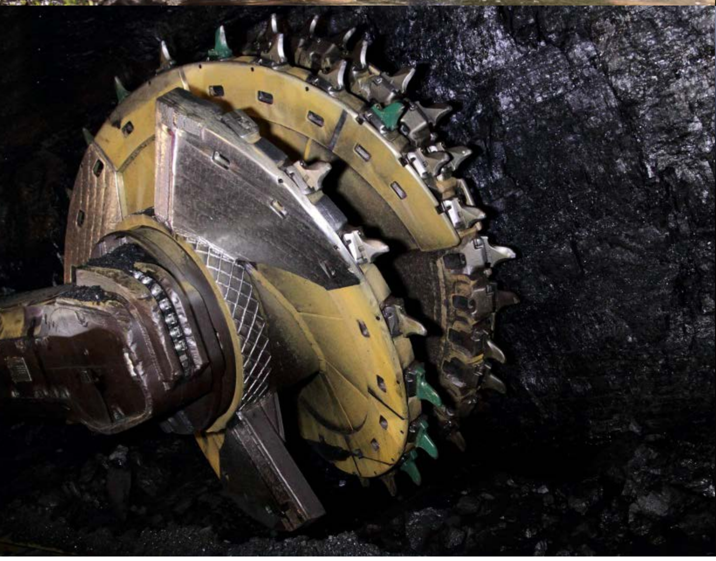
LONGWALL 37 END OF PANEL REPORT ILLLAWARRA COAL






ATTACHMENT E – LONGWALL 37 END OF PANEL REPORT

WEST CLIFF AREA 5 AQUATIC ECOLOGY ASSESSMENT

CARDNO ECOLOGY LAB, MAY 2015

West Cliff Longwalls 31 to 38

Aquatic Ecology Monitoring 2002 to 2014

59915064

Prepared for
BHP Billiton-Illawarra Coal

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Contact Information

Cardno (NSW/ACT) Pty Ltd
Level 9, The Forum
203 Pacific Highway
St Leonards NSW 2065

Telephone: 02 9496 7700
Facsimile: 02 9499 3902
International: +61 2 9496 7700
www.cardno.com.au

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				Gary Brassington (BHPBIC)	GB
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Executive Summary

Introduction and Methods

BHP Billiton Illawarra Coal (BHPBIC) is extracting coal from the Bulli Seam in Area 5 of the West Cliff Colliery in the Southern Coalfield of New South Wales using longwall mining techniques. The sequence of longwall extraction is as follows:

> Longwalls 31-33: July 2005 to September 2011;

> Longwall 34: February 2010 to September 2011;

> Longwall 35: October 2011 to July 2013;

> Longwall 36: August 2013 to May 2014;

> Longwall 37: April 2014 to February 2015; and

> Longwall 38: February 2015 to February 2016 (estimated).

Cardno Ecology Lab was commissioned by BHPBIC to design and implement a monitoring program to detect potential changes in aquatic ecology that may arise due to the impact of mining-related subsidence on the physical and chemical characteristics of sections of the Georges River.

The latest round of aquatic ecology monitoring, undertaken on 1 and 2 December 2014, included post-extraction monitoring for Longwalls 35 and 36, monitoring during extraction for Longwall 37 and further pre-extraction monitoring for Longwall 38.

The monitoring program focuses on three main indicators:

> Aquatic habitat, including fish habitat, aquatic macrophytes and riparian vegetation;

> Aquatic macroinvertebrates sampled in accordance with the Australian River Assessment System (AUSRIVAS);

> Fish sampled using backpack electrofishing.

Limited in situ water quality sampling is undertaken to assist with interpretation of trends in the above indicators.

The results of this survey were compared with those obtained in May 2002, March 2005, November 2007, September 2008, May 2010, May 2012, December 2012 and November 2013.

Identified Mining Impacts and Assessment

Data collected during the current survey suggests that the indicators of aquatic ecology affected by the extraction of Longwall 35 during the previous survey (November 2013) are recovering from, previous disturbance. This is attributed to the additional releases of water from Brennans Creek Dam which were implemented as an ameliorative measure following the physical mining impacts associated with the extraction of Longwall 35. These findings are supported by statistical analysis, which does not indicate that any widespread or persistent impacts have occurred following the commencement of extraction of Longwall 35. There is no evidence to suggest the extraction of Longwalls 36 and 37 has had any impact on aquatic ecology. This finding is not surprising considering that no physical impacts (additional to those observed for Longwall 35), or any significant impacts to water quality have resulted from extraction of these longwalls.

The physical impacts of mining were first identified and associated with extraction of Longwall 35 in February 2013, and included fracturing of bedrock, loss of water flow and reductions in pool water levels. Reductions in the number of macroinvertebrate taxa and the numbers of fish and large mobile invertebrates were also observed at one of the two sites on the Georges River affected by subsidence and evidence of a reduction in the OE50 Taxa Score (a biotic measure of aquatic habitat quality) was observed at the other site. Aquatic macrophytes also became desiccated at both sites. These changes were attributed to subsidence caused by mining and consequential loss of aquatic habitat and reduction in river connectivity. The re-establishment

of pool water levels and flow following releases of water from Brennans Creek Dam in the second half of 2014 likely explains the observed increase in the number of macroinvertebrate taxa and fish, and improvement in habitat quality, at the sites impacted in November 2013. As no changes to ecological indicators were evident at sites further downstream in November 2013, and due to the recovery in these indicators at affected areas in December 2014, impacts due to extraction of Longwall 35 appear to have been localised and short-term.

Analysis of water quality and flow data collected by other consultants as part of End of Panel Reports for Longwalls 35, 36 and 37 did not indicate any significant changes attributed to mining. Also, there was no evidence of impacts to water quality data collected by Cardno Ecology Lab. This finding suggests that the impacts to aquatic indicators observed in November 2013 were due to the physical disturbance associated with extraction of Longwall 35.

Recommendations

It is recommended that increased discharges from Brennans Creek Dam are maintained for as long as practicable whenever low pool water levels and flow are experienced in the Georges River. This will reduce impacts to aquatic biota associated with loss of habitat, flow and connectivity.

Due to the observed impacts associated with Longwall 35 in November 2013, it is also recommended that additional post-extraction monitoring be undertaken for Longwall 35 during the spring 2015 AUSRIAVS sampling season to provide at least two years of post-extraction data for this longwall following recovery of aquatic biota and habitats. This will provide further information on the persistence and recovery of previously identified impacts to aquatic indicators associated with Longwall 35. This monitoring would also provide further post-extraction data for Longwall 36, the first year of post-extraction data for Longwall 37 and during extraction data for Longwall 38. The collection of additional during and post mining data will facilitate the assessment of the impact of longwall extraction on the aquatic habitat and biota in the Georges River. It will also help inform any future remediation efforts in the Georges River following the completion of mining in West Cliff Area 5. This monitoring event should occur during the spring 2015 AUSRIVAS sampling season to allow valid comparisons with previous data collected during this season.

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1 Introduction and Aims

BHP Billiton Illawarra Coal (BHPBIC) is using longwall mining techniques to extract coal from the Bulli Seam in Area 5 of the West Cliff Colliery in the Southern Coalfield of New South Wales. The schedule of Longwall extraction is as follows:

> Longwalls 31-33: July 2005 to September 2011;

> Longwall 34: February 2010 to September 2011;

> Longwall 35: October 2011 to July 2013;

> Longwall 36: August 2013 to May 2014;

> Longwall 37: April 2014 to February 2015; and

> Longwall 38: February 2015 to February 2016 (estimated).

Cardno Ecology Lab (formerly The Ecology Lab Pty Ltd) was commissioned by BHPBIC to assess the potential impact of longwall mining-related subsidence on ecological indicators of the Georges River and other nearby watercourses within the West Cliff Area 5 mine area through the implementation of an aquatic ecological monitoring programme. The aims of the monitoring programme are to:

> Assess the occurrence of fish and macroinvertebrates and condition of aquatic habitat that may be affected by subsidence related impacts; and,

> Determine whether any changes observed in aquatic habitat or biota may be linked to subsidence related impacts.

This report provides the results of investigations undertaken in November 2014 in accordance with the recommendations made in the Subsidence Management Plans (SMPs) for Longwalls 34 to 36. The investigations also incorporate the monitoring associated with the extraction of Longwalls 37 and 38 as detailed in the Extraction Plan (BHPBIC 2014a) and associated Biodiversity Management Plan (BHPBIC 2014b) for these longwalls. The specific aims of the November 2014 investigations were to:

> Undertake the second year of post-extraction monitoring for Longwall 35, the first year of post-extraction monitoring for Longwall 36, the first year of during-extraction monitoring for Longwall 37 and undertake further pre-extraction monitoring for Longwall 38;

> Determine whether any changes in aquatic habitat or biota have occurred at sites adjacent to longwall extraction by comparing the findings of the November 2014 investigation with those from previous investigations undertaken at these and at control sites ;

> Determine if any changes are due to potential subsidence-related impacts; and

> Provide recommendations on further studies, if any, that would be required to identify impacts to ecological indicators, and, if so, suggest any ameliorative and impact minimisation strategies that may be warranted.

2 Previous Investigations

The Ecology Lab Pty Ltd has produced a number of reports on the aquatic habitat and biota associated with the Georges River and other watercourses in the vicinity of West Cliff Area 5. These have incorporated the results of baseline surveys, predictions of mine-subsidence impacts, threatened species assessments and results of monitoring during and after mining.

The potential effects of subsidence on aquatic habitats and biota have been assessed in several reports. The effects of Longwalls 29 to 33 were assessed by The Ecology Lab (2003). Further reports on aquatic habitats and biota potentially subject to impacts from the proposed mining of Longwalls 31 to 33 (The Ecology Lab 2005a) and 34 to 36 (The Ecology Lab 2008a) were included in the Subsidence Management Plans (SMPs) submitted to The Department of Primary Industries (Mineral Resources), as part of the approvals process. The effects of mining of Longwalls 37 and 38 on aquatic habitat and biota were assessed in the Flora and Fauna Assessment for these longwalls (Cardno Ecology Lab 2012a) which formed part of the Extraction Plan (BHPBIC 2014a) and Biodiversity Management Plan (BHPBIC 2014b).

The results of ongoing monitoring undertaken during and / or immediately after the extraction of Longwalls 31 to 36 have been described in their respective End of Panel Reports (The Ecology Lab 2007, 2008b; Cardno Ecology Lab 2010a; 2011, BHPBIC 2014c) and in the 2008, 2010, 2011 and 2012 Aquatic Ecology Monitoring reports (The Ecology Lab 2008c; Cardno Ecology Lab 2010a, 2012b, 2013 and 2014).

2.1 Predicted Impacts

The predictions of potential impacts on aquatic habitats and biota due to the extraction of Longwalls 31-33, 34-36 and 37-38 are summarised below:

2.1.1 Longwalls 31 to 33

> Flow diversion and pool drainage may occur due to fracturing, and spring discharge of groundwater to the Georges River may occur due to upland subsidence (MSEC 2005). These impacts may in turn result in changes to water quality, acidification, and increased metal concentrations, with the magnitude of these impacts being dependent on the volumes of any diversions, discharges and flow within the river (Ecoengineers 2005); and,

> The loss of aquatic habitat and biota due to pool drainage and flow diversions would be limited and temporary, assuming water levels returned to background levels not long after disturbance (The Ecology Lab 2005a). Drained pools would constitute barriers to fish passage. However, licensed discharges and ameliorative measures should allow flow to resume, resulting in only transient impacts, if any, to migratory fish.

2.1.2 Longwalls 34 to 36

> Minor localised increases in levels of ponding and flooding in the Georges River may occur, together with very small changes in river alignment and minor fracturing, but no significant water loss (MSEC 2007). Compressive buckling and dilation of the topmost bedrock may occur along the alignments of Mallaty Creek and Leafs Gully and, to a lesser extent, along the alignments of Nepean Creek. In areas with exposed bedrock, there may be some sub-surface diversion of flows and drainage of pools;

> Subsidence induced fracturing in the Georges River and Mallaty Creek may result in some sub-surface diversion of flows and drainage of pools (MSEC 2007). These impacts were expected to have only minor, localised impacts on aquatic biota in the Georges River (The Ecology Lab 2008a);

> Flow diversions could lead to minor, short-term and localised increases in the acidity of water, reductions in dissolved oxygen levels and increased concentrations of heavy metals (Ecoengineers 2007). However, such changes in water quality were likely to have significant impacts on aquatic ecology only if they coincide with low flows. Any concurrent impacts on aquatic biota and ecology are otherwise likely to be minor, localised and short term (The Ecology Lab 2008a).

> Any water loss in Mallaty Creek could result in the loss of aquatic habitat and biota from the affected area. Once flow is re-established, re-colonisation by aquatic flora and fauna should occur (The Ecology Lab 2008a);

2.1.3 Longwalls 37 to 38

> No significant impacts to the physico-chemical features of the Georges River due to the extraction of Longwalls 37 and 38 were predicted (MSEC 2012). While fracturing and flow diversion may occur, these impacts are expected to be short-lived, minor and localised in their extent;

> There would be negligible diversion of flows, negligible changes in the natural drainage behaviour of pools, negligible iron staining and negligible increases in turbidity in at least 80% of the Georges River (BHPBIC 2014a);

> The predicted changes in ponding, flooding and stream alignment due to vertical subsidence would be negligible (BHPBIC 2014a);

> Fracturing of the river bed and the induction or enhancement of ferruginous springs would be localised and would have negligible effects on aquatic habitats or biota in the Georges River (BHPBIC 2014a);

> If fracturing occurs, there may be some diversion of surface flows and draining of pools in areas with exposed bedrock, however, in areas with alluvial beds fractures are likely to be filled with alluvium during subsequent flow events (BHPBIC 2014a);

> Flow diversions and draining of pools in drainage lines would result in localised reductions in aquatic habitat. These would be temporary if infilling of fractures occurred. Due to the relatively limited aquatic habitat supported by ephemeral habitat and its abundance in the local area, such effects would likely be negligible in a local and regional context (Cardno Ecology Lab 2012a).

2.2 Findings

The predictions of potential impacts to aquatic habitats and biota due to the extraction of Longwalls 31-33, 34-36 and 37-38 are summarised below:

2.2.1 Longwalls 31 to 33

Longwall 31

> The surface monitoring undertaken by BHPBIC during and following extraction of Longwall 31 did not reveal any fracturing of the pool substratum or retaining rock bars or loss of water within the Georges River (Comur Consulting 2007). No impacts to water quality were identified; and

> There was no indication of any impacts to aquatic habitat and macroinvertebrates in the Georges due to extraction of Longwall 31 (The Ecology Lab 2007).

Longwall 32

> The surface monitoring undertaken during and/or following extraction of Longwall 32, indicated that minor iron staining, minor rock bar fracture and limited gas release had occurred (BHPBIC 2008);

> There were no detectable impacts on flow, levels of ponding, scouring or desiccation within the Georges River (MSEC 2008). The analysis of water quality undertaken after extraction of this longwall did not identify any significant changes in salinity, pH, DO, sulphate, nickel or zinc levels (Ecoengineers 2008); and

> No evidence of any impacts to aquatic ecology that could be associated with extraction of Longwall 32 (The Ecology Lab 2008b).

Longwall 33

> Monitoring undertaken by the Illawarra Coal Environmental Field Team (ICEFT) indicated rock fractures, flow diversions and low water levels, iron staining and gas releases in the Georges River (Comur Consulting 2010);

> No significant impact on water quality due to gas releases, although a small loss of flow associated with flow diversions was observed (Ecoengineers 2010). Short term elevations in manganese and zinc

concentrations and reductions in dissolved oxygen in the Georges River that did occur may have been due to iron staining;

> No evidence of impacts to aquatic habitats and biota (Cardno Ecology Lab 2010a). Changes in the condition of aquatic habitats and biota were not linked with changes to water quality; and,

> There was no evidence to suggest that small changes in the condition of the aquatic macroinvertebrates observed following extraction of Longwall 33 were related to subsidence (Cardno Ecology Lab 2012b and 2013). There was no evidence of any adverse effects on aquatic habitat or fish populations.

2.2.2 Longwalls 34 to 36

Longwall 34

> Monitoring undertaken by ICEFT indicated two zones of minor fracturing in the Georges River at Rockbars 40, 41 and 43 and an associated zone of minor iron staining in Pool 40d, above Rockbar 41 (Comur Consulting 2012). No flow diversions were identified in these areas and pool water levels were consistent with baseline levels. In Mallaty Creek, minor compression fracturing, surface flow diversions and localised reductions in pool water levels were observed at Pool MC 109, but water was present at the pools upstream and downstream; and,

> No significant water quality impacts were observed in the Georges River and Mallaty Creek (Ecoengineers 2011) and no evidence of any impacts to aquatic ecology in the Georges River were observed during extraction of Longwall 34 (Cardno Ecology Lab 2010b). There was no evidence to suggest that the small changes in the condition of the aquatic macroinvertebrates observed following extraction of Longwall 34 were related to the effects of subsidence (Cardno Ecology Lab 2012b and 2013). There was no evidence of any adverse effects on aquatic habitat or fish populations in the Georges River.

Longwall 35

> Monitoring undertaken by ICEFT in the Georges River between February and November 2013 indicated physical mining impacts (fracturing, diversion of flows and lowering of pool water levels and associated loss of river connectivity during low flow conditions) associated with the extraction of Longwall 35 (BHPBIC 2013a to c). Fracturing in Pools 56 and 57 and reductions in water levels below baseline levels in Pools 38, 44, 51, 54, 56, 57, 58 and 60 were also observed. Gas releases and iron staining were observed in some of these pools. Additional releases from Brennans Creek Dam were successful in returning pool water levels to pre-mining levels (at least temporarily). However, following cessation of additional releases, pool water levels fell below baseline levels. On 20 November 2013, following further additional releases from Brennans Creek Dam two weeks after the November 2013 aquatic ecology field investigations, pool water levels were at or above pre-mining levels (BHPBIC 2013c).

> Analysis of flow and water quality data did not identify any significant water quality impacts in the Georges River due to extraction of Longwall 35 (BHPBIC 2013a, Ecoengineers 2013).

> Subsidence associated with extraction of Longwall 35 appears to have impacted aquatic indicators (Cardno Ecology Lab 2014). These impacts included a direct loss of aquatic habitat, reductions in numbers of macroinvertebrate taxa, evidence of a reduction in aquatic habitat quality and the desiccation of macrophytes adjacent to affected areas. There also appears to have been a reduction in the numbers of fish and larger mobile macroinvertebrates at one site. No changes to aquatic indicators were evident at sites further downstream; impacts to aquatic ecology that did occur appeared restricted to the areas directly affected by mining. Increased water releases from Brennans Creek Dam temporarily restored pool water levels, which would have minimised impacts to aquatic ecology.

The results of the current survey undertaken in December 2014 are presented and discussed in **Sections 4** to **6** of this report.

As two or more years of post-extraction data have been collected for Longwalls 33 and 34 (Cardno Ecology Lab 2012b), and there is no evidence of more than minor and short term impacts to aquatic ecology associated with these longwalls, no further ongoing monitoring in relation to these longwalls is considered necessary. Notwithstanding this, identification of any mining impacts (such as fracturing and reductions in pool water levels) potentially associated with these longwalls would trigger additional surveys of aquatic ecology.

3 Study Methods

3.1 Field Methods

3.1.1 Study Sites and Sampling Dates

The following sites in the Georges River (and their designation in relation to the monitoring program) were sampled on 1 and 2 December 2014 (**Figure 3.1**):

> Site 6 (upstream control site);

> Site 7 (upstream control site);

> Site 8 (impact site for Longwalls 35 and 38);

> Site 9 (impact site Longwalls 35 and 36);

> Site 10 (impact site Longwalls 36 and 37); and,

> Site 11 (downstream controls site).

Monitoring at Sites 1 to 4 adjacent to Longwalls 29 to 32 ceased after autumn 2010 and monitoring at Site 5 adjacent to Longwall 32 ceased after November 2011. Following a review of the monitoring program and the very limited aquatic habitat supported by Mallaty Creek, monitoring at Site 12 on this creek was discontinued November 2011.

Although at least two years of post-extraction monitoring have been completed for Longwalls 33 and 34, monitoring at Sites 6 and 7 (adjacent to these longwalls) has continued to provide upstream comparative data for Longwalls 35 to 38. Previously, Sites 6 and 7 provided impact data for Longwalls 33 and 34, but in the absence of any detectable changes to aquatic indicators occurring at these sites that could be associated with mining (see **Section 2.2**), they have now been re-defined as controls sites.

Each study site is approximately 100 m long. Their GPS co-ordinates are listed in **Appendix A** and the timing of the aquatic surveys relative to the extraction of each longwall is shown in **Table 3.1**.

Table 3-1 Timing of aquatic ecology surveys relative to extraction of West Cliff Longwalls 31 to 38. (Pre, Dur and Pos indicate whether surveys were done pre, during or post-extraction of each Longwall (LW)).

LW	Extraction Period		Monitoring Events									
No.	Start	Finish	May 2002*	Mar 2005*	Nov 2007**	Sep 2008	May 2010	Nov 2011	May 2012***	Dec 2012	Nov 2013	Dec 2014
Report Reference			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
31	Aug 06	Dec 06	Pre	Pre		Pos	Pos	Pos	Pos			
32	Feb 07	Jun 08	Pre	Pre		Dur	Pos	Pos	Pos			
33	Jul 08	Dec 09	Pre	Pre		Pre	Dur	Pos	Pos	Pos		
34	Feb 10	Sep 11			Pre	Pre	Pre	Dur	Pos	Pos		
35	Oct 11	Jul 13			Pre	Pre	Pre	Pre	Dur	Dur	Pos	Pos
36	Aug 13	May 14			Pre	Pre	Pre	Pre	Pre	Pre	Dur	Pos
37	Apr 14	Feb 15			Pre	Pre	Pre	Pre	Pre	Pre	Pre	Dur
38	Apr 15	Underway			Pre	Pre	Pre	Pre	Pre	Pre	Pre	Pre

(1)The Ecology Lab (2003), (2)The Ecology Lab (2005a), (3)The Ecology Lab (2008a), (4)The Ecology Lab (2008c), (5)Cardno Ecology Lab (2010b), (6)Cardno Ecology Lab (2012b), (7)Cardno Ecology Lab (2012a), (8) Cardno Ecology Lab (2013), (9) Cardno Ecology Lab (2014) and (10) current study.

*Sites 7 to 11 not sampled in May 2002 and March 2005, **Sites 10 and 11 not sampled in November 2007, ***AUSRIVAS sampling not undertaken in May 2012.

3.1.2 Habitat Assessment

A qualitative assessment of the condition of aquatic habitats was compiled for the Georges River, based on the following attributes:

> In-stream features such as sequence of pools, runs and riffles (shallow areas with broken water);

> Stream substratum;

> Potential refuge areas during periods of low flow (e.g. large deep pools);

> Presence of fish habitat including snags, bank undercuts and aquatic plants, and,

> Presence of any barriers to fish passage.

Photographs of the watercourse at each site on the Georges River were taken using a digital camera to assist in the descriptions.

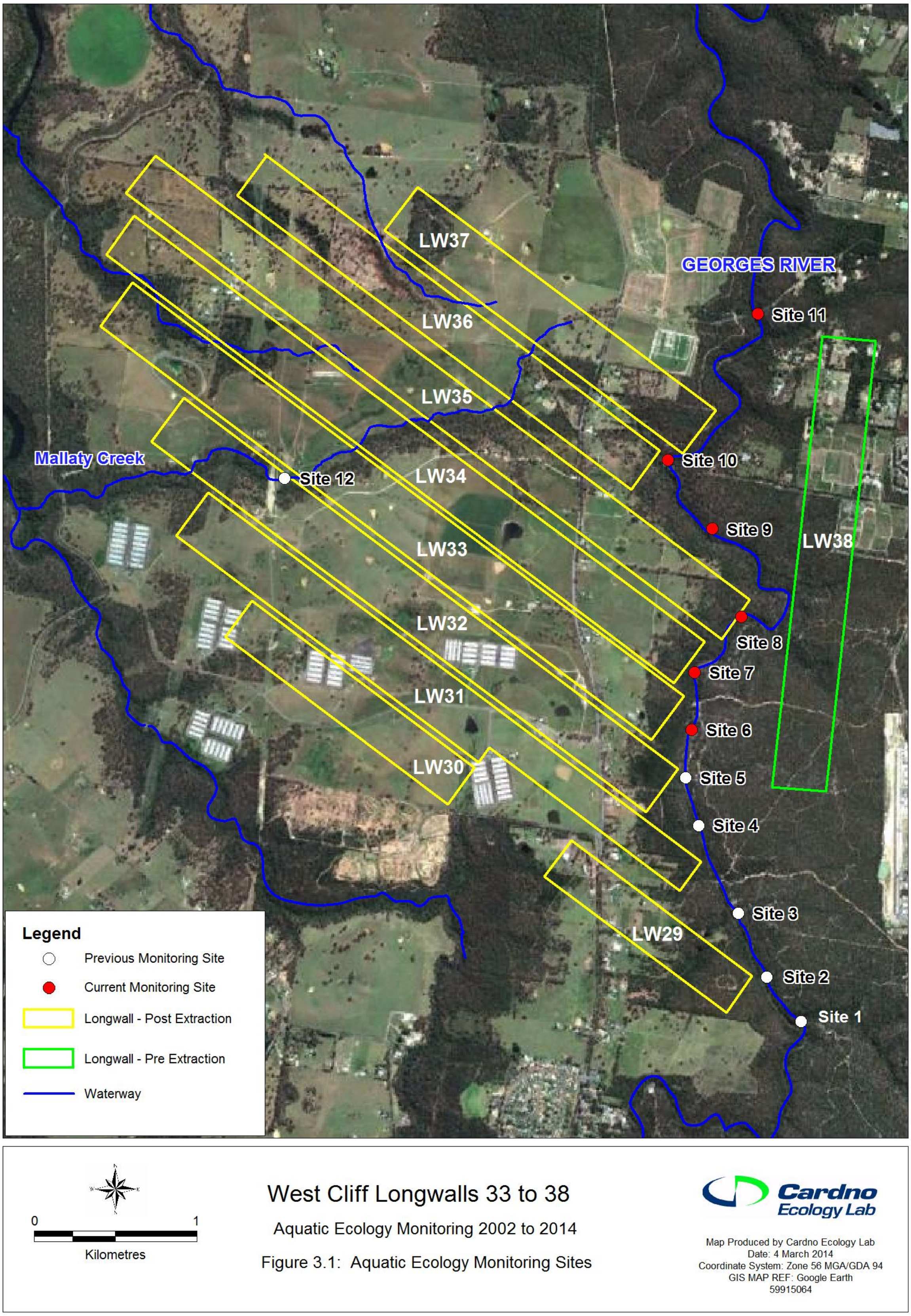

Figure 3-1 Aquatic Ecology Monitoring Sites for the West Cliff Area 5 Aquatic Ecology Monitoring Program

3.1.3 Water Quality

Water quality was measured *in situ* with a YSI 6920 water quality probe and meter that were calibrated prior to sampling. Water quality was measured at each site before aquatic fauna were sampled to avoid disturbance to the waterway. The following variables were recorded just below the surface:

> Temperature (°C);

> Conductivity (µs/cm);

> pH;

> Dissolved oxygen (% saturation);

> Oxidation reduction potential (ORP) (mV); and,

> Turbidity (ntu).

Duplicate readings of each variable were taken in accordance with Australian Guidelines for protection of aquatic ecosystems (ANZECC/ARMCANZ 2000).

3.1.4 Aquatic Macroinvertebrates

Aquatic macroinvertebrates associated with edge habitats were sampled using the AUSRIVAS rapid assessment methodology (RAM) (Turak *et al*. 2004). Riffle habitat was not sampled, because this habitat was not represented in all the stretches of creek surveyed. Edge samples were collected with dip nets (250 µm mesh) over a period of 3-5 mins from a 10 m length of habitat within a 100 m reach of the creek at each site. The dip net was used to agitate and scoop up material from vegetated river edge habitats. Where the habitat was discontinuous, patches of habitats with a total length of 10 m were sampled over the 100 m reach. Each RAM sample was rinsed from the net onto a white sorting tray from which animals were picked live using forceps and pipettes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten minute intervals either until no new specimens had been found or total of 60 minutes (i.e. the initial 40 minutes plus up to another 20 minutes) had elapsed. Care was taken to collect cryptic and fast moving animals in addition to those that were conspicuous and / or slow-moving. The animals collected at each site were placed into a labelled jar containing 70% alcohol / water.

Environmental variables, including alkalinity, modal river width and depth, percentage boulder or cobble cover, latitude and longitude were recorded in the field. These are required for running the AUSRIVAS predictive model for edge habitat. Distance from source, altitude, and land-slope were determined from appropriate topographic maps. Mean annual rainfall was determined in the laboratory from the regional precipitation maps presented in the AUSRIVAS Sampling and Processing Manual (Turak *et al*. 2004).

3.1.5 Fish

Fish and large mobile invertebrates, such as freshwater crayfish, occurring at each site were sampled using a back-pack electrofisher (Model Smith-Root LR24). The back-pack electrofisher was operated around the edge of pools, around snags and aquatic vegetation, overhanging banks and rocky crevices. Electrofishing was conducted in sets of four, two minute shots at each site. Fish were collected in a small scoop net, identified and measured. Native species were released unharmed, non-indigenous species were not returned to the water, as per the conditions of our scientific collection permit.

3.2 Laboratory Methods

AUSRIVAS samples were sorted under a binocular microscope (at 40 X magnification) and identified to family level with the exception of Oligochaeta and Polychaeta (to class), Ostracoda (to subclass), Nematoda and Nemertea (to phylum), Acarina (to order) and Chironomidae (to subfamily). Up to ten animals of each family were counted, in accordance with the latest AUSRIVAS protocol (Turak *et al.* 2004).

3.3 Data Analysis

3.3.1 Water Quality

Mean water quality measurements were compared with the (ANZECC/ARMCANZ 2000) default trigger values (DTVs) for protection of aquatic ecosystems for physical and chemical stressors for slightly disturbed upland rivers in southeast Australia.

Water quality data collected during the aquatic ecology monitoring programme were intended to aid in the interpretation of macroinvertebrate data. More detailed water quality monitoring, analysis and assessment is undertaken by the ICEFT and other consultants.

3.3.2 Aquatic Macroinvertebrates

The AUSRIVAS protocol uses an internet-based software package to determine the environmental condition of a waterway based on predictive models of the distribution of aquatic macroinvertebrates at reference sites (Coysh *et al.* 2000). The ecological health of the creek is assessed by comparing the macroinvertebrate assemblages collected in the field (i.e. 'observed') with macroinvertebrate assemblages expected to occur in reference waterways with similar environmental characteristics. The data from this study were analysed using the NSW models for pool edge habitat sampled in spring and autumn. The AUSRIVAS predictive model generates the following indices:

> OE50Taxa Score – The ratio of the number of macroinvertebrate families with a greater than 50% predicted probability of occurrence that were actually observed (i.e. collected) at a site to the number of macroinvertebrate families expected with a greater than 50% probability of occurrence. OE50 taxa scores provide a measure of the impairment of macroinvertebrate assemblages at each site, with values close to 0 indicating an impoverished assemblage and values close to 1 indicating that the condition of the assemblage is similar to that of the reference streams.

> Overall Bands derived from OE50Taxa scores which indicate the level of impairment of the assemblage. These bands are graded as described in **Table 3.1**.

Table 3-2 AUSRIVAS Bands and corresponding OE50 Taxa Scores for AUSRIVAS edge habitat sampled in spring

Band	Description	Spring OE50 Score
X	Richer invertebrate assemblage than reference condition	>1.16
A	Equivalent to reference condition	0.84 to 1.16
B	Sites below reference condition (i.e. significantly impaired)	0.52 to 0.83
C	Sites well below reference condition (i.e. severely impaired)	0.20 to 0.51
D	Impoverished (i.e. extremely impaired)	≤0.19

The SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was also used to determine the environmental quality of sites on the basis of the presence or absence of families of macroinvertebrates. This method assigns grade numbers between 1 and 10 to each macroinvertebrate family, based largely on their responses to chemical pollutants. The sum of all grade numbers for that site was then divided by the total number of families recorded in each site to obtain an average SIGNAL2 index. The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site. SIGNAL2 values are as follows:

> SIGNAL > 6 = Healthy habitat;

> SIGNAL 5 – 6 = Mild pollution;

> SIGNAL 4 – 5 = Moderate pollution; and,

> SIGNAL < 4 = Severe pollution.

3.3.3 Multivariate Analyses

A matrix of differences in the types of taxa between all possible pairs of samples was compiled by calculating their respective Bray-Curtis dissimilarity coefficients. Permutational analysis of variance (PERMANOVA+ in Primer v6) was used to examine spatial differences and temporal changes, and their interaction, in macroinvertebrate assemblage presence / absence data sampled using AUSRIVAS. Differences in the levels of factors and interaction terms were examined by *Post-hoc* permutational t-tests. Only statistical differences with a significance level of P ≤ 0.05 were considered. Significant differences between groups (e.g. impact versus control) may arise due to differences between group means, differences in dispersion (equivalent to variance) among groups or a combination of both. Each of these outcomes could be indicative of an impact.

The analyses were undertaken on data collected from sites relevant to Longwall 35 only (impact Sites 8 and 9 and control Sites 6, 7 and 11), as all the physical mining impacts observed in the Georges River following commencement of extraction of this longwall have been attributed to its extraction. Data collected in May 2010 were not included in the analyses as autumn data may confound the analyses which are otherwise undertaken using data collected in spring only. Data from May 2002 and March 2005 were not included as data are only available from Site 6 (monitoring for Longwall 35 did not commence until November 2007).

The analytical design was:

> **Phase**: A fixed factor with two levels: Before (commencement of extraction), and After (commencement of extraction);

> **Treatment**: A fixed factor with two levels, Control and Impact; and

> **Site**: A random factor with two to three levels nested within Treatment (Sites 8 and 9 are nested in the level 'Impact', and Sites 6, 7 and 11 nested in the level 'Control', of the Factor Treatment).

A factor representing the variation associated with different surveys was not included in the design as only one AUSRIVAS sample was collected per site per survey, hence there was no replication at each site within surveys. Thus, there is no test for differences among surveys at each site. Therefore, the analyses described here (and in **Section 3.3.4**) seek to detect changes in macroinvertebrates occurring among Phases (i.e. impacts that persist for several surveys).

Multivariate patterns in the data were examined using the Principal Coordinates Ordination (PCO) routine in Permanova+. This is a generalised form of Principal Components Analysis (PCA) in which samples are projected onto linear axes based on their dissimilarities in a way that best describes the patterns among them using as few dimensions as possible (Clarke and Gorley 2006). The amount of variation "explained" by each principal axis is indicated and the dissimilarity between data points can be determined from their distances apart on the axes (Anderson et al. 2008).

The Similarity Percentages (SIMPER) routine was used to determine which taxa were responsible for discriminating between groups for significant factors (Clarke 1993). The taxa responsible for statistically significant differences between pairs of sites when assemblage data were compared across treatments were determined. SIMPER could not be used to determine which taxa were responsible for differences between individual surveys at each site as only one replicate was available per site per survey.

3.3.4 Univariate Analyses

Permanova+ was used to examine spatial differences and temporal changes in the number of taxa, OE50 Taxa Scores and SIGNAL2 Indices derived from AUSRIVAS modelling. In this case, the analyses were based on a Euclidean distance matrix of all possible pairs of samples of the variable of interest. Only statistical differences with a significance level of P ≤ 0.05 are considered.

The PERMANOVA approach does not require the data conform to a normal distribution unlike "traditional" ANOVA. As is the case with multivariate analyses, significant differences between groups (e.g. impact versus control) may arise due to differences between group means, differences in dispersion (variance) among groups or a combination of both. A potential impact could be expected to affect both the magnitude and dispersion of an indicator (e.g. number of taxa). If a statistically significant difference between groups is detected that could be indicative of a mining impact, the proportion of the statistical difference attributable to the difference in variance between pairs of groups would be explored using the PERMDISP procedure. This procedure tests for a statistical difference between variances. If there is no statistical difference between variances, the statistical difference detected between groups is most likely due to differences between group means. When a statistical difference between variances is detected, the difference between groups could be due to both the difference in variance and the mean between groups.

3.3.5 Approach to Interpretation of Analyses and Data Presentation

The primary aim of the statistical analyses are to identify differences in the selected indicators of aquatic ecology at the impact sites associated with Longwall 35 that are in a different direction, or of a different magnitude, to those at the control sites. Statistically significant differences provide evidence that an impact may have occurred. Evidence is assessed by examination of significant interaction terms in the PERMANOVA tests and the results of the *Post-hoc* tests.

Statistically significant main effects are not indicative of an impact, and, as such, are not described in detail or graphed. For each biotic index, the value for each survey at each site was graphed and interpreted visually to identify any trends that could be indicative of an impact.

3.3.6 QA/QC Procedures

Data generated in the field were checked for accuracy and completeness before leaving each site. On return to the laboratory, field data sheets were photocopied, entered into spreadsheet format and checked. Spreadsheet files were locked prior to analysis to prevent accidental over-writes or corruption.

In the laboratory, the remains of each macroinvertebrate sample were retained and checked by another staff member to ensure that no animals were missed. A staff member with appropriate training and experience checked the identifications and counting of samples. These activities were recorded on the Laboratory Management Sheet. Data were entered into an electronic spreadsheet and data for each sample were printed and checked by a second staff member.

4 Results

4.1 Aquatic Habitat and General Observations

The section of the Georges River within the study area is fed by a number of tributaries which drain rural properties, urban development and vegetated areas. The upstream section of the river (Site 6) (**Figure 3.1**) is characterised by long shallow pools connected by sections of shallow flow over bedrock. Further downstream (Sites 7-11) the river consists of deeper pools with connecting flow through boulder fields. The substratum throughout the study area includes large areas of sandstone bedrock, accumulations of sand and silt within pools, and sections with boulders and cobbles.

Riparian vegetation was in good condition. It consisted predominantly of native species such as mat rush (*Lomandra* sp.) and sawgrass (*Gahnia* sp.) plus a few introduced taxa. Mature trees were common and gaps in vegetation generally occurred only at road crossings.

During the current survey large dense beds of cumbungi (*Typha* sp.) and smaller patches of spike rush (*Juncus* sp.) and clubrush (*Isolepis* sp) were the most common emergent aquatic macrophytes. Pondweed (*Potamogeton* sp.) was also present at Sites 7 and 8 and *Vallisneria* sp. at Site 6. All these species have been observed previously. At least 20 species of aquatic macrophytes have been recorded in the reach of the Georges River within and adjacent to the current monitoring sites (**Appendix B**).

Small waterfalls and cascades were present at many of the sites sampled. The only artificial structure present in this section of the river was the culvert at the Blackburn Road crossing near Site 10. During the current survey, flowing water was present at each site visited. This included Sites 8 (**Plate 1a** and **b**) and 9 (**Plate 1e** and **f**) where flow and pools were observed. During November 2013, the majority of the watercourse at these sites was dry (**Plate 1c** and **d, Plate 1g** and **h**) (Cardno Ecology Lab 2014). Lowering of pool water levels during the November 2013 survey had also resulted in the desiccation of macrophytes (e.g. **Plate 1c**).

4.2 Water Quality

The mean values of the water quality indicators measured *in situ* from 2002 to 2014 (including May 2012) are presented in **Appendix C**.

The main findings across the surveys are summarised as follows:

> Temperature of the water ranged from 10.3° to 24.0° C and reflected seasonal trends. The measurements taken during particular surveys varied by between 2° and 5° C across sites, but there were no obvious trends along the river;

> Conductivity ranged from 748 to 2353 µS/cm and exceeded the upper DTV (ANZECC ARMCANZ 2000) on each occasion. The lowest and highest levels were recorded in September 2008 and May 2010 during extraction of Longwalls 33 and 34, respectively. Conductivity was similar across sites during November 2011 and May 2012 but differed during the other surveys. It was relatively high in May 2010, December 2012 and November 2013. This finding may have been related to releases from Brennans Creek Dam and other catchment inflows;

> pH ranged from 7.6 to 9.2 and exceeded the upper DTV on all but two occasions (Site 8, May 2010 and Site 10, November 2013);

> Dissolved oxygen levels ranged from 52.4% to 121.3% saturation. Levels were below the lower DTV at every site on at least one occasion. Values in excess of the upper DTV were recorded once each at Sites 6 and 8. The 52.4% saturation level recorded at Site 10 in November 2013 was by far the lowest recorded at any site during the monitoring program;

> Oxidation reduction potential (ORP) ranged from 50 to 465 mV. ORP levels were fairly similar across sites in each sampling event. The ORP values recorded in September 2008, November 2013 and the current survey were less than those during the other surveys; and

Plate 1 a to h: Sites 8 and 9 on the Georges River in November 2013 and December 2014

> Turbidity ranged from 0.2 to 59.4 ntu. The turbidity dropped below the lower DTV at least once at all the sites on the Georges River. Values in excess of the upper DTV were recorded once each at Sites 7 and 10.

It should be noted that the water quality data collected by Cardno Ecology Lab is intended to assist in the interpretation of aquatic ecology data and allows only limited conclusions to be drawn about temporal variation in the various indicators. Water quality data are collected more frequently and interpreted by BHPBIC and Ecoengineers Pty. Ltd.

4.3 Aquatic Macroinvertebrates

4.3.1 General Findings

In total, 47 macroinvertebrate taxa were identified from the AUSRIVAS edge samples from Sites 6 to 11 in December 2014 (**Appendix D**). Nine taxa, including Chironomidae (non-biting midges), Dytiscidae (diving beetles) and Hydrophilidae (water scavenger beetles) occurred at all sites. These pollution tolerant taxa live near the pool edge and can survive for some time out of water (Gooderham and Tsyrlin 2002). Caenidae (a family of mayfly), another pollution tolerant species, were also found at each site and pollution tolerant baetid mayflies were found at each site except Site 11. Relatively few pollution sensitive taxa were found in the Georges River, though Telephlebiidae (dragonflies) and Leptophlebiidae (prong-gilled mayflies) were found at every site, and Austrocorduliidae (a Genus of dragonfly) were recorded at Site 11 in December 2014.

The occurrence of leptophlebiids has varied somewhat among surveys. For example, in November 2013 leptophlebiids were found at all sites except Site 9; in December 2012 this taxon was found only at Sites 6, 10 and 11; and in November 2011 it was not found at any of the sites sampled during this current survey. Caenid and baetid occurrence has also been similarly variable among surveys. In November 2013 caeinds were present at all sites except Site 9, and baetids occured at all sites except Sites 9 and 10. Chrionomidae have occurred at every site and occasion from May 2002 to December 2014. In addition to the mayflies; Leptophlebiidae, Caeindae and Batidae, several other common taxa (those sampled at Site 9 and at other sites during several surveys) were absent from Site 9 in November 2013. These included Physidae, Ostracoda, Coenagrionidae, Hemicordulidae, Tanhypodinea and Ecnomidae. The majority of these taxa are pollution tolerant (SIGNAL2 grade 5 or less), although Leptophlebiidae is pollution sensitive (grade 8).

The Genus Austrocorduliidae includes the Sydney hawk dragonfly (*Austrocordulia leonardi*), listed as threatened under the Fisheries Management Act 1994. The two specimens collected at Site 11 were not identified as the Sydney hawk dragonfly. However, as a precautionary measure, these identifications will be confirmed by an external taxonomic expert, where available, and BHPBIC notified of the presence of any listed threatened species. The Adams emerald dragonfly (*Archaeophya adamsi*), also listed as threatened under the Fisheries Management Act 1994, was not present in any of the samples.

The SIGNAL2 Index ranged from 4.0 to 4.4 at Sites 7, 9, 10 and 11 and was indicative of moderate pollution. The SIGNAL2 Score at Sites 6 and 8 was 3.6 and 3.9, respectively, which is indicative of severe pollution.

4.3.2 Changes in Macroinvertebrate Fauna

The objective of the following comparisons of macroinvertebrate fauna among surveys (May 2002 to December 2014) and sites (Sites 6 to 11) was to determine whether any changes to ecological indicators may have occurred following the commencement of extraction of Longwall 35. Potential changes in indicators associated with mining impacts that occurred following commencement of extraction of Longwalls 31 to 34 were considered in previous reports and are summarised in **Section 2.2**.

Subsidence impacts (including fracturing of bedrock and reductions in pool water levels) associated with the extraction of Longwall 35 were first identified in the Georges River during February to November 2013 (i.e. after the December 2012 survey and just prior to the November 2013 survey (see **Section 2.2**)). The following comparisons consider the ongoing effects of extraction of Longwall 35 on aquatic indicators in the Georges River and any mining impacts that may have occurred following the commencement of extraction of Longwalls 36 (August 2013) and 37 (April 2014).

AUSRIVAS data collected from May 2002 to December 2014 at Sites 6 to 11 are presented in **Appendix E**.

PERMANOVA analyses are presented in **Table 4.1**. The statistical analyses did not yield any statistically significant variation among Treatments or Sites that could be indicative of an impact occurring following the commencement of extraction of Longwall 35. The only statistically significant variation was the main effect of Site when assemblage data were compared across Treatments. This is not indicative of an impact (**Section 4.3.2.5**).

Table 4-1 Summary of results of PERMANOVA analyses undertaken using AUSRIVAS data collected in spring surveys from November 2007 to December 2014. * = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001, ns = not statistically significant. See Appendix F for full results.

Indicator	Phase	Treatment	Site (Treatment)	Phase x Treatment	Phase x Site (Treatment)
Assemblage	ns	ns	*	ns	ns
Number of Taxa	ns	ns	ns	ns	ns
OE50 Taxa Score	ns	ns	ns	ns	ns
SIGNAL2 Index	ns	ns	ns	ns	ns

4.3.2.2 Number of Taxa

The number of taxa sampled ranged from 9 to 32. The numbers of taxa sampled at Sites 6, 8 and 9 were relatively variable compared with the other sites, with the variation at Site 6 being the greatest (**Figure 4.1**). The number of taxa sampled at Site 9 in November 2013 (13 taxa) was the least of all sites surveyed during that survey and the least during all previous surveys at all sites except for Site 6 in March 2005 (9 taxa) and November 2011 (13 taxa). Prior to November 2013 the number of taxa sampled at Site 9 was relatively consistent, ranging from 20 to 30. The number of taxa sampled at Site 9 in December 2014 (26 taxa) was comparable to that sampled prior to November 2013. At the remaining sites, the number of taxa sampled in November 2013 and December 2014 was comparable to that found in earlier surveys.

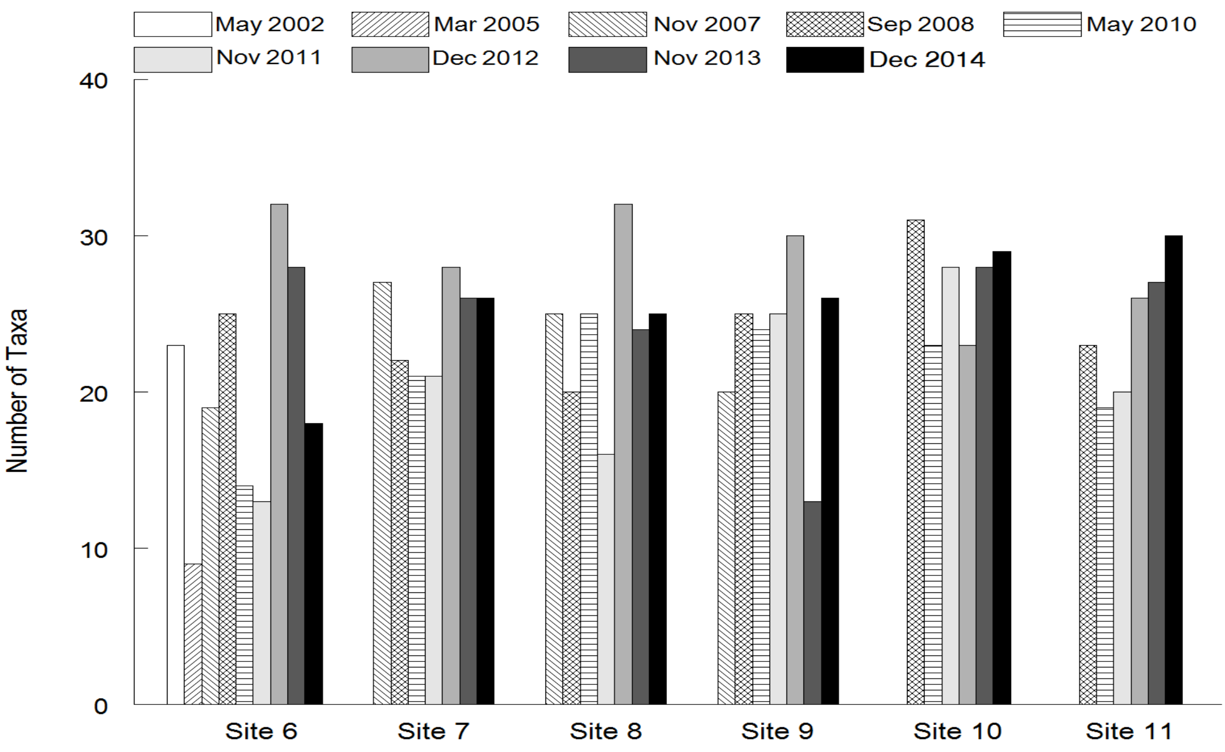

Figure 4-1 Number of macroinvertebrate taxa found in AUSRIVAS Samples Collected from Edge Habitat at Sites 6 to 11 on the Georges River May 2002 to December 2014.

4.3.2.3 OE50 Taxa Scores

OE50 Taxa Scores ranged from 0.32 to 1.02, indicating that the macroinvertebrate assemblages on the Georges River ranged from severely impaired relative to reference watercourses selected by the AUSRIVAS model to equivalent to AUSRIVAS references watercourses (**Figure 4.2**). The majority of the OE50 Taxa Scores were also below 1.00, indicating that number of taxa observed was less on most occasions than would be expected relative to the AUSRIVAS reference watercourses.

Sites 6 to 8 have shown the greatest variation in OE50 Taxa Scores through time. The OE50 Taxa Score at Sites 6 and 7 in May 2010 and November 2011, and the OE50 Taxa Score at Site 8 in November 2011 and November 2013, were relatively low compared with the other surveys at each of the sites. The OE50 Taxa Score for Site 8 in November 2013 (0.37) was the lowest recorded at this site (although that in November 2011 was also relatively low (0.44)) during this survey and lower than that during previous surveys at each site apart from Site 6 in May 2010 (0.35) and November 2011 (0.32).

The trends in AUSRIVAS Bands generally reflected those in the OE50 Taxa Scores upon which they are based. The condition of the aquatic macroinvertebrate fauna at the sites on the Georges River has ranged from Band A (equivalent to AUSRIVAS reference condition) to Band C (severely impaired) (**Figure 4.2**). At all the study sites, changes in the condition of the fauna equivalent to at least one AUSRIVAS Band have occurred.

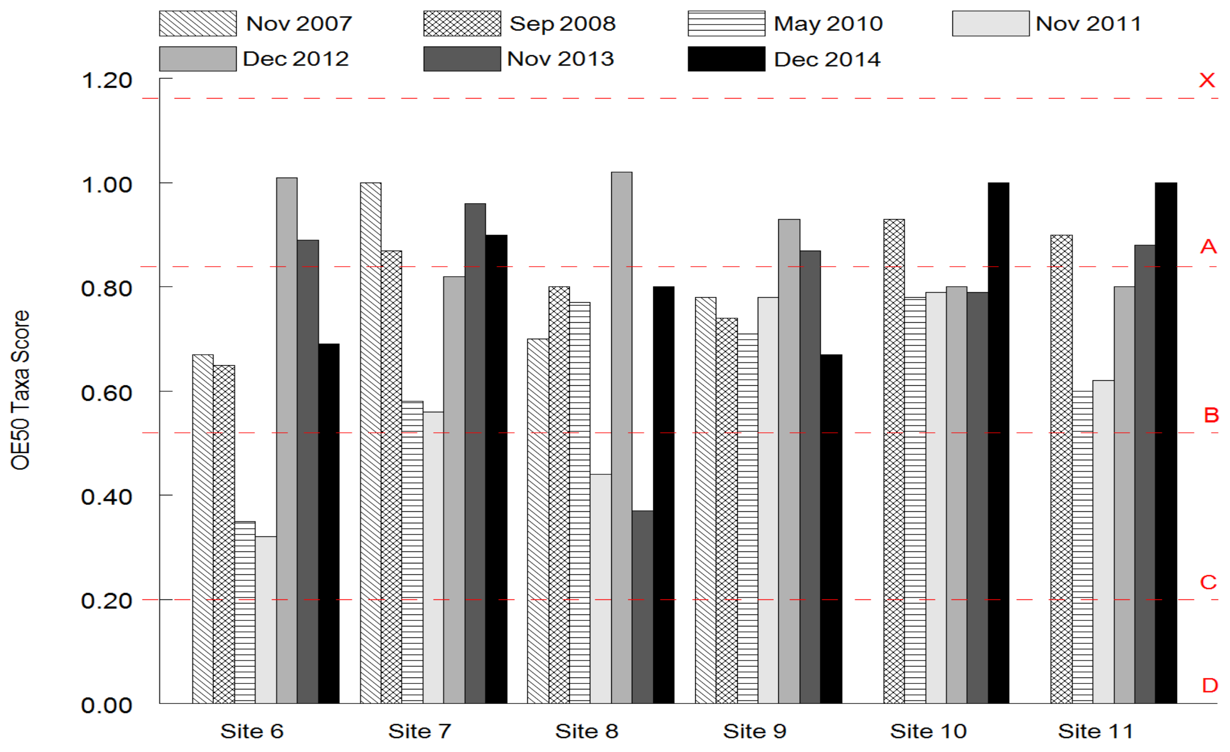

Figure 4-2 OE50 Taxa Scores and their respective Band Scores (A-D) from AUSRIVAS Samples Collected from edge habitat at Sites 6 to 11 on the Georges River from November 2007 to December 2014

4.3.2.4 SIGNAL2 Index

The SIGNAL2 Index ranged from 2.8 (indicative of severe degradation) to 4.7 (indicative of moderate pollution) (**Figure 4.3**). A large proportion of the SIGNAL2 values were less than 4, indicating macroinvertebrate assemblages dominated by pollution tolerant taxa. In general, the SIGNAL2 Indices at the sites sampled in November 2013 and December 2014 were within, or towards the upper end, of the range of SIGNAL2 Indices sampled during May 2002 to December 2013.

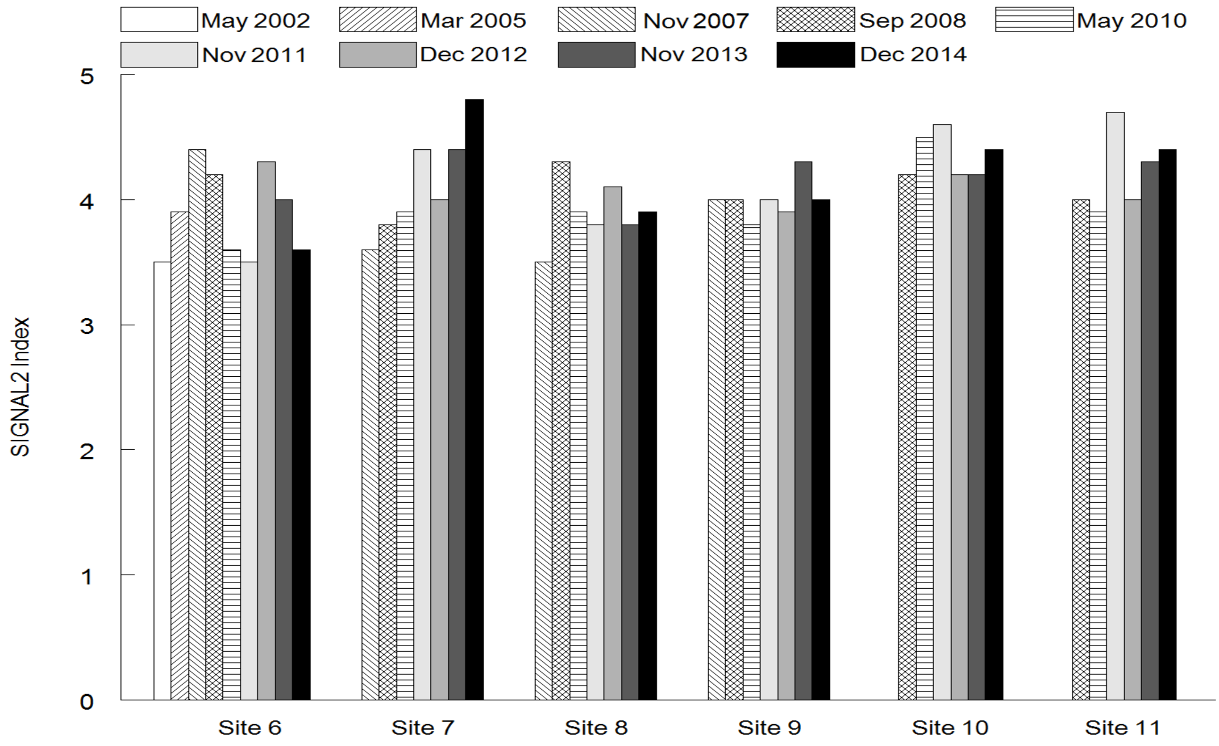

Figure 4-3 SIGNAL2 Indices for AUSRIVAS samples collected from edge habitat at Sites 6 to 11 on the Georges River from May 2002 to December 2014

4.3.2.5 Assemblages

PERMANOVA indicated statistically significant differences among sites within treatments. *Post hoc* tests showed that this was due to differences between structure of the macroinvertebrate assemblages only at the control sites (i.e. Site 11 and those at Sites 6 and 7 - **Appendix F**).

The Principle Component Ordination (PCO) suggests that the assemblage sampled at Site 9 in November 2013 differed from those at this site during all other surveys and from those sampled at other sites during every survey (**Figure 4.4**). It is also evident that the assemblage sampled at Site 6 in November 2011 differed from those at this site during each other survey and from those sampled at other sites during every survey. There is some limited evidence to suggest that assemblages sampled prior to commencement of extraction differed from those sampled at each site after commencement of extraction of Longwall 35. (see Figure 4-4: open symbols tend to group to the bottom left, and closed symbols to group to the top right of the PCO). This does not indicate an impact associated with Longwall 35 has occurred as differences were also apparent at control sites. Also, assemblages sampled from Site 6 and 7 tend to group at the bottom right, and those from Site 11 tend to group at the top left, of the PCO. This finding supports the results of the PERMANOVA tests, which yielded a statistically significant difference between assemblages at the site furthest downstream (Site 11) and those at the two sites furthest upstream (Sites 6 and 7) (**Section 4.3.2**).

SIMPER analyses indicated that no taxon contributed disproportionally more to the differences detected between sites (**Appendix G**). The contribution of individual taxa to the difference between Site 11 and Site 6 ranged between 3.8 % and 0.7 % and the contribution of individual taxa to the difference between Site 11 and Site 7 ranged from 3.9 % to 0.7 %.

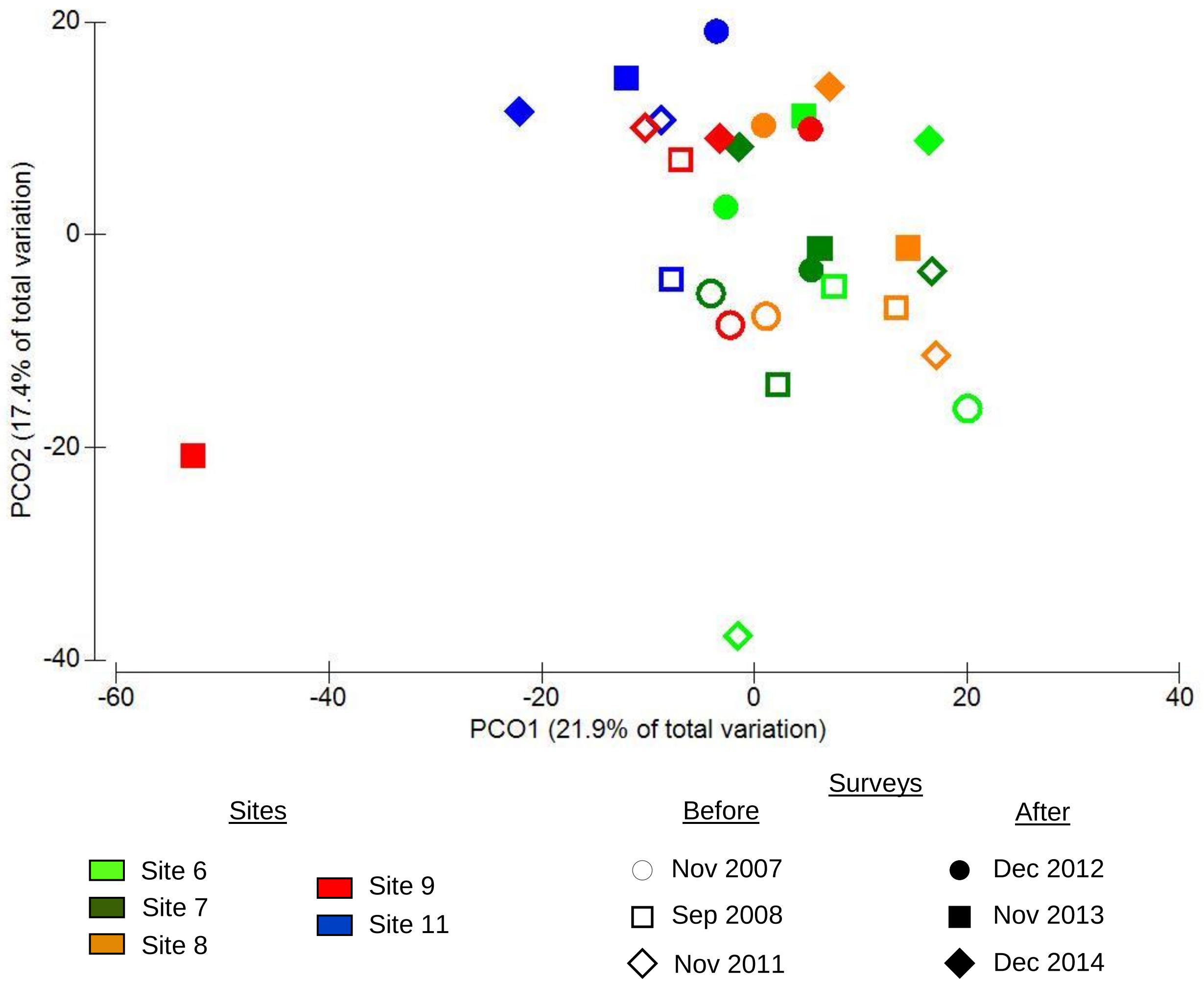

Figure 4-4 Principle Component Ordination (PCO) of AUSRIVAS macroinvertebrate edge assemblages sampled at Sites 6 to 8 and 11 on the Georges River during spring surveys November 2007 to December 2014. Each symbol represents one survey at each site.

4.4 Fish

Six fish species were caught by electrofishing in December 2014 (**Table 4.2**). Several freshwater eels were observed, but not caught whilst electrofishing. These could have been either long-finned (*Anguilla reinhardtii*) or short-finned (*Anguilla australis*) eels. The native Cox's gudgeon (*Gobiomorphus* coxii) and introduced eastern gambusia (*Gambusia holbrooki*I) were the most widespread and abundant species. The genus *Hypseleotris* sp. (carp gudgeons), which were caught at Sites 10 and 11, include several species of fish including firetail gudgeon (*Hypseleotris galii*). Although it is often difficult to differentiate this species from other carp gudgeons in the field, some individuals from Sites 10 and 11 were likely to be firetail gudgeon. Freshwater crayfish (Family Parastacidae) and freshwater shrimp (Family Atyidae) were also observed and caught at each site in AUSRIVAS dip nets and whilst electrofishing. All of these species have been recorded during previous electrofishing surveys undertaken for the monitoring program (**Appendix H**).

During December 2014 gudgeons (Famility Eleotridae) were generally more abundant at the three most downstream sites, and eastern gambusia more abundant at the three upstream most sites. There are no obvious trends in fish data collected in earlier surveys.

No fish were caught at Site 9 in November 2013, despite fish being caught there in November 2011, May 2012 and December 2012. No fish were caught at Site 9 in September 2008, however, few fish were also caught at the other sites during this survey. Four species of fish were caught at Site 9 in December 2014.

Flathead gudgeon (*Philypnodon gradiceps*) were caught at Site 9 in December 2014. Although this species was not caught previously, it is a common and widespread species that has been caught in the Georges River (Cardno Ecology Lab 2012a).

No observations were made that would suggest other major changes to fish assemblages at the impact sites (e.g. fish kills).

Table 4-2 Fish species caught by backpack electrofishing at Sites 6 to 11 on the Georges River during the aquatic ecology monitoring undertaken for the West Cliff Longwalls from 2002 to 2013.

Scientific Name	Common Name	May 2002(1)	Mar 2005(2)	Sep 2008(3)	May 2010(4)	Nov 2011(5)	May 2012(6)	Dec 2012(7)	Nov 2013(8)	Dec 2014(9)
Anguilla sp.	Freshwater eel							x	x	x
Anguilla australis	Short-finned eel							x		x
Anguilla reinhardtii	Long-finned eel	x	x	x		x	x	x	x	x
Gambusia holbrooki	Eastern gambusia	x	x	x	x	x	x	x	x	x
Gobiomorphus coxii	Cox's gudgeon					x	x	x	x	x
Hypseleotris spp.	Carp gudgeon	x	x	x	x	x	x	x	x	x
Philypnodon gradiceps	Flathead gudgeon									x

(1)The Ecology Lab (2003), (2)The Ecology Lab (2005a), (3)The Ecology Lab (2008b), (4) Cardno Ecology Lab (2010b), (5) Cardno Ecology Lab (2012b), (6)Cardno Ecology Lab (2012a), (7) Cardno Ecology Lab (2013), (8) Cardno Ecology Lab (2014) and (9).current study.

5 Discussion

5.1 Physical Mining Impacts Associated with Longwalls 35 to 37

Several mining related physical impacts (fracturing of bedrock and resulting diversion of flows and reductions in pool water levels) were observed in the Georges River by the ICEFT following extraction of Longwall 35 in February to November 2013, and by Cardno Ecology Lab in November 2013 (as described in **Section 2.2**).

Monitoring associated with Longwalls 36 and 37 by ICEFT did not identify any new gas release zones, changes in pool water level and flow or changes to the appearance of the Georges River that were attributed to these longwalls (BHPBIC 2014c and 2015). Some rock fracturing and iron staining and impacts to flow and water levels were identified during this monitoring, however, these impacts were attributed to extraction of Longwall 35.

5.2 Water Quality

No impacts to water quality in the Georges River have been identified that could be associated with the extraction of Longwall 36 (Ecoengineers 2013) (BHPBIC 2014c) (**Section 2.2**). Although relatively low dissolved oxygen and high turbidity levels were recorded at Site 10 by Cardno Ecology Lab in November 2013, there was no evidence of any changes in macroinvertebrates, fish or macrophytes at this site (see **Section 5.4**). The quality of water at the remaining sites in November 2013 and December 2014 (including Sites 8 and 9) was comparable to previous surveys and there was no indication of change that could be attributed to mining. No significant impacts to water quality in the Georges River were observed following extraction of Longwall 37 (Ecoengineers 2015).

Cardno Ecology Lab has undertaken several investigations into the effect of mine water discharge from West Cliff Colliery and Appin Colliery on the aquatic ecology of the Georges River (The Ecology Lab 2004a to g, 2005b, 2006a and b). These studies indicated that diverse aquatic macroinvertebrate assemblages occur at ECs within 1000 to 4000 µS/cm. Some taxa, including pollution tolerant (SIGNAL2 Grade: 3) freshwater shrimp (Family: Atyidae), and pollution sensitive (SIGNAL2 Grade 8) leptophelbiid mayflies, were found to be less abundant at sites subject to discharge than at reference sites not subject to discharge. Other taxa, such as the pollution tolerant baetid (SIGNAL2 Grade: 5) and caenid (SIGNAL2 Grade: 4) mayflies, were more abundant at sites subject to discharge. All these taxa were sampled during current and previous surveys (see **Section 5.4**).

Further investigations into the effect of mine water discharge from West Cliff Colliery were undertaken in relation to West Cliff Colliery Pollution Reduction Program (PRP) 10, including a freshwater shrimp translocation experiment (Cardno Ecology Lab 2009 and 2010c). The findings of these studies, together with those from an Australian Coal Association Research Program (ACARP) funded study into the effects of saline water discharge on aquatic biota in the Southern and Hunter Coalfields of NSW (Cardno Ecology Lab 2010d) indicated that while elevated salinity does affect aquatic biota, it is not the primary cause of aquatic ecotoxicity associated with mine water discharge. It should be noted that the Georges River may naturally have a somewhat high EC (Ecoengineers 2012). To further investigate the 'whole of effluent' toxicity of the of the mine water discharge from West Cliff Colliery (which may include aluminium, arsenic, nickel and zinc, and flocculants), an ecotoxicology study was undertaken by Ecoengineers (2012) as part of Pollution Reduction Program 11. Water collected from Brennans Creek Dam and water being discharged from the dam via the Licensed Discharge Point (LDP) 10 collected between May and June 2012 was not found to be ecotoxic to water flies (*Ceriodaphnia* sp.) and freshwater shrimp (*Parataya* sp.). However, untreated, and to a lesser extent, clarified (dosed with flocculent) mine process water was found to be ecotoxic to these species.

More recent PRPs, including PRP 18 and 19, are aimed at further minimising the impact of discharges from Brennans Creek Dam by modifying the discharge point (PRP 18) and reducing the level of contaminants in discharge water (PRP 19). PRP 20 requires the implementation of an Aquatic Health Monitoring Program to investigate the effect of mine discharge of aquatic ecology of Brennans Creek and the Upper Georges River and to assess the success of PRP 19. The first round of baseline aquatic health monitoring prior to the implementation of PRP 20 was undertaken in October and November 2013 (Niche Environment and Heritage 2014). The initial findings of that study were similar to those of earlier studies undertaken by Cardno Ecology Lab, with pollution sensitive Leptophlebiidae being more abundant, and pollution tolerant taxa, including Caenidae less abundant, at sites subject to discharge compared with reference sites not subject to discharge.

The quality of water within this reach of the upper Georges River is determined by rainfall, rural and urban runoff and licensed discharges of mine water from Appin East and West Cliff pit tops, in addition to any potential effects associated with mine-induced subsidence. A change in the relative contributions of the major inputs to the river is most likely responsible for the relatively high conductivities noted in the Georges River in May 2010, December 2012, November 2013 and December 2014.

5.3 Aquatic Habitat

The aquatic habitat in sections of Georges River visited in this study is generally in good condition. The relatively undisturbed riparian strip present at the section of river visited would help to enhance aquatic habitat and biota in this section of the Georges River. It would help to stabilise river banks and help prevent erosion and sediment mobilisation. Furthermore, riparian vegetation is a source of in-stream woody debris, which provides important habitat for many species of aquatic fauna, including fish. The relatively dense beds of macrophytes observed at the sites visited would also fulfil many important ecological roles, including the provision of refuge and nursery habitat for aquatic fauna, serve as a source of food for macroinvertebrates and fish and are important in nutrient cycling.

Under normal flow conditions, the deep pools present at the majority of study sites would provide habitat for fish and may be important refuge areas for them during extended dry periods with low flows. Natural features such as small waterfalls and cascades may impede fish passage during low to moderate flows, as would the culvert at Site 10. During high flows, fish should be able to pass these barriers with little difficulty. Eels (*Anguilla* spp.) and Cox's gudgeon are likely to be able to do so even during periods of relatively low flow.

The physical impacts of mining observed in the Georges River following the commencement of extraction of Longwall 35 have led to concurrent impacts on aquatic habitat. During the November 2013, survey reductions in pool water levels and the complete drying of some pools at Sites 8 and 9 had led to a direct loss of aquatic habitat and possibly some biota. The desiccation of macrophytes represented both a loss of aquatic biota and also habitat, as these plants would have provided shelter and food for many other aquatic species. Other impacts to aquatic ecology associated with the physical impacts included the loss of longitudinal connectivity during low flow conditions due to the drying of pools and loss of flow over rock bars. However, during the current investigation in December 2014 water levels and flow at Sites 8 and 9 appeared to be unaffected. Water and flow was present in pools that were dry in November 2013 and there was little evidence of any desiccation of macrophytes. Additional releases from Brennans Creek Dam in the second half of 2014 likely resulted in the re-establishment of pool water levels and flow in the Georges River during the December 2014 survey (BHPBIC 2014c).

5.4 Macroinvertebrates

The aquatic macroinvertebrate fauna in the Georges River appears to have experienced some degree of environmental stress prior to, and hence independent of, mining and continues to do so. The greater number of taxa and OE50 Taxa Score observed at Sites 9 and 8, respectively, in December 2014 compared with November 2013 suggest that the macroinvertebrate assemblages at these sites has recovered since the changes to these indicators first reported in Cardno Ecology Lab (2014). This finding is almost certainly related to the additional flows released from Brennans Creek Dam and the resulting re-establishment of pool water levels, flow and connectivity in affected sections of river. As such, there is no evidence of impacts to macroinvertebrates occurring in data collected in December 2014. However, potential contaminants in water discharged from Brennans Creek Dam may be affecting macroinvertebrates in the Georges River (**Section 5.2**). The suggested recovery in macroinvertebrate data is supported by the results of the PERMANOVA tests which did not detect a statistically significant interactive effect of Phase x Site within treatment for any indicator, which would otherwise have been indicative of a persistent impact occurring at individual sites over the course of several surveys.

The relatively low number of macroinvertebrate taxa in the AUSRIVAS sample collected at Site 9 and the relatively low OE50 Taxa Score from Site 8 in November 2013 could be related to subsidence associated with the extraction of Longwall 35. Site 8 is just downstream of Pool 44, and Site 9 is downstream of Pools 51 and 54, and encompasses part of Pool 56 (**Figure 5.1**). Reductions in water levels have been observed in all of these pools. The loss of connectivity and flow associated with the drying of these pools could explain why fewer taxa were found at these sites. Colonisation of pools by macroinvertebrates could be hindered or prevented by a lack of connectivity during low flow conditions, and while relatively mobile taxa may be able to colonise disconnected pools, others may not. It would also take some time for taxa to colonise previously dry pools, especially pools that were disconnected from upstream and/or downstream flow. As well as the direct physical impacts related with extraction of Longwall 35, changes to water quality associated with physical impacts could have influenced aquatic ecology, however, none have been identified (**Section 5.2**).

While relatively few taxa were sampled at Site 9 in November 2013, the macroinvertebrate assemblage that was sampled was indicative of undisturbed habitat, as seen by the high OE50 Taxa Score and AUSRIVAS Band (Band A). The relatively large decrease in the OE50 Taxa Score at Site 8 in November 2013, compared with previous surveys, suggest that the fauna at this site had become impoverished, supporting fewer taxa than reference streams (as selected by the AUSRIVAS model) with similar physical attributes. Despite fewer taxa being found at this site than what may otherwise be expected, there was no evidence in the SIGNAL2 Index data to suggest that the macroinvertebrate fauna at this, or any other site sampled, was becoming increasingly dominated by pollution tolerant taxa.

The presence of pollution sensitive Leptophlebiidae and pollution tolerant Caenidae at each site in December 2014 could suggest that this section of the Georges River currently experiences an intermediate influence due to mine water discharge from West Cliff Colliery. Each of these taxa has been shown to respond to potential pollution in mine water discharge to the Georges River (**Section 5.2**). The absence of several taxa (including leptophlebiids and caenids) from Site 9 only, and the absence of baetids from Sites 9 and 10 only, in November 2013 may be related to the physical mining impacts described here and associated with extraction of Longwall 35. However, the occurrence of these taxa, and also Atyidae, all of which have been shown to respond to mine water discharge in the Georges River, is relatively variable among sites and surveys. This suggests either relatively great natural variability and / or variability in the timing and volume of mine water discharge to the Georges River. The difference between the assemblage sampled at Site 9 in November 2013 and all other assemblages sampled apparent in the PCO (**Figure 4.4**), appears due to the absence of several pollution tolerant taxa and one pollution sensitive taxon at Site 9. This is likely to be due to the reduction in aquatic habitat and flow observed here, rather than changes in water quality. The PCO also illustrates the difference observed at Site 9 in November 2013.

Despite the changes to aquatic ecology indicators observed at Sites 8 and 9 in November 2013, similar changes were not apparent downstream at Sites 10 and 11, suggesting impacts to macroinvertebrates were localised to the areas directly affected by physical mining impacts. This finding is supported by the lack of a statistically significant interactive effect of Phase x Treatment for each indicator, which suggest that wide scale (i.e. occurring at multiple sites) and persistent impacts did not occur as a result of Longwall 35 extraction.

The results of the PERMANOVA tests and PCO indicate that the structure of macroinvertebrate assemblages at Site 11 differed to those at Sites 6 and 7. This may be explained by several factors, including differences between habitats irrespective of mining (the aquatic habitat at Site 11 is somewhat different to that at Site 6, **Section 4.1**), differences in water flow and the influence of potential contaminants associated with water releases from Brennans Creek Dam or a combination of these factors. In any case, the SIMPER analyses indicates that differences between Site 11 and Sites 6 and 7 appear due to difference in the occurrence of numerous taxa, rather than a few.

5.5 Fish

On the whole, species composition of the fish assemblages sampled in December 2014 was comparable with that observed during the previous surveys. Carp gudgeons are relatively undescribed and several species may be present on the east coast of Australia. At least two species have been identified from the Georges River over the course of the monitoring program, likely firetail gudgeon and possibly also Lake’s carp gudgeon Other species within this genus may also have been sampled, however, due to many overlapping characteristics and in the absence of published taxonomic keys it is impossible to identify them with any confidence. Flathead gudgeon were sampled for the first time in the Georges River as part of this monitoring program, though this species is known from other work to occur here (Cardno Ecology Lab 2012a). Each fish species sampled in previous surveys was recorded in the current survey. There is no evidence in data collected in December 2014 of impact to fish assemblages.

The absence of fish and larger mobile invertebrates (freshwater crayfish and shrimp) at Site 9 in November 2013 suggests these fauna experienced impacts associated with the extraction of Longwall 35. It is possible that some of the pools that were present at this site had drained earlier in 2013 and that fish and larger mobile invertebrates have not yet had the opportunity to recolonise these pools. During November 2013, several of the pools were disconnected from upstream or downstream flow, or both. The presence of four native species of fish at Site 9 during the current survey (December 2014) suggest that fish have returned to this section of the river along with the increases in flow and water levels, suggesting that the fish assemblage is recovering from the impacts observed during November 2013. Although a loss of river connectivity during low flow conditions could impact the passage of migratory fish species (e.g. eels and the Cox's gudgeon), with potential consequences for these species upstream and downstream of the affected areas, there are no data to suggest an impact to fish occurred at sites upstream and downstream of Site 9 in November 2013.

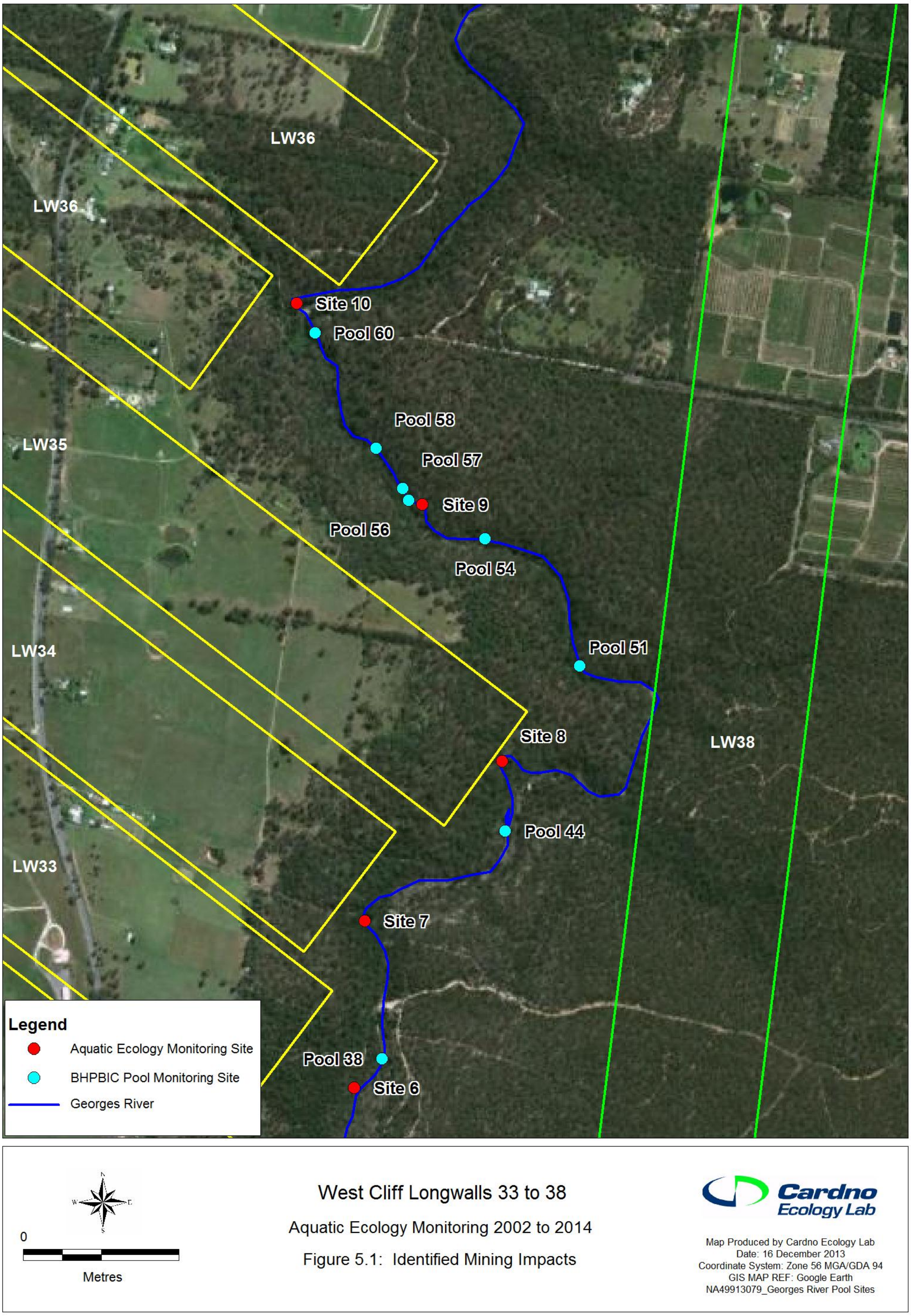

Figure 5-1 BHPBIC pool monitoring sites where mining impacts (e.g. pool water loss) associated with Longwall 35 have been identified. No additional impacts associated with Longwalls 36 and 37 have been observed.

6 Conclusion

The data collected during this current survey suggest that aquatic habitat, macroinvertebrates and fish have recovered following the impacts observed in November 2013 and associated with the extraction of Longwall 35. This finding is almost certainly a result of the restoration (at least temporarily) of pool water levels and flow in affected areas of the Georges River following the increased releases from Brennans Creek Dam. This measure would have reduced impacts to aquatic ecology related to reduced water levels and flow and changes to river connectivity.

There is no evidence to suggest the extraction of Longwalls 36 and 37 has had any impact on indicators of aquatic ecology. This is not surprising considering that no physical impacts (additional to those observed for Longwall 35), or any significant impacts to water quality have been attributed to these longwalls. However, while no additional impacts were observed, it is possible that cumulative impacts associated with the extraction of Longwall 36 and 37 may have contributed to the severity and extent of impacts to aquatic ecology attributed to Longwall 35.

Potential changes to water quality due to subsidence could also be a contributing factor to the observed impacts to aquatic indicators, however, there is no evidence of any impacts to water quality (from data collected by Cardno Ecology Lab) due to extraction of Longwalls 35, 36 and 37. Potential pollutants associated with mine water discharge from the West Cliff Colliery via Brennans Creek Dam could also be influencing macroinvertebrates (and other aspects of aquatic ecology) in this section of the river. However, the presence of pollution sensitive Leptophlebiidae, which have been shown to be less abundant at sites on the Georges River subject to discharge compared with reference sites, suggests that this section of river is not influenced to any great extent by any potential contaminants in mine water discharge.

The impacts to aquatic ecology observed in November 2013 appear to be linked with the direct loss of aquatic habitat and river connectivity associated with the lowering of pool water levels and loss of flow following subsidence. Impacts to river connectivity would also be expected to affect migratory fish species upstream and downstream of the affected areas, although there is no evidence of this in the data collected in November 2013. As no changes to aquatic ecology were evident at sites further downstream in November 2013, and due to the recovery in aquatic ecology at affected areas in December 2014, impacts to aquatic ecology due to extraction of Longwall 35 appear localised and short term. Also, the results of the PERMANOVA tests do not indicate any widespread (i.e. more than one site) or persistent impacts have occurred following the commencement of extraction of Longwall 35.

It is possible that the volume of water discharged from Brennans Creek Dam, and the contributions to Georges River flow from rainfall, rural and urban run-off, together with potential effects due to flow diversions following subsidence, have a greater influence on aquatic biota than any effect due to potential pollution in mine water discharge, at least in the section of river sampled in this study.

7 Recommendations

It is recommended that increased discharges from Brennans Creek Dam be maintained for as long as practicable whenever low pool water levels and flow resulting from mining are experienced in the Georges River. This will help minimise impacts to aquatic ecology associated with loss of habitat, flow and connectivity. It may also assist in maintaining water flow and connectivity during drought.

Due to the observed impacts associated with Longwall 35 in November 2013, it is also recommended that further monitoring be undertaken during the spring 2015 AUSRIVAS sampling season to provide at least two years of post-extraction data for this longwall following recovery of aquatic ecology. This would provide additional information on the persistence and recovery of previously identified impacts to ecological indicators associated with this longwall. This monitoring would also provide further post-extraction data for Longwall 36, the first year of post-extraction data for Longwall 37 and (depending on the progress of mining), during extraction data for Longwall 38. The collection of additional during and post mining data will facilitate the assessment of the impact of the longwall extraction on the aquatic habitat and biota in the Georges River. It will also provide information that will help further assess the impacts to aquatic ecology associated with the extraction of Longwall 35, and help inform any future remediation efforts in the Georges River following the completion of mining in West Cliff Area 5. The ongoing aquatic ecology monitoring associated with PRP 20 will provide invaluable information on the effect of mine water discharge from West Cliff Colliery on the Georges River.

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APPENDIX A

GPS COORDINATES OF AQUATIC ECOLOGY MONITORING SITES ON THE GEORGES RIVER SAMPLED IN DECEMBER 2014

Site	6	7	8	9	10	11
Easting	296877	296886	297145	296970	296709	297204
Northing	6216094	6216418	6216736	6217230	6217614	6218446

Datum: WGS 84, Zone 56H

West Cliff Longwalls 31-38

Aquatic Ecology Monitoring 2002-2014

APPENDIX B

AQUATIC MACROPHYTES RECORDED ON THE GEORGES RIVER

Cardno
Shaping the Future

Taxa	Bioanalysis (2009) (Site GR1))	Bioanalysis (2009) (Site GR2)	Cardno Ecology Lab (2012b)
Baumea articulata			x
Baumea juncea			x
Chorizandra cymbaria	x		
Eleocharis sphacelata	x		
Eleocharis sp.			x
Fimbristylis sp.		x	
Gahnia clarkei	x		
Hemarthria uncinata		x	
Isolepis prolifer			x
Isolepis inundata	x	x	
Isolepis sp.			x
Juncus fockei		x	
Juncus usitatus			x
Juncus polyanthemus	x		
Lepidosperma filiforme	x	x	
Potamogeton sulcatus	x		
Potamogeton ticarinatus			x
Potamogeton sp.			x
Schoenus melanostachys		x	
Tristaniopsis laurina		x	
Typha orientalis	x		
Typha spp.			x
Vallisneria sp.			x

West Cliff Longwalls 31-38

Aquatic Ecology Monitoring 2002-2014

APPENDIX C

MEAN VALUES OF WATER QUALITY INDICATORS FOR SITES 6-11, GEORGES RIVER, 2002 TO 2014

Variable	DTV	May 2002		March 2005		November 2007		September 2008		May 2010		November 2011		May 2012		December 2012		November 2013		December 2014	
		M	SE	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE
Site 6																					
Temperature (°C)		n/a	n/a	24.0	n/a	18.0	0.0	19.8	0.0	12.9	0.0	20.5	0.0	10.5	0.0	20.5	0.4	20.1	0.3	22.7	0.0
EC (µS/cm)	30-350	748	0	1578	n/a	1239	2	841	0	2353	7	1356	1	1028	0	2054	0	2069	5	1909	14
pH	6.5-8.0	8.0	0.0	8.7	n/a	8.8	0.0	8.8	0.0	9.2	0.0	8.5	0.0	8.3	0.0	8.8	0	8.5	0.0	8.8	0.0
ORP (mV)				249	n/a	429	1	144	0	414	1	398	2	447	2	77	9.1	59.3	2.4	142	3
DO (% Sat)	90-110	100.3	0.2	103.9	n/a	80.9	0.1	*No data*		121.3	3.9	100.4	1.6	106.9	1.6	86.8	18.2	106.3	2.05	91.6	1.0
Turbidity (NTU)	2-25	8.1	0.8	18.0	n/a	4.1	0.0	14.0	2.6	1.0	0.1	10.6	0.7	5.8	0.9	0.2	0.1	2.1	0.0	13.8	0.3
Site 7																					
Temperature (°C)						17.4	0.0	15.9	0.0	13.8	0.0	20.2	0.0	*Not sampled*		22.0	0.1	20.7	0.2	22.1	0.0
EC (µS/cm)	30-350					1033	3	823	0	2275	1	1325	2			1905	12	1998	2	1719	0
pH	6.5-8.0					8.9	0.0	8.9	0.0	8.8	0.0	8.3	0.0			8.4	0.0	8.4	0.0	8.4	0.0
ORP (mV)						451	0	118	1	422	1	411	1			94	2.6	50.4	1.7	127	0
DO (% Sat)	90-110					90.8	0.8	95.0	0.1	77.4	3.9	76.6	0.5			88.1	10	86.5	1.9	82.5	0.0
Turbidity (NTU)	2-25					37.9	0.8	5.9	0.2	0.8	0.0	21.9	0.7			2.0	0.3	1.7	0.2	10.9	0.0
Site 8																					
Temperature (°C)						17.1	0.0	16.4	0.0	14.5	1.0	19.7	0.0	10.7	0.2	21.0	0.3	20.5	0.6	23.9	0.0
EC (µS/cm)	30-350					1043	0	844	1	2035	0	1285	5	1007	1	1824	5	1761	30	917	916
pH	6.5-8.0					8.8	0.0	9.1	0.0	8.0	0.0	8.5	0.0	8.3	0.0	8.7	0	8.1	0.0	8.7	0.0
ORP (mV)						436	1	119	0	442	0	392	2	465	7	95	0.5	57.5	3.0	123	1
DO (% Sat)	90-110					79.6	0.5	97.6	0.1	97.9	1.6	96.6	0.1	81.6	0.7	114.9	8.5	98.1	3.5	103.3	0.4
Turbidity (NTU)	2-25					2.7	0.0	5.8	0.1	11.3	0.1	22.0	0.4	1.1	0.2	1.1	0.1	6.0	0.2	8.1	0.1

(SE=Standard Error), n=2, except for turbidity where n=6). Default Trigger Values (DTVs) are for the protection of slightly disturbed upland rivers of South-east Australia (ANZECC/ARMCANZ 2000). Shading indicates mean values are outside of DTVs.

Variable	DTV	May 2002		March 2005		November 2007		September 2008		May 2010		November 2011		May 2012		December 2012		November 2013		December 2014	
		M	SE	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE
Site 9																					
Temperature (°C)						16.6	0.0	16.5	0.0	11.5	0.0	21.6	0.0	10.6	0.4	20.0	0.0	18.5	0.0	22.3	0.0
EC (µS/cm)	30-350					1043	3	969	1	2167	3	1293	0	1013	5	1801	2.0	1728	0	1743	9
pH	6.5-8.0					8.8	0.0	9.0	0.0	8.8	0.0	8.6	0.0	8.4	0.0	8.8	0.0	8.4	0.0	8.6	0.0
ORP (mV)						411	2	135	0	432	0	415	1	421	2	105	1	66.6	0.4	123	0
DO (% Sat)	90-110					83.3	0.3	107.3	0.0	92.6	2.0	94.6	0.5	100.5	3.0	93.1	0.7	81.7	0.2	86.4	0.1
Turbidity (NTU)	2-25					3.4	0.7	7.1	0.0	0.9	0.0	11.1	0.2	7.2	0.2	1.4	0.4	3.6	0.1	11.9	0.3
Site 10																					
Temperature (°C)								15.4	0.0	11.5	0.0	21.5	0.0	10.3	0.0	19.8	0.5	16.6	0.0	22.1	0.0
EC (µS/cm)	30-350							950	1	2187	5	1292	2	1033	3	1826	5.5	1556	1	1719	0
pH	6.5-8.0							9.0	0.0	8.8	0.0	8.5	0.0	8.5	0.0	8.8	0	7.6	0.0	8.4	0.0
ORP (mV)								103	2	438	1	423	1	447	2	63	7.2	80.5	1.0	127	0
DO (% Sat)	90-110							90.7	0.1	100.4	0.2	80.6	0.3	89.8	0.8	92.1	8.6	52.4	0.3	82.5	0.0
Turbidity (NTU)	2-25							6.8	0.0	1.2	0.0	8.0	0.4	0.7	0.1	2.6	0.6	28.9	0.0	10.9	0.0
Site 11																					
Temperature (°C)								14.6	0.0	11.6	0.0	20.6	0.0	10.7	0.0	19.1	0.1	17.8	0.3	22.7	0.0
EC (µS/cm)	30-350							751	2	2190	1	1274	5	1034	3	1775	2.5	1469	4	1703	2
pH	6.5-8.0							8.8	0.0	8.7	0.0	8.6	0.0	8.6	0.0	8.8	0.0	8.3	0.0	8.4	0.0
ORP (mV)								138	0	465	15	465	1	443	1	106	1	53.4	0.1	126	0
DO (% Sat)	90-110							106.0	0.1	105.2	1.3	101.0	2.0	95.8	0.5	87.7	1.0	107.5	1.4	84.0	0.5
Turbidity (NTU)	2-25							9.6	0.1	0.9	0.0	10.0	0.4	5.9	0.3	1.1	0.3	9.3	0.4	9.7	0.0

(SE=Standard Error), n=2, except for turbidity where n=6). Default Trigger Values (DTVs) are for the protection of slightly disturbed upland rivers of South-east Australia (ANZECC/ARMCANZ 2000). Shading indicates mean values are outside of DTVs.

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APPENDIX D

MACROINVERTEBRATE TAXA FROM EDGE HABITAT AT SITES 6-11 ON THE GEORGES RIVER IN DECEMBER 2014

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Taxon	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
Aeshnidae		x	x	x	x	x
Araneae						x
Atyidae					x	x
Austrocorduliidae (=Corduliidae)						x
Baetidae	x	x	x	x	x	
Caenidae	x	x	x	x	x	x
Calamoceratidae		x			x	x
Ceratopogonidae		x			x	x
Chironomidae/Chironominae	x	x	x	x	x	x
Chironomidae/Orthocladiinae	x	x			x	
Chironomidae/Tanypodinae	x	x	x	x	x	x
Cladocera		x				
Coenagrionidae	x	x	x	x	x	x
Copepoda		x		x	x	
Cordulephyidae (=Corduliidae)	x	x	x	x	x	x
Corixidae					x	x
Dixidae						x
Dytiscidae	x	x	x	x	x	x
Ecnomidae			x			
Elmidae		x	x			x
Entomobryidae					x	
Gerridae				x		
Glossiphoniidae				x		
Gomphidae		x		x	x	x
Gyrinidae	x	x	x	x		
Haliplidae			x			
Hemicorduliidae (=Corduliidae)	x	x	x	x	x	x
Hydracarina	x	x	x		x	x
Hydrometridae						x
Hydrophilidae	x	x	x	x	x	x
Hydroptilidae	x	x	x	x		
Isostictidae	x	x	x	x	x	x
Leptoceridae	x	x	x	x	x	x
Leptophlebiidae		x	x	x	x	x
Megapodagrionidae			x	x	x	x
Notonectidae	x		x		x	x
Oligochaeta				x		
Ostracoda	x	x	x	x	x	x
Parastacidae	x					
Physidae			x	x		x
Psephenidae				x		
Scirtidae (= Helodidae, Cyphonidae)					x	x
Stratiomyidae			x		x	
Synlestidae		x	x	x	x	x
Synthemistidae (=Corduliidae)						x
Telephlebiidae (=Aeshnidae)		x			x	
Tipulidae				x		

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APPENDIX E

NUMBERS OF MACROINVERTEBRATE TAXA, OE50 TAXA SCORES AND SIGNAL2 INDICES FOR AUSRIVAS EDGE SAMPLES COLLECTED AT SITES ON THE GEORGES RIVER 2002 TO 2014

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	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
Number of Taxa						
May 2002	23					
March 2005	9					
November 2007	19	27	25	20		
September 2008	25	22	20	25	31	23
May 2010	14	21	25	24	23	19
November 2011	13	21	16	25	28	20
December 2012	32	28	32	30	23	26
November 2013	28	26	24	13	28	27
December 2014	18	26	25	26	29	30
OE50 Taxa Score						
November 2007	0.67	1.00	0.70	0.78		
September 2008	0.65	0.87	0.80	0.74	0.93	0.90
May 2010	0.35	0.58	0.77	0.71	0.78	0.60
November 2011	0.32	0.56	0.44	0.78	0.79	0.62
December 2012	1.01	0.82	1.02	0.93	0.80	0.80
November 2013	0.89	0.96	0.37	0.87	0.79	0.88
December 2014	0.69	0.90	0.80	0.67	1.00	1.00
SIGNAL2 Index						
May 2002	3.5					
March 2005	3.9					
November 2007	4.4	3.6	3.5	4.0		
September 2008	4.2	3.8	4.3	4.0	4.2	4.0
May 2010	3.6	3.9	3.9	3.8	4.5	3.9
November 2011	3.5	4.4	3.8	4.0	4.6	4.7
December 2012	4.3	4.0	4.1	3.9	4.2	4.0
November 2013	4.0	4.4	3.8	4.3	4.2	4.3
December 2014	3.6	4.8	3.9	4.0	4.4	4.4

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APPENDIX F

PERMANOVA COMPARING MACROINVERTEBRATE ASSEMBLAGES, NUMBER OF TAXA, OE50 TAXA SCORES AND SIGNAL2 INDICES OBTAINED FROM AUSRIVAS SAMPLES COLLECTED FROM SITES 6, 7, 8, 9 AND 11 ON THE GEORGES RIVER NOVEMBER 2007 TO DECEMBER 2014

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Assemblage

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	2106	2106	2.866	0.072
Treatment	1	301	301	0.201	0.983
Site (Treatment)	**3**	**4630**	**1543**	**1.835**	**0.012**
Phase x Treatment	1	331	331	0.466	0.713
Phase x Site (Treatment)	3	2183	728	0.865	0.675
Residual	19	15980	841		
Total	28	25746			

Assemblage - Pairwise tests of Site (Treatment)

Comparisons among Treatments	t	*P*
Within level ‘Control’ of factor ‘Treatment’		
Site 11, Site 6	**1.549**	**0.012**
Site 11, Site 7	**1.876**	**0.006**
Site 6, Site 7	0.783	0.833
Within level ‘Impact’ of factor ‘Treatment’’		
Site 8, Site 9	1.263	0.167

Number of Taxa

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	135.92	135.92	9.091	0.063
Treatment	1	1.94	1.94	0.323	0.681
Site (Treatment)	3	21.46	7.15	0.283	0.834
Phase x Treatment	1	8.18	8.18	0.573	0.486
Phase x Site (Treatment)	3	44.27	14.76	0.584	0.627
Residual	19	480.50	25.29		
Total	28	712.69			

OE50 Taxa Score

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	0.11	0.11	7.024	0.072
Treatment	1	0.02	0.02	0.552	0.514
Site (Treatment)	3	0.11	0.04	1.078	0.384
Phase x Treatment	1	0.02	0.02	1.357	0.335
Phase x Site (Treatment)	3	0.05	0.02	0.456	0.714
Residual	19	0.63	0.03		
Total	28	0.96			

SIGNAL2 Index

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	0.039	0.039	0.507	0.521
Treatment	1	0.231	0.231	2.334	0.223
Site (Treatment)	3	0.295	0.098	0.845	0.487
Phase x Treatment	1	0.000	0.000	0.026	0.882
Phase x Site (Treatment)	3	0.235	0.078	0.674	0.575
Residual	19	2.208	0.116		
Total	28	2.982			

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APPENDIX G

RESULTS OF SIMPER ANALYSES INDICATING THE CONTRIBUTION OF INDIVIDUAL TAXA TO DIFFERENCES BETWEEN MACROINVERTEBRATE ASSEMBLAGES AT SITES 6 AND 11 AND SITES 7 AND 11

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Site 6 and Site 11

Taxon	Individual Contribution (%)	Cumulative Contribution (%)
Isostictidae	3.79	3.79
Elmidae	3.66	7.45
Hydroptilidae	3.23	10.69
Ecnomidae	3.18	13.86
Sialidae	2.89	16.75
Notonectidae	2.75	19.51
Atyidae	2.69	22.19
Gomphidae	2.60	24.80
Megapodagrionidae	2.59	27.39
Baetidae	2.59	29.98
Telephlebiidae	2.54	32.52
Copepoda	2.48	35.00
Cordulephyidae	2.48	37.49
Corixidae	2.46	39.95
Physidae	2.43	42.37
Gyrinidae	2.41	44.78
Ceratopogonidae	2.35	47.13
Ostracoda	2.28	49.41
Aeshnidae	2.27	51.68
Cladocera	2.25	53.94
Coenagrionidae	2.23	56.16
Hydracarina	2.09	58.25
Calamoceratidae	2.06	60.30
Araneae	2.04	62.35
Synlestidae	2.04	64.39
Leptophlebiidae	2.01	66.40
Gerridae	1.94	68.34
Austrocorduliidae	1.87	70.21
Parastacidae	1.85	72.07
Scirtidae	1.85	73.91
Chironomidae - Orthocladiinae	1.85	75.76
Synthemistidae	1.80	77.56
Oligochaeta	1.79	79.34
Dugesiidae	1.67	81.01
Culicidae	1.47	82.48
Libellulidae	1.39	83.87
Hydraenidae	1.32	85.19
Veliidae	1.31	86.49
Stratiomyidae	1.31	87.80
Gelastocoridae	1.30	89.11
Dixidae	1.29	90.40

Cumulative % cut-off 90%

Site 7 and Site 11

Taxon	Individual Contribution (%)	Cumulative Contribution (%)
Isostictidae	3.94	3.94
Hydroptilidae	3.87	7.81
Copepoda	3.86	11.67
Gomphidae	3.20	14.87
Chironomidae - Orthocladiinae	2.88	17.75
Ecnomidae	2.84	20.58
Elmidae	2.83	23.41
Baetidae	2.82	26.24
Megapodagrionidae	2.76	28.99
Gyrinidae	2.74	31.73
Calamoceratidae	2.73	34.46
Atyidae	2.60	37.06
Cordulephyidae	2.52	39.59
Sialidae	2.51	42.10
Notonectidae	2.40	44.50
Leptophlebiidae	2.39	46.89
Cladocera	2.37	49.26
Synlestidae	2.36	51.62
Oligochaeta	2.33	53.95
Physidae	2.24	56.20
Corixidae	2.21	58.41
Telephlebiidae	2.18	60.59
Hydracarina	2.09	62.68
Coenagrionidae	2.03	64.71
Aeshnidae	2.00	66.71
Gerridae	1.97	68.68
Araneae	1.95	70.63
Libellulidae	1.90	72.53
Austrocorduliidae	1.90	74.43
Synthemistidae	1.83	76.27
Hydrophilidae	1.59	77.85
Veliidae	1.52	79.37
Dugesiidae	1.50	80.88
Stratiomyidae	1.49	82.37
Ostracoda	1.48	83.84
Parastacidae	1.46	85.30
Protoneuridae	1.43	86.73
Tipulidae	1.38	88.11
Gelastocoridae	1.37	89.47
Scirtidae	1.32	90.80

Cumulative % cut-off 90%

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APPENDIX H

NUMBERS OF FISH CAUGHT BY ELECTROFISHING AT SITES 6 TO 11 ON THE GEORGES RIVER 2008 TO 2014

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Scientific Name	Common Name	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
December 2014							
Anguilla sp.	Freshwater eel				1		1
Anguilla australis	Short-finned eel	2	1		1		
Anguilla reinhardtii	Long-finned eel			1			2
Gambusia holbrooki	Eastern gambusia	16	29	32	1		2
Gobiomorphus coxii	Cox's gudgeon	1			1	5	9
Hypseleotris spp.	Carp gudgeons					4	1
Philypnodon gradiceps	Flathead gudgeon				1		
November 2013							
Anguilla sp.	Freshwater eel	1	1				2
Anguilla australis	Short-finned eel						
Anguilla reinhardtii	Long-finned eel						1
Gambusia holbrooki	Eastern gambusia	4	>50			>50	
Gobiomorphus coxii	Cox's gudgeon		2	5		2	5
Hypseleotris spp.	Carp gudgeons	4					
Philypnodon gradiceps	Flathead gudgeon						
December 2012							
Anguilla sp.	Freshwater eel				2		
Anguilla australis	Short-finned eel	1					4
Anguilla reinhardtii	Long-finned eel	1	1	4	2	1	4
Gambusia holbrooki	Eastern gambusia	32	5	44	5	7	5
Gobiomorphus coxii	Cox's gudgeon	1	1	1	1	1	3
Hypseleotris spp.	Carp gudgeons				2	5	
Philypnodon gradiceps	Flathead gudgeon						
May 2012							
Anguilla sp.	Freshwater eel						
Anguilla australis	Short-finned eel						
Anguilla reinhardtii	Long-finned eel			1	1	4	2
Gambusia holbrooki	Eastern gambusia	3	2	2	4	11	3
Gobiomorphus coxii	Cox's gudgeon						1
Hypseleotris spp.	Carp gudgeons		1		5	5	1
Philypnodon gradiceps	Flathead gudgeon						
November 2011							
Anguilla sp.	Freshwater eel						
Anguilla australis	Short-finned eel						
Anguilla reinhardtii	Long-finned eel		4	1		2	
Gambusia holbrooki	Eastern gambusia		17	6	11	4	27
Gobiomorphus coxii	Cox's gudgeon		1		1		
Hypseleotris spp.	Carp gudgeons	8	1	2		6	12
Philypnodon gradiceps	Flathead gudgeon						
May 2010							
Anguilla sp.	Freshwater eel						
Anguilla australis	Short-finned eel						
Anguilla reinhardtii	Long-finned eel						
Gambusia holbrooki	Eastern gambusia	15		>100		3	
Gobiomorphus coxii	Cox's gudgeon						
Hypseleotris spp.	Carp gudgeons			1		3	
Philypnodon gradiceps	Flathead gudgeon		*ns*		*ns*		*ns*

Scientific Name	Common Name	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
September 2008							
Anguilla sp.	Freshwater eel						
Anguilla australis	Short-finned eel						
Anguilla reinhardtii	Long-finned eel						1
Gambusia holbrooki	Eastern gambusia	32	36	61			1
Gobiomorphus coxii	Cox's gudgeon						
Hypseleotris spp.	Carp gudgeons						11
Philypnodon gradiceps	Flathead gudgeon						

ns = not sampeld