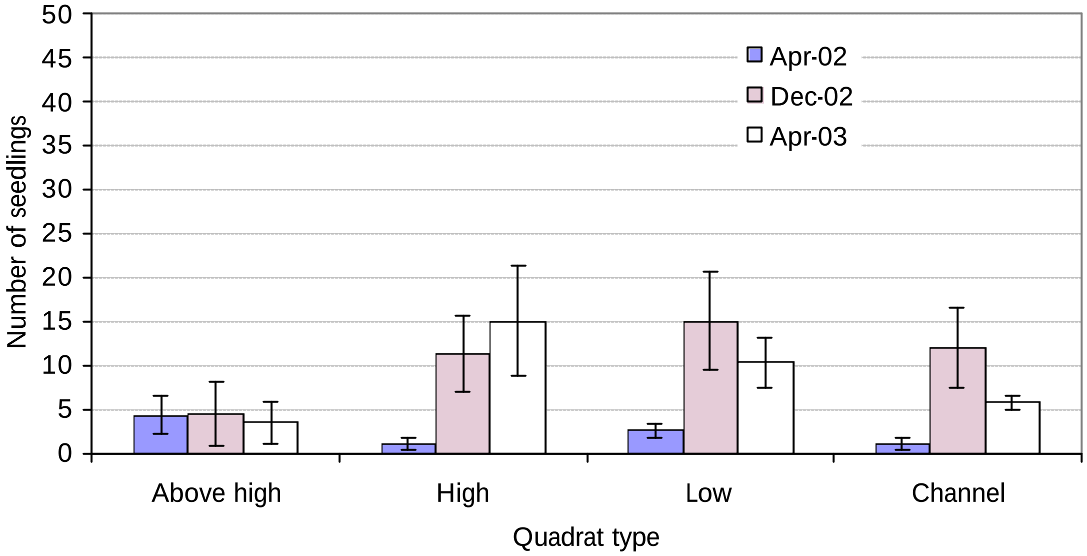


Figure 6.6 Average seedling count (±S.E.M.) by quadrat type for Zone 4 bank sites in the Gordon River for April 2002, December 2002 and April 2003 monitoring sessions.

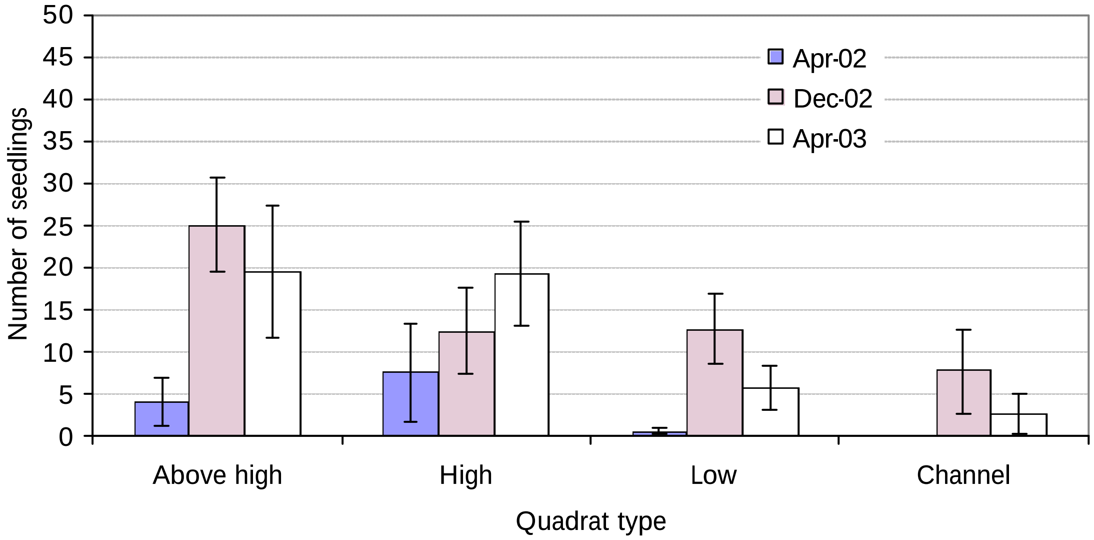


Figure 6.7 Average seedling count (±S.E.M.) by quadrat type for Zone 5 bank sites in the Gordon River for April 2002, December 2002 and April 2003 monitoring sessions.

6.3.4.2 Reference river sites

The schedule presently does not allow for summer monitoring of seedling recruitment in the reference rivers. Average seedling numbers for April 2002 and 2003 are given for the Franklin River in Figure 6.8 and the Denison River in Figure 6.9. The absence of summer data means that the seasonal pattern observed in the Gordon River sites cannot be verified in reference rivers.

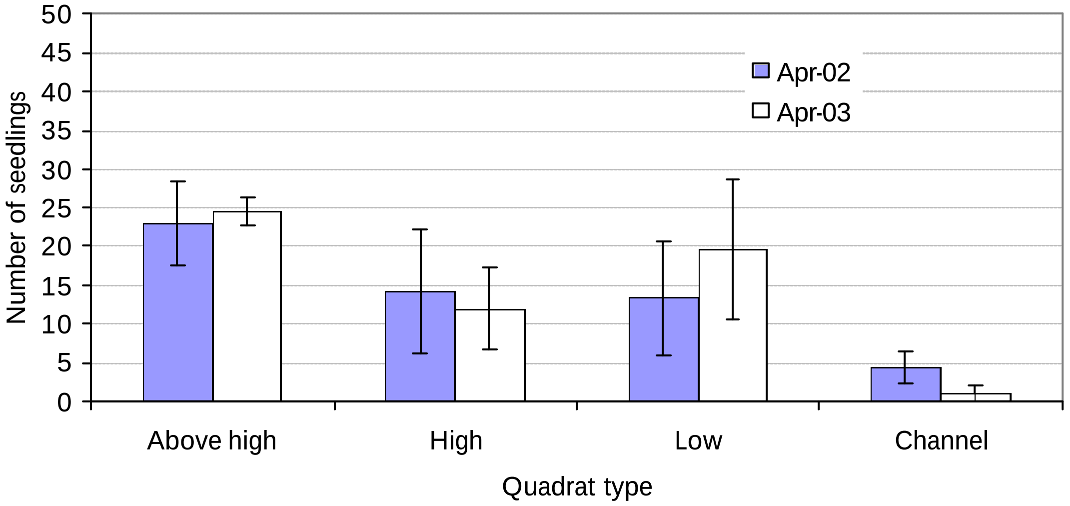


Figure 6.8 Average seedling count (±S.E.M.) by quadrat type for the Franklin River in April 2002 and April 2003 monitoring sessions.

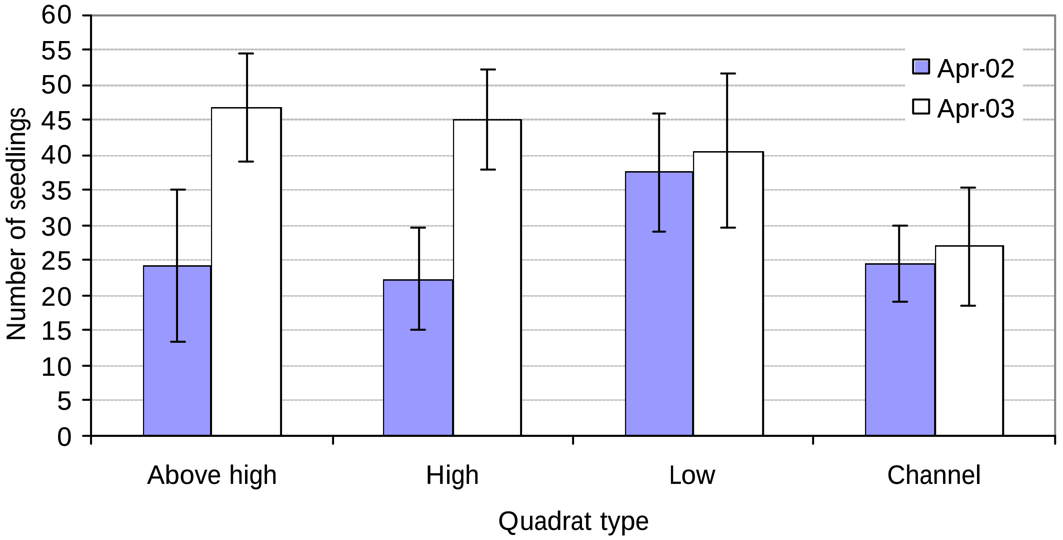


Figure 6.9 Average seedling count (±S.E.M.) by quadrat type for the Denison River in April 2002 and April 2003 monitoring sessions.

Seedling counts in the Denison River (Figure 6.9) were very high in all quadrats including the channel quadrats. The seedlings included an abundance of *Acacia* spp. and *Clematis aristata* seedlings in all quadrat types. *Coprosma moorei, Nothofagus cunninghamii, Leptospermum riparium* and 'unknown dicotyledon' seedlings were also widespread but not as prolific as the *Acacia* spp. and *Clematis aristata* seedlings. All these species are frequent colonisers in the other rivers, however, they are generally not as abundant.

Most of the seedlings on the Denison River occurred in the <5 cm size class with a few *Leptospermum* sp. seedlings also occurring in the 5-10 cm size class. The Franklin River data had numerous seedlings in the 5-10 cm size class, a spread not recorded at other sites.

6.4 Conclusion

Stratification within the sites on the Gordon River continued to be the dominant feature of the riparian vegetation. There was little variation in species cover data between the summer and autumn sampling periods.

The seedling recruitment showed large degrees of variation between sampling periods. Most of this variation is likely to be a result of normal seasonal variation, as it is widely acknowledged that spring is the peak recruitment period for a majority of the species present. Further seasonal data are required to clarify patterns of recruitment in the Gordon River.

7 Macroinvertebrates

7.1 Introduction and Methods

Macroinvertebrate sampling was conducted in spring (October) 2002 and autumn (March) 2003. 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. Monitoring was also conducted at six ‘reference’ sites in rivers within the Gordon catchment but in undisturbed and unregulated condition.

7.1.1 Monitoring Sites

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

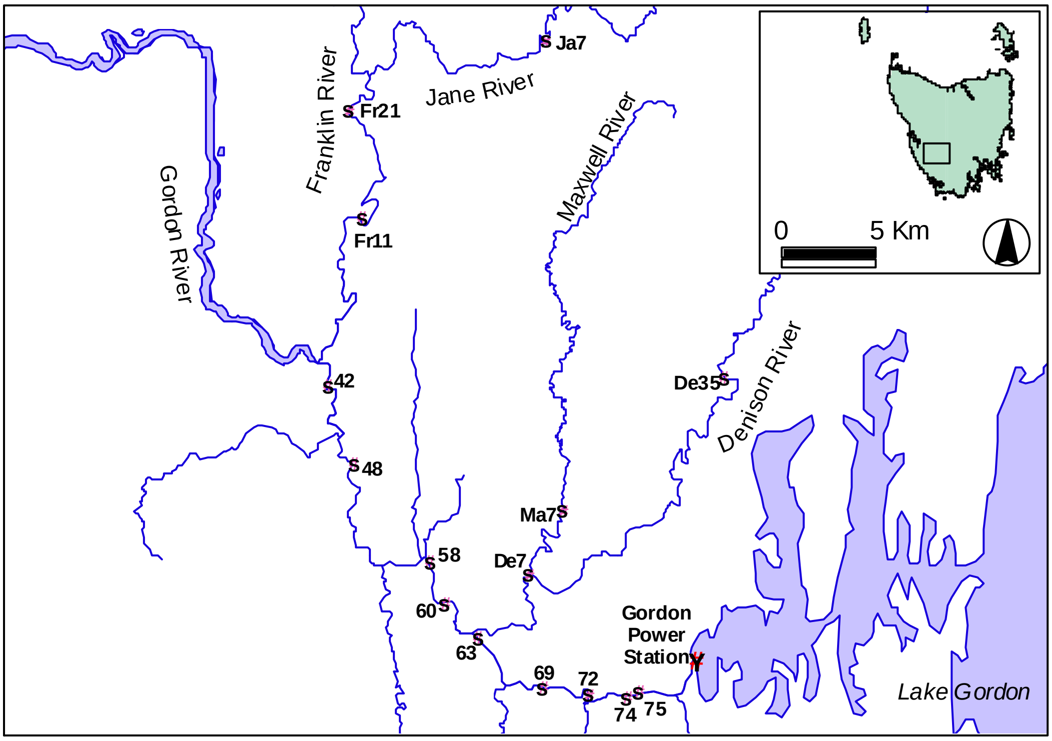


Figure 7.1. Map of the locations of macroinvertebrate monitoring sites in the Gordon, Denison and Franklin Rivers.

7.1.2 Macroinvertebrate sampling

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

- collecting 10 surber samples (30 x 30 cm area, 500 micron mesh) by hand disturbance of substrate to a depth of 10 cm and washing into the net; and
- disturbing substrate by foot and hand immediately upstream of a standard 250 micron kick net over a distance of 10 m.

All surber samples from a site were pooled and preserved (10% formalin) prior to laboratory 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.

7.1.3 Habitat variables

A set of standard habitat variables were recorded at each site, and a number of variables were recorded from maps.

7.1.4 Analysis

All RBA data were analysed using the Hydro RIVPACS models developed by Davies *et al*. (1999), with predictions and O/Epa and O/Erk values derived using the RBA macroinvertebrate data in combination with key 'predictor' habitat variables. O/Epa and O/Erk values were derived for combined seasons and for single seasons, using models specifically prepared for the Basslink monitoring program during 2002. Paired t-tests were conducted to assess between-year and between-season differences in O/Epa, O/Erk, total abundance and number of taxa.

7.2 Results

7.2.1 Quantitative (surber) sampling

Data from surber samples are shown in Table 7.1 and Table 7.2, below. The trend of increasing number of taxa and total abundance with increasing distance downstream of the power station that was apparent in previous years was not evident in 2002-03 (see Figure 7.2). For the Gordon River sites, the number of taxa was consistently low at site 75 (2 km downstream of the power station), while the remainder showed more variation between seasons than between sites. In the spring 2002 monitoring, sites 69 and 60 recorded similar numbers of taxa to the reference sites. In the autumn 2003 monitoring, all Gordon River sites recorded lower values than reference sites for abundance ($p < 0.0002$ by t-test, degrees of freedom (df) = 13) and diversity ($p < 0.0005$ by t-test, df = 13). Site 75 again recorded the lowest numbers.

For both number of taxa and total abundance, there was no difference apparent between sites upstream and downstream of the Denison junction.

Table 7.1. Quantitative macroinvertebrate data (abundances as n per 0.18 m^2) for Gordon and reference sites sampled in Spring 2002.

		Date :	**Spring (October 2002)**														
		Type :	Monitoring									Reference					
		River :	Gordon									Franklin		Denison		Maxwell	Jane
		Site :	75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Phylum/Class	**Class/Order**	**Family**															
Platyhelminthes	Turbellaria		1			1						3	2				2
Nematoda				2				1			3	1					2
Mollusca	Bivalvia	Sphaeriidae				1	2									1	
	Gastropoda	Hydrobiidae				4		2	5	2	3	2		1		3	
		Ancylidae											3				
Annelida	Oligochaeta			2	15	25		17	20	78	37	65	55	7	1	47	90
Arachnida	Hydracarina											1		1			
Crustacea	Amphipoda	Paramelitidae	1		2	3		2		3	1			1			
	Isopoda	Phreatoicidea				2											
		Janiridae	45	43	18	9	4	1	3	5		1	5	1			2
	Ostracoda					2											
Insecta	Plecoptera	Eustheniidae				4		4	2	1	2	1			2		
		Austroperlidae	1			1	1										
		Gripopterygidae	5	27	10	26	68	20	3	10	16	20	20	8	9	10	7
		Notonemouridae	1	1	3	1	1	2									
	Ephemeroptera	Leptophlebiidae		2	11	9	8	54	10	13	17	56	38	57	25	95	38
		Baetidae										3			3	24	10
Diptera	Chironomidae	Chironominae		1	4		4		3	2	71		1	2	3		
		Orthocladiinae		27	7	24	25	4	2	2		2	3	3	7	1	
		Podonominae	10	1	5	18	9		4	3	2	4	1	4	1	4	2
		Tanypodinae															
		Diamesinae	36	70	16	18	7	1					2		3		1
		Simuliidae		2	11	51	4	54	35	27	8	221	163	30	67	5	18
		Tipulidae				1							2	1	1	1	
		Athericidae						1									
		Blephariceridae		2				2		7	2	13	42	4	4		8
		Ceratopogonidae				1							6	1	6		
		Empididae								1							
		Unid. pupae	4	4	18	12	7	15	4	6	6	2		2		4	2
	Trichoptera	Calocidae												1			1
		Conoesucidae				1	4	2			1	4	4		4	2	5
		Glossosomatidae										2			1	2	2
		Helicophidae											1				
		Hydrobiosidae	3	3	5	7		2	1	1	1	4	6	1	2	4	3
		Hydropsychidae			1		34	118	35		1	2	5		1		
		Hydroptilidae			1												
		Leptoceridae						4	1				2	2		1	1
		Philorheithridae										2	1		2	3	
	Coleoptera	Adult Elmidae					3	9	1		1	8	8	20	15	17	13
		Larval Elmidae			2	2	2	14	4	4		82	33	66	84	43	167
		Larval Scirtidae			1	3			1	2		1	5	4	4	1	1
		Larval Psephenidae						6				1		3	1	1	1
Tardigrada																	
		Number of taxa	**10**	**14**	**17**	**24**	**16**	**22**	**17**	**17**	**16**	**24**	**23**	**22**	**22**	**20**	**21**
		Total abundance	**107**	**187**	**130**	**226**	**183**	**335**	**134**	**167**	**172**	**501**	**408**	**220**	**246**	**269**	**376**

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

		Date :	Autumn (March 2003)														
		Type :	Monitoring									Reference					
		River :	Gordon									Franklin		Denison		Maxwell	Jane
		Site :	75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Phylum/Class	**Class/Order**	**Family**															
Platyhelminthes	Turbellaria			1			4	2	2			4	30	1	2	1	1
Nematoda				1				2		2			5		1	1	
Mollusca	Bivalvia	Sphaeriidae					4		1		1				1		
	Gastropoda	Hydrobiidae			1		6	1	13	12	1	2		1		6	
		Ancylidae										22	52				
		Glacidorbidae			1						1						
	Oligochaeta		2	22	5	1	15	38	34	42	21	34	113	5	93	9	163
Arachnida	Acarina									1		3	5		2	2	1
Crustacea	Amphipoda	Paramelitidae	8						5	8	2	1	2			1	
		Ceinidae										1					
	Isopoda	Phreatoicidea					1										
		Janiridae	66	2	2	1	4		1	5	3	2	98				2
Insecta	Collembola																1
	Plecoptera	Eustheniidae		1			1					1		1		1	
		Gripopterygidae		13	81	6	27	12	4	15	4		6	3	4	4	4
		Notonemouridae		1				1		2							
	Ephemeroptera	Leptophlebiidae	2	1	12	6	15	7	6	5	11	61	115	38	78	50	104
		Baetidae			1	1			1			37	78	5	14	57	71
	Diptera	Chironomidae :															
		sub fam Chironominae			1	2			4	5			3			2	3
		sub fam Orthocladiinae		2	9	3	6	5	5	3	3	3	16	1	4	4	4
		sub fam Podonominae											1	2	1		
		sub fam Aphroteniinae											1				
		Simuliidae		37	82	23	58	60	14	33	33	61	13	169	73	33	52
		Tipulidae					1	1		1					1		1
		Athericidae											1		1		
		Blephariceridae						2		1	1	3	1	2	3		1
		Ceratopogonidae		1										1			
		Empididae			1		1						1				
		Unid. pupae		2			2	2		1		2	1	3	5	1	
		Calocidae							1				1			7	18
	Trichoptera	Conoesucidae		1						1	1		22	2	1	14	9
		Glossosomatidae			1		5			1		7	2			1	6
		Hydrobiosidae	1		3	2	8	5	11	2		7	18	3	10	7	9
		Hydropsychidae		3		1	103	76	1	1	3	2	27	5	3	18	5
		Leptoceridae		1			1	1			1	8	26	4	10	8	9
		Philorheithridae										2	5		8	8	9
		Polycentropodidae									1		1				
		Unid. pupae											2	1		1	
	Coleoptera	Adult Elmidae		2	1		1	4	3	2	1	23	100	26	54	38	94
		Adult Limnichidae															1
		Larval Elmidae			2	4	5	5	13	5		71	186	33	160	83	322
		Larval Scirtidae						7	3			43	66	19	105	23	120
		Larval Psephenidae					4						17	1	1	4	3
		Larval Dytiscidae											1				
Nematomorpha		Gordiidae						2									
		N taxa	**5**	**16**	**15**	**11**	**21**	**19**	**18**	**21**	**16**	**23**	**33**	**22**	**24**	**26**	**25**
		Total abundance	**79**	**91**	**203**	**50**	**272**	**233**	**122**	**148**	**88**	**400**	**1016**	**326**	**635**	**384**	**1013**

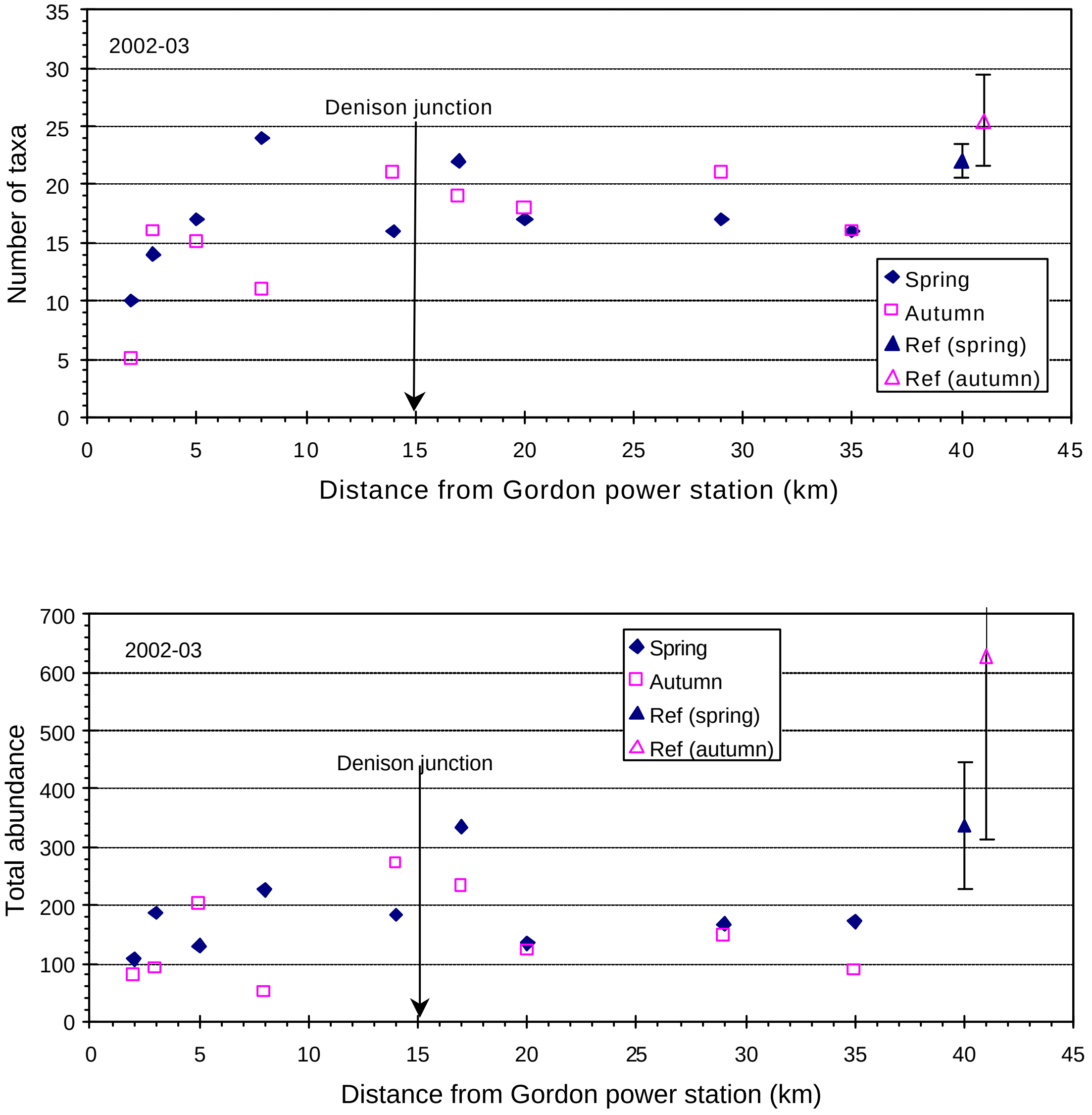


Figure 7.2. Trends in diversity (number of taxa) and total abundances of macroinvertebrates in the Gordon River with distance downstream of the Gordon Power Station. Mean values for the reference sites sampled at the same time are also shown, with error bars (±1 Standard Deviation (SD)).

7.2.2 RBA (kick) sampling

Data from of RBA kick-sampling and live picking are shown in Table 7.3 and Table 7.4, 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 7.5. The O/E values for both models (pa and rk) are plotted against distance downstream of the power station in Figure 7.3, accompanied by values for reference sites sampled at the same time.

Table 7.3. RBA macroinvertebrate data (abundances per live picked sample) for Gordon and reference sites sampled in spring 2002. Values are means of two samples.

		Date :	Spring (October 2002)														
		Type :	Monitoring									Reference					
		River :	Gordon									Franklin		Denison		Maxwell	Jane
		Site :	75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Phylum/Class	**Class/Order**	**Family**															
Platyhelminthes	Turbellaria								1			1					
Mollusca	Gastropoda	Hydrobiidae								2	1	3				1	
Annelida	Oligochaeta		1	1.5	4	2	3	7.5	12	25	31	12	9	14	3	16	22
Arachnida	Hydracarina											1		1		1	
Crustacea	Amphipoda	Paramelitidae		2	1	1	2	1	13.5	8	2.5		1	1			
	Isopoda	Janiridae	4														
Insecta	Plecoptera	Eustheniidae	2	1			2	3	2.5	3	4	1	1	1	3.5		1
		Austroperlidae				1	2				1					1	
		Gripopterygidae	15	31	32.5	8.5	35	16.5	9	18.5	17.5	9.5	8	8.5	10	10.5	6.5
		Notonemouridae	3.5	2	9	4	4		1	2	1						
	Ephemeroptera	Leptophlebiidae	3.5	5.5	44	5	21	63	64	25	29.5	32	33	50	34.5	48	56
		Baetidae							2			4	1	1	15.5	20	11
		Telephlebiidae													1		
	Hemiptera	Saldidae				1											
	Diptera	Chironominae					4		1.5	1.5	7			1	2		
		Orthocladiinae	12	17.5	4.5	1.5	5	1	1		1		1	1		1	
		Podonominae	8	7	58.5	101	25.5	35	17	43.5	3.5	4.5	17.5	26.5	10.5	9.5	15
		Tanypodinae	1														
		Diamesinae	33	93	17	6									2		
		Simuliidae	2	2	9	5	1	11	20	11.5	9.5	17	35	10	17	4.5	11.5
		Tipulidae						2	1	1.5	1	2	1	4	2	1.5	1.5
		Athericidae									1						
		Blephariceridae						1	1	4.5	2	4	14.5	1.5	1	1	3
		Ceratopogonidae				1											
		Empididae					1			2		1					
		Unid. pupae		1	12.5	5	1.5	2	1	2	2				1	2	
	Trichoptera	Conoesucidae					3	1			2	1.5	2	1	1.5	2	3
		Glossosomatidae										2		1		1	
		Helicopsychidae														1	
		Hydrobiosidae	25	30.5	49.5	18	29.5	19.5	12.5	18.5	11.5	11	9	10	8	10.5	11
		Hydropsychidae					58.5	17	17	1	4	1					
		Leptoceridae									1.5	1					
		Philopotamidae	1							1							
		Philorheithridae			1		1	1.5		1	1			1	2	3	3
		Polycentropodidae														1	
		Unid. pupae					1	1				1	1		6	1	
	Coleoptera	Adult Elmidae		1			2	4.5	2.5	1.5	1	7	4	6.5	8	12	14
		Larval Elmidae							1			3.5	2	4	1.5	3	11
		Larval Scirtidae			1	1.5	1	3		1	1		1.5	2		1	2
		Larval Psephenidae					1		2	1	1	1	2	2	1	2	
Nematomorpha		Gordiidae													1		
		N taxa	**13**	**13**	**13**	**15**	**21**	**18**	**20**	**21**	**24**	**22**	**18**	**21**	**21**	**24**	**15**
		Total abundance	**111**	**195**	**244**	**161**	**204**	**191**	**183**	**175**	**138**	**121**	**144**	**148**	**132**	**154.5**	**172**

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

		Date :	Autumn (March)														
		Type :	Monitoring									Reference					
		River :	Gordon									Franklin		Denison		Maxwell	Jane
		Site :	75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Phylum/Class	**Class/Order**	**Family**															
Platyhelminthes	Turbellaria		3	1	2	1	3.5	1	4			1					
Nematoda				1					1		2		1			1	1
Mollusca	Bivalvia	Sphaeriidae				1	1										
	Gastropoda	Hydrobiidae		1			1		3			2				10	
Annelida	Oligochaeta		8.5	19.5	1	4	11	9.5	17.5	20	45	13.5	11.5	6.5	26	3	33
Arachnida	Acarina										1	2	1.5	3	1	7	2
Crustacea	Amphipoda	Paramelitidae	16	1	1.5	2.5	1.5	1.5	15	20	1			2		5.5	
		Ceinidae		1													
	Isopoda	Phreatoicidea						4	1								
		Janiridae	25.5	4				1	1			1	2				
Insecta	Plecoptera	Eustheniidae		3.5	1		1.5	1	1	1	3	3.5	3	9	5.5	2	3
		Austroperlidae		3	2	1	1										
		Gripopterygidae	1	82.5	65	15	49	34.5	13.5	27.5	24	3.5	3	33	20.5	10.5	9.5
		Notonemouridae				2	2									1	
	Ephemeroptera	Leptophlebiidae	10	2.5	26	23	23.5	36	18.5	27.5	34.5	56.5	26	40.5	57	38.5	84
		Baetidae							1	1		19	18.5	11	18.5	10.5	27
		Telephlebiidae														1	
	Hemiptera	Corixidae				1											
	Diptera	Chironomidae :															
		sub fam Chironominae				4		1			1			2	1	4	
		sub fam Orthocladiinae	3.5	1	1.5	4	1		2.5		1	4	1.5	4	2	2	3
		sub fam Podonominae								1	2	7.5	10.5	8.5	5		3
		sub fam Diamesinae					1										
		sub fam Aphroteniinae															1
		Simuliidae		57.5	34	28.5	25.5	81.5	25	35	38	31	13	35.5	45.5	4	12.5
		Tipulidae		1	1	2.5	2	2	3		1	1	1	1	1	1	4
		Athericidae											1				
		Blephariceridae		1				3			1		1	3	1.5		1
		Chaoboridae	5														
		Empididae				1		1						1			
		Unid. pupae					1			1	1				1		
	Trichoptera	Calocidae											1		1		1.5
		Conoesucidae		1	1			1				2.5		1		21.5	2.5
		Glossosomatidae					3.5					18.5	3				
		Helicopsychidae											1			1	
		Hydrobiosidae	10.5	21	15.5	18	26	13	10.5	11	10	21.5	18	22.5	17	4.5	29
		Hydropsychidae					20	32.5	4.5	4	3	1		1		16.5	1
		Hydroptilidae														1	
		Leptoceridae	1	1	1		2		1	1	2	4	5.5	2	3.5	12.5	2.5
		Philopotamidae						1									
		Philorheithridae							2.5	1	3	3	3.5	1	2	13.5	3
		Unid. pupae				1			1				2	1			
	Coleoptera	Adult Elmidae		2.5	1.5	2	5	5	9.5		4	23	13.5	25.5	23	37.5	35
		Adult Dytiscidae						1									
		Larval Elmidae		1			1	2	1			5.5	3	3	1	3.5	6.5
		Larval Scirtidae								1		18.5	1	15	10	7.5	16.5
		Larval Psephenidae			1		1		1.5	1		3	1.5	6	1	4.5	2
Nematomorpha		Gordiidae															1
		N taxa	**10**	**20**	**15**	**17**	**22**	**20**	**22**	**15**	**19**	**23**	**25**	**24**	**21**	**26**	**24**
		Total abundance	**84**	**207**	**155**	**111.5**	**184**	**232.5**	**138.5**	**153**	**177.5**	**246**	**147.5**	**238**	**244**	**224.5**	**284.5**

Table 7.5. Mean O/E values derived from combined season 2002-03 RBA macroinvertebrate data for Gordon River and reference sites. O/Epa, O/Erk values were derived using presence/absence and rank abundance data, respectively. Each value is the mean of two RBA samples. Band values indicate the impairment band into which the site falls. A = unimpacted (not different from reference), B = significantly impaired (lower than reference), and C = highly impacted (much lower than reference).

Site	River	O/Epa	Band	O/Erk	Band
Monitoring					
75	Gordon	0.54	B	0.43	C
74	Gordon	0.71	B	0.60	B
72	Gordon	0.72	B	0.72	B
69	Gordon	0.65	B	0.48	B
63	Gordon	0.83	A	0.88	A
60	Gordon	0.93	A	0.90	A
58	Gordon	0.93	A	0.93	A
48	Gordon	0.89	A	0.95	A
42	Gordon	0.86	A	0.92	A
Reference					
Fr11	Franklin	1.22		1.13	
Fr21	Franklin	1.08		1.00	
De7	Denison	1.08		1.04	
De35	Denison	1.08		1.04	
Ma7	Maxwell	1.22		1.07	
Ja7	Jane	1.19		1.08	

7.3 Discussion

7.3.1 Combined season O/E values

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) and Davies and Cook (2001) and in the first year of Basslink monitoring in 2001-02 (Hydro Tasmania 2002).

Table 7.5 shows that the O/E values were low for Gordon River sites 75, 74, 72 and 69. These are the sites closest to the power station and all are upstream of the Denison River junction. They fell into the 'B' band (significantly impaired). Site 75, under the 'rk' model, recorded an O/E value in the 'C' band (highly impacted).

The O/E values for all the remaining Gordon River sites (63 – 42) were in the 'A' band (unimpacted). Site 63 is upstream of the Denison junction, while the remainder are downstream. This pattern is also apparent in Figure 7.3

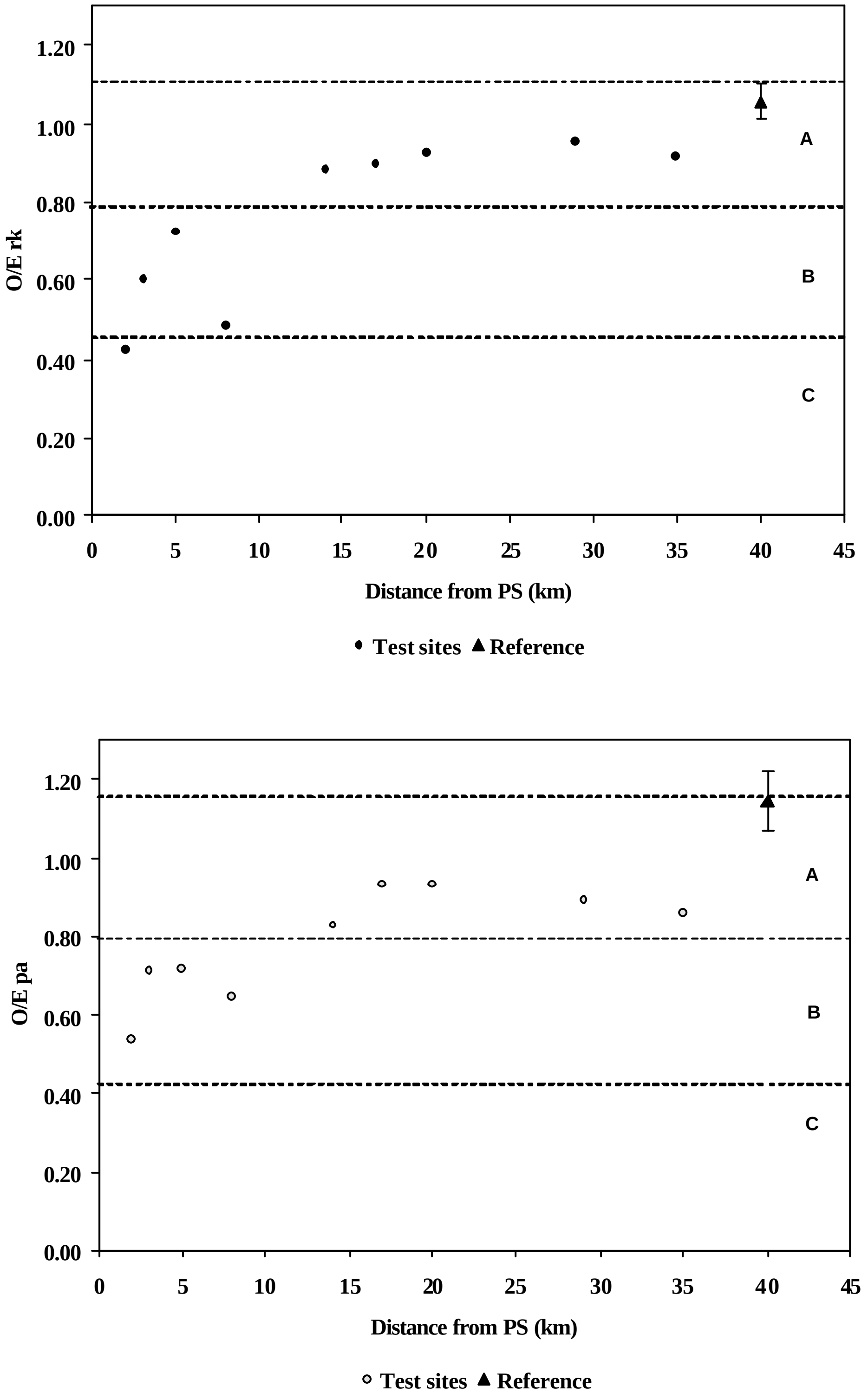


Figure 7.3. Trends in O/Epa and O/Erk values for macroinvertebrates in the Gordon River with distance downstream of the Gordon Power Station. Mean values for the reference sites sampled at the same time are also shown, with error bars (+/- 1 SD). Horizontal lines indicate bounds of impairment bands A,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

7.3.2 Single season O/E values

Data from the RBA samples were analysed using the new single-season Hydro RIVPACS models developed for this project during 2002 from the original reference site data sets (see Davies *et al.* 1999).

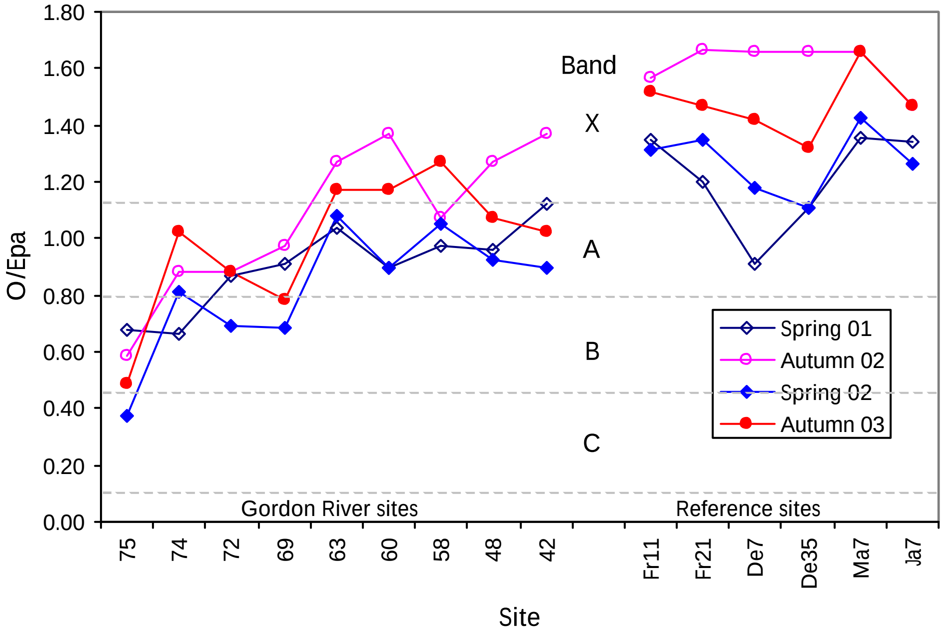
All RBA samples from both years (2001-02 and 2002-03) of pre-Basslink monitoring were analysed using the relevant autumn and spring models, to generate O/Epa an O/Erk values for each sampling occasion. Results for 2002-03 were generated for each duplicate sample, and the mean O/E values are reported here. Results are shown in Table 7.6, and are plotted in Figure 7.4.

The overall trends in O/E values for both O/Epa and O/Erk models are similar to those recorded for the combined seasons models (section 7.3.1), with low values in the sites below the power station, which increase with distance downstream.

Figure 7.4 shows that, in some seasons (spring 2002 in the O/Epa model and autumn 2002 in the O/Erk model), site 75 recorded values in the 'highly impacted' band (C). Sites 75 and 69 recorded values in the 'B' band, generally, with some sites recording 'A' band values for some seasons in both models. From site 63 downstream, all sites recorded 'A' band (unimpacted) values in both models and all seasons.

Table 7.6. Single season O/E values for all sites monitored in the Gordon and Reference rivers from spring 2001 to autumn 2003.

	Year :	**2001**		**2002**		**2002**		**2003**	
	Season :	**Spring**		**Autumn**		**Spring**		**Autumn**	
	O/E output :	**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
	74	0.66	0.64	0.88	0.66	0.81	0.61	1.03	0.83
	72	0.87	0.97	0.88	0.71	0.69	0.77	0.88	0.73
	69	0.91	1.12	0.98	0.73	0.68	0.61	0.78	0.74
	63	1.04	1.16	1.27	1.11	1.08	1.06	1.17	0.95
	60	0.90	1.12	1.37	1.11	0.90	1.14	1.17	0.83
	58	0.97	1.06	1.08	0.86	1.05	1.12	1.27	1.08
	48	0.96	0.98	1.27	0.95	0.92	1.17	1.08	0.93
	42	1.12	1.17	1.37	1.01	0.90	1.13	1.03	0.85
Reference									
Franklin	Fr11	1.35	1.40	1.57	1.01	1.31	1.17	1.52	1.16
	Fr21	1.20	1.18	1.66	1.21	1.35	1.17	1.47	1.18
Denison	De7	0.91	1.00	1.66	1.36	1.18	1.14	1.42	1.13
	De35	1.11	1.03	1.66	1.21	1.11	1.01	1.32	1.14
Maxwell	Ma7	1.35	1.41	1.66	1.21	1.43	1.04	1.66	1.14
Jane	Ja7	1.34	1.15	1.47	1.06	1.26	1.07	1.47	1.19



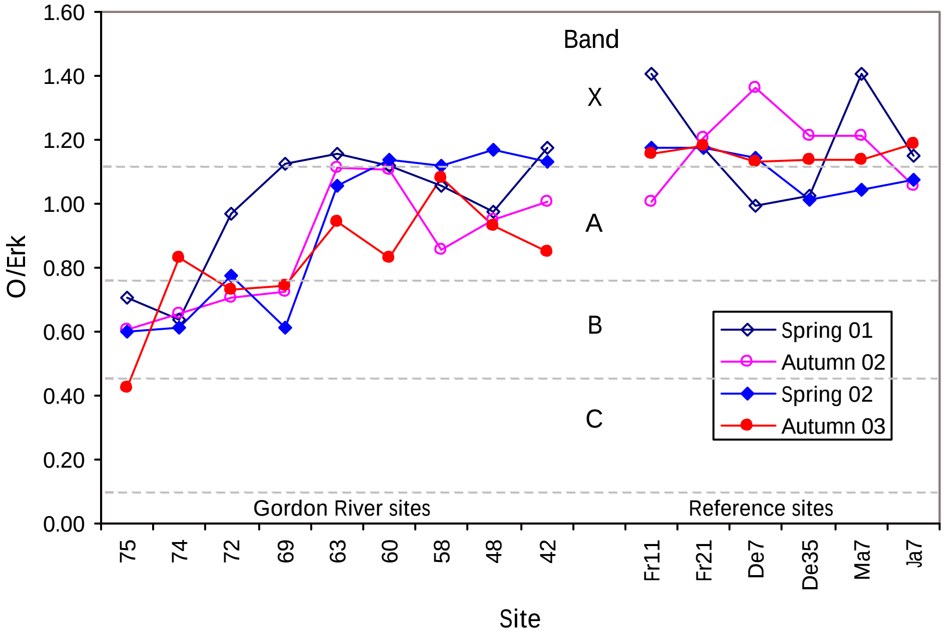


Figure 7.4. Values of O/Epa (top) and O/Erk (bottom) for the Gordon River sites, and the reference sites, for the four seasons sampled to date.

There was little inter-annual variation in O/E values. However, the O/Epa model has produced values which are significantly different by season. Under the O/Epa model, autumn values are significantly higher than the spring values for both Gordon River and reference sites (paired t-test; p < 0.001, df = 29). This pattern is not evident in the O/Erk model (see Figure 7.4).

The overall level of variation is not great, indicating that the original power analyses conducted on the 1999-2000 survey results are likely to remain broadly valid for the overall analysis of pre-post Basslink changes in O/E.

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 was consistent for both years of the monitoring, and for all four sampling occasions.

Paired t-tests were conducted to assess between year differences in O/Epa, O/Erk, total abundance and number of taxa. There were no significant differences between the two years for any of these parameters (all $p > 0.05$).

Using the O/E values from the combined season models, the values of O/Epa were significantly greater than those of O/Erk for the reference sites in both years, but not for the Gordon River sites. This issue will be further investigated following completion of data collection for the third year of pre-Basslink monitoring.

7.4 Conclusion

Overall patterns of diversity, community composition and abundance were similar to those observed in previous studies (Davies *et al*. 1999, Davies and Cook 2001), and in 2001-02, and there was no evidence of any substantial changes since those surveys. For 2002-03, there were lower total abundances recorded at some sites in the lower Gordon (sites 48 and 42). These latter differences may be due to background variability in abundance.

O/E values followed the same trend as observed by Davies and Cook (2001) and in 2001-02 (Hydro Tasmania 2002). Reference site values generally fell at the upper range or above the previously established bounds for the reference condition, as observed in previous years. However, paired t-tests of O/Epa and O/Erk values for all sites did not suggest a significant change between this survey and that conducted in 1998-99 or 2001-02 (all with $p > 0.1$). This indicates that no consistent significant 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 and Methods

Benthic algae were surveyed in spring 2002 and autumn 2003. 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.

8.1.1 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.

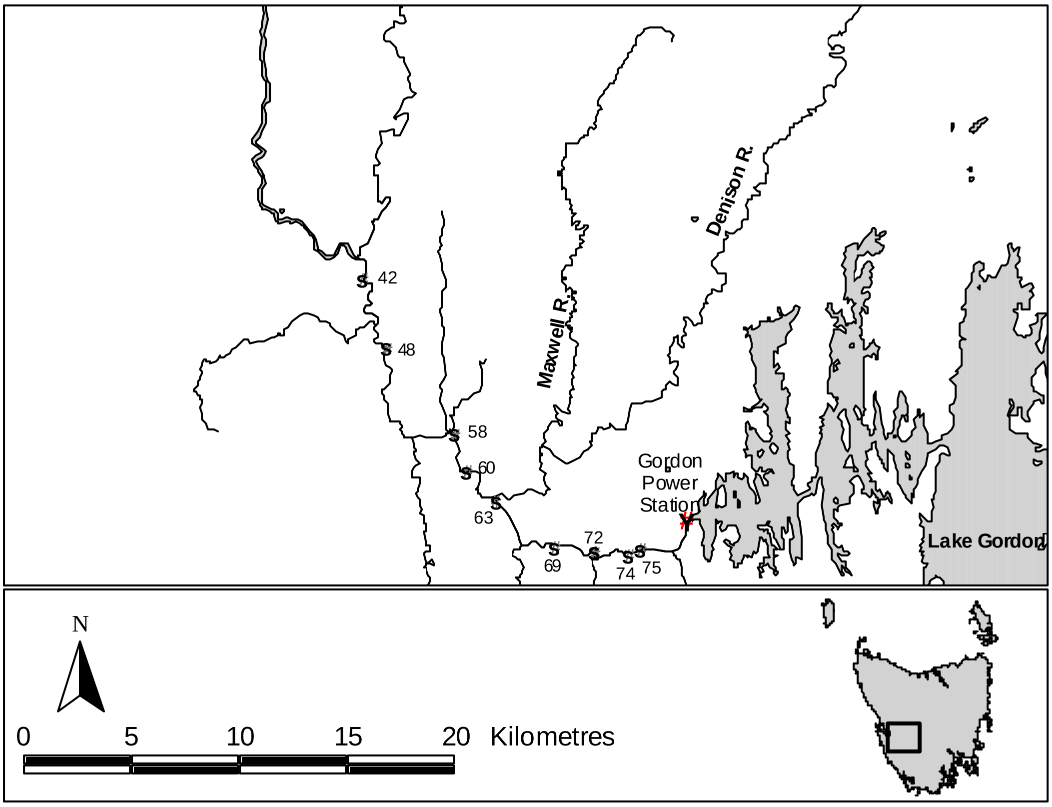


Figure 8.1. Map of the algal monitoring sites in the Gordon River.

8.1.2 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 2002-03 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.

8.1.3 Analysis

The 2002-03 algal monitoring provided a second year’s data on benthic algae in the Gordon River. Analyses conducted for this report include: summaries of plant cover scores; examining summary trends; and conducting paired t-tests on moss and filamentous algae data between the 2001-02 and 2002-03 years.

8.2 Results

8.2.1 Year 2002-03

Monitoring was successfully completed across the entire river channel for sites 75, 74, 72, 69, 63 and 60. The presence of deep, fast water prevented survey across the entire channel for sites 57, 48 and 42. An average 65 m of river bed was surveyed across all sites in October 2002, and 74 m in March 2003.

Data from the monitoring are summarised in Table 8.1. Aquatic flora had 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. Mean moss cover was highly variable, ranging from 0 to 11.7%.

Table 8.1. Summary cover data for algae, moss and macrophytes surveyed in spring 2002 and autumn 2003 for Gordon River sites. Total distances surveyed from the transect head pegs are indicated.

		Mean % cover				Width
Site	Date	Moss	Filamentous green	Characeous	Macrophytes	surveyed
75	Oct-02	1.33	17.35			67.5
74	Oct-02	4.61	35.81	3.69		62.5
72	Oct-02	0.04	2.23	5.79	0.03	80
69	Oct-02	3.73	3.40			75
63	Oct-02	3.15	9.41			70
60	Oct-02	0.19	0.07			80
57	Oct-02		0.17			50
48	Oct-02	0.16	0.25			62.5
42	Oct-02	0.06	0.48			37.5
75	Mar-03	2.81	2.41			67.5
74	Mar-03	11.70	5.66	2.37		65
72	Mar-03	1.70	1.65	0.06	6.95	100
69	Mar-03	3.10	7.16			85
63	Mar-03	1.77	3.77			75
60	Mar-03	0.07				94.6
57	Mar-03	0.49	0.02			55
48	Mar-03	0.91	0.27			72.5
42	Mar-03	0.06	0.40			47.5

Characeous algae were only observed at sites 74 and 72, with both *Chara* sp. and *Nitella* evident. Macrophytes were recorded only at site 72. Both *Callitriche* sp. (starworts) and *Isolepis fluitans* were observed.

A trend of decreasing algae and moss cover with distance from the Gordon Power Station was evident (see Figure 8.2), with some higher cover in sites upstream of the Denison River junction. As in 2001-02, low values were observed in both seasons at site 72, 5 km downstream of the power station.

Mean site percent moss and filamentous algal cover were positively correlated in both spring 2002 and autumn 2003 ($p < 0.05$, Pearson correlation), as shown in Figure 8.3.

8.2.2 Between year comparisons

Overall mean percent cover values 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 8.2. Pairwise t-tests were conducted to assess changes in the Gordon River below the power station between the 2001-02 and 2002-03 years.

There was no significant difference in percent cover of filamentous algae, but a halving in percent moss cover in 2002-03 (with grand means of 3.88% moss cover in 2001-02 compared with 1.99% in 2002-03). This was statistically significant ($p < 0.05$, $t = 2.31$, $df = 8$). Decreases in mean moss cover were evident for most transects throughout the river. It is not possible at this stage to identify any particular cause for these changes, and more data are required to assess the degree of inter-annual variability in moss cover and whether it relates to changes in flow regime between years.

Moss and filamentous algal cover were highly correlated between the two years (r = 0.844 with p < 0.005, and r = 0.946 with p < 0.0001, respectively, with n = 9).

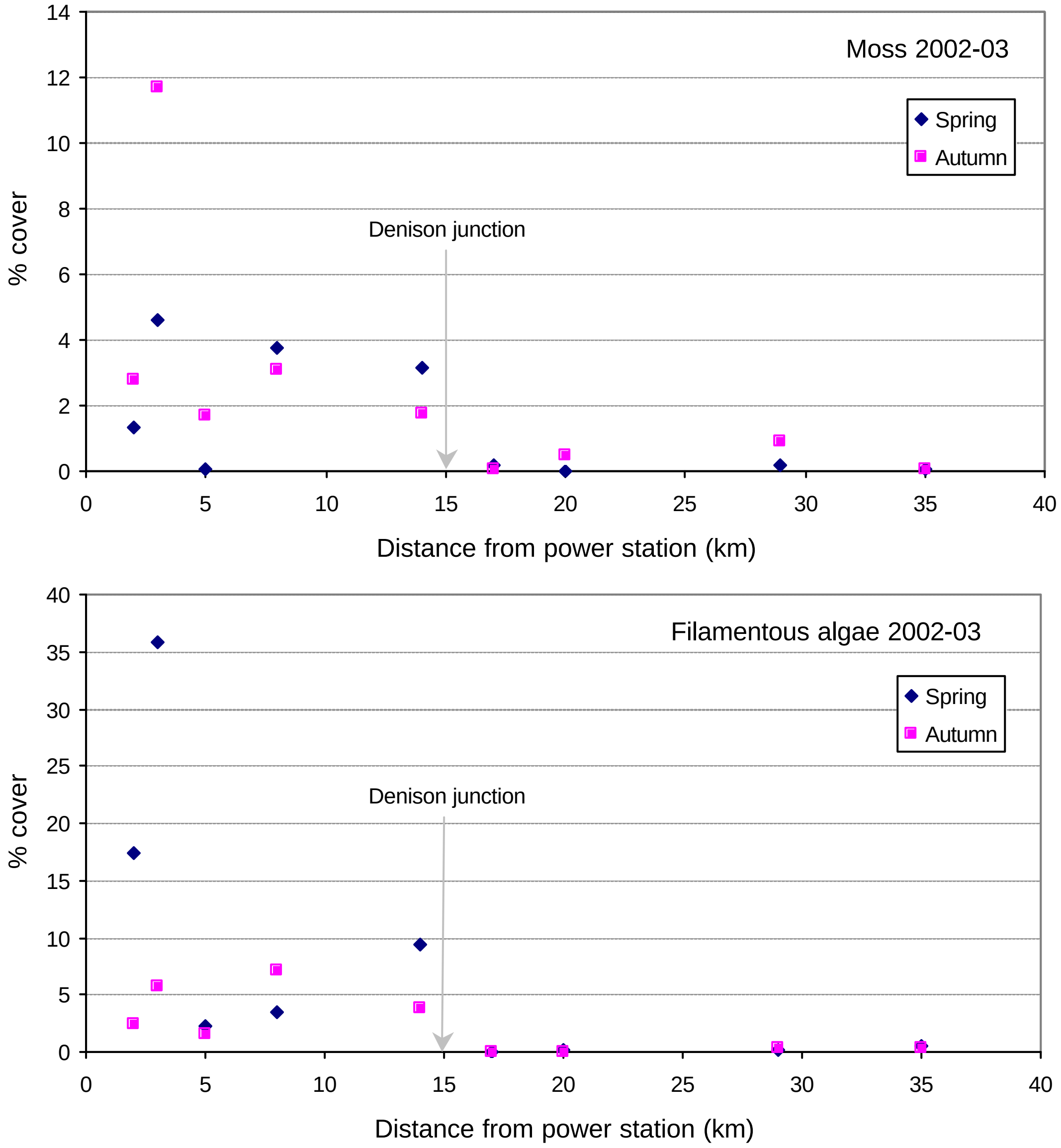


Figure 8.2. Mean percent cover for moss (top) and filamentous algae (bottom) recorded for spring 2002 and autumn 2003 in the Gordon River.

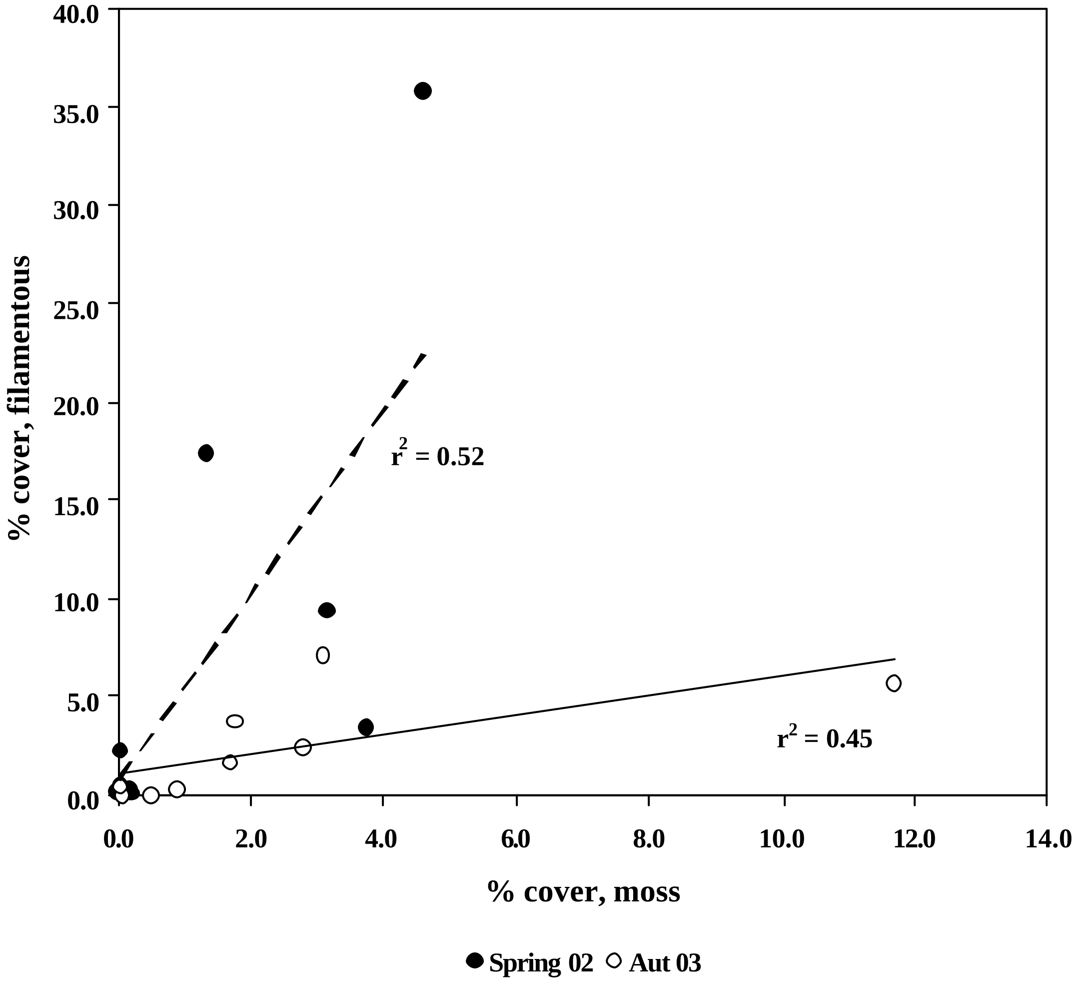


Figure 8.3. Relationship between mean percent filamentous algal and moss cover in the Gordon River in spring 2002 and autumn 2003.

Table 8.2. Mean percent cover for moss and filamentous algae at all transects in 2001-02 and 2002-03 in the lower Gordon River.

	2001-02 mean		2002-03 mean	
Site	Moss	Filamentous	Moss	Filamentous
75	6.09	7.79	2.07	9.88
74	10.63	17.00	8.16	20.73
72	1.61	1.59	0.87	1.94
69	8.50	3.35	3.42	5.28
63	1.05	2.19	2.46	6.59
60	0.33	1.51	0.13	0.03
57	0.80	0.01	0.25	0.09
48	2.84	1.72	0.54	0.26
42	3.10	3.72	0.06	0.44
Grand mean	3.88	4.32	1.99	5.03
Mean upstream Denison	5.57	6.39	3.39	8.88
Mean downstream Denison	1.77	1.74	0.24	0.21

8.3 Conclusion

Algal monitoring was conducted successfully, using the higher-resolution sampling methods developed in 2001-02.

Overall aquatic algal and plant cover was low, and decreased downstream from the Gordon Power Station, with a marked drop in percent cover downstream of the Denison River junction. There were no substantial differences in overall cover between years, although percent moss cover was lower in 2002-03 than in 2001-02.

More comprehensive data analysis is scheduled when three year’s data have been acquired.

9 Fish

9.1 Introduction

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

- quantify pre-Basslink variability in the relative abundance of fish populations to allow statistical comparison post-Basslink and with appropriate reference sites;
- assess 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 changes in catch per unit effort (CPUE) 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 improved under Basslink.

This report summarises the monitoring results of the two surveys undertaken during 2002-03.

9.2 Methods

Monitoring was conducted in December 2002 and March 2003. Thirty-one Gordon catchment 'test' sites were monitored on each occasion; 3 river and approximately 3 tributary sites in each of the 5 Gordon catchment zones. These are listed in Table 9.1. For 2002-03, one of the Denison River sites (zone 3) was not sampled due to access difficulties. This site was replaced with a site in the Orange River.

Figure 9.1 shows the Gordon catchment fish monitoring zones. A discussion on zone allocations is contained in Howland *et al.* (2001). Additionally, seven river 'reference' sites and 4 tributary 'reference' sites were monitored in conjunction with the Gordon catchment sites. These sites are shown in Table 9.2.

Nine optional sites, listed in Table 9.3, were included in the monitoring for 2002-03. These sites were monitored when time and logistics permitted. Optional sites consist of 9 'test' and 5 'reference' tributary and river sites and were included to provide opportunistic supplementary data for the monitoring program. All core sites were monitored in both December 2002 and March 2003. Four optional sites were monitored in December 2002, and nine optional sites were sampled in March 2003 (see Table 9.3).

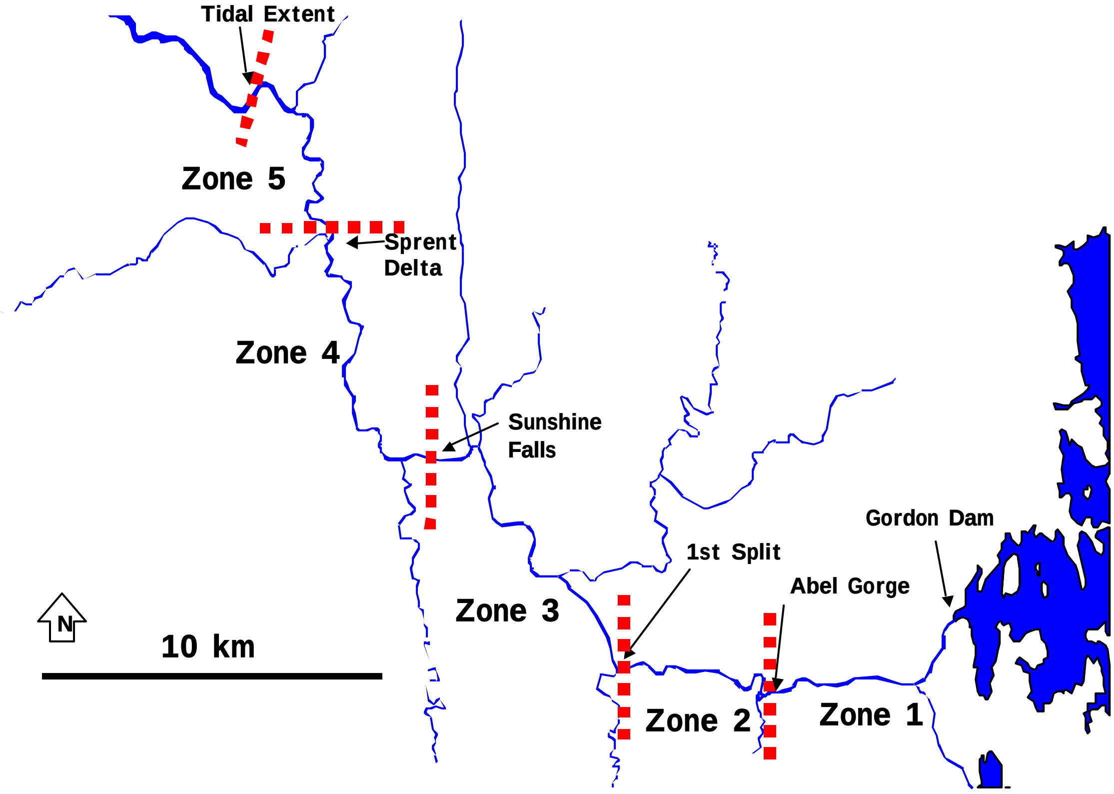


Figure 9.1. Fish monitoring zones in the Gordon River.

Table 9.1. Gordon catchment 'test' fish monitoring sites.

Zone	River Sites	Tributary Sites
1	75, 74, 73	Serpentine River, Indigo Creek, Piguenit Rivulet (1 site each)
2	72, 71, 69	Albert River, Splits Creek and Mudback Creek (1 site each)
3	68, 63, 57	Smith River (1 site), Harrison Creek (1 site), Orange River (1 site) and Denison River (2 sites - u/s Gorge, @ Maxwell)
4	54, 51, 46	Howards Creek, Olga River, Platypus Creek, Sprent River (1 site each)
5	45, 44, 42	Franklin @ Pyramid Island

Table 9.2. 'Reference' fish monitoring sites.

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

Table 9.3. Optional sites surveyed during 2002-03.

Zone	River Sites	Monitored	Tributary Sites	Monitored
1	76 (G2)	March 2003	Left bank Creek @ site 75	no
2	Gordon @ Grotto Creek	March 2003	Grotto Creek	March 2003
3	Site 60 (G9), Gordon @ G8 Gordon @ Fluffies	March 2003 no March 2003	Denison @ Denison Camp	no
4	none		Howards Creek inundation Olga @ Riffles	no Dec 02 & Mar 03
5	Gordon @ Angel Cliffs	Dec 02 & Mar 03	none	
8 (Franklin)	Franklin @ Forester Creek Franklin @ Wattle Camp Creek	Dec 02 & Mar 03 Dec 02 & Mar 03	none	
14 (Henty)	Henty @ West Sister	no	none	

Fish surveys were undertaken by backpack electrofishing following the methods described in Howland *et al.* (2001). Surveys were typically conducted by up to 3 teams, each consisting of two people, with an electrofishing target of greater than 1200 seconds shocking time at each site.

The targeted electrofishing time allowed the development of catch-per-unit-effort (CPUE) values, whereby the number of fish caught at a site was normalised to 'fish per 1200 seconds'.

9.3 Results and Discussion

A total of 1031 fish (402 in December and 629 in March), comprising ten species, were captured during 2002-03. The species consisted of:

- three exotic species (*Salmo salar*, *Salmo trutta* and *Perca fluviatilis*);
- one species of eel (*Anguilla australis*);
- two species of lamprey (*Mordacia mordax* and *Geotria australis*);
- three galaxiid species (*Galaxias brevipinnis*, *G. maculatus*, *G. truttaceus*); and
- one bovichthyid species, the Sandy or freshwater flathead (*Pseudaphritis urvillii*).

Eight fish species were caught in the 1999 and 2000 surveys (Howland *et al.* 2001). Redfin perch (*Perca fluviatilis*) were first caught in December 2001, and in all subsequent surveys. The third exotic species, Atlantic salmon (*Salmo salar*), had not been caught prior to the March 2003 monitoring.

Analysis of catch data to assess temporal changes in catch rates in comparison to reference sites was not undertaken as too few data exist to support rigorous statistical analysis. Catch data will be systematically analysed following the completion of the third pre-Basslink monitoring year in 2004. A general summary of the data is provided in the following sections.

9.3.1 Exotic Species

9.3.1.1 Brown trout (Salmo trutta)

A total of 373 brown trout (123 in December, 250 in March) were captured during 2002-03. A mean total CPUE of 2.36 (fish per 1200 seconds) was returned for the December sample and 4.32 for the March sample. Averaged over all sites, these values were the highest of all fish species sampled during the year's monitoring.

The catch per unit effort (CPUE) values are shown in Table 9.4 for Gordon River and tributary sites sampled between December 2001 and March 2003. Catch rates in the river appear similar to those recorded during the previous two surveys but lower than those of the initial survey in December 2001, while tributary catch rates generally appeared lower in zone 1 but higher than the previous surveys in zone 3 and 4.

Table 9.4. Catch Per Unit Effort (CPUE) for *S. trutta* in the Gordon River and tributaries between December 2001 and March 2003.

	River sites				**Tributary sites**			
Zone	**Dec-01**	**Apr-02**	**Dec-02**	**Mar-03**	**Dec-01**	**Apr-02**	**Dec 02**	**Mar-03**
1	0.74	0.20	0.25	0.20	1.29	3.15	1.30	0.97
2	5.34	2.11	2.58	3.48	3.77	2.15	3.87	3.17
3	7.50	1.62	1.59	3.47	8.98	10.58	5.22	14.44
4	3.24	2.26	0.77	2.62	7.93	5.30	3.20	8.47
5	2.08	0.94	1.81	0.95	-	-	-	-

A single brown trout was captured from the Sorell River during the March 2003 monitoring. This was the first capture of an exotic species from the Birches Inlet rivers during the Basslink surveys. The reasons for the virtual absence of trout from the Sorell River and its tributaries are not clear, but fish appear to be able to freely migrate from Macquarie Harbour into Sorell River, inferring that sea-run trout can access the rivers flowing into Birches Inlet. The brown trout collected from the Sorell River was only 185 mm in length and its colouration was consistent with that of a resident river fish. It was unlikely to have been a returning sea-run spawner.

9.3.1.2 Atlantic salmon (Salmo salar)

A single large Atlantic salmon was captured at the Olga @ Gordon site on 31 March 2003. The 645 mm long female was captured from a snag adjacent to a riffle.

Atlantic salmon are farmed in cages in Macquarie Harbour, occasionally escaping from damaged pens. It appears that the salmon was an escapee that had swum at least 75 km upstream from Macquarie Harbour prior to entering the Olga River. The fish had had significant fin-rub damage and virtually no stomach. This latter observation is consistent with the observation that escapees are not well adapted for feeding away from captivity (Edgar, 1977). Its gonads, however, were well developed.

9.3.1.3 Redfin perch (Perca fluviatilis)

A total of 28 redfin perch were collected from zones 1 and 2 of the middle Gordon River during 2002-03. Seven were caught in December 2002 and 21 in March 2003. Redfin perch were not captured from any of the Gordon tributary streams in this, or previous, surveys
Table 9.5 gives the number of redfin caught and the capture locations from December 2001 to March 2003.

Redfin were the dominant species in terms of catch per unit effort in zone 1 in the December survey, however climbing galaxias and short fin eels were co-dominant with redfin in zone 1 during the March monitoring. The redfin catch in zone 2 was the second highest of all species in this zone, and the highest CPUE recorded for redfin to date in the Gordon River. The size range of redfin captured during 2002-03 was similar to that recorded for previous surveys (115 mm to 195 mm).

Six of the 13 redfin captured from site 72 were stranded live fish collected from a cobble riffle draining the backwaters of this site. Redfin perch were not captured from any of the Gordon tributary streams in this, or previous, surveys

Table 9.5. Capture locations and numbers caught for redfin perch (*Perca fluviatilis*) between December 2001 and March 2003. (*stranded on river bank, N/S not sampled).

Site	**Dec-01**	**Apr-02**	**Dec 02**	**March-03**
Zone 1				
Gordon @ Serpentine	***2**	N/S	N/S	N/S
Site 76 (Gordon @ G2)	N/S	0	N/S	0
Site 73 (Gordon @ G3, d/s)	0	**2**	0	**3**
Site 73 Gordon @ G3, u/s)	0	0	0	0
Site 75 (Gordon @ G4)	0	0	**3**	0
Site 74 (Gordon @ G4a)	0	0	**2**	0
Zone 2				
Site 72 (Gordon @ G5, lower)	0	**2**	0	**3**
Site 72 (Gordon @ G5, upper)	0	**7**	**2**	**13**
Site 71 (Gordon @ G5a, pipe)	0	0	0	0
Site 71(Gordon @ G5a, water)	0	**2**	0	**2**
Site 64 (Gordon @ Grotto Creek)	N/S	0	N/S	0
Site 69 (Gordon @ G6)	**1**	N/S	0	0

9.3.2 Eels and lampreys

In December 2002, several decaying lampreys were observed at sites in the upper Franklin and Henty Rivers. Their state of decay did not allow a specific identification to be made, however these individuals ranged between 300 mm – 500 mm long which is indicative of both migrating *Mordacia mordax* (smaller individuals around 300 – 400 mm) and *Geotria australis* (larger individuals around 500 – 600 mm) (McDowall, 1996). It is highly likely that these fish were casualties of the upstream spawning migration, which usually occurs in spring or early summer (Fulton 1990).

9.3.2.1 Short-headed lampreys (Mordacia mordax)

In December 2002, a single short-headed lamprey ammocete was collected from the Gordon River adjacent to Platypus Creek. Low numbers of ammocetes were also collected from the Franklin River, Sorell River and Henty River.

In March 2003, most short-headed lamprey specimens were captured in zones 3 - 5 of the Gordon River. Five individuals were captured from a zone 2 tributary (Albert River). This was unusual, as *M. mordax* have not been captured above zone 3 during previous Basslink monitoring surveys, and indicates that lamprey ammocetes can negotiate the Splits under certain conditions.

The size range of captured individuals ranged between 60 mm and 107 mm indicating that individuals were either in the ammocete stage or larger macrophthalmia stage. No adults were collected. A small number of short-headed lampreys were collected from the Henty, Sorell and Pocacker reference sites.

9.3.2.2 Pouched lampreys (Geotria australis)

With the exception of zone 1, pouched lampreys were captured in all river zones of the Gordon River during 2002-03. This species was dominant in terms of catch per unit effort (CPUE) in zone 3, zone 4 and the Henty River sites. The majority of specimens ranged from 16 mm to 106 mm, however a single, stranded 450 mm adult was captured from zone 3 in the Gordon River. It is interesting to note that a single pouched lamprey ammocete was captured above the Splits in the current survey, and the only other confirmed occasion this species had been collected above the Splits was from a zone 2 tributary in April 2002. It appears that *G. australis* are able to migrate past the Splits under certain conditions.

The Franklin River zones returned low CPUEs for pouched lampreys, while the Henty and Birches Inlet Rivers returned moderate CPUEs for this species. Table 9.6 shows the CPUE for *G. australis* between December 2001 and March 2003. The data indicate that autumn catches of ammocetes were greater than those recorded for early summer.

Table 9.6. CPUE values for *G. australis* in the Gordon and Franklin Rivers between December 2001 and March 2003.

Zone	**Dec-01**	**Apr-02**	**Dec -02**	**Mar-03**
Zone 1	0	0	0	0
Zone 2	0	0	0	0.13
Zone 3	0	4.55	0.64	5.12
Zone 4	0	1.29	0	2.94
Zone 5	1.66	2.11	0.23	2.46
Franklin d/s Big Fall	0	2.74	0	1.90
Franklin u/s Big Fall	0	0	0	2.57

9.3.2.3 Short-finned eels (Anguilla australis)

Short-finned eels were captured throughout the Gordon, Franklin, Henty River and Birches Inlet zones and, with the exception of zone 1, most of the Gordon tributary zones. The highest catch rate for this species was recorded from zone 5 of the Gordon River. Catch rates for *Anguilla australis* for the four monitoring surveys are shown in Table 9.7.

Catch rates of *A. australis* were moderate in the Birches Inlet and Henty River sites.

Table 9.7. CPUE values for *A. australis* in the Gordon and Franklin Rivers between December 2001 and March 2003. (* denotes stranded)

Zone	**Dec-01**	**Apr-02**	**Dec-02**	**Mar-03**
Zone 1	2.22	0.20*	0.25	0.61
Zone 2	0.38	0.00	1.13	0.13*
Zone 3	1.99	0.97	2.86	0.73
Zone 4	4.05	3.56	0	0.33
Zone 5	5.19	6.32	2.26	7.57
Franklin d/s Big Fall	0.38	4.52	1.92	0.95
Franklin u/s Big Fall	1.06	3.58	1.98	0.96

9.3.3 Galaxiids and Sandys

Summaries of CPUE values for galaxiids and Sandys captured in the Gordon and Franklin Rivers and their tributaries from December 2001 to March 2003 are provided in Tables 9.8 to 9. 11. With the exception of climbing galaxias (*G. brevipinnis*), galaxiids were absent from the Gordon River and it's tributaries between zone 1 and zone 3 inclusive. Low to moderate catches of all three galaxiid species were recorded from zone 5 of the river, while *G. truttaceus* was captured in zone 4. *P. urvillii were* recorded from zones 4 and 5 of the Gordon River and zone 4 tributaries.

Table 9.8. CPUE values for galaxiids (*G. brevipinnis*, *G. maculatus*, *G. truttaceus*) and Sandys (*P. urvillii)* captured in the Gordon River between December 2001 and March 2003.

Zone	**Species**	**Dec-01**	**Apr-02**	**Dec-02**	**Mar-03**
Zone 1	*G. brevipinnis*	0	0	0	0.61
Zone 2	All (galaxiids and sandys)	0	0	0	0
Zone 3	All (galaxiids and sandys)	0	0	0	0
Zone 4	*G. truttaceus*	0.81	0.64	0.77	0
	P. urvillii	0	0	0	0.33
Zone 5	*G. brevipinnis*	0	0.47	2.71	0.76
	G. maculatus	0.42	2.34	0.45	0.57
	G. truttaceus	4.98	3.98	3.39	3.03
	P. urvillii	2.91	2.34	1.81	0.76

Table 9.9. CPUEvalues for galaxiids (*G. brevipinnis*, *G. maculatus* , *G. truttaceus*) and Sandys (*P. urvillii*) captured in the Gordon River tributaries between December 2001 and March 2003.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03
Zone 1 tribs.	*G. brevipinnis*	8.07	1.75	1.30	2.60
Zone 2 tribs.	All (galaxiids and sandys)	0	0	0	0
Zone 3 tribs.	*G. truttaceus*	0	0.12	0	0
	P. urvillii	0.18	0	0	0
Zone 4 tribs.	*G. brevipinnis*	0.28	0	0.38	0
	G. truttaceus	4.53	1.56	2.26	2.52
	P. urvillii	0.28	0.31	0	0.90

Table 9.10. CPUEvalues for galaxiids (*G. brevipinnis, G. maculatus, G. truttaceus*) and Sandys (*P. urvillii*) captured in the Franklin River between December 2001 and March 2003.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03
Zone 7 (Franklin d/s Big Fall)	*G. brevipinnis*	3.43	0	3.83	0
	G. maculatus	0	1.51	2.88	0
	G. truttaceus	1.91	2.51	8.63	3.80
	P. urvillii	1.91	3.01	0.96	2.85
Zone 8 (Franklin u/s Big Fall)	*G. brevipinnis*	1.33	0	1.54	0
	G. truttaceus	0.53	0.45	0.44	0
	P. urvillii	0.27	0.45	0.44	1.29

Table 9.11. CPUE values for galaxiids (*G. brevipinnis*, *G. maculatus* , *G. truttaceus*) and Sandys (*P. urvillii*) captured in the Franklin River tributaries between December 2001 and March 2003.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03
Zone 8 (Franklin u/s Big Fall)	*G. brevipinnis*	1.61	1.28	2.86	4.54
	G. truttaceus	4.02	2.87	1.43	0.60

9.3.3.1 Climbing galaxias (Galaxias brevipinnis)

In December 2002, populations of *G. brevipinnis* were sampled in the zone 1 tributaries, however catches were restricted to Indigo Creek and no climbing galaxias were collected from the Serpentine River. In March 2003, low to moderate catches of mature *G. brevipinnis* (110 mm - 180 mm) were sampled in two zone 1 tributaries, (Serpentine River and Indigo Creek) and a single site in the Gordon River (site 75). The size range captured in both surveys was similar to that recorded in previous years, indicating a mature population with no detectable recruitment of juvenile fish.

In March 2003, the species was co-dominant in terms of CPUE with *A. australis* and *P. fluviatilis* in the river zone, but dominated the zone 1 tributaries. Interestingly, climbing galaxias collected from

Gordon River at site 75 were electrofished from riffles immediately upstream of the Indigo Creek inflow. These fish may have dropped down from the tributary. The log jam that forms a small quartz gravel bedded pool in the middle reaches of the tributary has been undermined resulting in the near complete drainage of the pool. In past surveys small but significant numbers of climbing galaxias have been collected from this area, and so recent drainage of the pool, particularly if it occurred rapidly, may have flushed its residents downstream into the main channel of the Gordon River.

In the lower Gordon River, climbing galaxias were restricted to zone 5, several kilometres above the confluence with the Franklin River. Reasonable catches of climbing galaxias were also collected from the Franklin River and its tributaries. The fish from the above sites ranged in size from approximately 40 mm to 68 mm, which is indicative of recent recruitment into these zones. The Henty River sites returned a low to moderate catch rate for climbing galaxias, all of which fell within a size range similar to that described above. The Birches Inlet sites returned very few climbing galaxias.

9.3.3.2 Spotted galaxias (Galaxias truttaceus*)*

Spotted galaxias were not captured from zone 4 during the March 2003 survey. With the exception of zone 4, the CPUE statistics for *Galaxias truttaceus* in the Gordon River were similar to previous years (Table 9.8). In December 2002, a CPUE of 8.63 was recorded in zone 7 (Franklin River d/s Big Fall), which was the highest zone CPUE recorded for any species to date. The CPUE for spotted galaxias in zone 8 (Franklin River u/s Big Fall) was relatively low (Table 9.10), suggesting that Big Fall may inhibit upstream migration of spotted galaxias.

The size range and the average size of *G. truttaceus* was larger in the zone 4 tributaries than in zone 5 of the river, and a comparison of length frequency data indicated that a mature population of *G. truttaceus* exists in the tributaries upstream of the species' known range in the Gordon River.

Spotted galaxias had a relatively high catch rate in the Henty River and moderate catches were recorded from the Birches Inlet rivers.

9.3.3.3 Jollytails (Galaxias maculatus)

Jollytails were not captured from any of the Gordon or Franklin tributary sites, but were present in the lowest Gordon and Franklin river zones at relatively low catch rates (Table 9.8 and Table 9.10).

In December 2002, catch rates of *G. maculatus* in the Birches Inlet rivers were relatively high. A CPUE of 7.60 was recorded for these rivers. However, in March 2003, catch rates of *G. maculatus* in the Birches Inlet rivers were low (CPUE = 0.45). Conversely, *G. maculatus* were absent from the Henty River catches in December 2002 but were collected at moderate catch rates (CPUE = 2.98) in March 2003.

9.3.3.4 Sandys (Pseudaphritis urvillii)

Low catches of *P. urvillii* were collected in zone 4 and zone 5 of the Gordon River and in the zone 4 tributaries, although catch rates were generally lower than in previous years. Catches were higher in the Franklin River, with zones 7 and 8 (below and above Big Falls) returning moderate CPUEs. Sandys were not collected from the Franklin River tributaries.

Catch rates were high throughout the Birches Inlet sites, while catch rates in the Henty River were low, and of similar magnitude to previous samples from this zone.

9.3.4 Fish stranding

There was little evidence of fish stranding during the December 2002 monitoring. However, several brown trout were observed in shallow backwaters at site 72 and isolated cobble bar pools at site 71. These areas were partially dewatered as a result of power station shutdown, and were marginal habitat for long-term trout survival due to their exposure to predation, their susceptibility to wide fluctuations in temperature, shallow depth and exposed position.

Also in December 2002, redfin perch were trapped in the shallow backwaters of site 72. Six redfin were collected by hand while attempting to swim out of these backwaters and a further four redfin were electrofished from the same riffle. A single large stranded pouched lamprey of 450 mm length was collected from site 68. Although the lamprey was alive, it appeared as though it had been stranded for several days following shutdown of the power station.

In March 2003, a single short-finned eel, 1070 mm in length, was collected from site 72. The dead eel was collected from beneath some woody debris adjacent to a backwater at this site. Researchers observed that the eel had a large bruise to its flank, and the shape of the bruise appeared consistent with that caused by turbine injury. Presumably the eel had recently passed through the Gordon Power Station and had struck a turbine runner or guide vane during its passage.

9.4 Conclusion

Brown trout and short-finned eels continue to be the two most widespread species sampled during the surveys, and were present in the majority of river and tributary zones at both test and reference sites. Juvenile eels (elvers) have a well-developed ability to climb steep, moist surfaces and this would be a significant contributing factor to the species' wide distribution in the catchment. Brown trout were particularly dominant in the Gordon River tributary streams.

The March 2003 survey recorded the highest number of redfin captured to date. Redfin perch catch rates appear to show seasonal variation, with the highest catch rates recorded in the autumn monitoring. While catches appear to be increasing, the size range of redfin appears to be relatively stable with the majority of fish <200 mm in length. It is interesting that redfin were consistently collected from shallow backwaters, marginal lies in runs or from semi-stranded positions in riffles. It appears that the redfin collected from the Gordon River were not particularly well adapted to the changing habitat availability associated with a highly variable flow regime.

Low to moderate numbers of short-headed lampreys were captured in the Gordon, Franklin, Sorell and Henty Rivers during the 2002-03 monitoring.

Pouched lamprey captures were significant during the March 2003 monitoring. The majority were collected from the Gordon River sites, and comprised mostly ammocetes and, to a lesser extent, macrophthalmia stages. The Gordon River appears to provide a significant recruitment opportunity for this species. Reference streams in the Henty and Birches Inlet rivers also returned moderate catches of ammocetes and macrophthalmia.

Galaxiid catches in the Gordon River were generally similar to previous surveys, with little change in distribution. One notable observation of the March 2003 data was the presence of mature climbing galaxias in zone 1 of the main river channel, adjacent to Indigo Creek. Climbing galaxias appear to show a seasonal recruitment pattern in the Franklin River (zones 7 and 8) and, to a lesser extent, in the zone 4 Gordon River tributaries, with recruitment pulses of juvenile galaxiids observed in December 2001 and December 2002.

G. maculatus and *P. urvillii* catches were confined to the lower reaches of the Gordon (zones 4 and 5) and Franklin Rivers (zones 7 and 8), but were not found in their tributaries. Catch rates of both species were high in the Birches Inlet rivers.

Juvenile galaxiids have not been collected from the upper zones of the Gordon River in any of the Basslink monitoring surveys.

The results of the monitoring to date indicate that fish stranding following power station shut-down is not common. The backwaters and shallow channels of site 72 recorded the greatest number of potentially stranded fish (redfin perch and trout) and these strandings appear to be the result of relatively rapid dewatering of the river channel due to power station operations. One stranded lamprey was recorded at a downstream site.

10 References

ANZECC. 1992. *Australian Water Quality Guidelines for Fresh and Marine Waters.* Australian and New Zealand Environment and Conservation Council. November 1992

ANZECC. 2001. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Volume 1: The Guidelines'. Australian and New Zealand Environment and Conservation Council.

APHA. 1995. *Standard Methods for the Analysis of Water and Wastewater*. 19th edition. American Public Health Association, Washington DC, USA.

Basslink Joint Advisory Panel. 2002. Appendix 15: Draft Deed of Amendment to Hydro Tasmania's Special Water Licence. *Draft Panel Report: Basslink – proposed interconnector linking the Tasmanian and Victorian electricity grids* (Volume 2: Appendices).

Davies, P.E. and Cook, L.S.J. 2001. Gordon River Macroinvertebrates and Aquatic Mammals Assessment. *Basslink Integrated Impact Assessment Statement - Potential Effects of Changes to Hydro Power Generation*. Appendix 7: Hydro Tasmania, Hobart.

Davies, P.E., Cook, L.S.J. and McKenny, C.E.A. 1999. *The influence of changes in flow regime on aquatic biota and habitat downstream of hydro-electric dams and power stations in Tasmania*. Hydro Technical Report Project No. 95/034. Hobart Tasmania 128 pp.

Edgar, G.J. 1997. *Australian Marine Life*. Reed, Kew.

Fulton, W. 1990. *Tasmanian freshwater fishes*. Fauna of Tasmania Handbook no. 7. University of Tasmania, Hobart. 80 pp.

Howland, M.B., Davies, P.E., Blühdorn, D.R. & Andrews, D. 2001. Gordon River Fish Assessment. Appendix 8: *Basslink Integrated Impact Assessment Statement - Potential Effects of Changes to Hydro Power Generation*. Hydro Tasmania, Hobart.

Hydro Tasmania. 2002. *Gordon River Basslink Monitoring Annual Report 2001-02*. Hydro Tasmania, Hobart.

Koehnken, L. 1992. *Pieman River Environmental Monitoring Program.* Technical Report August 1992. Department of Environment & Planning, Tasmania.

Koehnken, L., Locher, H. and Rutherfurd, I. 2001. Gordon River Fluvial Geomorphology Assessment *Basslink Integrated Impact Assessment Statement - Potential Effects of Changes to Hydro Power Generation*. Appendix 4. Hydro Tasmania, Hobart.

Locher, H. 2001. Summary Report: *Basslink Integrated Impact Assessment Statement: Potential Effects of Changes to Hydro Power Generation*. Hydro Tasmania, Hobart.

McDowall, R.M. 1996. *Freshwater fishes of south-eastern Australia*. Reed Books, New South Wales.