Annex K

NRE No. 1 Mine V Mains Area - Effects Of Mine Subsidence On Aquatic Habitats And Biota

Cardno Ecology Lab

Shaping the Future

Marine and Freshwater Studies

NRE No 1 Mine V Mains Area

Effects of Mine Subsidence on Aquatic Habitats and Biota

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Executive Summary

Background

Gujarat NRE Minerals Limited (Gujarat) proposes to use pillar extraction methods to extract coal from a remnant section of the Bulli Seam located within the V Mains area of the NRE No. 1 Mine at Russell Vale, in the Southern Coalfield. Environmental Resources Management, Australia (ERM), on behalf of Gujarat, commissioned Cardno Ecology Lab Pty Ltd to describe the existing aquatic habitats and biota potentially subject to impacts from the proposed mining and to provide an assessment of the likelihood and significance of these impacts, with recommendations for ongoing monitoring prior to, during and after mining . This assessment will be included in the Subsidence Management Plan (SMP) currently being prepared for submission to the Department of Primary Industries Minerals and Petroleum (DPIMP), as part of the approval process required to extend the mine.

Overview of Aquatic Habitats and Biota

The Application Area is traversed by the main channel and an ephemeral tributary of Wallandoola Creek. The eastern end of the Application Area is situated 100-160 m to the west of the upper reach of Lizard Creek. Both watercourses drain into Cataract River between Broughtons Pass Weir and Cataract Dam. The surrounding land is moderately to gently undulating and relatively undisturbed due to the inclusion of the greater Cataract River catchment within the Metropolitan Special Area. Wallandoola Creek is poorly defined within the Application Area and dominated by swamp vegetation, with only a few small permanent pools. The unnamed tributary that traverses the Application Area is characterised by small areas of semi-permanent aquatic habitat. The reach of Lizard Creek adjacent to the Application Area is characterised by extended, shallow, reed-filled pools bounded by isolated sandstone ridges. The most upstream area of significant permanent aquatic habitat in Lizard Creek is situated approximately 120 m east of the Application Area and is characterised by headwater swamp habitat. The downstream reaches of these watercourses are characterised by deeply incised sandstone gorges with cascades and waterfalls.

The quality of water in Wallandoola Creek and Lizard Creek has been assessed in the vicinity of V Mains, but not directly above the Application Area as there was not suitable permanent water courses present. The water sampling was undertaken at locations immediately down stream of the application area and these are appropriate for the study of the water quality and the possible impacts that might arise from mining. The water quality has generally been found to be within the acceptable range for potable water, except for pH, which was below the ANZECC 2000 guidelines. The filtered zinc, copper, aluminium, total nitrogen and phosphorus levels have on occasion been above the 95% species protection level for freshwater aquatic ecosystem guidelines.

The baseline aquatic ecology surveys showed that permanent aquatic habitats in the headwater swamp sections of the creeks immediately downstream and to the east of the Application Area support instream aquatic macrophytes, such as ribbonweed (*Vallisneria gigantea*) and spikerush (*Eleocharis* sp.), and native sedge (*Juncus* sp.). In spring 2007, the macroinvertebrate fauna in this region of the two creeks was

categorized as significantly impaired relative to the AUSRIVAS reference condition, with only 20 taxa being recorded in Wallandoola Creek and 23 in Lizard Creek. No fish were caught in the upper reaches of Wallandoola Creek and Lizard Creek, however, native freshwater crayfish (*Euastacus* sp.) were observed.

Assessment of Impacts

The mine-induced subsidence predictions for the V-Mains Area indicate that there are unlikely to be observable adverse effects on stream flow or water quality. It is consequently highly unlikely that there would be any observable flow-on effects on aquatic habitats or their biota within or immediately downstream of the Application Area.

There is, however, a possibility of a localised increase in the natural stream gradient, because the maximum predicted tilt exceeds the gradient of the creeks flowing through the Application Area. This, in turn, could lead to an increase in flow rate, migration of flow channels, erosion of the stream bank and bed, and reduction in the volume and retention time of pools. The mobilization of sediment could reduce the quality of some of the habitats available for occupation by aquatic biota. The changes in pool volume and retention time could decrease the connectivity between habitats, particularly during periods of low flow. The impact on aquatic biota within the Application Area could be locally significant within a small 300m reach of the watercourse directly above the mine area, because there are only a few small, permanent pools within this section of Wallandoola Creek and a few small areas of semi-permanent aquatic habitat within its unnamed tributary. This represents only a very small proportion of the local aquatic habitat. The relatively large pools 300m downstream in Wallandoola Creek would be largely unaffected.

Three threatened species, Adam's Emerald Dragonfly (*Archaeophya adamsi*), Sydney Hawk Dragonfly (*Austrocordulia leonardi*) and Macquarie Perch (*Macquaria australasica*) could potentially occur within the Application Area. A formal assessment of impacts is not considered necessary for Sydney Hawk Dragonfly, because the nearest suitable habitat is in the Cataract River, which is beyond the influence of mining. Nor is one considered necessary for Macquarie Perch, because the waterfalls that occur on the creeks downstream of the Application Area would prevent upstream passage of this fish. The headwater swamp section of Wallandoola Creek that flows through the Application Area does not contain suitable habitat for Adam's Emerald Dragonfly. There does, however, appear to be a limited amount of suitable habitat, in the form of cascade-riffles, available in the sandstone gorge sections of Wallandoola and Lizard Creeks downstream of the Application Area. Although a seven-part test has been included for Adam's Emerald Dragonfly, a species impact statement is not considered necessary, because there is no suitable habitat within the Application Area.

Recommendations for Monitoring

The strategic review of the environmental impacts of underground coal mining in the Southern Coalfield recommends that monitoring should be undertaken prior to, during and after mining within the Application Area and at comparable control locations outside the area affected by mining. The nearest permanent aquatic habitats suitable for monitoring the aquatic ecology of Wallandoola Creek and Lizard Creek is located within the headwater swamp region of the creeks approximately 300

m downstream and 120 m to the east of the Application Area, respectively. The monitoring sites that were established in these regions are thus only suitable for assessment of far-field effects of the mine. As a precautionary measure, it is recommended that additional observations of aquatic habitats be made and surveys of aquatic macroinvertebrates be undertaken only in the headwater swamp regions of the potential impact and control locations during and after mining. If changes in the depth and quality of the water within Wallandoola Creek and Lizard Creek that are greater than anticipated on the basis of the subsidence predictions are detected, an immediate survey of aquatic macroinvertebrates should be triggered at the monitoring sites within the headwater swamp region of all four creeks.

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1 Introduction

1.1 Background and Aims

Gujarat NRE Minerals Limited (Gujarat) proposes to use pillar extraction methods to extract coal from a remnant section of the Bulli Seam located within the V Mains area of the NRE No. 1 Mine at Russell Vale, in the Southern Coalfield. The remnant section of coal is situated between the longwall panels of the former Cordeaux Colliery and the 200 series longwall panels of the former South Bulli Colliery (now NRE No. 1 Colliery). The extraction of coal from this remnant block has the potential to impact on aquatic habitats and biota within watercourses located within, and downstream of, the mine area.

Environmental Resources Management, Australia (ERM), on behalf of Gujarat, commissioned Cardno Ecology Lab Pty Ltd (formerly The Ecology Lab) to describe the existing aquatic habitats and biota potentially subject to impacts from the proposed mining and to provide an assessment of the likelihood and significance of these impacts, with recommendations for ongoing monitoring prior to, during and after mining. This assessment is to be included in the Subsidence Management Plan (SMP) for the 'Application Area' currently being prepared by ERM, on behalf of Gujarat, for submission to the Department of Primary Industries Mineral Resources (DPIM), as part of the required approval process. The 'Application Area' is defined as the surface area within the wedge shape block of remnant coal ranging from 75 m to 340 m wide and approximately 2 km in length referred to as the V Mains.

1.2 Legislative Context

1.2.1 Mining Act 1992

Primary regulatory control of mining is exercised by the Department of Primary Industry Minerals and Petroleum (DPIMP) through the provisions of the *Mining Act* 1992 and the conditions attached to mining leases granted under the provisions of that Act. The NSW Government introduced a new subsidence management policy and approvals process in 2004 with the objective of improving the assessment, management and regulation of subsidence effects due to underground coal mining (NSW DPI 2006). The policy and approvals process requires mining operators to prepare a Subsidence Management Plan (SMP) to provide for the protection of important natural and built features.

1.2.2 Fisheries Management Act 1994

The *Fisheries Management Act* 1994 *(FM Act)* provides for the declaration and listing of threatened species of fish and marine vegetation, endangered populations and ecological communities and key threatening processes. One of the major features of this legislation is the integration of threatened aquatic species into the development control processes under the *Environmental Planning and Assessment Act* 1979 (*EP& A Act*) (see Section 1.2.4).

1.2.3 Threatened Species Conservation Act 1995

The *Threatened Species Conservation Act* (*TSC Act*), administered by the NSW Department of Environment and Climate Change, outlines the protection of threatened species, populations, communities and critical habitat in New South Wales. The *TSC Act* also identifies key threatening processes that increase the risk of extinction of species and recommends strategies for enhancing the recovery of threatened species and abatement of key threatening processes. Alteration of habitat following subsidence due to longwall mining is listed as a key threatening process. The Minister of the Environment has determined that the SMP process addresses this key threatening process and that a Threat Abatement Plan is unnecessary (NSW DPI 2006).

1.2.4 Environmental Assessment and Planning Act 1979

The *EP&A Act* sets out the factors to be considered in a preliminary assessment of whether a development is likely to have significant effects on threatened species. Seven factors are considered in a process referred to as the Seven-Part Test. The test is a series of questions, the answers to which assist in determining whether a planned action will significantly affect threatened species, populations, ecological communities or their habitats. The Seven-Part Test is relevant only if there is a likelihood of one or more threatened species occurring in the area affected by the proposal. If the approval agency, on the basis of the Seven-Part Test, determines that the proposal is likely to significantly affect threatened species, populations, ecological communities or their habitats, a Species Impact Statement (SIS) must be prepared as part of the environmental assessment process for SMP approval of the proposal under Part 5 of the EP&A Act.

1.2.5 Environmental Protection and Biodiversity Conservation Act 1999

The Commonwealth Government's instrument for national environmental protection is the *Environmental Protection and Biodiversity Conservation Act 1999* (*EPBC Act*). Under the *EPBC Act*, any action which has, will have, or is likely to have a significant impact on a matter of national environmental significance, or is undertaken on Commonwealth land is defined as a controlled action and as such requires approval by the Minister for the Environment. The *EPBC Act* has provisions for the listing of threatened species and threatened ecological communities and requires proponents to consider impacts on threatened species.

2 Overview of Aquatic Habitats and Biota within the Application Area Sampling Design

The overview of aquatic habitats and biota in within and in the vicinity of the Application Area draws upon two studies of aquatic ecology undertaken previously in the V Mains area:

- NRE No. 1 Mine – V Mains Aquatic Ecology Baseline Monitoring Program June-August 2007 Survey Baseline Progress Report 1(The Ecology Lab 2007); and
- NRE No. 1 Mine – V Mains. Aquatic Ecology Baseline Monitoring Program Baseline Report (The Ecology Lab 2008).

Reference is also made to the surface water and groundwater assessment for V Mains prepared by Geoterra (2009).

2.1 Physical Setting

The V Mains area of NRE No. 1 Mine is located within the Cataract River Catchment of the Upper Hawkesbury – Nepean River system. The natural environment in this area is relatively undisturbed due to the restrictions on access and development arising from the inclusion of the greater Cataract River catchment within the Metropolitan Special Area administered by Sydney Catchment Authority (SCA). The landscape is moderately to gently undulating within the V-Mains Area, but characterised by rolling to steep hills further downstream (Geoterra 2009). The 'Application Area' is traversed by the main channel and an ephemeral tributary of Wallandoola Creek. The eastern end of the Application Area is situated 100-160 metres to the west of the upper reach of Lizard Creek. This creek will not be undermined by the V Mains. Both watercourses drain into the reach of the Cataract River located between Broughtons Pass Weir and Cataract Dam.

The upper reach of Wallandoola Creek traverses the eastern side of the Application Area and the unnamed tributary crosses the western side of the area. The reach of the creek drops approximately 10 m over the 1250 m stretch within the Application Area and has an average gradient of 0.8 mm/m (Geoterra 2009). The upper reach of Lizard Creek situated to the east of the Application Area drops approximately 10 m over the 1400 m stretch adjacent to the Application Area and has an average gradient of 0.71 mm/m (Geoterra 2009). There is also a valley infill swamp area (also referred to as a headwater swamp) along the riparian channel periphery of Wallandoola Creek within the Application Area (Geoterra 2009).

The reaches of Wallandoola and Lizard Creek immediately downstream of the Application Area are characterised by headwater swamps, with relatively low gradient (The Ecology Lab 2008). DECC considers the cluster of headwater swamps associated with Wallandoola Creek to be significant because they provide large contiguous areas of similar habitat (NSW Planning 2008). Further downstream, the stream gradient increases and watercourses are characterised by deeply incised sandstone gorges. There are numerous cascades and waterfalls on these creeks between the proposed mining area and their confluence with the Cataract River.

2.2 Water Quality

The quality of water within the reaches of Wallandoola Creek and Lizard Creek in the vicinity of the V Mains Area has been assessed on several occasions since September 2001 (Australian Water Technologies 2001; Seedsman Geotechnics 2001; Geoterra 2002; The Ecology Lab 2008). Regular monitoring has also been undertaken at several locations between July 2007 and July 2008 (ERM 2008). None of these monitoring sites are located within the Application Area.

The regular monitoring undertaken since July 2007 indicates that the water in these creeks was generally within the acceptable range for potable water, except for pH, which was lower (i.e. more acidic) than the ANZECC 2000 default trigger values (Geoterra 2009). The measurements of pH taken in both the headwater swamp and sandstone gorge regions of these creeks during August and November 2007 were also below the trigger values (The Ecology Lab 2008). It should, however, be noted that relatively acid streams are quite common in the Hawkesbury Sandstone watercourses of the Southern Highlands and Illawarra. The Ecology Lab (2008) also noted that turbidity levels in both creeks were generally below the lower trigger value during both sampling periods and that in November the dissolved oxygen concentration was below the lower ANZECC trigger value, particularly in Lizard Creek. The regular monitoring program also showed that on some occasions the filtered zinc, copper and aluminium and total nitrogen and phosphorus levels were above the 95% species protection level for freshwater aquatic ecosystem guidelines.

2.3 Aquatic Habitats

The information on the aquatic habitats in the upper reaches of Wallandoola Creek and Lizard Creek presented below is derived from The Ecology Lab (2008) and Geoterra (2009).

2.3.1 Wallandoola Creek

The section of Wallandoola Creek traversing the Application Area is poorly defined and dominated by swamp vegetation with only a few small permanent pools (The Ecology Lab 2008). There are two small areas of semi-permanent aquatic habitat within the section of the unnamed tributary of Wallandoola Creek traversing the Application Area (The Ecology Lab 2007). At the upstream end of this location, there is a pool (approximately 15 m long, 3 m wide with a maximum depth of 2 m) with swamp habitat. At the downstream end of this location, the outflow from the swamp flowed over a bedrock cascade into a small pool.

The Ecology Lab (2007) noted a series of large pools (> 100 m long x 10 m wide) approximately 300 m downstream (north) of the Application Area. The substratum at this location is dominated by sandstone bedrock, but gravel, sand and silt are also present. There are several deep (approximately 3 m) holes in the bedrock which would provide permanent refuge habitat during extended dry periods. There are several aquatic habitat features within this location, including snags, overhanging bank vegetation, rock crevices, earthen banks and beds of aquatic plants. The pools are backed up behind isolated exposed sandstone ledges and there is a small (< 0.5 m) drop from upstream to downstream pools (Geoterra 2009). The stream banks are up to 1.0 m high and vegetated by riparian sedge or upland swamp. There is no

sign of significant erosion, bank instability and no significant iron floc within the section of the creek traversing the Application Area.

The watercourse approximately 250 m north of the western extent of the proposed mining area is characterised by sandstone gorge habitat (The Ecology Lab 2008). At the upstream end of this location, there is shallow flow over a 10 m wide section of sandstone bedrock. There are a few holes (approximately 1.5 m deep) containing sand in the bedrock. The upstream and downstream ends of this location are separated by a waterfall, which is approximately 15 m high and has a large plunge pool at its base. At the downstream end of the location, there are large boulders interspersed with small pools containing some sand and gravel. Further downstream, there is a moderate size pool (approximately 30 m long and 7 m wide with a maximum depth of 1.2 m) with a sandy substratum and some large sandstone boulders. The banks are lined with a variety of native grasses and shrubs. Iron staining, a feature which is often observed in streams in Hawkesbury Sandstone areas, is present throughout this location. There are several aquatic habitat features within this location, including cascade-riffles, snags, overhanging bank vegetation, rock crevices, earthen banks and beds of aquatic plants.

2.3.2 Lizard Creek

The reach of Lizard Creek to the east of the Application Area is characterised by extended, shallow, reed-filled pools bounded by isolated sandstone ridges (Geoterra 2009). Most of the banks are <0.5 m high and vegetated by flanking riparian sedge or upland swamps. Iron floc is present within the reed-filled sections of the channel upstream and downstream of the of the No. 4 Shaft access road crossing.

The most upstream area of significant permanent aquatic habitat identified by the Ecology Lab (2008) is situated at the point of outflow from the headwater swamp approximately 300 m upstream of the No. 4 Shaft access road crossing. At the upstream end of this location, there is a series of gentle cascades over bedrock substratum with one small pool with a maximum depth of 1.5 m. Approximately 300 m downstream of this, there are two large pools with a maximum depth of 3 m separated by a large stand of spikerush (*Eleocharis* sp.). The substratum varies between sandstone bedrock, and deposits of sand and silt in the pools. The aquatic habitats within this location include snags, overhanging bank vegetation, rock crevices, earthen banks and aquatic plants.

The unnamed tributaries of Lizard Creek are small ephemeral watercourses with very little permanent aquatic habitat (The Ecology Lab 2008).

2.4 Aquatic Macrophytes

No published information is available on the distribution of aquatic macrophytes within or in the vicinity of the watercourses in the Application Area. The species found instream and along the creek banks at the study sites investigated during the baseline surveys are recorded in The Ecology Lab (2008).

2.4.1 Wallandoola Creek

Numerous instream aquatic macrophytes, including ribbonweed (*Vallisneria gigantea*) and spikerush (*Eleocharis* sp.), were observed within the large pools in the

headwater swamp location. The native sedge *Juncus* sp. was common along the banks of these pools. At the sandstone gorge location, ribbonweed was observed instream while native plants, such as *Juncus* sp., sawsedge (*Gahnia* sp.), and numerous small ferns, were found along the stream banks.

2.4.2 Lizard Creek

At the headwater swamp location, ribbonweed and spikerush were observed instream and native sedge *Juncus* sp. was common along the banks. At the sandstone gorge location, ribbonweed was found instream while *Juncus* sp., *Gahnia* sp., and numerous small ferns, were observed along the bank.

2.5 Aquatic Macroinvertebrates

During the baseline surveys, a rapid assessment method based on the AUSRIVAS protocol and a quantitative sampling methodology was used to collect macroinvertebrates from the edges of pools at sites in the headwater swamp and sandstone gorge regions of Wallandoola and Lizard Creeks (The Ecology Lab 2008). A full complement of AUSRIVAS samples was collected in November, but only two sites were sampled in August. The results from the quantitative samples are not described, because they focus on temporal changes and spatial differences among creeks rather than the structure of assemblages in the individual creeks.

It should be noted that aquatic macroinvertebrates are susceptible to naturally occurring environmental such as drought, bush fire and flood. These can effect the assemblage of species within a watercourse and this may be reflected in AUSRIVAS results.

2.5.1 Wallandoola Creek

In November 2007, slightly fewer macroinvertebrate fauna were collected from the upstream end (17) than from the downstream end (20) of the headwater swamp location. The fauna at the upstream end of the headwater swamp was assessed as being significantly impaired (i.e. had fewer families than expected, while that at the downstream end was rated as equivalent to the AUSRIVAS reference condition (i.e. had most or all the expected families). At the sandstone gorge location, 16 taxa were collected at each sampling site. The fauna at both of these sites was rated as significantly impaired.

Growns *et al.* (1997) sampled the macroinvertebrate fauna associated with riffles and pool edge habitats at a site within Wallandoola Creek as part of an assessment of the cost and efficiency of six methods of sample processing. This study showed that there were slightly more macroinvertebrate families in the pool edge (21) than in the riffle sample (18). The Stream Invertebrate Grade Number – Average Level (SIGNAL) scores derived from the data indicates that the water at the study site was unpolluted.

2.5.2 Lizard Creek

In November 2007, slightly more macroinvertebrate fauna were collected from the upstream end (23) than from the downstream end (21) of the headwater swamp location. The fauna at the upstream end lacked a greater number of families with a

50% expected probability of occurrence (OE50 taxa score = 0.59) than the downstream end (OE50 taxa score = 0.81). Despite this, the AUSRIVAS predictive model rated the fauna at both sites as significantly impaired. Slightly fewer taxa were collected from the upstream (17) than the downstream end (19) of the sandstone gorge location. The AUSRIVAS predictive model rated the fauna at these sites as being significantly impaired and equivalent to the AUSRIVAS reference condition, respectively.

The macroinvertebrates associated with the edge habitat at a site in Lizard Creek adjacent to Fire Road 8 were also sampled in spring 2004 as part of Sydney Catchment Authority's Macroinvertebrate Monitoring Program: 2004 undertaken by (Ecowise 2005). The AUSRIVAS bands and SIGNAL2 scores for this site indicate respectively that the fauna was significantly impaired and the water was probably moderately polluted.

2.6 Fish

No fish were caught in the upper reaches of Wallandoola Creek and Lizard Creek during the initial baseline survey, undertaken using a backpack electrofisher and baited traps (The Ecology Lab 2007). However, native freshwater crayfish (*Euastacus* sp.) were observed and their burrows were found at both of the locations surveyed in each creek.

The fish sampling undertaken as part of the "Audit of Sydney Drinking Water Catchment 2007" indicated that three endemic species were present within Wallandoola Creek and that five endemic, one translocated and one introduced species were present in the Cataract River, downstream of Cataract Dam (DECC 2007). The only information given about the identity of the fish caught in these watercourses was that Macquarie Perch (*Macquaria australasica*), a species listed as vulnerable under the *FM Act*, was caught in the Cataract River at Jordans Pass.

The Ecology Lab (2003 and 2005) caught three native species, Macquarie Perch, Flathead Gudgeon (*Philypnodon grandiceps*), and Australian Smelt (*Retropinna semoni*) and one introduced species, the Mosquito Fish (*Gambusia holbrooki*) in the Cataract River between Cataract Dam and Broughtons Pass Weir. They also noted that native freshwater crayfish (*Euastacus* sp.) were present throughout this reach of the river.

3 Assessment of Impacts

3.1 Description of Proposed Works

Gujarat NRE Minerals Limited (Gujarat) proposes to use pillar extraction methods to extract coal from a 2.5 m thick remnant section of the Bulli Seam located within the V Mains area of the NRE No. 1 Mine at Russell Vale. The extraction of the remnant section of the Bulli Seam will result in a wedge-shaped goaf, approximately 2 km long and between 75 m and 300 m wide (Seedsman Geotechnics 2009). This goaf will be situated 165 m from the goaf edge of the 200 series of the South Bulli longwall panels, and 120 m from the Cordeaux longwalls.

The proposed works will undermine a section of the upper reach of Wallandoola Creek and of an unnamed tributary of this creek, but not Lizard Creek. The reaches of Wallandoola Creek to the north and south of NRE No. 1 Mine have been undermined previously by the longwall panels of the former South Bulli Colliery and Cordeaux Colliery, respectively. The reach of Lizard Creek to the east of the Application Area has also been undermined previously by the longwall panels of Cordeaux Colliery. The effects of the extraction of these longwalls on stream flow, water quality and the upland swamps associated with Wallandoola and Lizard Creeks were not documented.

3.2 Physical Impacts Associated with Mine Subsidence

The principal physical impact resulting from underground coal mining is subsidence (lowering of the surface above areas that are mined) (Booth *et al.* 1998, Holla and Barclay 2000). The maximum subsidence predictions for the V-Mains area estimated by Seedsman Geotechnics (2009) are as follows:

- Vertical movement of 1.02 m;
- Horizontal movement of 0.43 m;
- Tilt of 6.1 mm/m;
- Curvature of -0.05-0.09 km^{-1}; and
- Horizontal strain of -6.5 mm/m to 3.3 mm/m.

Systematic impacts are expected to dominate, because the overlying terrain is relatively flat with few rocky outcrops (Seedsman Geotechnics 2009). The greatest vertical movement is expected to occur over the middle to eastern half of the Application Area (Seedsman Geotechnics 2009). The predicted subsidence is of similar magnitude to that observed in the adjacent Cordeaux and South Bulli collieries.

3.3 Impacts on Creeks

3.3.1 Alterations to Flow

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

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

Extraction of the remnant block from the Application Area is not expected to result in any observable loss of surface water, because the predicted horizontal strains (-6.5 mm/m to 3.3 mm/m) are too small to cause tensile cracking of stream rock bars and the depth of the extraction will prevent the formation of inter-connected cracks between the surface and seam (Seedsman Geotechnics 2009).

If diversion of surface water does occur, it will most likely be due to either leakage of pools through rock bars or transfer to shallow, near-surface, ephemeral, groundwater systems (Geoterra 2009). These losses are likely to be transient, because stream flow will deposit the sediment that occurs within these creeks into the fractures in rock bars.

3.3.2 Water Quality

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

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

The occurrence of orange-brown iron staining, resulting from dissolution of iron sulphide or iron carbonate, exposed when sandstone fractures, and emission of gas bubbles are likely to be the most conspicuous changes in stream water. It should be noted that precipitation of iron hydroxide also occurs within streams that are not affected by mining.

As subsidence arising from the mining of V-Mains is not expected to have any observable effects on stream flow or have adverse effects on upland swamps in the

NRE No 1 Mine Area, there is unlikely to be any observable adverse effects on water quality (Geoterra 2009).

3.3.3 Aquatic Habitats and Biota

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

There is, however, a possibility of a localised increase in the natural stream gradient, because the maximum predicted tilt (6.1 mm/m) within the Application Area exceeds the stream bed gradient of Wallandoola Creek (0.8mm/m) and Lizard Creek (0.71 mm/m). The increase in gradient could lead to an increase in flow rate, migration of flow channels and erosion of the stream bank and bed erosion (NSW Planning 2008). If erosion occurs, the quality of some of the habitats available for occupation by aquatic biota would decline. An increase in the stream gradient could also lead to a reduction in the volume and retention time of pools within the Application Area (Geoterra 2009). This could affect the continuity of the watercourses by decreasing the connectivity between habitats, particularly during periods of low flow. As there are only a few small, permanent pools within this section of Wallandoola Creek and a few small areas of semi-permanent aquatic habitat within its unnamed tributary, the impact on aquatic biota could be locally significant within a small 300m reach of the watercourse directly above the mine area. This represents only a very small proportion of the local aquatic habitat. If there is a localised increase in the stream gradient, the relatively large pools with deep holes that occur in Wallandoola Creek 300m downstream of the Application Area, should continue to provide permanent refuge habitat.

3.4 Impacts on Upland Swamps

In the Southern Coalfield, little is known about the impact of mine-induced subsidence on upland swamps (NSW Department of Planning 2008). There is also no generally accepted technique for prediction of subsidence impacts on swamps. It is thought that subsidence may cause tensile cracking and tensile/shear movement of joint and bedding planes in the rocks below headwater swamps, as it does in streams and rivers. These movements, in turn, could lead to a drop in the perched water table, loss of standing pools and drainage of swamps into the fracture network of the underlying watercourse. Drainage of swamps could facilitate erosion and scouring during high flow events, increase vulnerability to fire damage, result in changes in associated vegetation and have adverse effects on water quality. These changes, in turn, could lead to the loss of both aquatic and terrestrial components of swamp ecology. The impact of subsidence on groundwater systems could also change the water table and water chemistry of headwater swamps.

A drop in the perched water table and/or drainage of headwater swamps could decrease the extent of the permanent aquatic habitats situated at or close to the point of outflow of the headwater swamps, such as the large pools in Wallandoola Creek situated approximately 300 m downstream of the proposed mining development. There would also be a reduction in downstream flow within the upper

reaches of these creeks. On the basis of the maximum subsidence predictions, Geoterra (2009) have concluded that extraction of coal from the V-Mains area will not have any observable adverse effects on upland swamps.

3.5 Sensitive Aquatic Features

3.5.1 Threatened Species

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

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

3.5.1.1 Adam's Emerald Dragonfly

Adam's Emerald Dragonfly is extremely rare, having been collected only in small numbers at a few locations in the greater Sydney region (NSW DPI 2005). There are no records of Adam's Emerald Dragonfly occurring south of Sydney despite active collecting in the Hawkesbury-Nepean River catchment (Fisheries Scientific Committee 2008) and no records of this species occurring within Wallandoola or Lizard Creek catchments or the greater Cataract River catchment. No specimens were found in the headwater swamp or sandstone gorge location within these creeks surveyed during the baseline studies.

Adam's Emerald Dragonfly has a predominantly aquatic life cycle. The larvae live for approximately seven years before metamorphosing into adults, which fly away from water to mature, but then return to water to breed (NSW DPI 2005a). The adults are believed to live for only a few months. The larvae of Adam's Emerald Dragonfly inhabit small creeks with gravel or sandy bottoms and are typically found in narrow shaded riffle zones with moss and extensive riparian vegetation. The baseline surveys indicated that there was suitable habitat for Adam's Emerald Dragonfly, albeit of limited extent, within Wallandoola and Lizard Creek close to the proposed mine area. Although the current distribution records suggest that this species is unlikely to occur within the Application Area, a Seven-Part Test has been prepared as part of the environmental assessment of this project (see Appendix 1), because there is potential habitat for this species close to the Application Area.

3.5.1.2 Sydney Hawk Dragonfly

Sydney Hawk Dragonfly is extremely rare, having been collected in small numbers at only a few locations in a small area south of Sydney, from Audley to Picton (NSW DPI 2005b). There are no records of this species occurring within Wallandoola or

Lizard Creek catchments or the greater Cataract River catchment. No specimens were found in the headwater swamp or sandstone gorge location within these creeks surveyed during the baseline studies.

This species spends most of its life as an aquatic larva, before metamorphosing and emerging from the water as an adult, which lives for only a few weeks. 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 DPI 2005b). 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.).

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

3.5.1.3 Macquarie Perch

Macquarie Perch has been recorded within the reach of the Cataract River between Broughtons Pass Weir and the Cataract Dam, into which Lizard Creek and Wallandoola Creek flow from the proposed mine area (DECC 2007). It is, however, highly unlikely that Macquarie Perch would be present in the proposed mine area, because the waterfalls that occur over sandstone cliffs between these creeks and the Cataract River constitute substantial barriers to the upstream passage of fish. In view of this, there is no need to consider the impacts of the proposed mine on this species.

3.5.2 Sensitive Aquatic Habitats

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

4 Recommendations for Monitoring

4.1 General Principles

The strategic review of the environmental impacts of underground coal mining in the Southern Coalfield recommends that baseline monitoring of ecological characteristics should be undertaken several times in the 18-24 month period prior to the commencement of mining (NSW Department of Planning 2008). This monitoring should be undertaken within the Application Area and at comparable control locations outside the area affected by mining. This time frame is needed to gain an understanding of natural temporal variability, particularly in the biological characteristics monitored. Further monitoring of the physical, chemical and biological characteristics of the same set of headwater swamps and creeks should be undertaken during and after mining. The adoption of this so-called BACI (before/after, control/impact) type of sampling design in the monitoring program will enable the use of advanced statistical procedures that can distinguish subsidence-induced impacts from natural temporal variability (Green 1979, Underwood 1991, 1992, 1993, 1994; Keough and Mapstone 1995).

4.2 Aquatic Ecology Monitoring Program

The baseline aquatic ecology monitoring for the V-Mains area undertaken in winter and spring 2007 focused on water quality, aquatic macroinvertebrates and fish within headwater swamp and sandstone gorge habitats in two potential impact creeks (Wallandoola and Lizard) and two control creeks (Loddon and an unnamed tributary of Cataract Dam) (The Ecology Lab 2007 and 2008). None of the sites surveyed are located within the Application Area (Figure 1). The nearest permanent aquatic habitats of sufficient extent for monitoring of aquatic ecology within Wallandoola Creek and Lizard Creek were located within the headwater swamp region of the creeks approximately 300 m downstream and 120 m to the east of the Application Area, respectively. The monitoring sites that were established at these locations appear to be outside the predicted 20 mm subsidence zone and thus suitable only for assessment of far-field effects of the mine.

The assessment of impacts indicates that mining of V-Mains is unlikely to have any observable adverse effects on aquatic habitats and biota. Despite this and as a precautionary measure, it is recommended that additional observations of aquatic habitats should be made and surveys of aquatic macroinvertebrates should be undertaken in the headwater swamp regions of potential impact and control creeks during and after mining. Further monitoring at the locations within the sandstone gorge region is considered unnecessary because of their distance from the Application Area. Additional monitoring of fish is unlikely to be productive because they appear to be scarce.

If the regular water quality monitoring program detects changes in the depth and quality of the water within Wallandoola Creek and Lizard Creek that are greater than anticipated on the basis of the subsidence predictions, an immediate survey of aquatic macroinvertebrates should be triggered at the monitoring sites within the headwater swamp region of all four creeks. The information gained from the control

creeks will enable changes due to mining to be distinguished from those due to natural temporal variation.

5 Acknowledgements

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

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7 Figures

Figure 1: Aquatic ecology monitoring sites in Wallandoola Creek and Lizard Creek in the vicinity of the V mains area.

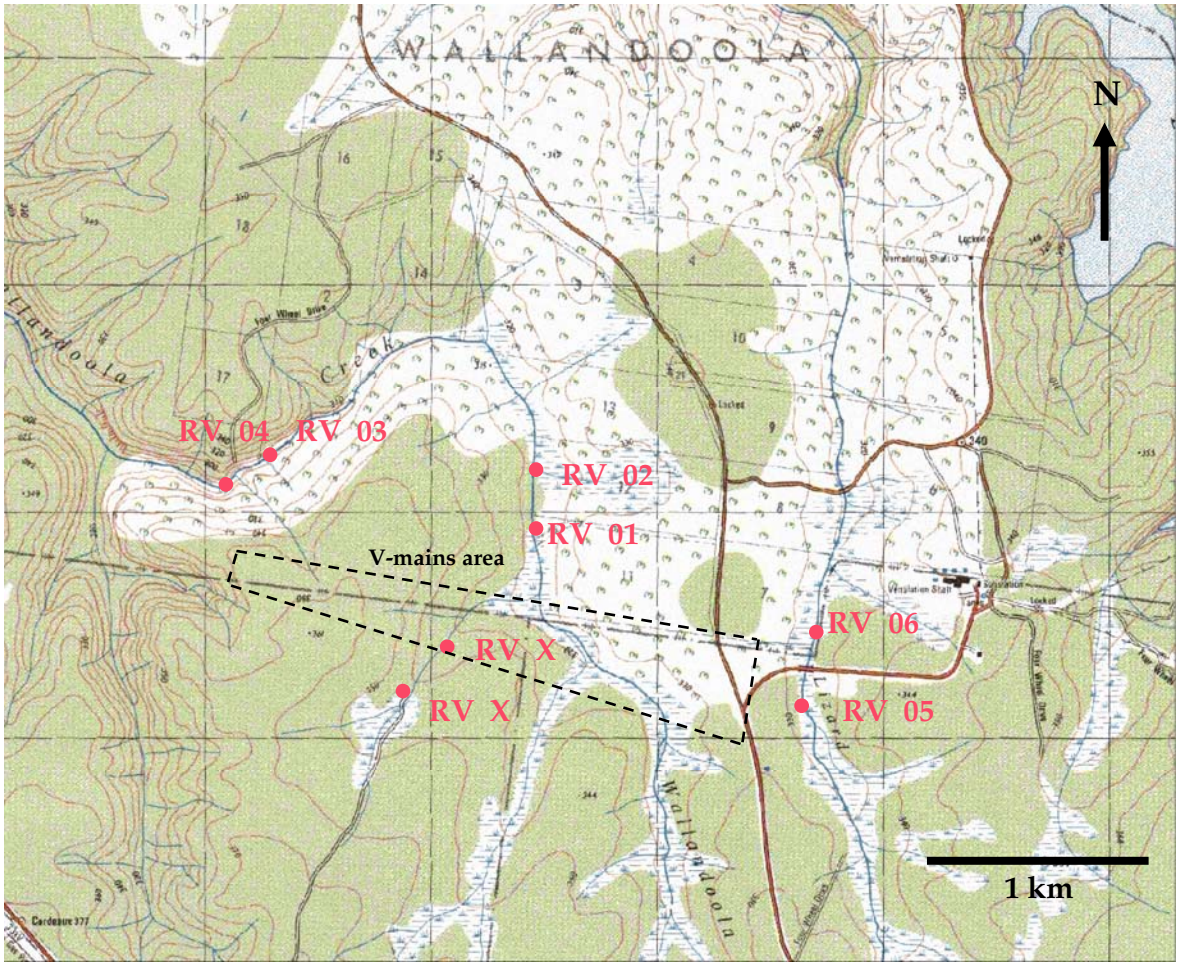

Figure 1: Aquatic ecology monitoring sites in Wallandoola Creek and Lizard Creek in the vicinity of the V-mains area.

8 Appendix

Appendix 1: Seven Part Test for the Adam's Emerald Dragonfly in relation to the proposed mining of the V-Mains Area.

Appendix 1. Seven Part Test for the Adam's Emerald Dragonfly in Relation to the Proposed Mining of the V-Mains Area.

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

The larvae of Adam's Emerald Dragonfly are aquatic and relatively long-lived (i.e. can survive for seven years). They inhabit small creeks with gravel or sandy bottoms and are typically found in narrow, shaded riffle zones with moss and riparian vegetation (NSW DPI 2005a). The headwater swamp section of Wallandoola Creek that traverses the Application Area does not appear to contain aquatic habitats suitable for Adam's Emerald Dragonfly. There does, however, appear to be a limited amount of suitable habitat, in the form of cascade-riffles, in the sandstone gorge sections of Wallandoola and Lizard Creeks downstream of the Application Area. Disturbances that result in significant alteration of this habitat could potentially have an adverse effect on the life cycle of this dragonfly, if they are present. As the sandstone gorge sections of these creeks are downstream of the predicted 20 mm subsidence zone for the V Mains area, the proposed mining is unlikely to have an adverse effect on the life cycle of Adam's Emerald Dragonfly.

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

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

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

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

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

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

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

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

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

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

The proposed mining is unlikely to result in the removal, fragmentation or modification of habitat for Adam's Emerald Dragonfly, because none occurs within the predicted 20 mm subsidence zone for the V Mains area.

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

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

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

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

Conclusion

The headwater swamp section of Wallandoola Creek that flows through the Application Area does not appear to contain suitable habitat for Adam's Emerald Dragonfly. There does, however, appear to be a limited amount of suitable habitat, in the form of cascade-riffles, available in the sandstone gorge sections of Wallandoola and Lizard Creeks downstream of the Application Area. As this habitat is not expected to be affected by the proposed mining, the preparation of a species impact statement is not considered necessary for Adam's Emerald Dragonfly.