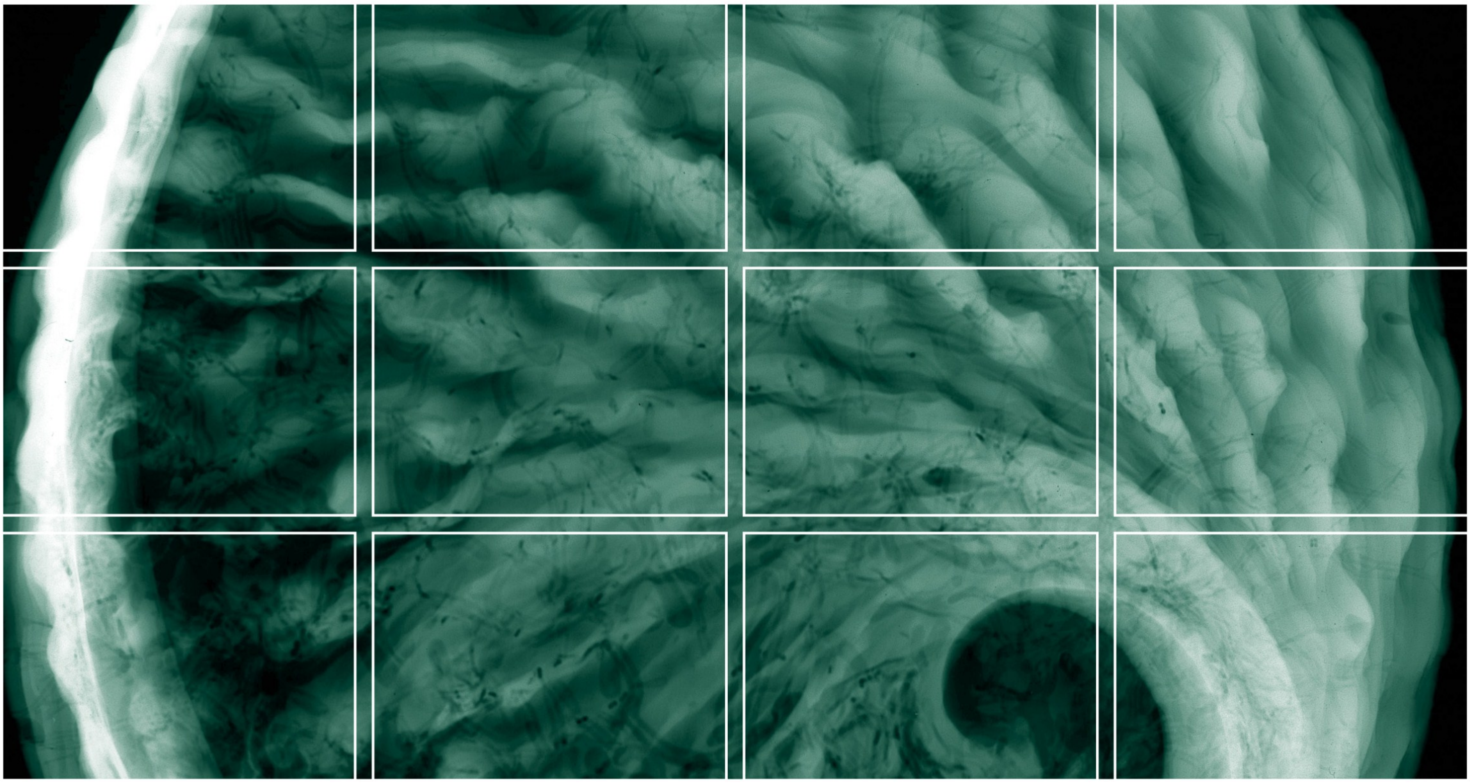


PART C

LONGWALL MINING

17 *PROPOSED UNDERGROUND MINING*

This chapter provides a description of the proposed underground mining operations.

17.1 UNDERGROUND MINING OPERATION

17.1.1 *Mining Method*

The proposed underground mining methods are separated into two separate processes, first workings and secondary, longwall, extraction as described below.

First Workings

First working will be used initially to develop all proposed mining areas. First workings will involve development of headings or roadways within the coal seam, and interconnecting cut-throughs with approximate dimensions of 5.2m wide by 3.2m high. These will provide access to the coal resource, mine ventilation and corridors for personnel and material movement within the seam and coal conveyor network.

First workings will be developed using continuous miners typically with integrated roof and rib bolting rigs. The roadway roof will be supported by installation of steel roof bolts into the stone above the coal seam, and by forming pillars of coal, which are left behind. Coal will be transported from the continuous miners to the conveyor system via shuttle cars.

First workings leave the coal pillars intact and the overlying strata fully supported resulting in 'zero' subsidence, which is defined by Department of Resources and Energy (DRE) as vertical downward movement of the ground surface that is less than or equal to 20mm.

Longwall Mining

Following the completion of first workings, the retained panels of coal in the Wonga East and Wonga West areas will be extracted by the retreating longwall mining method of secondary extraction. This mining method uses an electrically powered shearer, which passes back and forth across the width of the longwall panel cutting the coal. The coal is continuously removed from the working face on to a series of conveyors that transfer the coal to the surface. As the face is extracted, both the shearer and the hydraulic roof supports advance forward for the next shear, and the unsupported strata behind the longwall face collapses in to the goaf.

17.1.2 *Mining Areas*

The project is divided into two distinct domains identified as Wonga East and Wonga West. Both Domains are accessed via the Wonga Mains driveage. Mining is proposed primarily within the Wongawilli seam with additional first workings within the Balgawnie and Bulli seams in the Wonga West domain.

Wonga Mains

The Project includes the continuation of the westward development of the existing 'Wonga Mains' driveage from Russell Vale to access the underground working areas in Wonga East and Wonga West. Access to the driveage is via three portal entries at the Russell Vale site.

The driveage will be developed using first workings. This will involve continued development of three headings or roadways within the coal seam, and interconnecting cut-throughs with approximate dimensions of 5.5m wide by 3.2m high. These will provide access to the coal resource, mine ventilation and corridors for personnel and material movement within the seam and coal conveyor network.

Wonga East

Mining of the Wongawilli seam in the Wonga East area is located 500m to the west of the Illawarra Escarpment. The proposed Wonga East panels are subdivided into Area 1 to the east and Area 2 to the west of Mount Ousley Road (see *Figure 17.1*)

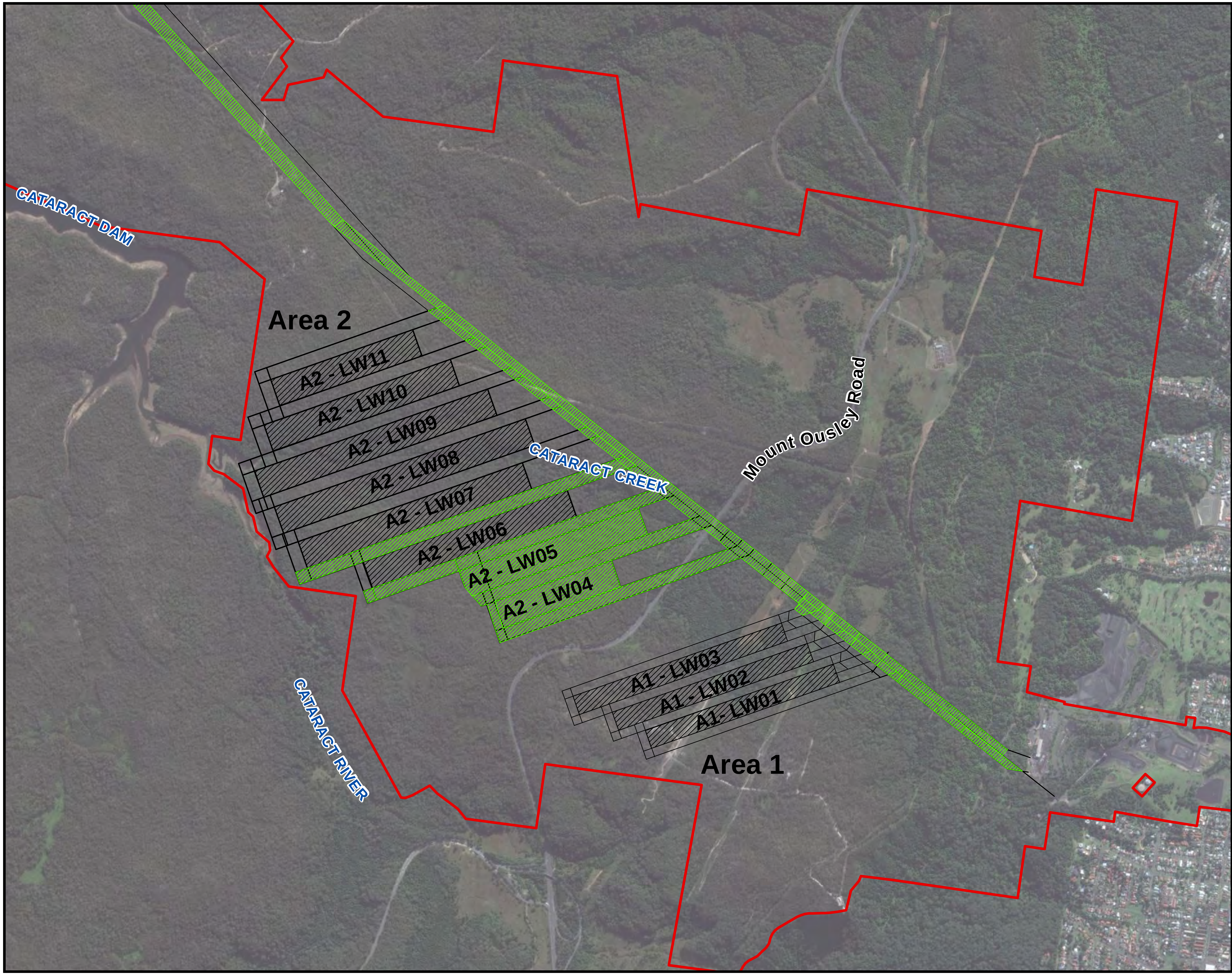
Area 1 comprises three, 105m wide panels referred to as Longwall Panels A1 LW1 to A1 LW3, with 40m wide pillars. This configuration is to accommodate projected geological conditions and allow safe mining operations beneath the overlying Balgownie and Bulli seam workings.

Area 1 underlies steeply sloping, northerly draining, 1st and 2nd order tributaries of Cataract Creek and two upland swamps with a depth of cover to the Wongawilli seam of approximately 237m to 255m. Downstream of the longwall panels, the undermined tributaries join to form a third order stream which immediately to the east of Mount Ousley Road forms a fourth order, steeply sloping, westerly draining main channel of Cataract Creek.

Area 2 lies between Cataract Creek and Cataract River. Area 2 comprises eight panels referred to as Longwall Panels A2 LW4 to A2 LW11. The panels are 145 to 150m wide with 60m wide pillars with a depth of cover to the Wongawilli seam of approximately 267m to 320m.

In keeping with an approved subsidence management plan development and longwall extraction of Longwall A2 LW4 has been undertaken in 2012. A subsequent modification to Stage 1 of the expansion of NRE No 1 Colliery (the Preliminary Works Project MP 10_0046), under Section 75W of the EPA Act was approved on 24 December 2012. This modification approves longwall mining of A2 LW4 and A2 LW5 as well as the establishment of maingates for Longwall Panel A2 LW6 (MP 10_0046_MOD 1). These panels and gateroads are shown as approved workings in the graphics.

Longwall Panels in Area 2 underlie 1st and 2nd order tributaries of Cataract Creek with Longwall Panels A2 LW8 and A2 LW9 under the 4th order channel of Cataract Creek. The western end of Longwall Panel A2 LW9 and A2 LW10 also marginally underlie the peripheral high water mark of the upper backwaters of Cataract Reservoir.



Legend
Project Application Area
Proposed Longwalls
Approved Workings (MP10_0046)

Figure 17.1

Proposed Wonga East Longwalls

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No.1 Colliery Environmental Assessment
Drawing No:	0079383s_EARPA2012_G024_R0.mxd
Date:	7/02/2013 Drawing Size: A3
Drawn By:	KB Reviewed By: NB
Projection:	GDA 1994 MGA Zone 56
Scale:	Refer to scale bar

N 0 200 400 600m

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The Longwall Panels are positioned so that vertical subsidence under 3rd order or higher stream channels will be restricted to less than 250mm, except over Longwall Panel A2 LW8.

Eleven upland headwater swamps overly the proposed Area 2 Longwall Panels. One of these swamps occurs in the Cataract River catchment (CRUS1) and partly overlies the initial part of Longwall A2 LW6. Eight upland headwater swamps occur in the Cataract Creek catchment and two in the Bellambi Creek catchment.

Narrow extraction panels and wide chain pillars are proposed at Wonga East to provide a management tool for subsidence risks on all surface features, including Cataract Creek and the upland swamps.

Wonga West

The Wonga West mining area is located to the west of Cataract Reservoir (see *Figure 17.2*). No longwall mining is proposed under: the main channel of Lizard Creek or Wallandoola Creek; under the Cataract Reservoir; or within one kilometre of the Cataract Reservoir dam wall and spillway.

In Wonga West the panel layout has been designed to avoid subsiding and related impacts on the bed of Lizard Creek or Wallandoola Creek. Accordingly, Area 3 is located to the south west of Lizard Creek, and Area 4 to the north east of Lizard Creek.

Area 3 comprises five panels referred to as Longwall Panels A3 LW1 to A3 LW5. In Area 3, longwall mining is proposed approximately 40m below the Bulli coal seam with an orientation determined by the previously mined Bulli longwalls. Depth of cover to the Wongawilli Seam ranges from approximately 455m to 510m in Area 3. The panels are planned to be up to approximately 390m wide and separated by 65m wide chain pillars. The chain pillars, which form the gateroads for each longwall panel, are designed to be directly beneath the goaf of the overlying Bulli longwalls to minimise in-situ stress and adverse ground conditions by adding to the stability of these gateroads.

The five panels underlie the watersheds and steeply sloping 1st to 3rd order streams within sub-catchments of Lizard Creek and Wallandoola Creek. Twelve upland swamps overlie the proposed panels in Area 3 including five in the Wallandoola Creek catchment and seven in the Lizard Creek catchment

Area 4 is located to the north of Lizard Creek and comprises Longwall Panels A4 LW6 and A4 LW7. Depth of cover to the Wongawilli seam ranges from approximately 460 to 495m. These panels are 155m wide with 65m pillars located at least one kilometre from the Cataract Reservoir dam wall and positioned to avoid subsiding or cracking Lizard Creek, as well as to avoid generating a hydraulic connection via subsidence cracking between the 20mm subsidence zone and Cataract Reservoir. There are no upland swamps mapped over the longwall panels in Area 4 though one of the upland swamps in the Lizard Creek catchment overlies the gateroad to Longwall A4 LW6.

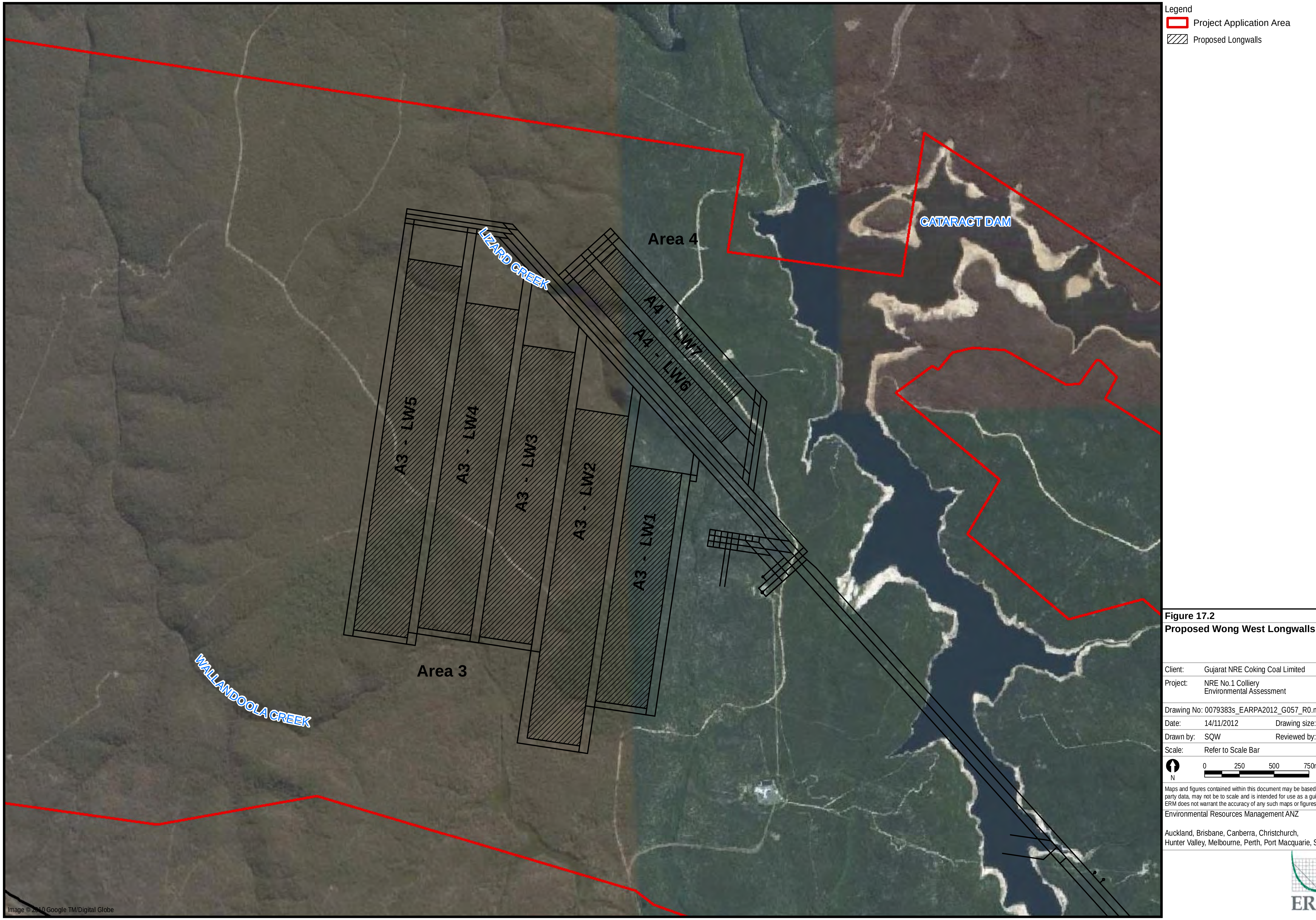

Figure 17.2

Proposed Wong West Longwalls

Client:	Gujarat NRE Coking Coal Limited		
Project:	NRE No.1 Colliery Environmental Assessment		
Drawing No:	0079383s_EARPA2012_G057_R0.mxd		
Date:	14/11/2012	Drawing size:	A3
Drawn by:	SQW	Reviewed by:	NB
Scale:	Refer to Scale Bar		

N

0 250 500 750m

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Bulli West

The 'Bulli West' development is for underground access roadways only and secondary pillar extraction of the Bulli seam in the 'Bulli West' area does not form part of this Project.

Development of the 'Bulli West' area, is proposed via first workings following development of the V Mains area (existing workings). The layout of workings within the Bulli West area is shown in *Figure 3.2, Figure 3.3* and *Figure 17.2*.

Balgownie west

Limited mining is proposed in the Balgownie seam beneath existing Bulli seam workings to access the Wonga West area following development of 'S-mains' (existing workings). The layout is shown in *Figure 17.1* and *Figure 17.2.* Any mining operations in the Balgownie seam will be limited to the formation of pillars identified as first workings only. Secondary extraction of the Balgownie seam does not form part of this Project.

17.1.3 *Underground Plant and Equipment*

New mining equipment required will include:

- continuous miners;
- longwall machines and associated equipment;
- conveyor systems; and
- additional transport machinery.

17.1.4 *Ventilation*

Ventilation of underground areas will be provided by use of existing ventilation shafts within the PAA. All ventilation shafts to be utilised under the project are currently in use under existing approvals.

No.3 Shaft

Ongoing maintenance and refurbishment of No.3 Shaft will be required to meet mine ventilation requirements and connect with the deeper Wongawilli seam workings. No.3 Shaft may be converted to an upcast shaft with the commissioning of a replacement ventilation fan.

The electrical switch yard and substation will be re-established within the existing footprint for the site to meet current standards.

No.5 Shaft

The No. 5 Shaft is an upcast shaft that assists in providing ventilation to the mine as well as the opportunity to provide power and compressed air services via a borehole adjacent to the shaft.

There are no plans to change this. Refurbishment of the ventilation fan and the surface compressors will be necessary as they require repair and maintenance and possibly replacement. The switch yard and electrical power facilities will require upgrading, maintenance and repair in keeping with current and future power needs.

17.1.5 *Gas Drainage*

In-situ gas levels within the coal seams mined are currently insufficient to require pre-mining drainage. As mining progresses to the west with deeper cover, it is predicted that the gas content of the coal will gradually increase. This gradual increase will necessitate installation of a gas drainage network separate from the mine's ventilation in order to reduce the in-situ gas to prescribed levels to facilitate safe mining conditions.

Initially the gas (predicted to consist predominantly of methane) quantities will not be sufficient to support gas re-use via gas engines to generate electricity. Under these conditions, the gas will need to be captured into a gas drainage and extraction network with flares on the surface.

It is not possible at present to fix or determine when such an arrangement will be required to be established.

In the long term, when gas concentrations and quantities permit, there may be opportunity to feed the gas extracted by the gas drainage network into a series of gas engines, thereby burning the gas and using it to generate electricity. This is the long term aim as it will reduce greenhouse gas emissions and represents a far better utilisation of the gas which is in the coal. Such utilisation works will be subject to a separate application.

17.1.6 *Personnel and Material Access and Egress*

For the duration of mining in the Wonga East area, the majority of personnel and materials will access the mine from Russell Vale Site. Following completion of mining in Wonga East, No.4 Shaft will be the primary access for personnel and some materials.

18 *SUBSIDENCE*

This chapter assesses the amount and type of subsidence predicted to occur as a result of underground mining.

18.1 *INTRODUCTION*

In the context of mining, subsidence refers to the deformation of the earth's surface as a result of underground mining. Subsidence effects include changes to the ground mass including both vertical and horizontal displacement, tilt, strain and curvature. Subsidence impacts include the physical changes to the ground, principally vertical movement, compressive and tensile strain and shearing which can lead to cracking of the rock mass. These ground movements have the potential to induce localised buckling of strata caused by valley closure and upsidence in addition to the formation of subsidence depressions or troughs.

Subsidence consequences are any change in the amenity or function of the land or a specific feature of the land that arises from subsidence effects or impacts. The consequence of subsidence on built and natural features is a major consideration in the assessment of the environmental impact of underground mining proposals. It is the risk of detrimental impacts on significant features, and more importantly features assigned special significance status, that requires the assessment and to undertake this task the calculation and prediction of the likely magnitude of subsidence effects and impacts is required.

In the Southern Coalfields Inquiry the terms *Subsidence Effect; Subsidence Impact* and *Subsidence Consequence* were identified using the following terminology:

- The term *Subsidence Effect* (the effect) describes the subsidence itself;
- The term *Subsidence Impac*t (the impact) concerns any physical change to the fabric of the ground caused by subsidence; and
- The term *Subsidence Consequence* (the consequence) relates to any change in the amenity or function of the land or a specific feature of the land that arises from subsidence.

Major subsidence consequences have been eliminated by the mine layout, eg longwall mining will not be undertaken directly beneath Mount Ousley Road or within 1km of the Cataract dam wall. Where effects could not be eliminated, alternative mine layouts using narrower longwalls and wide chain pillars were substituted into the plan to reduce the likely impacts.

Where effects are considered to be unavoidable, engineering and administrative controls are proposed to manage the remaining risk of impact. Subsidence assumptions and predictions will be confirmed through ongoing monitoring and validation of existing workings at the site and, where required, the start or finish points of longwalls may be adjusted to manage the consequences of these impacts.

18.2 *BACKGROUND TO SUBSIDENCE PREDICTIONS*

Predictions of the subsidence effects of the proposed mine plan have been undertaken by Seedsman Geotechnics Pty Ltd (Seedsman) in their report titled *Gujarat NRE No.1 Colliery Management of Subsidence Risks Associated with Wongawilli seam Extraction* dated 2012 (Seedsman, 2012) and presented in *Annex M*. The Seedsman (2012) assessment primarily predicts subsidence effects above the Wonga East and Wonga West mining areas and includes an assessment of subsidence consequences on built features including assets such as Mount Ousley Road and Cataract Reservoir. Subsidence impacts on natural features are assessed in relevant technical assessments with summaries of these assessments included in separate chapters of this EA. *Chapter19* includes a summary of subsidence impacts on natural features based on the subsidence predictions in the Seedsman (2012) assessment and findings of other technical assessments.

Pells (2011), in an independent peer review of the initial subsidence predictions made for the Project identifies that predictions of subsidence, and in particular tilts and ground surface strains, is subject to uncertainty (refer to *Annex N*). The Seedsman (2012) report accepts that the uncertainties in subsidence predictions are greater for multiple seam layouts and recognition of this has led to a risk management approach.

The subsidence assessment is supported by a sensitivity analysis in the form of a review of the subsidence prediction methodology and adopts the Failure Mode and Effects Analysis (FMEA) framework to examine the potential risks associated with the methodology used in the subsidence assessment. The review is discussed in *Section 22.5* and the full report *NRE No.1 Colliery Wongawilli Longwalls Risk Associated With Subsidence Prediction Methodology Failure Mode and Effects Analysis Report* (Olsen, 2010) is provided as Annex B of Seedsman (2012) assessment (refer to *Annex M*). It should be noted that this is a separate FMEA to that discussed in *Chapter 6* of this EA.

The Olsen (2010b) FMEA considered the methodology behind the subsidence predictions and the various strategies taken to manage subsidence impacts with respect to significant surface features. The Olsen (2010b) report contained a number of recommendations that focussed on developing the most up to date representation of mine workings, especially for the historical extraction in the Bulli and Balgownie seams. The review of historical mine records was incorporated into an updated mine plan and consequently used to re-assess the potential subsidence impacts, especially for the proposed Wonga East area. Seedsman (2012) subsequently revised the initial reporting to consider the recommendations of the Olsen (2010b) FMEA and to address any changes that arose from the review of the historical data of extraction in the Bulli and Balgownie coal seams.

Ongoing consultation with Government agencies has highlighted continuing concerns with the accuracy of the subsidence predictions as outlined in *Section 5.2*. Post lodgement for adequacy an independent peer review was undertaken on an earlier iteration of the Subsidence assessment by Pells Consulting (2011) with recommendations included in their report titled *Review of subsidence and groundwater facets of the NRE No 1 Colliery – underground expansion project draft environmental assessment* (refer to *Annex N).*

The findings of this independent peer review in relation to subsidence predictions was:

> *"Given the inherent uncertainty in subsidence predictions, it is recommended that a predicted range of subsidence effects, rather than a single value, is presented.*
>
> *A review of mapping of Old Bulli Seam workings was undertaken and the available data was found to be of satisfactory accuracy.*
>
> *An independent analysis of subsidence was undertaken, and it was found that the settlement predictions in the EA fall within our computed range. We judge that there is about an 85% chance of settlements being greater than our 'low' values and 15% chance of their being greater than our 'high' values.*
>
> *It was also found that the tilts and strains given in the EA were within the typical range of our calculations. However, we noted that at some locations where we had included faults, or major joint systems, in our model there were anomalous high strains. This is exactly what happens in the real world, but we are unable to predict the true position of anomalous movements because the requisite knowledge of geological structures would never be available."*

The Seedsman (2012) predictions have subsequently been revised to provide base case and upper bound predictions. These predictions have also been refined based on subsidence monitoring undertaken in respect of A2 LW4 on 27 June 2012 following the initial retreat of A2 LW4. The various technical assessments are based on this upper bound prediction.

SCT Operations (2012) have recently completed and issued a monitoring report entitled *Response to Subsidence Related Comments on Longwalls 4 and 5 and MG6, 7, 8 Pt3A Modification Application.* This report discusses recent longwall mining subsidence monitoring results in WE-A2-LW4. Monitoring results show vertical subsidence of up to 1.384 metres.

Seedsman (2013) has reviewed the surveys above LW4 and observed that maximum strains have been over-predicted, maximum tilts have been reasonably accurately predicted, and the maximum vertical subsidence in the contours has been under-predicted (refer to Seedsman's 2013 addendum to *Annex M).* Seedsman (2013) concludes that:

> *"…it is assessed that there is no need to revise the information previously supplied for the Wonga East area in the light of LW4 retreat. There has been no additional data on which to base a review or change in the predictions and visualisations for the Wongawilli West area".*

On the basis that the review of the most recent empirical subsidence data by Seedsman (2013) has concluded that, given the inherent uncertainties of subsidence prediction a revision of subsidence predictions is not required, so subsidence consequences have not been reassessed. Thus the subsidence impacts and consequences presented in this EA and technical assessments are based on the predictions of effect included in Seedsman (2012).

NRE have committed to an adaptive management approach whereby subsidence data will be used to refine mine plans and longwall layouts to achieve the required outcomes.

This approach represents an iterative and active management approach which can be ostensibly incorporated as an approval condition in accordance with the draft model conditions for State Significant Developments in the underground mining category through the use of extraction plan approvals.

18.3 *PROPOSED MINING*

The proposed mining areas are defined in *Chapter 3*.

The Project's main headings have been designed around long-term stable pillars, the underground roadways to remain open and the overlying strata to be fully supported, resulting in 'zero' subsidence. This chapter focuses only on areas where subsidence may occur, in the proposed longwall domains of Wonga East and Wonga West.

The use of key subsidence assumptions will be tested by ongoing monitoring, review and validation of prediction assumptions associated with multiple seam extraction, such that subsidence is managed and coal extraction can be optimised. Progressive extraction of longwall panels will provide key information on how the mining process should proceed. Subsidence monitoring of the approved A2 LW5 in Wonga East have been upgraded to three dimensional modelling to allow greater understanding of overburden behaviour and in particular, potential for valley closure.

18.3.1 *Potential Subsidence Footprint*

The potential subsidence footprint is determined from the predicted surface ground movements resulting from extraction of the proposed longwalls in the Wonga East and Wonga West areas. The lateral extent of the potential subsidence footprint has been defined by the predicted vertical 20mm subsidence contour, recognising that there exists the potential for far field horizontal movements.

There are a number of significant features that lie outside the potential subsidence footprint that may be affected by far-field horizontal movements. These features include the Cataract Dam wall and the Illawarra Escarpment. The Dam Safety Committee (DSC) initially established a 1km radius around the dam wall, in which assessment is to be focused. As part of the risk management approach adopted by NRE, no longwall mining will take place within one kilometre of the Cataract Dam wall.

It is noted that the DSC have subsequently increased their assessment zone around the dam wall to 1.5km. Prior to mining longwalls within 1.5km of the dam wall a reassessment of the potential impacts will be undertaken using the data that has been gathered from all the previous multi seam extraction. Any subsequent mining will only occur with the consent of the DSC.

18.3.2 *Approach to Subsidence Management*

There are a number of significant natural and built features present above the proposed mining areas (*Table 18.1*). Identification of these significant features was part of the iterative process used to inform mine planning and design. The focus of subsidence management and mine planning has been to eliminate the subsidence impacts to these significant features as much as possible.

Several mining layout options were considered (see *Chapter 3*) before deciding on the preferred option, which aims to minimise impact to significant features while optimising resource recovery and maintaining economic returns.

The mine planning and subsidence assessment applied the following hierarchy of risk controls:

- elimination;
- substitution;
- engineering controls; and
- administrative controls.

18.4 *EXISTING ENVIRONMENT*

18.4.1 *Surface Features*

A brief description of significant natural features and built features is provided in *Table 18.1* along with a brief statement of risk controls. Detailed assessment of subsidence consequences for these features is included in the relevant annexures and summarised in various chapters of this EA. *Chapter 19* includes a summary of subsidence impacts on features assigned special significance status in accordance with the SCI methodology.

Table 18.1 Surface Features

Feature	Description and Risk Controls
Significant Natural Features	
Significant Streams	The lower reaches of Cataract Creek, Lizard Creek and Cataract River are fourth order streams. Narrow longwalls are proposed under Cataract Creek. No longwall extraction will be undertaken under 4th order Lizard Creek. In addition, the proponent has provided an undertaking that it will terminate mining beneath Cataract Creek if subsidence and ground movements are predicted to exceed 250mm and the creek experiences greater than minimal impact. Should this prove not to be possible with the current mine plan the layout will be adjusted to achieve this goal. There are four 3rd order streams within the Wonga West mining areas, Lizard Creek, Lizard Creek Tributary 1, Lizard Creek Tributary 2 and Wallandoola Creek. Lizard Creek becomes a 4th order stream in the north west corner of Wonga West. These creeks have been previously subject to underground mining. A 3rd order stream occurs over the maingates to A2-LW4 in Wonga East. Precautionary and adaptive management procedures will be implemented to provide a systematic process for continually detecting impacts, validating predictions and improving mining operations to prevent adverse impacts on the stream systems overlying the proposed mining domains.
Upland swamps	Contiguous networks of intact upland swamps, including the Wallandoola Creek swamp cluster are present in both the Wonga East and Wonga West areas. There are 84 upland swamps in the Study Area. The swamps were noted to be in good condition in the upper regions of Wallandoola Creek and Lizard Creek, and were observed to provide habitat for a number of threatened species listed under the TSC Act (see *Annex S*).

Feature	Description and Risk Controls
	NRE has provided an undertaking that the mining operations will be modified as required through adaptive management measures informed through monitoring of actual subsidence impacts.
EECs	The EEC Shale Sandstone Transition Forest (made up of Transitional Shale Stringybark Forest and Transitional Shale Open Blue Gum Forest) is present above the Wonga West area. This ECC is listed on both the TSC Act and EPBC Act. The ground coverage in the Open Blue Gum Forest was observed to be disturbed due to historic fire events. The Stringy Bark Forest was observed to be in good condition (see *Annex S*). Upland Swamps are all representative of the recently listed Coastal Upland Swamp EEC as listed under the TSC Act. The swamps were all considered to be good condition. Further consideration of the upland swamps is provided in *Annex S, Annex Q* and *Chapters 22* and *23*. The swamps within the study area are not listed under the Federal EPBC Act as they are not considered as Temperate Highland Peat Swamps on Sandstone.
Threatened species habitat	Habitat for a variety of threatened species is present in both Wonga East and Wonga West. Impacts to habitat associated with Lizard or Wallandoola Creek have been minimised through mine layout.
Major cliff lines	Wallandoola Creek Gorge and Lizard Creek Gorge are two cliff lines located within the Wonga West area. Cliff lines are at risk from potential cracking and rock falls. To limit any impacts, no longwall mining is proposed under these gorges.
Illawarra Escarpment	A major cliff line east of the proposed mining areas. The escarpment may potentially be at risk from far field movements resulting in land instability. No mining is proposed under or in the vicinity of the escarpment. The escarpment is located approximately 560m east of the Wonga East mining area.
Significant Man Made Features	
Mount Ousley Road	Mount Ousley Road forms part of the Southern Freeway linking Sydney and Wollongong. It is understood that this road was realigned sometime after the Balgownie extraction as it lies directly above a Balgownie seam chain pillar and over Bulli seam extracted areas. The limiting subsidence deformation for road pavements is strain (such that the pavement does not crack). Longwall mining is not proposed within 100m of Mount Ousley Road. Picton Road Bridge is located approximately 840m south of the nearest proposed longwall. A detailed management plan to ensure the road remains safe and serviceable has been developed and implemented with the support of the RMS.
Cataract Dam wall and spillway	The DSC recognises that the Cataract Dam wall may be sensitive to far-field horizontal movements and has set a 1.5km radius around the dam wall where the assessment of potential mining impacts should be focussed. The mine plan was designed with longwall mining not to occur within 1km of the dam wall in accordance with the 1km exclusion zone that was current at the time. Further assessment and refinements to the mine plan will be undertaken when subsidence data from multi-seam mining is available and prior to any longwall mining within the 1.5km assessment zone.
Stored water and Notification Area of Cataract Reservoir	Cataract Reservoir is part of Sydney's water supply. Mining beneath the reservoir has the potential to cause subsidence resulting in impacts to stored waters. However, previous mining extracted narrow longwalls in the Bulli seam below the stored waters adjacent to the Wonga West area (500 series). Narrow longwalls are proposed in the Cataract Dam Notification Area in Wonga East. Most are offset from the stored water within the full supply level of Cataract Reservoir. However the western end of longwall A2-LW 10 and the maingate of A2-LW 9 are beneath stored waters. The Wonga East layout is expected to produce vertical subsidence similar to or less than that from the 500 series.

Feature	Description and Risk Controls
Aboriginal heritage sites	There are a number of Aboriginal heritage sites throughout the PAA, the majority of these have been avoided through the proposed mine layout. There are 21 sites located within the potential subsidence footprint.
Other Features	
Telstra cable	A Telstra optical fibre cable crosses the PAA north to south from Appin to Picton Road following Fire Trail No. 8.
No.8 Fire Trail	The No.8 Fire Trail crosses north to south through Wonga West.
Transmission Lines	Various transmission lines owned by Gujarat NRE, Integral Energy and TransGrid (one 330kV line, one 132kV line and several 33kV lines) occur in the Wonga East area.

18.4.2 *Previous Mining and Subsidence*

Wonga East

Mining in the Wonga East area has previously taken place in the Bulli and Balgownie seams, including under Cataract Creek and most recently in the Wongawilli seam in A2 LW4. Previous workings are shown on *Figure 2.3.*

The Bulli seam mining was conducted using the board and pillar method, with subsequent pillar extraction in the early parts of the last century, at least 70-80 years ago. The layouts are largely unstructured compared to modern practice, utilising prescribed panel configurations and systematic extraction. No subsidence monitoring was undertaken for Bulli seam mining.

Longwall mining was undertaking in the Balgownie seam in the 1970s and 1980s. Subsidence monitoring was undertaken for the Balgownie seam extraction and showed that the average subsidence was about 0.55m above the chain pillars with additional sag between the pillars of 0.2m to 0.8m.

A maximum subsidence of 1.4m was measured. A maximum of 3mm/m strain was measured and tilts ranged up to 20mm/m. The data shows a distinct difference in the behaviour of the overburden where the Bulli seam has been extracted, with greater vertical subsidence measured in these areas compared to where large pillars and barriers are present in the Bulli seam. The maximum vertical subsidence that developed where overlying coal seams have been extracted is 0.8m and 1.3m (average 1.1m), while the vertical subsidence where there are large pillars and barriers in the Bulli seam is 0.6m to 0.8m (average 0.76m).

Longwall mining was undertaken between April and September 2012 in the Wongawilli seam in Wonga East A2 LW4. Subsidence monitoring along the centreline of A2 LW4 undertaken on 27 June 2012 identified vertical subsidence of up to 1.1m (Seedsman 2012). This preliminary monitoring data was used by Seedsman (2012) to refine the subsidence model.

Subsidence monitoring results from the centreline, southern cross line (SX) and northern cross line (NX) of A2 LW4 survey undertaken on 10 October 2012 have been reported by SCT (2012a) in the their report titled *Longwalls 4 & 5 and Maingates 6, 7 &8 Addendum Response to Submissions*.

Subsidence monitoring results are summarised by SCT (2012A) as follows:

"The most important aspect that has been shown by the preliminary subsidence data is that the subsidence profile of LW4 is predominantly constrained to within the limits of the longwall panel mined in the Wongawilli Seam. The effect of the overlying Bulli Seam goaf is evident in the difference in behaviour between the north subsidence line where the Bulli Seam goaf extends either side of LW4 and the south subsidence line where the Bulli Seam goaf coincidentally extends only as far as the edges of the Longwall 4 goaf.

The Balgownie Seam goaf is not evident in the subsidence profiles. Preliminary indications are that strains are confined to the inside edge of the chain pillars and the centre of the longwall. The maximum observed horizontal tensile strain over the chain pillars was 4.68mm/m of tensile or expansive strain on the SX subsidence survey line. The maximum observed horizontal compressive strain was 5.03mm/m of compressive strain on the NX subsidence survey line. This compares favourably to the currently predicted 10-12mm/m maximum strain for LW5. ….vertical subsidence and strain are also constrained primarily to the Longwall panel with little extension beyond start and finish lines".

It is noted that these monitoring results exceed the upper bound predictions by up to 180mm for vertical subsidence. As acknowledged previously the subsidence predictions have been revisited in light of end of LW 4 monitoring results with Seedsman (2013) concluding that there is no need to revise the information previously supplied for the Wonga East area. In light of this, NRE have committed to an adaptive management approach where subsidence data will be used for mine planning so longwall layouts would be modified to achieve required outcomes, a commitment to this effect is included in the draft statement of commitments.

Wonga West

The Bulli seam was extracted in the Wonga West area in the 1980s and 1990s using longwall mining methods (200 and 300 series) including areas under the third order portion of both Lizard and Wallandoola Creeks. Impacts of previous mining on these creeks are addressed in *Chapter 20.*

Subsidence monitoring data from the 300 series longwall panels shows the pattern of sag above the panels between the chain pillars together with deformation above the chain pillars. The vertical subsidence was approximately 1.0m, the maximum tilts were about 4.5mm/m and the maximum strains about 1.5mm/m.

Narrow Bulli seam longwalls have been previously extracted east of Wonga West beneath the stored waters of the Cataract Reservoir as part of the 500 series longwalls. The panel widths were 150m with pillars 65m wide. The maximum vertical subsidence was approximately 300mm combining 240mm of pillar compression and approximately 60mm of sag. Maximum tensile strains of 0.8mm/m, maximum compressive strains of 1.3mm/m and maximum tilts of 0.8mm/m have been recorded. No valley closure across the reservoir was measured and no cracking of the rock outcrops was observed. Over the earlier 110m to 120m wide panels, the maximum vertical subsidence was 202mm with tensile strains less than 0.2mm/m and compressive strains less than 0.4mm/m.

18.5 *PREDICTION METHODOLOGY*

Seedsman (2012) provides a review of alternative subsidence prediction methodologies and their application to multiple seam extraction. Based on the current uncertainties with subsidence, predictions are for single seam operations (where there is a large experience base) and multiple seam operations (where there is a limited experience base). Given the lack of relevant data Seedsman (2012) has concluded that precedent practice cannot be used. Instead Seedsman (2012) adopts the approach of considering the engineering mechanics and applies this knowledge in conjunction with broad rock mechanics experience to produce a set of estimates for the various deformations. Adaptive management based on monitoring deformations above the early longwalls is then proposed to refine subsidence predictions to allow more detailed engineering controls to be implemented.

Seedsman's (2012) approach is to assume that the vertical subsidence will be the sum of the subsidence associated with the Wongawilli seam plus any residual subsidence that may develop due to previous mining in the upper seam.

For Wongawilli East this means:

- a nominal 300mm of vertical subsidence for the narrow Wongawilli longwall panels with no goafs above based on experience with narrow longwalls in the 500 series;
- plus the impact of the collapse of small Bulli Seam pillars that may be still standing after historical Balgownie longwall retreat mining; and
- plus two options for how to deal with the extraction goafs in the Balgownie and Bulli seams.

For Wongawilli West this means:

- 65% of Wongawilli extraction; plus
- collapse of the overburden above Bulli seam longwall panels so that the residual of 65% develops for that seam.

18.5.1 *Wonga East Predictions*

The basic geometric parameters for Wonga East area are:

- depths – 280m to 340m;
- extraction – 2.7m to 3.2m;
- panel width – 150.5m rib to rib; and
- pillar width – 59.5m rib to rib.

The Wonga East area is complex with a variety of overburden conditions including:

- Bulli seam first workings with pillars greater than 15m in width and no Balgownie seam longwall panels;

- Bulli Seam first workings with pillars greater than 15m in width with Balgownie seam longwall panels;
- Bulli seam pillar extraction goafs with no Balgownie seam longwall panels;
- Bulli seam pillar extraction goafs with Balgownie seam longwall panels;
- Bulli seam pillars with widths less than 15m and no Balgownie seam longwall panels; and
- Bulli seam pillars with widths less than 15m with Balgownie seam longwall panels.

Subsidence in the Southern Coalfield is controlled in part by the spanning capability of very thick to massive units within the Bulgo Sandstone. This capability may be destroyed by wide extraction panels formed by:

- wide pillar extraction panels in the Bulli seam;
- Balgownie longwalls inducing wider spans by undermining Bulli seam barriers; and/ or
- Wongawilli panels inducing wider spans by undermining Balgownie seam chain pillars.

The only reliable subsidence data relates to the Balgownie seam longwall empirical database and the recent A2 LW4 in the Wongawilli seam on which to determine maximum vertical subsidence. Therefore Seedsman (2012) has applied a large degree of judgement to determine the predicted maximum vertical subsidence outcomes. The model for subsidence in Wongawilli East is provided in *Table 18.2*.

Table 18.2 Model for Subsidence in the Wongawilli East area

LW	Balgownie goaf	Bulli goaf	Bulli pillars	Expected case Smax (mm)	Upper bound Smax (mm)
WE A1 LW1	No	No	Large	300	300
	No	Yes	No	1200	1200
	No	No	Large	300	300
WE A1 LW2	No	No	Large	300	300
	Yes	No	Large	300	1200
	No	No	Large	300	300
	Yes	No	Large	300	1200
	No	No	Large	300	300
WE A1 LW 3	Yes	No	Large	300	1200
	Yes	Yes	No	1200	1200
WE A2 LW 4	Yes	Yes	No	1200	1200
WE A2 LW 5	No	No	Large	300	300
	Yes	No	Large	300	1200
	No	Yes	No	1200	1200

WE A2 LW 6	Yes	Yes	No	1200	1200
	Yes	Yes	No	1200	1200
	Yes	No	Large	300	1200
	No	No	Large	300	300
	No	Yes	No	1200	1200
WE A2 LW 7	Yes	No	Large	300	1200
	No	Yes	No	1200	1200
	No	No	Small	1200	1200
	No	Yes	No	1200	1200
WE A2 LW 8	No	Yes	No	1200	1200
	No	No	Large	300	300
	Yes	Yes	No	1200	1200
	No	Yes	No	1200	1200
WE A2 LW 9	No	No	Large	300	300
	No	No	Small	1200	1200
	No	No	Large	300	300
	No	Yes	No	1200	1200
WE A2 LW 10	No	No	Large	300	300
	No	Yes	No	1200	1200
	No	No	Large	300	300
	No	Yes	No	1200	1200
	No	No	Small	1200	1200
WE A2 LW 11	No	Yes	No	1200	1200

Table 18.2 shows that in areas where there has been no Balgownie extraction and only Bulli first workings Seedsman (2012) predicts that the proposed narrow longwalls with wide pillars will result in vertical subsidence of 300mm. This is greater than that recorded above the Cataract 500 series panels under similar circumstances.

For areas of Bulli goaf, Seedsman (2012) predicted that there is a reduction in spanning capacity and the maximum vertical subsidence will be 1.2m. This is based on A2 LW4 subsidence monitoring data available at the time of assessment.

For areas of small Bulli pillars, Seedsman (2012) predicts that the Wongawilli longwalls will collapse the Bulli pillars and a maximum vertical subsidence of 1.2m will result.

Seedsman has considered two potential outcomes for subsidence above the Balgownie longwalls and large Bulli pillars. The base case is that the overburden will still have spanning capacity and subsidence will be limited to 300mm. An upper bound prediction assumes the spanning capacity has been disrupted by the Balgownie longwalls so that a 1.2mm maximum subsidence could develop.

18.5.2 *Wonga West Predictions*

The basic geometric parameters for Wonga West area are:

- depths – 440m to 500m;

- extraction – 2.7m to 3.2m – assume 3m average;
- panel width – 388m rib to rib; and
- pillar width – 59.5m rib to rib.

For the Wongawilli West area, the geometric situation is simpler with only the Bulli seam already extracted. It is proposed the difference is related to the spanning capacity of the Bulgo Sandstone across the previously mined Bulli seam panels which are less than 188m wide, and that this spanning capability may be reduced with wider panels.

The tabulated model for subsidence in Wongawilli West is provided in *Table 18.3*.

Table 18.3 Model for Subsidence in the Wongawilli West Area

	Previous Bulli Seam	Bulli residual potential	Wongawilli Seam only	Mining proposal	Combined
A	1.0m	0.6m	0.8m	1.4 m	2.4 m
B	0.8m	0.0	1.95m	1.95 m	2.75 m
C	1.0m	0.6m	1.95m	2.55 m	3.55 m

a) Above Bulli extraction panel, and above Wongawilli pillar.
b) Above Bulli Seam pillar and above Wongawilli panel.
c) Above Bulli and Wongawilli goafs.

Seedsman's subsidence prediction methodology was reviewed on 4 March 2010 by Dr Ken Mills (of SCT Operations Pty Ltd) and Arthur Waddington (of MSEC) via a Failure Mode and Effects Analysis workshop (FMEA) facilitated by OEC. The FMEA was to consider the risks associated with the subsidence prediction methodology. The full FMEA report is provided in *Annex B of Seedsman 2012 (refer to Annex M)*.

The primary objectives of the FMEA were to:

- confirm that the risk management approach adopted by Seedsman was robust and acceptable; and
- identify any factors or components that were either inadequately addressed or that had not yet been considered.

The main elements and a list of possible risks for the FMEA were prepared by NRE, Seedsman and OEC prior to the workshop. An exposure rating was then determined for each risk and where necessary additional actions were agreed upon to enhance the robustness of the mine subsidence assessment. These actions are summarised in *Table 18.4*. The full list of risks and panel comments is provided in *Annex F*.

Table 18.4 Actions Determined During FMEA

Item	Possible Failure	Potential Risk	Expert Panel Comments	Agreed Additional Actions	Exposure	Response
Illawarra Escarpment	Unacceptable impact on the Illawarra Escarpment. The eastern end of the proposed extraction footprint is located 700m from the crest of the Illawarra Escarpment (340m AHD).	The adequacy of the 700m standoff to allow confident prediction of impacts.	Standoff distance of 700m is appropriate.	Check actual standoff distance on current plans and adjust mine plan to accommodate the correct standoff distance. Check standoff distances and associated data with Dendrobium for comparison.	Low	The actual standoff distance has been checked and it is confirmed to be a minimum of 560m and is supported by practice used in other areas in NSW.
		Initiation of pillar run may adversely affect subsidence predictions.	Have to assume available plans are accurate. Previous extraction close to the escarpment will also reduce risk.	NRE to ensure the most accurate plans are obtained and used.	Low-medium	NRE have updated the mine plan and this was used in the assessment. A pillar run report was undertaken and concluded that a pillar run was unlikely (*Annex G*).
Mount Ousley Road	Unacceptable subsidence effects on Mount Ousley Road as a result of mine subsidence. Current relocated route of Mount Ousley Road lies directly above Balgownie seam chain pillar and over Bulli seam extracted areas. A longwall elimination zone under and within 100m of the road is recommended where the road is above Bulli seam extraction. For areas where the standing pillars in	The adequacy of the 100m standoff above areas of Bulli seam extraction to confidently predict negligible impacts.	The 100m standoff is appropriate and limits subsidence at Mount Ousley Road. It was noted that NRE advised that a management plan will be implemented in consultation with RTA.	Re-assess/cross-check the likely strains, tilts, angle of draw and deformation characteristics associated with Balgownie seam extraction.	Low-medium	A further analysis of the hazards associated with the proposed mining in the vicinity of Mount Ousley Road (*Annex N*) concludes that the standoff is appropriate. Management plan developed & actioned
		The acceptability of adopting engineering controls based on	Practical engineering controls are available. Engineering controls	Engineering controls includes any remediation work that may become	Low-medium	NRE have consulted the RMS and are currently actioning an agreed management plan

Item	Possible Failure	Potential Risk	Expert Panel Comments	Agreed Additional Actions	Exposure	Response
	the Bulli seam are indicated, engineering controls based on monitoring should be used to locate the finish line of the longwall panels.	monitoring in areas where standing pillars in the Bulli seam are indicated. The controls would define the location of the finish line of the longwall panels.	can be used to locate finish lines.	necessary as a result of mine subsidence management plan that will be implemented in consultation with RTA.		
		Lack of knowledge of RTA road construction and tolerability criteria.	Although standoff distances are predicted to avoid significant impacts, this information will be required to fully assess likely impact on structures.	Obtain RTA data on road construction, Cataract Creek culvert details as well as any RTA impact criteria. This will also be fully addressed in the Management Plan that will be developed with RTA input.	Low-medium	Monitoring will be undertaken along Mt Ousley Road as mining progresses and with agreement between RMS and NRE. A Built Features Management Plan has been implemented to facilitate the monitoring.
Cataract Dam Wall and Spillway	Unacceptable impacts on Cataract Dam wall and spillway as a result of mine subsidence. It has been decided that the DSC 1km boundary will form a boundary to longwall extraction.	The acceptability of the DSC 1km standoff to confidently predict negligible subsidence impacts.	The 1km standoff under the current mining layout is acceptable. The Expert Panel noted that it is ultimately subject to DSC approval.	Ongoing monitoring will supplement validation data.	Low-medium	Monitoring of the proposed longwalls closest to the Dam will be undertaken along with any other monitoring the DSC may impose via conditions.
		Inadequate knowledge of SCA structures limits ability to determine subsidence effects.	NA	Structures currently monitored by SCA. A Management Plan will be developed with DSC before mining in general area of structures commences.	Low	A management plan will be developed with the DSC as out lined in *Chapter 28.*

Item	Possible Failure	Potential Risk	Expert Panel Comments	Agreed Additional Actions	Exposure	Response
Cataract Dam Stored Water and DSC Notification Area	Unacceptable impacts on stored water and DSC Notification Area as a result of mining-induced subsidence. Narrow longwalls have been extracted from the Bulli seam in Wonga West area and additional longwall extraction is not proposed here. Within the DSC notification area, there has been no previous longwall extraction in the Wongawilli East area and narrow longwalls are now proposed. Proposed layouts should produce vertical subsidence similar to or less than those already experienced in the '500 series' panels.	Lack of geological data limits confidence in the ability to predict subsidence characteristics.	Geological data adequate (but see agreed action column). Mining in Notification Area will be subject to DSC approval.	Undertake further assessment of loading estimates for chain pillars in Bulli seam within the DSC Notification Area in Wonga East area.	Low-medium	Further assessment has been undertaken (*Annex M*). This assessment concluded that the loading is within acceptable limits. This matter will be further addressed in subsequent DSC approval.
Fourth Order Streams	Unacceptable impacts on Lizard Creek due to mine subsidence. The lower reaches of Lizard Creek are indicated to constitute a 4th order stream. Wide longwall extraction will not occur within a 200m offset from the centre of Lizard Creek.	Available mining history information not adequate to determine whether selected standoff distance or extraction proposal is appropriate to avoid impacts.	• Mining history data from adjacent mines can be applied. • The 200m standoff from Lizard Creek should mean any impacts are minor. • Further monitoring will provide an opportunity to refine standoffs with information from earlier longwalls.	• GeoTerra be commissioned to define exact location of third and fourth order streams. • Seedsman should review the consequences of a doubling of the upsidence and closure values given by the incremental data plots. • NRE to monitor earlier longwalls in Wonga West to obtain data of 'multiple seam extraction'.	Low-medium	This is addressed in *Chapter 20*. This doubling has been considered in the impact assessment (*refer to Annex O*). NRE will monitor initial longwalls in Wonga West to confirm predictions associated with multiple seam extraction.

Item	Possible Failure	Potential Risk	Expert Panel Comments	Agreed Additional Actions	Exposure	Response
	Unacceptable impacts on Cataract River and Cataract Creek due to mine subsidence. The majority of Cataract Creek is indicated to constitute a 4th order stream.	The potential for subsidence greater than 200mm to occur beneath Cataract Creek.	This subsidence prediction is based on data obtained from the 500 series of longwall extractions.	Seedsman to review predictions of 'no valley closure' in light of the predictions of up to 900mm subsidence elsewhere in the mined area. This review should be supported by GeoTerra assessing impact, should valley closure be predicted to occur.	Low	Seedsman has reviewed this prediction and advises that 1200mm of vertical subsidence and 50mm of closure is an appropriate value to identify hazards to Cataract Creek. An adaptive management approach will be adopted so that Longwall extraction under Cataract Creek is avoided unless it can be demonstrated prior to secondary extraction that negligible subsidence impacts will result. In accordance with the recommendations of the FMEA, GeoTerra has assessed the impacts associated with doubling the 50mm prediction of valley closure.
Shallow Groundwater	Unacceptable impacts on groundwater systems due to mine subsidence. Analyses indicate no significant change in fracture flow from surface to coal seam.	Loss of surface runoff to the mine workings.	Wider longwall panels and multiple seams mean that large degree of interpretation of empirical database is required. Experts could not achieve a common position.	Review risk assessment with external consultants as appropriate.	Low-medium	GeoTerra has assessed, through Groundwater modelling and interpretation of subsidence predictions, that there will be negligible potential for connectivity from mine workings to the surface (*Annex P*).

Source: Olsen (2010)

18.6 *SUBSIDENCE PREDICTIONS*

A summary of the Seedsman (2012) maximum predicted subsidence effects within the potential subsidence footprint, resulting from the extraction of the proposed longwalls in Wonga East and Wonga West is presented in this section. It has not been varied as the Seedsman (2013) review of A2 LW4 subsidence data did not advise of any need to change the base predictions for Wonga East or Wonga West.

18.6.1 *Wonga East*

Subsidence Effects

In Wonga East the maximum subsidence effects are predicted as:

- vertical subsidence of 1.2 metres;
- maximum tilt of 26 mm/m; and
- strains ranging between – 10 to +6 mm/m.

Subsidence visualisations of upper bound predictions of vertical subsidence are presented in *Figure 18.1*. These visualisations are derived directly from the Seedsman (2012) subsidence assessment.

Other Deformations

The prediction of closure and upsidence in Cataract Creek relies on the prediction of vertical subsidence. Seedsman (2012) advises that given the distance from Cataract Creek and the levels of subsidence, a value of 50mm of closure is an appropriate value to use to identify any hazards applying to this creek.

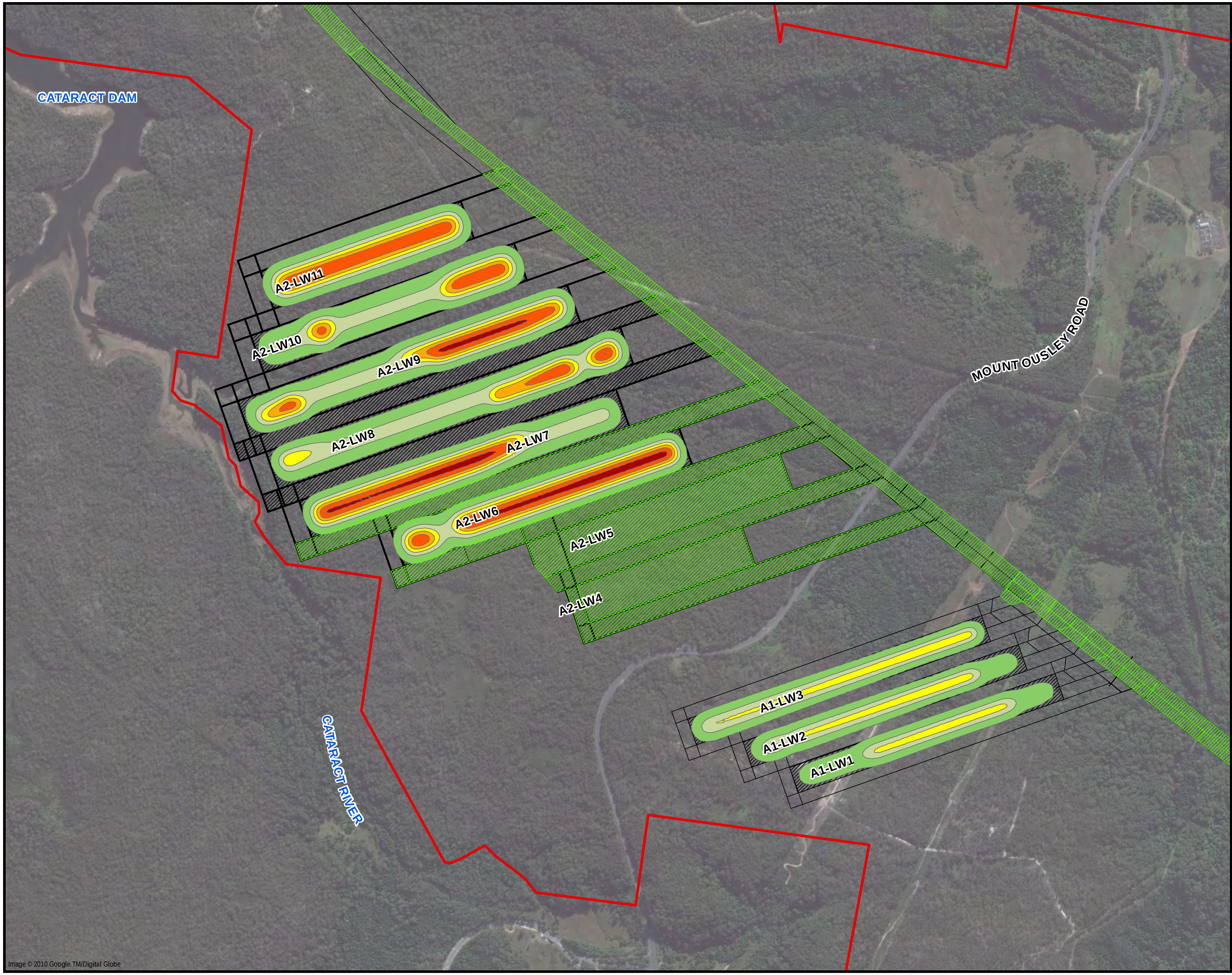
Where Cataract Creek crosses A2 LW8, the mine plan shows pillar extraction in the Bulli Seam and some longwall extraction in the Balgownie seam. Based on monitoring recently obtained from A2 LW4, it can be assumed that the vertical subsidence to be induced by the Wongawilli seam extraction will be in the order of 1.2-1.4m. NRE have committed to an adaptive management approach and secondary extraction in relevant sections of A2 LW8 will not occur unless it can be demonstrated by additional monitoring that no more than minor impacts will be experienced within Cataract Creek.

Wonga West

Subsidence Effects

In Wonga West the maximum predicted subsidence effects are predicted as:

- vertical subsidence of 2.5 metres;
- maximum tilt of 18 mm/m; and
- strains ranging between –12 to +14 mm/m.



Legend

- Project Application Area
- Approved Workings (MP10_0046)
- Proposed Longwalls

Predicted Subsidence Contour (m) (Seedsman 2012)

- -0.02 ► -0.19
- -0.2 ► -0.39
- -0.4 ► -0.59
- -0.6 ► -0.79
- -0.8 ► -0.99
- -1.0 ► -1.2

Figure 18.1

SDPS Visualisation of Predicted Vertical Subsidence (Wongawilli Seam Only) in Wonga East

Client:	Gujarat NRE Coking Coal Limited		
Project:	NRE No.1 Colliery Environmental Assessment		
Drawing No:	0079383s_EARPA2012_G032_R0.mxd		
Date:	28/11/2012	Drawing size:	A3
Drawn by:	KB	Reviewed by:	TM
Scale:	Refer to Scale Bar		

N

0 90 180 270Meters

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch,
Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM

Subsidence visualisations of predictions of vertical subsidence, of Wongawilli seam extraction only, are presented in *Figure 18.2*. These visualisations are derived directly from the Seedsman (2012) subsidence assessment.

Other Deformations

Seedsman (2012) advises that valley closures of about 100mm and upsidence of about 60mm should be anticipated in Wonga West and that comment by the FMEA review was that it would be good practice to double these estimates in the context of an impact risk assessment.

18.6.2 *Predicted subsidence impacts at significant built features*

Seedsman (2012) provides comment on subsidence consequences on built features and some natural features identified as being of special significance. Predicted subsidence consequences on built features are discussed in this section. A summary of subsidence consequences on natural features of special significance as assessed by relevant specialists is provided in *Chapter 19*.

Mount Ousley Road

Mount Ousley Road is above a chain pillar between two previously mined Balgownie longwall panels (Faces 6 and 7).

Both these centrelines show subsidence in excess of 'three feet' after the extraction of the Balgownie seam. Given that the seam thickness was in the order of 'four feet', Seedsman (2012) states with a very high degree of confidence that the overburden above both these faces fully collapsed following extraction of the Balgownie longwalls and that this collapsed zone will provide a barrier to any lateral progression of subsidence that may be induced by extraction of the proposed Wongawilli seam longwalls. No longwall mining is proposed directly beneath or with 100m of Mount Ousley Road. Therefore it is predicted that that no significant deformations will be imposed on Mount Ousley Road.

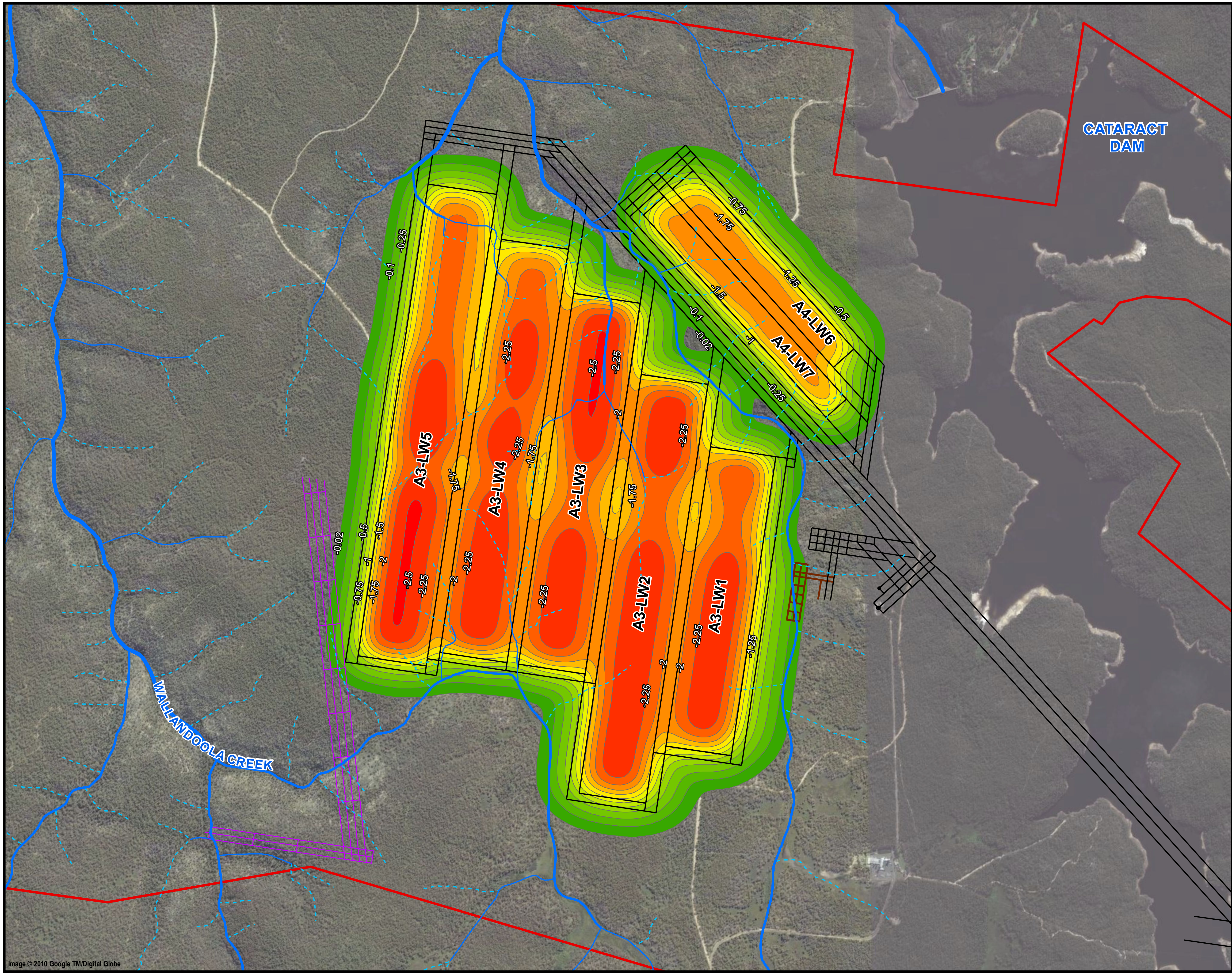
The bridge at Picton Road interchange that crosses over Mount Ousley Road is 840m south of the nearest longwall and is not predicted to be exposed to any mining induced movements.

Strata Engineering (2012) also conclude that the proposed longwall extraction in the Wongawilli seam is unlikely to induce a pillar run in the overlying Balgownie and Bulli seams which would otherwise adversely affect surface subsidence around Mt. Ousley Road.

Cataract Dam Wall and Spillway

The DSC recognises that the Cataract Dam wall may be sensitive to far-field horizontal movements and has set a 1.5km radius around the dam wall where the assessment of potential mining impacts should be focussed.

The mine plan was designed with no longwall mining within 1km of the dam wall in accordance with the 1km assessment zone that was current at the time.



Legend

- Project Application Area
- Proposed Longwalls
- Proposed Bulli Seam First Workings
- Proposed Balgownie Seam First Workings
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order and Above Stream

Predicted Subsidence Contour (m) (Seedsman 2012)

- -2.5 → -2.5
- -2.25 → -2.49
- -2.0 → -2.24
- -1.75 → -1.99
- -1.5 → -1.74
- -1.25 → -1.49
- -1.0 → -1.24
- -0.75 → -0.99
- -0.5 → -0.74
- -0.25 → -0.49
- -0.1 → -0.24
- -0.02 → -0.09

Figure 18.2

SDPS Visualisation of Predicted Vertical Subsidence (Wongawilli Seam Only) in Wonga West

Client: Gujarat NRE Coking Coal Limited

Project: NRE No.1 Colliery Environmental Assessment

Drawing No: 0079383s_EARPA2012_G033_R0.mxd

Date: 09/11/2012 Drawing size: A3

Drawn by: SQW Reviewed by: TM

Scale: Refer to Scale Bar

N

0 200 400 600m

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ERM

The risk assessment and expert subsidence panel formed to undertake the Olsen (2010b) FMEA concluded that a 1km standoff under the current mining layout was acceptable, but noted that it is ultimately subject to DSC approval.

Additional assessment of predicted impacts will be undertaken as more subsidence data from multi-seam mining is available and prior to any longwall mining within the 1.5km assessment zone.

Stored Water and Notification Area of Cataract Reservoir

No longwall mining is proposed under the stored waters of the Cataract Reservoir in Wonga West. In Wonga East limited mining is proposed with DSC approval whereby the maximum predicted subsidence under the full supply level of Cataract Reservoir is 250mm.

18.6.3 *Subsidence predictions for other built features:*

Telstra Optical Fibre Cable

A Telstra optical fibre cable has been installed along the alignment of Fire Trail No.8 which traverses the Wonga West longwall area. As such it will be subjected to the full range of subsidence associated with Wongawilli seam extraction (a maximum of 2.5m vertical movement; strains of +5mm/m and -7mm/m). A management plan has been established for previous mining beneath this cable and it is anticipated that this will be re-activated and upgraded in keeping with the projected ground movement for any further mining.

4wd Tracks and Fire Trails

The surface land overlying the Wonga West area has a number of unsurfaced roads and fire trails that are predominantly maintained by SCA. While these roads could be subject to the full range of subsidence (a maximum of 2.5m vertical movement; strains of +5mm/m and -7mm/m),the unsealed nature of these roads means that they can readily accommodate a wide range of ground movement and are therefore expected to remain safe and serviceable. A management plan to ensure the ongoing safe use of the fire trails.

Transmission Lines

Within the PAA a number of electrical transmission lines have been identified. One set of transmission lines (33kV) are owned and operated by Gujarat NRE Coking Coal and are used to supply power to the various shafts and related mine infrastructure within the PAA. A second set of transmission lines (11 line; 330kV) are owned and operated by TransGrid and Integral Energy own and operate another three sets of transmission lines (two sets of 33kV lines and one set of 132kV lines) all within the vicinity of longwall panels 1 to 3.

The TransGrid power lines are a 330 kV installation with a general north south orientation utilising steel towers. The extraction of longwall panels A1 LW1 to A1 LW3 is expected to cause a maximum vertical subsidence of 1.2m with the potential to impact on the stability of the towers and the tension in the power lines.

This relates primarily to the location of the towers relative to the extraction panels and the degree to which each tower can tolerate the predicted level of movement. There are a number of past examples where impacts of this extent can be managed by establishing a management plan in consultation with the owner of the power lines.

More particularly the management plan will detail a mechanism whereby monitoring is undertaken and any tower that could be impacted is stabilised with appropriate foundations and the residual tension in the transmission lines is adjusted to allow the towers to move without inducing excessive strain in the lines. Initial discussion has been held with TransGrid and it is proposed that the management plan will be developed and activated at least 6 months prior to extraction in the vicinity of the transmission line.

There are three Integral Energy Power lines (one 132kV line and two 33kV lines) all with a general north south orientation over the proposed Wonga East A1 LW1 to LW3. It is proposed that a management plan will be developed with the direct involvement of Integral Energy to ensure that they remain serviceable during the extraction of these panels. There has been initial discussion with Integral Energy and it is proposed that the management plan will be developed and activated at least six months prior to extraction in the vicinity of the transmission line. In most instances the management plan will be similar to that described above and will involve regular monitoring and adjustment to the tension in the transmission lines to accommodate any movement of the supporting poles as mining progresses.

18.7 *MANAGEMENT AND MITIGATION MEASURES*

NRE developed a mine plan for the Wonga West and Wonga East areas based on economic extraction requirements, taking into account significant natural and built features. There is currently minimal appropriate data to develop suitable models to predict detailed mine subsidence parameters for multiple seam extraction. In order to manage environmental risks, mine planning incorporated a risk assessment methodology and applied a hierarchy of risk management strategies as defined in *Section 18.3.2*.

The iterative mine planning process identified a number of surface features above the proposed mining that have special significance (*Table 18.1*). Using an elimination approach for risk management, NRE have decided not to undertake longwall extraction under or within close proximity to those identified significant features.

18.7.1 *Significant Natural Features*

In 2007 a map of 'ecological risk management zones' was provided to NRE for consideration and these areas included upland swamp communities, creek lines and riparian zones, significant fauna habitats and endangered ecological communities. These risk management zones provided the subsidence engineers and mine managers with an understanding of the locations of sites of ecological significance. It also provided an opportunity to reassess the mine plans based upon this information.

Significant Streams and Upland Swamps

In order to avoid impacts to ecological features, the design of longwall panel layouts has been such that potential impacts to 3rd and 4th order creeks and upland swamps are reduced (refer to *Chapter 22* and *Annex Q*). The proposed mine plans have avoided longwall extraction directly under the main channels of Lizard Creek and Wallandoola Creek.

Due to continuing production and operational constraints, mining under Cataract Creek at Wonga East has not been specifically ruled out. Therefore the risk control of substitution has been applied. Rather than using wide longwalls, which may result in high levels of surface deformations, NRE has decided to use narrower longwalls and wide chain pillars in Wonga East. The layout is similar to that previously used in the 500 series longwalls under the stored waters adjacent to Wonga West and is expected to result in a reduced effect compared to wider longwalls.

In the event that minimal subsidence impact cannot be demonstrated prior to secondary extraction under Cataract Creek, the specific longwall layout along with the start and end lines of applicable longwalls will be altered.

EEC and Threatened Species Habitat

Mitigation measures for the management of potential mining impacts on EECs and threatened species habitat is detailed in *Chapters 22* to *24*.

The Illawarra Escarpment and Major Cliff Lines

Limited secondary extraction is proposed in the vicinity of the Wallandoola and Lizard Creek gorges. The Cliff and Steep Slope report undertaken by SCT (2012b) has considered potential impacts in that the only items with any potential to be impacted are:

- a waterfall on Lizard Creek;
- a waterfall on Wallandoola Creek and
- a 300m long cliff line on the northern side of Lizard Creek.

It is proposed that the longwall layout will be adjusted based upon specific subsidence data to reduce any impacts to a minimum.

No mining is proposed beneath the Illawarra Escarpment. The escarpment is 500m east of the nearest longwall in Wonga East. The expert panel noted, during the review sessions, that mining induced movements, if any, would be small horizontal displacements and would not destabilise the escarpment.

18.7.2 *Significant Man Made Features*

Mount Ousley Road

Mount Ousley Road lies directly above a chain pillar in the Balgownie seam and partly above a wide extraction area and first working pillars in the Bulli seam. Subsidence monitoring undertaken in support of the Balgownie longwall extraction indicates that in the order of 1.4m was measured above face 10 and 1.5m above faces 7 and 8. This magnitude of subsidence suggests that the extraction of the Balgownie seam has combined with previous mining in the Bulli seam.

Hence, because of the pre-subsided nature of the strata, any Wongawilli longwall extraction directly under the road (even at comparatively narrow widths) had the potential to produce large vertical subsidence, and high localised tilts and strains.

To prevent these impacts on Mount Ousley Road, a Wongawilli seam longwall exclusion zone directly under and within 100m of the road has been established in the mine plan.

For areas where the standing pillars in the Bulli seam are indicated, engineering controls will be used. Engineering controls refer to the ability to change the location of the start and finish lines of each longwall panel. Subsidence will be monitored during mining and this data will assist in refining subsidence predictions for subsequent longwalls and related engineering controls. For areas where the standing pillars in the Bulli seam are present under and within 100m of Mount Ousley Road, subsidence will be monitored to assist in locating the finish line of the longwall panels.

Cataract Reservoir

No extraction is proposed in Wonga West directly under stored waters. The DSC has set a 1.5km radius from the dam wall as a threshold for more detailed studies. The sequencing of the longwalls in the Wonga West area will allow limited progressive collection of subsidence monitoring data. NRE has decided not to undertake longwall extraction inside the 1km radius previously specified. Depending on available data it may be necessary to reassess mining of A4-LW6 and 7 in Wonga West to avoid potential impacts to the dam wall.

Mining within the DSC Notification Area at Wonga East cannot be operationally avoided. Therefore NRE, has decided to use narrow longwalls and wide chain pillars in Wonga East. This is expected to result in a significantly reduced amount of surface impacts, compared to alternate longwall configurations. It is identified that any mining (both first and second workings) within the Notification Area will require approval by the DSC.

18.7.3 *Subsidence Management Plan*

The primary approach taken with the proposed mine layout and extraction is to restrict the subsidence effects which in turn reduces possible impacts. An adaptive Subsidence Management Plan (SMP) has been developed for A2-LW4 and 5 and will be revised prior to any subsequent mining which will detail the monitoring measures to be implemented to ensure that subsidence effects, impacts and consequences are consistent with those deemed acceptable. Ongoing assessment and review is proposed as is amendment of the longwall layout where necessary to better manage subsidence impacts and their consequences on both natural and built features. By applying this approach it is believed that potentially invasive mitigation and rehabilitation works will not be necessary. The SMP will include details of:

- appropriate triggers and monitoring systems to demonstrate how management strategies have been achieved and where improvements can be made;
- adaptive management processes for continually detecting impacts and, validating predictions;

- contingency planning for any unpredicted impacts; and
- remediation of unpredicted impacts.

A summary of management measures to be included in the subsidence management plan is provided in *Table 18.5*.

Table 18.5 Summary of subsidence monitoring measures

Issue	Monitoring Measure	Reference
Subsidence	• Ground movements will be monitored as mining occurs, to measure the extent to which the actual movements may differ from those predicted. Any predicted impacts will be periodically reviewed to include additional data as it becomes available.	*Section 18.5*
Surface water	• Ongoing monitoring and remediation program will be developed in consultation with the SCA, DRE and OEH.	*Chapter 20*
Groundwater	• A monitoring and management strategy along with an outline of a Trigger Action Response Plan (TARP) should be prepared to provide guidance on the procedures and actions required in regard to the surface water and groundwater systems in the proposed mining area.	*Chapter 21*
Upland Swamps	• A swamp monitoring plan has been developed for the extraction of A2 LW4 nd A2 LW5 in Wonga East as part of the Biodiversity Management Plan (Biosis 2012b) and the Subsidence Management Plan Monitoring Program for A2 LW4 and A2 LW5 (Gujarat NRE 2012). These monitoring plans will be revised and updated for this application in liaison with SCA, OEH and to the approval of DP&I.	*Chapter 22*
Aquatic Ecology	• Ongoing monitoring of water quality, aquatic habitat, macro invertebrates and fish during the same seasons as used for the baseline study. • Additional surveys of aquatic habitats and biota if fractures of the stream bed and associated loss of water from pools occur or significant changes in pH, dissolved oxygen, turbidity or metal concentrations are detected during routine surface monitoring.	*Chapter 23*
Terrestrial Ecology	• Monitoring for threatened species identified as having a moderate to high likelihood of occurring in the Study Area, and as vulnerable to the impacts of subsidence should be undertaken. Monitoring should be undertaken at annual intervals in appropriate seasonal timeframes for the detection of each individual species.	*Chapter 24*
Aboriginal Heritage	• Mine layout designed to avoid significant areas. • Monitoring and archival recording of high or moderately significant sites with moderate or high risk of impacts before, during and after mining.	*Chapter 25*
Historic Heritage	• No secondary extraction will occur beneath or within a 1km radius of the Cataract Dam wall.	*Section 14.3*

18.8 *CONCLUSION*

The SCI Report (DoP, 2008) identifies significant natural features as areas where subsidence assessment should be focused. A risk assessment workshop was undertaken to identify significant natural features and to help inform the EA process and appropriate specialist studies (see *Chapter 6*).

The proposed mine plans have been formulated to avoid significant natural and built features while maintaining suitable levels of resource recovery and economic viability.

NRE do not propose to undertake longwall mining directly under the main channel of Wallandoola or Lizard Creek, therefore, minimising impact to any swamps located within their riparian zones.

Mining under Cataract Creek and the DSC Notification Area in Wonga East has been designed with narrow longwalls and wide chain pillars which are predicted to be stable in comparison to wider panels. These longwalls are of a similar design to those successfully undertaken in the 500 series under the stored waters of the Cataract Reservoir. Subsidence monitoring data will be used to refine the subsidence predictions prior to mining under these features and engineering controls such as alternate layouts and altered start and end lines will be implemented where it cannot be demonstrated that only minor impacts will result or where more than minimal impacts are identified during secondary extraction.

No longwall mining is proposed under and within 100m of Mount Ousley Road where the road is above Bulli seam extraction. For areas where the standing pillars in the Bulli seam are present, engineering controls will be used. No mining is proposed within 1km of the Cataract Dam wall.

Monitoring and mitigation measures will be implemented for Aboriginal sites within the potential subsidence footprint.

Given the strategy to avoid mining beneath significant features within the potential subsidence footprint, the likely consequences from mining related surface impacts are significantly reduced. However, subsidence will be monitored during mining to validate and refine predictions and to ensure any unacceptable impacts can be prevented or addressed and appropriate remedial measures implemented, as required.

19 FEATURES OF SPECIAL SIGNIFICANCE

This chapter summarises the subsidence consequences on special significance features identified within the Study Area as identified in the technical assessments included in Annexes O *to* V. *The subsidence consequences are based on the subsidence predictions contained in* Annex M.

19.1 INTRODUCTION

Features of special significance status of the following types were identified within the Study Area and in some cases within the predicted subsidence footprint;

- Gorges, Cliffs and Steep Slopes;
- Third order and above streams; and
- Upland Swamps.

While Transitional Shale Forest EEC is present within the PAA and predicted subsidence footprint, this vegetation community has been assessed as having low susceptibility to subsidence impacts. With negligible potential for subsidence consequence to occur to this vegetation community it is not considered to warrant special protection in this instance.

All upland swamps in the PAA meet the definition of Coastal Upland Swamp EEC. The assessment of special significance status on these features has been undertaken in accordance with OEH guidelines on upland swamps and is not repeated.

All upland swamps and first and second order streams associated with these swamps are likely to, and in some instances do, provide habitat for various endangered frogs and plants. The assessment of significance of these swamps includes likelihood of impact which includes water flows to and from these swamps. Therefore the protection of the habitat features should be achieved through the appropriate management of upland swamps of special significance.

In addition to these feature types, four Aboriginal Heritage features of high significance were identified. They are included in the summary sections despite no particular special status being raised for these sites by Aboriginal groups involved in the assessment and consultation process to date.

The predicted subsidence impacts on these features is taken from the Seedsman (2012) subsidence assessment and are the predicted impacts in the absence of applying the full range of adaptive management and engineering control that may be available.

The likelihood of subsidence consequences on these features is taken from the relevant technical assessment as follows:

- Swamps – (Biosis 2012) refer to *Annex Q*;
- Streams – (GeoTerra 2012) refer to *Annex O*;
- Cliffs – (STC 2012b) refer to *Annex V*;

- Aboriginal Heritage Features (ERM 2012d) refer to *Annex U*; and

- Threatened Species and Endangered Ecological Communities (ERM 2013).

The proposed controls that require further refinement are contained in the draft statement of commitments included as *Chapter 29*.

The type, number, location and predicted subsidence consequences are summarised in the following sections. A brief discussion of how special significance status was determined is provided with the full assessment methodology in the various annexures referred to above.

19.2 *SOUTHERN COALFIELD INQUIRY, METROPOLITAN PAC AND BULLI PAC*

The Southern Coalfield Inquiry (SCI) identified that significant natural/environmental features include:

- Rivers;

- 3rd order steams and higher;

- Gorges;

- Significant cliff lines & overhangs (including waterfalls);

- Upland Swamps;

- Endangered Ecological Communities;

- Threatened Species Habitat; and

- Aboriginal heritage sites.

Special Significance Status can then be applied to these natural features based on an assessment of a natural feature that determines the feature to be so special that it warrants a level of consideration (and possibly protection) well beyond that accorded to others of its kind. It may be based on a rigorous assessment of scientific importance, archaeological and cultural importance, and uniqueness, meeting a statutory threshold or some other identifiable value or combination.

The approach to classifying Special Significance Status has been refined by the subsequent Metropolitan PAC and Bulli PAC as well as through the development of OEH guidelines. Each of the above natural features has been assessed in the proceeding chapters and the method of assigning Special Significance Status is included in each case.

19.3 *SUMMARY OF SPECIAL SIGNIFICANCE FEATURES IN THE STUDY AREA*

19.3.1 *Gorges, Significant Cliff Lines and Overhangs (Including Waterfalls)*

The PAC reports defined cliffs of special significance status as those that are:

- longer than 200m;

- higher than 40m; and
- higher than 5m that constitute waterfalls.

SCT (2012b) identified three features in the Study Area that are of special significance:

- a waterfall on Lizard Creek;
- a waterfall on Wallandoola Creek; and
- a 300m long cliff line on the northern side of Lizard Creek (SCT 2012b).

The Illawarra Escarpment is recognised as a feature of special significance. However, the mine plan was modified early in the planning process to provide the required risk management zone buffer to the escarpment.

19.3.2 *Upland Swamps*

As discussed in *Section 22.1.4*, all the upland swamps within the Study Area meet the criteria for statutory thresholds (Coastal Upland Swamp EEC) and closely proximate habitat (as all are part of the Wallandoola Creek cluster). Biosis (2012a) identified 15 upland swamps in the Study Area as being of 'special significance' based upon the most recent criteria defined by OEH (2012).

Wonga East

Biosis (2012) identified that seven (7) of the 39 uplands swamp in Wonga East are considered to be of 'special significance' according to criteria set out in OEH (2012) (see *Table 22.1*).

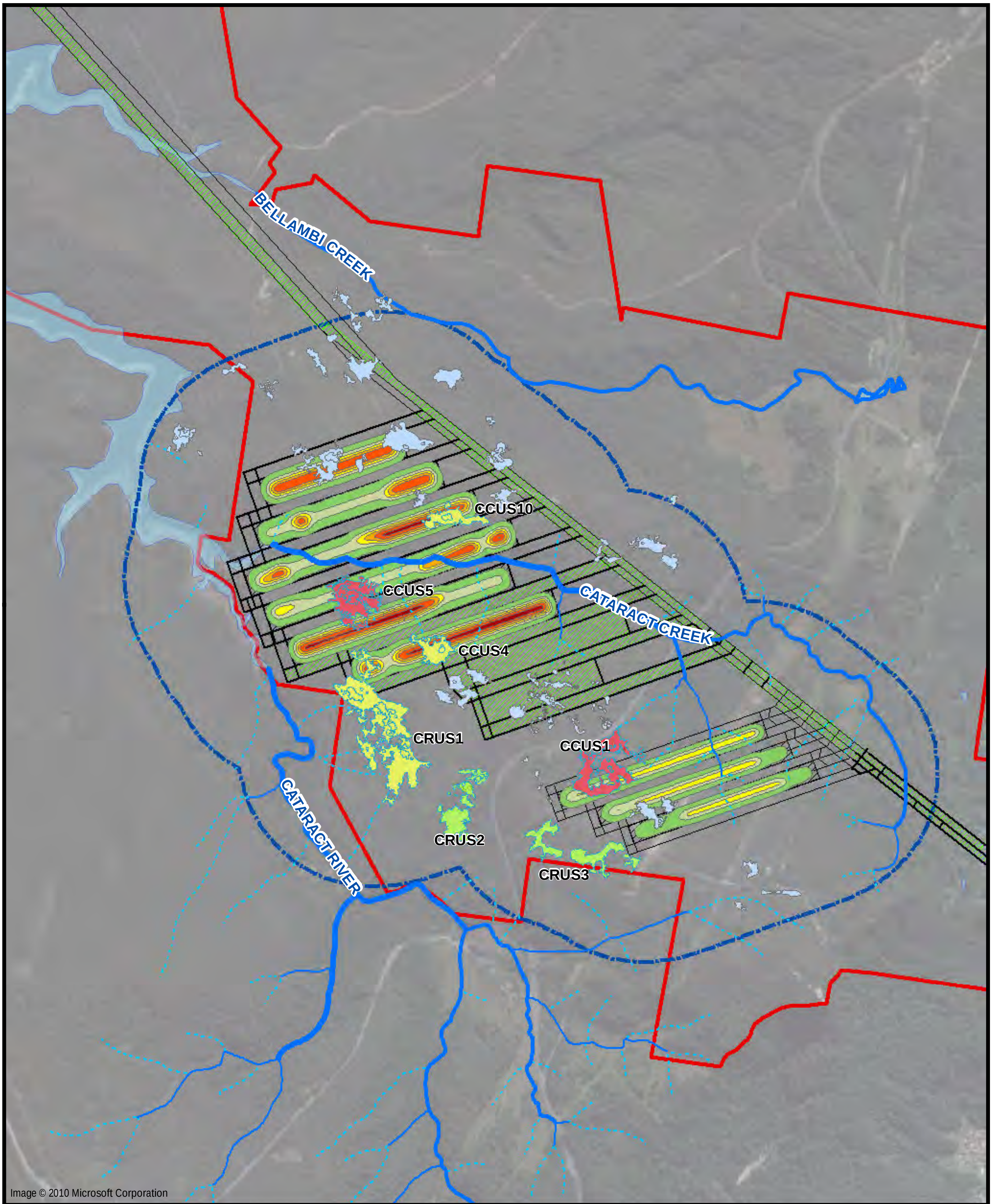
In addition to meeting the statutory and closely proximate habitat criteria, CRUS1 is considered to be of 'special significance' based on size, while CCUS1, CCUS4, CCUS5, CCUS10, CRUS2 and CRUS3 are considered to be of 'special significance' due to the complexity of vegetation sub-communities within these swamps, as all support Banksia Thicket, Tea-tree Thicket and Sedgeland-Heath Complex (see *Figure 19.1*).

Of the seven swamps of special significance, five have potential to be subject to subsidence (CCUS1, CCUS4, CCUS5, CCUS10 and CRUS1).

Wonga West

Biosis (2012) identified that eight of the 45 uplands swamp in Wonga West are considered to be of 'special significance' according to criteria set out in OEH (2012) (see *Table 22.2*). These are LCUS1, LCUS27, LCUS6, LCUS8, WCUS1, WCUS11, WCUS4 and WCUS7.

In addition to meeting the statutory and closely proximate habitat criteria all of the swamps of special significance in Wonga West are considered to be of 'special significance' due to the complexity of vegetation sub-communities within these swamps, as all support Banksia Thicket, Tea-tree Thicket and Sedgeland-Heath Complex (see *Figure 19.2*).



Legend

- Project Application Area
- Study Area - Wonga East
- Approved Workings (MP10_0046)
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order and Above Stream
- Streams of Special Significance

Predicted Subsidence Contour (m) (Seedsman 2012)

- -0.02 -0.19
- -0.2 -0.39
- -0.4 -0.59
- -0.6 -0.79
- -0.8 -0.99
- -1.0 -1.2

Swamps of Special Significance (Biosis 2012)

- Negligible Risk
- Low Risk
- Moderate Risk
- Significant Risk

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No.1 Colliery Environmental Assessment
Drawing No:	0079383s_EARPA2012_GIS048_R0.mxd
Date:	28/11/2012 Drawing size: A4
Drawn by:	DR Reviewed by: MK
Scale:	Refer to Scale Bar

N

0 250 500 750m

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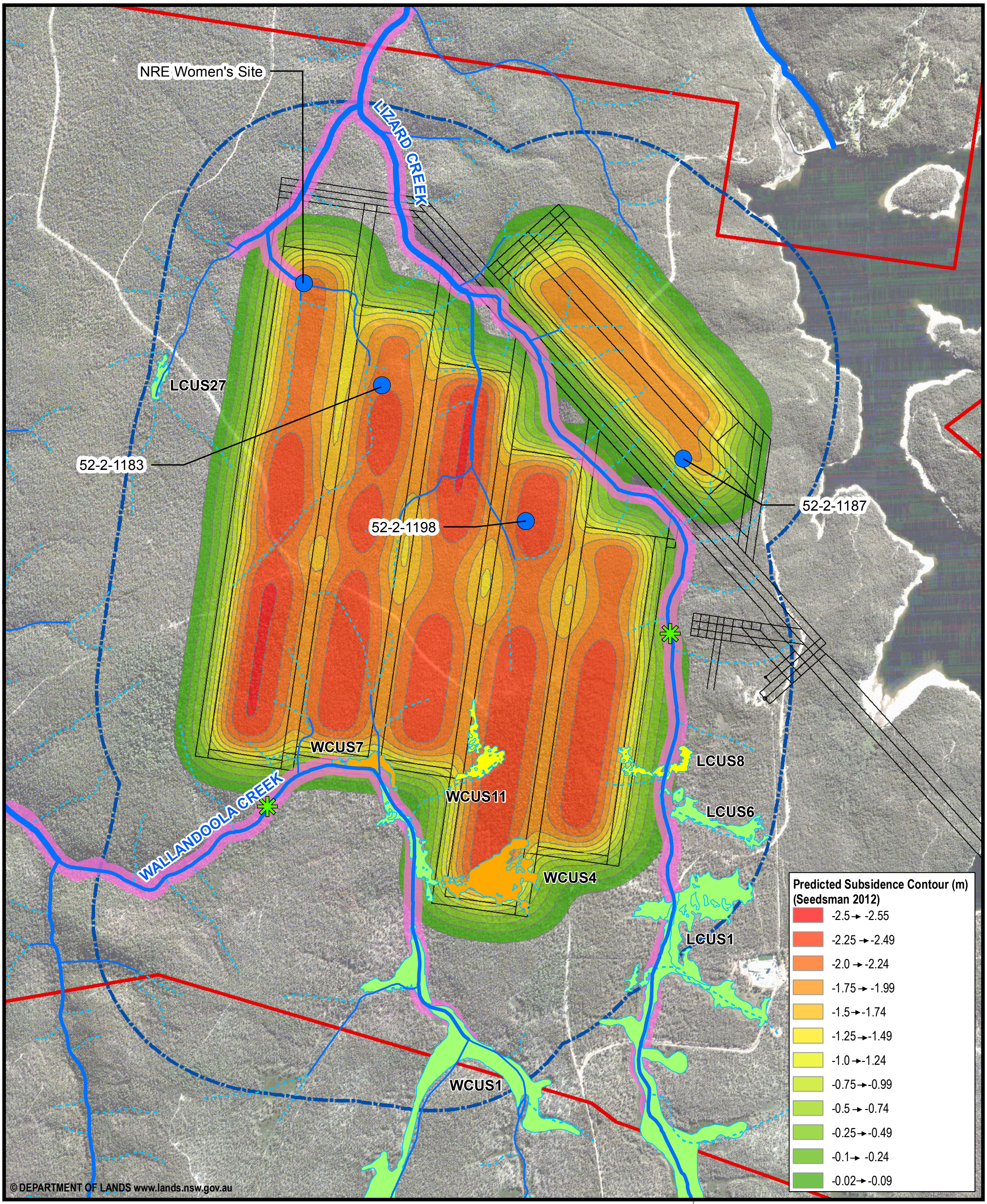
Figure 19.1

Features of Special Significance Wonga East

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM



Legend

- Project Application Area
- Study Area - Wonga West
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order and AboveStream
- Streams of Special Significance
- AHIMS Sites of High Significance
- Waterfall

Swamps of Special Significance (Biosis 2012)

- Negligible Risk
- Low Risk
- Moderate Risk

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No.1 Colliery Environmental Assessment
Drawing No:	0079383s_EARPA2012_G049_R0.mxd
Date:	15/11/2012 Drawing size: A4
Drawn by:	SQW Reviewed by: MK
Scale:	Refer to Scale Bar

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0 250 500 750m

Maps and figures contained within this document may be based on third party data, may not be to scale and is intended for use as a guide only. ERM does not warrant the accuracy of any such maps or figures.

Figure 19.2

Features of Special Significance Wonga West

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM

In addition to meeting three of the five criteria, three of the upland swamps meet a fourth criterion based on size being LCUS1 (129.9ha), WCUS1 (36.16ha) and WCUS4 (11.08ha).

Of the eight swamps of special significance, four have potential to be subject to subsidence (LCUS8, WCUS4, WCUS7 and WCUS11).

19.4 *STREAMS*

The SCI identified that streams of the Southern Coalfields are considered a high priority for protection if they have some or all of the following characteristics:

- perennial or intermittent/ephemeral streams with pools;
- a diverse array of in-stream habitats that provide feeding, breeding or drought refuge;
- and/or they support threatened species, iconic species or a high diversity of species (DECC 2007a).

The parameters that contribute to whether a stream is of 'significance' as outlined in the Metropolitan PAC (2009) and Bulli Seam Operations PAC (2010) include:

- importance to catchment yield;
- significance to water supply;
- permanence of flow;
- water quality;
- ecological importance;
- environmental quality (pristine, modified, severely modified);
- visual amenity (eg cascades runs, pools etc);
- community value (value the community attributes to protection); and
- regional significance.

The Sydney Catchment Authority in their submission to the SCI identified that Lizard Creek and Wallandoola Creek (for their full length) warranted protection from *negligible environmental consequences*.

Consideration of which streams in the PAA warrant 'special significance' status has been provided in *Annex P,* summarised in *Chapter 20*. This is based upon the consideration of use and non-use values as provided in Table 15 of the Bulli PAC (2010) (see *Table 19.1*).

Table 19.1 Stream Significance Summary

	Special Significance Consideration					
	Naturalness	**Water Supply Value**	**Within a Conservation Area**	**Connectivity with Swamp Complexes**	**Threatened Species and EEC**	**Special significance Status**
Cataract River	Y	Y	N	Y		Y
Cataract Creek	Y	Y	N	Y	Y	Y
Lizard Creek	Diminished	Y	N	Y	Y	N due to diminished naturalness but warrants special level of protection
Lizard Creek Tributary 1	Diminished	Y	N	Y	Y	N
Lizard Creek Tributary 2	Y	Y	N	Y	Y	Y
Wallandoola Creek	Diminished	Y	N	Y	Y	N due to diminished naturalness but warrants special level of protection

Special significance consideration based upon Section 7.6 and Table 15 of the Bulli PAC.

19.4.1 *Aboriginal Heritage Sites*

The SCI, Bulli and Metropolitan PAC report does not clearly identify when an Aboriginal heritage site should be assigned special significance status. The Bulli PAC identified two sites as having particular significance due to the level of interest in the sites exhibited by Aboriginal Groups and OEH. No particular significance has been advised by Aboriginal Groups to date and OEH advised that unless the subsidence footprint was to expand the approach taken in the Aboriginal Heritage assessment was deemed adequate. The approach taken to the Aboriginal heritage assessment was to follow the required guidelines. On this basis four sites have been recorded within the subsidence footprint as having high significance. These are:

- three rock shelters with high significance (52-2-1183 , 52-2-1187 and 52-2-1198); and
- one women's site with high significance (New NRE Women's Site).

All four high significance sites within the subsidence footprint are located in Wonga West.

19.4.2 *Summary of Predicted Subsidence Impacts to Features of Special Significance*

Table 19.2 summarises the predicted subsidence impacts and associated consequence risks to Features of Special Significance.

Table 19.2 Summary of Predicted Subsidence Impacts to Significant Features

Feature	Special Significance Status (or warrants special protection)	Maximum Subsidence	Maximum Tilt	Maximum Strain	Impact Likelihood	Potential Consequence
Cliffs						
Wallandoola Ck Waterfall	Yes	<0.02	<1.0	<+1.0	Low	Limited to no change to structural integrity of the waterfall.
Lizard Ck Waterfall	Yes	0.12	2.9	+3.5	Low	No change to structural integrity of the waterfall.
300m long cliff north of A3 LW2	Yes	0.25	3.0	5.0 to <-1.0	Unlikely to be significantly impacted by mining subsidence because horizontal subsidence movements are unlikely to be able to develop in a direction along the line of the cliff.	Not expected to cause large rock falls.
Discontinuous cliff lines associated with Lizard Ck gorges	Borderline	0.25	3.0	5.0 to <-1.0	Negligible to minor	Potential for horizontal compression movements to develop along the cliff formations located over Longwall A4 LW6 and rock falls on up to about 15% of the length of these cliff formations is considered possible because of their greater height and their alignment parallel to the direction of mining.
Cliffs associated with Wallandoola Ck Gorge	Potential based on stream significance	0.12	2.9	+3.5	Negligible	Nil
Streams						
Cataract River and Reservoir	Yes	<0.02	<0.1	<1.0 to <-1.0	No change to the fabric or structure of the reservoir or dam wall.	Negligible reduction in the quality and quantity of water resources reaching Cataract Reservoir. No connective cracking between the reservoir surface and the mine. Negligible leakage from Cataract Reservoir to the mine.

Feature	Special Significance Status (or warrants special protection)	Maximum Subsidence	Maximum Tilt	Maximum Strain	Impact Likelihood	Potential Consequence
					No change to fabric or structure of the stream bed or water quality.	Negligible potential for connective cracking, flow diversion, change in pool drainage, iron staining, water quality or gas releases.
Cataract Creek	Yes	0.8	<1.0	5.0 to -9.5	Potential cracking of 1st and 2nd order stream bed due to undermining by Longwalls A1 LW1, A1 LW2 and A1 LW3.	Potential impact on 1st and 2nd order stream flow with downstream flow re-emergence. There are no 3rd order pools or stream reaches in this section. Potential effect on iron hydroxide seepage, although iron hydroxide seepage is currently present in the 1st and 2nd order stream reaches.
					Potential cracking of up to 4th order stream bed due to subsidence near / over A2 LW7, A2 LW8, A2 LW9 and A2 LW10.	Potential impact on stream flow, with downstream flow re-emergence. Potential effect on pool holding capacity of rock bars CCRB10 to 15. Potential iron hydroxide seepage, although iron hydroxide seepage is currently occurring.
Lizard Creek	Warrants special protection	0.25	3.0	5.0 to <-1.0	Potential for cracking of creek bed between LC5 and LC7.	No connective cracking. Low potential impact on stream flow (with downstream flow re-emergence), as well as pool holding capacity, iron hydroxide seepage or gas release due to stream bed cracking. All of these aspects are currently adversely affected by existing Bulli workings subsidence.
						Up to 12m groundwater level reduction in upper Hawkesbury Sandstone with negligible predicted consequence of between 0.02ML/day gain to 0.10ML/day reduction, or 0.2% gain to 0.8%reduction of average flow of 17ML/day in Lizard Creek (GeoTerra, 2012).
Lizard Creek Tributary 2	Yes	1.9	9.0	4 to -6	Limited potential for cracking.	No connective cracking. Limited potential impact on the upper headwaters of the stream reach flow (with downstream flow re-emergence), as well as pool holding capacity, iron hydroxide seepage or gas release due to stream bed cracking.

Feature	Special Significance Status (or warrants special protection)	Maximum Subsidence	Maximum Tilt	Maximum Strain	Impact Likelihood	Potential Consequence
Wallandoola Creek	Warrants special protection	0.5	3.0	6.0 to <-1.0	Potential for cracking of creek bed between WC3 and WC4.	No connective cracking. Potential impact on stream flow (with downstream flow re-emergence), pool holding capacity, iron hydroxide seepage or gas release. Iron hydroxide seepage is currently present. Up to 12m reduction of groundwater level in upper Hawkesbury Sandstone with negligible predicted consequence of 0.06 – 0.25ML/day, or 0.0018 – 0.0075ML/km2/day, or 0.1 - 0.6% reduction in 33.0ML/day average flow in Wallandoola Creek.
Upland Swamps						
CRUS1	Yes	0.89	17.51	4.34 to – 7.2	Low	Does not show significant risk factors that would indicate susceptibility to impact.
CCUS1	Yes	-0.40	11.38	2.65 to - 6.79	Significant	Upland swamps CCUS1 may be subject to strains that would result in fracturing of the bedrock below this swamp. Areas of Cyperoid Heath (MU44c) located above Area 1 LW3, are particularly susceptible to any loss of groundwater in this area.
CCUS4	Yes	-1	21.04	4.63 to - 8.03	Low	Upland swamp CCUS4 may be subject to strains that would result in fracturing of the bedrock below this swamp. However, the location of the base of this swamp in areas subject to lower levels of strains indicates that impacts may be reduced.
CCUS5	Yes	-1	21.3	4.78 - -8.03	Significant	Upland swamp CCUS5 may be subject to strains that would result in fracturing of the bedrock below this swamp. This upland swamp spans two longwalls and a degree of compressive and tensile strains. Further, vegetation sub-communities within this swamp are reliant on benching in the sandstone, creating rockbars that are likely to hold back sections of Cyperoid Heath (MU44c) and Tea-tree Thicket (MU43).

Feature	Special Significance Status (or warrants special protection)	Maximum Subsidence	Maximum Tilt	Maximum Strain	Impact Likelihood	Potential Consequence
CCUS10	Yes	-1	21.39	4.6 to – 8.74	Low	Upland swamp CCUS10 may be subject to strains that would result in fracturing of the bedrock below this swamp. The swamp spans a large variation in strains and is reliant on benching of sandstone to maintain areas of Cyperoid Heath (MU44c) and Tea-tree Thicket (MU43).
CRUS2	Yes	0	0	0	Negligible	Does not show significant risk factors that would indicate susceptibility to impact.
CRUS3	Yes	0	0	0	Negligible	Does not show significant risk factors that would indicate susceptibility to impact.
LCUS1	Yes	-0.87	0	0	Negligible	Does not show significant risk factors that would indicate susceptibility to impact.
LCUS27	Yes	0	0	0	Negligible	Does not show significant risk factors that would indicate susceptibility to impact.
LCUS6	Yes	-0.96	1.93		Negligible	Does not show significant risk factors that would indicate susceptibility to impact.
LCUS8	Yes	-2.66	9.15	2.75 to - 2.64	Low	There is some potential for fracturing of the bedrock below the headwater section of LCUS8; however, it is likely to be limited in extent and degree given the location of this swamp largely above the pillar for Area 3 LW1. Further, this section of the swamp supports sub-communities that are less reliant on presence of permanent and frequent groundwater, and provided surface flows are maintained to a sufficient level to inhibit growth of trees impacts are unlikely to be significant.
WCUS1	Yes	-0.72	0	0	Negligible	Does not show significant risk factors that would indicate susceptibility to impact.
WCUS11	Yes	-3.27	8.02	5.35 to - 3.81	Low	Upland swamp WCUS11 may be subject to strains that would result in fracturing of the bedrock below this swamp. However, this swamp supports only small areas of Tea-tree Thicket (MU43) at the base of the swamp that will be subject to small tensile strains. Areas

Feature	Special Significance Status (or warrants special protection)	Maximum Subsidence	Maximum Tilt	Maximum Strain	Impact Likelihood	Potential Consequence
						subject to maximum strains support sub-communities that are less reliant on presence of permanent and frequent groundwater, and provided surface flows are maintained to a sufficient level to ensure trees are killed impacts are not predicted to be significant.
WCUS4	Yes	-3.35	10.58	5.03 to - 6.97	Moderate	Valley infill sections of WCUS4 do not show significant risk factors that would indicate susceptibility to impact. Upland swamp WCUS4 may be subject to strains that would result in fracturing of the bedrock below this swamp. The lower sections of the headwater swamp are subject to greatest strains, and these areas are particularly susceptible to impact as they support areas of Tea-tree Thicket (MU43) and Cyperoid Heath (MU44c).
WCUS7	Yes	-2.19	10.7	5.45 to - 0.01	Moderate	Upland swamp WCUS7 is likely to be subject to tensile strains sufficient to result in fracturing of bedrock below this swamp. This could result in fracturing of bedrock along Wallandoola Creek. There is substantial iron staining in this section of Wallandoola Creek. The cumulative impacts of mining cannot be adequately assessed.
Aboriginal Features						
AHIMS 52-2-1183	High significance status	2.2	2	-3	Moderate	Rock shelters may be adversely affected by cracking, movement along joints or bedding planes, by block fall and by water seepage. All these impacts may directly affect the stability of the shelter and consequentially any rock art within a shelter.
AHIMS 52-2-1187	High significance status	1.5	8	-6	Moderate	As above
AHIMS 52-2-1198	High significance status	2.3	2	-2.5	Moderate	As Above
NRE Women's Site	High significance status	0.5	16	5	Moderate	Potential for cracking and other impacts assess as possible for Lizard Creek Tributary 2.

19.5 *SPECIAL SIGNIFICANCE FEATURE MANAGEMENT MEASURES*

19.5.1 *Cliffs*

The Bulli PAC recommended that any approval be based on a Performance Criteria of negligible environmental consequences for all cliffs which have special significance status. Negligible was defined as having the meaning ascribed in the Metropolitan Coal Project Approval of small and unimportant so as not to be worth considering. Occasional displacement of boulders, hairline fracturing and isolated dislodgement of slabs from overhangs that in total do not impact on more than 0.5% of the total length of a cliff line are indicative of the scale of impacts falling within this category.

The Bulli PAC also recommended that any approval be based on a Performance Criteria of minor environmental consequences for all other cliffs in the Study Area. Minor environmental consequences was defined as meaning of relatively small in quantity, size and degree. Isolated rock falls of less than 30 m^3 that do not impact on Aboriginal heritage, EECs, public safety and the like; which affect less than 5% of the total length of cliffs and associated overhangs; and which affect less than 10% of any 100m interval of cliff line are indicative of the scale of impacts falling within this category.

Some minor and negligible environmental consequences are considered possible on up to 5% of the length of cliff formations located within the area directly above proposed longwall panels. The mine plan has avoided longwall mining directly under cliffs of special significance.

Environmental consequences for cliff formations located outside the area directly above proposed panels and intermediate chain pillars are expected to be negligible.

Impacts on steep slopes are expected to be limited to potential for subsidence cracks to develop at the top of slopes that are directly mined under. The environmental consequences of impacts on steep slopes are considered to be negligible.

Monitoring and adaptive management strategies are recommended to limit mining impacts on features of special significance and this has been committed to in the draft statement of commitments.

19.5.2 *Streams*

Recommendation 21 of the Bulli PAC (2010) applied the following performance criterion to waters of special significance status, as well as Lizard and Cascade Creeks and the Georges River in West Cliff Area 5:

'no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, minimal gas releases and continued maintenance of water quality at its pre-mining standard'.

Where the predicted subsidence impacts could lead to unacceptable environmental consequences for significant natural features, the PAC adopted a strategy of specifying outcomes to be achieved for a significant feature, rather than prescribing limits for subsidence effects and/or impacts, or setting arbitrary mining setbacks.

NRE have made a commitment to prepare a detailed water monitoring plan post-approval in liaison with SCA and OEH and to the approval of DP&I. *Section 20.6* of this EA provides an outline of the proposed monitoring. The monitoring plan would be linked to precautionary and adaptive management procedures to be implemented to provide a systematic process for continually detecting impacts, validating predictions and improving mining operations to prevent adverse impacts on the streams systems overlying the proposed mining domains.

Monitoring, evaluation, and reporting on management performance and ecological impact would be integrated into the site's management systems to progress the technical understanding and predictive capability of subsidence effects, and its impacts and consequences on the site's surface water systems.

19.5.3 *Swamps*

OEH (2012), summarising PAC (2009, 2010) and DoP (2008), states that negative environmental consequences for upland swamps considered to be of special significance are undesirable. If negative environmental consequences to upland swamps of special significance are predicted to occur mine plans should be adjusted so that negative environmental consequences are unlikely.

A swamp monitoring plan has been developed for the extraction of A2 LW4 and A2 LW5 in Wonga East as part of the Biodiversity Management Plan (Biosis 2012b) and the Subsidence Management Plan Monitoring Program for A2 LW4 and A2 LW5 (Gujarat NRE 2012). These monitoring plans will be revised and updated for this application in liaison with SCA, OEH and to the approval of DP&I.

NRE has provided an undertaking that the mining operations will be modified as required through adaptive management measures informed through monitoring of actual subsidence impacts, to reduce negative outcomes.

An adaptive management plan will be developed to use the monitoring program to detect the need for adjustment to the mining operations so that the subsidence predictions are not exceeded and subsidence impacts creating a risk of negative environmental consequences do not occur in upland swamps.

20 *CATCHMENT AREA SURFACE WATER*

This chapter provides an assessment of potential impacts on the catchment area surface water resources.

20.1 *INTRODUCTION*

This chapter is based on NRE No.1 Colliery Major Expansion Stream Assessment, prepared by GeoTerra (2012a). This report has been condensed in this chapter by ERM, and reviewed by GeoTerra for accuracy.

This chapter aims to provide an understanding of the catchment area surface water environment, past mining impacts, potential new mining impacts and a range of management, avoidance and mitigation measures. For a more thorough analysis of these issues, refer to *Annex O* which provides the GeoTerra report.

20.1.1 *Assessment Framework*

Director General Requirements

This assessment has been undertaken in accordance with the relevant surface water assessment components as outlined in the Director-General's Requirements (see *Annex A*) including:

- a description of the existing environment, using sufficient baseline data;
- an assessment of the potential impacts of all stages of the Project, including any cumulative impacts, taking into consideration any relevant guidelines, policies, plans and statutory provisions and the findings and recommendations of the recent Southern Coalfield Inquiry;
- a description of the measures that would be implemented to avoid, minimise, mitigate, rehabilitate/remediate, monitor and/or offset the potential impacts of the Project, including detailed contingency plans for managing any potentially significant risks to the environment, and;
- a detailed assessment of the potential impacts of the Project on the quantity, quality and long-term integrity of the surface water resources in the Project area, paying particular attention to the Upper Nepean River sub-catchment (Metropolitan Special Area), the discharge of mine water and surface runoff into Bellambi Gully Creek and Bellambi Lagoon (Note this second part is discussed in *Chapter* 8 and *Annex B)*.

Legislation, Guidelines and Policies

The assessment has been prepared with reference to a number of guidelines, policies, and legislation, in particular the *Water Management Act 2000,* as outlined in Chapter 3 of *Annex O.*

Southern Coalfields Strategic Review and Planning Assessment Commissions

In addition, the findings of the Southern Coalfields Strategic Review (SCSR) (DOP 2008), Metropolitan PAC (2009) and the Bulli PAC (2010) have guided the impact assessment and development of the surface water monitoring regimes.

The SCSR identified that Risk Management Zones (RMZs) should be applied to all streams of 3rd order or above in the Strahler stream classification and be defined from the outside extremity of the surface feature.

The PAC reports (2009, 2010) concluded that a project should achieve 'negligible environmental consequences' which includes:

- no diversion of flow;
- no change in the natural drainage behavior of pools;
- minimal iron staining;
- minimal gas releases; and
- continued maintenance of water quality at its pre-mining standard.

Where the predicted subsidence impacts could lead to unacceptable environmental consequences for significant natural features, the PAC adopted a strategy of specifying outcomes to be achieved for a significant feature, rather than prescribing limits for subsidence effects and/or impacts, or setting arbitrary mining setbacks.

The PAC reports identified key surface water related issues to be addressed within the predicted 20mm subsidence zone including catchment yield, stream health and stream flow reduction. They also further refined the concept of RMZs as developed by the SCSR.

The SCSR and PAC reports defined *subsidence effect*, *subsidence impact* and *environmental consequence* as summarised in Chapter 3 of *Annex O*. For the purposes of this assessment, an example of each may be as follows:

- tensile strain due to the ground surface being 'stretched' as a result of undermining is a *subsidence effect;*
- a crack resulting from the tensile strain is an *impact;*
- loss of water down the crack is an *environmental consequence;* and
- the drying of a water dependent ecosystem as a result of this loss of water is a *secondary consequence* (GeoTerra 2012a).

In reference to the assessment framework requirements outlined above, GeoTerra Pty Ltd was commissioned by NRE to assess monitoring data being collected by NRE and to address any potential surface water impacts relating to the proposed extraction and associated subsidence of the Wongawilli seam extraction in the Wonga East and Wonga West areas.

The stream and swamp monitoring has been conducted to assess the:

- functional nature of flow in streams over the panels;
- creek bed and bank erosion and channel bedload;
- stream and upland swamp water quality;
- stream bed and bank vegetation;
- sediment bedload;
- presence and appearance of pools;
- the presence or absence of bedrock, stream bed or bank cracking;
- any observed or inferred groundwater discharge zones; and
- presence of hydrocarbon gas.

20.1.2 *Study Area*

The Study Area for this assessment is defined as being the area within 600m from the edge of secondary longwall extraction, and encompasses parts of the catchments of Wallandoola, Lizard, Cataract and Bellambi Creeks and Cataract River (see *Figure 20.1* and *Figure 20.2*).

20.2 EXISTING ENVIRONMENT

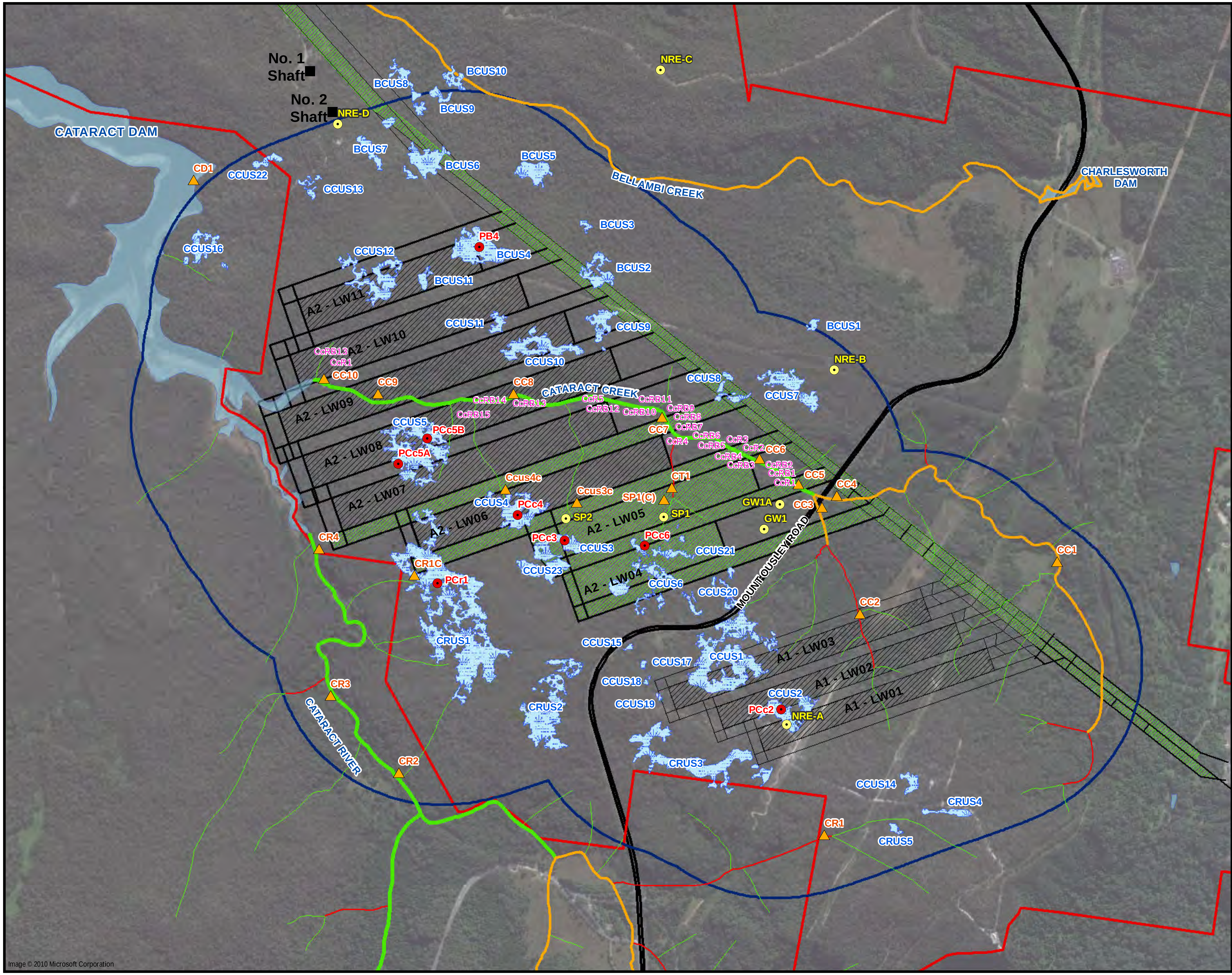
20.2.1 *General Description*

The mining area is within the SCA restricted access Metropolitan Special Area, which is principally undeveloped bushland apart from limited fire / mine site access trails, current and decommissioned mine ventilation shafts, as well as materials and personnel access shaft infrastructure sites.

NRE No. 1 Colliery is located at the southern end of the Permo-Triassic (225-270 My) Sydney Basin within the Illawarra Coal Measures, which contains the Bulli seam and underlying Balgownie and Wongawilli seams.

Outcropping Hawkesbury Sandstone is present in isolated exposures along creek lines and in elevated areas outside of the upland swamps, with a higher degree of exposure in the downstream reaches of incised creek beds to the north of the Wonga West area, along the Lizard and Wallandoola Creek catchments.

Hawkesbury Sandstone outcrops are also present in the western portion of the Wonga East area particularly in elevated areas, whilst the underlying Newport and Garie Formations, Bald Hill Claystone and a limited area of the Bulgo Sandstone are exposed along the incised bed and banks of Cataract Creek.



Legend

- Project Application Area
- Study Area
- Proposed Longwalls
- Approved Workings (MP 10_0046)
- Upland Swamps (Biosis 2012)
- Cataract Dam
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order and AboveStream
- Major Road
- Shaft Locations
- CC4 Stream Monitoring Sites (GeoTerra 2012)
- Swamp Piezometers (GeoTerra 2012)
- Basement Piezometers (GeoTerra 2012)

Figure 20.1

Proposed Wonga East Longwalls, Monitoring Locations and Stream Classification

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No.1 Colliery Environmental Assessment
Drawing No:	0079383s_EARPA2012_G020_R0.mxd
Date:	13/11/2012 Drawing size: A3
Drawn by:	SQW Reviewed by: NB
Scale:	Refer to Scale Bar

N

0 150 300 450m

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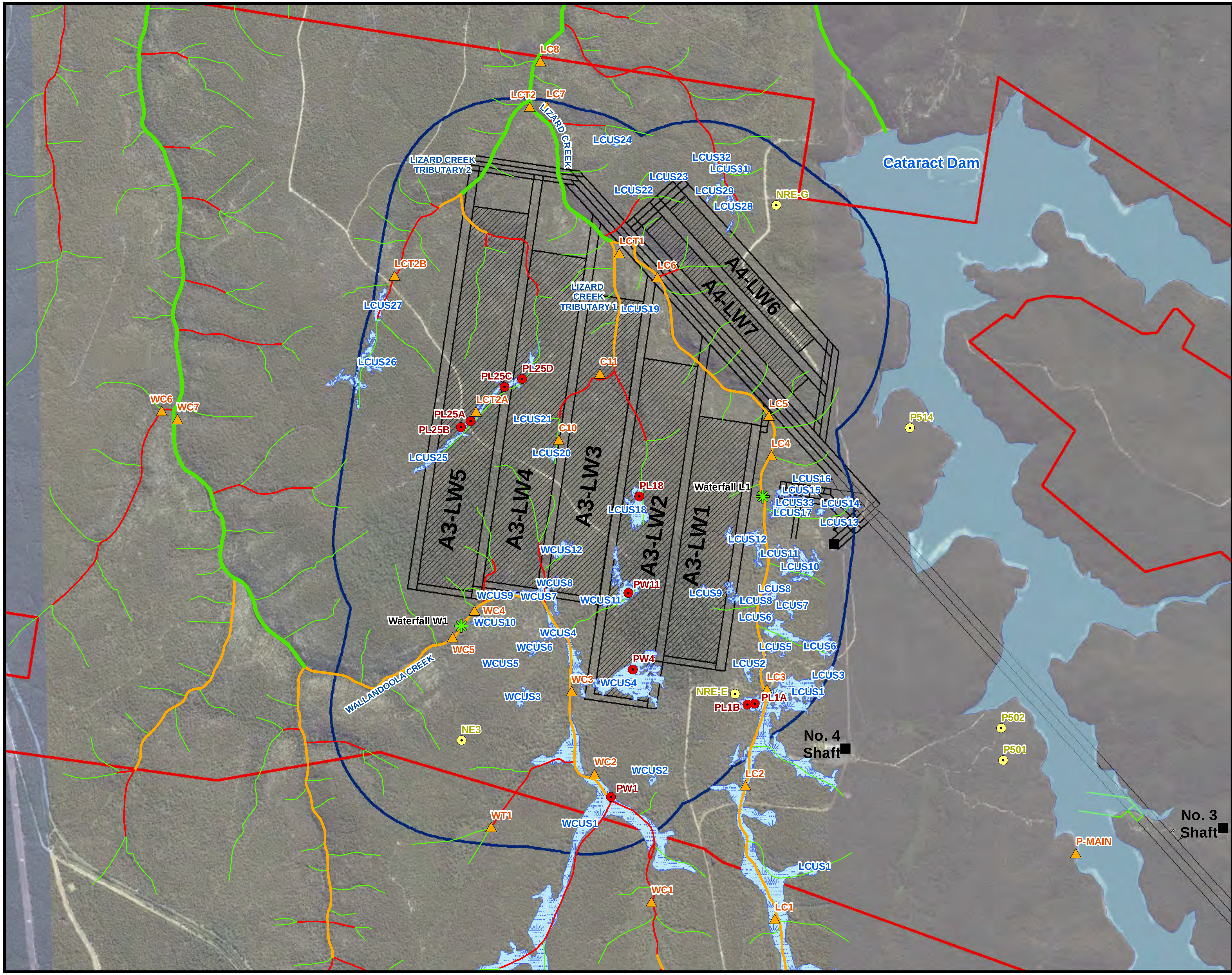

Figure 20.2

Proposed Wonga West Longwalls, Monitoring Locations and Stream Classification

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No.1 Colliery Environmental Assessment
Drawing No:	0079383s_EARPA2012_G019_R1.mxd
Date:	8/02/2013 — Drawing Size: A3
Drawn By:	SQW — Reviewed By: NB
Projection:	GDA 1994 MGA Zone 56
Scale:	Refer to scale bar

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20.2.2 *Proposed Mining and Associated Surface Water Features*

Wonga East

The proposed north east / south west trending Wonga East panels are subdivided into Area 1 to the east of Mount Ousley Road and Area 2 to the west (see *Figure 20.1*).

Area 1 comprises three, 105m wide panels with 40m wide pillars that underlie steeply sloping, northerly draining, 1st and 2nd order intermittent tributaries of Cataract Creek (see *Figure 20.1*) with a depth of cover to the Wongawilli seam of approximately 237m to 255m. The steeply sloping, easterly draining tributaries join downstream of the Area 1 longwall panels to form a 3rd order stream that in turn forms a 4th order stream to the west of Mount Ousley Road.

Area 2 comprises eight, 150m wide panels with 60m wide pillars that underlie 1st and 2nd order tributaries and the 4th order channel of Cataract Creek with approximately 267m to 320m depth of cover. A small proportion of the Bellambi Creek catchment overlies Area 2 Longwall Panels 10 and 11 (see *Figure 2.1*).

A small portion of the western end of Longwall Panel A2 LW10 also underlies the 289.87m AHD high water mark of Cataract Reservoir, in the upper backwaters of Cataract Creek, and during periods of high water levels in the dam, the panel edge may underlie this.

Fourteen upland swamps that meet the definition of the Coastal Upland Swamp Endangered Ecological Community lie within the predicted 20mm subsidence zone (see *Figure 20.1*).

Of these, seven were assessed to be of 'special significance' in accordance with the OEH criteria, and of those, five were predicted to be potentially subject to subsidence effects. A detailed discussion of upland swamps in Wonga East is provided in *Section 22.3.1* and *Annex Q*.

The proportion of catchment areas to be undermined in Wonga East is provided in *Table 20.1*.

Table 20.1 Stream Catchments in the Wonga East 20mm Subsidence Zone

Stream	Total Catchment (km^2)	Catchment within 20mm subsidence zone (km^2)	% of Catchment
Cataract Creek	5.2	2.5	48.1
Bellambi Creek	9.3	0.05	0.5
Cataract River	11.6	0.4	3.4

1. Source WRM Water and Environment in GeoTerra (2012a).

The panels are positioned so that vertical subsidence under 3rd or higher order stream channels will be restricted to less than 250mm, except over Longwall Panel A2 LW8 where subsidence may extend up to 0.8m in Cataract Creek.

All panels will be extracted down dip from south to north. The use of wide chain pillars at Wonga East provides a management tool for subsidence risks on Cataract Creek and the upland swamps (Seedsman, 2012).

Wonga West

The Wonga West panels are subdivided into Area 3, to the south west of Lizard Creek, and Area 4, to the north east of Lizard Creek, with the panel layout designed to avoid subsidence related cracking developing in the bed of Lizard or Wallandoola Creeks (see *Figure 20.2*)

No extraction is proposed under the main channel of Lizard Creek or Wallandoola Creek or under Cataract Reservoir. The proposed Wonga West main headings will be aligned with, and located in close proximity to, or underneath, Lizard Creek as shown in *Figure 20.2)* The panels are greater than one kilometre from the Cataract Reservoir dam wall and workings are positioned to avoid generating a hydraulic connection via subsidence cracking between the 20mm subsidence zone and the waters of Cataract Reservoir.

All seven panels in the Wonga West area underlie the watersheds and steeply sloping ephemeral 1st order and intermittent 2nd order tributaries of Lizard Creek and Wallandoola Creek. In addition, the 3rd order reach of the Lizard Creek tributary (LCT1) overlies Longwall Panel A3 LW3, along with a short reach of a 3rd order Lizard Creek tributary (LCT2) over panel A3 LW5.

The depth of cover to the Wongawilli Seam ranges from approximately 455m to 510m in Area 3, and approximately 460m to 495m in Area 4.

Thirty six swamps that meet the definition of the Coastal Upland Swamp Endangered Ecological Community lie within the predicted 20mm subsidence zone (see *Section 22.3.1* and *Figure 20.2*). Of those, eight were assessed to be of 'special significance' in accordance with the OEH criteria, and of those, seven were predicted to be potentially subject to subsidence effects. A detailed discussed of upland swamps in Wonga West is provided *Section 22.3.1* and *Annex Q*.

The proportion of catchment areas to be undermined in Wonga West is provided in *Table 20.2*.

Table 20.2 Stream Catchments in the Wonga West 20mm Subsidence Zone

Stream	Total Catchment (km^2)	Catchment within 20mm subsidence zone (km^2)	% of Catchment
Lizard Creek	17.1	6.3	36.8
Wallandoola Creek	33.2	2.0	6.0

1. Source WRM Water and Environment in GeoTerra (2012a).

20.2.3 *Stream Description*

Cataract Creek, Cataract River and Bellambi Creek are regulated catchments located upstream of Cataract Reservoir in the Wonga East area, whilst Lizard and Wallandoola Creeks are located in the Wonga West area, are unregulated and drain to the Cataract River downstream of the Cataract Reservoir dam wall.

Wonga East

A full description of the Wonga East stream morphology is provided in Chapter 10 of GeoTerra (2012a) in *Annex O* while a summary is provided in the following pages and *Figure 20.2* indicate stream classifications.

Cataract Creek flows in a westerly direction over Area 1 and 2 and the main channel has previously been undermined by longwalls in the Balgownie seam as well as bord and pillar workings in the overlying Bulli seam. Cataract Creek flows directly into Cataract Reservoir over the western end of Longwall Panel A2 LW10, (and Longwall Panel A2 LW9 during periods of high water levels in the reservoir) while its headwaters are located immediately to the west of the Illawarra Escarpment. It is not regulated by any dams or weirs.

The headwater tributaries have eroded through the Hawkesbury Sandstone and, in the deeper eroded areas, through to the Bald Hill Claystone and the underlying Bulgo Sandstone. The main channel has eroded sequentially into the Hawkesbury Sandstone, Newport and Garie Formations, and Bald Hill Claystone, with the Bald Hill Claystone and Bulgo Sandstone being exposed in the lower reach of the creek upstream of the reservoir and downstream of the freeway.

The creek is relatively steep, particularly in the two headwater valleys over Area 1 between monitoring sites CC1 to CC2 and CC3 to CC4 (see *Figure 20.1*). Downstream of Mount Ousley Road (between CC5 and CC9) there are a series of elongated pools that are constrained by low (<0.5m high) shallow rock bars, which predominate in the upper to mid-section, along with occasional, sand to gravel sized riffle sections that also predominate in the upper to mid-section of the study reach. Significant reaches of sandy based substrate dominate between CC7 and CC9, which has developed over an eroded, interspersed shale and sandstone sequence.

A limited number of rock bar constrained pools are present between CC7 and CC9, although two moderate sized pools of less than 2m deep have developed at significant bends at rock bars CcRB13 and CcRB14.

No waterfalls or highly stepped zones are present in the creek.

The stream bed and banks of the plateau streams are well vegetated and do not show significant erosion or bank instability. From the edge of the escarpment to downstream of Mount Ousley Road, heavily vegetated rainforest is developed which transgresses into heavily wooded forest between Mount Ousley Road and the Cataract Reservoir.

Ferruginous precipitation is generally observed at site CC5 and downstream of tributary CT1.

Photograph 20.1 shows a typical stream reach in Cataract Creek.

Photograph 20.1 Typical Stream Reach of Cataract Creek over A2 LW8 (GeoTerra, 2012a)

Given that Cataract River is not to be undermined and it is predicted that is will not be impacted by the mine in Area 1, detailed geomorphological assessment of the reach between the catchment headwaters and Mount Ousley Road has not been undertaken (GeoTerra 2012a).

Wonga West

A full description of the Wonga West stream morphology is provided in Section 10.1, 10.2 and 10.4 of GeoTerra (2012a) in *Annex O* and a summary is provided in the following pages.

Lizard Creek and Wallandoola Creek vary along their reach from 'losing streams' in the southern headwaters, where the shallow groundwater system is recharged from stream flow seeping from the creek to 'gaining streams' in the middle and northern portions of the PAA, where the creeks are incised into Hawkesbury Sandstone and recharged by groundwater baseflow.

Seepage rates from the Hawkesbury Sandstone are understood to be variable and can maintain a low volume stream baseflow, depending on the interaction between rainfall runoff / recharge and groundwater level applying at any one time.

Differentiation between the distribution of 'losing' and 'gaining' streams also varies depending on the amount of rainfall recharge into the sandstone plateau and the resultant standing water levels within the regional groundwater system.

Upstream of the incised stream sections and waterfalls, the two catchments are separated by a 15m to 25m high watershed, with the watershed height increasing significantly downstream of the waterfalls, where between 55m to 85m deep valleys are located in the northern, downstream section of the lease area.

Four channel types are present within the creeks:

- valley infill upland swamps with an indistinct channel;
- narrow indistinct overgrown channels associated with a low sedge / heath and a relatively thick sandy riparian soil with a streambed consisting of weathered bedrock and/or sandy material;
- rock platforms of variable width which are usually smooth except for minor depressions on joint planes and occasional potholes. These platforms normally grade into a thinly vegetated sandy soil on either bank and can exhibit deposition of hydrated iron oxide observed as orange to black discolouration of the rock surface; and
- channels incised in sandstone that exhibit rough riffle like surfaces, usually with accumulations of boulders and other sediments. These channels are usually bound by solid rock outcrop.

Four pool types can be present:

- shallow, linear, small pools located in depressions formed by joint systems or cross-bedding and sometimes associated with potholes. Accumulated water is usually less saline than in surrounding pools and have minor to no interaction with the local groundwater system;
- linear pools associated with narrow erosion channels in sandy soil. The soil is usually vegetated with heath like species, whilst the downstream end is constrained by a rockbar or outcrop;
- larger pools constrained by a downstream rockbar which can be undercut by erosion and exhibit signs of chemical weathering; and
- larger pools constrained downstream by sediments. The sediments may extend for a considerable distance downstream.

Wallandoola Creek

Wallandoola Creek flows in a northerly, then westerly direction within Wonga West Area 3 and has previously been undermined by longwall mining in the Bulli seam in both the BHP Cordeaux and NRE leases. Wallandoola Creek does not overlie the proposed Wongawilli seam panels, but is contained within the 20mm subsidence envelope to the south of Longwall Panels A3 LW3 and A3 LW4.

Within the Wonga West 20mm subsidence zone, the main channel of Wallandoola Creek is a Schedule 2, 3rd order stream (GeoTerra, 2012a) with ephemeral 1st and intermittent 2nd order tributaries, becoming increasingly incised into Hawkesbury Sandstone as it drains downstream. Wallandoola Creek becomes a 4th order stream approximately 1.7km downstream of the proposed workings (see *Figure 20.2*)

Wallandoola Creek joins the Cataract River approximately 8km (or 11km along the stream reach) north west of the Study Area edge, downstream of the Cataract Reservoir dam wall. Its headwaters are located south of the PAA over the previously longwall mined BHP Cordeaux Colliery workings. The creek is not regulated by any dams or weirs within the Study Area.

The stream gradient generally increases with distance downstream in the Wonga West Area 3. Wallandoola Creek in the Wonga West area is characterised by a long linear pool and rock bar at WC1 (see *Photograph 20.2*) and downstream a valley infill swamp, which overlies the BHP Cordeaux longwall subsidence area, upstream of the PAA boundary.

Photograph 20.2 Linear Pool and Rock Bar at WC1 on Wallandoola Creek, upstream of PAA (GeoTerra, 2012a)

Downstream of WC3 (see *Figure 20.2)*,Wallandoola Creek reverts back to an approximately 110m long valley infill swamp, then transposes into an approximately 300m long linear pool followed by a restricted channel flowing over exposed sandstone, at the downstream end of which is a pool with a distinct iron hydroxide orange colouring. The coloured pool terminates at a rock bar with a less than 3m high shallow 'step' and a 'clear' approximately 1.7km long pool situated immediately upstream of the less than 5m drop into a plunge pool at WC4.

Waterfall W1 has two major 'steps' of 11m and 16m, for a total drop of approximately 30m over a 1.1km stream reach. Downstream of the waterfalls, and outside of the 20mm subsidence zone, the stream gradient flattens out to a series of extended pools constrained by rock bars.

The waterfall is affected by cracking in the sandstone, as the stream has not been observed to flow over the falls during 'dry' periods (see *Photograph 20.3*) (GeoTerra 2012a). The sandstone streambed located approximately 100m upstream of Waterfall W1 is situated over the western edge of the old Bulli seam workings subsidence area, and it is assessed that the stream bed cracks are due to mine subsidence. Downstream of the waterfall, the plunge pool containing Site WC5 maintains a consistent pool, with a distinct orange ferruginous colour.

Photograph 20.3 Waterfall W1 on Wallandoola Creek (GeoTerra, 2012a)

The stream bed and banks of the plateau streams are well vegetated, and do not show significant erosion or bank instability.

Lizard Creek

Lizard Creek flows in a north to north westerly direction between the proposed Wonga West Area 3 and Area 4 mining domains. The creek has previously been undermined by longwall mining in the Bulli seam in both the BHP Cordeaux and NRE leases.

Lizard Creek does not overlie the proposed Wongawilli panels, although it is contained within the 20mm subsidence envelope.

The main channel of Lizard Creek upstream of Lizard Creek Tributary 1 is a Schedule 2, 3rd order stream (GeoTerra, 2012a) with ephemeral 1st to intermittent 2nd order tributaries, and becomes increasingly incised into Hawkesbury Sandstone as it drains downstream of Waterfall L1. Downstream of Lizard Creek Tributary 2 it is a 4th order stream with 1st to 3rd order tributaries (see *Figure 20.2*).

Lizard Creek joins the Cataract River approximately 6km (or 7km along the stream reach) to the north of the Study Area edge, downstream of the Cataract Dam wall, while its headwaters are located to the south of the PAA over the previously mined BHP Cordeaux Colliery longwall workings. The creek is not regulated by any dams or weirs.

Lizard Creek in the Wonga West area is characterised by a series of valley infill fringing upland swamps and pools between LC1 and just downstream of LC3. The pool levels are supported behind exposed sandstone rock bars, often with less than a 0.5m drop between pools which range up to approximately 500m long.

Shrubs, grasses and trees dominate along the creek banks downstream of LC3 where the stream becomes increasingly more incised into sandstone. The stream bed can be dry for a stream reach of approximately 750m between the downstream termination of valley fill swamp Lcus4 and the approximately 200m long, orange discoloured permanent pool upstream of Waterfall L1.

A 26m high waterfall / stepped zone (Waterfall L1) is located between LC3 and LC4. The waterfall is not observably affected by previous subsidence related cracking as it is located over an area of low subsidence Bulli seam first workings, however significant 'natural' underflow / through flow is observed to exit the face of the waterfall through bedding planes and joints.

Downstream of the waterfall, the stream flows through a sequence of elongated pools, rock bars, boulder fields and rock shelves to LC4 and onto LC5.

The creek has been observed to dry out after extended low rainfall periods between LC5 and LC6 over approximately 1.3km of stream reach in an area of sequential pools, rock bars, boulder fields and sandy sediment based pools. Permanent stream flow and pool depth is re-instated at LC6, where the water is highly orange iron hydroxide affected. Between LC6 and downstream of LC7, the stream gradient flattens out where permanent elongated pools held behind rock bars are prevalent. The northern boundary of the Gujarat lease is located at LC8, which is located in a permanent elongated pool held back by a sandstone rock shelf. From the lease boundary, the creek gradient steepens, with a series of pools held behind rock bars and elongated sandstone shelves, ending in a 20m high step / waterfall zone. Downstream of the waterfall, Lizard Creek subsequently flows into Cataract Creek.

Plates 2A, 2B and 3 in *Annex O* show the changes in morphology within the PAA.

The stream bed and banks of the plateau streams are well vegetated, and do not show significant erosion or bank instability.

Two 3rd order tributaries flow into Lizard Creek over Area 3. Lizard Creek Tributary 1 (LCT1) has its headwaters over proposed Area 3 Longwalls LW2 and LW3, with the 3rd order reach overlying the northern end of Longwall 3, downstream of monitoring point C11. Swamp LCUS18 is located in its headwaters.

All of the 1st, 2nd and 3rd order components of LCT1 have previously been subsided by the Bulli seam longwalls, with stream bed cracking, subsurface transfer of stream flow and ferruginous seeps present in the channel. During extended dry periods, the 3rd order reach of the tributary can be dry.

The headwaters of Lizard Creek Tributary 2 (LCT2) originate in upland swamp LCUS25, which overlies the proposed Area 3 Longwalls LW4 and LW5, as well as swamp LCUS26, which lies to the west of the proposed longwalls.

The 1st and 2nd order tributaries flow over Area 3 Longwalls LW4 and LW5, joining as a 3rd order stream in the northwest corner of the proposed LW5, which then becomes 4th order over the proposed first workings.

Tributary LCT2A and swamp LCUS25 have been undermined by first workings in the Bulli seam, although the downstream end of LCUS25 has also been partially undermined by Longwall 310. Tributary LCT2B and swamp LCUS26 have not been undermined.

The 3rd and 4th order reach of Tributary LCT2 generally contains flowing or ponded water and does not have significant ferruginous precipitates, although it tends to be ponded during extended dry periods.

20.2.4 *Stream Flow and Pool Depths*

Pool height monitoring and subsequent initial volumetric stream flow monitoring has been conducted at various sites within Lizard Creek, Wallandoola Creek, Cataract Creek and Cataract River since September 2009, to provide baseline data for identification of any adverse effects on stream flow continuity, stream ponding and pool drainage rates and holding capacities. A detailed description of the monitoring that has been undertaken to date is provided in Section 10.4 of *Annex O*.

20.2.5 *Water Quality*

Water quality monitoring in the Study Area commenced in September 2001 with data collected generally bimonthly from July 2007. Monitoring has been undertaken at six sites in Wallandoola Creek, nine sites in Lizard Creek and seven sites in Cataract Creek. Details of the regular stream water quality and water level monitoring locations are provided in Section 10.5 of *Annex O*.

Monitoring parameters have included:

- pH;
- dissolved oxygen (DO);
- salinity (electrical conductivity, EC);
- temperature;
- redox potential (Eh);
- total and filtered iron (Fe);
- total and filtered manganese (Mn);
- sulphate levels (SO4);
- zinc (Zn);
- copper (Cu);
- total nitrogen (N);
- total phosphorus (P); and
- aluminium (Al).

Wonga East

Along Cataract Creek, monitoring sites CC1 to CC5, CC9 and CD1 have been monitored on a bi-monthly basis since August 2008. Monitoring at CC10 commenced in 2008 and was discontinued shortly thereafter when it was assessed that the site was within the high water mark of the dam. Additional monitoring sites have been sequentially installed for upland swamp monitoring at CCUS2, CCUS3, CCUS4, CCUS5 and CCUS6 (March 2012), and at CT1 (April 2012), with monitoring sites CC6 to CC8 currently being established.

The pH of Cataract Creek ranges from 4.84 to 6.56, with a median pH trend rising from 5.5 to 6.1 down the length of its catchment. This pH range is outside the ANZECC 2000 South Eastern Australia Upland Stream criteria.

The median creek salinity ranges from 130 – 145 µS/cm, with the median salinity reducing with distance downstream.

A peak in sulfate has been identified in the CC2 to CC3 tributary, which could represent the dissolution of sulfuric acid following iron sulfide weathering as a result of shallow subsurface flow through cracks in the subsided and cracked basement strata and / or weathering of the Hawkesbury Sandstone units.

Monitoring indicates the creek is within the acceptable range for potable water, however it is generally outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines depending on the flow conditions at the time of sampling for the following:

- filtered zinc at CC1, CC4 and CD1, with a high variability;
- filtered copper occasionally;
- aluminium on one occasion at CC1;
- total phosphorus at all sites, generally; and
- total nitrogen, at all sites, infrequently and with a high variability.

Cataract River stream flow, height and water quality monitoring commenced in May 2012 at three sites (see *Figure 20.1)*

During the limited monitoring period, the pH of the river has ranged from 5.1 to 6.4, and salinity has ranged from 52 – 117 µS/cm. This pH range is outside the ANZECC 2000 South Eastern Australia Upland Stream criteria.

Ongoing data collection will provide longer term trends for iron, manganese and sulfate.

Monitoring to date indicates the creek is within the acceptable range for potable water, however is generally outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines depending on the flow conditions at the time of sampling for filtered zinc, total phosphorus and total nitrogen.

Wonga West

Water quality monitoring in Wallandoola Creek commenced in 2001, with regular monitoring undertaken since 2007.

The pH in Wallandoola Creek ranges from 3.35 to 6.83, with the median pH ranging from 5.49 to 6.19. This pH range is outside the ANZECC 2000 South Eastern Australia Upland Stream criteria.

Salinity in the creek ranges from 53µS/cm to 199µS/cm and generally rises by approximately 70µS/cm between sites WC1 and WC6. Since regular monitoring began, it has been observed that the stream's median salinity generally rises with distance downstream then becomes less saline downstream of site WC5.

Iron levels in the creek do not show any significant recurring trend with distance downstream apart from an isolated peak in iron oxy-hydroxide precipitation at WC4 over Longwalls 209 and 210 near the major bend in the creek. Median total iron levels discharging from downstream of the subsided Bulli workings is 0.5mg/L.

Monitoring indicates the creek is within the acceptable range for potable water, however it can exceed the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for the following parameters, depending on the flow conditions at the time of sampling:

- filtered zinc at all sites for the majority of the time;
- total nitrogen at some sites for part of the time with no regular pattern;
- total phosphorus occasionally at each site, with no regular pattern; and
- filtered copper occasionally.

The pH in Lizard Creek ranges from 2.50 to 7.1. It shows a general trend to lower acidity downstream, except between LC5 and LC6 during low flow periods where the stream has a subterranean flow and downstream upwelling component.

Since July 2007, the creek has had a slight overall rise in pH (ie becomes less acid) by approximately 0.5 to 1.0 pH unit. This pH range is outside the ANZECC 2000 South Eastern Australia Upland Stream criteria.

The creek salinity ranges from 19µS/cm to 290µS/cm and generally rises by approximately 60µS/cm between LC2 and LC8, outside of the LC5 to LC6 reach. Since regular monitoring began in July 2007, it has been observed that the stream's overall average salinity rises with distance downstream by approximately 90µS/cm.

The median total and filtered iron levels discharging to Cataract River at, and downstream of LC8 are approximately 0.64mg/L and 0.17mg/L respectively.

A peak in sulfate is generally identified at LC4 and LC5, downstream of waterfall L1, after which sulfate falls at LC6, then gradually rises downstream. The rise in sulfate would relate to a marginal rise in sulfuric acid generation through iron sulfide weathering as a result of enhanced subsurface flow through cracks in the subsided Hawkesbury Sandstone over and downstream of the subsided Bulli longwalls.

Monitoring indicates the creek is within the acceptable range for potable water, however is generally outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines depending on the flow conditions at the time of sampling for:

- filtered zinc occasionally at all sites, with a high variability;
- total nitrogen and total phosphorus at all sites, infrequently;
- nickel and filtered copper, occasionally; and
- aluminium, very infrequently.

20.2.6 *Stream Significance*

The SCI identified that streams of the Southern Coalfields are considered a high priority for protection if they have some or all of the following characteristics:

- perennial or intermittent/ephemeral streams with pools;
- a diverse array of in-stream habitats that provide feeding, breeding or drought refuge; and/ or
- they support threatened species, iconic species or a high diversity of species (DECC 2007a).

The parameters that contribute to whether a stream is of special significance as outlined in the Bulli Seam Operations PAC (2010) include:

- importance to catchment yield;
- significance to water supply;
- permanence of flow;
- stream water quality;
- ecological importance;
- environmental quality (pristine, modified, severely modified);
- visual amenity (eg cascades runs, pools etc);
- community value (value the community attributes to protection); and
- regional significance.

The PAC reports note that the assessment of stream significance should indicate the qualities of a waterway that characterise its environmental and aesthetic value. Application of one of the standard assessment approaches could provide a consistent basis for comparing the condition of the waterway before and after the impacts of mining.

The Metropolitan PAC report (2009) noted that assessment of the significance of individual watercourses in the context of acceptability of the risk of subsidence impacts and consequences, is difficult, and also noted the absence of objective measures of significance and the lack of policy guidance on this issue. A series of five steps were suggested by the Metropolitan PAC report to ensure adequate relevant information is available to the decision maker and to focus attention on key issues. These steps are listed in Section 12 of *Annex O*.

An assessment of stream values has been undertaken for the Project and is presented in Appendix B of *Annex O*. The stream significance assessment has been conducted in accordance with the procedures outlined in the SCI and the Metropolitan and Bulli Seam Operations Planning Assessment Commission reports. Only stream reaches within the predicted Wongawilli seam workings 20mm subsidence zone were considered in this assessment.

Details of the assessment are contained in GeoTerra (2012a) in *Annex O* and summarised in *Table 20.3*. An assessment of ecology significance is contained in *Chapter 23*.

Table 20.3 Stream Reach Significance Summary

	Significant	Reason
Wonga East		
Cataract Creek (upstream of Cataract Reservoir)	Yes	Permanent Flow. Macquarie Perch and Silver Perch present and potential habitat for Adams Emerald Dragonfly ,although not identified on site (refer Section 12.3 of *Annex O*).
Cataract River (in 20mm subsidence zone upstream of Cataract Reservoir)	Yes	Permanent Flow. Macquarie Perch and Silver Perch present and potential habitat for Adams Emerald Dragonfly and Sydney Hawk Dragonfly, although not identified on site (refer Section 12.4 of *Annex O*).
Wonga West		
Lizard Creek	**Warrants special protection**	Conforms to some of the special significance criteria (refer Section 12.1 of *Annex O*), however was not considered to qualify for 'special significance' by the Bulli PAC on the basis of degradation resulting from previous mining. As a result, the 3rd order or higher reach of the main channel of Lizard Creek within the Study Area is not deemed to have special significance.
Waterfall L1	Yes	It has an absence of adverse effects due to a lack of subsidence as it overlies an area of only first workings in the Bulli seam, although it does have elevated ferruginous precipitates in its vertical seepage face.
LCT1	No	Conforms to some of the special significance criteria (refer Section 12.1.2 of *Annex O*), however was not considered to qualify for 'special significance' by the Bulli PAC on the basis of degradation resulting from previous mining. As a result, the 3rd order reach of LCT1 is not deemed to have special significance.

	Significant	Reason
LCT2	Yes	Conforms to some of the special significance criteria (refer Section 12.1.3 of *Annex O*), thus the 3rd order reach of LCT2 is deemed to have special significance.
Wallandoola Creek	**Warrants special protection**	Conforms to some of the special significance criteria (refer Section 12.2 of *Annex O*), however on the basis of degradation resulting from previous mining within the reach in the Study Area (WC4-WC5), is not considered to have special significance.
Waterfall W1	Yes	Not considered of special significance on the basis of degradation of the stream bed, however is considered to be of special significance as a cliff structure.

20.3 *PAST MINING IMPACTS*

20.3.1 *Introduction*

The previous operators of NRE No.1 Colliery and the decommissioned BHP Billiton Cordeaux Colliery to the south and west of NRE No.1 Colliery have undermined sections of both Lizard and Wallandoola Creeks in and adjacent to the proposed Wonga West area.

Bord and pillar extraction of the Bulli seam, along with longwall mining in the Balgownie seam was conducted to the east of Cataract Reservoir at Wonga East. In the 200 series longwalls, no subsidence was measured with 190m wide panels and 35m wide chain pillars, while the same layout to the north in the 300 series panels, recorded 0.9m of subsidence. Longwall mining generated a maximum vertical subsidence of 1.1m for 155m wide longwalls with 30m wide pillars, while the 205m wide panels in Cordeaux Colliery with 30m wide chain pillars generated up to 1.3m of subsidence (Seedsman, 2012).

Monitoring at Bellambi West indicated rock fracturing extended to approximately 100m above the Bulli seam, while monitoring between Longwalls 501 and 502 indicates that the hydraulic integrity of the Bulli seam and the Hawkesbury Sandstone was not adversely affected (Seedsman, 2011).

No publicly available pre and post mining surveys of the creek flow and water quality are known to be available over the BHPB Cordeaux longwalls.

The following sections outline the observed effects of subsidence due to the previous extraction of the Bulli seam and the underlying Balgownie seam in the Study Area.

In general, where adverse subsidence effects are noted on stream flow and ponding, there is an associated precipitation of an orange brown coloured iron hydroxide floc, which raises the total filtered iron contect of the stream water.

No enhanced stream bed or bank erosion has been observed within Lizard, Wallandoola or Cataract Creeks, apart from the headward erosion at the downstream end of the valley fill swap section of swamp Lcus4 in Lizard Creek.

20.3.2 *Wonga East*

Cataract Creek has been undermined by the Bulli seam bord and pillar as well as Balgownie seam longwall workings.

The 1st and 2nd order tributaries containing Sites CC1 to CC4 and CC2 to CC3 (see *Figure 20.2)* have been continuously flowing during all site visits and have not been observed to dry out, and usually contain ferruginous precipitates.

The 4th order stream channel between CC5 and CC9 has also been continuously flowing, and ferruginous precipitation is generally observed at site CC5 and downstream of tributary CT1.

No evidence of stream bed cracking, flow loss or adverse effects on pool levels has been observed in Cataract Creek in the areas undermined by the Bulli, Balgownie or Wongawilli seam workings.

20.3.3 *Wonga West*

The Wonga West area has undergone up to approximately 1m of subsidence following extraction of the 200 and 300 series longwalls and both Wallandoola Creek and Lizard Creek, as well as their associated upland and valley infill swamps, have been previously undermined by the Bulli seam workings.

Both Wallandoola Creek and Lizard Creek have also been previously undermined by longwall panels of the BHP Cordeaux workings to the south of the NRE PAA. No published studies have been conducted on the subsidence effects over the Cordeaux workings on stream flow, water quality or upland swamps. As a result of the lack of pre or post mining data, it is not possible to indicate whether, or not, subsidence has had an adverse effect on the surface water system over the BHP Cordeaux panels.

Inspection of the various surface water features above the Wonga West area has revealed a range of impacts attributable to previous mining induced subsidence. Full details and photographs of these observations are provided in Section 11 of *Annex O*. In summary, several streams show evidence of bed cracks leading to pond lowering or total drying, loss of flows, discharge of iron precipitate rich waters, and headward erosion. A sample of photographs from GeoTerra (2012a) follows.

Photograph 20.4 Bed cracking adjacent to a pool in Wallandoola Creek (WC4) (GeoTerra, 2012a)

Photograph 20.5 Bed cracking in a dry pool on Lizard Creek downstream of Lcus4 and upstream of Waterfall L1 (GeoTerra, 2012a)

Photograph 20.6 Ferruginous flows into Lizard Creek downstream end of Swamp Lcus4 (GeoTerra, 2012a)

Photograph 20.7 Headward erosion of valley infill swamp (Lcus4) in Lizard Creek (GeoTerra, 2012a)

Photograph 20.8 Ferruginous pond on a Lizard Creek Tributary LCT1 (GeoTerra, 2012a)

20.4 *POTENTIAL IMPACTS*

20.4.1 *Stream Flow, Rock Bars and Pool Holding Capacity*

Assessment Approach

The assessment of potential impacts to streamflow and ponding has been guided by the outcomes of the Bulli PAC. As a result, this assessment of potential effects on stream flow and pool water holding capacity of the subject streams places the emphasis on predicted strains in creek valleys, rather than predicted valley closure.

Wallandoola Creek

Based on the less than 20mm of predicted subsidence and associated low strains, it has been assessed that there will be no adverse consequences in the Wcus1 and Wcus2 valley infill swamps and associated sandstone based / rock bar constrained elongated pools up to the main bend in Wallandoola Creek, downstream of site WC3 at Wonga West Area 3.

The predicted strains of up to 6mm/m in the reach up to midway between Site WC3 and WC4 is not expected to generate any adverse effects on stream flow as the channel is dominated by either sandy based sediments or thick valley infill swamp vegetation, which can absorb low strain levels without generating connected stream bed cracking and the associated loss of stream flow or enhanced pool drainage.

At the northern extent of the main bend in Wallandoola Creek, to the south of proposed Longwall Panels A3 LW3 and A3 LW4, and upstream of Site WC4, the predicted stream bed subsidence ranges from 0.25 – 0.5m (Seedsman, 2012), which could cause adverse consequences.

The predicted strains of up to 6 mm/m in the stream bed directly south of proposed Longwall Panels A3 LW3 and A3 LW4 could generate cracking in the exposed Hawkesbury Sandstone. The degree and extent of cracking is difficult to determine, however it could potentially enable enhanced drainage of the approximately 100m long pool upstream of the rock shelf. If subsidence effects do occur, it could manifest through rock bar leakage or transfer to the underlying sandstone substrate through the pool base.

Cracks generally form in the base of a stream and are generally prevalent in more incised reaches where sandstone lifts and 'dilates'. Based on observations in similar topography to Wallandoola Creek, the cracked zone can extend up to 10m below surface. Studies into the depth of dilation of a river bed due to upsidence and closure of Waratah Rivulet at Metropolitan Colliery indicate that cracking occurred to 9m within a zone monitored to 27m below surface in a 60m wide valley that subsided by up to 1.3m, with 140mm of vertical dilation of the strata due to uplift (Mills and Huuskes, 2004 in GeoTerra, 2012a).

Given that the stream bed upstream of Waterfall W1 is already affected by previous Bulli seam subsidence, if cracking occurs directly beneath the subject reach of the stream, it is assessed that any through flow into the cracks will re-surface downstream.

Due to the sequential and migratory development of uplift as mining progresses panel by panel, the development of stream bed cracking may also migrate downstream as mining advances from Longwall A3-LW2 to A3-LW4. If cracks develop, water flow to the new voids may occur as the strain sequentially develops along the creek bed, with the rate of inflow controlled or modified by the:

- time frame of uplift;
- location of uplift;
- depth and width of cracking in the bedrock; and
- degree of filling in cracks with sediment.

Modification of stream flow can affect the function and integrity of ecological systems, whilst enhanced recharge from streams to shallow aquifers can raise the underlying groundwater table and potentially dry up restricted portions of a stream.

It is possible, although not anticipated to be likely, that cracking could occur in the creek bed to the south of Longwalls A3-LW3 and A3-LW4, which could lead to loss of flow into the underlying dilated strata or enhanced drainage of pools. However, if it did occur, the cracking is not anticipated to generate a net loss of water volume discharge from subsidence affected creek systems since the subterranean flow, if it occurred, would re-emerge under gravity drainage further downstream in the catchment.

After heavy rain, the majority of runoff would flow along the creek bed, with a lesser proportion flowing through the dilated, subsided strata, whilst during low flows, a greater proportion of water would move as underflow through the shallow stream bed substrate.

It is not anticipated that the predicted strains of between 1 – 3 mm/m and subsidence of 0.02 – 0.25m at the rock shelf constrained pool immediately upstream of Site WC4 and to the south of longwall A3-LW5 will be sufficient to adversely affect the stream flow or water holding capacity of the subject pool.

Based on the subsidence assessment, valley closures of up to 200mm and upsidence of up to 120mm could occur.

No adverse subsidence effects, impacts or consequences are anticipated at or downstream of Waterfall W1 due to very low levels of predicted subsidence and strains at that location.

Groundwater modelling indicates a potential 12m reduction in groundwater levels and an associated baseflow reduction to Wallandoola Creek of 0.06 ML/day after the end of Stage 1 (V Mains and Area 1 and 2) and 0.25 ML/day at the end of Area 4). It is assessed that this would generate negligible environmental consequences except potentially during extended dry periods due to depressurisation in the upper Hawkesbury Sandstone aquifer in the gaining portions of the stream, downstream of Waterfall W1.

No reduction in stream flow is anticipated in the reach of the creek upstream of the waterfall.

There is no predicted change in the semi-confining properties of the Bald Hill Claystone following extraction of the proposed panels, and it has been assessed that the modelled stream flow reduction of 0.06 – 0.25 ML/day would be accommodated within the secondary porosity generated through bedding plane separation and fracturing through subsidence of the mid to upper Hawkesbury Sandstone. The additional stored water would flow under gravity and with a delay, discharge either to a downstream reach of Wallandoola Creek or to an adjoining down gradient catchment, such as the Cataract River.

Based on the modelled outcome that no additional water passes through the Bald Hill Claystone into the underlying Narrabeen Group or Illawarra Coal Measures following extraction of the Wongawilli longwalls, it is assessed there would be no net loss to the water volume flowing into the Cataract River.

Stream flow modelling (WRM Water & Environment, 2012) indicates the average daily flow from Wallandoola Creek to the Cataract River is 33.0ML/day. Therefore, a potential 0.06 – 0.25ML/day flow reduction represents approximately 0.2 – 0.8% of the Wallandoola Creek stream flow into the Cataract River.

Waterfall W1 is predicted to undergo less than 0.02m of subsidence and less than 1mm/m of extensional strain, therefore is predicted to have a low risk of subsidence related cracking and a low risk of enhanced stream bed throughflow.

A low potential risk to the integrity of rock bar constrained pools could be present in the area that may potentially undergo 6mm/m of tensile strain to the south of Longwall Panels A3 LW3 and LW4. It should be noted however that the pool holding capacity in this reach is adversely affected by previous subsidence associated with the Bulli seam longwalls. Pool depths and duration have been shown to be dependent upon rainfall and runoff in the catchment, with WC4 pool having been observed to dry out in low flow periods.

Lizard Creek

It has been assessed that there will be no adverse impacts, effects or consequences in the Lcus1 or Lcus 4 valley infill swamps or in the sandstone based and rock bar constrained pools as a result of the predicted 20mm to 25mm of subsidence (Seedsman, 2012) along the length of Lizard Creek at Wonga West Areas 3 and 4.

Between sites LC1 and LC5, the predicted strains along Lizard Creek are predominantly less than 3mm/m, which is also not expected to generate any adverse effects, impacts or consequences on stream flow.

To the north of Longwall Panel A3 LW2, mid-way between sites LC5 and LC6, maximum strains of between 3 – 7 mm/m are predicted over a stream reach of approximately 300m (Seedsman, 2012), which could generate cracking in the Hawkesbury Sandstone creek bed.

Lizard Creek was undermined at this location by Bulli seam longwalls 304 to 306 between 1986 and 1989, and monitoring has identified that the LC5 to LC6 reach completely dried up for periods of between 6 to 45 days since December 2009.

The degree and extent of cracking cannot be determined with any accuracy, however, as the predicted strains are not large and the stream flow and pool holding capacity has already been adversely impacted by previous subsidence, it is not anticipated that any significant change will be observed in the creek.

If subsidence consequences do occur on the bed of Lizard Creek in this reach, it could manifest through additional rock bar leakage, enhanced transfer of stream flow to the underlying sandstone substrate or by an enhanced pool drainage rate.

As is observed with current stream flow conditions in this reach, it is expected that any subterranean flow transfer that may occur due to subsidence or uplift cracking in the stream bed from the proposed Wongawilli Panels, will re-emerge downstream, without loss of stream discharge from the subsided catchment.

No significant, observable uplift or valley closure is anticipated within the channel of Lizard Creek. Because of the decision to eliminate longwall extraction under named 3rd order creeks, the systematic strains in these creeks can only be tensile. Block rotations above the longwall extraction panels may result in some compressive strains transferred to the creeks.

Groundwater modelling indicates a potential 12m reduction in groundwater level and an associated baseflow reduction to Lizard Creek of 0.02 ML/day after the end of Stage 1 (V Mains and Area 1 and 2) and 0.10 ML/day at the end of Area 4. It has been assessed that this would generate negligible environmental consequences except potentially during extended dry periods due to depressurisation in the upper Hawkesbury Sandstone aquifer in the gaining portions of the stream, downstream of Waterfall L1.

No reduction in stream flow is anticipated in the 'losing' reach of the creek upstream of the waterfall.

There is no predicted change to the semi-confining properties of the Bald Hill Claystone following extraction of the proposed panels, therefore it has been assessed that the modelled stream flow reduction of 0.02 – 0.1 ML/day would be accommodated within the secondary porosity generated through bedding plane separation and fracturing after subsidence of the mid to upper Hawkesbury Sandstone. The additional stored water would flow under the regional gravity profile and with a delay, discharge as baseflow recharge to the streams of either a downstream reach of Lizard Creek or to an adjoining down gradient catchment, such as the Cataract River.

Based on the modelled outcome that no significant additional water passes through the Bald Hill Claystone into the underlying Narrabeen Group or Illawarra Coal Measures following extraction of the Wongawilli longwalls, it has been assessed there would be no net loss to the water volume flowing into the Cataract River.

Stream flow modelling (WRM Water & Environment, 2012) indicates the average daily flow from Lizard Creek to the Cataract River is 17.0 ML/day. Therefore, a 0.02 – 0.1 ML/day flow reduction represents approximately 0.1 – 0.6% of the Lizard Creek stream flow into Cataract River.

No adverse effects, impacts or consequences are anticipated at Waterfall L1 as a result of the predicted subsidence of less than 12mm and extensional strain of 3.5mm/m, and has been assessed as having a low risk of subsidence related cracking and a low risk of enhanced stream bed throughflow.

A low potential risk to the integrity of rock bar constrained pools could be present in the area that may potentially undergo 6 - 7mm/m of tensile strain to the north of Longwall Panel A3 LW2 and south of the northern end of Longwall Panel A4 LW5. It should be noted however that the pool holding capacity in this reach is already adversely affected by subsidence over the Bulli longwalls, with the pool depths and duration being dependent upon rainfall and runoff in the catchment, with two pools (one upstream of Waterfall L1, and the other between LC5 and LC6) having been observed to dry out in low flow periods.

Cataract Creek

Due to the proposed location and orientation, as well as panel and pillar widths used (Seedsman, 2010), it is not anticipated that cracks of any significance will be developed in the 3rd order reach of Cataract Creek, upstream of Mt Ousley Road. This means it is anticipated there will be negligible transfer of stream flow through stream bed subsidence / uplift cracking in the 3rd order reach of Cataract Creek due to extraction of Area 1.

No cracking of significance is anticipated in the 4th order reach of Cataract Creek, downstream of Mt Ousley Road, except potentially over Longwalls LW8 and possibly, LW9. On the basis that adaptive management of the mine workings ensures that less than 250mm of subsidence occurs in the bed of Cataract Creek, it is anticipated there will be negligible transfer of stream flow through stream bed subsidence / uplift cracking in the 3rd order reach of Cataract Creek due to extraction of Area 1.

Valley closures of up to 100mm and upsidence of up to 60mm may occur at Wonga East.

Stream reaches flowing over the Newport and Garie Formation as well as the Bald Hill Claystone lithology's may also not experience the same degree of surface cracking that could occur in the Hawkesbury Sandstone or Bulgo Sandstone reaches due to the higher relative ductility of the clay dominated strata.

Beneath the plateau area of the multi seam mined Bulli and Balgownie workings between Cataract Creek and Bellambi Creek, extraction of the proposed Wongawilli seam longwalls is modelled to generate up to 4m of depressurisation in the upper Hawkesbury Sandstone at the end of mining Area 2 and V Mains.

The modelled, localised reduction is anticipated to reduce the regional phreatic surface gradient from the plateau to the creek, as well as toward Cataract reservoir, thereby potentially reducing baseline seepage flow volumes to the creek and dam.

It is also possible that, if they exist, the location of seepage points in the stream bed may be relocated up to 4m lower down the catchment.

Based on interpreted local groundwater contours the 4m modelled reduction in the phreatic surface over the proposed workings represents a change in gradient of flow toward Cataract reservoir from 0.0212 to 0.0196.

On the basis that there is no direct free drainage flow path to the workings, which is supported by water balance investigations and assessment in the current workings, the water level decline will be temporary, as the water table is anticipated to recover once the mining at Wonga East has been completed.

Groundwater modelling predicts a 0.06 ML/day reduction in stream flow in Cataract Creek at the end of mining Area 2 / V Mains, and a 0.07mL/day reduction after Area 4 is completed.

There is no predicted free drainage connection from the stream bed to the proposed workings (Seedsman, 2012), thus where the Bald Hill Claystone is not eroded and there is no change in its semi-confining vertical flow properties following extraction of the proposed panels, it has been assessed that the modelled stream flow reduction of 0.06 – 0.07 ML/day would be accommodated within the secondary porosity generated through bedding plane separation and fracturing after subsidence of the Hawkesbury Sandstone and the upper Bulgo Sandstone. The additional stored water would flow under gravity and with a delay, discharge either to a downstream reach of either Cataract Creek, Cataract River or Bellambi Creek, and subsequently flow into Cataract Reservoir.

Based on the assessment that no vertical free drainage to the workings is generated following extraction of the Wongawilli longwalls, it has been assessed that there would be no net loss to the water volume flowing into the SCA water storage at Cataract Reservoir.

Stream flow modelling (WRM Water & Environment, 2012) indicates the average daily flow from Cataract Creek to Cataract Reservoir is 11.73 ML/day. Therefore, a 0.06 – 0.07 ML/day flow reduction represents approximately 0.5 – 0.6% of the Cataract Creek stream flow into Cataract Reservoir.

Low potential risk to the integrity of rock bar constrained pools could be present in the area adjacent to Longwall Panels A2 LW5, 6, 7 and 10. A potential risk to the integrity of rock bar constrained pools is present in the area overlying Longwall Panel A2 LW8 that may potentially undergo up to 5mm/m tensile and 9.5mm/m compressive strain. No rock bar constrained pools are present over Longwall Panel A2 LW9.

Cataract River and Bellambi Creek

Cataract River and Bellambi Creek are not proposed to be undermined, nor is mining proposed to be undertaken in close proximity to the main streams, thus valley closures of less than 100mm and upsidence of less than 60mm is anticipated (Seedsman, 2012), and therefore negligible stream flow effects, impacts or consequences are anticipated to occur in Cataract River or Bellambi Creek upstream of Cataract Reservoir.

Groundwater modelling indicates that there is not anticipated to be a potential reduction in recharge or stream flow to the Cataract River and Bellambi Creek catchments as a result of the proposed Wonga East panel extraction (Golder Associates, 2012).

There is no potential risk to the integrity of rock bar constrained pools in Cataract River or Bellambi Creek.

20.4.2 *Tributaries*

Lizard Creek

The 1st, 2nd and 3rd order tributaries that overlie the proposed 20mm subsidence zone are at risk of subsidence related stream bed cracking, enhancement of stream bed underflow, discharge of ferruginous springs and reduced stream water quality at their confluence with Lizard Creek. It is not anticipated, however, that the total volume of water entering Lizard Creek will be adversely affected.

Adverse impacts, effects or consequences are possible on the sandstone based pools due to the predicted 2.5m of subsidence (Seedsman, 2012) in the 3rd order reach of LCT1 and up to 1.9m of subsidence along the 3rd order reach of LCT2 at Wonga West Area 3.

The 3rd order reach of LCT1 was undermined by Bulli longwalls 306 to 308 between 1989 and 1991, whilst the 3rd order reach of LCT2 was not undermined by the Bulli longwalls.

The predicted strains in the 3rd order reach of LCT1 may range up to 7mm/m (tensile) to-7 mm/m (compressive), whilst the 3rd order reach of LCT2 may experience up to 4 mm/m to -6 mm/m, which could generate stream bed cracking. The degree and extent of cracking cannot be determined with accuracy, however, as the stream flow and pool holding capacity has already been adversely impacted by the pre-existing effects of previous subsidence in the 3rd order reach of LCT1, it is not anticipated that any significant change will be observed in that tributary. Adverse effects may occur, however, in LCT2.

If subsidence consequences do occur on the tributaries, it could manifest in the tributaries through additional rock bar leakage, enhanced transfer of stream flow to the underlying sandstone substrate, by an enhanced pool drainage rate or through enhanced discharge of ferruginous seepage.

It is expected that if any subterranean flow transfer occurs due to subsidence or uplift cracking in the stream bed from the proposed Wongawilli Panels, the flow will re-emerge downstream in Lizard Creek, without loss of total stream discharge from the subsidence area.

Wallandoola Creek

The 1st and 2nd order tributaries which overlie the proposed 20mm subsidence zone are at risk of subsidence related stream bed cracking, enhancement of stream bed underflow, discharge of ferruginous springs and reduced stream water quality at their confluence with Wallandoola Creek. However, it is not anticipated that the total volume of water entering Wallandoola Creek will be adversely affected.

Cataract Creek

The 1st and 2nd order tributaries which overlie the proposed 20mm subsidence zone are at risk of subsidence related stream bed cracking, enhancement of stream bed underflow, discharge of ferruginous springs and reduced stream water quality at their confluence with Cataract Creek. However, it is not anticipated that the total volume of water entering Cataract Creek will be adversely affected.

Cataract River and Bellambi Creek

The 1st order tributaries which overly the proposed 20mm subsidence zone are at low risk of subsidence related stream bed cracking, enhancement of stream bed underflow, discharge of ferruginous springs and reduced stream water quality at their confluence with Cataract River or Bellambi Creek.

20.4.3 ***Upland Swamp Outflow***

A detailed significance and risk assessment of the swamps is contained in *Annex Q*, and summarised below in relation to predicted impacts to swamp overflows.

Lizard Creek

Lcus8 swamp overlying Longwall Panel A3 LW1 is anticipated to be at low risk of adverse subsidence related effects, while Lcus1, Lcus6 and Lcus27 are anticipated to be at a negligible risk of adverse subsidence related effects.

It is considered that the risk of swamp drainage, reduction of discharge to downstream gullies and adverse effects on water quality are low, and that the total volume of water entering Lizard Creek will not be observably affected.

The valley fill swamps along Lizard Creek, to the south of the proposed subsidence zone, are not anticipated to be at significant risk of adverse effects.

Wallandoola Creek

The headwater swamps overlying the proposed Wonga West subsidence area have the potential to undergo subsidence related bedrock cracking. In particular, the headwater swamp of the Wcus4 complex, which overlies Longwall Panel A3 LW2, is anticipated to be at moderate risk of adverse subsidence related effects, while Wcus11 also over Longwall Panel A3 LW2 is anticipated to be at a low risk of environmental consequences.

The valley infill swamp Wcus7, located to the south of Longwall Panel A3 LW3 and LW4 is anticipated to be at risk of adverse subsidence related effects, while the valley infill swamp located along Wallandoola Creek within the Wcus4 complex, and to the south of Longwall Panel A3 LW2 is anticipated to be at negligible risk of adverse effects.

It is considered that the risk of swamp drainage, reduction of discharge to downstream gullies and adverse effects on water quality are low, and that the total volume of water entering Wallandoola Creek from the headwater swamps, or from the valley infill swamps will not be observably affected.

Cataract Creek

The headwater swamps overlying the proposed Wonga East subsidence area have the potential to undergo subsidence related bedrock cracking. In particular, Ccus1 located over Longwall Panel A1 LW3, and CCUS5 located over Longwall Panel A2 LW7 and A2 LW8, are identified as being at significant risk of negative environmental consequences. CCUS4 and CCUS10 are identified as being at low risk of negative environmental consequences.

It is considered that the risk of swamp drainage, reduction of discharge to downstream gullies and adverse effects on water quality are low, and that the total volume of water entering Cataract Creek from the headwater swamps will not be observably affected.

Cataract River and Bellambi Creek

The headwater swamps overlying the proposed Wonga East subsidence area have the potential to undergo subsidence related bedrock cracking. However it is considered that the risk of swamp drainage, reduction of discharge to downstream gullies and adverse effects on water quality are low, and that the total volume of water entering Cataract River or Bellambi Creek from the headwater swamps will not be observably affected.

20.4.4 *Water Quality*

Previous observations in similar geomorphological, hydrological and mining environments within the Southern Coalfields, with a similar depth of cover to the mined seam, have determined that water quality can be adversely affected through:

- increased groundwater discharge to a stream following direct undermining and subsidence;
- lowered dissolved oxygen, lowered pH, elevated dissolved Fe / Ni / Zn / Mn / Al, and elevated sulfate and salinity from flow through fresh cracks in cliff and stream bed

sandstone following subsidence, which manifests as orange-brown, low dissolved oxygen plumes in receiving waters; and

- pool depth reduction and enhanced stagnation and evaporative concentration which enhances low dissolved oxygen and elevated salinity.

The main observable change in stream waters results from dissolution of freshly exposed diffused iron sulfide minerals (such as marcasite) from cracked sandstone. This precipitates on discharge to a receiving water body as an orange-brown iron hydroxide floc, along with the generation of sulfuric acid and increased levels of dissolved iron, manganese, aluminium, nickel and zinc species. Where a seep discharges into a stream, the stream can exhibit a more acidic and higher salinity water quality immediately downstream of subsidence affected areas, which with in stream diffusion and mixing, reduces in concentration downstream.

The increased concentration of dissolved aluminium may be due to dissolution from kaolinite in the fractured bedrock along the groundwater flow-path or if it is remobilised from precipitated hydrous iron, manganese or aluminium oxides due to dissolution by humic and fulvic acids originating from the organic rich upland swamps.

In addition, enhanced armouring of stream bed substrate with precipitated iron hydroxide has been observed at discharge areas, however this effect has also been observed in streams unaffected by mining in the NRE lease area.

The generation of the ferruginous orange brown plumes decreases over a time frame of years due to armouring of marcasite with iron ox hydroxide precipitates (Nicholson et al, 1990 in GeoTerra, 2010a).

The diversity and abundance of aquatic species within the Study Area might be affected by the comparitively acidic water (that often occurs naturally in Hawkesbury Sandstone based streams), as well as dissolved aluminium and zinc. Sulfate and dissolved humic and fulvic acids may be insufficient to form complexes with the dissolved aluminium and thus reduce the stream water ecotoxicity.

If additional adverse seepage to a stream occurs, it could be significantly diluted, with the resultant lowering of dissolved pollutant concentrations in the stream at the point of emergence. This assumes, however that the possible discharge occurs at an isolated identifiable location in a stream, whereas it is equally possible that the seepage may be disseminated at various points along a stream depending on the subsidence induced flow regime, with the resultant additional enhanced dilution, precipitation and adsorption effects described above.

Studies at Elouera Colliery (currently operated as the Gujarat NRE Wonga Pty Ltd Wongawilli Colliery) in a similar geomorphological and hydrological environment to the Study Area, indicate there are no residual ecotoxic effects from acidic pH along with dissolved aluminium, nickel or zinc, with the chemical effects of undermining requiring less than 10 years to be ameliorated. It has also been observed in streams over the Elouera workings that natural attenuation of an affected stream reach can occur up to 750m downstream of the seepage location (BHP Billiton, 2009 in GeoTerra, 2010a).

The effect of acidity is reduced mainly through dilution with receiving waters as well as buffering from alkaline solutes such as bicarbonate ($HCO3^-$) and, to a lesser degree hydroxide species (OH^-).

The increased acidity and lowered dissolved oxygen in receiving waters is generally only observed close to the discharge point, and depends on the flow rate and volume at the discharge point.

Dilution of the discharge as well as precipitation of iron and manganese hydroxides, adsorption of dissolved Ni and Zn onto the iron hydroxides, as well as binding and adsorption onto dissolved / total organic carbon significantly improves water quality away from the emergence point.

Further downstream of the emergence point, the receiving water can be affected by moderately elevated salinity, however this also quickly diminishes on mixing with the stream water.

Monitoring of the creeks in the Study Area has identified numerous ferruginous seeps within both the main channel and tributaries of all three creeks.

Potential consequences on stream water quality due to the predicted subsidence are discussed in the following sections.

Cataract Creek and Cataract River

The Cataract Creek catchment at and upstream of site CC5, and within and downstream of CT1 is currently affected by ferruginous precipitates, however, no observable adverse effects on stream flow or pool holding capacity, water opacity or reduced dissolved oxygen is apparent.

No stream bed cracking is predicted thus no adverse effects on stream water quality are anticipated in Cataract Creek upstream of Cataract Reservoir.

The headwaters of the 1st and 2nd order streams draining off the proposed Wonga East subsidence area have the potential to undergo subsidence related bedrock cracking, however it is considered that the risk of adverse steam water quality changes are low, and that the quality of water entering Cataract River and Bellambi Creek from the headwater streams will not be observably affected.

Wallandoola Creek

The stream reach to the south of the proposed Longwall Panels A3 LW3 and A3 LW4 is currently affected by ferruginous precipitates.

If stream bed cracks form to the south of the proposed panels and diversion of stream flow through the underlying sandstone substrate occurs, then orange discolouration of the water, generation of bacterial mats and elevated levels of total / filtered iron, zinc and possibly copper and aluminium, and increased opacity and reduced dissolved oxygen could result.

Minimal or no subsidence and strains are predicted in the main channel, thus there is a lack of potential for generation of stream bed cracking and substrate flow through, and therefore no adverse effect on stream water quality is anticipated outside of the Longwall Panel A3 LW3 and A3 LW4 stream reach.

Lizard Creek

The stream reach to the north of the proposed Longwall Panel A3 LW1 is currently affected by ferruginous precipitates, and reduced stream flow and pool holding capacity as a result of previous Bulli Seam longwall subsidence.

If additional stream bed cracks form to the north of the proposed panel and enhanced diversion of stream flow through the underlying sandstone substrate occurs, then orange discolouration of the water, further elevation of already high levels of total / filtered iron, zinc and possibly copper and aluminium, and increased opacity and reduced dissolved oxygen could result.

Minimal or no subsidence and strain are predicted in the main channel, thus there is a lack of potential for generation of stream bed cracking and substrate through flow, and therefore no adverse effect on stream water quality is anticipated outside of the Longwall Panel A3 LW1 stream reach.

If stream bed cracks form in the LCT1 or LCT2 3rd order or higher tributaries and enhanced diversion of stream flow through the underlying sandstone substrated occurs, then orange discolouration of the water, elevation of levels of total / filtered iron, zinc and possibly copper and aluminium, and increased opacity and reduced dissolved oxygen could occur in LCT1 or be generated in LCT2 and potentially discharge into Lizard Creek.

As a result, observable, adverse effects on stream water quality in the 3rd order or higher tributaries of LCT1 and LCT2, as well as the receiving waters of Lizard Creek, could occur.

20.4.5 *Stream Bed and Bank Stability*

Wonga West

It is anticipated there will not be significant subsidence in Wallandoola Creek (<0.25 - 0.5m) or Lizard Creek (<0.5m). In addition, the stream beds are dominated by exposed sandstones and the swamps are heavily vegetated, thus no adverse effects on stream bed or bank stability are anticipated in the 3rd order or higher main channels.

Up to 2.5m of subsidence is predicted in the 3rd order or higher tributary of LCT1, which could cause a reduction in stream bed and bank stability, however this reach is currently significantly affected by previous subsidence over the Bulli longwalls, and it is not anticipated that there will be additional, adverse effects from extraction of the proposed Wongawilli Seam longwalls.

Up to 1.9m of subsidence is predicted in the 3rd order or higher tributary of LCT2, which could cause a reduction in stream bed and bank stability in the 3rd order reach, but not in the 4th order reach, which does not overlie the proposed workings.

Wonga East

It is not predicted that there will be significant subsidence in Cataract River or Bellambi Creek. In addition, the stream beds are dominated by exposed sandstone and the swamps are heavily vegetated, thus no adverse effects on stream bed or bank stability are anticipated in the 3rd order or higher main channels.

As a worst case scenario, subsidence of up to 0.8m may occur in Cataract Creek over Longwall Panel A2 LW8, which may make it potentially prone to stream bed and bank instability. NRE has committed to an adaptive management strategy where by monitoring of subsidence will be undertaken and when subsidence reaches 250mm the longwall will be discontinued.

The stream bed located over or adjacent to the other panels at Wonga East are not anticipated to be at risk of stream bed or bank instability.

20.4.6 *Gas Emissions*

The dilation in the strata immediately beneath the base of a stream due to valley bulging is restricted to the shallow surface strata, up to 20m below the surface, and does not provide a direct conduit for the release of gases from underlying, deeper strata.

Due to the pre existing subsidence and crack development in the overburden over Wonga East and Wonga West, emission of gases at the surface is not anticipated to be an issue.

20.4.7 *Cataract Dam and Broughtons Pass Weir*

Cataract Dam

No reduction in the water quality of Cataract Reservoir is anticipated from the Cataract Creek, Cataract River or Bellambi Creek catchment outflows.

A 0.06 – 0.07ML/day (or 5 - 6%) reduction in flow from the Cataract Creek catchment to Cataract Reservoir is predicted at the end of mining Wonga East Area 2. However, it should be noted that this quantum is insignificant when compared to the average daily evaporation from the reservoir, and taking into account the limitations in using the surface water and groundwater models to estimate creek flows, groundwater seepage and inflow to the workings.

It has been assessed that there is a low risk of reduced water yield to Cataract Reservoir, and surface water and groundwater modelling indicates a low risk of potential change to the water holding capacity of, or loss of water from Cataract Reservoir.

It is worth noting that the PAC report for the Metropolitan Coal project indicated the following:

analyses based on standard flow measurement techniques at discrete points are not capable of providing a definitive position on the likelihood or otherwise of water loss from a catchment (ie, Woronora Reservoir at Metropolitan), nor is a definitive position provided by hydrologic modeling. However, the local and regional groundwater conditions coupled with the mine parameters would suggest that the likelihood of water being lost from the surface water system as a consequence of mining, and then by passing (Woronora Reservoir) is very low.

As the issue was not beyond reasonable doubt, the PAC recommended that a program of monitoring should be developed between the proponent and the SCA to further investigate the existence or otherwise of catchment yield impacts.

The structural integrity of the Cataract dam wall and Cataract Reservoir will not be affected by the proposed mining. Further, the proposed workings have been positioned at sufficient distance from the Cataract Reservoir and there are no known geological structures which could cause a mining induced hydraulic connection between the workings and the base of the reservoir.

Broughtons Pass Weir

As the potential adverse subsidence impacts on stream flow, pool holding capacity and stream water quality in Lizard Creek and Wallandoola Creek are anticipated to be localised, if they occur at all, then the discharge out of the two creeks into the Cataract River is not anticipated to cause any adverse impacts on the water quality in Broughtons Pass Weir. The Cataract dam wall is located approximately 5km upstream of the Lizard Creek junction and 10.5km of the Wallandoola Creek junction, whilst Broughtons Pass Weir is located approximately 1.2km downstream of Wallandoola Creek.

20.4.8 *Cumulative Impacts*

Lizard and Wallandoola Creeks

<u>Stability and Connectivity</u>

The Bulli seam underlying both Lizard and Wallandoola Creeks has been mined in the previous NRE and Cordeaux leases with up to 1.5m subsidence.

Due to a lack of pre and post extraction data, the impacts, effects and consequences to stream flow and stream connectivity from the previous Cordeaux longwall workings located upstream of the proposed Area 3 and Area 4 mining domains in both the Lizard and Wallandoola Creek catchments cannot be quantified. However, observations for this study indicate that the stream flow discharging from the Cordeaux lease area is essentially perennial and contains ferruginous seepages.

No additional workings are currently proposed in the Cordeaux lease, or in the BHP Billiton lease between the proposed NRE workings and the Cataract River.

The proposed extraction in Wonga West is predicted to result in up to an additional 0.25m subsidence in the main channel of Lizard Creek and up to an additional 0.5m subsidence in the main channel of Wallandoola Creek. This will result in a cumulative subsidence effect with the subsidence caused through the previous Bulli workings, however no site specific, cumulative effect on the creek bed and bank stability or pool levels is anticipated due to the additional subsidence.

A potential cumulative effect of subsidence on the stream flow from 1st and 2nd order streams, which may or may not also contain upland swamps, is possible if the subsurface transfer of the tributary / swamp water outflows does not report back into the lower reach of the tributary before it discharges into the main 3rd order channel of Lizard or Wallandoola Creek.

However, it is anticipated that the upper tributaries / swamps will discharge the stream flow back into the 3rd order flow system of the main creeks at or near their confluence with the main stream, so that negligible volumes of tributary / swamp outflow will be 'lost' to the system.

Pool Heights

The Cordeaux lease area located upstream of the proposed NRE workings in the Lizard and Wallandoola Creek catchments is predominantly composed of valley infill upland swamps, and as such, any pools that are present are predominantly shallow and of limited extent.

The proposed mining at Wonga West Area 3 and 4 is not anticipated to generate sufficient subsidence, strains or tilts to adversely affect the pools in the Cordeaux lease area.

No mining is currently proposed between the northern NRE lease and the Cataract River junctions.

Stream Water Quality

The water quality discharging from the Cordeaux lease has a median pH of 6.02 and EC of 124µS/cm. Parameters that exceed the ANZECC 2000 water quality criteria discharging from the Cordeaux lease (as monitored at sites LC2 and WC2, can include copper, zinc, aluminium, total nitrogen and total phosphorus.

As there is no new mining planned in the Cordeaux lease, and as the Cordeaux catchments are interpreted as having attained a 'steady state', there are no new anticipated cumulative impacts on the water quality within, or discharging from, the proposed NRE mining area.

Cataract Creek, Bellambi Creek and Cataract River

Stability and Connectivity

The Bulli, Balgownie and Wongawilli workings, which underlie the Cataract Creek catchment, have been mined in the previous NRE and Cordeaux leases by longwall extraction with up to 1.4m of subsidence. The proposed Wongawilli Seam extraction at Wonga East will generate up to a predicted additional 1.2m subsidence in the Cataract Creek catchment.

As a worst case scenario, the main channel of Cataract Creek is predicted to undergo up to an additional 0.8m of subsidence over Longwall Panel A2 LW8 (Seedsman Geotechnics, 2012), however NRE has committed to an adaptive management strategy where by monitoring of subsidence will be undertaken and when subsidence reaches 250mm the longwall will be discontinued.

The proposed extraction in Wonga East will result in a cumulative subsidence effect with the subsidence caused through the previous Bulli, Balgownie and Wongawilli workings, however no site specific, cumulative effect on the creek bed and bank stability or pool levels is anticipated due to the additional subsidence.

To date, with three seams being mined in the Cataract Creek catchment, there has been no observable adverse effects on stream bed and bank stability or pool levels.

A potential cumulative effect of subsidence on the stream flow from 1st and 2nd order streams, which may or may not also contain upland swamps, is possible if the subsurface transfer of the tributary / swamp water outflows does not report back into the lower reach of the tributary before it discharges into the main 3rd order channel of Cataract Creek. However, it is anticipated that the upper tributaries / swamps will discharge the stream flow back into the 3rd order flow system of the main creeks at or near their confluence with the main stream, so that negligible volumes of tributary / swamp outflow will be 'lost' to the system.

To date, with three seams being mined in the Cataract Creek catchment, there has been no observable adverse effects on tributary, upland swamp and the main channel stream flow connectivity.

Stream Water Quality

There are no anticipated cumulative impacts on the water quality within, or discharging from, the proposed NRE mining area.

20.5 *STREAM RISK ASSESSMENT*

Cataract Creek and Cataract River

Due to the proposed mine plan which incorporates narrow longwalls with wide pillars, the proposed mining at Wonga East is not anticipated to be a significant risk to either Cataract Creek or Cataract River (upstream of Cataract Reservoir) in regard to stream flow, stream pools, water quality or aquatic ecosystems.

Wallandoola Creek

Due to the designed set back from the main channel of Wallandoola Creek (and the associated lack of subsidence and uplift), the proposed Wongawilli seam mine layout is anticipated to avoid potential adverse effects on the main channel of Wallandoola Creek. However, a localised potential risk to the integrity of stream flow and connectivity in Wallandoola Creek may be present in the area that may potentially undergo up to 6 mm/m of tensile strain and up to 0.5m of subsidence to the south of Longwalls A3 LW3 and A3 LW4. It should be noted however that the stream flow in this reach has already been observed to be altered by previous subsidence associated with the extraction of Bulli seam in this area.

The pool water holding capacity in Wallandoola Creek or its tributaries is not anticipated to be adversely affected due to the low predicted tilts. The valley infill swamps along Wallandoola Creek are also not anticipated to be adversely affected due to the predicted subsidence tilts and strains. A detailed swamp significance and risk assessment of the Wallandoola Creek valley infill and headwater swamps is contained in (GeoTerra, 2010a) and (Biosis, 2012).

Lizard Creek

Due to the designed set back from the main channel of Lizard Creek (and the associated lack of subsidence and uplift), the proposed Wongawilli seam mine layout is anticipated to avoid potential adverse effects on the main channel of Lizard Creek, including the deemed 'significant' section at Waterfall L1.

However, a localised low potential risk to the integrity of stream flow and connectivity in Lizard Creek may be present in the area that may potentially undergo 6 - 7mm/m of tensile strain to the north of Longwall A3 LW2 and south of the northern end of Longwall A4 LW5. It should be noted however that the stream flow in this reach has already been altered by previous subsidence associated with the extraction of Bulli seam in this area.

The third order tributary stream bed and banks from the LCT1 / LCT2 junction to Lizard Creek is anticipated to have a low to minor potential risk of adverse effects due to extraction of Longwall A3 LW5.

The third order tributary stream bed and banks from C11 to Lizard Creek is anticipated to have a potential risk of adverse effects due to extraction of Longwall A3 LW5. It should be noted however that the stream flow and pool holding capacity in this stream reach has been observed to be altered, possibly by previous subsidence associated with the extraction of the Bulli seam in this area.

The pool water holding capacity in Lizard Creek or its tributaries is not anticipated to be adversely affected due to the low predicted tilts and steep gradients in the incised sections of the creek catchment.

The valley infill swamps in the flatter gradient section along Lizard Creek are also not anticipated to be adversely affected due to the lack of predicted subsidence in those areas.

A detailed swamp significance and risk assessment of the Lizard Creek valley infill and headwater swamps is contained in (GeoTerra, 2010a) and (Biosis, 2012).

It has been noted from baseline monitoring that the quantum and duration of flow in Lizard Creek is dependent upon the quantum and duration of storm events as well as the nature of long term rainfall in the catchment.

20.6 *MONITORING, MANAGEMENT AND CONTINGENCIES*

A detailed water monitoring plan will be developed post-approval in liaison with SCA and OEH and to the approval of DP&I. The following sections provide an outline of the proposed monitoring. In summary the plan would detail monitoring parameters and locations, set trigger values and discuss the logistics of monitoring in this relatively inaccessible area.

20.6.1 *Stream Pools and Flow*

Daily automated monitoring of selected pool water depths and stream flow at suitable locations upstream, within and downstream of the Study Area will be conducted and compared to rainfall in the local area. The monitoring sites would be sited upstream, within and downstream of the proposed 20mm subsidence area, at locations that are permanently under water.

Monitoring will assess the inputs from catchment runoff and any flow variations within the Project Area before, during and after the extraction period, particularly for low flows.

20.6.2 *Stream Water Quality*

Water quality monitoring will be conducted in Cataract Creek and Cataract River, upstream of Cataract Reservoir, and Wallandoola and Lizard Creeks upstream, within and downstream of the mining area before, during and after mining.

Monitoring would concentrate on regular visits to the main channel sites that would be monitored for identifiable inputs from catchment runoff and all key water quality parameter variations for the duration of mining and for an appropriate period following completion of mining.

Monitoring parameters to be measured include, but are not limited to:

- pH, electrical conductivity, dissolved oxygen, oxidation/reduction potential and temperature;
- total dissolved solids;
- Na / Ca / K / SO4 /Mg / Cl / F;
- total alkalinity;
- dissolved organic carbon;
- total / filterable Fe, Mn, Al;
- filterable Ni, As, Li, Ba, Sr, Cu, Pb, Zn; and
- total nitrogen and total phosphorus.

20.6.3 *Stream Erosion and Destabilisation*

Bed and Bank Erosion

Subsidence may induce minor bed or bank erosion over the proposed panels, particularly in the headward and downstream sections of any subsidence troughs, as well as over the chain pillars.

As the creek banks are well vegetated, no significant change is anticipated and it is not envisaged that stream bank remediation will be required, however any changes to the current state will be visually monitored after significant stream flow events. If adverse impacts due to mining, such as subsidence/uplift, are identified a specific management and rehabilitation plan would be developed for the affected areas.

Bedload Movement

If erosion occurs in a stream, it may cause a minor increase in potential bedload movement in and downstream of the subsidence area, which will be visually monitored during and after significant flow events.

Stream Gradient

It is not anticipated that significant observable changes to stream gradients will occur as a result of subsidence, therefore it is not anticipated that stream gradient rehabilitation measures will be required, however this will be visually monitored and specific management and rehabilitation measures developed for affected areas if required

Riparian Vegetation

Vegetation in the stream and banks will be visually monitored over the proposed mining area before and after any stream is undermined, particularly after significant flow events.

Waterfalls

The integrity and overland flow of the waterfalls will be monitored, along with specific subsidence measurements to indicate any potential adverse effects to waterfalls. Should monitoring identify any significant adverse impacts, appropriate adaptive management measures would be developed and implemented.

Rockbars

The integrity and pool holding capacity of rockbars in the potential subsidence zone would be monitored to identify any potential adverse effects to rockbars. Should monitoring identify any potential significant adverse impacts, appropriate adaptive management measures would be developed and implemented.

20.6.4 ***Mine Inflows***

Mine inflows will be monitored through measurement of all water pumped, where practicable, into and out of the mine workings.

20.6.5 ***Rainfall***

Rainfall will continue to be monitored daily at the mine's and the nearest Bureau of Meteorology weather station/s for the duration of mining.

The quantity and variability of stream flow in Wallandoola, Lizard and Cataract Creeks will be monitored by data loggers to assess the rainfall / runoff relationship, with photography used to monitor flow conditions in both creeks and their unnamed tributaries.

20.6.6 ***Reporting***

An end of panel report, or its equivalent, will be prepared for each mined panel, to summarise all monitoring over the period. The report will outline any changes in the surface water or groundwater system over the mined out areas.

All monitoring and management activities will be reported in the Annual Environmental Management Report (AEMR), or its equivalent, in subsequent years.

All results would be reviewed one year after each panel has been completed and an updated ongoing monitoring and remediation program will be developed in consultation with the SCA, DRE and OEH.

20.6.7 *Contingency Measures*

Precautionary and adaptive management procedures will be implemented to provide a systematic process for continually detecting impacts, validating predictions and improving mining operations to prevent adverse impacts on the streams systems overlying the proposed mining domains.

Monitoring, evaluation, and reporting on management performance and ecological impact would be integrated into the site's management systems to progress the technical understanding and predictive capability of subsidence effects, and its impacts and consequences on the sites surface water systems.

It is anticipated that mining would commence in Longwall Panels A2 LW6 to A2 LW7, which do not overlie the main channel or significant tributaries of Cataract Creek. This will assist in ongoing 'baseline' monitoring to assess the effect of subsidence on fracture propagation and development through the overburden; height of fracturing; development of cracking at surface; changes to the upland swamp perched water systems of CRUS1 and CCUS4; flow and water quality in Cataract Creek; and any mine inflow changes.

As a worst case scenario, the main channel of Cataract Creek is predicted to undergo up to an additional 0.8m of subsidence over Longwall Panel A2 LW8 (Seedsman Geotechnics, 2012), however NRE has committed to an adaptive management strategy where by monitoring of subsidence will be undertaken and when subsidence reaches 250mm the longwall will be discontinued.

Data gained from monitoring a suite of extensiometers, vibrating wire piezometer arrays and open standpipe piezometers as well as geochemical monitoring of groundwater and surface water and stream flow regimes over and around the panels, would then be used to update the current geotechnical, hydrogeological and hydrological assessments for the proposed mining and to incorporate, if required, adaptive management measures for future mining.

If monitoring indicates there have been significant hydrologic or aquatic ecotoxic effects, then some management and mitigation may be required in accordance with a Stream Management Contingency Plan to be prepared post-approval. This plan will ideally:

- formulate intervention trigger levels for a range of physical and chemical parameters;
- provide further details for the adaptive management process;
- provide a range of applicable management measures;
- provide a range of applicable rehabilitation measures;

- clarify any further approvals that might be required for such management or rehabilitation; and
- set out the consultation, reporting and approval process.

Contingency measures will be developed in consideration of the specific circumstances of the exceedance and the assessment of environmental consequence. Potential contingency measures for an exceedance of the water resource or watercourse performance measures could include, if appropriate:

- additional monitoring that increases the monitoring frequency or additional sampling to inform the proposed contingency measures;
- implementation of stream remediation measures to reduce the extent of fracturing;
- implementation of revegetation measures to remediate impacts of gas releases on riparian vegetation;
- provision of a suitable offset(s) to compensate for the reduction in the quantity of water resources reaching Cataract Reservoir or Cataract River; or
- implementation of adaptive management measures, such as reducing the thickness of the coal seam extracted, narrowing of the longwall panels and/or increasing the setback of the longwalls from the affected area.

20.7 *SUMMARY*

Surface water features in the Study Area consist of:

- 1^{st} to 3^{rd} order streams of Wallandoola Creek that drain into the Cataract River downstream of the Cataract Reservoir dam wall;
- 1^{st} to 4^{th} order streams of Lizard Creek that drain into the Cataract River downstream of the Cataract Reservoir dam wall;
- 1^{st} to 4^{th} order streams of Cataract Creek and Cataract River that flow into Cataract Reservoir;
- 1^{st} and 2^{nd} order tributaries of Cataract River and Bellambi Creek (upstream of the reservoir) which will not be undermined by the Wonga East workings;
- Cataract Reservoir, which will not be undermined by the Wonga East workings, although the western end of longwall Panel A2 LW10 extends into the reservoir high water mark in Cataract Creek;
- thirty nine swamps within 600m of the proposed workings at Wonga East that meet the definition of the Coastal Upland Swamp Endangered Ecological Community, fourteen of which lie within the predicted 20mm subsidence zone. Of those fourteen, seven are assessed to be of 'special significance' according to the NSW Office of Environment and Heritage criteria (OEH, 2012), and of those, five are predicted to be

potentially subject to subsidence effects (Biosis, 2012) including CRUS1, CCUS1, CCUS4, CCUS5 and CCUS10; and

- forty five swamps within 600m of the proposed workings at Wonga West that meet the definition of the Coastal Upland Swamp Endangered Ecological Community. Of these, thirty six lie within the predicted 20mm subsidence zone. Of those thirty six, eight are assessed to be of 'special significance' according to the NSW Office of Environment and Heritage criteria (OEH, 2012), and of those, seven are predicted to be potentially subject to subsidence effects (Biosis, 2012) including LCUS1, LCUS6, LCUS8, LCUS27, WCUS4, WCUS 7 and WCUS11.

All of the creeks, swamps, Cataract River and the Cataract Reservoir are contained within the Sydney Catchment Authority controlled Metropolitan Special Area.

NRE proposes to extract the Wongawilli seam via longwall mining methods in two areas at their NRE No.1 Colliery. The Study Area has previously been mined by various operations in the Bulli, Balgownie and Wongawilli seams.

Maximum subsidence is predicted to range up to 1.2m in the Wonga East catchment and up to 2.55m at Wonga West. The maximum subsidence and uplift of the main channel of Lizard and Wallandoola Creeks is predicted to be 500mm subsidence and 120mm uplift. Cataract Creek is predicted to undergo 1.2m subsidence and 60mm uplift, however the proponent has committed to an adaptive management strategy where by monitoring of subsidence will be undertaken and when subsidence reaches 250mm in Cataract Creek, the longwall beneath the creek (A2 LW8) will be discontinued.

The potential effects, impacts and consequences of the proposed mining on surface water features are summarised in *Table 20.4* to *Table 20.8*.

Table 20.4 Lizard Creek Potential Effect, Impact and Consequence Summary

Stream reach	Effect	Impact	Consequence
LC1 - 3	<0.02m S_{max} <1mm/m strain <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality.	Negligible potential impact on flow diversion, no connective cracking, pool drainage, iron staining, water quality or gas releases.
LC3 - 4	0.02m S_{max} <2mm/m strain <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality.	Negligible potential effect on flow diversion, no connective cracking, pool drainage, iron staining, water quality or gas releases.
LC4 - 5	<0.02m S_{max} <1mm/m strain <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality.	Negligible potential effect on flow diversion, no connective cracking, pool drainage, iron staining, water quality or gas releases.

Stream reach	Effect	Impact	Consequence
LC5 - 6	0.25m S_{max} <7mm/m (extension) strain <4mm/m tilt <200mm valley closure <120mm uplift	Potential cracking of creek bed due to the proximity of the northern end of Longwall Panel A3 LW2 to creek bed.	No connective cracking. Low potential impact on stream flow (with downstream flow re-emergence), pool holding capacity, iron hydroxide seepage or gas release due to stream bed cracking, although all of these aspects are currently adversely affected by existing Bulli workings subsidence.
LC6 - 7	0.25m S_{max} <6mm/m (extension) strain <1mm/m tilt <200mm valley closure <120mm uplift	Potential cracking of creek bed due to the proximity of the northern end of Longwall A4 LW7 to the creek bed.	No connective cracking. Low potential impact on stream flow (with downstream flow re-emergence), pool holding capacity, iron hydroxide seepage and gas release, although all of these aspects are currently adversely affected by existing Bulli workings subsidence.
LCT1	2.25m S_{max} -7mm/m (compression) to <7mm/m (extension) strain <6mm/m tilt <200mm valley closure <120mm uplift	Potential cracking of 3rd order tributary bed due to undermining by Longwall A3 LW3.	No potential for connective cracking. Potential impact on stream flow, pool holding capacity, iron hydroxide seepage and gas releases, although all of these aspects are currently adversely affected by existing Bulli workings subsidence.
LCT2	0.25m S_{max} <4mm/m (extension) strain <1mm/m tilt <200mm valley closure <120mm uplift	Limited potential for cracking of 3rd order tributary due to the proximity of the northern end of Longwall A3 LW5 to the creek bed.	No connective cracking. Limited potential impact on the upper headwaters of the stream reach flow (with downstream flow re-emergence), pool holding capacity, iron hydroxide seepage and gas release due to stream bed cracking.
All reaches	Regional groundwater depressurisation	Up to 12m groundwater level reduction in upper Hawkesbury Sandstone.	Negligible impact to daily average flow in Lizard Creek (0.02ML/day gain to 0.10ML/day reduction, or 0.2% gain to 0.8% reduction).
NOTE: S_{max} = maximum subsidence			

Table 20.5 Wallandoola Creek Potential Effect, Impact and Consequence Summary

Stream reach	Effect	Impact	Consequence
WC1 - 3	<0.02m S_{max} <2mm/m strain <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality.	No connective cracking. Minimal to no potential for flow diversion, change in pool drainage, iron staining, water quality or gas releases.
WC3 - 4	<0.5m S_{max} <6mm/m (extension) strain <4mm/m tilt <200mm valley closure	Potential cracking of 3rd order stream bed due to proximity of the southern end of Longwall A3 LW3 and A3 LW4 to the	No connective cracking. Potential impact on stream flow (with downstream flow re-emergence), pool holding capacity, iron hydroxide seepage and gas release.

Stream reach	Effect	Impact	Consequence
	<120mm uplift	stream. A3 LW5 has limited potential to generate stream bed cracking.	Iron hydroxide seepage is currently present.
WC4 - 5	<0.02m S_{max} <2mm/m (extension) strain <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality.	No connective cracking. Minimal to no potential for flow diversion, change in pool drainage, iron staining, water quality or gas releases.
All reaches	Regional groundwater depressurisation	Up to 12m reduction of groundwater level in upper Hawkesbury Sandstone.	Negligible reduction in daily average flow in Wallandoola Creek (0.06–0.25ML/day, or 0.1-0.6%).
NOTE: S_{max} = maximum subsidence			

Table 20.6 Waterfalls Potential Effect, Impact and Consequence Summary

Reach	Effect	Impact	Consequence
Waterfall L1	<0.12m Smax <3.5mm/m (extension) strain <2.9mm/m tilt <200mm valley closure <120mm uplift	Limited to no change to structural integrity of the waterfall.	Limited to no potential for flow diversion through waterfall, iron staining or water quality.
Waterfall L2	<0.02m Smax <1mm/m strain <1mm/m tilt <200mm valley closure <120mm uplift	No change to structural integrity of the waterfall.	Minimal to no potential for flow diversion through waterfall, iron staining or water quality.
NOTE: Smax = maximum subsidence			

Table 20.7 Cataract Creek Potential Effect, Impact and Consequence Summary

Stream reach	Effect	Impact	Consequence
CC1 – 4	<0.02m S_{max} <-1 to 1mm/m strain <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality.	Negligible potential for connective cracking, flow diversion, change in pool drainage, iron staining, water quality or gas releases.
CC2 – 3	<0.16m S_{max} < -2 to 1mm/m strain <3mm/m tilt <200mm valley closure <120mm uplift	Potential cracking of 1st and 2nd order tributary bed due to undermining by Longwalls A1 LW1, LW2 and LW3.	Potential impact on 1st and 2nd order stream flow with downstream flow re-emergence. There are no 3rd order pools or stream reaches in this section. Potential effect on iron hydroxide seepage, although iron hydroxide seepage is currently present in the 1st and 2nd order stream reaches.

Stream reach	Effect	Impact	Consequence
CC5 - 9	<0.8m S_{max} <-9.5 to 5mm/m strain <4mm/m tilt <200mm valley closure <120mm uplift	Potential cracking of up to 4th order stream bed due subsidence near/over Longwalls A2 LW7, LW8, LW9 and LW10.	Potential impact on stream flow, with downstream flow re-emergence. Potential effect on pool holding capacity of rock bars CCRB10-15. Potential iron hydroxide seepage, although iron hydroxide seepage is currently occurring.
All reaches	Regional groundwater depressurisation	Up to 4m groundwater level reduction in eroded Hawkesbury / upper Bulgo Sandstone.	Predicted reduction of daily average flow in Cataract Creek (0.06 – 0.07ML/day, 0.5 – 0.6%). The proponent has committed to an adaptive management strategy where by monitoring of subsidence will be undertaken and when subsidence reaches 250mm in Cataract Creek, the longwall beneath the creek (A2 LW8) will be discontinued.

NOTE: Smax = maximum subsidence

Table 20.8 Cataract Reservoir, Cataract River and Bellambi Creek Potential Effect, Impact and Consequence Summary

	EFFECT	IMPACT	CONSEQUENCE
Cataract Reservoir	<0.02m S_{max} <1mm/m strain <1mm/m tilt no valley closure or uplift	No change to the fabric or structure of the reservoir or dam wall.	Negligible reduction in the quality and quantity of water resources reaching Cataract Reservoir. No connective cracking between the reservoir surface and the mine. Negligible leakage from Cataract Reservoir to the mine.
Cataract River	<0.02m S_{max} <1mm/m strain <1mm/m tilt no valley closure or uplift	No change to the fabric or structure of the reservoir or dam wall.	Negligible potential for connective cracking, flow diversion, change in pool drainage, iron staining, water quality or gas releases.
Bellambi Creek	<0.02m S_{max} <1mm/m strain <1mm/m tilt no valley closure or uplift	No change to the fabric or structure of the reservoir or dam wall.	Negligible potential for connective cracking, flow diversion, change in pool drainage, iron staining, water quality or gas releases.

NOTE: Smax = maximum subsidence

21 *GROUNDWATER*

This chapter provides an assessment of potential impacts on the groundwater resources within the Study Area.

21.1 INTRODUCTION

This chapter aims to provide an understanding of the groundwater environment as it relates to basement hydrogeology, past mining impacts, potential new mining impacts and a range of management, avoidance and mitigation measures. It is based on NRE No.1 Colliery Major Expansion Groundwater Assessment prepared by GeoTerra (2012b) which is reproduced in *Annex P*. The groundwater environment of upland swamps and other groundwater dependent ecosystems is addressed in *Chapter 20* and *Annex Q*.

21.1.1 *Assessment Requirements*

This assessment has been undertaken in accordance with the following:

- Director-General's Requirements (DGRs) for Application No. 09_0013, (20/3/2009) (see *Annex A*);
- NSW Department of Planning (2008) - Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield – Strategic Review;
- NSW Planning Assessment Commission (2009) - The Metropolitan Coal Project Review Report, and
- NSW Planning Assessment Commission (2010) - Bulli Seam Operations PAC Report.

The Director-General's Requirements for groundwater include the need to provide:

- *a description of the existing environment, using sufficient baseline data;*
- *an assessment of the potential impacts of all stages of the project, including any cumulative impacts, taking into consideration any relevant guidelines, policies, plans and statutory provisions and the findings and recommendations of the recent Southern Coalfield Inquiry;*
- *a description of the measures that would be implemented to avoid, minimise, mitigate, rehabilitate/remediate, monitor and/or offset the potential impacts of the project, including detailed contingency plans for managing any potentially significant risks to the environment; and*
- *a detailed assessment of the potential impacts of the project on the quantity, quality and long-term integrity of the groundwater resources in the project area, paying particular attention to the Upper Nepean River sub-catchment (Metropolitan Special Area).*

The combined groundwater related issues highlighted in the PAC reports referred to in the DGRs, which are addressed in this study are:

- the use of 3D groundwater numerical modelling that can adequately address high contrasts in hydraulic properties and steep hydraulic gradients in non-steady state flow domains;
- aquifer numerical modelling used as a management tool for the ongoing prediction of impacts attributed to longwall extraction;
- adequate density and duration of observations with respect to redirected surface flows and regional strata depressurisation, ideally with a minimum two years of baseline environmental data collected at appropriate frequency and scale; and
- the possibility of a fault or dyke, or other linear features providing a potential leakage conduit from surface to below the Bald Hill Claystone and development of a strategy to characterise the structure and determine the magnitude and extent of the leakage.

GeoTerra Pty Ltd was commissioned by NRE to monitor the existing baseline status and to address any potential groundwater impacts relating to the proposed extraction and associated subsidence of the Wongawilli seam in the Wonga East and Wonga West mining areas.

21.1.2 *Study Area*

The Study Area for the purpose of the groundwater assessment is defined as containing the predicted 20mm subsidence zone above the proposed Wongawilli seam workings in both Wonga East and Wonga West, as well as the regional catchments that surround the PAA.

Potential Significant Feature Zones have been defined as 600m wide zones that extend from the edge of the secondary extraction footprint for assessment of any potentially significant natural features (NSW Planning Assessment Commission, 2009). In addition, Risk Management Zones have been identified for significant natural features including rivers, significant streams, significant cliff lines and valley infill swamps (DoP, 2008). Where either of these two zones extends outside the footprint of the 20mm subsidence zone, they have also been incorporated in the Study Area for the groundwater assessment.

21.1.3 *Existing Environment*

The existing basement hydrogeology of the Study Area was determined based on a review of existing literature and data and a hydrogeological investigation program, which was developed to establish a baseline.

This section describes the basement hydrogeology, the hydrogeological investigation program and its initial outcomes, and water quality.

21.1.4 *Basement Hydrogeology*

The following five hydrogeological domains have been identified in the Study Area:

- the hydraulically disconnected (perched), ephemeral weathered Hawkesbury Sandstone soil and upland swamps;
- the deeper Hawkesbury Sandstone, which is hydraulically separated from the underlying Bulgo Sandstone and deeper lithologies at Wonga West by the Bald Hill Claystone, but is not in the deeper eroded channel of Cataract Creek at Wonga East;
- the Narrabeen Group sedimentary lithologies, the lower portions of which have already been locally fractured and depressurised above the existing workings, and will be fractured and depressurised over the proposed workings up to the upper Bulgo Sandstone;
- the Illawarra Coal Measures, which contains the Bulli, Balgownie and Wongawilli seam aquifers that have also been fractured and depressurised by the existing workings and will be locally fractured and depressurised by the proposed workings, and
- the sedimentary sequence of aquifers and aquitards underneath the Wongawilli seam.

The following sections describe each of the aquifer systems present in the Study Area above the Wongawilli seam.

Hawkesbury Sandstone

Apart from aquifers in the coal seams, the main aquifer in the Study Area is the dual porosity (ie interstitial pore space plus fractures and joint porosity) Hawkesbury Sandstone which, although having generally low permeability, can provide relatively higher groundwater yields compared to other lithologies in the area.

The Hawkesbury Sandstone outcrops over the majority of the lease area and has been partially eroded away in the central base of the Cataract Creek valley to expose the upper Bulgo Sandstone.

Regional water levels within the shallow overburden result from interaction between rainfall infiltration (recharge) through the shallow weathered zone into the underlying clastic rocks and topography. Rainfall infiltration elevates the water table whilst drainage channels incised through to the water table provide seepage pathways that constrain groundwater levels to the elevation of stream beds through seepage into 'gaining' streams.

Evapo-transpiration losses from deep and shallow rooted vegetation would also reduce the phreatic surface of the water table to varying degrees.

The groundwater flow regime within the Hawkesbury Sandstone is primarily horizontal with a lesser vertical component due to the dominant horizontal bedding planes and bedding discontinuities interspersed with generally poorly connected vertical joints.

Ephemeral perched water tables within the upper 20m of the Hawkesbury Sandstone, which are generally hydraulically disconnected from the underlying regional aquifer, can occur following extended rainfall recharge periods.

Vertical hydraulic connectivity between the Hawkesbury Sandstone and the Bargo Sandstone is retarded by the semi-confining layer of the Bald Hill Claystone that extends across the Study Area, except where it is eroded away at Wonga East.

In rainfall recharge periods, water levels in shallow aquifers respond by rising, whilst in dry periods, levels are lowered through seepage to the local watercourses. During dry periods the salinity in surface drainages normally rises as the basement baseflow seepage proportionally increases.

Measured standing water levels in the Hawkesbury Sandstone range from to 12m to 39m below surface.

While high yields of up to 30 L/s have been identified in this formation within the Sydney Basin, they are not located in or near the Study Area

Water quality in the Hawkesbury Sandstone generally has low salinity (81 – 420 µS/cm) with relatively acidic pH (3.22-5.45) and can contain high iron levels up to 12.0 mg/L in the Study Area.

Narrabeen Group Lithologies.

The Narrabeen Group has generally low permeabilities. The sandstones can provide porous storage with limited fracture flow and low transmitivity, whilst the mudstones, siltstones and shales effectively retard vertical flow. In some localities, groundwater flow may be enhanced by localised, secondary fracturing where faulting and/or jointing associated with bedding flexure or where igneous intrusions may increase the hydraulic conductivity.

Some local scale faults and dykes are present in the Study Area although they are not anticipated to be large enough to enable loss of stream flow into the workings if dislocated by subsidence.

The Newport and Garie Formations, along with the underlying Bald Hill Claystone and the upper Bulgo Sandstone outcrop within the base of the headwater valleys within the Wonga East area, and would be directly recharged by stream flow leakage from Cataract Creek.

The base of the Narrabeen Group is marked by the Wombarra Claystone which has very low permeability in its unsubsided state.

The Narrabeen Group lithologies have significantly lower yielding aquifers (<1.0L/sec) compared to the Hawkesbury Sandstone, with very minor productive supplies obtained in the Southern Coalfields due to its generally deeper elevation below surface and its very low permeability. The highest (although still low) yields are obtained from the coal seams, with low to minimal yield obtained from the mudstone, shale, sandstone and conglomerates.

No water level monitoring has been conducted in the Narabeen Group lithologies by NRE or its predecessors. The Bulgo Sandstone can contain salinities of up to 1500 mg/L (KBR, 2008 in GeoTerra, 2010b) whilst the Scarborough Sandstone (Short et al. 2007 in GeoTerra, 2010b) can average around 850 µS/cm.

Illawarra Coal Measures

The Illawarra coal measures, consisting of the Bulli, Balgownie and Wongawilli seams, do not outcrop within the Study Area, although they outcrop along the lower section to the base of the Illawarra Escarpment. They would be recharged by vertical infiltration from overlying lithologies, with no direct, vertical, free draining, hydraulic connection between the seams and the surface creeks.

Since coupled pumping in/ out monitoring began in October 2005, groundwater inflows from 0.02 - 0.97ML/day (median 0.59ML/day) have occurred into the NRE No.1 workings.

Water quality varies regionally both within and between coal seams and interburden in the Illawarra coal measures due to the complexity of groundwater flow, with the water being mostly brackish to saline.

Existing Private Bores

No groundwater extraction is conducted from private bores or wells in the Study Area, with the nearest private registered bore on the Woronora Plateau being a test bore at Appin Colliery, which is located approximately 4.9km to the north of the PAA.

At present, one monitoring piezometer P514 (GW102223) is recorded in the NSW Natural Resource Atlas database in the vicinity of the proposed workings. No regional data within the Study Area is available on bore yields.

21.1.5 *Hydrogeological Investigation Program*

Drilling, piezometer installation, low flow pump out tests, falling head tests, packer tests and installation of open standpipe and vibrating wire piezometers, as well as groundwater level and water chemistry monitoring has been conducted within the Study Area between 1992 and the present.

The majority of drilling and monitoring has been conducted since July 2009 to provide input data to the development of the 'FEFLOW' model and assessment of the hydrogeological characteristics of the:

- upland swamps;
- Hawkesbury Sandstone;
- Narrabeen Group lithologies; and
- Illawarra Coal Measures.

To date, the groundwater investigation has involved installation of eighteen swamp piezometers, eight open standpipes and seven vibrating wire array piezometers extending up to 335m below surface. Piezometer locations are shown on *Figure 20.1* and *Figure 20.2*.

Groundwater drilling for the Project was contained within the NRE No 1 lease area, however the groundwater model domain includes adjacent BHPB and Peabody lease areas and current, decommissioned and proposed workings and peripheral areas within the major watersheds outside of the lease. Geological logs and piezometer construction details are provided in Appendix B of *Annex P.*

21.1.6 *Upland Swamps*

Recent mapping and assessment of upland swamps has identified that 39 upland swamps meeting the definition of the Coastal Upland Swamp Endangered Ecological Community are located within Wonga East, and 45 are located within Wonga West. Of these, it has been assessed that seven in Wonga East and eight in Wonga West are considered to be of 'special significance' in accordance with the OEH criteria. Detailed impact assessment for the 'special significance' swamps, including an initial risk assessment, comparative analysis, groundwater assessment, flow accumulation modelling and analysis of strains and potential for fracturing of bedrock has been undertaken by Biosis (2012) as provided in *Annex Q.*

The field mapping, aerial photography and Lidar interpretation has indicated that swamps in the Wonga West area are generally larger and more spatially continuous, whilst those in the Wonga East area are generally drier, shallower and less spatially continuous (Biosis, 2012).

Swamps in the Study Area have relatively small upstream catchments, with their saturation and storage capacity relying on direct rainfall recharge into the sandy sediments, seepage out of upslope Hawkesbury Sandstone, and the degree of contained humic material. The storage and water transmission characteristics of the surrounding and underlying Hawkesbury Sandstone are therefore critical in sustaining these environments.

The swamps occur in either headwater tributary valleys that are characteristically derived from colluvial sand erosion from Hawkesbury Sandstone dominated ridgelines or along the riparian zone of the major creeks. They are only located over weathered Hawkesbury Sandstone which provides a low permeability base on which the swamp sediments and organic matter accumulate.

Regional groundwater flow within the Hawkesbury Sandstone is hydraulically beneath, and separated by approximately 15m from the surficial swamps.

Due to their gentle slope, only the larger swamps can contain small, shallow, poorly defined open channels, which are generally short and located at the downstream reaches, whilst ephemeral patches of saturated sediment can be present in the headwater sections.

The headwater swamps are located within gently sloping, shallow trough shaped gullies and do not extend onto any steep slopes, benches or valley sides, where the plateau is not dissected by the Study Area creeks.

The central axes of the swamps are generally saturated after substantial recharge events, though the margins can comparatively dry out after extended dry periods.

The sand and humic material increases the swamp's water holding capacity and subsequently discharges rainfall infiltration, groundwater seeps and low-flow runoff into the local streams. Rainfall saturates the swamp after storms and with a slow, delayed discharge due to the low slopes when the recharge exceeds evaporation.

Sediments below, and laterally lensing into the humic material, are variable in nature and can be composed of fine to medium grained sands that can contain clayey bands and comprise a grey to mottled red-orange colour due to in-situ weathering.

Figures 22.1 and *22.2* illustrate the location of upland swaps within the Study Area. A detailed discussion and assessment of the upland swamps is provided in *Annex Q* and *Chapter 22.*

21.1.7 *Groundwater flows*

Multi-level piezometers have been installed at selected depths between the Upper Hawkesbury Sandstone and the Scarborough Sandstone since July 2009 in four bores at Wonga East (NRE–A, NRE-B, NRE-D, GW1) and NRE-3P501 and P502 at Wonga West.

Four open standpipe piezometers have been installed at Wonga East (NRE-A, C, D and GW1A) and four at Wonga West (NE-3, NRE-E, NRE-G and P514). All open standpipe piezometers were completed in Hawkesbury Sandstone, except GW1A, which was completed in the Bulgo Sandstone.

Monitoring of regional aquifer pressures in the dual porosity basement strata indicates a topographically driven flow regime which is potentially enhanced in the weathered shallower strata by flow through more open joints, fractures or bedding planes.

Groundwater flow is essentially horizontal to sub-horizontal due to the prominent, although shallow, bedding plane and strata dip to the north-west, although the flow is locally modified by gravity flow to the base of local valleys and Cataract Reservoir.

The data from the open standpipe and upper vibrating wire piezometer intakes as well as assumed water levels in the base of valleys and along Cataract Reservoir indicate a general flow at Wonga East from the escarpment to the Cataract Reservoir, whilst at Wonga West, the regional groundwater flow is essentially to the Cataract River in the north and to Cataract Reservoir in the east (*Annex M).*

21.1.8 *Water Quality*

Since commencement of monitoring in 2009, groundwater within the upper Hawkesbury Sandstone at Wonga West and Wonga East ranges from 81 to 420µS/cm, with a pH range from 4.1 to 6.7.

The moderate pH acidification and low salinity indicate rainfall recharge into the Hawkesbury Sandstone, with the salinity and pH range being typical of similar lithologies across the Southern Coalfields.

On the basis that the shallow groundwater discharges through seeps into the local streams, monitoring indicates the groundwater salinity is generally within the acceptable range for potable water. However it is generally outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH, and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for the following parameters:

- filtered copper, lead, zinc and aluminium (where the pH exceeds 6.5, which rarely occurs); and
- total nitrogen and total phosphorous.

21.2 *PAST MINING IMPACTS*

Mining has occurred in parts of the Study Area since the turn of the century, with each of the existing or decommissioned adjacent underground mines having the potential to interact with the groundwater pressure regime within and adjacent to the proposed NRE No.1 Wongawilli Seam workings.

Excavation of the adjacent underground mines has resulted in localised depressurisation of the Bulli Seam and overburden, which has altered regional groundwater flow toward each of the workings.

Combined pressure losses from the decommissioned, existing and proposed BHP Billiton Illawarra Coal (BHPBIC) operations (Appin, Westcliff and Northcliff) and Peabody's Metropolitan Colliery to the north of Cataract River have been predicted through groundwater modelling to have the following potential drawdowns in the Gujarat lease after 31 years of operation:

- negligible drawdown in the mid Hawkesbury Sandstone;
- 1 to 3m in the lower Hawkesbury Sandstone;
- 5 to 20m in the upper Bulgo Sandstone; and
- 10m in the Bulli Seam.

The ultimate shape of the depressurised surface will be governed by the prevailing hydraulic properties of the coal measures, connectivity of strata through jointing and fracturing and the cumulative impacts of the regional mines.

Previous operations within the NRE No.1 Colliery, the decommissioned BHP Cordeaux Colliery to the south, and the BHP Bulli bord and pillar mine to the east, have all undermined the catchments of Cataract River (upstream of Cataract reservoir), Lizard, Wallandoola, Cataract and Bellambi Creeks within the Study Area.

Within the Wonga West area, up to 1.3m of subsidence has been generated by extraction of the Bulli seam in the 200, 300 and 500 series longwalls to the west of and beneath Cataract Reservoir. In addition, bord and pillar mining as well as pillar extraction of the Bulli seam, longwall mining in the Balgownie seam and extraction of longwall WE-A2-LW4 in the Wongawilli Seam has been conducted to the east of Cataract Reservoir within the Wonga East area.

Due to the highly localised effects of subsidence on streams overlying subsided workings, it is not anticipated that free draining vertical connectivity to the underground workings has been instigated, and no transmitted effects on streamflow within the NRE No.1 lease or adjacent BHPBIC workings have been observed.

No measureable change in groundwater quality has been reported, or is anticipated, within the Study Area as a result of mining within the NRE No.1 lease area or adjoining existing, decommissioned or proposed underground workings, however no publicly available pre and post mining surveys of groundwater levels or groundwater quality are known to be available over the BHPB Cordeaux or Bulli mine workings.

Observations from vibrating wire piezometer arrays over the 500 series Bulli seam panels and the Bulli short-wall workings have been undertaken and indicated:

- up to 15m of drawdown in the Hawkesbury Sandstone, followed by a four month recovery and;

- up to 31m drawdown in the lower to mid Bulgo Sandstone, followed by a four month period in which the water level recovered to approximately 24m below its original level.

Studies commenced over Longwall 501 (P501) and 502 (P502) in 1992 and 1993 respectively, and over Longwall 514 (P514) in 1998 to monitor potential depressurisation and subsidence fracturing indicated:

- seepage from Longwall panels 501 and 502 or overlying goaf was too small to measure;

- the deeper P502 piezometers did not show any clear link with the mining operations, and the upper Bulgo Sandstone piezometer at 240m above the seam floor did not record any measurable pressure changes;

- vibrating wire piezometer monitoring between Longwalls 501 and 502 indicates that the hydraulic integrity of the Bulli Seam and the Hawkesbury Sandstone has not been adversely affected;

- over longwall panels 501 and 502, vertical interconnected fracturing extended for less than 153m above the Bulli Seam, with a low permeability connection from the lower Bulgo Sandstone to the Bulli Seam goaf. Based on this, it was interpreted that linked vertical fracturing was unlikely to have extended up into the mid Bulgo Sandstone, however it was potentially affected by horizontal bed separation; and

- monitoring in P514 indicated that the majority of fracturing was concentrated in the Coalcliff and Scarborough Sandstones, to approximately 100m above the Bulli seam.

Monitoring of vibrating wire and open standpipe piezometers at Wonga East indicate there is a restriction to downward flow in the upper Bulgo Sandstone. Further, the pressure profile indicates that the vertical flow rate is likely to be relatively insignificant in comparison to rainfall recharge, while the magnitude of downward flow indicated by the profile depends on the hydraulic conductivity of the overburden strata.

The phreatic groundwater surface through NRE-A, GW1 and GW1A to Cataract Creek indicates the groundwater essentially follows the ground surface, and that the creek has a 'losing' relationship to the regional groundwater at that locality.

No adverse effects have been observed on the shallow, ephemeral, perched, colluvial groundwater systems or groundwater seepage to streams within (or from) any headwater upland swamps within the NRE No.1 lease area due to subsidence over the Bulli, Balgownie or Wongawilli seam workings.

Most known impacted swamps are valley infill swamps, however investigations undertaken by the Metropolitan PAC could not be certain that subsidence either initiated or contributed to the damage of these swamps.

Further details are provided in *Annexes M* and *P.*

21.3 *GROUNDWATER MODELLING*

Assessment of the current and potential mining related impacts due to extraction of the proposed Wongawilli seam longwalls on the groundwater systems in the Study Area involved conceptualisation of the local groundwater flow processes, measurement of hydraulic parameters in the field, simulation using computer based mathematical modeling with FEFLOW, imposition of changes brought about by the proposed extraction, and assessment of the resulting impacts.

The FEFLOW model structure, modelling approach and simulations generated by Golder Associates Pty Ltd in association with GeoTerra Pty Ltd are detailed in *Annex P*. The model provides an assessment of the existing groundwater system status and predicts the potential effects from extraction of the proposed Wongawilli longwalls.

The model was developed to represent the anticipated strata depressurisation where a freely draining connected cracking 'goaf' zone is anticipated to extend into the mid Bulgo sandstone, with an overlying 'constrained' vertical connectivity zone with enhanced secondary porosity, enhanced horizontal conductivity bedding flexure, although, without enhancement of vertical permeability or vertical free drainage, that extends to 20m below surface. A zone of enhanced vertical connective cracking is anticipated to overly the 'constrained' zone and to extend from 20m below surface over the proposed Wongawilli longwalls.

Due to the pre-existing depressurisation from the existing workings in the NRE No.1 mine as well as the adjoining Cordeaux and Bulli mines, and to minimise the use of assumed water level and hydraulic parameters outside of the Study Area, the model was set up to represent the current and proposed longwalls at selected time intervals within the model domain shown in *Annex P***.**

The intervals correlated to the;

- current period;
- end of extracting V Mains as well as Wonga East Areas 1 and 2;
- end of extraction in Wonga West Areas 3 and 4; and
- 10 years after mining has finished in Wonga West Area 4.

Uncertainty is associated with the lack of direct field measurement of post subsidence hydraulic conductivities being applied to represent the strata above the existing workings. In addition, assumptions were incorporated regarding the interactive effect of adjoining mines and workings within the overall Study Area.

It should be noted that the modelling requires simplification of the groundwater system in regard to lithological thicknesses, their hydraulic properties and applied stresses including previous subsidence, rainfall infiltration, creek leakage and underground seepage. It is also challenging, within the model limitations, to represent steep hydraulic gradients above the mine workings and the potential for zero pore pressure horizons.

Due to limitations of the modelling, the effect of structures such as faults and dykes were not assessed, which is in accord with other modelling studies conducted in the Southern Coalfields as outlined in *Annex P*.

Details of the conceptual groundwater sub domains, height of fracturing and associated assumptions, model calibration and sensitivity analyses taken into account when developing and running the model are provided in *Annex P*.

21.4 *POTENTIAL SUBSIDENCE EFFECTS, IMPACTS AND CONSEQUENCES*

The potential subsidence effects, impacts and consequences have been considered in *Chapter 18* and upland swamps in *Chapter 22*. This section looks at the impact to basement groundwater levels only.

21.4.1 *Upland Swamps*

A number of potential impacts to the upland swamps have been identified and assessed through various technical reports, including those associated with potential impacts to groundwater flow regimes and quality. A full discussion of the potential impacts to upland swamps is provided in *Chapter 22*.

21.4.2 *Basement groundwater levels*

Predicted subsidence of up to 1.2m at Wonga East and 2.55m at Wonga West and associated overburden cracking will cause depressurisation immediately above the seam in the free draining goaf zone and the vertically, hydraulically connected zone, and increased horizontal permeability in the overlying ‘constrained’ bedding delamination zone, which will in turn induce seepage to the workings from beneath the upper Bulgo Sandstone.

It is anticipated that the Bald Hill Claystone will retain its semi-confining properties and maintain its low vertical permeability hydraulic separation between the Hawkesbury Sandstone and Quaternary alluvial aquifers from the underlying Bulgo Sandstone and deeper systems.

Although the Bald Hill Claystone is partially to fully eroded in Cataract Creek to expose the Bulgo Sandstone, mine pump-out monitoring indicates there is no induced or enhanced direct vertical free drainage connection from Cataract or Bellambi Creeks, or the Cataract River to the mine workings due to previous mining subsidence.

Based on the restricted progression of overburden cracking into the upper section of the Bulgo Sandstone, it is not anticipated there will be free draining connective cracking from Wonga East or Wonga West to the proposed Wongawilli seam workings.

The impact of anticipated subsidence on the basement groundwater levels is summarised below and in *Table 21.1* for the current period, end of mining in V-Mains and Wonga East Areas 1 and 2, end of mining in Wonga West Areas 3 and 4 and ten years after the completion of mining in Wonga West Area 4.

21.4.3 *Groundwater Inflow to the workings*

The average daily modelled inflow to the NRE No.1 workings for each stage is shown in *Table 21.1*.

Table 21.1 Predicted Mine inflows at the end of mining area 4

Stage	Current Inflow (ML/day)	Predicted Wongawilli Workings Inflow (ML/day)	Predicted Wongawilli Workings Inflow (ML/year)
Wonga East	0.2	1.4	511
Wonga West	0.9	1.7	621
TOTAL	**1.1**	**3.1**	**1131**

Based on observations at other mines in the Southern Coalfield that have intersected major structures, if unidentified fracture related storages are intercepted, short term increases in the modelled seepage rates, of up to 0.1 - 0.5 ML/day into the workings may occur, which should dissipate over a period of weeks to months as outlined in *Annex P*.

NRE submitted an application to NOW for a Water Access Licence for 365mL/year on 22 January 2009. The application has not yet been approved, however, it will need to be modified to account for the predicted 1131mL/year of inflow during extraction of the Wongawilli seam workings.

Table 21.2 Summary of predicted impacts to groundwater levels

Aquifer	Current Period	End of V Mains and Areas 1 and 2	Areas 3 and 4	10 Years after mining
Shallow, Perched, Ephemeral, Hawkesbury Sandstone		shallow groundwater within this layer could undergo a water level reduction over the proposed workings following subsidence. Subsidence of Layer 1 is not anticipated to have a significant overall effect on stream baseflow or stream water quality where the temporary aquifers seep into local catchments. However, temporary, localised effects may be observed.		
Upper Hawkesbury Sandstone	17 – 48m below surface at Wonga East; and 18 – 40m below surface at Wonga West.	Up to 4m drawdown following mining. The upper sandstone may exhibit a heightened response to recharge due to the higher secondary porosity and hydraulic connection in the aquifer.	Up to 12m drawdown following mining. The upper sandstone may exhibit a heightened response to recharge due to the higher secondary porosity and hydraulic connection in the aquifer.	Up to 12m of water level recovery is predicted, although localised ongoing depressurisation of up to 10m may be present under the upper Wallandoola and Lizard Creek catchments.
Lower Hawkesbury Sandstone		Up to 4m of drawdown over Wonga East Area 2.	Up to 4m drawdown over Wonga East and up to 12m over Wonga West.	Up to 20m of water level recovery is predicted at Wonga East, although localised depressurisation of up to 6m may be present under the plateau between the headwaters of Lizard and Wallandoola Creeks.
Upper Bulgo Sandstone		Up to 8m of drawdown over Wonga East and V Mains.	Up to 5m of drawdown over Wonga East and up to 100m over Wonga West.	Partial water level recovery at Wonga East and depressurisation of up to 110m over Wonga West. The degree of drawdown increases with increasing depth towards the workings in the upper, mid to lower Bulgo Sandstone in association with an upward migration of zero pore pressures over subsided Wongawilli longwalls.

Aquifer	Current Period	End of V Mains and Areas 1 and 2	Areas 3 and 4	10 Years after mining
Scarborough Sandstone		Up to 40m drawdown at Wonga East and 110m over V Mains.	Up to 20m of drawdown at Wonga East and 140m over Wonga West.	Up to 60m of water level recovery at Wonga East and up to 120m over Wonga West.
Bulli seam		Up to 40m drawdown at Wonga East and up to 130m drawdown over V Mains.	Up to 10m of drawdown at Wonga East and 120m at Wonga West.	Up to 110m of water level recovery at Wonga East and up to 190m over Wonga West.
Wongawilli seam		Up to 50m drawdown at Wonga East and up to 60m over Wonga West / V Mains.	Up to 90m of drawdown at Wonga East and main drive workings and up to 40m over Wonga West.	Up to 160m of water level recovery at Wonga West and up to 100m at Wonga East.

21.4.4 *Groundwater Quality*

Previous observations at NRE No.1 indicate that groundwater quality within the regional groundwater system has not been adversely affected by undermining. However, there may be increased iron hydroxide precipitation and lowering of pH if the groundwater is exposed to 'fresh' surfaces in the strata through dissolution of unweathered iron sulfide or carbonate minerals.

The degree of iron hydroxide and pH change is difficult to predict, and can range from no observable effect to a distinct discolouration of the formation water. The discolouration does not pose a health hazard, however it can cause iron hydroxide precipitation at seepage points in local streams which can also be associated with algal matting and / or lowering of dissolved oxygen levels in the creek at the seepage point.

It should be noted that many Hawkesbury Sandstone aquifers in the Southern Coalfield already have significant iron hydroxide levels, and that ferruginous seeps can also be observed in previously un-subsided catchment areas.

As a result of the proposed workings, pH acidification of up to 1 order of magnitude may occur, however the change may be less if the aquifer has sufficient bicarbonate levels.

Outside of isolated iron hydroxide seepages, no adverse impacts to groundwater quality are anticipated due to discharge from the proposed Wongawilli seam workings subsidence areas.

21.4.5 *Loss of Bore Yield*

There will be no loss of bore yield as there are no private bores in the Study Area.

21.4.6 *Stream Bed Alluvium and Plateau Colluvium Aquifers*

There are no anticipated subsidence effects on stream bed alluvium or plateau colluvium aquifers as there is no significant accumulation of Quaternary sediments (or contained aquifers) within the Study Area.

21.4.7 *Cumulative Impacts*

Basement Groundwater

The cumulative impact of the existing and proposed NRE No. 1 workings along with the surrounding mines has been incorporated and assessed in the groundwater model through inclusion of the effects of:

- subsidence and associated fracture propagation and hydraulic permeability distribution over non-mining areas, as well as over bord and pillar / pillar extraction or longwalls of variable widths on the regional groundwater pressure distribution;

- known or estimated degree of flooding in the adjoining workings; and

- separation distance of adjoining workings (ie the Appin/ Westcliff/ Northcliff/ Metropolitan/Tahmoor mining areas were interpreted to be sufficiently distant from the existing and proposed NRE No. 1 workings to be discounted).

Upland Swamps

The cumulative impacts of past and proposed mining activities on the upland swamps have been identified and assessed in *Chapter 22*.

21.5 MONITORING, MANAGEMENT AND CONTINGENCIES

A detailed water monitoring plan will be developed post-approval in consultation with SCA, OEH and to the approval of DP&I. The following sections provide an outline of the proposed monitoring.

In summary, the plan would detail monitoring parameters and locations, set trigger values and discuss the logistics of monitoring in the Study Area.

21.5.1 *Swamp Monitoring*

The proposed swamp monitoring regime is outlined in *Chapter 22*.

21.5.2 *Basement Groundwater Monitoring*

Groundwater Levels

Piezometers to be included in the monitoring suite are shown in *Table 21.3* The suite is divided into standpipe and vibrating wire piezometers, with water level transducers and vibrating wire piezometers used to twice daily monitor standing water levels or pressure heads to assess variations in the colluvial and basement formations.

Table 21.3 Groundwater Level Monitoring Suite

Type	Location	Piezometer Type
Basement	NREA, C, D, E, G, NRE3, GW1A	Open Standpipe
	NREA, B, D, NRE3, GW1	VWP
Colluvium	SP1, SP2	Open Standpipe
Swamps	PL1A, 1B PL18, PL25, B, D	Lizard Creek catchment open standpipe
	PW1, 4, 11	Wallandoola Creek catchment open standpipe
	PCc2, 3, 4, 5A, 5B, 6	Cataract Creek catchment open standpipe
	PCr1	Cataract River catchment open standpipe
	PB4	Bellambi Creek catchment open standpipe

1. VWP = vibrating wire piezometer.

Inclusion of additional groundwater monitoring locations and depths will be incorporated, if required, following discussions with the SCA and NOW.

Monitoring will also involve bi-monthly manual standing water level measurement in all open standpipe basement piezometers, and at intervals as required for swamp piezometers, at which time the loggers will be downloaded and re-initiated as shown in *Table 21.4*.

Table 21.4 Standing Water Level Monitoring Method and Frequency

Monitoring Site	Sampling Method	Frequency / Download	Units
NREA, C, D, E, G, NRE3, GW1A	Water level logger / dip meter	twice daily / bi-monthly	mbgl
NREA, B, D, NRE3, GW1A	Vibrating wire piezometer	twice daily / quarterly	m head pressure
SP1, SP2	Water level logger / dip meter	as required	mbgl
PL1A, B PL18, PL25A, B, C, D	Water level logger / dip meter	as required	mbgl
PW1, 4, 11	Water level logger / dip meter	as required	mbgl
PCc2, 3, 4, 5A, 5B, 6	Water level logger / dip meter	as required	mbgl
PCr1	Water level logger / dip meter	as required	mbgl
PB4	Water level logger / dip meter	as required	mbgl

1. mbgl = meters below ground level.

Groundwater Quality

Tables 21.5 and *21.6* present the parameters to be measured, frequency of monitoring and sampling method for groundwater quality monitoring. Monitoring will continue for 12 months after mining has ceased.

Table 21.5 Groundwater Quality Monitoring Parameters

ANALYTES	Units	FREQUENCY
EC, pH	µS/cm, pH units	Bi – monthly for basement piezometers and as required for swamp piezometers
(EC, pH) + TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, hardness, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd (metals filtered)	µS/cm, pH units + mg/L	Start / finish of panel for where a piezometer is adjacent to a panel, or in an active mining area, otherwise 1 sample per year for basement piezometers and as required for swamp piezometers

The frequency of monitoring will be reassessed after mining is complete as it may be possible, depending on results, to lengthen the intervals. The frequency of monitoring and the parameters to be monitored may be varied by NOW once the variability of the groundwater quality is established.

Table 21.6 Groundwater Quality Monitoring Method and Frequency

Monitoring Site	Sampling Method	Frequency
Open standpipe piezometers	Pumped field meter readings	Bi – monthly for basement piezometers and as required for swamp piezometers
Open standpipe piezometers	Pumped sample for laboratory analysis	Start / finish of panel for where a piezometer is adjacent to a panel, or in an active mining area, otherwise 1 sample per year for basement piezometers and as required for swamp piezometers

Groundwater samples would be collected and analysed at a NATA registered laboratory for major ions and selected metals.

It is anticipated that the groundwater program would be maintained in its current status, with modification of the program as required in successive water monitoring and management plans.

Additional piezometers may be added to the existing suite if required.

The groundwater monitoring program is anticipated to be extended beyond the active mining period in order to assess the potential long term change in groundwater level recovery and quality changes for at least 12 months after completion of mining.

Surface Water and Groundwater Connectivity

The potential for enhanced surface water and groundwater system hydraulic vertical connectivity would be assessed through monitoring of stream flows in and near actively mined areas as well as through monitoring and interpretation of the basement groundwater open standpipe and vibrating wire piezometers water levels / pressures and mine inflow changes.

Mine Water Pumping

The volume of water pumped into and out of the NRE No. 1 workings would be monitored daily to enable the differential groundwater seepage into the workings to be assessed.

Ground Survey

The ground surface over the proposed underground workings would be surveyed in accordance with DRE subsidence monitoring requirements.

Rainfall

Daily rainfall data would be obtained from a local weather station for the duration of mining in the NRE No.1 catchment area.

Ongoing Monitoring

All results would be reviewed after each panel is completed and an updated monitoring and remediation program would be developed, as required in successive water monitoring and management plans, in association with NOW and DRE.

Quality Assurance and Control

QA/QC would be attained by calibrating all measuring equipment, ensuring that sampling equipment is suitable for the intended purpose, using NATA registered laboratories for chemical analyses and ensuring that site inspections and reporting follow procedures outlined in the ANZECC 2000 Guidelines for Water Quality Monitoring and Reporting.

21.5.3 *Contingency Measures*

Contingency procedures would be developed as required, with the measures to be developed being dependent on the issue to be addressed.

The procedures would be used to manage any impacts identified by monitoring that demonstrate the groundwater management strategies may not have adequately predicted or managed the groundwater system's anticipated response to mining.

Activation of contingency procedures would be linked to the assessment of monitoring results, including water quality, aquifer hydrostatic pressure levels and the rate of water level changes.

Performance indicators would be identified prior to extraction of the proposed underground workings and a statistical assessment would be undertaken to detect when, or if, a significant change has occurred in the groundwater system which would benchmark the natural variation in groundwater quality and standing water levels.

A monitoring and management strategy along with an outline of a Trigger Action Response Plan (TARP) would be prepared to provide guidance on the procedures and actions required in regard to the surface water and groundwater systems in the proposed mining area.

21.5.4 *Potential Rehabilitation Measures*

Potential rehabilitation measures are available for upland swamps and are described in *Chapter 22*. Rehabilitation measures for basement aquifers are not considered due to the limited available options.

21.5.5 *Reporting*

Following completion in extraction of each panel, a report would be prepared for all prior panels that summarises all relevant monitoring to date. The report would outline any changes in the groundwater system over the relevant mining area.

The report would contain an interpretation of the data along with:

- a basic statistical analysis (mean, range, variable, standard deviation) of the results for the parameters measured;
- an interpretation of water quality and standing water level changes supported with graphs or contour plots; and
- an interpretation and review of the results in relation to the impact assessment criteria.

Relevant monitoring and management activities for each year would also be reported in the AEMR.

21.5.6 *Adaptive Management*

An adaptive management plan would be developed to use the monitoring program to detect the need for adjustment to the mining operation so that the subsidence predictions are not exceeded and subsidence impacts creating a risk of negative environmental consequences do not occur. The adaptive management procedures would be implemented to provide a systematic process for continually detecting impacts, validating predictions and improving mining operations to prevent further adverse impacts on the swamp and basement groundwater systems overlying the proposed mining domains.

Monitoring, evaluation, and reporting on management performance and ecological impact would be integrated into the site's core management systems to progress the technical understanding and predictive capability of subsidence effects, impacts and consequences on the sites surface water systems.

An evidence-based approach would be used to validate the extent to which outcomes are being achieved, with the monitoring results being related to, and demonstrating how management strategies have been achieved or where improvements can be made.

As Longwalls A2 LW 4 to LW 7 are planned to be mined first, and as they are not overlain by the main channel or significant tributaries of Cataract Creek, they would provide a 'baseline' monitoring opportunity to assess the potential effect of subsidence on fracture propogation and development through the overburden. They would also provide specific data about height of fracturing, development of cracking at surface, changes to an upland swamp perched water system (Crhs1) as well as flow and water quality in Cataract Creek and any changes in mine inflows.

Data gained from monitoring a suite of extensiometers, vibrating wire piezometer arrays and open standpipe piezometers as well as geochemical monitoring of groundwater and surface water and stream flow regimes over and around the panels would then be able to be used to update the curent geotechnical, hydrogeological and hydrological assessments for the proposed mining and to incorporate, if required, adaptive management measures for future panels.

Additional groundwater related monitoring that could be used to enhance the adaptive management process may include conducting:

- continuation of the existing mine water pump monitoring and updating the mine water balance;
- additional drilling, with a range of vibrating wire piezometers and core testing to establish the mechanical and hydraulic properties of the overburden in proximity to water dependent systems in the catchments (including swamps);
- installation of additional deep vibrating wire piezometers and extensiometers to assess/quantify the potential impacts of fracturing within the subsidence zone;
- installation of paired shallow piezometers targeting swamps and the underlying shallow Hawkesbury Sandstone aquifer to assess their potential hydraulic connection and climatic implications;
- sediment profiling in swamps to characterise type, thickness and sensitivity to differential subsidence, and
- update the numerical modelling when sufficient additional data becomes available to enhance the prediction of subsidence zone fracture distributions, connectivity and groundwater transmission capacities.

21.6 *CONCLUSIONS*

The existing hydrogeological environment has been described and investigations have been commenced to provide an environmental baseline.

A FEFLOW groundwater model has been developed the represent the aquifers and to predict potential impacts. Within the limitations and constraints of the model, it is predicted that the proposed mining could depressurise the overburden up to the upper Bulgo Sandstone. However, it is predicted that the Bald Hill Claystone will remain intact and retain its semi-confining properties, maintaining hydraulic separation between the Hawkesbury Sandstone and Quaternary alluvial aquifers from the Bulgo Sandstone and deeper systems.

Mine water seepage is predicted to rise from the current 1.1 ML/day (402 ML/year) to 3.1 ML/day (1131 ML/year) at the end of mining (for total inflow at Wonga East and West). However, if unidentified fracture related storages are intercepted, short terms increases in the modelled seepage rates of up to 0.1 - 0.5 ML/day into the workings may occur, which should dissipate over a period of weeks to months.

Changes to inflow into Cataract Reservoir and to stream baseflow within the Lizard, Wallandoola and Cataract Creeks have been predicted, however these are anticipated to be minor as outlined *Chapter 20* and *Annex O*.

A monitoring regime, as well as adaptive management and the development of contingency measures has been developed to monitor changes to the groundwater system and implement management measures should unexpected impacts occur, or are likely to occur based on ongoing monitoring and updated predictions due to mining.

22 *UPLAND SWAMPS*

This chapter describes the upland swamps located within the Study Area and provides an assessment of the potential impacts and consequences to these swamps as a result of mining in Wonga East and Wonga West.

22.1 *INTRODUCTION*

This chapter describes the upland swamps located within the Study Area and provides an assessment of the potential impacts and consequences to these swamps as a result of mining in Wonga East and Wonga West. It is based primarily on the NRE No.1 Colliery Major Expansion Upland Swamp Assessment (2012), prepared by Biosis (2012) and provided in full in *Annex Q*, and the NRE No 1 Colliery Groundwater Assessment (2012) prepared by GeoTerra (2012b) (see Chapter 8 of *Annex P*). Consideration of threatened species that may occur in upland swamps is provided in *Chapter 16* and in the Terrestrial Ecology Report prepared by ERM (see *Annex S*).

Upland swamps are vegetated freshwater wetlands occurring in shallow basins located in low hills, plateaus of mountains. Upland swamps are significant biodiversity features that provide habitat for a high diversity of plant and animal species, many of which are threatened or endemic (DECC 2007a). Upland swamps regulate the quality and quantity of surface-water discharge by releasing moisture over extended (often dry) periods. This water availability means that many species are dependent upon upland swamps and their associated streams for some or all of their lifecycle.

22.1.1 *Processes*

On the Woronora Plateau most of the upland swamps are located over weathered Hawkesbury Sandstone, which provides a low permeability base on which the swamp sediments and organic matter accumulates. The storage and water transmission characteristics of the surrounding and underlying Hawkesbury Sandstone is critical in sustaining these environments. Saturation of swamps is dependant upon the following features:

- rainfall recharge directly into the sandy sediments;
- seepage out of upslope Hawkesbury Sandstone; and
- the degree of accumulated organic matter which influences water retention.

Upland swamps are formed on floors of low gradient/low flow valleys or in seepage zones along benched slopes, by a positive feedback mechanism, where sediment is accumulated through some type of initial blockage (eg rock benches, obstruction by large logs etc).

This results in impeded drainage, waterlogging of the soil, increased soil moisture, killing of trees due to waterlogging and an increase in dense hydrophilic vegetation. This process reduces the transpiration capacity of the vegetation, which allows the water table to rise more frequently than if trees were present, reinforcing the process (Young 1982, Keith *et al.* 2006, Tompkins & Humphrey 2006, NSW Scientific Committee 2012).

The SCI made a distinction between 'headwater' swamps or 'valley infill swamps' based on location in the landscape and susceptibility to subsidence (DoP 2008). In some swamps, in particular larger swamps, it may be difficult to distinguish between where they are headwater and where they are valley infill swamps.

Headwater swamps are situated in areas high in the catchment near catchment divides, located in areas of shallow, impervious substrate formed by either sandstone or clay horizons (DoP 2008). Rainfall is likely to exceed evaporation in these swamps and as a result headwater swamps are likely to have perched water tables within the sediments that are independent of the regional water table in the Hawkesbury Sandstone (PAC 2009). The degree of saturation is dependent upon prevailing climatic conditions. Groundwater seepage from these swamps contributes to downstream baseflows (PAC 2010). Baseflow is a sustained (but diminishing) flow following rainfall, which is important in maintaining aquatic and riparian ecosystems and habitats (PAC 2010).

Valley infill swamps are less common on the Woronora Plateau than headwater swamps. Valley infill swamps form on the floor of incised second or third order stream valleys on sediment deposited possibly as a result of channel blockage such as a log jam (DoP 2008). Valley infill swamps are likely to have direct connection to regional water table and may receive water from multiple sources including rainfall, streamflow and groundwater seepage (PAC 2010).

22.1.2 *Biodiversity*

Upland swamps support wetland vegetation communities of primarily sedges and wet heaths that fall within the Coastal Heath Swamps class of Keith (2004). These wetlands are restricted to sites of permanently or periodically waterlogged soils and tend to be treeless with a dense to sparse shrub layer depending on fire history.

On the Woronora Plateau upland swamps support a mosaic of Sedgeland-Heath Complex, Tea-tree Thicket and Banksia Thicket (NPWS 2003) in response to soil moisture and fertility. Of these communities, Tea-tree Thicket is dependent upon permanently wet habitat while the others are more tolerant of decreased moisture levels (OEH 2012). The presence of Tea-tree Thickets is an indicator that a swamp is likely to support a more complex vegetation structure.

Vegetation

The Native Vegetation of the Woronora, O'Hares and Sydney Metropolitan Catchments (NPWS 2003) mapped four vegetation communities associated with upland swamps in the Woronora Plateau:

- Upland Swamps: Banksia Thicket (MU 42);
- Upland Swamps: Tea-tree Thicket (MU43);
- Upland Swamps: Sedgeland Heath Complex (MU44) a mosaic of three sub-communities including Sedgeland (MU44(a)), Restioid Heath (MU44(b)), Cyperoid Heath (MU44(c)); and
- Upland Swamps: Fringing Eucalypt Forest (MU 45).

Biosis (2012) in their assessment of upland swamps describe vegetation communities and soils. In areas of frequent waterlogging/high groundwater levels and/or permanent moisture, soils contain a high organic content, are generally deeper and tend to support areas of Tea-tree Thicket dominated by Tea-tree (*Leptospermum* spp.), *Melaleuca squarrosa* and *Acacia rubida*, with an understorey of Coral Fern (*Gleichenia* spp.).

In areas of intermittent waterlogging and or moisture, soils consist of a mix of organic material and mineral sands, and tend to support Cyperoid heath, dominated by dense stands of large sedges from the Cyperaceae family including *Gymnoschoenus sphaerocephalus*, *Lepidosperma limicola*, *Chorizandra sphaerocephala* and *Baumea rubiginosa*.

In the driest parts of upland swamps, soils can vary in depth and composition, with driest areas supporting mineral sands of a few centimetres in depth. These areas intergrade with deeper, wetter soils mentioned above. These drier areas support a mix of Restioid Heath, Sedgeland and Banksia Thicket. Sedgeland, located in areas subject to periodic waterlogging and seepage, is comprised of a low dense cover of sedges such as Slender Twine-rush (*Leptocarpus tenax*), Zig-zag Bog-sedge (*Schoenus brevifolius*) and *S. paludosus* with some small shrubs such as *Baeckea imbricata,* Pink Swamp Heath (*Sprengelia incarnata*) and *Actinotus minor*. Restioid Heath, located on swamp margins and upper slopes where the water table rarely reaches the surface, is comprised of a low shrub layer of *Banksia oblongifolia*, Swamp Banksia (*Banskia robur)*, Blunt-leaf Heath (*Epacris obtusifolia*) and a dense ground cover of species such as *Empodisma minus, Lepyrodia scariosa, Leptocarpus tenax* and *Schoenus brevifolius*. Banksia Thicket is located on swamp margins and upper slopes where the water table rarely reaches the surface, forms a dense heath, often on the margins of upland swamps or in smaller swamps located along benched terraces (pers comm N. Garvey, Biosis).

Upland Swamps: Fringing Eucalypt Woodland occurs on the drier fringes of headwater swamps and is an ecotone between dry sandstone woodlands and the wetter swamp communities. These areas often resembled the adjoining sandstone woodlands in species composition and soil moisture. This community consisted of Scribbly Gum (*Eucalyptus racemosa) and* Broad-leaved Scribbly Gum *(Eucalyptus haemastoma)* with *Banksia oblongifolia* and *Petrophile sessilis,* dominating the ground coverage (NPWS 2003). Common mid-storey species of this community include Heath-leaved Banksia (*Banksia ericifolia* subsp. *ericifolia*), Fern-leaved Banksia (*Banksia oblongifolia*) and Finger Hakea (*Hakea dactyloides*). Dominant understorey species include Slender Twine-rush (*Leptocarpus tenax*) and Pink Swamp Heath (*Sprengelia incarnata*) (NPWS 2003).

Notwithstanding the mapping of NPWS (2003) and naming convention which includes Fringing Eucalypt Forest as a vegetation unit in upland swamps, this community has not been included in the determination of Coastal Upland Swamp EEC and not in the definition of the upland swamps in the OEH (2012) guidelines for assessment of upland swamps (see *Section 22.1.3*). Areas of Upland Swamp: Fringing Eucalypt Forest have not been included within the assessment of upland swamps provided by Biosis (2012a) and summarised in this chapter.

Fauna Habitats

Upland swamps are habitats of high conservation value supporting high diversity of flora species and providing habitat, in particular drought refuge for invertebrate and vertebrate fauna. On the Woronora Plateau, upland swamps are the highest priority habitat for conservation of vertebrate fauna (DECC 2007c). Upland swamps provide key habitat for at least 12 priority fauna species including the Ground Parrot (*Pezoporus wallicus wallicus*), Eastern Bristlebird (*Dasyornis brachypterus*), Beautiful Firetail (*Stagonopleura bella*) and Giant Burrowing Frog (*Heleioporus australiacus*) (DECC 2007c).

The Woronora Plateau (Woronora, O'Hares Creek and Metropolitan Special Areas) represent approximately 90% of the upland swamp habitat in the Greater Southern Sydney Region. Maddens Plains is the most extensive system with other important upland swamp habitats idnentified in the southern Avon Catchment and Wallandoola Creek (DECC 2007c).

Consideration of threatened species in upland swamps is provided in *Annex S* and *Chapter 24* of this EAR.

22.1.3 *Legislative Status*

Upland swamps throughout the PAA are representative of the *Coastal Upland Swamp in Sydney Basin Bioregion EEC* listed under the state TSC Act.

The determination notes that the key threatening process '*Alteration of habitat following subsidence due to longwall mining*' is a threatening process for this EEC.

The Bulli PAC report (2010) identified that OEH consider upland swamp communities within the Woronora Plateau to be consistent with the Commonwealth listed *Temperate Highland Peat Swamps on Sandstone* (THPSS) EEC. Biosis (2012a) reviewed whether the upland swamps are representative of the THPSS EEC and concluded that the upland swamps in the PAA are not representative of the current listing (see Section 1.2.3 of *Annex Q*). This was based on the upland swamps in the PAA not meeting three criteria of altitudinal range, distribution and soils.

22.1.4 *Special Significance*

The Southern Coalfield Inquiry (DoP 2008) found that the coalfields underlie a landscape containing highly significant ecological features that are sensitive to subsidence impacts as a result of longwall mining. The sensitive landscape features include streams, swamps, rocky habitats, endangered ecological communities (EECs) and threatened species.

In response to the SCI, DECC identified four contiguous networks of intact upland swamps to be of particular conservation significance (DECC 2007a) including the Wallandoola Creek swamp cluster, that is mapped as extending across the majority of the Study Area.

Further consideration of the significance of upland swamps was provided in the PAC review for the Metropolitan Colliery (PAC 2009) and Bulli Seam Operations (BSO) (PAC 2010). The PAC identified that some highly significant ecological features are classified as features of 'special significance'. Where, 'special significance' status is based on assessment of a natural feature that determines the feature to be so special that it warrants a level of consideration (and possibly protection) well beyond that accorded to others of its kind. It may be based on a rigorous assessment of scientific importance, archaeological and cultural importance, 'uniqueness', meeting a statutory threshold or some other identifiable value or combination of values (PAC 2009).

According to the criteria for special significance, as set out by the PAC (2010), an upland swamp is considered of special significance where it is either:

- a large swamp in the upper 10 percentile in the Woronora Plateau being greater than 9.3ha as larger swamps transmit a higher volume of water in the catchment, contain a wider range of habitats and are less vulnerable to edge effects;

- complex supporting a greater diversity of vegetation communities and biodiversity with presence of tea-tree thicket being an indicator; or

- contiguous habitat defined by a swamp being proximate to other swamps that is part of a cluster of swamps, with particular significance given to the Maddens Plain (O'Hares and Cataract catchments), Wallandoola Creek (Cataract catchment), North Pole (southern Avon catchment) and Stockyard (southern Nepean catchment) swamp clusters (DECC 2007); or

- presence of Endangered Ecological Communities or threatened species identified as upland swamp specialists and/or species that cannot withstand loss of habitat in the Hawkesbury- Nepean Catchment (HNC) as determined by BioBanking database; or

- swamps occur within study area of long term scientific study eg 'Dharawal upland swamp scientific research area' established in 1983. Site of scientific research importance if it meets any of the following criteria:

    - a) an important reference area for ecosystem and landscape processes that operate over a larger region;

    - b) contains features or resources for which few alternative opportunities exist for scientifically valid study;

    - c) part of a network of research sites, in which the damage, degradation or uncontrolled change to component sites would compromise the scientific validity of inferences drawn from the study; and

    - d) part of a research project providing important insights.

- Aboriginal and cultural significance;

- value as a refuge and foraging habitat for fauna; and

- swamp contribution to catchment hydrology.

With the listing of the EEC Coastal Upland Swamp in the Sydney Basin Bioregion all upland swamps would meet the criteria for special significance. In light of this, and to provide a best practice guide for assessment and management of upland swamps, OEH have developed draft assessment guidelines for the underground mining industry operating in the southern coalfields (OEH 2012).

In accordance with the OEH (2012) guidelines, an upland swamp is of special significance when it meets three of the following five criteria:

- statutory thresholds, indicated by the presence of threatened ecological communities or threatened species; or
- swamp size greater than 7.4ha being in the top 10% of swamps in the region; or
- unusual complexity or biodiversity supported by a full range of habitats associated with a mosaic of hydrological characteristics from drier fringing areas to permanently wet areas. Where vegetation mapping has been undertaken, complexity is indicated by the presence of Banksia Thicket, Tea-tree Thicket and Sedgeland-Heath Complex. Where mapping of NPWS (2003) is relied upon, the presence of Tea-tree Thicket is an indicator of unusual complexity; or
- closely proximate habitat being a swamp occurring in one of the four key clusters of swamps (as defined by the PACs); or
- importance for scientific research being those swamps in Dharawal upland swamp scientific research area plus paired reference sites.

All upland swamps mapped as a part of this assessment meet the statutory threshold criterion as they are representative of the Coastal Upland Swamp EEC. In addition, a number of upland swamps within the Study Area are, either known to support threatened species and / or provide potential habitat for threatened species.

All upland swamps in the Study Area form part of the Wallandoola Creek swamp cluster while none meet the criterion of importance of scientific research. Accordingly, determination of 'special significance' for each of the upland swamps identified in the PAA by Biosis was based upon whether it is a large swamp, or unusual complexity or biodiversity (see *Section 22.4* and Section 4.1 of *Annex Q* for this assessment).

22.2 *UPLAND SWAMP ASSESSMENT METHODOLOGY*

Biosis were engaged to undertake detailed mapping, assessment of significance of upland swamps and assessment of the potential impacts of longwall mining to identify those swamps of special significance considered at risk of negative environmental consequences. Biosis built upon and refined the NPWS (2003) mapping of the Study Area and previous investigations undertaken by ERM. Biosis's assessment is included in full in *Annex Q*.

The methodology was based upon the steps identified in the PAC reports (2009, 2010) and the draft upland swamp environmental impact assessment guidelines (OEH 2012).

22.2.1 *Mapping of Upland Swamps*

Upland swamps were mapped through:

- using Light Detection and Ranging (LiDAR) data to define areas of 'potential wetland polygons' requiring further investigation (see Section 2.1.1 of *Annex Q* for detailed description of this methodology);

- ground truthing of these areas in the field by a team of botanists to determine whether 'potential' wetland polygons were upland swamps, to define swamp boundaries using a GPS, and map swamp sub-communities; and

- use of a Geographic Information System (GIS) to spatially represent vegetation community data and upland swamp boundaries.

The upland swamps were named based on the catchment they were positioned within. Where possible, swamps were further classified into 'headwater' and 'valley infill' swamps based upon position in the landform and an analysis of slope and flow accumulation modelling (see Section 2.1.3 of *Annex Q*). For some of the upland swamp systems in Wonga West the distinction between areas that are defined as valley infill and/or headwater swamps was problematic and these swamps were considered to form one functional unit for the purposes of mapping. However, given the differences in type and degree of impacts they were considered separately where appropriate.

22.2.2 *Analysis of Upland Swamps*

LiDAR data and GIS special anaylsis tools were used to produce layers and to categorise the terrain and water flow (not stream flow) through individual swamp vegetation communities. The steps used to create this data are outlined in detail in Section 2.2 of *Annex Q*.

Seedsman's (2012) predicted effects of modelled 'upper bound scenario' mining subsidence were analysed using GIS to produce a predictive surface levels following vertical subsidence and to show changes in water movement relative to the pre-mining flow accumulation models.

22.2.3 *Comparison to Regional Vegetation Mapping*

Upland swamp mapping undertaken for this Project was compared with mapping of upland swamps by NPWS (2003) restricted to those communities that define the Coastal Upland Swamp EEC (see Section *22.1.3*).

22.2.4 *Significance Assessment and Assessment of Potential for Impact*

The impact assessment was undertaken in two stages (see Section 2.4 of *Annex Q*). The first stage involved the undertaking of an assessment of 'special significance' of upland swamps according to the draft *Upland Swamp Environmental Impact Assessment Guidelines* (OEH 2012) as outlined in *Section 22.1.4*.

The second stage involved an assessment of the potential for upland swamps of 'special significance' to be impacted based on a variety of features, including an initial risk assessment according to OEH (2012), comparative analysis of upland swamps that have previously been undermined, changes to flow accumulation and potential for fracturing of bedrock and desiccation.

OEH (2012) requires proponents to undertake a preliminary prediction of subsidence levels under upland swamps and compare this to subsidence criteria outlined in PAC (2010) to determine upland swamps considered to be at risk of negative environmental consequences.

These criteria include:

- all swamps subject to systematic tensile strains > 0.5mm/m;
- all swamps subject to systematic compressive strains > 2mm/m;
- all swamps with depth of cover less than 1.5 times longwall panel width;
- all swamps subject to tilt (transient or final) > 4mm/m;
- all swamps subject to valley closure of > 200mm/m; and
- all swamps subject to a maximum observed closure strain > 7.0mm/m.

However, given the inexact nature of subsidence predictions OEH (2012) also request that a comparative analysis of subsidence levels from past mining operations and observed impacts to upland swamps is undertaken.

Due to the difficulty with obtaining subsidence data on previous mining operations in conjunction with monitoring data from upland swamps an alternate approach was considered warranted by the current assessment (Biosis 2012a). Hydrology, particularly shallow groundwater and surface water flows, is a key component in the formation and maintenance of upland swamps. As detailed in Section 1.2.4 of *Annex Q*, changes in hydrology resulting from subsidence associated with longwall mining have potential to result in impacts to upland swamps. Thus it was deemed that an assessment of hydrology was critically important to undertaking any risk assessment.

For this reason the following work was also undertaken by Biosis (2012a) to inform the risk assessment:

- review of hydrological assessment undertaken by Geoterra Pty Ltd;
- analysis of flow accumulation pre- and post-mining, taking into account subsidence predictions (Seedsman 2012); and,
- predicted compressive and tensile strains to determine areas that may be subject to fracturing of bedrock.

It was deemed that these analyses, considered in conjunction, would provide predictions for upland swamps considered at risk of impact as a result of longwall mining in Wonga East and Wonga West (Biosis 2012a).

22.3 *RESULTS OF UPLAND SWAMP MAPPING*

22.3.1 *Wonga East*

A total of thirty-nine (39) upland swamps were recorded within Wonga East Study Area (see *Figure 22.1*). A description of each upland swamp within Wonga East is provided in *Appendix 1* of *Annex Q*.

All swamps within Wonga East are headwater swamps, ranging in size from 0.04ha to 9.84ha with an average of 1.26 ha. Within the Wonga East mining domain, as defined by the 600m RMZ, the total area of upland swamps is 49.06 ha.

The majority (34 of the 39) of upland swamps in Wonga East support Banksia Thicket, with twenty (20) upland swamps supporting only this vegetation sub-community. Ten (10) upland swamps support Tea-tree Thicket. Six (6) upland swamps support the complete range of upland swamp vegetation sub-communities.

Relative to the upland swamps mapped by NPWS (2003) Biosis have mapped an additional 11 upland swamps, determined that the total area of upland swamp was approximately 20ha less than NPWS (2003) mapping and confirmed the presence of Tea-tree Thicket.

22.3.2 *Wonga West*

A total of forty-five (45) upland swamps were recorded within Wonga West Study Area (see *Figure 22.2*). A description of each upland swamp within Wonga West is provided in *Appendix 1* of *Annex Q*.

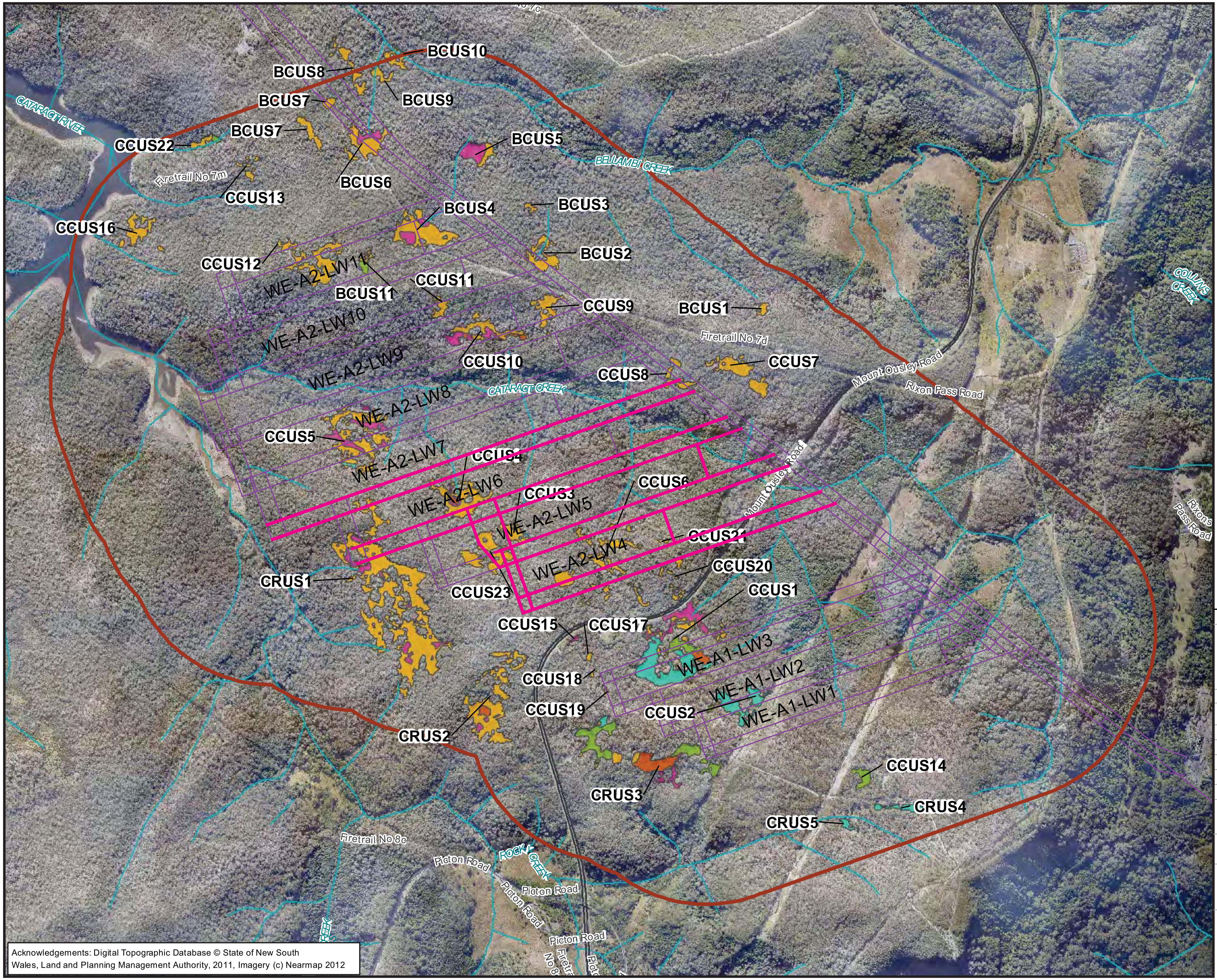
Swamps within Wonga West and immediate environs range in size from 0.06ha to the large LCUS1 complex covering 129.89 ha, with an average size of 4.79 ha. Within the Wonga West mining domain as defined by the 600m RMZ the total area of upland swamps is 72.13 ha. (Note that the boundary of LCUS1 extend upstream of the PAA beyond the RMZ.)

Upland swamps in Wonga West are diverse in the vegetation sub-communities they support. Restioid Heath sub-community of the Sedgeland-Heath Complex was the most abundant vegetation community in the upland swamps, with twenty-seven (27) upland swamps supporting this community of which thirteen (13) supporting only this community. Twenty-six (26) upland swamps support Banksia Thicket, with twelve (12) upland swamps supporting only this vegetation sub-community. Thirteen (13) upland swamps support Tea-tree Thicket. Six (6) upland swamps support the complete range of upland swamp vegetation sub-communities.

Relative to the upland swamps mapped by NPWS (2003) Biosis have mapped an additional 26 upland swamps and determined that the total area of upland swamp was 21.34ha more than NPWS (2003) mapping. Biosis's mapping has identified within the Wonga West area that Banksia Thicket and Tea-tree Thicket were more prevalent.

Wonga West contains both headwater and valley infill swamps. Four of the upland swamps in Wonga West (LCUS1, LCUS6, LCUS8 and WCUS4) contain both headwater and valley infill swamp types however, as these swamps are functioning as one larger swamp they have been named as such (Biosis 2012a).

Valley infill swamps occur along the well-defined drainage line of Wallandoola and Lizard Creeks, occupying the flatter, un-dissected upper sections of streams within the main valleys and can form through sediment deposition behind logs at choke points in a stream, or terminate at 'steps' in the underlying sandstone substrate (GeoTerra 2012b). Following is a description of the valley infill swamps and streams from GeoTerra (2012b).



Legend

Vegetation Sub-Communities

- MU42 Upland Swamps: Banksia Thicket
- MU43 Upland Swamps: Tea-Tree Thicket
- MU44a Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
- MU44b Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
- MU44c Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

Survey Area

- Wonga East Study Area
- Longwalls
- Approved Workings (MP10_0046)

Matter: 15094,
Date: 31 October 2012,
Checked by: NMG, Drawn by: apritchard
Location:P:\15000s\15094\Mapping\Report Figures\15094 F4_Wonga East Swamps

Figure 22.1
Upland Swamps in Wonga East

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No.1 Colliery Environmental Assessment
Drawing No:	0079383h_EARPA2012_C024_R1.cdr
Date:	07/02/13
Drawing size:	A3
Drawn by:	JD
Reviewed by:	NB
Source:	Biosis 2012
Scale:	Refer to Scale Bar

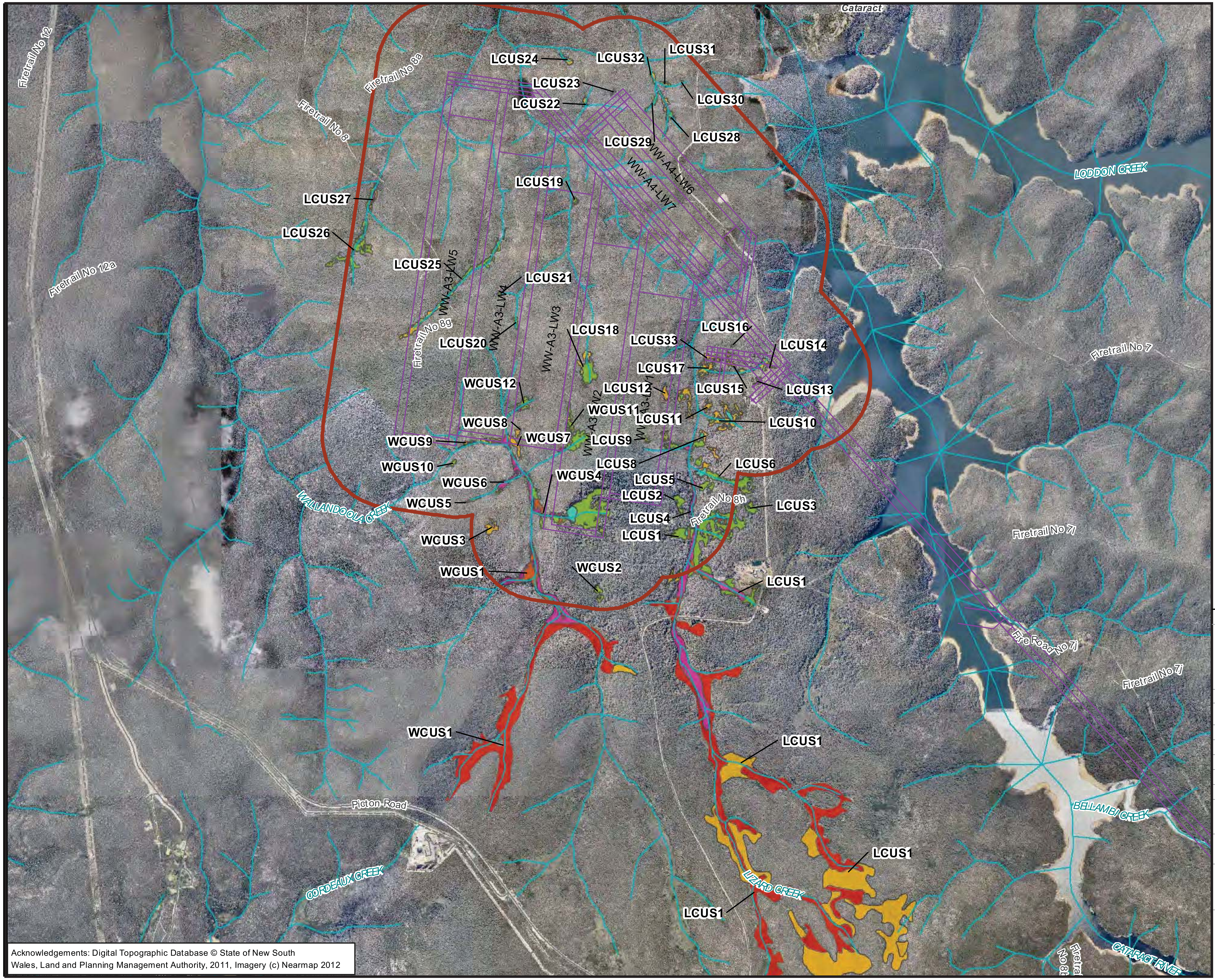
0 0.15 0.3 0.45km

N

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM



Legend

Vegetation Sub-Communities

- MU42 Upland Swamps: Banksia Thicket
- MU43 Upland Swamps: Tea-Tree Thicket
- MU44a Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
- MU44b Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
- MU44c Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

Vegetation Outside Current Study Area (NPWS 2003)

- MU44 Upland Swamps: Sedgeland-Heath Complex

Survey Area

- Wonga East Study Area
- Longwalls

Matter: 15094,
Date: 31 October 2012,
Checked by: NMG, Drawn by: apritchard
Location:P:\15000s\15094\Mapping\Report Figures\15094 F5_Wonga West Swamps

Figure 22.2

Upland Swamps in Wonga West

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No.1 Colliery Environmental Assessment
Drawing No:	0079383h_EARPA2012_C025_R1.cdr
Date:	07/02/13 Drawing size: A3
Drawn by:	JD Reviewed by: NB
Source:	Biosis 2012
Scale:	Refer to Scale Bar

N 0 0.3 0.6 0.9km

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM

WCUS1 occurs in the upper reaches of Wallandoola Creek (see *Figure 22.2* and *Figure 22.2*). WCUS1 extends up to approximately 120m wide with Wallandoola Creek present as an indiscernible channel in the upper reaches of the swamp, forming a more distinctive channel with a series of open pools upstream and downstream of monitoring point WC3 (GeoTerra 2012b).

WCUS4 is located downstream of WCUS1 and includes a headwater swamp component that overlies part of panel A3 LW2. WCUS4 extends from the confluence of the headwater swamp to the major bend in the creek to the south of the proposed Longwalls A3 LW3 and A3 LW4, upstream of monitoring site WC4 (GeoTerra 2012b).

Swamp LCUS1 extends up to approximately 170m wide where the channel is essentially indiscernible with associated, isolated open water pools in the upper reaches of the creek near the southern boundary of the PAA between stream monitoring sites LC1 and LC3 (GeoTerra 2012b). The swamp narrows to approximately 45m wide upstream of stream monitoring site LC3, primarily without any discernible channel, then reduces to less than 10m wide at the fire road crossing, where the exposed sandstone channel is distinctive, although the banks are less than 0.5m high. Downstream of LC3, the creek transitions into a constricted channel with a rock bar controlled pool to the west of proposed panel A3 LW1 that extends for approximately 110m downstream of the crossing (GeoTerra 2012b). Headwater swamp sections of LCUS1 straddle the east and west banks of Lizard Creek upstream of stream monitoring site LC3 (GeoTerra 2012b).

LCUS4 is present downstream of the rock pool, and extends for approximately 250m, ending in a 2.5m to 3m deep pool developed upstream of a sandstone rock bar at the confluence of headwater swamp LCUS6.

22.3.3 *Hydrology and Groundwater Dependency*

Swamp complexes within the Study Area occur in either headwater tributary valleys, that are characteristically derived from colluvial sand erosion from Hawkesbury Sandstone dominated ridgelines; or are valley infill swamps along the riparian zone of the major creeks.

The upland swamps are perched systems that are hydraulically separated from the deeper, regional groundwater table in the Hawkesbury Sandstone. They can however, be connected to shallower, ephemeral seepage from the upper Hawkesbury Sandstone where bedding discontinuities or low permeability enhances horizontal flow into a swamp after high rainfall periods (GeoTerra 2012b). Accordingly, upland swamps constitute groundwater dependent ecosystems under the NSW State Groundwater Dependent Ecosystem policy (DLWC 2002), given that they are partially dependent upon ephemeral seepage of near surface groundwater inflow from shallow Hawkesbury Sandstone aquifers.

The upland swamps have relatively small upstream catchments, with saturation levels relying on rainfall recharge directly into the sandy sediments, seepage out of upslope Hawkesbury Sandstone and the degree of accumulated organic matter. The storage and water transmission characteristics of the surrounding and underlying Hawkesbury Sandstone is critical in sustaining these environments (GeoTerra 2012b). The

Hawkesbury Sandstone provides a low permeability base on which the swamp sediments and organic matter accumulate (GeoTerra 2012b).

Due to their gentle slope, only the larger swamps can contain small, shallow, poorly defined open channels, which are generally short and located at the downstream reaches, while ephemeral patches of saturated sediment can be present in the headwater sections. The headwater swamps are located within gently sloping, shallow trough shaped gullies and do not extend onto any steep slopes, benches or valley sides, where the plateau is not dissected by the Study Area creeks. In some headwater swamps, groundwater seepage can occur along outcropping sandstone, along the edge or downstream portions of a swamp however, rainfall is the primary source of water. The central axes of the swamps are generally saturated after substantial recharge events, though the margins can be comparitively dry after extended dry periods (GeoTerra 2012b).

The sand and humic material increases the swamp's water holding capacity and subsequently discharges rainfall infiltration, groundwater seeps and low-flow runoff into the local streams. Rainfall saturates the swamp after storms and with a slow, delayed discharge due to the low slopes when the recharge exceeds evaporation. Sediments below and laterally lensing into the humic material are variable in nature and can be composed of fine to medium grained sands that can contain clayey bands and comprise a grey to mottled red-orange colour due to insitu weathering (GeoTerra 2012b).

The Wonga West swamps generally comprise moderate to low permeability humic clays, silts and sands up to approximately two metres thick which are rainfall dependent with a highly variable, shallow water table. The Wonga East swamps, on the other hand, are generally shallower, less expansive, with less humic content, more rainfall dependant and drier than those in Wonga West.

Groundwater data is available for a limited number of uplands swamps in the Study Area and is discussed in Section 4.2.3 of *Annex Q*, in Section 10.1 and 10.3 of *Annex P*.

Groundwater levels within Wonga West perched valley fill and headwater swamps have been monitored since July 2006 (at PL25A and PL25B), along with more recent installations since July 2009. Groundwater levels with Wonga East headwater swamps have been monitored since February 2012.

Available data from peizometers indicate that the upland swamps CCUS4, CCUS5, CRUS1, LCUS1, WCUS4 (PW4) and WCUS11 (PW11) have shallow groundwater recharges to surface following rainfall with some taking three to four months for groundwater to dry out following rain (ie WCUS11, WCUS4, LCUS1) while the groundwater in vicinity of piezometer in CRUS1 (PCr1) and CCUS2 (PCc2) appear to dry out within one month following rainfall. Some of the swamps CCUS3 (PCc3), CCUS6 (PCc6) and BCUS4 (PB4) have essentially been dry since piezometers were installed in March or May 2012 (GeoTerra 2012b). The groundwater in WCUS1 (PW1) is saturated with a moderated response to rainfall and the peizometer is in direct contact with stream seepage along Wallandoola Creek valley (see Table 10 and 11 in *Annex Q*).

Paired swamp piezometers and basement groundwater piezometers indicate that the regional groundwater flow within the Hawkesbury Sandstone is hydraulically beneath, and separated from the surficial swamps (GeoTerra 2012b). Where paired measurements are available, the swamps are hydraulically seperated from the underlying regional Hawkesbury Sandstone aquifer by up to approximately 10.5m at LCUS1 in Wonga West, and by between one to 15m at CCUS2 in Wonga East, with the lower separation occurring during extended wet periods where the variable regional groundwater level rises up to near the ground surface (GeoTerra 2012b).

22.3.4 *Water Quality*

Water quality data for the swamps was collected from eight piezometers in Wonga East, four piezometers in Lizard Creek swamps and three in Wallandoola Creek swamps:

- Lizard Creek - LCUS1 (PL1A), LCUS18 (PL18), LCUS25 (PL25B and PL5D);
- Wallandoola Creek - WCUS1 (PW1), WCUS4 (PW4) and WCUS11 (PW11); and
- Cataract Creek – CCUS2 (PCc2), CCUS3 (PCc3), CCUS4 (PCc4), CCUS5 (PCc5A and PCc5B) and CCUS6 (PCc6);
- Cataract River – CRUS1 (PCr1); and
- Bellambi Creek – BCUS4 (PB4).

It is noted, that the piezometers in Wonga East have limited data from March 2012 while those in Lizard Creek have data from 2007 and Wallandoola Creek from 2009.

A series of water quality parameters were monitored in these swamps including:

- field pH, electrical conductivity, temperature;
- total dissolved solids;
- Na / Ca / K / SO4 / Mg / Cl / F;
- total alkalinity;
- total / filterable Fe, Mn, Al;
- filterable Ni, As, Li, Ba, Sr, Cu, Pb, Zn; and
- total nitrogen and total phosphorus.

The Lizard Creek swamps at Wonga West have electrical conductivities ranging from 64 to 305µS/cm, with the salinity varying in relationship to rainfall recharge that occurs prior to sampling, along with the degree of brackish seepage from the weathered Hawkesbury Sandstone. The pH ranges from 3.6 to 7.5 and also varies with rainfall prior to sampling. Swamp salinity is generally within the acceptable range for potable water however, it is outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH; and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for filtered copper, lead, zinc, nickel, and occasionally aluminium (where its pH exceeds 6.5, which it rarely occurs); as well as total nitrogen, and total phosphorous (GeoTerra 2012b).

The Wallandoola Creek swamps have electrical conductivities ranging from 86 to 1,120µS/cm, with the salinity varying in relationship to rainfall recharge that occurs prior to sampling, along with the degree of brackish seepage from the weathered Hawkesbury Sandstone. The pH ranges from 5.1 to 7.4 and also varies with rainfall prior to sampling. Monitoring indicates that swamp salinity is generally within the acceptable range for potable water, except generally in WCUS11 (PW11); however, it can be outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH; and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for filtered copper, lead, zinc, nickel, and occasionally aluminium (where its pH exceeds 6.5, which rarely occurs), as well as total nitrogen, and total phosphorous (GeoTerra 2012b).

The Cataract Creek, Bellambi Creek and Cataract River swamps at Wonga East have electrical conductivities ranging from 70 to 170µS/cm, with the salinity varying in relationship to rainfall recharge that occurs prior to sampling, along with the degree of brackish seepage from the weathered Hawkesbury Sandstone. The pH ranges from 3.8 to 7.3 and also varies with rainfall prior to sampling. Monitoring indicates that swamp salinity is within the acceptable range for potable water, however it is generally outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for filtered copper, lead, zinc, nickel, and occasionally aluminium (where its pH exceeds 6.5, which rarely occurs), as well as total nitrogen, and total phosphorous (GeoTerra 2012b).

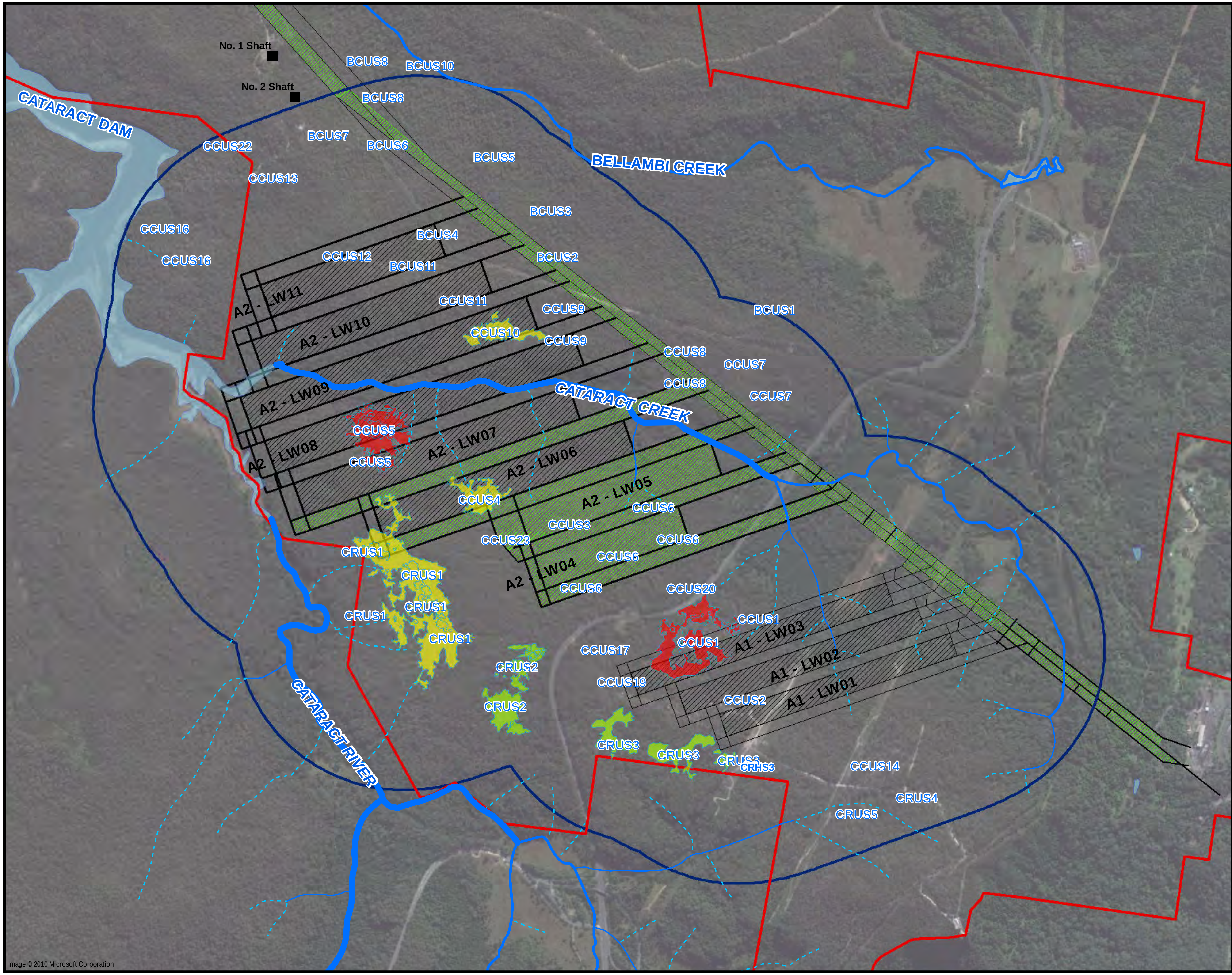
22.3.5 *Habitat Condition*

Generally, swamp condition was observed to be very good, with the exception of some of the headwater swamps in Cataract Creek that showed signs of disturbance. For example, in CCUS1 and CRUS3 there were signs of disturbance from vehicles, rubbish dumping and/or trail bikes. The disturbance in CCUS1 is relatively superficial and does not appear to be significantly affecting the hydrology or floristic features of the swamp at this stage.

All swamps, with the exception of the north-western most swamp within the Study Area, occur within the Wallandoola Significant Swamp Cluster, identified by DECC (2007) as providing large contiguous areas of habitat for swamp-dependant species within the Southern Coalfields. As such, they are considered to have significant ecological values because they provide refuge for swamp dependant species during extended dry periods, and provide highly diverse habitat for a range of threatened species.

22.4 *SWAMPS OF SPECIAL SIGNIFICANCE*

As discussed in *Section 22.1.4* all of the upland swamps within the Study Area meet the criteria for statutory thresholds (Coastal Upland Swamp EEC) and closely proximate habitat (as all are part of the Wallandoola Creek cluster). Biosis (2012a) identified 15 upland swamps in the Study Area as being of 'special significance' based upon the most recent criteria defined by OEH (2012). Upland swamps of special significance are mapped on *Figure 22.3* and *22.4*.



Legend

- Project Application Area
- Study Area
- Proposed Longwall
- Approved Workings (MP10_0046)

Risk Assessment (Biosis 2012)

- Negligible
- Low
- Moderate
- Significant
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order and Above Stream
- Shaft Locations

Figure 22.3

Risk Assessment of the Upland Swamps of Special Significance in Wonga East

Client: Gujarat NRE Coking Coal Pty Limited

Project: NRE No.1 Colliery EAR Post Adequacy 2012 Environmental Assessment

Drawing No: 0079383s_EARPA2012_G046_R0.mxd

Date: 15/11/2012 Drawing size: A3

Drawn by: GJ Reviewed by: NB

Scale: Refer to Scale Bar

N 0 150 300 450m

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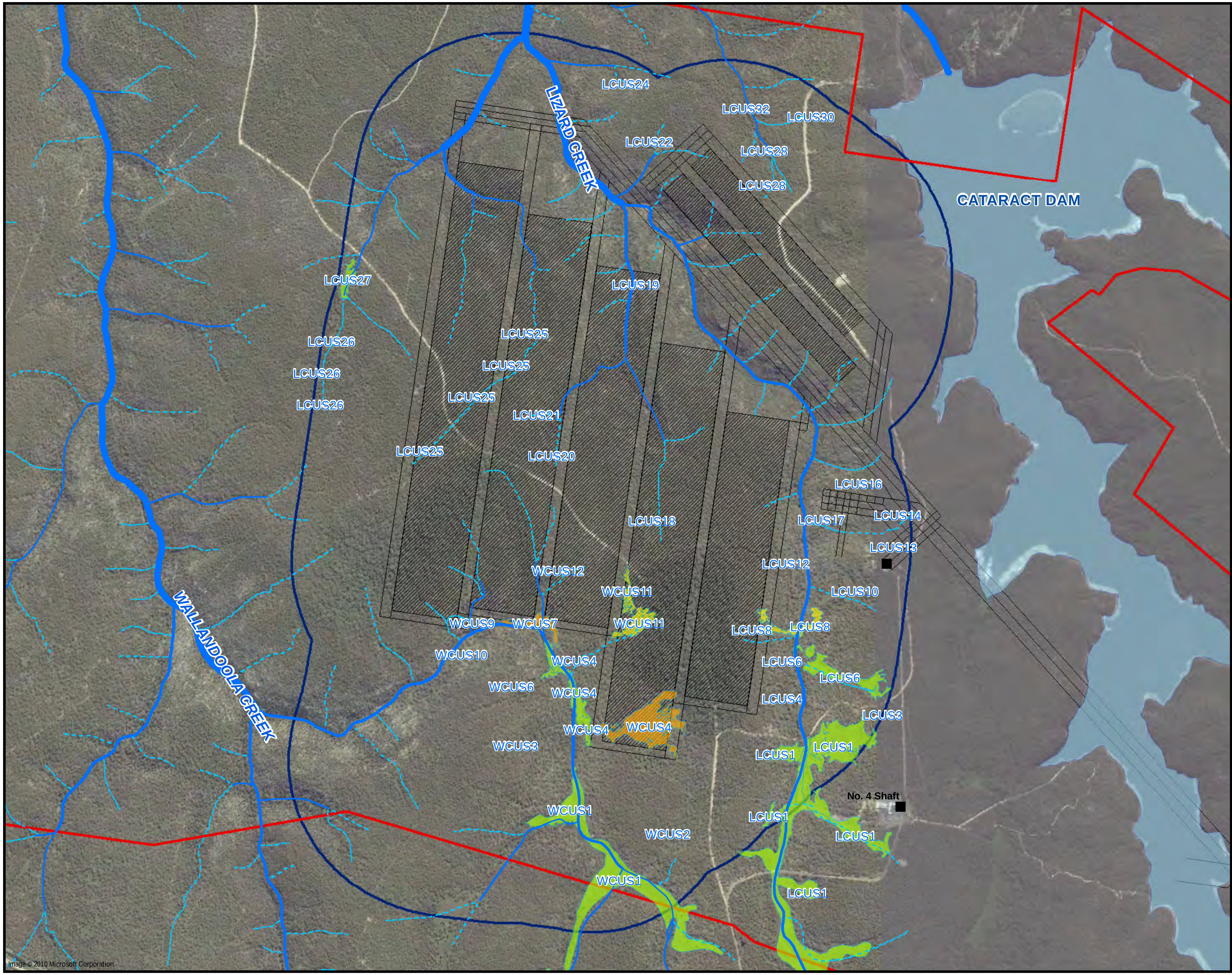
Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM



Legend

- Project Application Area
- Study Area
- Proposed Longwall

(Risk Assessment biosis 2012)

- Negligible
- Low
- Moderate
- Significant
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order and Above Stream
- Shaft Locations

Figure 22.4

Risk Assessment of the Upland Swamps of Special Significance in Wonga West

Client: Gujarat NRE Coking Coal Pty Limited

Project: NRE No.1 Colliery EAR Post Adequacy 2012 Environmental Assessment

Drawing No: 0079383s_EARPA2012_G047_R0.mxd

Date: 15/11/2012 Drawing size: A3

Drawn by: SQW Reviewed by: MB

Scale: Refer to Scale Bar

N 0 220 440 660m

Environmental Resources Management ANZ

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ERM

22.4.1 *Wonga East*

Biosis (2012) identified that seven (7) of the 39 uplands swamp in Wonga East are considered to be of 'special significance' according to criteria set out in OEH (2012) (see *Table 22.1*).

In addition to meeting the statutory and closely proximate habitat criteria, CRUS1 is considered to be of 'special significance' based on size, while CCUS1, CCUS4, CCUS5, CCUS10, CRUS2 and CRUS3 are considered to be of 'special significance' due to the complexity of vegetation sub-communities within these swamps, as all support Banksia Thicket, Tea-tree Thicket and Sedgeland-Heath Complex.

Of the seven swamps of special significance, five have potential to be subject to subsidence (CCUS1, CCUS4, CCUS5, CCUS10 and CRUS1).

22.4.2 *Wonga West*

Biosis (2012) identified that eight of the 45 uplands swamp in Wonga West are considered to be of 'special significance' according to criteria set out in OEH (2012) (see *Table 22.2*).

In addition to meeting the statutory, closely proximate habitat criteria all of the swamps of special significance in Wonga West are considered to be of 'special significance' due to the complexity of vegetation sub-communities within these swamps, as all support Banksia Thicket, Tea-tree Thicket and Sedgeland-Heath Complex. In addition to meeting three of the five criteria three of the upland swamps meet a fourth criterion based on size being LCUS1 (129.9 ha), WCUS1 (36.16 ha) and WCUS4 (11.08 ha).

Of the eight swamps of special significance, four have potential to be subject to subsidence (LCUS8, WCUS4, WCUS7 and WCUS11).

Table 22.1 Upland Swamps of Special Significance in Wonga East

Swamp Name	Special Significance Criteria					
	Statutory	**Size (ha)**	**Complexity**	**Closely Proximate Habitat**	**Scientific**	**Reason**
CCUS1	Coastal Upland Swamps EEC	4.81	Yes (MU42, MU43, MU44b, MU44c)	All part of the Wallandoola Swamp Cluster	No	Statutory, complexity, closely proximate habitat
CCUS10		1.63	Yes (MU42, MU43, MU44c)			Statutory, complexity, closely proximate habitat
CCUS4		1.77	Yes (MU42, MU43, MU44c)			Statutory, complexity, closely proximate habitat
CCUS5		3.45	Yes (MU42, MU43, MU44a)			Statutory, complexity, closely proximate habitat
CRUS1		9.84	No (MU42, MU43)			Statutory, complexity, closely proximate habitat
CRUS2		3.12	Yes (MU42, MU43, MU44c)			Statutory, complexity, closely proximate habitat
CRUS3		3.42	Yes (MU42, MU43, MU44a, MU44b, MU44c)			Statutory, complexity, closely proximate habitat

Source: Biosis (2012a)

Vegetation communities are: MU42 = Upland Swamp Banksia Thicket; MU43 = Upland Swamp Tea-tree Thicket; MU44a = Sedgeland-Heath Complex (Sedgeland); MU44b = Sedgeland-Heath Complex (Restioid Heath) and MU44c = Sedgeland-Heath Complex (Cyperoid Heath).

Table 22.2 Upland Swamps of Special Significance in Wonga West

Swamp Name	Special Significance Criteria					
	Statutory	**Size (ha)**	**Complexity**	**Closely Proximate Habitat**	**Scientific**	**Reason**
LCUS1	Coastal Upland Swamps EEC	129.9	Yes (MU42, MU43, MU44b)	All part of the Wallandoola Swamp Cluster	No	Statutory, complexity, size, closely proximate habitat
LCUS27		1.04	Yes (MU42, MU43, MU44b)			Statutory, complexity, closely proximate habitat
LCUS6		3.74	Yes (MU42, MU43, MU44a, MU44b, MU44c)			Statutory, complexity, closely proximate habitat
LCUS8		2.09	Yes (MU42, MU43, MU44a, MU44b)			Statutory, complexity, closely proximate habitat
WCUS1		36.16	Yes (MU42, MU43, MU44c)			Statutory, size, complexity, closely proximate habitat
WCUS11		2.79	Yes (MU42, MU43, MU44b)			Statutory, complexity, closely proximate habitat
WCUS4		11.08	Yes (MU43, MU44a, MU44b, MU44c)			Statutory, size, closely proximate habitat
WCUS7		1.97	Yes (MU42, MU43, MU44c)			Statutory, complexity, closely proximate habitat

Source: Biosis (2012a)

Vegetation communities are: MU42 = Upland Swamp Banksia Thicket; MU43 = Upland Swamp Tea-tree Thicket; MU44a = Sedgeland-Heath Complex (Sedgeland); MU44b = Sedgeland-Heath Complex (Restioid Heath) and MU44c = Sedgeland-Heath Complex (Cyperoid Heath).

22.5 *PAST MINING IMPACTS*

As noted in *Appendix 2* of *Annex Q* and Table 2 of *Annex P* the majority of the upland swamps in Wonga East and Wonga West have been previously undermined by either Bulli or Balgownie seam workings. All of the upland swamps in Wonga West have been undermined and subsided by Bulli longwall workings, apart from the valley infill section of WCUS1 that overlies the unmined barrier between NRE No 1 colliery and Cordeaux colliery (GeoTerra 2012b). All the headwater swamps at Wonga East have been undermined and subsided by Bulli bord and pillar, Bulli pillar extraction, Balgownie longwall, and recently, the Wongawilli seam Longwall A2 LW4 (GeoTerra 2012b).

Based upon field observations it would appear that there have been no obvious adverse effects on any headwater upland swamps and associated first order streams or valley infill upland swamps within the NRE No.1 lease area due to subsidence. The following comments on past mining and environmental consequences as noted in the field were provided by GeoTerra (2012b).

Swamp WCUS4 was undermined by the NRE No 1 Bulli seam workings between 1985 and 1988 with no observable adverse effects on stream or swamp flow, water quality or ecosystem health (GeoTerra 2012b).

LCUS1 was undermined by the western edge of the BHP Cordeaux Bulli seam workings as well as first workings in the southern Gujarat lease area, with no observable adverse effects on stream or swamp flow, water quality or ecosystem health (GeoTerra 2012b).

LCUS4 was undermined previously by first workings in the Bulli seam as well as the eastern margin of LW202 during 1979; with no observable adverse effects on the majority of the swamp, although the northern end has undergone headward erosion of the up to 1.5m deep peaty material within the main channel of the creek (GeoTerra 2012b).

WCUS11 was undermined by Bulli seam longwalls 206, 207 and 208 between 1985 and 1989, with no observable adverse effects on stream / swamp flow, water quality or ecosystem health (GeoTerra 2012b).

LCUS6 was not undermined by any longwalls, but overlies the main headings adjacent to LW202, and has not had any observable adverse effects on stream/swamp flow, water quality or ecosystem health (GeoTerra 2012b).

LCUS18 was undermined by the Bulli Seam workings LW206 in 1986 with no observable adverse effects on stream/swamp flow, water quality or ecosystem health (GeoTerra 2012b).

LCUS25 was not undermined by any Bulli seam longwall panels, but was subsequently undermined by secondary bord and pillar extraction in T and W Mains since February 2008, with no observable adverse effects on stream / swamp flow, water quality or ecosystem health. The maximum measured subsidence over T and W Mains has been 147mm, with 1.09mm/m maximum strain (Ecoengineers, 2009 in GeoTerra 2012b).

LCUS28 was undermined by the Bulli seam workings LW304 in 1985 with no observable adverse effects on stream/swamp flow, water quality or ecosystem health.

CCUS1 and CCUS2 were undermined by Bulli seam first workings in the early 1900's and subsequently by Bulli seam pillar extraction and the Balgownie longwalls with no observable adverse effects on stream / swamp flow, water quality or ecosystem health.

Swamps CCUS3, CCUS4, CCUS5 and CCUS6 were undermined by Bulli seam first workings in the early 1900's and subsequently by Bulli seam pillar extraction and the Balgownie longwalls. CCUS6 was also recently undermined by the Wongawilli seam Longwall A2 LW4. None of the four undermined swamps have had observable adverse effects on stream / swamp flow, water quality or ecosystem health.

Swamps CCUS10, CCUS11 and CCUS12 were undermined by Bulli seam first workings, but not by Bulli seam pillar extraction or the Balgownie longwalls, with no observable adverse impacts from subsidence (GeoTerra 2012b).

Swamp CRUS1 was undermined by Bulli seam first workings, but not by Bulli pillar extraction or the Balgownie longwalls, and has had no observable adverse effects on stream / swamp flow, water quality or ecosystem health.

Bellambi Creek swamps BCUS4 and BCUS11 were undermined by Bulli seam first workings, but not by Bulli pillar extraction or the Balgownie longwalls, and have had no observable adverse effects on stream / swamp flow, water quality or ecosystem health (GeoTerra 2012b).

22.6 *POTENTIAL IMPACTS*

The SCI identified that the *subsidence impacts* for valley infill swamps were tensile cracking and movement of joint and bedding planes; and buckling and localized upsidence in the stream bed below the swamp. The primary *environmental consequences* for valley infill swamps are:

- draining of swamps leading to:
  - drying and potential erosion and scouring of dry swamp;
  - loss of standing pools within the swamp;
  - vulnerability to fire damage;
  - change to swamp vegetation communities; and
  - adverse water quality impacts eg iron bacterial matting; and
- loss of stream base flow (DoP 2008).

Secondary *environmental consequences* for valley infill swamps include:

- loss of terrestrial and aquatic habitats and associated fauna, including threatened species dependent on swamp ecosystems; and
- loss of water purification and flow regulation function for downstream ecosystems.

The SCI Panel upon review of available information at that time concluded that *undermining of valley infill swamps has or will cause drainage, water table drop and consequent degradation of swamp water quality and associated vegetation* (DoP 2008).

Headwater swamps are susceptible to *subsidence impacts* from tensile cracking and tensile/shear movement of joint and bedding planes in the rock below the swamp. The primary *environmental consequences* are potential drop in the perched water table leading to draining of the swamp (DoP 2008). The SCI noted that the impacts on headwater swamps are likely to be similar in character but less extensive and less significant than for valley infill swamps (DoP 2008). Secondary consequences are the same as for valley infill swamps (DoP 2008).

GeoTerra (2012b) in their assessment of impacts on groundwater identified that, subsidence could affect swamps directly overlying the proposed longwalls due to either transient and/or spatial changes in porosity and permeability of a swamp or its underlying weathered sandstone substrate through generation of cracks or differential displacement of the perched aquifer. If a swamp overlies an extracted longwall panel, it may undergo temporary extensional 'face line' cracking (perpendicular to the long axis of the panel) as a panel advances, followed by re-compression as the maximum subsidence occurs at any one location.

In addition, where a swamp overlies a longwall, it may also undergo both longer term extensional 'rib line' cracking (parallel to the long axis of the panel) along the outer edge of the panel, and compression within the central portion of a panel's subsidence trough. The more susceptible portions of a swamp to increased secondary porosity and/or permeability changes are where it undergoes 'rib line' cracking. Any adverse effects, if they occur, would be related to the extent and degree of cracking that occurs in the underlying weathered sandstone, as cracking is unlikely to manifest in a swamp due to its saturated, clayey, humic, plastic nature (GeoTerra 2012b).

It should be noted that within the Study Area headwater swamps have undergone up to 1.0m or more of subsidence, up to 1.5mm/m of strain and up to 4.5mm/m of tilt due to undermining by the Bulli 200 and 300 series longwalls at Wonga West, along with the Bulli bord and pillar, Bulli seam pillar extraction and Balgownie longwall extraction at Wonga East between 1979 and 1989. Previous undermining has had no apparent adverse effects on their water holding capacity (GeoTerra 2012a) or ecology.

A comparative analysis of past mining and subsidence impacts on upland swamps was undertaken by Biosis (2012a). Biosis (2012a) notes in Section 4.2.2 of *Annex Q* there is a significant paucity of data available to undertake such a comparative analysis.

At the time, the SCI identified that they are unaware of any significant impacts on headwater swamps caused by mining subsidence with most known impacted swamps being valley infill swamps (DoP 2008). The Bulli PAC (2010) stated that impacts to a number of upland swamps has been observed, including Swamp 18, Swamp 1 in Dendrobium Area 2 and Swamp 32. Also recorded in PAC (2010) is "*the panel observed that multiple swamps either side of an undermined (and severely impacted) reach of Lizard Creek appeared to be dry and undergoing compositional change from invasion by wattles and eucalypts*".

Biosis (2012a) identified through literature review of locations beyond the Study Area boundaries, that impacts to a very small number of upland swamps, located above mining areas, have been observed. The most notable and widely reported include Swamp 37 (Drillhole Swamp) and Swamp 18 in the Avon catchment (EarthTech 2003; Tomkins and Humphrey 2006) and Flatrock Swamp in the Woronora catchment (Tompkins and Humphrey 2006).

EarthTech (2003) provides an analysis of seven upland swamps where longwall mining has occurred as well as 11 upland swamps where bord and pillar or shortwall mining has been undertaken. These upland swamps, including a mix of headwater and valley infill swamps, were located in proximity to the former Elouera Colliery. Mining in this area has been undertaken across an extensive period of time, with bord and pillar mining being undertaken prior to the extraction of coal from the Elouera mine commencing in 1993 and extending northwards under a number of upland swamps.

Based on data presented by EarthTech (2003) Biosis conclude that subsidence of 1.2m is known to have resulted in dewatering of one of five upland swamps located directly above the former Elouera colliery. This subsidence effect, in conjunction with other factors such as fire and intense rainfall, may have contributed to the erosion and scouring of 'Swamp 18'. However, a lack of impact to four subsided swamps may indicate that mining-induced subsidence is not a sole cause of erosion of upland swamps.

Tompkins and Humphrey (2006) undertook an assessment of three upland swamps within the Avon and Woronora catchments to assess the causes and triggers for erosion of upland swamps. Tompkins and Humphrey looked at past aerial photography, swamp stratigraphy, subsidence effects and fire history of Swamp 18, Swamp 37a (Drillhole Swamp) and Flatrock Swamp. All of these swamps have undergone erosion, scouring and gully formation and all have been undermined, either by longwall mining or bord and pillar mining. Tompkins and Humphrey (2006) identified that while scouring, erosion and filling of upland swamps are a natural process; dewatering and drying of upland swamps as a result of fracturing of the bedrock may increase the erosion potential. It was noted that no single factor could be directly implicated in the erosion of upland swamps 18, 37a and Flatrock Swamp.

Sustained impacts to groundwater levels around two upland swamps (swamp 12 and 15a) within BHP Billiton's (BHPB) Dendrobium Area 3A mine have been recorded; as well as Swamp 1 in Dendrobium Area 2 following longwall mining. This reduction in groundwater levels coincided with observations of surface fracturing (Biosis 2012a). To date no observable impacts to upland swamps 12 and 15a have resulted however changes in flora species composition within Swamp 1 appears to be changing at a faster rate than control swamps, with species richness and diversity declining since this area was undermined (Biosis 2012a). It is too early to tell whether reductions in groundwater in Swamps 12 and 15a will result in impacts to these swamps. Observed changes in flora composition at Swamp 1 are confounded by the fire history of this swamp, with post-fire successional change occurring as predicted by Keith *et al.* (2006).

Although hypothesised to be a contributing factor, subsidence has not been determined to be a sole reason for any observed impacts to upland swamps; however, subsidence effects are believed to be a contributing factor (Biosis 2012a).

22.7 ASSESSMENT OF POTENTIAL IMPACTS

As described in *Section 22.2.4* Biosis undertook a staged assessment of potential impacts of the proposed mining on upland swamps with consideration given to the impact assessment outlined by OEH guidelines (2012) and GIS analysis of potential changes in local flow accumulation paths within the upland swamps. This assessment focused on the 15 upland swamps of 'special significance'. The results of the assessment are provided in full in Section 4.2 of *Annex Q*.

22.7.1 *Initial Risk Assessment*

The initial risk assessment on upland swamps of 'special significance' involved identification of predicted subsidence levels and comparison to subsidence criteria outlined in PAC (2010) to determine upland swamps considered to be at risk of negative environmental consequences. These investigation criteria include:

- all swamps subject to systematic tensile strains > 0.5mm/m;
- all swamps subject to systematic compressive strains > 2mm/m;
- all swamps with depth of cover less than 1.5 times longwall panel width;
- all swamps subject to tilt (transient or final) > 4mm/m;
- all swamps subject to valley closure of > 200mm/m; and,
- all swamps subject to a maximum observed closure strain > 7.0mm/m.

The Bulli PAC (2010) noted that these levels do not conclude that a swamp will be impacted or suffer adverse consequences.

Appendix 2 of *Annex Q* identifies the depth of cover and the predicted subsidence levels including tensile strains, compressive strains and tilts of the proposed longwalls for all of the upland swamps. These values include predicted vertical subsidence information presented in Seedsman (2012) and predicted tilts and strains data provided by Seedsman to Biosis and GeoTerra. Tables 8 and 9 of *Annex Q* present this data for the upland swamps of 'special significance'. This data is provided in a summary of potential impacts in *Section 22.7.4*.

Swamps identified as being at risk of negative consequences include CCUS1, CCUS4, CCUS5, CCUS10, CRUS1, LCUS8, WCUS4, WCUS7 and WCUS11.

Special significance upland swamps CRUS2 and CRUS3 in Wonga East and LCUS1, LCUS6, LCUS27 and WCUS1 in Wonga West are considered not at risk of negative environmental consequences based on these subsidence criteria.

22.7.2 *Flow Accumulation Modelling of Impacts*

Biosis (2012a) undertook GIS analysis to identify local flow accumulation paths within upland swamps and related this to distribution of vegetation communities within each swamp. It should be noted that the flow pathways identified do not represent streams 'per se' and should not be considered as such (Biosis 2012a).

Predicted effects of modelled 'upper bound scenario' mining subsidence from Seedsman (2012) were analysed using GIS to produce a predictive surface levels following vertical subsidence, to show changes in water movement relative to the pre-mining flow accumulation models. The results of this analyses are presented in full in Table 12 and Table 13 of *Annex Q*.

In summary, areas of valley infill swamp in Wonga West are not predicted to undergo significant changes in flow accumulation, largely due to the fact that they are located along the main channels of Lizard and Wallandoola Creek, are not located above longwalls and are thus largely subject to minimal levels of subsidence (Biosis 2012a).

Areas of Tea-tree Thicket and Cyperoid Heath are associated with existing flow accumulation paths within the headwater swamps. These communities are susceptible to changes in flow accumulation as they are reliant on permanent or frequent waterlogging. In CCUS1 flow accumulation modelling post-mining indicates that tilts in A1 LW3 may result in a reduction of flow accumulation and therefore reduced saturation in the area of Cyperoid Heath and potential for changes in vegetation composition. Conversely, in CCUS4 the modelling predicts an increase in flow accumulation and increased saturation in Cyperoid Heath in the west of the swamp (Biosis 2012a).

Flow accumulation modelling indicated that upland swamps CCUS1, CCUS4, CCUS5 and WCUS4 may undergo changes in flow accumulation that may result in changes in groundwater availability. This change in groundwater availability could result in changes in vegetation communities within these swamps (Biosis 2012a).

22.7.3 *Compressive and Tensile Strains Impacts*

Swamps located parallel to a longwall and in areas of low tilts and strains are less likely to undergo changes in gradient due to tilts and/fracturing resulting from strains. Swamps spanning multiple longwall panels undergo significant and multiple changes in gradient and strains are most susceptible to impact. The vegetation communities within a swamp also determine susceptibility to impacts. In particular, Tea-tree Thicket is reliant upon permanent water and Cyperoid Heath is reliant on frequent waterlogging, and are susceptible to reduction in water flows. While other communities are more able to withstand some loss of water flow provided that rainfall recharge is adequate such that trees cannot establish in the swamp.

Based on Biosis's (2012a) assessment of risk factors relating to compressive and tensile strains, and comparison of data observed at other locations, it was identified that:

- upland swamps CRUS1, CRUS2, CRUS3, LCUS1, LCUS6, LCUS27, WCUS1, and the valley infill section of WCUS4 do not show significant risk factors that would indicate susceptibility to impact;

- upland swamp CCUS1 may be subject to strains that would result in fracturing of the bedrock below this swamp. Areas of Cyperoid Heath (MU44c) located above A2 LW3 and adjacent pillar are particularly susceptible to any loss of groundwater in this area;

- upland swamp CCUS4 may be subject to strains that would result in fracturing of the bedrock below this swamp. However, the location of the base of this swamp in areas subject to lower levels of strains indicates that impacts may be reduced;

- upland swamp CCUS5 may be subject to strains that would result in fracturing of the bedrock below this swamp. This upland swamp spans two Longwalls (A2 LW7 and A2 LW8) and a degree of compressive and tensile strains. Further, vegetation sub-communities within this swamp are reliant on benching in the sandstone, creating rockbars that are likely to hold back sections of Cyperoid Heath (MU44c) and Tea-tree Thicket (MU43);

- upland swamp CCUS10 may be subject to strains that would result in fracturing of the bedrock below this swamp. The swamp spans a large variation in strains and is reliant on benching of sandstone to maintain areas of Cyperoid Heath (MU44c) and Tea-tree Thicket (MU43);

- there is some potential for fracturing of the bedrock below the headwater section of LCUS8; however, it is likely to be limited in extent and degree given the location of this swamp largely above the pillar for A3 LW1. Further, this section of the swamp supports sub-communities that are less reliant on presence of permanent and frequent groundwater, and provided surface flows are maintained to a sufficient level to inhibit growth of trees impacts are unlikely to be significant;

- upland swamp WCUS4 may be subject to strains that would result in fracturing of the bedrock below this swamp. The lower sections of the headwater swamp are subject to greatest strains, and these areas are particularly susceptible to impact as they support areas of Tea-tree Thicket (MU43) and Cyperoid Heath (MU44c);

- upland swamp WCUS7 is likely to be subject to tensile strains sufficient to result in fracturing of bedrock below this swamp. This could result in fracturing of bedrock along Wallandoola Creek. There is substantial iron staining in this section of Wallandoola Creek. The cumulative impacts of mining cannot be adequately assessed; and

- upland swamp WCUS11 may be subject to strains that would result in fracturing of the bedrock below this swamp. However, this swamp supports only small areas of Tea-tree Thicket (MU43) at the base of the swamp that will be subject to small tensile strains. Areas subject to maximum strains support sub-communities that are less reliant on presence of permanent and frequent groundwater, and provided surface flows are maintained to a sufficient level to ensure trees are killed impacts are not predicted to be significant.

22.7.4 *Conclusion of Risk Assessment*

In summary, Biosis (2012a) assessed the impacts of the proposed longwall mining operation on upland swamps in the PAA in accordance with the OEH (2012) guidelines. This assessment was based upon field mapping of vegetation communities and definition of the extent of upland swamps (see *Section 22.3*). The assessment identified upland swamps of 'special significance' (see *Section 22.4*) using the definition for special significance as provided in the OEH (2012) guidelines.

A risk assessment for the upland swamps of 'special significance' was undertaken in accordance with the OEH guidelines (see *Section 22.7.1* and *Section 22.7.3*). In addition to the guidelines, Biosis (2012a) undertook GIS analyses to identify flow accumulation pathways for upland swamps (see Section *22.7.2*).

Table 22.3, Figure 22.3 and *Figure 22.4* summarise the findings of the risk assessment process for the upland swamps of 'special significance'.

Based on an analysis of potential impacts to upland swamps Biosis concluded that:

- there is a negligible likelihood of negative environmental consequences for seven (7) upland swamps, including CRUS2, CRUS3, LCUS1, LCUS6, LCUS27, WCUS1 and WCUS4-valley infill swamp. NRE can proceed to mining and monitoring in these areas;

- there is a low likelihood of negative environmental consequences for five (5) upland swamps, including CCUS4, CCUS10, CRUS1, LCUS8 and WCUS11. It is recommended that NRE undertake monitoring and consider where possible minor changes to longwall layout to reduce impacts to these swamps. It is noted that CCUS4 is in the middle of A2 LW6;

- there is a moderate likelihood of negative environmental consequences for upland swamps WCUS4-headwater swamp and WCUS7. It is recommended that NRE revise mine plans for Area 3 Longwall panels 2, 3 and 4 to avoid, minimise and mitigate impacts to these swamps; and

- there is a significant likelihood of negative environmental consequences for upland swamps CCUS1 and CCUS5 in Wonga East. It is recommended that NRE revise the mine layout of Longwall panels A1 LW3, A2 LW7 and A2 LW8 to avoid, minimise and mitigate impacts to these swamps.

Table 22.3 Summary of Risk Assessment for Upland Swamps of Special Significance in PAA

Swamp Name	Position Relative to Longwalls	Depth of Cover:Panel Width Ratio	Predicted Subsidence (m)	Tensile Strain (mm/m)	Compressive Strain (mm/m)	Max Tilt (mm/m)	Modelled Flow Accumulation Pathway	Conclusion
CCUS1	Spans A1 LW3 panel and gateroad.	2.47	-0.40	**2.65**	**-6.79**	**11.38**	Along longwall panel. Reduction in flow in Cyperoid Heath in south of swamp.	Significant risk of negative environmental consequences.
CCUS4	Spans middle of A2 LW6.	1.91	-1.00	**4.63**	**-8.03**	**21.04**	Perpendicular to longwall panel. Small scale reduction in flows in Tea-tree Thicket in north, increase flows in south of swamp.	Low risk of negative environmental consequences.
CCUS5	Spans A2 LW7 and A2 LW8.	1.89	-1.00	**4.74**	**-8.03**	**21.30**	Perpendicular to longwall panel. Changes at edge of A2 LW8 reducing flow to east of swamp.	Significant risk of negative environmental consequences.
CCUS10	Spans A2 LW9 and gateroad to A2 LW8.	1.92	-1.00	**4.60**	**-8.74**	**21.39**	Dispersed flow. Rockbars result in accumulation of water. No significant change predicted.	Low risk of negative environmental consequences.
CRUS1	Majority of swamp not undermined. Small northern section overlies A2 LW6.	1.85	-0.89	**4.34**	**-7.2**	**17.51**	No substantial flow path above longwall. No significant change predicted.	Low risk of negative environmental consequences.
CRUS2	Not located above longwalls.	-	0.0	0	0	0	No significant change predicted.	Negligible risk of negative environmental consequences.
CRUS3	Not located above longwalls.	-	0.0	0	0	0	No significant change predicted.	Negligible risk of negative environmental consequences.
LCUS1	Not located above longwalls.	-	-0.87	0	0	0	Dispersion flow in headwater swamp. In valley infill flow through main channel of Lizard Creek.	Negligible risk of negative environmental consequences.

Swamp Name	Position Relative to Longwalls	Depth of Cover:Panel Width Ratio	Predicted Subsidence (m)	Tensile Strain (mm/m)	Compressive Strain (mm/m)	Max Tilt (mm/m)	Modelled Flow Accumulation Pathway	Conclusion
LCUS6	Not located above longwalls.	-	0.96	0	0	1.93	Small flow in headwater swamp. In valley infill flow through main channel of Lizard Creek. Post mining negligible reduction in headwater swamp. Increase flow in valley infill.	Negligible risk of negative environmental consequences.
LCUS8	Upper extent of western headwater swamp above A3 LW1.	**1.27**	-2.66	**2.75**	**-2.64**	9.15	Perpendicular to longwall panel in eastern headwater swamp. Small change in flow in headwater swamp, increase in valley infill section.	Low risk of negative environmental consequences.
LCUS27	Not located above longwalls.	-	0.0	0	0	0	No significant change predicted.	Negligible risk of negative environmental consequences.
WCUS1	Not located above longwalls.	-	-0.72	0	0	0	Parallel to panel, negligible changes in flows.	Negligible risk of negative environmental consequences.
WCUS4 valley infill	To south of A3 LW2.	-	0.5	**6.0**	**<-1.0**	3	Located along main channel of Wallandoola Creek.	Negligible risk of negative environmental consequences.
WCUS4 headwater	Above southern end of A3 LW2. Flow pathway perpendicular to longwall.	**1.28**	-3.35	**5.03**	**-6.97**	10.58	Perpendicular to longwall panel. Change in flow in north of swamp not significant change.	Moderate risk of negative environmental consequences.
WCUS7	Above pillar for A3 LW3 and A3 LW4.	**1.31**	-2.19	**5.45**	-.0.1	10.70	Perpendicular to longwall panel. Main channel of Wallandoola Creek. No significant effects predicted.	Moderate risk of negative environmental consequences.
WCUS11	Above western end A3 LW2.	**1.31**	-3.27	**5.35**	**-3.8**	8.02	Parallel to longwall. Main flow accumulation in downstream extent. Little change predicted.	Low risk of negative environmental consequences.

1. Source: Biosis (2012a) *Annex Q*. Based upon subsidence data files provided by Ross Seedsman and flow accumulation pathways as modelled by Biosis.
2. Bold numbers indicate that values for subsidence exceed the criteria at which the upland swamp are considered to be at risk of negative environmental consequences as established by the PAC (2010) and OEH (2012) and listed in *Section 22.7.1*.

22.7.5 *Evidence of Cumulative Impacts*

The cumulative impact of previous subsidence effects on the adjoining, upstream swamp systems in the Cordeaux mine lease area cannot be definitively assessed as the pre-mining status of the associated Lizard Creek and Wallandoola Creek stream and swamp systems have not been monitored (GeoTerra 2012b).

Current pool height and water quality monitoring data collected indicates the Cordeaux swamps maintain seepage flow in to the NRE lease area, whilst ferruginous seepage is present in the streams. However, due to the lack of pre-mining data, no comment can be made as to whether the seepage is mining induced or not (GeoTerra 2012b).

No other adjoining previous mining operations provide a cumulative impact on swamps in the Study Area.

The potential for adverse environmental impacts to some upland swamps within the Study Area has been reduced by the proposed layout particularly by restricting longwall mining beneath the main channels of Lizard and Wallandoola Creeks. For the Cataract Creek, the proponent has provided an undertaking that it will terminate mining beneath Cataract Creek if subsidence and ground movements are predicted to exceed 250mm and the creek experiences greater than minimal impact.

22.8 *MONITORING, MANAGEMENT AND CONTINGENCIES*

A swamp monitoring plan has been developed for the extraction of A2 LW4 in Wonga East as part of the Biodiversity Management Plan (Biosis 2012b) and the Subsidence Management Plan Monitoring Program for A2 LW4 and A2 LW5 (Gujarat NRE 2012). These monitoring plans will be revised and updated for this application in liaison with SCA, OEH and to the approval of DP&I.

The following sections provide an outline of the proposed monitoring. In summary the plan would detail monitoring parameters and locations, set trigger values and discuss the logistics of monitoring in this relatively inaccessible area.

22.8.1 *Detection of Negative Environmental Outcomes*

OEH (2012) in their upland swamp environmental assessment guidelines provide a framework for monitoring of negative environmental outcomes for upland swamps.

Performance measures to demonstrate negligible environmental consequences for swamps (as adopted by NRE for A2 LW4) are:

- negligible drainage of water from the swamp, or redistribution of water within the swamp;
- negligible change in the size of the swamp;
- negligible change in the function of the swamp; and
- negligible change in the composition or distribution of species within the swamp.

Where negligible has the same meaning as in the PAC, "*small and unimportant, such as to be not worth considering*".

For the purposes of monitoring upland swamps, OEH identify that monitoring of changes in water levels within the swamp is an appropriate and in particular early indicator that other negative environmental consequences may occur. Drawdown of water levels is one of the first parameters that can be detected following the fracture of rock strata (OEH 2012). Negative environmental outcomes have occurred if there is a statistically significant decrease in water levels within the swamp that is directly attributable to subsidence.

22.8.2 *Upland Swamp Monitoring*

The existing suite of shallow piezometers installed within the upland swamps in the Study Area will gauge any changes in standing water levels and swamp groundwater quality over an active mining area and all key water quality parameters on a regular basis for the duration and an appropriate time following mining.

It should be noted that no vehicular access is available within the upland swamps, and installation of any further piezometers will require entry on foot.

Prior to mining under or adjacent to a swamp, a risk assessment will be incorporated into the Biodiversity Management Plan to demonstrate predicted subsidence to ensure the size and functioning of the swamp, including potential changes in species composition or distribution within the swamp will not be adversely affected. It will ensure that water drainage from the swamps will not be adversely affected due to subsidence or be re-distributed to an extent where such potential adverse changes could occur.

A monitoring program will be designed and implemented to:

- assess the swamp hydrology;
- provide advance warning of potential breaches of subsidence predictions;
- detection of adverse impacts on a swamp and underlying strata hydrology; and
- characterise the relationship between swamp/s and their role in recharging the regional groundwater systems.

Swamp Water Levels

Water levels will be measured automatically, twice daily by pressure transducers and regularly by manual dip meter from a network of shallow piezometers in potentially impacted swamps and reference sites, before and after mining.

Evaporation and rainfall data will also be collected.

Should the standing water level or groundwater quality be unacceptably affected due to subsidence, the Colliery will investigate methods to ameliorate the situation until the water level or water quality recovers.

Swamp Groundwater Quality

At least one appropriately purged and collected, stored and transported groundwater sample will be collected from each swamp piezometer pre and post undermining to enable ongoing assessment of any subsidence related changes in groundwater quality. Groundwater quality assessment criteria and triggers will be in keeping with those identified in the GeoTerra (2012b.)

Reconnaissance of Cracking in Rock

Regular ground monitoring of the surface around swamps, and in swamps where visibility permits, will be undertaken at regular intervals of a period of at least 18 months following mining. Inspection transects will be randomly selected varying at each survey to maximise detection. Inspections will record cracking in rock outcrops, slumping or erosion of soil, changes in flow patterns within the swamps evident as channelization or development of knick points (OEH 2012).

22.8.3 *Reporting*

An end of panel (EoP) report, or its equivalent, will be prepared upon completion of each mined panel, to summarise all monitoring over the period. The report will outline any changes in the surface water or groundwater system over the mined out areas.

All monitoring and management activities will be reported in the Annual Environmental Management Report (AEMR), or its equivalent, in subsequent years.

All results will be reviewed one year after each panel has been completed and an updated ongoing monitoring and remediation program will be developed in consultation with the SCA, DRE and OEH.

22.8.4 *Contingency Measures*

Contingency measures to address potential subsidence impacts on upland swamps and other groundwater systems have been described in *Chapter 21*.

22.8.5 *Adaptive Management*

NRE has provided an undertaking that the mining operations will be modified as required through adaptive management measures informed through monitoring of actual subsidence impacts, to reduce negative outcomes.

An adaptive management plan will be developed to use the monitoring program to detect the need for adjustment to the mining operations so that the subsidence predictions are not exceeded and subsidence impacts creating a risk of negative environmental consequences do not occur in upland swamps.

Recommendations provided by Biosis (2012a) in their assessment of upland swamps will be considered in development of the adaptive management plan and future mining plans.

22.9 *POTENTIAL REHABILITATION MEASURES*

Implementation of any management measures should be considered with regard to the specific circumstances of the subsidence impact, such as the location, nature and extent of the impact and the assessment of the potential environmental consequences of the remediation technique used.

It is noted that the OEH (2012) guidelines require offsets to be negotiated where impacts are not able to be remediated to the level of no negative environmental outcomes. Further, offsets are not an alternative to taking actions to avoid impacts in particular impacts to swamps of special significance.

The following remediation measures were identified by GeoTerra (2012b) and may be appropriate for use to minimise potential impacts on upland swamps:

Installation of Coir Log Dam Erosion Control Structures at Knick Points In A Swamp

Tilting of the swamp can re-direct runoff leading to scour and erosion or alter water distribution in a swamp. However, no swamps in the Study Area have been assessed with a moderate or higher risk of drainage line alignment change in terms of their erosion and scour potential. Coir logs can be installed at knick points for construction of small dams, and have been used successfully in swamp rehabilitation in the Blue and Snowy Mountains (BHP Billiton Illawarra Coal, 2009).

A trench is initially cut into the swamp so the first coir logs sits on the substrate or at ground level and is held by wooden stakes and bound with wire. The dam slows the flow and enables siltation behind the log with coir log dams constructed at intervals down the erosion channel. For increased flow filtering, the coir logs can be wrapped in jute fibre matting.

The main objective of siting erosion control structures is to maintain the saturated water level in the soil profile by reversing the hydraulic head to enable water to permeate back into the swamp (BHP Billiton Illawarra Coal, 2009).

The coir log dams can also capture sediment to restore an incised channel to the level of the surrounding intact soil layer and provide a barrier to headward erosion.

Water Spreading Techniques

Maintenance of swamp moisture can be enhanced by installing coir logs and hessian `sausages' linked across a swamp contour to build up water flow and enhance seepage through the spreaders which can be positioned in shallow trenches.

Erosion control and water spreading involves soft-engineering materials that would contribute to and function as part of the swamp system but would degrade and be integrated into the swamp (BHP Billiton Illawarra Coal, 2009).

Sealing of Surface Cracks Through the use of Grouting Products

Where bedrock controlled features within or on the margins of a swamp are impacted from subsidence and there is limited ability for fractures to infill naturally, surface cracks can be sealed with grout, such as small quantities of cement with various additives mixed on-site and placed by hand with bunds used to contain local spillage.

Injection Grouting

Grouts and filler materials can be injected to fill voids in fractured strata via hand held drilling equipment to achieve a low permeability layer one to two metres thick below the depth of a controlling rock bar.

Where colluvial soils overlie the sandstone, a grout may be injected through rods to seal voids in or under the soil or peat material.

22.10 *CONCLUSIONS*

Biosis (2012a) assessed the impacts of the proposed longwall mining operation on upland swamps in the PAA in accordance with the OEH (2012) guidelines. This assessment was based upon field mapping of vegetation communities and definition of the extent of upland swamps using LiDAR data and field verification.

The assessment identified that there are 84 upland swamps in the Study Area that meet the definition of the Coastal Upland Swamp Endangered Ecological Community. The 39 upland swamps in Wonga East are characterised as headwater swamps. The 45 uplands swamps in Wonga West include 40 headwater swamps associated with 1st and 2nd order tributaries of Lizard Creek and Wallandoola Creek; one valley infill swamp (WCUS1); and four of upland swamps (LCUS1, LCUS6, LCUS8 and WCUS4) contain both headwater and valley infill swamp types but are functioning as one larger swamp.

The initial stages of the impact assessment identified that seven (7) upland swamps in Wonga East and eight (8) upland swamps in Wonga West are considered to be of 'special significance' (see *Section 22.4*) using the definition for special significance as provided in the OEH (2012) guidelines.

A risk assessment for the upland swamps of 'special significance' was undertaken in accordance with the OEH guidelines. In addition to the guidelines, Biosis (2012a) undertook GIS analyses to identify flow accumulation pathways for upland swamps.

The detailed impact assessment process for the upland swamps of 'special significance' concluded that:

- there is a negligible likelihood of negative environmental consequences for seven (7) upland swamps, including CRUS2, CRUS3, LCUS1, LCUS6, LCUS27, WCUS1 and WCUS4-valley infill swamp. NRE can proceed to mining and monitoring in these areas;

- there is a low likelihood of negative environmental consequences for five (5) upland swamps, including CCUS4, CCUS10, CRUS1, LCUS8 and WCUS11. It is recommended that NRE undertake monitoring and consider where possible minor changes to longwall layout to reduce impacts to these swamps. It is noted that CCUS4 is in the middle of Longwall A2 LW6;

- there is a moderate likelihood of negative environmental consequences for upland swamps WCUS4-headwater swamp and WCUS7. It is recommended that NRE revise mine plans for Area 3 Longwall panels 2, 3 and 4 to avoid, minimise and mitigate impacts to these swamps; and

- there is a significant likelihood of negative environmental consequences for upland swamps CCUS1 and CCUS5 in Wonga East. It is recommended that NRE revise the mine layout of Longwall panels A1 LW3, A2 LW7 and A2 LW8 to avoid, minimise and mitigate impacts to these swamps.

A number of recommendations to avoid or minimise impacts to upland swamps considered to meet the criteria for 'special significance', including:

- adjust the layout in respect of Longwall A1 LW3 to avoid impacts to CCUS1;

- adjust the layout in respect of Longwall A2 LW7 and A2 LW8. If this is not feasible, detailed monitoring of CCUS5 should be undertaken during the extraction of Longwalls 7 and 8. Detailed triggers relating to changes in gradient, groundwater monitoring and/or observational monitoring should be developed, and if triggered measures to minimise impacts should be considered;

- adjust the layout in respect of Longwall A3 LW2 to minimise impacts on the headwaters of WCUS4; and

- adjust the layout in respect of Longwall A3 LW3 and A3 LW4 to reduce predicted strains to WCUS7 and Wallandoola Creek.

A monitoring regime has been proposed as well as potential rehabilitation measures should they be required.

23 *AQUATIC ECOLOGY*

This chapter provides an assessment of potential impacts on aquatic ecological values within the Study Area resulting from the Project.

23.1 *INTRODUCTION*

An assessment of the potential mine subsidence impacts on aquatic habitat and biota was undertaken by Cardno Ecology Lab (2012). The full report is provided in *Annex R*.

The assessment draws on existing information from relevant literature and databases as well as previous field work conducted in the Cataract River catchment. The existing environment has been further characterised through monitoring of the aquatic ecology values of the Study Area undertaken between October 2008 and Spring 2011 using techniques recommended in the Southern Coalfields Report. The result of the baseline monitoring programme are provided in Cardno Ecology Lab (2011). This report is also provided in full in *Annex R*.

The impact assessment provided in this chapter has been based on the results of the monitoring program (Cardno Ecology Lab, 2011), the surface water report (GeoTerra, 2012a) (see *Annex O*) and the subsidence reports (Seedsman, 2012) (see *Annex M*).

23.2 *METHODOLOGY*

23.2.1 *Review of Existing Information*

A review of existing literature and threatened species assessments for the Study Area was undertaken to characterise the existing environment. The results of this review are provided in Chapter 2 of Cardno Ecology Lab (2012). The review identified that information on the aquatic ecology of the Study Area is limited.

There is no published information on the aquatic macrophytes within or near the watercourse in the Study Area. Information on aquatic macroinvertebrates was available for Lizard Creek from the SCA Macroinvertebrate Monitoring Program. A review was undertaken of data collected in fish surveys undertaken in the Cataract River between the dam and Broughtons Pass Weir (downstream of the PAA) and in streams of the Metropolitan Special Area as part of the audit of Sydney Drinking Water Catchment in 2007.

The literature and data review identified that the following species listed as threatened under the *NSW Fisheries Management Act 1994* (FM Act) and/or the EPBC Act were identified as potentially occurring within watercourses of the upper Nepean catchment:

- Macquarie Perch (*Macquaria australasica*) listed as Vulnerable (FM Act), Endangered (EPBC Act);
- Trout Cod (*Maccullochella macquariensis*) listed as Endangered (FM Act), Endangered (EPBC Act);
- Adam's Emerald Dragonfly (*Archaeophya adamsi*) listed as Vulnerable (FM Act);

- Sydney Hawk Dragonfly (*Austrocordulia leonardi*) listed as Endangered (FM Act);
- Murray Cod (*Maccullochella peelii peelii*) listed as vulnerable under the EPBC Act; and
- Silver Perch (*Bidyanus bidyanus*) listed as vulnerable under the FM Act.

23.2.2 *Baseline Monitoring Program*

The baseline monitoring program undertaken by Cardno Ecology Lab was designed to satisfy the recommendations of the SCI (DoP 2008) in that the assessment focused on surveying of aquatic ecological indicators within the third order or higher watercourses of the RMZs within the Wonga East and Wonga West areas prior to mining for a minimum of two years.

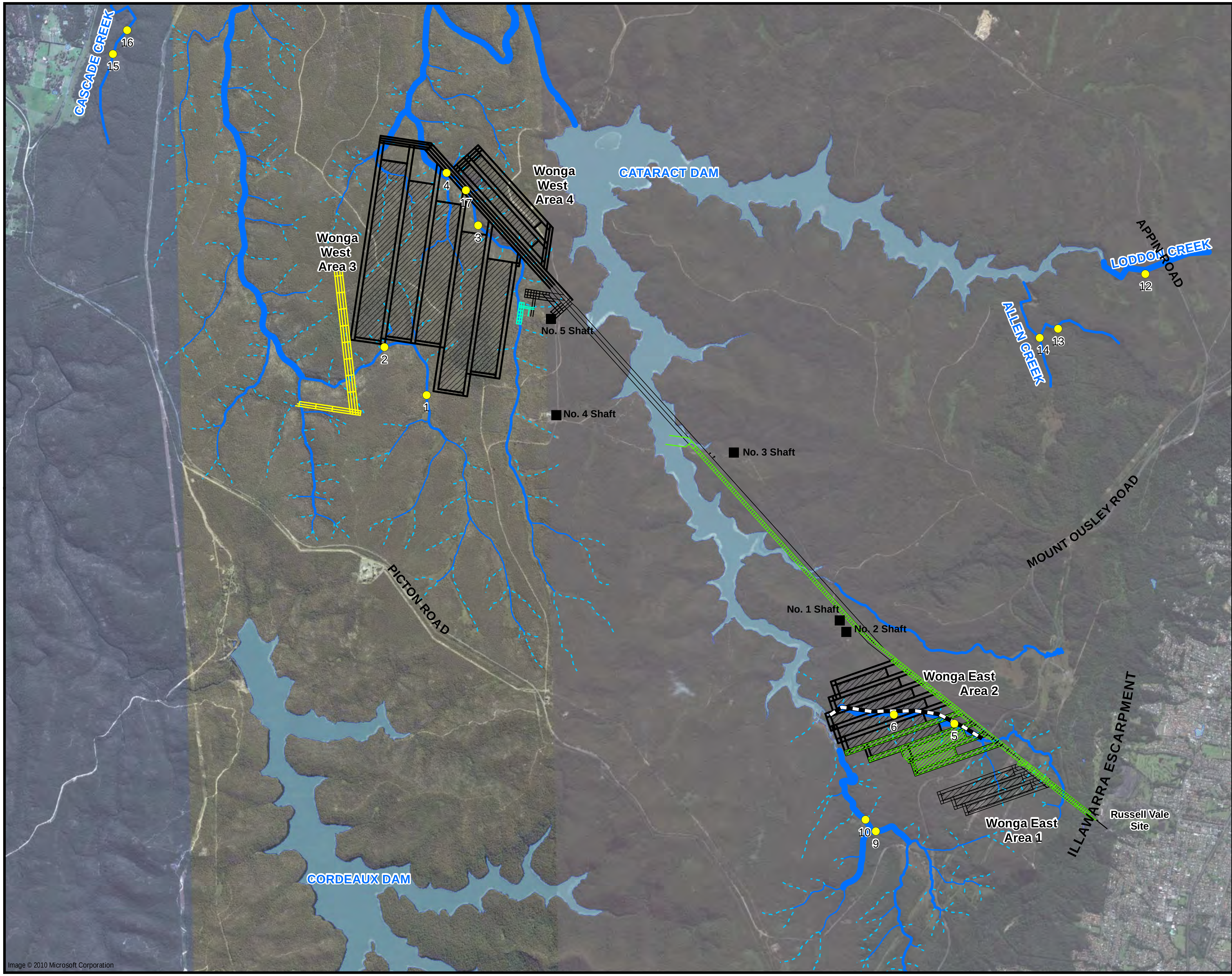
The following ecological indicators were surveyed in Spring and Autumn:

- aquatic habitat;
- aquatic macroinvertebrate fauna;
- fish fauna; and
- water quality.

A detailed description of the ecological indicators sampled, methods and results of the baseline monitoring undertaken at 'control' and 'potential impact' sites is presented in Chapter 2 of Cardno Ecology Lab (2011) provided in Annexure 1 of *Annex R* of the EA. Within each of the four watercourses that may be impacted by mining two 'impact' monitoring sites were established. The location of all sampling sites is shown in *Figure 23.1.* Details of the site selection criteria are provided in Cardno Ecology Lab (2011) in *Annex R*.

Four ecologically comparable watercourses in the Cataract catchment that will not be affected, directly or indirectly by the Project, were identified and two 'control' sites were established for monitoring in each stream. The 'control' sites allow for identification of background environmental variability within the greater Cataract catchment as distinct from any mine subsidence impacts. The control watercourses are: Upper Cataract River, Loddon Creek, Allen Creek and Cascade Creek.

The sampling design chosen for the baseline assessment will enable Beyond BACI (Before/After, Control/Impact) analyses to be used to assess the potential impacts of mining subsidence on aquatic ecology, provided that similar assessments are made during or after mining. The Beyond BACI technique is a modification to the BACI approach that has been developed specifically to distinguish environmental impacts from natural changes. The investigations undertaken to date provide two years of aquatic ecological baseline data for 'control' and 'potential impact'. This constitutes the 'before' component of the Beyond BACI study designed for monitoring of mine subsidence related impacts from the proposed Wonga East and Wonga West longwalls.



Legend
- Project Application Area
- Approved Workings (MP10_0046)
- Proposed Longwalls
- Proposed Balgownie Seam First Workings
- Proposed Bulli Seam First Workings
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order and Above Stream
- Macquarie Perch Survey Transect
- Shaft Locations
- Aquatic Sampling Sites

Figure 23.1
Aquatic Ecology Study Sites

Client: Gujarat NRE Coking Coal Limited

Project: NRE No.1 Colliery EAR Post Adequacy 2012 Environmental Assessment

Drawing No: 0079383s_EARPA2012_G003_R0.mxd

Date: 28/11/2012 Drawing size: A3

Drawn by: KB Reviewed by: NB

Scale: Refer to Scale Bar

N 0 500 1,000 1,500m

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM

Field methods used for the monitoring included:

- aquatic habitat description;
- monitoring of water quality (temperature, conductivity, pH, oxidation reduction potential, dissolved oxygen and turbidity);
- fish sampling including a targeted threatened species survey and baseline monitoring site survey; and
- aquatic macroinvertebrate sampling using artificial collectors and AUSRIVAS sampling techniques.

Where samples could not be identified in the field, they were returned to the laboratory to be examined under binocular microscope. If identification could not be made using this technique, the samples were referred to the Australian Museum for further investigation. Further details of laboratory methods used are provided in *Annex R* as are the methods used to analyse data from AUSRIVAS samples and the artificial collectors.

Baseline monitoring commenced in spring (October) 2008 and was completed in Spring (September) 2011. Surveys were conducted in October 2008, December 2008, March 2009, May 2009, November 2009, March 2010, September 2010, April 2011 and September 2011 (Cardno Ecology Lab 2011).

23.2.3 *Threatened Fish Surveys*

The initial site inspection undertaken by Cardno Ecology Lab in 2008 identified that habitat within Cataract Creek was suitable for the threatened Macquarie Perch that occurs in the waters of Cataract Dam. A preliminary fish survey was undertaken within Cataract Creek in November 2008 confirming presence of Macquarie Perch within the current supply level of the dam and inflow of the creek (Cardno Ecology Lab 2011, Table 4). In addition, freshwater cod juveniles, possibly a hybrid of the threatened Murray Cod and Trout Cod, were captured in the dam and in Cataract Creek (Cardno Ecology Lab 2011, Table 4). A specimen was sent to the Australian Museum for further analysis, but a positive identification could not be reached.

Further targeted backpack electrofishing surveys for Macquarie Perch and other threatened fish species were undertaken during the Summers of 2009/2010, 2010/2011 and 2011/2012 along a section of Cataract Creek downstream of Mount Ousley Road as shown on *Figure 23.1*. A description of the sampling methods and results of these surveys are provided in Cardno Ecology Lab (2011).

The survey extended from the confluence of Cataract Creek and Cataract River, upstream, as far as a rockbar that affords a fish barrier to further upstream migration in Cataract Creek. Surveys were not undertaken in Lizard Creek or Wallandoola Creek given that the presence of waterfalls would act as a barrier to the movement of fish species into the reaches of these streams within the RMZ.

23.3 *EXISTING ENVIRONMENT*

23.3.1 ***Wonga West Investigation Area***

Wallandoola Creek and Lizard Creek are deeply-incised streams cut into Hawkesbury Sandston. The surrounding vegetation of Wallandoola and Lizard Creeks within the Study Area was generally open dry sclerophyll woodland and heath. Within the Study Area both creeks are unshaded to moderately shaded and the substratum dominated by bedrock and boulders with sand and fine sediment accumulated in some of the deeper pools and channel sections. Aquatic macrophytes including *Vallisineria gigantea* and *Eleocharis* sp. are present.

There is a variety of different habitat features within these creeks including relatively deep, permanent pools and sections of shallow flow over bedrock bars. Soft sediment banks with overhanging vegetation and instream features such as submerged woody debris is also present.

Wallandoola Creek

Within the investigation area the most upstream reach of Wallandoola Creek is characterised as an upland swamp and there is no clearly defined channel. The two monitoring sites (Sites 1 and 2) within this creek were established further downstream of the investigation area where the channel became permanent and well defined. These sites are in close proximity to water quality monitoring sites WC3 and WC4 respectively (GeoTerra, 2012a).

Downstream of these sites, there are a series of waterfalls as the creek drops from the plateau before eventually entering Cataract River downstream of Cataract Dam. The waterfalls create significant barriers to fish passage. Natural variations in water levels at the two sites within Wallandoola Creek are particularly noteworthy. Fractures in bedrock bars were identified throughout the reach of the creek. Iron staining and associated iron flocculant was also noted to be present in high levels in this creek.

Lizard Creek

There is evidence of extensive existing cracked bedrock throughout the Lizard Creek reach lying within the Study Area. This is believed to be a consequence of past mining activities. Upstream Site 3 is within a chain of deep pools upstream and downstream of cracked sections of the creek. Water flows down Lizard Creek are strongly rainstorm dependent and this monitoring site was noted to drain completely over the course of the monitoring at a rate that appeared to be significantly greater than fluctuations observed in the same creek at different locations as well as other creeks in the area over the same period (GeoTerra, 2012a). Due to the dry nature of this site in autumn 2009, an alternative monitoring site was established in Lizard Creek approximately 0.5km downstream (Site 17). This reach had similar physical characteristics, although there was a considerable amount of iron flocculant in-stream and water levels remained relatively consistent over the six weeks of the autumn monitoring period.

Lizard Creek Site 4 was over one kilometre downstream of Site 3. Sites 4 and 17 were located in close proximity to water quality monitoring site LC6 (GeoTerra, 2012a). There was a considerable amount of iron flocculant in this section of Lizard Creek as well as in a small watercourse (LCT1) that flowed into the site from the south west. Natural variation in water level at the site was rainfall dependent and considered minimal over the baseline monitoring period.

A significant waterfall is located between Site 4 and the two upstream monitoring sites (Sites 3 and 17) as well as other significant waterfalls between the investigation area and the Cataract River. These waterfalls create significant barriers to fish passage.

23.3.2 *Wonga East Investigation Area*

The proposed Wonga East longwalls are located within the Lake Cataract catchment, to the north east of the Cataract River arm of the reservoir. Cataract Creek is a 4th order stream bordered by temperate rainforest riparian vegetation. The canopy is closed and the creek shaded. The channel morphology of the creek is characterised by an alternating series of long pools and shorter bars and riffles. Cataract Creek is predominantly shallow with occasional deep holes. Bars and riffles are composed of various combinations of bedrock, boulders, cobble, pebble and gravel. Large woody debris was relatively common, forming dams and submerged snags in pools. There is natural variation in water levels both within and between seasons.

Aquatic habitats suitable for the threatened Macquarie Perch were identified in Cataract Creek Sites 5 and 6. The current supply level of Cataract Reservoir extends upstream into Cataract Creek and provides suitable habitat for Macquarie Perch. Occasional riffles and bars further upstream may create minor barriers to passage during low to moderate flows or when water levels within the Cataract Dam are low (Cardno Ecology Lab 2012).

23.3.3 *Control Creeks*

Control creeks were selected for monitoring based on their similarities to the potentially impacted creeks within Wonga East and Wonga West.

Loddon Creek (Sites 11 and 12) and Cascade Creek (Sites 15 and 16) are more similar to the creeks in the Wonga West area. The riparian vegetation of Loddon Creek is dominated by heath with some sections of open dry sclerophyll woodland and that of Cascade Creek dominated more by the open dry sclerophyll woodland. The channels of both watercourses are characterised by long pool sections with infrequent riffles. The stream bed in the shallower sections of both Loddon Creek and Cascade Creek is characterized by bedrock.

Swamp habitat is present in areas above both Wonga West control upstream sites (Sites 11 and 15) and a large waterfall was located below the Loddon Creek downstream site (Site 12) and just above the Cascade Creek downstream site (Site 16).

The Upper Cataract River (Sites 9 and 10) and Allens Creek (Sites 13 and 14) are similar to the creeks in the Wonga East investigation area. The riparian vegetation is composed of dense temperate rainforest and the channel forms and bed composition are very similar to those of Cataract Creek and Bellambi Creek with alternating pool and riffle sequences and a diverse range of rocky substratum. Similar to the potential impact sites, both of the control creeks flow into Lake Cataract.

23.3.4 *Water Quality*

Water quality in Wallandoola Creek and Lizard Creek was generally within the acceptable range for potable water, except for pH, which was often lower (ie more acidic); and dissolved oxygen (DO) was generally lower that the ANZECC/ARMCANZ 2000 default trigger values for slightly disturbed upland rivers in south-east Australia. DO levels were below the lower default trigger value on all occasions in the control site in Cascade Creek and on most sampling occasions in Loddon Creek. Turbidity was also below the lower default trigger value during a few surveys in Wallandoola Creek, Lizard Creek and Loddon Creek. Regular monitoring 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 (Cardno Ecology Lab 2011).

Although the water quality parameters measured often deviated from the guidelines, there was no evidence to suggest that the overall quality of the water at the 'potential impact' sites in Wallandoola Creek and Lizard Creek was poorer than that at the 'control' sites. Generally DO was lower indicating that conditions may not be optimal for aquatic life (Cardno Ecology Lab 2011). Cardno Ecology Lab (2011) and GeoTerra (2012a) have both noted that relatively acid streams are quite common in the Hawkesbury Sandstone of the Southern Highlands and Illawarra.

Water quality monitoring in Cataract Creek identified that while DO levels were generally below the lower default trigger value, electrical conductivity, pH and turbidity levels only deviated from the guidelines occasionally (Cardno Ecology Lab 2011).

23.3.5 *Fish Sampling*

Targeted Threatened Species Survey

The threatened Macquarie Perch was captured in Cataract Creek on all sampling occasions with the greatest number of individuals (37) captured on 25 January 2011 (Cardno Ecology Lab 2011). During each sampling season individuals were captured further upstream as the season progressed. The furthest upstream an individual was captured was in February 2011 at the rock bar at Site 6 (Cardno Ecology Lab 2011).

The hybrid freshwater cod were recorded in all four surveys with numbers also increasing as the season progressed. Silver Perch were recorded only in late January and February 2011 (Cardno Ecology Lab 2011).

Baseline Monitoring Site Surveys

The species and numbers of fish and large crustaceans collected from each site during the baseline monitoring are listed in Cardno Ecology Lab (2011) in *Annex R*. In Wonga West, no fish were caught in Wallandoola Creek, while Climbing Galaxias (*Galaxias brevipinnis*) and Australian Smelt (*Retropinna semoni*) were observed in Lizard Creek (Cardno Ecology Lab 2011). Freshwater Crayfish (*Euastacus* sp.) was present in both creeks (Cardno Ecology Lab 2011). Native species of climbing galaxias, Australian smelt and freshwater crayfish were regularly captured or observed at other study sites.

The limited sampling and observations made during the baseline monitoring program suggest that the fish fauna in the watercourses above the proposed longwalls in Wonga West is depauperate. No fish species were observed at the 'potential impact' sites in Wallandoola Creek and only two species were found at those in Lizard Creek. The 'control sites' also appeared to be depauperate with only one and three species being recorded in Cascade Creek and Loddon Creek, respectively. The paucity of fish species is most likely due to the presence of barriers to fish passage in the form of waterfalls downstream of the study sites (Cardno Ecology Lab 2011).

The limited sampling and observations made during the baseline monitoring program in Wonga East suggest that the fish fauna is also depauperate. No fish species were observed at the 'control' sites in Allens Creek and only two species were found in Cataract Creek and Cataract River (Cardno Ecology Lab 2011). However, backpack electrofishing survey technique employed in the targeted fish surveys identified seven species in Cataract Creek (Cardno Ecology Lab 2011).

23.3.6 *Aquatic Macroinvertebrates*

Macroinvertebrates were assessed using the AUSRIVAS Rapid Assessment Method (RAM) to collect and assess samples during surveys in Spring and Autumn over two years. The results from the quantitative edge habitat artificial collectors have been summarised and presented in Figure 3 (Wonga West) and Figure 6 (Wonga East) of Cardno Ecology Lab (2011) in *Annex R.* The averages between the control creeks (17 taxa) and potential impact creeks (15 taxa) were not significantly different as determined from a PERMANOVA test (see Table 3 of Cardno Ecology Lab (2011) in *Annex R*).

Macroinvertebrate Assemblages

The 'health' of the macroinvertebrate assemblages were assessed using the AUSRIVAS predictive spring and autumn models for NSW pool edge habitats. This model uses bands derived from OE50Taxa scores, which indicate the level of impairment of the assemblage.

The OE50Taxa score is the ratio of the number of macroinvertebrate families with a greater than 50% predicted probability of occurrence that were actually observed at a site to the number of macroinvertebrate families expected with a greater than 50% probability of occurrence.

The bands derived from the OE50 taxa scores are graded as:

- Band X = Richer invertebrate assemblage than reference condition;
- Band A = Equivalent to reference condition;
- Band B = Sites below reference condition (ie significantly impaired);
- Band C = Sites well below reference condition (ie severely impaired); and
- Band D = Impoverished (ie extremely impaired).

The revised Stream Invertebrate Grade Number Average Level (SIGNAL2) was used to determine the environmental quality of sites. SIGNAL2 value is based on the presence or absence of families of macroinvertebrates with values greater than 6 indicating that quality of water is clean, between 5 and 6 (mildly degraded), between 4 and 5 (moderately degraded), and less than 4 (severely degraded).

Wonga West

The results of Wonga West Study Area AUSRIVAS Bands, OE50 taxa score and SIGNAL2 Scores in Spring and Autumn are provided in Figures 4 and 5 of Cardno Ecology Lab (2011) in *Annex R*.

There was considerable variation in the 'health' of the macroinvertebrate fauna at the majority of monitoring sites in Wonga West across the Spring and Autumn surveys. During the spring surveys, the changes in condition of the fauna, as indicated by differences in AUSRIVAS banding, was generally greater at the 'potential impact' sites than at the 'control' sites. During the Autumn surveys, two of the 'potential impact' sites on Lizard Creek showed smaller changes in 'health' than the other 'potential impact' and 'control sites'. The amount of change in AUSRIVAS bands observed at some of the monitoring sites is of concern (eg, X to B or A to C or D), because it indicates the composition of the macroinvertebrate fauna is naturally highly variable.

Discussion of the effectiveness of AUSRIVAS bands, and the OE50 taxa scores from which they are derived, as effective indicators of any impacts on aquatic macroinvertebrates associated with the proposed mining activities in Wonga West is provided in Section 4.1.3 of Cardno Ecology Lab 2011 in *Annex R*.

The SIGNAL2 scores from the spring surveys indicated the fauna at the 'potential impact' sites on Wallandoola Creek and Lizard Creek was more degraded (less than 4 in September 2010 and 2011) than that at the 'control sites' in Loddon Creek (between 4 and 5), but not necessarily those in Cascade Creek (less than 4). A similar trend was evident in the SIGNAL2 scores from the Autumn surveys.

The SIGNAL2 scores were less variable than the AUSRIVAS bands, particularly in Autumn, and could therefore be a better indicator of changes in the macroinvertebrate fauna associated with mine-induced subsidence. However, as these scores are based primarily on the sensitivity of individual taxa to pollution, it is not clear whether they will respond to changes in aquatic habitats arising from the impact of subsidence on physical features (Cardno Ecology Lab 2011).

Wonga East

The results of Wonga East Study Area AUSRIVAS Bands, OE50 taxa score and SIGNAL2 Scores in Spring and Autumn are provided in Figures 7 and 8 of Cardno Ecology Lab (2011) in *Annex R*.

There was considerable variation in the 'health' of the macroinvertebrate fauna at the monitoring sites in Wonga East across the Spring and Autumn surveys. During the Spring surveys, the changes in condition of the fauna, as indicated by differences in AUSRIVAS banding, was generally greater at the 'control' sites on Cataract River than at the 'potential impact sites on Cataract Creek and 'control' sites on Allens Creek. During the Autumn surveys, one of the 'potential impact' sites on Cataract Creek and one of the 'control sites' on Cataract River showed larger changes in 'health' than the other monitoring sites. The amount of change in AUSRIVAS bands observed at the more variable sites was in the same order as that observed in the Wonga West Study Area (ie X to B or A to C). The less variable nature of the monitoring sites in this Study Area suggests that AUSRIVAS bands, and the OE50 taxa scores from which they are derived, may be more effective indicators of impacts on aquatic macroinvertebrates associated with extraction of the Wonga East longwalls.

The SIGNAL2 scores from both the Spring and Autumn surveys indicated the fauna at the 'potential impact' sites on Cataract Creek were between 4 and 5 for most surveys except for September 2011 when dropped below 4. These scores were generally similar to that at the 'control sites' on Cataract River and Allens Creek. The SIGNAL2 scores were less variable than the AUSRIVAS bands, as was the case in the Wonga West Study Area, suggesting that it might potentially be a better indicator of changes in the macroinvertebrate fauna associated with mine-induced subsidence.

23.4 *IMPACT ASSESSMENT*

Longwall mining has the potential to impact aquatic ecology through subsidence effects which could result in changes to the flow and ponding in creek systems and changes to water quality by:

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

The impact of subsidence on the flow and ponding in creek systems and water quality has been assessed by GeoTerra (2012a), and described in detail in *Annex O* and summarised in *Chapter 20*.

Section 3.3 of (Cardno Ecology Lab 2012) in *Annex R,* provides a detailed discussion of the primary *environmental consequences* of *subsidence impacts* on the creeks including changes to surface flows ponding and surface water quality; and the *secondary environmental consequences* to aquatic biota and threatened species in the Study Area.

23.4.1 *Aquatic Habitats and Biota*

Wonga East

GeoTerra (2012a) predicts that there are not expected to be any detectable effects on stream flow, pond drainage and/or water quality within Cataract Creek, provided that the proposed adaptive management plan is adhered to. The intent of the adaptive management plan is to prevent subsidence-induced fracturing of the Cataract Creek bed. This requires close monitoring of subsidence as the longwall progresses and if a threshold that could lead to fracturing is exceeded then the layout of the longwalls would be revised. On this basis the extraction of the proposed longwalls within Wonga East is unlikely to have any observable effects on aquatic habitats or their biota (Cardno Ecology Lab 2012).

The reduction in baseflow recharge to the Cataract Creek due to changes in the water table resulting from depressurisation of the Hawkesbury sandstone would be negligible (0.07 ML/d) (GeoTerra 2012a), so it is unlikely that it would have any detectable effects on the availability of aquatic habitat in this creek.

Minor, transient increases in sediment mobility and turbidity of the water that occur within and downstream of the subsidence area, are likely to have only a minimal impact on aquatic habitats and biota, because of their periodic exposure to such conditions during heavy rainfall events (Cardno Ecology Lab 2012).

Wonga West

If extraction fractures the sandstone rock shelf in the bed of Wallandoola Creek to the south of proposed Longwalls A3 LW3 and A3 LW4 and causes the pool upstream of the shelf to drain, there would be loss of aquatic habitat and associated biota within this pool. Organisms that are left stranded in air or that are unable to move to areas that are damp or submerged, would be significantly impacted.

The ability of organisms to cope with pool drainage varies, depending on their tolerance and response to desiccation and rapid changes in water level, ability to move, weather conditions at the time, the underlying substratum and duration of exposure.

The drainage of this pool would also reduce longitudinal connectivity along the creek and prevent mobile aquatic fauna, particularly fish, from accessing upstream habitat for feeding or spawning purposes. The extent and duration of these losses would depend on the degree of drainage, rainfall and inflows from further upstream, with pool habitat being re-established once inflows exceed diversionary flows. During periods of low rainfall, losses would be greater and more prolonged.

Downstream transfer of fine sediments, nutrients, organic material, seeds, spores, vegetative fragments of aquatic plants and drift of macroinvertebrates is unlikely to be adversely affected because the water lost is expected to re-emerge further downstream.

The diversion of the water lost from the pool through the underlying sandstone substratum could lead to iron staining and elevated dissolved metal concentrations in the water where the flow re-emerges on the surface. The precipitation of iron hydroxide is often followed by the growth of bacterially-mediated iron flocs and mats in pools which can, in turn, cause a reduction in dissolved oxygen levels and have eco-toxic effects. High levels of iron floc within a watercourse can also smother the surface of aquatic macrophytes, snags, boulders and bank edge and reduce the amount and variety of habitats suitable for occupation by aquatic organisms.

The more acidic pH, reduced oxygen concentrations and elevated metal concentrations in the re-emerging water may also affect the diversity and abundance of aquatic organisms. These changes would be restricted to the area immediately downstream of rock fractures, where the flow re-emerges. The duration of these impacts would depend on the dilution, flushing and re-aeration effects of surface flows.

Impacts would be more protracted during periods of low flows. It should be noted that the quality of the water within Wallandoola and Lizard Creeks is already highly variable and that pH and filtered zinc levels often exceed the ANZECC/ARMCANZ (2000) criteria (GeoTerra, 2012a). The aquatic flora and fauna in the Study Area may therefore already have been adversely affected (Cardno Ecology Lab 2012).

These impacts would be localised, minor in extent and transient in nature and therefore unlikely to be significant. There are not expected to be any adverse effects on the aquatic habitats, flora and fauna in the other sections of Wallandoola Creek and Lizard Creek.

23.4.2 *Threatened Species*

Section 23.2.1 lists threatened species that could potentially occur within the Study Area. Targeted fish surveys have identified that the Macquarie Perch, Silver Perch and a hybrid of the freshwater cods Trout Cod and Murray Cod occur within the waters of Cataract Dam and reaches of Cataract Creek downstream of Mount Ousley Road (Cardno Ecology Lab 2011).

In addition Cardno Ecology Lab have identified that there is suitable habitat for Adam's Emerald Dragonfly (*Archaeophya adamsi*) in Cataract Creek, Wallandoola and Lizard Creek. Conversely, there are no records of the threatened Sydney Hawk Dragonfly and the three creeks were assessed as unsuitable habitat for this species (Cardno Ecology Lab 2012).

Assessments of significance in accordance with Section 5A of the EP&A Act are provided in Appendices 1 to 5 of Cardno Ecology Lab (2012) in *Annex R*. Following is a summary of the assessments.

The two species of freshwater cod and the Macquarie Perch are listed as threatened under the Commonwealth EPBC Act. Accordingly, an impact assessment for these species have been undertaken in accordance with the EPBC Act *Significant Impact Guidelines 1.1* (DEWHA 2009). These are provided in Annex B of the Matters of National Environmental Significance Assessment report for this Project (see *Annex T*).

Adams Emerald Dragonfly

Adam's Emerald Dragonfly is extremely rare. There are no records of Adam's Emerald Dragonfly occurring south of Sydney despite active searching in the Hawkesbury-Nepean River catchment (Fisheries Scientific Committee 2008 in Cardno Ecology Lab, 2012).

There are no historical records of this species occurring within Cataract, Wallandoola or Lizard Creek catchments or the greater Cataract River catchment.

No specimens were found within these creeks in surveys during the baseline studies. Suitable habitat for Adam's Emerald Dragonfly, albeit of limited extent, does however occur within Cataract, Wallandoola and Lizard Creeks above the proposed mine area.

Although, the current distribution records suggest that this species is unlikely to occur within the Study Area, an Assessment of Significance has been prepared (see Appendix 1 of Cardno Ecology Lab (2012) in *Annex R*), because there is potential habitat for this species close to the Study Area.

If a viable population of Adam's Emerald Dragonfly is present within Cataract Creek or Lizard Creek it highly unlikely that the proposed mining operations would have any significant impact on the species, because no alteration of habitat is expected. If a viable population of the species exists in Wallandoola Creek, it may be subject to temporary, localised, minor impacts.

Sydney Hawk Dragonfly

There are no records of the Sydney Hawk Dragonfly occurring within the Cataract, Wallandoola or Lizard Creek catchments or the greater Cataract River catchment. Habitat assessments identified that the streams in the Study Area do not support habitat suitable for this species. Further, no specimens were found within these creeks in surveys during the baseline studies and the Sydney Hawk Dragonfly was considered highly unlikely to occur in the Study Area. Accordingly, an Assessment of Significance is therefore unnecessary for this species.

Macquarie Perch

The Murray-Darling form of the Macquarie Perch is found in the upper reaches of the Murray-Darling Basin in NSW, Victoria and the ACT and the eastern form is confined to the Hawkesbury-Nepean and Shoalhaven river systems (DSEWPC 2011). In the locality, the Macquarie Perch is known from Cataract Dam (translocated population), the Nepean River, and one record in the Georges River near Campbelltown (DSEWPC 2011). There is a viable population of Macquarie Perch in the reach of the Cataract River between the dam and Broughtons Pass Weir, near Appin (Cardno Ecology Lab 2012).

The species is known to occur in Cataract Dam and baseline surveys by Cardno Ecology Lab (2011) have confirmed that the Macquarie Perch occurs in Cataract Creek up to the rock bar over Longwalls A2 LW08 and A2 LW07 in Wonga East (Cardno Ecology Lab 2012). Waterfalls act as a physical barrier to prevent the species reaching Lizard Creek and Wallandoola Creek in Wonga West (Cardno Ecology Lab 2012).

This species is known to migrate upstream to spawn in riffles in late Spring to Summer, fish caught in Summer 2011 were of a size that may have been migrating from the dam to spawn upstream (Cardno Ecology Lab 2011). The reach of Cataract Creek within the Wonga East area is periodically occupied by the Macquarie Perch and is potentially important habitat for this species.

The Assessment of Significance under the TSC Act (see Appendix 2 of Cardno Ecology Lab (2012) in *Annex R*) and the EPBC Act (see Annex B of *Annex T*) conclude that the proposed mining operation does not pose a significant threat to local populations of this species provided that an adaptive mine plan is implemented and the predicted subsidence impacts on Cataract Creek are minimised.

Trout Cod

The Trout Cod is native to the Murray Darling drainage but was translocated into areas outside of their natural range including Cataract Dam before 1915. The Trout Cod still occurs in the dam and the Trout Cod Recovery Team (2008) indicates that the cod population within Cataract Dam is composed largely of hybrids of Trout Cod and Murray Cod. In the absence of any significant barriers to movement, the Trout Cod may occur in Cataract Creek.

Unidentified juvenile and adult freshwater cod caught recently in the Cataract Creek arm of Cataract Dam may be a Trout Cod, Murray Cod or a hybrid of these species (Cardno Ecology Lab 2011, 2012).

Little is known about the behavioural ecology of Trout Cod, and the likelihood of this species utilising the habitat within creeks of the Wonga East area at any stage of their life cycle is unknown.

An Assessment of Significance under the TSC Act (see Appendix 4 of Cardno Ecology Lab (2012) in *Annex R*) and the EPBC Act (see Annex B of *Annex T*) conclude that the proposed mining of Wonga East does not pose a significant threat to the local populations of Trout Cod within the Cataract River catchment provided that an adaptive mine plan is implemented and the predicted subsidence impacts on Cataract Creek are minimised.

Murray Cod

The Murray Cod is the largest freshwater fish in Australia. It is found throughout the Murray-Darling basin except for the upper reach of some tributaries, with some local extinctions. It inhabits a diverse range of habitats including warm water habitats, clear rocky streams through to slow flowing turbid rivers and billabongs with woody debris, large rocks or overhanging vegetation for cover.

Translocated populations have been established in NSW and Victoria, including within Cataract Dam. The population in the dam is composed largely of hybrids of Murray Cod and Trout Cod (Cardno Ecology Lab 2012). Unidentified juvenile and adult freshwater cod caught recently in the Cataract Creek arm of Cataract Dam may be a Murray Cod, Trout Cod or a hybrid of these species (Cardno Ecology Lab 2011, 2012).

An Assessment of Significance under the TSC Act (see Appendix 5 of Cardno Ecology Lab (2012) in *Annex R*) and the EPBC Act (see Annex B of *Annex T*) conclude that the proposed mining of Wonga East does not pose a significant threat to the local populations of Murray Cod within the Cataract River catchment provided that an adaptive mine plan is implemented and the predicted subsidence impacts on Cataract Creek are minimised.

Silver Perch

Historical records show that Silver Perch occurred throughout most of the Murray-Darling drainage (NSW DPI 2006). This species has undergone a dramatic decline in abundance and distribution over the last few decades and is now absent from most of its natural range. Silver perch have been stocked at numerous sites within the Murray-Darling Basin. This fish has also been translocated into many areas outside their natural range, including some catchments along the east coast of NSW and Lake Cataract (NSW DPI 2006). The population in Lake Cataract was translocated in the early part of the 20th century and is secure and self-sustaining. I&I NSW research surveys indicate that Silver Perch were still present in this dam in 1994 and 2006.

The subsidence predictions indicate that there are not likely to be any physical or chemical impacts on the aquatic habitat that Silver Perch may periodically occupy in the reach of Cataract Creek that traverses the Wonga East area. Further the existing Silver Perch habitat in the Lake Cataract catchment is well outside of the predicted subsidence impact area (Cardno Ecology Lab 2012).

An Assessment of Significance under the TSC Act (see Appendix 3 of Cardno Ecology Lab (2012) in *Annex R*) conclude that the proposed mining of Wonga East does not pose a significant threat to the local populations of Silver Perch within the Cataract River catchment, provided that an adaptive mine plan is implemented and the predicted subsidence impacts on Cataract Creek are minimised.

23.4.3 *Sensitive Aquatic Habitats*

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

23.5 *MANAGEMENT AND MITIGATION MEASURES*

The potential impacts of longwall mining on the aquatic ecology of the Study Area have largely been mitigated through the design of the proposed longwall layout, in particular in the Wonga West area, and will be further managed through an adaptive mine plan, ongoing monitoring of subsidence, water quality, aquatic habitat, macro invertebrates and fish. This will provide best practice environmental monitoring of aquatic ecology and allow statistically powerful analysis of the nature and extent of mine subsidence impacts, if any. The objective of this monitoring will be to validate the predictions about the consequences of subsidence on aquatic habitats and biota and assess any unexpected impacts on these that may occur.

If significant effects on aquatic habitats and/or biota are detected during subsidence monitoring it may be necessary to reduce further impacts and environmental consequences by adopting one of the following strategies:

- the commitment by the proponent that it will terminate mining beneath Cataract Creek if subsidence and ground movements exceed 250mm and the creek experience greater than minimal impact;
- modifying mine layout to further reduce potential subsidence impacts; and
- increasing the setback of the longwall being extracted and future longwalls from the affected watercourse.

Other measures include implementing remediation measures to reduce the extent of fracturing of the stream bed (eg grouting of rock bars) and using standard erosion and sediment control measures to prevent mobilised sediments entering watercourses.

23.6 *PROPOSED ONGOING MONITORING*

The monitoring of the ecological impacts of longwall mining will be done in accordance with the recommendations made in the *Strategic Review of Impacts of Coal Mining on Natural Features in the Southern Coalfields* (DoP 2008). The pertinent recommendations in that report are:

- collection of a minimum of two years of baseline data (including threatened species monitoring);
- use of Before, After, Control, Impact (BACI) designs for monitoring (current best practice); and
- monitoring of third order or higher streams in the vicinity of predicted subsidence footprints.

Cardno Ecology Lab has now collected three years of baseline data from 'potential impact' sites on the Cataract, Wallandoola and Lizard Creeks and 'control' sites on nearby streams (Allen, Loddon and Cascade Creeks and the Upper Cataract River). These data constitute the 'before' component of the BACI ('Before, After, Control, Impact') study design.

The following components have been monitored in Spring and Autumn using the methods specified:

- physico-chemical water quality parameters measured with a portable multi-probe meter;
- condition of aquatic habitat based on standard scoring for variables listed within the AUSRIVAS protocol;
- macroinvertebrates in pool edge habitats collected using:
  - (i) the standard AUSRIVAS rapid assessment methodology and SIGNAL2 scores; and
  - (ii) artificial collectors, a sampling method that provides a standardised habitat unit for macroinvertebrates to colonise and results in quantitative estimates of abundance and diversity that are independent of the quality or quantity of habitat present within the creeks; and
- fish sampled using dip nets.

Targeted surveys of Macquarie Perch and other threatened fish species within the reach of Cataract Creek overlying the Wongawilli East Mine Area have been undertaken in the Summer of 2009/2010, 2010/2011 and 2011/2012.

Further monitoring of all of these components will be undertaken during and following the extraction of these longwalls using the same survey sites and methods and during the same seasons as used for the baseline study.

This will provide best practice environmental monitoring of aquatic ecology and allow statistically powerful analysis of the nature and extent of mine subsidence impacts, if any. The objective of this monitoring is to validate the predictions about the flow-on effects of subsidence-related disturbances on aquatic habitats and biota and assess any unexpected impacts on these that may occur.

Additional surveys of aquatic habitats and biota should be undertaken as soon as possible if fractures of the stream bed and associated loss of water from pools or significant changes in water quality are detected during routine surface monitoring of the potential impact creeks. The objective of these surveys would be to determine whether there have been any effects on aquatic ecology.

If fish or yabby kills are noted during routine surface monitoring, further studies should be undertaken to determine the extent of impact on aquatic ecology and whether there is a need for management/mitigation measures.

24 *TERRESTRIAL ECOLOGY*

This chapter provides an assessment of potential impacts on ecological values of the PAA resulting from the Project. Measures to mitigate these impacts are also provided.

24.1 *INTRODUCTION*

24.1.1 *Introduction*

A Terrestrial Flora and Fauna Assessment was undertaken for the Project by ERM and is provided in full in *Annex S.* The assessment was undertaken in order to satisfy the Director-General's Requirements and the Guidelines for Threatened Species Assessment under Part 3A prepared by OEH and the DPI. In keeping with these guidelines the ecological assessment report provides:

- an evaluation of the impacts of the proposal including consideration of the potential effects of the proposal on threatened species, populations and ecological communities; and

- a discussion of measures to avoid impacts and where this is not possible measures to mitigate impacts.

The assessment was based on literature review, database review and field investigations with consideration given to a number of reports including the DECC (2007) Submission on the Strategic Review of the Impacts of Underground Mining in the Southern Coalfield; SCI Report (2008); the PAC report for the Metropolitan (PAC 2009) and Bulli Seam Operations (PAC 2010); and upland swamp assessment by Biosis (2012) provided in *Annex Q*.

The Terrestrial Flora and Fauna Assessment informed the Assessment of the EPBC Act Matters of National Environmental Significance report prepared by ERM and provided in full in *Annex T*.

This chapter sets out a summary of the key findings of the assessment.

24.1.2 *Purpose of the Assessment*

The purpose of the Flora and Fauna Assessment Report is to detail the terrestrial ecological assessment of the Study Area to address the Director-General's Requirements, provided in *Annex A*, and to meet the following objectives:

- identify and describe the conservation significance of ecological communities, flora, fauna and wildlife habitat within the Study Area;

- assess the type and degree of potential mining-induced impacts on terrestrial ecological communities known to, or considered likely to occur in the Study Area;

- assess the type and degree of consequences of mining induced impacts to ecological communities, flora and fauna of conservation significance in the Study Area, as a result of subsidence effects;

- identify measures to avoid impacts and consequences of mining induced effects to terrestrial ecological values;
- identify mitigation measures to ameliorate the impacts and consequences of mining-induced subsidence effects on terrestrial ecological values; and
- provide a benchmark against which future changes to habitats and biota can be compared.

The assessment addresses the legislative requirements of state and Commonwealth legislation as identified in *Chapter 4* including the EPBC Act, SEPP 44, EP&A Act and TSC Act.

24.2 *STUDY AREA*

The Study Area for ecological assessment was determined by the recommendations of the SCI Report (2008) and defined as the proposed longwall footprints in Wonga East and Wonga West including a surrounding surface perimeter of 600m. The Study Area contains approximately 2,623ha. This Study Area is reduced in size from that originally defined at the commencement of this ecological study, due to modifications in the mine plan to avoid significant environmental values.

The proposed longwall mining areas of Wonga East and Wonga West underlie the Metropolitan Special Area (MSA), which is managed jointly by the SCA and the OEH. The Special Areas are managed for the dual purposes of water supply protection and maintenance of ecological condition (SCA 2007). Over 26 significant plant species, 30 threatened animal species and 10 endemic fish species have been identified in the Special Areas (DECC 2007). The Study Area forms part of the Great Eastern Ranges initiative (formerly the Alps to Atherton Conservation Corridor) (DECC 2007b).

Comprehensive vegetation mapping of the Woronora, O'Hares and Metropolitan Catchments was produced by NSW Department of Environment and Conservation (NPWS 2003) and covers the Study Area. The mapping indicates that the PAA is predominantly covered by dry sclerophyllous woodlands on the exposed sandstone plateau with extensive upland swamp areas within shallow drainage basins.

Within the gullies and gorges tall moist forests predominate with some temperate rainforest also occurring in the deeper gullies in Wonga East. Large areas are un-fragmented for both flora and fauna and therefore important both locally and regionally.

Native vegetation has previously been cleared for existing infrastructure, including at the Russell Vale site, the primary personnel and equipment shaft (Shaft 4), other ventilation shafts and along access tracks.

The SCI Report (DoP, 2008) found that the Southern Coalfields underlie a landscape containing highly significant ecological features that are sensitive to subsidence impacts as a result of longwall mining. Ecologically sensitive features are discussed in detail in *Section 2.4* and *Section 2.5* of *Annex S*. The sensitive landscape features include streams, upland swamps, rocky habitats, endangered ecological communities (EECs) and threatened species.

The Study Area contains ephemeral and perennial streams and channel pools, and extensive swamps that are expected to provide habitat for a diverse array of species, particularly in dry periods. Watercourses in the Study Area include Cataract Creek, Bellambi Creek, Lizard Creek, Wallandoola Creek and the Cataract River. Stream headwaters in the PAA are characterised by extensive upland swamps leading into broad, shallow streams with poorly defined channels and a low bed gradient (GeoTerra 2012a, Biosis 2012a).

Upland swamps are recognized as significant biodiversity features that provide habitat for a high diversity of plant and animal species, many of which are threatened or endemic (DECC 2007a). As discussed in *Chapter 22* upland swamps regulate the quality and quantity of surface water discharge by releasing moisture over extended (often dry) periods. This water availability means that many species are dependant upon upland swamps and their associated 1st and 2nd order streams for some or all of their lifecycle. Contiguous networks of intact upland swamps, including the Wallandoola Creek swamp cluster are considered to be of particular conservation significance (DECC 2007). The Wallandoola Creek significant swamp cluster extends across part of the Study Area, including the majority of swamps in the Lizard Creek and Wallandoola Creek uplands.

Detailed discussion of the upland swamps that characterise the Study Area is provided in *Chapter 22*. The terrestrial flora and fauna assessment focuses on the habitat value of upland swamps and associated 1st order and 2nd order streams, in particular for threatened species that are susceptible to subsidence.

24.3 *SURVEY METHODOLOGY*

The ecological assessment included a desktop survey and field investigations. Detailed description of the survey methodology is provided in *Chapter 3* of *Annex S*. The assessment was undertaken in accordance with the *Draft guidelines for Threatened Species Assessment under Part 3A of the Environment Planning and Assessment Act 1979* (DEC 2005) and the *Threatened Biodiversity Survey and Assessment: Guidelines for Development Activities* (DEC 2004)

Desktop research included analysis of relevant literature, including surveys conducted within the PAA and immediate environs, an analysis of state and Commonwealth wildlife databases, and analysis of existing vegetation mapping for the Study Area by NPWS.

Field investigations were undertaken over a number of seasons between 2009 and 2011, and are described in detail in *Section 3.2* of *Annex S*. For the purposes of field survey planning, the Study Area was delineated into eight stratification units for both Wonga East and Wonga West in accordance with DEC (2004).

Survey sites were allocated to the stratification units according to the proportionate area that they covered within the Study Area, their ecological significance and their sensitivity to impacts from subsidence due to longwall mining following DECC (2007a) and DoP (2008). For example, upland swamps are considered significant ecological values, and are more susceptible to negative impacts of subsidence than terrestrial woodland ecosystems

(DECC 2008), so proportionately more survey effort per unit area was allocated to swamps.

Survey effort for each stratification unit is outlined in *Table 24.1*. The ecological survey locations are shown in *Figure 24.1, Figure 24.2* and *Figure 24.3*.

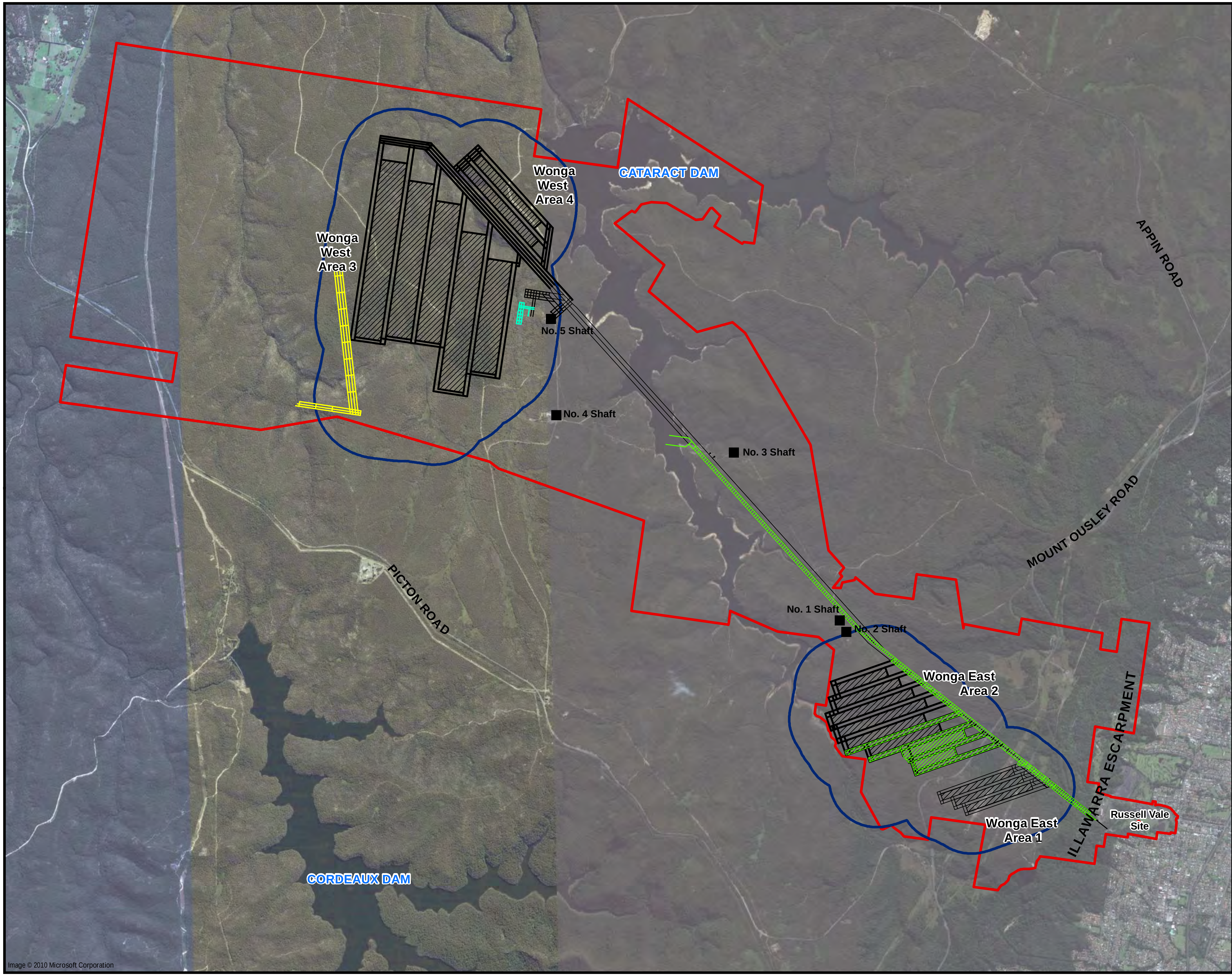
Survey techniques and timing of surveys are described in *Section 3.2* of *Annex S*.

Table 24.1 ERM Survey Effort per Stratification Unit

Stratification unit	**Floristics (no. of quadrats)**	**Threatened flora search (person hours)**	**Bird area (2 ha) searches**	**Bird point counts**	**Anabat surveys (Anabat nights)**	**Hair Funnels (no. funnel nights)**
Exposed sandstone woodland	5		6		4	480
Moist forest	5			1	4	240
Rocky habitats	1			2	4	
Shale sandstone transition forest (EEC)	4		2		4	240
Tall gully forest	5		2	4		240
Upland Swamp	24	19.1	15	4	2	840
Waterways					4	
Disturbed land	2			1	2	
Total	**46**	**19.1**	**25**	**12**	**24**	**2040**

1 Note that survey effort in Upland Swamps does not include effort undertaken by Biosis (2012a).

2 Survey effort does not include the effort of the sub-consultant herpetologists as described in their reports in Annex B of Annex S.



Legend

- Project Application Area
- Approved Workings (MP10_0046)
- Proposed Longwalls
- Proposed Balgownie Seam First Workings
- Proposed Bulli Seam First Workings
- Shaft Locations

Figure 24.1

Ecological Assessment Study Area

Client: Gujarat NRE Coking Coal Limited

Project: NRE No.1 Colliery EAR Post Adequacy 2012 Environmental Assessment

Drawing No: 0079383s_EARPA2012_G003_R0.mxd

Date: 28/11/2012 Drawing size: A3

Drawn by: KB Reviewed by: NB

Scale: Refer to Scale Bar

N 0 500 1,000 1,500m

Maps and figures contained within this document may be based on third party data, may not be to scale and is intended for use as a guide only. ERM does not warrant the accuracy of any such maps or figures.

Environmental Resources Management ANZ

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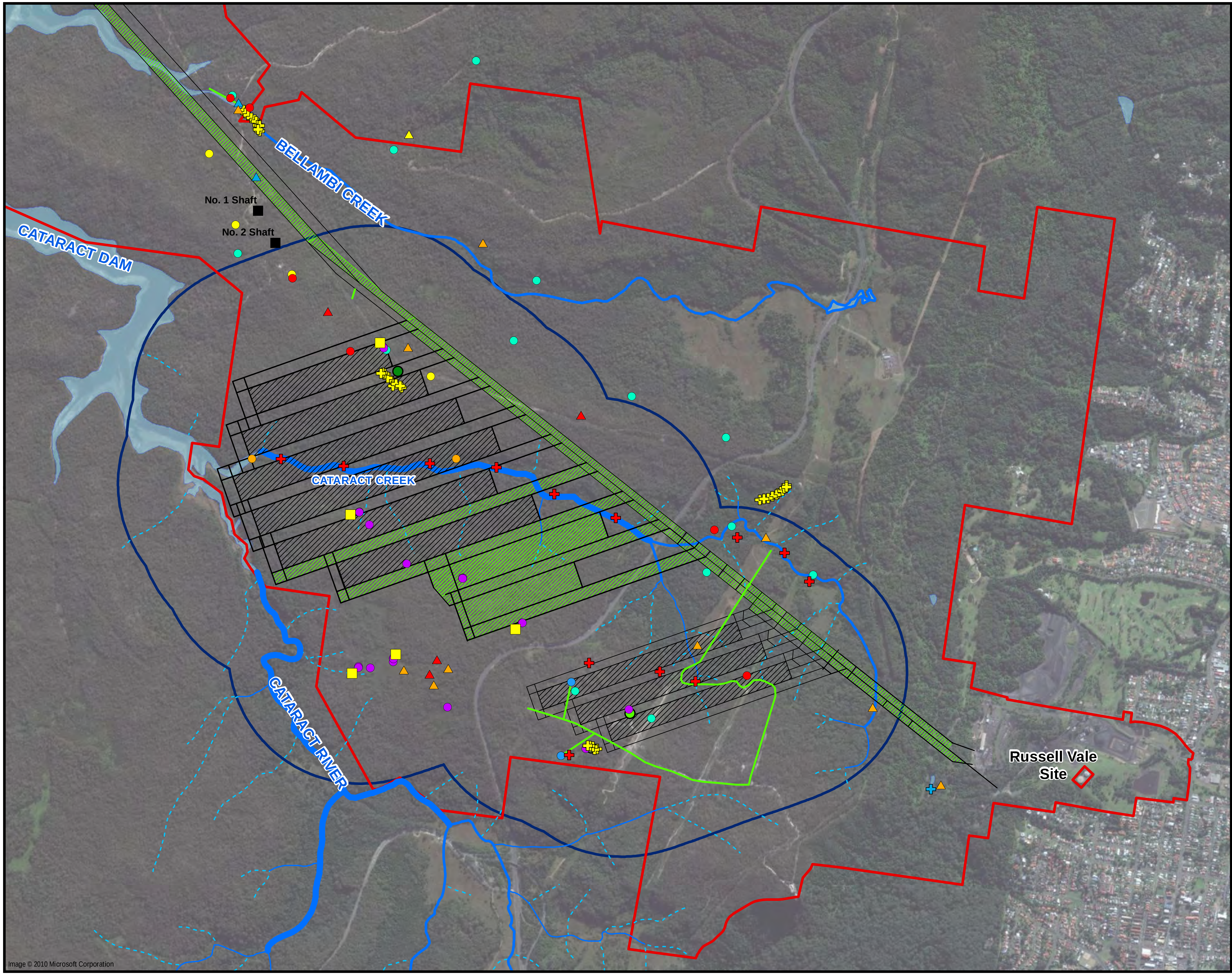
ERM



Legend

- Project Application Area
- Study Area
- Approved Workings (MP10_0046)
- Proposed Longwall
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order and Above Stream
- Shaft Locations

Survey Effort

- Spotlight Routes
- Diurnal Herpetofauna Search
- Habitat Assessment
- Habitat Assessment
- Nocturnal Frog Call-playback
- Diurnal Frog Call-playback
- Frog Habitat Survey 2011
- Frog Habitat Survey 2009
- Hair Funnels
- Anabat Locations
- Bird Area Search
- Bird Point Counts
- Call Broadcasting
- Floristic Quadrat Sites Sept 11
- Floristic Quadrat Sites Oct 09

Threatened Flora Search Oct 09

- Swamp5
- Swamp6
- Swamp7

Figure 24.2

Ecological Survey Locations in Wonga East

Client: Gujarat NRE Coking Coal Limited

Project: NRE No.1 Colliery EAR Post Adequacy 2012 Environmental Assessment

Drawing No: 0079383s_EARPA2012_G012_R0.mxd

Date: 13/11/2012 Drawing size: A3

Drawn by: SQW Reviewed by: MB

Scale: Refer to Scale Bar

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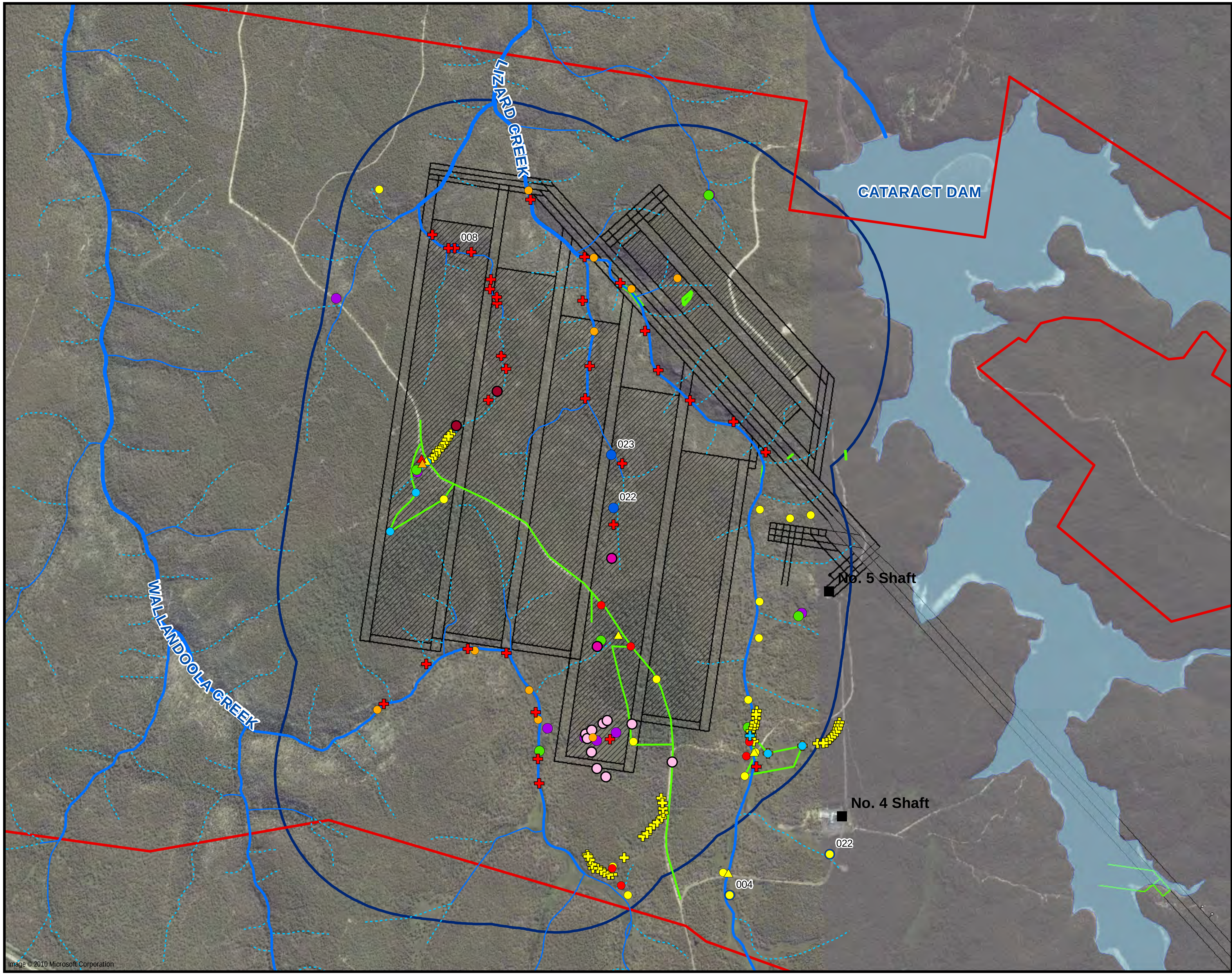

Legend

- Project Application Area
- Study Area
- Proposed Longwall
- Cataract Dam
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order and Above Stream
- Spotlighting Routes
- Anabat Locations
- Bird Area Search
- Bird Point Counts
- Call Broadcasting
- Frog Habitat Survey
- Hair Funnels
- Spotlighting
- Diurnal Frog Call-playback
- Habitat Assessment
- Nocturnal Frog Call-playback
- Nocturnal Upland Swamp Search

Threatened Flora Search Oct 09

- Swamp1
- Swamp2
- Swamp3
- Floristic Quadrant Sites Sept 09
- Floristic Quadrat Sites Sept 11
- Frog Habitat Survey Sept 11

Figure 24.3

Ecological Survey Locations in Wonga West

Client: Gujarat NRE Coking Coal Limited

Project: NRE No.1 Colliery Environmental Assessment

Drawing No: 0079383s_EARPA2012_G013_R0.mxd

Date: 28/11/2012 Drawing size: A3

Drawn by: KB Reviewed by: MK

Scale: Refer to Scale Bar

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As described in *Chapter 22*, Biosis were engaged to undertake detailed mapping, identification of upland swamps of special significance, and assessment of the potential impacts of longwall mining to identify those swamps of special significance considered at risk of negative environmental consequences. Biosis built upon and refined the NPWS (2003) mapping of the Study Area and previous investigations undertaken by ERM. Biosis's assessment is included in full in *Annex Q* of the EA (ERM 2012a).

The methodology was based upon the steps identified in the PAC reports (2009, 2010) and the draft upland swamp environmental impact assessment guidelines (OEH 2012) and is described in detail in *Section 22.2*.

Targeted herpetofauna surveys were undertaken in 2009 by Biosis Research Pty Ltd (Biosis) and Eco Logical Australia Pty Ltd (Eco Logical) as sub-consultancies, with assistance and follow up surveys by ERM. The sub-consultant survey effort is not represented in *Table 20.1*. Those reports, including graphics showing survey locations, are provided in *Annex B* of *Annex S*.

In addition to these surveys Biosis have undertaken monitoring in Wonga East as part of the Biodiversity Management Plan monitoring for Longwall A2 LW4 and the propose A2 LW5. These field inspections have identified breeding habitat for Heath Frog, Giant Burrowing Frog and Stuttering Barred Frog in Wonga East. Biosis have ranked the quality of breeding habitat for these three species. This has been combined with diurnal searches for frogs along the 1st and 2nd order streams associated with upland swamps CRUS1, CRUS2 and CCUS3 (N. Garvey Biosis, pers comm).

24.4 *RESULTS*

24.4.1 *Database Search Results*

The OEH Wildlife Atlas returned records of eight flora species and 46 terrestrial fauna species that have been recorded within 10km of the Study Area. The locations of these records are shown in *Figure 4.1* and *Figure 4.2* of *Annex S*.

The EPBC Act Protected Matters Search Tool determined that four Threatened Ecological Communities, 65 threatened species and 52 Migratory species listed under the EPBC Act have the potential to occur, or rely on habitat that may potentially occur, within 10km of the Study Area. A summary of the OEH output is provided in *Annex C* of *Annex S*. The Protected Matters Search tool output is provided in *Annex C* of *Annex T*.

24.4.2 *Flora Survey Results*

A total of 254 plant species was recorded in the floristic assessments of the Study Area. One introduced species was recorded, although a comprehensive inventory of introduced species in disturbed areas was not collected. A full list of plant species recorded during the floristic assessment is provided in *Annex D* of *Annex S*.

The condition of floristic survey sites was found to be very good, with little evidence of disturbance throughout the majority of quadrats. There was evidence of clearing of vegetation along fire roads and vehicle tracks, historic mine survey lines and around existing mine infrastructure.

The condition of vegetation in the Wonga East area was generally more degraded than Wonga West due to greater disturbance as a result of construction and maintenance of two large transmission lines; small gravel quarries, trespassing by vehicles, motorbikes and other associated disturbances.

Vegetation Mapping

Nineteen vegetation communities are identified as occurring within the Study Area from interrogation of NPWS (2003) vegetation datasets (refer to *Figure* 24.4 and *Figure 24.5*). Field survey did not attempt to validate all vegetation communities throughout the entire Study Area, instead concentrating on those communities of ecological significance and those susceptible to subsidence. The original vegetation mapping (NPWS 2003) was determined to be accurate within the Study Area at all locations surveyed during the initial surveys.

Upland swamp surveys conducted by Biosis (2012a) provided detailed field verified mapping of the upland swamps that supersedes the mapping of the Upland Swamp communities by NPWS (2003). Biosis provides commentary on differences between the field verified mapping and that of NPWS (2003) in their report tabled as *Annex Q* for the Project.

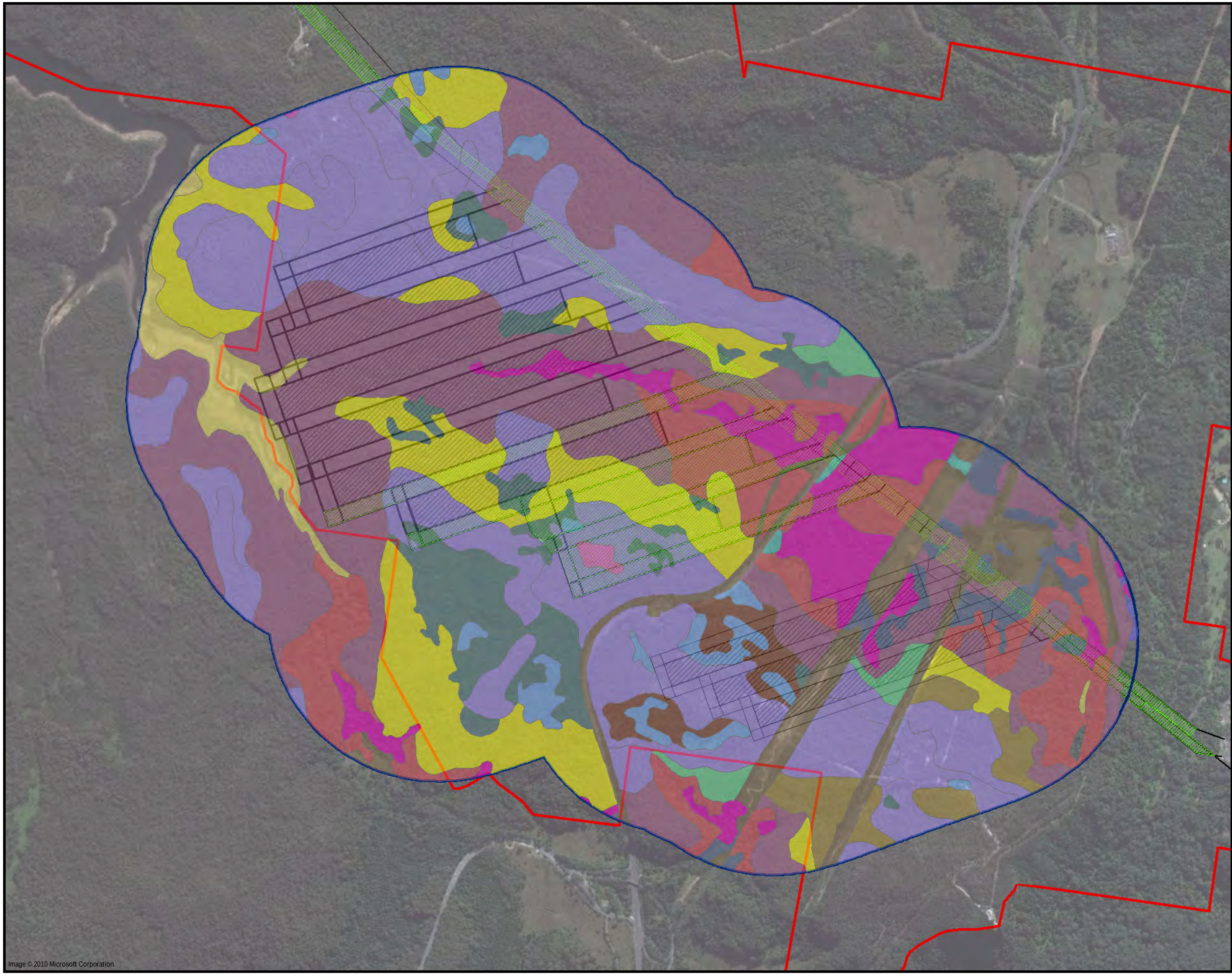
Fourteen vegetation communities were recorded during field investigations of the Study Area including Transitional Shale Open Blue Gum Forest, Transitional Shale Stringybark Forest, Exposed Sandstone Scribbly Gum Woodland, Sandstone Gully Peppermint Forest, Upland Swamp: Fringing Eucalypt Woodland, Upland Swamp: Sedgeland Heath Complex, Upland Swamp: Tea Tree Thicket, Upland Swamp: Banksia Thicket, Tall Open Blackbutt Forest, Moist Blue Gum Blackbutt Forest, Coachwood Warm Temperate Rainforest, Rock-Plate Heath-Mallee, Regenerating Vegetation and Cleared.

Stands of regenerating vegetation were observed and described in Wonga East near the cleared transmission line easements and vehicle tracks (see *Figure 24.4*). This regenerating vegetation was comprised of Blackbutt (*Eucalyptus pilularis*) and Turpentine (*Syncarpia glomulifera* subsp. *glomulifera*), often with *Acacia irrorata* and *Lomandra* sp dominating the understorey. This regenerating vegetation could not be identified to community level due to the disturbed and disparate nature of its composition. There were areas of cleared land around mine shafts, transmission lines, roads, vehicle tracks and other infrastructure. Cleared land was only encountered in small parts of the Study Area (see *Figure 24.4*).

Detailed descriptions of the other 12 communities are provided in *Section 4.3.3* of *Annex S*.

Rare and Threatened Flora

Two rare plant species listed on the RoTAP register, *Darwinia grandiflora* (listed as 2RCi) and *Monotoca ledifolia* (listed as 3RC-) were recorded during the field survey in the Wonga West and East domains. The distribution of the recorded specimens is shown in *Figure 24.6* and *24.7.* In addition, the RoTAP species Shining Guinea Flower (*Hibbertia nitida*) is also known to occur in the Study Area (Kevin Mills and Associates 2005).



Legend

- Project Application Area
- Study Area
- Proposed Longwalls
- Approved Workings (MP10_0046)
- Cleared
- Coachwood Warm Temperate Rainforest
- Escarpment Blackbutt Forest
- Escarpment Edge Silvertop Ash Forest
- Exposed Sandstone Scribbly Gum Woodland
- Moist Blue Gum-Blackbutt Forest
- Moist Coastal White Box Forest
- Regenerating Vegetation
- Rock Plate Heath-Mallee
- Sandstone Gully Peppermint Forest
- Tall Open Blackbutt Forest
- Tall Open Peppermint-Blue Gum Forest
- Transitional Shale Open Blue Gum Forest
- Transitional Shale Stringybark Forest
- Upland Swamps: Banksia Thicket
- Upland Swamps: Fringing Eucalypt Woodland
- Upland Swamps: Sedgeland-Heath Complex
- Water
- Weeds and Exotics
- Western Sandstone Gully Forest

Figure 24.4
Vegetation Mapping Of Wonga East Study Area (NPWS 2003)

Client: Gujarat NRE Coking Coal Limited
Project: NRE No.1 Colliery Environmental Assessment
Drawing No: 0079383s_EARPA2012_G004_R0.mxd
Date: 12/09/2012 Drawing size: A3
Drawn by: SQW Reviewed by: MB
Scale: Refer to Scale Bar

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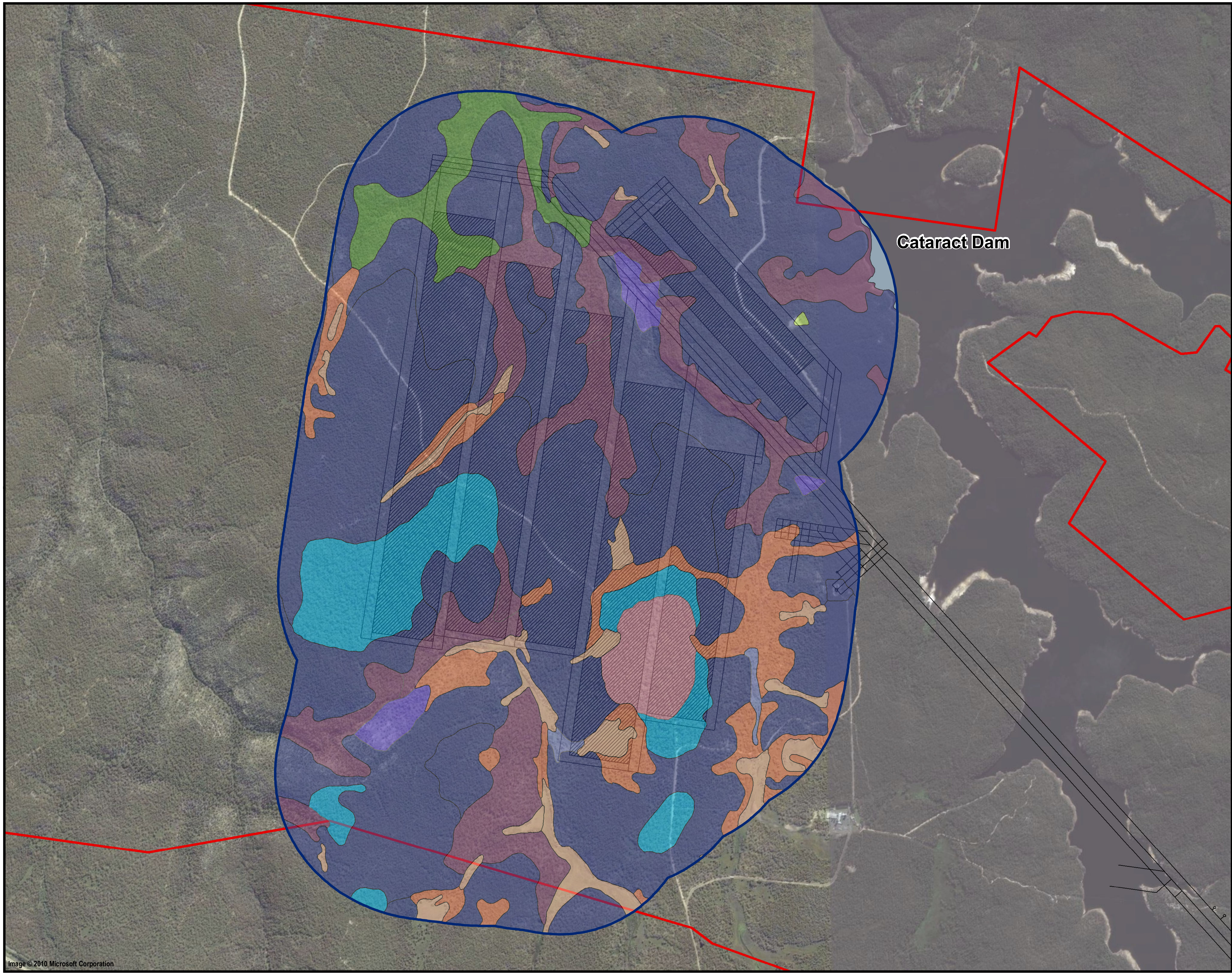

Legend

- Project Application Area
- Study Area

Vegetation Communities

- Cleared
- Exposed Sandstone Scribbly Gum Woodland
- Rock Plate Heath-Mallee
- Sandstone Gully Peppermint Forest
- Transitional Shale Open Blue Gum Forest
- Transitional Shale Stringybark Forest
- Upland Swamps: Banksia Thicket
- Upland Swamps: Fringing Eucalypt Woodland
- Upland Swamps: Sedgeland-Heath Complex
- Water
- Western Sandstone Gully Forest

Figure 24.5

Vegetation Mapping Of Wonga West Study Area (NPWS 2003)

Client: Gujarat NRE Coking Coal Limited

Project: NRE No.1 Colliery Environmental Assessment

Drawing No: 0079383s_EA_GIS044_R0.mxd

Date: 20/12/2010 Drawing size: A3

Drawn by: NS Reviewed by: MB

Scale: Refer to Scale Bar

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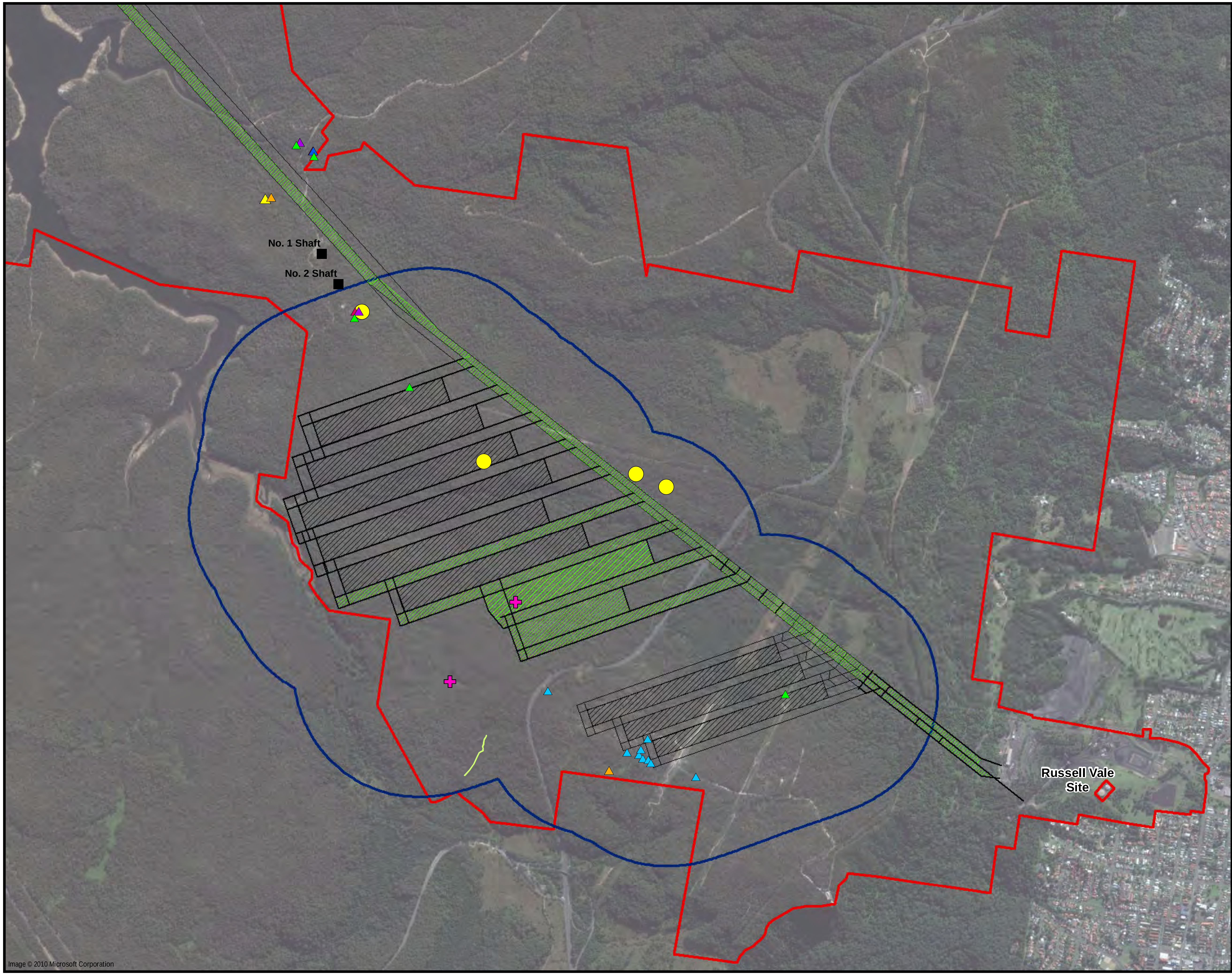

Legend

- Project Application Area
- Study Area
- Approved Workings (MP10_0046)
- Proposed Longwalls
- Shaft Locations
- *Pultenaea aristata* (Biosis 2012)
- *Pultenaea aristata* (ERM 2011)
- Beautiful Firetail
- *Darwinia grandiflora*
- East Coast Freetail Bat
- Eastern Bentwing Bat
- Eastern Falsistrelle
- Glossy Black-cockatoo
- Southern Emu-wren
- Giant Burrowing Frog Tadpoles (Biosis 2012)

Figure 24.6

Threatened And Rare Species Recorded In the Wonga East Study Area

Client: Gujarat NRE Coking Coal Limited

Project: NRE No.1 Colliery EAR Post Adequacy 2012 Envionmental Assessment

Drawing No: 0079383s_EARPA2012_G051_R0.mxd

Date: 29/11/2012 Drawing size: A3

Drawn by: KB Reviewed by: MB

Scale: Refer to Scale Bar

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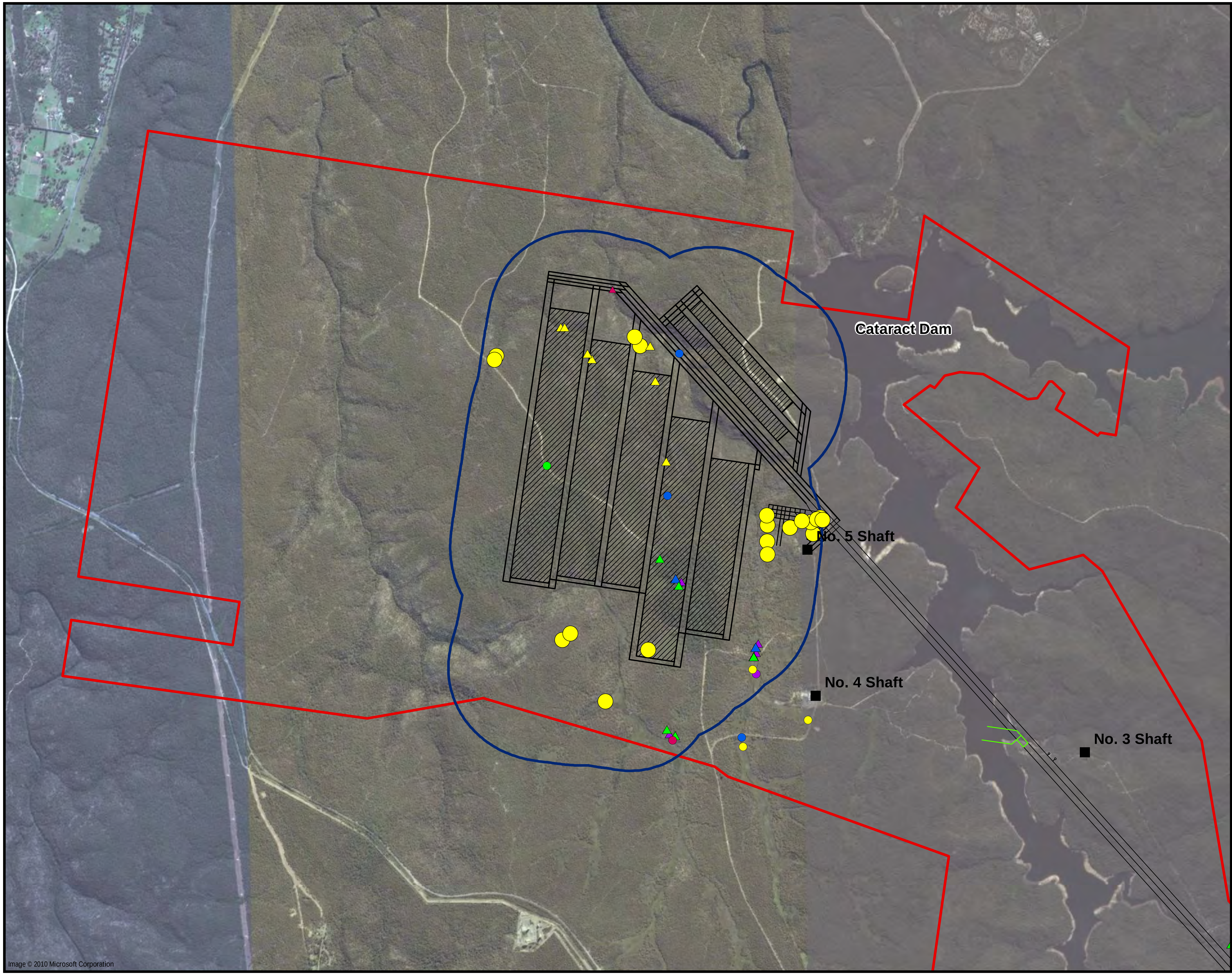

Figure 24.7

Threatened And Rare Species Recorded In the Wonga West Study Area

Client: Gujarat NRE Coking Coal Limited

Project: NRE No.1 Colliery EAR Post Adequacy 2012 Environmental Assessment

Drawing No: 0079383s_EARPA2012_G050_R0.mxd

Date: 07/12/2010 Drawing size: A3

Drawn by: NS Reviewed by: MB

Scale: Refer to Scale Bar

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Two threatened species listed on the TSC Act are also known to occur within the Study Area: Prickly Bush-pea (*Pultenaea aristata*); and Hairy Geebung (*Persoonia hirsuta* subsp *hirsuta*) (Kevin Mills and Associates, 2005). In addition, it is recognised that potential habitat is available for the following seven flora species:

- *Acacia baueri* subsp. *aspera;*
- Bargo Geebung *(Persoonia bargoensis);*
- *Epacris purpurascens* var. *purpurascens;*
- Deane's Melaleuca (*Melaleuca deanei*);
- Needle Geebung *(Persoonia acerosa);*
- Small-flower Grevillea *(Grevillea parviflora* subsp. *parviflora);* and
- Woronora Beard-heath (*Leucopogon exolasius*).

Endangered Ecological Communities (EECs)

Shale Sandstone Transition Forest, as listed under Part 3 of Schedule 1 of the TSC Act, and under the Commonwealth EPBC Act, is represented by two recorded vegetation communities in the Study Area:

- Transitional Shale Stringybark Forest; and
- Transitional Shale Tall Open Blue Gum Forest.

Shale-Sandstone Transition Forest occurs at the edges of the Cumberland Plain where shale rock and clay soils gradually change to sandstone. Within the Study Area this EEC was represented by a healthy and intact canopy in discreet elevated patches of shale based soils in the Wonga West area (see *Figure 24.4*). The community is in good condition.

Coastal Upland Swamp in the Sydney Basin Bioregion EEC

Coastal Upland Swamp in the Sydney Basin bioregion has recently been given gazetted as an EEC under Part 3, Schedule 1 of the TSC Act. Coastal Upland Swamp EEC occurs in the Sydney Basin bioregion and is associated with periodically waterlogged soils on Hawkesbury sandstone plateau (DEC 2011). Floristically this EEC is described as Upland Swamps: Banksia Thicket; Upland Swamps: Tea Tree Thicket; and Upland Swamps: Sedgeland-Heath Complex. Upland swamps supporting these communities are mapped throughout the Study Area (see *Figure 22.1* and *Figure 22.2*). Detailed consideration of these areas of ecologically sensitivity is provided in *Chapter 22* and *Annex Q*.

24.4.3 *Fauna Survey Results*

Frogs

A total of 13 frog species was recorded within the Study Area by ERM, Biosis (2009) and Eco Logical (2009). The location of threatened species records is shown in *Figure 24.6* and

Figure 24.7. A full list of frog species recorded within the Study Area is provided in *Table 4.2* in *Annex S*.

Two of these species, Red-crowned Toadlet (*Pseudophryne australis*) and Giant Burrowing Frog (*Heleioporus australiacus*), are listed as vulnerable under the TSC Act, and the latter species is also listed as vulnerable under the EPBC Act.

Habitat searches identified suitable habitat for the Stuttering Barred Frog (*Mixophyes balbus*), which is listed as endangered under the TSC Act and vulnerable under the EPBC Act. Favourable habit exists in Cataract Creek in the Wonga East area, although no individuals were observed (Eco Logical 2009).

Suitable habitat for Heath Frog (*Litoria littlejohni*) was recorded within the Wonga West area during field surveys by both Eco Logical (2009) and Biosis (2009) and in some of the 1st and 2nd order streams associated with upland swamps CRUS1, CRUS2 and CCUS4 in Wonga East (N. Garvey Biosis pers comm). The condition of the habitat varied from good to poor condition in Wonga West. The greatest extent of suitable habitat for this species was recorded within the upper reaches of Lizard Creek, the Lizard Creek swamp complex, and within the pooled sections of Wallandoola Creek (Biosis 2009, Eco Logical 2009).

In the 2009 surveys, the Giant Burrowing Frog was recorded within LCT1 and LCT2. Recent assessments undertaken by Biosis for the A2 LW4 and A2 LW5 SMP has identified breeding habitat for the Giant Burrowing Frog in the 1st order streams associated with upland swamps CRUS1, CRUS2 and CCUS4. Tadpoles of Giant Burrowing Frog were located in the 1st order stream to the south of CRUS2 in August 2012 (N. Garvey Biosis pers comm).

Reptiles

A total of 13 reptile species was recorded by ERM, Biosis (2009) and Eco Logical (2009) within the Study Area. None of the species recorded are listed on either the TSC Act or the EPBC Act. A list of reptile species recorded in the Study Area is provided in *Table 4.3* in *Annex S*.

Habitat searches identified presence of the indicator species Leseur's Velvet Gecko (Biosis 2009, Eco Logical 2009) and potential wintering habitat for Broad-headed Snake along a number of sandstone benches and outcrops adjacent to Lizard Creek with some smaller isolated outcrops in the Wonga East area (see *Annex S*). However, in many instances the areas of exfoliating sandstone shelters contained sand, soil and leaf debris due to previous fire and erosion events, and were considered sub-optimal for the species. In addition, these areas of suitable habitat generally did not have a north-west aspect as preferred by the species. Accordingly, the Study Area is not expected to provide habitat for a significant proportion of a population of this species, as extensive outcropping of rock benches, which would provide critical wintering habitat, was not recorded in the Study Area (Eco Logical 2009).

Suitable habitat for Rosenberg's Goanna (*Varanus rosenbergi*) was recorded within the Study Area, although no individuals were observed (Biosis 2009, Eco Logical 2009).

Ground termitaria were recorded at discrete locations (See *Figure 24.6* and *Figure 24.7*). It is not expected that the Study Area contains extensive tracts of habitat that would support a significant population of this species (Eco Logical 2009).

Birds

A total of 87 native bird species was recorded within the Study Area. No introduced species were recorded. The majority of these species are widespread and/or abundant species that commonly occur in woodland, heathland, regrowth vegetation and various other habitats. Two species listed as vulnerable under the TSC Act were recorded; Glossy Black Cockatoo (*Calyptorhynchus lathami*), and Powerful Owl (*Ninox strenua)* and a third vulnerable species, Brown Treecreeper (*Climacteris picumnus victoriae*) is known to occur (ERM 2009).

Two migratory species listed on the EPBC Act were recorded, Black-faced Monarch (*Monarcha melanopsis*) and Rufous Fantail (*Rhipidura rufifrons*). Two species identified as susceptible to subsidence by DECC (2007a) were also recorded: Beautiful Firetail (*Stagonopleura bella*) and Southern Emu Wren (*Stipiturus malachurus*).

The location of threatened, migratory and rare bird records within the Study Area is shown in *Figure 24.6* and *Figure 24.7*. A full list of bird species recorded in the Study Area is provided in *Annex C* of *Annex S.*

Suitable habitat for Eastern Ground Parrot (P*ezoporus wallicus wallicus*) was recorded in upland swamps within upper Lizard Creek and upper Wallandoola Creek. Marginal habitat for the Eastern Bristlebird (*Dasyornis brachypterus*) was recorded within some areas of dense upland swamp and surrounding fringing eucalypt woodland. There is only a remote possibility that the Eastern Bristlebird still exists in Southern Sydney (DECC 2007c). Habitat in the Study Area is not as dense as areas of known habitat in Jervis Bay and Holsworthy (Mark Branson ERM pers comm) and accordingly this species is assessed as a low likelihood of occurrence in Study Area. Call broadcasting, spotlighting and searches of suitable habitat failed to detect any evidence of either species.

Mammals

A total of 28 mammal species was recorded within the Study Area, including 11 non-volant species, 16 microbats and one flying-fox. Five microbat species recorded in the Study Area are listed on the TSC Act; Eastern Falsistrelle (*Falsistrellus tasmaniensis*), Eastern Bentwing-bat (*Miniopterus schreibersii oceanensis*), Eastern Freetail-bat (*Mormopterus norfolkensis*), Freetail Bat (*Mormopterus sp.2*) and Greater Broad-nosed Bat (*Scoteanax rueppellii*). Locations of threatened species records are shown in *Figure 24.6* and *Figure* 24.7. A full list of mammal species recorded in the Study Area is provided in *Table 4.5* in *Annex S.*

The Eastern Pygmy-possum (*Cercartetus nanus*) is also known to occur in upland swamp and heath environments in Wallandoola Creek uplands (ERM 2009). Suitable habitat for Spotted-tailed Quoll (*Dasyurus maculatus*) occurs quite extensively in the Wonga West area, although field surveys failed to detect any evidence of this species in the Study

Area. Spotted-tailed Quoll has been recently sighted in the area to the north of Cataract Creek (DECC 2007c).

Searches of rocky outcrops and overhangs, disused mine infrastructure, road culverts and power supply housings did not detect any bat roosts. Scats collected from a low cave in Wonga East are likely to be from a micro bat (N. Garvey Biosis, pers comm). No permanent flying fox camps were detected within the Study Area during the entire survey period. Only one individual flying-fox, a Little Red Flying-fox (*Pteropus scapulatus*), was recorded within Study Area. However, timing of the surveys was not optimal for detecting a high abundance of nectar and fruit eating bats. It is considered likely that Grey-headed Flying-fox (listed as vulnerable under the TSC Act and EPBC Act) would utilise the Study Area for foraging during flowering periods.

24.4.4 *Habitat Condition*

Following is a summary of habitat condition within the Study Area. Detailed descriptions of habitats are provided in *Section 4.5* of *Annex S*.

Creeks

A number of 3rd order and above creeks have the potential to be impacted by the proposed action in the Study Area, and their condition is discussed in *Chapter 20*.

The Study Area contains ephemeral 1st order streams, intermittent 2nd order streams and perennial 3rd and 4th order streams and channel pools, and extensive upland swamps that are expected to provide habitat for a diverse array of species, particularly in dry periods. Watercourses in the Study Area include Cataract Creek, Lizard Creek, Wallandoola Creek and the Cataract River.

Wallandoola Creek and Lizard Creek are deeply-incised streams cut into Hawkesbury Sandstone. The surrounding vegetation of Wallandoola and Lizard Creeks within the Wonga West Study Area was generally open dry sclerophyll woodland and heath. Within the Study Area both creeks are unshaded to moderately shaded and the substratum dominated by bedrock and boulders with sand and fine sediment accumulated in some of the deeper pools and channel sections. Aquatic macrophytes including *Vallisineria gigantea* and *Eleocharis* sp. are present (Cardno Ecology Lab 2012).

There is a variety of different habitat features within these creeks including relatively deep, permanent pools and sections of shallow flow over bedrock bars. Soft sediment banks with overhanging vegetation and instream features such as submerged woody debris is also present (Cardno Ecology Lab 2012).

Wallandoola Creek varies from good to moderate condition across the Study Area and within the upper reaches contains a number of shallow perennial ponds that are suitable breeding habitat for Heath Frog, particularly around the valley infill swamp WCUS4.

Suitable habitat for Giant Burrowing Frog was observed on many of the rock benches within Wallandoola Creek adjacent to this area. Downstream of the swamp near WC4 stream flow is reduced and creek condition becomes degraded with water disappearing from the surface for a distance over 100m (GeoTerra 2012a). Iron-oxidising bacteria flocculation was observed in many small pools and habitat condition for aquatic and amphibian species is degraded below WC4.

Lizard Creek varies from good to poor condition and is the longest drainage occurring within the Study Area. In the upper reaches the surrounding swamp was undisturbed and contains habitat for Southern Emu-wren (*Stipiturus malachurus*) and Red-crowned Toadlet. Giant Burrowing Frog tadpoles were recorded within LCT1 and LCT2 (*see Photograph 24.2*).

There were extensive stretches of Lizard Creek which were observed to be dry and degraded, presumably due to historic mining (GeoTerra, 2012a). This was particularly evident east of Longwall A3 LW1, in areas of previous mining activity (GeoTerra 2012a). Habitat condition for aquatic and amphibian species in these reaches was poor.

The proposed Wonga East longwalls are located within the Cataract River catchment, to the north east of the Cataract River arm of the reservoir. Cataract Creek is a 4th order stream bordered by temperate rainforest riparian vegetation that joins Cataract River in the waters of the reservoir. The canopy along Cataract Creek is a closed temperate rainforest and the creek is shaded. The channel morphology of the creek is characterised by an alternating series of long pools and shorter bars and riffles. Cataract Creek is predominantly shallow with occasional deep holes. Bars and riffles are composed of various combinations of bedrock, boulders, cobble, pebble and gravel. Large woody debris was relatively common, forming dams and submerged snags in pools. There is natural variation in water levels both within and between seasons (Cardno Ecology Lab 2012).

Cataract Creek has been identified as providing potential breeding habitat for the Stuttering Barred Frog (*Mixophyes balbus*) (see *Photograph 24.1*). However, condition of the creek downstream (west of longwall A2 LW9) is poor showing signs of bank erosion, forest degradation and weed incursion due to the influence of fluctuating waters in Cataract Dam.

A number of 1st order streams in Wonga East were assessed as providing suitable breeding habitat for Heath Frog (*Litoria littlejohni*) and/or the Giant Burrowing Frog (*Heleioporus australiacus*). Giant Burrowing Frog tadpoles were recorded in the 1st order stream associated with the upland swamp CRUS2 in Wonga East.

Upland Swamps

All swamps, with the exception of the north-western most swamp within the Study Area, occur within the Wallandoola Significant Swamp Cluster, identified by DECC (2007a) as providing large contiguous areas of habitat for swamp-dependant species within the Southern Coalfields.

Photograph 24.1 Stuttering Barred Frog habitat in Cataract Creek (Eco Logical 2009)

Photograph 24.2 Giant Burrowing Frog habitat in good condition in LCT1

Generally swamp condition was observed to be good, with the exception of some headwater swamps which showed signs of scouring and erosion, such as LCUS25. Further detail on swamp habitat condition, including for threatened and rare species is provided in *Chapter 22*.

Upland swamps are habitats of high conservation value supporting high diversity of flora species and providing habitat, in particular drought refuge for invertebrate and vertebrate fauna. On the Woronora Plateau, upland swamps are the highest priority habitat for conservation of vertebrate fauna (DECC 2007c). Upland swamps provide potential habitat for fauna species including the Ground Parrot, Giant Burrowing Frog, Heath Frog and Long-nosed Potoroo (*Potorous tridactylus*) (DECC 2007c).

Rocky Habitat

The Study Area occurs on a predominantly sandstone geology and therefore contains numerous sandstone outcrops, escarpments, benches and overhangs. The majority of sandstone outcropping occurs along creeks and other drainages, particularly along Lizard Creek and Wallandoola Creek and their tributaries.

The Study Area does not contain extensive north western and western facing sandstone benches that could be considered critical wintering habitat for the Broad-headed Snake or Rosenberg's Goanna (Eco Logical 2009). However, there are sandstone benches and overhangs, some with good quality exfoliating slabs that provide areas of habitat for Broad-headed Snake, and the species is expected to inhabit these areas. Similarly, Rosenberg's Goanna is expected to occur in moderate densities due to the suitability of the sclerophyll woodland and nearby historic records.

Bat Habitat

Two threatened cave-roosting bats were recorded in the Study Area using Anabat units; Eastern Bentwing-bat and the Large-footed Myotis (*Myotis macropus*). Field surveys in 2009 and 2010 did not record any caves or overhangs, which were considered suitable for cave-roosting bats though a cave with a scat likely to be from a micro bat has been recently identified in Wonga East (N. Garvey, Biosis pers comm). The Study Area is not considered to contain suitable geology that would support maternity roosts for the Eastern Bentwing-bat (See *Annex S*).

It is likely that rock fissures, cracks and sandstone overhangs within or adjacent to the Study Area provide daytime roosts for small numbers of Eastern Bentwing-bat, Large-footed Myotis and potentially Large-eared Pied Bat (*Chalinolobus dwyeri*), although this species was not recorded. Each of these species is also known to use other roost types including disused mine shafts and tree hollows (Strahan *et. al*. 1995).

It is likely that the Large-footed Myotis roosts and breeds within tree hollows along Lizard Creek and potentially along Wallandoola Creek, although the locations of these roosts cannot be determined without further detailed investigation.

Koala Habitat Assessment

The ecology assessment has assessed whether the Study Area contains potential or core Koala habitat in accordance with SEPP 44. *Eucalyptus haemastoma* was the only tree species listed on Schedule 2 of SEPP 44 that was recorded in the Study Area. *E. haemastoma* is a dominant canopy tree in two vegetation communities in the Study Area: Exposed Sandstone Scribbly Gum Woodland; and Upland Swamp – Fringing Eucalypt Woodland.

The Study Area is considered to represent Potential Koala Habitat under SEPP 44 of the EP&A Act, given the representation of *E. haemastoma* as a dominant tree species (over 15% of canopy cover) in the two vegetation communities. The Study Area is not considered

Core Koala Habitat, as there is no evidence to indicate the presence of a resident population of Koalas or recent sightings or historical records of a resident population (See *Annex S*).

24.5 *EVALUATION OF IMPACTS*

Detailed discussion of potential impacts of the Project is provided in *Chapter 5* of *Annex S*.

The proposal does not require clearance of native vegetation communities within the Study Area. The most direct environmental impact of longwall mining is subsidence, which causes changes in the level of the ground surface overlying and adjacent to the area of extraction. The following paragraphs outline the likely impacts on flora and fauna as a consequence of tilt, strain, subsidence, clearing, cracking and alterations to surface and groundwater flows from longwall mining. As the first workings extraction methods in the Study Area are not expected to result in any subsidence greater than 20mm, and there will be no measurable surface deformations (Seedsman, 2012), the only aspect of the proposed action predicted to cause subsidence is longwall mining.

The SCI Report (DoP, 2008) outlines subsidence impacts primarily as tensile and shear cracking of the rock mass and localised buckling of strata caused by valley closure and upsidence, and subsidence depressions or troughs. As a depression/trough is formed, the ground surface is subjected to tilts and strains depending on the geology, depth of cover, panel dimensions and position above the panel (DoP, 2008).

Geographical features susceptible to the impacts of subsidence include aquatic ecosystems (streams and creeks), swamps (including upland swamps), and rocky environments (including caves and overhangs) (DECC 2007, DoP 2008). It is generally recognised that the impacts of subsidence due to longwall mining on terrestrial ecosystems (including Shale Sandstone Transition Forest) are likely to be less significant than those experienced by aquatic-dependant ecosystems (DECC 2008), although rocky habitats are particularly vulnerable (DECC 2007a). Threatened species and ecological communities that rely on some or all of these geographic features in the Southern Coalfields are considered highly susceptible to the impacts of subsidence due to longwall mining (DECC 2007a).

Potential, direct and indirect impacts from subsidence are outlined in *Annex S*.

24.5.1 *Subsidence Impacts*

Seedsman Geotechnics (2012) has predicted subsidence impacts from multiple seam assessment of the Study Area and provided visualisation of subsidence predictions. Seedsman provided subsidence value data for extraction undertaken in the EA (ERM 2012b) and specialist reports including GeoTerra (2012a and 2012b), Biosis (2012) and SCT (2012b).

It is acknowledged that there are a number of constraints and assumptions that are fundamental to the subsidence predictions (Seedsman, 2012), and therefore ERM acknowledges that any impact assessments are also subject to a level of uncertainty based on these assumptions.

24.5.2 *Subsidence Effects*

This section describes the effects of subsidence that are likely to be experienced within flora and fauna habitat in the Study Area in particular those ecological features of special significance as shown in *Figure 24.8* and *Figure 24.9*.

Predicted Alterations to Surface Water

Surface water features within 600m of the proposed secondary workings consist of:

- 1st to 3rd order streams of Wallandoola Creek which drain into the Cataract River, downstream of the Cataract Dam wall at Wonga West;
- 1st to 4th order streams of Lizard Creek which drain into the Cataract River, downstream of the Cataract Dam wall at Wonga West;
- 1st to 4th order streams of Cataract Creek and Cataract River which flow into Cataract reservoir;
- 1st and 2nd order tributaries of Cataract River and Bellambi Creek (upstream of the reservoir) which will not be undermined by the Wonga East workings; and
- Cataract Reservoir, which will not be undermined by the Wonga East workings, although the western end of Longwall WE-A2-LW10 extends into the reservoir high water mark in Cataract Creek.

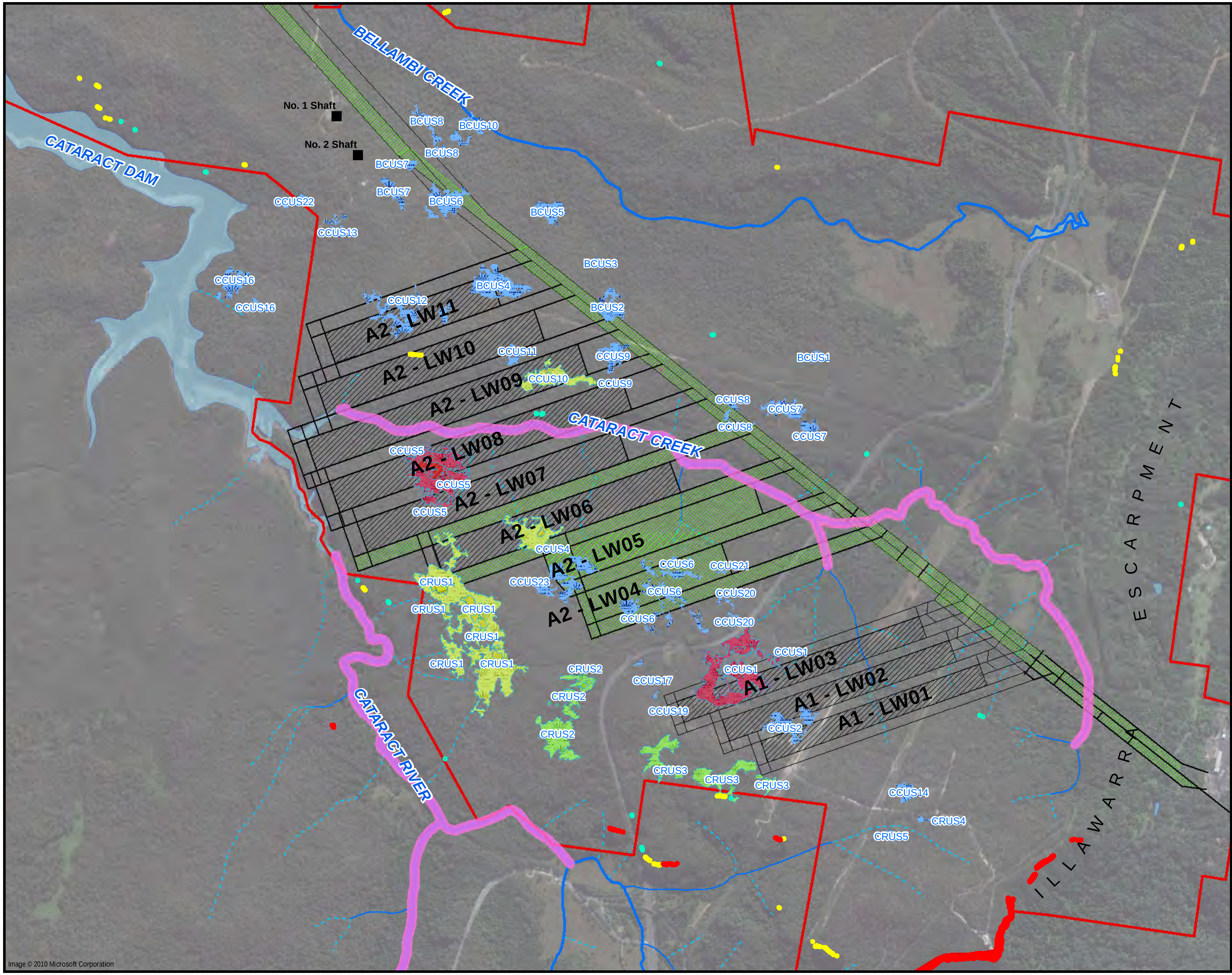
No extraction is proposed under the 3rd order or higher main channel of Lizard and Wallandoola Creeks, with the panel layout designed to avoid or minimise subsidence impacts on the bed of the creeks and Cataract reservoir.

A potential risk to the integrity of stream flow and connectivity in Wallandoola Creek could be present in the area that may potentially undergo up to 0.5m of subsidence and 6mm/m of tensile strain to the south of Longwalls A3 LW3 and A3 LW4.

There is a low potential risk to the integrity of stream flow and connectivity in Lizard Creek in the area that may potentially undergo 6 to 7mm/m of tensile strain to the north of Longwall A3 LW2 and south of the northern end of Longwall A4 LW5.

The 1st, 2nd and 3rd order tributaries, in particular LCT1 (over Longwall A3 LW3) and LCT2 (near the northern end of Longwall A3 LW5) which overly the proposed 20mm subsidence zone are at risk of subsidence related stream bed cracking, enhancement of stream bed underflow, discharge of ferruginous springs and reduced stream water quality at their confluence with Lizard Creek. It is not anticipated however, that the total volume of water entering Lizard Creek will be adversely affected. It is noted, that all of these aspects of LCT1 are currently adversely affected by existing Bulli workings subsidence (GeoTerra 2012a).

No extraction is proposed under the 3rd order or higher channels of Cataract River (upstream of the reservoir) or Bellambi Creek at Wonga East. Negligible stream flow effects, impacts or consequences are anticipated to occur in Cataract River or Bellambi



Legend
- Project Application Area
- Study Area
- Proposed Longwalls
- Cataract Dam
- Upland Swamps (Biosis 2012)
- Cliffs over 10m
- Cliffs 0 to 5m
- Cliffs 5 to 10m

Swamps of Special Significance (Biosis 2012)
- Negligible Risk
- Low Risk
- Moderate Risk
- Significant Risk
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order and Above Stream
- Streams of Special Significance
- Shaft Locations

Figure 24.8
Wonga East Ecologically Significant Areas

Client: Gujarat NRE Coking Coal Limited
Project: NRE No.1 Colliery EAR Post Adequacy 2012 Enviromental Assessment
Drawing No: 0079383s_EARPA2012_G054_R0.mxd
Date: 30/11/2012 Drawing size: A3
Drawn by: KB Reviewed by: NB
Scale: Refer to Scale Bar
N 0 150 300 450m

Maps and figures contained within this document may be based on third party data, may not be to scale and is intended for use as a guide only. ERM does not warrant the accuracy of any such maps or figures.

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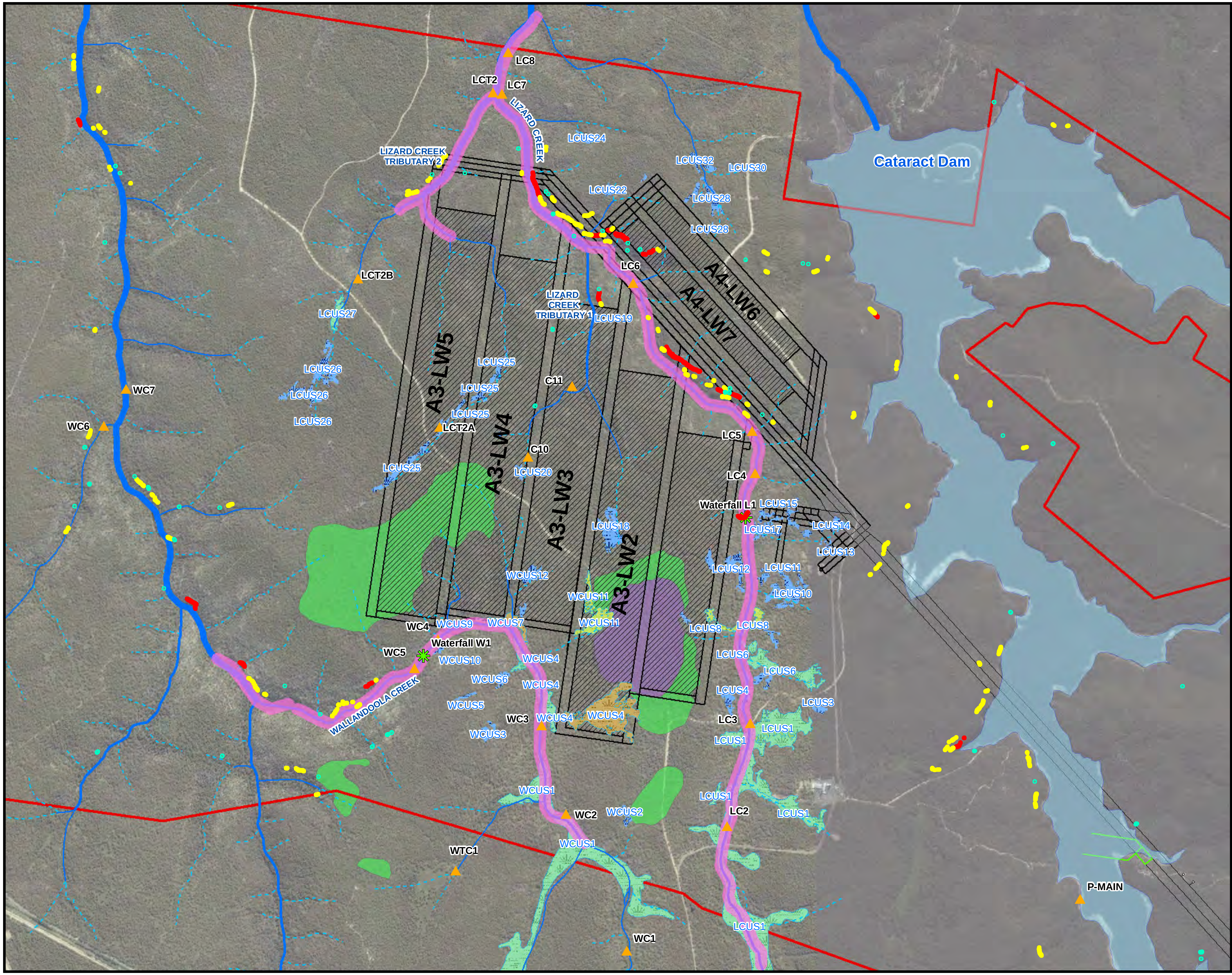

Legend

- Project Application Area
- Study Area
- Proposed Longwall
- Cataract Dam
- Upland Swamps (Biosis 2012)
- Transitional Shale Open Blue Gum Forest EEC
- Transitional Shale Stringybark Forest EEC

Swamps of Special Significance (Biosis 2012)

- Negligible Risk
- Low Impact Risk
- Moderate Impact Risk
- Cliffs 0 to 5m
- Cliffs 5 to 10m
- Cliffs over 10m
- Streams of special significance
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order and Above Stream
- Shaft Locations
- Stream Monitoring Sites (GeoTerra 2010a)

Figure 24.9

Wonga West Ecologically Significant Areas

Client: Gujarat NRE Coking Coal Limited

Project: NRE No.1 Colliery EAR Post Adequacy 2012 Environmental Assessment

Drawing No:

Date: 7/02/2013 Drawing Size: A3

Drawn By: KB Reviewed By: NB

Projection: GDA 1994 MGA Zone 56

Scale: Refer to scale bar

N 0 250 500 750m

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Creek, upstream of Cataract Reservoir, due to the low to absent levels of predicted strains and subsidence (GeoTerra 2012a).

Cataract Creek is proposed to be undermined by longwalls in Wonga East (Area 2), with a predicted maximum subsidence of 0.8m, along with up to 10mm/m compressive and 5mm/m tensile strains over A2 LW8 (GeoTerra 2012a). Potential subsidence impacts include potential cracking of the 4th order stream bed due to subsidence near or over A2 LW7, A2 LW8, A2 LW9 and A2 LW10. Environmental consequences are potential impact on stream flow, with downstream flow re-emergence; potential effect on pool holding capacity of rock bars and potential iron hydroxide seepage. It is noted, that iron hydroxide seepage is currently occurring (GeoTerra 2012a).

Predicted Alterations to Groundwater

The interaction between groundwater and upland swamps is discussed in *Chapter 21* and *Chapter 22*.

Predicted Alterations to Rocky Habitat

The main features of rocky habitats that are of value to flora and fauna include caves, rock shelters (including crevices and exfoliating rock), and cliff faces for orchids, falcons and other rock dwelling species. Rocky habitats are known to be susceptible to the impacts of subsidence, strain and tilt. When flora and fauna habitats are affected by these processes it is generally the process of cracking which reduces shelter and important habitat feature for a species.

Potential but sub-optimal habitat exists for cave-roosting bats. There is a low to negligible risk of damage to cliff features used as shelter sites by these species within Wonga West mainly along the incised valley of Lizard Creek.

A number of threatened bat species were recorded in the Study Area using Anabats including Eastern Bentwing-bat. This species is an obligate cave-roosting bat and it is suspected that it is utilising either disused mining shafts in the surrounding region or some suitable cave habitats in addition to the cave recorded recently. It is unlikely that any maternity roost for Eastern Bentwing-bat occur in the Study Area, as the sandstone geology is not capable of naturally developing the large humid caverns required for breeding (Brad Law, Forests NSW, *pers. comm*).

Potential Impacts on Vegetation

The most significant impacts likely to affect flora are associated with subsidence and cracking induced decrease in surface water availability for swamp and aquatic plant communities, loss of groundwater for groundwater dependant ecosystems including swamps, and fracturing of rocky habitats for rock-dwelling species. Additional effects on vegetation which are not as clearly defined in the literature include the impacts of tilt and strain.

Subsidence causes a surface trough centred above each longwall panel (assuming that the surface is flat). Tilt occurs at the edges of troughs, generally above the supporting chain pillars. A series of longwall panels and chain pillars can cause sequential subsidence and upsidence (or alternating tilts), which may cause trees and other surface features to lean off axis, and may also cause strain effects on plant root systems. ERM is not aware of any models currently available for predicting the impact of tilt on vegetation therefore the following reasoning is applied.

Within the significant habitat features there is a maximum permanent predicted tilt up to 16mm/m under the Shale Sandstone Transition Forest. For a tree of 25m height, this translates to a lean off-axis of 375mm at the crown. It is not expected that a lean of 375mm at the crown would be sufficient to cause tree instability, although there is a possibility that trees which already have a steep lean in the direction of predicted tilt may fall.

It is unlikely that any isolated falls that may occur would significantly alter vegetation community composition in the Study Area, as trees fall in woodland and forest communities as part of an ecosystems lifecycle. However, if numerous or widespread tree falls were to occur, percentage canopy cover would be reduced and increased light penetration may lead to alteration of midstorey and ground storey community composition. Tilting due to subsidence is not expected to cause measurable short or long-term damage to any threatened plants or endangered ecological communities within the Study Area at the subsidence levels predicted.

Tensile and compressive strains pull and push on structures, commonly damaging inflexible material by stretching and rupturing. As ERM is not aware of any models currently available for predicting the impact of strain on terrestrial vegetation, the following reasoning is applied.

Compressive and tensile strains caused by subsidence are likely to act on plant roots much the same as root pressure when trees bend due to high winds. Compressive strains of 10mm/m on a 25m high tree would correspond to the impact of wind-induced leaning of 375mm at the tree crown. Such a lean is plausible under natural wind conditions, although no field measurements have been made to confirm these figures.

Those plants with shallow root systems are less likely to be impacted by strain due to the opportunity for strain to be ameliorated by low level soil expansion at the surface.

Potential Impacts on Fauna

The primary impacts to fauna as a result of the Project are likely to be associated with degradation and alteration of aquatic habitats including streams and swamps, and degradation of rocky habitats, which have been discussed above.

There is a significant risk posed to the stream condition or extent in Cataract Creek based on predicted maximum subsidence of 0.8m, along with up to 10mm/m compressive and 5mm/m tensile strains over Longwall A2 LW8 (GeoTerra 2012a). Potential subsidence impacts include potential cracking of the 4^{th} order stream bed due to subsidence near or over Longwalls A2 LW7, A2 LW8, A2 LW9 and A2 LW10. Environmental consequences are potential impact on stream flow, with downstream flow re-emergence; potential effect on pool holding capacity of rock bars and potential iron hydroxide seepage.

Suitable habitat and good quality breeding habitat for the Stuttering Barred Frog (*Mixophyes balbus*) has been identified in the reaches of Cataract Creek upstream of proposed Longwall A2 LW8 in Wonga East. Based on worst case subsidence predictions, habitat for the Stuttering Barred Frog above Longwalls A2 LW8 and A2 LW7 will be adversely affected by the proposed action. A large section of habitat for this species occurs upstream of the affected reach of Cataract Creek and the proposed action is predicted to have negligible environmental consequences.

In response NRE have made a commitment to monitor subsidence in Cataract Creek and when vertical subsidence approaches 250mm longwall mining in the associated longwall will be cease.

Impacts to creeks and streams in Wonga West are likely to include cracking of creek substrate beds and standing pools in creeks above and adjacent to longwall panels in Area 3. Subsidence is expected to cause cracking in LCUS18 and LCT2 below LCUS25 (Ross Seedsman, Seedsman Geotechnics, *pers. comm*). These two creeks are known to provide habitat for two threatened frog species, Giant Burrowing Frog and Red-crowned Toadlet. It is likely that surface cracking as a result of mine subsidence will lead to a reduction in surface water availability including standing pools within these creeks (Andrew Dawkins, GeoTerra *pers. comm.*). This is expected to have direct consequences for the availability of breeding habitat for Giant Burrowing Frog, and to a lesser extent Red-crowned Toadlet.

There is potential for impacts on the availability of rock fissures and caves for microbat species including Eastern Bentwing-bat, Large-footed Myotis and Large-eared Pied Bat.

The habitat for these species amongst the sandstone areas of the Study Area for these species is considered to be sub-optimal and it is unlikely that a significant population of any of these species occurs. Impacts to the species have been considered in the Assessments of Significance.

Habitat for threatened reptiles including Broad-headed Snake and Rosenberg's Goanna, including wintering outcrops and exfoliating slabs occur in the Study Area. Many suitable wintering sites for Broad-headed Snake include exfoliating sandstone, which is separated from the sandstone bedrock, but is lying on sandstone benching. Rosenberg's Goanna is reliant upon numerous habitat features including ground termitaria and west facing sandstone benches (Eco Logical, 2009). There may be localised impacts on winter shelter availability for these species, and both were subject to an Assessment of Significance.

Threatened Species and EEC Consideration

Threatened species and ecological communities listed on the TSC Act and/or EPBC Act known or predicted to occur in the locality have been considered for their potential to occur in the Study Area and potential to be affected by subsidence (see *Table 5.5*, *5.6* and *5.7* of *Annex S*).

Assessments of Significance were prepared for those species recorded in the Study Area or considered to have a moderate to high or high likelihood of occurrence in the area and that are known to be vulnerable to the impacts of subsidence. Species which are not vulnerable to the impacts of subsidence according to DECC (2007), or are considered to have a low likelihood of occurrence in the study area have not been subject to an Assessment of Significance.

24.5.3 *Assessments of Significance*

Assessments of significance were undertaken for threatened species, and endangered ecological communities. The assessments are provided in *Annex S*, following is a summary of the assessment of significance for some of the threatened species listed under the TSC Act.

The assessments concluded that the Project was likely to have a significant impact on habitat for local populations of the Red-crowned Toadlet and Giant Burrowing Frog specifically in the tributaries of Lizard Creek in the Wonga West area. Two species, which may occur in the Study Area:Large-eared Pied Bat and Heath Frog, also have the potential to be impacted by the Project. The Project will have an adverse effect on potential breeding habitat for the Heath Frog associated with upland swamps and associated streams. If a population is present within the affected areas, the Project would accordingly have an effect on the life cycle of this species such that the local populations may be placed at risk of extinction.

The assessment for the Large-eared Pied Bat and other cave-dependent bats including the Large-footed Myotis and Eastern Bentwing-bat concluded that there is a negligible to low risk that the Project could modify, destroy, remove or isolate or decrease the availability or quality of breeding habitat associated with the cliffs and/or steep slope habitat in the Study Area.

Another species that occurs in upland swamps that was recorded in the area was the Prickly Bush-pea (*Pultenaea aristata*). *Pultenaea aristata* has been recorded in 15 of the 84 upland swamps in the area. The majority of these records were in the Wonga West area to the west of Shaft No 5. Of the 65ha of confirmed upland swamp habitat in the Study Area approximately 23ha is at a greater than negligible risk of negative environmental consequences. The changes to hydrology in these areas have been generally reported to be 'potential and minor'. Given that this species is associated with drier vegetation on the fringes of the upland swamps, it is unlikely that the habitat for this species will be modified. Terrestrial habitat for this species will be not removed and is unlikely to be modified by the proposed subsidence. Further discussion of the assessment outcome for this species is provided in *Section 24.5.4*.

The upland swamps are representative of the Coastal Upland Swamp EEC as listed under the TSC Act. Approximately 265ha of Coastal Upland Swamp are present in Wonga East and Wonga West domains of the Study Area. The Project will not directly clear any areas of the EEC. However, the proposed longwall mining may result in subsidence and alter hydrological processes of the swamps, in particular the headwater swamps, as the mine plan has been revised to avoid the more sensitive valley infill upland swamps along Lizard Creek and Wallandoola Creek in Wonga West.

Biosis's (2012a) risk assessment for upland swamps of special significance as summarised in *Section 22.7* was used to inform the assessment. The Project has a negligible or greater risk of negative environmental consequences for approximately 29 of the 84 upland swamps being approximately 60ha or 23% of the community in the Study Area. Implementation of subsidence monitoring and an adaptive mine plan as discussed in *Section 22.8* and *Section 22.9* will provide for minimising impact on the upland swamps in particular the larger, more complex swamps of special significance.

24.5.4 *Matters of National Environmental Significance*

This section provides a summary of the Matters of NES, which are likely to occur within the Study Area, and addresses the potential for impacts to these matters under the EPBC Act *Significant Impact Guidelines 1.1* (DEWHA 2009). A detailed assessment is provided in *Annex T*.

Protected Matters Search Tool

The EPBC Act Protected Matters Search Tool identified EECs, threatened species and migratory species listed under the EPBC Act which "*have the potential to occur, or rely on habitat that may potentially occur, within 10km of the Study Area*". The output of the search is provided in *Annex T.* The ecological assessment has considered all EECs, threatened species and migratory species listed by the search tool when undertaking the impact assessment. Only those species considered likely to occur within the Study Area that are vulnerable to subsidence impacts are discussed in this section.

A summary of the assessment of threatened fish species listed under the EPBC is provided in *Chapter 23*.

Potential for Impacts to Matters of NES

The proposed action is expected to cause subsidence due to longwall mining, which has the potential to impact upon the EEC and threatened species. There is potential for a range of impacts including tilt, strain, surface cracking and valley closure as described by Seedsman (2012). Subsidence impacts that have the potential to affect threatened species include alteration to aquatic environments including upland swamps and streams, and damage to rocky habitats such as cliffs, outcrops, caves and shelters, as discussed in *Section 24.5.1*.

Matters of NES Likely to Occur

The ecological assessment has identified a number of EECs and threatened species which are likely to occur within the Study Area. Table A.1 of *Annex T* assesses the likelihood of occurrence of species and communities based on their habitat requirements and records from the Southern Sydney regional studies (DECC 2007c, d).

Terrestrial species and communities which are likely to occur in the Study Area and are vulnerable to subsidence impacts are further assessed under the EPBC Act *Significant Impact Guidelines 1.1* (DEWHA 2009) in *Annex B* of *Annex T* including:

- Shale/Sandstone Transition Forest EEC;
- Woronora Beard Heath;

- Prickly Bush-pea;
- Deane's Paperbark;
- Small-flower Grevillea;
- Bargo Geebung;
- Giant Burrowing Frog;
- Heath Frog;
- Stuttering Barred Frog;
- Broad-headed Snake;
- Spotted-tailed Quoll; and
- Large-eared Pied Bat.

The significant impact assessment for the Giant Burrowing Frog concluded that the proposed action may have a significant impact on the species, in particular the population in the tributaries of Lizard Creek in Wonga West. The assessment found that, the proposed action was likely to: lead to a long-term decrease in the size of an important population of a species; reduce the area of occupancy of an important population; fragment an existing important population into two or more populations; disrupt the breeding cycle of an important population; and modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline. The assessment also found that although the local population may be impacted, the proposal is not predicted to interfere substantially with the recovery of the species as a whole.

Heath Frog is considered likely to occur within the Wallandoola Creek drainage, and suitable habitat for breeding occurs within the valley infill swamp WCUS7. This swamp is likely to be subject to subsidence impacts and cracking of substrate may occur (GeoTerra 2012b). If cracking of pond bars or substrate were to occur, habitat condition may become degraded to a point such that Heath Frog could no longer successfully breed there. The assessment found that if that were the case, the proposed action may disrupt the breeding cycle of an important population.

The significant impact assessment for the Large-eared Pied Bat concluded that, while the Project has the potential to disrupt the breeding cycle of an important population, if present in the cliff habitat along Lizard Creek, there is a negligible to low risk that the Project could modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Suitable habitat and good quality breeding habitat for the Stuttering Barred Frog (*Mixophyes balbus*) has been identified in the reaches of Cataract Creek upstream of proposed Longwall A2 LW8 in Wonga East. Based on worst case subsidence predictions, habitat for the Stuttering Barred Frog above A2 LW8 and A2 LW7 will be adversely affected by the Project. NRE have made a commitment to monitor actual subsidence of longwall panels to validate the predictions about the consequences of subsidence on aquatic habitats and biota to assess any unexpected impacts that may occur. NRE will terminate mining beneath Cataract Creek if subsidence and ground movements exceed 250mm and the creeks experience greater than minimal impact. With adaptive management, the action is unlikely to affect the population of these species (Cardno Ecology Lab 2012). A large section of habitat for this species occurs upstream of the affected reach of Cataract Creek and the proposed action is predicted to have negligible environmental consequences.

The Spotted-tailed Quoll (*Dasyurus maculatus*) and Broad-headed Snake (*Hoplocephalus bungaroides*), rely upon rocky habitats (overhangs, shelves and or caves) that occur predominantly along Lizard Creek and Wallandoola Creek. Due to the topography of the Study Area and the location of the proposed longwalls, it appears that conflicts between the Project and the habitat requirements of these threatened species have been avoided.

Prickly Bush-pea (*Pultenaea aristata*) has previously been recorded in Wonga West near Shaft No 5 (Kevin Mills and Associates 1995) and was recorded in Wonga East and Wonga West in September 2011 and in 2012. It may be present in a range of vegetation types, from heath in upland swamps to dry sclerophyll woodlands such as Exposed Sandstone Scribbly Gum Woodland and Upland Swamp Fringing Eucalypt Woodland and Upland Swamp: Restioid Heath that are widespread in the Study Area. While the Project will not clear potential habitat or directly decrease the size of the population in the Study Area there is potential for adverse impact to the drier edges of the Upland Swamps that are favoured by this species.

GeoTerra (2012a) and Biosis (2012) reported possible changes to swamp water level, water storage, stream seepage and water quality due to substrate cracking in upland swamps. The changes to hydrology in the majority of the swamps have been predicted to be 'potential and minor'. Given that Prickly Bush-pea is associated with drier vegetation on the fringes of the upland swamps, it is considered unlikely that the Project will lead to an impact on an important population of the Prickly Bush-pea.

It is generally recognised that the impacts of subsidence due to longwall mining on terrestrial ecosystems (including Shale Sandstone Transition Forest EEC) are likely to be less significant than those experienced by aquatic-dependent ecosystems (DECC 2008). Subsidence prediction values for the areas of Shale/Sandstone Transition Forest EEC indicate a maximum predicted subsidence of 2.3m and maximum permanent predicted tilt of 15mm/m under the EEC in the Study Area. This subsidence is considered unlikely to result in significant impacts on the EEC.

The Woronora Beard-heath (*Leucopogon exolasius*), Deane's Paperbark (*Melaleuca deanei*), Small-flower Grevillea (*Grevillea parviflora* subsp. *parviflora*) and Bargo Geebung (*Persoonia bargoensis*) may occur in the Study Area. All of these species are reliant upon the 'terrestrial' sandstone woodland, forest or dry heath habitats. While maximum subsidence predictions in these potential habitat areas is approximately 2.3m and maximum predicted tilt of 15mm/m, the mine design approach has recognised that the majority of the surface can be safely subsided (Seedsman 2012) and this level of subsidence is unlikely to impact on terrestrial vegetation communities and the species within them. It is unlikely that the changes in conditions would cause significant damage to vegetation communities and subsequently a long-term decrease in the size of an important population of these species.

The Project is unlikely to impact on other matters of NES in particular migratory species that have been recorded in the Study Area.

NRE are currently preparing a referral to the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) for the Project.

Migratory Species

Field surveys recorded a number of EPBC listed migratory species in the Study Area, including Black-faced Monarch (*Monarcha melanopsis*); Rufous Fantail (*Rhipidura rufifrons*) and Peregrine Falcon (*Falco peregrinus*). In addition the Study Area is likely to provide habitat for other migratory passerines including Rainbow Bee-eater (*Merops ornatus*) and Satin Flycatcher (*Myiagra cyanoleuca*) and other raptors from the families Falconidae and Accipitridae. There is no suitable habitat for marine reptiles, mammals or seabirds, and habitat for wetland birds including egrets, snipes and waders is also absent from the Study Area.

None of the migratory species, which may occur in the Study Area are dependent upon habitat that are likely to be vulnerable to the effects of subsidence impacts, and as such, none are likely to be significantly impacted by the Project, according to the *Significant Impact Guidelines 1.1* (DEWHA 2009).

24.5.5 *Regionally Significant Species*

A number of regionally significant species identified by OEH as likely to occur in the Study Area were considered in *Section 5.5* of *Annex S*. Of these species the Eastern Three-lined Skink (*Acritoscincus duperreyi*), Chestnut-rumped Heath-wren (*Calamanthus pyrrhopygius*), Tawny-crowned Honeyeater (*Gliciphila melanops*), Beautiful Firetail (*Stagonopleura bella*), Southern Emu-wren (*Stipiturus malachurus*) and Platypus (*Ornithorhynchus anatinus*) are reliant upon upland swamp and streams for part of or all of their lifecycle.

It is likely that effects of subsidence such as shorter duration wetting events for valley infill swamps, increased dry periods, an increase in fire occurrence may reduce habitat suitability in the swamps in the PAA. However, the relative abundance of these species in the Study Area, the connectivity of the Study Area to surrounding healthy habitat areas, and the ability of these animals to disperse within suitable habitat is likely to minimise the impacts of the Projects on populations of these species within the Study Area.

24.5.6 *Rare or Threatened Australian Plants*

Three Rare or Threatened Australian Plant (ROTAP) species have been recorded in the Study Area and all are considered vulnerable to the impacts of subsidence according to DECC (2007).

Darwinia grandiflora was recorded in Wonga East in sandy soils on the side of the road and in adjacent woodland within Sandstone Scribbly Gum Woodland and in Upland Swamp: Fringing Eucalypt Forest. The subsidence impacts and risk of negative environmental consequences in the Sandstone Scribbly Gum Woodland is negligible. There is not likely to be any impacts to this species in this area.

Shining Guinea Flower has been previously recorded in the Study Area by Kevin Mills and Associates (2005) but the location of the records is unknown. The species is commonly recorded on exposed slopes in coastal areas. The likelihood of impacts to this species is not known.

Monotoca ledifolia was recorded in Upland Swamp LCUS6 in the Sedgeland Heath Complex adjacent to Lizard Creek. This section of the swamp is considered to have a negligible risk of adverse impacts from the Project (Biosis 2012a). Based on this information *M. ledifolia* has a low likelihood of experiencing adverse effects of subsidence impacts.

24.6 *MANAGEMENT AND MITIGATION MEASURES*

This section evaluates the impacts expected from the Project in light of the measures taken by NRE to avoid, minimise and mitigate these impacts. Avoidance measures have been the primary mechanism by which NRE has aimed to reduce the impact of theProject on the ecology of the Study Area.

24.6.1 *Iterative Mine Planning*

The proposed mining will be in the Wongawilli seam in an area where the Bulli seam and in some places, the Balgownie seam has already been extracted (Olsen, 2009). In order to manage environmental risks, the mining proposal incorporated a risk assessment methodology and applied a hierarchy of risk management strategies during planning. Details of the strategies and the projected outcomes are included in a report prepared by Seedsman Geotechnics Pty Ltd (Seedsman, 2012).

As the baseline surveys of the Study Area progressed, NRE used an iterative mine planning process to avoid and mitigate impacts to the values identified by ERM and associated consultants. The progressive mine plans that were considered and altered throughout the iterative mine planning process are described in Seedsman (2012). The process for avoiding and mitigating impacts to ecological values is discussed below.

Avoidance Measures

The iterative mine planning process involved ongoing examination of longwall options in light of ecological constraints, in order to avoid impact to areas of high conservation value. In 2007 a map of 'ecological risk management zones' was provided to NRE for consideration and these areas including upland swamp communities as known at the time, streams and riparian zones, significant fauna habitats and the Shale/Sandstone Transition Forest EEC as determined at the time. An additional risk management zone of 250m around swamps, and 50m around streams 3rd order or higher was applied. These risk management zones provided the subsidence engineers and mine managers with an understanding of the locations of sites of ecological significance within the Study Area. It also provided an opportunity to refine the mine plans based upon this information.

Areas of ecological significance including upland swamps, streams and sensitive habitat areas for threatened fauna, flora and ecological communities were identified during the ecological assessment in 2009. Utilising an elimination approach for risk management, NRE decided not to undertake longwall extraction under or close to features of ecological significance (Olsen, 2009). In order to avoid impacts to surface features, the design of longwall panel layouts has been such that potential for impacts to 3rd and 4th order streams are reduced (Seedsman, 2012).

The proposed mine plans have avoided longwall extraction directly under Lizard Creek, Wallandoola Creek and Cataract River (Seedsman, 2012).

Seedsman (2012) outlines the current mine plans and the abandoned plans which show that the mine plan avoids:

- extraction under the main channel of Lizard Creek and associated upland swamps;
- extraction under Wallandoola Creek and the upland swamp WCUS1; and
- extraction under Cataract River.

Further impacts have been avoided through location of the underground driveage between Wonga East and Wonga West, which will be fully supported (resulting in no subsidence), under Lizard Creek.

The possibility of reducing the width of longwall panels in Wonga West was examined in order to assess feasibility of reduction in magnitude of subsidence above the longwalls. However, the technical options for location of longwall gate roads under Lizard Creek meant that the longwall layouts became uneconomic under these circumstances (Seedsman, 2012).

Mitigation

NRE has provided an undertaking that the mining operations will be modified as required through adaptive management measures informed through monitoring of actual subsidence impacts, to reduce negative outcomes.

An adaptive management plan will be developed to use the monitoring program to detect the need for adjustment to the mining operations so that the subsidence predictions are not exceeded and subsidence impacts creating a risk of negative environmental consequences do not occur in upland swamps, streams and rocky habitats associated with cliffs and steep slopes.

Further measures to mitigate potential small scale affects of subsidence are recommended within the Study Area, in order to assist in amelioration of impacts as follows:

- if fracturing does occur and is confirmed to be a result of mining, remediation will be implemented as soon as possible. Methods could include grouting, although the success of this measure is case dependant and potentially non-beneficial. All remediation works undertaken will be controlled and implemented in accordance with a Biodiversity Management Plan;

- if fracturing occurs leading to loss of surface water these areas will be prioritised for remediation, and extraction will be ceased in areas with similar fracture risks;
- if significant cracking occurs in vegetated areas and is confirmed to be a result of mining, then measures such as temporary fencing will be implemented. This will ensure that fauna are not injured or trapped; and
- prior to any remediation works, advice will be sought from an ecologist regarding the potential impacts of such remediation works to plant and animal populations within the area.

In order to mitigate the impacts at the scale of the entire Study Area, ongoing monitoring of sensitive habitats needs to be implemented in accordance with a Biodiversity Management Plan.

In addition to the above measures *Section 22.8* outlines monitoring, management and contingency measures for the upland swamps.

Monitoring

Although not a mitigation tool, monitoring of the important habitat areas (such as the upland swamps, creeks and rocky habitats) should occur pre and post mining, to allow early detection of impacts as a result of the proposed action. This would enable mobilisation of mitigation and remediation works to be undertaken in accordance with Biodiversity Management Plans.

OEH (2012) in their upland swamp environmental assessment guidelines provide a framework for monitoring of negative environmental outcomes for upland swamps. While these measures relate specifically to upland swamps, monitoring of these high priority conservation areas will ensure that impacts to swamp dependent species and species associated with upland swamp habitats are detected and minimised through adaptive management plan.

Performance measures to demonstrate negligible environmental consequences for swamps (as adopted by NRE for A2 LW4 and A2 LW5) are:

- negligible drainage of water from the swamp, or redistribution of water within the swamp;
- negligible change in the size of the swamp;
- negligible change in the function of the swamp; and
- negligible change in the composition or distribution of species within the swamp.

Where negligible has the same meaning as in the PAC, "*small and unimportant, such as to be not worth considering*".

For the purposes of monitoring upland swamps, OEH identify that monitoring of changes in water levels within the swamp is an appropriate and in particular early indicator that other negative environmental consequences may occur.

Drawdown of water levels is one of the first parameters that can be detected following the fracture of rock strata (OEH 2012). Negative environmental outcomes have occurred if there is a statistically significant decrease in water levels within the swamp that is directly attributable to subsidence.

The biodiversity management plan prepared by NRE for A2 LW4 and 5 (NRE 2012) also outlines measures for management of threatened species and ecological communities. Monitoring effort should focus on natural features at risk of subsidence effects in particular upland swamps and streams in particular, Coastal Upland Swamp EEC, Giant Burrowing Frog, Heath Frog, Red-crowned Toadlet, Stuttering Barred Frog and Broad-headed Snake.

Performance measures to demonstrate negligible environmental consequences for threatened species and EECs (as adopted by NRE for A2 LW4 and A2 LW5) are negligible environmental consequences.

Monitoring will inform the ongoing development of longwall panels over time as part of the Project.

Monitoring will be undertaken at regular intervals in appropriate seasonal timeframes for the detection of each individual species. In particular, potential habitat in areas which subsidence risk is greatest will be targeted. The design of ongoing ecological monitoring will be outlined in the Biodiversity Management Plan and should be flexible to account for seasonal and inter-annual variation in ecological conditions.

The objective of the monitoring will be to identify subsidence impacts as early as possible; identify other areas that are vulnerable to similar impacts; and provide recommendations to the proponent to alter the mine plan to reduce the risk of subsidence impacts affecting similar values. In this case, the mitigation measure would be to alter the extraction plans to minimise risk to sensitive features, based on the knowledge gained through ongoing monitoring. A monitoring program would be developed to ensure that the monitoring activities do not cause adverse impact on the species and habitats.

A monitoring plan as outlined in the Biodiversity Management Plan for Longwalls A2 LW4 and A2 LW5 (NRE 2012) will be adopted and expanded for the proposed long wall mining operation in Wonga East and Wonga West. The current monitoring is undertaken according to the Before-After Control-Impact (BACI) design where data is collected before (baseline) and after impact at control and impact sites. Data collected during baseline monitoring will be used for comparison of data collected during and after mining and data collected at impact sites will be compared to data collected at control sites (control-impact) (NRE 2012). Although two years baseline data collection is preferential to ensure adequate variance in biological systems is considered in planning of the mine, planning and changes to sampling methods has meant that the design of the monitoring program has changed.

However, impacts to many of the species dependent upon ecologically sensitive areas vulnerable to subsidence are not likely to occur over short intervals and are likely to be preceded by changes to other variables in particular surface and groundwater flows. Therefore, although minimal baseline data has been collected overall trending declines can still be used to identify whether subsidence impacts have negative environmental consequences on flora and fauna.

Monitoring will continue for the duration of mining and for a suitable period post mining as determined in consultation with agencies and the DP&I with consideration given to the annual reports and observed impacts to surface features, surface water and groundwater. Monitoring will be undertaken for a minimum of two years post mining up to five years (NRE 2013).

A summary of the biodiversity monitoring program is provided in *Table 24.2*.

Table 24.2 Biodiversity Monitoring Program Framework

Monitoring	Methodology	Frequency
Vegetation – Upland Swamps	Transect based- thirty (30) 0.5m by 0.5m flora quadrats recording presence only. A species can have a maximum score of 30 for any one transect, indicating presence in all quadrats.	Autumn and Spring.
Vegetation creeklines	Three 20m by 20m (400m^2) quadrats along Cataract Creek and 3rd order tributaries of Cataract Creek and Lizard Creek	Once in Autumn and once in Spring.
Frogs	Initial survey to identify significant habitat features including breeding pools and sheltering habitat. Diurnal surveys for all potential habitat identified in the initial survey to map habitat features (pools, rockbars) noting presence of species. Ongoing monitoring searching for adult frogs and tadpoles and noting habitat variables	Ongoing monitoring will be undertaken once per season ie four per Annum.
Rocky Habitats	Initial survey to identify significant habitat features including overhangs, potential caves and over wintering habitat. Diurnal surveys for potential habitat identified in the initial survey to map habitat features noting presence of species. Ongoing monitoring including searching for adults and juveniles and noting habitat variables and use of Anabat monitoring of suitable habitat to identify species presence.	Ongoing monitoring will be undertaken once per season, ie four per Annum.

1. Framework based upon the Biodiversity Managmenet Plan prepared by NRE (2012) for A2 LW4 and A2 LW5.

24.7 CONCLUSIONS

The Study Area contains a number of features of ecological significance including threatened species, endangered ecological communities, regionally significant species and ROTAPs. The Study Area also contains a number of upland swamps of special significance, which provide habitat for threatened and rare species.

The condition of habitat within the Study Area is generally very good owing to the area's ongoing protection as part of the SCA Special Areas. The Wallandoola Swamp Cluster provides extensive tracts of valley infill swamp and headwater swamp habitat for threatened species and regulate a lot of the surface water flows within creeks of the Study Area (GeoTerra 2012a). There are extensive areas of habitat suitable for threatened species within the swamps and creeks, which are in good condition and the area is well connected to surrounding habitat.

There is limited surface disturbance around fire roads, existing mine shafts, transmission line easements and frequently trespassed areas within Wonga East. There are indications of previous subsidence impacts within Lizard Creek and Wallandoola Creek, as evidenced by cracking within the creek beds and loss of surface water flows for extensive reaches (GeoTerra 2012a). The condition of Cataract Creek is good, although some tributaries leading into the creek show signs of heavy iron-oxidising bacteria flocculation, and the lower reaches are degraded due to water level fluctuations of Cataract Dam. There is some evidence of scouring and erosion within upland headwater swamp LCUS25.

Elimination of many potential impacts on terrestrial ecology has been achieved by:

- realigning the longwall panel layouts to avoid sensitive areas identified by ERM in 2007 and the subsequent FMEA (Olsen, 2009);
- abandoning plans for longwall panels underneath the main channel of Lizard Creek and Wallandoola Creek;
- abandoning plans for longwall panels underneath Lizard Creek valley infill swamps and much of the Wallandoola Creek valley infill swamps;
- locating the fully supported driveage underneath Lizard Creek; and
- realigning and reducing the width of longwall panels in Wonga East.

Despite this approach, there remains a risk to a number of the ecological values of the Study Area.

Significant impact assessments under the EPBC Act *Significant Impact Guidelines 1.1* (DEWHA, 2009) found that:

- significant impacts may occur for the Large-eared Pied Bat;
- that they are likely for the Giant Burrowing Frog;
- that disruption to the breeding cycle of Heath Frog may occur; and

- that some of the upland swamps that are representative of the Coastal Upland Swamp EEC are at risk of negative environmental consequences as highlighted in *Chapter 22*.

The assessments determined that the proposed mine plans have the potential to impact local populations of these species, the Project is not predicted to interfere substantially with the recovery of any of these species as a whole.

The Project is not likely to significantly impact an endangered ecological community or any species listed as migratory on the EPBC Act.

Assessments of Significance under the TSC Act concluded that the Project was likely to have a significant impact on habitat for local populations of the Red-crowned Toadlet and Giant Burrowing Frog. Two species which may occur in the Study Area; Large-eared Pied Bat and Heath Frog, also have the potential to be significantly impacted by the Project. It is likely that the Project will have an adverse effect on breeding habitat and therefore the life cycle of these species such that viable local populations are likely to be placed at risk of extinction.

The alteration of habitat following subsidence due to longwall mining is listed as a key threatening process (KTP) under the TSC Act. The alteration or modification of habitat was considered likely to occur for majority of species and the Coastal Upland EEC assessed as a result of the Project and for these species this is considered the operation of a KTP.

25 *ABORIGINAL HERITAGE ASSESSMENT*

This chapter provides a summary of the Aboriginal heritage assessment undertaken for the Project including impacts on Aboriginal heritage values within the PAA. Measures to mitigate these impacts are recommended.

25.1 *INTRODUCTION*

An Aboriginal heritage assessment (AHA) was undertaken for the Project by ERM. The AHA concerns possible impacts to Aboriginal heritage arising from underground mining in the Wonga East and Wonga West areas of the lease as well as the impacts from surfaces works at the Russell Vale site.

This chapter sets out the key findings of the assessment. Further details are provided in the *NRE No.1 Colliery Aboriginal Heritage Assessment* presented in *Annex U.*

25.1.1 *Study Area*

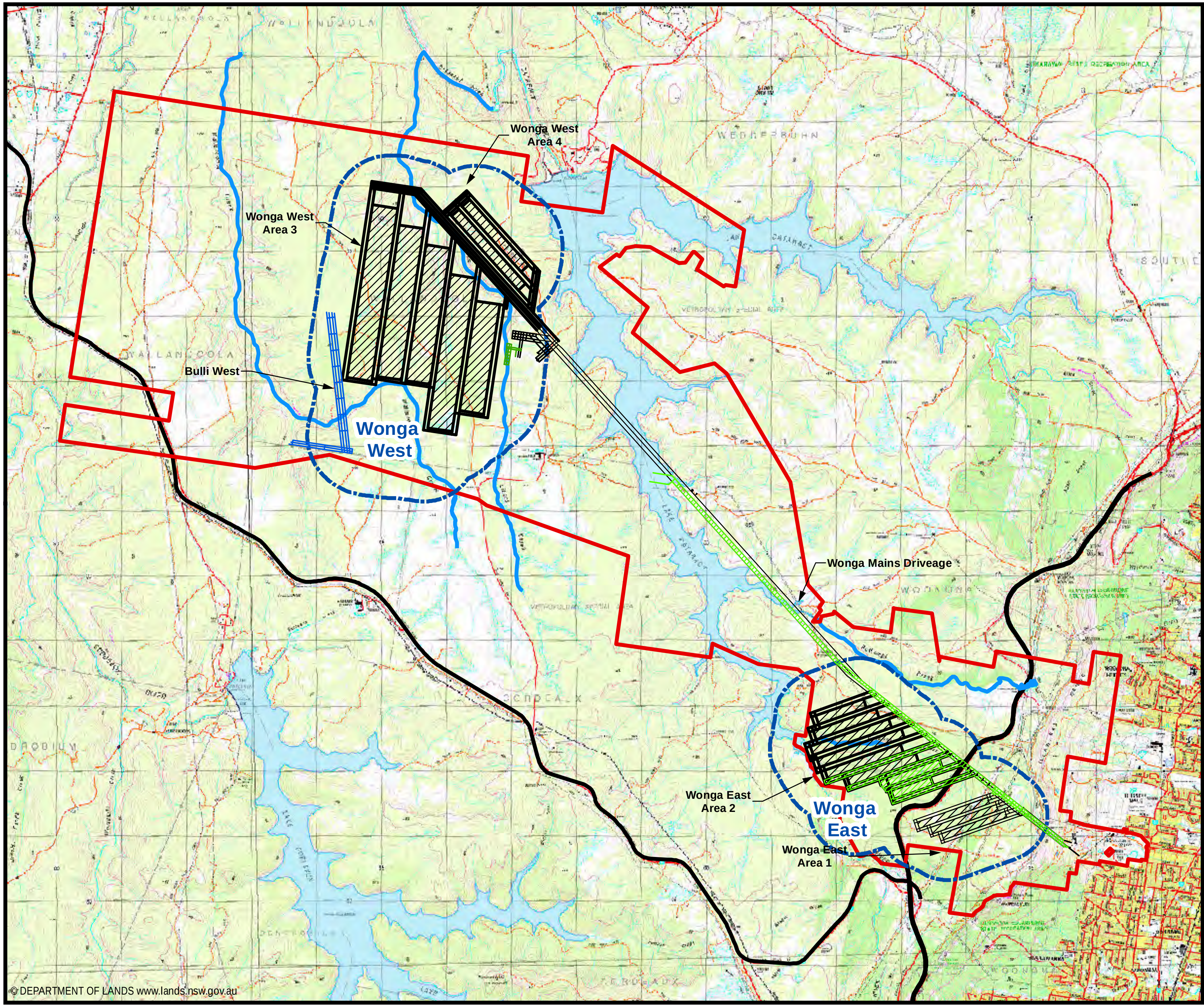
The Study Area for this assessment focuses on areas with the potential for surface disturbance resulting from mine related subsidence. In accordance with the Southern Coalfields Inquiry, land within 600m of the underground extraction area and associated potential subsidence footprint have been included in the Study Area. The Study Area is divided into two separate areas. The eastern Study Area, referred to as the 'Wonga East Study Area', encompasses the proposed Wonga East mining area and adjacent land. The western Study Area, referred to as the 'Wonga West Study Area', encompasses the Wonga West and V Mains mining areas and adjacent land, as shown in *Figure 25.1*.

The Russell Vale site contains the coal handling facilities and related mine infrastructure. An Aboriginal Heritage assessment of this site has also been prepared. The Project does not include new areas of surface disturbance at the Russell Vale site therefore a new Aboriginal heritage assessment was not undertaken at this site. The previous investigation supporting the preliminary works project is included as *Annex A* of the Cultural Heritage Assessment contained in *Annex U*.

25.2 *ABORIGINAL CONSULTATION*

Aboriginal consultation is required for any assessment of Aboriginal heritage. The OEH adheres to the 'Interim Community Consultation Requirements Guideline' (2005) for Aboriginal consultation in relation to any study that might eventually be used to support an application under Part 3A of the *Environmental Planning and Assessment Act 1979*.

The Aboriginal community consultation for this Project has been carried out in accordance with the OEH guideline. Groups identified for consultation were contacted through the instructions and addresses issued by the OEH, requesting their registration for the Project. The complete log of all communications between ERM and local Aboriginal stakeholders is presented in *Annex U*.



Legend

- Project Application Area
- Study Areas
- Approved Workings (MP10_0046)
- Proposed Longwalls
- Proposed Bulli Seam first workings
- Proposed Balgownie Seam first workings
- Major Road
- Creek/River

Figure 25.1

Aboriginal Heritage Study Area

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No. 1 Colliery EAR Post Adequacy 2012 Environmental Assessment
Drawing No:	0079383s_EARPA2012_GIS010_R0.mxd
Date:	12/09/2012 Drawing size: A4
Drawn by:	SQW Reviewed by: MK
Scale:	Refer to Scale Bar

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ERM

25.3 *EXISTING ENVIRONMENT*

25.3.1 *Environmental Context*

The underlying geology of the Study Area was favourable for the creation of Aboriginal sites. Outcrops of sandstone on hill slopes can form overhangs that were favourable camping locations and were used as art sites. The horizontal outcrops of sandstone revealed by water erosion caused by the creeks and tributaries would have provided useful locations to sharpen stone axes and thus lead to the formation of grinding grooves over time.

The numerous water resources in the area, including Wallandoola and Lizard Creeks and their associated swamplands, would have provided habitat for numerous species of fauna and flora, which would have been exploited by Aboriginal peoples for food, medicines and implement making.

Within the majority of the PAA (outside of surface lease areas), soils are likely to be relatively deep and undisturbed and only minor disturbance has occurred in relation to the construction of access roads, mining infrastructure and bushfires. As a result, any archaeological sites are likely to be well preserved. Also, the majority of the PAA is within the SCA Metropolitan Special Area, with limited and restricted access.

25.3.2 *Aboriginal Heritage Background*

Archaeological studies have confirmed that Aboriginal people have occupied the Australian sub-continent for at least 40,000 years (c.f. Allen and O'Connell 2003). This date is frequently challenged with tentative indications that occupation may extend back into the early Pleistocene.

However, such early dates for the Sydney basin and surrounds have not been established. The earliest proven occupation dates in the Illawarra area are around 20,000 BP.

The regional social organisation of the Illawarra Aboriginal groups has been understood from oral histories, early historical accounts and linguistic studies. The tribal group in the Illawarra area, prior to European occupation, was the Wodi Wodi (DEC Undated; 2005 and Tindale 1974) who spoke a variant of the Dharawal language (Tharawal across the current Study Area [Mathews 1901:127]).

25.3.3 *Study Area AHIMS Data*

A search of the OEH AHIMS database for an area 12km by 12 km, with the proposed NRE No.1 longwalls at the centre of the search, was undertaken on 17 October 2008. The search identified 254 recorded Aboriginal sites, the substantial majority of which were shelter sites containing a combination of art, archaeological deposits and grinding grooves. This search was refined focussing on the Wonga East and Wonga West Study Areas.

Fifty recorded Aboriginal sites are located within the Study Areas. The number and ratio of these sites in the Study Areas is listed in *Table 25.1* and the location of sites is shown on

Figure 25.2 and *Figure 25.3*. The full list of AHIMS recorded sites within the Study Areas as well as AHIMS site cards are provided in *Annex U*.

Table 25.1 Number of AHIMS recorded Aboriginal sites within the Study Area

Site Type	Count	Frequency
Artefact Scatter	1	2%
Axe Grinding Groove	14	28%
Shelter with Art and/or Artefacts, Grinding Grooves	35	70%
Total	**50**	**100%**

25.4 *FIELD WORK*

25.4.1 *Survey Methodology*

The Study Area was surveyed in two field trips throughout 2009. The survey methodology was prepared in light of the archaeological background undertaken for this study (see *Annex U),* the guidelines provided by NPWS for Archaeological survey and by the requirements contained within the DGRs for this application.

The surveys took the form of a pedestrian survey. Owing to the difficult nature of the terrain and low ground surface visibility in much of the Study Area, conventional survey transects were not able to be walked. The survey targeted locations of previously recorded archaeological sites, ridgelines, areas associated with sandstone overhangs, large sandstone platforms associated with water and creek lines, where unregistered sites may have been present. Ground surface visibility was variable, and generally low, ranging from 0% to 10%.

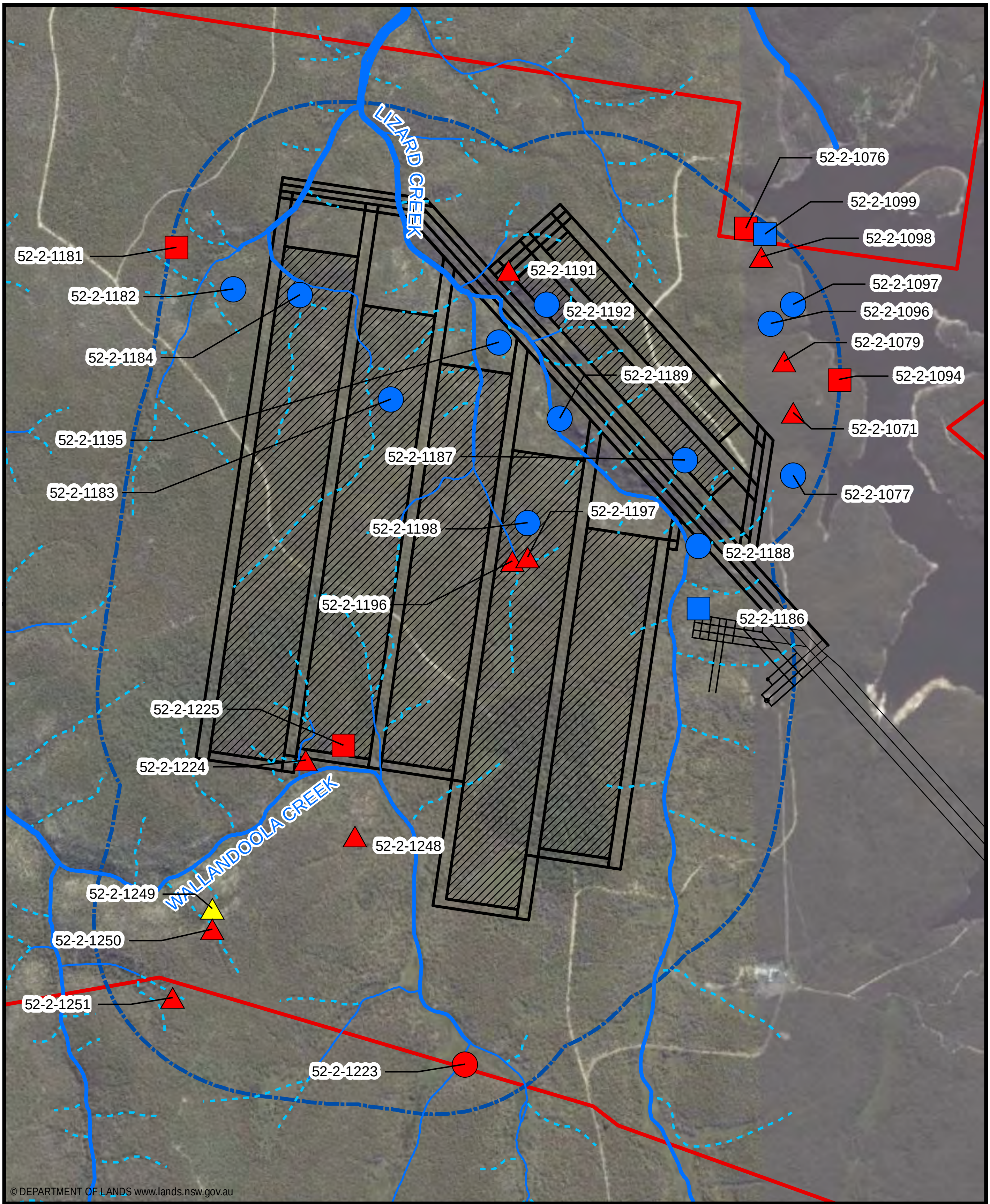
Previously recorded sites were targeted to determine their current condition. Sites that were relocated were assessed against the original detail on the site cards to determine any changes that may have impacted the sites.

Fieldwork Constraints & Limitations

The survey was limited by a number of factors including restricted access to the survey area following wet weather; imprecise co-ordinates for previously recorded archaeological sites; dense vegetation cover coupled with low ground surface visibility and extreme weather conditions.

A large part of the PAA is designated as a Schedule 1 Restricted Access Area and access into and through the area is restricted by the SCA following wet weather.

The archaeological sites previously recorded in the Study Area were recorded by the Illawarra Prehistory Group during voluntary surveys in the mid to late 1980s. The co-ordinates of the sites were estimated using topographic map series available at the time. The inaccuracy of recorded co-ordinates coupled with the dense vegetation and low visibility, made locating previously recorded sites difficult. In some cases, sites were over 350m from their recorded position. As a result, a methodology of multiple relocation techniques was adopted (see *Annex U*), although not all sites were able to be relocated.



Legend
- Project Application Area
- Study Area - Wonga West
- Proposed Longwalls
- Study Areas
- 1st order stream
- 2nd order stream
- 3rd order stream
- 4th order and above stream

AHIMS Site Type
- Axe Grinding Groove
- Axe Grinding Groove, Shelter with Art
- Axe Grinding Groove, Shelter with Deposit
- Shelter with Art
- Shelter with Art, Shelter with Deposit
- Shelter with Deposit

Client: Gujarat NRE Coking Coal Limited

Project: NRE No. 1 Colliery EAR Post Adequacy 2012 Environmental Assessment

Drawing No: 0079383s_EARPA2012_G011_R0.mxd

Date: 18/10/2012 Drawing size: A4

Drawn by: SQW Reviewed by: NB

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Figure 25.2

AHIMS Sites within the Wonga West Study Area

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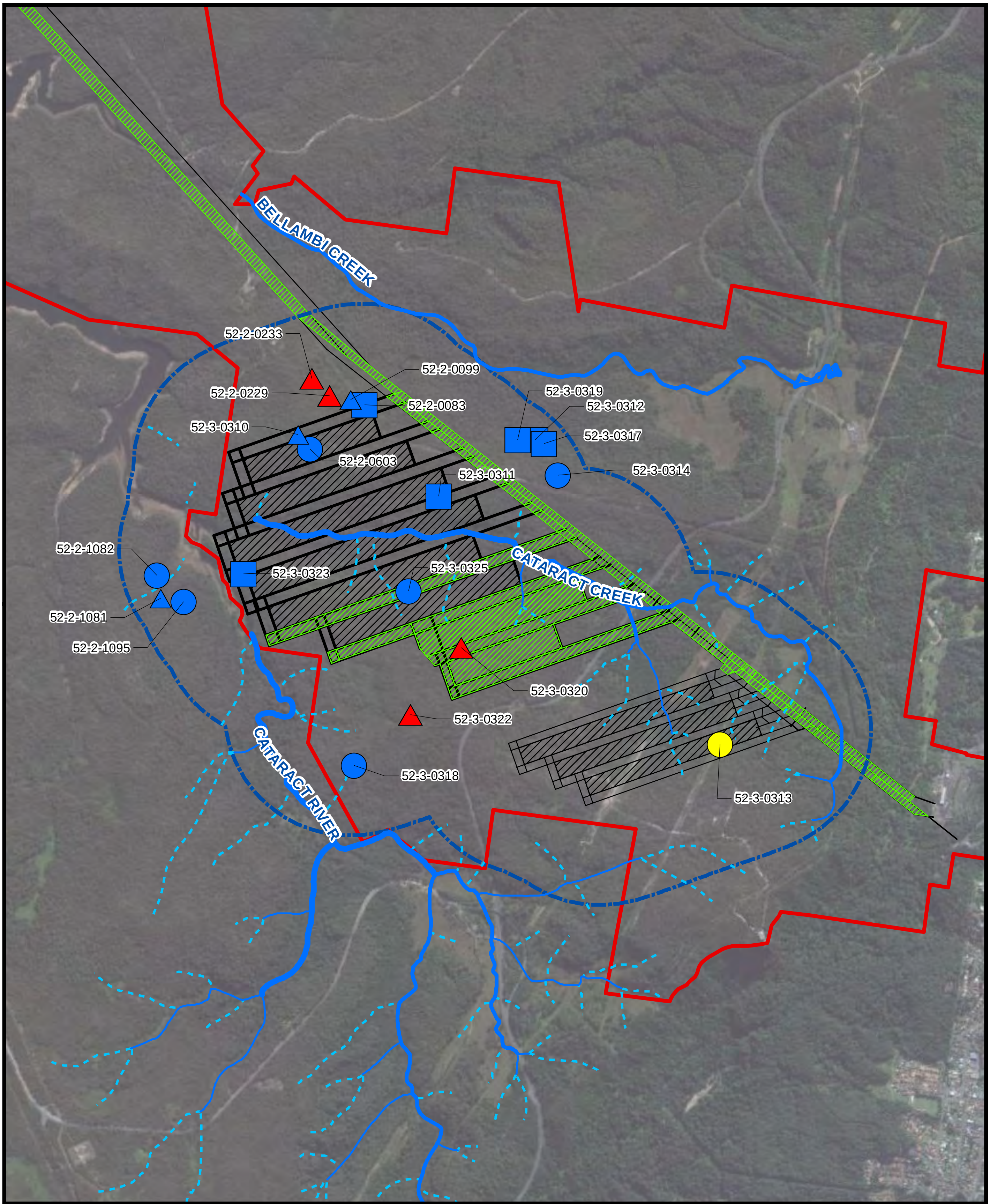
ERM



Legend

- Project Application Area
- Study Area - Wonga West
- Approved Workings (MP10_0046)
- Proposed Longwalls
- 1st order stream
- 2nd order stream
- 3rd order stream
- 4th order and above stream

AHIMS Site Type

- Axe Grinding Groove
- Axe Grinding Groove, Shelter with Art
- Axe Grinding Groove, Shelter with Deposit
- Shelter with Art
- Shelter with Art, Shelter with Deposit
- Shelter with Deposit

Client: Gujarat NRE Coking Coal Limited

Project: NRE No. 1 Colliery EAR Post Adequacy 2012 Environmental Assessment

Drawing No: 0079383s_EARPA2012_GIS034_R0.mxd

Date: 13/09/2012 Drawing size: A4

Drawn by: SQW Reviewed by: MK

Scale: Refer to Scale Bar

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Figure 25.3

AHIMS Sites within the Wonga East Study Area

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM

The Study Area contains few fire access trails and large areas of bushland over dissected plateaux terrain, much of which has not been burnt for some years. The density of vegetation restricts movement and poses a health and safety risk, especially in terms of concealing cliffs, drops and dangerous wildlife. Extreme weather conditions during the time of the field survey also presented additional risks to surveying in remote bushland. While all precautions were taken, excessive heat, bushfire risk and the potential for electrical storms during the field survey limited the distances that could be safely surveyed. The survey team therefore only accessed areas which did not pose a high level of risk to safety and could easily be evacuated in the event of an emergency.

25.4.2 *Results*

Three new sites were identified during fieldwork and Fifteen AHIMS registered sites were relocated including 13 rock shelters, one grinding groove site and one artefact scatter.

Three additional sites referred to as Wonga East 1, 2 and 3 were also identified by Biosis while undertaking fieldwork associated with a separate application to modify the Preliminary Work Project (MP 10_0046). These sites were not visited by ERM. Details of these new sites were provided to ERM by Biosis to ensure consistency in reporting.

A summary of the ERM survey results and additional sites identified by Biosis is provided in *Table 25.2*. The location of the sites is shown in *Figure 25.4*, *Figure 25.5*. A description of each of the sites, including additional sites identified by Biosis is provided in *Annex U*.

Table 25.2 Aboriginal sites relocated and identified within the Study Area

AHIMS Site Number	AHIMS Site Name	AHIMS Site Type
Wonga West		
52-2-1223	Wallandoola Site 2	Shelter with Deposit and Axe grinding groove
52-2-1094	Gillbird Site 50	Shelter with Art and Deposit
52-2-1182	Lizard Creek Site 16	Shelter with Art
52-2-1183	Lizard Creek Site 14	Shelter with Art
52-2-1184	Lizard Creek Site 15	Shelter with Art
52-2-1188	Lizard Creek Site 2	Shelter with Art
52-2-1196	Lizard Creek Site 11	Axe Grinding Grooves
52-2-1225	Wallandoola Site 3	Shelter with Art and Deposit
52-2-1249	Wallandoola Site 13	Shelter with Art and axe grinding grooves
New NRE Women's Site	NRE Women's Site	Water Hole with Aboriginal Ceremony & Dreaming
New NRE Scarred Tree	NRE Scarred Tree 1	Scarred Tree
New LC Shelter 1	Lizard Creek Shelter 1	Shelter with Art
Wonga East		
52-2-0312	Bulli Mine Shaft Site 23	Shelter with Deposit
52-2-0314	Bulli Mine Shaft Site 21	Shelter with Art
52-2-0319	Bulli Mine Shaft Site 24	Shelter with Deposit
52-2-0603	Bulli Mine Shaft Site 19	Shelter with Art

AHIMS Site Number	AHIMS Site Name	AHIMS Site Type
52-3-0310	Bulli Mine Shaft Site 18	Shelter with Art and Deposit and Axe grinding Grooves
52-3-0313	Bulli Mine Shaft Site 29	Artefact scatter
-	Wonga East 1	Shelter with Deposit
-	Wonga East 2	Shelter with Deposit
-	Wonga East 3	Shelter with Deposit

25.5 *SIGNIFICANCE ASSESSMENT*

Aboriginal heritage sites, objects and places hold value for communities in many different ways. The nature of those heritage values is an important consideration when deciding how to manage a heritage site, object or place and balance competing land use options.

ERM's approach to the Aboriginal heritage assessment is based upon identifying the key Aboriginal heritage values which are likely to be both tangible and intangible. This approach needs to consider the values assessment from the scientific and Aboriginal community perspectives, in accordance with Australian best practice documents.

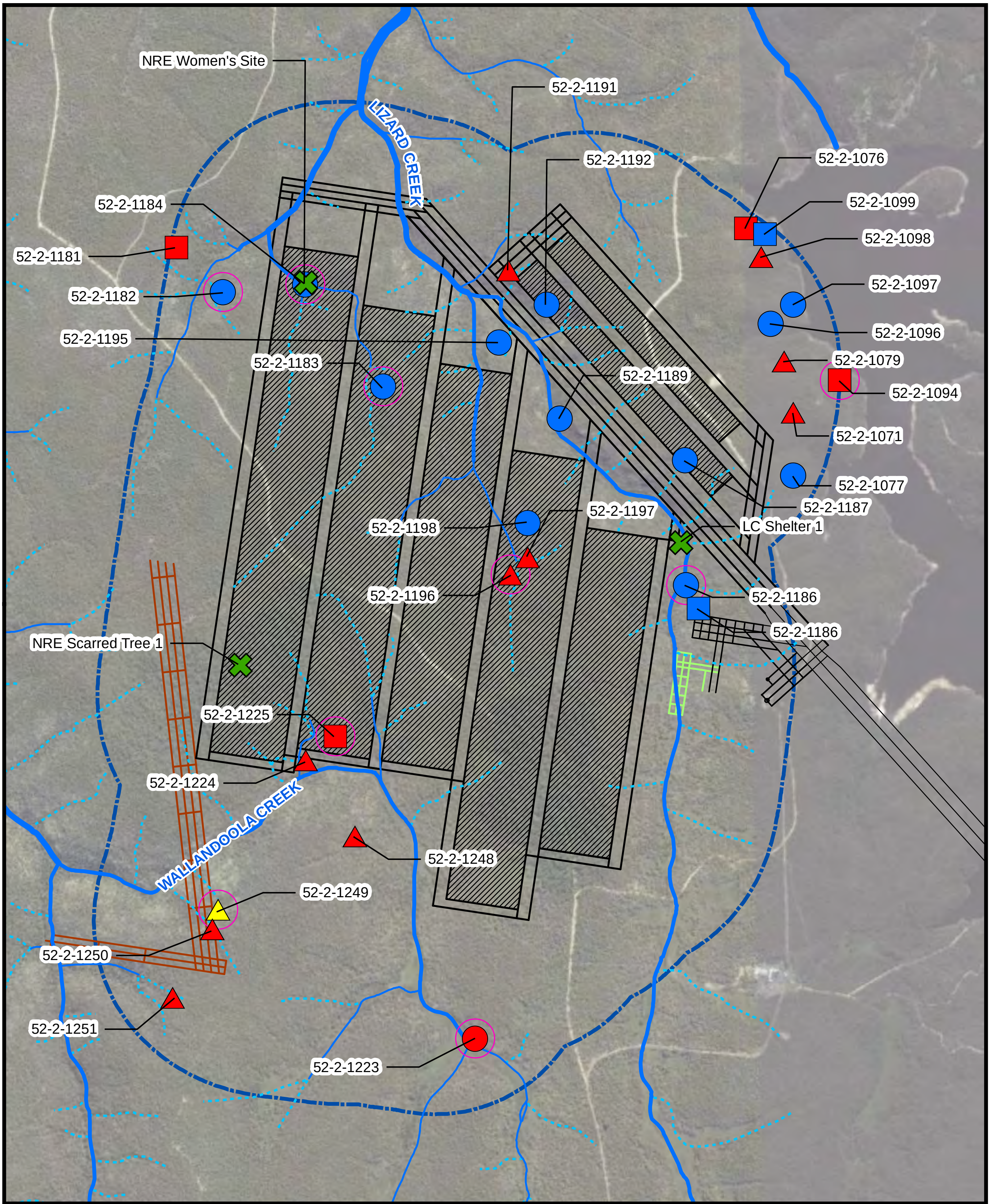
The ERM assessment (*Annex U*) focuses upon the scientific significance assessment of the sites observed and recorded during their survey, and the AHIMS sites located within the Study Area. The Aboriginal community provided input into the survey and assessment and has been afforded the opportunity to comment on the report about a cultural and social significance assessment of the sites recorded.

25.5.1 *Archaeological Potential*

Archaeological potential relates to the likelihood of discovering an Aboriginal object or site, within a location. Areas with archaeological potential were identified according to the definitions in *Table 25.43.*

Table 25.3 Definitions of Archaeological Potential

Rank	Definition	Example
No potential	Artefacts cannot occur in-situ.	Eroded landforms, reconstructed landscapes, hazardous landscape, developed areas.
Low potential	Artefacts are not normally found in comparable contexts but could occur in low densities making detection unlikely.	Landforms with no specific focus for use, ie with no water sources or undifferentiated slopes.
Moderate potential	Artefacts are known to occur in comparable landforms in detectable densities (~1 artefact/m^2) and there is an unknown possibility for detection.	Landforms with an environmental focus which may have seen seasonal visitation.
High potential	Artefacts are consistently found in comparable landforms or similar environmental contexts and thus will certainly be found in any ground breaking works.	Landforms with known environmental focus encouraging repeat visitation to specific locale, ie margins of swamp or near high order creeks.



Legend

- Project Application Area
- Study Area - Wonga West
- Proposed Longwalls
- Proposed Bulli Seam first workings
- Proposed Balgownie Seam first workings
- 1st order stream
- 2nd order stream
- 3rd order stream
- 4th order and above stream
- Identified Heritage Site (ERM 2009)
- Relocated AHIMS Site (ERM 2009)

AHIMS Site Type

- Axe Grinding Groove
- Axe Grinding Groove, Shelter with Art
- Axe Grinding Groove, Shelter with Deposit
- Shelter with Art
- Shelter with Art, Shelter with Deposit
- Shelter with Deposit

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No. 1 Colliery EAR Post Adequacy 2012 Ecological Assessment
Drawing No:	0079383s_EARPA2012_GIS014_R0.mxd
Date:	13/09/2012 Drawing size: A4
Drawn by:	SQW Reviewed by: MK
Scale:	Refer to Scale Bar

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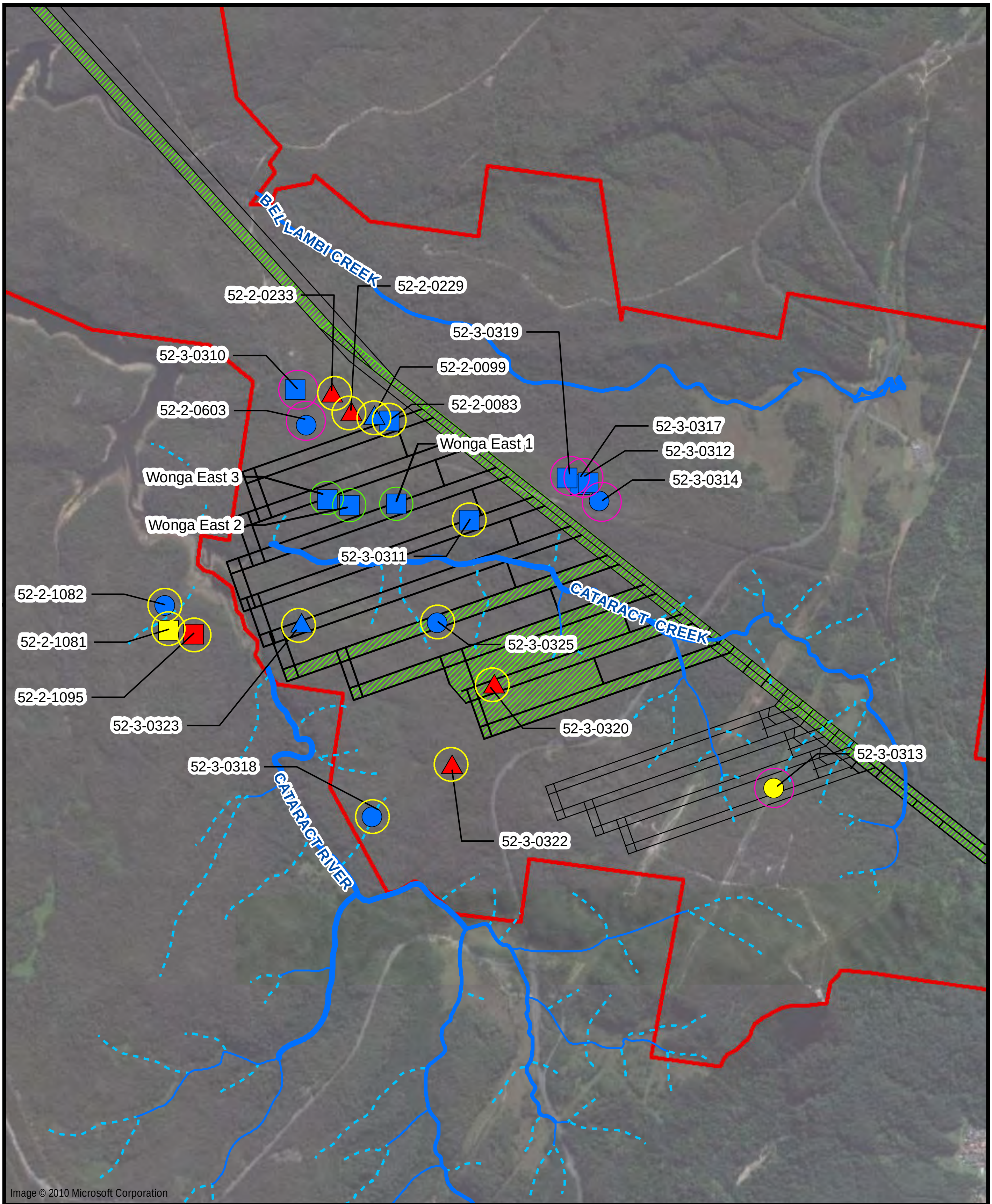
Figure 25.4

Archaeological sites relocated and identified in the Wonga West study area

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM



Legend

- Project Application Area
- Study Area - Wonga East
- Approved Workings (MP10_0046)
- Proposed Longwalls
- 1st order stream
- 2nd order stream
- 3rd order stream
- 4th order and above stream

AHIMS Site Type

- Axe Grinding Groove
- Axe Grinding Groove, Shelter with Art, Shelter with Deposit
- Open Camp Site
- Shelter with Art
- Shelter with Deposit
- Relocated AHIMS Site (Biosis 2012)
- Relocated AHIMS Site (ERM 2009)
- New AHIMS Site (Biosis 2012)

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No.1 Colliery Environmental Assessment
Drawing No:	0079383s_EARPA2012_GIS015_R0.mxd
Date:	09/11/2012 Drawing size: A4
Drawn by:	KB Reviewed by: MK
Scale:	Refer to Scale Bar

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Figure 25.5

Archaeological sites relocated and identified in the Wonga East study area

Environmental Resources Management Australia Pty Ltd

Brisbane, Canberra, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM

25.5.2 *Archaeological Potential*

Archaeological potential relates to the likelihood of discovering an Aboriginal object or site, within a location. Areas with archaeological potential were identified according to the definitions in *Table 25.4.*

Table 25.4 Definitions of Archaeological Potential

Rank	Definition	Example
No potential	Artefacts cannot occur in-situ.	Eroded landforms, reconstructed landscapes, hazardous landscape, developed areas.
Low potential	Artefacts are not normally found in comparable contexts but could occur in low densities making detection unlikely.	Landforms with no specific focus for use, ie with no water sources or undifferentiated slopes.
Moderate potential	Artefacts are known to occur in comparable landforms in detectable densities (~1 artefact/m^2) and there is an unknown possibility for detection.	Landforms with an environmental focus which may have seen seasonal visitation.
High potential	Artefacts are consistently found in comparable landforms or similar environmental contexts and thus will certainly be found in any ground breaking works.	Landforms with known environmental focus encouraging repeat visitation to specific locale, ie margins of swamp or near high order creeks.

25.5.3 *Scientific Significance Assessment*

There are seven key criteria which may be used to examine the scientific value/significance of a site. These are listed in *Table 25.5*.

Table 25.5 Scientific significance criteria

Criteria	Definition
Rarity	Whether any or all aspects of a site can be considered common or rare within a local, regional or national context.
Representativeness	The comparative rarity of the site when considered and contrasted against other similar sites conserved at the local and/or regional level.
Archaeological landscapes	The study of the cultural sites relating to Aboriginal peoples within the context of their interactions in the wider social and natural environment they inhabited.
Connectedness	Whether the site can be connected to other sites at the local or regional level.
Integrity and condition	Integrity refers to the level of modification a site has been subject to (the cultural and natural formation process) and whether the site could yield intact archaeological deposits. Condition takes into account the state of the material.
Complexity	The demonstrated or potential ability of a site to yield a complex assemblage and/or features.
Archaeological potential	The potential to yield information that will contribute to an understanding of contemporary archaeological interest, or which could be saved for future research potential.

25.6 *STATEMENT OF HERITAGE SIGNIFICANCE*

Fifty AHIMS listed sites and six new Aboriginal cultural heritage sites have been identified as occurring within the Study Areas. A statement of heritage significance for each archaeological site is provided is *Annex U*. *Table 25.6* provides a summary of the scientific and cultural significance assessment for all sites within the Study Areas.

No significant or moderate changes were observed to the relocated sites during the survey. All relocated sites were in generally the same condition as described on the original site card. It has therefore been assumed that sites that could not be relocated will be in generally the same condition as described on the original site card. The significance and impact assessment for the non relocated sites are therefore based on the information recorded on the AHIMS site cards.

Table 25.6 Summary of Significance Assessment

AHIMS Site Number	Context	Archaeological potential	Scientific significance[1]	Aboriginal social significance[2]
Wong West				
52-2-1071	Open site	None	Low	High
52-2-1076	Enclosed Shelter	Moderate	High	High
52-2-1077	Enclosed Shelter	Moderate	High	High
52-2-1079	Open site	None	Moderate	High
52-2-1094	Enclosed Shelter	High	High	High
52-2-1096	Enclosed Shelter	High	High	High
52-2-1097	Enclosed Shelter	High	High	High
52-2-1098	Open site	Moderate	Moderate	High
52-2-1099	Enclosed Shelter	Low	Moderate	High
52-2-1181	Enclosed Shelter	Moderate	Moderate	High
52-2-1182	Enclosed Shelter	Moderate	Low	High
52-2-1183	Enclosed Shelter	High	High	High
52-2-1184	Enclosed Shelter	Low	Low	High
52-2-1186	Enclosed Shelter	Moderate	Moderate	High
52-2-1187	Enclosed Shelter	Moderate	High	High
52-2-1188	Enclosed Shelter	Low	Low	High
52-2-1189	Enclosed Shelter	Low	Low	High
52-2-1191	Open Site	Low	Low	High
52-2-1192	Enclosed Shelter	Low	Low	High
52-2-1195	Enclosed Shelter	Low	Low	High
52-2-1196	Open Site	Low	Low	High
52-2-1197	Open Site	None	Low	High
52-2-1198	Enclosed Shelter	High	High	High
52-2-1224	Open Site	None	Low	High
52-2-1225	Enclosed Shelter	Low	Low	High
52-2-1248	Open Site	None	Low	High
52-2-1223	Enclosed Shelter	Moderate	Moderate	High
52-2-1249	Enclosed Shelter	Moderate	High	High
52-2-1250	Open Site	None	Low	High
52-2-1251	Open Site	None	Low	High
New LC1	Enclosed Shelter	Moderate	Moderate	High
New NRE	Open Site	None	High	High

AHIMS Site Number	Context	Archaeological potential	Scientific significance[1]	Aboriginal social significance[2]
Women's Site				
New NRE Scarred Tree	Open Site	None	Low	High
Wonga East				
52-2-0083	Enclosed Shelter	Moderate	Moderate	High
52-2-0099	Enclosed Shelter	None	Low	High
52-2-0229	Open site	None	Low	High
52-2-0233	Open site	None	Low	High
52-2-0603	Enclosed Shelter	Low	Low	High
52-2-1081	Enclosed Shelter	Moderate	Moderate	High
52-2-1082	Enclosed Shelter	Moderate	Moderate	High
52-2-1095	Enclosed Shelter	High	High	High
52-3-0310	Enclosed Shelter	High	High	High
52-3-0311	Enclosed Shelter	High	Moderate	High
52-3-0312	Enclosed Shelter	High	Moderate	High
52-3-0313	Open Site	Low	Low	High
52-3-0314	Enclosed Shelter	Moderate	High	High
52-3-0317	Enclosed Shelter	Moderate	Moderate	High
52-3-0318	Enclosed Shelter	Moderate	Moderate	High
52-3-0319	Enclosed Shelter	Moderate	Moderate	High
52-3-0320	Open Site	None	Low	High
52-3-0322	Open Site	None	Low	High
52-3-0323	Enclosed Shelter	Moderate	Moderate	High
52-3-0325	Enclosed Shelter	Moderate	Moderate	High
Wonga East 1	Enclosed Shelter	High	Moderate	High
Wonga East 2	Enclosed Shelter	High	Moderate	High
Wonga East 3	Enclosed Shelter	High	Moderate	High

1. For non- relocated sites the scientific significance was determined from the condition described in the AHIMs site card (see *Section 25.6).*
2. Derived from discussion with local Aboriginal community representatives in relation to site types identified.

25.7 *IMPACT ASSESSMENT*

Seedsman (2012) provides predicted subsidence, tilt and strain parameters for Wonga East and Wonga West. The potential subsidence footprint is defined as the area where subsidence is predicted to be greater than 20 mm.

The following impact assessment is based on the predications made by Seedsman (2012).

OEH have previously provided comment regarding the protection of Aboriginal Cultural Heritage features. In particular OEH advise that the performance measures for Aboriginal cultural heritage need to be aligned with the Bulli PAC recommendations and that in particular this should include the quantification of potential impacts to Aboriginal cultural heritage as a result of mining. The survey methodology and field work for this assessment was completed prior to the release of the Bulli PAC. As such, a commitment has been made that additional monitoring and risk assessment in accordance with the Bulli PAC, for sites particularly within the predicted subsidence footprint will be undertaken prior to LW mining relevant Longwalls.

25.7.1 *Consequences of Subsidence on Aboriginal Sites*

The following discussion provides an assessment of the potential impacts of mining on Aboriginal heritage site types recorded within the Study Area. It should be noted that different effects of subsidence have the potential to impact on heritage sites different ways.

Rock shelters may be adversely affected by cracking, movement along joints or bedding planes, by block fall and by water seepage. All these impacts may directly affect the stability of the shelter and consequentially any rock art within a shelter.

Impacts arising from valley closure can put additional strain on the cliff tops, which may cause consequential strain on any rock shelters present beneath the upper most landforms. Grinding grooves can be affected by upsidence only where they are located at or near the valley floor and thereby causing cracking as well as cracking from strain.

Artefact scatters can be indirectly impacted by tilt, causing rain water to run off in differing ways resulting in increased levels of erosion. Artefact scatters are the least likely Aboriginal site type to be impacted by mining subsidence (DoP 2008b).

25.7.2 *Sites within the Potential Subsidence Footprint*

All sites within the Study Area were considered in the Aboriginal heritage assessment. However, only 21 of these sites are within the potential subsidence footprint (as predicted by Seedsman 2012*). Figure 25.6* and *Figure 25.7* illustrate sites which are located within the potential subsidence footprint.

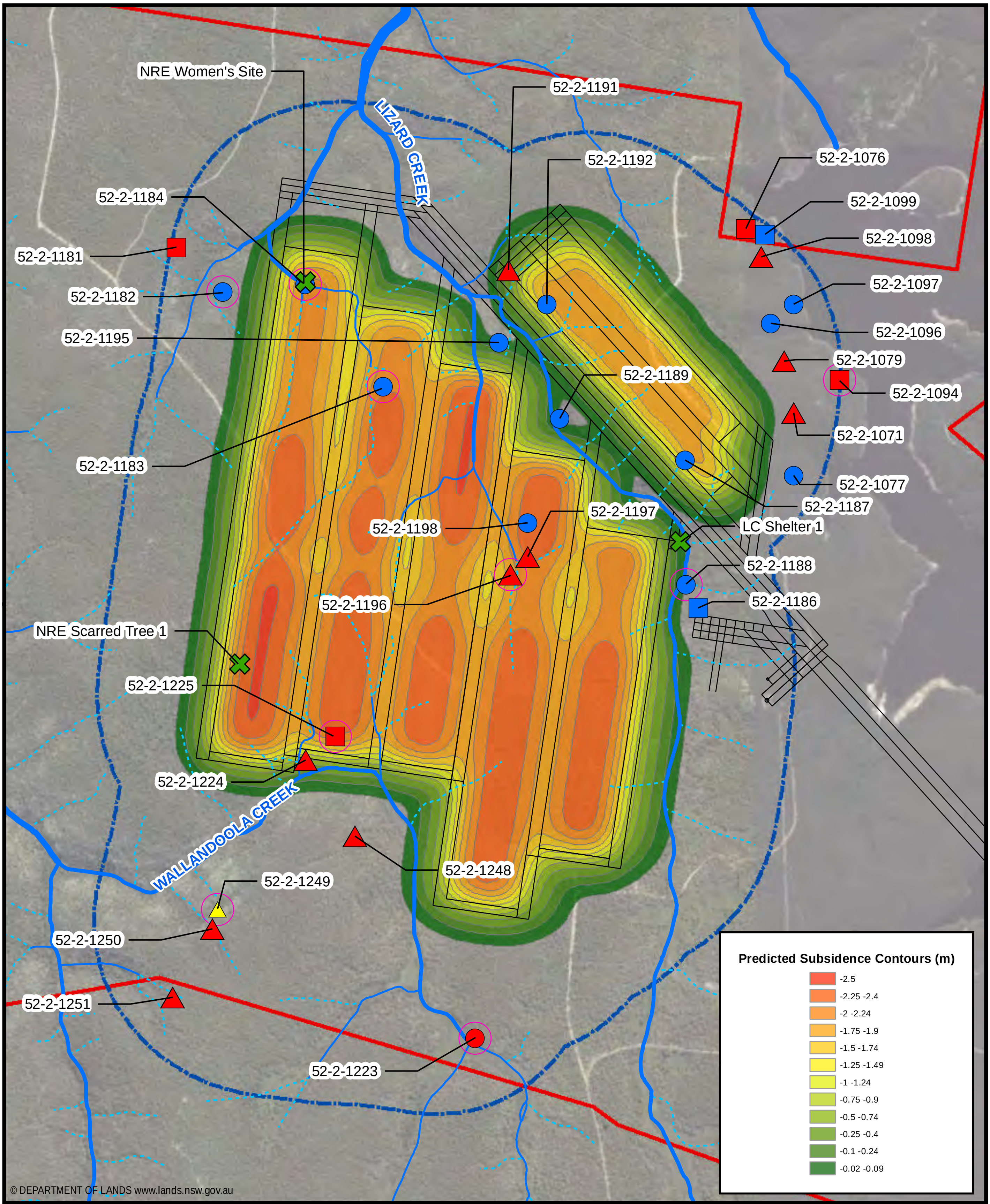
The impact assessment has focused on the sites within the potential subsidence footprint. There are 15 sites within the Wonga West area and six sites within the Wonga East area that are within the potential subsidence footprint.

25.7.3 *Predicted Impacts to Sites*

The predicted subsidence, strain and tilt at each Aboriginal site within the potential subsidence footprint have been inferred from visualisations of Seedsman (2012) subsidence predictions. This information along with the size of the rock shelter and the placement of the site in relation to the goaf (factors identified as relevant by Sefton 2000) have been allocated a scaling in order to quantify the likelihood of impacts to the Aboriginal sites within the predicted subsidence footprint. The scaling is presented in *Table 25.7.*

Table 25.7 Impact Likelihood Factors Scaling

Risk Factor	Low	Medium	High
Subsidence	0-1000mm	1001-2000mm	2001+mm
Tilt	0-9mm/m	10-19mm/m	20+mm/m
Strain (+ or -)	0-9mm/m	10-19mm/m	20+mm/m
Size of Overhang	less 50m^3		Over 50m^3
Over Goaf	No		Yes



Legend

- Project Application Area
- Study Area - Wonga West
- Subsidence Footprint
- 1st order stream
- 2nd order stream
- 3rd order stream
- 4th order and above stream
- Identified Heritage Site (ERM 2009)
- Relocated AHIMS Site (ERM 2009)

AHIMS Site Type

- Axe Grinding Groove
- Axe Grinding Groove, Shelter with Art
- Axe Grinding Groove, Shelter with Deposit
- Shelter with Art
- Shelter with Art, Shelter with Deposit
- Shelter with Deposit

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No. 1 Colliery EAR Post Adequacy 2012 Environmental Assessment
Drawing No:	0079383s_EARPA2012_GIS016_R0.mxd
Date:	18/10/2012 — Drawing size: A4
Drawn by:	SQW — Reviewed by: MK
Scale:	Refer to Scale Bar

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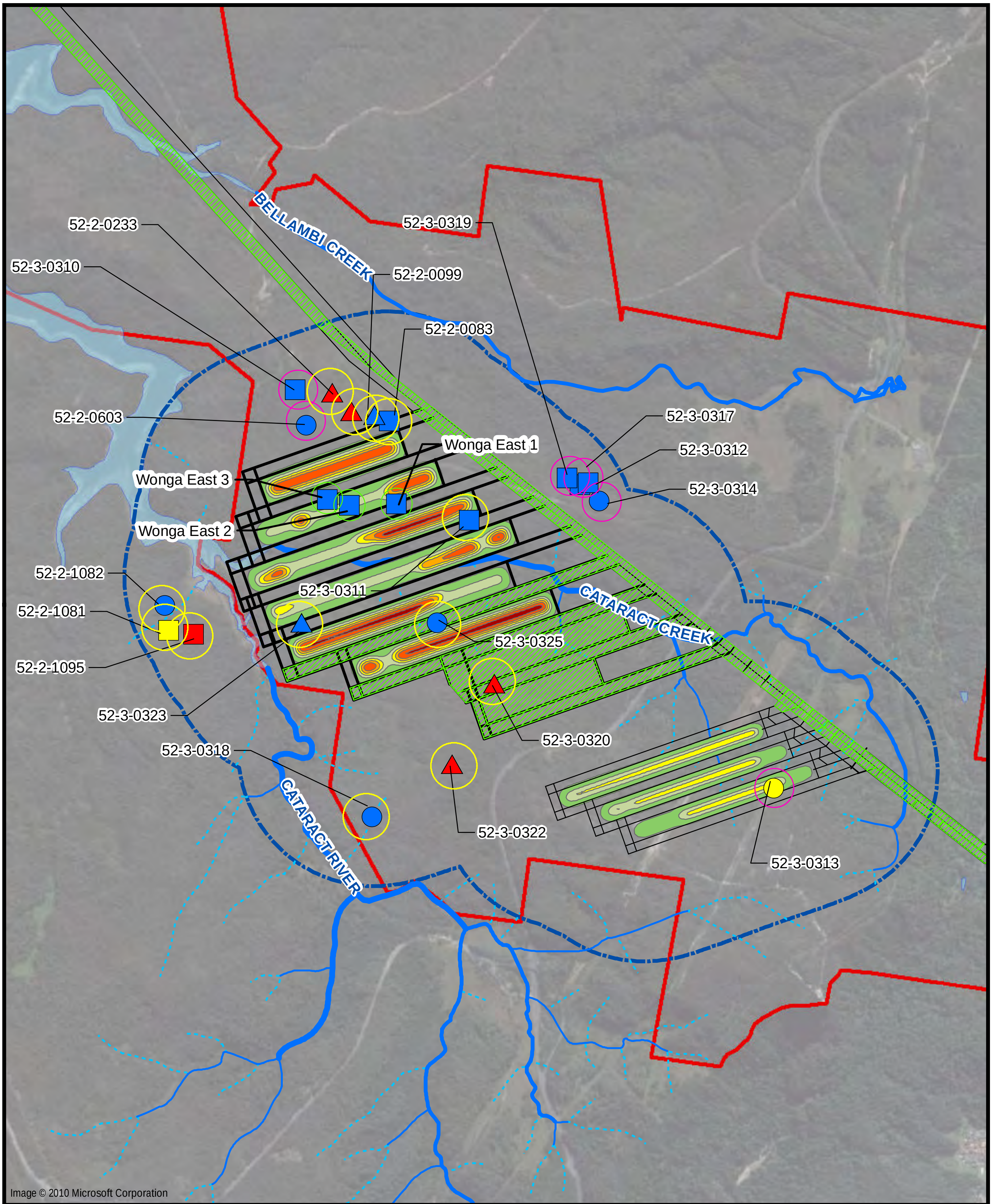
Figure 25.6

Archaeological sites located within the Wonga West subsidence footprint

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM



Legend

- Project Application Area
- Approved Workings (MP10_0046)
- Study Area - Wonga East

AHIMS Site Type

- Axe Grinding Groove
- Axe Grinding Groove, Shelter with Art, Shelter with Deposit
- Open Camp Site
- Shelter with Art
- Shelter with Deposit
- Relocated AHIMS Site (Biosis 2012)
- Relocated AHIMS Site (ERM 2009)
- New AHIMS Site (Biosis 2012)

- 1st order stream
- 2nd order stream
- 3rd order stream
- 4th order and above stream

Predicted Subsidence Contour (m) (Seedsman 2012)

- -0.02 -0.19
- -0.2 -0.39
- -0.4 -0.59
- -0.6 -0.79
- -0.8 -0.99
- -1.0 -1.2

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No.1 Colliery Environmental Assessment
Drawing No:	0079383s_EARPA2012_GIS017_R0.mxd
Date:	28/11/2012 Drawing size: A4
Drawn by:	KB Reviewed by: MK
Scale:	Refer to Scale Bar

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Figure 25.7

Archaeological sites located within the Wonga East subsidence footprint

Environmental Resources Management Australia Pty Ltd

Brisbane, Canberra, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

Three levels of likelihood have been allocated to each risk factor. This information has been applied to each site to determine the impact risk. The results are presented in *Table 25.8*

Note that not all factors have been given the same weight. A higher weight has been applied to sites located over the goaf. The matrix used to determine the potential impact risk is presented in *Annex U.*

There are five levels of impact risk likelihood:

- high, where the potential impact risk to the site is likely;
- moderate, where the potential impact risk to the site is possible;
- low, where there is limited potential impact risk;
- very low, where potential impact risk is unlikely; and
- negligible, where potential impacts are not predicted to affect the site.

A moderate impact risk is the highest level recorded in this assessment.

Table 25.8 Impact Risk

AHIMS Site Number	Relocated	Subsidence (mm)	Final Tilt (mm/m)	Final Strain (mm/m)	Size of overhang	Over Goaf[1]	Impact Risk
Wonga West							
52-2-1183	Yes	2200 (H)	2 (L)	-3 (L)	$79m^3$ (H)	Yes (H)	Moderate
52-2-1184	Yes	1920 (M)	3 (L)	-4 (L)	$4m^3$ (L)	Yes (H)	Moderate
52-2-1187	No	1500 (M)	8 (L)	-6 (L)	$20m^3$ (L)	Yes (H)	Moderate
52-2-1189	No	20 (L)	0.9 (L)	1 (L)	$16.m^2$ (L)	No (L)	Negligible
52-2-1191	No	400 (L)	6 (L)	3.5 (L)	NA (L)	No (L)	Negligible
52-2-1192	No	1700 (M)	8 (L)	-5(L)	$18m^3$ (L)	Yes (H)	Moderate
52-2-1195	No	500 (L)	1.5 (L)	3 (L)	$54m^3$ (H)	No (L)	Very Low
52-2-1196	Yes	1800 (M)	4 (L)	-2(L)	NA (L)	Yes (H)	Moderate
52-2-1197	No	2250 (H)	3 (L)	-2.5(L)	NA (L)	Yes (H)	Moderate
52-2-1198	No	2300 (H)	2 (L)	-2.5(L)	$15m^3$(L)	Yes (H)	Moderate
52-2-1224	No	700 (L)	8 (L)	4(L)	NA(L)	No (L)	Negligible
52-2-1225	Yes	2200 (H)	6 (L)	-6(L)	$72m^3$(H)	Yes (H)	Moderate
New LC1	Yes	25 (L)	1.5 (L)	2 (L)	$81m^3$ (H)	No (L)	Very Low
New NRE Women's Site	Yes	500 (L)	16 (M)	5 (L)	NA(L)	Yes (H)	Moderate
New NRE Scarred Tree	Yes	1920 (M)	3 (L)	-4 (L)	NA(L)	Yes(H)	Moderate

AHIMS Site Number	Relocated	Subsidence (mm)	Final Tilt (mm/m)	Final Strain (mm/m)	Size of overhang	Over Goaf[1]	Impact Risk
Wonga East							
52-2-0083	No	20 (L)	0.5 (L)	0.5 (L)	5.6m³(L)	Yes (H)	Moderate
52-3-0311	No	110 (L)	0.5 (L)	0.5 (L)	62m³(H)	Yes (H)	Moderate
52-3-0313	Yes	130 (L)	1 (L)	-0.5 (L)	NA (L)	Yes (H)	Moderate
52-3-0320	No	500 (L)	6.5 (L)	2 (L)	NA (L)	Yes (H)	Moderate
52-3-0322	No	25 (L)	0.75 (L)	0.5 (L)	NA (L)	No (L)	Negligible
52-3-0323	No	50 (L)	0.75 (L)	0.5 (L)	63m³ (H)	No (L)	Very Low
52-3-0325	No	700 (L)	2 (L)	5.5 (L)	9m³ (L)	Yes (H)	Moderate

1. For sites that have not been relocated the location has been determined using the co-ordinates provided on the AHIMs site card which may be inaccurate. The location of re-located sites can be accurately stated.

25.7.4 *Rating the Impact Assessment*

In order to rank the level of potential impact to each Aboriginal site, an impact assessment score has been prepared. The impact assessment score combines, by summation, impact risk (as determined in *Table 25.8*) and the scientific significance of the site (as summarised in *Table 25.6*).

The impact assessment values listed in *Table 25.9* have been applied to generate the impact assessment scores listed in *Table 25.10* for Aboriginal features within the predicted subsidence footprint.

Table 25.9 Impact Assessment Values

Impact Risk	Value	Scientific significance	Value
High	1	High	1
Moderate	2	High/moderate	2
Low	3	Moderate	3
Very low	4	low	4
Negligible	5		

Table 25.10 Impact Assessment Score

AHIMS Site Number	Site Type	Impact Risk	Scientific significance	Impact Assessment Score
Wonga West				
2-2-1183	Shelter with Art	Moderate	High	3
52-2-1184	Shelter with Art	Moderate	Low	6
52-2-1187	Shelter with Art	Moderate	High	3
52-2-1189	Shelter with Art	Negligible	Low	9
52-2-1191	Axe grinding grooves	Negligible	Low	9
52-2-1192	Shelter with Art	Moderate	Low	6
52-2-1195	Shelter with Art	Very Low	Low	8
52-2-1196	Axe grinding grooves	Moderate	Low	6

AHIMS Site Number	Site Type	Impact Risk	Scientific significance	Impact Assessment Score
52-2-1197	Axe grinding grooves	Moderate	Low	6
52-2-1198	Shelter with Art	Moderate	High	3
52-2-1224	Axe grinding grooves	Negligible	Low	9
52-2-1225	Shelter with Art and Deposit	High	Low	5
New LC1	Shelter with Art	Very Low	Moderate	7
New NRE Women's Site	Water Hole with Aboriginal Ceremony and Dreaming	Moderate	High	3
New NRE Scarred Tree	Scarred Tree	Moderate	Low	6
Wonga East				
52-3-0311	Shelter with Deposit	Moderate	Moderate	5
52-3-0313	Artefact Scatter	Moderate	Low	6
52-3-0320	Axe grinding grooves	Moderate	Low	6
Wonga East 1	Shelter with deposit	Moderate	Moderate	5
Wonga East 2	Shelter with deposit	Moderate	Moderate	5
Wonga East 3	Shelter with deposit	Very Low	Moderate	7

AHIMS Site Number	Site Type	Impact Risk	Scientific significance	Impact Assessment Score
Wonga West				
2-2-1183	Shelter with Art	Moderate	High	3
52-2-1184	Shelter with Art	Moderate	Low	6
52-2-1187	Shelter with Art	Moderate	High	3
52-2-1189	Shelter with Art	Negligible	Low	9
52-2-1191	Axe grinding grooves	Negligible	Low	9
52-2-1192	Shelter with Art	Moderate	Low	6
52-2-1195	Shelter with Art	Very Low	Low	8
52-2-1196	Axe grinding grooves	Moderate	Low	6
52-2-1197	Axe grinding grooves	Moderate	Low	6
52-2-1198	Shelter with Art	Moderate	High	3
52-2-1224	Axe grinding grooves	Negligible	Low	9
52-2-1225	Shelter with Art and Deposit	High	Low	5
New LC1	Shelter with Art	Very Low	Moderate	7
New NRE Women's Site	Water Hole with Aboriginal Ceremony and Dreaming	Moderate	High	3
New NRE Scarred Tree	Scarred Tree	Moderate	Low	6
Wonga East				
52-3-0311	Shelter with Deposit	Moderate	Moderate	5
52-3-0313	Artefact Scatter	Moderate	Low	6
52-3-0320	Axe grinding grooves	Moderate	Low	6
Wonga East 1	Shelter with deposit	Moderate	Moderate	5
Wonga East 2	Shelter with deposit	Moderate	Moderate	5
Wonga East 3	Shelter with deposit	Very Low	Moderate	7

The impact assessment scores are between 3 and 9; where 3 is a moderate risk to a highly significant site and 9 is a negligible risk to a low significance site. Sites with an impact assessment score between 2 and 5 need to be actively managed.

25.8 *MANAGEMENT AND MITIGATION MEASURES*

OEH have previously provided comments regarding the protection of Aboriginal Cultural Heritage features that the performance measures for Aboriginal cultural heritage be aligned with the Bulli Seam Project PAC recommendations. Further, OEH has previously advised that any monitoring programme must include any Aboriginal objects that may be impacted by mining activities and that the mining footprint for these purposes includes the maximum extent of predicted subsidence.

25.8.1 *Strategy - Avoidance*

The focus of mine planning was to eliminate subsidence risks where possible by avoiding significant environmental features including Aboriginal heritage sites.

The iterative mine planning process involved consideration of longwall options in light of archaeological constraints, in order to avoid impact to areas of high conservation value. A number of surface features of special significance above the proposed mining area were identified through the risk management workshop process and NRE has decided to not undertake longwall extraction under these features (Olsen, 2009).

The proposed mine plans have where possible avoided longwall extraction directly under third and fourth order creeks with the exception of an unnamed tributary of Lizard Creek and a portion of Cataract Creek. This approach has enabled a large number of significant Aboriginal sites to be avoided, particularly those sites located adjacent to Cataract Dam.

There are 56 Aboriginal archaeological sites recorded within Study Area comprising 12 sites of high scientific significance, 20 sites of moderate scientific significance and 24 sites of low significance. The avoidance strategy has ensured that 35 of these sites are not within the potential subsidence footprint. Eight high significance sites, 15 moderate significance sites and 12 of the low significance sites have been avoided.

25.8.2 *Strategy – Monitoring*

Twenty one sites are within the potential subsidence footprint.

In Wonga West there are 15 sites within the potential subsidence footprint including:

- three rock shelters with high significance (52-2-1183 , 52-2-1187 and 52-2-1198);
- one rock shelters with moderate significance (New NRE Rock Shelter 1);
- five rock shelters with low significance (52-2-1184, 52-2-1189, 52-2-1192, 52-2-1195 and 52-2-1225);
- four axe grinding grooves with low significance (52-2-1191, 52-2-1196, 52-2-1197 and 52-2-1224);
- one women's site with high significance (New NRE Women's Site); and
- one scarred tree with low significance (New NRE Scarred Tree).

In Wonga East there are six sites within the potential subsidence footprint. These include:

- four rock shelters with moderate significance (52-3-0311, Wonga East 1, Wonga East 2 & Wonga East 3);
- one axe grinding grooves with low significance (52-3-0320); and
- one artefact scatter with low significance (52-3-0313).

Four of these sites are of high archaeological significance and five sites are of moderate archaeological significance.

NRE have committed that where high or moderately significant sites within the envelope defined by a 600m barrier around the mining footprint at Wonga East and Wonga West are at moderate or high risk they will be actively managed and monitored throughout and following the mining period.

There are five site types present within the potential subsidence footprint. These are axe grinding grooves, artefact scatters, scarred trees, water holes and rock shelters. These will be managed in different ways as the subsidence will impact these sites in different ways.

Open Sites

Axe grinding grooves and artefact scatter sites within the potential subsidence footprint have an impact assessment score of 7 or more and are therefore at a low or very low risk from mine related subsidence. Where relocation of these sites is able to be achieved, monitoring will involve visual inspection and update to the AHIMS site card pre and post mining.

The scarred tree has an impact assessment score of six and therefore is unlikely to be adversely impacted by the project. It requires no further management or mitigation.

The women's site has a score of three and requires further management. Consultation will continue with female elders regarding the management of this site. It is recommended that this site be photographically recorded and plans drawn, prior to mining. The women's site will be included in a monitoring program developed in consultation with the female elders as this site may be sensitive and may be taboo for males to visit.

Enclosed Sites

Seven enclosed (shelter) sites will be monitored; these are 52-2-1183, 52-2-1187, 52-2-1198 and 52-2-1225 in the Wonga West Study Area; and 52-3-0311 Wonga East 1 and Wonga East 2 in the Wonga East Study Area.

The monitoring program will include monitoring in line with Sefton's (2000) program. All seven shelters will be subject to monitoring at the following times:

- pre mining;
- three months after mining beneath the shelter;

- six months after mining beneath the shelter; and
- post mining.

Archival photographic recording of the three Wonga West sites with high significance (52-2-1183, 52-2-1187 and 52-2-1198) will be undertaken in conjunction with the initial pre mining monitoring. This will include:

- photographic recording of the art and the shelter in its entirety; and
- archival recording including sketch plans of the art and shelter.

This information will be produced in a report to be provided to NRE, and a copy given to OEH. The AHIMS site cards will be updated with the information.

If any of the sites show changes during the course of monitoring, additional management and mitigation measures will be determined on a case by case basis by a qualified archaeologist in consultation with an Aboriginal representative.

The remaining shelters in the potential subsidence footprint do not require monitoring. These shelters will be relocated if possible and monitored pre and post mining. The AHIMS site cards will be updated as the sites are located.

The monitoring of all the sites will be undertaken by a qualified archaeologist with the involvement of the Aboriginal community. As the rock shelters with art are of high significance, and the area in which they are found is not generally accessible to the Aboriginal community, sites officers from the Aboriginal community groups will be invited along to attend the monitoring inspection. This will provide sites officers with a teaching and learning experience regarding these cultural heritage sites

25.8.3 *Summary of Recommendations*

Table 25.11 provides a summary of the management recommendations for sites within the potential subsidence footprint.

Table 25.11 Management Measures for the Identified Aboriginal Sites

AHIMS Site Number	Site Type	Relocated during survey	Impact Assessment Score	Management Requirement
Wonga West				
52-2-1183	Shelter with Art	Yes	3	Monitoring and photographic archival recording with aboriginal sites officer. Update AHIMS Site card.
52-2-1184	Shelter with Art	Yes	6	Monitor pre and post mining with Aboriginal sites officers. Update AHIMS Site card.
52-2-1187	Shelter with Art	No	3	Relocate if possible. Monitoring and photographic archival recording with aboriginal sites officer. Update AHIMS Site card.

AHIMS Site Number	Site Type	Relocated during survey	Impact Assessment Score	Management Requirement
52-2-1189	Shelter with art	No	9	Relocate if possible. Monitoring pre and post mining with Aboriginal sites officers. Update AHIMS Site card.
52-2-1191	Axe grinding grooves	No	9	Relocate if possible. Visual inspection Pre & Post mining Update AHIMS site card.
52-2-1192	Shelter with Art	No	6	Relocate if possible. Monitoring pre and post mining with Aboriginal sites officers. Update AHIMS Site card.
52-2-1195	Shelter with Art	No	8	Relocate if possible. Monitoring pre and post mining with Aboriginal sites officer. Update AHIMS Site card.
52-2-1196	Axe grinding grooves	Yes	6	Visual inspection Pre & Post mining. Update AHIMS site card.
52-2-1197	Axe grinding grooves	No	6	Relocate if possible. Visual inspection Pre & Post mining. Update AHIMS site card.
52-2-1198	Shelter with Art	No	3	Relocate if possible. Monitoring and photographic archival recording with aboriginal sites officer. Update AHIMS Site card.
52-2-1224	Axe grinding grooves	No	9	Relocate if possible. Visual inspection Pre & Post mining. Update AHIMS site card.
52-2-1225	Shelter with Art and Deposit	Yes	5	Monitoring pre and post mining with Aboriginal sites officer. Update AHIMS Site card.
New LC1	Shelter with Art	Yes	7	Monitoring pre and post mining with Aboriginal sites officers. Update AHIMS Site card.
New NRE Women's Site	Water Hole with Aboriginal Ceremony and Dreaming	Yes	3	Monitoring programme to be established in consultation with the female elders. Update AHIMS site card.
New NRE Scarred Tree	Scarred Tree	Yes	6	Visual inspection Pre & Post mining and update AHIMS site card.
Wonga East				
52-3-0311	Shelter with Deposit	No	5	Relocate if possible. Monitoring and Update AHIMS Site card.
52-3-0313	Artefact Scatter	Yes	6	Visual inspection Pre & Post mining with aboriginal sites officer. Update AHIMS site card.
52-3-0320	Axe grinding grooves	No	6	Relocate if possible. Visual inspection Pre & Post mining with aboriginal sites officer. Update AHIMS site card.

AHIMS Site Number	Site Type	Relocated during survey	Impact Assessment Score	Management Requirement
Wonga East 1	Shelter with Deposit	No	5	Relocate if possible Monitoring pre and post mining with Aboriginal sites officers. Update AHIMS Site card.
Wonga East 2	Shelter with Deposit	No	5	Relocate if possible Monitoring pre and post mining with Aboriginal sites officers. Update AHIMS Site card
Wonga East 3	Shelter with Deposit	No	7	Relocate if possible. Visual inspection Pre & Post mining. Update AHIMS site card.

26 *CLIFFS AND STEEP SLOPES*

This chapter summarises the potential subsidence consequences on cliffs and steep slopes within the Study Area.

26.1 *INTRODUCTION*

The Bulli PAC (2010) made several recommendations in relation to the assessment of impacts on cliffs and steep slopes. The first recommendation was that a hierarchy of mining-induced consequences on cliffs be established as follows:

"i. nil environmental consequences – where nil has the meaning of none whatsoever;

ii. negligible environmental consequences - where negligible has the meaning ascribed in the Metropolitan Coal Project Approval of small and unimportant so as not to be worth considering. Occasional displacement of boulders, hairline fracturing and isolated dislodgement of slabs from overhangs that in total do not impact on more than 0.5% of the total length of a cliff line are indicative of the scale of impacts falling within this category; and

iii. minor environmental consequences – where minor has the meaning of relatively small in quantity, size and degree. Isolated rock falls of less than 30m^3 that do not impact on Aboriginal heritage, EECs, public safety and the like; which affect less than 5% of the total length of cliffs and associated overhangs; and which affect less than 10% of any 100m interval of cliff line are indicative of the scale of impacts falling within this category. "

The second recommendation was that cliffs having the following attributes are afforded *special significance* status:

"i. Cliffs longer than 200m;

ii. Cliffs higher than 40m;

iii. Cliffs higher than 5m that constitute waterfalls".

The third recommendation was that any approval be based on a Performance Criteria of *negligible* environmental consequences for all cliffs which have:

"i. special significance status; or which

ii. flank or are within streams that have been described in this report (Bulli PAC) as warranting special significance status.

That any approval be based on a Performance Criteria of minor environmental consequences for all other cliffs in the Study Area".

Impacts to cliff faces and steep slopes associated with the proposed project have been assessed by STC (2012b) in their letter report titled *Assessment of Mining Impacts on Cliffs and Steep Slopes for NRE No 1 Colliery Underground Expansion Project (MP 09_0013) Part 3A.* This document is included as *Annex V.*

26.2 *METHODOLOGY*

SCT (2012) assessment of Cliffs and Steep Slopes was based on the following methodology.

26.2.1 *Review of LiDAR Data*

An analysis was undertaken by Mine Subsidence Engineering Consultants (MSEC) of LiDAR information to provide slope gradients and the adjacent cliff formations to a 1m resolution. MSEC's LiDAR outputs are shown in *Figure 26.1* and *Figure 26.2.*

26.2.2 *Site Visits*

Wonga East

A site inspection of Wonga East was undertaken by SCT on 23 August 2012. The length of Cataract Creek was walked downstream of Mount Ousley Road to inspect adjacent cliff formations and steep slopes above the proposed Wonga East mining area.

Wonga West

A site inspection of Wonga West was undertaken by SCT on 13 September 2012. The length of the reach of Lizard Creek above the proposed Wonga West mining area was walked.

The inspection commenced at the waterfall on Lizard Creek and continued downstream to the intersection with Lizard Creek Tributary 2 (LCT2), to the north of the proposed mining area, and then south along Lizard Creek Tributary 1 (LCT1), located above proposed longwall A3 LW3, up to and including both branches of this tributary.

The cliffs and steep slopes on either side of these streams were inspected mainly from the valley floor with closer inspection of some of the larger cliffs. The waterfall on Wallandoola Creek was also inspected.

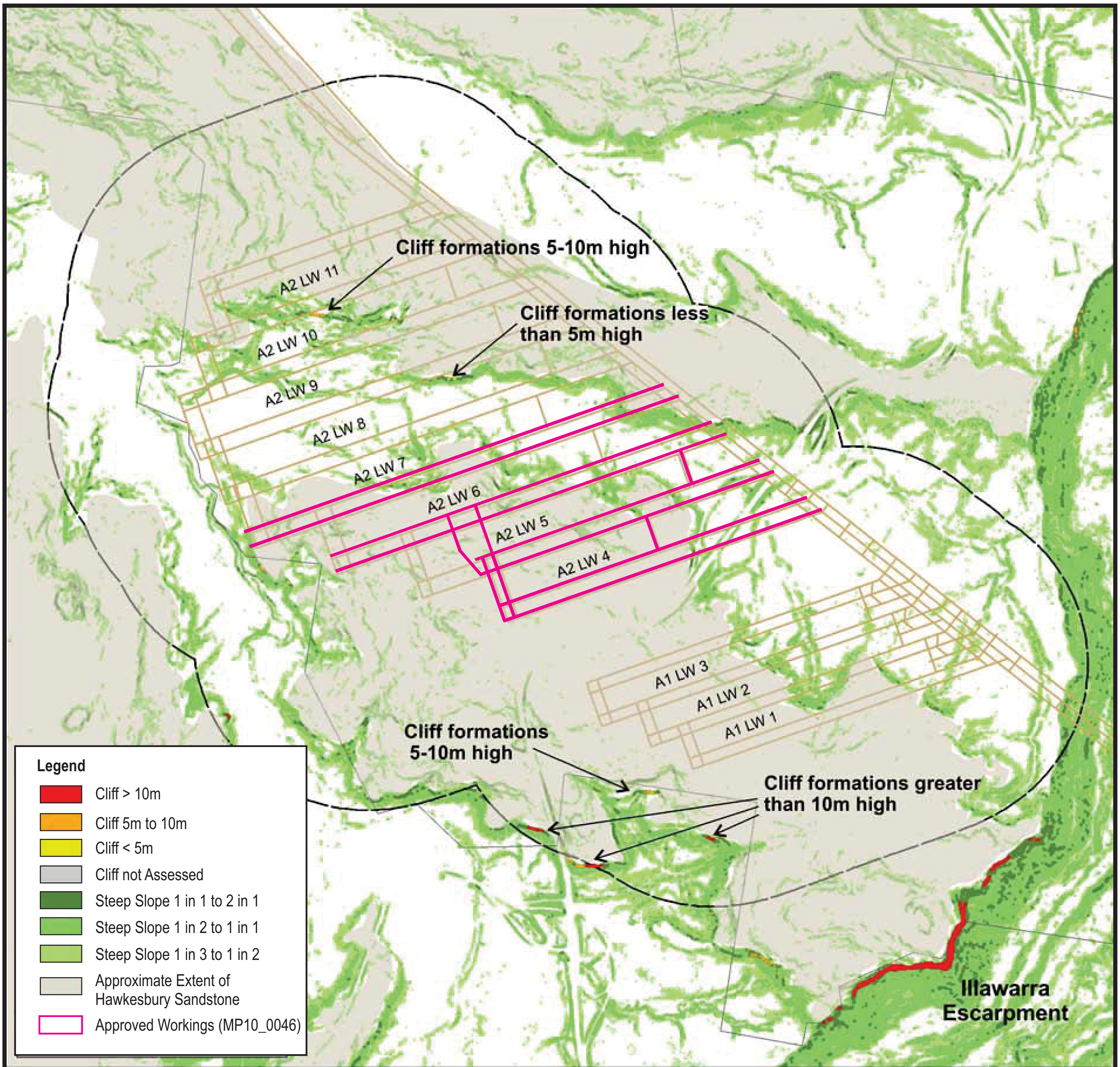
26.2.3 *Past Experience of Monitoring Subsidence Impacts on Cliff Formations*

SCT has studied the impacts of mining on sandstone cliff formations at various sites in the Western Coalfields of NSW and the Southern Coalfields of NSW. Findings from previous studies were examined and reviewed against the site conditions of the Wonga East and Wonga West area. These findings are provided in *Chapter 4* of *Annex V* and summarised in *Section 26.4.1*.

26.3 *EXISTING ENVIRONMENT*

26.3.1 *Wonga East*

Rock outcrops that are representative of the Wonga East area comprised of sandstone typically less than 20m in length. Features of the area include sections of overhang and isolated and toppled boulders. *Figure 2* in *Annex V* provides photographs of sandstone cliff formations typical of Wonga East area. The location of cliffs and steep slopes in Wonga East are shown on *Figure 26.1*.



Source:
SCT Operations Pty Ltd 2012 Fg1 and MSEC Dwg No.MSEC572-101, 11/07/2012

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No.1 Colliery Environmental Assessment
Drawing No:	0079383h_EARPA2012_C022_R1.cdr
Date:	07/02/2013 Drawing size: A4
Drawn by:	JD Reviewed by: NB
Scale:	Not To Scale

N

Maps and figures contained within this document may be based on third party data, may not be to scale and is intended for use as a guide only. ERM does not warrant the accuracy of any such maps or figures.

Figure 26.1

Cliffs and Steep Slopes in Wonga East

Environmental Resources Management Australia ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM

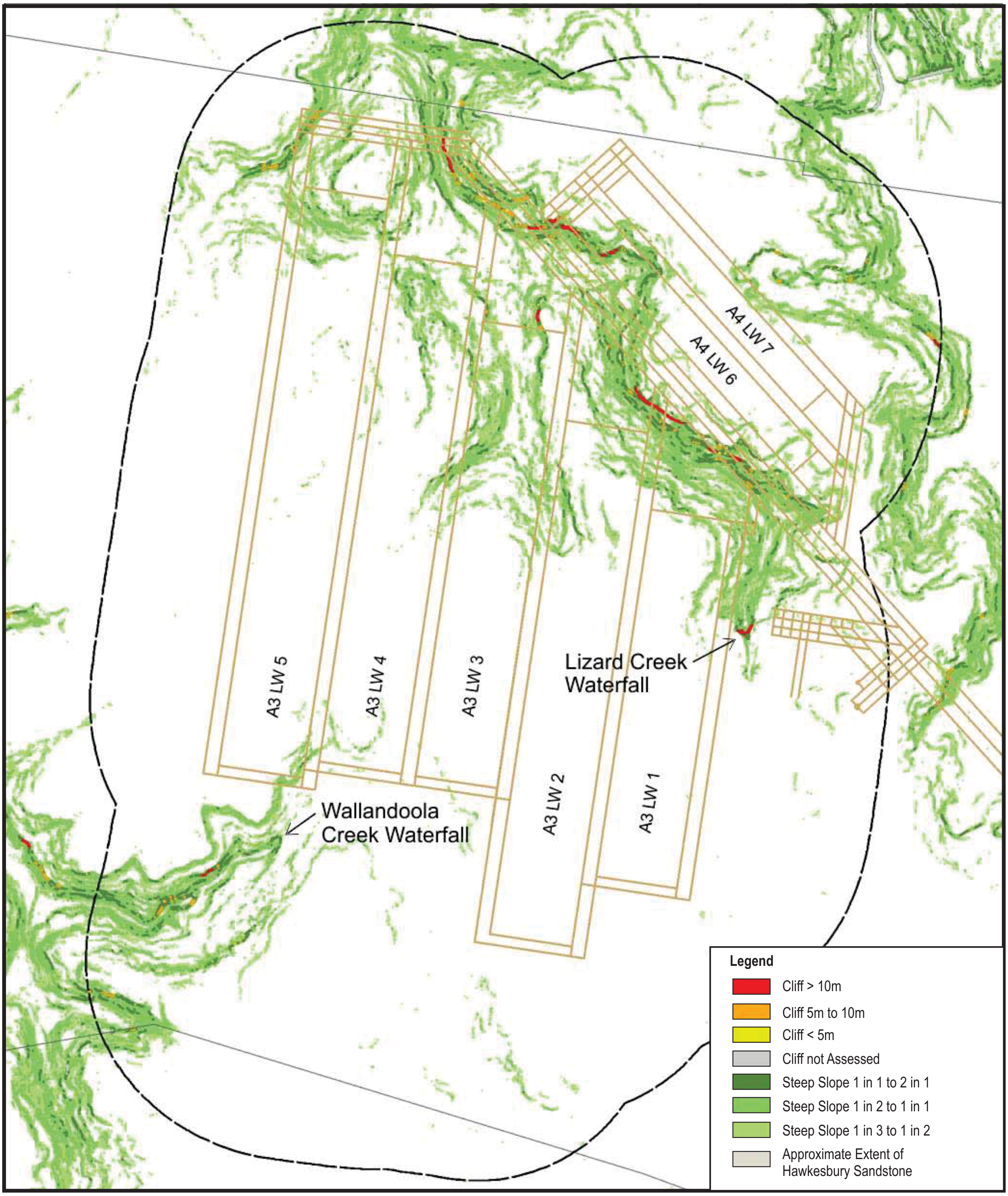


Figure 26.2

Cliffs and Steep Slopes in Wonga West

Client:	Gujarat NRE Coking Coal Limited
Project:	NRE No.1 Colliery Environmental Assessment
Drawing No:	0079383h_EARPA2012_C023_R1.cdr
Date:	07/02/2013 Drawing size: A4
Drawn by:	JD Reviewed by: NB
Scale:	Not To Scale

N

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Environmental Resources Management Australia ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM

Source:

SCT Operations Pty Ltd 2012 Fg3 and MSEC Dwg No.MSEC572-102, 11/07/2012

Cliff formations are typically less than a few metres high in this area within the vicinity of the longwall panels. Cliff formations up to five metres high and 30m in length occur above A2 LW8, while cliff formations between five and 10m in height and 50m in length occur above proposed longwall A2 LW10.

The Illawarra Escarpment is located 480m from the eastern corner of longwall A1 LW1, however at this point the cliffs have been completely eroded away. The nearest location of cliff formations that forms part of the Illawarra Escarpment is 780m from the proposed longwall panels. Cliff formations higher than 10m are located along the southern edge of the Hawkesbury Sandstone outcrop, 350 to 750m directly to the south of longwall A1 LW1. A smaller formation five to 10m high is located along a tributary to the Cataract River, approximately 250m to the south, south east of longwalls A1 LW1 and A1 LW2.

The site walk found evidence of minor rock falls at a sandstone outcrop considered likely to be caused from previous mining in the Balgownie seam. The impact of this rock fall was considered minor in relation to ongoing natural erosion. A search of the bushland above the historic Balgownie longwalls did not detect any evidence of surface cracking. Surface cracking of hard rock surfaces was observed above Wongawilli Seam longwall A2 LW4 near the start of the panel and it is understood that a further crack is evident on the northern subsidence line near the eastern edge of the panel as a result of mining subsequent to the site visit.

Based on observations during the site inspection impacts from previous mining of the Bulli and Balgownie Seams are considered to have been nil to negligible, using the assessment of significance detailed in NSW PAC (2010).

26.3.2 *Wonga West*

Wonga West surface is located entirely within Hawkesbury Sandstone strata and predominantly comprise gentle slopes with areas of steep slopes and tiers of small cliff formations located along stream channels, associated with down-cutting erosion, located downstream of the waterfalls on Lizard and Wallandoola Creeks and along Lizard Creek Tributary 1 (SCT 2012b). The location of cliffs and steep slopes in Wonga West are shown on *Figure 26.2*.

The only cliff formations located directly above the longwalls, that are individually higher than five metres, is a semi-continuous feature that extends for approximately 300m and reaches heights of just over 10m in short sections above the north western end of proposed longwall A4 LW6. This cliff extends for a further 700m over the main headings as a series of disconnected cliffs. These are mainly less than 10m high but there are several sections of greater than 10m (SCT 2012b).

A separate 300m long section of continuous cliff greater than 10m high is located on the north side of Lizard Creek over the main headings (Wonga Driveage) and approximately 120m from Longwall A3 LW2 and 200m from A4 LW6 (SCT 2012b). There are several similar features over other parts of the Wonga driveage. These are typically less than five metres high but, particularly alongside Lizard Creek, there are often several tiers of cliff formations that 'steep' up the slope (SCT 2012b).

Numerous steep slopes and smaller sandstone cliff formations are located along Lizard Creek Tributary 1, over the proposed longwall A3 LW3. These formations individually extend laterally for more than 20m. A 10 to 15m high cliff formation is located at the northern end of longwall A3 LW3. This cliff formation was previously undermined by longwall panels in the Bulli Seam without perceptible impact (SCT 2012b).

The cliff formation associated with Lizard Creek waterfall is greater than 10m high and extends approximately 100m. It is located 90m east of longwall A3 LW1.

The Wallandoola Creek waterfall is approximately five metres high and is located 280m south of longwall A3 LW5. The areas under both waterfalls have previously been mined from the Bulli Seam (SCT 2012b). Evidence of this impact is noted as physical disturbance, cracking and general iron staining of the water.

The site inspection identified iron staining and the development of a spring at the top of the Lizard Creek waterfall that was consistent with previous mining activity and the horizontal movements that would be expected to develop from valley closure (SCT 2012b). Surface cracking was identified in the adjacent rock formations to the Wallandoola Creek Waterfall (SCT 2012b).

Evidence of minor rock falls was observed adjacent to Lizard Creek however; it was uncertain whether previous mining in the area or natural events caused this. No large rock falls were observed.

Excluding impacts on the two waterfalls, impacts on cliff formations from previous mining in the area was considered to have been nil to negligible in the Wonga West area.

26.3.3 *Features of Special Significance*

The assessment identified three cliff features within the area likely to be affected by mining subsidence that are considered of special significance. They are:

- waterfall on Lizard Creek, approximately 20m high;
- waterfall on Wallandoola Creek, approximately 5m high; and
- 300m long line of cliff formations on the northern side of Lizard Creek but outside of the footprint of the proposed longwall panels.

All of the features of special significance occur in the Wonga West area (see *Figure 26.2*).

In addition to these, the line of cliff formations above longwall A4 LW6, that is semi-continuous over the panel and extends for approximately 700m to the north west of the panel, is considered 'border line' special significance, depending on how the length of cliff is defined. Although there is approximately 300m or so of the cliff line directly above the panel, the cliff line is discontinuous and isolated rock falls are not considered likely to be of high significance (SCT 2012b).

The Illawarra Escarpment, to the east of Wonga East mining domain, is also considered of special significance but is outside of the predicted impact area for subsidence, given its remoteness from the nearest longwall panel.

26.4 *PREDICTED IMPACTS*

26.4.1 *General Experience of Mining Under Sandstone Cliff Formations*

The following findings arise from investigations SCT have undertaken in similar environments in the Western and Southern Coalfields of NSW. These findings were considered when determining the potential impacts for the Project:

- previous experience indicates that rock falls occur as a result of lateral compression of rock formations in a direction along the length of a formation. Except in special circumstances such as waterfalls, horizontal compression movements occur almost entirely within the area directly above the longwall panels and the chain pillars between adjacent panels;

- cliff formations less than 20m in lateral extent are less susceptible to mining impacts unless they collide with adjacent formations. Such movements of these formations are unable to generate enough force to overload the rock fabric;

- high overhanging cliff formations tend to be more susceptible to rock falls than smaller isolated formations. Rock falls are most likely to occur at locations where there is an indent in the line of the rock formation as this is the location where horizontal compressive movements tend to be concentrated;

- waterfalls tend to act as concentration points for horizontal movement and are susceptible to impacts. Movements can be generated by vertical subsidence occurring remotely from the waterfall Mitigation measures used for the protection of vertical subsidence are not necessarily sufficient to provide a high level of protection;

- longwall mining at a depth of cover (or overburden) of between 150 and 220m has the potential to induce rock falls along 15-20% of the length of the cliff formation that is directly above the area mined. This percentage decreases as the depth of cover increases. Experience from locations within the Southern Coalfield indicates that at 500m depth of cover, the potential for any impact reduces to less than 3% of a typical cliff likely to be impacted by rock falls, excluding especially vulnerable features;

- in the Western Coalfield surface cracking has been observed to occur at a distance outside of the longwall panels up to 0.4 times, the overburden. This surface cracking is associated with tensile stretching of the ground surface and is independent to the compressive processes that cause rock falls, however the depth of cover in the Western Coalfield is often less than 300 m; and

- horizontal movements in a downslope direction (ie valley closure) and horizontal movements associated with stress relief have the potential to generate low level tesile cracks. Tensile cracking typically occurs at the top of slopes and on hard exposed surfaces. This can occur at distances beyond the goaf edge of greater than 0.4 times the depth, dependent on surface terrain and the nature of the surface.

26.4.2 *Assessment of Likely Subsidence Impacts*

Allowing for an increased level of subsidence, associated with multi-seam mining, and an intermediate depth of cover between 300 to 500m, it is likely that approximately 5% of the length of cliff formations directly mined under could experience rock falls (SCT 2012b). Rock falls are not likely to occur on rock formations less than 20m in lateral extent.

This prediction considers the increased level of subsidence associated with multi-seam mining, and an intermediate overburden depth of approximately 300-500m. This would be classed as a minor impact.

Low height rock formations in Wonga East are expected to experience minimal rock falls, limited to areas such as gullies where there is the potential for collision of rock strata moving in different directions. Given the relatively large chain pillars, compared to the width of the longwall panels, compressive horizontal movements are expected to be limited only to the central part of each longwall.

In Wonga West, there are no individual cliffs higher than five metres above the mining area except for the semi-continuous 10 to 15m high cliff formation over proposed longwall A4 LW6. There is the potential for horizontal compression movements to occur along this formation, with rock falls to occur up to approximately 15% of the length of the cliff. This is due to the height and their alignment parallel to the direction of mining. Mitigation measures will be implemented to reduce these impacts.

There is the potential for impacts from horizontal movements to develop in the vicinity of the Lizard Creek waterfall and the Wallandoola Creek waterfall (SCT 2012b). Both waterfalls have previously been impacted from the mining of the Bulli Seam. Mitigation measures will be implemented to reduce these impacts.

Cliff formations alongside Lizard Creek that are not directly above the longwall panels, including the 300m long cliff line of special significance that exceeds 10m in height, are unlikely to be significantly impacted by subsidence. This is because horizontal subsidence movements are unlikely to develop in a direction along the cliff line (SCT 2012b).

There is the potential for surface cracking to occur at the top of steep slopes, particularly where the direction of mining matches the direction of slope (SCT 2012b). It is unlikely that surface cracking would be perceptible in the bushland setting. Areas of potential visibility include ground surface above proposed longwall A4 LW6 as it approaches the steep slope adjacent to Lizard Creek and in steep slopes in the southern parts of Wonga East that form the Hawkesbury Sandstone unit (SCT 2012b).

26.4.3 *Assessment of Significance*

The environmental impacts to steep slopes within the mining area are considered to be negligible. Minor and negligible environmental consequences are considered possible for cliff formations located directly above the proposed longwall panels. However, no cliff features assigned special significance status are located directly above longwall mining areas. Environmental consequences for cliff formations not above the area of mining are expected to be nil to negligible.

26.5 *MITIGATION MEASURES*

The following mitigation measures will be implemented to reduce impacts to cliffs and steep slopes:

- monitoring and adaptive management strategies will be implemented to limit mining impacts on features of special significance; and

- to avoid additional impacts to Lizard Creek waterfall and the Wallandoola Creek waterfall a trigger, action, and response plan will developed which limits horizontal movements to low levels in these areas.