Annex L

Aquatic Ecology

i. NRE Nebo Mine Area Aquatic Habitats and Biota

ii. Gujarat NRE Wongawilli Mine Nebo Area – Assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota

iii. Aquatic Ecology Monitoring for NRE Wongawilli Nebo Mine Area - First Year Baseline Report

Cardno Ecology Lab

Shaping the Future

Marine and Freshwater Studies

NRE Nebo Mine Area

Aquatic Habitats and Biota

Job Number: EL0809110

Prepared for Gujarat NRE

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1 Introduction

In 2011, Gujarat NRE FCGL Pty Ltd (NRE) proposes to use the retreat longwall mining method to extract coal from a remnant section of the Wongawilli Seam located within the Nebo mine area in the north-eastern corner of the NRE Wongawilli Mine, in the NSW Southern Coalfield (ERM 2009). The remnant section of coal is situated in the vicinity of the longwall panels of the former Elouera Colliery. The proposed Nebo longwalls would be located in the vicinity of Little Wattle Tree Creek, Wattle Creek and unnamed tributaries. The extraction of coal from this remnant block has the potential to impact on aquatic habitats and biota within the reaches of these watercourses located within and downstream of the mine area.

NRE commissioned Cardno Ecology Lab Pty Ltd to describe the existing aquatic habitats and biota potentially subject to impacts from the proposed mining and to prepare and implement a pre-mining baseline monitoring plan. The description of existing aquatic habitats and biota is based on a preliminary field investigation of aquatic habitats and compilation of existing information. A separate assessment of impacts on aquatic habitat and biota will be made based upon information provided by other specialist consultants working for NRE within the Nebo mine area, namely mine subsidence predictions (MSEC) and surface water quality impact predictions (Geoterra).

The reports prepared by Cardno Ecology Lab will be included in the Environmental Assessment for the Part 3A application for the 'Application Area' currently being prepared by Environmental Resources Management, Australia (ERM), on behalf of NRE, for submission to the Department of Planning, as part of the required approval process. The 'Application Area' is defined as the surface area within the subsidence prediction line as provided by MSEC based upon current mine plans.

2 Watercourses of the Application Area

Field surveys within the Application Area were completed by staff from Cardno Ecology Lab Pty Ltd on 7 July 2009. The Nebo Mine Area is located in the upper reaches of the Cordeaux River catchment (Figure 1). There are two named watercourses present within the Application Area: Wattle Creek and Little Wattle Tree Creek. These watercourses flow into the small reservoir created by the Upper Cordeaux Number 2 dam from the West. The land overlying the proposed longwalls lies within the Metropolitan Special Area administered by the Sydney Catchment Authority.

2.1 Wattle Creek

Wattle Creek runs directly above the northern extent of the proposed Nebo Area workings. This reach of the creek is a "significant stream" as described by the Southern Coalfield Strategic Review and is a third order watercourse using Strahlers' stream order system (NSW DPI, 2008). Wattle Creek was accessed by Fire Road 6D where it crosses the watercourse. A small road culvert presents a barrier to fish passage (b1) at this location (Plate 1a). Less than 1 km downstream of this road crossing the full supply level of Cordeaux Number 2 reservoir is reached (Plate 1b).

Wattle Creek is located within a steep sandstone valley with vegetation dominated by native rainforest species with *Lomandra* sp., ferns and palms in the understory and a eucalypt-dominated vegetation on the gully sides. This native vegetation extends to the edge of the watercourse to create considerable shading of the creek (Plate 1c-d).

The main channel of Wattle Creek has a moderate gradient and continuous flow that is characterised by relatively small, shallow pools with few holes deeper than 1 meter, and rarely wider than 3 metres (Plate 2a). These pools are separated by frequent short riffle sequences (Plate 2b). The stream banks consist mainly of well vegetated sandy soil or large boulders with little erosion or undercutting evident and extensive overhanging vegetation along the stream margin. There were numerous in-stream habitat features including snags, tree roots and organic detritus. No aquatic macrophytes were observed within the stream channel.

The dominant substratum types present in the main channel of Wattle Creek were sandstone bedrock, boulder and cobble. The stream bottom is stable with very little loose sediment accumulation. Multiple sections along this watercourse are composed of predominantly bedrock habitat (Plates 3a-c) and in many cases this bedrock has signs of extensive historical cracking (Plate 4a). The water in Wattle Creek was generally clear and showed no visual sign of pollution although a few short sections of the creek contained iron flocculance (Plate 4b). The creek would likely reduce to small disconnected pools during periods of prolonged drought.

A small tributary of Wattle Creek that runs along the south-eastern edge of the Application Area was also inspected and found to contain very little aquatic habitat. Some water was observed in shallow shaded pools in the lower reaches of the tributary however no flow and diminishing pools were observed in a brief inspection of the upper reaches. A raised, single-pipe road culvert from a remnant fire road approximately 200 meters upstream of the confluence of Wattle Creek created a substantial fish barrier (b2) within the Wattle Creek catchment (Plate 2c). The substratum in this tributary gradually becomes dominated by soft sediment and the channel accumulated large amounts of organic detritus further upstream (Plate 3d).

The overall condition of the aquatic habitat in Wattle Creek was assessed to be in an excellent and relatively undisturbed condition with suitable habitat for an extensive suite of aquatic biota characteristic of ephemeral streams in the area. .

2.2 Little Wattle Tree Creek

One small section of the upper reach of Little Wattle Tree Creek is located within the Application Area of the mine. The creek is a first order watercourse at this location and becomes a second order further downstream of the Application Area. There is limited aquatic habitat within this watercourse, apart from some small ephemeral pools separated by narrow shallow riffles (Plates 4c-d). These pools and shallow riffles are not expected to persist through prolonged dry periods. A culvert consisting of two pipes exists on Little Wattle Tree Creek at the Fire Road 6D crossing and would create a significant fish barrier (b3) during periods of low to moderate flow (Plate 2d).

3 Threatened Species

A review of the information that is available on the geographic distribution of aquatic organisms listed as threatened under state and federal legislation indicates that three threatened species could potentially occur within the Application Area. These species are:

- Adam's Emerald Dragonfly (*Archaeophya adamsi*), listed as vulnerable under the FM Act;
- Sydney Hawk Dragonfly (*Austrocordulia leonardi*), listed as endangered under the FM Act; and
- Macquarie Perch (*Macquaria australasica*), listed as vulnerable under the FM Act and as endangered under the EPBC Act.

These species are briefly considered below, with reference to historical distribution, documented findings and suitable habitat. Recommendations are made as to whether further assessment of the significance of potential impacts on threatened species are required to be undertaken in accordance with the Guidelines for Threatened Species Assessment for applications assessed under Part 3A of the EP and A Act.

3.1.1 Macquarie Perch

Macquarie perch are found in both river and lake habitats; particularly the upper reaches of rivers and their tributaries (NSW DPI 2005a). They have been recorded at various locations within the Hawkesbury-Nepean catchment, including Lake Cordeaux downstream of Upper Cordeaux Number 2 Dam (BIONET 2009). There are no existing records of Macquarie perch having been found upstream of the Upper Cordeaux Number 2 dam, into which watercourses of the application area flow. The Number 2 dam is approximately 12 meters high and forms an impassable barrier (b4, Figure 1) to upstream migration for this species. The upper Cordeaux River (upstream of the Number 2 dam) contains extensive suitable habitat for this species, and is within its understood historical range. It is therefore considered possible that a remnant population of this species could exist in this sub-catchment.

The lower reaches of Wattle Creek and Little Wattle Tree Creek contain suitable spawning habitat, including pools and riffles, for this species (Plate 1b). If a remnant population is present within the Number 2 reservoir, it is possible that the lower reaches of these creeks may be utilised by this species.

In the event that a population of Macquarie Perch is present within the Number 2 reservoir, and utilises either of these creeks, it is considered highly unlikely that this utilisation would extend into the Application Area, as barriers to passage in the form of road causeways are present between the Application Area and the reservoir (b1-b3, Figure 1).

Although the current distribution records, and barriers to passage, suggest that this species is unlikely to occur within the Application Area, it is recommended, as a precautionary approach, that a Seven-Part Test be prepared for this species as part of the environmental assessment of this project once mine subsidence predictions are available because of the presence of this potential habitat downstream, and the potential for changes in water quality to impact upon this habitat.

3.1.2 Adams Emerald Dragonfly

Adam's Emerald Dragonfly is extremely rare, having been collected only in small numbers at four locations in New South Wales: Somersby Falls and Floods Creek in

Brisbane Waters National Park near Gosford; Berowra Creek near Berowra and Hornsby; Bedford Creek in the Lower Blue Mountains; and Hungry Way Creek in Wollemi National Park (Fisheries Scientific Committee 2008b). There are no records of Adam's Emerald Dragonfly occurring elsewhere in the Hawkesbury-Nepean River catchment or in the Sydney region and no records of this species occurring within Wattle Creek, Little Wattle Tree Creek or Cordeaux River catchment. No specimens were found in the creeks surveyed during the baseline studies. The Upper Cordeaux River does however fall into the understood historical range for this species.

Adam's Emerald Dragonfly is a relatively large, robust species with a predominantly aquatic life cycle. The larvae inhabit small creeks with gravel or sandy bottoms and are typically found in narrow shaded riffle zones with moss and extensive riparian vegetation. The larvae live for approximately seven years before metamorphosing into adults, which fly away from water to mature, but then return to water to breed (NSW DPI 2005a). The adults are believed to live for only a few months.

Preliminary investigations indicate that there is suitable habitat for Adam's Emerald Dragonfly, albeit of limited extent, within Wattle Creek in the application area (Plate 2a). Although the current distribution records suggest that this species is unlikely to occur within the Application Area, it is recommended, as a precautionary approach, that a Seven-Part Test be prepared for this species as part of the environmental assessment of this project once mine subsidence predictions are available, because of the presence of this potential habitat.

3.1.3 Sydney Hawk Dragonfly

Sydney Hawk Dragonfly is extremely rare, having originally been collected in small numbers at only a few locations in a small area south of Sydney, from Audley to Picton (NSW DPI 2005c). The initial records of this species are from a deep pool behind a weir on the Woronora River, which has subsequently been removed, Kangaroo Creek near Audley and the Nepean River at Maldon Bridge, near Wilton. This species has recently been rediscovered at the latter site and found for the first time in pools at three sites along the Georges River near Campbelltown (Theischinger *et al.* 2009). However, it was not found during targeted surveys of deep pools in Waratah Rivulet and O'Hares Creek. There are no records of this species occurring within Wattle Creek, Little Wattle Tree Creek or the Cordeaux River catchment

The Sydney Hawk Dragonfly spends most of its life as an aquatic larva, before metamorphosing and emerging from the water as an adult, which lives for only a few weeks. This species appears to have specific habitat requirements, having only been found in deep, shady pools with cool, slow-flowing water in steep-sided rocky rivers (NSW DPI 2005c).

The nearest watercourse to the proposed mine area containing suitable habitat for the Sydney Hawk Dragonfly is likely to be the Cordeaux River, which is beyond the influence of significant subsidence impacts. An assessment of impact is therefore unnecessary for this species.

4 Baseline Aquatic Monitoring Program

The baseline monitoring program designed by Cardno Ecology Lab is based on surveys of aquatic ecological indicators within significant watercourses (third order or higher) within the Nebo area of investigation identified above, undertaken prior to the commencement of mining. The indicators chosen for these surveys include:

- Aquatic habitat
- Aquatic macroinvertebrate fauna
- Fish fauna
- Water quality

This monitoring program utilises a suite of methods that have been developed by Cardno Ecology Lab in previous mine subsidence impact assessments in the Southern Coalfields, including: Russel Vale No. 1, Dendrobium, West Cliff, Appin and Tahmoor Mines. These monitoring methods have been developed in consideration of the recommendations made by the NSW Department of Planning's 'Strategic Review of Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield' (NSW DoP, 2008).

Specific recommendations within this review that are relevant to aquatic ecological investigations include:

- Streams within the mine subsidence area of 3rd order or above, under the Strahler stream classification scheme are to be considered as Risk Management Zones (RMZs).

- A minimum of 2 years of baseline data, collected at appropriate frequency and scale should be provided for significant natural features.
- The use of Before, After, Control, Impact (BACI) designed ecological studies for monitoring of mine subsidence impacts.

Within Wattle Creek, the only third order watercourses identified within the investigation area, two sites were selected for monitoring. These are termed ‘potential impact’ sites as they may be subject to mine subsidence impacts during and after longwall extraction. Two ecologically comparable watercourses in the Upper Cordeaux catchment that are not proposed to be mined beneath were also identified, and within each of these, two sites were selected for monitoring. These are termed ‘control’ sites and allow a determination of the background environmental variability within the greater Upper Cordeaux catchment as distinct from any mine subsidence impacts. The control watercourses used in this study are: Kentish Creek (flows into Lake Cordeaux) and the Upper Cordeaux River (flows into Upper Cordeaux No. 1 Dam).

The sampling design chosen for the baseline assessment will enable Beyond BACI (Before/After, Control/Impact) analyses to be used to assess the potential impacts of mining subsidence on aquatic ecology, provided that similar assessments are made during and/or after mining. The Beyond BACI technique is a modification to the BACI approach that has been developed specifically to distinguish environmental impacts from natural changes (Underwood 1991, 1992, 1993 and 1994).

Baseline investigations were commenced in October 2009, and are scheduled for completion in April 2010. These will provide one year (four sampling events, two seasons) of aquatic ecological baseline data for “control” and “potential impact” locations. This will constitute one year of the “before” component of the Beyond BACI study designed for monitoring of mine subsidence related impacts from the proposed Nebo Longwalls.

5 References

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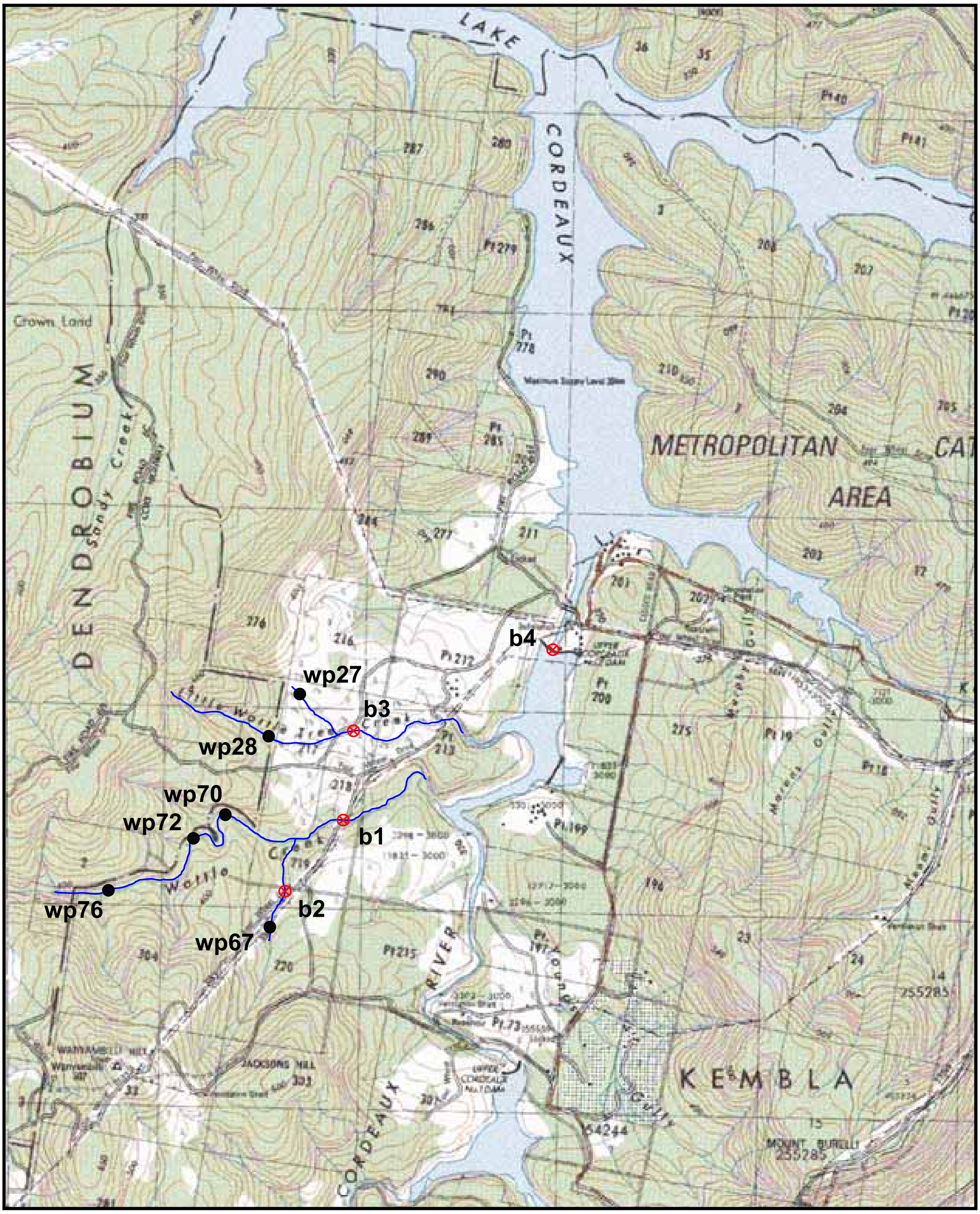
6 Figure

Figure 1: Reaches of aquatic habitat inspected on foot (dark blue line) during site inspection of Nebo Mine application area on 7 July, 2009. Barriers to fish passage are marked with a red x.



7 Plates

Plate 1 (a) Barrier to fish passage at Wattle Creek (b1); (b) the full supply level of Lake Cordeaux in Wattle Creek; (c) typical riparian vegetation; and (d) shading of the channel in Wattle Creek.

Plate 2 Typical (a) pool habitat in Wattle Creek; (b) riffle habitat in Wattle Creek; and barriers to fish passage in (c) a tributary of Wattle Creek (b2); (d) Little Wattle Tree Creek (b3).

Plate 3 Wattle Creek bedrock habitat within mine application area (a) upstream extent (wp76), (b) downstream of Site 1 (wp72) and (c) along LWN4 (wp70). (d)Soft sediment substratum habitat within tributary of Wattle Creek (wp67).

Plate 4 (a) Historic cracking in Wattle Creek; (b) iron flocculance in Wattle Creek; (c) northern branch of Little Wattle Tree Creek (wp27); and (d) southern branch of Little Wattle Tree Creek (wp28).

Gujarat NRE Wongawilli Mine Nebo Area

Assessment of Mine Subsidence Impacts on Aquatic Habitats and Biota

Job Number: EL0809110

Prepared for Gujarat NRE FCGL Pty Ltd

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Cover Image: Freshwater Crayfish (*Euastacus spinifer)* in Wattle Creek, October 2009.
Photographer: Matt Harper, Cardno Ecology Lab

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1 Introduction

1.1 Background and Aims

Gujarat NRE FCGL Pty Ltd (NRE) proposes to use the retreat longwall mining method to extract coal from a remnant section of the Wongawilli Seam located within the Nebo mine area in the north-eastern corner of the NRE Wongawilli Mine, in the NSW Southern Coalfield. The remnant section of coal is situated in the vicinity of the longwall panels of the former Elouera Colliery. The six proposed Nebo longwalls would be located in the vicinity of Little Wattle Tree Creek, Wattle Creek and unnamed tributaries. The extraction of coal from this remnant block has the potential to impact on aquatic habitats and biota in the reaches of these watercourses within and downstream of the mine Application Area.

NRE commissioned Cardno Ecology Lab Pty Ltd to provide an assessment of the likelihood and significance of potential impacts on aquatic habitat and biota, with recommendations for ongoing monitoring prior to, during and after mining. This assessment will be included in the submission that is being prepared by Environmental Resources Management (Australia) Pty Ltd (ERM), on behalf of NRE, for submission to the Department of Primary Industries Mineral Resources, NSW Planning (DoP), as part of the required approval process under the Part 3A (NSW EP&A Act) process.

1.2 Area of Investigation

Cardno Ecology Lab was provided with mine plans and an ‘Application Area’ for the proposed Nebo longwalls by NRE, the most recent of these in March 2010. The Application Area is defined as the surface area potentially subject to mine subsidence impacts resulting from extracting proposed Longwalls N1 to N6 (Figure 1).

The Nebo Mine Area is located in the upper reaches of the Cordeaux River catchment. There are two named watercourses present within the Application Area: Wattle Creek and Little Wattle Tree Creek, and five small unnamed tributaries. These watercourses flow into the small reservoir created by the Upper Cordeaux Number 2 dam from the West. The land overlying the proposed longwalls lies within the Metropolitan Special Area administered by the Sydney Catchment Authority.

The lower reaches of Wattle Creek is a ‘third order’ stream, as defined by the Strahler Stream Classification used in the ‘Strategic Review of Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield’ (NSW DoP, 2008). The other watercourses within the Application Area are first or second order streams. A detailed description of the aquatic habitat within these creeks is presented in Cardno Ecology Lab’s (2009) report for the Nebo Mine Area. There is significant aquatic habitat within the entire reach of Wattle Creek within the Application Area, but no significant aquatic habitat in Little Wattle Tree Creek or the unnamed tributaries.

1.3 Aquatic Monitoring Program

The baseline monitoring program is based on surveys of aquatic ecological indicators within the watercourse with significant aquatic habitat (Wattle Creek) located within the Nebo area of investigation identified above. The indicators chosen for the surveys undertaken prior to the commencement of mining include:

- Aquatic habitat
- Aquatic macroinvertebrate fauna
- Fish fauna
- Water quality

This monitoring program utilises a suite of methods that have been developed by Cardno Ecology Lab in previous and ongoing mine subsidence impact assessments in the Southern Coalfields, including: Russel Vale No. 1, Dendrobium, West Cliff, Appin and Tahmoor Mines. These monitoring methods have been developed in accordance with the recommendations made by the NSW Department of Planning's 'Strategic Review of Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield' (NSW DoP, 2008).

Specific recommendations within this review that are relevant to aquatic ecological investigations are:

- Streams within the mine subsidence area classified as 3rd order or above under the Strahler stream classification scheme are to be considered as Risk Management Zones (RMZs).
- A minimum of 2 years of baseline data, collected at appropriate frequency and scale, should be provided for significant natural features.
- A Before, After, Control, Impact (BACI) design should be used for monitoring of mine subsidence impacts.

Two sites located in the reach of Wattle Creek within the investigation area were selected for monitoring. These are termed 'potential impact' sites as they may be subject to mine subsidence impacts during and after longwall extraction. Two ecologically comparable watercourses in the Upper Cordeaux catchment that are not proposed to be mined beneath were also identified, and within each of these, two sites were selected for monitoring. These are termed 'control' sites and provide a measure of the background environmental variability within the greater Upper Cordeaux catchment as distinct from any mine subsidence impacts. The control watercourses used in this study are: Kentish Creek which flows into Lake Cordeaux and the Upper Cordeaux River which flows into Upper Cordeaux No. 1 Dam. The locations of the impact monitoring sites are shown in Figure 1.

The sampling design chosen for the baseline assessment will enable Beyond BACI (Before/After, Control/Impact) analyses to be used to assess the potential impacts of mining subsidence on aquatic ecology, provided that similar assessments are made during and/or after mining. The Beyond BACI technique is a modification to the BACI approach that has been developed specifically to distinguish environmental impacts from natural changes.

Baseline investigations commenced in October 2009 and are scheduled for completion in April 2010. These will provide one year (four sampling events, two seasons) of aquatic ecological baseline data for "control" and "potential impact" locations. This will constitute one year of the "before" component of the Beyond BACI study designed for monitoring of mine subsidence related impacts from the proposed Nebo Longwalls. Results of this first year of baseline monitoring are to be presented in a Baseline Report following the completion of data collection and analysis in mid 2010.

2 Assessment of Impacts

This assessment of impacts on aquatic habitat and biota as a result of mine subsidence from extraction of the proposed NRE Nebo mine area is based on predictions of mine subsidence produced by Mine Subsidence Engineering Consultants (MSEC) (2010). These subsidence predictions and visualisations are presented in Chapter 5 of MSEC (2010). References made to potential impacts on surface water quality and flow are based on Geoterra's (2010) surface water, which is also based on the subsidence predictions from MSEC (2010).

2.1 Physical Impacts Associated with Mine Subsidence

The principal physical impact resulting from underground coal mining is subsidence (lowering of the surface above areas that are mined) (Booth *et al.* 1998, Holla and Barclay 2000). In contrast to most of the coal seams in the NSW Southern Coalfields which are overlaid by sedimentary strata, five of the proposed Nebo Longwalls (2-6) are overlain by a large igneous sill extrusion known as Cordeaux Crinanite, which is an order of magnitude stronger than the other strata found in the area (MSEC 2010). The assessment of the effects of undermining the Cordeaux Crinanite undertaken by Strata Control Technologies indicates that this stratum will reduce the levels of sag subsidence over the longwalls and the compression of strata within surrounding pillars. The extraction of Longwalls 2-5 is consequently expected to result in very low predicted subsidence values, compared with that generally observed at mines in the Southern Coalfields. The extraction of Nebo Longwall 1, however, will result in goafing and subsidence that is comparable with sedimentary strata within the Southern Coalfield.

The maximum predicted valley-related movements along the watercourses are upsidences of 80 mm and 25 mm and closures of 50 mm and 20 mm in Wattle Creek and Little Wattle Tree Creek, respectively. In the 3rd order section of Wattle Creek, the maximum predicted upsidence and closure are 15 mm and 20 mm, respectively (MSEC 2010). The likelihood of these movements occurring along these watercourses is considered to be very low, because of the low *in-situ* horizontal stresses expected within and above the crinanite. For the section of Wattle Creek within the Application Area, the maximum predicted mining-induced subsidences is 250 mm along the upper reach above Longwall N5, but only 50 mm along the lower reach. For Little Wattle Tree Creek, the maximum predicted subsidence is 50 mm, near the starting line of Longwall N5.

2.1.1 Alterations to Flow

Mining-induced subsidence has the potential to alter flow in the creeks by:

- diverting surface water flows through fractures and joints in the bedrock into subterranean flows;
- draining water in pools and ponds through fractures and joints in rock bars;
- reducing inflow into pools as a result of upstream diversion of surface flows into the near surface groundwater system; and
- creating inter-connected cracks between the seam and surface which lead to loss of surface water into the mine.

The extraction of Longwalls N1-N6 is predicted to result in maximum tensile and compressive strains of 0.7 mm/m and 1.3 mm/m, respectively along Wattle Creek and of <0.1 mm/m along Little Wattle Tree Creek. The presence of crinanite combined with the low predicted subsidence and strain values indicate that extraction of Longwalls N2-N6 is unlikely to fracture the bedrock along the watercourses and lead to any observable loss of surface water (MSEC 2010).

The extraction of the Nebo Longwalls is predicted to cause a 0.2% (1.8 mm/m) maximum decrease and a 0.3% (2.8 mm/m) maximum increase in stream gradient, with both occurring along the upper reaches of Wattle Creek (MSEC 2010). The predicted changes in stream gradient are much smaller than the natural stream gradients within the Application Area, so are unlikely to cause additional ponding, flooding or scouring.

2.1.2 Water Quality

Fracturing of bedrock and diversion of flows has the potential to alter water quality by:

- Increasing groundwater discharge to streams;
- Lowering dissolved oxygen and pH levels;
- Elevating concentrations of dissolved iron, nickel, aluminium, zinc and manganese, sulphate and salinity through weathering of newly-exposed rock faces;
- Elevating salinity and decreasing oxygen concentrations in pools through reduction in their depth, enhanced evaporation and stagnation; and
- Facilitating periodic emission of gases, such as methane, into watercourses.

Subsidence arising from the extraction of the Nebo Longwalls is not expected to have any adverse effects on water quality in the sections of Wattle Creek or Little Wattle Tree Creek within the Application Area (Geoterra 2010).

2.1.3 Aquatic Habitats and Biota

As subsidence arising from the mining of Nebo Longwalls is not expected to have any adverse effects on stream flow or water quality, it is highly unlikely that there would be any observable flow-on effects on aquatic habitats or their biota within or immediately downstream of the Application Area.

2.2 Threatened Species

A review of the information that is available on the geographic distribution of aquatic organisms listed as threatened under state and federal legislation indicates that three threatened species could potentially occur within the Application Area. These species are:

- Adam's Emerald Dragonfly (*Archaeophya adamsi*), listed as vulnerable under the FM Act;
- Sydney Hawk Dragonfly (*Austrocordulia leonardi*), listed as endangered under the FM Act; and
- Macquarie Perch (*Macquaria australasica*), listed as vulnerable under the FM Act and as endangered under the EPBC Act.

These species are briefly considered below, with reference to historical distribution, documented findings and suitable habitat. Recommendations are made as to whether further assessment of the significance of potential impacts on threatened species are required to be undertaken in accordance with the Guidelines for Threatened Species Assessment for applications assessed under Part 3A of the EP and A Act.

2.2.1 Macquarie Perch

Macquarie perch are found in both river and lake habitats; particularly the upper reaches of rivers and their tributaries (NSW DPI 2005a). They have been recorded at various locations within the Hawkesbury-Nepean catchment, including Lake Cordeaux downstream of Upper Cordeaux Number 2 Dam (BIONET 2009). There are no existing records of Macquarie perch having been found upstream of the Upper Cordeaux Number 2 dam, into which watercourses of the application area flow. The Number 2 dam is approximately 12 meters high and forms an impassable barrier to upstream migration for this species. The upper Cordeaux River (upstream of the Number 2 dam) contains extensive suitable habitat for this species, and is within its understood historical range. It is therefore considered possible that a remnant population of this species could exist in this sub-catchment.

The lower reaches of Wattle Creek and Little Wattle Tree Creek contain suitable spawning habitat, including pools and riffles, for this species. If a remnant population is present within the Number 2 reservoir, it is possible that the lower reaches of these creeks may be utilised by this species.

In the event that a population of Macquarie Perch is present within the Number 2 reservoir, and utilises either of these creeks, it is considered highly unlikely that this utilisation would extend into the Application Area, as barriers to passage in the form of road causeways are present between the Application Area and the reservoir, and there are very few persistent pools that could provide habitat for this species.

During the Spring 2009 baseline monitoring for the Nebo Mine Area, an electrofishing survey was undertaken in Wattle Creek from its inflow into the Cordeaux No. 2 reservoir, upstream to the barrier created by Fire Rd 6D. No Macquarie Perch were found in this survey.

On the basis of current distribution records, available habitat, and barriers to passage, it is considered that this species is highly unlikely to occur within the Application Area. A Seven-Part Test is therefore considered unnecessary for this species.

2.2.2 Adams Emerald Dragonfly

Adam's Emerald Dragonfly is extremely rare, having been collected only in small numbers at four locations in New South Wales: Somersby Falls and Floods Creek in Brisbane Waters National Park near Gosford; Berowra Creek near Berowra and Hornsby; Bedford Creek in the Lower Blue Mountains; and Hungry Way Creek in Wollemi National Park (Fisheries Scientific Committee 2008). There are no records of Adam's Emerald Dragonfly occurring elsewhere in the Hawkesbury-Nepean River catchment or in the Sydney region and no records of this species occurring within Wattle Creek, Little Wattle Tree Creek or Cordeaux River catchment. No specimens were found in the creeks surveyed during the baseline studies. The Upper Cordeaux River does however fall into the understood historical range for this species.

Adam's Emerald Dragonfly is a relatively large, robust species with a predominantly aquatic life cycle. The larvae inhabit small creeks with gravel or sandy bottoms and are typically found in narrow shaded riffle zones with moss and extensive riparian vegetation. The larvae live for approximately seven years before metamorphosing into adults, which fly away from water to mature, but then return to water to breed (NSW DPI 2005b). The adults are believed to live for only a few months.

Field investigations indicate that there is suitable habitat for Adam's Emerald Dragonfly, albeit of limited extent, within Wattle Creek in the Application Area. Although the current distribution records suggest that this species is unlikely to occur within the Application Area, as a precautionary approach, a Seven-Part Test has been prepared for this species as part of the environmental assessment of this project. This Seven-Part Test is presented in Appendix 1.

2.2.3 Sydney Hawk Dragonfly

Sydney Hawk Dragonfly is extremely rare, having originally been collected in small numbers at only a few locations in a small area south of Sydney, from Audley to Picton (NSW DPI 2005c). The initial records of this species are from a deep pool behind a weir on the Woronora River, which has subsequently been removed, Kangaroo Creek near Audley and the Nepean River at Maldon Bridge, near Wilton. This species has recently been rediscovered at the latter site and found for the first time in pools at three sites along the Georges River near Campbelltown (Theischinger *et al.* 2009). However, it was not found during targeted surveys of deep pools in Waratah Rivulet or O'Hares Creek. There are no records of this species occurring within Wattle Creek, Little Wattle Tree Creek or the Cordeaux River catchment

The Sydney Hawk Dragonfly spends most of its life as an aquatic larva, before metamorphosing and emerging from the water as an adult, which lives for only a few weeks. This species appears to have specific habitat requirements, having only been found in deep, shady pools with cool, slow-flowing water in steep-sided rocky rivers (NSW DPI 2005c).

The nearest watercourse to the proposed mine area containing suitable habitat for the Sydney Hawk Dragonfly is likely to be the Cordeaux River, which is beyond the influence of significant subsidence impacts. A Seven-Part Test is therefore considered unnecessary for this species.

2.3 Sensitive Aquatic Habitats

None of the aquatic reserves declared under the *FM Act*, proclaimed Ramsar or nationally important wetlands occur within or proximal to the proposed Application Area, hence there is no need to assess the effects of the proposed mine area on sensitive aquatic habitats.

3 Conclusions

The mine subsidence predictions and assessment of impacts on surface water quality indicate that extraction of the Nebo longwalls is unlikely to have any detectable impacts on the aquatic ecology of Wattle Creek or Little Wattle Tree Creek.

4 Acknowledgements

This report was written by Doug Hazell and reviewed by Dr Theresa Dye.

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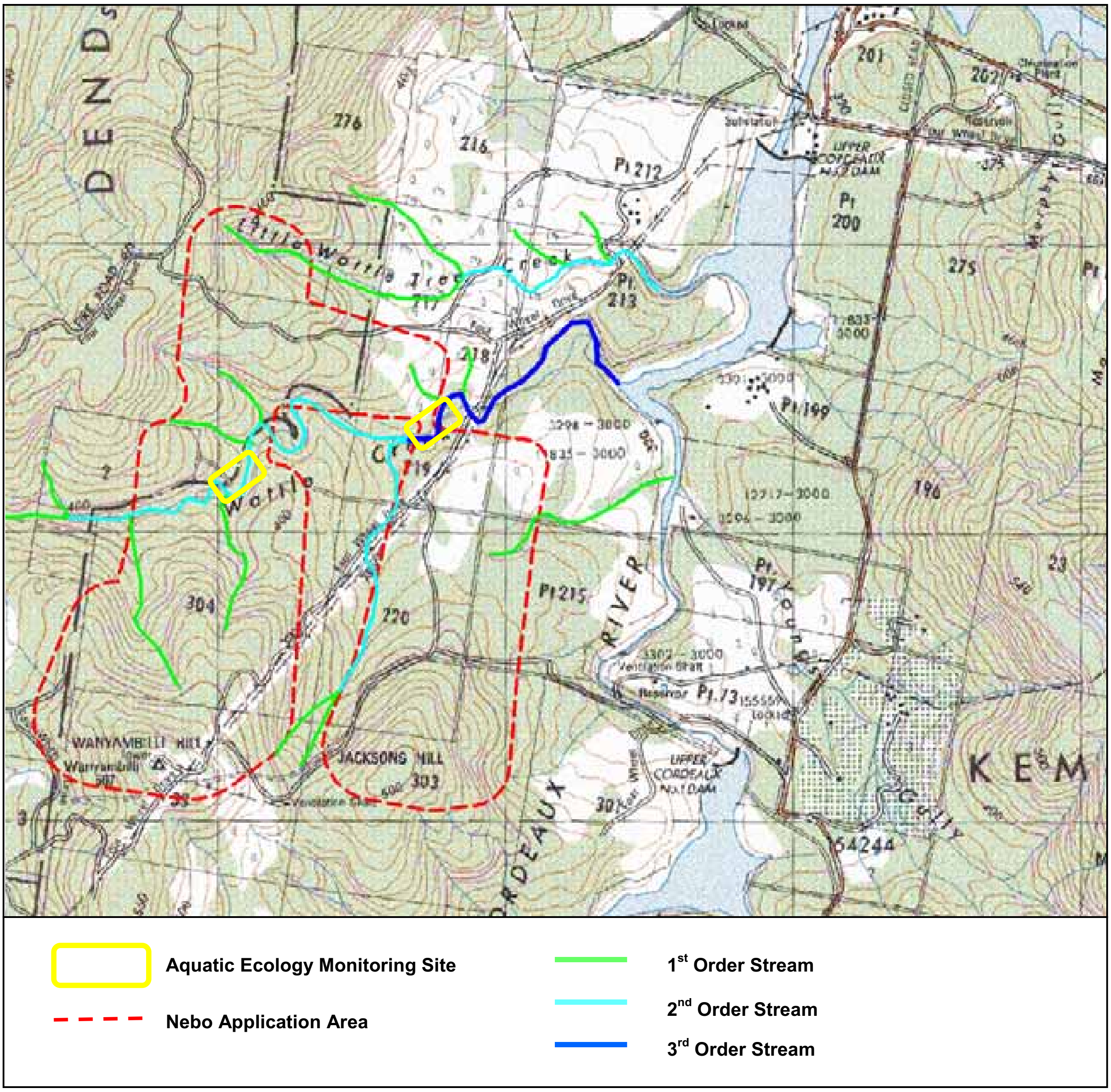
6 Figures

Figure 1: Nebo Mine Application Area



7 Appendix

Appendix 1:

Seven Part Test for the Adam's Emerald Dragonfly in Relation to the Proposed Mining of the Nebo Area.

a. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

The larvae of Adam's Emerald Dragonfly are aquatic and relatively long-lived (i.e. can survive for seven years). They inhabit small creeks with gravel or sandy bottoms and are typically found in narrow, shaded riffle zones with moss and riparian vegetation (NSW DPI 2005b). There appears to be suitable habitat, in Wattle Creek within the Application Area. Disturbances that result in significant alteration of this habitat could potentially have an adverse effect on the life cycle of this dragonfly, if they are present. Mine subsidence within this creek is not predicted to result in significant adverse impacts on the aquatic habitat or water quality (Sections 2.1 and 2.2). Therefore, the proposed mining is highly unlikely to have an adverse effect on the life cycle of Adam's Emerald Dragonfly if this species is present within this watercourse.

b. *In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.*

There are no threatened populations of Adam's Emerald Dragonfly listed on the Threatened Species Schedules of the FM Act.

c. *In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:*

(i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

(ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to placed at risk of extinction.

Adam's Emerald Dragonfly is not part of an endangered ecological community listed on the Threatened Species Schedules of the FM Act.

d. *In relation to the habitat of a threatened species, population or ecological community:*

(i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and

(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality

On the basis of predictions of mine subsidence within watercourses and resultant potential impacts on water quality (Sections 2.1 and 2.2), the proposed mining is unlikely to result in the removal, fragmentation or modification of habitat for Adam's Emerald Dragonfly.

e. *whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).*

There are no areas of critical habitat for Adam's Emerald Dragonfly listed on the NSW Register of Critical Habitat.

f. *whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan*.

At present there is no recovery or threat abatement plan for Adam's Emerald Dragonfly.

Conclusion

Wattle Creek appears to contain areas of suitable habitat for the Adam's Emerald Dragonfly within the Application Area. On the basis of historical records and surveys undertaken as part of the baseline monitoring for this mine area, it is considered unlikely that this species is present within this habitat. In the unlikely case that this species is present within the Application Area, it is considered highly unlikely that the proposed mining operations would have any significant impact on this species, as this habitat is not expected to be affected by the proposed mining. The preparation of a Species Impact Statement is therefore not considered necessary for Adam's Emerald Dragonfly.

Cardno Ecology Lab
Shaping the Future

Marine and Freshwater Studies

Aquatic Ecology Monitoring for NRE Wongawilli Nebo Mine Area

First Year Baseline Report

Job Number: EL0809110

Gujarat NRE FCGL Pty Ltd

June 2010

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Cover Image: Wattle Creek, within proposed Nebo Longwalls, 7 July 2009. Photographer Doug Hazell, Cardno Ecology Lab

Document Control

Job Number	Status	Date	Authors	Reviewer
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Summary

Introduction

Gujarat NRE FCGL Pty Ltd (NRE) proposes to use the retreat longwall mining method to extract coal from a remnant section of the Wongawilli Seam located within the Nebo mine area in the north-eastern corner of the NRE Wongawilli Mine, in the NSW Southern Coalfield. The six proposed Nebo longwalls would be located in the vicinity of Little Wattle Tree Creek, Wattle Creek and unnamed tributaries. The extraction of coal from this remnant block has the potential to impact on aquatic habitats and biota in the reaches of these watercourses within and downstream of the mine Application Area.

Cardno Ecology Lab was commissioned by NRE to undertake a baseline (pre-mining) study of aquatic habitat and biota in watercourses within the areas potentially subject to mine subsidence. This study was designed with reference to recommendations made by the NSW Department of Planning's 'Strategic Review of Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield' (NSW DoP, 2008).

This report outlines the study design and methods used in the baseline monitoring program, and the results of the first year of monitoring.

Field studies were undertaken of the following components:

- Aquatic habitats
- *In –situ w*ater quality
- Aquatic macroinvertebrates and
- Fish.

Aquatic habitat assessments showed that, potential impact and control watercourses contained relatively natural, undisturbed habitats.

Water quality sampling revealed dissolved oxygen levels within and below recommended guidelines throughout the study. pH, conductivity, and turbidity were generally within guidelines for most sites in most sampling events.

Two native fish species: climbing galaxias (*Galaxias brevipinnis*) and Australian smelt (*Retropinna semoni*) and the freshwater crayfish (*Euastacus sp.)* were found within sites during the baseline monitoring.

Macroinvertebrate sampling using the AUSRIVAS protocol showed most sites to be comparable to reference condition (Band A) or significantly impaired (Band B). A comparison between assemblages from control and impact sites showed similar characteristics indicating that control sites appear to be appropriate for the study.

This report presents one year (four sampling events, two seasons) of aquatic ecological baseline data at "control" and "impact" locations. This constitutes the "before" component of a BACI ("Before, After, Control, Impact") study designed for monitoring of mine subsidence related impacts from the proposed Nebo Mine Area Longwalls. It is recommended that ongoing monitoring be conducted during and after the extraction of these longwalls using the same survey sites and methods as outlined in this study. This will provide best practice environmental monitoring of aquatic ecology and allow statistically powerful analysis of the nature and extent of mine subsidence impacts if any. This monitoring plan conforms to the relevant recommendations made by the NSW Department of Planning's 'Strategic Review of Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield' (NSW DoP, 2008).

Table of Contents

1 Introduction

1.1 Background and Aims

Gujarat NRE FCGL Pty Ltd (NRE) proposes to use retreat longwall mining methods to extract coal from a remnant section of the Wongawilli Seam located within the Nebo mine area in the north-eastern corner of the NRE Wongawilli Mine, in the NSW Southern Coalfield. The remnant section of coal is situated in the vicinity of the longwall panels of the former Elouera Colliery. The six proposed Nebo longwalls would be located in the vicinity of Little Wattle Tree Creek, Wattle Creek and unnamed tributaries. The extraction of coal from this remnant block has the potential to impact on aquatic habitats and biota in the reaches of these watercourses that flow through and downstream of the mine Application Area.

The assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota within the Nebo mine area" undertaken by Cardno Ecology Lab (2010) was based on preliminary assessment of aquatic habitat and biota (Cardno Ecology Lab, 2009) mine subsidence predictions (MSEC, 2010) and predictions of impacts on water quality (Geoterra, 2010). This impact assessment is to be included in a submission to the NSW government for approval to mine these areas under the Part 3A (NSW EP&A Act) process, which is being coordinated by Environmental Resources Management (Australia) Pty Ltd (ERM) on behalf of NRE.

As part of the environmental investigations referred to in this submission, Cardno Ecology Lab was commissioned by NRE to undertake a baseline (pre-mining) study of aquatic habitat and biota in watercourses within the areas potentially subject to mine subsidence. The baseline study was designed with reference to recommendations made by the NSW Department of Planning's 'Strategic Review of Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield' (NSW DoP, 2008). Specific recommendations within this review that are relevant to aquatic ecological investigations include:

- Streams within the mine subsidence area of 3rd order or above, under the Strahler stream classification scheme, are to be considered as Risk Management Zones (RMZs).
- A minimum of 2 years of baseline data, collected at appropriate frequency and scale should be provided for significant natural features.
- The use of Before, After, Control, Impact (BACI) designed ecological studies for monitoring of mine subsidence impacts.

This report outlines the study design, methods used in the baseline monitoring program and results of the first year of monitoring.

1.2 Areas of Investigation

Cardno Ecology Lab was provided with mine plans and an 'Application Area' for the proposed Nebo longwalls by NRE, the most recent of these was supplied in March 2010. The Application Area is defined as the surface area potentially subject to mine subsidence impacts resulting from extraction of proposed Longwalls N1 to N6 (Figure 1).

The Nebo Mine Area is located in the upper reaches of the Cordeaux River catchment. There are two named watercourses present within the Application Area: Wattle Creek and Little Wattle Tree Creek, and five small unnamed tributaries. These watercourses flow into the small reservoir created by the Upper Cordeaux Number 2 Dam from the West. The land overlying the proposed longwalls lies within the Metropolitan Special Area administered by the Sydney Catchment Authority.

The lower reach of Wattle Creek is a 'third order' stream, as defined by the Strahler Stream Classification. The detailed description of the aquatic habitat within these creeks presented in Cardno Ecology Lab (2009) indicates there is significant aquatic habitat within the entire reach of Wattle Creek within the Application Area, but none in Little Wattle Tree Creek or the unnamed tributaries.

1.3 Aquatic Monitoring Approach

The baseline monitoring program designed by Cardno Ecology Lab is based on surveys of aquatic ecological indicators within the significant watercourses (third order or higher) within the Nebo Mine Application Area undertaken prior to the commencement of mining. The indicators chosen for these surveys include:

- Aquatic habitat
- Aquatic macroinvertebrate fauna
- Fish fauna
- Water quality

Two sites within the reach of Wattle Creek traversing the Application Area were selected for monitoring. These are termed 'potential impact' sites as they may be subject to mine subsidence impacts during and after longwall extraction. Two ecologically comparable watercourses in the Upper Cordeaux catchment that are not expected to be undermined were also identified, and within each of these, two sites were selected for monitoring. These are termed 'control' sites and allow mine subsidence impacts, if any, to be distinguished from the natural background environmental variability within the greater Upper Cordeaux catchment. . The control watercourses used in this study were: Upper Cordeaux River and Kentish Creek. Details of the ecological indicators sampled and the methods used are presented in Section 2.

The sampling design chosen for the baseline assessment will enable Beyond BACI (Before/After, Control/Impact) analyses to be used to assess the potential impacts of mining subsidence on aquatic ecology, provided that similar assessments are made during or after mining. The Beyond BACI technique is a modification to the BACI approach that has been developed specifically to distinguish environmental impacts from natural changes (Underwood 1991, 1992, 1993 and 1994).

The investigations undertaken to date provide one year of aquatic ecological baseline data for "control" and "potential impact" locations, derived from two sampling events in each of spring and autumn. This constitutes the "before" component of the Beyond BACI study designed for monitoring of mine subsidence related impacts from the proposed Nebo Longwalls.

2 Methodology

2.1 Field Methods

2.1.1 Aquatic Habitat Description and Monitoring

A qualitative description of the aquatic habitats at the study sites was made based on the following attributes:

- surrounding landform;
- instream features, such as sequence of pools, runs and riffles (shallow areas with broken water);
- presence, extent and type of aquatic vegetation;
- 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 barriers to fish passage into and beyond the study area.

In addition to the above habitat descriptors, the Riparian, Channel and Environmental Inventory (RCE) assessment was undertaken at each site (Chessman *et al.* 1997) (See Appendix 1). This assessment produces a score for each site based on a series of observations prompted by questions relating to the natural characteristics and, to a lesser extent, the degree of disturbance evident at the watercourse

Any changes to the initial observations were recorded in subsequent surveys.

A comprehensive photo record was also assembled for each site during each survey. Standardized photos were taken (with a 2m tall x 1m wide T-bar) at the top of the site looking downstream, at the middle of the site looking upstream and downstream, and at the bottom of the site looking upstream to gain an understanding of environmental variation within the watercourses.

2.1.2 Water Quality

Surface water quality was measured *in situ* using a Yeokal 611 water quality probe, with two readings being taken at each site. The following variables were recorded.

- Temperature (˚C);
- Conductivity (µS/cm);
- pH;
- Oxidation – Reduction Potential (ORP) (mV);
- Dissolved Oxygen (% saturation); and
- Turbidity (ntu).

Water quality data were compared with the ANZECC (2000) default trigger values for physical and chemical stressors for protection of slightly disturbed aquatic ecosystems in south-eastern Australia

2.1.3 Fish Sampling

During each survey, the fish occurring at each site were sampled using 250 µm mesh dip nets in conjunction with the AUSRIVAS macroinvertebrate collection. A 10 m length of representative edge habitat at each site was selected and thoroughly agitated and scooped for a period of 3–5 minutes. All captured fish and large crustaceans were immediately transferred to a fish box, filled with stream water, for identification and released as quickly as practicably possible. Additional identifications of fish observed instream along the length of each site were made by field staff during approximately 30 minute periods.

2.1.4 Aquatic Macroinvertebrate Sampling

Aquatic macroinvertebrates were collected using two methods: the AUSRIVAS protocol for NSW streams (Turak and Waddell, 2001), and aquatic macroinvertebrate collectors, a quantitative method developed by Cardno Ecology Lab for freshwater environmental impact assessment. Surveys were undertaken in spring of 2009 and autumn of 2010.

2.1.4.1 AUSRIVAS Sampling

During each survey, the aquatic macroinvertebrates associated with pool edge habitats at each site were sampled using dip nets (250 µm mesh) in accordance with the AUSRIVAS Rapid Assessment Method (RAM). Each RAM sample was collected over a period of 3-5 minutes from a 10 m length of representative edge habitat. If the required habitat was discontinuous, patches of habitats with a total length of 10 m were sampled. The dip net was used to agitate and scoop up material from vegetated river edges (Plate 1a). Each RAM sample was rinsed from the net onto a white sorting tray from which animals were picked using forceps and pipettes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten minute intervals for either a total of one hour or until no new specimens had been found. Care was taken to collect cryptic and fast moving animals in addition to those that were conspicuous or slow. The animals collected at each site were placed into a labeled jar containing 70% alcohol.

The chemical and physical variables required for running the AUSRIVAS predictive model were also recorded. Alkalinity, modal depth and width of the river, percentage bedrock, boulder or cobble cover, and latitude and longitude of each site were recorded in the field, whilst distance from source, altitude, land-slope and rainfall were determined in the laboratory.

2.1.4.2 Artificial Collectors

At the beginning of both the spring 2009 and autumn 2010 AUSRIVAS seasons, eight replicate artificial collector units providing habitat structure for aquatic macroinvertebrates were deployed at each site. The collectors consisted of 24 cm long x 3 cm diameter bundles of 18 wooden chopsticks held together with plastic cable ties (Plate 1b-1c). The collectors were attached to vegetation with nylon twine and submerged 1 metre apart at the edge of pools in 30-60 cm of water (Plate 1d). The collectors were retrieved during the second and fourth surveys, approximately six weeks after being deployed. During retrieval the collectors were carefully cut away from their anchors, placed individually into plastic bags, labeled and preserved in 70% ethanol for subsequent laboratory identification and analysis.

2.2 Laboratory Methods

2.2.1 Fish

Fish that could not be identified in the field were brought back to the laboratory for examination under a binocular microscope. Individuals whose identity still remained in doubt were sent to an expert at The Australian Museum for further investigation.

2.2.2 Aquatic Macroinvertebrates

2.2.2.1 AUSRIVAS Samples

In accordance with the AUSRIVAS protocol, RAM samples were sorted under a binocular microscope (at 40 X magnification), identified to family or sub-order level and up to ten animals of any one taxon counted (Turak et al. 2004). A randomly chosen 10% of the RAM sample identifications were checked by a second experienced scientist to validate macroinvertebrate identifications.

2.2.2.2 Artificial Collectors

The aquatic macroinvertebrates that had colonised each bundle of chopsticks were rinsed onto a 0.5 mm mesh sieve and examined in the laboratory using a binocular microscope. The samples were sorted and macroinvertebrates identified to family (most invertebrate taxa), sub-family (chironomids) or class (flatworms and leeches) level and counted.

2.3 Data Analysis

2.3.1 AUSRIVAS Samples

RAM data were analysed using the AUSRIVAS predictive spring and autumn models for NSW pool edge habitats (Coysh *et. al.,* 2000). The AUSRIVAS model generates the following indices.

- OE50Taxa Score - This is 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 values range from 0 to 1 and 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 follows:
    - Band X = Richer invertebrate assemblage than reference condition.
    - Band A = Equivalent to reference condition.
    - Band B = Sites below reference condition (i.e. significantly impaired).
    - Band C = Sites well below reference condition (i.e. severely impaired).
    - Band D = Impoverished (i.e. extremely impaired).
- SIGNAL (Stream Invertebrate Grade Number Average Level) scores – These biotic indices were developed by Chessman (1995 and 2003) as a means of determining water quality of sites based on the presence or absence of macroinvertebrate families. Grade numbers were assigned to each macroinvertebrate family or taxa based largely on their responses to chemical changes in the environment. Grade values range from 1 to 10, with a value of 1 indicating a family tolerant to chemical pollution and a value of 10 indicating a sensitive family.

The revised SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was also used to determine the “environmental quality” of sites. . This method assigns grade numbers to each macroinvertebrate family or taxa found, based largely on their responses to a range of environmental conditions. The sum of all grade numbers for that habitat is then divided by the total number of families recorded in each habitat to calculate the 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 greater than 6, between 5 and 6, 4 and 5 and less than 4 indicate that the quality of the water is clean, mildly, moderately or severely degraded, respectively.

2.3.2 Artificial Collectors

Differences in the types and relative abundance of the taxa in each pair of replicates were estimated by calculating their respective Bray-Curtis dissimilarity coefficients.

Spatial patterns in the composition of the assemblages were examined by means of non-metric Multi Dimensional Scaling (MDS) (Clarke 1993). MDS provides a graphical representation of assemblages based on their similarity within and among places or times sampled. In MDS plots, samples which have similar sets of organisms are grouped closer together than ones containing different sets of organisms. Permutational analysis of variance (PERMANOVA) was used to assess the statistical significance of differences in the diversity and structure of assemblages across the three streams and between each pair of streams, where appropriate.

These analyses were undertaken using the software package Primer (Plymouth Routines in Multivariate Ecological Research) version 6.1.1.1 (Clarke and Gorley 2006) and PERMANOVA + Version 1.0.1 (Anderson, Gorley and Clarke 2008).

3 Results

The first and second baseline surveys were conducted in spring 2009 and the third and fourth in autumn 2010. During the spring surveys (October and November) surveys, the weather was generally fine with no precipitation or significant cloud cover. During the third and fourth surveys, there was no precipitation and both overcast and sunny conditions were experienced. Heavy rainfall was experienced in the Cordeaux catchment following the March 2010 monitoring event in which it was evident that there had been periods of high flow in all watercourses of the study area.

Sampling dates and geographic coordinates for site locations are presented in Appendix 2.

3.1 Aquatic Habitats

The RCE scores for both of the potential impact sites were 51 out of a possible 52 (Table 1), which is indicative of natural, undisturbed habitat. RCE scores for sites within the control watercourses were also high (50 and 51) (Table 1), indicating negligible disturbance to these streams and the adjoining riparian habitat.

A brief qualitative description of the habitats within each creek is presented below and a photo summary of each site over the monitoring period is presented in Appendix 3.

3.1.1 Wattle Creek within Nebo Mine Project Area

Wattle Creek is bordered by temperate rainforest riparian vegetation. The canopy is generally closed and the creek shaded. The channel morphology is characterised by an alternating series of pools and short rock bars and riffles. The creek is predominantly shallow with occasional deeper holes. Bars and riffles are composed of various combinations of bedrock, boulders, cobble, pebble and gravel. The substratum is strongly influenced by the dominant Cordeaux Crininite (volcanic extrusion) geology. Large woody debris is relatively common, forming dams and submerged snags in pools. The site photos show the natural variation in water levels both within and between seasons (Appendix 3). In general, the aquatic habitat within Wattle Creek appeared relatively stable over the baseline sampling period, with no major environmental variations other than changes in stream flow observed.

3.1.2 Control Creeks

Kentish Creek and Upper Cordeaux were generally similar to the reach of Wattle Creek within the Project Area. The riparian vegetation was composed of dense temperate rainforest and the channel forms and bed composition are very similar to those of Wattle Creek with alternating pool and riffle sequences and a diverse range of rocky substratum. The underlying geology of these creeks, however, was dominated by sandstone rather than the volcanic crininite present in Wattle Creek.

3.2 Water Quality

Water quality results are presented in Appendix 4. The dissolved oxygen levels measured at all the sites surveyed throughout the monitoring program consistently ranged from within of the ANZECC (2000) guidelines to values below guidelines. In October 2009, dissolved oxygen was below guidelines at all sites except site 6 in Wattle Creek. In November 2009, dissolved oxygen in Sites 1 and 2 in Kentish Creek was below guidelines and Site 3 in Upper Cordeaux River was above guidelines. In March 2010, dissolved oxygen was within guidelines for all sites in the control creeks, but below guidelines in Wattle Creek. In May 2010, dissolved oxygen was below guidelines in all sites in all creeks.

pH was within guidelines within Wattle Creek on all sampling occasion. In Kentish Creek, pH was below guidelines in Site 1 in May 2010, and in Upper Cordeaux River was outside guidelines in Site 3 on all occasions except May 2010, and in Site 4 was within guidelines for all occasions except March 2010.

Salinity (conductivity) measures were generally within ANZECC guidelines throughout the monitoring in all watercourses except in Site 2 of Kentish Creek in November 2009. Turbidity measurements consistently ranged close to the lower limit or below guideline levels across all sites and surveys.

3.3 Fish Sampling

The species and numbers of fish and large crustaceans collected from each site during the baseline monitoring are listed in Appendix 5. Native species of climbing galaxias (*Galaxias brevipinnis*), Australian smelt (*Retropinna semoni*) and freshwater crayfish (*Euastacus sp.)* were regularly found within the majority of sites. Smelt were found in highest abundance in the Upper Cordeaux River in the spring 2009 surveys, and were absent from all watercourses in both of the autumn 2010 surveys. Galaxids were in highest abundance in the Upper Cordeaux River in the March 2010 autumn survey, and were absent from all watercourse in both of the spring 2009 surveys. All three species were present in each of the creeks (but not each site) during at least one of the surveys during the baseline monitoring program.

3.4 Aquatic Macroinvertebrates

3.4.1 AUSRIVAS Sampling

The results of the AUSRIVAS sampling and analysis are summarized in Table 2 and numbers of aquatic macroinvertebrates collected in the AUSRIVAS samples throughout the baseline survey are presented in Appendix 6.

In October 2009, the total number of taxa recorded at individual sites varied from 16 at Site 3 (Upper Cordeaux R) to 23 at Site2 (Kentish Ck) (Table 2a). In November 2009, the number of taxa recorded at individual sites varied from 15 at Site 3 (Upper Cordeaux R) to 22 at Site 5 (Wattle Ck) (Table 2b). Over both spring 2009 surveys, the sites in Upper Cordeaux River yielded fewer taxa on average than those in the other creeks.

In March 2010, the total number of taxa recorded at individual sites varied from 10 at Site 5 (Wattle Ck) to 24 at Site 1 (Kentish Ck) (Table 2c). In May 2010, the total number of taxa recorded at individual sites varied from 12 at Site 2 (Kentish Ck) to 23 at Sites 5 and 6 (Wattle Ck) (Table 2d). Hence, there was no discernible pattern in the number of taxa found in the creeks in during the autumn surveys.

The O/E50 Taxa Scores and AUSRIVAS Bands for each site derived from AUSRIVAS analyses undertaken on the spring 2009 and autumn 2010 datasets are presented in Table 2 and Figure 2. During the spring 2009 surveys, the fauna at the study sites were rated as either comparable to reference condition (band A) or significantly impaired (band B), respectively. The fauna at the sites in Kentish Creek were rated as comparable to reference condition during both surveys. One site each in Upper Cordeaux River and Wattle Tree Creek was rated as significantly impaired on both occasions. The rating of the fauna at the other sites was not consistent over time. In autumn 2010, the sites were again rated as either band A or B. The fauna at both sites in Kentish Creek and Wattle Creek and one of the sites in Upper Cordeaux River were rated as comparable to reference condition on both occasions, while that at Site 4 (Upper Cordeaux R) was consistently rated as significantly impaired. .

The Signal 2 Scores, derived independently of AUSRIVAS, are presented in Figure 3. In the spring 2009 surveys, the scores varied between 4.8 (moderately degraded) and 5.8 (mildly degraded). On both occasions, Sites 1, 3 and 6 were assessed as moderately degraded, while Site 2 was mildly degraded. The state of the other two sites varied, with the largest difference being evident at Site 4 (decline from 5.8 to 4.9). In the autumn 2010 surveys, the SIGNAL2 scores ranged from 4.4 (May survey, Sites 1) to 5.4 (March survey, Site 4). SIGNAL2 scores for the sites within Wattle Creek remained relatively consistent between March and May with mildly and moderately degraded systems for Sites 5 and 6 respectively. Site 3 in Upper Cordeaux River was also consistently rated as mildly degraded. At the other sites, the SIGNAL2 scores varied substantially between sampling events, with Site 1 (Kentish Creek) and 4 (Upper Cordeaux River) being downgraded from mildly to moderately degraded systems.

3.4.2 Artificial Collectors

The results from the quantitative edge habitat collectors are summarized in Table 3 and the numbers of the various invertebrate taxa sampled from every collector at each site during all of the baseline surveys are presented in Appendix 7.

In spring, the collectors deployed in Wattle Tree Creek yielded fewer taxa in total (20), than those placed in Kentish Creek (24) and the Upper Cordeaux River (35). Oligochaeta (segmented worms) followed by Chironominae (non-biting midges) and Leptophlebiidae (leptofleb mayflies) were the most abundant taxa retrieved from Wattle Tree Creek. The collectors placed in each of the reference streams, however, were dominated by Chironominae, followed by Leptophlebiidae and then Oligochaeta.

Differences in the mean number of taxa colonizing the collectors in each system were not statistically significant (Table 5; Figure 4). There were, however, significant differences in the multivariate structure of the assemblages among watercourses and between each pair of watercourses (Table 5). The MDS plot indicates that there were two distinct groups of assemblages in Wattle Tree Creek and one of these was generally distinct from the assemblages in the other two watercourses (Figure 5). The plot also shows that the assemblages in the Upper Cordeaux River and Kentish Creek were the most and least variable in structure, respectively.

In autumn, the collectors deployed in Wattle Tree Creek yielded slightly more taxa (26), than those placed in Kentish Creek (22) and the Upper Cordeaux River (20) (Figure 4). Samples from Wattle Tree Creek were dominated by Chironominae, followed by Ancylidae and Leptophlebiidae, whereas those from Kentish Creek and the Upper Cordeaux River were dominated by Scirtidae (marsh beetles), followed by Chironominae and Leptophlebiidae and by Chironominae, followed by Leptophlebiidae and Ecnomidae (free and caseless caddis flies), respectively. On this occasion, differences in the mean number of taxa colonising the collectors in each system were statistically significant (Table 4). There were fewer taxa on average on the collectors deployed in the Upper Cordeaux than in Kentish and Wattle Tree Creeks, but the average numbers found in the latter streams were not significant different (Figure 4). The structure of the assemblages again differed across the three watercourses and between each pair of watercourses (Table 5). The MDS plot shows that the assemblages in the three watercourses were generally distinct from each other and that those in Kentish Creek were the most variable in structure (Figure 5).

4 Ongoing Monitoring

This report presents one year (four sampling events, two seasons) of aquatic ecological baseline data at "control" and "impact" locations. This constitutes the "before" component of a BACI ("Before, After, Control, Impact") study designed for monitoring of mine subsidence related impacts from the proposed Nebo Mine Area Longwalls. It is recommended that ongoing monitoring be conducted during and after the extraction of these longwalls using the same survey sites and methods as outlined in this study. This will provide best practice environmental monitoring of aquatic ecology and allow statistically powerful analysis of the nature and extent of mine subsidence impacts, if any. This monitoring plan conforms to the relevant recommendations made by the NSW Department of Planning's 'Strategic Review of Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield' (NSW DoP, 2008).

5 Acknowledgements

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7 Tables

Table 1: Habitat assessment for each site surveyed based on RCE scores in Spring 2009 and Autumn 2010.

	Watercourse	Kentish Ck		Upper Cordeaux R		Wattle Ck	
	Descriptor	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
1	Land use pattern beyond the immediate riparian zone	4	4	4	4	4	4
2	Width of riparian strip of woody vegetation	4	4	4	4	4	4
3	Completeness of riparian strip of woody vegetation	4	4	4	4	4	4
4	Vegetation of riparian zone within 10m of channel	4	4	4	4	4	4
5	Stream bank structure	4	4	4	4	4	4
6	Bank undercutting	4	4	4	4	4	4
7	Channel form	3	3	3	3	3	3
8	Riffle/pool sequence	4	4	4	4	4	4
9	Retention devices in stream	4	4	4	4	4	4
10	Channel sediment accumulations	4	4	4	4	4	4
11	Stream bottom	3	4	4	4	4	4
12	Stream detritus	4	4	4	4	4	4
13	Aquatic vegetation	4	4	4	4	4	4
	Total score	50	51	51	51	51	51

Table 2: AUSRIVAS results and SIGNAL2 scores for macroinvertebrate assemblages collected in edge habitats in Spring, (a) October 2009 and (b) November 2009 and Autumn, (c) March 2010 and (d) May 2010.

a. Spring - October 2009

Location	Kentish Ck		Upper Cordeaux R		Wattle Ck	
Site	1	2	3	4	5	6
Number of Taxa Sampled	22	23	16	19	21	17
OE50 Taxa	1.09	1.03	1.1	1.18	1.18	1.12
BAND Grade	A	A	B	A	B	B
O0SIGNAL	4.8	5.1	5.1	5.5	4.9	4.6
SIGNAL2	4.9	5.1	4.9	5.8	5.0	4.8

b. Spring - November 2009

Location	Kentish Ck		Upper Cordeaux R		Wattle Ck	
Site	1	2	3	4	5	6
Number of Taxa Sampled	16	21	15	16	22	19
OE50 Taxa	1.04	1.1	1.1	1.11	1	0.98
BAND Grade	A	A	B	B	B	A
O0SIGNAL	4.6	5.1	4.7	4.8	4.8	4.7
SIGNAL2	4.8	5.2	4.8	4.9	4.9	4.8

Continued

Table 2: Continued

c. Autumn - March 2010

Location	Kentish Ck		Upper Cordeaux R		Wattle Ck	
Site	1	2	3	4	5	6
Number of Taxa Sampled	22	24	15	17	10	18
OE50 Taxa	0.92	0.83	0.83	0.68	1.04	0.82
BAND Grade	A	A	A	B	A	A
O0SIGNAL	4.6	4.8	5.1	4.8	4.9	4.7
SIGNAL2	5.0	4.5	5.1	5.4	5.1	4.8

d. Autumn - May 2010

Location	Kentish Ck		Upper Cordeaux R		Wattle Ck	
Site	1	2	3	4	5	6
Number of Taxa Sampled	15	12	21	16	23	23
OE50 Taxa	0.92	0.83	0.83	0.68	1.04	0.82
BAND Grade	A	A	A	B	A	A
O0SIGNAL	4.6	4.8	5.1	4.8	4.9	4.7
SIGNAL2	4.4	4.9	5.0	4.6	5.0	4.8

Table 3: Total number of taxa and individuals collected from the quantitative edge habitat collectors in each site during the baseline surveys in spring 2009 and autumn 2010.

Watercourse		No of Collectors Recovered		No of Taxa		No of Individuals	
	Site No	Spring 2009	Autumn 2010	Spring 2009	Autumn 2010	Spring 2009	Autumn 2010
Kentish Creek	1	8	4	6	22	555	242
	2	8	0	23		446	
Upper Cordeaux Rive	3	8	8	10	11	213	201
	4	5	8	21	19	176	297
Wattle Creek	5	8	8	18	17	475	459
	6	8	8	10	22	2516	338

Table 4: PERMANOVA results comparing the diversity of aquatic macroinvertebrate assemblages among the three river systems. Bold type indicates differences are statistically significant at *P* < 0.05.

A. Spring 2009
Main test based on 849 unique permutations

Source of variation	d.f.	SS	MS	Pseudo-F ratio	*P* (MC)
Sub Header	Sub Header	Sub Header	Sub Header	Sub Header	Sub Header
River	2	14.52	7.26	0.67	0.516
Residual	43	464.80	10.81		
Total	45	479.33			

B. Autumn 2010
Main test based on 248 unique permutations

Source of variation	d.f.	SS	MS	Pseudo-F ratio	*P* (MC)
Sub Header	Sub Header	Sub Header	Sub Header	Sub Header	Sub Header
River	2	110.25	55.13	9.65	**0.001**
Residual	33	188.50	5.71		
Total	35	298.75			

Pairwise tests

Groups	t	P(MC)	# of unique perms
Kentish vs Upper Cordeaux	3.539	**0.004**	35
Kentish vs Wattle Tree	2.028	0.057	28
Upper Cordeaux vs Wattle Tree	3.280	**0.003**	28

Table 5: PERMANOVA results comparing the structure of aquatic macroinvertebrate assemblages among the three river systems. Bold type indicates differences are statistically significant at $P < 0.05$.

A. Spring 2009
Main test based on 4980 unique permutations

Source of variation	d.f.	SS	MS	Pseudo-F ratio	*P* (MC)
Sub Header	Sub Header	Sub Header	Sub Header	Sub Header	Sub Header
River	2	16036.00	8018.20	4.25	**<0.001**
Residual	43	81059.00	1885.10		
Total	45	97096.00			

Pairwise tests

Groups	t	P(MC)	# of unique perms
Kentish vs Wattle Tree	1.942	**0.004**	4987
Kentish vs Upper Cordeaux	2.164	**0.007**	4991
Upper Cordeaux vs Wattle Tree	2.094	**0.002**	4984

B. Autumn 2010
Main test based on 4979 unique permutations

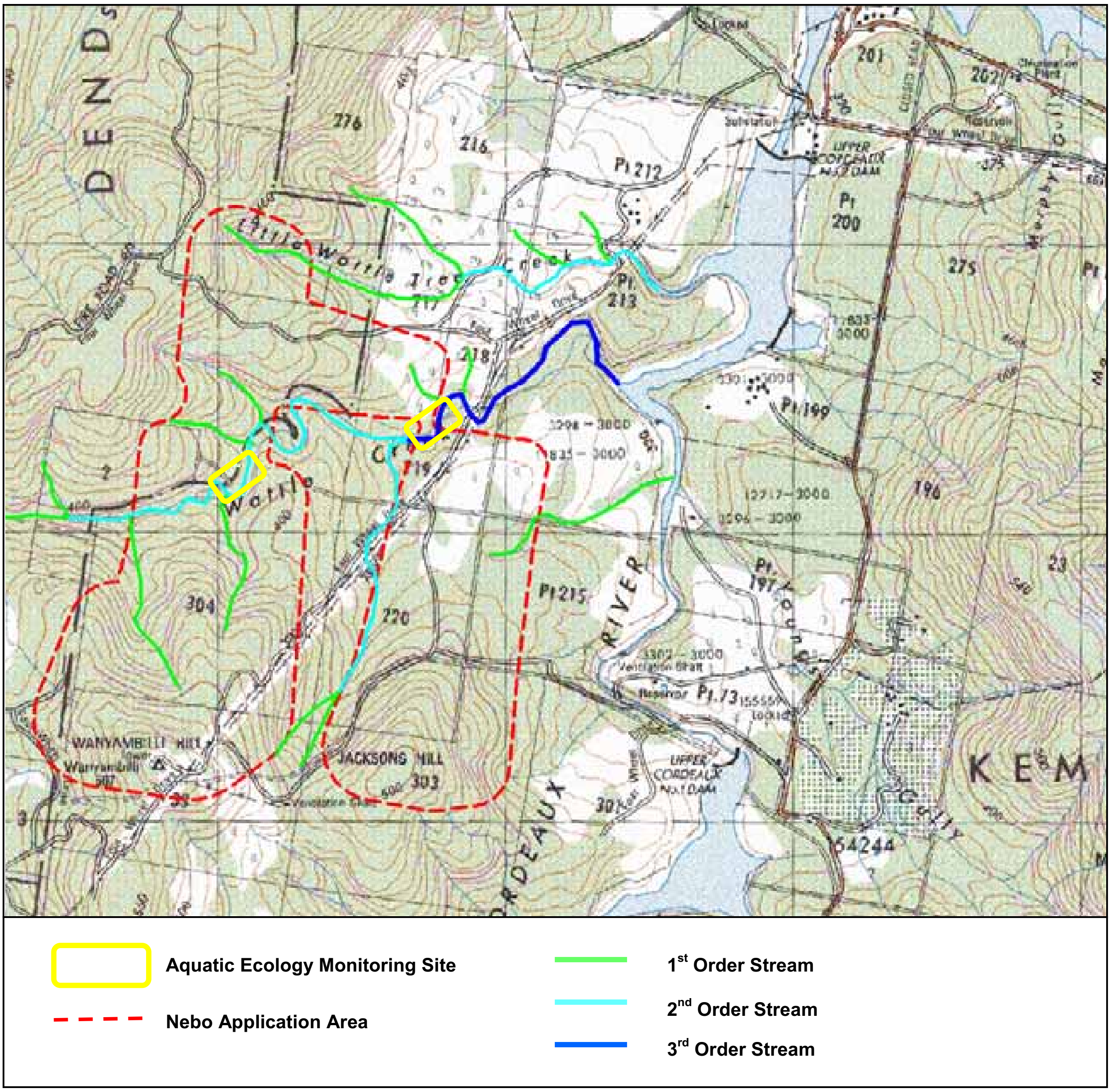
Source of variation	d.f.	SS	MS	Pseudo-F ratio	*P* (MC)
Sub Header	Sub Header	Sub Header	Sub Header	Sub Header	Sub Header
River	2	13868.00	6933.90	7.75	**<0.001**
Residual	33	29543.00	895.26		
Total	35	43411.00			

Pairwise tests

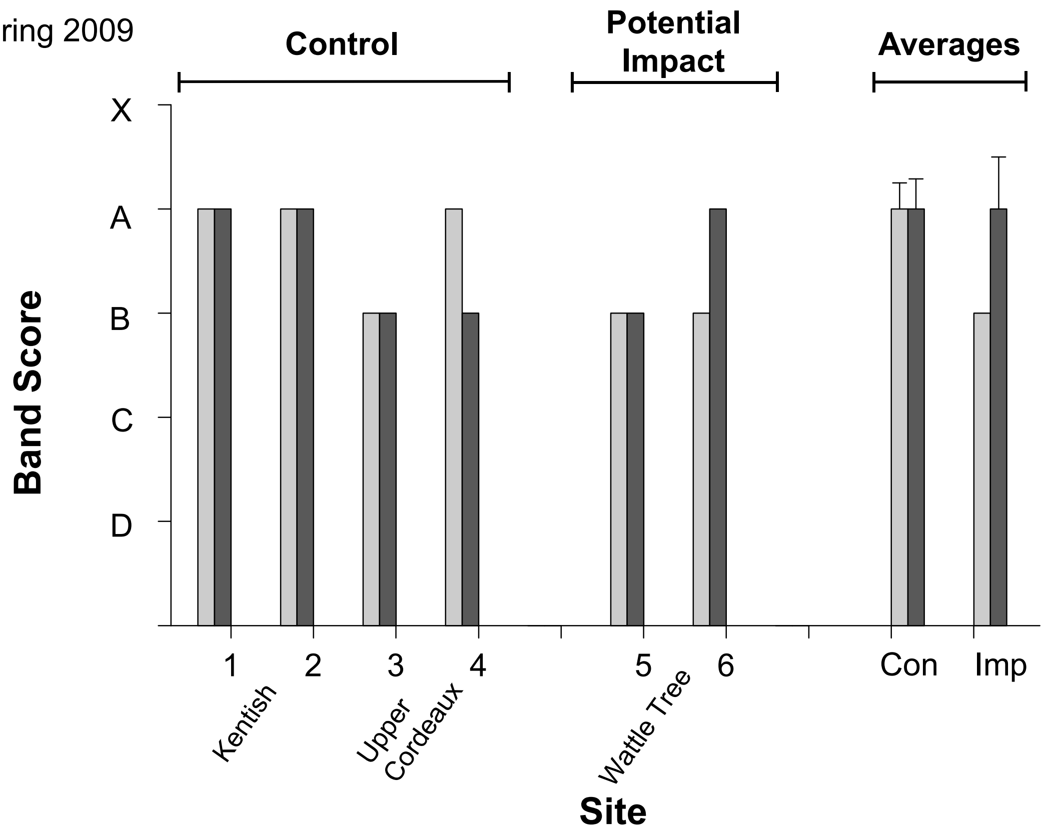
Groups	t	P(MC)	# of unique perms
Kentish vs Wattle Tree	2.735	**<0.001**	3107
Kentish vs Upper Cordeaux	2.516	**<0.001**	3123
Upper Cordeaux vs Wattle Tree	2.984	**<0.001**	4986

8 Figures

Figure 1: Nebo Mine Application Area



a. Spring 2009



b. Autumn 2010

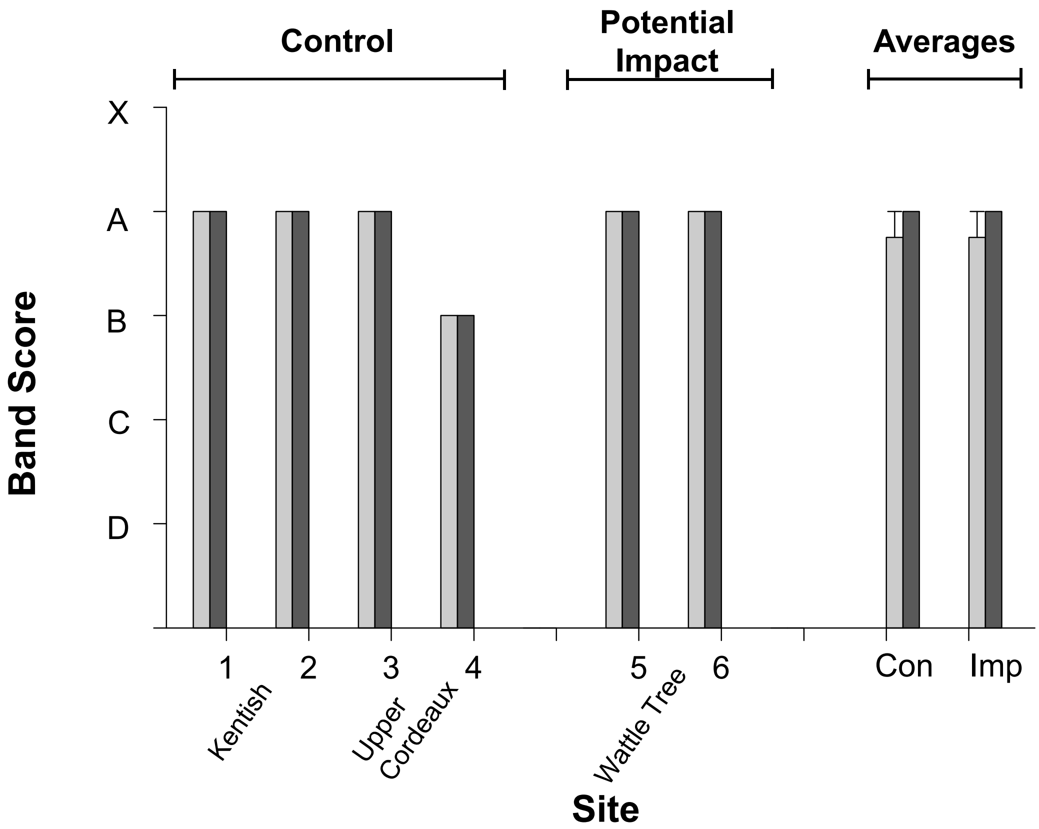


Figure 2: Comparison of AUSRIVAS Band Scores for the monitoring sites and the mean Band values (± SE) for these control and potential impact sites surveyed in (a) Spring, October 2009 (light grey bars) and December 2009 (dark grey bars) and (b) Autumn, March 2010 (light grey bars) and May 2010 (dark grey bars).

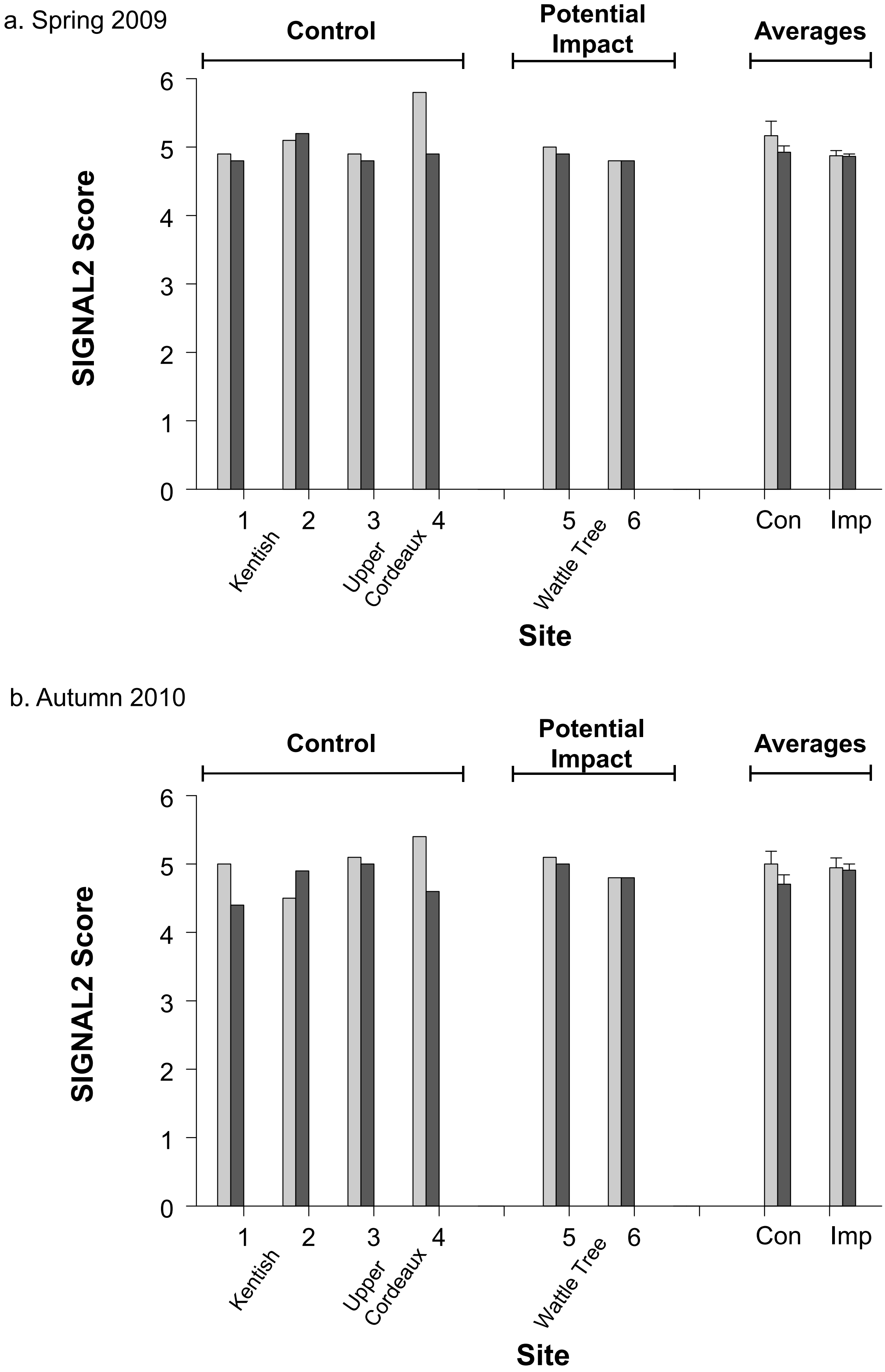


Figure 3: Comparison of SIGNAL2 scores from AUSRIVAS edge samples for the monitoring sites and the mean SIGNAL2 values (± SE) for these control and potential impact sites surveyed in (a) Spring, October 2009 (light grey bars) and December 2009 (dark grey bars) and (b) Autumn, March 2010 (light grey bars) and May 2010 (dark grey bars).

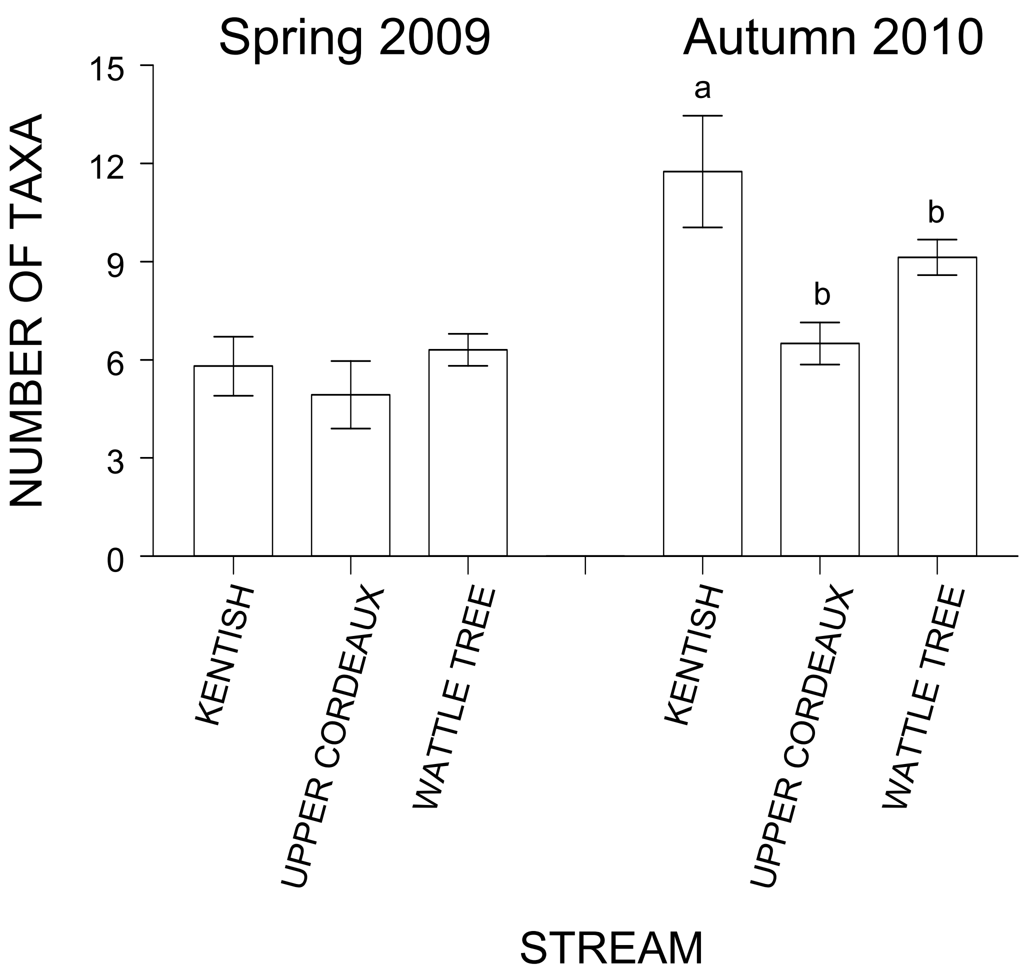


Figure 4: Mean (±S.E) number of taxa colonising the collectors deployed in Kentish Creek, Upper Cordeaux River and Wattle Tree Creek in spring 2009 and autumn 2010 (Different symbols above bars indicate significant differences in numbers of taxa).

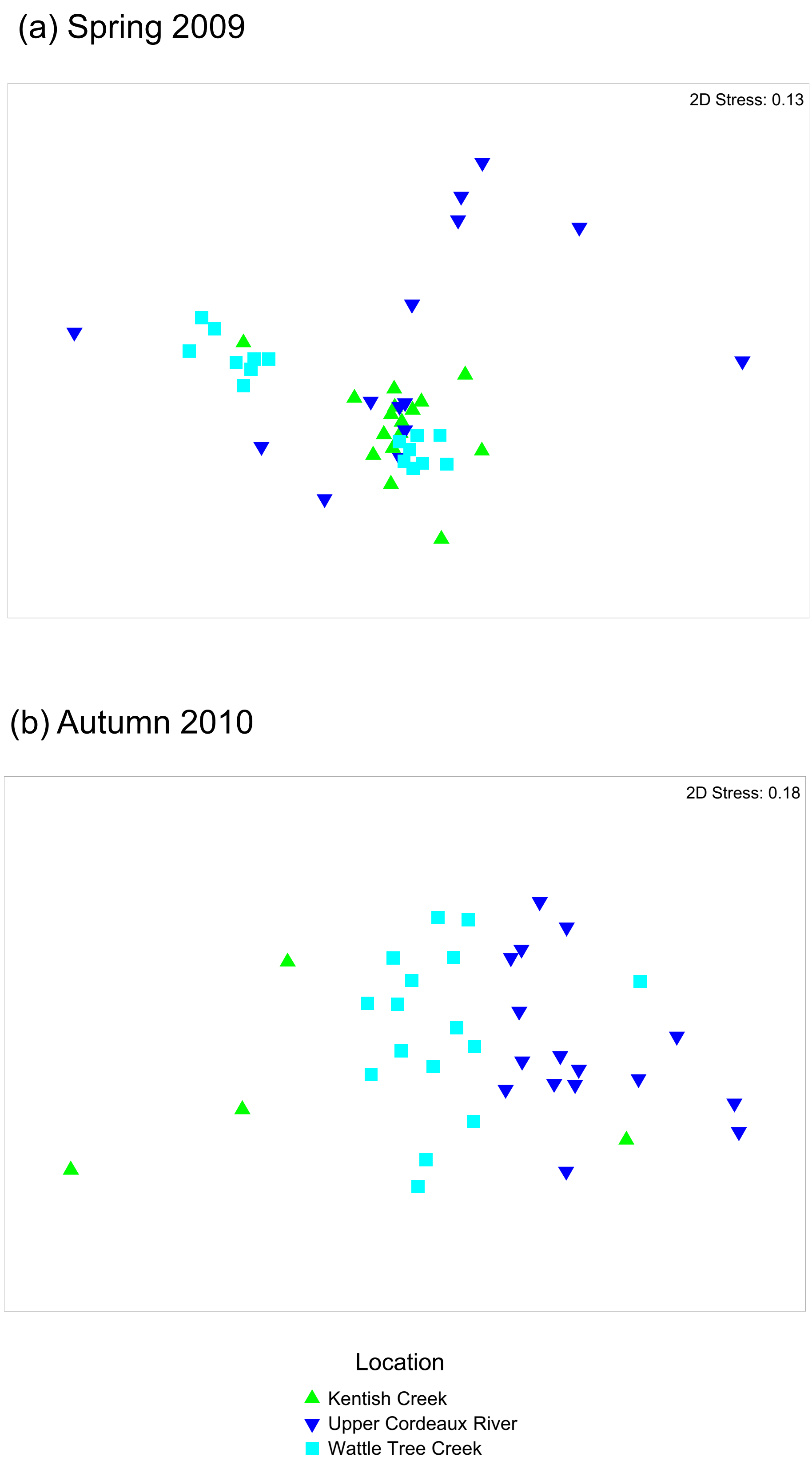


Figure 5: MDS plots comparing the structure of the macroinvertebrate assemblages colonising the collectors in (a) spring 2009 and (b) autumn 2010.

9 Plates

Plate 1: Aquatic macroinvertebrate collecting techniques used in baseline survey. (a) AUSRIVAS macroinvertebrate edge sampling technique; (b) Macroinvertebrate artificial collector, viewed head-on; (c) Macroinvertebrate artificial collector, side view; (d) Four artificial collectors (see arrows) in pool edge habitat.

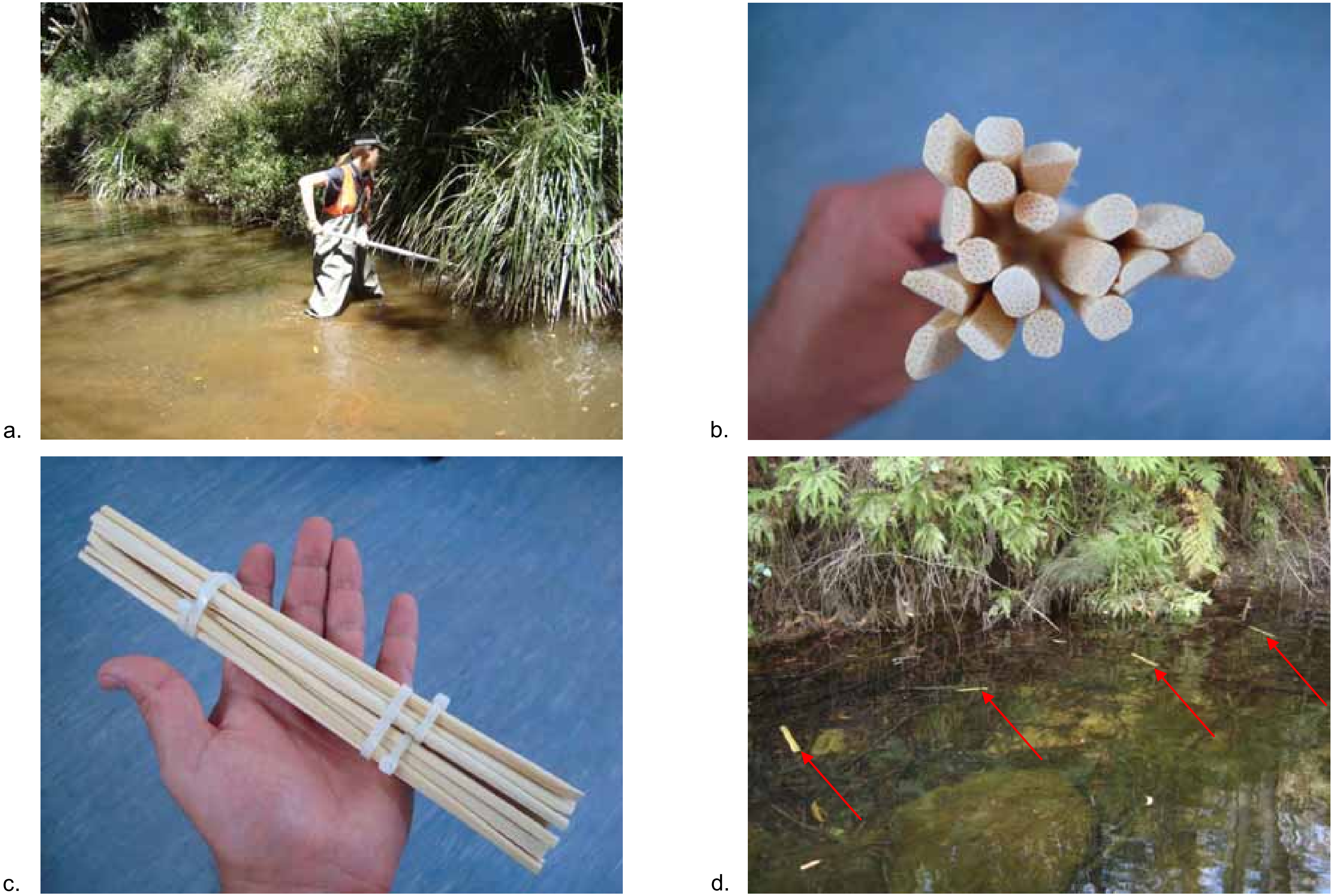


Plate 1a-d: Aquatic macroinvertebrate collecting techniques used in baseline survey. (a) AUSRIVAS macroinvertebrate edge sampling technique; (b) Macroinvertebrate artificial collector, viewed head-on; (c) Macroinvertebrate artificial collector, side view; (d) Four artificial collectors (see arrows) in pool edge habitat.

10 Appendices

Appendix 1: Site descriptors used to calculate RCE Scores (after Chessman et al. 1997).

Appendix 2: (a) Sampling dates and (b) Geographic coordinates of the study sites used for aquatic ecological monitoring of the Nebo Mine Area.

Appendix 3: Summary photo record of all sites sampled during spring 2009 and autumn 2010 for the Nebo Mine Area aquatic monitoring program. Each site contains four photo points that are located at the upstream extent of the reach, at the middle looking upstream, at the middle looking downstream and at the downstream extent of the reach.

Appendix 4: Mean (± S.E.) water quality readings for each site measured during the Nebo Mine baseline surveys undertaken in (a) Spring, October 2009 and November 2009 and (b) Autumn, March 2010 and May 2010 (n = 2, except for turbidity where n = 6).

Appendix 5: Species of freshwater fish and large macroinvertebrates recorded in the study area during the 4 baseline surveys (Oct. 2009, Nov. 2009, March 2010 and May 2010) conducted in the Nebo Mine Area.

Appendix 6: Numbers of aquatic macroinvertebrates in each AUSRIVAS sample taken from the edge habitat at each site in the Nebo Mine Area surveyed in (a) Spring, October 2009; (b) Spring, November 2009; (c) Autumn, March 2010; and (d) Autumn, May 2010.

Appendix 7: Numbers of aquatic macroinvertebrates from macroinvertebrate collectors deployed for six weeks in the edge habitat at each site in the Nebo Mine Area in (a) Spring, from October - November 2009; and (b) Autumn, from March - May 2010.

Appendix 1: Site descriptors used to calculate RCE Scores (after Chessman et al. 1997).

Descriptor and category	Score	Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone		8. Riffle / pool sequence	
Undisturbed native vegetation	4	Frequent alternation of riffles and pools	4
Mixed native vegetation and pasture/exotics	3	Long pools with infrequent short riffles	3
Mainly pasture, crops or pine plantation	2	Natural channel without riffle / pool sequence	2
Urban	1	Artificial channel; no riffle / pool sequence	1
2. Width of riparian strip of woody vegetation		9. Retention devices in stream	
More than 30 m	4	Many large boulders and/or debris dams	4
Between 5 and 30 m	3	Rocks / logs present; limited damming effect	3
Less than 5 m	2	Rocks / logs present, but unstable, no damming	2
No woody vegetation	1	Stream with few or no rocks / logs	1
3. Completeness of riparian strip of woody vegetation		10. Channel sediment accumulations	
Riparian strip without breaks in vegetation	4	Little or no accumulation of loose sediments	4
Breaks at intervals of more than 50 m	3	Some gravel bars but little sand or silt	3
Breaks at intervals of 10 - 50 m	2	Bars of sand and silt common	2
Breaks at intervals of less than 10 m	1	Braiding by loose sediment	1
4. Vegetation of riparian zone within 10 m of channel		11. Stream bottom	
Native tree and shrub species	4	Mainly clean stones with obvious interstices	4
Mixed native and exotic trees and shrubs	3	Mainly stones with some cover of algae / sil	3
Exotic trees and shrubs	2	Bottom heavily silted but stable	2
Exotic grasses / weeds only	1	Bottom mainly loose and mobile sediment	1
5. Stream bank structure		12. Stream detritus	
Banks fully stabilised by trees, shrubs etc	4	Mainly unsilted wood, bark, leaves	4
Banks firm but held mainly by grass and herbs	3	Some wood, leaves etc. with much fine detritus	3
Banks loose, partly held by sparse grass etc	2	Mainly fine detritus mixed with sediment	2
Banks unstable, mainly loose sand or soil	1	Little or no organic detritus	1
6. Bank undercutting		13. Aquatic vegetation	
None, or restricted by tree roots	4	Little or no macrophyte or algal growth	4
Only on curves and at constrictions	3	Substantial algal growth; few macrophytes	3
Frequent along all parts of stream	2	Substantial macrophyte growth; little algae	2
Severe, bank collapses common	1	Substantial macrophyte and algal growth	1
7. Channel form			
Deep: width / depth ratio less than 7:1	4		
Medium: width / depth ratio 8:1 to 15:1	3		
Shallow: width / depth ratio greater than 15:1	2		
Artificial: concrete or excavated channel	1		

Appendix 2 (a) Sampling dates and (b) Geographic coordinates of the study sites used for aquatic ecological monitoring of the Nebo Mine Area. Datum: WGS84 Zone: 56H

a. Sampling Dates

Season	Date
Spring 2009	15/10/09 - 16/10/09
Spring 2009	26/11/2009 -27/11/2009
Autumn 2010	19/03/2010 - 24/03/2010
Autumn 2010	06/05/2010 - 12/05/2010

b. Geographic Coordinates

	Site	Easting	Northing	Location
Watercourse				
Kentish Creek	1	299290	6194270	Upstream
Kentish Creek	2	298869	6194403	Downstream
Upper Cordeaux River	3	293274	6187451	Upstream
Upper Cordeaux River	4	293670	6187354	Downstream
Wattle Creek	5	294126	6189351	Upstream
Wattle Creek	6	294848	6189526	Downstream

Photo Point Summary

Appendix 3: Summary photo record of all sites sampled during Spring 2009 and Autumn 2010 for the Nebo Mine Area aquatic monitoring program. Each site contains four photo points that are located at the upstream extent of the reach, at the middle looking upstream, at the middle looking downstream and at the downstream extent of the reach.

Photo Point 1a: Upstream aquatic monitoring Site 1 in Kentish Creek, view from upstream extent of reach looking down, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 1b: Upstream aquatic monitoring Site 1 in Kentish Creek, view from middle of reach looking upstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).




Photo Point 1c: Upstream aquatic monitoring Site 1 in Kentish Creek, view from middle of reach looking downstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 1d: Upstream aquatic monitoring Site 1 in Kentish Creek, view from downstream extent of reach looking up, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 2a: Downstream aquatic monitoring Site 2 in Kentish Creek, view from upstream extent of reach looking down, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 2b: Downstream aquatic monitoring Site 2 in Kentish Creek, view from middle of reach looking upstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).




Photo Point 2c: Downstream aquatic monitoring Site 2 in Kentish Creek, view from middle of reach looking downstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 2d: Downstream aquatic monitoring Site 2 in Kentish Creek, view from downstream extent of reach looking up, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 3a: Upstream aquatic monitoring Site 3 in Upper Cordeaux River, view from upstream extent of reach looking down, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).




Photo Point 3b: Upstream aquatic monitoring Site 3 in Upper Cordeaux River, view from middle of reach looking upstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 3c: Upstream aquatic monitoring Site 3 in Upper Cordeaux River, view from middle of reach looking downstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 3d: Upstream aquatic monitoring Site 3 in Upper Cordeaux River, view from downstream extent of reach looking up, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 4a: Downstream aquatic monitoring Site 4 in Upper Cordeaux River, view from upstream extent of reach looking down, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 4b: Downstream aquatic monitoring Site 4 in Upper Cordeaux River, view from middle of reach looking upstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 4c: Downstream aquatic monitoring Site 4 in Upper Cordeaux River, view from middle of reach looking downstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 4d: Downstream aquatic monitoring Site 4 in Upper Cordeaux River, view from downstream extent of reach looking up, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 5a: Upstream aquatic monitoring Site 5 in Wattle Creek, view from upstream extent of reach looking down, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).




Photo Point 5b: Upstream aquatic monitoring Site 5 in Wattle Creek, view from middle of reach looking upstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 5c: Upstream aquatic monitoring Site 5 in Wattle Creek, view from middle of reach looking downstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 5d: Upstream aquatic monitoring Site 5 in Wattle Creek, view from downstream extent of reach looking up, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 6a: Downstream aquatic monitoring Site 6 in Wattle Creek, view from upstream extent of reach looking down, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 6b: Downstream aquatic monitoring Site 6 in Wattle Creek, view from middle of reach looking upstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 6c: Downstream aquatic monitoring Site 6 in Wattle Creek, view from middle of reach looking downstream, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Photo Point 6d: Downstream aquatic monitoring Site 6 in Wattle Creek, view from downstream extent of reach looking up, during observations in October 2009 (upper left), November 2009 (upper right), March 2010 (lower left), and May 2010 (lower right).

Appendix 4: Mean (± S.E.) water quality readings for each site measured during the Nebo Mine baseline surveys undertaken in (a) Spring, October 2009 and November 2009 and (b) Autumn, March 2010 and May 2010 (*n* = 2, except for turbidity where *n* = 6). Values in bold are outside the guidelines recommended by ANZECC (2000) for upland rivers in South-east Australia.

a. Spring

	Kentish Creek				Upper Cordeaux River				Wattle Creek			
	Upstream Site 1		Downstream Site 2		Upstream Site 3		Downstream Site 4		Upstream Site 5		Downstream Site 6	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
October 2009												
Temperature (^{0}C)	11.4	0.0	11.6	0.0	11.6	0.0	11.0	0.0	12.1	0.0	12.3	0.0
Conductivity (µS/cm)	73.0	0.0	112.0	2.0	41.0	0.0	55.0	0.0	95.0	0.0	88.5	1.5
Salinity (ppt)	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0
pH	6.7	0.1	7.3	0.1	**6.2**	0.0	6.7	0.0	7.5	0.0	7.3	0.1
ORP (mV)	153.0	1.0	171.0	3.0	187.5	0.5	208.0	0.0	209.0	0.0	195.5	0.5
DO (%sat'n)	**89.0**	0.3	**89.4**	0.4	**71.4**	6.4	**82.5**	3.8	**78.8**	6.7	90.6	0.8
Turbidity (ntu)	**0.6**	0.0	**0.7**	0.0	**0.6**	0.1	**0.8**	0.0	**0.7**	0.0	**0.6**	0.1
November 2009												
Temperature (^{0}C)	17.3	0.0	17.6	0.0	17.5	0.0	17.4	0.0	17.5	0.0	17.9	0.0
Conductivity (µS/cm)	67.0	0.0	**26.5**	4.5	55.0	2.0	71.0	0.0	89.0	0.0	32.5	6.5
Salinity (ppt)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
pH	6.7	0.0	6.9	0.0	**5.9**	0.1	6.6	0.0	7.1	0.0	7.1	0.0
ORP (mV)	361.0	1.0	343.5	3.5	398.5	7.5	312.5	0.5	432.5	0.5	407.0	2.0
DO (%sat'n)	**78.7**	3.1	**72.5**	3.4	**111.1**	0.8	93.0	6.2	92.7	0.6	101.0	3.2
Turbidity (ntu)	3.5	0.1	2.6	0.8	**0.4**	0.0	**0.5**	0.0	**1.7**	0.1	**1.4**	0.0

Appendix 4: Continued

b. Autumn

	Kentish Creek				Upper Cordeaux River				Wattle Creek			
	Upstream Site 1		Downstream Site 2		Upstream Site 3		Downstream Site 4		Upstream Site 5		Downstream Site 6	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
March 2010												
Temperature (^{0}C)	15.9	0.1	16.1	0.0	16.3	0.0	16.0	0.0	16.7	0.0	17.1	0.0
Conductivity (µS/cm)	100.5	2.5	120.0	0.0	66.0	0.0	73.5	2.5	114.0	0.0	118.0	0.0
Salinity (ppt)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
pH	6.5	0.0	6.7	0.0	**6.2**	0.0	**6.3**	0.0	7.1	0.0	6.8	0.0
ORP (mV)	475.0	1.0	448.5	0.5	455.0	1.0	433.5	0.5	453.5	0.5	463.5	0.5
DO (%sat'n)	99.1	0.8	100.7	0.3	92.0	0.0	93.0	0.2	**89.3**	0.1	**87.1**	0.1
Turbidity (ntu)	8.8	0.0	7.4	0.0	**0.5**	0.0	**0.4**	0.1	**0.7**	0.1	**0.5**	0.1
May 2010												
Temperature (^{0}C)	11.6	0.0	12.3	0.0	11.7	0.0	11.1	0.0	10.3	0.0	10.2	0.0
Conductivity (µS/cm)	116.0	0.0	126.0	0.0	205.0	2.0	111.0	6.0	111.0	0.0	187.0	2.0
Salinity (ppt)	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0
pH	**6.3**	0.0	6.8	0.0	6.5	0.1	6.5	0.0	7.1	0.0	7.2	0.0
ORP (mV)	403.0	19.0	396.0	5.0	379.5	2.5	247.0	0.0	238.5	0.5	272.5	3.5
DO (%sat'n)	**85.2**	1.3	**78.3**	0.0	**73.5**	0.5	**76.6**	0.2	**80.4**	0.3	**71.4**	0.0
Turbidity (ntu)	4.1	0.2	10.4	0.1	4.9	1.3	3.8	0.1	4.0	0.2	**1.3**	0.1

Appendix 5: Species of freshwater fish and large macroinvertebrates recorded in the study area during the 4 baseline surveys (Oct. 2009, Nov. 2009, March 2010 and May 2010) conducted in the Nebo Mine Area.

			Kentish Creek								Upper Cordeaux River								Wattle Creek							
Family Name	Species Name	Common Name	Site 1				Site 2				Site 3				Site 4				Site 5				Site 6			
		Survey	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias						2		1			10		7		30	1			2				1	
Retropinnidae	*Retropinna semoni*	Smelt					1	3			42	26			12	3				1			20	3		
Parastacidae	*Euastacus sp.*	Freshwater crayfish		2	1			1				2	2		1	1	4						1		1	

Appendix 6: Numbers of aquatic macroinvertebrates in each AUSRIVAS sample taken from edge habitat at each site surveyed in (a) Spring, October 2009; (b) Spring, November 2009; (c) Autumn, March 2010; and (d) Autumn, May 2010. The maximum number of any taxon of animals removed from each sample = 10.

a. Spring - October 2009

Location	Kentish Ck		Upper Cordeaux R		Wattle Ck	
Site	1	2	3	4	5	6
Order or Family						
Araneae	0	1	0	0	0	0
Athericidae	10	0	0	1	1	0
Atyidae	1	10	0	3	0	0
Caenidae	0	0	0	0	6	3
Ceratopogonidae	4	5	1	3	3	3
Chironomidae/Chironominae	5	0	5	10	5	7
Chironomidae/Orthocladiinae	2	0	0	0	0	0
Chironomidae/Tanypodinae	10	3	6	10	10	5
Cladocera	0	0	0	0	3	0
Copepoda	0	0	1	0	0	1
Corbiculidae/ Sphaeriidae	0	0	0	0	0	1
Culicidae	0	0	0	0	1	0
Diphlebiidae	0	0	0	0	0	1
Dixidae	0	4	0	2	3	0
Dytiscidae	1	10	1	0	1	4
Ecnomidae	0	2	1	1	0	0
Elmidae	0	2	0	1	0	0
Gerridae	0	1	0	0	0	0
Gomphidae	1	0	0	0	0	0
Gripopterygiidae	0	10	2	9	1	0
Gyrinidae	5	6	1	1	3	7
Helicopsychidae	1	5	0	0	0	0
Hydracarina	10	9	10	8	9	5
Hydraenidae (= Limnebiidae)	0	0	0	0	0	1
Hydrophilidae	2	0	0	0	0	0
Hydroptilidae	1	0	0	2	2	0
Hypogastruridae	1	0	0	0	0	0
Leptoceridae	10	10	10	10	10	10
Leptophlebiidae	10	10	10	10	10	10
Megapodagrionidae	3	0	0	0	2	0
Nematoda	1	0	1	0	0	0
Noteridae	0	2	0	0	0	0
Notonectidae	0	2	0	0	0	0
Odontoceridae	0	0	0	5	0	0
Oligochaeta	0	0	0	0	1	10
Oniscigastridae	0	10	1	0	0	0
Ostracoda	0	0	0	0	0	5
Parastacidae	0	1	0	0	0	0
Psephenidae	0	1	0	0	1	0
Scirtidae	2	7	2	4	3	1
Synlestidae	1	0	0	1	0	0
Synthemistidae	1	0	2	0	1	0
Talitridae	0	1	0	0	0	0
Telephlebiidae	2	4	0	1	1	3
Tipulidae	0	0	1	1	0	0

Appendix 6: Continued

b. Spring - November 2009

Location	Kentish Ck		Upper Cordeaux R		Wattle Ck	
Site	1	2	3	4	5	6
Order or Family						
Araneae	1	1	0	0	0	2
Athericidae	1	0	0	0	2	0
Atyidae	1	5	10	4	0	7
Caenidae	0	0	1	0	3	0
Calamoceratidae	0	0	0	0	0	1
Ceratopogonidae	0	0	1	4	2	0
Chironomidae/Chironominae	10	0	4	6	5	2
Chironomidae/Orthocladiinae	0	0	0	0	0	1
Chironomidae/Tanypodinae	4	2	10	8	10	6
Copepoda	0	0	0	1	0	0
Corbiculidae/ Sphaeriidae	1	1	0	0	0	0
Corydalidae	0	0	0	0	1	1
Curculionidae	0	0	0	0	0	1
Dixidae	0	6	0	0	2	1
Dytiscidae	7	7	0	0	0	1
Ecnomidae	0	0	4	3	1	0
Elmidae	0	0	0	1	4	0
Glossiphoniidae	0	0	0	0	1	0
Gomphidae	0	0	1	0	0	0
Gripopterygiidae	0	1	0	3	1	2
Gyrinidae	7	7	2	1	7	8
Helicopsychidae	0	1	0	0	0	0
Hirudinidae	1	1	1	1	0	2
Hydracarina	3	2	6	6	3	0
Isostictidae	0	0	0	0	1	0
Leptoceridae	10	10	10	10	10	10
Leptophlebiidae	6	10	10	10	10	10
Megapodagrionidae	5	3	0	0	0	0
Notonectidae	5	3	0	0	1	2
Oligochaeta	0	1	0	1	0	0
Oniscigastridae	0	2	0	0	0	0
Ostracoda	0	0	0	0	0	2
Parastacidae	0	1	0	0	1	0
Scirtidae	0	3	1	0	0	1
Synlestidae	1	3	0	0	0	0
Synthemistidae	0	0	2	4	0	0
Telephlebiidae	5	5	1	1	4	10
Temnocephalidae	0	0	0	0	3	0
Tipulidae	0	0	0	0	1	0
Veliidae	0	0	0	0	1	0

Appendix 6: Continued

c. Autumn - March 2010

Location	Kentish Ck		Upper Cordeaux R		Wattle Ck	
Site	1	2	3	4	5	6
Order or Family						
Araneae	0	2	1	1	0	1
Athericidae	0	0	4	1	2	0
Atyidae	3	8	10	7	0	7
Caenidae	0	0	0	0	0	5
Calamoceratidae	0	0	0	0	0	1
Ceratopogonidae	1	0	0	1	0	0
Chironomidae/Chironominae	1	5	3	1	1	4
Chironomidae/Orthocladiinae	0	0	0	1	0	0
Chironomidae/Tanypodinae	2	1	0	4	3	10
Copepoda	0	2	0	0	0	0
Corydalidae	1	0	0	0	0	0
Culicidae	0	1	0	0	0	0
Dixidae	1	1	0	0	0	0
Dytiscidae	0	6	0	0	0	1
Elmidae	0	0	3	1	0	0
Gomphidae	1	1	0	2	0	0
Gordiidae	0	0	0	0	1	0
Gripopterygiidae	3	6	3	0	0	0
Gyrinidae	6	10	1	1	8	6
Helicopsychidae	0	8	0	0	0	0
Hemicorduliidae (=Corduliidae)	1	0	0	0	0	0
Hydracarina	0	2	10	8	4	7
Hydrochidae	1	0	0	0	0	0
Hydrophilidae	0	1	0	0	0	0
Hydroptilidae	0	0	0	0	0	1
Leptoceridae	10	10	10	10	10	10
Leptophlebiidae	10	8	9	2	6	10
Megapodagrionidae	4	6	0	0	0	1
Nematomorpha	0	1	0	0	0	0
Nepidae	0	1	0	0	0	0
Noteridae	1	0	0	0	0	0
Notonectidae	7	8	1	0	1	7
Oligochaeta	0	1	0	0	0	0
Ostracoda	0	0	0	0	0	1
Philorheithridae	1	0	1	4	0	1
Psephenidae	0	0	0	0	0	2
Scirtidae	5	3	3	1	0	0
Synlestidae	1	0	0	0	0	0
Synthemistidae	1	0	3	1	0	0
Telephlebiidae	3	1	0	1	2	1
Tipulidae	0	0	3	0	0	0
Veliidae	3	1	0	0	0	0

Appendix 6: Continued

d. Autumn - May 2010

Location	Kentish Ck		Upper Cordeaux R		Wattle Ck	
Site	1	2	3	4	5	6
Order or Family						
Athericidae	0	0	2	3	1	0
Atyidae	3	6	3	2	1	7
Baetidae	0	0	0	0	1	1
Caenidae	0	0	0	0	7	10
Calamoceratidae	0	0	0	0	0	1
Ceratopogonidae	0	0	1	0	2	3
Chironomidae/Chironominae	1	0	3	1	1	3
Chironomidae/Orthocladiinae	1	0	1	1	0	0
Chironomidae/Tanypodinae	2	6	9	10	10	10
Conoesucidae	0	0	0	0	0	1
Copepoda	1	0	1	1	1	0
Dytiscidae	4	9	1	1	2	2
Ecnomidae	1	0	2	1	0	0
Elmidae	0	0	2	0	1	0
Empididae	1	0	0	0	0	0
Gordiidae	0	0	0	0	2	0
Gripopterygiidae	0	3	1	0	0	0
Gyrinidae	5	4	6	3	4	9
Helicopsychidae	0	0	0	0	1	1
Hydracarina	7	4	10	1	2	10
Hydraenidae	0	0	0	0	0	2
Hydroptilidae	0	0	5	1	5	7
Leptoceridae	10	10	10	10	10	10
Leptophlebiidae	3	10	7	7	10	10
Megapodagrionidae	0	0	0	0	1	1
Notonectidae	6	3	1	1	4	5
Notonemouridae	0	0	1	0	2	0
Oligochaeta	0	0	0	0	0	2
Oniscigastridae	0	3	0	0	0	0
Ostracoda	0	0	0	0	0	1
Philorheithridae	3	0	2	10	0	1
Psephenidae	0	0	1	0	0	4
Psychodidae	0	1	0	0	0	0
Scirtidae	1	0	3	7	3	0
Telephlebiidae	0	1	0	0	1	4
Tipulidae	0	0	0	0	2	0

Appendix 7: Numbers of aquatic macroinvertebrates from macroinvertebrate collectors deployed for six weeks in the edge habitat at each site in the Nebo Mine Area in (a) Spring, from October - November 2009; and (b) Autumn, from March - May 2010. Data from collectors that were found dry due to instream water loss or extreme flood events leaving the apparatus on the bank are marked with X.

a. Spring 2009

Location	Kentish Creek																Upper Cordeaux River																Wattle Creek															
Site	1								2								3								4								5								6							
Rep	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Order or Family																																																
Ancylidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	1	1	2	3	5	5	1	0	0	0	0	0	0	0
Aphididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Araneae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Athericidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Chironomidae/Chironominae	23	41	18	29	42	98	55	135	6	13	7	13	40	20	16	14	1	4	2	3	26	35	7	11	0	0	14	0	15	1	10	0	41	37	45	34	29	36	40	21	16	12	26	8	2	2	6	3
Chironomidae/Orthocladiinae	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae/Tanypodinae	7	9	7	13	2	6	0	6	0	0	1	5	0	3	3	7	0	2	0	0	2	5	6	4	0	0	2	0	6	0	4	0	3	2	5	4	2	2	0	3	5	4	1	4	2	2	1	2
Copepoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corbiculidae/ Sphaeriidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Corydalidae	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dolichopodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dugesiidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0
Dytiscidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Ecnomidae	0	1	1	0	7	1	1	4	0	0	0	0	0	0	1	0	0	1	0	0	4	1	5	2	0	0	4	0	0	0	0	0	0	2	1	0	2	0	0	0	0	0	0	4	1	0	0	0
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	2	0	0
Entomobryidae/Isotomidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gelastocoridae	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gripopterygiidae	0	0	0	0	0	0	0	0	1	2	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	1	0	0	0	0	0	2	0	1	0
Gyrinidae	0	0	0	0	0	0	0	0	1	0	0	0	2	0	5	5	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	2	1	1	0	1	0	0	0	0	0	0	0	0
Haliplidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helicopsychidae	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heteroceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydracarina	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hydraenidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydridae	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	1	1	0	0	0	0	1	0	1	3	0	2	2	1	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	2	0	0	0	1	1	0	0	0
Leptophlebiidae	6	14	6	10	5	2	0	2	11	7	0	4	13	25	6	36	0	0	0	0	24	29	12	18	0	0	10	0	12	0	1	0	19	34	16	17	3	1	14	3	0	0	0	4	2	0	0	3
Oligochaeta	0	0	0	0	0	0	0	0	0	3	117	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	3	0	3	0	21	0	0	0	0	0	0	0	0	0	217	84	182	482	221	167	243	800
Psychodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temnocephalidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 7: Continued

b. Autumn 2010

Location	Kentish Creek																Upper Cordeaux River																Wattle Creek															
Site	1								2								3								4								5								6							
Rep	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Order or Family																																																
Ancylidae	1	4	1	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	14	6	9	7	25	21	19	0	6	0	0	1	1	3	0
Athericidae	0	0	0	1	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	1	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
Baetidae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Caenidae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Calamoceratidae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0
Ceratopogonidae	7	4	0	2	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae/Chironominae	3	8	6	14	X	X	X	X	X	X	X	X	X	X	X	X	5	16	4	11	3	3	5	6	19	33	26	21	11	7	7	12	18	20	19	22	15	16	7	29	17	14	18	22	9	10	12	14
Chironomidae/Orthocladiinae	0	1	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	3	0	0	0	0	0	0	6	4	4	6	0	0	0	0	0	0	0	0	0	1	2	3	1	10	3	1	0	1	0	0
Chironomidae/Tanypodinae	1	3	0	5	X	X	X	X	X	X	X	X	X	X	X	X	0	3	0	1	1	2	2	0	7	2	7	2	3	0	2	2	4	5	3	9	5	4	3	8	8	8	6	14	2	2	2	0
Copepoda	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corydalidae	0	1	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Dixidae	0	1	0	2	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dugesiidae	0	0	0	1	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	3	2	1	0	1	0	1	0	0	0	0	0	0
Dytiscidae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	2	0	0	0	0	0	0	0	1	2	2	0
Ecnomidae	0	0	2	0	X	X	X	X	X	X	X	X	X	X	X	X	8	2	5	7	2	5	4	6	2	2	4	4	0	0	4	2	1	3	2	1	1	0	1	1	0	0	0	0	0	0	0	0
Elmidae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	1	0
Empididae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0
Entomobryidae/Isotomidae	4	1	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gripopterygiidae	0	1	1	2	X	X	X	X	X	X	X	X	X	X	X	X	1	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Gyrinidae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	2	0	1	1	0	1	0	0	0	0	0	0	1
Hebridae	1	0	0	1	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helicopsychidae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hydracarina	0	2	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0
Hydraenidae	3	2	0	5	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobiosidae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
Hydrophilidae	4	1	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydroptilidae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	5	1
Leptoceridae	7	2	0	2	X	X	X	X	X	X	X	X	X	X	X	X	0	2	0	2	0	7	1	0	1	0	1	0	1	1	1	2	2	2	2	6	19	5	1	2	5	3	1	6	2	7	2	0
Leptophlebiidae	0	5	9	9	X	X	X	X	X	X	X	X	X	X	X	X	2	9	2	14	10	14	10	13	17	5	14	5	6	6	5	6	5	12	8	8	2	3	7	13	10	6	3	5	3	16	6	14
Megapodagrionidae	1	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Notonemouridae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	0	0	1	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	2	21	0
Psephenidae	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Scirtidae	31	56	2	18	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Telephlebiidae	1	0	0	2	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0