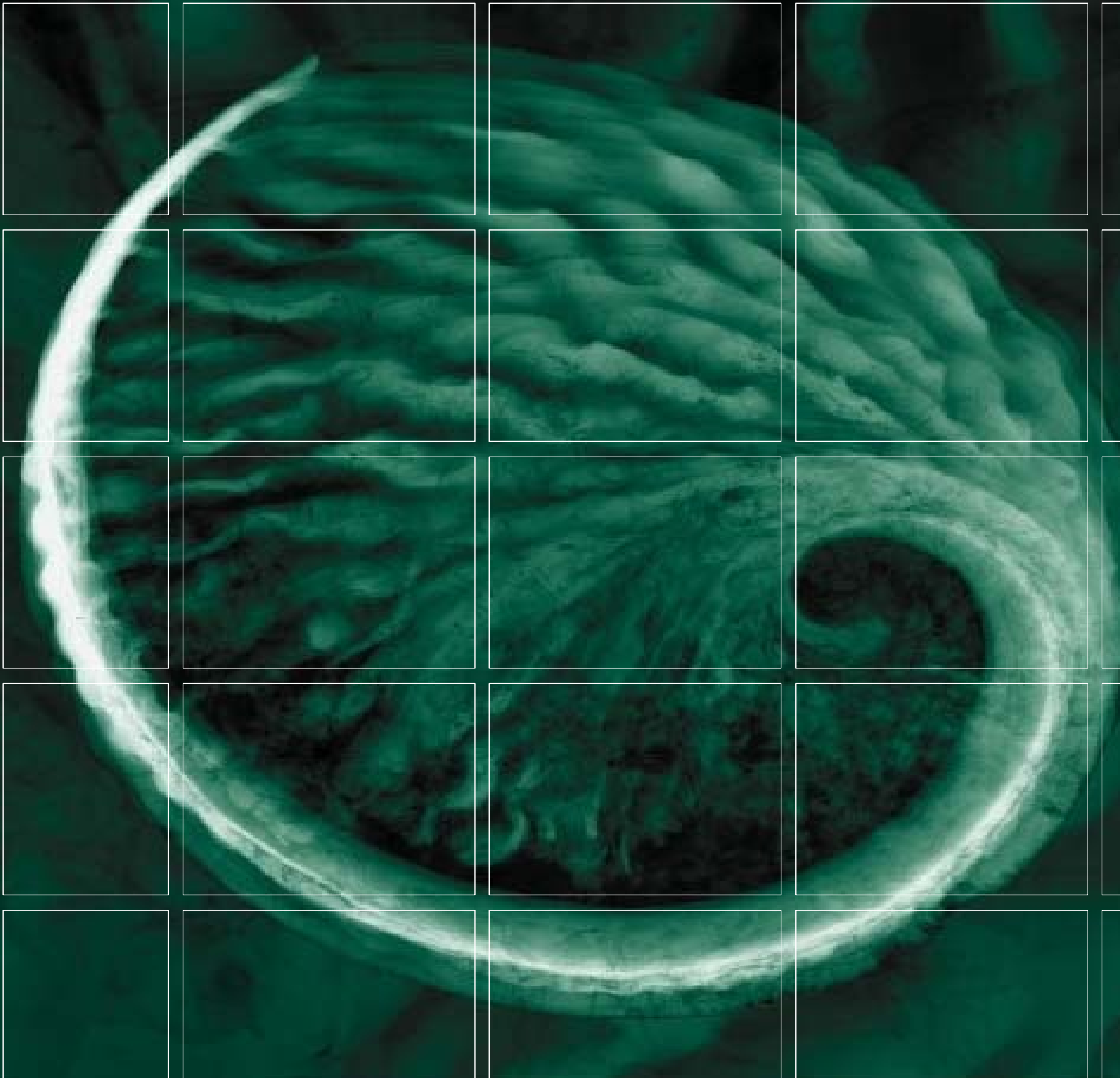
Subsidence Management Plan

ANNEX F

Flora and Fauna Baseline Monitoring - Bowmans Creek

Ashton Coal
Longwall Panels 1 - 4

Subsidence Management Plan
Written Report



Flora and Fauna Baseline Monitoring
Bowmans Creek

Ashton Coal Operations Pty Ltd

October 2006
0041622 Final

www.erm.com

Delivering sustainable solutions in a more competitive world

ERM

Approved by:	*Joanne Woodhouse*
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Date:	*11 October, 2006*
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Environmental Resources Management Australia Pty Ltd Quality System

Flora and Fauna Baseline Monitoring
Bowmans Creek

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1 INTRODUCTION

1.1 INTRODUCTION

Environmental Resources Management Australia Pty Ltd (ERM) was engaged by Ashton Coal to undertake a pre-mining assessment of the riparian and aquatic habitat along Bowmans Creek (see *Figure 1.1*). The monitoring was undertaken in accordance with the Ashton Coal Flora and Fauna Management Plan – Part 2 prepared in August, 2005.

The purpose of this report was to:

- identify and describe the vegetation communities and flora species, associated with Bowmans Creek;
- identify and describe the fauna habitats associated with Bowmans Creek;
- describe aquatic habitats of Bowmans Creek within areas potentially affected by underground mining works and selected control locations;
- establish baseline conditions of aquatic habitats, fish, and macro invertebrates; and,
- provide a post-mining monitoring program for the site based on the habitat assessment and baseline studies.

The aquatic field investigations and assessment were undertaken by The Ecology Lab Pty Ltd (see *Annexures A* and *B*).

1.2 BACKGROUND

Ashton Coal was granted conditional consent by the Minister for Planning on 11 October, 2002, for the development of an open cut mine, an underground mine, and construction and operation of associated surface facilities.

Of particular note are Consent Conditions 3.19 and 3.20, which require the applicant to 'undertake a detailed and ongoing monitoring program of subsidence resulting from mining. The monitoring program is required to extend from commencement of construction throughout the life of the mine and for a period of at least five years after the completion of mining …'.

Also included in the consent conditions was the preparation of a Flora and Fauna Management Plan (FFMP) and Monitoring Program. This FFMP was completed in August, 2005, and outlines the requirement for aquatic habitat monitoring.

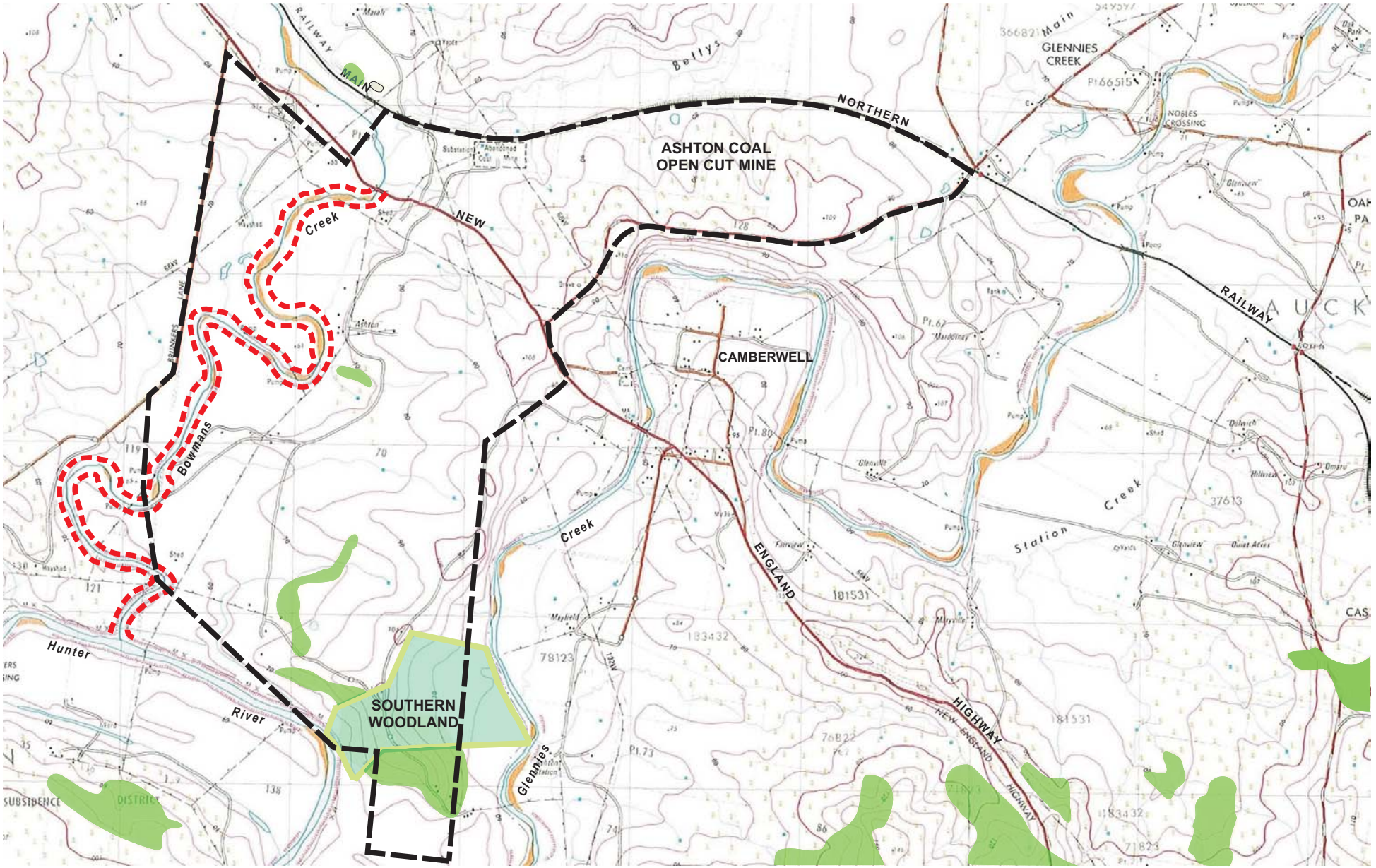

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Figure 1.1 **Locality Plan**

Ashton Coal - Bowmans Creek Monitoring, Camberwell NSW

The monitoring program is required to establish baseline data prior to the commencement of the underground mining activities. Monitoring will then take place bi-annually at established sites along Bowmans Creek and include:

- water quality parameters recorded at each site including flow velocity;
- macroinvertebrate sampling at each site;
- fish sampling at each site;
- riparian vegetation surveys along Bowmans Creek detailing weed incursion and habitat loss; and,
- incidental records of aquatic species or indicators of aquatic ecosystem health.

The monitoring program aimed to identify any impact of mine subsidence along Bowmans Creek and any scope for improvement of water quality and aquatic ecosystem health.

1.3 SITE DESCRIPTION

The site refers to Bowmans Creek and its associated riparian corridor extending from the Hunter River north to the New England Highway (see *Figure 1.1*). The site for the aquatic assessment includes a control location in Bowmans Creek upstream of the proposed longwall operation and an external control at Rouchel Brook (see *Annexures A* and *B*).

Bowmans Creek has its source in the Little Brothers Range and drains south into the Hunter River. It is located in the Hunter Valley within the Singleton Local Government Area. Approximately 4.5 kilometres of the creek lies over the proposed underground workings of the Ashton Coal Operations. The elevation of the reach in this area is between 50 and 70 metres. The elevation of the headwaters is about 650 metres Australian Height Datum (AHD).

The site has been previously disturbed by cattle grazing, weed encroachment, vegetation clearing and rubbish dumping. The riparian vegetation is characterised by *Casuarina* woodland with small sections of river red gum open forest. The area adjoining the riparian vegetation is characterised by continually grazed pasture and relatively isolated patches of open woodland. Surrounding land uses consist of rural properties with mining activities occurring immediately to the north of the New England Highway.

2 *POTENTIAL IMPACTS OF SUBSIDENCE*

The most direct environmental impact of underground mining is subsidence, which causes changes in the level of the ground surface.

The following section outlines potential impacts on flora and fauna from the proposed underground mining activities. These potential impacts have been considered within the baseline assessment and proposed monitoring program.

2.1.1 Tilt

Subsidence will cause a trough, centred above each longwall panel. Subsidence troughs are formed through the vertical settlement of rock into the void created as the coal is removed between the chain pillars. As a trough is formed, the ground surface is subjected to certain tilts and strains depending on the geology, depth of cover, panel dimensions and position above the panel.

As an example, where there is a maximum predicted tilt of 7.5 mm per metre, a vertical 20 metre high tree on the side of a trough may lean by up to 150 mm. Although this would not normally be sufficient to cause instability, there is a possibility that trees which already have a steep lean in the direction of predicted tilt will fall as a result of the additional tilt. Conversely, any trees leaning away from the subsidence induced tilt would be straightened. It is unlikely that any isolated falls that may occur, would significantly alter the community composition.

Tilt generally does not affect shrubs, herbs or grasses, as they are too short to exert significant leverage on root systems.

2.1.2 Strain

Tensile strains pull on structures commonly damaging inflexible material by stretching and rupturing. This is unlikely to impact on plant roots due to their inherent flexibility. Compressive and tensile strains caused by subsidence act on plant roots much the same as high winds. In windy weather, particularly on the leeward side of trees, roots are compressed as the trunk sways away from the wind. Roots on the windward side are placed under tension, although this alternates with compression as the trunk sways back and forth.

2.1.3 Ponding

Underground mining alters the topography such that ponds can form in subsidence troughs. These collect water that, if unmanaged, can cause dieback or a change in vegetation composition.

2.1.4 *Lowering of the Watertable Beyond the Reach of Plants*

Some plant communities rely on groundwater as opposed to moisture in the soil. Depressurisation of the coal seam aquifer will lower the standing water level in the long term.

2.1.5 *Subsiding Vegetation into the Groundwater Zone*

Subsiding vegetation communities close to the water table could potentially affect individual plants. For example, subsiding a dry community into the water table could cause dieback and a transition to those species more suited to wet conditions. Subsiding a wet community further into the water table may extend or improve the community, although not in every case.

2.1.6 *Vegetation Clearance*

Farming and grazing, the surrounding mining operations, and logging, have resulted in native vegetation clearance. The minor impacts of the proposed longwalls will not significantly increase the effects of the surrounding native vegetation clearance. The proposal will not remove fallen timber, which provides a foraging and shelter resource for native fauna.

2.1.7 *Rock Shelters and Burrows*

Surface cracking may become apparent on extensive bare surfaces such as access tracks or along the creek line.

Bats may roost in existing rock cracks and a number of burrowing animals such as wombats are known to occur within the locality. Subsidence may widen or close these fissures and burrows. It is not possible to quantify the likelihood or number of crack closures or burrow collapses. Whilst subsidence could threaten roosting and shelter sites, similar habitat is common within the local area. In some cases, cracking may actually increase the total roosting and shelter habitat for threatened species within the site.

2.1.8 *Increased Noise*

It is expected that there will be minor short term noise increases as a result of the underground mining activities. Native animals are relatively insensitive to low level noise emissions and no impact would be expected for the native fauna utilising the resources present on this site.

2.1.9 *Aquatic Habitats (Drying of Springs, Soaks and Dams)*

Subsidence may cause surface cracking and a consequent reduction in yield from soaks and springs. It may also cause changes in the habitat characteristics of Bowmans Creek and will form the basis of the aquatic monitoring program.

3 BASELINE SURVEY METHODOLOGY

3.1 RIPARIAN VEGETATION ASSESSMENT

3.1.1 Literature Review

Various sources of published information are available on flora and fauna within the site and locality. These were reviewed in the preparation of this assessment:

- ERM (2005) Ashton Coal Bi-annual Fauna Monitoring Autumn Census;
- HLA Envirosciences (2001) Flora and Fauna Survey Ashton Mine Project for White Mining Limited; and,
- Ashton Coal Mine (2005) Flora and Fauna Management Plan Part 2.

Vegetation mapped by the Lower Hunter and Central Coast Regional Environmental Management Strategy (LHCCREMS) vegetation mapping for the site and locality was reviewed (House 2003).

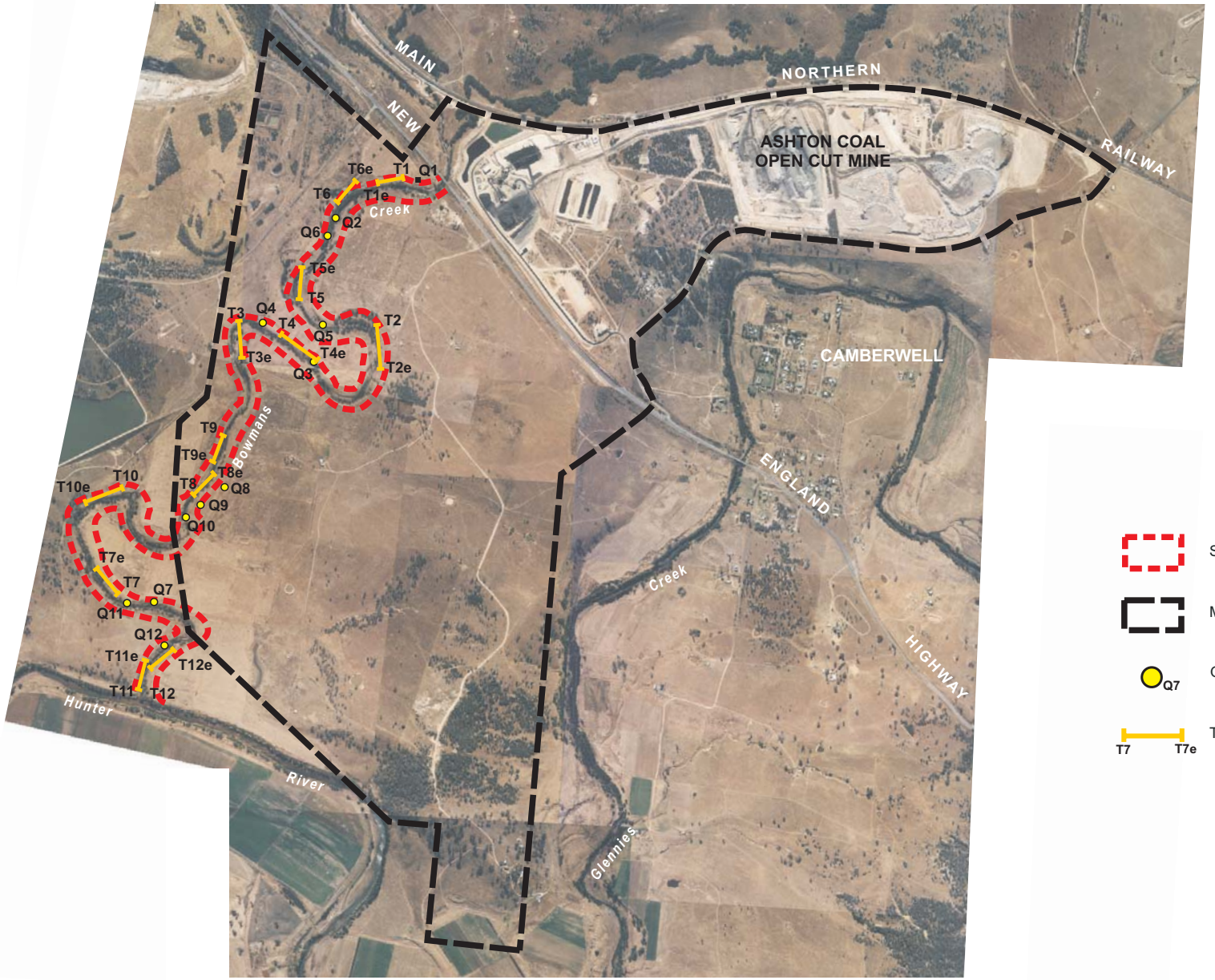
A search of the DEC Wildlife Atlas database was conducted for all recent records of threatened flora and fauna within the locality. This search revealed the presence of several threatened species within a 10 kilometre radius of the site. A search of the on-line database maintained by the Commonwealth Department of the Environment and Heritage (DEH) was completed to identify the presence of nationally listed threatened and migratory species in the locality.

3.1.2 Riparian Vegetation Surveys

Representative sites for monitoring were selected within the area of the creek to be undermined, as well as upstream and downstream control points. The location of the twelve transects and twelve plots were recorded using GPS and orientation of the quadrat or transect noted (refer to *Figure 3.1*).

Within each plot, the height (metres) of each primary structural layer, and relative cover abundance (%) of species was recorded as well as the location, elevation, slope, aspect and general soil type in the plot. Similarly, during transect surveys, all species observed within 2 metres either side of the transect were recorded as well as the physical attributes of the surrounding area.

The location of all quadrats east of Bowmans Creek was marked with a stake in the northwestern corner whilst those quadrats west of the creek were staked in the southeastern corner. The start of each transect was also marked with one stake.



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Approximate Only

Figure 3.1 **Monitoring Sites**

Ashton Coal - Bowmans Creek Monitoring, Camberwell NSW

During fieldwork, targeted surveys were undertaken for threatened flora species identified by literature and database searches. A full list of the flora species recorded within the site has been provided in *Annex C*. The results of the transects and quadrats are provided in *Annex D*.

3.1.3 Fauna Habitat and General Observations

The vegetation surveys and previous assessments in the vicinity of the site were used to identify and assess the distribution of habitat types. The riparian corridor contains two broad habitat types being, open woodland and pasture.

Opportunistic sightings of species and secondary indications (scats, scratches, diggings, tracks, and so on) of resident fauna were noted and included:

- opportunistic sightings of birds and terrestrial mammals;
- searches in suitable areas for herpetofauna (reptiles and frogs);
- searches for whitewash, prey remains and regurgitation pellets from owls;
- checking trees for scratches consistent with arboreal mammals;
- connectivity to adjacent areas of habitat; and,
- the extent and nature of previous disturbances.

3.2 AQUATIC ASSESSMENT

The field investigations and assessments were undertaken by The Ecology Lab Pty Ltd. Their reports have been reproduced in full in *Annexures A* and *B*.

3.2.1 Literature Review

The following literature sources were reviewed in the preparation of the aquatic assessment:

- the library database of The Ecology Lab was searched for relevant material from the locality;
- the NSW Fisheries (NSW Department of Primary Industries) and Department of Environment and Heritage websites were viewed and current schedules of threatened species, populations, and communities were obtained;
- the Government of NSW Legislation website was accessed to obtain relevant Key Threatening Processes; and,

- the NSW government Bionet system was used to search for government agency records of threatened species within the upper Hunter River system.

In reference to the current mining proposal, The Ecology Lab was provided with mine plans by Ashton Coal indicating the proposed layout of the Ashton Coal Project longwalls. In addition, the Camberwell and Rouchel Brook 1:25,000 topographic maps (Central Mapping Authority of NSW) and Camberwell 1:100,000 topographic map (Royal Australian Survey Corps) were used to identify the size, setting and elevation of Bowmans Creek and Rouchel Brook and surrounding land use patterns and to assist in site selection. The Ashton Coal Flora and Fauna Management Plan (2005) was used to determine potential impacts of the proposed underground mining.

3.2.2 Field Surveys

Field studies were undertaken by The Ecology Lab in December 2005 and May/June 2006. A qualitative assessment of aquatic habitats was compiled for each site, including the following attributes, and these are described in detail in *Annexures A* and *B*:

- GPS position (datum: WGS 84);
- general land use of surrounding areas;
- instream features such as sequence of pools, runs and riffles (shallow areas with broken water);
- flow, measured at each site using a flowmeter;
- stream substratum;
- presence, extent and type of instream and riparian vegetation;
- potential refuge areas during periods of low flow (e.g. large deep pools);
- presence of fish habitat including snags, bank undercuts and aquatic plants;
- presence of barriers to fish passage into and beyond the site;
- waterway type using a classification scheme outlined in Fish Passage Requirements for Waterway Crossings; and,
- bank structure, using Riparian, Channel and Environmental (RCE) scores.

4 RIPARIAN ASSESSMENT RESULTS

4.1 VEGETATION COMMUNITIES

The Bowmans Creek riparian corridor is characterised by three vegetation communities being *Casuarina cunninghamia* (river oak) woodland, river red gum open woodland, and pasture. The results of the surveys have been provided in *Annexures C* and *D*.

Scattered trees such as *Eucalyptus crebra* (narrow-leaved ironbark), *Eucalyptus melliodora* (yellow box) and *Eucalyptus moluccana* (grey box) were also recorded within the paddocks adjacent to the riparian vegetation corridor.

4.1.1 River Oak Woodland

Riparian vegetation on site was dominated by an overstorey of *Casuarina cunninghamia* (river oak) supporting a sparse to absent midstorey and moderate groundcover (see *Photograph 1)*. This community was characteristic of the northern two thirds of the site, with sporadic regeneration evident. Isolated occurrences of *Schinus areira* (pepper tree), *Angophora floribunda* (rough barked apple), *Populus alba* (white poplar) and *Salix babylonica* (weeping willow) were also noted throughout this community.

The shrub layer was restricted to scattered thickets of *Lycium ferrosum* (African boxthorn) and the occasional stand of *Arundo donax* (bamboo).

The groundcover was dominated by *Verbena bonariensis* (purpletop), *Cynodon dactylon* (common couch), *Gomphocarpus fruticosus* (narrow-leaved cotton bush) and *Bidens pilosa* (cobblers pegs).

In lower lying areas, sedges and rushes dominated the ground cover and included species such as *Juncus usitatus* and *Schoenus apogon* (river club rush). *Typha orientalis* (broad-leaved cumbungi) was commonly encountered in isolated pockets of the creek.

4.1.2 River Red Gum Open Woodland

This community was recorded within the southern portion of the site, outside of the proposed longwall panels (*Figure 3.2*). The canopy was dominated by *Eucalyptus camaldulensis* (river red gum), with isolated occurrences of *Eucalyptus crebra* (narrow-leaved ironbark) and *E. moluccana* (grey box) extending into the adjacent paddocks (*Photograph 2*).

Weeping willow was also noted where this community forms a transition zone with the river oak woodland. This species is not listed as a noxious weed however it is recommended for inclusion in the weed management plan for the riparian corridor.

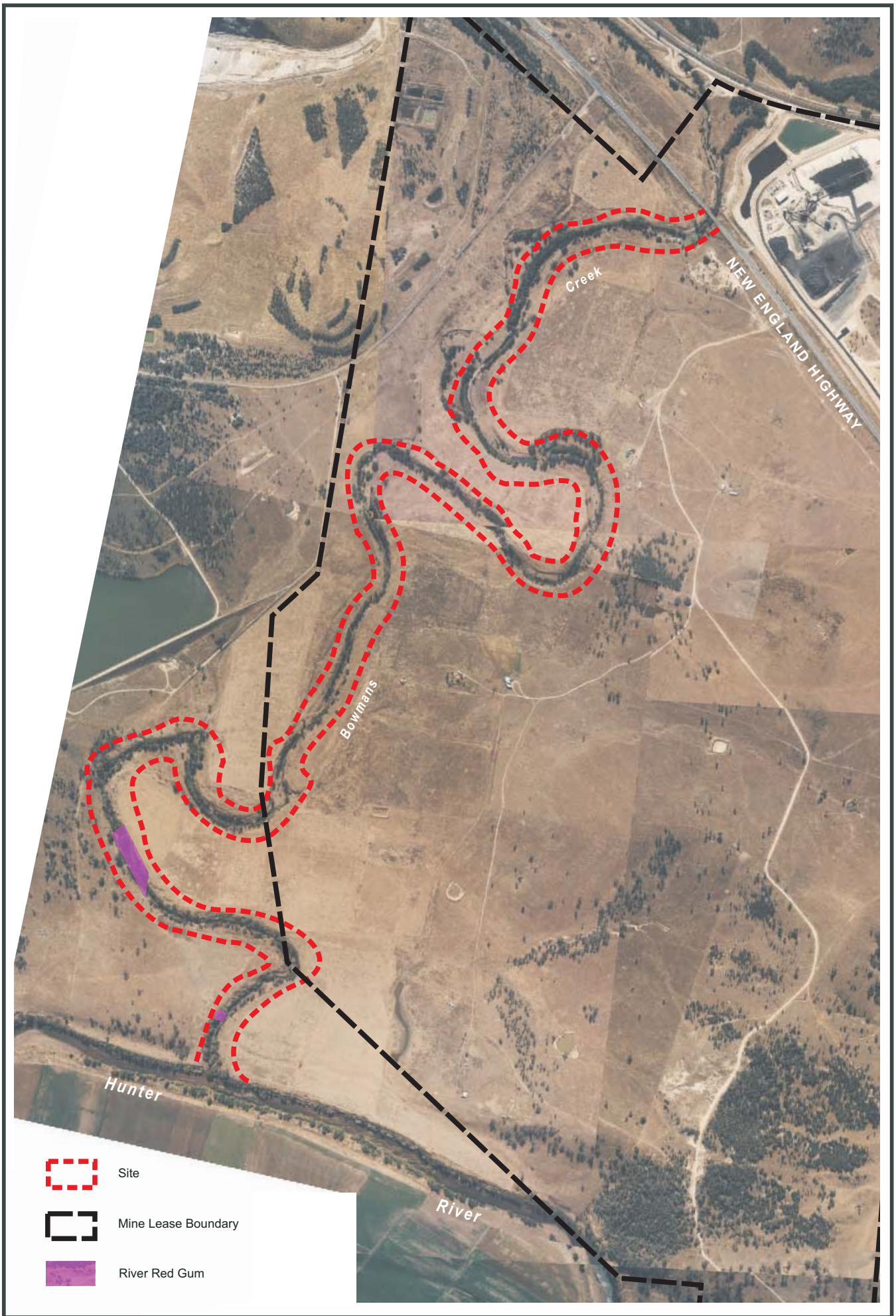

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Figure 3.2 **Vegetation Communities**

Ashton Coal - Bowmans Creek Monitoring, Camberwell NSW

Photograph 1

River oak woodland.

Photograph 2

River red gum population.

Targeted searches did not reveal any threatened plant species within the riparian corridor. However, the *Eucalyptus camaldulensis* (river red gum) open woodland constitutes an endangered population as discussed below.

4.2 *ENDANGERED POPULATIONS*

The river red gum population in the Hunter Catchment has been identified as an endangered population under Part 2 Schedule 1 of the TSC Act 1995. The population of river red gum in the Hunter is unique in NSW being the only one to occur in a coastal catchment.

4.2.1 *Habitat Description*

The river red gum population is of conservation significance as the community is dominant in distinct riparian and floodplain vegetation types. It generally occurs in association with *Eucalyptus tereticornis* (forest red gum), *Eucalyptus melliodora* (yellow box), *Casuarina cunninghamia* (river oak) and *Angophora floribunda* (rough barked apple) (DEC, 2005).

4.2.2 *Distribution*

The Hunter population occurs from the west at Bylong, south of Merriwa, to the east at Hinton, on the bank of the Hunter River, in the Port Stephens local government area. It has been recorded in the local government areas of Lithgow, Maitland, Mid-Western Regional, Muswellbrook, Port Stephens, Singleton and Upper Hunter.

The former range of suitable habitat for this population in the Hunter catchment was between 10 000 to 20 000 hectares. The river red gum population is currently restricted to approximately 100 hectares in 19 stands. Remnant size is restricted to one or several trees with the largest remnant between 15 to 20 hectares (DEC, 2005).

4.2.3 *Presence and Quality of Habitat*

The presence of this community within the site is restricted to a narrow band along either side of Bowmans Creek, to the south of the predicted subsidence area. No regeneration of *E. camaldulensis* is evident and the maximum diameter at breast height was 45 cm.

The understorey species were similar to the remaining vegetation communities and was characterised by both native and introduced grass species. Relatively high levels of disturbance were noted along the entire length of the site and included cattle grazing, clearing, weed invasion and erosion (see *Photograph 3*).

Photograph 3

Erosion of western side of Bowmans Creek.

Photograph 4

View of cobblestones looking south over Quadrat 1.

4.2.4 *Recommendations*

In accordance with the Conditions of Consent, the identification of this endangered population requires the development of appropriate amelioration measures prior to the commencement of mining under Bowmans Creek. A management plan is being developed for this endangered ecological population occurring on site, which may involve consultation with the Department of Environment and Conservation (DEC).

At this stage, it is recommended that cattle are excluded from the creekline, particularly in close proximity to the river red gum population. The health of the riparian corridor would then be reassessed during the next terrestrial habitat monitoring period (bi-annual surveys) and the necessary management measures implemented.

4.3 *FAUNA OBSERVATIONS*

Opportunistic fauna observations were recorded during the vegetation assessment (see *Table 4.1*). The grey-crowned babbler and speckled warbler were not recorded during these investigations however they have been recorded within connecting habitat to the east of the riparian corridor (ERM, 2005).

Table 4.1 Fauna Species List

Scientific Name	Common Name	Observation Type
Avifauna		
Eurystomus orientalis	dollarbird	o
Hirundo neoxena	welcome swallow	o
Merops ornatus	rainbow bee-eater	o
Poephila guttata	zebra finch	o
Rhipidura leucophrys	willy wagtail	o
Coracina novaehollandiae	black faced cuckoo shrike	o
Corvus coronoides	Australian raven	o
Gymnorhina tibicen	magpie	o
Strepera graculina	pied currawong	o
Platycercus eximius	eastern rosella	o
Cracticus nigrogularis	pied butcherbird	o
Cacatua roseicapilla	galah	o
Malurus assimilis	variegated wren	o
Gallinula tenebrosa	dusky moorehen	o
Philemon corniculatus	noisy friarbird	o
Ardea novaehollandiae	white faced heron	o
Chenonetta jubata	wood duck	o
Anas superciliosa	pacific black duck	o
Falco cenchroides	Australian kestrel	o
Reptiles		
Physignathus lesueurii	water dragon	o
Mammals		
Macropus giganteus	kangaroo	o
Lepus capensis	brown hare	o
Bos sp.	cow	o
Felis catus	cat	o

o = direct observation

4.4 TERRESTRIAL HABITAT RESOURCES

The myrtaceous trees in the areas of river red gum open woodland would provide a seasonal foraging resource for nectivorous birds and mammals (*Eucalyptus camaldulensis* flowers July to February). Eucalypts would also provide suitable feeding/foraging resources for folivorous fauna such as the common brushtail possum and insectivorous birds such as treecreepers. The availability of these myrtaceous species is relatively sparse due to the dominance of *Casuarina cunninghamia* (river oak).

The grasses and sedges provide seed and stem resources for granivorous and herbivorous species. The *Casuarina* species that dominates the riparian corridor provides a limited seasonal foraging resource for highly mobile granivorous fauna such as the glossy black cockatoo. Understorey species such as *Lycium ferocissimum* provide foraging resources for many species favouring fruits and berries.

This habitat type has a moderate layer of leaf litter (five centimetres deep), fallen logs and rock outcrops that provide sheltering resources for small ground-dwelling mammals and reptiles (see *Photograph 4*).

The site contains a limited number of mature trees that provide hollows capable of providing shelter and breeding habitat for a large number of bird and arboreal mammal species.

Bowmans Creek, although intermittent in nature, provides habitat for aquatic avifauna and frogs as well as a drinking resource for many native species.

4.5 HABITAT FRAGMENTATION AND CORRIDORS

Corridors are important for linking remnant areas of vegetation and for facilitating the many ecological processes required to sustain biodiversity. Corridors are seen to promote opportunities for fauna movement and the long-term viability of species as they reduce the effect of isolation of small remnant patches of vegetation.

The open woodland habitat identified within the riparian corridor is relatively well represented within the locality, although it currently provides only tenuous links with the surrounding vegetation. As indicated within *Figure 3.2, s*mall sections of wooded land occur immediately east of the northern-most oxbow of Bowmans Creek with isolated tracts of vegetation located approximately 650 metres to the east and larger tracts of vegetation identified as open grassy woodland located approximately 900 metres to the east. To the north, west and south, the woodland does not provide any vegetated links or wildlife corridors and is currently an isolated/remnant. There is, however, opportunity for the southern woodland to function as a wildlife corridor between the Hunter River to the south and Glennies Creek to the east as discussed below.

4.6 *RECOMMENDATIONS TO ENHANCE CONNECTIVITY BETWEEN EXISTING VEGETATED AREAS*

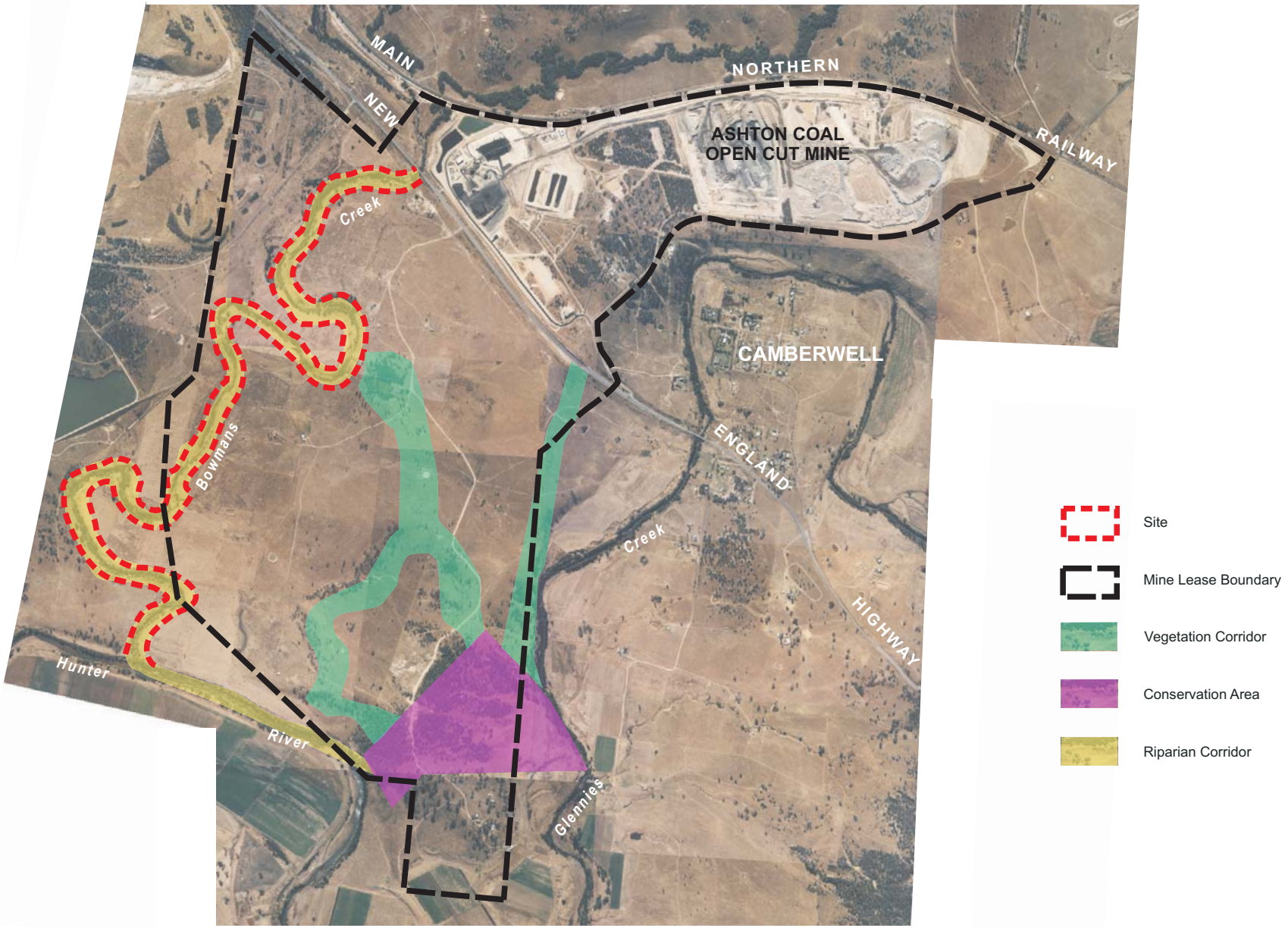
The Bowmans Creek riparian corridor currently provides habitat for a variety of native species although it is currently limited to those species that are highly mobile, that is birds and large mammals, or those species requiring small home ranges such as small terrestrial mammals and reptiles. If the corridor was extended to the east by approximately 50 to 100 metres it would act as a wildlife corridor between the two large water systems (Hunter River and Bowmans Creek), providing greater habitat and movement opportunities for a diverse range of native species.

Previous investigations (ERM, 2005) have identified the location of suitable vegetation corridors to enhance the habitat value of the riparian corridor (*Figure 3.3*). The following recommendations have been made:

- supplementary planting of locally occurring native species should be undertaken within the recommended vegetation corridors prior to the commencement of underground mining. This would establish a connection with the riparian vegetation associated with Glennies Creek to the east and enhance the connection with the southern woodland conservation area and riparian vegetation along the Hunter River to the south. Cattle must be excluded from all supplementary planting areas;

- Native tree species grown from local provenance seeds are recommended for the corridor areas. This is particularly important for enhancing the existing river red gum population in the Hunter catchment. Species to be used in revegetation corridors connecting Bowmans to habitat in the south and east could also include *Eucalyptus crebra, Eucalyptus moluccana, Eucalyptus fibrosa, Corymbia maculata, Eucalyptus blakelyi, Eucalyptus punctata, Daviesia ulicifolia, Acacia decora, Acacia amblygona* and *Acacia parvipinnula;* and;

- annual surveys should be conducted within the revegetated areas to ensure no significant loss of trees, as well as monitoring the use of the newly established corridors by native fauna.



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Approximate Only

Figure 3.3 **Vegetation Corridors**

Ashton Coal - Bowmans Creek Monitoring, Camberwell NSW

5 AQUATIC ASSESSMENT RESULTS

The results of the December and May/June aquatic surveys are provided in Chapter 3 of *Annexures A* and *B*, respectively. The rapid assessment method (RAM) sampling yielded a total of 58 macroinvertebrate taxa in the spring survey, 44 from Bowmans Creek (33 from edge and 24 from riffle) and 42 taxa from Rouchel Brook (29 from edge and 26 from riffle). This reduced to 46 in the autumn survey, with 38 from Bowmans Creek (31 from edge and 21 from riffle) and 29 taxa from Rouchel Brook (29 from edge and 0 from riffle).

5.1 SPECIES OF CONSERVATION SIGNIFICANCE

No specimens belonging to the threatened invertebrate species *Archaeophya adamsi* (Adam's emerald dragonfly*), Austrocordulia leonardi (*Sydney hawk dragonfly*)* or *Notopala sublineata (*river snail*)* were recorded in Bowmans Creek or Rouchel Brook. It is not expected that any threatened species native to the area will be found; however, if any were discovered, the Ashton Coal Environmental Officer would be contacted immediately and assistance given in consultations with the Department of Primary Industries (Fisheries) to identify an appropriate amelioration strategy.

5.2 AQUATIC HABITAT ASSESSMENT

Habitat assessment undertaken in Spring 2005 and Autumn 2006 has shown marked differences in aquatic habitat due to seasonal and climatic conditions. The most significant change was the reduction of water level in all sites, with the associated loss of habitat diversity and extent. Seasonal change in the amount of vegetative detritus within the watercourses and stream shading, due to exotic deciduous trees undergoing leaf-fall were also observed. These changes are independent of any potential future mine subsidence related impacts and need to be considered in any assessment of impacts during and following longwall extraction.

Bowmans Creek was found to be ephemeral within the site. In December 2005 it was noted that there were dry, exposed areas, at the downstream end of Site 3, and downstream of Sites 1 and 2. The exposed areas outside of the control locations in Bowmans Creek were thickly overgrown with grasses and rushes and appeared as though water had not flowed through in some time. The exposed area of Site 3, however, appeared to have flowed recently. In the Autumn survey it was noted that the sections of dry, exposed areas had increased. This change was minimal in Site 4 (impact area, most downstream site) in Bowmans Creek. However in all other sites this change was significant and extensive.

Riffle habitat was found at three of the six sites in the Spring 2005 survey, however only Site 4 in Bowmans Creek contained flowing riffle habitat that

could be sampled in the current survey. In Spring 2005, the remaining three sites had exposed cobble bars which could act as riffles after times of heavy rainfall.

In Spring 2005 it was noted that overhanging branches, macrophytes, and snags existed at all sites in Bowmans Creek and Rouchel Brook which could be used as habitat by fish. However, many of these that were within the watercourse during the Spring 2005 survey were exposed in the current survey and no longer provided fish habitat. Some aquatic habitat persisted at all sites in the Autumn survey, however pools that were considered permanent in the Spring 2005 survey at Sites 1, 3 and 6 provided only minimal refuge and would not be likely to persist longer that a few more weeks without significant rainfall within the catchment. These remaining isolated pools contained a high density of fish and while providing only poor habitat because of reduced extent, poor water quality, and little habitat variety, were very important environmental refuges. If fracturing were to occur due to subsidence, these important aquatic refuges could be drained.

Barriers to fish passage existed between all the sites in Bowmans Creek and had increased significantly since the December survey. The waterways classification as 'moderate fish habitat' given at all sites in Bowmans Creek reflects this. The fords in Rouchel Brook could act as barriers to fish passage in times of low rainfall, a condition reflected in the waterways classification of 'moderate-major fish habitat'.

The lowest riparian channel environment (RCE) scores were given to the control sites in Bowmans Creek and the highest to those in Rouchel Brook, although all were fairly similar. The difference in scores was due to less frequent riffles and fewer logs in Bowmans Creek than that of Rouchel Brook.

Rouchel Brook was not ideal as an external control due to its higher elevation and the presence of fords; however, due to the existence of 37 coal mines and 4 dams in the area, Rouchel Brook was the most similar creek to Bowmans that could be found. Like Bowmans Creek, Rouchel Brook had riffle pool sequences, nearby roads and similar vegetation and surrounding land use.

5.3 WATER QUALITY

Most water quality variables at all sites were within ANZECC guidelines. Differences in conductivity and salinity recorded at the Bowmans Creek and Rouchel Brook sites may be attributable to differences in distance from headwaters, catchment geology, input of saline groundwater and distance travelled underground. The low dissolved oxygen (DO) levels at all sites (all lower than ANZECC guidelines) could be a cause for concern as oxygen is essential to all forms of aquatic life. Variations in DO can occur seasonally and over shorter periods due to factors such as salinity, turbulence, temperature and biological activity (Chapman and Kimstach, 1992). There were some noticeable differences recorded in water quality between the

current survey and the Spring 2005 survey in conductivity, ORP and pH, however none of these variations were beyond the variability that would be expected within a large and extensively disturbed catchment such as the Hunter Valley.

5.4 FISH AND LARGE CRUSTACEANS

The reduction in area of fish habitat in the Autumn survey due to the greatly reduced water levels provided an opportunity to undertake a thorough survey of those species present. The combination of bait-trapping and electrofishing used in small isolated pools is likely to have accounted for most species present. Within the impact sites in Bowmans Creek, a variety of fish were found including commercial species (bully mullet, longfinned eel), recreational species (Australian bass and freshwater catfish) and introduced pest species (carp and mosquito fish). This has demonstrated that although Bowmans Creek has been described as being "moderate fish habitat" because of its ephemeral nature and many barriers to fish migration, it does provide habitat for a variety of species, and the fish fauna does form a significant and important part of the aquatic ecology of this watercourse.

5.5 MACROINVERTEBRATES

Overall, most sites, with the exception of Site 5 (Rouchel Brook), were impaired compared to reference conditions in the AUSRIVAS model. This is supported by low SIGNAL scores, with macroinvertebrate assemblages comprised primarily of pollution tolerant taxa, typical of impacted systems. Slight changes were observed between Spring 2005 and Autumn 2006, however, these changes should be considered within the associated summer climate and the contraction of available aquatic habitat, with organisms likely to retreat into densely populated refuge zones.

The RCE scores indicated that the surrounding riparian environments have undergone changes in land use activities, likely to influence these results. These impaired baseline conditions need to be considered when examining trends in data from long term monitoring.

5.6 KEY THREATENING PROCESSES

Threatening processes that are considered relevant to the aquatic assessment are discussed below:

Degradation of native riparian vegetation along New South Wales water courses (*FM Act*).

Mine subsidence impacts in the vicinity of Bowmans Creek have the potential to alter stream morphology which could result in increased erosion and degradation of riparian vegetation. Regular monitoring of mine subsidence impacts within Bowmans Creek would allow the rapid identification of such degradation, such that mitigation methods can be instigated, and remediation measures can be undertaken if required.

Alteration of habitat following subsidence due to longwall mining (*TSC Act*).

Aquatic habitats have the potential to be altered or removed as a result of subsidence-induced fracturing of the creek substratum due to longwall mining. This can lead to the alteration of habitats through the draining of pools, changes in water quality, and variation in flow characteristics. The proposed monitoring of aquatic habitats during and after longwall extraction outlined in this study, will allow the identification of such habitat alteration. The recommended monitoring proposal will also allow determination of the extent of such an impact, the likelihood of natural recovery or the need for, and nature of, remediation.

Predation by Gambusia holbrooki (mosquitofish) (*TSC Act*).

Mosquitofish are abundant throughout the site, with very high numbers recorded at all sites in Bowmans Creek (see *Annexures A* and *B*). Degradation of habitat through the loss of riparian vegetation or the deterioration of water quality resulting from subsidence in the vicinity of the creek, could provide conditions suitable for the increased proliferation of mosquitofish. This may have a detrimental effect on small native fish which inhabit the area. Regular monitoring of fish within the site, in combination with monitoring of aquatic habitat will identify such impacts.

6 DISCUSSION AND RECOMMENDATIONS

Bowmans Creek showed many signs of anthropogenic disturbance, including weed invasion, erosion, cattle grazing, low dissolved oxygen, high salinity, low fish diversity (particularly natives) and a pollution tolerant macroinvertebrate community. Comparison of results between the Autumn 2006 survey and the Spring 2005 survey shows that environmental variables, not associated with mining activity, have an extensive impact on the aquatic ecology of this watercourse. These degraded conditions, in combination with environmental variability may make the assessment of any future impacts caused by longwall mining difficult to detect.

The use of control sites that are not impacted by longwall mining will, however, allow comparisons between impact and non-impact areas. In regards to the aquatic assessment, a monitoring program that assesses multiple indicators of creek health will also assist with the detection of any future changes. It is recommended that the monitoring program outlined in the following chapter is undertaken twice a year, with a longer term post monitoring program to be established at the completion of the underground mining.

Opportunities for revegetation are recognised within the mine lease area south of the New England Highway and will provide a connection between the Bowmans Creek riparian corridor and habitat associated with the southern woodland conservation area, the Hunter River and Glennies Creek to the south and east.

It is recommended that a management plan be developed for the river red gum endangered population occurring on site, south of the proposed longwall panels. Cattle should also be excluded from the creekline, particularly within close proximity to this population. The health of the riparian corridor would then be reassessed during the next terrestrial habitat monitoring period and the necessary management measures implemented.

To provide a safe movement, high quality corridor, the following recommendations are given:

- revegetation of designated corridor areas with native tree species such as *C. cunninghamia*, *Eucalyptus crebra*, *E. moluccana*, *E. fibrosa*, *Corymbia maculata*, *E. blakelyi*, *E. punctata*, *Daviesia ulicifolia*, *Acacia decora*, *A. amblygona* and *A. parvipinnula*;

- all revegetation works must be fenced from cattle during the establishment stage to increase survival rate of planted tubestock. Periodic grazing by stock is encouraged once tree species reach a height of three metres to minimise fuel load within the corridor;

- annual monitoring of revegetated areas to assess survival and establishment rates through vegetation surveys;

- annual fauna monitoring census to assess fauna movement in revegetated corridors; and,

- preparation of a weed management plan for the Bowmans Creek riparian corridor.

7 RECOMMENDED POST-MINING MONITORING PROGRAM

This survey design is recommended for the post-mining assessment and should be undertaken within 12 months of the completion of the long wall mining.

7.1 AQUATIC MONITORING

Monitoring is an important tool for management of aquatic ecosystems as it allows early indication of impending impacts. This facilitates an accelerated response for mitigation or remediation of those impacts. Monitoring programs can include, amongst other components, use of biological and/or physico-chemical indicators. For Bowmans Creek within the proposed underground mining area, and at control sites and external control sites (in Rouchel Brook), it is recommended that a photographic catalogue, along with habitat assessment, water quality measurements, fish sampling and macroinvertebrate sampling be used to monitor any effects of mine subsidence. The methods outlined in this study are intended to be used in an ongoing monitoring program currently being developed by Ashton Coal operations that will allow assessment of impacts resulting from mine subsidence on aquatic ecology (refer to *Annexures A* and *B*).

We concur with the current plan to sample in predicted impact and control locations on one more occasion prior to the commencement of longwall mining (Ashton Coal, 2005). Sampling was done between 15 March, 2006, and 15 June, 2006, and coincided with autumn AUSRIVAS sampling times. This will allow for the establishment of an appropriate baseline of information which is essential for monitoring the effects of any subsidence and also the effectiveness of any remedial works, such as grouting of fractures.

Monitoring should be done twice within one year of the longwall passing beneath Bowmans Creek (Ashton Coal, 2005). We recommend that these monitoring times coincide with AUSRIVAS spring and autumn sampling times to allow the use of the AUSRIVAS predictive model. If sampling is to be undertaken outside of the sampling periods allowed for the AUSRIVAS model, we suggest that quantitative sampling methods be used. This immediate post-mining sampling will allow assessment of ecosystem changes by comparison with the baseline information. It will allow the assessment of impacts from subsidence or other mining impacts on fish, fish passage, macroinvertebrates, riparian vegetation aquatic habitat and assist with recommendations for any necessary remedial works.

Long-term monitoring will be required bi-annually for at least five years following the completion of longwall mining under Bowmans Creek (Ashton Coal 2005). This will allow assessment of long-term stability of ecosystems against the pre-mining baseline studies. Changes which may not have been obvious immediately after mining, such as those to vegetation communities, as well as impacts to fish, fish passage, macroinvertebrates, riparian vegetation and aquatic habitat, will therefore be able to be assessed. This sampling would coincide with AUSRIVAS spring and autumn sampling times.

7.2 *RIPARIAN VEGETATION AND HABITAT MONITORING*

The riparian vegetation and habitat monitoring component of the Bowmans Creek monitoring program will be undertaken twice within twelve months of the completion of the longwall mining. The aim of this monitoring will be to identify any changes in vegetation composition and structure that occurs as a result of underground mining. This will be undertaken by comparing the results of the surveys within the subsidence impact area with control sites located to the north and south of the longwall panels. These results will also be compared to the baseline results as outlined within this report.

A total of twelve transects and twelve quadrats will be surveyed at the established locations. These survey sites include the endangered river red gum population. The following attributes should be noted during the surveys:

- dominant species within each structural layer;
- percentage cover of each structural layer;
- level of disturbance;
- evidence of regeneration; and,
- searches for secondary indications and incidental observations of resident fauna.

It will also be important to keep a photographic database of the survey locations to show any long term changes in the riparian vegetation.

7.3 *REPORTING*

One report shall be produced following the two survey periods detailing the results of the post-mining monitoring program and comparison with the baseline data.

Based on the results of the post mining monitoring program and the identification of any impacts on Bowmans Creek as a result of the underground mining, a long term monitoring program would be designed. This monitoring program would assess the long term stability of the ecosystems against the baseline surveys and will be undertaken twice a year for at least 5 years following the completion of the long-wall mining.

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Annex A

The Ecology Lab Aquatic Assessment Spring 2005

Report to:

ERM Australia

Report 1

Ashton Coal Project: Aquatic Habitat Assessment and Recommendations for Monitoring

Final

October 2006

Report prepared by:

The Ecology Lab Pty Ltd

The Ecology Lab Pty Ltd

Marine and Freshwater Studies

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Ashton Coal Project: Aquatic Habitat Assessment and Recommendations for Monitoring

October 2006

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Environmental and Resources Management Australia

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1.0 INTRODUCTION

1.1 Background and Aims

Ashton Coal Operations Pty Ltd proposes to extend its Ashton Coal Project with the development of an underground mine. The project is located approximately 14 km northwest of Singleton in the Hunter Valley region of NSW. It includes an existing open cut mine, a Coal Handling and Preparation Plant and associated rail siding and infrastructure. The proposed underground mines include seven longwalls, three of which will lie beneath Bowmans Creek.

The Ecology Lab Pty Ltd was engaged by Environmental Resources Management Australia Pty Ltd to develop and undertake a stream monitoring program for Ashton Coal Operations as required by consent conditions 3.19 and 3.20 in Development Application DA No 309-11-2001-i issued by the Minister for Planning.

The study area included the reach of Bowmans Creek within the area of proposed underground workings (Figure 1), a control location in Bowmans Creek upstream of the proposed longwall operation and an external control in Rouchel Brook (Figure 2). Bowmans Creek and the reach of Rouchel Brook are both unregulated streams.

The proposed mining has the potential to affect aquatic habitats and biota within the study area and further downstream. Potential impacts of mining on aquatic ecology include the loss of refuge and alteration of habitat in waterbodies, impacts on fish passage (connectivity between up and downstream habitat), changes in water quality within and downstream of the impacted areas and impacts on species of conservation significance.

This document is a baseline report on aquatic habitats, fish and macroinvertebrates of Bowmans Creek and Rouchel Brook. It includes recommendations for further monitoring and discusses aquatic ecology issues as they relate to the proposed mining operation. Specifically, the aims of this report are to:

- describe aquatic habitats of Bowmans Creek within areas potentially affected by underground mining works and selected control locations,
- establish baseline conditions of aquatic habits, fish, and macroinvertebrates against which changes in these components can be assessed,
- recommend methods for monitoring that will assess impacts from longwall mining and potential mine subsidence affecting Bowmans Creek.

1.2 Existing Information

Coal mining is a major industry in the Hunter Valley. Long wall mining is known to have impacts on aquatic habitats located above the long walls. The most common effects observed are related to the subsidence of creek beds, with loss of water due to cracking, changes to fish habitat and alterations to fish passage. Secondary effects due to changes in water quality have also been reported.

Recorded effects of subsidence associated with underground coal-mining operations have included deformation of surface structures, loss of important terrestrial habitats, impacts on local and regional hydrology, including the alteration of preferential flow paths causing dewatering and rerouting of surface waters and ground water (Mather *et al*. 1969). The

effects of longwall mining beneath a stream in the United States included changes in the length of cascades, increases in pool volume and frequency, increases in grain size of sediments within pools and changes in stream morphology (Sidle *et al.* 2000). The loss of areas of wetlands and coastal saltmarsh habitats has been reported in other studies of subsidence resulting from human activities in the US (DeLaune 1990; White and Tremblay 1995). Bowmans Creek has been previously impacted by subsidence caused by longwall mining in reaches upstream of the present study area (Department of Sustainable Natural Resources 2003 cited in Web Reference 1).

Predicted effects of longwall mining include subsidence of parts of Bowmans Creek and draining of some aquatic habitats for a short period (Ashton Coal 2005). It is believed that cracks caused by subsidence are likely to fill with sediment and aquatic environments will re-establish once mining and further cracking ceases. Some minor rectification works may be necessary should nick points in Bowmans Creek occur or flows become altered. These works are predicted to prevent erosion and mobilisation of sediment, maintain flow velocities and prevent stream break out during periods of high flow (Ashton Coal 2005).

2.0 STUDY METHODS

2.1 Review of Existing Information

The library database of The Ecology Lab (containing over 20 000 specialist references concerning aquatic environments) was searched for relevant material on aquatic habitats and fish, water quality and macroinvertebrate surveys done in the area. In addition, the NSW Fisheries (NSW Department of Primary Industries) (Web Reference 2) and Department of Environment and Heritage (Web Reference 3) websites were viewed and current schedules of threatened species, populations, and communities were obtained. The Government of NSW Legislation website was accessed to obtain relevant Key Threatening Processes (Web Reference 4). The NSW government Bionet system (Web Reference 5) was used to search for government agency records of threatened species within the upper Hunter River system.

In reference to the current mining proposal, The Ecology Lab was provided with mine plans by Ashton Coal indicating the proposed layout of the Ashton Coal Project longwalls. In addition, the Camberwell and Rouchel Brook 1:25,000 topographic maps (Central Mapping Authority of NSW) and Camberwell 1:100,000 topographic map (Royal Australian Survey Corps) were used to identify the size, setting and elevation of Bowmans Creek and Rouchel Brook and surrounding land use patterns and to assist in site selection. The Ashton Coal Flora and Fauna Management Plan (2005) was used to determine potential impacts of the proposed underground mining.

2.2 Field Studies

2.2.1 Site Selection

Bowmans Creek was visited on the 1 December 2005. The length of the creek within the area potentially affected by longwall mining was inspected. This allowed potential impact sites to be chosen which would be representative of the potentially affected reach. Two study locations were selected, one within the area to be mined (predicted impact area) and one upstream of the proposed underground workings (control area). Sites were numbered with the lowest number furthest upstream. Wollombi Brook, Rixs Creek, and Glennies Creek were all inspected for their potential as external control sites. However, these were all unsuitable due to significant differences from Bowmans Creek, such as having large dams upstream (and cold water dam releases), different morphologies, flow rates and substratum, and coal mine discharges. The external control location chosen was at Rouchel Brook, first visited on 15 December 2005. Controls were defined as locations similar to the predicted impact location, which would not be affected by the proposed mining. Sampling in control locations provides an estimate of background variability against which changes at the putative impact site could be compared. The chosen control locations included reaches of the watercourses containing a similar variety of aquatic habitats as present in the Bowmans Creek study area. Within each location two study sites (consisting of 105 - 155 m reach of waterway) were identified.

2.2.2 Habitat Assessment

Field studies were carried out from 1 to 2 December and from 15 to 16 December 2005. A qualitative assessment of aquatic habitats was compiled for each site, including the following attributes:

- GPS position (datum: WGS 84),
- general land use of surrounding areas,
- instream features such as sequence of pools, runs and riffles (shallow areas with broken water),
- flow, measured at each site using a flowmeter,
- stream substratum,
- presence, extent and type of instream and riparian vegetation,
- potential refuge areas during periods of low flow (e.g. large deep pools),
- presence of fish habitat including snags, bank undercuts and aquatic plants,
- presence of barriers to fish passage into and beyond the study area,
- waterway type using a classification scheme outlined in Fish Passage Requirements for Waterway Crossings (Fairfull and Witheridge, 2003) (Appendix 1),
- bank structure, using Riparian, Channel and Environmental (RCE) scores. This methodology was developed by Petersen (1992), and later modified by Chessman and scores sites based on 13 different categories describing the adjacent land and the physical condition of the stream banks, channel and bed (Appendix 2). The scores are summed to provide the RCE score which provides an index of the environmental state of particular locations for use in management decisions. The version used in this study was based on modifications initiated by New South Wales Environmental Protection Authority. The highest possible score (52) would be assigned to a stream with little or no obvious human disturbance and containing very good habitat characteristics (e.g. diversity of habitats, good shelter, etc.). The lowest possible score (13) would be assigned to a stream with strong evidence of human disturbance and poor aquatic habitat.

A photographic record of the watercourses was obtained using a digital camera to assist in description of the site.

2.2.3 Water Quality Measurements

Water quality was measured at each site using a Yeo-Kal 611 probe. Variables measured included pH, dissolved oxygen (DO), salinity, oxidation-reduction potential (ORP), temperature, turbidity and conductivity. Two replicate measures were taken from just below the water surface at each site. Where applicable, the results were compared to ANZECC (2000) water quality guidelines for the protection of aquatic ecosystems.

2.2.4 Fish and Decapods

Fish and large mobile invertebrates such as crayfish were sampled using small baited traps and a back-pack electrofisher (Model 12-B Smith-Root). At each site, six baited traps were deployed in a variety of habitats such as amongst aquatic plants and around snags, in deep holes and over plant litter and bare substratum. The traps were 350 mm long, 200 mm wide with an entrance that tapered in to 45 mm, with 3 mm mesh size throughout. The traps were baited with approximately 70 ml of a mixture of chicken pellets and sardines and deployed for 1.5 hours. Fish caught were collected, identified and released. Alien species were not returned to the water.

Backpack electrofishing was undertaken to gain a qualitative overview of fish species present in each location. The reach of the watercourse was electrofished from downstream to upstream. The back-pack electrofisher was operated around the edge of pools, around snags and aquatic vegetation, overhanging banks, rocky crevices and in riffles. Electrofishing was conducted in five second shots. Stunned fish were collected in a small scoop net, identified and measured. Native species were released unharmed whilst alien species were not returned to water.

2.2.5 Macroinvertebrates

Aquatic macroinvertebrates were sampled in accordance with the Rapid Assessment Method (RAM) based on the Australian River Assessment Scheme (AUSRIVAS) (Turak *et al.* 2004, 2001). The AUSRIVAS model was developed by NSW EPA (now Department of Land and Conservation) to assess invertebrate assemblages against reference conditions derived from a range of waterways with similar physical and chemical characteristics. The model produces a rating based on a comparison of the invertebrate assemblage present at a site to the assemblage expected to occur at the site and is indicative of the environmental condition of a waterway Turak *et al.* 2001).

2.2.5.1 Field Sampling Methods

Field sampling for macroinvertebrates took place 15 and 16 December 2005 at 4 sites on Bowmans Creek and 2 sites on Rouchel Brook. The length of sites for RAM sampling were determined as distance of 10 x mode stream width or to a minimum of 100 m length, in accordance with the protocol. Dip nets with a mesh size of 250 μm were used to collect invertebrates from stream edge and riffle habitats. Edge habitat is defined as areas along creek banks with little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, macrophyte beds, overhanging banks and areas with trailing bank vegetation. Riffle habitat is defined as an area of broken water with fair to rapid current, with some cobble or boulder substratum (Turak *et al.* 2004).

Sampling Methodology - Edge Habitats

At each site edge habitat was sampled from slow moving pools. The dip net was first used to disturb animals by agitating bottom sediments and suspending invertebrates into the water column. The net was then swept through this cloud of material to collect invertebrates. Efforts were made to include surface dwelling animals. Samples were collected over a total length of 10 m, usually in 1-2 m sections, ensuring all significant edge subhabitats within the site were included in the sample (Turak *et al.* 2004).

Sampling Methodology - Riffle Habitats

Riffle habitat was sampled by holding the net into the riffle downstream of the samplers' feet. The sampler started at the lower reaches of the riffle and shuffled upstream actively disturbing the substratum with their feet to dislodge animals. Riffle habitats were sampled to a total length of 10 m, ensuring different riffles (where available) and riffle subhabitats were included in the sample (Turak *et al.* 2004).

Suitable riffle habitats were not available at the time of sampling for Sites 1, 2 and 3 on Bowmans Creek, therefore these sites only have edge RAM components. However as habitats can change over time suitable riffle habitat at these sites would be assessed again in autumn should sampling occur.

Each RAM sample was rinsed in the net with local water to minimise fine particles and placed into a white sorting tray. Animals were picked from the tray using forceps and pipettes. Trained staff removed animals for a minimum period of thirty minutes. Thereafter, removals were performed in ten minute periods to a total of one hour, in which picking would cease if no new taxa were found in the ten minute period. Usually, the full hour was required for picking. Care was taken to collect cryptic and fast moving animals in addition to conspicuous or slow moving specimens. Animals collected were placed into a labelled jar containing 70 % Ethanol. The chemical and physical variables required for running the AUSRIVAS predictive model were recorded at each site (Turak *et al*. 2004).

2.2.2.2 Laboratory Methods

Animals were removed from any sediment residue and identified using a binocular microscope and counted to a maximum of ten animals, as per the AUSRIVAS protocol. In most cases, taxa were identified to family level except for Copepoda, Hydracarina, Nematoda and Oligochaeta. The family Chironomidae was identified to subfamily level as required by the model. While some families of Anisoptera (dragonfly larvae) and Gastropoda (snails) were identified to lower taxonomic resolutions (genus and species) as they could potentially include three threatened aquatic species. To validate identification of animals a second experienced scientist performed QA checks on each sample.

2.4 Statistical Analyses

Macroinvertebrates

Field sample collections for the AUSRIVAS Predictive Model assessment are restricted to spring and/or autumn (Turak *et al.* 2004). Because field samples were collected for this study in December 2005, the spring season AUSRIVAS model was applied to these data. The principal outputs of the AUSRIVAS software package are observed/expected (OE) values. The observed values are based on results that were collected. The expected values are derived from an appropriate "reference" condition within the model, selected on the basis of physical and chemical characteristics. The reference conditions were compiled from samples collected at a large number of sites across NSW during the establishment of the model.

AUSRIVAS outputs include the following two types of OE values:

OE50taxa: The O (observed) value in OE50taxa parameter is the number of macroinvertebrate families that were predicted to have a probability of occurrence greater than 50 % at the site and were actually collected. The E (expected) value in OE50taxa is the sum of the probabilities of finding the predicted macroinvertebrate families (with greater than 50 % probability of occurrence). OE values closer to a ratio of 1 indicate

macroinvertebrates similar to those of reference streams and the smaller the OE50 value, the more impaired the macroinvertebrate community is considered to be.

OE50SIGNAL: The Stream Invertebrate Grade Number Average Level (SIGNAL) biotic index was developed by Chessman (1995, 2003) as a means of determining environmental 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, while a value of 10 indicates a sensitive family. OE50SIGNAL is the ratio of the observed to expected averaged SIGNAL grades per site for taxa groups recorded with a probability of occurrence of more than 50 %.

AusRivAS also assigns bands of impairment to each site based on the OE50 values ranging from much richer than reference condition to far poorer than reference condition and allocates a condition of habitat (BAND) for both edge and riffle (Turak *et al*. 2004, 2001).

The condition of habitat was graded into the following categories:

- 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.

The lowest band score obtained for the two habitats within each site was taken as the sites overall condition (Overall BAND), as recommended by the AUSRIVAS protocol.

SIGNAL Index: Following the guidelines in Chessman (2003) grade numbers were allocated to taxa as described in OE50SIGNAL section above. SIGNAL Index was calculated by the sum of all grade numbers for taxa found at each habitat divided by the total number of taxa recorded in each habitat. SIGNAL Index may be used assess communities independent of the AUSRIVAS Protocol. The SIGNAL Index is an indication of water quality and graded into the following categories (Chessman *et al.* 1997).

- SIGNAL Index > 6 = Healthy Unimpaired
- SIGNAL Index 5-6 = Mildly Impaired
- SIGNAL Index 4-5 = Moderately Impaired
- SIGNAL Index < 4 = Severely Impaired.

3.0 RESULTS

3.1 Review of Existing Information

3.1.1 Threatened Species and Key Threatening Processes

One aquatic species listed as vulnerable under the *Fisheries Management Act* (1994) has been identified which may be present within the freshwater reaches of the Hunter River. This is the Silver Perch (*Bidyanus bidyanus*). This species is considered further in section 3.1.4.

One key threatening processes listed under the *Fisheries Management Act* (1994) and two listed under the *Threatened Species Conservation Act* (1995) have been identified as potentially relevant to the proposed mine:

- Degradation of native riparian vegetation along New South Wales water courses (*FM Act*).
- Alteration of habitat following subsidence due to longwall mining (*TSC Act*).
- Predation by *Gambusia holbrooki* (mosquitofish) (*TSC Act*)

3.1.2 Bowmans Creek

Bowmans Creek has its source in the Little Brothers Range and drains south into the Hunter River. It is located in the upper Hunter Valley within the Singleton Local Government Area. Approximately 4.5 km of the creek lies within the proposed underground workings area of the Ashton Coal Operations. The elevation of the reach in this area is between 50 and 70 m. The elevation of the headwaters is about 650 m Australian Height Datum (AHD). The surrounding catchment is relatively flat and consists predominately of pasture and scattered vegetation.

3.1.3 Rouchel Brook

The Rouchel Brook catchment lies to the north of Bowmans Creek catchment. The headwaters are in the Little Losy Mountain ranges at about 1000m AHD and the brook runs west from here to join the Hunter River. The elevation at the study sites is 200 – 220 m AHD. The surrounding catchment is undulating and consists of scattered and medium density vegetation and pasture. A report by the (then) NSW Department of Land and Water Conservation found Rouchel Brook to be under low environmental stress (based on indicators including bank and bed erosion, riparian vegetation, land use, fish barriers etc) and medium hydrological stress (derived by proportioning water extraction to a streamflow estimate) (NSW DLWC 1998).

3.1.4 Macroinvertebrates

As part of a qualitative assessment of fish habitats for White Mining, Marine Pollution Research sampled macroinvertebrates from edge pools at two sites in Bowmans Creek in 2001. The same number of taxa (five families) was found at both sites. The downstream site was found to have a more tolerant community than the upstream site, as determined by SIGNAL scores. The maximum signal score for the creek was 7 and the minimum was1.

Results from a study on macroinvertebrates sampled from several sites in the Hunter River Catchment including Rouchel Brook at Rouchel Brook indicate the macroinvertebrate communities in that creek were impacted by degraded bank conditions due to agricultural practices (Chessman *et al* 1997). The mean SignalHU97B values calculated for all 42 sites sampled across the Hunter River system ranged from 7.2 to 3.4. The mean Signal HU97B calculated for Rouchel Brook was 4.7 indicating a more tolerant macroinvertebrate community than those found in many of the other sites sampled in this study (Chessman *et al.* 1997).

3.1.5 Fish and Large Crustaceans

A search on the Bionet website (which consists of information from the collections of the Australian Museum, the NSW Department of Environment and Conservation and the NSW Department of Primary Industries) yielded 45 species of fish from the Hunter Catchment which could potentially be found in Bowmans Creek or Rouchel Brook (Table 1). Seven of these species are introduced: goldfish (*Carassius auratus*), common carp (*Cyprinus carpio*), roach (*Rutilus rutilus*), mosquitofish (*Gambusia holbrooki*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*) and brook char (*Salvelinus fontinalis*).

Silver Perch (*Bidyanus bidyanus*) are listed as a vulnerable species under the *Fisheries Management Act 1994* (Schedule 5) and have been found in the Hunter Catchment. However, they are not native to the Hunter System (Morris *et al.* 2001) and their occurrence there is only due to stocking of dams. For example from Glenbawn Dam (60 000 fish in 2002/03) and Glennies Creek Dam (14 000 fish in 2002/03) (Web reference 6) which are adjacent to the Rouchel and Bowmans catchments, respectively. There are no records of this species in Bowmans Creek or Rouchel Brook and they will not be considered in detail at this time.

The 2001 study by Marine Pollution Research found common carp and mosquitofish in Bowmans Creek. They also report a kingfisher taking a crayfish from the creek.

The Australian Museum has recorded the Darling Hardyhead (*Craterocephalus amniculus*) in Bowmans Creek (cited in Morris *et al.* 2001). This species is relatively common in the upper reaches of the Darling River system (Allen *et al.* 2002), however, there is confusion over whether specimens found in the upper Hunter River drainage are a separate species (Morris *et al* .2001). Because of this the Darling Hardyhead is not listed as threatened under any legislation but is considered to be of conservation concern (NSW Fisheries 2003). The species is normally found in slow-flowing, clear water or among macrophytes and its life history is unknown (McDowall 1980).

The freshwater catfish *Tandanus tandanus* is a species of concern and has been found in areas near Bowmans Creek and Rouchel Brook. It has been recorded in Goorangoola Creek and Fal Brook in the Glennies Creek catchment (adjacent to the Bowmans Creek catchment) and in the Hunter River just upstream of its junction with Rouchel Brook (Web Reference 5). The freshwater catfish is currently not listed as a threatened species in NSW, however, it has been suggested that inland populations be listed as vulnerable (Morris *et al.* 2001). It is found in a wide variety of habitats, including rivers and creeks and generally prefers sluggish or still waters (Cadwallader and Backhouse, 1983 cited in Morris *et al.* 2001). Females lay demersal, non-adhesive eggs which are guarded and fanned by the male, short term fluctuations in water levels during spawning months can cause these nests to be abandoned if they are exposed (Lake 1971 cited in Morris *et al.* 2001). If this species was present in Bowmans Creek and subsidence caused a drop in water levels, it could be impacted.

No records could be found of fish in Rouchel Brook. However, brown trout fry were stocked in the brook at Rouchel and Aberdeen in 1996, 1998 and 2001 by the Scone Fishing Club and the New England Trout Acclimatisation Society (NSW Fisheries 2003).

3.1.6 Water Quality

No studies of water quality could be found for Bowmans Creek or Rouchel Brook. Daily measurements of conductivity, water temperature, stream water level and discharge are taken by the Department of Natural Resources (Web Reference 7) at Rouchel Brook (at Rouchel Brook which is upstream of Site 5) and Foy Brook (downstream of Bowmans Creek Bridge which is upstream of Site 1).

River salinity leading to poor water quality is recognised as a significant issue affecting the Hunter River (Hunter Catchment Management Trust 2000). Salinity of water is influenced by geological factors and the degree of land salinisation in a catchment. The Hunter River becomes progressively more saline as it flows downstream due to the catchment geology (DLWC 1988 cited in Hunter Catchment Management Trust 2000).

3.2 Field Studies

The weather was fine on all days of the study except for 16 December 2005 which was overcast with several showers and strong winds. Prior to the first trip (1 – 2 December 2005) there was heavy rainfall within the catchment. GPS co-ordinates for all the sites are presented in Appendix 3.

3.2.1 Habitat Assessment

3.2.1.1 Area to be Mined

The two sites within the area to be mined (potential impact Sites 3 and 4) are situated on Bowmans Creek between the New England Highway and the Hunter River (Figure 1). They are approximately 2.4 river km apart. Site 4 lies above proposed Longwall 7, and Site 3 above Longwall 6. The sites were accessed by private road on land owned by Ashton Coal Operations. The surrounding land is low lying, mostly cleared and flat and used as cattle pasture. No wetland areas were found along the reach between the New England Highway and the Hunter River.

At Site 4 in Bowmans Creek the western bank was steep (Plate 1 upper) while the eastern side was less steep (Plate 1 lower) but equally high (approximately 8 m). The site consisted of a long, deep, permanent pool (Plate 1 lower) and two small shallow riffles, one at each end of the site (Table 2a) (Plate 2 upper). The riffles were shallow (Table 2a) and it was presumed that during dry periods water would cease to flow across them. The downstream riffle had a cobble, gravel substrate while the upstream riffle also had silt.

Site 3 on Bowmans Creek consisted of a cobble bar (Plate 3 upper) at the downstream end and a large long pool for the remainder of the site (Table 2a). It was assumed that in high flow conditions the cobble bar would act as a riffle. At the time of sampling (despite recent heavy rainfall in the catchment) the cobble bar was dry at the downstream end of the site (Plate 3 upper) and covered in shallow, slow-flowing water (Table 2a) further upstream (Plate 3 lower) at the time of sampling. Upstream of the bar the pool (Plate 4 upper) varied

in width (Table 2a) and was approximately 100 m long. The substrate was cobble, pebble and silt.

The banks of Site 4 were covered in grass and some weeds and several willows (*Salix* spp.) (exotic species) (Plate 2 lower) and casuarinas (*Casuarina* spp, native species). Instream and marginal macrophytes included native and exotic species (Table 2b) (Plate 2 lower and Plate 4 lower).

Site 3 had denser stands of willows and casuarinas than Site 4 as well as unidentified exotic shrubs. The emergent native slender knotweed (*Persicaria decipiens*) grew in the shallows (Plate 3 lower) and other natives were submerged (Table 2b). Growing along the margins of the creek were native and exotic species (Plate 4 upper) (Table 2b).

The macrophytes, overhanging branches (Plate 2 lower), snags (Plate 1 upper) and submerged tree roots (Plate 4 lower) present at both sites would provide fish habitat. The riffles at either end of Site 4 could act as barriers to fish passage during dry periods, although it appears unlikely the deep pool would dry up. The cobble bar at Site 3 was exposed for over 100 m downstream of the site, posing a significant barrier to fish passage. Bowmans Creek at Sites 3 and 4 were considered to be a Class 2 waterway (i.e. moderate fish habitat).

The RCE score at Site 3 was 35 and at Site 4 was 36 (Appendix 4).

At Site 3, eight dead turtles were observed on the riverbank. No obvious reason for their deaths could be determined. They were most likely Eastern Snake-Necked Turtles (*Chelodina longicollis*).

3.2.1.2 Upstream of Area to be Mined

The control sites on Bowmans Creek, Sites 1 and 2 are upstream of the area to be mined (Figure 1). They were both situated north of the New England Highway. Site 2 was approximately 1.3 kilometres upstream of the proposed longwall area. The two control sites were approximately 2.5 river km apart. Site 2 was accessed by turning off the New England Highway and driving across a paddock. Site 2 was approximately 1 km upstream of the existing Ashton Coal mine. A railway line ran parallel to Bowmans Creek on the eastern side at Site 2 and the minimum distance from the creek was 30 m. On the western side was a grassed paddock with many species of weeds and few trees. Site 1 was accessed from the highway. A road bridge crossed the creek approximately 10 m downstream of Site 1 (Plate 5 upper). Cattle pasture lay on either side of the creek, partially covered with trees and shrubs. The road ran parallel to the river along the site, approximately 100 m away.

Site 2 consisted of two cobble bars with a large long pool (Plate 5 lower) in between (Table 2a). The substratum of the pool was cobble, pebble, sand and silt. The banks in parts were artificially constructed with railway fill. The cobble bars at either end of the pool were covered with shallow standing water and had no flow at the time of sampling, but it was presumed they could be riffles after rainfall. The downstream cobble bar (Plate 6 upper) continued into a dry exposed area out of the site.

The upstream control site of Bowmans Creek, Site 1, was made up of a downstream soft-sediment shallow pool (Plate 7 lower), a shallow 30 m long cobble and silt section (Plate 8 upper) and further upstream, a long, deep pool (Plate 8 lower) (Table 2a). The downstream soft-sediment pool had a silt bottom and cobbled bank with signs of use by cattle. The shallow cobble and silt section upstream narrowed in one section which increased the flow from an rate too slow to be measured to a mean of 0.31 (±0.08) m/s. Further upstream the

water was still in the long pool (Table 2a). A path on its eastern bank showed evidence of cattle use. Downstream of the site was an area with no surface flow of water.

Dense stands of casuarinas lined the downstream banks of Site 2 and different kinds of willow grew along and overhung the steeper eastern bank of the pool (Plate 6 lower). The western bank of the pool was densely covered in grasses and weeds including thistles, purpletop, and curled dock (*Rumex crispus*). Slender knotweed (Plate 7 upper) and grasses grew over the cobble bars (Plate 6 upper). Native and exotic macrophytes grew along the site and submerged in the pool (Plate 2b).

At Site 1, casuarinas, willows, peppercorn trees (exotic *Schinus areira*), planted poplars (*Populus nigra*) and other trees grew along the banks. Dense stands of cumbungi grew alongside and in the creek for the length of Site 2 (Plates 7 lower and 8). Spiny rush, buttercup (*Ranunculus* sp.) and beard rush grew marginally along the site and instream macrophytes were present (Table 2b). Grasses covered the banks and much of the downstream soft-sediment area (Plate 7 lower).

Fish habitat at Site 2 was provided by the many overhanging willows (Plate 6 lower), large beds of submerged and marginal emergent macrophytes (Plate 5 lower) and snags (Plate 6 lower). The cobble bars at both ends of the pool would provide a significant barrier to fish passage at drier times. At Site 1 macrophytes and snags provided fish habitat. Downstream of the site there was no flow at the time of sampling, restricting fish passage. The waterways classification at both sites was Class 2 – moderate fish habitat.

The RCE scores given were 34 at Site 2 and 32 at Site 1 (Appendix 4).

3.2.1.3 External Control Sites

The external control sites (Site 5 and 6) were located on Rouchel Brook, approximately 32 km north of Site 1 on Bowmans Creek. Both sites were accessed by road. Site 5 was nine km upstream of Site 6. Both sites were surrounded by mostly cleared pasture. Rouchel Road runs close by Site 5 (approximately 25 m away). Site 5 showed evidence of cattle usage.

Site 5 was located one metre downstream of a concrete road used by local landowners (Plate 9 upper) and consisted of a long pool (Plate 10 upper) with a riffle at the top of the site (Table 2a). The riffle had a boulder, cobble and gravel substrate (Plate 9 lower) and rapidly flowing water (Table 2a).

Further downstream at Site 6 there were two pools, one above and one below a seldom-used concrete ford (Plate 10 lower). Downstream was a rapidly flowing riffle with a pebble and cobble substrate. The long pool above the ford had a much slower flow (Table 2a). Between the ford and the downstream riffle were a smaller pool and a short riffle (Plate 11 lower) (Table 2a). The presence of a road running through and upstream of the external controls differed to the treatments Bowmans Creek, however, this was necessary to include similar riffle and pool habitats.

Both banks of Site 5 were lined with casuarinas, willows, peppercorn trees, mint (*Mentha* or *Prostanthera* sp.), grasses, and the weeds St Johns Wort (*Hypericum perforatum*), curled dock and purpletop. Clasped pondweed, *Myriophyllum* and a green filamentous alga grew submerged in the brook. Marginal macrophytes included umbrella sedge (*Cyperus eragrostis*), common rush (*Juncus usitatus*), and water couch (*Paspalum distichum*) which had not been found at the Bowman Creek sites.

At Site 6 casuarinas, wattle (*Acacia* sp.), willows, bamboo (*Phyllostachys* sp.), purple top, mint and grasses grew on both banks. Slender knotweed, umbrella sedge, river clubrush, water couch and buttercup grew along the edges of Rouchel Brook. Submerged macrophytes included the exotic Canadian pondweed (*Elodea Canadensis*) which was not found at any other sites.

Fish habitat at both sites was provided by macrophytes, overhanging vegetation and snags (Plate 10 upper and Plate 11 upper). Both sites had deep permanent pools. The fords upstream of Site 5 and within Site 6 could potentially act as barriers in times of low flow. At Site 5 at the time of sampling depth of water over the road was less than 5 cm and a drop of approximately 25 cm occurred on the downstream side of the road. A school of smelt were observed on the upstream side of the road. At Site 6 the road was completely submerged to a depth of 8 cm. The waterway classification given to both sites was Class 1–2 (major – moderate fish habitat).

The RCE score given to Site 5 was 38 and to Site 6 was 37 (Appendix 4).

3.2.2 Water Quality

The mean ($\pm$ s.e.) values for water quality variables are presented in Table 3 and compared to ANZECC (2000) guidelines. For comparisons with ANZECC guidelines, Bowmans Creek is classified as a lowland river and Rouchel Brook as an upland river. Turbidity readings are not presented due to probe malfunction. Temperatures at the control sites in Bowmans Creek were higher than those in the predicted impact area and those in Rouchel Brook (Table 3). Conductivity at the Bowmans creek control sites was slightly higher than at the predicted impact sites downstream, all conductivity values in Bowmans Creek were within ANZECC (2000) guidelines. The conductivity readings at Rouchel Brook were considerably lower than those in Bowmans Creek, and at Site 6 were slightly higher than the ANZECC guidelines. Salinity levels were similar at all sites in Bowmans Creek. Levels measured at Rouchel Brook were considerably lower. pH values at the control sites were slightly lower than those in the predicted impact area and these were lower than pH values at the external control sites in Rouchel Brook. All pH values were within ANZECC guidelines. ORP was within ANZECC guidelines at all sites. Dissolved oxygen (DO) was considerably lower than ANZECC guidelines at all sites. It varied within locations (Table 3).

3.2.3 Fish and Large Crustaceans

Seven species of fish were recorded in the study locations in Bowmans Creek and Rouchel Brook (Table 4). The native longfinned eel was found at all sites. The native flathead gudgeon (*Philypnodon grandiceps*) was found in all sites at Bowmans Creek, but not in Rouchel Brook. Two other natives Australian smelt (*Retropinna semoni*) and Cox's gudgeon (*Gobiomorphus coxii*) were only found in Rouchel Brook. The exotic pest mosquitofish (*Gambusia holbrooki*) was found at all sites and was particularly abundant in Bowmans Creek where it was found in the thousands at both the control and predicted impact locations. Another exotic pest, carp (*Cyprinus carpio*) was found at both locations in Bowmans Creek. Several large (> 0.3 m total length) individuals were observed at Site 4. Another exotic species, goldfish (*Carassius auratus*) was found at Site 5 in Rouchel Brook. A large fish, believed to be a native Australian bass (*Macquaria novemaculeata*) was observed, however, it was not captured so its identification can not be confirmed.

Freshwater shrimp (family Atyidae) were recorded from all sites and a large freshwater prawn (*Macrobrachium* sp.) was found in Rouchel Brook.

3.2.4 Macroinvertebrates

3.2.4.1 General Results

RAM sampling yielded a total of 58 macroinvertebrate taxa, 44 from Bowmans Creek (33 from edge and 24 from riffle) and 42 taxa from Rouchel Brook (29 from edge and 26 from riffle)(Table 5). The fewest taxa were recorded at Site 1 Edge (17 taxa) and the greatest number at Site 4 Edge (26 taxa) both in Bowmans Creek (Table 6). No specimens belonging to the threatened invertebrate species Adams Emerald Dragonfly (*Archaeophya adamsi),* Sydney Hawk Dragonfly *(Austrocordulia leonardi)* or River Snail *(Notopala sublineata)* were recorded in this data set.

3.2.4.2 AUSRIVAS Results

Overall, the AUSRIVAS model assessed the ecological condition of all sites using Band classification as poorer than expected (Overall BAND, Table 7). In all edge sites OE50taxa (Table 7) was low ranging from 0.4 – 0.7, therefore not as many taxa (with a probability of occurrence of greater than 50 %) were found as were expected. The OE50taxa value for riffle habitats was higher than edges ranging from 0.8 for Site 4 on Bowmans Creek, indicating fewer taxa were found than expected, to 1.07 at Site 5 on Rouchel Brook, where more taxa were found than expected. Both Rouchel Brook riffle sites (Sites 5 and 6) had values closer to 1, indicating that most of the taxa predicted were present at the site.

OE50SIGNAL (Table 7) values for Bowmans Creek in both edge and riffle habitats were between 0.7 and 0.8 indicating fewer sensitive taxa present than expected (with a 50 % probability). OE50SIGNAL values for Rouchel Brook edge and riffle sites were close to or greater than 1 indicating the SIGNAL grades of the taxa present were similar to those found in reference creeks used by the AUSRIVAS model.

3.2.4.3 SIGNAL Index

Both creeks and habitat types had representatives from both tolerant and sensitive families as graded by Chessman (2003) (Table 5). Of the sensitive taxa found, Rouchel Brook had the greatest number, with the most sensitive taxon in this dataset, Telephlebiidae (SIGNAL2 grade of 9) found in Site 5 edge. The sensitive taxon Leptophlebiidae (SIGNAL2 grade of 8) was found in Bowmans Creek Site 4 as well as all Rouchel Brook sites. However, SIGNAL scores at all sites in both creeks were lower than 5 indicating that overall, water quality was moderately to severely impaired and the macroinvertebrate communities were composed of tolerant animals (Table 8).

5.0 CONCLUSIONS

5.1 Species of Conservation Significance

No threatened species or species of concern were found in Bowmans Creek or Rouchel Brook. It is not expected that any threatened species native to the area will be found, however, if any were discovered the Ashton Coal Environmental Officer would be contacted immediately and assistance given in consultations with the National Parks and Wildlife Service to identify an appropriate amelioration strategy.

5.2 Key Threatening Processes

Degradation of native riparian vegetation along New South Wales water courses (*FM Act*).

Mine subsidence impacts in the vicinity of Bowmans Creek have the potential to alter stream morphology which could result in increased erosion and degradation of riparian vegetation. Regular monitoring of mine subsidence impacts within Bowmans Creek would allow the rapid identification of such degradation, such that mitigation methods can be instigated, and remediation measures can be undertaken if required.

Alteration of habitat following subsidence due to longwall mining (*TSC Act*).

Aquatic habitats have the potential to be altered or removed as a result of subsidence induced fracturing of the creek substratum due to longwall mining. This can lead to the alteration of habitats through the draining of pools, changes in water quality, and variation in flow characteristics. The proposed monitoring of aquatic habitats during and post longwall extraction outlined in this study will allow the identification of such habitat alteration. The recommended monitoring proposal will also allow determination of the extent of such an impact, the likelihood of natural recovery, or the need for and nature of remediation.

Predation by Gambusia holbrooki (mosquitofish) (*TSC Act*)

Mosquitofish are abundant throughout the study area, with very high numbers recorded at all sites in Bowmans Creek (Table 4). Degradation of habitat through the loss of riparian vegetation or the deterioration of water quality resulting from subsidence in the vicinity of the creek could provide conditions suitable for the increased proliferation of mosquitofish. This may have a detrimental effect on small native fish which inhabit the area. Regular monitoring of fish within the study area, in combination with monitoring of aquatic habitat will identify such impacts.

5.3 Habitat Assessment

Bowmans Creek was found to be ephemeral within the study areas. There were dry, exposed areas at the time sampling, at the downstream end of Site 3, and downstream of Sites 1 and 2. The exposed areas outside of the control locations in Bowmans Creek were thickly overgrown with grasses and rushes and appeared as though water had not flowed through in some time. The exposed area of Site 3, however, appeared to have flowed recently. Pools and riffles were found at three of the six sites, the remaining three had exposed cobble bars which could act as riffles after times of heavy rainfall. Many weeds and

exotic species were found at all sites, although native macrophytes were also present and healthy at all sites.

Overhanging branches, macrophytes, and snags existed at all sites in Bowmans Creek and Rouchel Brook which could be used as habitat by fish. Deep permanent pools were found at all sites, which are likely to provide fish habitat at times of low flow under natural conditions. However, if cracking were to occur due to subsidence, they could be drained. Barriers to fish passage existed between sites all the sites in Bowmans Creek. The waterways classification as "moderate fish habitat" given at all sites in Bowmans Creek reflects this. The fords in Rouchel Brook could act as barriers to fish passage in times of low rainfall a condition reflected in the waterways classification of "moderate-major fish habitat". The lowest RCE scores were given to the control sites in Bowmans Creek and the highest to those in Rouchel Brook, although all were fairly similar. The differences in scores were due to less frequent riffles and fewer logs in Bowmans Creek than Rouchel Brook.

Rouchel Brook was not ideal as an external control due to its higher elevation and the presence of fords, however, due to the existence of 37 coal mines and 4 dams in the area, Rouchel Brook was the most similar creek to Bowmans that could be found. Like Bowmans Creek, Rouchel Brook had riffle pool sequences, nearby roads and similar vegetation and surrounding land use.

5.4 Water Quality

Most water quality variables at all sites were within ANZECC guidelines. Differences between the sites in Bowmans Creek and Rouchel Brook in conductivity and salinity and may be attributable to differences in distance from headwaters, catchment geology, input of saline groundwater and distance travelled underground. The low dissolved oxygen (DO) levels at all sites (all lower than ANZECC guidelines) could be a cause for concern as oxygen is essential to all forms of aquatic life. Variations in DO can occur seasonally and over shorter periods due to factors such as salinity, turbulence, temperature and biological activity (Chapman and Kimstach 1992).

5.5 Fish and Large Crustaceans

Native fish were found in all locations although the most abundant fish was the exotic pest mosquitofish. Few species were caught at both sites and only two native species were found in Bowmans Creek. Many shrimp were trapped or observed at all sites however, no crayfish were caught or observed. The low number of fish taxa found may make post-mining changes to fish assemblages based on fish species difficult to detect. Changes in the numbers of exotic fish present post-mining may be a better indicator of habitat changes affecting fish abundance.

5.6 Macroinvertebrates

Overall most sites were impaired compared to reference conditions in the AUSRIVAS model and SIGNAL Index showed mostly tolerant macroinvertebrate communities, reflecting impacted systems. RCE scores showed that the riparian environment was altered by agriculture and other anthropogenic influences, which could account for these results. These impaired baseline condition need to be considered when examining trends in data from long term monitoring.

5.7 General Conclusions

Bowmans Creek showed many signs of negative human impact at the time of sampling, including numerous weeds and exotic plants, low dissolved oxygen and high salinity, very few species of fish (particularly natives) and a tolerant macroinvertebrate community. These degraded conditions may make the assessment of any future impacts caused by longwall mining difficult to detect. The use of control sites within Bowmans Creek and at Rouchel Brook that are not impacted by longwall mining will, however, allow comparisons between impact and non-impact areas. A monitoring program that assesses multiple indicators of creek health will also assist with the detection of any future changes.

6.0 RECOMMENDATIONS FOR MONITORING

Monitoring is an important tool for management of aquatic ecosystems as it allows early indication of impending impacts. This facilitates an accelerated response for mitigation or remediation of those impacts. Monitoring programs can include, amongst other components, use of biological and/or physico-chemical indicators. For Bowmans Creek within the proposed underground mining area and at control sites and external control sites (in Rouchel Brook) it is recommended that a photographic catalogue, along with habitat assessment, water quality measurements, fish sampling, and macroinvertebrate sampling be used to monitor any effects of mine subsidence. The methods outlined in this study are intended to be used in an ongoing monitoring program currently being developed by Ashton Coal operations that will allow assessment of impacts resulting from mine subsidence on aquatic ecology.

We concur with the current plan to sample in predicted impact and control locations on one more occasion prior to the commencement of long-wall mining (Ashton Coal 2005). We recommend this be done between 15 March 2006 and 15 June 2006 to coincide with autumn AUSRIVAS sampling times. This will allow for the establishment of an appropriate baseline of information which is essential for monitoring the effects of any subsidence and also the effectiveness of any remedial works, such as grouting of fractures.

Monitoring should be done twice within one year of the longwall passing beneath Bowmans Creek (Ashton Coal 2005). We recommend that these monitoring times coincide with AUSRIVAS spring and autumn sampling times to allow the use of the AUSRIVAS predictive model. If sampling is unable to be undertaken outside of the sampling periods allowed for AUSRIVAS model, we suggest that quantitative sampling methods be used. This immediate post-mining sampling will allow assessment of ecosystem changes by comparison with the baseline information. It will allow the assessment of impacts from subsidence or other mining impacts on fish, fish passage, macroinvertebrates, riparian vegetation aquatic habitat, and assist with recommendations for any necessary remedial works.

Long-term monitoring will be required biannually for at least five years following the completion of longwall mining under Bowmans Creek (Ashton Coal 2005). This will allow assessment of long term stability of ecosystems against the pre-mining baseline studies. Changes such as those in vegetation communities, which may not have been obvious immediately after mining, will be able to be assessed, as well as impacts to fish, fish passage, macroinvertebrates, riparian vegetation and aquatic habitat. It is recommended that this sampling coincide with AUSRIVAS spring and autumn sampling times.

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Web Reference 2: http://www.dpi.nsw.gov.au/fisheries: NSW Department of Primary Industries, NSW Fisheries website.

Web Reference 3: http://www.deh.gov.au: Commonwealth Department of Environment and Heritage website.

Web Reference 4: http://www.legislation.nsw.gov.au: The Government of NSW Legislation website

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TABLES

Table 1. Freshwater fish species recorded from the Hunter catchment area (using the bionet website, web reference 3).

Family	Species	Common name	Native/Introduced	Status/occurrence in catchment
Ambassidae	*Ambassis marianus*	Silver Perchlet, Estuary Perchlet	N	
Anguillidae	*Anguilla australis*	Short-finned Eel, Silver Eel	N	
	Anguilla reinhardtii	Long-finned Eel, Marbled Eel, Spotted Eel	N	
Atherinidae	*Atherinosoma microstoma*	Small-mouthed Hardyhead, Greyback	N	
	Craterocephalus amniculus	Darling River Hardyhead	N	(species of concern)
	Craterocephalus marjoriae	Marjorie's Hardyhead	N	
Clupeidae	*Potamalosa richmondia*	Freshwater Herring , Nepean Herring	N	
Cyprinidae	*Carassius auratus*	Goldfish	I	
	Cyprinus carpio	Common Carp	I	
	Rutilus rutilus	Roach	I	
Eleotridae	*Gobiomorphus australis*	Striped Gudgeon	N	
	Gobiomorphus coxii	Cox's Gudgeon, Mulgoa Gudgeon, Nepean Gudgeon	N	
	Hypseleotris compressa	Carp Gudgeon, Empirefish, Empire Gudgeon	N	
	Hypseleotris galii	Firetailed Gudgeon, Gale's Gudgeon	N	
	Hypseleotris klunzingeri	Western Carp Gudgeon	N	
	Philypnodon grandiceps	Flathead Gudgeon, Big-headed Gudgeon, Bull Head	N	
Galaxiidae	*Galaxias brevipinnis*	Climbing Galaxias	N	
	Galaxias maculatus	Common Jollytail, Common Galaxias	N	
	Galaxias olidus	Mountain Galaxias, Inland Galaxias	N	
Gobiidae	*Afurcagobius tamarensis*	Tamar River Goby, Tasman Goby	N	
	Arenigobius bifrenatus	Bridled Goby	N	
	Pseudogobius olorum	Swan River Goby, Bluespot Goby, Southern Goby	N	
	Redigobius macrostoma	Compressed Goby, Largemouth Goby	N	
Lutjanidae	*Lutjanus argentimaculatus*	Mangrove Jack, Creek Red Bream, Dog Bream	N	
Megalopidae	*Megalops cyprinoides*	Oxeye Herring, Tarpon	N	
Melanotaeniidae	*Melanotaenia splendida*	Eastern Rainbowfish	N	
Mugilidae	*Liza argentea*	Brown-back Mullet, Bull-nose Mullet, Flat-tail Mullet, Tiger Mullet	N	
	Mugil cephalus	Sea Mullet, Bully Mullet, Flathead Mullet, Mangrove Mullet, Hardgut Mullet	N	
	Myxus elongatus	Bully Mullet, Lano, Poddy, Sand Mullet, Tallegalene	N	
	Myxus petardi	Freshwater Mullet, Pinkeye	N	
	Valamugil georgii	Fantail Mullet, Silver Mullet	N	
Percichthyidae	*Macquaria ambigua*	Golden Perch, Murray Perch, Yellowbelly	N	stocked
	Macquaria colonorum	Estuary Perch	N	
	Macquaria novemaculeata	Australian Bass, Freshwater Perch	N	stocked
Plotosidae	*Tandanus tandanus*	Freshwater Catfish, Tandan, Freshwater Jewfish	N	(species of concern)
Poeciliidae	*Gambusia holbrooki*	Gambusia, Plague Minnow, Mosquitofish	I	
Pseudomugilidae	*Pseudomugil signifer*	Southern Blue-eye, Pacific Blue-eye	N	
Retropinnidae	*Retropinna semoni*	Australian Smelt	N	
Salmonidae	*Oncorhynchus mykiss*	Rainbow Trout , Steelhead	I	stocked
	Salmo trutta	Brown Trout, Sea Trout	I	stocked
	Salvelinus fontinalis	Brook Char, Brook Trout	I	
Scorpaenidae	*Notesthes robusta*	Bullrout, Kroki	N	
Sparidae	*Acanthopagrus butcheri*	Black Bream, Blue-nosed Bream	N	
Terapontidae	*Bidyanus bidyanus*	Silver Perch, Bidyan	N	vulnerable/stocked

Table 2a. Site attributes of Bowmans Creek and Rouchel Brook taken between 15 - 16 December 2005.

Treatment Description	Site	Plates	Habitat (upstream to downstream)	Substratum	Length (m)	Width (m)	Max depth (m)	Mean average flow m/s (± SE)	RCE score
Area to be mined	Bowmans Creek Site 4	1-2	riffle	cobble, pebble, silt	15	1.5	0.15	0.35 (0.045)	36
			pool	cobble, pebble, silt	90	2-10	1.5	0	
			riffle	cobble, gravel	12	0.7	0.1	0.32 (0.005)	
Area to be mined	Bowmans Creek Site 3	3-4	pool	cobble, pebble, silt	100	4-15	1.5	0	35
			cobble bar/riffle	cobble	15	7	0.1	0.02 (0)	
Upstream of area to be mined	Bowmans Creek Site 2	5-7	cobble bar	cobble, pebble, silt	20	5	0.1	0	34
			pool	cobble, pebble, sand, silt	85	5-20	1.7	0	
			cobble bar	cobble	30	4	0.1	0	
Upstream of area to be mined	Bowmans Creek Site 1	7-8	pool	boulder, cobble, pebble, silt	100	10	1.5	0	32
			cobble bar	cobble, gravel, silt	30	0.7-14	0.3	0.31 (0.08)	
			pool	silt	25	10	0.1	0	
External control sites	Rouchel Brook Site 5	9-10	riffle	boulder, cobble, gravel	25	4	0.1	0.52 (0.13)	38
			pool	gravel, pebble, cobble	80	12	1.5	0	
External control sites	Rouchel Brook Site 6	10-11	pool (above ford)	gravel, pebble, cobble	70	20	0.8	0.06 (0.02)	37
			pool (below ford)	gravel, pebble, cobble	20				
			riffle	cobble, pebble	10	2.5	0.1	0.68 (0.015)	

Table 2b. Riparian and macrophyte vegetation at Bowmans Creek and Rouchel Brook.

Treatment Description	Site	Riparian vegetation: native (n), exotic (e)	Instream macrophytes: native (n), exotic (e)	Marginal macrophytes: native (n), exotic (e)
Area to be mined	Bowmans Creek Site 4	(n) casuarinas; (e) willows, grasses, weeds, thistles	(n) sago pondweed, *Myriophyllum* sp, clasped pondweed; (e) watercress	(n) cumbungi, river clubrush; (e) spiny rush
Area to be mined	Bowmans Creek Site 3	(n) casuarinas; (e) willows, weeds, thistles, purpletop	(n) sago pondweed, *Myriophyllum* sp, slender knotweed	(n) cumbungi, river clubrush; (e) spiny rush
Upstream of area to be mined	Bowmans Creek Site 2	(n) casuarinas; (e) willows, grasses, weeds, purpletop, curled dock	(n) sago pondweed, curly pondweed, *Myriophyllum* sp, slender knotweed	(n) cumbungi, river clubrush, *Maundia triglochinoides* ; (e) spiny rush
Upstream of area to be mined	Bowmans Creek Site 1	(n) casuarinas; (e) willows, peppercorn trees, poplars, grasses	(n) sago pondweed, curly pondweed, *Myriophyllum* sp, slender knotweed	(n) cumbungi; (e) spiny rush, buttercup, beard rush
External control sites	Rouchel Brook Site 5	(n) casuarinas; (e) willows, peppercorn trees, mint, grasses, St Johns Wort, curled dock, purpletop	(n) clasped pondweed, *Myriophyllum* sp, green filamentous algae	(e) umbrella sedge, slender knotweed, common rush, river clubrush, water couch
External control sites	Rouchel Brook Site 6	(n) casuarinas, wattle; (e) willows, bamboo, purpletop, mint, grasses	(n) clasped pondweed, *Myriophyllum* sp; (e) canadian pondweed	(e) umbrella sedge, slender knotweed, river clubrush, water couch, buttercup

Table 3. Water quality variables measured in Bowmans Creek and Rouchel Brook between 15 - 16 December 2005. Bowmans Creek is considered as lowland rivers and Rouchel Brook as upland rivers. Mean values outside of ANZECC guidelines are shaded. Water quality measured with Yeo-Kal 611 probe. Turbidity readings not reported due to probe malfunction.

Date			15/12/2005				15/12/2005			
Time			13:00				12:20			
Watercourse	ANZECC (2000) Recomm. Range		Bowmans Creek				Bowmans Creek			
Site			1				2			
	Upland Rivers	Lowland Rivers								
Elevation (m)	Above 150 m	Below 150 m	80				70			
Replicate			1	2	mean	s.e.	1	2	mean	s.e.
Temperature (°C)			27.40	26.70	27.05	0.35	25.02	24.42	24.72	0.30
Conductivity (µS/cm)	30-350	125-2200	2056	2064	2060	4.00	1899	1904	1901.50	2.50
Salinity (ppt)			0.9	0.91	1	0.01	0.84	0.85	0.85	0.00
pH	6.5-8.0	6.5-8.0	6.82	6.85	6.84	0.02	6.76	6.92	6.84	0.08
ORP (mV)			253	240	246.50	6.50	434	395	414.50	19.50
DO (%sat'n)	90-110	85-110	76.8	71.0	73.90	2.90	54.8	52.8	53.80	1.00

Date			15/12/2005				15/12/2005			
Time			11:30				10:00			
Watercourse	ANZECC (2000) Recomm. Range		Bowmans Creek				Bowmans Creek			
Site			3				4			
	Upland Rivers	Lowland Rivers								
Elevation (m)	Above 150 m	Below 150 m	60				60			
Replicate			1	2	mean	s.e.	1	2	mean	s.e.
Temperature (°C)			23.64	23.49	23.57	0.08	23.05	22.97	23.01	0.04
Conductivity (µS/cm)	30-350	125-2200	1766	1777	1771.50	5.50	1842	1835	1838.50	3.50
Salinity (ppt)			0.79	0.79	0.79	0.00	0.83	0.83	0.83	0.00
pH	6.5-8.0	6.5-8.0	6.84	6.97	6.91	0.07	7.01	7.11	7.06	0.05
ORP (mV)			520	489	504.50	15.50	496	455	475.50	20.50
DO (%sat'n)	90-110	85-110	76.5	82.6	79.55	3.05	67.1	65.0	66.05	1.05

Table 3. *cont'd.*

Date			16/12/2005				16/12/2005			
Time			12:30				9:30			
Watercourse	ANZECC (2000) Recomm. Range		Rouchel Brook				Rouchel Brook			
Site			5				6			
	Upland Rivers	Lowland Rivers								
Elevation (m)	Above 150 m	Below 150 m	220				200			
Replicate			1	2	mean	s.e.	1	2	mean	s.e.
Temperature (°C)			22.73	22.75	22.74	0.01	23.00	23.17	23.09	0.08
Conductivity (µS/cm)	30-350	125-2200	336	336	336.00	0.00	351	355	353.00	2.00
Salinity (ppt)			0.14	0.14	0.14	0.00	0.13	0.13	0.13	0.00
pH	6.5-8.0	6.5-8.0	7.57	7.62	7.60	0.02	7.35	7.39	7.37	0.02
ORP (mV)			227	199	213.00	14.00	256	248	252.00	4.00
DO (%sat'n)	90-110	85-110	72.1	73.3	72.70	0.60	42.1	42.3	42.20	0.10

Table 4. Species of fish recorded using bait trapping and electrofishing in Bowmans Creek and Rouchel Brook from 1 - 2 and 15 - 16 December 2005. Shaded rows indicate introduced species.

Bait Traps (totals for 6 replicates, set for 90 minutes each)

		Date	2/12/2005	2/12/2005	1/12/2005	1/12/2005	16/12/2005	16/12/2005
		Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Rouchel Brook	Rouchel Brook
		Site	1	2	3	4	5	6
Family	Common Name	Species						
Poeciliidae	Mosquito Fish	*Gambusia holbrooki*	153				8	117
Gobiidae	Flathead Gudgeon	*Philypnodon grandiceps*		1				
Palaemonidae	Freshwater Prawn	*Macrobrachium* sp.						1

Electrofishing (conducted in 5 second shots throughout site)

		Date	2/12/2005	2/12/2005	1/12/2005	1/12/2005	16/12/2005	16/12/2005
		Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Rouchel Brook	Rouchel Brook
		Site	1	2	3	4	5	6
		Total time (sec)	394	434	423	433	325	355
Family	Common Name	Species						
Anguillidae	Long finned eel	*Anguilla reinhardtii*	4	2	2	13	12	12
Gobiidae	Flathead Gudgeon	*Philypnodon grandiceps*	1		1	1		
Poeciliidae	Mosquito Fish	*Gambusia holbrooki*		1000's	1000's	9		100's
Cyprinidae	Carp	*Cyprinus carpio*		1	1	1		
Cyprinidae	Goldfish	*Carassius auratus*					1	
Retropinnidae	Australian Smelt	*Retropinna semoni*					48	
Gobiidae	Cox's Gudgeon	*Gobiomorphus coxii*					4	

Table 5. Macroinvertebrate families identified from AUSRIVAS samples, collected from Edge and Riffle habitats on Bowmans Creek and Rouchel Brook on 15-16 December 2005. The Signal2 Grade that each family was awarded is based on Chessman (2003) (blank SIGNAL2 Grade indicate no appropriate grade for that group).

Location	Bowmans Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Rouchel Brook	Rouchel Brook	Bowmans Creek	Rouchel Brook	Rouchel Brook	SIGNAL2 Grade
Site	1	2	3	4	5	6	4	5	6	Awarded to
Habitat	Edge	Edge	Edge	Edge	Edge	Edge	Riffle	Riffle	Riffle	Family
Order or Family										
Ancylidae				1						4
Araneae		1	1	3	1	2				
Atyidae	6	6	9	10	10	9	5	8	10	3
Baetidae			3	2	2		10	10	8	5
Caenidae	5	4	3	10	4	3	10	3	5	4
Ceratopogonidae	1	1	4	4						4
Chironomidae/Chironominae	10	10	8	10	4	8	10	7	8	3
Chironomidae/Orthocladiinae								10	4	4
Chironomidae/Tanypodinae	2	5	3			1	4	7	8	4
Cladocera					1					
Coenagrionidae	7	10	9	8	7	7				2
Copepoda					2	4				
Corbiculidae				2						4
Corbiculidae/ Sphaeriidae					2		10			5
Corixidae		1	6	1	10	10		6	10	2
Corydalidae							1	1	1	7
Dolichopodidae							1			3
Dugesiidae		1		1			1	1		2
Dytiscidae		1			1	2	2			2
Ecnomidae	1			2			8	3	4	4
Elmidae								3	5	7
Entomobryidae/Isotomidae		1		1						
Erpobdellidae						1				1
Gerridae					1					4
Glossiphoniidae									2	1
Gomphidae							1	5	5	5
Gyrinidae							1			4
Hemicorduliidae	1			1	1					5
Hydracarina	10	7	10	6	1	2		2		6
Hydraenidae				3						3
Hydrobiidae			1	2						4
Hydrobiosidae									1	8
Hydrochidae			1							4
Hydrophilidae	1			4		1	1			2
Hydropsychidae					1	1	10	10	10	6
Isostictidae						1				3

Table 5. Macroinvertebrate families identified from AUSRIVAS samples, collected from Edge and Riffle habitats on Bowmans Creek and Rouchel Brook on 15-16 December 2005. The Signal2 Grade that each family was awarded is based on Chessman (2003) (blank SIGNAL2 Grade indicate no appropriate grade for that group).

	Location	Bowmans Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Rouchel Brook	Rouchel Brook	Bowmans Creek	Rouchel Brook	Rouchel Brook	SIGNAL2 Grade
	Site	1	2	3	4	5	6	4	5	6	Awarded to
	Habitat	Edge	Edge	Edge	Edge	Edge	Edge	Riffle	Riffle	Riffle	Family
Order or Family											
Leptoceridae		5	10	2	8	5	10	1	3	3	6
Leptophlebiidae						2	3	10	8	10	8
Libellulidae			1		1		1		3		4
Lymnaeidae		3	3	2	8						1
Nematoda								2			3
Notonectidae						10	6				1
Oligochaeta		3	1	2	1		5	10	3	10	2
Ostracoda					1			10			
Philopotamidae										1	8
Physidae		2		2			3			1	1
Protoneuridae		3	2	1	4						4
Psephenidae									1	6	6
Sciomyzidae				1							2
Scirtidae						1	1	10			6
Sialidae						1					5
Simuliidae								10	4		5
Stratiomyidae		1		1	1	1					2
Tabanidae										1	3
Telephlebiidae						1					9
Temnocephalidae			1								5
Tipulidae		1						2	3		5
Veliidae			2	1	4			1			3

Table 6. Summary Statistics for macroinvertebrate families identified from AUSRIVAS samples, collected from Edge and Riffle habitats on Bowmans Creek and Rouchel Brook on 15-16 December 2005.

Location	Bowmans Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Rouchel Brook	Rouchel Brook	Bowmans Creek	Rouchel Brook	Rouchel Brook
Site	1	2	3	4	5	6	4	5	6
Habitat	Edge	Edge	Edge	Edge	Edge	Edge	Riffle	Riffle	Riffle
Number of individuals	**62**	**68**	**70**	**99**	**69**	**81**	**131**	**101**	**113**
Number of worms	3	3	2	2	0	6	13	4	12
Number of crustaceans	6	6	9	11	13	13	15	8	10
Number of molluscs	5	3	5	13	2	3	10	0	1
Number of insects	38	47	43	63	52	55	93	87	90
Number of mayflies	5	4	6	12	8	6	30	21	23
Number of damselflies/dragonflies	11	13	10	14	9	9	1	8	5
Number of bugs	0	3	7	5	21	16	1	6	10
Number of beetles	1	1	1	7	2	4	14	4	11
Number of true flies	15	16	17	15	5	9	27	31	21
Number of caddis-flies	6	10	2	10	6	11	19	16	19
Number of other insects	0	0	0	0	1	0	1	1	1
Number of other taxa	10	9	11	10	2	4	0	2	0
Number of taxa	**17**	**19**	**20**	**26**	**22**	**21**	**24**	**21**	**21**
Number of worm taxa	1	3	1	2	0	2	3	2	2
Number of crustacean taxa	1	1	1	2	3	2	2	1	1
Number of mollusc taxa	2	1	3	4	1	1	1	0	1
Number of insect taxa	12	11	13	15	16	14	18	17	17
Number of mayfly taxa	1	1	2	2	3	2	3	3	3
Number of damselfly/dragonfly taxa	3	3	2	4	3	3	1	2	1
Number of bug taxa	0	2	2	2	3	2	1	1	1
Number of beetle taxa	1	1	1	2	2	3	4	2	2
Number of true fly taxa	5	3	5	3	2	2	5	5	4
Number of caddis-fly taxa	2	1	1	2	2	2	3	3	5
Number of other insect taxa	0	0	0	0	0	0	0	0	0
Number of other taxa	1	3	2	3	2	2	0	1	0

Table 7. AUSRIVAS scores for edge and riffle habitats sampled December 2005. Outputs include observed versus expected taxa (OE50Taxa) based on those taxa predicted with a greater than 50% probability of occurring. AUSRIVAS bands: A = Similar to AUSRIVAS references; B = Poorer than AUSRIVAS references; C = Much poorer than AUSRIVAS references. The bands of biological condition are based on the OE50Taxa and not the OE50SIGNAL values. OE50SIGNAL is the ratio of expected to observed averaged SIGNAL Grades based on Chessman (2003).

a) Dec 2005: Edge Habitats

	Bowmans Creek				Rouchel Brook	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Band	C	B	C	B	B	B
Expected no of taxa (NTE50)	17	13	14	15	12	11
Observed/expected no of taxa (OE50)	0.48	0.6	0.44	0.75	0.6	0.55
Observed SIGNAL (O50SIGNAL)	3.5	3.13	3.5	3.09	4.29	4.5
Expected SIGNAL (E50SIGNAL)	4.2	4.32	4.4	4.29	4.06	3.87
Observed/Expected SIGNAL scores (OE50SIGNAL)	0.83	0.72	0.8	0.72	1.06	1.16

b) Dec 2005: Riffle Habitats

	Bowmans Creek				Rouchel Brook	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Band	No suitable habitat			B	A	A
Expected no of taxa (NTE50)				14	13	14
Observed/expected no of taxa (OE50)				0.8	1.07	0.98
Observed SIGNAL (O50SIGNAL)				4.73	5.07	5.29
Expected Signal (E50SIGNAL)				5.45	5.66	5.38
Observed/Expected SIGNAL scores (OE50SIGNAL)				0.87	0.9	0.98

c) Dec 2005: Edge and riffle habitats combined

	Bowmans Creek				Rouchel Brook	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Overall Band	C	B	C	B	B	B

Table 8. SIGNAL Index calculated from SIGNAL grades assigned to all taxa in each site (Chessman, 2003). SIGNAL Index is calculated as the sum of all SIGNAL Grades for families present divided by total number of families. SIGNAL Index > 6 = Healthy Unimpaired, 5-6 = Mildly Impaired, 4-5 = Moderately Impaired, < 4 = Severely Impaired (Chessman 1997).

a) Dec 2005: Edge Habitats

	Bowmans Creek				Rouchel Brook	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Signal Index	3.41	3.00	3.10	3.04	4.42	3.47

b) Dec 2005: Riffle Habitats

	Bowmans Creek				Rouchel Brook	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Signal Index	No suitable habitat			4.22	4.67	4.62

FIGURES

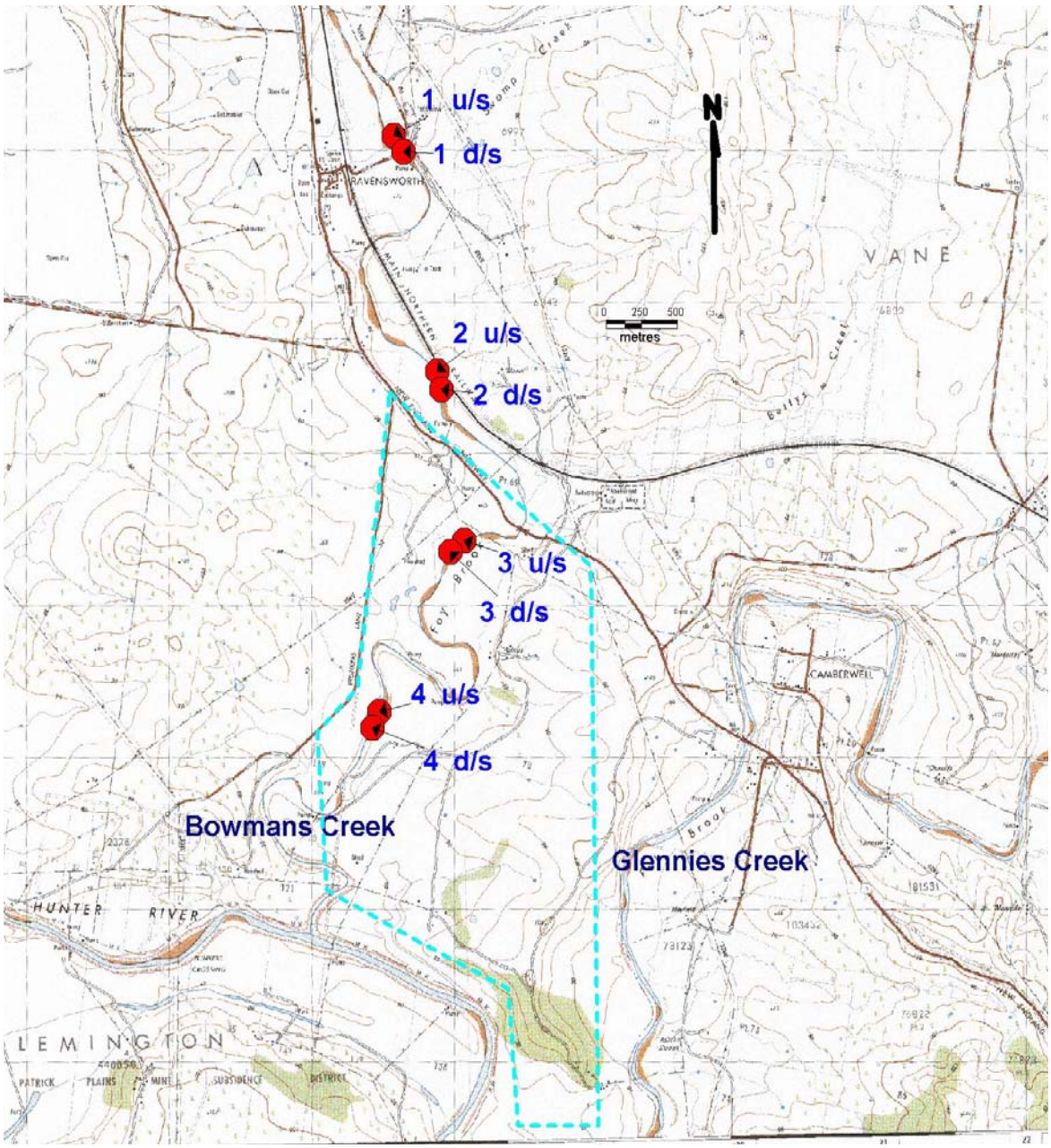

Figure 1. Map showing Bowmans Creek Sites 1-4. U/s indicates upstream extent of site, d/s indicates downstream extent of site. Blue dotted line shows proposed long wall mining area.

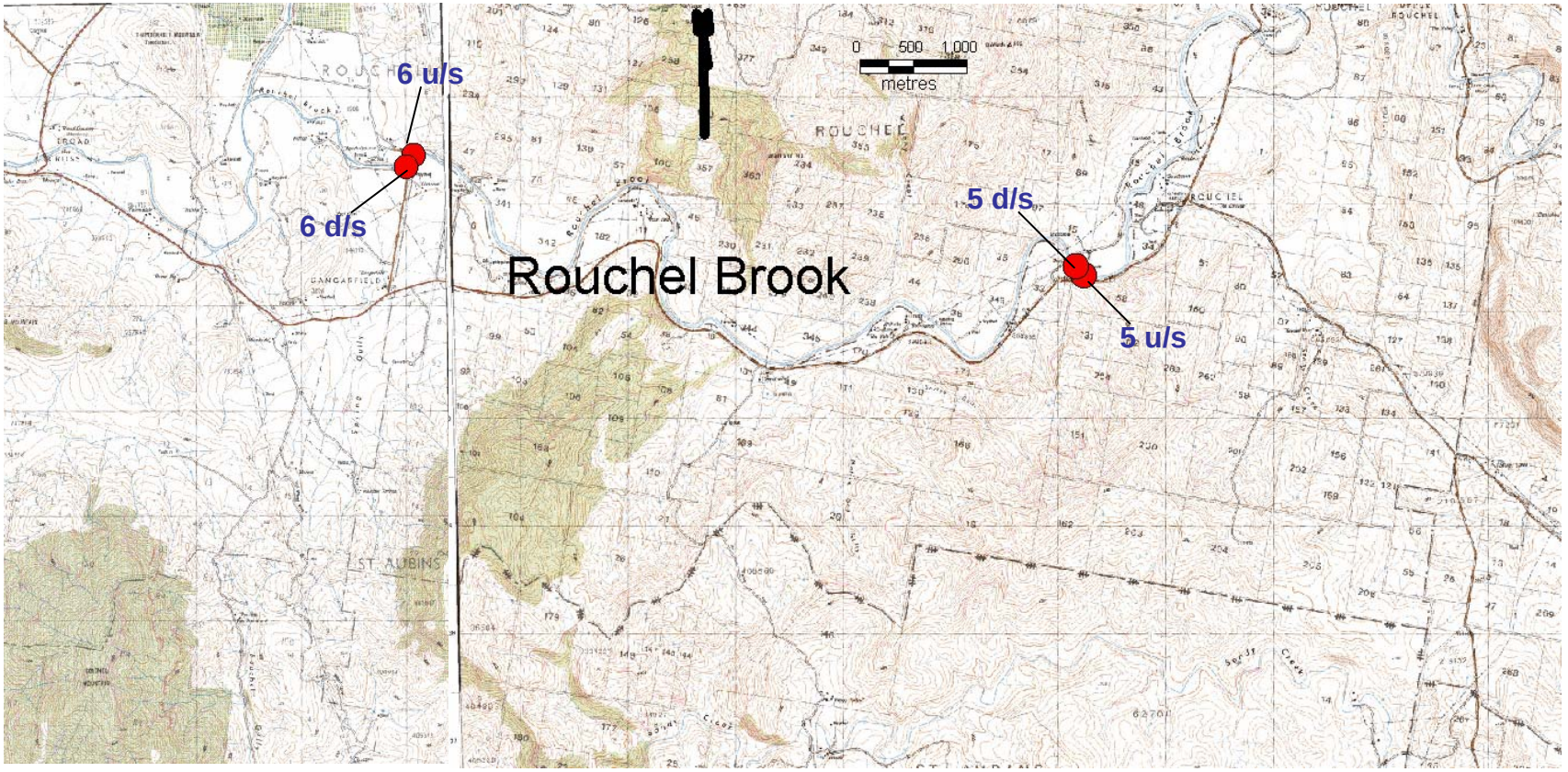

Figure 2. Map showing Rouchel Brook Sites 5 and 6. U/s indicates upstream extent of site, d/s indicates downstream extent of site.

PLATES

Plate 1 Upper: Steep bank on western side of Bowmans Creek Site 4, looking upstream. Large clumps of spiny rush can be seen growing along both sides of the creek.

Plate 1 Lower: Pool at Bowmans Creek Site 4, looking upstream and towards the eastern bank.

Plate 2 Upper: Riffle at downstream end of Bowmans Creek Site 4, looking upstream.

Plate 2 Lower: Bowmans Creek Site 4, looking upstream. A willow is overhanging the stream, cumbungi is growing along the margins and pondweed is submerged.

Plate 3 Upper: Dry cobble bar at Bowmans Creek Site 3, looking downstream.

Plate 3 Lower: Cobble bar at Bowmans Creek Site 3, looking upstream. Slender knotweed can be seen growing in the middle of the stream.

Plate 4 Upper: Pool at Bowmans Creek Site 3, looking upstream. Casuarinas, willows and spiny rush can be seen along the banks.

Plate 4 Lower: Pool at Bowmans Creek Site 3. Note the overhanging tree branches, submerged tree roots, exotic shrub, sago pondweed and floating organic detritus.

Plate 5 Upper: Bowmans Creek Site 1, looking downstream from bottom of site.

Plate 5 Lower: Pool at Bowmans Creek Site 2, looking downstream. Note purpletop in foreground, cumbungi on right hand side, submerged pondweed and casuarina in background.

Plate 6 Upper: Downstream cobble bar at Bowmans Creek Site 2.

Plate 6 Lower: Pool at Bowmans Creek Site 2, looking across to eastern bank. Note overhanging willows and snags, and purpletop in foreground.

Plate 7 Upper: Downstream cobble bar at Bowmans Creek Site 2. Note slender knotweed growing in shallow water.

Plate 7 Lower: Shallow soft-sediment pool at Bowmans Creek Site 1.

Plate 8 Upper: Shallow cobble and silt section at Bowmans Creek Site 1, looking across to western bank. Blue bait-trap deployed by The Ecology Lab can be seen next to cumbungi.

Plate 8 Lower: Deep pool at Bowmans Creek Site 1, looking upstream. Casuarinas and cumbungi can be seen on the banks.

Plate 9 Upper: Ford upstream of Rouchel Brook Site 5.

Plate 9 Lower: Riffle at top of Rouchel Brook Site 5, looking downstream.

Plate 10 Upper: Pool at bottom of Rouchel Brook Site 5, looking upstream. Note overhanging willows and submerged clasped pondweed.

Plate 10 Lower: Rouchel Brook, Site 6, showing ford across brook and large upstream pool.

Plate 11 Upper: Long pool at Rouchel Brook Site 6, upstream of ford.

Plate 11 Lower: Small pool and riffle at Rouchel Brook Site 6, downstream of ford.

Plate 1 Upper: Steep bank on western side of Bowmans Creek Site 4, looking upstream. Large clumps of spiny rush can be seen growing along both sides of the creek.

Plate 1 Lower: Pool at Bowmans Creek Site 4, looking upstream and towards the eastern bank.

Plate 2 Upper: Riffle at downstream end of Bowmans Creek Site 4, looking upstream.

Plate 2 Lower: Bowmans Creek Site 4, looking upstream. A willow is overhanging the stream, cumbungi is growing along the margins and pondweed is submerged.

Plate 3 Upper: Dry cobble bar at Bowmans Creek Site 3, looking downstream.

Plate 3 Lower: Cobble bar at Bowmans Creek Site 3, looking upstream. Slender knotweed can be seen growing in the middle of the stream.

Plate 4 Upper: Pool at Bowmans Creek Site 3, looking upstream. Casuarinas, willows and spiny rush can be seen along the banks.

Plate 4 Lower: Pool at Bowmans Creek Site 3. Note the overhanging tree branches, submerged tree roots, exotic shrub, sago pondweed and floating organic detritus.

Plate 5 Upper: Bowmans Creek Site 1, looking downstream from bottom of site.

Plate 5 Lower: Pool at Bowmans Creek Site 2, looking downstream. Note purpletop in foreground, cumbungi on right hand side, submerged pondweed and casuarina in background.

Plate 6 Upper: Downstream cobble bar at Bowmans Creek Site 2.

Plate 6 Lower: Pool at Bowmans Creek Site 2, looking across to eastern bank. Note overhanging willows and snags, and purpletop in foreground.

Plate 7 Upper: Downstream cobble bar at Bowmans Creek Site 2. Note slender knotweed growing in shallow water.

Plate 7 Lower: Shallow soft-sediment pool at Bowmans Creek Site 1.

Plate 8 Upper: Shallow cobble and silt section at Bowmans Creek Site 1, looking across to western bank. Blue bait-trap deployed by The Ecology Lab can be seen next to cumbungi.

Plate 8 Lower: Deep pool at Bowmans Creek Site 1, looking upstream. Casuarinas and cumbungi can be seen on the banks.

Plate 9 Upper: Ford upstream of Rouchel Brook Site 5.

Plate 9 Lower: Riffle at top of Rouchel Brook Site 5, looking downstream.

Plate 10 Upper: Pool at bottom of Rouchel Brook Site 5, looking upstream. Note overhanging willows and submerged clasped pondweed.

Plate 10 Lower: Rouchel Brook, Site 6, showing ford across brook and large upstream pool.

Plate 11 Upper: Long pool at Rouchel Brook Site 6, upstream of ford.

Plate 11 Lower: Small pool and riffle at Rouchel Brook Site 6, downstream of ford.

Annex B

The Ecology Lab Aquatic Assessment Autumn 2006

Report to:

ERM Australia

Report 2

Ashton Coal Project: Aquatic Habitat Assessment and Recommendations for Monitoring

Final

October 2006

Report prepared by:

The Ecology Lab Pty Ltd

The Ecology Lab Pty Ltd

Marine and Freshwater Studies

Report 2

Ashton Coal Project: Aquatic Habitat Assessment and Recommendations for Monitoring

October 2006

Report Prepared for:

Environmental and Resources Management Australia

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1.0 INTRODUCTION

Ashton Coal Operations Pty Ltd proposes to extend its Ashton Coal Project with the development of an underground mine. The project is located approximately 14 km northwest of Singleton in the Hunter Valley region of NSW. It includes an existing open cut mine, a Coal Handling and Preparation Plant and associated rail siding and infrastructure. The proposed underground mine include seven longwalls, three of which will lie beneath Bowmans Creek.

The Ecology Lab Pty Ltd was engaged by Environmental Resources Management Australia Pty Ltd to develop and undertake a stream monitoring program for Ashton Coal Operations as required by consent conditions 3.19 and 3.20 in Development Application DA No 309-11-2001-i issued by the Minister for Planning. This monitoring incorporates assessment of aquatic habitat and biota within the mine subsidence impact area, and at control locations. This document is the second report of this monitoring program. It presents the results of the Autumn 2006 (pre-mining) survey and discusses environmental changes observed between this survey and the previous (Spring 2005) survey.

The study area included the reach of Bowmans Creek within the area of proposed underground workings (Figure 1), a control location in Bowmans Creek upstream of the proposed longwall operation and an external control in Rouchel Brook (Figure 2). Bowmans Creek and the reach of Rouchel Brook are both unregulated streams.

The proposed mining has the potential to affect aquatic habitats and biota within the study area and further downstream. Potential impacts of mining on aquatic ecology include the loss of refuge and alteration of habitat in waterbodies, impacts on fish passage (connectivity between up and downstream habitat), changes in water quality within and downstream of the impacted areas and impacts on species of conservation significance.

This document is a continuation of the baseline report on aquatic habitats, fish and macroinvertebrates of Bowmans Creek and Rouchel Brook. Specifically, the aims of this report are to:

- describe aquatic habitats of Bowmans Creek within areas potentially affected by underground mining works and selected control locations;
- establish baseline conditions of aquatic habits, fish, and macroinvertebrates against which changes in these components can be assessed; and,
- Recommend methods for monitoring that will assess impacts from longwall mining and potential mine subsidence affecting Bowmans Creek.

2.0 STUDY METHODS

2.1 Field Studies

2.1.1 Site Selection

Selection of impact and control sites was conducted as part of the initial field studies undertaken in December 2005. Two study locations were selected with Bowmans Creek, one within the area to be mined (predicted impact area) and one upstream of the proposed underground workings (control area). Sites were numbered with the lowest number furthest upstream. The external control location chosen was at Rouchel Brook, first visited on 15 December 2005. Controls were defined as locations similar to the predicted impact location, which would not be affected by the proposed mining. Sampling in control locations provides an estimate of background variability against which changes at the putative impact site could be compared. The chosen control locations included reaches of the watercourses containing a similar variety of aquatic habitats as present in the Bowmans Creek study area. Within each location two study sites (consisting of 105 - 155 m reach of waterway) were identified.

2.1.2 Habitat Assessment

Field studies were carried out from May 30 to June 2. A qualitative assessment of aquatic habitats was compiled for each site, including the following attributes:

- GPS position (datum: WGS 84);
- general land use of surrounding areas;
- instream features such as sequence of pools, runs and riffles (shallow areas with broken water);
- flow, measured at each site using a flowmeter;
- stream substratum;
- presence, extent and type of instream and riparian vegetation;
- potential refuge areas during periods of low flow (e.g. large deep pools);
- presence of fish habitat including snags, bank undercuts and aquatic plants;
- presence of barriers to fish passage into and beyond the study area;
- waterway type using a classification scheme outlined in Fish Passage Requirements for Waterway Crossings (Fairfull and Witheridge, 2003) , and,
- Bank structure, using Riparian, Channel and Environmental (RCE) scores. This methodology was developed by Petersen (1992), and later modified by Chessman (1995) and scores sites based on 13 different categories describing the adjacent land and the physical condition of the stream banks, channel and bed. The scores are summed to provide the RCE score which provides an index of the environmental state of particular locations for use in management decisions. The version used in this study was based on modifications initiated by New South

Wales Environmental Protection Authority. The highest possible score (52) would be assigned to a stream with little or no obvious human disturbance and containing very good habitat characteristics (e.g. diversity of habitats, good shelter, etc.). The lowest possible score (13) would be assigned to a stream with strong evidence of human disturbance and poor aquatic habitat.

A photographic record of the watercourses was obtained using a digital camera to assist in description of the site.

Results of the habitat assessment from this study are compared with those found in the previous field study undertaken in December, 2005.

2.1.3 Water Quality Measurements

Water quality was measured at each site using a Yeo-Kal 611 probe. Variables measured included pH, dissolved oxygen (DO), salinity, oxidation-reduction potential (ORP), temperature, turbidity and conductivity. Two replicate measures were taken from just below the water surface at each site. Where applicable, the results were compared to ANZECC (2000) water quality guidelines for the protection of aquatic ecosystems.

2.1.4 Fish and Mobile Macroinvertebrates

Fish and large mobile invertebrates such as freshwater crayfish were sampled using small baited traps and a back-pack electrofisher (Model LR24 Smith-Root). At each site, six baited traps were deployed in a variety of habitats such as amongst aquatic plants and around snags, in deep holes and over plant litter and bare substratum. The traps were 350 mm long, 200 mm wide with an entrance that tapered in to 45 mm, with 3 mm mesh size throughout. The traps were baited with approximately 70 ml of a mixture of chicken pellets and sardines and deployed for 1.5 hours. Fish caught were collected, identified and released. Alien species were not returned to the water.

Backpack electrofishing was undertaken to gain a qualitative overview of fish species present in each location. The reach of the watercourse was electrofished from downstream to upstream. The back-pack electrofisher was operated around the edge of pools, around snags and aquatic vegetation, overhanging banks, rocky crevices and in riffles. Electrofishing was conducted in five second shots. Stunned fish were collected in a small scoop net, identified and measured. Native species were released unharmed whilst alien species were not returned to water.

2.1.5 Macroinvertebrates

Aquatic macroinvertebrates were sampled in accordance with the Rapid Assessment Method (RAM) based on the Australian River Assessment Scheme (AUSRIVAS) (Turak *et al.* 2004, 2001a,b). The AUSRIVAS model was developed by NSW EPA (now Department of Land and Conservation) to assess invertebrate assemblages against reference conditions derived from a range of waterways with similar physical and chemical characteristics. The model produces a rating based on a comparison of the invertebrate assemblage present at a site to the assemblage expected to occur at the site and is indicative of the environmental condition of a waterway (Turak *et al.* 2001).

2.1.5.1 Field Sampling Methods

Field sampling for macroinvertebrates took place from May 31 to June 2 at 4 sites on Bowmans Creek and 2 sites on Rouchel Brook. The length of sites for RAM sampling were determined as distance of 10 x mode stream width or to a minimum of 100 m length, in accordance with the protocol. Dip nets with a mesh size of 250 μm were used to collect invertebrates from stream edge and riffle habitats. Edge habitat is defined as areas along creek banks with little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, macrophyte beds, overhanging banks and areas with trailing bank vegetation. Riffle habitat is defined as an area of broken water with fair to rapid current, with some cobble or boulder substratum (Turak *et al.* 2004).

Sampling Methodology - Edge Habitats

At each site edge habitat was sampled from slow moving pools. The dip net was first used to disturb animals by agitating bottom sediments and suspending invertebrates into the water column. The net was then swept through this cloud of material to collect invertebrates. Efforts were made to include surface dwelling animals. Samples were collected over a total length of 10 m, usually in 1-2 m sections, ensuring all significant edge sub-habitats within the site were included in the sample (Turak *et al.* 2004).

Sampling Methodology - Riffle Habitats

Riffle habitat was sampled by holding the net into the riffle downstream of the samplers' feet. The sampler started at the lower reaches of the riffle and shuffled upstream actively disturbing the substratum with their feet to dislodge animals. Riffle habitats were sampled to a total length of 10 m, ensuring different riffles (where available) and riffle sub-habitats were included in the sample (Turak *et al.* 2004).

Suitable riffle habitats were not available at the time of sampling for Sites 1, 2 and 3 on Bowmans Creek and Sites 5 and 6 in Rouchel Brook; therefore these sites only have edge RAM components. However as habitats can change over time, suitable riffle habitat at these sites would be assessed again in future should sampling occur.

Each RAM sample was rinsed in the net with local water to minimise fine particles and placed into a white sorting tray. Animals were picked from the tray using forceps and pipettes. Trained staff removed animals for a minimum period of thirty minutes. Thereafter, removals were performed in ten minute periods to a total of one hour, in which picking would cease if no new taxa were found in the ten minute period. Usually, the full hour was required for picking. Care was taken to collect cryptic and fast moving animals in addition to conspicuous or slow moving specimens. Animals collected were placed into a labelled jar containing 70% Ethanol. The chemical and physical variables required for running the AUSRIVAS predictive model were recorded at each site (Turak *et al*. 2004).

2.1.5.2 Laboratory Methods

Animals were removed from any sediment residue and identified using a binocular microscope and counted to a maximum of ten animals, as per the AUSRIVAS protocol. In most cases, taxa were identified to family level except for Copepoda, Hydracarina, Nematoda and Oligochaeta. The family Chironomidae was identified to subfamily level as required by the model. While some families of Anisoptera (dragonfly larvae) and Gastropoda (snails) were identified to lower taxonomic resolutions (genus and species) as

they could potentially include three threatened aquatic species. To validate identification of animals a second experienced scientist performed QA checks on each sample.

2.2 Statistical Analyses

Macroinvertebrates

Field sample collections for the AUSRIVAS Predictive Model assessment are restricted to spring and/or autumn (Turak *et al.* 2004). Because field samples were collected for this study in May/June, the autumn season AUSRIVAS model was applied to these data. The principal outputs of the AUSRIVAS software package are observed/expected (OE) values. The observed values are based on results that were collected. The expected values are derived from an appropriate "reference" condition within the model, selected on the basis of physical and chemical characteristics. The reference conditions were compiled from samples collected at a large number of sites across NSW during the establishment of the model.

AUSRIVAS outputs include the following two types of OE values:

- OE50taxa; and,
- OE50SIGNAL.

OE50taxa: The O (observed) value in OE50taxa parameter is the number of macroinvertebrate families that were predicted to have a probability of occurrence greater than 50% at the site and were actually collected. The E (expected) value in OE50taxa is the sum of the probabilities of finding the predicted macroinvertebrate families (with greater than 50% probability of occurrence). OE values closer to a ratio of 1 indicate macroinvertebrates similar to those of reference streams and the smaller the OE50 value, the more impaired the macroinvertebrate community is considered to be.

OE50SIGNAL: The Stream Invertebrate Grade Number Average Level (SIGNAL) biotic index was developed by Chessman (1995, 2003) as a means of determining environmental 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, while a value of 10 indicates a sensitive family. OE50SIGNAL is the ratio of the observed to expected averaged SIGNAL grades per site for taxa groups recorded with a probability of occurrence of more than 50%.

AUSRIVAS also assigns bands of impairment to each site based on the OE50 values ranging from much richer than reference condition to far poorer than reference condition and allocates a condition of habitat (BAND) for both edge and riffle (Turak *et al*. 2004, 2001).

The condition of habitat was graded into the following categories:

- 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.

The lowest band score obtained for the two habitats within each site was taken as the sites overall condition (Overall BAND), as recommended by the AUSRIVAS protocol.

SIGNAL Index: Following the guidelines in Chessman (2003) grade numbers were allocated to taxa as described in OE50SIGNAL section above. SIGNAL Index was calculated by the sum of all grade numbers for taxa found at each habitat divided by the total number of taxa recorded in each habitat. SIGNAL Index may be used assess communities independent of the AUSRIVAS Protocol. The SIGNAL Index is an indication of water quality and graded into the following categories (Chessman *et al.* 1997).

- SIGNAL Index > 6 = Healthy Unimpaired
- SIGNAL Index 5-6 = Mildly Impaired
- SIGNAL Index 4-5 = Moderately Impaired
- SIGNAL Index < 4 = Severely Impaired.

3.0 RESULTS

3.1 Field Studies

Field studies were carried out from May 30 to June 2. The weather was fine on all days of the survey with some moderate and variable winds. There had been little significant rainfall within the catchments of the study area in the month prior to sampling.

3.1.1 Habitat Assessment

Results of the habitat assessment for all sites are presented in Tables 2a and 2b. Where these results are notably different from the Spring 2005 survey they are presented in greater detail in this section.

Extensive environmental change was observed within all impact and control sites within the study area in this survey compared with the Spring 2005 survey. Seasonal changes had resulted in an increased amount of organic detritus within watercourses mainly due to the large number of exotic deciduous trees (poplars and willows) amongst the riparian vegetation that had undergone, or were undergoing leaf-fall. A reduction in the shading of watercourses was also noted due to the same process. Prolonged drought within the Hunter Valley had resulted in a reduction of available aquatic habitat within Bowmans Creek and Rouchel Brook. Plates 1 - 9 show photos of the same areas of aquatic habitat within all sites in Spring 2005 and Autumn 2006 and illustrate the nature of this environmental change. General changes seen throughout the study area include:

- Reduction and/or loss of riffle habitat;
- Reduction of pool depth and surface area;
- Exposure of beds of aquatic macrophytes;
- Colonisation of stream bed by terrestrial plants;
- Reduction of upstream – downstream habitat connectivity; and,
- Reduction of extent and variety of fish and aquatic macroinvertebrate habitat.

Changes observed within individual locations and sites are outlined below.

3.1.1.1 Area to be Mined

Site 4 consisted of a long, deep, permanent pool and two small shallow riffles, one at each end of the site. The riffles were shallow however they were still flowing despite the prolonged dry conditions. The downstream riffle had a cobble, gravel substrate while the upstream riffle also had silt. Aquatic habitat was continuous throughout the site and showed only a small reduction in water level compared to the Spring 2005 survey (Plate 6).

Site 3 on Bowmans Creek had experienced an extensive loss of aquatic habitat compared with the Spring 2005 survey. The dry cobble bar at the downstream end of the site had been extensively colonised by exotic terrestrial weed species and native grasses (Plate 4). Beds of aquatic macrophytes (*Typha* sp.) that were exposed (out of the water) but healthy in the Spring 2005 survey were greatly reduced and were present only as stands of desiccated plants. The upstream pool within Site 3 had been greatly reduced (Plate 5) from

approximately 100 m to 40 m in length, 12 m to 7 m width and 1.5 m to 0.5 m maximum depth (Table 2a). Much of the aquatic vegetation previously within this pool had been exposed as had the roots of the riparian vegetation within the bank. Leaf-fall from willow trees amongst the riparian vegetation had contributed significantly to vegetative detritus within the stream bed.

3.1.1.2 Upstream of Area to be Mined

Site 2 consisted of two cobble bars with a pool in between. The substratum of the pool was cobble, pebble, sand and silt. The extent of this pool had been significantly reduced since the Spring 2005 survey (Plate 3) with length reduced from approximately 85 m to 50 m, width from 12 m to 8 m, and maximum depth from 1.7 m to 0.5 m (Table 2a). Aquatic macrophytes (*Typha* sp. and *Persicaria* sp.) that were present in the cobble bar at the downstream end of the site had been generally displaced by terrestrial shrubs and grasses.

Within Site 1, aquatic habitat had also been extensively reduced (Plates 1 and 2). In Spring 2005 this site had consisted of a downstream soft-sediment shallow pool approximately 30 m long, and upstream, a long (100m), deep pool making aquatic habitat almost continuous except for a small area of exposed cobble bar at the most downstream end of the site. The only remaining aquatic habitat present in the current survey was two small pools with a combined length of approximately 30 m and a maximum depth of 0.3 m. The extensive beds of *Typha* sp. present in the Spring 2005 survey remained although they were generally exposed. The majority of the foliage of these macrophytes was dry, however green leaves at the base of the plants indicated that they were still alive. Erosion of the banks due to cattle access to the creek, which had been observed in Spring 2005, has been concentrated and was considered to be severe in the parts of the stream bed that retained some water.

3.1.1.3 External Control Sites

Site 5 consisted of a long pool with a riffle at the upstream end of the site. The riffle had been reduced from a rapid flow with a width of 4 m to a trickle that only just allowed flow connectivity with aquatic habitat upstream (Plate 7). This flow was not sufficient to enable invertebrate or fish sampling within the riffle. The downstream pool still provided a significant area of aquatic habitat although the depth and surface area had been reduced. Within this site the presence of dense mats of the floating macrophyte *Azolla* sp. were noted in the stationary waters of the pool (Plate 8, lower). This macrophyte was not present in the Spring 2005 survey.

At Site 6 in Spring 2005 there were two pools, one above and one below a concrete ford with a rapidly flowing riffle with a pebble and cobble substrate downstream. The aquatic habitat within the site in the current survey had been reduced to a single small shallow pool of 5 m length and 0.1 m depth (Plate 9). Beds of emergent macrophytes (sedges and rushes) that were growing within the margins of the stream were completely exposed, and submerged macrophytes (*Myriphyllum* sp.) found in the Spring 2005 survey were no longer present. Within the small remaining pool, and in persistent pools upstream and downstream of the study area, vegetative debris from exotic deciduous willows in the riparian zone was extensive.

3.1.2 Water Quality

The mean (± s.e.) values for water quality variables are presented in Table 3 and compared to ANZECC (2000) guidelines. For comparisons with ANZECC guidelines, Bowmans Creek is classified as a lowland river and Rouchel Brook as an upland river. Conductivity at the all sites in Bowmans Creek was relatively high (1500 – 1850 µS/cm) however this was within ANZECC (2000) guidelines (125 - 2200 µS/cm) for lowland rivers. The conductivity readings at Rouchel Brook were considerably lower than those in Bowmans Creek however these values exceeded the ANZECC guidelines for upland rivers. Conductivity readings were generally lower in Bowmans Creek, and higher in Rouchel Brook than those recorded in Spring 2005.

pH values within Bowmans Creek showed little variation between all sites and were all within ANZECC guidelines. Higher pH readings were noted in Rouchel Brook, with pH at Site 5 just exceeding ANZECC guidelines. pH readings were higher at all sites than those recorded in the Spring 2005 survey. Dissolved oxygen (DO) was considerably lower than ANZECC guidelines at all sites, as was the case in the Spring 2005 survey. Turbidity varied considerably within Bowmans Creek and Rouchel Brook with results for the impact Site 4 being below ANZECC guidelines and results for impact Site 3 exceeding ANZECC guidelines. Turbidity within Site 6 in Rouchel Brook also exceeded the guidelines.

3.1.3 Fish and Mobile Macroinvertebrates

Nine species of fish were recorded in electrofishing and bait-trapping surveys in Bowmans Creek and Rouchel Brook (Table 4). The native species; longfinned eel (*Anguilla reinhardtii*) (Plate 12, upper), bully mullet (*Mugil cephalus*) (Plate 10, upper) and flathead gudgeon (*Philypnodon grandiceps*), and the introduced species; mosquitofish (*Gambusia holbrooki*) and European carp (*Cyprinus carpio*) (Plate 10, lower) were found in sites in both Bowmans Creek and Rouchel Brook. Four other native species; empire gudgeon (*Hypseleotris compressa*) (Plate 11, upper), striped gudgeon (*Gobiomorphus australis*), Australian bass (*Macquaria novemaculeata*) (Plate 11, lower), Australian smelt (*Retropinna semoni*) and freshwater catfish (*Tandanus tandanus*) were found only in Bowmans Creek.

Five native fish species; bully mullet, empire gudgeon, striped gudgeon, Australian bass and freshwater catfish, were found in the current survey that were not found in Spring 2005. Two species; Coxs gudgeon (*Gobiomophus coxii*) and the exotic goldfish (*Carassius auratus*), were found in the Spring 2005 survey but not in the current survey. The exotic pest species, mosquito fish, which was found in very high numbers in the Spring 2005 survey was still present in all sites, but was found in much smaller numbers.

Freshwater shrimp (family Atyidae) were recorded from all sites and a freshwater prawn species (*Macrobrachium* sp.) was found in Bowmans Creek and Rouchel Brook.

3.1.4 Macroinvertebrates

3.1.4.1 General Results

The AUSRIVAS Random Assessment Method (RAM) returned a total of 46 macroinvertebrate taxa from all sites in Autumn 2006. This is markedly lower compared with the results from 2005 Spring survey, which returned a total of 58 taxa. These results are summarised below.

	No. Edge Taxa	No. Riffle Taxa	Total No. Of Taxa
Bowmans Creek (Spring 2005)	33	24	44
Bowmans Creek (Autumn 2006)	31	21	38
Rouchel Brook (Spring 2005)	29	26	42
Rouchel Brook (Autumn 2006)	29	0	29

None of the listed threatened species; Adams Emerald Dragonfly (*Archaeophya adamsi),* Sydney Hawk Dragonfly *(Austrocordulia leonardi)* or River Snail *(Notopala sublineata)* were recorded in the macroinvertebrate specimens collected.

3.1.4.2 AUSRIVAS Results

The indices generated from the AUSRIVAS analyses are presented in Table 7.

The AUSRIVAS model for Autumn 2006 assessed the ecological health with Band classifications as poorer than expected for Bowmans Creek sites. Band classification for Rouchel Brook was "poorer than reference condition" at Site 6, while Site 5 was similar to the expected reference condition (Overall BAND, Table 7). These bands are comparable to those in Spring 2005, showing a slight increase in the overall Band classifications for 2 out of 4 sites in Bowmans Creek and 1 of 2 sites for Rouchel Brook. In Autumn 2006 edge sites, the number of expected taxa with a greater than 50% probability of occurring (OE50taxa) ranged from a low of 0.49 at Site 1 (Bowmans Creek) up to 0.93 at Site 5 (Rouchel Brook). This was higher compared to Spring 2005, with a range from 0.44 at Site 3 (Bowmans Creek) to 0.75 at Site 4 (Bowmans Creek). The only existing riffle in Autumn 2006 returned an OE50taxa score of 0.84 at Site 4 (Bowmans Creek), which showed no marked increase compared to Spring 2005 (0.80). Only Rouchel Brook edge Site 5 showed a value close to 1 (most taxa predicted were present), whilst the remaining sites had fewer taxa than expected.

The observed versus expected SIGNAL scores (OE50SIGNAL) for Autumn 2006 in Bowmans Creek ranged from 0.72-0.89, indicating lower than expected number of sensitive taxa were collected (with greater than 50% chance of occurring), which was equivalent to results from Spring 2005. OE50SIGNAL scores from Rouchel Brook returned a range of 0.63-0.93 for Autumn 2006 edge, with no available riffle habitat to sample. The Spring 2005 results for Rouchel Brook, however, showed a markedly lower OE50SIGNAL range for edge habitat of 0.55-0.60, whilst OE50SIGNAL for riffle habitats ranged from 0.98-1.07, indicating the SIGNAL scores of the taxa present were similar to those found in reference creeks used by the AUSRIVAS model.

From the macroinvertebrate taxa expected to occur in the AUSRIVAS models, one taxon collected from Rouchel Brook was not present in Bowmans Creek. Three taxa that were present in Bowmans Creek were absent in Rouchel Brook. Elmidae was absent from all edge samples and found only at Site 4 riffle. Three expected taxa were not collected from any of the sites in either Bowmans Creek or Rouchel Brook. Both Gerridae and Gomphidae were conspicuously absent from all sites. Calamoceratidae was not recorded in either watercourse.

3.1.4.3 SIGNAL Index

The macroinvertebrates collected from sites in both watercourses contained taxa with both tolerant and sensitive SIGNAL scores as assigned by Chessman (2003) (Table 5). The most sensitive taxa in the collection, Leptophlebiidae (SIGNAL2 grade 8), was present at both Site 5 and Site 4 (riffle). Elmidae (SIGNAL2 grade 7) was recorded at Site 4 (riffle). Of the tolerant taxa present, Atyidae (SIGNAL2 grade 3) and Chironominae (SIGNAL2 grade 3) were recorded at all sites in large numbers. Overall, the SIGNAL scores awarded to all sites indicated water quality to be moderately to severely impaired (Table 8), due to the greater number of pollution tolerant taxa present at sites. Bowmans Creek edge sites ranged from 3.22-3.5 (severely impaired), with the riffle at Site 4 scoring a 4.47 (moderately impaired). The sites in Rouchel Brook were similarly low. These results are similar to the Spring 2005 SIGNAL site scores, with slight increases in Bowmans edge sites and decrease in Bowmans riffle site. Rouchel Brook showed both an increase and decrease across sites.

4.0 CONCLUSIONS

4.1 Species of Conservation Significance

No threatened species were found in Bowmans Creek or Rouchel Brook. It is not expected that any threatened species native to the area will be found, however, if any were discovered the Ashton Coal Environmental Officer would be contacted immediately and assistance given in consultations with the NSW DPI - Fisheries to identify an appropriate amelioration strategy. The freshwater catfish (*Tandanus tandanus*) is not currently listed as threatened under NSW legislation but populations are considered to be reduced in numbers and restricted in distribution. Four individuals were found within the potential impact area of Bowmans Creek in the Autumn 2006 survey demonstrating that this reach of the creek is suitable habitat for this species. However, the Spring 2005 fish survey did not record this species within any watercourses of the study area. Continued fish surveys and habitat assessment of Bowmans Creek during and after longwall extraction (see Section 5, recommendations for monitoring) will monitor the status of this species.

4.2 Key Threatening Processes

Degradation of native riparian vegetation along New South Wales water courses (*FM Act*).

Mine subsidence impacts in the vicinity of Bowmans Creek have the potential to alter stream morphology which could result in increased erosion and degradation of riparian vegetation. Regular monitoring of mine subsidence impacts within Bowmans Creek would allow the rapid identification of such degradation, such that mitigation methods can be instigated, and remediation measures can be undertaken if required.

Alteration of habitat following subsidence due to longwall mining (*TSC Act*).

Aquatic habitats have the potential to be altered or removed as a result of subsidence induced fracturing of the creek substratum due to longwall mining. This can lead to the alteration of habitats through the draining of pools, changes in water quality, and variation in flow characteristics. The proposed monitoring of aquatic habitats during and post longwall extraction will allow the identification of such habitat alteration. The recommended monitoring proposal will also allow determination of the extent of such an impact, the likelihood of natural recovery, or the need for and nature of remediation.

Predation by Gambusia holbrooki (mosquitofish) (*TSC Act*)

Mosquitofish are abundant throughout the study area, with high numbers recorded in Bowmans Creek (Table 4). Degradation of habitat through the loss of riparian vegetation or the deterioration of water quality resulting from subsidence in the vicinity of the creek could provide conditions suitable for the increased proliferation of mosquitofish. This may have a detrimental effect on small native fish which inhabit the area. Regular monitoring of fish within the study area, in combination with monitoring of aquatic habitat will identify such impacts.

4.3 Habitat Assessment

Habitat assessment undertaken in Spring of 2005 and Autumn of 2006 has shown marked differences in aquatic habitat due to seasonal and climatic conditions. The most significant

change was the reduction of water level in all sites, with the associated loss of habitat diversity and extent. Seasonal change in the amount of vegetative detritus within the watercourses and stream shading, due to exotic deciduous trees undergoing leaf-fall were also observed. These changes are independent of any potential future mine subsidence related impacts and need to be considered in any assessment of impacts during and following longwall extraction.

Bowmans Creek was found to be ephemeral within the study areas. There were increased sections of dry, exposed areas at the time of sampling, compared to Spring 2005. This change was minimal in Site 4 (impact area, most downstream site) in Bowmans Creek. However in all other sites this change was significant and extensive. Riffle habitat was found at three of the six sites in the Spring 2005 survey, however only Site 4 in Bowmans Creek contained flowing riffle habitat that could be sampled in the current survey.

Overhanging branches, macrophytes, and snags existed at all sites in Bowmans Creek and Rouchel Brook which could be used as habitat by fish, however many of these that were within the watercourse during the Spring 2005 survey were exposed in the current survey and no longer provided fish habitat. Some aquatic habitat persisted at all sites in the current survey, however pools that were considered permanent in the Spring 2005 survey in Sites 1, 3 and 6 provided only minimal refuge and would not be likely to persist longer that a few more weeks without significant rainfall within the catchment. These remaining isolated pools contained a high density of fish and while providing only poor habitat because of reduced extent, poor water quality, and little habitat variety, were very important environmental refuges. If fracturing were to occur due to subsidence, these important aquatic refuges could be drained.

Barriers to fish passage existed between all the sites in Bowmans Creek, and had increased significantly since the Spring 2005 survey. The waterways classification as "moderate fish habitat" given at all sites in Bowmans Creek reflects this. The fords in Rouchel Brook could act as barriers to fish passage in times of low rainfall a condition reflected in the waterways classification of "moderate-major fish habitat". The lowest RCE scores were given to the control sites in Bowmans Creek and the highest to those in Rouchel Brook, although all were fairly similar. The differences in scores were due to less frequent riffles and fewer logs in Bowmans Creek than Rouchel Brook.

4.4 Water Quality

Most water quality variables at all sites were within ANZECC guidelines. Differences between the sites in Bowmans Creek and Rouchel Brook in conductivity may be attributable to differences in distance from headwaters, catchment geology, landuse, input of saline groundwater and distance travelled underground. The low dissolved oxygen (DO) levels at all sites (all lower than ANZECC guidelines) could be a cause for concern as oxygen is essential to all forms of aquatic life. Variations in DO can occur seasonally and over shorter periods due to factors such as salinity, turbulence, temperature and biological activity (Chapman and Kimstach 1992). There were some noticeable differences recorded in water quality between the current survey and the Spring 2005 survey in conductivity, ORP and pH, however none of these variations were beyond the variability that would be expected within a large and extensively disturbed catchment such as the Hunter Valley.

4.5 Fish and Large Crustaceans

The reduction of fish habitat due to the greatly reduced water levels in the watercourses of the study area provided an opportunity to undertake a thorough survey of those species present. The combination of bait-trapping and electrofishing used in small isolated pools is likely to have accounted for most species present. Within the impact sites in Bowmans Creek, a variety of fish were found including; commercial species (bully mullet, longfinned eel), recreational species (Australian bass and freshwater catfish) and introduced pest species (carp and mosquito fish). This has demonstrated that although Bowmans Creek has been described as being "moderate fish habitat" because of its ephemeral nature and many barriers to fish migration, it does provide habitat for a variety of species, and the fish fauna does form a significant and important part of the aquatic ecology of this watercourse.

4.6 Macroinvertebrates

The results from the AUSRIVAS model indicated that most sites were impaired when compared to the reference condition, with the exception of Site 5 (Rouchel Brook). This is supported by low SIGNAL scores, with macroinvertebrate assemblages comprised primarily of pollution tolerant taxa, typical of impacted systems. Slight changes were observed between Spring 2005 and Autumn 2006, however, these changes should be considered within the associated summer climate and the contraction of available aquatic habitat, with organisms likely to retreat into densely populated refuge zones.

The RCE scores indicated that the surrounding riparian environments have undergone changes in land use activities, likely to influence these results. These impaired baseline conditions need to be considered when examining trends in data from long term monitoring.

4.7 General Conclusions

Bowmans Creek showed many signs of negative human impact at the time of sampling, including numerous weeds and exotic plants, low dissolved oxygen and high conductivity, introduced fish species and a pollution tolerant macroinvertebrate community. Comparison of results between this survey and the Spring 2005 survey shows that environmental variables not associated with mining activity have an extensive impact on the aquatic ecology of this watercourse. These degraded conditions, in combination with environmental variability may make the assessment of any future impacts caused by longwall mining difficult to detect. The use of control sites within Bowmans Creek and at Rouchel Brook that are not impacted by longwall mining will, however, allow comparisons between impact and non-impact areas. A monitoring program that assesses multiple indicators of creek health will also assist with the detection of any future changes.

5. RECOMMENDATIONS FOR MONITORING

Monitoring is an important tool for management of aquatic ecosystems as it allows early indication of impending impacts. This facilitates an accelerated response for mitigation or remediation of those impacts. Monitoring programs can include, amongst other components, use of biological and/or physico-chemical indicators. For Bowmans Creek within the proposed underground mining area and at control sites and external control sites (in Rouchel Brook) it is recommended that a photographic catalogue, along with habitat assessment, water quality measurements, fish sampling, and macroinvertebrate sampling be used to monitor any effects of mine subsidence. The methods outlined in this study are intended to be used in an ongoing monitoring program currently being developed by Ashton Coal operations that will allow assessment of impacts resulting from mine subsidence on aquatic ecology.

Monitoring should be done twice within one year of the longwall passing beneath Bowmans Creek (Ashton Coal 2005). We recommend that these monitoring times coincide with AUSRIVAS Spring and Autumn sampling times to allow the use of the AUSRIVAS predictive model. If sampling is unable to be undertaken outside of the sampling periods allowed for AUSRIVAS model, we suggest that quantitative sampling methods be used. This immediate post-mining sampling will allow assessment of ecosystem changes by comparison with the baseline information. It will allow the assessment of impacts from subsidence or other mining impacts on fish, fish passage, macroinvertebrates, riparian vegetation aquatic habitat, and assist with recommendations for any necessary remedial works.

Long-term monitoring will be required biannually for at least five years following the completion of longwall mining under Bowmans Creek (Ashton Coal 2005). This will allow assessment of long term stability of ecosystems against the pre-mining baseline studies. Changes such as those in vegetation communities, which may not have been obvious immediately after mining, will be able to be assessed, as well as impacts to fish, fish passage, macroinvertebrates, riparian vegetation and aquatic habitat. It is recommended that this sampling coincide with AUSRIVAS Spring and Autumn sampling times.

6.0 ACKNOWLEDGEMENTS

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Web Reference 1: http://www.bionet.nsw.gov.au: NSW Government Bionet System website.

TABLES

Table 1. Freshwater fish species recorded from the Hunter catchment area (using the bionet website, web reference 1).

Family	Species	Common name	Native/Introduced	Status/occurrence in catchment
Ambassidae	*Ambassis marianus*	Silver Perchlet, Estuary Perchlet	N	
Anguillidae	*Anguilla australis*	Short-finned Eel, Silver Eel	N	
	Anguilla reinhardtii	Long-finned Eel, Marbled Eel, Spotted Eel	N	
Atherinidae	*Atherinosoma microstoma*	Small-mouthed Hardyhead, Greyback	N	
	Craterocephalus amniculus	Darling River Hardyhead	N	(species of concern)
	Craterocephalus marjoriae	Marjorie's Hardyhead	N	
Clupeidae	*Potamalosa richmondia*	Freshwater Herring , Nepean Herring	N	
Cyprinidae	*Carassius auratus*	Goldfish	I	
	Cyprinus carpio	Common Carp	I	
	Rutilus rutilus	Roach	I	
Eleotridae	*Gobiomorphus australis*	Striped Gudgeon	N	
	Gobiomorphus coxii	Cox's Gudgeon, Mulgoa Gudgeon, Nepean Gudgeon	N	
	Hypseleotris compressa	Carp Gudgeon, Empirefish, Empire Gudgeon	N	
	Hypseleotris galii	Firetailed Gudgeon, Gale's Gudgeon	N	
	Hypseleotris klunzingeri	Western Carp Gudgeon	N	
	Philypnodon grandiceps	Flathead Gudgeon, Big-headed Gudgeon, Bull Head	N	
Galaxiidae	*Galaxias brevipinnis*	Climbing Galaxias	N	
	Galaxias maculatus	Common Jollytail, Common Galaxias	N	
	Galaxias olidus	Mountain Galaxias, Inland Galaxias	N	
Gobiidae	*Afurcagobius tamarensis*	Tamar River Goby, Tasman Goby	N	
	Arenigobius bifrenatus	Bridled Goby	N	
	Pseudogobius olorum	Swan River Goby, Bluespot Goby, Southern Goby	N	
	Redigobius macrostoma	Compressed Goby, Largemouth Goby	N	
Lutjanidae	*Lutjanus argentimaculatus*	Mangrove Jack, Creek Red Bream, Dog Bream	N	
Megalopidae	*Megalops cyprinoides*	Oxeye Herring, Tarpon	N	
Melanotaeniidae	*Melanotaenia splendida*	Eastern Rainbowfish	N	
Mugilidae	*Liza argentea*	Brown-back Mullet, Bull-nose Mullet, Flat-tail Mullet, Tiger Mullet	N	
	Mugil cephalus	Sea Mullet, Bully Mullet, Flathead Mullet, Mangrove Mullet, Hardgut Mullet	N	
	Myxus elongatus	Bully Mullet, Lano, Poddy, Sand Mullet, Tallegalene	N	
	Myxus petardi	Freshwater Mullet, Pinkeye	N	
	Valamugil georgii	Fantail Mullet, Silver Mullet	N	
Percichthyidae	*Macquaria ambigua*	Golden Perch, Murray Perch, Yellowbelly	N	stocked
	Macquaria colonorum	Estuary Perch	N	
	Macquaria novemaculeata	Australian Bass, Freshwater Perch	N	stocked
Plotosidae	*Tandanus tandanus*	Freshwater Catfish, Tandan, Freshwater Jewfish	N	(species of concern)
Poeciliidae	*Gambusia holbrooki*	Gambusia, Plague Minnow, Mosquitofish	I	
Pseudomugilidae	*Pseudomugil signifer*	Southern Blue-eye, Pacific Blue-eye	N	
Retropinnidae	*Retropinna semoni*	Australian Smelt	N	
Salmonidae	*Oncorhynchus mykiss*	Rainbow Trout , Steelhead	I	stocked
	Salmo trutta	Brown Trout, Sea Trout	I	stocked
	Salvelinus fontinalis	Brook Char, Brook Trout	I	
Scorpaenidae	*Notesthes robusta*	Bullrout, Kroki	N	
Sparidae	*Acanthopagrus butcheri*	Black Bream, Blue-nosed Bream	N	
Terapontidae	*Bidyanus bidyanus*	Silver Perch, Bidyan	N	vulnerable/stocked

Table 2a. Site attributes of Bowmans Creek and Rouchel Brook recorded 30 May - 2 June 2006.

Treatment Description	Site	Plates	Habitat (upstream to downstream)	Substratum	Length (m)	Mode Width (m)	Max depth (m)	Mean average flow m/s (± SE)	RCE score
Area to be mined	Bowmans Creek Site 4	6	riffle	cobble, pebble, gravel	15	1	0.15	0.36 (0.05)	36
			pool	cobble, pebble, gravel, silt	90	4	1.4	0	
			riffle	cobble, gravel	12	0.5	0.1	0.32 (0.05)	
Area to be mined	Bowmans Creek Site 3	4, 5	pool	gravel, sand, silt	40	7	0.5	0	35
			dry cobble bar	cobble	75	-	-	-	
Upstream of area to be mined	Bowmans Creek Site 2	3	dry cobble bar	cobble, pebble, silt	45	-	-	-	34
			pool	pebble, gravel, sand, silt	50	8	0.5	0	
			dry cobble bar	cobble	40	-	-	-	
Upstream of area to be mined	Bowmans Creek Site 1	1, 2	pool	cobble, pebble, gravel, sand, silt	30	4	0.3	0	32
			dry cobble bar	cobble, gravel, silt	125	-	-	-	
External control sites	Rouchel Brook Site 5	7, 8	riffle	boulder, cobble, gravel	25	0.25	0.1	-	38
			pool	boulder, cobble, pebble, gravel	80	8	1.4	0	
External control sites	Rouchel Brook Site 6	9	pool (above ford)	gravel, pebble, cobble	5	2	0.1	0	37
			dry cobble bar	cobble, pebble	100	-	-	-	

Table 2b. Riparian and macrophyte vegetation at Bowmans Creek and Rouchel Brook 30 May - 2 June 2006.

Treatment Description	Site	Riparian vegetation: native (n), exotic (e)	Instream macrophytes: native (n), exotic (e)	Marginal macrophytes: native (n), exotic (e)
Area to be mined	Bowmans Creek Site 4	(n) casuarinas; (e) willows, grasses, weeds, thistles	(n) sago pondweed, *Myriophyllum* sp, clasped pondweed; (e) watercress	(n) cumbungi, river clubrush; (e) spiny rush
Area to be mined	Bowmans Creek Site 3	(n) casuarinas; (e) willows, weeds, thistles, purpletop	(n) sago pondweed, *Myriophyllum* sp, slender knotweed	(n) cumbungi, river clubrush; (e) spiny rush
Upstream of area to be mined	Bowmans Creek Site 2	(n) casuarinas; (e) willows, grasses, weeds, purpletop, curled dock	(n) sago pondweed, curly pondweed, *Myriophyllum* sp, slender knotweed	(n) cumbungi, river clubrush, *Maundia triglochinoides* ; (e) spiny rush
Upstream of area to be mined	Bowmans Creek Site 1	(n) casuarinas; (e) willows, peppercorn trees, poplars, grasses	(n) sago pondweed, curly pondweed, *Myriophyllum* sp, slender knotweed	(n) cumbungi; (e) spiny rush, buttercup, beard rush
External control sites	Rouchel Brook Site 5	(n) casuarinas; (e) willows, peppercorn trees, mint, grasses, St Johns Wort, curled dock, purpletop	(n) clasped pondweed, *Myriophyllum* sp, *Azolla* sp, green filamentous algae	(e) umbrella sedge, slender knotweed, common rush, river clubrush, water couch
External control sites	Rouchel Brook Site 6	(n) casuarinas, wattle; (e) willows, bamboo, purpletop, mint, grasses	(n) clasped pondweed, *Myriophyllum* sp; (e) canadian pondweed	(e) umbrella sedge, slender knotweed, river clubrush, water couch, buttercup

Table 3. Water quality variables measured in Bowmans Creek and Rouchel Brook from 30 May - 2 June 2006. Bowmans Creek is considered a lowland river and Rouchel Brook an upland river. Mean values outside of ANZECC guidelines are shaded. Water quality measured with Yeo-Kal 611 probe.

Date			31/05/2006				31/05/2006			
Time			11:00				10:00			
Watercourse	ANZECC (2000) Recomm. Range		Bowmans Creek				Bowmans Creek			
Site			1				2			
	Upland Rivers	Lowland Rivers								
Elevation (m)	Above 150 m	Below 150 m	80				70			
Replicate			1	2	mean	s.e.	1	2	mean	s.e.
Temperature (°C)			10.29	9.90	10.10	0.20	8.09	8.28	8.19	0.10
Conductivity (µS/cm)	30-350	125-2200	1845	1843	1844	1.00	1512	1516	1514.00	2.00
Salinity (ppt)			1.06	1.07	1	0.01	0.86	0.86	0.86	0.00
pH	6.5-8.0	6.5-8.5	7.44	7.44	7.44	0.00	7.61	7.59	7.60	0.01
ORP (mV)			26	-24	1.00	25.00	219	204	211.50	7.50
DO (%sat'n)	90-110	85-110	70.0	65.0	67.50	2.50	68.3	66.2	67.25	1.05
Turbidity (ntu)	2-25	6-50	50.3	39.5	44.90	5.40	31.1	25.6	28.32	2.75

Date			30/05/2006				30/05/2006			
Time			13:00				11:00			
Watercourse	ANZECC (2000) Recomm. Range		Bowmans Creek				Bowmans Creek			
Site			3				4			
	Upland Rivers	Lowland Rivers								
Elevation (m)	Above 150 m	Below 150 m	60				60			
Replicate			1	2	mean	s.e.	1	2	mean	s.e.
Temperature (°C)			9.36	10.11	9.74	0.38	11.46	11.54	11.50	0.04
Conductivity (µS/cm)	30-350	125-2200	1598	1565	1581.50	16.50	1715	1761	1738.00	23.00
Salinity (ppt)			0.92	0.88	0.90	0.02	0.93	0.96	0.95	0.02
pH	6.5-8.0	6.5-8.5	7.52	7.36	7.44	0.08	7.62	7.61	7.62	0.01
ORP (mV)			342	301	321.50	20.50	-20	-60	-40.00	20.00
DO (%sat'n)	90-110	85-110	89.4	80.1	84.75	4.65	79.4	76.8	78.10	1.30
Turbidity (ntu)	2-25	6-50	52.1	63.7	57.93	5.80	3.5	4.1	3.80	0.27

continued...

Table 3. continued

Date			1/06/2006				1/06/2006			
Time			10:00				12:00			
Watercourse	ANZECC (2000) Recomm. Range		Rouchel Brook				Rouchel Brook			
Site			5				6			
	Upland Rivers	Lowland Rivers								
Elevation (m)	Above 150 m	Below 150 m	220				200			
Replicate			1	2	mean	s.e.	1	2	mean	s.e.
Temperature (°C)			8.07	9.19	8.63	0.56	12.81	11.28	12.05	0.77
Conductivity (µS/cm)	30-350	125-2200	499	504	501.50	2.50	599	583	591.00	8.00
Salinity (ppt)			0.26	0.28	0.27	0.01	0.34	0.32	0.33	0.01
pH	6.5-8.0	6.5-8.5	8.04	8.08	8.06	0.02	7.12	7.18	7.15	0.03
ORP (mV)			224	194	209.00	15.00	-201	-169	-185.00	16.00
DO (%sat'n)	90-110	85-110	62.4	69.3	65.85	3.45	36.1	44.4	40.25	4.15
Turbidity (ntu)	2-25	6-50	4.2	11.5	7.85	3.65	47.3	78.1	62.68	15.42

Table 4. Species of fish recorded using bait trapping and electrofishing in Bowmans Creek and Rouchel Brook from 30 May - 2 June 2006. Shaded rows indicate introduced species.

Bait Traps (totals for 6 replicates, set for 90 minutes each). Traps were deployed from 31/05/2006 - 2/06/2006

		Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Rouchel Brook	Rouchel Brook
		Site	1	2	3	4	5	6
Family	Common Name	Species						
Poeciliidae	Mosquito Fish	*Gambusia holbrooki*	99	7	16			7
Retropinnidae	Australian Smelt	*Retropinna semoni*		15	62			

Electrofishing (conducted in 5 second shots throughout site).

		Date	1/06/2006	1/06/2006	2/06/2006	2/06/2006	1/06/2006	1/06/2006
		Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Rouchel Brook	Rouchel Brook
		Site	1	2	3	4	5	6
		Total time (sec)	119	595	520	558	510	208
Family	Common Name	Species						
Anguillidae	Long finned eel	*Angulla reinhardtii*	7	2	7	6	10	2
Gobiidae	Flathead Gudgeon	*Philypnodon grandiceps*		3	1		2	
Poeciliidae	Mosquito Fish	*Gambusia holbrooki*	4	9		1	5	
Cyprinidae	Carp	*Cyprinus carpio*	9	1	1		2	2
Gobiidae	Empire Gudgeon	*Hypseleotris compressa*				1		
Gobiidae	Striped Gudgeon	*Gobiomorphus australis*			7	2		
Mugilidae	Bully Mullet	*Mugil cephalus*		1	3			1
Palaemonidae	Freshwater Prawn	*Macrobrachium* spp.			3		9	3
Percichthydae	Australian Bass	*Macquaria novemaculeata*			2			
Plotosidae	Freshwater Catfish	*Tandanus tandanus*			4			

Table 5. Macroinvertebrate families identified from AUSRIVAS samples, collected from Edge and Riffle habitats in Bowmans Creek and Rouchel Brook from 30 May - 2 June 2006. Signal2 Grade based on Chessman (2003) (blank SIGNAL2 Grade indicate no appropriate grade for that group).

Location	Bowmans Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Rouchel Brook	Rouchel Brook	Bowmans Creek	Rouchel Brook	Rouchel Brook	SIGNAL2 Grade
Site	1	2	3	4	5	6	4	5	6	Awarded to
Habitat	Edge	Edge	Edge	Edge	Edge	Edge	Riffle	Riffle	Riffle	Family
Order or Family										
Atyidae	5	6	10	10	6	10	4	Dry	Dry	3
Baetidae	1			3	3	10	10			5
Caenidae	5	8	10	4	10	5	10			4
Ceratopogonidae						1				4
Chironomidae/Chironominae	10	2	5	5	10	10	5			3
Chironomidae/Orthocladiinae		2		1	5	7	3			4
Chironomidae/Tanypodinae					4	1				4
Cladocera					10	1				
Coenagrionidae	8	10	10	6	1					2
Copepoda		2	6	5	5	10				
Corbiculidae/ Sphaeriidae				1	1		6			5
Corixidae	1		8	1	7	10				2
Dugesiidae			1				3			2
Dytiscidae	2	2	3	1	8					2
Ecnomidae	1	1	2				2			4
Elmidae							1			7
Entomobryidae/Isotomidae					1		1			
Ephydridae		1								2
Gastropoda							1			1
Glossiphoniidae			1				1			1
Haliplidae		1								2
Hemicorduliidae (=Corduliidae)		1	2							5

Continued…

Table 5. continued

Location	Bowmans Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Rouchel Brook	Rouchel Brook	Bowmans Creek	Rouchel Brook	Rouchel Brook	SIGNAL2 Grade
Site	1	2	3	4	5	6	4	5	6	Awarded to
Habitat	Edge	Edge	Edge	Edge	Edge	Edge	Riffle	Riffle	Riffle	Family
Order or Family										
Hydracarina	3	2	10	2	2			Dry	Dry	6
Hydrophilidae		3	1							2
Hydropsychidae							8			6
Hydroptilidae					1	1				4
Isostictidae			1							3
Leptoceridae		1		2	2	1	3			6
Leptophlebiidae					5		4			8
Libellulidae				1	3		1			4
Mesoveliidae				1	2					2
Nematoda			1							3
Notonectidae					1					1
Oligochaeta	1	1		1	1		5			2
Ostracoda				1			1			
Parastacidae					4					4
Physidae				1	2					1
Planorbidae				1						2
Pleidae				1						2
Protoneuridae			1		4					4
Psephenidae							1			6
Scirtidae (= Helodidae, Cyphonidae)					1		1			6
Sialidae	1					1				5
Simuliidae				3			10			5
Temnocephalidae					3					5
Veliidae					1	1				3

Table 6. Summary Statistics for macroinvertebrate families identified from AUSRIVAS samples, collected from Edge and Riffle habitats on Bowmans Creek and Rouchel Brook from 30 May - 2 June 2006. Rouchel Brook riffle habitats were dry.

Location	Bowmans Creek	Bowmans Creek	Bowmans Creek	Bowmans Creek	Rouchel Brook	Rouchel Brook	Bowmans Creek	Rouchel Brook	Rouchel Brook
Site	1	2	3	4	5	6	4	5	6
Habitat	Edge	Edge	Edge	Edge	Edge	Edge	Riffle	Riffle	Riffle
Number of individuals	38	43	72	51	103	69	81	Dry	Dry
Number of worms	1	1	3	1	4	0	9		
Number of crustaceans	5	8	16	16	25	21	5		
Number of molluscs	0	0	0	3	3	0	7		
Number of insects	29	32	43	29	68	48	59		
Number of mayflies	6	8	10	7	18	15	24		
Number of damselflies/dragonflies	8	11	14	7	8	0	1		
Number of bugs	1	0	8	3	11	11	0		
Number of beetles	2	6	4	1	9	0	3		
Number of true flies	10	5	5	9	19	19	18		
Number of caddis-flies	1	2	2	2	3	2	13		
Number of other insects	1	0	0	0	0	1	0		
Number of other taxa	3	2	10	2	3	0	1		
Number of taxa	11	15	16	20	27	14	21	Dry	Dry
Number of worm taxa	1	1	3	1	2	0	3		
Number of crustacean taxa	1	2	2	3	4	3	2		
Number of mollusc taxa	0	0	0	3	2	0	2		
Number of insect taxa	8	11	10	12	17	11	13		
Number of mayfly taxa	2	1	1	2	3	2	3		
Number of damselfly/dragonfly taxa	1	2	4	2	3	0	1		
Number of bug taxa	1	0	1	3	4	2	0		
Number of beetle taxa	1	3	2	1	2	0	3		
Number of true fly taxa	1	3	1	3	3	4	3		
Number of caddis-fly taxa	1	2	1	1	2	2	3		
Number of other insect taxa	0	0	0	0	0	0	0		
Number of other taxa	1	1	1	1	2	0	1		

Table 7. AUSRIVAS scores for edge and riffle habitats sampled 30 May - 2 June 2006. Outputs include observed versus expected taxa (OE50Taxa) based on those taxa predicted with a greater than 50% probability of occurring. AUSRIVAS bands: A = Similar to AUSRIVAS references; B = Poorer than AUSRIVAS references; C = Much poorer than AUSRIVAS references. The bands of biological condition are based on the OE50Taxa and not the OE50SIGNAL values. OE50SIGNAL is the ratio of expected to observed averaged SIGNAL Grades based on Chessman (2003).

a) May 2006: Edge Habitats

	Bowmans Creek				Rouchel Brook	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Band	B	B	B	B	A	B
Expected no of taxa (NTE50)	14.17	13.78	13.79	14.04	12.93	14.24
Observed/expected no of taxa (OE50)	0.49	0.58	0.51	0.71	0.93	0.63
Observed SIGNAL (O50SIGNAL)	3.57	3.75	3.14	3.90	4.17	3.78
Expected SIGNAL (E50SIGNAL)	4.38	4.39	4.39	4.40	4.41	4.40
Observed/Expected SIGNAL scores (OE50SIGNAL)	0.81	0.85	0.72	0.89	0.94	0.86

b) May 2006: Riffle Habitats

	Bowmans Creek				Rouchel Brook	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Band	No suitable habitat			B	No suitable habitat	
Expected no of taxa (NTE50)				15.48		
Observed/expected no of taxa (OE50)				0.84		
Observed SIGNAL (O50SIGNAL)				4.69		
Expected Signal (E50SIGNAL)				5.47		
Observed/Expected SIGNAL scores (OE50SIGNAL)				0.86		

c) May 2006: Edge and riffle habitats combined

	Bowmans Creek				Rouchel Brook	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Overall Band	B	B	B	B	A	B

Table 8. SIGNAL Index calculated from SIGNAL grades assigned to all taxa in each site (Chessman, 2003). SIGNAL Index is calculated as the sum of all SIGNAL Grades for families present divided by total number of families. SIGNAL Index > 6 = Healthy Unimpaired, 5-6 = Mildly Impaired, 4-5 = Moderately Impaired, < 4 = Severely Impaired (Chessman 1997).

a) May 2006: Edge Habitats

	Bowmans Creek				Rouchel Brook	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Signal Index	3.45	3.50	3.22	3.48	3.85	4.14

b) May 2006: Riffle Habitats

	Bowmans Creek				Rouchel Brook	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Signal Index	No suitable habitat			4.47	No suitable habitat	

FIGURES

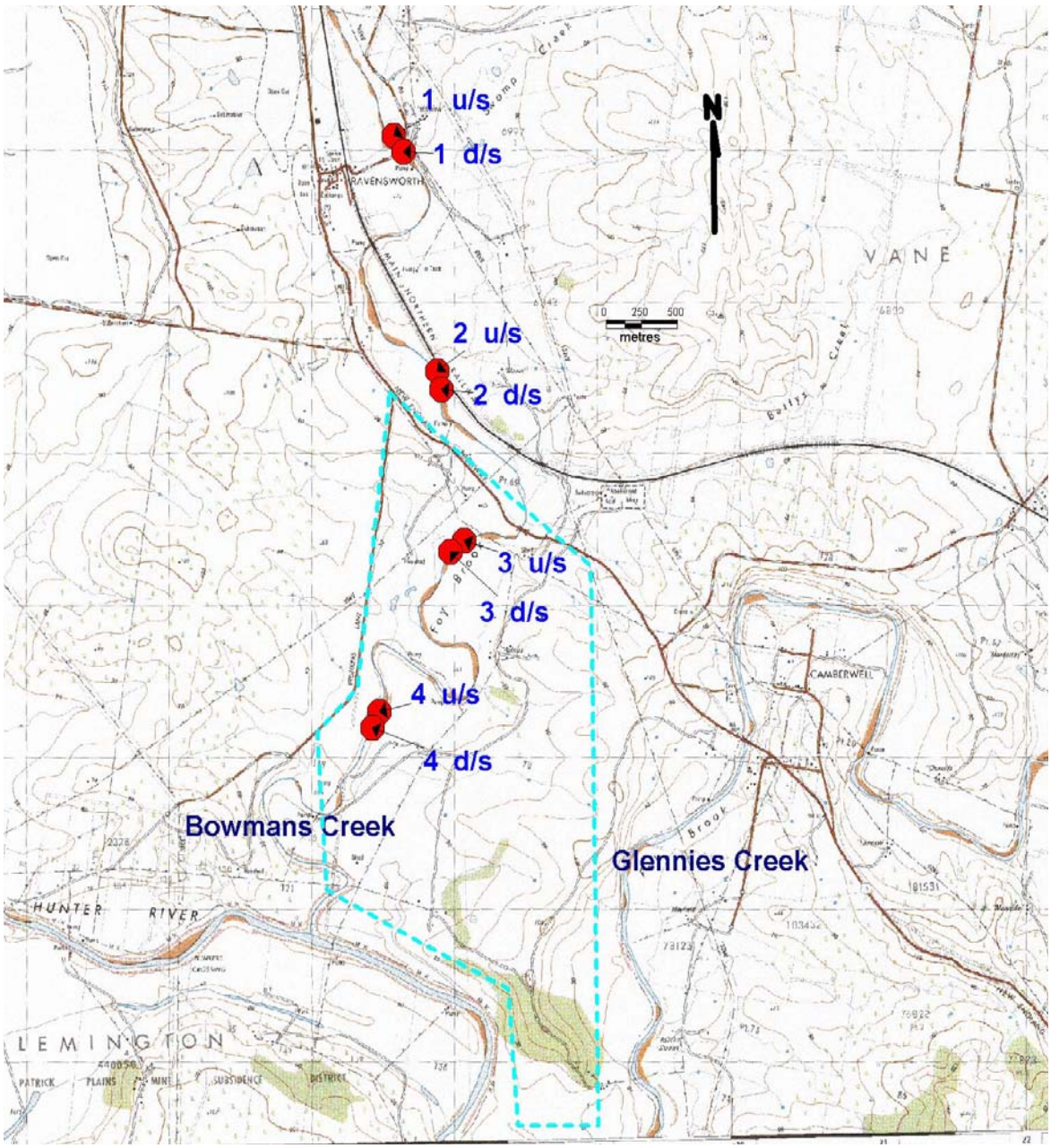

Figure 1. Map showing Bowmans Creek Sites 1-4. U/s indicates upstream extent of site, d/s indicates downstream extent of site. Blue dotted line shows proposed long wall mining area.

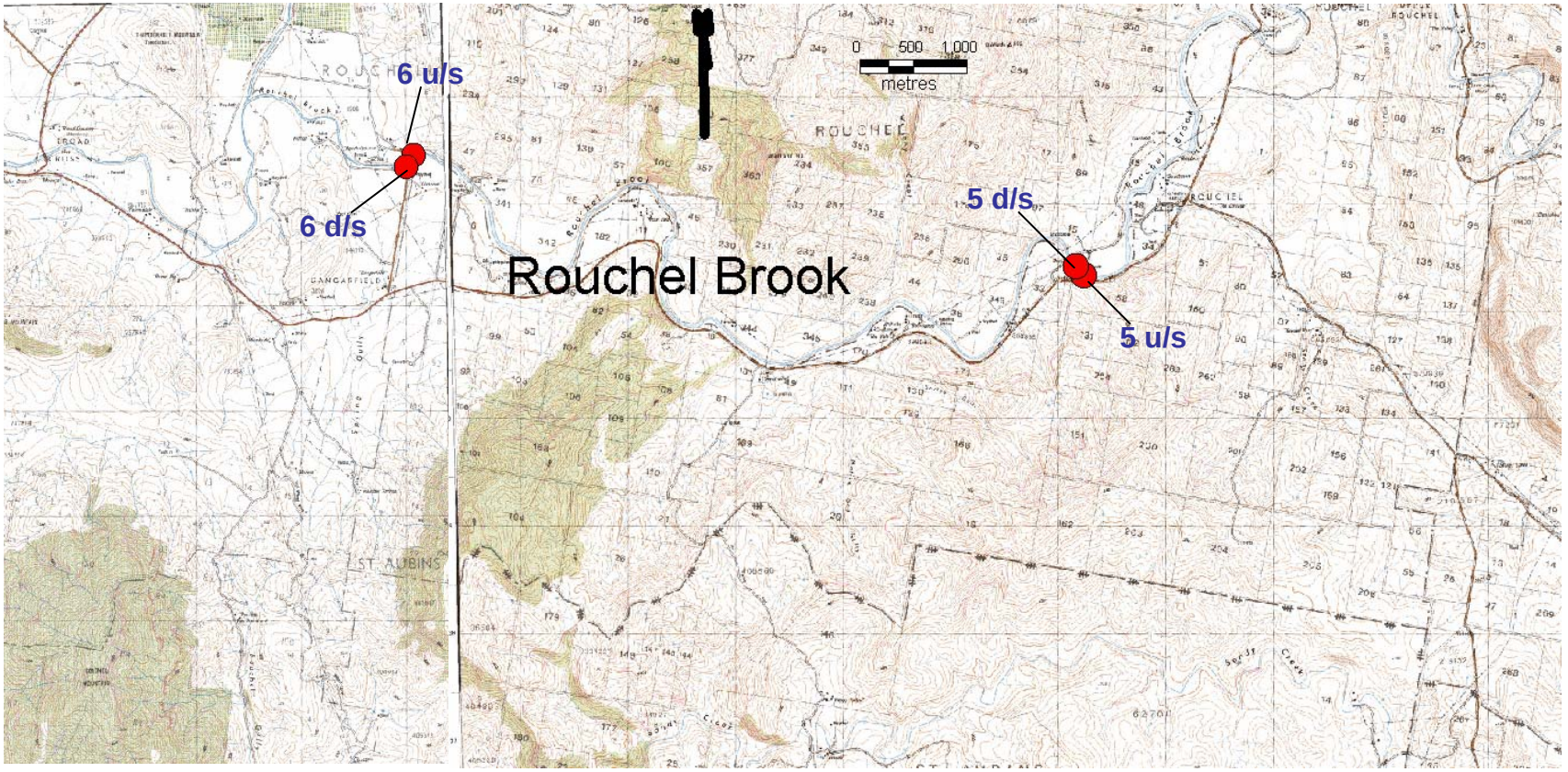

Figure 2. Map showing Rouchel Brook Sites 5 and 6. U/s indicates upstream extent of site, d/s indicates downstream extent of site.

PLATES

Plate 1 Upper: Site 1 in Bowmans Creek (Spring 2005).

Plate 1 Lower: Site 1 in Bowmans Creek (Autumn 2006).

Plate 2 Upper: Site 1 in Bowmans Creek (Spring 2005).

Plate 2 Lower: Site 1 in Bowmans Creek (Autumn 2006).

Plate 3 Upper: Site 2 in Bowmans Creek (Spring 2005).

Plate 3 Lower: Site 2 in Bowmans Creek (Autumn 2006).

Plate 4 Upper: Site 3 in Bowmans Creek (Spring 2005).

Plate 4 Lower: Site 3 in Bowmans Creek (Autumn 2006).

Plate 5 Upper: Site 3 in Bowmans Creek (Spring 2005).

Plate 5 Lower: Site 3 in Bowmans Creek (Autumn 2006).

Plate 6 Upper: Site 4 in Bowmans Creek (Spring 2005).

Plate 6 Lower: Site 4 in Bowmans Creek (Autumn 2006).

Plate 7 Upper: Site 5 in Rouchel Brook (Spring 2005).

Plate 7 Lower: Site 5 in Rouchel Brook (Autumn 2006).

Plate 8 Upper: Site 5 in Rouchel Brook (Spring 2005).

Plate 8 Lower: Site 5 in Rouchel Brook (Autumn 2006).

Plate 9 Upper: Site 6 in Rouchel Brook (Spring 2005).

Plate 9 Lower: Site 6 in Rouchel Brook (Autumn 2006).

Plate 10 Upper: Sea Mullet (*Mugil cephalus*) caught at Site 6 in Rouchel Brook

Plate 10 Lower: Carp (*Cyprinus carpio*) caught at Site 5 in Rouchel Brook.

Plate 11 Upper: Empire Gudgeon (*Hypseleotris compressa*) caught at Site 3 in Bowmans Creek.

Plate 11 Lower: Australian Bass (*Macquaria novemaculeata*) caught at Site 3 in Bowmans Creek.

Plate 12 Upper: Longfinned Eel (*Anguilla reinhardtii*) caught at Site 4 in Bowmans Creek.

Annex C

Flora Species List

Table C.1 Flora List – Bowmans Creek Riparian Corridor

Scientific Name	Common Name
ANACARDIACEAE	
Schinus areira	pepper tree
APIACEAE	
Apium leptophyllum	slender celery
Foeniculum vulgare	fennel
ASCLEPIADACEAE	
Gomphocarpus fruticosus	narrow leaved cotton bush
ASTERACEAE	
Ageratina adenophora	crofton weed
Bidens pilosa	cobblers pegs
Carthamus lanatus	saffron thistle
Cirsium vulgare	spear thistle
Conyza albida	tall fleabane
Lactuca serriola	prickly lettuce
Onopordum acanthium	scotch thistle
Senecio madagascariensis	fireweed
Senecio quadridentatus	cotton fireweed
Sonchus oleraceus	common sow thistle
Tagetes minuta	stinking roger
Taraxacum officinale	dandelion
Tragopogon porrifolius	oyster plant
Xanthium spinosum	Bathurst burr
Xanthium occidentale	Noogora burr
AZOIACEAE	
Galenia pubescens	
Galenia secunda	galenia
BASELLACEAE	
Anredera cordifolia	madeira vine
BRASSICACEAE	
Brassica juncea	Indian mustard
Brassica fruticulosa	
Lepidium hyssopifolium	peppercress
BORAGINACEAE	
Heliotropium amplexicaule	blue heliotrope
CACTACEAE	
Opuntia aurantiaca	tiger pear
Opuntia humifusa	prickly pear
CARYOPHYLLACEAE	
Petrorhagia nanteuilii	proliferous pink
Stellaria media	chickweed
CASUARINACEAE	
Casuarina cunninghamia	river she-oak
CHENOPODIACEAE	
Atriplex sp.	saltbush
Einadia nutans	native seaberry
Einadia hastata	
CLUSIACEAE	
Hypericum perforatum	St John's wort
COMMELINACEAE	
Commelina cyanea	scurvy weed
CONVOLVULACEAE	
Convolvulus erubescens	

Scientific Name	Common Name
CRASSULACEAE	
Bryophyllum delagoense	mother of millions
CYPERACEAE	
Cyperus eragrostis	
Cyperus exaltatus	
Cyperus gracilis	
Cyperus sanguinolentus	
Schoenus apogon	river club rush
EUPHORBIACEAE	
Chamaesyce drummondii	caustic weed
Euphorbia peplus	petty spurge
Ricinus communis	castor oil plant
FABACEAE	
Glycine clandestina	love creeper
GENTIANACEAE	
Centaurium erythraea	common centaury
JUNCACEAE	
Baumea articulata	jointed twig rush
Juncus acutus	
Juncus sarophorus	
Juncus subsecundus	finger rush
Juncus usitatus	
LAMIACEAE	
Marrubium vulgare	white horehound
LOMANDRACEAE	
Lomandra longifolia	mat rush
MALVACEAE	
Pavonia hastata	pavonia
Sida rhombifolia	paddy's lucerne
MELIACEAE	
Melia azedarach	white cedar
MIMOSOIDEAE	
Acacia farnesiana	mimosa bush
Prosopis juliflora	mesquite
MYOPORACEAE	
Eremophila debilis	amulla
MYRTACEAE	
Angophora floribunda	rough barked apple
Eucalyptus camaldulensis	river red gum
Eucalyptus crebra	narrow leaved ironbark
Eucalyptus melliodora	yellow box
Eucalyptus microcarpa	grey box
ONAGRACEAE	
Oenothera indecora ssp. *bonariensis*	small flower evening primrose
Oenothera stricta	common evening primrose
OXALIDACEAE	
Oxalis corniculata	yellow wood sorrel
PAPAVERACEAE	
Argemone ochroleuca	Mexican poppy
PHYTOLACCACEAE	
Phytolacca octandra	inkweed
PITTOSPORACEAE	
Plantago lanceolata	plantain
POACEAE	
Anisopogon avenaceus	oat speargrass

Scientific Name	Common Name
Aristida vagrans	three awn spear grass
Arundo sp.	
Austrodanthonia sp	wallaby grass
Avena fatua	wild oats
Bromus catharticus	prairie grass
Bromus molliformis	soft brome
Chloris ventricosa	tall windmill grass
Chloris truncata	windmill grass
Cynodon dactylon	common couch
Dichelachne crinata	longhair plume grass
Dichelachne micrantha	short haired plume grass
Digitaria coenicola	
Eleusine tristachya	
Enneapogon nigricans	bottle washers
Setaria geniculata var *pauciseta*	slender pigeon grass
Setaria verticillata	whorled pigeon grass
Sporobolus creber	slender rat's tail grass
Stipa bigeniculata	yanganbill
Panicum maxima	
Panicum simile	two colour panic
Paspalum dilatatum	common paspalum
Pennnisetum clandestinum	kikuyu grass
Phalaris minor	lesser canary grass
Phyllostachys sp.	bamboo
Stipa scabra	rough speargrass
POLYGONACEAE	
Acetosa sagittata	turkey rhubarb
Rumex acetosella	sheep sorrel
Rumex brownii	swamp dock
Rumex conglomeratus	clustered dock
Rumex crispus	curled dock
Persicaria decipiens	
Persicaria praetermissa	
PRIMULACEAE	
Anagalis arvensis	scarlet pimpernel
RANUNCULACEAE	
Ranunculus sp.	buttercup
RUTACEAE	
Geigera parviflora	wilga
ROSACEAE	
Prunus sp	peach tree
Rosa sp	rose
SALICACEAE	
Populus nigra	lombardy poplar
SCHIZAEACEAE	
Cheilanthes distans	bristly cloak fern
Cheilanthes sieberi	mulga fern
SOLANACEAE	
Cestrum parqui	green cestrum
Lycium ferocissimum	African boxthorn
Solanum pseudocapsicum	Jerusalem cherry
SCROPHULARIACEAE	
Verbascum virgatum	twiggy mullein
SALICACEAE	
Salix babylonica	weeping willow

Scientific Name	Common Name
TYPHACEAE	
Typha orientalis	
VALLISNERIA	
Vallisneria gigantea	ribbon weed
VERBENACEAE	
Verbena bonariensis	purpletop
Verbena rigida	
ZYGOPHYLLACEAE	
Tribulus terrestris	cat head

Annex D

Vegetation Survey Data

D.1 TRANSECT 1

Date: 12/01/2006
MGA Coordinates: Start - 318380E, 6406653N
Finish - 318260E, 6406640N
Locality Description: East of Bowmans Creek
Length: 200m
Disturbance History: Grazing, dumping, weed encroachment

Table D.1 Transect 1

	Scientific Name	Common Name
Canopy		
	Casuarina cunninghamia	river she-oak
Mid Stratum		
	Lycium ferocissimum	african boxthorn
	Typha orientalis	
Groundcover		
	Schoenus apogon	river club rush
	*Cynodon dactylon**	common couch
	Opuntia humifusa	prickly pear
	Heliotropium amplexicaule	
	Cirsium vulgare	spear thistle
	Plantago lanceolata	plantain
	Sonchus oleraceus	common sow thistle
	Panicum simile	two colour panic
	Paspalum dilatatum	common paspalum
	Conyza albida	tall fleabane
	Rumex brownie	swamp dock
	*Tagetes minuta**	stinking roger
	Solanum pseudocapsicum	Jerusalem cherry
	Oenothera indecora ssp. bonariensis	small flower evening primrose
	*Petrorhagia nanteuilii**	proliferous pink
	Persicaria decipiens	
	Commelina cyanea	scurvy weed
	Chamaesyce drummondii	caustic weed
	*Verbena bonariensis**	purpletop
	*Juncus usitatus**	
	Xanthium occidentale	noogora burr
	*Gomphocarpus fruticosus**	narrow leaved cotton bush

* = Dominant species

D.2 TRANSECT 2

Date: 12/01/2006
MGA Coordinates: Start - 318258E, 6405901N
Finish - 318277E, 6405690N
Locality Description: East of Bowmans Creek on Oxbow
Distance 200m
Disturbance History Grazing, dumping, weed encroachment

Table D.2 Transect 2

	Scientific Name	Common Name
Canopy		
	Casuarina cunninghamia	river she-oak
	Salix babylonica	weeping willow
	Prunus sp	peach tree
	Populus alba	white poplar
Mid Stratum	*Typha orientalis*	
	Prosopis juliflora	mesquite
	Lycium ferocissimum	african boxthorn
	Arundo sp.	bamboo
Groundcover		
	Schoenus apogon	river club rush
	*Verbena bonariensis**	purpletop
	Juncus acutus	
	Setaria geniculata var pauciseta	slender pigeon grass
	Dichelachne crinata	longhair plume grass
	Eleusine tristachya	
	Phytolacca octandra	
	Opuntia humifusa	prickly pear
	Ricinus communis	castor oil plant
	Cyperus gracilis	
	*Cynodon dactylon**	common couch
	Plantago lanceolata	plantain
	Optuntia aurantiaca	tiger pear
	Onopordum acanthium	scotch thistle
	Bryophyllum delagoense	mother of millions
	Foeniculum vulgare	fennel
	Chloris truncate	windmill grass
	Petrorhagia nanteuilii	proliferous pink
	Sporobolus creber	slender rat's tail grass
	Digitaria coenicola	
	Cyperus eragrostis	
	Austrodanthonia sp	wallaby grass
	Tragopogon porrifolius	oyster plant
	Rumex conglomeratus	clustered dock
	Commelina cyanea	scurvy weed
	Oxalis corniculata	yellow wood sorrel
	Cheilanthes distans	bristly cloak fern
	Galenia secunda	Galenia
	Galenia pubescens	

	Scientific Name	Common Name
Climber	*Glycine clandestine*	love creeper
	Glycine clandestine	love creeper

* = Dominant species

D.3 TRANSECT 3

Date: 12/01/2006
MGA Coordinates: Start - 317569E, 6405917N
Finish - 317583E, 6405744N
Locality Description: East of Bowmans Creek
Distance: 200m
Slope: west facing
Disturbance History: Grazing, erosion, weed encroachment
Additional Comments: 4 dead turtles (old shells), weir

Table D.3 Transect 3

	Scientific Name	Common Name
Canopy		
	Casuarina cunninghamia	river she-oak
	Salix babylonica	weeping willow
Mid Stratum		
	Arundo sp.	bamboo
	Lycium ferocissimum	African boxthorn
	*Typha orientalis**	
Groundcover		
	Schoenus apogon	river club rush
	Cirsium vulgare	spear thistle
	*Verbena bonariensis**	purpletop
	*Gomphocarpus fruticosus**	narrow leaved cotton bush
	Plantago lanceolata	plantain
	Brassica juncea	Indian mustard
	*Cynodon dactylon**	common couch
	Pennisetum clandestinum	kikuyu grass
	Persicaria decipiens	
	Stellaria media	chickweed
	Argemone ochroleuca	Mexican poppy
	Verbascum virgatum	twiggy mullein
	Conyza albida	tall fleabane
	Dichelachne micrantha	short haired plume grass
	Bromus molliformis	soft brome
	Galenia pubescens	
	*Juncus usitatus**	

* = Dominant species

D.4 TRANSECT 4

Date: 12/01/2006
MGA Coordinates: Start - 317783E, 6405854N
Finish - 317954E, 6405728N
Locality Description: West of Bowmans Creek
Distance: 200m
Disturbance History: Grazing, erosion, weed encroachment
Additional Comments: shed, hollow bearing casuarina

Table D.4 Transect 4

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
	Schinus areira	pepper tree
Mid Stratum		
	Lycium ferocissimum	African boxthorn
	Typha orientalis	
Groundcover		
	Brassica juncea	Indian mustard
	Juncus usitatus	
	Rumex brownii	swamp dock
	Stipa bigeniculata	yanganbill
	Opuntia humifusa	prickly pear
	Bidens pilosa	cobblers pegs
	Foeniculum vulgare	fennel
	Setaria verticillata	whorled pigeon grass
	Bromus catharticus	prairie grass
	Dichelachne micrantha	short haired plume grass
	Apium leptophyllum	slender celery
	Stipa bigeniculata	yanganbill
	Plantago lanceolata	plantain
	Sporobolus creber	slender rat's tail grass
	Oenothera indecora ssp.	
	Bonariensis	small flower evening primrose
	*Cynodon dactylon**	common couch
	Phalaris minor	lesser canary grass
	Phytolacca octandra	inkweed
	Commelina cyanea	scurvy weed
	Verbena rigida	
	Galenia pubescens	
	*Verbena bonariensis**	purpletop
Climber		
	Anredera cordifolia	madeira vine

* = Dominant species

D.5 TRANSECT 5

Date: 12/01/2006
MGA Coordinates: Start - 317865E, 6406044N
Finish - 317876E, 6406193N
Locality Description: West of Bowmans Creek
Distance: 100m
Disturbance History: Grazing, erosion, weed encroachment
Additional Comments: Fenced off sections prevent cattle access

Table D.5 Transect 5

	Scientific Name	Common Name
Canopy		
	Casuarina cunninghamia	river she-oak
	Salix babylonica	weeping willow
	Schinus areira	pepper tree
Mid Stratum		
	Lycium ferocissimum	African boxthorn
Groundcover		
	Setaria geniculata var pauciseta	slender pigeon grass
	Onopordum acanthium	scotch thistle
	Chloris truncata	windmill grass
	Senecio madagascariensis	fireweed
	Xanthium spinosum	Bathurst burr
	Rumex crispus	curled dock
	Sonchus oleraceus	common sow thistle
	Cirsium vulgare	spear thistle
	Conyza albida	tall fleabane
	Bidens pilosa	cobblers pegs
	Plantago lanceolata	plantain
	Cynodon dactylon	common couch
	Brassica juncea	Indian mustard
	Juncus sarophorus	
	Xanthium occidentale	Noogora burr
	Cestrum parqui	green cestrum
	Setaria verticillata	whorled pigeon grass
	Bromus molliformis	soft brome
	Enneapogon nigricans	bottle washers
	*Verbena bonariensis**	purpletop
	Juncus usitatus	
	Lepidium hyssopifolium	peppercress
	Commelina cyanea	scurvy weed/creeping christian
	Galenia secunda	Galenia

* = Dominant species

D.6 TRANSECT 6

Date:	12/01/2006
MGA Coordinates:	Start - 318055E, 6406531N
	Finish - 318139E, 6406633N
Locality Description:	West of Bowmans Creek on Oxbow
Distance:	200m
Disturbance History:	Grazing, erosion, weed encroachment
Additional Comments:	Dense thickets of boxthorn, casuarina

Table D.6 Transect 6

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
	Salix babylonica	weeping willow
Mid Stratum		
	Lycium ferocissimum	African boxthorn
Groundcover		
	*Verbena bonariensis**	purpletop
	Ricinus communis	castor oil plant
	Plantago lanceolata	plantain
	Austrodanthonia sp	wallaby grass
	Juncus usitatus	
	Panicum simile	two colour panic
	Panicum maxima	
	Conyza albida	tall fleabane
	Cynodon dactylon	common couch
	Stipa bigeniculata	yanganbill
	Brassica juncea	Indian mustard
	Optuntia aurantiaca	tiger pear
	Bromus catharticus	prairie grass
	Bidens pilosa	cobblers pegs
	Commelina cyanea	scurvy weed

* = Dominant species

D.7 TRANSECT 7

Date: 13/01/2006
MGA Coordinates: Start - 316971E, 6404533N
Finish - 316864E, 6404664N
Locality Description: East of Bowmans Creek
Distance: 200m
Disturbance History: Erosion, weed encroachment
Additional Comments: Stand of 6 river red gum 316885E, 6404645N
extent of species 316811E, 6404800N

Table D.7 Transect 7

	Scientific Name	Common Name
Canopy		
	Eucalyptus camaldulensis	river red gum
	Casuarina cunninghamia	river she-oak
	Salix babylonica	weeping willow
	Geigera parviflora	wilga
Mid Stratum		
	Arundo sp.	bamboo
	Typha orientalis	
Groundcover		
	Senecio madagascariensis	fireweed
	Cirsium vulgare	spear thistle
	Conyza albida	tall fleabane
	Plantago lanceolata	plantain
	*Cynodon dactylon**	common couch
	Brassica juncea	Indian mustard
	Oenothera stricta	common evening primrose
	Brassica fruticulosa	
	Schoenus apogon	river club rush
	Cyperus sanguinolentus	
	Bromus catharticus	prairie grass
	Juncus subsecundus	finger rush
	Stipa bigeniculata	yanganbill
	Opuntia aurantiaca	tiger pear
	*Bidens pilosa**	cobblers pegs
	Paspalum dilatatum	common paspalum
	Xanthium occidentale	Noogora burr
	Commelina cyanea	scurvy weed / creeping christian
	Galenia pubescens	
	*Verbena bonariensis**	purpletop
	Juncus usitatus	
	Einadia nutans	native seaberry

* = Dominant species

D.8 TRANSECT 8

Date: 13/01/2006
MGA Coordinates: Start - 317347E, 6405041N
Finish - 317443E, 6405142N
Locality Description: East of Bowmans Creek
Distance: 200m
Disturbance History: Erosion, weed encroachment
Additional Comments: Hollows in casuarinas

Table D.8 Transect 8

	Scientific Name	Common Name
Canopy		
	Casuarina cunninghamia	river she-oak
	Salix babylonica	weeping willow
Mid Stratum		
	Typha orientalis	
Lower Stratum		
	Chloris ventricosa	tall windmill grass
	Chloris truncata	windmill grass
	Opuntia aurantiaca	tiger pear
	Sporobolus creber	slender rat's tail grass
	Cirsium vulgare	spear thistle
	Conyza albida	tall fleabane
	*Bidens pilosa**	cobblers pegs
	*Cynodon dactylon**	common couch
	Brassica juncea	Indian mustard
	Xanthium occidentale	Noogora burr
	Plantago lanceolata	plantain
	Schoenus apogon	river club rush
	Senecio madagascariensis	fireweed
	Oenothera indecora ssp. *bonariensis*	small flower evening primrose
	Juncus acutus	
	Dichelachne micrantha	short haired plume grass
	Lepidium hyssopifolium	peppercress
	Galenia pubescens	
	Einadia nutans	native seaberry
	*Gomphocarpus fruticosus**	narrow leaved cotton bush
	*Verbena bonariensis**	purpletop

* = Dominant species

D.9 TRANSECT 9

Date: 13/01/2006
MGA Coordinates: Start - 317494E, 6405343N
Finish - 317444E, 6405216N
Locality Description: East of Bowmans Creek
Distance: 200m
Disturbance History: Grazing, erosion, weed encroachment

Table D.9 Transect 9

	Latin Name	Common Name
Canopy		
	Casuarina cunninghamia	river she-oak
Mid Stratum		
	Typha orientalis	
Groundcover		
	Conyza albida	tall fleabane
	*Cynodon dactylon**	common couch
	Brassica juncea	Indian mustard
	Schoenus apogon	river club rush
	Foeniculum vulgare	fennel
	Lepidium hyssopifolium	peppercress
	Bromus catharticus	prairie grass
	Dichelachne micrantha	short haired plume grass
	Persicaria praetermissa	
	Sporobolus creber	slender rat's tail grass
	Baumea articulate	jointed twig rush
	Stipa bigeniculata	yanganbill
	Avena fatua	wild oats
	Heliotropium amplexicaule	blue heliotrope
	Cyperus eragrostis	
	Juncus acutus	
	Opuntia aurantiaca	tiger pear
	*Bidens pilosa**	cobblers pegs
	Galenia pubescens	
	Einadia nutans	native seaberry
	*Verbena bonariensis**	purpletop
	Xanthium occidentale	Noogora burr

* = Dominant species

D.10 TRANSECT 10

Date: 13/01/2006
MGA Coordinates: Start - 316991E, 6405077N
Finish - 316801E, 6405000N
Locality Description: West of Bowmans Creek
Distance 200m
Disturbance History: Erosion, weed encroachment
Additional Comments: Exposed sandstone in creek bed, little water, bed covered in thick layer of sedges, rushes and bamboo.

Table D.10 Transect 10

	Scientific Name	Common Name
Canopy		
	Casuarina cunninghamia	river she-oak
	Angophora floribunda	rough barked apple
Mid Stratum		
	Typha orientalis	
	Lycium ferocissimum	African boxthorn
	Acacia farnesiana	mimosa bush
	Arundo sp.*	bamboo
Groundcover		
	Panicum simile	two colour panic
	Panicum maxima	
	*Bidens pilosa**	cobblers pegs
	Juncus acutus	
	Dichelachne micrantha	short haired plume grass
	Foeniculum vulgare	fennel
	Cirsium vulgare	spear thistle
	Stipa bigeniculata	yanganbill
	Paspalum dilatatum	common paspalum
	Sporobolus creber	slender rat's tail grass
	Cirsium vulgare	spear thistle
	Conyza albida	tall fleabane
	Brassica juncea	Indian mustard
	Plantago lanceolata	plantain
	Senecio madagascariensis	fireweed
	Rumex brownie	swamp dock
	Paspalum dilatatum	common paspalum
	Aristida vagrans	three awn spear grass
	Setaria geniculata var *pauciseta*	slender pigeon grass
	Taraxacum officinale	dandelion
	Lepidium hyssopifolium	peppercress
	Lomandra longifolia	mat rush
	Rosa sp	rose
	Optuntia aurantiaca	tiger pear
	*Cynodon dactylon**	common couch
	*Verbena bonariensis**	purpletop
	Commelina cyanea	scurvy weed
	Oxalis corniculata	yellow wood sorrel
	Einadia nutans	native seaberry
	Convolvulus erubescens	

* = Dominant species

D.11 TRANSECT 11

Date: 13/01/2006
MGA Coordinates: Start - 316991E, 6405077N
Finish - 317112E, 6404201N
Locality Description: West of Bowmans Creek at confluence with Hunter River heading north
Distance: 200m
Disturbance History: Grazing, erosion, weed encroachment
Additional Comments: River red gum at end of transect 317112E, 6404021N.

Table D.11 Transect 11

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
	Salix babylonica	weeping willow
	Populus alba	white poplar
Mid Stratum		
	Lycium ferocissimum	African boxthorn
Groundcover		
	Panicum simile	two colour panic
	*Bidens pilosa**	cobblers pegs
	Dichelachne micrantha	short haired plume grass
	Foeniculum vulgare	fennel
	*Stipa bigeniculata**	yanganbill
	Paspalum dilatatum	common paspalum
	*Sporobolus creber**	slender rat's tail grass
	Cirsium vulgare	spear thistle
	Conyza albida	tall fleabane
	Plantago lanceolata	plantain
	Chloris truncate	windmill grass
	Pavonia hastate	pavonia
	Avena fatua	wild oats
	Cheilanthes sieberi	mulga fern
	Cestrum parqui	green cestrum
	Oxalis corniculata	yellow wood sorrel
	Opuntia aurantiaca	tiger pear
	*Cynodon dactylon**	common couch
	*Verbena bonariensis**	purpletop
	Galenia pubescens	
	Commelina cyanea	scurvy weed
	Oxalis corniculata	yellow wood sorrel
	Einadia nutans	native seaberry

* = Dominant species

D.12 TRANSECT 12

Date	13/01/2006
MGA Coordinates	Start - 317129E, 6404155N Finish - 317249E, 6404259N
Locality Description	West of Bowmans Creek at confluence with Hunter River heading north.
Distance	200m
Disturbance History	Erosion, weed encroachment

Table D.12 Transect 12

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
	Salix babylonica	weeping willow
	Angophora floribunda	rough barked apple
	Melia azedarach	white cedar
Mid Stratum		
	Acacia farnesiana	mimosa bush
	Lycium ferocissimum	African boxthorn
Groundcover		
	Panicum maxima	
	Dichelachne micrantha	short haired plume grass
	Foeniculum vulgare	fennel
	Paspalum dilatatum	common paspalum
	Conyza albida	tall fleabane
	Senecio quadridentatus	cotton fireweed
	Lactuca serriola	prickly lettuce
	Rumex acetosella	sheep sorrel
	Brassica juncea	Indian mustard
	*Bidens pilosa**	cobblers pegs
	Carthamus lanatus	saffron thistle
	Cyperus exaltatus	
	*Cynodon dactylon**	common couch
	Ricinus communis	castor oil plant
	Galenia pubescens	
	Commelina cyanea	scurvy weed
	*Verbena bonariensis**	purpletop
	Einadia nutans	native seaberry
Climber		
	Convolvulus erubescens	

* = Dominant species

D.13 QUADRAT 1

Date: 12/01/2006
Quadrate size: 20 x 20m
MGA Coordinates: 318451E, 6406641N
Locality Description: Eastern side of Bowmans Creek, south of the New England Highway
Slope: 0-5 degrees
Aspect : Westerly
Disturbance History: Grazing, clearing, erosion, weed encroachment
Additional Comments: High level of weed invasion

Table D.13 Quadrat 1

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
Groundcover		
	Senecio madagascariensis	fireweed
	*Cynodon dactylon**	kikuyu grass
	Ageratina adenophora	crofton weed
	Juncus usitatus	
	Opuntia humifusa	prickly pear
	Cirsium vulgare	spear thistle
	Plantago lanceolata	plantain
	Centaurium erythraea	common centaury
	Verbena rigida	
	*Verbena bonariensis**	purpletop
	*Gomphocarpus fruticosus**	narrow leaved cotton bush

* = Dominant species

D.14 QUADRAT 2

Date	12/01/2006
Quadrate size	20 x 20m
MGA Coordinates	318040E, 6406444N
Locality Description	Eastern side of Bowmans Creek, north of oxbow
Disturbance History	Grazing, erosion, dumping weed encroachment

Table D.14 Quadrat 2

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
Groundcover		
	Lepidium hyssopifolium	peppercress
	Bromus molliformis	soft brome
	Aristida vagrans	three awn spear grass
	Juncus usitatus	
	Cirsium vulgare	spear thistle
	*Plantago lanceolata**	plantain
	Centaurium erythraea	common centaury
	Rumex brownii	swamp dock
	Sporobolus creber	slender rat's tail grass
	Verbena rigida	
	Commelina cyanea	scurvy weed
	*Verbena bonariensis**	purpletop
	*Gomphocarpus fruticosus**	narrow leaved cotton bush

* = Dominant species

D.15 QUADRAT 3

Date: 12/01/2006
Quadrate size: 20 x 20m
MGA Coordinates: 317939E, 6405720N
Locality Description: Eastern side of Bowmans Creek, south of oxbow
Disturbance History: Grazing, clearing, erosion, dumping, weed encroachment
Additional Comments: Low diversity, rocky substrate, two hollow bearing casuarinas

Table D.15 Quadrat 3

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
Groundcover		
	Juncus usitatus	
	*Plantago lanceolata**	plantain
	Centaurium erythraea	common centaury
	*Bidens pilosa**	cobblers pegs
	Anagalis arvensis	scarlet pimpernel
	*Cynodon dactylon**	common couch
	Brassica juncea	Indian mustard
	Sonchus oleraceus	common sow thistle
	Galenia pubescens	
	Persicaria praetermissa	
	Stipa bigeniculata	yanganbill
	Anagalis arvensis	scarlet pimpernel
	Oenothera indecora ssp. *Bonariensis*	small flower evening primrose
	*Verbena bonariensis**	purpletop

* = Dominant species

D.16 QUADRAT 4

Date: 12/01/2006
Quadrate size: 20 x 20m
MGA Coordinates: 317678E, 6405915N
Locality Description: Western side of Bowmans Creek, north of weir
Slope: 0-5 degrees
Disturbance History: Grazing, clearing, erosion, weed encroachment
Additional Comments: Low diversity, rocky substrate, two hollow bearing casuarinas

Table D.16 Quadrat 4

	Scientific Name	Common Name
Canopy		
	Casuarina cunninghamia	river she-oak
	Salix babylonica	weeping willow
Mid Stratum		
	Lycium ferocissimum	African boxthorn
Groundcover		
	Juncus usitatus	
	Opuntia aurantiaca	tiger pear
	Verbena rigida	
	Plantago lanceolata	plantain
	Bidens pilosa	cobblers pegs
	*Cynodon dactylon**	common couch
	*Brassica juncea**	Indian mustard
	Galenia pubescens	
	Oenothera indecora ssp. *bonariensis*	small flower evening primrose
	Stipa bigeniculata	yanganbill
	Senecio madagascariensis	fireweed
	Rumex crispus	curled dock
	Commelina cyanea	scurvy weed
	Cyperus gracilis	
	Sida rhombifolia	paddy's lucerne
	Anisopogon avenaceus	oat speargrass
	Dichelachne micrantha	short haired plume grass
	Verbena bonariensis	purpletop

* = Dominant species

D.17 QUADRAT 5

Date: 12/01/2006
Quadrate size: 20 x 20m
MGA Coordinates: 317983E, 6405907N
Locality Description: Western side of Bowmans Creek, north of oxbow
Disturbance History: Grazing, clearing, erosion, weed encroachment

Table D.17 Quadrat 5

	Scientific Name	Common Name
Canopy		
	Casuarina cunninghamia	river she-oak
	*Salix babylonica**	weeping willow
Mid Stratum		
	Lycium ferocissimum	African boxthorn
Groundcover		
	Juncus usitatus	
	Verbena rigida	
	Plantago lanceolata	plantain
	*Cynodon dactylon**	common couch
	*Brassica juncea**	Indian mustard
	Galenia pubescens	
	Senecio madagascariensis	fireweed
	Sida rhombifolia	paddy's lucerne
	Acetosa sagittata	turkey rhubarb
	Sonchus oleraceus	common sow thistle
	Stipa bigeniculata	yanganbill
	Taraxacum officinale	dandelion
	Conyza albida	tall fleabane
	Verbena bonariensis	purpletop

* = Dominant species

D.18 QUADRAT 6

Date: 12/01/2006
Quadrate size: 20 x 20m
MGA Coordinates: 317998E, 6406355N
Locality Description: Western side of Bowmans Creek
Disturbance History: Grazing, erosion, weed encroachment
Additional Comments: Lots of cattle tracks causing increased erosion

Table D.18 Quadrat 6

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
Mid Stratum		
	Lycium ferocissimum	African boxthorn
Groundcover		
	Juncus usitatus	
	*Verbena rigida**	
	*Cynodon dactylon**	common couch
	*Brassica juncea**	Indian mustard
	Sida rhombifolia	paddy's lucerne
	Stipa bigeniculata	yanganbill
	Conyza albida	tall fleabane
	Commelina cyanea	scurvy weed
	Opuntia humifusa	prickly pear
	Optuntia aurantiaca	tiger pear
	Marrubium vulgare	white horehound
	Bromus molliformis	soft brome
	Lactuca serriola	prickly lettuce
	Enneapogon nigricans	bottle washers
	Verbena bonariensis	purpletop

* = Dominant species

D.19 QUADRAT 7

Date: 13/01/2006
Quadrate size: 20 x 20m
MGA Coordinates: 317145E, 6404501N
Locality Description: Eastern side of Bowmans Creek, north of big dam.
Slope: 40 degrees
Disturbance History: Grazing, fire, clearing, erosion, weed encroachment
Comments: Steep slope, moderate erosion, fallen timber.

Table D.19 Quadrat 7

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
	Salix babylonica	weeping willow
Groundcover		
	Juncus usitatus	
	*Cynodon dactylon**	common couch
	*Brassica juncea**	Indian mustard
	Sida rhombifolia	paddy's lucerne
	Conyza albida	tall fleabane
	Commelina cyanea	scurvy weed
	*Bidens pilosa**	cobblers pegs
	Convolvulus erubescens	
	Plantago lanceolata	plantain
	Panicum maxima	
	Paspalum dilatatum	common paspalum
	Dichelachne micrantha	short haired plume grass
	Galenia pubescens	
	Aristida vagrans	three awn spear grass
	Verbena bonariensis	purpletop

* = Dominant species

D.20 QUADRAT 8

Date: 13/01/2006
Quadrate size: 20 x 20m
MGA Coordinates: 315780, 6404963N
Locality Description: Eastern side of Bowmans Creek, south of second house.
Slope: 20 degrees
Disturbance History: Grazing, erosion and weed encroachment

Table D.20 Quadrat 8

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
Groundcover		
	*Bidens pilosa**	cobblers pegs
	Plantago lanceolata	plantain
	Dichelachne micrantha	short haired plume grass
	Galenia pubescens	
	*Cynodon dactylon**	common couch
	Sida rhombifolia	paddy's lucerne
	Juncus usitatus	
	Conyza albida	tall fleabane
	Paspalum dilatatum	common paspalum
	Typha orientalis	
	Commelina cyanea	scurvy weed
	Xanthium occidentale	Noogora burr
	Panicum maxima	
	Opuntia humifusa	prickly pear
	Lepidium hyssopifolium	peppercress
	*Verbena bonariensis**	purpletop

* = Dominant species

D.21 QUADRAT 9

Date: 13/01/2006
Quadrate size: 20 x 20m
MGA Coordinates: 317375, 6404990N
Locality Description: Eastern side of Bowmans Creek, north of second house.
Slope: 0-5
Disturbance History: Grazing, erosion and weed encroachment

Table D.21 Quadrat 9

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
Mid Stratum		
	Salix babylonica	weeping willow
Groundcover		
	Gomphocarpus fruticosus	narrow leaved cotton bush
	*Bidens pilosa**	cobblers pegs
	Dichelachne micrantha	short haired plume grass
	*Cynodon dactylon**	common couch
	*Juncus usitatus**	
	Conyza albida	tall fleabane
	Paspalum dilatatum	common paspalum
	Commelina cyanea	scurvy weed
	Xanthium occidentale	Noogora burr
	*Plantago lanceolata**	plantain
	Onopordum acanthium	scotch thistle
	Senecio madagascariensis	fireweed
	Sonchus oleraceus	common sow thistle
	*Brassica juncea**	Indian mustard
	Oenothera indecora ssp. *bonariensis*	small flower evening primrose
	Petrorhagia nanteuilii	proliferous pink
	Verbena bonariensis	purpletop

* = Dominant species

D.22 QUADRAT 10

Date: 13/01/2006
Quadrate size: 20 x 20m
MGA Coordinates: 317303, 6404928N
Locality Description: Western side of Bowmans Creek, south of second house.
Slope: 0-5 degrees
Disturbance History: Grazing, erosion and weed encroachment
Additional Comments: Large cobblestones

Table D.22 Quadrat 10

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
Groundcover		
	Gomphocarpus fruticosus	narrow leaved cotton bush
	*Bidens pilosa**	cobblers pegs
	Dichelachne micrantha	short haired plume grass
	*Plantago lanceolata**	plantain
	Onopordum acanthium	scotch thistle
	Oenothera indecora ssp. bonariensis	small flower evening primrose
	Petrorhagia nanteuilii	proliferous pink
	Verbena rigida	
	Galenia pubescens	
	*Verbena bonariensis**	purpletop

* = Dominant species

D.23 QUADRAT 11

Date: 13/01/2006
Quadrate size: 20 x 20m
MGA Coordinates: 317303, 6404928N
Locality Description: Western side of Bowmans Creek
Disturbance History: Grazing, erosion, clearing, fire and weed encroachment

Table D.23 Quadrat 11

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
	*Salix babylonica**	weeping willow
Groundcover		
	*Bidens pilosa**	cobblers pegs
	*Cynodon dactylon**	common couch
	Persicaria praetermissa	
	Einadia hastata	
	Apium leptophyllum	slender celery
	Tribulus terrestris	cat head
	Paspalum dilatatum	common paspalum
	Brassica juncea	Indian mustard
	Juncus usitatus	
	Conyza albida	Tall fleabane
	Galenia pubescens	
	Xanthium occidentale	Noogora burr
	Stipa bigeniculata	yanganbill
	*Verbena bonariensis**	purpletop

* = Dominant species

D.24 QUADRAT 12

Date: 13/01/2006
Quadrate size: 20 x 20m
MGA Coordinates: 317200, 6404276N
Locality Description: Western side of Bowmans Creek, north of Hunter River
Disturbance History: Grazing, erosion and weed encroachment
Additional Comments: Steep bank to Bowmans Creek

Table D.24 Quadrat 12

	Scientific Name	Common Name
Canopy		
	*Casuarina cunninghamia**	river she-oak
	*Salix babylonica**	weeping willow
	Populus alba	white poplar
Groundcover		
	Bidens pilosa	cobblers pegs
	*Cynodon dactylon**	common couch
	Einadia hastata	
	Brassica juncea	Indian mustard
	Juncus usitatus	
	Conyza albida	tall fleabane
	Stipa bigeniculata	yanganbill
	Onopordum acanthium	scotch thistle
	Cirsium vulgare	spear thistle
	Dichelachne micrantha	short haired plume grass
	Commelina cyanea	scurvy weed
	Sonchus oleraceus	common sow thistle
	Cestrum parqui	green cestrum
	*Verbena bonariensis**	purpletop

* = Dominant species

Annex E

Riparian Vegetation Photographic Database

Photograph E1

Transect 1: Start of Transect looking south.

Photograph E2

Transect 1: End of Transect looking north.

Photograph E3

Transect 2: Start of Transect looking south.

Photograph E4

Transect 2: End of Transect looking north.

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Photograph E5

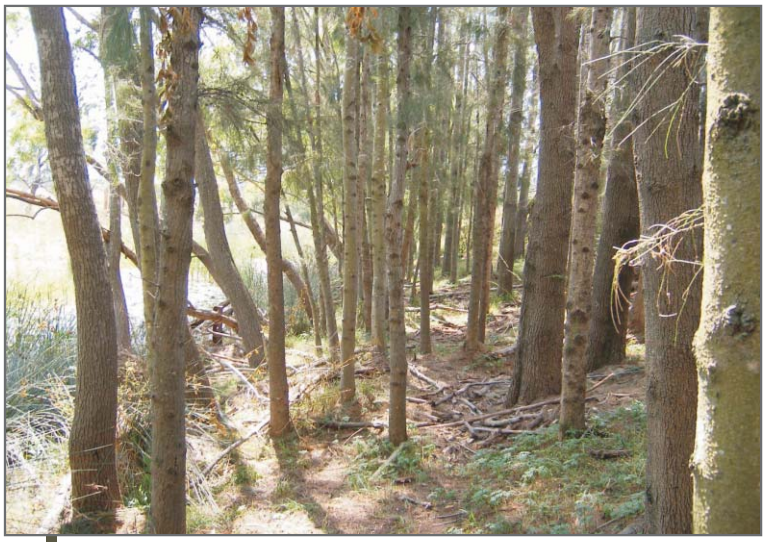
Transect 3: Start of Transect looking south.

Photograph E6

Transect 3: End of Transect looking north.

Photograph E7

Transect 4: Start of Transect looking north.



Photograph E8

Transect 4: End of Transect looking south.

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Photograph E9

Transect 4: Start of Transect looking north.

Photograph E10

Transect 5: End of Transect looking south.

Photograph E11

Transect 6: Start of Transect looking north.

Photograph E12

Transect 6: End of Transect looking south - habitat.

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Photograph E13

Transect 7: Start of Transect looking north.

Photograph E14

Transect 7: End of Transect looking south.

Photograph E15

Transect 8: Start of Transect looking north.

Photograph E16

Transect 8: End of Transect looking south.

Photograph E17

Transect 9: Start of Transect looking south.

Photograph E18

Transect 9: End of Transect looking north.

Photograph E19

Transect 10: Start of Transect looking south.

Photograph E20

Transect 10: End of Transect looking north.

Photograph E21

Transect 11: Start of Transect looking north.

Photograph E22

Transect 11: End of Transect looking south.

Photograph E23

Transect 12: Start of Transect looking north.

Photograph E24

Transect 12: End of Transect looking south.

Photograph E25

Quadrat 1: NW corner looking south.

Photograph E26

Quadrat 1: SE corner looking north.

Photograph E27

Quadrat 2: NW corner looking south.

Photograph E28

Quadrat 2: SE corner looking north.

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Photograph E29

Quadrat 3: NW corner looking south.

Photograph E30

Quadrat 3: SE corner looking north.

Photograph E31

Quadrat 4: SE corner looking north.

Photograph E32

Quadrat 4: NW corner looking south.

Photograph E33

Quadrat 5: SE corner looking north.

Photograph E34

Quadrat 5: NW corner looking south.

Photograph E35

Quadrat 6: SE corner looking north.

Photograph E36

Quadrat 6: NW corner looking south.

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Photograph E37

Quadrat 7: NW corner looking south.

Photograph E38

Quadrat 7: SE corner looking north.

Photograph E39

Quadrat 8: NW corner looking south.

Photograph E40

Quadrat 8: SE corner looking north.

Photograph E41

Quadrat 9: NW corner looking south.

Photograph E42

Quadrat 9: SE corner looking north.

Photograph E43

Quadrat 10: SE corner looking north.

Photograph E44

Quadrat 10: NW corner looking south.

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Photographs

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Photograph E45

Quadrat 11: SW corner looking north.

Photograph E46

Quadrat 11: NW corner looking south.

Photograph E47

Quadrat 12: NW corner looking south.

Photograph E48

Quadrat 2: SE corner looking north.

ERM consulting services worldwide **www.erm.com**

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