Report to:

BHP Billiton - Illawarra Coal

West Cliff Colliery Area 5 Longwalls 34-36 Assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota

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The Ecology Lab Pty Ltd

Marine and Freshwater Studies

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SUMMARY

BHP Billiton Illawarra Coal (BHPBIC) proposes to extend its underground coal mining operations at West Cliff Colliery in the Southern Coalfield, New South Wales, by extracting coal from Longwalls 34 to 36 within the Bulli Seam. BHPBIC is currently preparing an assessment of potential impacts for submission to the Department of Primary Industries - Mineral Resources for a Subsidence Management Plan approval (SMP) for the proposed longwalls. BHPBIC commissioned The Ecology Lab Pty Ltd to undertake literature and field-based investigations of aquatic ecology within the SMP Area and assess the potential impacts on aquatic ecology resulting from mine subsidence.

Existing Information

The 1:25,000 topographic map indicates that a 2.8 km long section of the upper reaches of the Georges River crosses the eastern side of the SMP Area. There are also three ephemeral drainage lines within the SMP Area, Mallaty Creek, Nepean Creek and Leafs Gully, all of which eventually drain into the Nepean River. Mallaty Creek runs through the centre of the SMP Area and is located directly above all three proposed longwalls, whereas Leaf Gully and Nepean Creek are situated in the northern half of the SMP Area and are located mostly above Longwalls 34 and 36, respectively. The reach of the Georges River within the SMP Area comprises a series of continuously-flowing pools separated by rock bars. Dry weather flow in the Georges River is mainly due to the licenced discharges from Appin and West Cliff Collieries. Rainfall in the catchment contributes to wet weather flows in the Georges River. If the discharges from the collieries ceased during an extended dry period, the river would probably be reduced to a series of disconnected pools (MSEC 2007).

Substantial information is available on aquatic habitats, quality of water, macroinvertebrate and fish fauna in the upper reaches of the Georges River, at sites adjacent to the proposed SMP Area. The initial studies were undertaken prior to the commencement of longwall mining (Campbelltown City Council, Jarvis 1997 and MPR 2001). Recent studies have focused on the general effects of mine subsidence (The Ecology Lab 2002a, 2003, 2005), effects of remediation following fracturing of the riverbed at Marhnyes Hole (The Ecology Lab 2002b and 2004a) and effects of the discharge of mine water from Appin and West Cliff Collieries (The Ecology Lab 2004c-g, 2006 a and b). The aquatic ecology of Mallaty Creek and Leafs Gully has also been described (The Ecology Lab 2003). In 2007, additional surveys of aquatic habitats, water quality and macroinvertebrates associated with stream edge habitats were undertaken at sites in the Georges River and Mallaty Creek, located within or immediately adjacent to the SMP Area for Longwalls 34 to 36. The results of these studies are summarised in the section entitled "Assessment of Aquatic Habitats".

The quality of water within the reach of the Georges River within the SMP area is determined by the relative contribution of rainfall inputs from the catchment and licenced discharges of mine water from Appin and West Cliff Collieries. Baseline water quality is dominated by flows from the West Cliff licenced discharge.

The macroinvertebrate fauna in the upper reaches of the Georges River is relatively diverse and dominated numerically by dytiscid beetles and water scavengers (hydrophilids). SIGNAL score for sites in the vicinity of Longwalls 31 to 33 suggest that the sites were probably moderately to severely polluted from upstream activities.

The fish populations in the upper reaches of the Georges River are less diverse than those downstream of the mine concession area. Long-finned eels, mosquito fish and fire-tailed gudgeons have also been recorded at sites to the north-east of Appin and in the vicinity of

the SMP Area for Longwalls 31-33 (The Ecology Lab 2003 and 2005). Western carp gudgeon have also been caught in the latter area. Flathead gudgeon have been caught in Mallaty Creek, but no fish were found in Leafs Gully (The Ecology Lab 2003).

Three threatened species, Sydney Hawk Dragonfly (*Austrocordulia leonardi*), Adams Emerald Dragonfly *(Archaeophya adamsi)* and Macquarie Perch (*Macquaria australasica*) could potentially occur in the study area. There are recent unconfirmed reports of Macquarie Perch in the upper reaches of the Georges River, but no evidence that the threatened dragonflies occur in the area. No threatened populations or ecological communities are known to occur within the Study Area.

Assessment of Aquatic Habitats

Additional surveys were conducted in November 2007 at four sites in the Georges River and a single site within Mallaty Creek. At each site, qualitative assessments were made of aquatic habitats, *in situ* water measurements were taken and macroinvertebrates in stream edge habitats were sampled.

Sites in upstream reaches of the Georges River are characterized by long, shallow pools connected by sections of shallow rapid flow over retaining sandstone rock bars. In the middle and downstream reaches, the pools are deeper with connecting flow through boulder fields. Some pools are likely to become isolated during periods of low flow. The substratum included large areas of sandstone bedrock, accumulations of sand and silt within pools and areas of boulder and cobble. Large stands of bull rush and patches of spike rush and *Isolepis* sp occur throughout the reach within the SMP area. Mat rush, saw grass and numerous ferns, grasses and sedges are common along the banks. This reach of the river has extensive areas of fish habitat, including large deep pools, large snags, overhanging bank vegetation, stands of aquatic macrophytes and sections of fast-flowing water. Several barriers to fish passage were identified, including small waterfalls at rockbars and the pipe culvert at the Blackburn Road crossing. However, fish may be able to surmount these barriers during high flow events. This reach of the Georges River contains Class 1 fish habitat (major fish habitat), but its tributaries contain only Class 3 to 4 (minimal to moderate) fish habitat.

Mallaty Creek runs through cattle pasture and has a narrow strip of riparian vegetation, dominated by privit, an exotic species. The bank structure has been degraded by cattle. The natural flow has been modified by farm dams and by the Eastern Gas Pipeline crossing which traverses the creek within the SMP area. This watercourse is ephemeral and would consist of a series of semi-permanent pools, except during periods of high rainfall. The substratum in the upper reaches is dominated by soft sediments, but consists of large boulders and sediment accumulations in pools in steeper sections of the creek. Mallaty Creek is considered as class 3 (moderate) fish habitat, for species including freshwater crayfish and eels. A sampling site has been established in a semi-permanent series of pools upstream of the eastern gas pipeline.

Leafs Gully has a clearly defined, narrow channel with a substratum consisting of boulder, cobble and silt. Riparian vegetation is dense on the upper slopes, but limited to a thin band in the middle and upper reaches. The surrounding land use is predominantly cattle pasture. The large farm dam in the middle of the reach within the SMP area forms a significant barrier to fish passage and interrupts natural flows. The watercourse below the dam had turbid flowing water and would probably be reduced to isolated pools during dry periods. The natural channel of Leafs Gully contains class 3 (minimal) fish habitat.

At the time of inspection, the Nepean Creek consisted of small standing pools, despite recent rainfall. There are a few isolated sandstone rockbars in the lower reaches of the creek within the SMP area, but flow is limited. There is a small pool approximately mid-reach within the SMP area, containing floating pondweed, spikerush, ribbonweed and *Isolepsis* sp. Common rush occurs along the rest of the creek. The riparian vegetation is thin in the upper reaches, but wider downstream. It is dominated by native species, but there are also exotics, such as blackberry and lantana. Iron floc was observed in the creek within the SMP area. Fish habitat was classed as minimal to unlikely.

Forty-two macroinvertebrate taxa were collected at the sites in the Georges River and twenty at the site in Mallaty Creek. The fauna at the upstream sites in the Georges River was less diverse than at the sites within the SMP area. The fauna at most of the sites within the SMP area and at all the upstream sites were rated as slightly impoverished relative to the AUSRIVAS reference condition. The fauna at one site in the George River within the SMP Area and at the site in Mallaty Creek, however, were rated as similar to the reference condition. The Signal scores indicated that the fauna was subject to moderate to severe pollution.

Assessment of Subsidence-Induced Impacts

The assessment of potential impacts of longwall mining on aquatic habitat and biota is based on predictions of mine subsidence and its effect on natural features (MSEC 2007) and predictions about impacts on water quality within surface watercourses (Ecoengineers 2007). Ground movements resulting from longwall mining can change levels of ponding, flooding and scouring of banks along watercourses, the alignment of watercourses and alter surface water flows through fracturing of river and streams beds. The fracturing of bedrock and diversion of surface flows into the dilated strata can lead to weathering and leaching of minerals which, in turn, can have a localised impact on the quality of water in rivers and creeks, particularly during low flow conditions. Mine-related subsidence can also result in the formation of upland springs which can affect water quality through the leaching of minerals.

The subsidence predictions indicate that levels of ponding, flooding or scouring of banks will not increase significantly in the reach of the Georges River within the SMP Area. There could, however, be some localized, minor increases in levels of ponding or flooding in areas of the river where the predicted maximum tilts coincide with existing pools, steps or cascades and in the creeks and gullies if the predicted maximum tilts coincide with areas with small natural gradients. These are expected to have only minor, localised impacts on aquatic habitats.

Changes in the alignment of the Georges River are expected to be very small and an order of magnitude smaller than natural cross-bed gradients (MSEC 2007). Impacts resulting from changes in stream alignment on aquatic habitat are consequently expected to be insignificant. Additional scouring of aquatic habitats is also likely to be minimal, because the river bed is composed primarily of sandstone.

The extraction of coal from Longwalls 34 to 36 may cause minor fracturing along the Georges River and this is most likely to occur adjacent to the proposed maingate of Longwall 35 (MSEC 2007). It is unlikely that any such minor fracturing will lead to significant water loss from the Georges River or give rise to permanent pool water loss. Compressive buckling and dilation of the topmost bedrock may occur along the alignments of Mallaty Creek and Leafs Gully and, to a lesser extent, along the alignments of Nepean Creek and the tributaries. In areas with exposed bedrock, there may be some sub-surface diversion of flows and drainage of pools, however, in creeks and gullies with alluvial deposits overlying sandstone bedrock, surface fracturing is less likely to occur, and, if it does, the cracks will be filled with alluvial material during subsequent flows. Diversionary flows that exceed the entry flow to a pool for a lengthy period of time could lead to temporary loss of aquatic habitat. Any sudden drainage of pools and rapid drops in stream flow are likely to have a significant, but localised impact on aquatic biota, particularly if organisms are left stranded in air or unable to move to damp or submerged areas. The survival of mobile organisms is difficult to predict, because it depends on their tolerance and response to desiccation and rapid changes in water level, ability to move, weather conditions, the underlying substratum and duration of exposure.

Diversion of surface to sub-bed flows could lead to weathering and leaching of minerals and result in increased acidity, decreased oxygen levels and increased concentrations of heavy metals in downstream areas where flows re-emerge on the surface. Increased iron concentrations could, in turn, result in the formation of iron reducing bacteria flocs. As only minor fracturing is expected to occur, impacts on water quality resulting from diversion of surface flows are expected to be minor, short-term and localised. Reductions in oxygen level in the watercourses within the SMP area are only likely to have a significant impact on aquatic biota, if they coincide with low flow conditions. If metal concentrations in the watercourses rise above the ANZECC (2000) guideline levels, they could become toxic, particularly to aquatic organisms stranded in small pools. These localised effects are likely to be short-term, because the dissolved ions will be flushed downstream when flow is re-established or changed into less toxic complexes by the bicarbonate/carbonate alkalinity in the West Cliff discharge.

The location of the watercourses relative to the layout of the proposed longwalls suggests that the likelihood of ferruginous springs forming is minor in Mallaty Creek, Leafs Gully Creek and the Upper Nepean catchment and minimal in the Georges River (Ecoengineers 2007). The induction of ferruginous springs could lead to reductions in dissolved oxygen levels and increases in the concentration of ecotoxic nickel and zinc species at the spring emergence point. In the Georges River, a decrease in dissolved oxygen levels at the emergence point is likely to be insignificant, provided that the spring flow rate does not exceed 0.1 ML/day and river flow drops below 0.3 ML/day. In this system, ecotoxic nickel and zinc species derived from such springs will be complexed by the bicarbonate/carbonate alkalinity in the West Cliff discharge. In the ephemeral creeks, the formation of ferruginous springs is unlikely to have any significant impact on water quality than that already occurring as a result of their damming for agricultural use and access by cattle. Ecoengineers (2007) consider it unlikely that the formation of ferruginous springs in these streams would have any impact on the Nepean River, into which they flow.

Although habitat for Macquarie Perch, Sydney Hawk Dragonfly and Adams Emerald Dragonfly has been identified as unlikely, but possible to occur, within the SMP area and surrounding watercourses, assessments of potential impacts on these threatened species were undertaken in accordance with State and Commonwealth legislation. These assessments indicate that the proposed longwall mining does not pose a significant threat to any of these species.

Aquatic Monitoring Plan

A comprehensive monitoring plan has been designed to assess the potential impacts of mine subsidence on aquatic habitat and biota within watercourses of the West Cliff Area 5, Longwalls 34 – 36. This plan is based on the same survey methods as used in the existing aquatic monitoring program being undertaken for West Cliff Area 5, Longwalls 29 – 33 (The Ecology Lab 2005), but includes additional monitoring sites within Georges River and

Mallaty Creek specifically relevant to the Longwall 34-36 layout, where there is moderate to significant aquatic habitat. At each site, aquatic habitats and water quality will be assessed and macroinvertebrates surveyed. Additional sampling of fish is recommended at sites within the SMP area prior to the commencement of mining.

Management Measures

The detection of primary impacts, such as rockbar fractures resulting in water loss in a pool within an area of 'significant' or 'moderate' aquatic habitat or significant changes in water chemistry within such areas, would trigger investigations into potential impacts on aquatic ecology. Observations of fish/crayfish kills or die-off of macrophyte beds would trigger a rapid response aquatic monitoring plan to determine the nature and extent of secondary impacts on aquatic ecology. The level of impact found would determine the type of response. It could, for example, include rehabilitation of aquatic habitat being undertaken in conjunction with mitigative works, such as grouting, followed by monitoring to assess recovery. Significant changes in aquatic biota detected 'during mining' monitoring events would also provide triggers for further investigation.

Conclusions

The SMP Area is traversed by part of the upper reaches of the Georges River and by Mallaty Creek, Leafs Gully and Nepean Creek. This reach of the Georges River supports "significant" aquatic habitats. The creeks have already been extensively modified and degraded and, with the exception of Mallaty Creek which has some areas of "moderate" aquatic habitat, contain "minimal" aquatic habitat. The aquatic fauna is consequently more diverse in the Georges River than in the drainage lines.

Within this reach of the Georges River, the proposed mining could cause localised, minor increases in levels of ponding or flooding in some areas, very small changes in alignment, minor fracturing of bedrock, but no significant water loss. Changes of these magnitudes are expected to have only minor, localised impacts on aquatic habitats and biota.

Subsidence may, however, cause some sub-surface diversion of flows and drainage of pools in Mallaty Creek, Leafs Gully and Nepean Creek. The loss of water from pools would have a significant, localised impact on aquatic biota, but the habitat would be recolonised by aquatic organisms once flow is re-established.

The diversion of surface flows could lead to minor, short-term, localised increases in the acidity of the water, reductions in dissolved oxygen levels and increased concentrations of heavy metals. The proposed mining could also induce the formation of ferruginous springs, which could, in turn, lead to reductions in dissolved oxygen levels and increases in ecotoxic nickel and zinc species at the spring emergence point. This is unlikely to happen in the Georges River and there is only a minor chance of it occurring in the ephemeral creeks. Reductions in oxygen level and increases in heavy metal concentration are only likely to have a significant localised impact on biota, if they coincide with low flow conditions. These effects will diminish downstream of spring emergence points and once moderate flows are re-established. The buffering effect of the carbonate alkalinity in the West Cliff discharge will counteract any increase in acidity.

The specific assessments of impacts undertaken for Macquarie Perch, Sydney hawk dragonfly and Adams emerald dragonfly indicate that the proposed longwall mining does not pose a significant threat to these species.

1.0 INTRODUCTION

BHP Billiton Illawarra Coal (BHPBIC) proposes to continue its longwall coal mining operations at West Cliff Colliery in the Southern Coalfield of New South Wales, by extracting coal from Longwalls 34 to 36 within the Bulli Seam. A Subsidence Management Plan (SMP) for Longwalls 34 to 36 is currently being prepared for submission to the NSW Department of Primary Industries - Mineral Resources (DPI), as part of the approval processes required prior to commencement of mining. The general SMP Area is the area likely to be affected by the proposed mining and has been defined as the surface area enclosed by a 35 degree angle of draw line from the limit of proposed mining and the 20 mm subsidence contour resulting from the extraction of the proposed Longwalls 34 to 36 (MSEC 2007).

The Ecology Lab Pty Ltd has been commissioned by BHPBIC to undertake investigations of aquatic ecology in the section of the Georges River within the proposed SMP area and to assess the potential impacts on aquatic ecology resulting from mine subsidence.

The specific aims of these investigations were to:

- Review existing information of aquatic ecology within the area;
- Identify aquatic ecological features, including potential sensitive features using topographic maps, high-resolution areal photos, and GIS layers of mine plans and surface features provided by BHPBIC;
- Conduct a site inspection and habitat survey of the reach of the Georges River and other watercourses within the proposed SMP area to identify sensitive aquatic features and sites for ongoing monitoring;
- Assess the potential impacts of the proposed longwall mining on aquatic ecology for incorporation into a SMP; and
- Compile an aquatic monitoring plan.

2.0 EXISTING INFORMATION ON AQUATIC ECOLOGY

2.1 Introduction

The Appin 1:25000 topographic map (APPIN 9029-1-S) issued by the Central Mapping Authority of NSW was used to identify watercourses that cross or are in the vicinity of the proposed SMP Area. Information on the current status of the rivers and drainage lines within the SMP Area were obtained from MSEC (2007). The library database of The Ecology Lab was searched for literature on aquatic habitats, water quality, macroinvertebrates and fish in the general vicinity of the SMP area. Threatened aquatic species, populations and ecological communities that occur or could potentially occur within the Study Area were identified by reviewing the current listings on the appropriate websites (NSW DPI/Fisheries 2007) and searching the BIONET and EPBC databases.

Baseline studies on the aquatic ecology of the upper Georges River above the proposed West Cliff longwall mining lease at Appin were undertaken prior to the commencement of longwall mining by Campbelltown City Council, Jarvis (1997) and MPR (2001). These studies were intended to provide a baseline against which the impacts of longwall mining could be assessed. The studies completed after mining commenced have focused on the general effects of mine subsidence (The Ecology Lab 2002a, 2003, 2005), effects of remediation following fracturing of the riverbed at Marhnyes Hole resulting from longwall mining (The Ecology Lab 2002b and 2004a) and effects of the discharge of mine water from Appin and West Cliff Collieries (The Ecology Lab 2004c-g, 2006 a and b). The components examined, locations sampled and time period over which these studies were conducted are summarised in Table 1.

2.2 Watercourses

The most significant watercourse within the SMP Area is the 2.8 km long section of the upper reaches of the Georges River, which crosses the eastern side of the SMP Area. This stretch of the river is moderately incised, with Hawkesbury Sandstone at its base and to the east and Wianamatta Shale outcrops to the west (BHPBIC, 2004a). The Georges River has an average gradient of 8mm/m, which is considered moderately steep, but the gradient varies from 1-50 mm/m (MSEC 2007). Areas along the Georges River are covered mostly by natural vegetation, but there are some exotics.

There are also three drainage lines within the SMP Area: Mallaty Creek, Nepean Creek and Leafs Gully, all of which drain into the Nepean River. These drainage lines are ephemeral, thus water generally only flows during and for a short time after rainfall events. Mallaty Creek is located directly above the proposed Longwalls 34 to 36 and flows in a westerly direction into Ousedale Creek, which is situated approximately 1.4 km south-west of Longwall 34. The natural gradient of Mallaty Creek within the SMP Area averages 30mm/m, but varies from 10-100mm/m. Leafs Gully is located directly above the proposed Longwalls 34 and 35 and flows in a north-westerly direction before joining the Nepean River approximately 830 m west of Longwall 36. The natural gradient of Leafs Gully within the SMP Area averages 50mm/m, but varies from 10-125 mm/m. Nepean Creek is situated in the southern part of the SMP Area, directly above the proposed Longwall 34, and flows in a southerly direction into Ousedale Creek approximately 800 m south of Longwall 34. The natural gradient of this creek averages 40mm/m, but varies from 10-150 mm/m. There are also a number of tributaries located directly above and across the proposed longwalls. The catchments of these creeks have been developed as either cattle pasture and/or chicken farms, hence most of the native vegetation has been cleared and only thin bands of riparian vegetation remain. Mallaty Creek and Leafs Gully also have farm dams positioned along the main channel which disrupt flow.

2.3 Flow Characteristics

The licenced discharges from Appin and West Cliff Collieries are the major sources of dry weather flow in the section of the Georges River within the SMP Area (MSEC 2007). The surface flow is continuous with inputs from the combined licensed discharges ranging from 0-2 -7.2 ML/day, but being typically between 0.5 and 3.0 ML/day and averaging 1.6 ML/day. Dry weather flows upstream of the licenced discharge points are low, averaging 0.3 ML/day and varying from 0 - 4.2 ML/day, and are derived from precipitation in the catchment. If the input of water from the collieries ceased, the upper Georges River would probably be reduced to a series of disconnected pools during extended dry periods.

2.4 Water Quality

The quality of water in the reach of the Georges River within the SMP area is currently determined by the relative contribution of rainfall inputs from the catchment and licenced discharges of mine water from Appin and West Cliff Collieries (MSEC 2007). The discharges contain elevated salinity, pH levels, and dissolved iron, manganese, nickel and zinc concentrations and have a marked effect on water quality, particularly during prolonged dry periods when there is minimal dilution from runoff from the upper Georges River catchment (Ecoengineers, 2005). The Ecology Lab (2005) noted that the conductivity of the surface water exceeded the ANZECC guidelines for upland rivers at all their study sites in the Georges River, and that the pH of the water at West Cliff was also consistently higher than the guidelines. The Ecology Lab also found some evidence of stratification of the water column near the confluence of Brennans Creek and Georges River.
The water quality measurements taken by Cambelltown City Council and Jarvis (1997) prior to the commencement of longwall mining are summarised in MPR (2001). The latter authors concluded that the pattern of land use in the upper Georges River had had some impact on water quality, particularly at Marhynes Pool, and that the overall water quality in the section of the river between its confluence with Brennans Creek and Marhynes Pool Falls was degraded. The latter conclusion was based on the fact that water quality was poor and did not comply with ANZECC (1992) guidelines at any of the sampling times. It is not clear whether the results presented in these studies provide an adequate measure of the natural variability in water quality in the upper Georges River.

It should be noted that the occasional water quality measurements taken by The Ecology Lab (2002a, 2003, 2004a-e and 2005) are intended to provide background information that is directly relevant to the time of sampling of biota rather than measures of changes in water quality.

2.5 Aquatic Habitats

The section of the Georges River within the SMP area comprises a series of pools and rock bars with small races over the bars. The pools vary on length from 5 m to 315 m (Pool 61), are mostly shallow and there are small hydraulic gradients between successive pools (MSEC 2007). The rock bars vary in length from 3 m to 145 m (Rock Bar 41) and are generally low with many being submerged during moderate flows. If environmental flows from the licensed discharge points at Appin and West Cliff mines are discontinued during prolonged dry weather, this stretch of river is likely to be reduced to a series of disconnected pools, some of which may subsequently naturally drain either partially or completely (MSEC 2007). The monitoring of depth of water in Pools 23 to 40 undertaken by BHPBIC in 2004/2005 has shown that some pools drained completely, whilst others drained partially when upstream entry flows were stopped during remediation works upstream of the SMP Area. The monitoring suggests that surface flow diversions occurred in the section of the river between Pools 31 and 33 and possibly Pool 30. These flow diversions are thought to be due to natural weathering and erosion, but may have been influenced by mining of Longwall 29.

2.6 Aquatic Macroinvertebrates

Jarvis (1997) sampled macroinvertebrates in the upper Georges River at the same sites and times as he measured water quality. He collected replicate samples from both edge and riffle habitats using a two-minute kick sampling technique. Jarvis (1997) identified 122 taxa from 79 macroinvertebrate families, the majority of which were insects. Nine taxa accounted for 70% of the animals sampled, but most of the others were represented by only a few individuals. Dytiscid beetles, a pollution tolerant taxon, dominated the fauna at six of the study sites and accounted for 40% of the animals sampled. In both habitats, macroinvertebrate diversity and overall abundance increased downstream to Marhynes Pool, but decreased below this site. The structure of assemblages at upstream sites was also found to differ from that downstream, but it was not clear whether this was due to a change in altitude or water quality.

Macroinvertebrates in riffle and pool edge habitats at sites up- and downstream of Marhnyes Hole were also sampled, prior to the commencement of longwall mining, but only on one occasion, using dip net sweeps. The taxa collected were common taxa recorded by Jarvis (1997), with dytiscid beetles again being the numerical dominant.

Similar methods were used to survey macroinvertebrates associated with pool edge habitats within and upstream of Marhynes Hole before and after remediation (The Ecology Lab 2004a), however, in this case data were also analysed using the AUSRIVAS predictive modelling software. A total of 58 taxa were recorded across the six sites and four survey periods, with Dytiscidae (beetles) and Hydrophilidae (water scavengers) generally being the most common taxa. The AUSRIVAS analyses suggested that the fauna at the remediation sites was in a similar condition to that at the upstream sites before and after remediation. This implies that remediation work had no significant effect on the macroinvertebrate fauna. Macroinvertebrate samples were also collected from rocks in pools. These contained 53 taxa in total and were dominated by Chironomidae (midge larvae), followed to a lesser extent by Caenidae (mayflies) and Hydrophilidae. Significant differences in these assemblages were evident between locations, sites and times, but no obvious differences due to remediation. Fewer Hydrophilidae were found at the remediation location than elsewhere in the first survey after remediation, but not during subsequent surveys. This decline may have been due to the effects of mine subsidence or the physical disturbance associated with remediation.
The macroinvertebrate fauna in riffle and edge habitats at sites within and upstream of the SMP Area for Longwalls 31 to 33, West Cliff Area 5 was investigated three times prior to the commencement of mining (The Ecology Lab 2005). A total of 56 taxa were recorded, but only Caenidae, Chironomidae and Hydrophilidae were consistently present at all sites. The SIGNAL score, an index of sensitivity to pollution, indicated that all sites were probably

moderately to severely polluted. Temporal changes in SIGNAL scores were evident, but could not be assessed because replicate samples were not collected from each site.
The effects of saline discharges from Appin and West Cliff Collieries on the macroinvertebrate fauna associated with the edge habitat in the upper Georges River was assessed in relation to that found in three adjacent control creeks (The Ecology Lab 2004b-e, 2006a-b). At each study site, individual samples were collected using the rapid assessment method (RAM) based on the AUSRIVAS protocol and three replicate quantitative samples were collected by dip netting. The RAM samples yielded fewer taxa than expected at the potentially impacted and control locations. According to AUSRIVAS analyses, the fauna at West Cliff and Appin was either slightly or moderately impaired, whereas that at the Control locations was either similar or slightly impaired relative to the reference condition. Differences in assemblages were evident between mine discharge and control treatments through time and between all the pairs of locations through time. Leptoceridae, Chironomidae, Leptophlebiidae, Ceinidae, Atyidae and Baetidae were the major taxa contributing to the differences in assemblages between treatments. Although there were consistent differences in some macroinvertebrate indicators between treatments, there was no indication that the macroinvertebrate assemblages in the vicinity of the West Cliff and Appin Collieries were impoverished or that taxon richness and abundances were very small relative to those at controls. Temporal changes in macroinvertebrate indicators were more common within the Mine Discharge than Control treatment, but not different in magnitude. The temporal variability in macroinvertebrates appeared to be related to the effects of changes in the volume and frequency of discharge on the quality of the edge habitat rather than the variability in water quality.
The macroinvertebrate fauna in Mallaty Creek has also been investigated (The Ecology Lab 2003). The number of taxa collected per site varied from 13 and 21. Chironominae and Dytiscidae were the dominant taxa. The SIGNAL indices indicate that the fauna at these sites were mildly tolerant of pollution.

No Adams Emerald or Sydney Hawk dragonflies were collected during any of these studies.

2.7 Fish

There have been a number of surveys of fish in the upper reaches of the Georges River. Those undertaken by the Australian Museum and NSW Fisheries focused on areas downstream of the mining concession area, whereas those by MPR (2001) and The Ecology Lab (2002a, 2003, 2004 and 2005) were carried out in the vicinity of mining concessions. The species caught or observed in these studies are listed in Table 2.

The Australian Museum records indicate that eight species of fish have been found in the upper Georges River between 1889 and 1980 (Table 2). Three of these species, golden perch, silver perch and trout cod, were caught in the vicinity of Appin. One of the other records is for a specimen of Macquarie Perch, a species considered to be threatened under both NSW and Commonwealth legislation. It should be noted that this record dates back to 1889 and is for a fish caught at Campbelltown. No specimens of Macquarie Perch have been caught in recent surveys of fish populations in the upper reaches of the Georges River, however, there are unconfirmed reports of this species occurring in the upper reaches of this river (Andrew Bruce, DPI pers. comm.). The NSW Fisheries (c. 2000) records of fish species at four locations (Holsworthy, Macquarie Fields, Liverpool and Kentlyn) in the Georges River upstream of the tidal limits, but downstream of the proposed SMP Area indicate that 12 species are present, two of which were exotic (mosquito fish, *Gambusia holbrooki* and goldfish *Carassius auratus*) (Table 2).

The studies undertaken in the vicinity of the mining concessions indicate that the fish populations further upstream in the upper reaches of the Georges River are less diverse (MPR 2001, The Ecology Lab 2002a, 2003, 2004a and 2005). MPR (2001) noted that mosquito fish (*Gambusia holbrooki*) were present above and below Marhynes Hole and that two native species, firetailed gudgeon and dwarf flathead gudgeon occurred below Marhynes Hole. Subsequent studies undertaken by The Ecology Lab (2002a and 2004a) indicate that long- and short-finned eel, striped gudgeon, Midgley's carp gudgeon and an unidentified gudgeon species also occur in the vicinity of Marhynes Hole (Table 2). Long-finned eels, mosquito fish and fire-tailed gudgeons have also been recorded at sites to the north-east of Appin (The Ecology Lab 2003) and in the vicinity of the SMP Area for Longwalls 31-33 (The Ecology Lab 2005). Western carp gudgeon have also been caught in the latter area.

Fish surveys have also been undertaken in Mallaty Creek and Leafs Gully, but only the former yielded any fish, all of which were flathead gudgeon (The Ecology Lab 2003).

2.8 Threatened Species/ Populations and Ecological Communities

Threatened native fish and aquatic invertebrate species, populations and ecological communities are protected by the NSW Threatened Species Conservation Act 1995 (TSC Act), NSW Fisheries Management Act 1994 (FM Act) and Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Searches of the BIONET and EPBC databases indicated that three listed aquatic species: Macquarie Perch (*Macquaria australasica*), Sydney Hawk Dragonfly (*Austrocordulia leonardi*), and Adams Emerald Dragonfly *(Archaeophya adamsi)* could potentially occur in the study area. Existing information on the occurrence and ecology of each of these species is summarized and conclusions about their likely occurrence in the study area are provided below. No threatened populations or ecological communities are known to occur within the Study Area.

2.8.1 Macquarie Perch

Macquarie perch is listed as a vulnerable species under both the FM Act and TSC Act and as an endangered species under the EPBC Act. This species occurs in both lake and river habitats, particularly the upper reaches of rivers and their tributaries (NSW DPI 2005). It is endemic to the southern tributaries of the Murray-Darling River System, and is also found in the Hawkesbury-Nepean and Shoalhaven River systems in the eastern coastal drainages of New South Wales (NSW DPI Fisheries Scientific Committee 2006). There are two historical records of the species having occurred in the Georges River drainage (BIONET Web Reference 1). These records are from the Australian Museum collection and occurred prior to 1920. One record is located near Campbelltown, and the other is well downstream near Holsworthy. There have been recent unconfirmed reports of Macquarie perch within the Georges River catchment at two locations, near the confluence with Punchbowl Creek, and within O'Hares Creek (Andrew Bruce, NSW DPI freshwater fisheries research, pers. comm.). There are no recent records of this species within the upper Georges River in proximity to the SMP area, despite extensive fish sampling undertaken by The Ecology Lab and MPR within this reach of the river (Section 2.6). On the basis of historical records, recent surveys and consideration of downstream barriers to fish passage, such as the Wedderburn Road culvert, it is highly unlikely that Macquarie perch are present within the SMP area.

The SMP area contains several small watercourses that drain to the Nepean River between Douglas Park Weir and Menangle Weir. This reach of the Nepean River contains potential habitat for Macquarie perch, however, steep watercourse grades, barriers to passage and lack of suitable habitat preclude these watercourses from consideration as Macquarie perch habitat.

2.8.2 Sydney Hawk Dragonfly

The Sydney Hawk Dragonfly is listed as an endangered species under the FM Act 1994. This species is extremely rare, having been collected in small numbers at only a few locations in a small area to the south of Sydney, between Audley and Picton (NSW Fisheries, 2004). The species is also known from the Hawkesbury-Nepean, Georges River and Port Hacking drainages. It was discovered in 1968 from Woronora River and Kangaroo Creek, south of Sydney and has subsequently been found in the Nepean River at Maldon Bridge near Wilton (NSW Fisheries Scientific Committee 2004). There are no records for this species within or in the vicinity of the SMP Area.

Most of the lifecycle of this species is spent as an aquatic larva, with adults living for only a few weeks. The larvae appear to have specific habitat requirements, being found under rocks in deep, cool, shady pools (NSW DPI, 2007b). Relative environmental stability appears to be an important habitat feature, with rapid variation in water level and flow rate likely to have a negative effect on the suitability of habitat for larvae (G. Theischinger, pers. comm.). Habitat within the Georges River and other small watercourses within the SMP area do not appear suitable for this species, because of flow variation and lack of deep shady pool habitat. Furthermore, this species has not been found during the invertebrate sampling undertaken by The Ecology Lab and others (see Section 2.5).

2.8.3 Adam's Emerald Dragonfly

Adam's Emerald Dragonfly is listed as a vulnerable species under both the FM Act and TSC Act. It is extremely rare, having been collected only in small numbers at a few locations in the greater Sydney region (NSW Fisheries, 2002). Specimens have been collected at five localities: Somersby Falls and Floods Creek in Brisbane Waters National Park near Gosford; Berowra Creek near Berowra and Hornsby; Bedford Creek in the Lower Blue Mountains; and Hungry Way Creek in Wollemi National Park (NSW Fisheries Scientific Committee 2006). There are no records for this species within the Study Area or Georges River catchment.

The larvae of Adam's Emerald Dragonfly inhabit small creeks with gravel or sandy bottoms in narrow, shaded riffle zones with moss and lush riparian vegetation (NSW Fisheries 2002). The larvae live for approximately 7 years before metamorphosing into adults which probably live for only a few months. They are thought to have a low natural rate of recruitment and limited dispersal abilities. There does not appear to be suitable habitat for this species within the SMP area or surrounding watercourses. Furthermore, this species has not been found during the invertebrate sampling undertaken by The Ecology Lab and others (see Section 2.5).

3.0 FIELD INVESTIGATIONS

3.1 Methods

3.1.1 Habitat Assessment

Initial field investigations of watercourses within the area of investigation were carried out on 21 – 22 of August 2007. The initial surveys included an inspection and habitat assessment of all watercourses (as marked on the Appin 1:25 000 topographical map) within the SMP Area. Further targeted surveys were carried out on 5 – 8 of November 2007 at four sites within the area of investigation in the Georges River and at a single site within Mallaty Creek, which drains to the Nepean River via Ousedale Creek (Figure 1). The most upstream site in the Georges River has been used in previous West Cliff Area 5 investigations (The Ecology Lab 2005). The most downstream site within the Georges River lies outside the final SMP area (Figure 1). A qualitative assessment of aquatic habitats (as outlined in NSW Fisheries, 1999) was compiled for each watercourse, including the following attributes:

- GPS position,
- instream features such as sequence of pools, runs and riffles (shallow areas with broken water),
- presence, extent and type of aquatic vegetation,
- stream substratum,
- potential refuge areas during periods of low flow (e.g. large deep pools),
- presence of fish habitat including snags, bank undercuts and aquatic plants, and
- presence of barriers to fish passage into and beyond the study area.

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

3.1.2 Water Quality Measurements

At each site, the water quality variables pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), temperature, turbidity, salinity and conductivity were measured using a Yeo-Kal 611 probe. 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. Water quality measurements undertaken in this study are intended to provide information relevant to the time of sampling only; more detailed studies of water quality are presented in Ecoengineers (2007).

3.1.3 Macroinvertebrates

Aquatic macroinvertebrates in stream edge habitats were sampled at each of the four sites selected within the SMP area of Georges River and the site within Mallaty Creek. The opportunity was also taken to repeat surveys in sites in the Georges River upstream of the current SMP area used for previous West Cliff Area 5 longwall investigations. These are referred to hereafter as 'upstream sites'. This sampling was undertaken in the November 2007 investigations. The procedure followed the AUSRIVAS protocol developed under the

National River Health Program (Turak and Waddell, 2001). There was very little 'riffle habitat' available, so only 'edge habitat' was sampled. Aquatic habitat with little, or no current, or backwaters with leaf litter present were sampled with a hand-held dip net with a 300 x 250 mm x 600 mm deep opening and 0.25 mm mesh size. The net was swept from open water towards the shore, working over a bank length of approximately 10 m. The contents of the dip net were then transferred to an enamel tray and samples were sorted according to the method outlined in the AUSRIVAS manual. The taxa collected were then placed in labelled containers, preserved with 70% alcohol and transported to the laboratory for identification.

Macroinvertebrate Identification

In most cases, taxa were identified to the levels required for calculating SIGNAL2 values. However, dragonfly larvae (Odonata) were identified to their lowest possible taxonomic resolution, due to the listing of two dragonfly species in the FM Act 1994.

Signal Indices

The procedure outlined in Chessman (1995) was used to characterise the macroinvertebrate data collected using the AUSRIVAS protocol. The revised SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was used to determine the environmental quality of sites on the basis of the presence or absence of families of macroinvertebrates in pool edge habitats. This method assigns grade numbers to each macroinvertebrate family or taxa found, based largely on their responses to chemical pollutants. The sum of all grade numbers for that habitat was then divided by the total number of families recorded in each habitat to calculate the SIGNAL2 index. The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site. SIGNAL2 values greater than 6, between 5 and 6, 4 and 5 and less than 4 indicate that the quality of the water is clean, doubtful, mildly, moderately or severely polluted, respectively.

3.2 Results

3.2.1 Habitat Assessment

Georges River

The reach of the Georges River within the study area is fed by a number of tributaries which drain rural properties, urban development and vegetated areas. The river lies within a sandstone gorge that is vegetated with mainly native plants and some exotic species. During each inspection period, the river had continuous flow throughout the reach within the SMP Area. There had been substantial rainfall in the area in the months prior to inspections being undertaken and there was evidence of significant flood waters along the river banks indicated by flood debris (Plate 1a). The sites within the SMP area have been denoted as Sites 1 to 4 from upstream to downstream (Figure 1). Sites 1 and 2 are located upstream and downstream of the Lysaghts Road crossing, with site 1 having been incorporated into previous West Cliff Area 5 investigations (The Ecology Lab 2005). Site 3 is located upstream of the Blackburn Road crossing in the mid reach of the SMP Area. Site 4 is located downstream of the final SMP Area and was accessed by the powerline easement.

All of the tributaries of the Georges River within the SMP Area are small ephemeral drainages, and were not considered to contain significant aquatic habitat, however, during the field investigations many of these tributaries were flowing following recent rainfall.

Two main river forms were observed. In the upstream reaches (sites 1 and 2), long, shallow pools were connected by sections of shallow rapid flow over retaining sandstone rock bars (Plate 1b). In the middle and downstream reaches (sites 3 and 4) the river consisted of deeper pools (Plate 2a) with connecting flow through boulder fields (Plate 2b). It is expected that during periods of low flow, pools throughout the reach of the SMP area would become isolated. The substratum throughout the reach within the SMP area included large areas of sandstone bedrock, accumulations of sand and silt within pools, as well as sections of boulder and cobble.

Aquatic vegetation throughout the reach of the SMP area included large stands of bull rush (*Typha* sp.) (Plate 3a) with spike rush (*Juncus* sp.) and *Isolepis* sp. Mat rush (*Lomandra* sp.) saw grass (*Gahnia* sp.) and numerous ferns, grasses and sedges were common along the banks.

Extensive and varied fish habitats were present throughout the reach of the Georges River within the SMP area. These included numerous large deep pools (particularly within the lower reach of the area) which would provide important refuge areas during extended dry periods with low flow. Other important fish habitat noted included the presence of large snags which provide preferential habitat for many native species (Plate 3b). Overhanging bank vegetation, stands of aquatic macrophytes and sections of fast-flowing water were also present, all of which provide habitat for fish.

A number of barriers to fish passage were noted within the SMP area, including natural barriers such as small waterfalls at rockbars, and the presence of a pipe culvert at the Blackburn Road crossing (Plate 4a). The recent flood levels evidenced by flood debris indicate that these barriers could be surmounted during high flow events. Fish species, such as eels, would be capable of negotiating these barriers during lower flows. The reach of the Georges River within the SMP Area is considered as Class 1 fish habitat (major fish habitat) according to Fairfull and Witheridge (2003). The tributaries of this reach contain minimal to unlikely fish habitat and are therefore considered as Class 3 to 4 fish habitat.

Mallaty Creek

Mallaty Creek lies to the west of Appin Road and traverses the SMP Area. This creek flows into Ousedale Creek and ultimately the Nepean River between Douglas Park Weir and Menangle Weir. The creek runs through cattle pasture within the SMP area with a narrow strip of riparian vegetation. Riparian vegetation consists of native and exotic species, with privit (*Ligustrum* sp.), an exotic species, being dominant in many areas. Cattle have access to the creek in a number of places and have heavily degraded the bank structure. Mallaty Creek is essentially an ephemeral watercourse and would be reduced to a series of semi-permanent pools, except during periods of high rainfall. Farm dams within the watercourse of this creek have modified natural flow. The substratum of the upper reaches of Mallaty Creek is dominated by soft sediments. The creek becomes steeper as it approaches Ousedale Creek and in this area the substratum is dominated by large boulders with some accumulations of sand and silt in smaller pools. The Eastern Gas Pipeline traverses Mallaty Creek within the SMP area. This crossing involved extensive excavation of the sandstone gully of the creek and the earthworks included flow diversion and sedimentation control devices in the main channel of the creek (Plate 4b). A single sampling site (Site 5) was selected upstream of the eastern gas pipeline in an apparently semi-permanent series of pools (Plate 5a). Mallaty Creek is considered as class 3 (moderate) fish habitat, for species including freshwater crayfish and eels.

Leafs Gully

Leafs Gully is an ephemeral watercourse flowing from a small farm dam to the north-west through the SMP area and into the Nepean River. It has a clearly defined, narrow channel between 1 – 2 metres in width, with a substratum consisting primarily of boulder, cobble and silt. Riparian vegetation is dense on the upper slopes, but limited to a thin band of vegetation alongside the stream in the middle and upper reaches. The surrounding land use is predominantly cattle pasture. There is a large farm dam in the middle of the reach of the watercourse within the SMP area, occupying an area of approximately 500 m^2 (Plate 5b). The dam wall consists of earth and rubble, rises approximately 25 m and therefore forms a significant barrier to fish passage and interrupts natural flows. The watercourse below the dam had turbid flowing water, which would probably be reduced to isolated pools during dry periods. The large farm dam may provide moderate artificial fish habitat when dam levels are high, however, fish habitat within the natural channel of Leafs Gully is considered as class 3 (minimal). No sampling sites were established within Leafs Gully.

Nepean Creek

The watercourse flows from a small farm dam (with an area of roughly 50 m^2) through cattle pasture (Plate 6a). There is a thin riparian strip in the upper reaches, flowing through tea tree shrubs within eucalypt woodland. The creek is ephemeral with only small standing pools during the time of inspection, despite recent rainfall. There are some isolated sandstone rockbars within the lower reaches of the creek within the SMP area, however water flow is limited. There is a small pool (with an area of approximately 25 m^2) within Nepean Creek, approximately mid-reach within the SMP area, containing several macrophytes, including floating pondweed (*Potamogeton tricarinatus*), spikerush (*Eleocharis* sp.), ribbonweed (*Triglochin procerum*), and *Isolepsis* sp. Common rush (*Juncus* sp.) occurs along the rest of the creek. Downstream of the pool, the riparian vegetation strip is around 50 m wide, and contains similar vegetation to that found in the upstream habitat. It is dominated by native species, but there are also some exotics present, including blackberry and lantana. Iron floc was observed in the creek within the SMP area. Fish habitat was classed as minimal to unlikely within Nepean Creek, so no sampling sites were established.

3.2.2 Water Quality

The pH and electrical conductivity measures were above ANZECC (2000) guidelines at all the sites in the Georges River (Table 3). The DO levels, in contrast, were below ANZECC (2000) guidelines at all the sites in the Georges River, except Site 2. Within Mallaty Creek, all the water quality parameters were within guidelines, except for DO which was well below recommended levels.

3.2.3 Macroinvertebrates

The samples yielded a total of 46 taxa, with 42 taxa being collected at the sites in the Georges River Creek and 20 at the site in Mallaty Creek. Within the Georges River, 28 taxa were recorded in the upstream sites, whilst 39 taxa were recorded from the sites within the SMP area. The number of taxa recorded per site in the Georges River ranged from 16 – 21 upstream and from 20 – 26 within the SMP area. This suggests that the fauna at the sites within the SMP area were less impoverished than those at the upstream sites.

The fauna at most of the sites within the SMP area and at all the upstream sites in the Georges River were rated as slightly impoverished relative to the AUSRIVAS reference condition, on the basis of observed to expected numbers of taxa (Table 4). The fauna at one of the sites in the reach of the George River within the SMP Area and at the site in Mallaty

Creek were rated as similar to the reference condition. The Signal scores varied from 3.44 to 4.25 and are indicative of severe to moderate pollution.

Several taxa expected to occur were absent from all sites in the George River, including Gerridae (water striders), Gripopterygidae (stonefly larvae) and Scirtidae (marsh beetles. Several other taxa were also absent from most sites in the Georges River, including Atyidae (Freshwater shrimp - 6 sites), Notonectidae (backswimmers - 7 sites), and Elmidae (riffle beetles – 7 sites). In Mallaty Creek, 5 out of 14 taxa expected to occur were absent, including Gerridae (water striders), Gyrinidae (whirligig beetles), Synlestidae (damselfly larvae), Aeshnidae (dragonfly larvae), and Tanypodinae (non-biting midge larvae).

4.0 ASSESSMENT OF IMPACTS

The following assessment of impacts on aquatic biota is based on subsidence predictions for final longwall layouts provided by MSEC (2007) and on assessment of impacts on surface water chemistry provided by Ecoengineers (2007). The assessment covers the 2.8 km long section of the upper reaches of the Georges River and the three drainage lines, Mallaty Creek, Leafs Gully and Nepean Creek, which lie within the SMP Area and sections of these watercourses outside the general SMP area that may experience valley-related movements. The latter include an additional 0.5 km stretch of the Georges River. It is understood that the proposed Longwalls 34 to 36 will abut, but not pass beneath the Georges River. However, for the purposes of this SMP Application, the two sections of the river have been considered an *area of environmental sensitivity* (MSEC 2007). The area that is susceptible to subsidence-related impacts is located between Rock Bar 37 and Rock Bar 65.

Longwall mining related ground movement can impact on watercourses in a number of ways, including subsidence of uplands, plateaus and ridge tops, bulging of incised valleys and gorge walls and upward strain of creek and river beds. Valley closure and down slope movements associated with incised valley and gorge walls can, in turn, result in the erosion of slopes, mobilisation of sediment and its deposition in watercourses. The upsidence and closure caused by valley bulging can also lead to the fracturing of the substratum of creeks and rivers and result in changes to the stream morphology, such as the draining of pools, increased or decreased ponding, scouring and subsurface flow diversion (MSEC 2007). These changes in turn, can impact upon the aquatic ecology of a watercourse through loss of habitat, desiccation, sedimentation in pools, stream discontinuity, and deterioration in water quality due to leaching of minerals through fractured bedrock or groundwater inflows.

4.1 Description of Proposal

BHPBIC proposes to continue its underground coal mining operations at West Cliff Colliery in the Southern Coalfield of New South Wales, by extracting coal from Longwalls 34 to 36 within the Bulli Seam. These longwalls are located immediately north of Longwalls 29 to 33 for which approval has already been obtained. It is understood that the void width and solid chain pillar width of the proposed longwalls will be 305 m and 42 m, respectively and that Longwalls 34 and 35 will be considerably longer (4065 m and 4235 m, respectively) than Longwall 36 (2815 m). The depth of cover above the proposed longwalls will vary from 470 m to 540m.

4.2 Aquatic Habitats

Ground movements associated with longwall mining can impact on the availability of aquatic habitats by changing the levels of ponding, flooding and scouring of banks along watercourse, changing the alignment of streams by altering the cross-bed gradient and altering surface water flows through the fracturing of river and streams beds.

4.2.1 Changes in Level of Ponding, Flooding and Scouring of Banks

The potential for changes to the level of ponding, flooding and scouring of banks along watercourses depends on whether the net vertical movements brought about by longwall mining alters the gradients of the watercourses. MSEC (2007) predicted that the maximum change in the grade of the potentially affected stretch of the Georges River will be very small (i.e. less than 0.1%) as would be that in the creeks and gullies (0.6%). Changes of this magnitude are not likely to cause any significant increase in the levels of ponding, flooding, or scouring of the river banks. There could, however, be some localised increases in levels of ponding or flooding in the river where the predicted maximum tilts coincide with existing pools, steps or cascades and in the creeks and gullies if the predicted maximum tilts coincide with areas with small natural gradients. As changes of this type are expected to be minor, only minimal impacts are expected on aquatic habitats.

4.2.2 Changes in Alignment of Streams

The potential for changes in alignment of streams depends on the ground movements induced by mining, the natural river cross-bed gradients and the depth, velocity and rate of surface water flows (MSEC 2007). Changes in stream alignment can affect riparian vegetation and result in additional scouring of river banks. MSEC (2007) estimated that changes in cross-bed gradients in the stretch of the Georges River within the SMP Area due to maximum predicted systematic tilt and total upsidence would be 1 in 665 and 1 in 165, respectively. These changes are very small and an order of magnitude smaller than natural cross-bed gradients. Impacts resulting from changes in stream alignment on aquatic habitat are consequently expected to be insignificant. The impacts of scouring on aquatic habitats are also likely to be minimal, because the river bed is composed of sandstone.

4.2.3 Fracturing of Bedrock and Diversion of Surface Flows

Fracturing of bedrock and diversion of surface flows depends on subsidence, valley-related upsidence and closure movements (MSEC 2007). Substantial fracturing of river beds usually only occurs when longwalls are mined directly under rivers (MSEC, 2007). As the section of the Georges River within the SMP Area will not be undermined, only minor fracturing of the river bed and sub-bed diversion of flows may occur. The systematic subsidence movements that are likely to occur above Longwalls 34 to 36 are not expected to be of sufficient magnitude to cause significant fracturing of sandstone bedrock or result in significant diversion of surface water flow. The maximum predicted closure movements along the Georges River are also expected to be smaller than those which have caused major fracturing or flow diversions in nearby river and creek systems, except along the 110 m section of the river adjacent to the proposed maingate of Longwall 35. In this section of the river, which includes Rock Bars 56A and 56B, the closure movements are expected to be of a magnitude that may cause localised fracturing or flow diversion and associated pool drainage. The predicted closures at Rock Bars 55, 57 and 59 are expected to be of a magnitude that may result in minor fracturing along the Georges River. This minor fracturing is most likely to occur adjacent to the proposed maingate of Longwall 35 and may extend up to 400 m away from the proposed longwalls.

The extraction of the proposed longwalls could cause a slight increase in the current rate of surface water flow diversions in the Georges River, but MSEC (2007) consider this to be unlikely, as it has not been observed in other rivers abutted by longwalls. Surface water flow diversions could lead to temporary loss of aquatic habitat if the diversionary flow exceeds the entry flow to a pool for an extended period of time (MSEC, 2007). If the upstream licenced discharges from West Cliff and Appin mines cease, there is a possibility that some sections of the river could dry out during periods of low rainfall and the river becoming a series of disconnected pools. The duration of these impacts on aquatic habitats will depend on the characteristics of the river bed and subsequent flow events. In some areas, cracks in bedrock may be filled partially or completely by alluvial deposits during subsequent flow events. In other cases, remediation work may be necessary to restore flows.

Pool habitat would be re-established once flows from licensed discharge points exceed diversionary flows or remediation works such as grouting of fractures reduce diversionary flows.

MSEC (2007) indicate that some compressive buckling and dilation of the topmost bedrock could occur along the alignments of Mallaty Creek and Leafs Gully and also occur, but to a lesser extent, along the alignments of Nepean Creek and the tributaries. In creeks and gullies where there are alluvial deposits above the sandstone bedrock, fracturing is unlikely to continue up to the surface, however, if it does the cracks formed are likely to be filled with alluvial material during subsequent flows. In areas with exposed bedrock, there may be some diversion of flows into the underlying dilated strata and drainage of pools within the alignments. The diversion of flows is likely to be greater during low flow periods than during heavy rainfall events and this could affect the quality and quantity of water flowing in the creeks and gullies. The diverted surface water is likely to re-emerge further downstream.

Aquatic habitat can also be adversely affected by changes in water quality resulting from mine subsidence impacts. Changes in aquatic habitat of this nature are considered in Sections 4.3 and 4.4.

4.3 Effects on Water Quality

The fracturing of bedrock and diversion of surface flows into the dilated strata can lead to weathering and leaching of minerals which, in turn, can have a localised impact on the quality of water in rivers and creeks, particularly during low flow conditions. Mine-related subsidence could also induce the formation of ferruginous springs which can affect water quality through the leaching of minerals (Ecoengineers 2007). These mechanisms are not expected to give rise to significant water quality impacts in the Georges or Nepean river or the named creeks that flow into these rivers.

4.3.1 Diversion of Surface Flows

Potential impacts on water quality resulting from diversion of surface to sub-bed flows include increased acidity, decreased dissolved oxygen and increased levels of metals, such as nickel and zinc (Ecoengineers, 2007). These impacts, if they occur, will be restricted to areas downstream of rock fractures, where flows re-emerge into the surface waters. If there are significant amounts of marcasite in the unweathered sandstone bedrock, at the peak of its dissolution, the short-term worst case effects on water quality are predicted to vary as follows with flows:

1. if 0.5 ML/day is diverted through freshly fractured bedrock, and there is no diluting surface flow, the emerging waters would be highly reduced, virtually devoid of DO, and have very low levels of dissolved Ni and Zn;
2. if sub-bed diversion flows are less than one third of the total flow, the emerging waters would not exceed the national water quality guidelines for pH, DO and dissolved ecotoxic cationic Ni, but would exceed those for dissolved cationic Zn by a considerable amount; and
3. for river flows up to at least 2.5 ML/day where there is at least one third diversion through the fractured riverbed, the emerging waters would exceed the national water quality guidelines for DO, dissolved, ecotoxic cationic Zn by a considerable

amount and exceed the guidelines for ecotoxic cationic Ni by only a minor amount (Ecoengineers 2007).

As extraction of coal is only expected to result in minor fracturing along the section of the Georges River within the SMP Area and this is most likely to occur adjacent to the proposed maingate of Longwall 35, impacts on water quality resulting from diversion of surface flows are expected to minor, short-term and localised. It should also be noted that the bicarbonate/ carbonate alkalinity in the West Cliff discharge will "buffer out" any increase in acidity and reduce the concentration of cationic forms of the heavy metals by inducing the formation of complexes. Ecoengineers (2007) also indicate that diversion of flows could result in the formation of mats of iron reducing bacteria (flocs), and that this would have a significant aesthetic impact on the river.

4.3.2 Ferruginous Spring Formation

Ecoengineers (2007) concluded that the potential risk to water quality from the formation of ferruginous springs is minor in Mallaty Creek, Leafs Gully Creek and the upper Nepean catchment and rare in the Georges River. This is because the proposed Longwalls 34 and 36 will run more or less diagonally and lengthwise, respectively under these creeks, but not undermine the river.

If mining did result in the formation of a ferruginous spring in the Georges River, Ecoengineers (2007) predicted that the worst case long term effects on water quality would vary with flow rates as follows:

1. If discrete spring flows into the river exceed 0.1 ML/day and river flows fall below about 0.3 ML/day, the water at the spring mergence point would not meet the 85% default lower limit for dissolved oxygen in the national water quality guidelines;
2. If discrete spring flows into the river are below 0.2 ML/day and river flows below about 0.5 ML/day, the cationic ecotoxic nickel and zinc species in the water at the spring emergence point would not exceed the 95% default limit for nickel and zinc in the national water quality guidelines;
3. If the discrete spring flows into the river exceed 0.15 ML/day and river flows are below about 1.0 ML/day, the dissolved oxygen content of the water at the spring emergence point would fall just below the default lower limit in the national water quality guidelines.

As the water in the Georges River would typically be re-aerated over a very short distance, the decrease in dissolved oxygen levels at the point of spring emergence is not generally expected to have any significant impact. A considerable oxygen deficit is only likely to occur at the emergence point if the spring flow rate exceeds 0.1 ML/day and river flows drop below 0.3 ML/day. These conditions have occurred less than 15% of the time since August 2004. The ecotoxic nickel and zinc species derived from such springs are unlikely to exceed the water quality guidelines owing to the complexing effect of the bicarbonate/carbonate alkalinity in the West Cliff discharge.

The creeks are fully mantled by Wianamatta Shale clay soils, which are marine in origin and therefore contain elevated levels of dissolved iron, manganese, nickel and zinc. As Leafs Gully discharges into the Nepean River and Mallaty Creek does so via Lower Ousedale Creek, there is a risk of elevated levels of these metals being transported into this system, if ferruginous springs form. In view of the ephemeral nature of these creeks, their damming for agricultural use and their history of water quality degradation through cattle access, Ecoengineers (2007) consider it unlikely that the formation of ferruginous springs in these streams would not have any significant impact on water quality above that occurring at present. The formation of ferruginous springs in these creeks is not expected to have any significant impact on the Nepean River, into which they flow.

4.4 Aquatic Biota

Changes in water quantity and quality resulting from the diversion of surface water flows to dilated substrata and formation of ferruginous springs could potentially have impacts on aquatic organisms.

4.4.1 Diversion of Surface and Sub-surface Flows

The sudden drainage of pools or rapid drop in stream flow due to subsidence are likely to have localised, significant impact on aquatic biota, particularly on organisms that are left stranded in air or unable to move to areas that are damp or submerged.

Aquatic plants and sessile animals are particularly vulnerable to desiccation, because of their inability to move elsewhere to other available habitat. The survival of mobile organisms is difficult to predict, because it depends on their tolerance and response to desiccation, and rapid changes in water level, ability to move, weather conditions, the underlying substratum and duration of exposure. Simple experimental observations indicate that net-spinning caddis-fly larvae (Hydropsychid) respond to aerial exposure by commencing crawling before stones dried out, but cased caddis-fly larvae (Conoesucidae) do not move until stones are dry and then they simply drop off (Bergey 2000). This suggests that net-spinning caddis fly larvae may attempt to follow receding water by crawling, whereas cased caddis fly larvae are more likely to fall into crevices among stones. Gastropod molluscs also differ in their responses to aerial exposure with physids crawling off stones, but potamopyrgids crawling onto the underside and remaining in place. Streams with soft sediment banks are likely to contain moisture within interstices and this may prolong the survivorship of stranded animals. In streams with a bedrock substrate where there are few natural refugia, except cracks and cavities, few organisms may survive complete pool drainage. The survival times of mobile animals are likely to be longer on cool and rainy days than on hot days. More hardy species, such as freshwater crayfish and yabbies, may be able to relocate to other areas of aquatic habitat. These species can also withstand prolonged periods of drought by retreating into their burrows (NSW DPI 2006). Species of fish, such as freshwater eels and climbing galaxids, may also be able to relocate provided sufficient damp surfaces are available (McDowall 1996). Other species of fish asphyxiate when exposed to air. The drainage of a pool following river bed or rock bar fracturing could also prevent downstream drift of invertebrates and result in a temporary barrier to fish passage.

The predictions about the impact of subsidence on aquatic habitat outlined in Section 4.2 indicate that impacts of these types are likely to be localised and will not persist once flow is restored. As the aquatic habitat within the SMP area is fairly extensive, localized losses of aquatic biota are unlikely to have a significant impact on the size of populations. Such impacts could be rapidly ameliorated by the increased input of water from licensed discharge points or by the remediation of pool habitat using techniques such as grouting of fractures.

4.4.2 Changes in Water Quality

Changes in water quality, in the form of reductions in dissolved oxygen levels and increases in acidity and metal concentrations, resulting from the diversion of sub-surface flows and weathering or leaching of minerals or formation of ferruginous springs may impact on aquatic biota.

4.4.2.1 Reduction in Dissolved Oxygen

Low concentrations of dissolved oxygen are known to have adverse effects on many aquatic organisms, particularly fish and invertebrates that depend upon oxygen for their functioning (ANZECC, 2000). It is important to note that dissolved oxygen content decreases with increasing water temperature, and that it is difficult to recommend acceptable levels, because some organisms exhibit special adaptations to low concentrations (Rahel and Nutzman, 1994; Williamson, 1991). A laboratory-based study on the effects of low levels of dissolved oxygen on New Zealand native species, such as galaxiids, gudgeons, smelt, eels and shrimp, and juvenile rainbow trout showed that eels were the only species that could survive exposure to 1 mg/L for 48 hours at 15 ^{o}C and that only trout suffered mortalities at 3 mg/L. (Dean and Richardson, 1999). It was also noted that most fish moved towards the surface within the first few hours of exposure to 1 mg/L and that one of the galaxid species responded by leaving the water completely. Reductions in oxygen level in the watercourses within the SMP due to mining, if they occur, are likely to be short-term and localised and will thus only have a significant impact on aquatic biota if they coincide with low flow (< 0.3 ML/day) conditions.

4.4.2.2 Increase in Heavy Metal Concentrations

Iron, manganese zinc and nickel are essential trace elements required by many aquatic organisms that can become toxic at higher concentrations (ANZECC, 2000). The ANZECC (2000) guidelines for the limits of acceptable concentrations of these metals in freshwater ecosystems have been derived from numerous studies of aquatic organisms. Manganese, for example, is ecotoxic at levels over about 3.6 mg/L in disturbed (80% level of protection) ecosystems. If metal concentrations in the watercourses rise above these guidelines, they could become toxic, particularly to aquatic organisms stranded in small pools. However, when flow is re-established, these dissolved ions will be flushed downstream. In the Georges River, the dissolved ions will also be changed into less toxic complexes by the bicarbonate/carbonate alkalinity in the West Cliff discharge.

Predictions about the impacts of increased heavy metals on biota must take into account the current levels of these metals in the watercourses. The aquatic fauna and flora within the stretch of the Georges River that lies within the SMP area have been subjected to elevated levels of these metals above the ANZECC guidelines since the commencement of mine water discharge from West Cliff and Appin Collieries in the mid 1960's (G. Brassington, *pers. comm.*). They have consequently had ample time to adapt to these levels. If increased levels of zinc and nickel resulting from mine subsidence impacts occur within this stretch of the Georges River, they are likely to be localised and temporary in nature due to consistent river flows. Negative impacts on aquatic biota are therefore likely to be limited to a very small area over a short period of time. Increased levels of nickel and zinc are not expected to have a significant impact on the aquatic ecology within the SMP area, given the extensive aquatic habitat and biota within the SMP area.

Increases in concentrations of iron and manganese due to fresh fractures in Hawkesbury Sandstone could accelerate the natural bio-geochemical process of floc formation by bacteria. These flocs may be visible for several hundred metres downstream of fractures. Their presence, however, may be masked by high flows in the river and effects appear to diminish over several months. Dissolved oxygen levels may also be locally reduced in area where flocs occur (The Ecology Lab, 2002). The ecological effects of these flocs on aquatic biota are largely unknown, but may include reduction of interstitial benthic habitat (smothering), reduced light penetration and reduction in dissolved oxygen.

If mine subsidence results in the formation of such flocs, potential impacts on aquatic ecology could be minimised or avoided by rapid remediation works, such as grouting of fractures to prevent sub-bed flow diversion, and, maintenance of river flow to disperse the floc. Simultaneous discharges from both Appin and West Cliff Collieries for short periods of time could result in surface flows strong enough to flush attached floc from the river bed. If these mitigation strategies are implemented, metals and bacterial flocs resulting from the mining are not expected to have a significant impact on aquatic ecology.

4.5 Threatened Species

Habitat for three listed threatened species: Macquarie perch, Sydney hawk dragonfly, and Adams emerald dragonfly, has been identified as unlikely although possible to occur within the SMP area or surrounding watercourses (section 2.5). As a precautionary approach, assessment of potential impacts on these species from the proposed West Cliff longwalls 34 – 36 has been undertaken. These assessments take the form of a Seven-Part Test as required by the FM Act for all three species, and EPBC assessment of significance for the federally listed Macquarie perch.

These assessments have been prepared using specific mine subsidence predictions for West Cliff longwalls 34-36 and an understanding of the likely mine subsidence impacts in relation to watercourses and water chemistry as described by MSEC (2007) and Ecoengineers (2007) and summarised in sections 4.1, 4.2, 4.3 and 4.4 above.

4.5.1 Seven-Part Test for Macquarie Perch

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

Life history studies of Macquarie Perch have been largely carried out on western drainage populations. These populations are known to spawn just above riffles in shallow upland streams in October and November when water temperatures rise to around 16^{0}C (McDowall, 1996). Eastern populations, however, inhabit rivers with very different hydrological conditions to the inland populations and very little is known of their life cycle.

Deep, permanent pools within the lower reach of the Georges River and the Nepean River between Douglas Park Weir and Menangle Weir may provide important habitat areas for Macquarie Perch within various stages of the life cycle of the species. It is considered highly unlikely that the species is present within the SMP area for this development, because of a lack of suitable habitat and barriers to fish passage from downstream.

Potential impacts on water quality such as increased acidity, reduced dissolved oxygen and increased heavy metal concentration which may impact on the habitat quality and hence the population viability of this species downstream are not expected to occur as a result of mine subsidence because no significant fracturing is likely to occur in the substratum of Georges River (Ecoengineers, 2007). Some increased salinity is expected to occur within surface water of Mallaty Creek and Leafs Gully, which drain to the Nepean, however this is predicted to be indistinguishable from existing levels within this reach of the Nepean beyond the creek/river confluence (Ecoengineers, 2007), and is therefore not expected to have any impact on water quality within this potential habitat area.

It is considered that mine subsidence resulting from West Cliff longwalls 34 - 36 will not have any adverse effect on potential populations of Macquarie Perch within the Georges or Nepean Rivers that would be likely to place them at risk of extinction.

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

No endangered populations of Macquarie Perch have been listed on the Schedules of the FM Act.

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

1. *is likely to have an adverse effect on the extent of the ecological community such that it local occurrence is likely to be placed at risk of extinction, or*
2. *is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction*

The eastern form of the Macquarie Perch is not part of a listed endangered ecological community.

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

1. *the extent to which habitat is likely to be removed or modified as a result of the action proposed*

The study area does not include any areas considered as appropriate habitat for Macquarie perch, and as such, no habitat is likely to be removed or modified as a result of mine subsidence. Ecoengineers (2007) predict that significant changes in water quality will not occur in the Georges River as a result of mine subsidence impacts, and that there will therefore not be any downstream impacts of water quality degradation. Potential increases in salinity in Mallaty Creek and Leafs Gully, attributable to spring formation, are not expected to have a significant effect on water quality in the Nepean River beyond the immediate discharge point and will not therefore result in degradation of this potential downstream habitat.

2. *whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and*

Potential Macquarie Perch habitat in the Georges River catchment and the Nepean River are well outside of the predicted subsidence impact area, and as such no fragmentation or isolation of habitat is predicted.

3. *the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality*

It is not expected that any habitat will be significantly removed, modified, fragmented or isolated within the Georges or Nepean Rivers as a consequence of mine subsidence.

Whether the action is likely to have an adverse effect on critical habitat (either directly or indirectly)

There is no listed critical habitat for Macquarie Perch within the study area.

Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan

Recovery objectives for Macquarie Perch in this region include prevention of siltation and erosion, preservation of natural flows and removal of existing barriers to fish passage (Morris *et al.* 2001). Some short-term minor siltation and erosion may occur as a result of mine subsidence -induced mobilisation of sediments that ultimately are transported into the Georges and Nepean Rivers. These inputs are likely to be relatively minor compared with those occurring during normal storm events (Ecoengineers, 2007). The minor fracturing that may occur within Georges River is not expected to result in any significant diversion of surface water which would affect the existing flow regime of the Georges River (MSEC 2007).

Whether the action proposed constitutes or is part of a key threatening process or is likely too result in the operation of, or increase the impact of, a key threatening process

The proposed action is not classed as a Key Threatening Process under the *FM* Act 1994, under which Macquarie Perch are listed. However under the TSC Act, 1995, longwall mining resulting in the alteration of habitat has recently been listed as a Key Threatening Process. This does not define the action as a threatening process as described under the required assessment (seven-part test) for threatened species under the *FM* Act.

Conclusion

The proposed mining of West Cliff longwalls 34 - 36 does not pose a significant threat to the potential local populations of Macquarie Perch within the Nepean and Georges River catchments. As such, the preparation of a Species Impact Statement as prescribed under the EP&A Act is not required.

4.5.2 Assessment of Significance (EPBC Act) for Macquarie Perch

Is the action likely to lead to a long-term decrease in the size of an important population of a species?

Potential populations of Macquarie Perch occur within the Nepean River between Douglas Park Weir and Menangle Weir, and downstream of the study area within the Georges River. The mining of Longwalls 34 – 36 in West Cliff Area 5 will not lead to degradation of water quality, habitat loss or degradation, habitat isolation or fragmentation that could lead to a long term decline in the population.

Will the action reduce the area of occupancy of an important population?

There are no impacts on aquatic habitat such as degradation of water quality, increased saltation and scouring or water loss, predicted to occur within the potential area of occupancy of Macquarie Perch within the Georges or Nepean River systems.

Will the action fragment an existing important population into two or more populations?

There are no impacts on aquatic habitat such as subsurface flow diversion or pool water loss predicted to occur within the potential area of occupancy of Macquarie Perch within the Georges or Nepean River systems. As such, no habitat fragmentation is likely to occur.

Will the action adversely affect habitat critical to the survival of the species?

If this species occurs within the Georges River or Nepean River downstream of the planned longwall development, habitat is well outside the predicted area of subsidence impacts, and as such, habitat critical to the survival of the species will not be affected.

Will the action disrupt the breeding cycle of an important population?

Little is known of the life history of the eastern population of Macquarie Perch, however the apparent absence of this species from the study area, and the unlikely occurrence of downstream impacts resulting from water quality degradation or increased sedimentation in areas of potential habitat indicate that mining is highly unlikely to disrupt the breeding cycle of this species.

Will the action modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

Mine subsidence impacts that could result in the creation of barriers to upstream migration, draining of pools and degradation of water quality have been considered in relation to the above questions. It is considered highly unlikely that the development of West Cliff Longwalls 34 - 36 will have any adverse impacts on Macquarie Perch habitat within the Georges and Nepean River catchments that will cause a decline in this species.

Will the action result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat?

There are no processes associated with the mining of West Cliff Longwalls 34 - 36 that could potentially facilitate the introduction of invasive species harmful to Macquarie Perch into the catchments of the Georges or Nepean Rivers.

Will the action introduce disease that may cause the species to decline?

There are no processes associated with the mining of West Cliff Longwalls 34 - 36 that could potentially facilitate the introduction of diseases harmful to Macquarie Perch into the catchments of the Georges or Nepean Rivers.

Will the action interfere substantially with the recovery of the species?

In view of the above points, it is highly unlikely that the mining of West Cliff Longwalls 34 - 36 and subsequent potential mine subsidence impacts will have any significant impact on the potential Macquarie Perch population within the catchments of the Georges or Nepean Rivers.

Conclusion

The proposed mining of West Cliff Longwalls 34 -36 does not pose a significant threat to the potential local viable population of Macquarie Perch with the catchments of the Georges and Nepean Rivers. As such, referral of this development in relation to Macquarie Perch to the Department of Environment and Water (DEW) as prescribed by the EPBC Act is not required.

4.5.3 Seven-Part Test for Sydney Hawk Dragonfly

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

Sydney Hawk Dragonfly is extremely rare, having been collected only in small numbers at a few locations. Specimens (adults or larvae) have been collected from three locations in a small area south of Sydney, from Audley to Picton (NSW Fisheries, 2004). There are no records for this species within Georges River or the Nepean River between Douglas Park Weir and Menangle Weir.

Most of the lifecycle of this species is spent as an aquatic larva, while adults are present for only a few weeks. The larvae of Sydney Hawk Dragonfly appear to have specific habitat requirements, including deep, cool, slow-flowing water in rocky rivers with steep sides (NSW Fisheries, 2004). Relative environmental stability appears to be an important habitat feature, with rapid variation in water level and flow rate likely to have a negative affect on the suitability of habitat for larvae (G. Theischinger, pers. comm.).

Large permanent pools of the Georges River and the Nepean River within and downstream of the study area appear to provide suitable habitat for the larva of Sydney Hawk Dragonfly. However, the sampling done by The Ecology Lab and others (Section 2.5) in this area, along with historical survey records for the Sydney area suggest the waterways of the study area do not support an established population of Sydney Hawk Dragonfly. Therefore the lifecycle of this species is unlikely to be disrupted. In the unlikely case that a population of Sydney Hawk Dragonfly does exist within the large permanent pools of these watercourses, they are unlikely to be significantly negatively impacted by the development of West Cliff longwalls 34 – 36. This conclusion is based on the predictions of mine subsidence effects on watercourses (MSEC 2007) and water quality (Ecoengineers 2007) which predict that if subsidence impacts do lead to habitat loss (through rock bar fracture and pool draining) and changes in water quality, this will be of a localised and temporary nature.

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

To date, there are no threatened populations of Sydney Hawk Dragonfly listed on the Schedules of the FM Act 1994. Thus, the proposal will not affect a threatened population as currently listed.

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

1. *is likely to have an adverse effect on the extent of the ecological community such that it local occurrence is likely to be placed at risk of extinction, or*
2. *is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction*

The Sydney Hawk Dragonfly is not part of a listed endangered ecological community.

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

1. *the extent to which habitat is likely to be removed or modified as a result of the action proposed*

Historical survey records for the region indicate there is no viable population of Sydney Hawk Dragonfly occurring in the study area. However, there is potential habitat in large pools. In the unlikely case that a population of Sydney Hawk Dragonfly does exist within the large permanent pools of the Georges River, it is unlikely that this habitat will be extensively removed or modified by the development of West Cliff longwalls 34 - 36. This conclusion is based on the predictions of mine subsidence effects on watercourses (MSEC 2007) and water quality (Ecoengineers 2007) which predict that there will only be minor localised impacts within the Georges River resulting from possible effects such as rock fracturing, increased flooding, ponding and scouring, or reduced water quality.

2. *whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and*

The Sydney Hawk Dragonfly has an adult life stage in which it is capable of flying. As such it is not impacted by the effects of habitat fragmentation or isolation within a localised area such as the SMP area.

3. *the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality*

It is considered unlikely that there is any important habitat within the SMP area. It is not expected that if any habitat does occur, that it will be significantly removed, modified, fragmented or isolated within the Georges River as a consequence of mine subsidence.

Whether the action is likely to have an adverse effect on critical habitat (either directly or indirectly)

No areas of critical habitat in relation to Sydney Hawk Dragonfly have yet been listed on the Threatened Species Schedules of the *FM* Act 1994.

Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan

There is no recovery or threat abatement plan for the Sydney Hawk Dragonfly.

Whether the action proposed constitutes or is part of a key threatening process or is likely too result in the operation of, or increase the impact of, a key threatening process

The proposed action is not classed as a Key Threatening Process under the *FM* Act 1994, under which Sydney Hawk Dragonfly is listed. However under the TSC Act, 1995, longwall mining resulting in the alteration of habitat has recently been listed as a Key Threatening Process. This does not define the action as a threatening process as described under the required assessment (seven-part test) for threatened species under the *FM* Act.

Conclusion

It is unlikely that a viable population of Sydney Hawk Dragonfly exists within the SMP area. However, because of the presence of possible suitable habitat, this species has been considered. The proposed mining of West Cliff longwalls 34 - 36 does not pose a significant threat to a potential population that may occur. As such, the preparation of a Species Impact Statement as prescribed under the EP&A Act is not required. Aquatic macroinvertebrate monitoring has incorporated a procedure for the identification to family, genus and species of dragonfly larvae as a precautionary measure.

4.5.4 Seven-Part Test for Adams Emerald Dragonfly

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

Adam's Emerald Dragonfly is extremely rare, having been collected only in small numbers at a few locations despite widespread and consistent efforts since the 1960's (NSW Fisheries, 2002). In NSW, specimens (adults or larvae) have been collected from five localities: Somersby Falls, Floods Creek in Brisbane Waters National Park near Gosford; Tunks and Berowra Creeks near Berowra and Hornsby; Bedford Creek in the Lower Blue Mountains; and Hungry Way Creek in Wollemi National Park. There are no records for Adams Emerald Dragonfly south of Sydney despite active collecting in the Georges and Nepean River catchments (NSW Fisheries, 2002).

The larvae of Adam's Emerald Dragonfly inhabit small to moderate sized creeks within a well vegetated catchment. They are typically found in riffle and/or cascade habitat, or nearby pools. For example, in Tunks Creek they were found in narrow riffles with medium to large boulders and cobbles, gravel and some sand. Similarly, the Bedford Creek site in the Blue Mountains was relatively pristine riffle habitat with cobbles and sandy banks (NSW Fisheries, undated).

There does appear to be habitat features within the West Cliff longwalls 34 – 36 SMP area that contains habitat elements suitable for this species. However, macroinvertebrate sampling within the Georges River by The Ecology Lab and others (section 2.5) has not identified this species. Survey records for the Sydney area suggest the waterways of the study area do not support an established population of Adam's Emerald Dragonfly. Based on existing information, it is considered that this species is unlikely to occur within the SMP area. However, if a population of this species were to exist within the SMP area, it is unlikely that there would be any disruption to its lifecycle due to habitat degradation resulting from mine subsidence impacts. This conclusion is based on the prediction that any impacts such as sedimentation in riffles, water loss due to flow diversion into fractures, increased levels of ponding, flooding or scouring or degradation of water quality will be minor and localised in nature and will be unlikely to have a significant impact in the context of the available habitat within the study area (MSEC 2007 & Ecoengineers 2007).

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

To date, there are no threatened populations of Adams Emerald Dragonfly listed on the Schedules of the FM Act 1994. Thus, the proposal will not affect a threatened population as currently listed.

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

1. *is likely to have an adverse effect on the extent of the ecological community such that it local occurrence is likely to be placed at risk of extinction, or*
2. *is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction*

The Adams Emerald Dragonfly is not part of a listed endangered ecological community.

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

1. *the extent to which habitat is likely to be removed or modified as a result of the action proposed*

Survey records for the region indicate there is no viable population of Adams Emerald Dragonfly occurring in the SMP area. However, there is some potential habitat within the Georges River. In the unlikely case that a population of this species does exist within the shaded riffle habitat within the SMP area, it is unlikely that this habitat will be removed or significantly modified by the development of Dendrobium Area 3 as predictions of mine subsidence effects on watercourses (MSEC 2007) and water quality (Ecoengineers 2007) indicate only local, minor impacts resulting from possible effects such as rock fracture, increased flooding, ponding and scouring, or degraded water quality.

2. *whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and*

The Adams Emerald Dragonfly has an adult life stage in which it is capable of flying. As such, it is not impacted by the effects of habitat fragmentation or isolation within a localised area such as the SMP area. Furthermore, mine subsidence impacts are predicted to result in minor, localised flow diversion and pool draining within the Georges River that would lead to fragmentation of this potential habitat (MSEC 2007).

3. *the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality*

It is considered unlikely that there is any important habitat within the SMP area. It is not expected that if any habitat does occur, that it will be significantly removed, modified, fragmented or isolated within the Georges River as a consequence of mine subsidence.

Whether the action is likely to have an adverse effect on critical habitat (either directly or indirectly)

No areas of critical habitat in relation to Adams Emerald Dragonfly have yet been listed on the Threatened Species Schedules of the *FM* Act 1994.

Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan

There is no recovery or threat abatement plan for the Adams Emerald Dragonfly.

Whether the action proposed constitutes or is part of a key threatening process or is likely too result in the operation of, or increase the impact of, a key threatening process

The proposed action is not classed as a Key Threatening Process under the *FM* Act 1994, under which Adams Emerald Dragonfly is listed. However under the TSC Act, 1995, longwall mining resulting in the alteration of habitat has recently been listed as a Key Threatening Process. This does not define the action as a threatening process as described under the required assessment (seven-part test) for threatened species under the *FM* Act.

Conclusion

It is unlikely that a viable population of Adams Emerald Dragonfly exists within the SMP area. However, because of the presence of some suitable habitat elements, this species has been considered. The proposed mining of West Cliff longwalls 34 - 36 does not pose a significant threat to a potential population that may occur. As such, the preparation of a Species Impact Statement as prescribed under the EP&A Act is not required. Aquatic macroinvertebrate monitoring has incorporated a procedure for the identification to family, genus and species of dragonfly larvae as a precautionary measure.

5.0 MONITORING PLAN

A comprehensive monitoring plan designed to assess the potential impacts of mine subsidence on aquatic habitat and biota within watercourses of the West Cliff Area 5, Longwalls 34 - 36 is outlined below. This monitoring plan supports an application to the Department of Primary Industries for SMP approval for mining of these longwalls. It assesses and measures potential impacts on habitats, biodiversity and threatened species from the mining and associated activities.

This monitoring plan is a continuation of the existing aquatic monitoring program being undertaken for West Cliff Area 5, Longwalls 29 – 33 (The Ecology Lab 2005), and as such incorporates the same survey methods, but includes additional monitoring sites specifically relevant to the current longwall layout. This monitoring plan incorporates baseline sampling to be done prior to the commencement of longwall mining (part of which has already been done and results presented in Section 3). During-extraction and post-extraction monitoring would be undertaken at the same seasonal periods (Spring and Autumn) to determine the extent and nature of any impacts and recovery. Sites to be monitored are those within Georges River and Mallaty Creek, where there is moderate to significant aquatic habitat (Figure 1).

Methods to be used will include habitat assessment, macroinvertebrate (AUSRIVAS) survey and water quality assessment as described in section 3. Additional fish surveys are recommended within sites within the SMP area prior to the commencement of mining. This would involve backpack electrofishing and bait trap techniques.

Reports will be produced at the conclusion of each survey that provide sufficient information to describe the habitats and biota that may be affected by subsidence after mining. Reports would include:

- Background information and review of relevant literature, including information on threatened aquatic species, and
- Maps indicating locations of threatened species, populations or aquatic ecological communities known to exist. No separate map would be produced should no threatened species, populations or aquatic ecological communities be identified, but observation points would be provided,
- Methodology used, including field, statistical and laboratory procedures,
- Descriptions of sites sampled, including GPS coordinates and photographs,
- Results, presented in Tables and Figures. Raw or summarised data would be presented in Appendices,
- Identification of issues and impacts on habitats / biota,
- Recommendations for mitigation of impacts for components of a Subsidence Management Plan,
- Discussion of results,
- Recommendations for future monitoring, if appropriate.

6.0 MANAGEMENT MEASURES

The aquatic ecology monitoring program outlined in Section 5 has been designed to detect and determine the extent and nature of impacts on aquatic habitat and biota resulting from mine subsidence impacts within watercourses. Impacts on aquatic ecology are considered as 'secondary' impacts, as they are flow-on effects of 'primary' physical and chemical impacts directly resulting from mine subsidence. Changes in aquatic habitat and biota detected through the aquatic monitoring program therefore need to be considered within the context of primary physical and chemical impacts. Primary impacts detected within watercourses by routine surface monitoring that would constitute a trigger for further investigation into potential impacts on the aquatic ecology include:

- Rockbar fracture resulting in water loss in a pool within an area of 'significant' or 'moderate' aquatic habitat; and
- Significant change in water chemistry (particularly pH, dissolved oxygen, turbidity, or metal concentration) within an area of 'significant' or 'moderate' aquatic habitat.

Other observations made during routine surface monitoring that would constitute a trigger for further investigation of the aquatic ecology include:

- fish/crayfish kills,
- die-off of macrophyte beds,

These triggers would initiate a rapid response aquatic monitoring plan. This would necessitate a sampling event (as described in Section 5) being undertaken as soon as possible to determine the nature and extent (if any) of secondary impacts on aquatic ecology flowing on from primary impact triggers. Analysis of the level of impact would then determine appropriate response, including rehabilitation of aquatic habitat if appropriate. This would be undertaken in conjunction with any mitigative works (e.g. grouting) which may be required. Such restorative actions would be subject to further monitoring to determine the success of recovery in comparison to baseline data.

The aquatic monitoring program incorporates monitoring events throughout the duration of mine working regardless of observed primary impacts within watercourses. Analysis of data from these 'during mining' sampling times can also provide triggers for further investigation. However these need to be considered with caution and in the context of primary mine subsidence impacts. These triggers include:

- Reduction in stream health as determined using the AUSRIVAS model for sites associated with observed mine subsidence impacts.
- Detectable change in fish and crayfish diversity and/or abundance associated with mine subsidence impacts.

Response actions to such triggers would vary depending on the nature of the impact, and may range from continued monitoring to determine the nature, timing and extent of recovery, to active rehabilitation in conjunction with other mitigative works such as grouting of rock bar fractures.

7.0 CONCLUSIONS

The SMP Area is traversed by part of the upper reaches of the Georges River and three ephemeral drainage lines, Mallaty Creek, Leafs Gully and Nepean Creek. This reach of the Georges River consists of continuously flowing pools separated by rock bars and supports "significant" aquatic habitats. Mallaty Creek, Leafs Gully and Nepean Creek have already been extensively modified and degraded. The first of these creeks, however, still contains areas of "moderate" aquatic habitat, but the others have "minimal" aquatic habitat.

The assessment of the impacts of the proposed mining on natural features provided by MSEC (2007) indicates that within this reach of the Georges River there may be localised, minor increases in levels of ponding or flooding in some areas, very small changes in river alignment, minor fracturing of bedrock, but no significant water loss. Changes of these magnitudes are expected to have only minor, localised impacts on aquatic habitats and biota in the Georges River. In Mallaty Creek, Leafs Gully and Nepean Creek, subsidence may result in some sub-surface diversion of flows and drainage of pools. The loss of water from pools is likely to have a significant, localised impact on aquatic biota, particularly if organisms are left stranded or unable to move to damp or submerged areas. This impact will be temporary, because recolonisation of the habitat will occur soon after flow is re-established.

The assessment of the effects of the proposed mining on water quality provided by Ecoengineers (2007) indicates that diversion of surface flows could lead to increases in the acidity of the water, reductions in dissolved oxygen levels and increased concentrations of heavy metals. These impacts would be minor, short-term and localised. Reductions in oxygen level and increases in heavy metal concentration are only likely to have a significant impact on biota if they coincide with low flow conditions. These effects are likely to be localised and short-term and will be removed once adequate flow is re-established. The bicarbonate/ carbonate alkalinity in the West Cliff discharge will "buffer out" any increase in acidity and reduce the concentration of cationic forms of the heavy metals. The proposed mining could also result in the formation of ferruginous springs, however, this is unlikely to happen in the Georges River and there is only a minor chance of it occurring in the ephemeral creeks. The induction of ferruginous springs could lead to reductions in dissolved oxygen levels and increases in ecotoxic nickel and zinc species at the spring emergence point. These, in turn, are likely to have only a localised impact on biota, owing to re-aeration and dilution effects further downstream.

It has been established that three threatened species, Sydney hawk dragonfly, Adams emerald dragonfly and Macquarie Perch could potentially occur within the SMP Area and surrounding watercourses. Assessments of potential impacts undertaken in accordance with State and Commonwealth legislation indicate that the proposed longwall mining does not pose a significant threat to any of these species.

The detection of primary impacts, such as rockbar fractures resulting in water loss in a pool within an area of 'significant' or 'moderate' aquatic habitat or significant changes in water chemistry within such areas, would trigger investigations into potential impacts on aquatic ecology. Observations of fish/crayfish kills or die-off of macrophyte beds would trigger a rapid response aquatic monitoring plan to determine the nature and extent of secondary impacts on aquatic ecology. The level of impact found would determine the type of response. Significant changes in aquatic biota detected 'during mining' monitoring events would also provide triggers for further investigation. The implementation of such management measures would help reduce impacts on aquatic ecology.

8.0 ACKNOWLEDGEMENTS

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TABLES

Table 1: Summary of existing information on aquatic ecology in the upper reaches of the Georges River in the vicinity of West Cliff Area 5.

Location	Time Period	Component Studied	Source
Nine sites between Cataract Scout Camp and Dwyers Crossing	July 1995 and May 1996	Water Quality Macroinvertebrates	Jarvis (1997) in MPR (2001)
Dwyers Crossing	January 1997 to May 1998	Water Quality	Campbelltown City Council in MPR (2001)
Ten sites between the pool above Kings Falls Bridge and Dwyers Crossing	April 1999	Aquatic Habitats Macroinvertebrates Fish	MPR (2001)
Four sites above, within and below Marhnyes Hole	March 2002	Aquatic Habitats Water Quality Fish	The Ecology Lab (2002a)
Four sites within and upstream of Marhnyes Hole	October 2002	Aquatic Habitats Macroinvertebrates	The Ecology Lab (2002b)
Six sites in the Georges River to the northeast of Appin, two sites in Leafs Gully and 3 sites in Mallaty Creek	May 2002	Aquatic Habitats Water Quality Macroinvertebrates Fish	The Ecology Lab (2003)
Two sites within and six sites upstream of Marhnyes Hole.	October 2002 to May 2004	Water Quality Macroinvertebrates Fish	The Ecology Lab (2004a)
Three sites adjacent to the discharge points from Appin and WestCliff Collieries	June 2004	Water Quality Macroinvertebrates	The Ecology Lab (2004b-e)
Four sites within the SMP Area for Longwalls 31-33 and two sites downstream of this area	May 2002, March and October 2005	Aquatic Habitats Water Quality Macroinvertebrates Fish	The Ecology Lab (2005)
Three sites adjacent to the discharge points from Appin and WestCliff Collieries	June 2004, June and September/October 2005	Water Quality Macroinvertebrates	The Ecology Lab (2006 a and b)

Table 2: Species of fish recorded in the upper reaches of the Georges River and in Mallaty Creek (✓ = species recorded).

Common name	Species	Source	NSW Fisheries	Australian Museum	MPR (2001)	The Ecology Lab (2002a)	The Ecology Lab (2003)	The Ecology Lab (2004)	The Ecology Lab (2005)
		Location	Holsworthy[1], Macquarie Fields[2], Liverpool[3] and Kentlyn[4]	Campbelltown[1], Minto[2], Appin[3]	Just above Kings Falls Bridge to Dwyers Crossing	Marhynes Hole	Sites to the north-east of Appin[1] and Mallaty Creek[2]	Marhynes Hole[1] and sites upstream[2]	Within and downstream of SMP Area for Longwalls 31-33
Short-finned eel	*Anguilla australis*							✓[2]	
Long-finned eel	*Anguilla reinhardtii*		✓[1,2,3,4]	✓[1,2]		✓	✓[1]	✓[1,2]	✓
Freshwater herring	*Potamalosa richmondi*			✓[1]					
Galaxids	*Galaxias spp.*			✓[1]					
Australian smelt	*Retropinna semoni*		✓[2,4]						
Goldfish	*Carassius auratus*		✓[1]						
Freshwater catfish	*Tandanus tandanus*		✓[2]						
Mosquito fish	*Gambusia holbrooki*		✓[4]		✓	✓	✓[1]	✓[1,2]	✓
Australian bass	*Macquria novemaculata*		✓[1,2]						
Golden perch	*Macquria ambigua*			✓[3]					
Macquarie perch	*Macquaria australasica*			✓[1]					
Estuary perch	*Macquria colonorum*			✓[1]					
Silver perch	*Bidyanus bidyanus*			✓[3]					
Trout cod	*Maccullochella macquariensis*			✓[3]					
Sea mullet	*Mugil cephalus*			✓[1]					
Striped gudgeon	*Gobiomorphus australis*		✓[1,2]			✓			
Cox's gudgeon	*Gobiomorphus coxii*		✓[2]	✓[1]					
Empire gudgeon	*Hypseleortis compressa*		✓[1,2]						
Firetailed gudgeon	*Hypseleotris galii*		✓[4]		✓	✓	✓[1]	✓[1,2]	✓
Midgley's carp gudgeon	*Hypseleortis sp.*							✓[1,2]	
Western carp gudgeon	*Hypseleortis klunzingeri*								✓
Flathead gudgeon	*Philynodum grandiceps*		✓[2]				✓[2]		
Dwarf flathead gudgeon	*Philynodum spp. 1*				✓				
Unidentified gudgeon	Eleotridae					✓			

Table 3: Mean and standard error (SE) values for water quality variables measured in the study area during November 2007. Recommended ANZECC guidelines (2000) values for upland rivers are included after some variables and bold values are those which were outside the recommended guidelines.

a) Georges River (Current SMP area)

	Site 6		Site 7		Site 8		Site 9	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	17.97	0.03	17.44	0.00	17.09	0.00	16.59	0.00
Conductivity (µS/cm) (30-350)	**1238.5**	1.5	**1032.5**	2.5	**1043.0**	0.0	**1042.5**	2.5
Salinity (ppt)	0.59	0.01	0.49	0	0.49	0	0.5	0
pH (6.5 - 7.5)	**8.845**	0.015	**8.88**	0	**8.82**	0	**8.795**	0.005
ORP (mV)	429	1	451	0	435.5	0.5	411	2
DO (%saturation) (90 - 110)	**80.9**	0.1	90.8	0.8	**79.55**	0.55	**83.25**	0.25
DO (mg/L)	7.65	0.05	8.65	0.05	7.65	0.05	8.15	0.05
Turbidity (ntu) (2 - 25)	4.1	0	**37.9**	0.8	2.7	0	3.4	0.7

b) Georges River (Upstream of SMP area)

	Site 1		Site 2		Site 3		Site 4		Site 5	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	18.88	0.00	18.3	0.1	19.4	0.0	18.4	0.0	17.67	0.02
Conductivity (µS/cm) (30-350)	**1197**	0.0	**1213.0**	1.0	**1290.0**	2.0	**1269**	0	**1244.5**	1.5
Salinity (ppt)	0.57	0.0	0.6	0.0	0.6	0.0	0.6	0	0.595	0.015
pH (6.5 - 8.0)	**8.325**	0.0	**8.6**	0.0	**8.7**	0.0	**8.73**	0	**8.96**	0.03
ORP (mV)	426	2.0	398.0	3.0	396.0	3.0	445.5	0.5	415	1
DO (%saturation) (90 - 110)	**80.55**	0.0	**84.3**	0.8	**83.1**	0.2	**77.9**	0.1	**81.65**	4.35
DO (mg/L)	7.45	0.0	7.9	0.1	7.6	0.0	7.3	0	7.8	0.4
Turbidity (ntu) (2 - 25)	8.65	0.15	10.45	0.35	3.8	0.1	3.6	0	4.45	0.05

c) Malaty Creek

	Site 10	
Variable	Mean	SE
Temperature (^{0}C)	15.56	0.02
Conductivity (µS/cm) (30-350)	285.5	4.5
Salinity (ppt)	0.11	0
pH (6.5 - 7.5)	7.545	0.065
ORP (mV)	469.5	3.5
DO (%saturation) (90 - 110)	**59.9**	1.8
DO (mg/L)	5.95	0.15
Turbidity (ntu) (2 - 25)	2.5	0.7

Table 4: AUSRIVAS scores for observed versus expected macroinvertebrates from edge habitat in May 2007. Ausrivas band categories are: Band X = macroinvertebrate assemblage at the site is richer (more taxa) than the reference condition; Band A = assemblage is similar to the reference condition; Band B = assemblage is significantly impaired relative to the reference condition; Band C = assemblage is severely impaired relative to the reference condition; Band D = the assemblage is impoverished.

Index	Georges River Current SMP Area				Malaty Creek	Georges River Upstream of SMP Area				
	Site 1	Site 2	Site 3	Site 4	Site 15	Site U1	Site U2	Site U3	Site U4	Site U5
Expected no. taxa	14.96	16.03	17.05	14.17	10.46	16.03	15.04	15.52	16.25	16.15
O/E no. taxa (%)	67	100	70	78	86	69	73	77	74	80
Band	B	A	B	B	A	B	B	B	B	B
Signal Score	4.25	3.7	3.57	3.84	3.44	4.06	3.94	3.8	3.78	3.76

FIGURES

Figure 1: Map showing The Ecology Lab aquatic monitoring locations (indicated by red circles) in relation to proposed longwalls 34 to 36 and the SMP Area. Base map supplied by MSEC (2007).

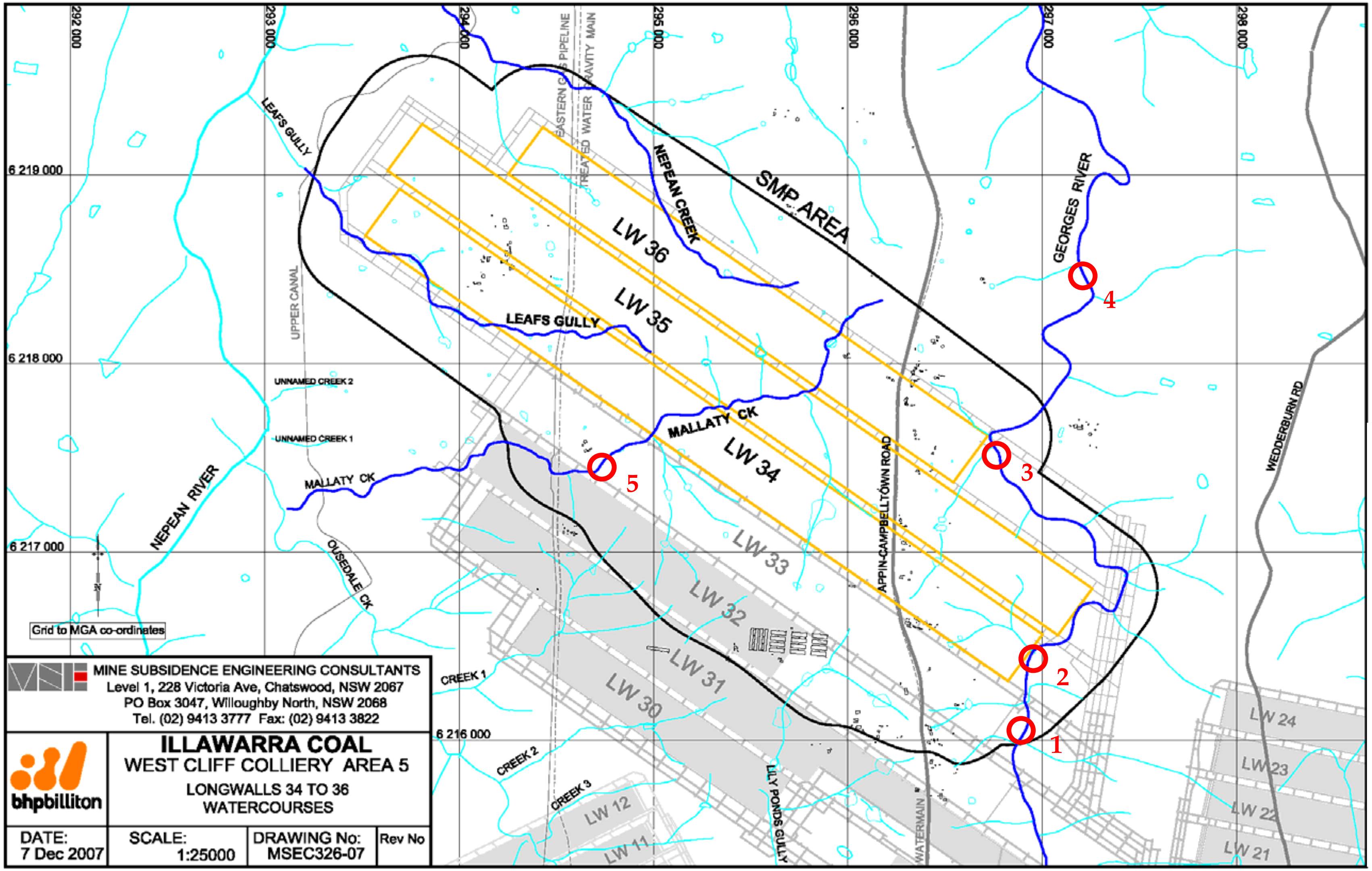

Figure 1. Map showing The Ecology Lab aquatic monitoring locations (indicated by red circles) in relation to the proposed Longwalls 34 to 36 and the SMP Area. Base map supplied by MSEC (2007).

PLATES

Plate 1a. Flood debris within the Georges River indicating recent high flows.

Plate 1b. Shallow flow over retaining sandstone rock bar in the upper Georges River reach of the SMP area.

Plate 2a. Deep pool habitat within lower Georges River reach of the SMP area.

Plate 2b. Rapid flow through boulder field adjoining deep pools in the lower Georges River reach of the SMP area.

Plate 3a. Large stand of bull rushes (*Typha* sp.) with the Georges River.

Plate 3b. Deep pool in lower Georges River reach of the SMP area with numerous snags providing native fish habitat.

Plate 4a. Pipe culvert at Blackburn Road crossing of Georges River creating a barrier to fish passage.

Plate 4b. Extensive earthworks within the channel of Mallaty Creek associated with the Eastern Gas pipeline.

Plate 5a. Site 5 in Mallaty Creek upstream of the Eastern Gas pipeline crossing.

Plate 5b. Large farm dam on Leafs Gully within the SMP area.

Plate 6a. Small farm dam on Nepean Creek within the SMP area.

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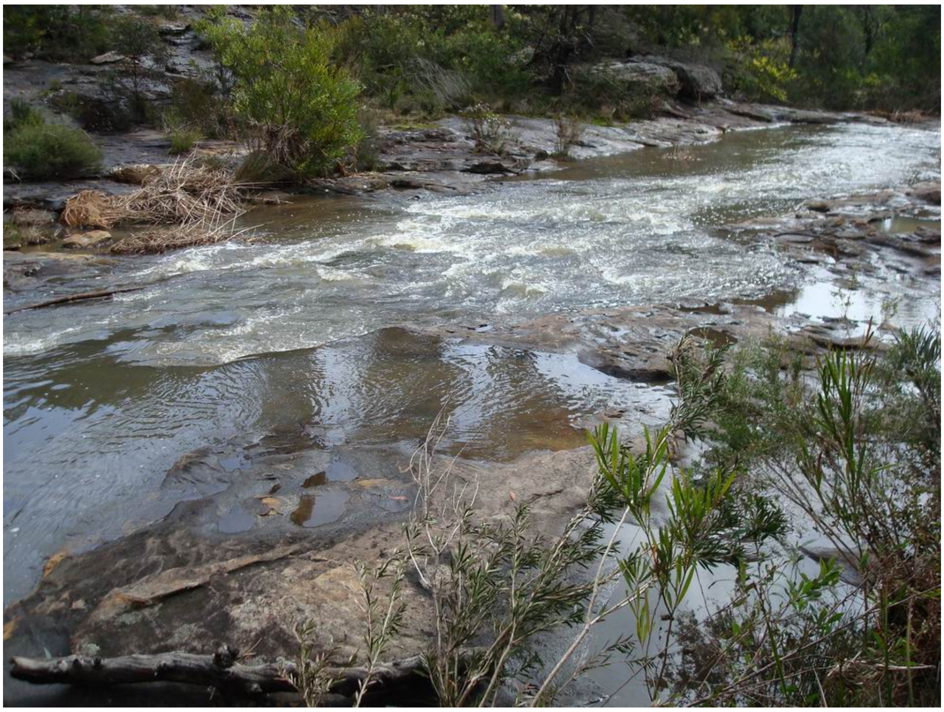

Plate 1.b. Shallow flow over retaining sandstone rock bar in the upper Georges River reach of the SMP area.

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