UNDERGROUND EXPANSION PROJECT

PREFERRED PROJECT REPORT

INCLUDING RESPONSE TO SUBMISSIONS

Gujarat NRE Coking Coal Ltd

CONTENTS

FIGURES

TABLES

PREFERRED PROJECT REPORT

PREFERRED PROJECT REPORT (PPR)

1. Overview of Preferred Project

After serious consideration of community and agency submissions, involving predominantly environmental opposition to the original proposal, Gujarat NRE Coking Coal Ltd (NRE) has taken the decision to modify the scope of its mine layout for the Underground Expansion Project Pt3A application. The elements of the surface facilities upgrade will remain the same. An outline of the Preferred Project follows.

1. The estimated project life has been reduced to a maximum of 5 years.
2. The Wonga East Longwall (LW) layout has been extensively modified to minimise impacts to identified significant features while attempting to maximise the recovery of coal reserves (see **Figure 2**, pg 11).
3. The Wonga Mains driveage will not be extended northwards under the south arm of the Cataract Reservoir through the known geological feature (in the Bulli Seam) (see **Figure 1**, pg 10).
4. The Wonga West longwalls will be removed from this application. The Wonga West longwall layout will be revised and resubmitted as a separate application at a later date (see **Figure 1**, pg 10 for the location of the originally proposed Wonga West longwalls).
5. The Western Balgownie and Western Bulli Seam first workings will be removed from this application.
6. There is no change proposed to the Pit Top upgrade, 3 million tonnes per annum (Mtpa) extraction rate or peak coal transport rates as presented in the original Environmental Assessment (EA).

As a result of the changes, the Preferred Project now effectively represents Stage 2 of the development of NRE No.1 Colliery rather than the establishment of the Colliery's operations for the next 20 years as was presented by NRE in the original EA.

The Preferred Project, via the revised Wonga East layout, will provide NRE with an ongoing, albeit reduced, income stream to continue to establish environmental baseline data and undertake the necessary additional environmental studies required to demonstrate the practicality of the environmentally responsible extraction of the existing large volumes of economically viable ROM coal in the remaining central and western areas of the lease.

A more detailed summary comparing the original proposal presented in the EA with the current Preferred Project is presented in **Table 1,** pg 14.

Figure 1 - PPR Application Area and Proposed Mine Layout

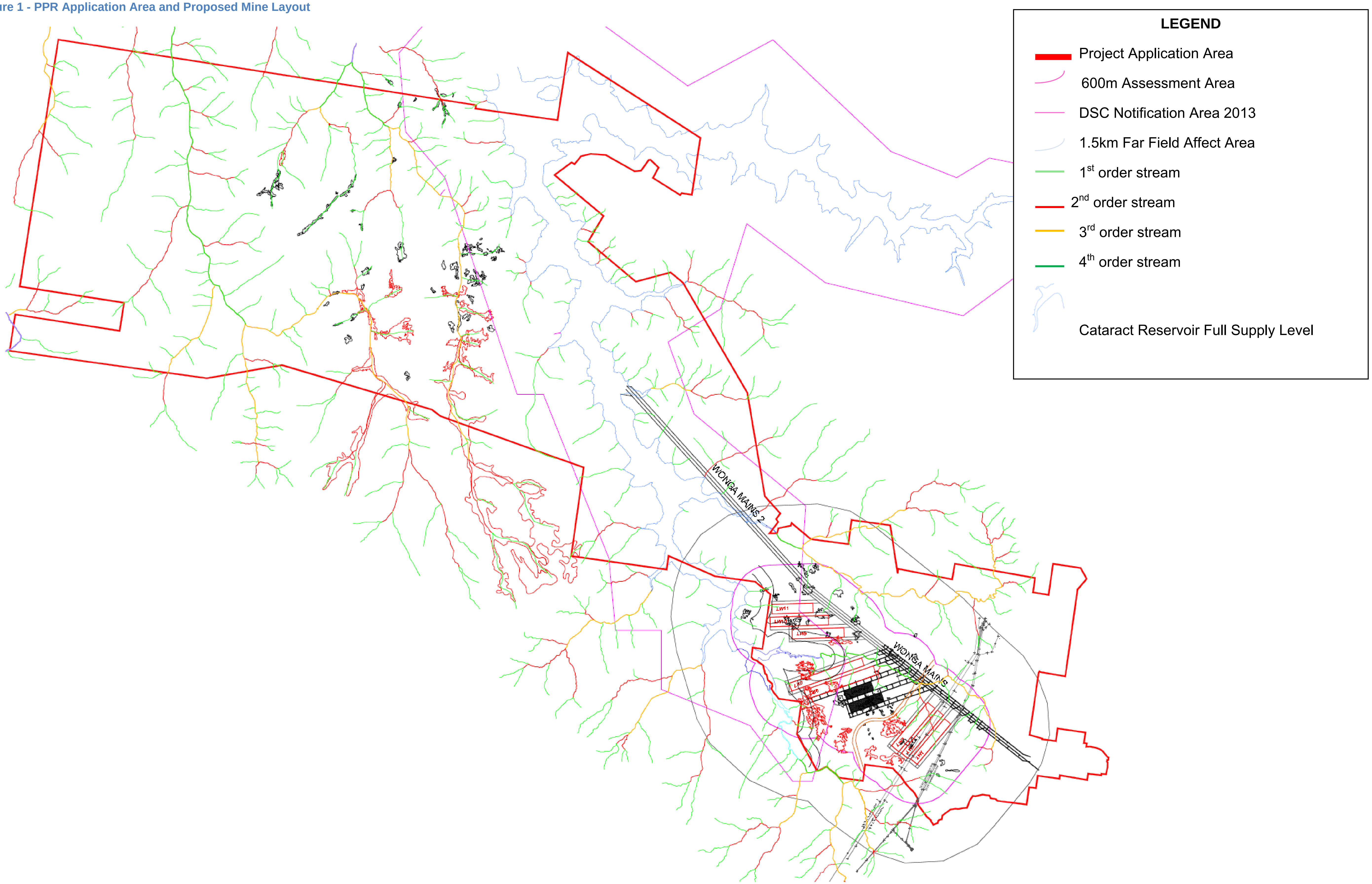


Figure 2 - PPR Proposed Wonga East Mine Layout

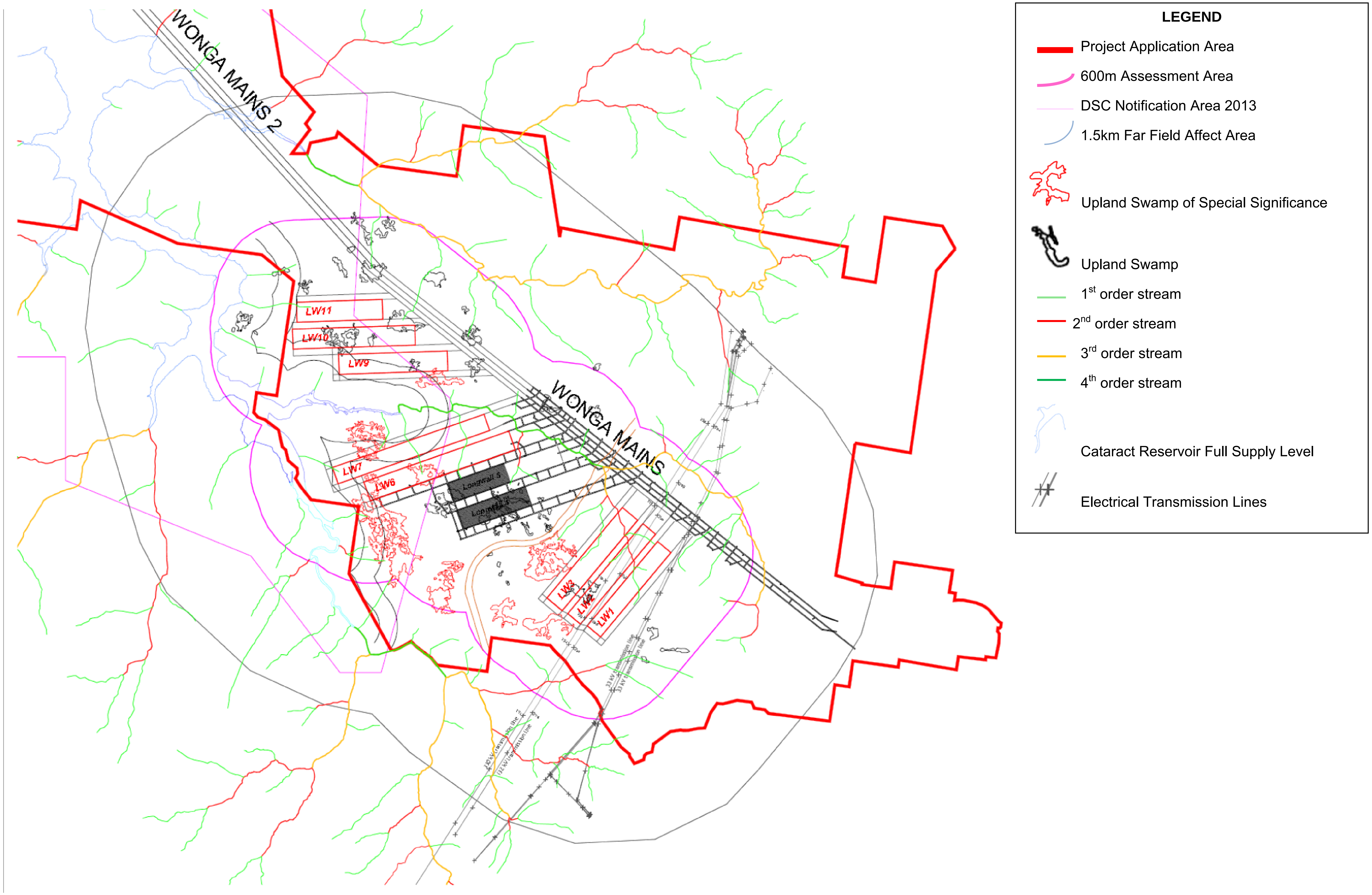


Figure 3 - Comparison of Original EA Proposal and PPR Mine Layout

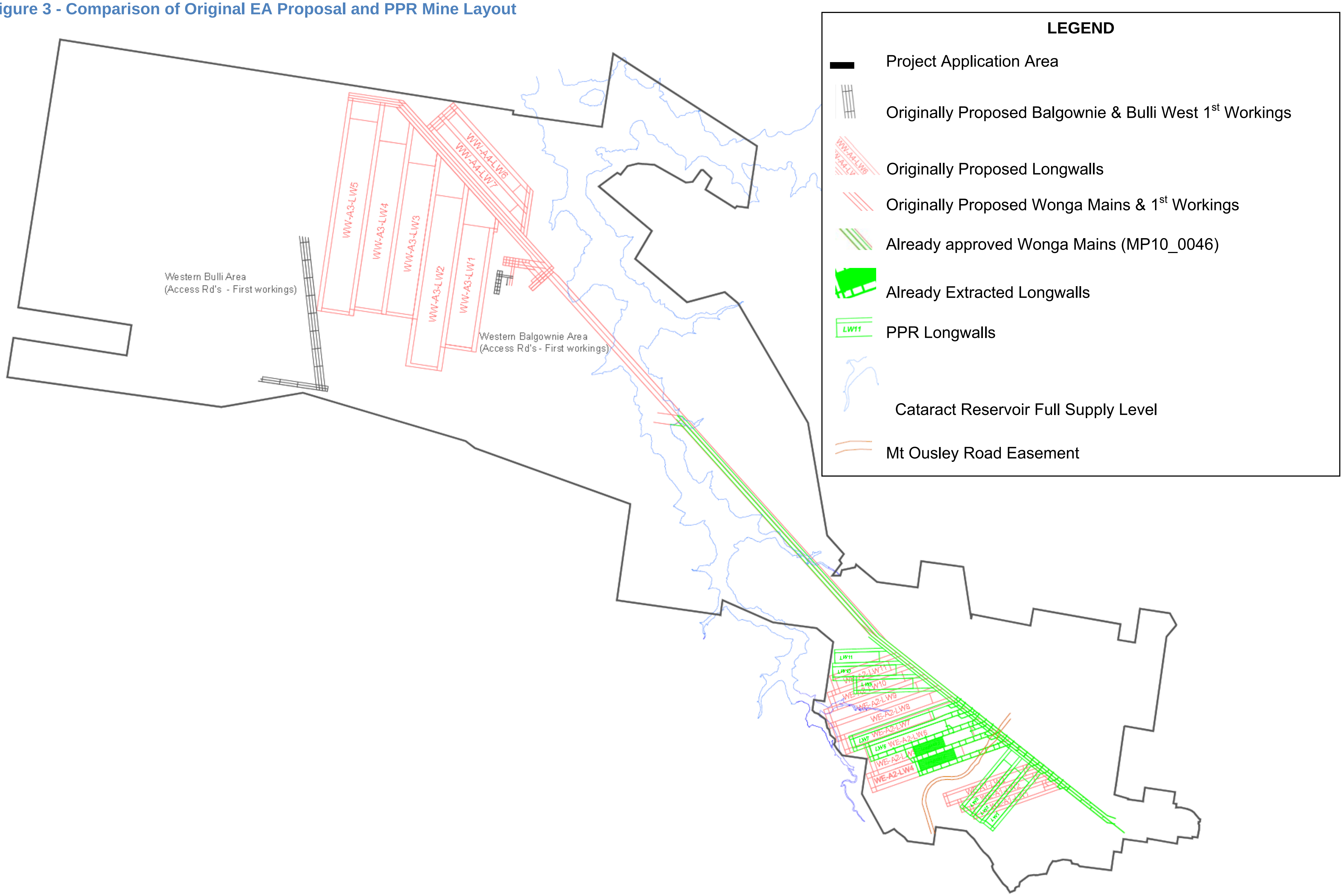
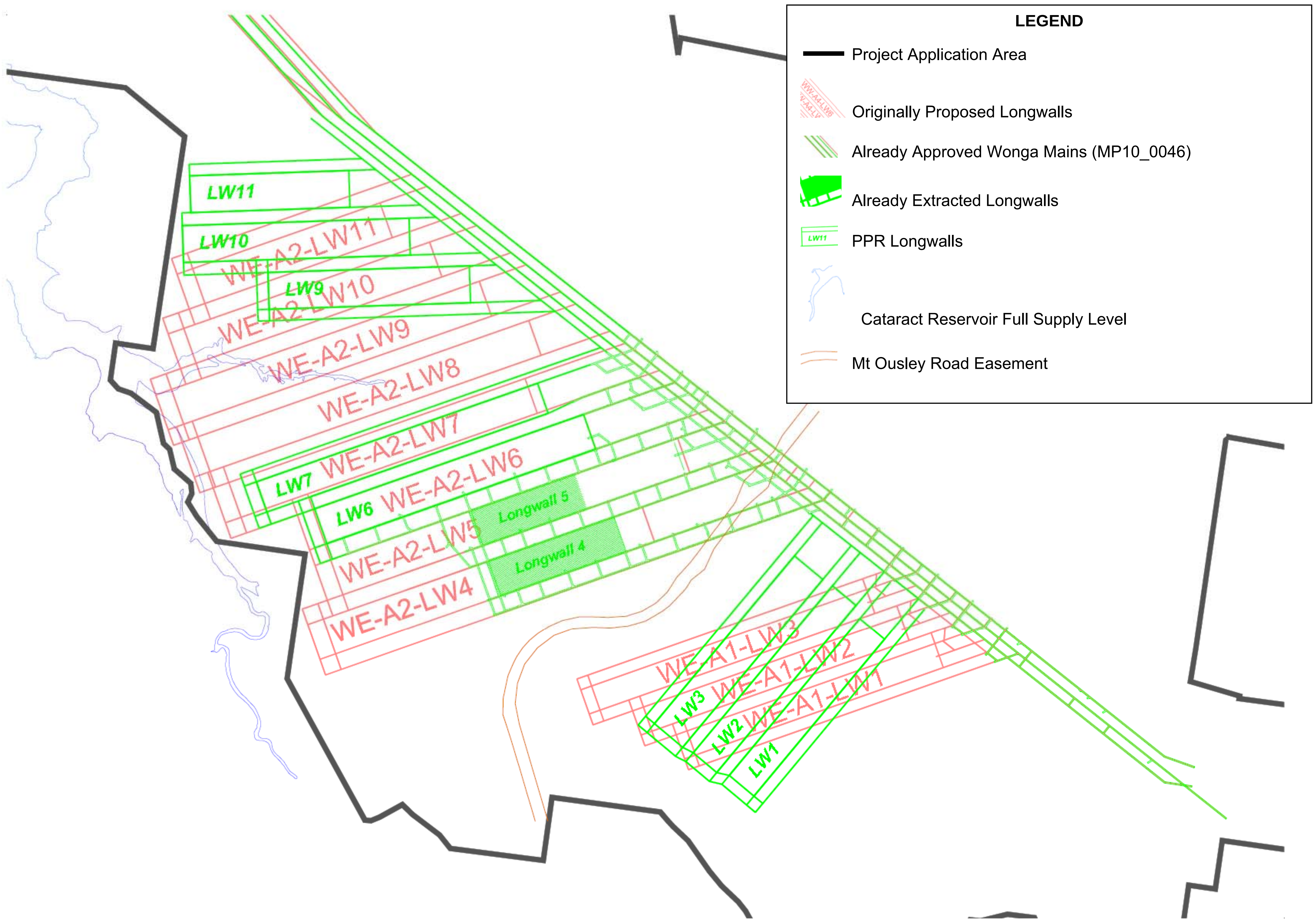


Figure 4 - Comparison of Original EA Wonga East and PPR Proposed Wonga East Mine Layouts



1.1 Comparison of PPR vs. Original Proposal

Table 1 - Summary of Project Changes

PROJECT AREA	ORIGINAL PROJECT	PPR
Project Application Area	• As per the historical Colliery Holdings/lease boundary	• No changes proposed
Estimated Project Life	• 18 years	• 5 years
Annual Production Rate	• 3 million tonnes	• No changes proposed
Pit Top	• Two new stockpiles of 140,000 tonnes capacity each (SP2 & SP3) with associated reclaim facilities • New truck loading facilities • Designated coal dispatch road • Progressive upgrading of trucking fleet • Continued road haulage of Run of Mine (ROM) coal to the Port Kembla Coal Terminal (PKCT) • 6ML Settling Pond and associated upgrades of water management system • Continuing use of No.4 Shaft for mine access, bathhouse, parking and offices • Ongoing maintenance and refurbishment of ventilation shafts, water and electrical facilities • Ongoing geological and geotechnical investigations to determine coal quality and geotechnical conditions using drilling and related techniques	• No changes proposed
Wonga East longwalls	• 9 longwalls in 2 Areas o Area 1 – LW's 1-3 o Area 2 – LW's 6-11 • Total ROM Coal = 6.5 Million tonnes	• 8 longwalls in 2 Areas o Area 1 – LW's 1-3 modified length, width and reoriented to the south o Area 2 – LW 6 shortened o Area 2 – LW7 modified length, width & position o Area 2 – LW 8 removed o Area 2 – LW9-11 modified length, position and reoriented to the west • Total ROM Coal = 4.7 Million tonnes
Wonga Mains	• Mains drivage from the end of the Preliminary Works Pt3A approved drivage heading northwest, beneath Cataract Reservoir to bisect the proposed Wonga West Areas 3 and 4.	• No extension from Preliminary Works Pt3A approval i.e. no proposed workings beneath southern arm of Cataract Storage Reservoir through Geological structure (in Bulli seam)
Wonga West longwalls	• 7 longwalls in two Areas o Area 3 – LW's 1-5 o Area 4 – LW's 6-7 • Total ROM Coal = 24.6 Million tones	• Removed from this application. To be revised and to be resubmitted as a separate application to DPI at a later date. • Total ROM Coal = 0 Million tonnes
Bulli West - Bulli Seam 1st Workings	• 1st workings to access the Bulli Seam in the western area of the Project Application Area	• Removed from this application and to be reviewed for inclusion in a future application
Balgownie Seam 1st Workings	• 1st workings to access the Balgownie Seam in the western area of the Project Application Area	• Removed from this application and to be reviewed for inclusion in a future application
Capital Value	• $250 million	• $85 million

Table 2 - Summary of Pit Top Impact Prediction Changes

ISSUE	ORIGINAL PROJECT	PPR
Air Quality	• Compliance with EPA Impact Criteria o PM$_{10}$, (24hr) of 50µg/m^3 (1 potential modelled exceedance) o PM$_{10}$, (Annual) of 30µg/m^3 o TSP (Annual) of 90µg/m^3 o Deposited Dust of 2g/m^2/month	• No changes proposed
Biodiversity	• No impacts predicted	• No changes proposed
Greenhouse Gas	• Total project direct (Scope 1 & 2) emissions of 45,872,154 tCO_2-e • Total project direct and indirect (Scope 1, 2 & 3) emissions of 165,971,970 tCO_2-e • Peak year direct (Scope 1 & 2) emissions of 2,548,453 tCO_2-e • Peak year direct and indirect (Scope 1, 2 &3) project emissions of 9,220,665 tCO_2-e • Total project emissions could add a maximum of 1.18% of 1ppm of CO_2-e to the global atmosphere or 0.008% of 1^{o}C to global temperatures • Emissions intensity of 0.85 t CO_2-e/ t ROM coal	• Total project direct (Scope 1 & 2) emissions of 767,789 tCO_2-e • Total project direct and indirect (Scope 1, 2 & 3) emissions of 8,109,009 tCO_2-e • Peak year direct (Scope 1 & 2) emissions of 82,673 tCO_2-e • Peak year direct and indirect (Scope 1, 2 &3) project emissions of 3,365,236 tCO_2-e • Total project emissions could add a maximum of 0.06% of 1ppm of CO_2-e to the global atmosphere or 0.0004% of 1^{o}C to global temperatures • Emissions intensity of 0.35t CO_2-e/t ROM coal
Noise	• Minor exceedances of less than 2dB(A) at two receivers during the evening period from Pit Top operations • Increase of $LA_{eq,\ 1hr}$ noise levels of less than 2dB(A) along Bellambi Lane compared to existing road traffic	• No changes proposed
Rehabilitation	• Progressive rehabilitation over 18 yr project life • General rehabilitation objectives set • General post mining land use • No final mine closure plan but process outlined in Mine Operations Plan (MOP) • Conceptual landform design to remain as current topography of site	• Progressive rehabilitation over the 5yr project life • Indicative post mining land use • Conceptual rehabilitation objectives • Conceptual rehabilitation methods • Conceptual completion criteria • Conceptual final land use plans
Water	• Water pump out from mine operations through Licenced Discharge Point (LDP2) of approximately 2ML/day at end of Project mining	• Current discharge averages 1,350kL/day • Final pumpout rate at end of Preferred Project to be confirmed when groundwater remodelling completed
Traffic & Transport	• Transport of ROM coal to PKCT at a rate of up to 3Mtpa • ROM coal haulage limited to a maximum of 95 hours per week with haulage rates generally lower than this on average.	• No changes proposed
Cultural Heritage	• No impacts to current historic heritage • Aboriginal archaeology to be managed by heritage consultant if found during construction works	• No changes proposed

Table 3 - Summary of Subsidence Impact Prediction Changes

ISSUE	ORIGINAL PROJECT	PPR WONGA EAST
Biodiversity	*Upland Swamps* • Negligible impact to Upland Swamps CRUS2, CRUS3, LCUS1, LCUS6, LCUS27, WCUS1 • Low impact to CCUS4, CCUS10, CRUS1, LCUS8 & WCUS11 • Moderate impact to WCUS4 & WCUS7 • Significant impact to CCUS1 & CCUS5 *Aquatic Ecology* • Negligible impact on Cataract Creek aquatic habitat • Negligible impact on Wallandoola and Lizard Creeks aquatic habitat • Potential temporary, localised, minor impacts to Adams Emerald Dragonfly habitat • No impact on Macquarie Perch, Trout Cod, Murray Cod or Silver Perch *Terrestrial Ecology* • Significant impact on Giant Burrowing Frog, Red Crowned Toadlet and Heath Frog habitat in Wonga West • No impact to terrestrial fauna including bat habitat • No impact to endangered flora	*Upland Swamps* • No impact to LCUS1, LCUS6, LCUS8, LCUS27, WCUS1, WCUS4, WCUS7, WCUS11 due to removal of Wonga West from the Preferred Project; • Negligible impact to Upland Swamps of special significance' CRUS2 & CRUS3, • Low impact to Upland Swamps of 'special significance' CCUS1, CCUS5, CCUS10, & CRUS1, • Moderate impact to Upland Swamp of 'special significance' CCUS4 *Aquatic Ecology* • Negligible impact on Cataract Creek aquatic habitat • No impact on Wallandoola and Lizard Creeks aquatic habitat due to removal of Wonga West from the Preferred Project • No impact to Adams Emerald Dragonfly habitat • No impact on Macquarie Perch, Trout Cod, Murray Cod or Silver Perch *Terrestrial Ecology* • No impact on Giant Burrowing Frog, Red Crowned Toadlet and Heath Frog habitat due to removal of Wonga West from this application • No impact to terrestrial fauna including bat habitat • No impact to endangered flora

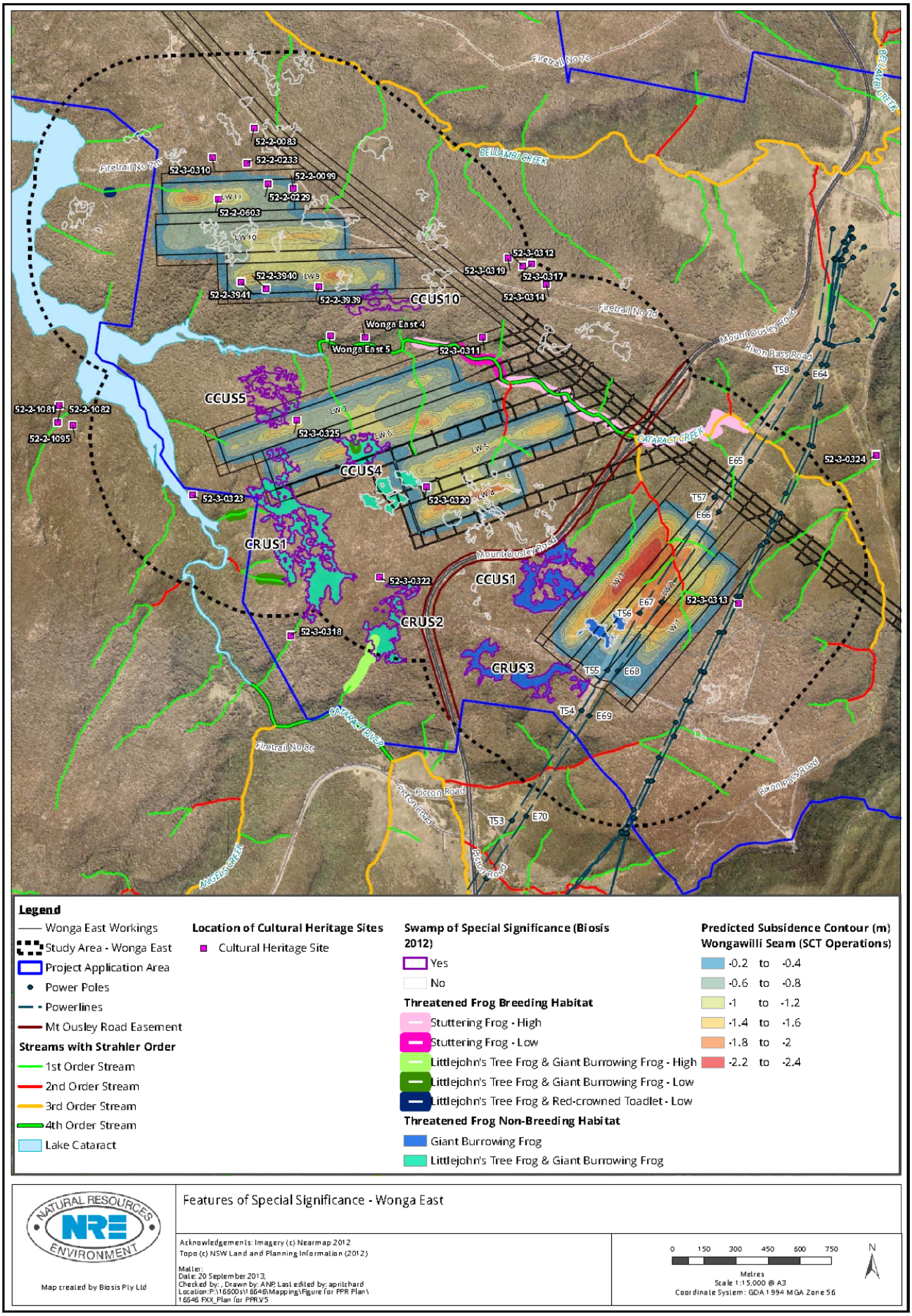
Cultural Heritage	• No. of sites of potential moderate or higher impact from subsidence:
	  o Wonga West = 10 of 34 identified sites
	  o Wonga East = 5 of 23 identified sites
	  o Total = 15 of 57 identified sites
		• 1 of 21 sites have a potential for moderate or higher impact from subsidence:

Ground Water	• Mine Groundwater inflow rates of up to
	  o 1.4ML/day or 511 ML/year in Wonga East
	  o 1.7ML/day or 621 ML/year in Wonga West
	• No impact on groundwater quality
	• Groundwater aquifer levels to reduce between:
	  o 12-140m in Wonga West depending on aquifer (*Table 21.1, pgs 343 - 344, of the EA*)
	  o 12-90m in Wonga East depending on aquifer (*Table 21.1, pgs 343 -344, of the EA*)
		• Potential impacts will be determined based on the outcomes of current ground and surface water remodelling. Outcomes will vary due to the modification of the Wonga East layout and removal of Wonga West from this application.

Infrastructure	• Negligible impacts to Mt Ousley Rd or Picton Rd interchange • Possible moderate but manageable impact to electrical transmission lines • Possible significant but manageable impact to Telstra Optical Fibre Cable and Fire Trails/4WD tracks • Possible unquantifiable far field effects on Cataract Dam wall	• Negligible impacts to Mt Ousley Rd or Picton Rd interchange • Possible moderate but manageable impact to electrical transmission lines • No impact on Cataract Reservoir

Surface Water	• Moderate potential for creek bed cracking, pool leakage and subsurface flow from Wallandoola and Lizard Cks but negligible impact on Cataract Ck
	• Low risk of damage to waterfalls W1 & L1
	• Potential reduction in groundwater provided baseflow for all 3 creeks of between 0.02 – 0.1ML/day
	• Water quality impacts could occur as:
	  o Observable impacts on water quality in 3rd order or higher stream channels in Lizard Ck and in Wallandoola Ck over LWs 3-4 of Area 3
	  o Negligible impacts on Cataract Ck water quality
		• Potential impacts will be determined based on the outcomes of current ground and surface water remodelling. Outcomes will vary due to the modification of the Wonga East layout and removal of Wonga West from this application

Figure 5 - Overview of PPR Subsidence Predictions and Surface Features



1.2 *Detailed Description of the Preferred Project*

1.2.1 Preferred Project Description

NRE intends to extract and export ROM coal from 8 longwalls in the Wongawilli Seam in the Wonga East area of the mine lease over an estimated Preferred Project life of 5 years. The proposed mine workings are illustrated in **Figure 2**, pg 11. Mining methods will include 1st workings and secondary extraction. 1st workings development will involve approximately 3.2m x 5.5m supported main and longwall access roadways (longwall gateroads). Following the completion of the gateroads, the remaining coal will be extracted by the retreat longwall mining method of secondary extraction. Longwall extraction heights will vary from approximately 2.5m to 3.0m, based on ROM coal quality. It is expected that during the extraction of multiple longwalls the extraction rate will, at times, approach 3 Mtpa. This will require the upgrade of surface facilities with increased peak trucking rates. There are no proposed changes to the hours of operation for both surface and underground activities, which are 24 hours per day, 7 days per week. Coal haulage will occur between the hours of 7am to 10pm Monday to Friday and 8am to 6pm Saturday's, Sundays and Public Holidays. Peak trucking schedules will be dictated by shipping frequencies, combined with stockpile and coal production operations.

As a result of this estimated extraction rate, and in preparation for future mining activities in the remainder of the NRE No.1 Colliery lease areas, coal handling infrastructure will be further upgraded to improve operational efficiency and reduce impacts on the environment and local community. The upgrades will be the same as indicated in *Section 7, pg 131, of the EA* and the proposed EA upgrades are summarised in **Table 1**, pg 14. The surface facility upgrade process will be undertaken as dictated by production requirements, global economic conditions, financial viability assessments and any other relevant issues. Construction Environment Management Plans (CEMP) will be developed in liaison with the Environment Protection Agency (EPA) focusing on ensuring compliance, in particular, with the relevant site water, noise and air quality criteria. The CEMP's will be submitted to the Department of Planning & Infrastructure (DPI) for approval prior to the construction of all or any part of the proposed facilities upgrade.

All impact assessments for the surface facilities construction and operation remain as presented in Part B of the original EA unless modified in this PPR.

1.2.2 Project Application Area

The Project Application Area (PAA) for the PPR will cover the entire NRE No.1 Colliery Holdings/lease areas, despite the removal of the Wonga West mining. The total area remains unchanged for the following reasons:

1. The Preliminary Works Pt3A and associated approved extraction will be incorporated into any approval given for this PPR;
2. NRE will still require access to existing underground workings and surface infrastructure in the central and western areas of the lease for safety, ventilation, roadway maintenance and other activities;
3. Exploration activities still need to be undertaken in the central and western areas of the lease; and
4. The central and western areas are still subject to intensive environmental monitoring for future longwall areas including the proposed Wonga West longwall area which will be resubmitted as a separate application

1.2.3 Description of Wonga East Longwall Mining Layout changes

Beyond the existing approvals for LW4 and LW5, changes have been made in an attempt to minimise the impacts on significant surface features and still recover a commercially viable percentage of the available coal resource.

The approach is focused on balancing the predicted environmental impacts on natural and man-made surface features against the legacy of the existing underground roadways and the economics of the reserve within current mining operations.

The redesign goals are:

- No secondary extraction below 3rd order streams and above;
- No substantial undermining of swamps of special significance;
- No secondary extraction below Cataract Reservoir stored waters or within the Wongawilli Seam 35 degree Angle of Draw of the full supply level storage;
- To minimise the potential for significant surface and ground water connectivity;
- To minimise impacts on steep slopes and cliffs (including the Illawarra Escarpment);
- To minimise impacts on infrastructure (Mt Ousley Road, Picton Road, powerlines)
- To take into account known geological structures of the area; and
- To take into account the underground mining conditions and the consequential impact on the economics of the mining operation.

As a result, the original Wonga East longwalls have either been eliminated, or the lengths, widths, position and/or alignment have been changed. The geometry of the design:

- eliminates mining below the 3rd and 4th ordered sections of Cataract Creek;
- has removed longwall extraction from below the Full Supply Level (FSL) and outside the 35 degree Angle of Draw (for Wongawilli Seam) from the Cataract Storage Reservoir;
- minimises mining through Dyke D8 (previously referred to as Rixons Pass Fault) and avoids intersecting the dyke on LWs 9 -11 (see **Figure 36,** pg 124, for dyke locations);
- has moved longwall extraction areas away from swamps of special significance CCUS1, CCUS5, and CCUS10;
- in the case of LWs1-3, has moved the nearest longwall extraction further away from Mt Ousley Road and also further away from the Illawarra Escarpment, whilst avoiding undermining swamp CCUS1; and
- has reduced the impacts on cliffines whether related to heritage sites, endangered species habitat or clifflines of special significance.

A comparison of the dimension changes between the Preferred Project and the EA are shown in **Table 4**, pg 20.

Table 4 - Comparison of Longwall Dimensions between the PPR and EA

Longwall No.	Longwall Width (rib to rib) (m)		Longwall length (m)		Maingate Pillar Width (m)	
	EA	PPR	EA	PPR	EA	PPR
Longwall 1	105	131	1040	805	40	40
Longwall 2	105	125	1080	858	40	40
Longwall 3	105	150	1150	863	40	40
Longwall 6	150	150	1125	1120	60	45
Longwall 7	150	131	1230	1175	60	45
Longwall 8	150	-	1375	-	60	-
Longwall 9	150	150	1280	796	60	45
Longwall 10	150	150	1020	896	60	45
Longwall 11	150	150	780	630	60	40

1.2.4 Indicative Underground Works Schedule

The project is expected to extend the working life of the mine for 5 years while additional applications for longwall extraction are prepared.

Table 5 - Extraction Schedule

Wonga East Mining	ROM Coal Extracted (tonnes)	Estimated Commencement	Estimated Completion
1st Workings	620,000	2014	2018
LW 6	684,000	2014	2014
LW 7	625,000	2014	2014
LW 1	388,000	2014	2015
LW 2	396,000	2015	2015
LW 3	485,000	2015	2016
LW 9	500,000	2016	2016
LW 10	564,000	2017	2017
LW 11	403,000	2018	2018

1.2.5 Indicative Construction Times

Given the unknown factors mentioned in **Section 1.2.1,** pg 18, it is not possible to provide a detailed construction schedule for the surface facility upgrade. It is however, possible to estimate the time it will take to construct individual elements from the commencement of the approval of the Preferred Project and these are given in **Table 6**, pg 21.

Table 6 - Estimated Construction Element Times

Construction Stage	Mining Element	Estimated Construction Time
1	Truck Loading Facilities, Associated Road Works and Parking Area	30 months from approval date
2	6ML Settling Pond and Associated Drainage Works	12 months from completion of Construction Stage 1
3	Stockpiles 2 & 3	18 months from completion of Construction Stage 2

1.2.6 Capital Investment Value

The Capital Investment Value (CIV) has been significantly reduced as a result of the changes to the project and changes in other circumstances in the period between the initial project application in 2009 and the PPR in 2013. The critical changes that have substantially reduced the CIV are:

1. The Wonga Mains will no longer be extended beyond the original Preliminary Works Pt3A which was a substantial contributor to the original CIV estimate. The CIV to extend the Wonga Mains from its present extent near LW7 main gate to its approved extent was already captured in the CIV for the Preliminary Works Pt3A;
2. The purchase of a new longwall was originally included in the CIV for the EA but this was purchased as part of an SMP application for LW4 and has been removed from the CIV for the Preferred Project;
3. Maingates 4, 5 & 6 and tailgate 4 were approved as part of both SMP and the LW4 & 5; MG 6, 7 & 8 Pt3A modification application;
4. The revised layout of the gateroads has reduced the length of drivage substantially reducing the CIV of that element to around $67 million; and
5. The surface facilities upgrade is the only element of the original application CIV that remains unchanged and is currently estimated to cost around $18 million to complete.

Hence the modified CIV for the Preferred Project is **$85 million**.

2. Preferred Project Impact Assessment

This Preferred Project impact assessment will only address issues that have changed as a result of the modification to the mine plan.

This section is separated into three sections

2.1Pit Top

2.1.1 Greenhouse Gas Emissions

2.1.1.1 Background

From samples of coal taken during exploration drilling and from in seam drilling undertaken in advance of mining operations, it is known that the coal within the Wonga East extraction area has a total gas content of 4m^3/tonne at 95% methane.

Of this gas, laboratory tests show that only 40% (i.e. 1.6m^3/tonne) is desorbable and would be released during mining, stockpiling and transportation. The remaining gas (2.4m^3/tonne) stays entrained within the coal and is only released when the coal is consumed or converted into coke.

It follows that the action of mining the coal within the Wonga East area will release an average of 33,604 t CO_2-e/annum or 77,292 t CO_2-e/annum based upon a peak production level of 2.15 million tonnes of ROM coal in the 2014 calendar year.

In addition to any gas which might be liberated as a direct consequence of mining related to this Preferred Project, there will be additional greenhouse gas released into the mine's ventilation system from old mine workings which liberate small amounts of methane and carbon dioxide. The gas from these old mine workings combines with gas from the mined coal in the ventilation system for the mine to give an average concentration of 0.16% methane and 0.23% carbon dioxide in the air discharged from the mine. The ventilation system expels approximately 152 m^3/second of air from the mine representing 4,793 x 10^6 m^3 of air per year. These low concentrations but high volumes of air represent approximately 129,761 t CO_2-e/annum.

Table 7 - Greenhouse Gas Emission Sources in this Assessment

Scope 1 – Direct Emissions	Scope 2 - Indirect Emissions from Purchased Energy	Scope 3 – Other Indirect Emissions
GHG vented during coal extraction	Electricity usage on site (machinery, conveyor belts, overhead cranes, compressors, ancillary plant and administration facilities)	Road transport of ROM coal product from site to PKCT and empty truck return journey
GHG vented from coal extraction – post mining		Shipping transportation of ROM coal product from PKCT to India
Fuel use onsite – diesel used in mining and processing equipment		Use of saleable coal as coking coal for steel manufacture
Diesel consumption from construction		Use of saleable coal as thermal coal for power generation
		Indirect emissions for fuel extraction associated with diesel supply

2.1.1.2 Methodology

The following assumptions have been made for the purposes of this assessment:

- Equipment and infrastructure for the extraction, stockpiling, and transportation of ROM coal, will be upgraded;
- The assumed extraction volumes for calculation purposes are:
  - Peak extraction in 2014 of 2.15Mtpa ROM coal; and
  - Average – 935,000 tpa ROM coal for the project life of 5 years.
- The operational lifetime of the Preferred Project will be 5 years, from 2014 – 2018;
- ROM coal will not be washed prior to transportation;
- Coal will be transported to PKCT at peak rates of up to 3 Mtpa;
- Extracted coal is anticipated to be of varying grades. Therefore, on average, of the ROM coal product shipped, 52.4% will be used as saleable coking coal and 28.6% will be used as saleable thermal coal. Consequently, an average, 19% of the exported product will be rock/waste.
- The average total gas content of the ROM coal from Wonga East is $4m^3$/tonne. Approximately 40% of total gas content in Wonga East or $1.6m^3$/tonne is desorbable (i.e. the gas that can be released without combustion). Of that $1.6m^3$/tonne, $1.53m^3$/tonne (95%) is CH_4 is and $0.08m^3$/tonne (5%) is CO_2.
- It is appropriate to apply Method 4 from Section 3.6 of the current *National Greenhouse and Energy Reporting (Measurement) Determination 2008* which gives the conversion factor for CH_4 from m^3 to tonnes CO_2-e as 0.0006784 x 21 and the conversion factor for CO_2 from m^3 to tonnes CO_2-e as 0.001861.
- It is appropriate to apply Method 1 from Section 3.17, Subdivision 3.2.2.4 of the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* which gives an emission factor of 0.014 CO_2-e / tonne of ROM coal.
- The majority of diesel use on site is for underground mobile plant with only negligible amounts used for stationary power generation. It is appropriate to use Table 4 - Fuel combustion emission factors -fuels used for transport energy purposes from the *National Greenhouse Accounts Factors—July 2012* for calculation of diesel use in operations and construction as it is a higher emission factor than Table 3 - Fuel combustion emission factors - liquid fuels and certain petroleum based products for stationary energy purposes. The emissions factors in this table equate to 38.6 GJ/kL of diesel and 0.0669 tonnes CO_2-e/ GJ of diesel consumed.

2.1.1.3 Modelling Results

Table 8 - Scope 1 Source Emission Estimates for an Average Year of Production

Source	Timeframe	Activity	Scope 1 Emissions Factor	Estimated Emissions (t $CO2_{-e}$)
GHG vented during coal extraction	Average production[1]	934,771 tonnes ROM coal mined	0.0218 (tonnes CO_2-e vented from vented CH_4 /tonne ROM coal extracted)[2] 0.00015 (tonnes CO_2 vented / tonnes ROM coal extracted)[3]	20,518
GHG vented from coal extraction (post mining)	Average production	934,771 tonnes ROM coal mined	0.014 CO_2-e / tonne ROM coal[4]	13,086
Diesel Use – on site operations[5]	Average production	660kL[5]	0.0699 (CO_2-e / GJ)	1,740
Diesel Use - construction	1 Year of Construction[6]	23.5kL	0.0699 (CO_2-e / GJ)	63
TOTAL				**35,407**

1. Average production is calculated to be 934,754 tonnes of ROM coal per calendar year
2. 1.53 (*m^3 CH_4/tonne ROM coal*) x 0.0006784 x 21 (*conversion factor m^3 to tonnes CO_2-e*)
3. 0.08 (*m^3 CO_2/tonne ROM coal*) x 0.001861(*conversion factor m^3 CO_2 to tonnes CO_2-e*)
4. Method 1 from Section 3.17, Subdivision 3.2.2.4 of the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* which gives an emission factor of 0.014 CO_2-e / tonne of ROM coal
5. The original volume of diesel predicted to be used for on-site operations at 3Mtpa production has been reduced by 66% from 1,995kL in the original EA. The original project EA assumed all diesel on site is used for transport purposes and 95% of that is used underground, which is already captured in ventilation emissions. This assumption is NOT used in this PPR so as to produce maximum potential emissions for the project.
6. Construction will take approximately 3 years to complete. As such the volume of diesel use estimated for 1 year of construction in the original EA (39.1kL) has been averaged over the 5 years. (i.e. 39.1 x 3/5)

Table 9 - Scope 1 Source Emission Estimates for the Peak Year of Production

Source	Timeframe	Activity	Scope 1 Emissions Factor	Estimated Emissions (t $CO2_{-e}$)
GHG vented during coal extraction	Peak production[1]	2, 150,000 tonnes ROM coal mined	0.0218 (tonnes CO_2-e vented from vented CH_4 vented/tonne ROM coal extracted)[2] 0.00015 (tonnes CO_2 vented / tonnes ROM coal extracted)[3]	47,192
GHG vented from coal extraction (post mining)	Peak production	2,150,000 tonnes ROM coal mined	0.014 CO_2-e / tonne ROM coal[4]	30,100
Diesel Use – on site operations[5]	Peak production	1,995kL	0.0699 (CO_2-e / GJ)	5,275
Diesel Use - construction	1 Year of Construction[6]	39.1kL	0.0699 (CO_2-e / GJ)	106
TOTAL				**82,673**

1. Peak production is calculated to be 2,147,475 tonnes of ROM coal during the 2014 calendar year. This has been rounded up to 2.15Mtpa for the purposes of greenhouse emissions calculation purposes.
2. 1.53 (*m^3 CH_4/tonne ROM coal*) x 0.0006784 x 21 (*conversion factor m^3 to tonnes CO_2-e*)
3. 0.08 (*m^3 CO_2/tonne ROM coal*) x 0.001861(*conversion factor m^3 CO_2 to tonnes CO_2-e*)
4. Method 1 from Section 3.17, Subdivision 3.2.2.4 of the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* which gives an emission factor of 0.014 CO_2-e / tonne of ROM coal
5. The original project EA assumed all diesel on site is used for transport purposes and 95% of that is used underground which is already captured in ventilation emissions. The original volume of diesel predicted to be used for 3Mtpa production has been retained from the original EA and added at 100% to emissions calculation in this PPR so as to produce maximum potential emissions for the Preferred Project.
6. Assumes that construction coincides with peak production which is unlikely

Table 10 - Scope 2 –Source Emission Estimates for an Average Year of Production

Source	Timeframe	Activity	Scope 2 Emissions Factor	Estimated Emissions (t $CO2_{-e}$)
Energy from consumption of grid electricity	Average production[1]	134,291 MW/h/annum (Net Power Consumption)	0.88 (tonnes CO_2-e/MWh)[2]	118,176
TOTAL				**118,176**

1. Energy consumption is estimated to be relatively constant throughout the operations lifetime of the Project.
2. Emission factor for NSW grid electricity of 0.88 CO_2-e/MWh) from Table 5 of the *National Greenhouse Accounts Factors—July 2012*

Table 11 - Scope 3 Source Emission Estimates for an Average Year of Production

Source	Volume	Activity Level / Conversion Factor	Scope 3 Emission Factor	Estimated Emissions (t $CO2_{-e}$)
Road transportation of ROM coal from the site to PKCT	934,754 tpa(1)	15.3km one way journey (1 truck movement) 49,200 truck movements/annum(2)	0.546L/km(3)	1,109
Shipping transportation of ROM coal from PKCT to India	934,754 tpa	Assumed distance of journey: 12,000km 6 shipping journeys per year(4)	0.000007 tCO_2 per tonne km (5)	88,941
Use of saleable coal as coking coal for steel manufacturing	489,811 tpa used as coking coal	30 GJ/tonne(6)	0.09022 (tonnes CO_2-e/GJ)(6)	1,325,722
Use of saleable coal as thermal coal for power generation	267,340 tpa used as thermal coal	22.5 GJ/tonne(6)	0.0087 (tonnes CO_2-e/GJ)(6)	52,332
Indirect emission for fuel extraction associated with diesel supply	683kL	38.6 GJ/kL	0.0053 (tonnes CO_2-e/GJ)(7)	140
TOTAL				**1,468,244**

1. Average production is calculated to be 934,754 tonnes of ROM coal per calendar year
2. Based on 934,754 tonnes of ROM coal hauled per year at an average load of 38 tonnes ROM coal per trip
3. Source – Table 4: Fuel consumption rates for 'Heavy Trucks' in *AGO Factors and Methods Workbook 2006*. 'Heavy Trucks' are assumed to be 'articulated trucks' by the Workbook
4. Assuming shipping load capacity of 175,000 tonnes DWT
5. UK, Department for Environment Food and Rural Affairs (Defra) greenhouse gas (GHG) conversion methodology 2008. Assuming large bulk carrier.
6. Source - Table 1: Fuel combustion emission factors (Stationary Energy) from *National Greenhouse Accounts Factors—July 2012*
7. Source – Table 39: Scope 3 emission factors – liquid fuels and certain petroleum based products in the *National Greenhouse Accounts Factors—July 2012*

Table 12 - Scope 3 Source Emission Estimates for the Peak Year of Production

Source	Volume	Activity Level / Conversion Factor	Scope 3 Emission Factor	Estimated Emissions (t $CO2_{-e}$)
Road transportation of ROM coal from the site to PKCT	2,150,000 tpa[(1)]	15.3km one way journey (1 truck movement) 113,158 truck movements/annum[(2)]	0.546L/km[(3)]	2,492
Shipping transportation of ROM coal from PKCT to India	2,150,000 tpa	Assumed distance of journey: 12,000km 13 shipping journeys per year[(4)]	0.000007 tCO_2 per tonne km [(5)]	192,706
Use of saleable coal as coking coal for steel manufacturing	1,126,600 tpa used as coking coal	30 GJ/tonne[(6)]	0.09022 (tonnes CO_2-e/GJ)[(6)]	3,049,255
Use of saleable coal as thermal coal for power generation	614,900 tpa used as thermal coal	22.5 GJ/tonne[(6)]	0.0087 (tonnes CO_2-e/GJ)[(6)]	120,367
Indirect emission for fuel extraction associated with diesel supply	2,034kL	38.6 GJ/kL	0.0053 (tonnes CO_2-e/GJ)[(7)]	416
TOTAL				**3,365,236**

1. Peak production is calculated to be 2.15Mt of ROM coal per calendar year
2. Based on 2.15Mt of ROM coal hauled per year at an average load of 38 tonnes ROM coal per trip.
3. Source – Table 4: Fuel consumption rates for 'Heavy Trucks' in *AGO Factors and Methods Workbook 2006*. 'Heavy Trucks' are assumed to be 'articulated trucks' by the Workbook
4. Assuming shipping load capacity of 175,000 tonnes DWT
5. UK, Department for Environment Food and Rural Affairs (Defra) greenhouse gas (GHG) conversion methodology 2008. Assuming large bulk carrier.
6. Source - Table 1: Fuel combustion emission factors (Stationary Energy) from *National Greenhouse Accounts Factors—July 2012*
7. Source – Table 39: Scope 3 emission factors – liquid fuels and certain petroleum based products in the *National Greenhouse Accounts Factors—July 2012*

Table 13 - Summary of Greenhouse Gas Emissions for the 5 Year Project Life

Emissions Scope	Source	Estimated Total Emissions ($t\ CO_2$-e/annum
Scope 1	GHG vented during coal extraction	102,590
	GHG vented from coal extraction (post mining)	65,430
	Diesel Use – on site operations	8,700
	Diesel Use – construction	189
Scope 1 Total		**176,909**
Scope 2	Energy from consumption of grid electricity	590,880
Scope 2 Total		**590,880**
Scope 1 & 2 Total		**767,789**
Scope 3	Road transportation of ROM coal from the site to PKCT	5,545
	Shipping transportation of ROM coal from PKCT to India	444,705
	Use of saleable coal as coking coal for steel manufacturing	6,628,610
	Use of saleable coal as thermal coal for power generation	261,660
	Indirect emission for fuel extraction associated with diesel supply	700
Scope 3 Total		**7,341,220**
Scope 1,2 & 3 Total		**8,109,009**

2.1.1.4 Emissions Comparison

Table 14 - Greenhouse Gas Emissions Comparison

Scale	Year	Scope	t CO_2-e / annum	Notes
Australia	2011	1,2	563,140,390	1) Source: The Commonwealth Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education's 2011 National Greenhouse Gas Inventory - Kyoto Protocol Accounting Framework (http://ageis.climatechange.gov.au/NGGI.aspx) 2) Assumes this represents Scope 1 & 2 emissions only
NSW	2011	1,2	158,991,280	1) Source: The Commonwealth Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education's 2011 State Greenhouse Gas Inventory for NSW (http://ageis.climatechange.gov.au/SGGI.aspx#) 2) Assumes this represents Scope 1& 2 emissions only
Wollongong LGA Residents	2012	1,2	4,404,952	1) Based on the NSW long term annual average of 21.8 t CO_2-e per person (Source: Section 1.2 of the 2012 NSW State of the Environment Report, http://www.environment.nsw.gov.au/soe/soe2012/chapter1/chp_1.2.htm#1.2.55) 2) Used an estimated 2012 resident population in the Wollongong LGA of 202,062 (Source: profile.id Community Profile http://profile.id.com.au/wollongong/population-estimate) 3) Assumes this represents Scope 1 & 2 emissions only
2517/2518 Postcode Residents	2011	1,2	579,902	1) Based on the NSW long term annual average of 21.8 t CO_2-e per person (Source: Section 1.2 of the 2012 NSW State of the Environment Report, http://www.environment.nsw.gov.au/soe/soe2012/chapter1/chp_1.2.htm#1.2.55) 2) A 2011 resident population in Woonona, Russell Vale, Corrimal, East Corrimal and Bellambi of 26,601 (profile.id Community Profile http://profile.id.com.au/wollongong/population?WebID=450) 3) Assumes this represents Scope 1 & 2 emissions only
NRE ***(Scope 1 & 2)***	Average Project Year	1,2	153,583	Source: PPR, average source emission estimates for Scope 1 and 2 emissions for an average production year.
NRE ***(Scope 1,2 & 3)***	Average Project Year	1,2,3	1,621,827	Source: PPR, average source emission estimates for Scope 1, 2 & 3 emissions for an average production year.

If the assumptions underlying the figures above can be accepted, an average year of NRE production from this Preferred Project will produce around 0.027% of Australia's and 0.097% of NSW's annual Scope 1 & 2 greenhouse gas emissions.

The Preferred Project will also produce just over one quarter (26.5%) of the equivalent annual Scope 1 & 2 greenhouse gas emissions of the residents of the surrounding suburbs, (i.e. Woonona, Russell Vale, Corrimal, Corrimal East and Bellambi), and 3.5% of the annual emissions by Wollongong Local Government Area (LGA) residents. A visual comparison is shown in **Figure 6**, pg 31, and **Figure 7** on pg 31.

Figure 6 - Comparison of Scope 1 & 2 Annual Emissions from the PPR with Local Residents

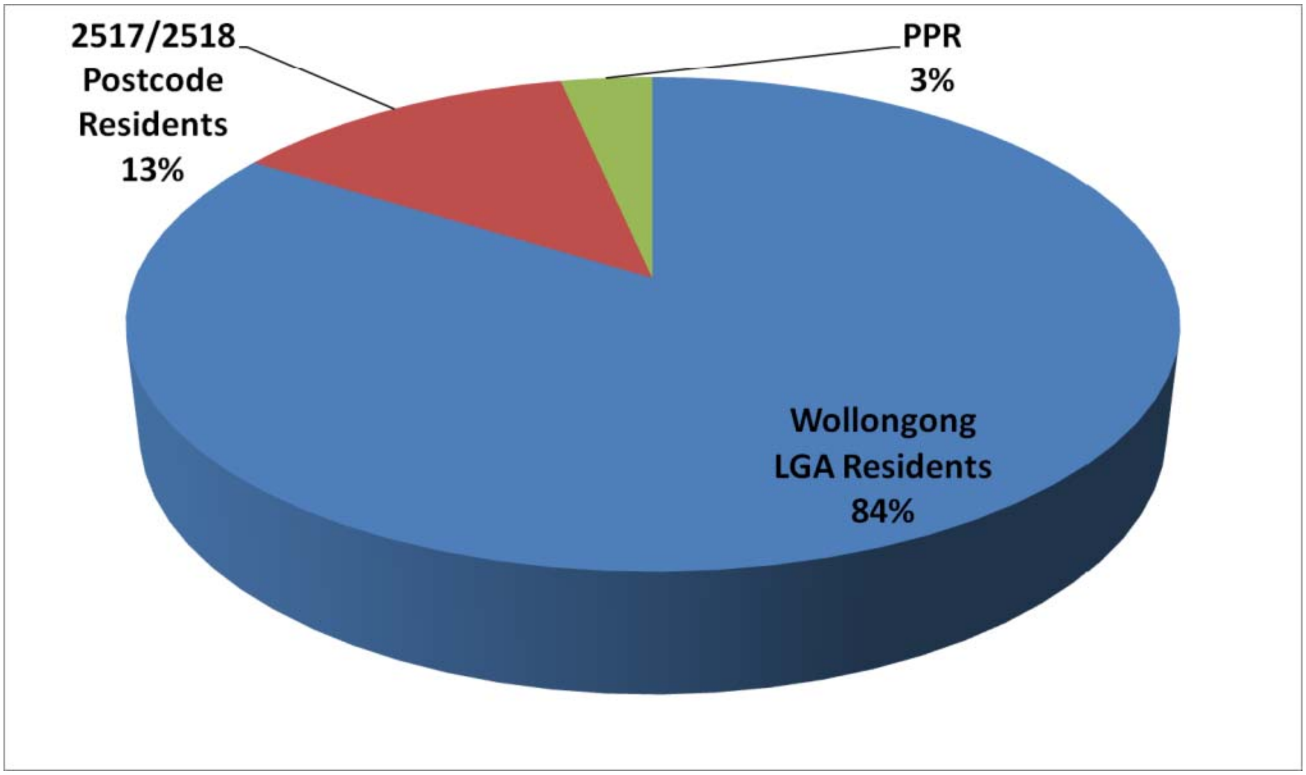
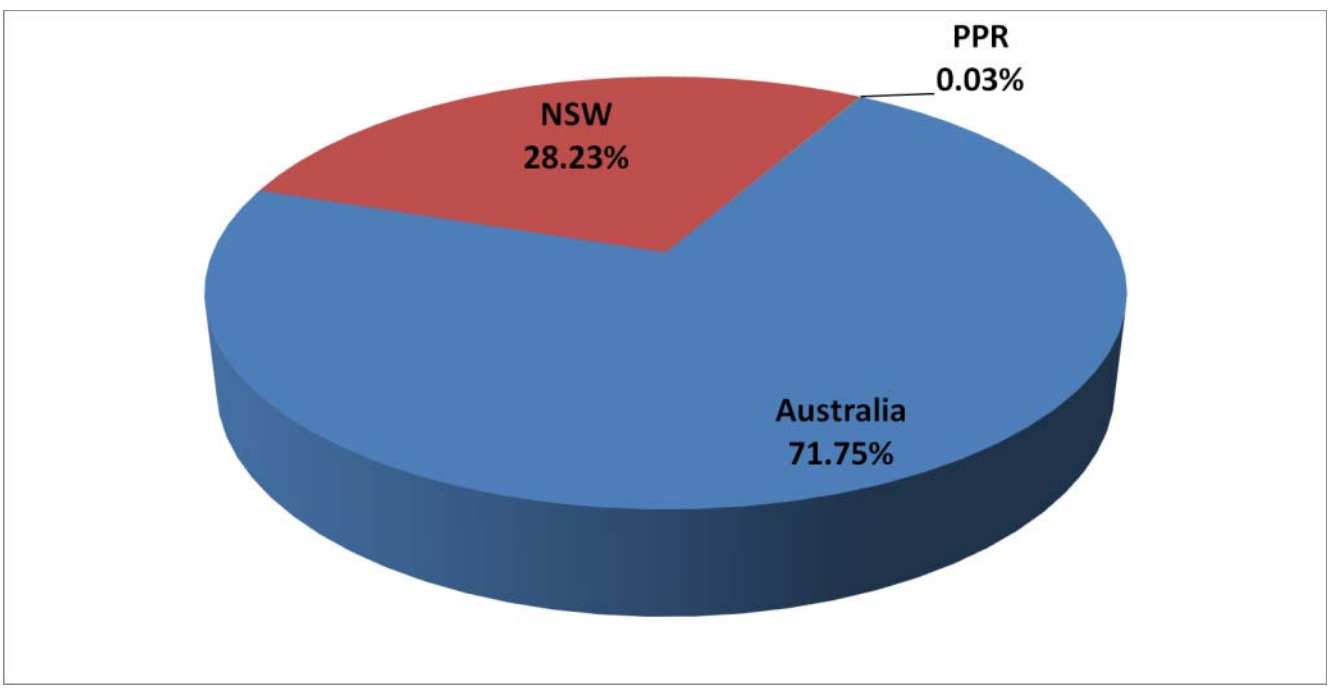


Figure 7 - Comparison of Scope 1 & 2 Annual Emissions from the PPR with NSW & Australia



2.1.1.5 Impact Assessment

The following has been calculated based on data from the Carbon Dioxide Information Analysis Centre of the US Department of Energy. During the period of 1950 to 2006 for which data was available, the annual total global CO_2 emissions (tCO_2) can be divided by the annual global change in CO_2 concentration (ppm) and correct for three years of significant volcanic activity (1964, 1982, and 1992). This gives an emission mass of 14,138 $MtCO_2$ for every 1ppm global increase in the concentration of CO_2 in the atmosphere.

There has been an approximate 120ppm increase in CO_2 concentrations in the atmosphere in the last 150 years, from 280ppm to 400ppm. According to the Intergovernmental Panel on Climate Change (IPCC), in the same period global average temperatures have risen around 0.8°C. For impact calculation purposes, this gives approximate values of:

- 14,138 $MtCO_2$ per 1ppm global increase in CO_2 concentration; and
- 150ppm per 1°C global temperature rise

The current estimated mass of CO_2 in the global atmosphere is around $3.1x10^{12}$ tonnes. Total Preferred Project related greenhouse gas emissions (Scope 1, 2 & 3) are estimated at approximately 8,109,009 t CO_2-e for the 5 years of the project life. If the above assumptions regarding increases in CO_2 are accepted and that for the case of this calculation, CO_2-e can be used in the place of CO_2 concentrations, the project would contribute the following to global warming.

- This would represent 0.06% (6 one-hundredths of 1%) contribution to a 1ppm rise in global CO_2 (or equivalent); or
- a 0.0004% (4 ten-thousandths of 1%) contribution toward a 1°C global temperature rise over the life of the project.

It would therefore take approximately 250,000 Preferred Projects to account for a 1°C change in global temperature based on current observations of climate change.

NOTE: This is a conservative calculation as it includes Scope 1, 2 & 3 emissions and doesn't take into account that methane only has a 12 year average residence time in the atmosphere, compared to 100 years for CO_2. To try to determine the specific impact on the local or global environment as a result of this scale of emission is beyond the scope of most models.

2.1.1.6 Emissions Management

The currently approved AQGGMP contains the following undertakings with regard to greenhouse gas management.

1. The feasibility of mechanisms and technological processes to capture fugitive CSG in the 'Western Mining Area' will be formally assessed in 2015. Based on the outcomes of the assessment, it is expected that NRE will further investigate opportunities to capture and/or re-use interseam pre-drained gases.
2. The inventory of emissions developed for the EA will be maintained.
3. Emissions and abatement strategies will be reported annually as part of internal environmental reporting and National Greenhouse Energy Reporting Scheme (NGERS) obligations.
4. The efficiency of all upgraded mobile and fixed equipment has been considered during procurement for fuel-powered equipment and it is anticipated that there will be fuel efficiency gains associated with upgraded equipment. Consequently, GHG emissions

will be minimised as required by Condition 18/ Schedule 3 of the Preliminary Works Pt3A approval.

Section 11.6, pgs 192-193, of the EA contains a number of other more detailed current and future approaches to minimising greenhouse gas emissions that are reproduced below.

1. Current activities being undertaken by the Colliery include:
   - o [improving] current gas and ventilation monitoring and measurement systems to improve data capture;
   - o the inventory of emissions developed for this assessment will be maintained;
   - o emissions and abatement strategies will be reported annually as part of internal environmental reporting and NGERS obligations;
   - o sealing of areas of the mine that are currently classed as ‘old and waste workings’ or large areas of standing pillars;
   - o rationalising ventilation systems to ventilate only essential roadways and production areas to reduce background emissions to as low as possible;
   - o eliminating old ventilation circuits as new areas of the mine come online to replace these transport and conveyor intake roadways and returns through the older parts of the mine; and
   - o site equipment will be maintained to retain energy efficiency.

   Recent works including reducing the fan speed at No.5 Shaft and sealing off old areas of the mine have reduced emissions from the No.5 Shaft ventilation from 117,164 t CO_2-e/annum to 26,952 t CO_2-e/annum. This represents a 90,212 t CO_2-e/annum (77%) reduction in emissions from the No.5 Shaft ventilation.

2. Additional activities proposed as part of this PPR include:
   - o the efficiency of all upgraded mobile and fixed equipment will be considered during procurement for fuel-powered equipment. It is anticipated that there will be fuel efficiency gains associated with upgraded equipment;
   - o upgrades to internal surface haulage routes will improve efficiency of on-site operations; and
   - o energy audits will be held when practicable to ensure that the Colliery is using effective techniques to minimise energy use and is operating at optimum energy levels;

3. Longer term reduction strategies currently being considered to cover the anticipated 20+ year mine life (to be addressed by future development applications) include:
   - o understanding the in-situ gas content of the coal to be mined and de-stressed by the mining process;
   - o minimising the gas available to enter the mine ventilation as a result of coal production and goaf formation by means of effective gas drainage and piping of gas to the surface;
   - o sealing active goaf areas as longwall blocks are completed to limit fugitive emissions from these sources and ‘tapping’ these areas as gas builds up to complement gas drainage capture;
   - o capturing fugitive emissions and either flaring or using the gas to produce energy;
   - o investigation of potential gas collection and utilisation systems such as replacing flaring with gas engine/gas turbine technology. Gas utilisation could include power generation or addition of seam gas to existing natural gas pipelines; and

- in the future the increased scale of the proposed operation will likely enable NRE to achieve greater economies of scale in production and therefore increase production efficiency. Increased efficiency may contribute to further reduction in the greenhouse intensity of the operation beyond what is modeled in this assessment.

2.1.1.7 Conclusion

This chapter has provided an assessment of the greenhouse gas impact from activities associated with the revised project. The impact assessment has presented estimates of the Preferred Project's direct emissions, as well as the indirect emissions beyond NRE's operational control.

In this assessment, total emissions over the lifetime of the Preferred Project (Scope 1, 2 and 3) have been calculated as being 8,109,009t CO_2–e. Peak annual emissions are predicted to occur in 2014, contributing 1,672,093t CO_2–e to atmosphere from all sources

Peak year direct greenhouse gases emissions (Scope 1 and 2) are estimated to be approximately 203,849t CO_2-e/annum in 2014, meaning that the greenhouse intensity of the Preferred Project will equate to approximately 0.35t CO_2-e for each tonne of ROM coal extracted. Total direct emissions (Scope 1 and 2) over the operational lifetime of the Project are estimated at 767,789t CO_2-e.

Measures identified by the company have the potential to reduce total emissions by at least 59%. These will be progressively used, not just to reduce total emissions, but also to promote safe mining operations. The progressive sealing of old mine areas, the use of gas drainage, and the burning of the waste gas to generate power are all achievable and practical options that will be used as mining progresses.

In calculating the total emissions profile, it is estimated that the Project will contribute no more than 0.03% of Australia's and 0.1% of NSW's annual Scope 1 and 2 greenhouse gas emissions.

2.1.2 Rehabilitation

NRE has undertaken further work on the proposed rehabilitation in *Section 16, pg 229, of the EA*. Greater detail of the conceptual Pit Top and surface lease rehabilitation has been included in this PPR.

Specifically, NRE has addressed the Division of Resources and Energy (DRE) requirement for:

- **Section 2.1.2.1 - Indicative post mining land use**, pg 36;
- **Section 2.1.2.2 - Conceptual rehabilitation objectives**, pg 44;
- **Section 2.1.2.3 - Conceptual rehabilitation methods**, pg 46; and
- **Section 2.1.2.4 - Conceptual completion criteria**, pg 50.

2.1.2.1 Indicative Post Mining Land Use

There will be three main post mining land uses on NRE freehold and leasehold land. These correspond with the following Domains

1. **Domain 1** - Escarpment Foothills (Areas zoned RU1 and E3 on the escarpment foothills including the Russell Vale Pit Top)
2. **Domain 2** – Escarpment Face (areas zoned E2 from the foothills to the top of the escarpment)
3. **Domain 3** – Woronora Plateau (areas west of the escarpment edge)

The indicative post mining uses for each domain are as follows:

1. **Domain 1** - Dwelling houses;
2. **Domain 2** - Amalgamation of E2 land with the Illawarra Escarpment State Conservation Area (IESCA); and
3. **Domain 3** - Amalgamation of E2 land with the SCA's Metropolitan Special Area.

The indicative post mining land use for each parcel of NRE freehold and land covered by NRE leases is set out in detail in **Table 15**, pg 36. A graphical representation of the areas to be rehabilitated are presented in **Figure 8**, pg 40**, Figure 9**, pg 41**, Figure 10**, pg 42 and **Figure 11**, pg 43.

Table 15 - Indicative Post Mining Land Use for NRE Freehold and Leasehold Lands

NOTE: *This table may change over time to reflect future changes to land zonings. Grey shaded rows indicate properties covered by NRE surface leases but not owned by NRE. Data from Wollongong City Council Planning and Constraint Map 22 March 2013.*

EPI	Zone	Purpose of Zoning	Allowable End Use	Locality	Identifier	Address	Owner	Indicative End Use
Wollongong Local Environment Plan 2009	RU1	• To encourage sustainable primary industry production by maintaining and enhancing the natural resource base. • To encourage diversity in primary industry enterprises and systems appropriate for the area. • To minimise the fragmentation and alienation of resource lands. • To minimise conflict between land uses within this zone and land uses within adjoining zones.	Agricultural produce industries; Agriculture; Animal boarding or training establishments; Business identification signs; Dwelling houses; Environmental protection works; Extractive industries; Farm buildings; Forestry; Intensive livestock agriculture; Intensive plant agriculture; Open cut mining; Roads; Roadside stalls	Pit Top Area from western boundary of Lot 1 DP 1046070 to Princes Hwy	Lot 31 DP 1006012	7 Princes Highway, Corrimal	NRE	Dwelling Houses
					Lot 1 DP 534522 Lot 1 DP 77407 Lot 1 DP 986676 Lot 1 DP 1046070 Lot 1 DP 1052074	Lot 1 Princes Highway, Corrimal	NRE	
					Lot 2 DP 1052074	Lot 2 Princes Highway, Corrimal	NRE	
					Lot 3 DP 1052074	Lot 3 Rixons Pass Road, Cataract	NRE	
	E3	• To protect, manage and restore areas with special ecological, scientific, cultural or aesthetic values. • To provide for a limited	Animal boarding or training establishments; Bed and breakfast accommodation; Building identification signs; Business identification signs; Community facilities; Dwelling houses;	Lot at southern edge of Pit Top at end of Lyndon St. Lot extends west from Lyndon St and then wraps around southwards to encapsulate the conveyor portal	Lot 1 DP 534522	Lot 1 Princes Highway, Corrimal	NRE	Dwelling Houses

EPI	Zone	Purpose of Zoning	Allowable End Use	Locality	Identifier	Address	Owner	Indicative End Use
		range of development that does not have an adverse effect on those values.	Environmental facilities; Environmental protection works; Extensive agriculture; Farm buildings; Farm stay accommodation; Forestry; Home-based child care; Recreation areas; Roads; Secondary dwellings	Eastern side of Lot on escarpment face directly to the north of Lot 1 DP104670 and directly north west of Pit Top	Lot 1 DP 630761	Lot 1 Rixons Pass Road, Russell Vale	NRE	
				Eastern side of lot on escarpment face east of Lot 68 DP751301	Lot 6501 DP 1083715	Lot 6501 Rixons Pass Road, Woonona	NRE	
				Lot on escarpment face in the south east corner of Lot 6501 DP1083715	Lot 6502 DP 1083715	Lot 6502 Rixons Pass Road, Woonona	NRE	
				Southern edge of Lot on escarpment face directly north of Lot 6501 DP1077301	Lot 6001 DP 1077301	Lot 6001 Forestview Way, Woonona	NRE	
				Lot on northern edge of Lot 6500 DP 1083715	Lot 6000 DP 1077301	Lot 6000 Forestview Way, Woonona	Illawarra Land Pty Ltd	NA
	E2	See next page	See next page	Small lot on escarpment face directly north west of the Pit Top and directly north of Lot 67 DP 751301	Lot 1 DP 175437	Lot 1 Rixons Pass Road, Russell Vale	Private	NA
Wollongong Local Environment Plan 2009	E2	• To protect, manage and restore areas of high ecological, scientific, cultural or aesthetic values. • To prevent development that could destroy, damage or otherwise have an adverse effect on those values. • To retain and enhance the visual and scenic qualities of the Illawarra Escarpment. • To maintain the quality of the water supply for Sydney and the Illawarra by protecting land forming part of the Sydney drinking water catchment (within the meaning of *State*	Environmental facilities; Environment protection works; Extensive agriculture; Recreation areas	Lot on top of the escarpment to the west of Lot 32 DP751301 and adjoining Mt Ousley Rd	Pt Lot 34 DP 751301	Pt Lot 34 Rixons Pass Road, Cataract	Private	NA
				Lot on escarpment face directly north of Lot 66 DP751301	Lot 67 DP 751301	Lot 67 Rixons Pass Road, Russell Vale	Private	NA
				Lot on escarpment face directly east of Lot 6501 DP 1083715	Lot 6500 DP 1083715	Lot 6500 Rixons Pass Road, Woonona	Illawarra Land Pty Ltd	NA
				Lot directly north of Lot 6000 DP1077301	Lot 611 DP 1065600	Lot 611 Forestview Way, Woonona	Private	NA
				Lot on top of escarpment west of Mt Ousley Rd and north of Lot 1 DP 1046069	Lot 270 DP 1138691	Lot 270 Mount Ousley Road, Bulli	Private	NA
				Small lot directly north of Lot 270 DP1138691	Lot 11 DP736121	Lot 11 Mount Ousley Road, Bulli	Private	NA
				Lot on escarpment face directly west of Lot 1 DP534522	Lot 1 DP 77407	Lot 1 Princes Highway, Corrimal	NRE	Amalgamate with IESCA

EPI	Zone	Purpose of Zoning	Allowable End Use	Locality	Identifier	Address	Owner	Indicative End Use
		Environmental Planning Policy (Sydney Drinking Water Catchment) 2011) to enable the management and appropriate use of the land by the SCA.		Lot covering escarpment face and escarpment top directly west of Pit Top	Lot 1 DP 1046070	Lot 1 Princes Highway, Corrimal	NRE	Amalgamate with SCA land and/or IESCA
				Lot at top of escarpment directly to the north of Brokers Nose	Lot 32 DP 751301	Lot 32 Rixons Pass Road, Cataract	NRE	Amalgamate with SCA land and/or IESCA
				Lot at top of escarpment containing Brokers Nose	Lot 63 DP 751301	Lot 63 Rixons Pass Road, Cataract	NRE	Amalgamate with SCA land and/or IESCA
				Lot on top of escarpment to the west of Mt Ousley Rd and to the north of Picton Rd	Lot 6 DP 793358	Lot 6 Rixons Pass Road, Cataract	NRE	Amalgamate with SCA land
				Western side of Lot on escarpment face directly to the north of Lot 1 DP104670 and directly north west of Pit Top	Lot 1 DP 630761	Lot 1 Rixons Pass Road, Russell Vale	NRE	Amalgamate with IESCA
				Lot on face and top of escarpment directly to the north of Lot 1 DP104670 and directly to the west of Lot 1 DP630761	Lot 66 DP 751301	Lot 66 Rixons Pass Road, Russell Vale	NRE	Amalgamate with SCA land and/or IESCA
				Lot on top of escarpment on both east and west of Mt Ousley Rd	Lot 30 DP 751301	Lot 30 Rixons Pass Road, Cataract	NRE	Amalgamate with SCA land and/or IESCA
				Lot on escarpment face and top directly west of Lot 67 DP751301	Lot 31 DP 751301	Lot 31 Rixons Pass Road, Cataract	NRE	Amalgamate with SCA land and/or IESCA
				Lot on escarpment face directly east of Lot 30 DP751301	Lot 68 DP 751301	Lot 68 Rixons Pass Road, Cataract	NRE	Amalgamate with SCA land and/or IESCA
Wollongong Local Environment Plan 2009	E2	• To protect, manage and restore areas of high ecological, scientific, cultural or aesthetic values. • To prevent development that could destroy, damage or otherwise have an adverse effect on those values. • To retain and enhance the visual and scenic qualities of the Illawarra	Environmental facilities; Environment protection works; Extensive agriculture; Recreation areas	Western side of lot on escarpment face east of Lot 68 DP751301	Lot 6501 DP 1083715	Lot 6501 Rixons Pass Road, Woonona	NRE	Amalgamate with IESCA
				Northern section of Lot on escarpment face directly north of Lot 6501 DP1077301	Lot 6001 DP 1077301	Lot 6001 Forestview Way, Woonona	NRE	Amalgamate with the IESCA
				Furthest north lot on escarpment face adjacent to the IESCA	Lot 3 DP 60975	Lot 3 Rixons Pass Road, Woonona	NRE	Amalgamate with the IESCA
				Small lot on escarpment top directly east of Mt Ousley Rd and directly north of Lot 12 DP736121	Lot 69 DP 751301	Lot 69 Rixons Pass Road, Cataract	NRE	Amalgamate with SCA land and/or IESCA

EPI	Zone	Purpose of Zoning	Allowable End Use	Locality	Identifier	Address	Owner	Indicative End Use
		Escarpment. • To maintain the quality of the water supply for Sydney and the Illawarra by protecting land forming part of the Sydney drinking water catchment (within the meaning of *State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011*) to enable the management and appropriate use of the land by the SCA.		Small lot on escarpment top directly east of Mt Ousley Rd and directly north of Lot 69 DP 751301	Lot 2 DP 1046069	Lot 2 Rixons Pass Road, Woonona	NRE	Amalgamate with SCA land
				Lot on top of escarpment west of Mt Ousley Rd	Lot 70 DP 751301	Lot 70 Rixons Pass Road, Cataract	NRE	Amalgamate with SCA land
				Lot on top of escarpment west of Mt Ousley Rd and north of Lot 70 DP751301	Lot 1 DP 1046069	Lot 1 Rixons Pass Road, Cataract	NRE	Amalgamate with SCA land
				Part of lot at Western boundary of Pit Top Area	Lot 1 DP 1046070	Lot 1 Princes Highway, Corrimal	NRE	Amalgamate with SCA land and/or IESCA
				Lot directly to the north of Lot 1 DP104670 and directly north west of Pit Top	Lot 1 DP 630761	Lot 1 Rixons Pass Road, Russell Vale	NRE	Amalgamate with IESCA
				Lot on top of escarpment directly west of Lot 70 DP751301	Lot 71 DP 751301	Lot 71 Rixons Pass Road, Cataract	NRE	Amalgamate with SCA land
				No.1, No.2, No.3 & No4 Shafts	Various lots	NA	SCA	Remediated and returned to SCA uses
				Access roads in catchment	Various lots	NA	SCA	To be retained as access roads for SCA and firefighting if required. Otherwise they will be rehabilitated
Wollondilly Local Environment Plan 2011	E2	• To protect, manage and restore areas of high ecological, scientific, cultural or aesthetic values. • To prevent development that could destroy, damage or otherwise have an adverse effect on those values.	Environmental facilities; Environmental protection works; Information and education facilities; Roads; Water supply systems	No.4 & No5 Shafts in Metropolitan Special Area	Various lots	NA	SCA	Remediated and returned to SCA uses
				Access roads in catchment	Various lots	NA	SCA	To be retained as access roads for SCA and firefighting if required. Otherwise they will be rehabilitated

Figure 8 - Location of No.1 Colliery Rehabilitation Domains

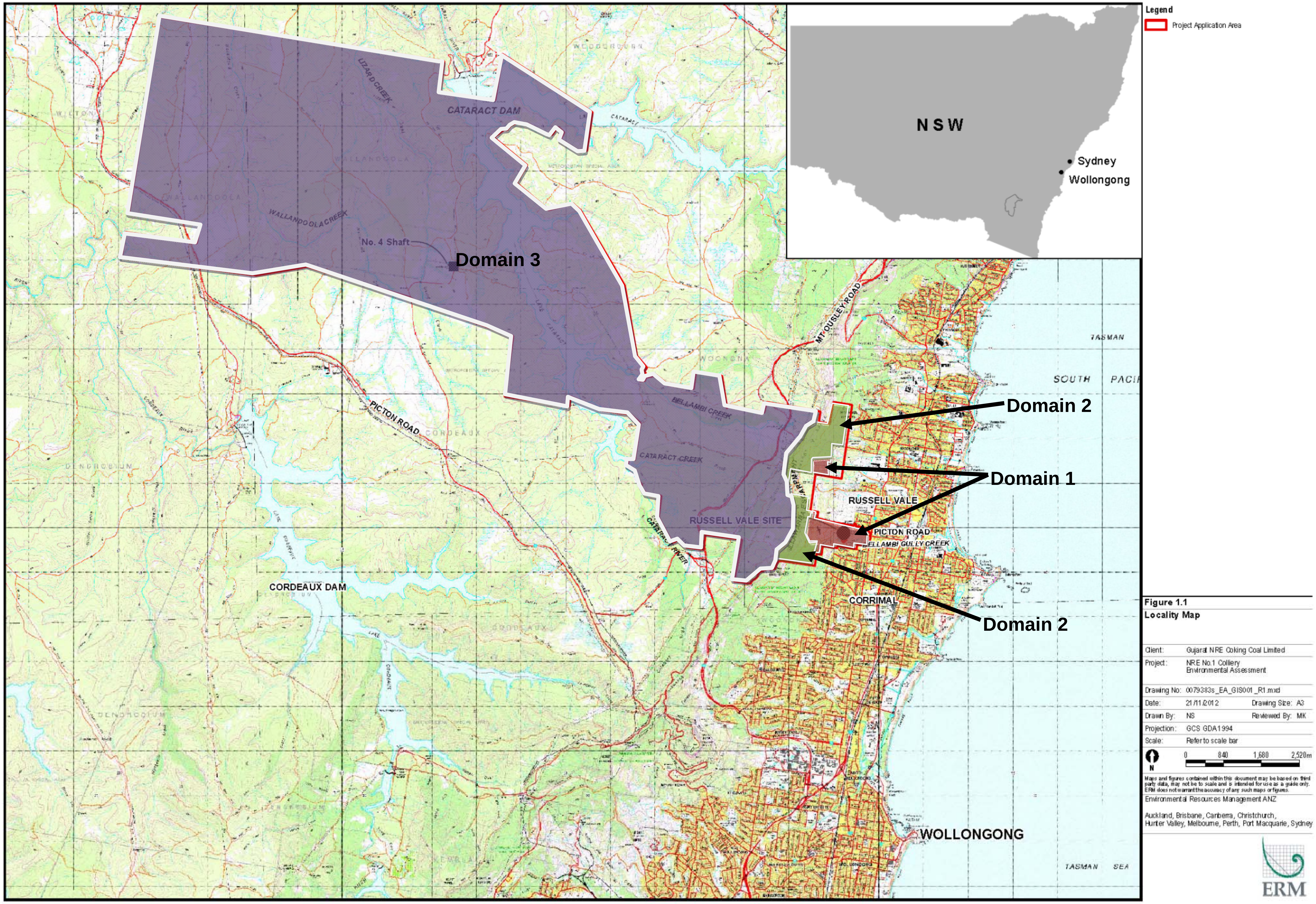
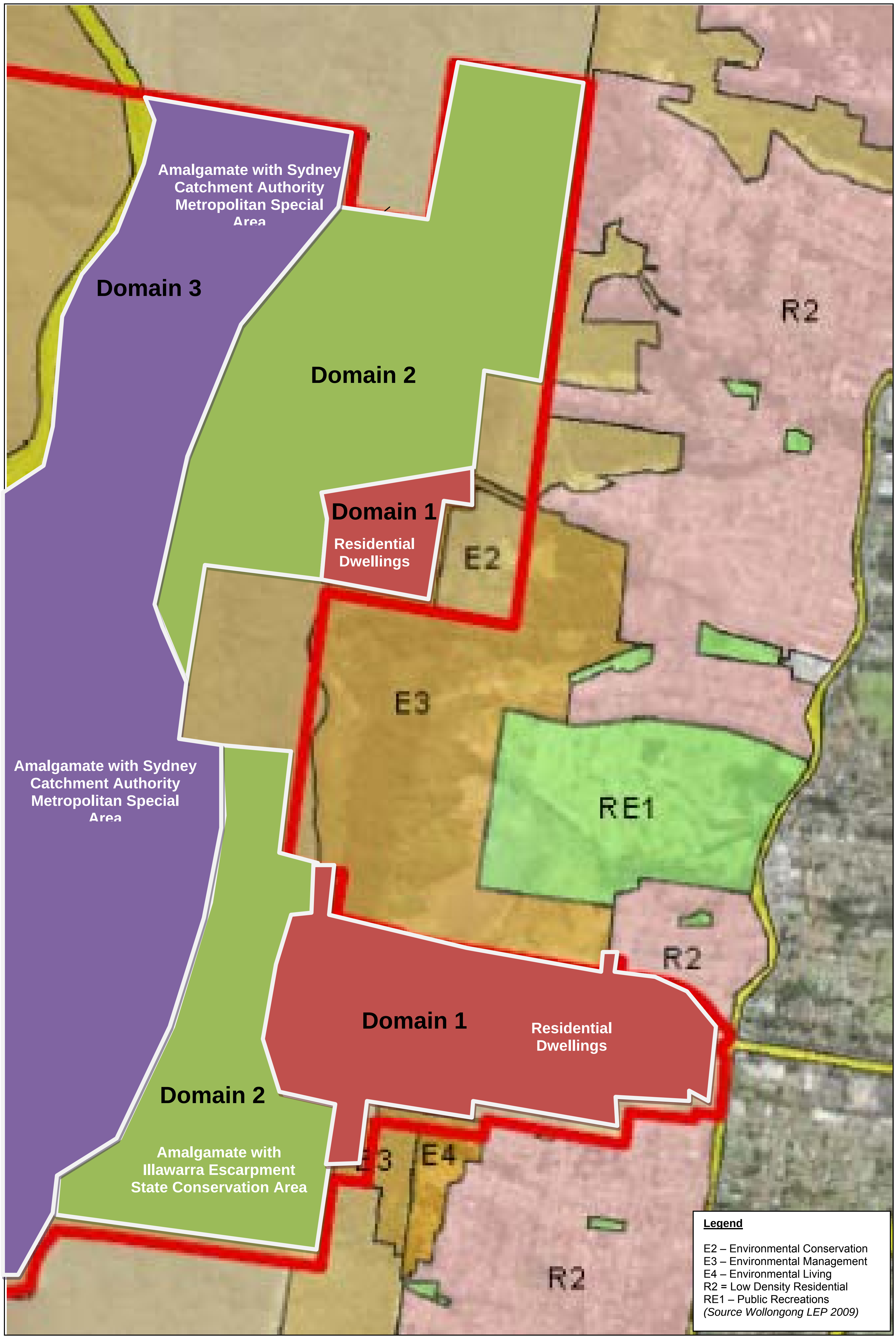
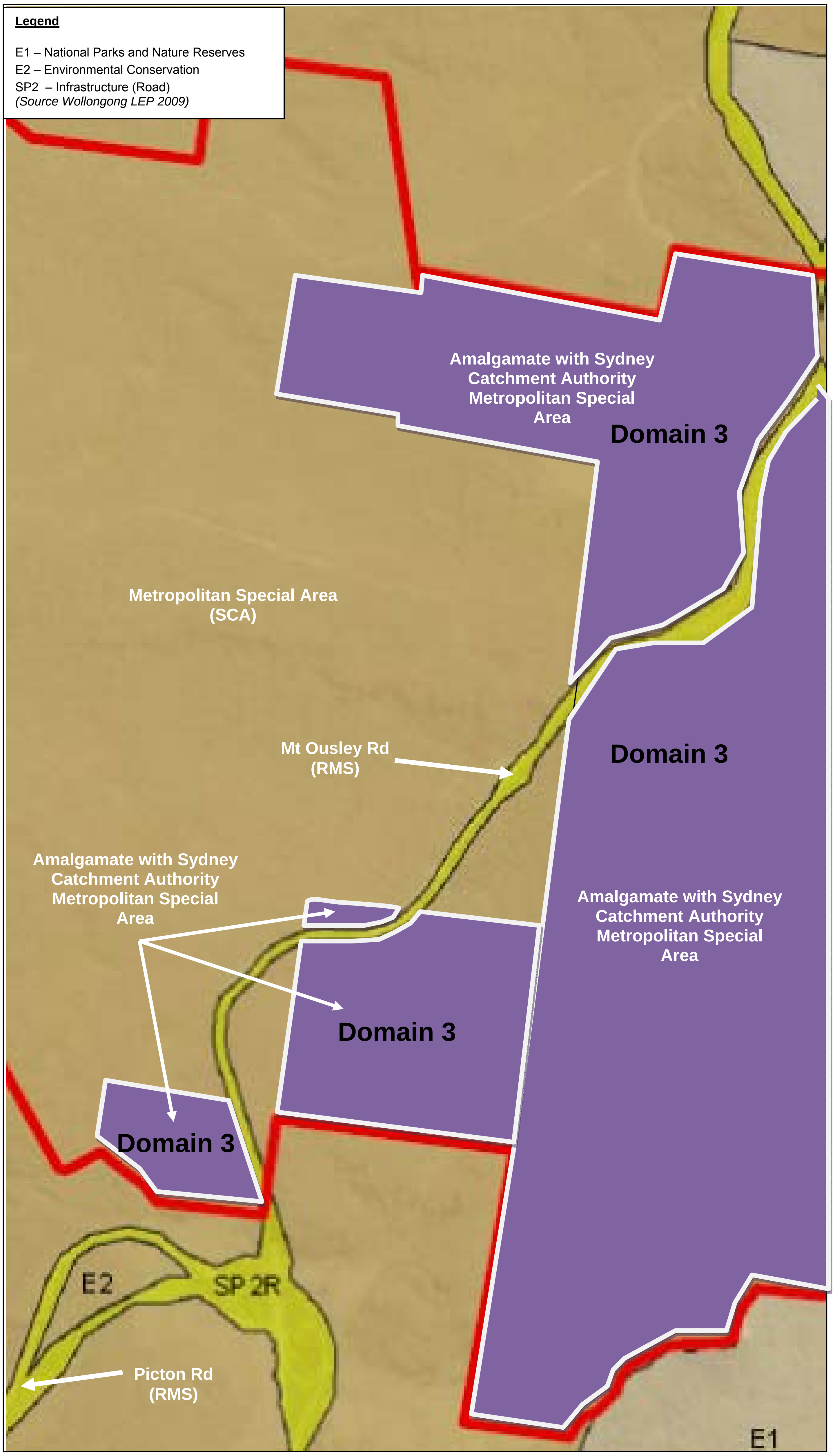


Figure 9 - NRE Freehold Land (East) Indicative Post Mining Land Use



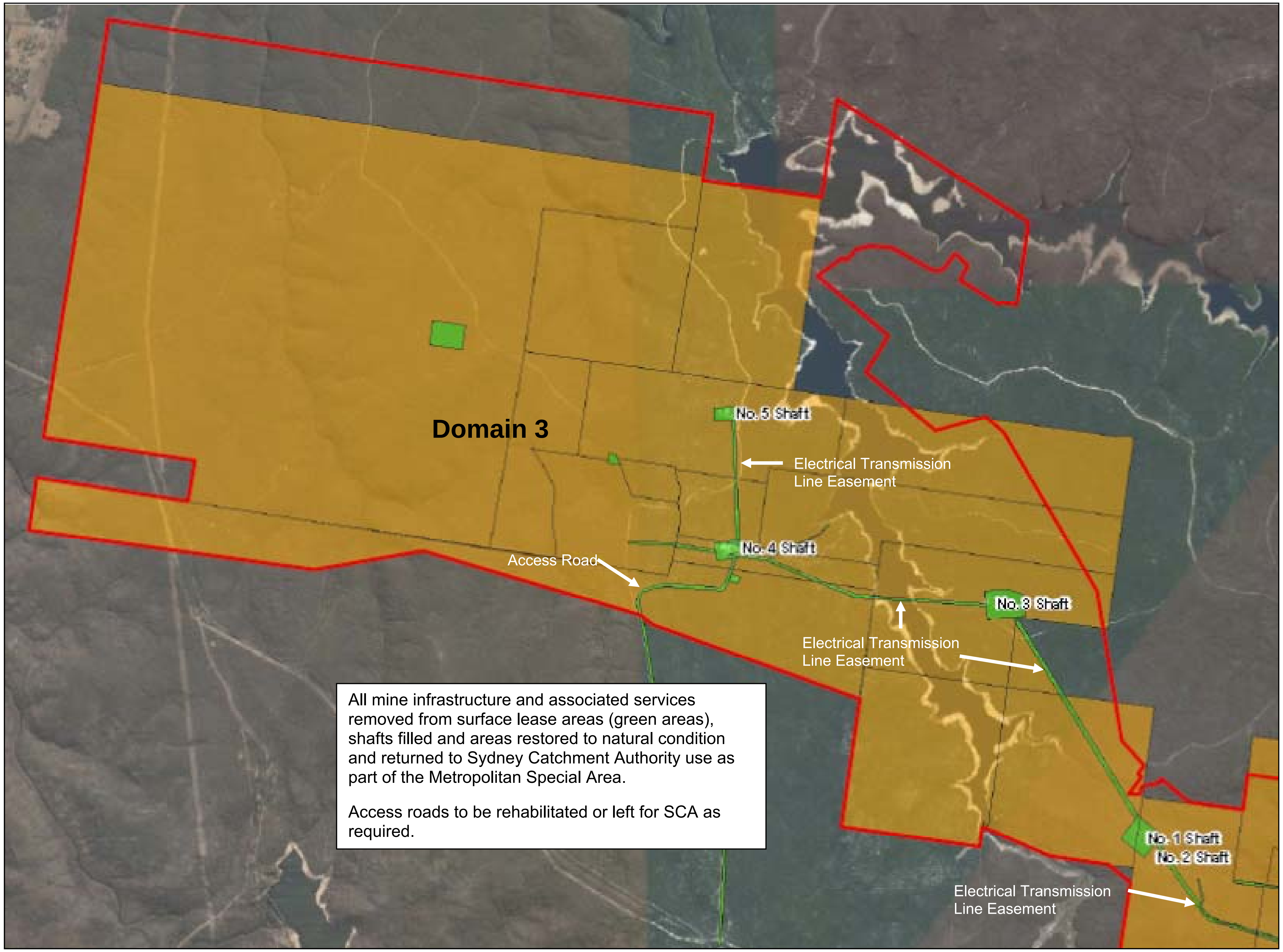
Source: Wollongong City Council Online Zoning Plan

Figure 10 - NRE Freehold Land (West) Indicative Post Mining Land Use



Source: Wollongong City Council Online Zoning Plan

Figure 11 - Metropolitan Special Area Surface Lease Indicative Post Mining Land Use



2.1.2.2 Conceptual Rehabilitation Objectives

General Lease Area Rehabilitation Objectives

1. Sites shall remain in a safe, stable, non-polluting and sustainable state;
2. The socio-economic benefits of the rehabilitated sites will be maximised;
3. Long term maintenance of the sites will not be greater than the surrounding environment;
4. The agreed post-mining land use will be compatible with the surrounding land fabric and land use requirements; and
5. The rehabilitated landforms will have no greater management requirements than the surrounding landforms and land uses.

Domain 1 Rehabilitation Objectives

The rehabilitation objectives for the RU1 zoned Russell Vale Pit Top and E3 zone to the north are based on preparing the land for residential development that will follow.

The ***Unplanned Closure*** rehabilitation objectives are:

1. Seal all mine entries to DRE and Dams Safety Committee (DSC) satisfaction; and
2. Immediate implementation of works to achieve Long Term rehabilitation objectives

The ***Short Term*** rehabilitation objectives (1 to 5 years) are:

1. Progressive removal of redundant, non-heritage mine infrastructure; and
2. Progressive revegetation of unused disturbed areas with grasses and shrubs.

The ***Long Term*** rehabilitation objectives (end of mine life) are:

1. Preservation of all site heritage items as required by legislation or in liaison with regulatory authorities;
2. Removal of all non-heritage mine infrastructure and services;
3. Sealing of all mine entries to DRE and DSC satisfaction;
4. Geotechnical stabilisation of all site benches and slopes as necessary;
5. Removal of site water quality control ponds unless required for future use in residential development;
6. Removal of identified noxious weeds; and
7. Revegetation of all disturbed areas of site with grasses and shrubs.

Domain 2 Rehabilitation Objectives

The rehabilitation objectives for the freehold E2 zones on the escarpment face are based on preparing the land for integration into the IESCA.

The **Unplanned Closure** rehabilitation objectives are:

1. Removal of identified noxious weeds in disturbed areas;
2. Revegetation of unused disturbed areas with appropriate local species;
3. Maintain roads in serviceable condition; and
4. Immediate implementation of works to achieve Long Term rehabilitation objectives.

The **Short Term** rehabilitation objectives (1 to 5 years) are:

1. Removal of identified noxious weeds in disturbed areas;
2. Revegetation of unused disturbed areas with appropriate local species; and
3. Maintain roads in serviceable condition.

The **<u>Long Term</u>** rehabilitation objectives (end of mine life) are:

1. Preservation of all site heritage items as required by legislation or in liaison with regulatory authorities;
2. Removal of all non-heritage mine infrastructure and services;
3. Maintain roads in a serviceable condition for National Parks & Wildlife Service (NPWS) and Rural Fire Service (RFS) use.
4. Geotechnical stabilisation of all site benches and slopes as necessary;
5. Removal of dams;
6. Removal of identified noxious weeds in disturbed areas
7. Revegetation of all disturbed areas appropriate local species

<u>Domain 3 Rehabilitation Objectives</u>

The rehabilitation objectives for the freehold and leasehold E2 zones on the Woronora Plateau are based on preparing the land for integration into the SCA's Metropolitan Special Area.

The **<u>Unplanned Closure</u>** rehabilitation objectives are:

1. Remove identified noxious weeds in disturbed areas;
2. Revegetation of unused disturbed areas with appropriate local species;
3. Maintain roads in a serviceable condition; and
4. Immediate implementation of works to achieve Long Term rehabilitation objectives

The **<u>Short Term</u>** rehabilitation objectives (1 to 5 years) are:

1. Removal of identified noxious weeds in disturbed areas;
2. Revegetation of unused disturbed areas with appropriate local species;
3. Rehabilitation of mine subsidence impacts to agency and infrastructure stakeholder satisfaction and in accordance with approved SMP's; and
4. Maintain roads in serviceable condition

The **<u>Long Term</u>** rehabilitation objectives (end of mine life) are:

1. Preservation of all heritage items as required by legislation or in liaison with regulatory authorities;
2. Removal of all non-heritage mine infrastructure and services;
3. Sealing of all shafts to regulatory standards;
4. Removal of environmental monitoring infrastructure;
5. Sealing of all boreholes to regulatory standards and revegetation of all exploration and monitoring boreholes to SCA satisfaction;
6. Maintain roads in a serviceable condition for SCA and RFS use;
7. Removal of water treatment dams;
8. Removal of identified noxious weeds in disturbed areas;
9. Rehabilitation of mine subsidence impacts to agency and infrastructure stakeholder satisfaction and in accordance with approved SMPs; and
10. Revegetation of all disturbed areas to SCA satisfaction.

2.1.2.3 Conceptual Rehabilitation Methods

Heritage Items

Preservation of heritage items will be undertaken in accordance with the HMP (*a requirement of DPI conditions for major projects*) at the time of the mine closure. The implementation of the plan will involve a site inspection by an appropriate heritage expert to assess the listed heritage items and make recommendations as to what heritage preservation actions may be required. These recommendations could range from full restoration and display of items of mobile heritage, interpretive signage or full restoration of heritage structures.

Surface Infrastructure

All surface infrastructure will be removed in accordance with current planning and building regulatory requirements for this type of activity. Structures will be removed first, followed by services and finally the ground will be broadly re-profiled, where possible, to match the surrounding ground contours. During this stage soil and water will be managed via the site's dirty water management system. All waste materials will be recycled, reused or disposed of at an appropriate licensed waste disposal facility. These details will be spelled out in detail in a CEMP or project plan.

Mine Entrances

Adit Filling and Capping

All adits will be sealed to DRE standards. All bulkheads and bulkhead seals will be designed by an engineer who has visited the site and will take into account any possible fretting of the adit perimeter. A bulkhead will be constructed not less than 20 metres from the surface entry point with a minimum depth of cover of 15 metres of solid strata. Any man-made structures or fittings in the adit will be removed if it is safe to do so. The void from the bulkhead to the adit entrance will be filled with high integrity fill materials in a manner that ensures there are no voids in the adit. The surrounding strata at the entrance to the adit will be secured and protected against weathering and spalling weakening the adit beyond the lip of the solid rock. A bulkhead seal will be erected at the entrance to the adit and the adit bulkhead and surrounds will be completely covered by mounding earth over the area if possible. A plaque will be placed on the portal bulkhead or in a visible position with the name of the colliery, adit name and date of sealing inscribed on it.

The design engineer will certify that the bulkheads were completed in compliance with the original design or indicate alterations to the original design. These 'as constructed' drawings will be supplied to the DRE.

Drift Filling and Capping

All drifts will be sealed to DRE standards. All bulkheads and bulkhead seals will be designed by an engineer who has visited the site and will take into account any possible fretting of the drift perimeter. A bulkhead will be constructed at a point with a minimum depth of cover of 15 metres of solid strata. Where there is a possibility of fretting of the strata surrounding the bulkhead, the bulkhead design will include provision for strata reinforcement to prevent any reduction of the strength of the bulkhead. The inbye bulkhead may be designed to permit the passage of water but will prevent the flow of any gas from the workings. If the bulkhead is designed with allowance for water passage, the fill material used outbye of the bulkhead will be resistant to water causing it to become fluid or capable of flowing when wet. Any man-made structures or fittings in the drift will be removed if it is safe to do so. The void from the inbye bulkhead to the drift entrance will be filled with high integrity fill materials in a manner that ensures there are no voids in the adit. The surrounding strata at the entrance to the adit will be secured and protected against weathering and spalling weakening the adit beyond the lip of the solid rock. A bulkhead seal will be erected at the portal mouth to prevent the ingress of water and escape of gas. The final void behind the portal bulkhead will be stowed completely to the roof. The portal may be covered by mounded earth. A plaque will be placed on the portal bulkhead or in a visible position with the name of the colliery, adit name and date of sealing inscribed on it.

Shaft Filling and Capping

All shafts will be sealed to DRE standards. The area around the shaft will be fully enclosed by a man-proof security fence prior to the commencement of shaft filling. All bulkheads and shaft caps will be designed by an engineer. Where seam inserts are still accessible, substantial bulkheads will be constructed to prevent fill material from flowing into the mine workings. Where insert bulkheads are installed they will permit the passage of water from one side of barrier to the other to reduce the requirement for design against substantial hydraulic head. The engineer will certify that the bulkheads were constructed to the specified design. Where seam inserts are inaccessible, material will be used to fill the shaft to a level above the seam insert so if the material below the insert moves, the insert will remain completely sealed to prevent any material flowing into the insert. The level of hard rock fill above inserts will be confirmed by plumbing of the shaft. Suitable fill material should be used to fill the remainder of the shaft. All fill material to be used in the filling of the shaft will be approved by the DRE.

If surface demolition material is used for shaft fill, it will be crushed and broken to a suitable size to avoid wedging in the shaft. Where the shaft contains water or maybe subject to water inflow, the filling will ensure that the material will remain in place in the event of the workings being holed, dewatered, or affected by a seismic event. The use of a concrete plug at each insert will be considered. A full-time competent supervisor will be appointed to oversee filling operations as they are taking place. Where possible, fill material will be introduced centrally into the shaft and a water spray will be used at all times when fill is being placed into the shaft. The surface capping of the shaft will be founded on bedrock. Excavation of surface soil down to bedrock to allow the surface capping to be installed will be done after the shaft is filled to this point. The shaft collar will be removed down to bedrock. The engineer will inspect the site prior to designing of the surface capping and the shaft capping will be designed using a design loading and uniformly distributed load of at least 7kPa. The design of the shaft capping structure will not include support given by the shaft fill material. The design of the surface capping will take into account any possible fretting of material at the shaft perimeter. All steel reinforcement used in the surface capping structure will have a minimum of 100mm of concrete cover and provision will be made in the surface capping to allow for topping up of fill with additional fill if necessary. The shaft capping will either be left uncovered or be covered to natural ground level based on the preference of the SCA. If still exposed the shaft collar will be engraved with the mine and shaft name and date sealed but if covered then a plaque will be fixed to a suitable concrete footing to display the sealing details.

The engineer will certify that the completion of the capping was in accordance with the approved design and ‘as constructed’ drawings of shaft capping and shaft fill details will be supplied to the DRE.

All non natural materials will be removed from the site. The surface casing will be removed to a depth below ground that meets the requirements of the SCA. The vegetation will be rehabilitated in accordance with the SCA’s preferred method.

Boreholes

Sealing

All borehole sealing activities will comply with the latest DRE design guidelines or other best practice guidelines relevant to the activity. All boreholes will be filled in from the total depth to the surface with approved cement mixtures. To avoid excess being deposited on the surface, which may interfere with any land use activities, approved cement mixtures will support the maximum allowable length of grout and provide an effective seal within the hole. The cement mixtures won't be deposited in more than 200m of vertical depth in any borehole at any one time. Setting and weight testing will be completed and recorded before any further cement mixtures can be deposited in the borehole. Samples of the concrete mixture will be kept for strength determinations if the DRE requires.

Records will be kept to demonstrate the method used to seal the hole, volumes and types of materials used and information on the drill hole such as depth, diameter and casing string(s) left in the hole. Any loss of cement mixture due to high flow aquifers or permeable strata will be recorded as well as the method used to overcome these problems. All records relating to the sealing of boreholes will be provided to the DRE together with a declaration by NRE confirming that the work was carried out according to current guidelines and documenting any variations with supporting explanation.

All boreholes will be sealed by pumping the cement mixture from either the base of the hole or the bottom of the previously cemented section of the hole. Depending on requirements, the cement may be preceded and/or followed by plugs. The position of the plugs in the borehole will be determined before further grouting. In the event that a number of plugs are used within a borehole, the plugs must be placed so as not to leave a significant unfilled section between the plug and the underlying previously cemented section. When grouting the surface casing the cement mixture won't extrude from the annulus between the casing and the borehole wall or another larger diameter casing string. All boreholes will be depth tested between all grouting and plug operations to determine if the level of the grout in the borehole is higher than shown in the calculations. All depth testing for this purpose will be recorded. No cement mixture excess will be deposited on the surface. All casing strings that are not cemented into place will be removed prior to or during the sealing of the hole. Where non-grouted casing cannot be removed, the casing will be perforated and grout will be pumped under pressure to fill the annulus behind the unsealed casing. If necessary a suitable bridge or plug will be placed near the base of the affected casing in order to facilitate the injection of grout behind the casing.

Surface Rehabilitation

All non natural materials will be removed from the site. The surface casing will be removed to a depth below ground that meets the requirements of the SCA. The vegetation will be rehabilitated in accordance with the SCA's preferred method.

Survey

All rehabilitated boreholes will be surveyed to determine their horizontal and vertical positions and survey details will be provided to the DRE. A permanent steel identification plate or reference mark will be placed at the location of each borehole for relocation purposes. All boreholes will be surveyed with a vertical position accuracy of +/- 0.3 metres and a horizontal position accuracy of +/- 1.0 metres. The vertical position will be referenced to the Australian Height Datum (AHD) level values and the horizontal position will be referenced to the Integrated Survey Grid (ISG) co-ordinate values.

NRE will ensure compliance with any conditions set by relevant regulatory agencies. The DRE will be notified when the borehole is abandoned via a modification of the MOP or Rehabilitation and Environment Management Plan (REMP), whichever is in force at the time.

Mine Subsidence

Impacts of a minor nature will not be remediated or rehabilitated if agreed by relevant regulators. Where possible more significant mine subsidence impacts such as creek bed cracking or connectivity to Cataract Reservoir will be rehabilitated using methods approved by DRE, DSC and/or SCA as required. If rehabilitation is not possible then NRE will discuss options for offsets with the appropriate regulatory agencies. See **Table 50,** pg 195**,** for a full listing of the rehabilitation options collated from the EA.

2.1.2.4 Conceptual Completion Criteria

The completion criteria in **Table 16**, pg 50, **Table 17**, pg 50, and **Table 18**, pg 51, are general long term criteria based on the relevant rehabilitation objectives for each of the Domains at NRE No.1 Colliery. When detailed Closure Plans are completed the general criteria will be refined to become specific and measurable.

Table 16 - Domain 1 - Long Term Rehabilitation Indicators

REHABILITATION PHASE	COMPLETION CRITERIA
Decommissioning	o Heritage structures and locations preserved; o Infrastructure removed; o Mine entries sealed to DRE standards and DSC satisfaction with regard to water egress; o Services decommissioned (electricity, water, etc.); o Mine dams removed unless required for future residential development; o Contamination remediated.
Landform Establishment	o Slopes geotechnically stable; o Substrate characterised across Pit Top; and o Drainage system established.
Growth Medium Development	o Growth medium types and depths suitable for grass cover establishment.
Ecosystem Establishment	o Rapid growth grasses; o Sterile grasses used to establish ground cover; and o Non-invasive residential grasses for permanent ground cover.
Ecosystem Development	o Non invasive ground covers maintained in healthy state

Table 17 - Domain 2 - Long Term Rehabilitation Indicators

REHABILITATION PHASE	COMPLETION CRITERIA
Decommissioning	o Heritage structures and locations preserved; o Infrastructure removed; o Services decommissioned (electricity, water, etc.); o Mine dams removed unless required for future residential development Contamination remediated; and o Roads remain serviceable
Landform Establishment	o Slopes geotechnically stable; o Substrate characterised in disturbed areas; and o Drainage system established.
Growth Medium Development	o Growth medium types and depths suitable for local native species regeneration.
Ecosystem Establishment	o Rapid growing sterile native grasses used to establish initial ground cover; o Local native groundcover for substrate stabilisation; o Rapid growing local native colonisers for initial native community structure establishment; and o Local native species used for mature canopy development.
Ecosystem Development	o Groundcovers established; o Colonisers established; o Mature canopy species established; o Recruitment of local native flora species evident; o Out-competition of noxious weeds by native flora species evident; and o Utilisation of site by local native fauna species evident.

Table 18 - Domain 3 - Long Term Rehabilitation Indicators

REHABILITATION PHASE	COMPLETION CRITERIA
Decommissioning	o Heritage structures and locations preserved; o Infrastructure removed; o Dams and reticulation systems removed; o Services decommissioned (electricity, water, etc.); o Shafts sealed to regulatory standards; o Boreholes sealed to regulatory standards; o Environmental monitoring equipment removed; o Contamination remediated; and o Roads serviceable.
Landform Establishment	o Slopes geotechnically stable; o Substrate characterised in disturbed areas; o Drainage system established; o Subsidence impacted waterways remediated where possible or offset to regulator satisfaction; and o Subsidence impacted swamps offset to regulator satisfaction.
Growth Medium Development	o Growth medium types and depths suitable for local native species regeneration.
Ecosystem Establishment	o SCA approved revegetation methods used in rehabilitation of all catchment disturbance areas.
Ecosystem Development	o Native species naturally re-established; o Out-competition of noxious weeds by native flora species evident; o Utilisation of site by local native fauna species evident; and o SCA satisfied with rehabilitation.

Figure 12 - No.1 Colliery Pit Top Conceptual Post-Rehabilitation Final Landform Plan

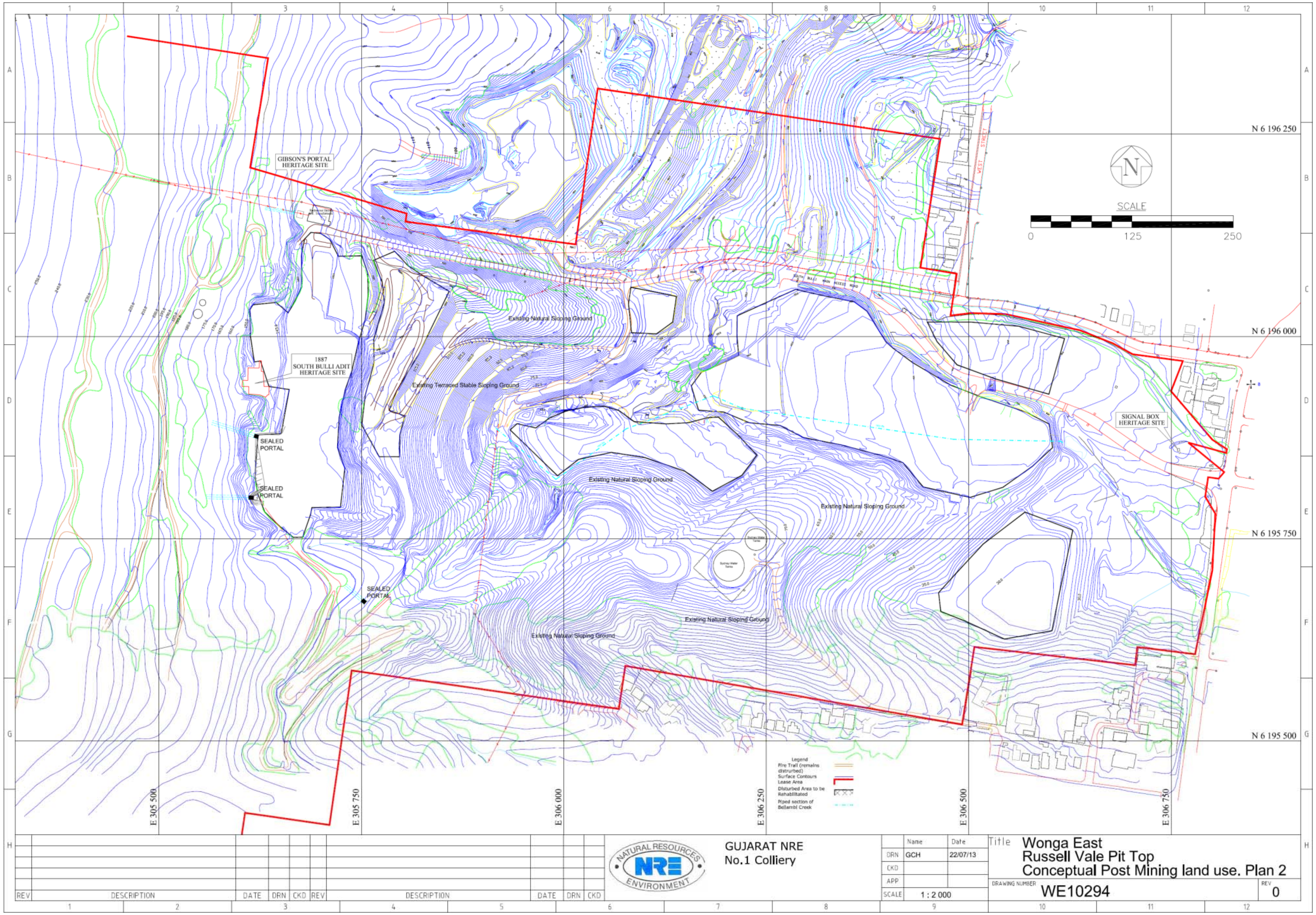


Figure 13 - No.1 and No.2 Shafts Conceptual Post-Rehabilitation Final Landform Plan

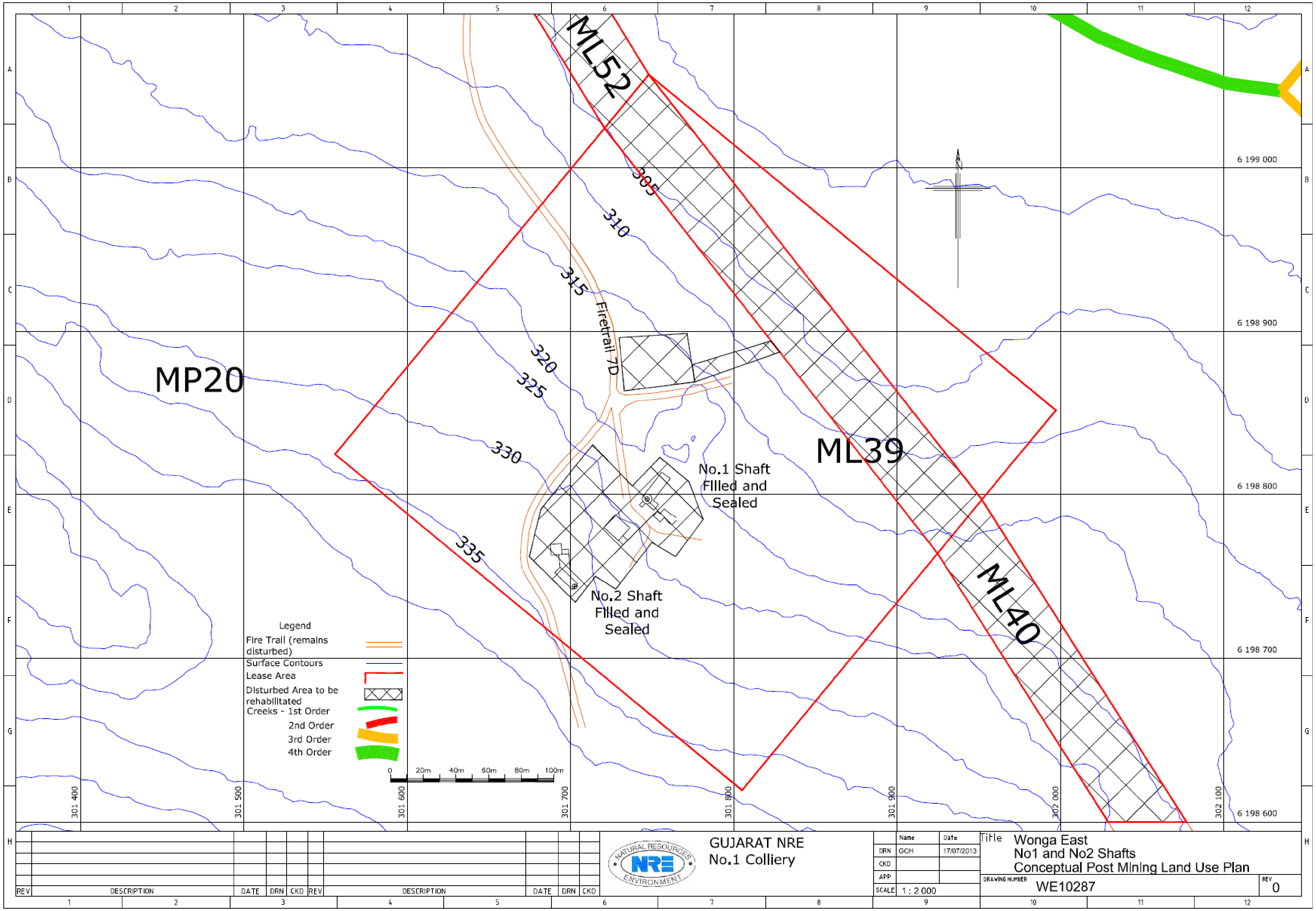


Figure 14 - No.3 Shaft Conceptual Post-Rehabilitation Final Landform Plan

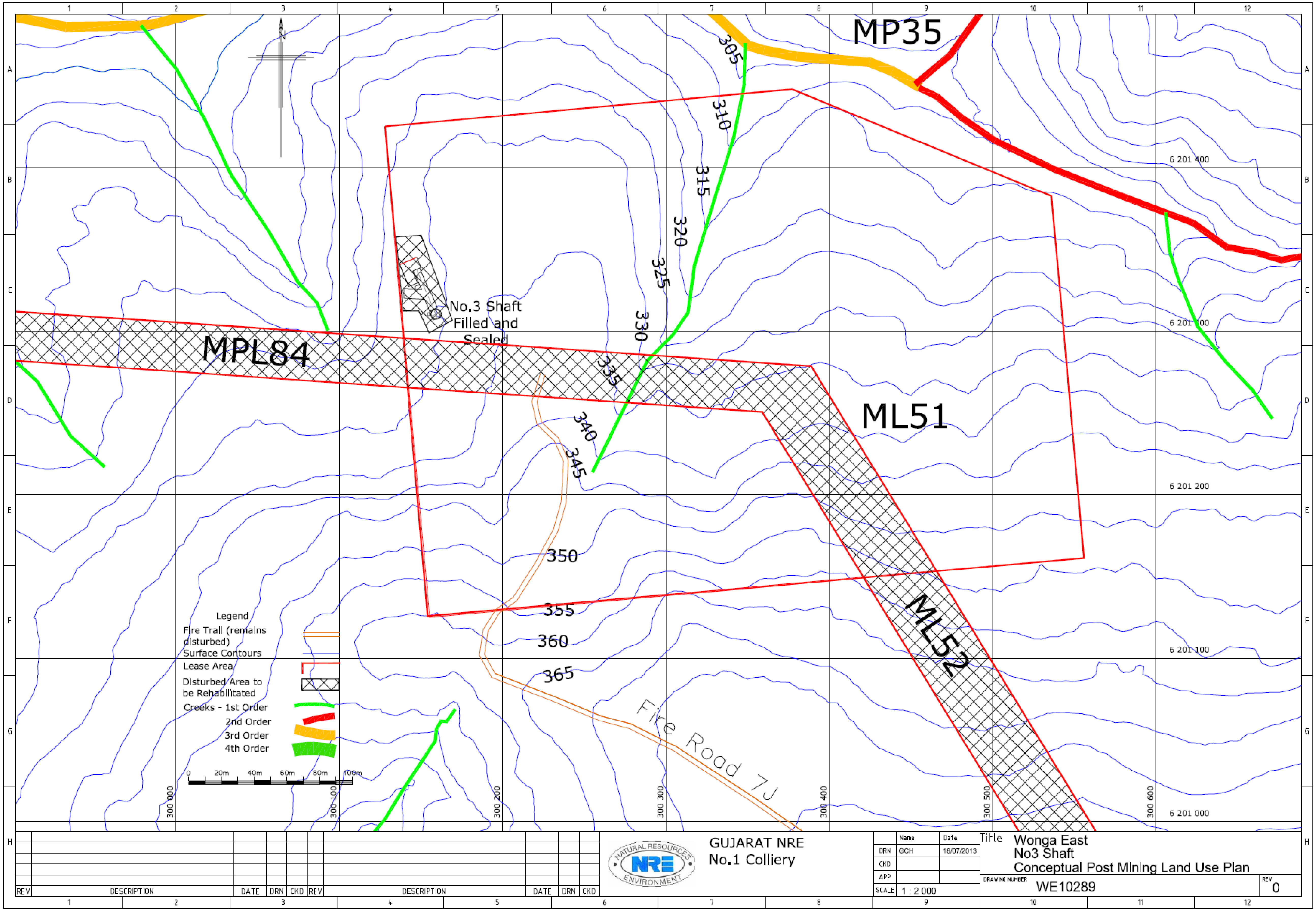


Figure 15 - No.4 Shaft Conceptual Post-Rehabilitation Final Landform Plan

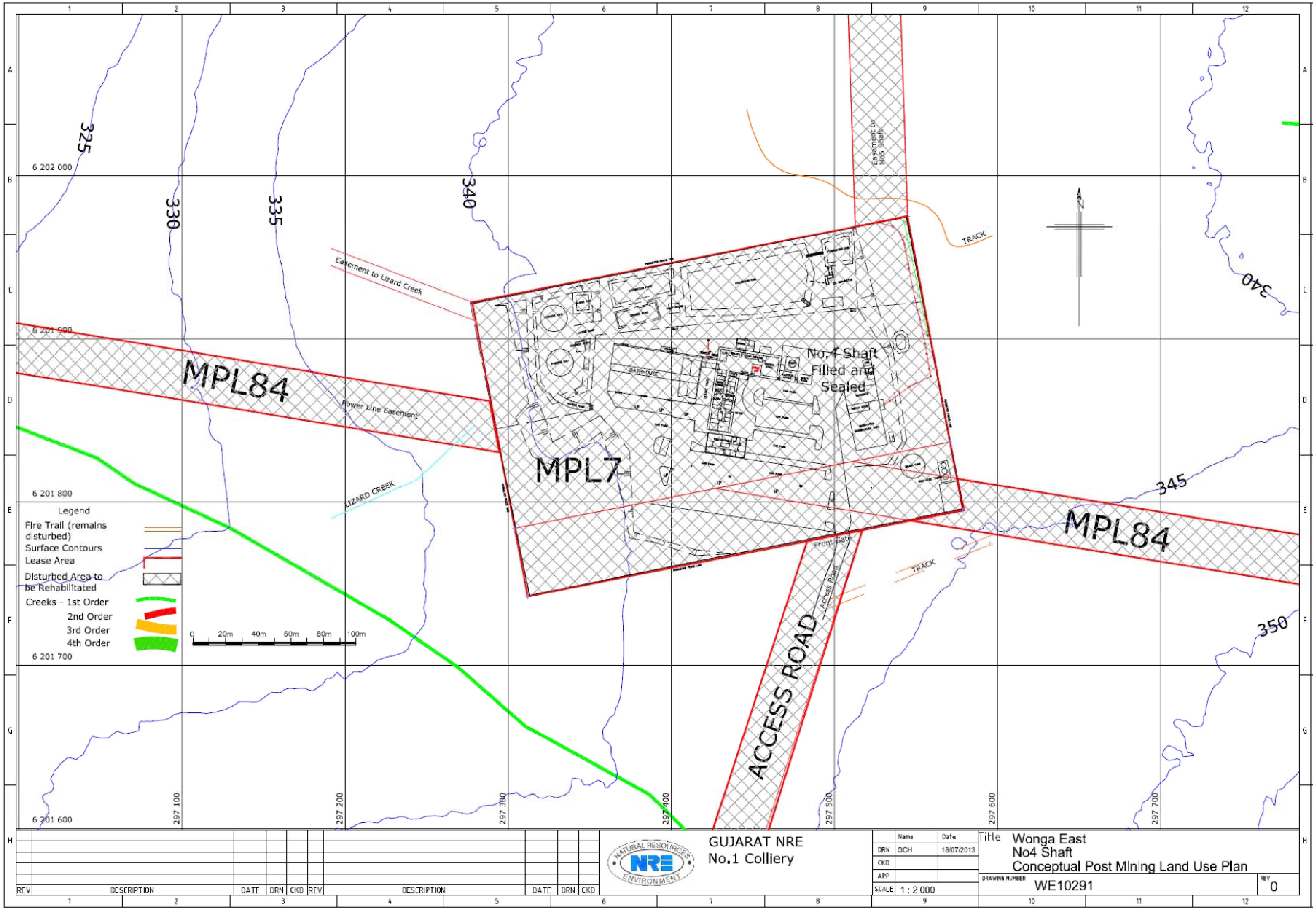
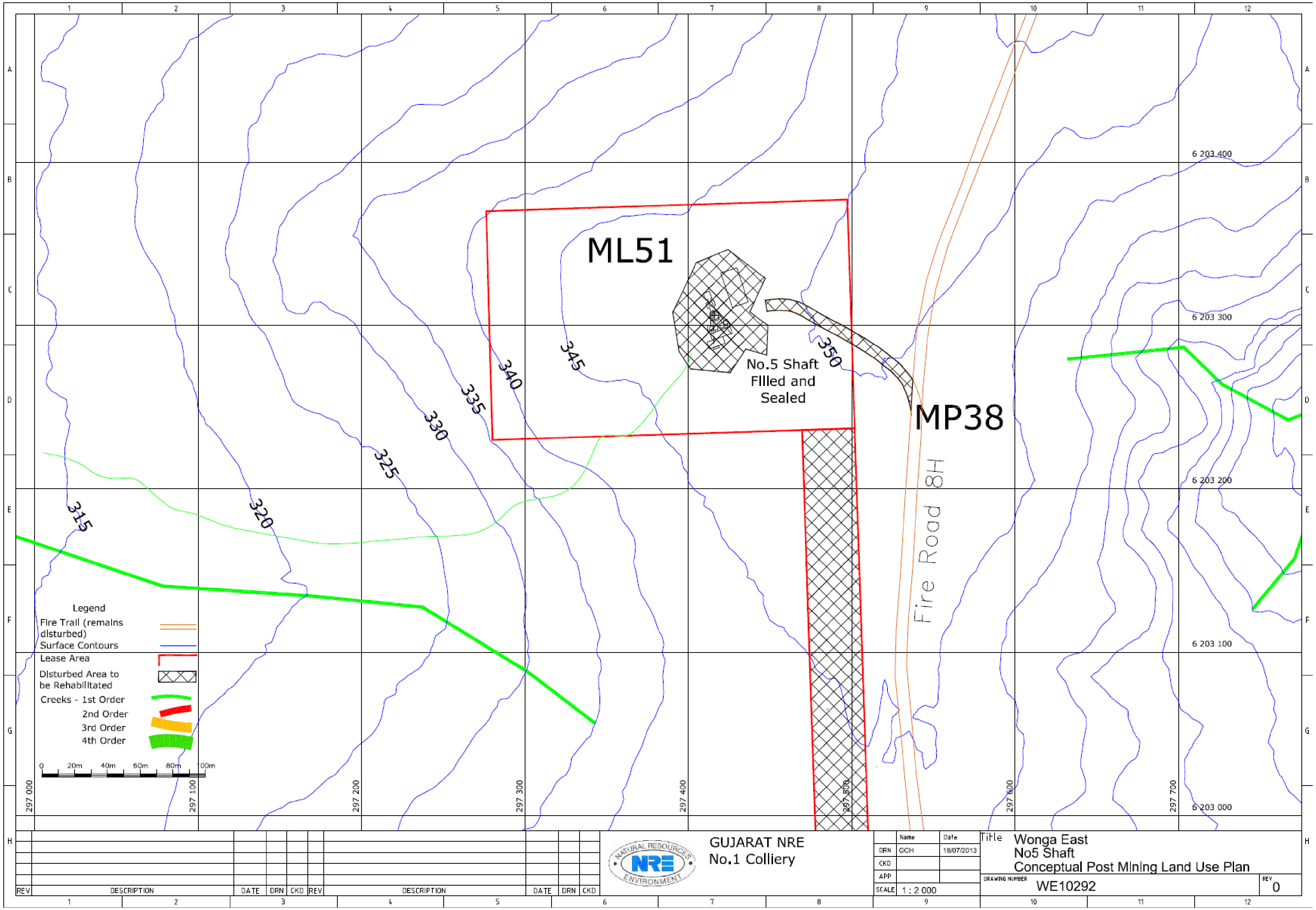


Figure 16 - No.5 Shaft Conceptual Post-Rehabilitation Final Landform Plan



2.2 Mining

2.2.1 Biodiversity

2.2.1.1 Background

A number of issues were raised during the public exhibition period regarding what were considered significant issues in the EA. These concerns broadly covered:

1. inadequate swamp monitoring;
2. inadequate Upland Swamp risk and impact assessments as a result of uncertain subsidence predictions;
3. potential for significant Upland Swamp impacts;
4. concerns regarding endangered fish habitat impacts in Cataract Creek; and
5. levels of survey effort for certain terrestrial endangered species such as the Adams Emerald Dragonfly.

Significant additional work has been undertaken to address the issues raised in the EA, including the use of an alternative mine subsidence modelling approach to use as the basis of new impact assessments. NRE is also proposing to design and undertake a significant water balance assessment of CCUS4 and possibly CCUS5 catchment in liaison with scientific and regulatory agency experts to provide improved data on the subsidence impacts on swamps and the downstream dependant hydrological and ecological communities.

These changes have resulted in the following changes to significant natural features in the Wonga East area:

- Cataract Creek will no longer be undermined;
- A reduction in undermining of cliffs associated with Cataract Creek;
- Upland swamp CCUS1 will no longer be undermined;
- Minimisation of the extent of upland swamps CCUS5 and CCUS10 that will be undermined; and,
- Changes in impacts to significant natural features based on revised subsidence predictions.

This Section will provide an overview of the Biodiversity of the Wonga East area with further detail available in **Attachment A,** pg 350**.**

2.2.1.2 Significance Assessment

This section provides a revised impact assessment for ecological features within the Wonga East study area. The study area is defined as the area located within 600m of proposed secondary extraction for the revised longwall layout as shown on **Figure 2,** pg 11. The Wonga East study area supports a wide range of ecological features, including the following significant natural features:

- Thirty-two upland swamps (an endangered ecological community (EEC));
- Third and fourth order streams, including Cataract Creek and Cataract River;
- Rocky habitats, including rocky outcrops and cliffs; and,
- Threatened species and their habitats.

Significant natural features are shown in **Figure 5**, pg 17.

This revised impact assessment focuses on those species, populations and communities listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and/or the NSW *Threatened Species Conservation Act 1995* (TSC Act) and deemed at risk of impact due to subsidence associated with longwall mining. This includes species that are reliant on natural features at risk of impact; particularly aquatic ecosystems (streams and creeks), upland swamps and rocky environments (including caves and overhangs). Experience with longwall mining in the Southern Coalfield indicates that impacts to terrestrial ecosystems are generally less significant than those to aquatic ecosystems, upland swamps and rocky environments. Terrestrial ecosystems are considered to be at negligible risk of impact from subsidence associated with longwall mining and are not considered further.

Terrestrial Ecology

Species, populations and communities either recorded during previous assessment, or considered likely to occur within the study area, and considered vulnerable to impacts due to subsidence are listed in **Table 19**, pg 58.

Table 19 - Threatened Species, Populations and Communities n the Study Area

Scientific name	Common name	EPBC Act status	TSC Act status
Flora			
Acacia baueri ssp. aspera	-	-	V
Epacris purpurascens var. purpurascens	-	-	V
Grevillea parviflora ssp. parviflora	Small-flowered Grevillea	V	V
Leucopogon exolasius	Woronora Beard-heath	V	V
Melaleuca deanei	Deane's Melaleuca	V	V
Persoonia bargoensis	Bargo Geebung	V	E
Pultenaea aristata	Prickly Bush-pea	V	V
Threatened ecological communities			
-	Coastal Upland swamp in the Sydney	-	E
Birds			
Pezoporus wallicus wallicus	Eastern Ground Parrot	-	V
Mammals (excl. bats)			
Cercartetus nanus	Eastern Pygmy Possum	-	V
Dasyurus maculatus maculatus	Spotted-tailed Quoll	E	V
Mammals - Bats			
Chalinolobus dwyeri	Large-eared Pied Bat	V	V
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	-	V
Myotis macropus	Large-footed Myotis	-	V
Reptiles			
Hoplocephalus bungaroides	Broad-headed Snake	V	E
Varanus rosenbergi	Rosenberg's Goanna	-	V
Frogs			
Heleioporus australiacus	Giant Burrowing Frog	V	V
Litoria littlejohni	Littlejohn's Tree frog	V	V
Pseudophryne australis	Red-crowned Toadlet	-	V
Mixophyes balbus	Stuttering Frog	V	E
Invertebrates			
Petalura gigantea	Giant Dragonfly	-	E

Terrestrial Flora

Table 20, pg 60, provides a reassessment of habitat for these species, the potential for this habitat to occur within the study area, and a determination of the reliance of these species on microhabitats that are at risk of impacts from subsidence associated with the Preferred Project.

Table 20 - Terrestrial flora species vulnerable to impacts from subsidence (DECC 2007a), and an assessment of microhabitats within the study area

Species	Description	Does the species occur in, and is it reliant on, susceptible microhabitats within the study area?
Acacia baueri ssp. aspera	Acacia baueri ssp. baueri occurs in damp heaths associated with sandstone woodland (ERM 2013b) and often occurs in small depressions on rocky outcrops. Further, targeted and opportunistic surveys in the study area have not recorded this species. The Wonga East area does not contain many rocky outcrops, and suitable habitat for this species within the study area is limited.	**Yes** **Rocky outcrops**
Epacris purpurascens var. purpurascens	Epacris purpurascens var. purpurascens is found within a wide range of habitat, usually associated with moisture, most of which have a strong shale influence (ERM 2013b, BHPBIC 2009). It is not considered to be a swamp specialist. This habitat is considered to be at negligible risk of impact. Further, targeted and opportunistic surveys in the study area have not recorded this species.	No
Small-flowered Grevillea	Small-flower Grevillea grows in sandy or light clay soils, usually over thin shales, and occurs in a wide range of vegetation types (ERM 2013b). Habitat for this species is considered to be at negligible risk of impact. Further, targeted and opportunistic surveys in the study area have not recorded this species.	No
Woronora Beard-heath	Woronora Beard-heath occurs in a wide range of habitat types, including woodland, rocky hillsides and creeks (ERM 2013b). The wide range of habitats this species occurs in are considered to be at negligible risk of impact. Further, targeted and opportunistic surveys in the study area have not recorded this species.	No
Deane's Melaleuca	Deane's Paperbark grows in heath communities on sand, and has been recorded from ridgetops, dry ridges and slopes. It is often associated with sandy loam soils (ERM 2013b). This species is not considered to be reliant on microhabitats that are at risk of impact due to subsidence. Further, targeted and opportunistic surveys in the study area have not recorded this species.	No
Bargo Geebung	Bargo Geebung grows in woodland and dry Sclerophyll forest on a wide variety of soils types. This species is not reliant on microhabitats at risk of impact from subsidence. Further, targeted and opportunistic surveys in the study area have not recorded this species.	No
Prickly Bush-pea	Prickly Bush-pea has been recorded within the study area from open habitats, including upland swamps and adjacent woodland. The species occurs where drainage is impeded (NPWS 2003), usually in areas where low degree slopes result in slowing of surface and groundwater flows (Biosis pers. obs.). Since the original EA (ERM 2013a) was submitted this species has been recorded at a number of additional locations and the species is known to be common and widely distributed in the study area.	**Yes** **Upland swamps**

Terrestrial Fauna

Table 21, pg 62, provides a reassessment of habitat for these species, the potential for this habitat to occur within the study area, and a determination of the reliance of these species on microhabitats that are at risk of impacts from subsidence.

Table 21 - Terrestrial fauna species vulnerable to impacts from subsidence (DECC 2007a), and an assessment of microhabitats within the study area

Species	Description	Does the species occur in, and is it reliant on, susceptible microhabitats within the study area?
Eastern Ground Parrot	The Eastern Ground Parrot was previously thought to be extinct within the local area (DECC 2007b) prior to several observations of this species during surveys for the Metropolitan Coal Project and the Bulli Seam Operations Project. The Eastern Ground Parrot occurs in low heathlands and sedgelands, generally below one metre in height and very dense (OEH 2013b). Habitat within the study area is largely limited to MU 44 Upland swamp: Sedgeland-Heath Complex. This vegetation community is severely restricted and highly fragmented within the study area. The previous assessment (ERM 2013b) assessed that this species could potentially occur in the Wonga West area, but was unlikely to occur within the Wonga East area. This species is considered unlikely to occur within the study area.	No
Eastern Pygmy Possum	The Eastern Pygmy Possum occurs in a wide variety of habitat types, including rainforest, sclerophyll forest and heaths (DECC 2007b) and upland swamps (Biosis pers. obs., DECC 2007a). Given the wide range of habitat types that this species inhabits it is not considered to be at significant risk of impact from subsidence.	No
Spotted-tailed Quoll	The Spotted-tailed Quoll utilises a wide range of habitat types, with cliffs, rock benches or overhangs listed as habitat with potential to be impacted (DECC 2007a). Given the widespread nature of this species' habitat the risk of impact is considered to be negligible.	No
Large-eared Pied Bat	The Large-eared Pied Bat is considered rare within the local area and has narrow habitat requirements, including productive land close to suitable roosting habitats (DECC 2007b). The species roosts in caves and overhangs, and it is this habitat which is of high conservation significance (DECC 2007b). Cliffs that may provide suitable roosting sites within the study area are limited in extent, and restricted to an area over LW9.	**Yes** **Cliffs over LW9**
Eastern Bentwing-bat	The Eastern Bentwing-bat is common in the local area, being one of the most commonly recorded bats during surveys (Biosis pers. obs.). This species has been recorded within the study area. The species forages within a wide range of habitat types and across a large area. The species roosts in caves and overhangs, and it is this habitat which is of high conservation significance (DECC 2007b). Cliffs that may provide suitable roosting sites within the study area are limited in extent, and restricted to an area over LW9.	**Yes** **Cliffs over LW9**

Large-footed Myotis	The Large-footed Mytois is considered to be rare in the local area (DECC 2007b). The species forages along waterways, including disturbed waterways in urban environments, and is more common in more highly productive environments, although the species has been recorded on the Woronora plateau. The species roosts in caves and overhangs, and it is this habitat, which is of high conservation significance (DECC 2007b). Cliffs that may provide suitable roosting sites within the study area are limited in extent, and restricted to an area over LW9. Cataract Creek provides potential foraging habitat for this species. The species may be susceptible to changes in water quality or natural flow regimes (DECC 2007b).	**Yes** **Cliffs over LW9 and Cataract Creek**
Broad-headed Snake	The Broad-headed Snake occurs on exposed rocky outcrops with bedrock providing suitable winter sheltering habitat. This species is extremely rare in the local area (DECC 2007b). Due to the presence of this species on rocky outcrops that are susceptible to fracturing due to subsidence, the species is listed by DECC (2007a) as being at risk of impact from longwall mining. Biosis has previously undertaken monitoring of rocky outcrops for the Dendrobium, Wongawilli and Nebo mines. While subsidence effects, including fracturing of rocky outcrops, have been observed, no impacts to sheltering habitat for reptiles was observed in these areas. The Wonga East area does not contain many rocky outcrops, and suitable habitat for this species within the study area is limited. The risk of impact to this species is considered minimal. However, if specific locations for this species were identified these would be considered of high conservation value given the species' rarity. For this reason, the species is considered further below.	**Yes** **Rocky outcrops**
Rosenberg's Goanna	Rosenberg's Goanna inhabits ridgetops with higher levels of rocks and shrubs that provide habitat for prey species (DECC 2007b). Although this species is located on rocky outcrops which are at risk of impacts from subsidence (DECC 2007a) the species or its prey do not rely on specific habitat features at risk of impact. Thus the species is considered at negligible risk of impact from the preferred project.	No
Giant Burrowing Frog	The Giant Burrowing Frog occurs in sandstone environments and is generally associated with first and second order intermittent creeks that provide suitable breeding pools (Biosis pers. obs.). Although often associated with upland swamps, DECC (2007b) assert that this association is not direct, rather that upland swamps are associated with minor drainage lines that provide suitable breeding pools and burrowing habitat for this species. Detailed habitat mapping was undertaken by Biosis (2012b, 2013a) with suitable breeding habitat for this species mapped at four locations in the study area (Figure 5). Targeted surveys undertaken by Biosis as a part of the ecological monitoring program for Longwalls 4 and 5 in August and December 2012 and February, April and May 2013 have detected tadpoles for the Giant Burrowing Frog in a tributary of CRUS2. A total of 17 tadpoles were observed in three breeding pools located along the 245 metre transect (Figure 5). This tributary of CRUS2 is located approximately 700 m from the nearest longwall (LW4) and is outside the active subsidence zone. The species has not been recorded elsewhere within the study area.	**Yes** **Creeks**

Littlejohn's Tree frog	Littlejohn's Tree Frog occurs in sandstone environments and is generally associated with first and second order intermittent creeks that provide suitable breeding pools (Biosis pers. obs.). The species has been recorded within a wide variety of vegetation types, all associated with more open habitat and intermittent creeks. This includes, but is not restricted to, upland swamps (Biosis pers. obs.). Detailed habitat mapping was undertaken by Biosis (2012b, 2013a) with suitable breeding habitat for this species mapped at four locations in the study area (Figure 5). Targeted surveys undertaken by Biosis as a part of the ecological monitoring program for Longwalls 4 and 5 in August and December 2012 and February, April and May 2013 have not recorded this species.	**Yes Creeks shown in Figure 5**
Red-crowned Toadlet	The Red-crowned Toadlet is fairly common in preferred ridgetop habitat and first order ephemeral creeks below ridges (DECC 2007b) and has been recorded, using drainage lines, sheltering under bushrock on ridgetops and in depressions along fire trails (Biosis pers. obs.). Habitat for this species within the study area has not been mapped, as it is widely distributed and common. Targeted surveys for the Red-crowned Toadlet have been undertaken by Biosis as a part of the ecological monitoring program for Longwalls 4 and 5 (Biosis 2013a). Surveys were conducted using auditory recording devices located in suitable breeding habitat along two ephemeral creeks below ridgelines above Longwall 4 and Longwall 5 (Figure 4). The Red-crowned Toadlet was recorded calling at both sites (Biosis 2013a). However, preferred habitat for this species is considered to be at limited risk of impact.	No
Stuttering Frog	The Stuttering Frog is generally considered rare within the Sydney Basin bioregion and is now close to extinction in the local area (DECC 2007b). Detailed habitat mapping was undertaken by Biosis (2012b, 2013a) with suitable breeding habitat for this species mapped along Cataract Creek in the study area (Figure 5). Cataract Creek has been impacted by past mining of the Bulli and Balgownie coal seams, with an iron seep located along a tributary of Cataract Creek resulting in moderate to high levels of iron flocculent in the creek. This past impact is likely to reduce the suitability of the habitat for this species (ERM 2013b). Targeted surveys undertaken by Biosis as a part of the ecological monitoring program for Longwalls 4 and 5 in October, November and December 2012 and February 2013 have not recorded the Stuttering Frog along Cataract Creek.	**Yes Cataract Creek (Figure 5)**
Giant Dragonfly	The Giant Dragonfly is found in upland swamps with open vegetation and free water (OEH 2013d). Suitable habitat for this species within the study area is limited to lower sections of upland swamp CCUS4. Given the limited extent of suitable habitat within the study area this species is considered unlikely to occur within the study area.	No

Aquatic Ecology

Cardno Ecology Lab and Biosis have undertaken seasonal assessments of aquatic habitat condition and macroinvertebrate assemblages at impact and control monitoring reaches in spring and autumn each year since 2008. These assessments provide a comprehensive inventory and understanding of the aquatic biodiversity values present in the Wonga East area. Biosis has undertaken surveys of additional sections of Cataract Creek upstream of the sites surveyed by Cardno Ecology Lab (see Fish Reach 19US in **Figure 17**, pg 66 and Additional Fish Reach in **Figure 18**, pg 67). These additional surveys did not record any threatened fish species.

Table 22 - Aquatic species likely to occur in the study area and vulnerable to impacts due to subsidence

Scientific name	Common name	EPBC Act status	FM Act status
Fish			
Macquaria australasica	Macquarie Perch	E	E
Maccullochella macquariensis	Trout Cod	E	E
Maccullochella peelii	Murray Cod	V	-
Bidyanus bidyanus	Silver Perch	-	V
Macroinvertebrates			
Archaeophya adamsi	Adam's Emerald Dragonfly	-	E
Austrocordulia leonardi	Sydney Hawk Dragonfly	-	E

Numbers of Macquarie Perch, Murray Cod, Silver Perch and Trout Cod recorded between 2009 and 2013 are presented in **Table 23**, pg 65. The locations of Macquarie Perch and Murray Cod captured during the most recent survey undertaken in Cataract Creek are presented in **Figure 18**, pg 67.

Table 23 - Numbers of threatened fish captured in Cataract Creek

	2009/2010	2010/2011	20011/2012	2012/2013
Macquarie Perch	30	90	18	14
Murray Cod	0	0	0	16
Silver Perch	9	9	0	0
Trout Cod	0	0	0	0

In order to ascertain the presence/absence of two species of threatened dragonfly listed under the NSW *Fisheries Management Act 1994* (FM Act), Adam's Emerald Dragonfly and Sydney Hawk Dragonfly, surveys undertaken in autumn 2013 included an assessment of habitat suitability for these two species, based on the habitat requirements outlined in DPI (2007) and DPI (2012), as well as targeted searches for exuviae. Furthermore, the presence of individuals of the appropriate dragonfly family was assessed during live-picking of macroinvertabrates undertaken in the field. Neither of the two threatened dragonfly species has been recorded during aquatic surveys in the Wonga East area since 2008.

Figure 17 - Study Area and Catchment of Monitoring Reaches

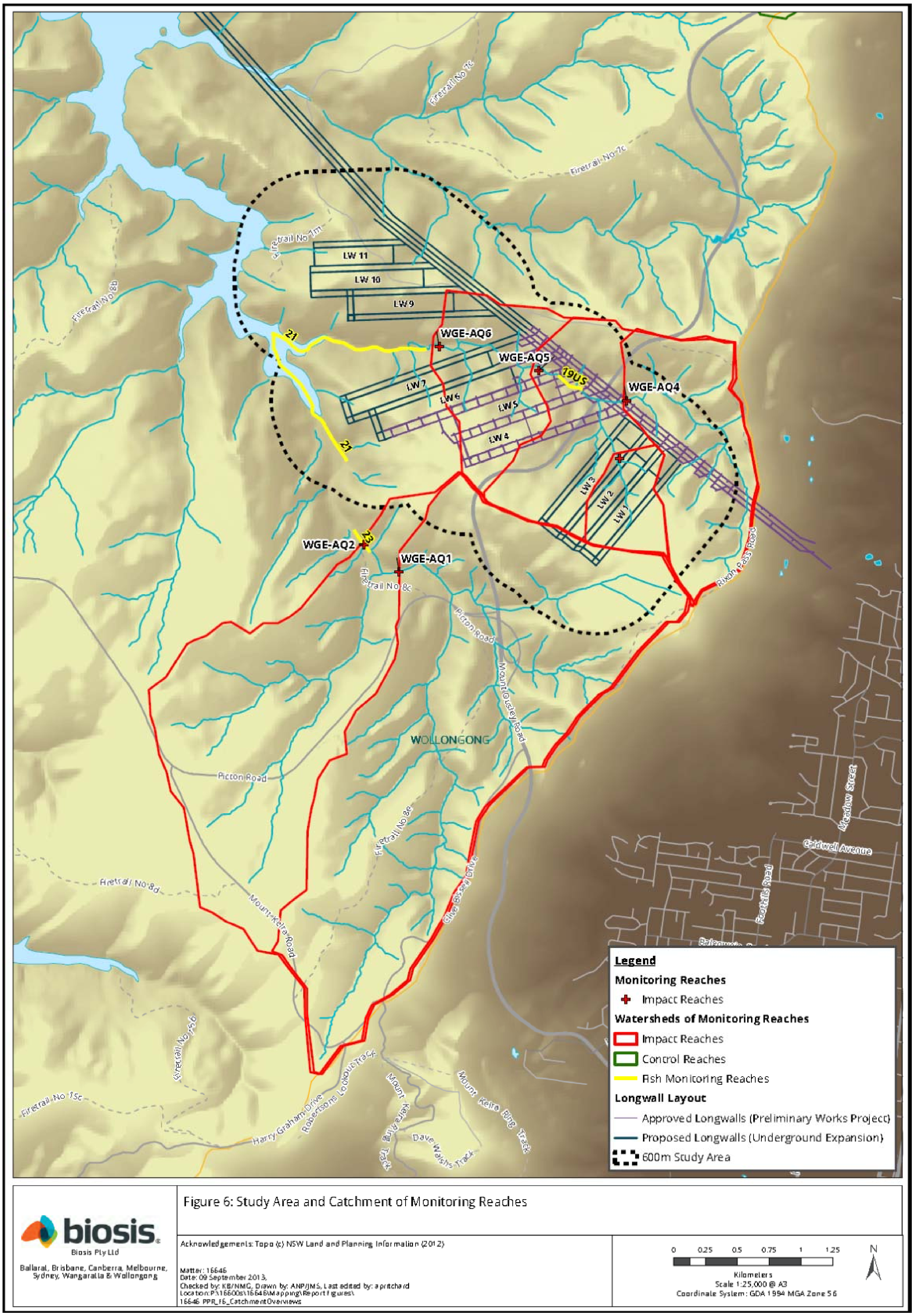
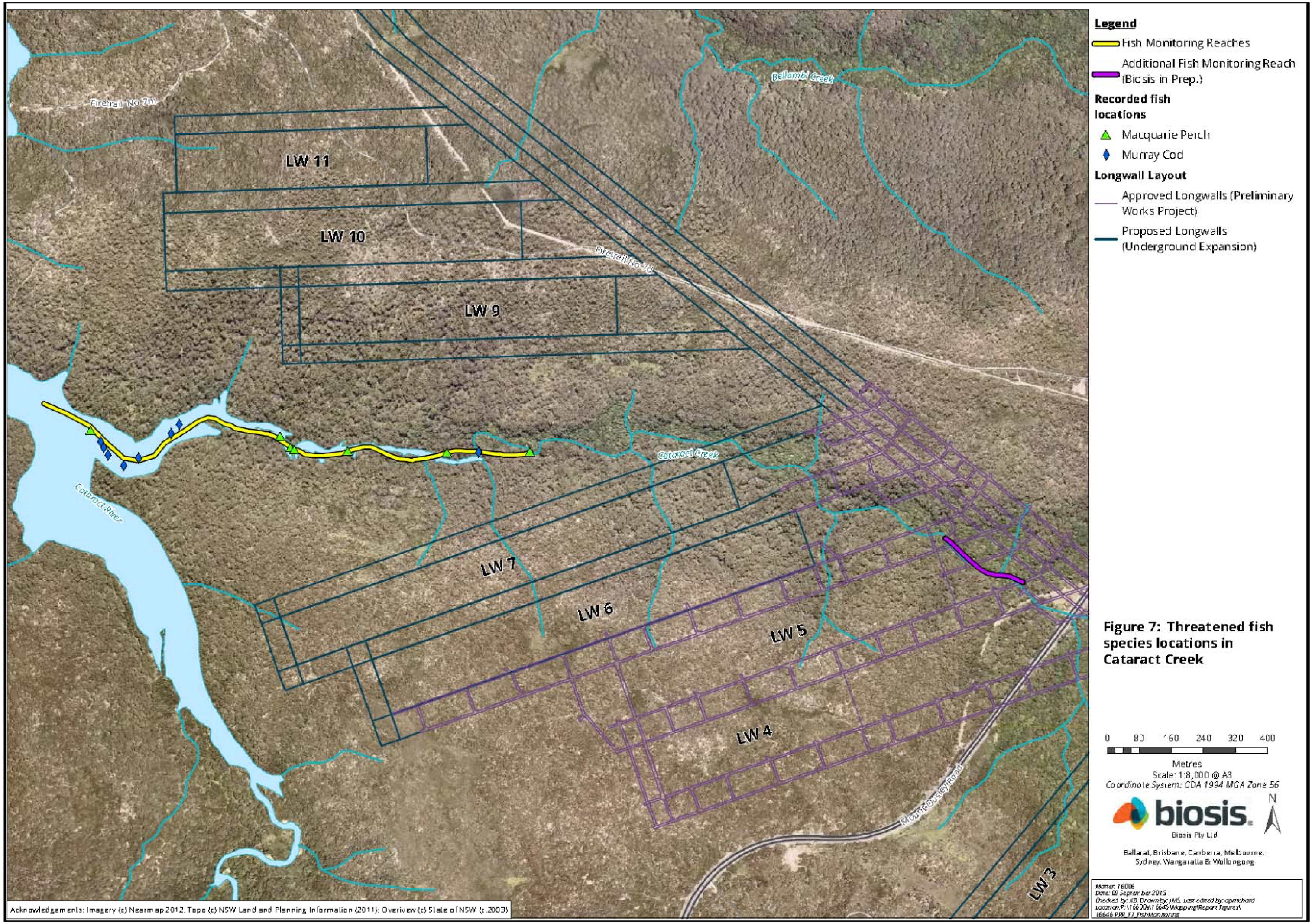


Figure 18 - Threatened fish species locations in Cataract Creek



<u>Aquatic Macroinvertebrates</u>

The number of taxa collected at each monitoring reach varied at a temporal and spatial scale Samples collected from Cataract Creek were generally less diverse than those collected from Cataract River and Allen's Creek. However, AUSRIVAS and OE50 Taxa scores indicate that there is little difference in the macroinvertebrate assemblage present in Cataract Creek when compared to control sites. SIGNAL2 scores indicate that, while Cataract Creek is moderately polluted, there is little difference in the presence or absence of pollution sensitive aquatic macroinvertebrate species when compared to control sites. Further detail is provided in **Attachment A**, pg 350.

<u>Upland Swamps</u>

Mapping and characterisation of upland swamps in the Wonga East and Wonga West area was undertaken by Biosis (2012b). This previous assessment included assessment of the 'special significance' of upland swamps in the project area using criteria outlined in OEH (2012). This assessment of upland swamps for the preferred project should be read in conjunction with Biosis report submitted with the original EA.

In summary, 39 upland swamps have been mapped as occurring within the study area **Figure 19**, pg 69. *Section 3.1* and *Appendix 1* of the Biosis report for the EA provide a summary of upland swamps within the study area, while *Table 6* in the same report provides an assessment of 'special significance' against criteria outlined in OEH criteria. This assessment identified that seven upland swamps in the Wonga East area meet the criteria of 'special significance', including CCUS1, CCUS4, CCUS5, CCUS10, CRUS1, CRUS2 and CRUS3. Swamps of 'special significance' are shown in **Figure 20**, pg 70.

Figure 19 - Upland swamps in the study area

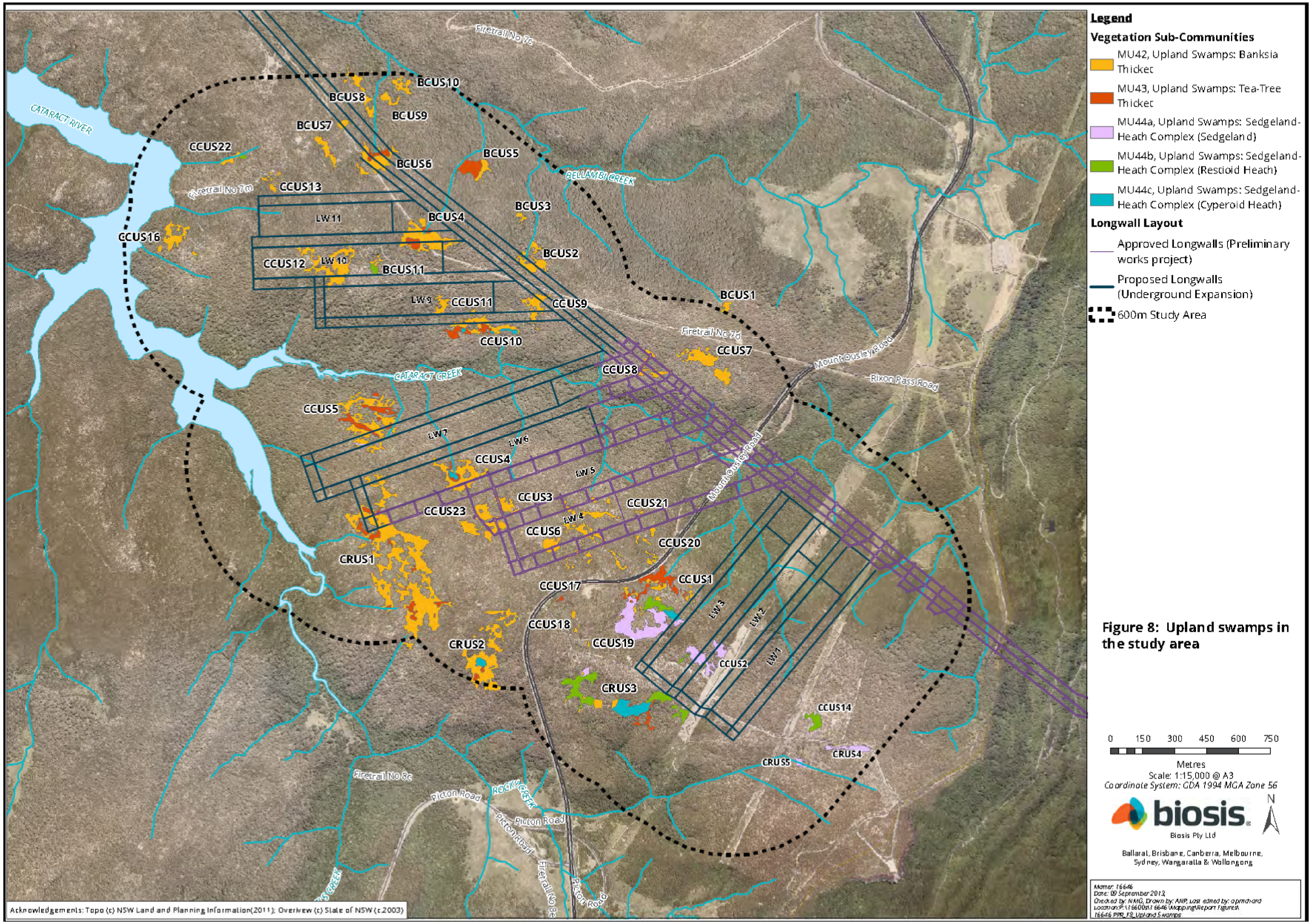
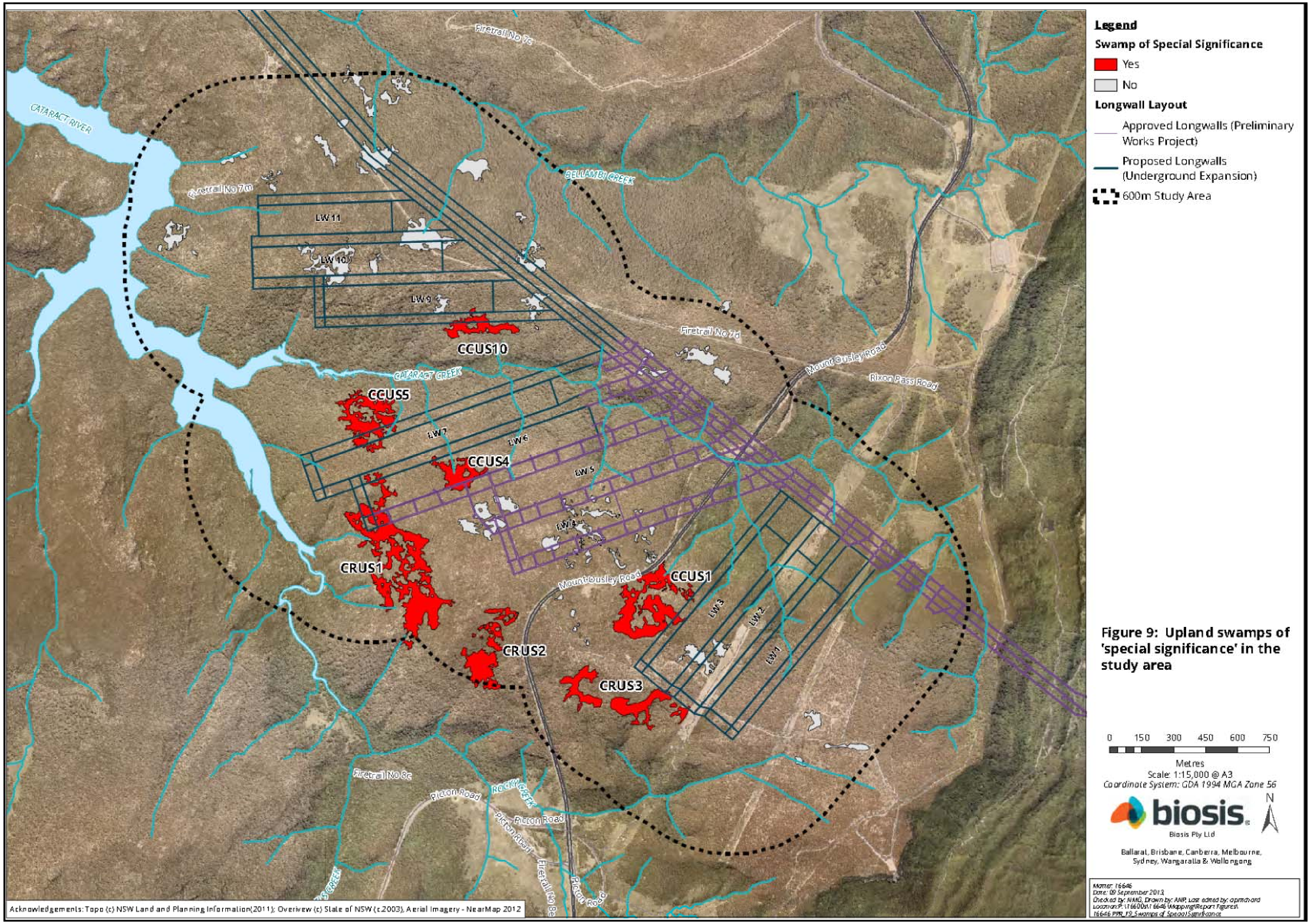


Figure 20 - Upland swamps of 'special significance' in the study area



2.2.1.3 Impact Assessment

General

This section assesses the potential impacts of past mining of the Bulli and Balgownie seams, before assessing the impacts of the original project versus the preferred project on these significant natural features. Within the study area, the Bulli seam was extracted via hand workings and pillar extraction between 1890 and 1960. The Balgownie seam was extracted using continuous miner pillar extraction in 1969 and the retreat longwall mining method from 1970 to 1982. **Table 24**, pg 71, provides subsidence predictions for identified significant natural features from the extraction of the Bulli and Balgownie Seams in the Wonga East area.

Table 24 - Balgownie seam subsidence predictions for selected significant features in the study area

	Bulli seam and Balgownie seam Subsidence (m)	Balgownie seam Tilt (mm/m)	Balgownie seam Max Tensile Strain (mm/m) and Typical (in brackets)	Balgownie seam Max Compressive Strain (mm/m) and Typical (in brackets)	Balgownie seam Closure (mm)
Threatened frog habitat CRUS2 Trib	0.5	5	3	4	-
Threatened frog habitat CRUS1 Trib1	0.5	5	3	4	-
Threatened frog habitat CRUS1 Trib2	0.9	11	3	4	-
Threatened frog habitat CCUS4 Trib	1.2	18	7.5 (3)	14 (4)	-
Cliffs over LW9	0.5	N/A	N/A	N/A	-
Cataract Creek	1.4	15	N/A	N/A	310

Available data indicates that past mining of the Bulli and Balgownie Seams is likely to have resulted in fracturing of bedrock beneath identified threatened frog habitat, and that closure in Cataract Creek is likely to have been sufficient to have resulted in diversion of surface flows using currently accepted criteria identified by MSEC.

Based on this data, it is likely that there are pre-existing impacts to identified natural features, as outlined above. There is evidence to support this conclusion, with iron seeping from a tributary of Cataract Creek resulting in a significant amount of iron flocculent in Cataract Creek and signs of likely prior mining-induced collapse. Further detail of cliff impacts is located in **Section 2.2.2**, pg 88. This assessment of past mining in the Wonga East area indicates that natural features in the study area have been subject to subsidence resulting from extraction of the Bulli and Balgownie Seams. This data provides a baseline against which assessments of potential impacts resulting from extraction of the Wongawilli Seam, as part of the preferred project, must be assessed.

The extraction of the Wongawilli Seam in the Wonga East area will result in a predicted maximum of 2.1 m of subsidence, with tilts between 24 and 51 mm / m, tensile strain of between 7 and 15 mm / m and compressive strains between 14 and 31 mm / m. Cataract Creek is likely to be subject to closure of 200 mm.

Terrestrial Ecology

A summary of subsidence predictions for extraction of the Wongawilli Seam in the Wonga East area is provided in **Table 25**, pg 72. This table provides predicted subsidence parameters for each longwall, as well as predicted subsidence for significant natural features.

Table 25 - Wongawilli seam subsidence predictions selected significant features in the study area

	Overburden depth to Wongawilli Seam (m)	Subsidence predicted (m) and measured (in brackets)	Tilt predicted (mm/m) and measured (in brackets)	Tensile strain predicted (mm/m) and measured (in brackets)	Compressive strain predicted (mm/m) and measured (in brackets)	Closure on Cataract Creek (mm)
Threatened frog habitat CRUS2 Trib	300	0	0	0	0	-
Threatened frog habitat CRUS1 Trib1	320	0	0	0	0	-
Threatened frog habitat CRUS1 Trib2	320	0.02	0	0	0	-
Threatened frog habitat CCUS4 Trib	270	1.5	28	8	17	-
Cliffs over LW9	330	2.1	32	10	19	-
Cataract Creek	260	0.1	1	0	N/A	200

As can be seen from **Table 25**, pg 72, the majority of significant natural features within the study area are at minimal risk of impact, with subsidence predictions indicating subsidence effects are likely to be minimal. The exception to this is threatened frog habitat in CRUS4 Trib and cliffs over LW9.

Tilts, tensile strains and compressive strains in CRUS4 Trib are sufficient to result in fracturing of the bedrock beneath this tributary. However, no threatened frogs have been recorded at this location to date. Known habitat in CRUS2 Trib will not be impacted.

Subsidence predictions for cliffs over Longwall 9 indicate the potential for tensile cracking and collapse of the rock strata that are likely to occur where horizontal compression exceeds 50 – 100 mm per 20 m length of cliff formation. It's difficult to predict precisely where impacts may occur. Given the limited extent of suitable roosting sites for microchiropteran bats the risk of impact is considered low, given that the risk of collapse is considered minimal and the adequate availability of suitable habitat in the local area.

Subsidence predictions for Cataract Creek indicate that this waterway is unlikely to be subject to negative environmental consequences. Closure will not exceed 200 mm / m, and tilts, compressive and tensile strains are unlikely to be of sufficient magnitude to result in fracturing of the bedrock of Cataract Creek. However, fracturing of tributaries of Cataract Creek may result in decreased inflow into Cataract Creek, and an increase in iron seepage at the base of these tributaries and resultant potential for increased iron flocculent in Cataract. It is difficult to determine whether these impacts will result in observable impacts to Cataract Creek above and beyond those present.

Table 26, pg 74, provides impact assessments, including an assessment of impacts from the original project compared to the preferred project, for natural features.

Table 26 - Impact assessment for species at risk of subsidence, including comparison of risks from the original project and preferred project

Species	Microhabitats at significant risk of impact from subsidence	Potential impacts to critical microhabitat	Notes	Risk of impact from original project	Risk of impact from Preferred Project
Acacia baueri ssp. aspera	Rocky outcrops	Fracturing of the base of minor depressions in rocky outcrops, leading to reduced moisture in these areas and potential loss of individual plants.	The general risk of fracturing of rocky outcrops within the study area is considered moderately high; however suitable habitat (i.e. rocky outcrops with minor depressions) is limited within the study area	Low	Low
Prickly Bush-pea	Upland swamps	Fracturing of bedrock resulting in changes in water availability or changes in vegetation composition resulting in increased competition. Changes in slope gradient resulting in decreased water availability.	The species is widespread and common within the study area, having been recorded at a greater number of locations since the submission of the EA (ERM 2013b). Although there is potential for fracturing of bedrock beneath suitable upland swamp habitat, and changes in hydrology, impacts to wider habitat are predicted to be minimal.	Low	Low
Large-eared Pied Bat. Eastern Bentwing-bat , and Large-footed Myotis	Cliffs	Overhang collapse resulting in destruction of roosting habitat	Potential roosting habitat within the study area is limited in extent, and restricted to an area above LW9. Further, the risk of collapse of these cliffs is considered to be low (~5%; K. Mills pers. comm.). The removal of Wonga West from the project, where suitable habitat was much more prevalent along Lizard and Wallandoola Creeks, has resulted in a reduction in risk.	Moderate (Wonga West)	Low

Species	Microhabitats at significant risk of impact from subsidence	Potential impacts to critical microhabitat	Notes	Risk of impact from original project	Risk of impact from Preferred Project
	Cataract Creek (Large-footed Mytois only)	Fracturing of stream bed resulting in diversion of flows along sections of creeks. Increased iron entering the waterway, resulting in changes in water quality and choking of vegetation by iron flocculent.	The revision of the mine plan now avoids mining below Cataract Creek. No impacts to the bed of Cataract Creek are predicted to occur and diversion of flows is unlikely (A. Dawkins pers. comm.). There is potential for fracturing of the base of tributaries of Cataract Creek, resulting in diversion of flows, decreased inflow into Cataract Creek and iron seepage (A. Dawkins pers. comm.). The extent and magnitude of impact will be dependent on past impacts from extraction of the Bulli and Balgownie seams.	Low	Low
Broad-headed Snake	Rocky outcrops	Fracturing of rocky outcrops leading to a loss or change in shelter sites for this species or its prey.	The general risk of fracturing of rocky outcrops within the study area is considered moderately high with perceptible cracking in up to 30% of bare rock areas located directly above longwalls (k. Mills pers. comm.). However suitable habitat (i.e. rocky outcrops with suitable shelter) is limited within the study area. Suitable habitat for the species, identified within the EA (ERM 2013b) was largely limited to Wonga West	Moderate (Wonga West)	Low

Species	Microhabitats at significant risk of impact from subsidence	Potential impacts to critical microhabitat	Notes	Risk of impact from original project	Risk of impact from Preferred Project
Giant Burrowing Frog **Littlejohn's Tree frog**	Creeks shown in **Figure 5**, pg 17	Fracturing of stream bed resulting in diversion of flows along sections of creeks providing breeding habitat, resulting in loss of breeding pools. Fracturing of the base and draining of breeding pools. Increased iron entering the waterway, resulting in changes in water quality and choking of vegetation by iron flocculent. Release of methane gas into the water column, resulting in vegetation dieback in riparian environments and impacts to water quality.	Suitable habitat for these species has been identified in three tributaries of Cataract River and one tributary of Cataract Creek (Figure 5; Biosis 2012a, Biosis 2013a). Surveys undertaken as a part of the ecological monitoring program for Longwalls 4 and 5 have identified Giant Burrowing Frog tadpoles at one of these locations, in a tributary of Cataract River below CRUS2. This site is located outside of the predicted subsidence impact zone. These species have not been recorded at any other sites. Additional targeted surveys and the removal of Wonga West from the project application have resulted in a significant reduction in risk of impact to this species.	High	Low
Stuttering Frog	Yes Cataract Creek **Figure 5**, pg 17	Fracturing of stream bed resulting in diversion of flows along sections of creeks providing breeding habitat, resulting in impacts to suitable breeding habitat. Fracturing of the base and draining of breeding pools. Increased iron entering the waterway, resulting in changes in water quality and choking of vegetation by iron flocculent. Release of methane gas into the water column, resulting in vegetation dieback in riparian environments and impacts to water quality.	Suitable habitat for this species has been identified in Cataract Creek (Figure 5; Biosis 2012a, Biosis 2013a). Surveys undertaken as a part of the ecological monitoring program for Longwalls 4 and 5 have not recorded this species in the study area. Additional targeted surveys have resulted in a reduction in risk of impact to this species	Moderate	Low

Aquatic Ecology

The main aquatic habitat present in the Wonga East area is along Cataract Creek, which provides habitat for several threatened fish species. Macroinvertebrate monitoring of Cataract Creek indicates that there is a lower diversity of macroinvertebrate taxa, but AUSRIVAS, OE50 Taxa and SIGNAL2 scores indicate that there is little difference between Cataract Creek and control sites in Cataract River and Allen's Creek. Lower diversity of macroinvertebrate taxa in Cataract Creek may be indicative of historic impacts to this waterway from extraction of the Bulli and Balgownie seams.

Extraction of the Bulli seam has resulted in up to 0.2 m of subsidence, whilst extraction of the Balgownie seams has resulted in subsidence of 1.1 m beneath Cataract Creek. Based on compressive tilts and strains, fracturing of the base of Cataract Creek and its tributaries is likely to have occurred. This has resulted in observable impacts to Cataract Creek, particularly iron flocculent within the creek.

There are unlikely to be any direct impacts to Cataract Creek; however additional fracturing of tributaries of Cataract Creek may result in decreased inflow into Cataract Creek and an increase in iron seepage at the base of these tributaries (A. Dawkins pers. comm.). Increases in iron flocculent has potential to smother eggs of Macquarie Perch and result in changes in water quality, whilst reduced flows into Cataract Creek have the potential to reduce the quality of habitat for Macquarie Perch and result in changes to community composition of macroinvertebrate communities. However, given past mining, it is considered unlikely that these impacts will result in observable changes to Cataract Creek above and beyond those present.

Upland Swamps

Extraction of the Bulli and Balgownie seams has occurred within the Wonga East area. **Table 27**, pg 79 and

Table 28, pg 80 provides modelled subsidence data for upland swamps within the study area.

Table 27 - Subsidence data from extraction of the Bulli seams for upland swamps within the study area

*Values in **bold** exceed subsidence criteria in OEH 2012*

Swamp	Subsidence (m)	Overburden Depth (m)	Longwall Panel Width	Ratio of Overburden to Panel Width	Max Tensile Strain (mm/m)	Max Compressive Strain (mm/m)	Max Tilt (mm/m)
CCUS1	0.7	285	945	**0.30**	**3.7**	**7.4**	**12**
CCUS2	0.1	285	-	-	**0.5**	1.1	2
CCUS3	1	300	55	5.45	**5.0**	**10.0**	**17**
CCUS4	0.1	290	50	5.80	**0.5**	1.0	2
CCUS5	0.5	272	230	**1.18**	**2.8**	**5.5**	**9**
CCUS6	1	285	605	**0.47**	**5.3**	**10.5**	**18**
CCUS7	1	270	276	**0.98**	**5.6**	**11.1**	**19**
CCUS8	0.1	270	20	13.50	**0.6**	1.1	2
CCUS9	0.1	293	25	11.72	**0.5**	1.0	2
CCUS10	0.5	280	185	1.51	**2.7**	**5.4**	**9**
CCUS12	0.5	355	185	1.92	**2.1**	**4.2**	**7**
CCUS13	0.1	335	195	1.72	0.4	0.9	1
CCUS14	1	275	-	-	**5.5**	**10.9**	**18**
CCUS15	0.1	325	40	8.13	0.5	0.9	2
CCUS16	0.5	300	-	-	**2.5**	**5.0**	**8**
CCUS17	0.1	325	45	7.22	0.5	0.9	2
CCUS18	0.1	325	30	10.83	0.5	0.9	2
CCUS19	0.1	325	10	32.50	0.5	0.9	2
CCUS20	1	290	570	**0.51**	**5.2**	**10.3**	**17**
CCUS21	1	280	490	**0.57**	**5.4**	**10.7**	**18**
CCUS22	0.5	317	150	2.11	**2.4**	**4.7**	**8**
CCUS23	0.1	310	45	6.89	0.5	1.0	2
CRUS1	0.5	300	310	**0.97**	**2.5**	**5.0**	**8**
CRUS2	0.5	210	280	**0.75**	**3.6**	**7.1**	**12**
CRUS3	0.4	295	45	6.56	**2.0**	**4.1**	**7**
BCUS1	1	270	270	**1.00**	**5.6**	**11.1**	**19**
BCUS2	0.5	285	40	7.13	**2.6**	**5.3**	**9**
BCUS3	0.5	265	80	3.31	**2.8**	**5.7**	**9**
BCUS4	0.5	295	230	**1.28**	**2.5**	**5.1**	**8**
BCUS5	0.5	273	105	2.60	**2.7**	**5.5**	**9**
BCUS6	0.1	308	15	20.53	0.5	1.0	2
BCUS11	0.5	335	225	**1.49**	**2.2**	**4.5**	**7**

Table 28 - Subsidence data from extraction of the Balgownie seams for upland swamps within the study area

*Values in **bold** exceed subsidence criteria in OEH 2012*

Swamp	Subsidence Used (m)	Overburden Depth (m)	Longwall Panel Width	Ratio of Overburden to Panel Width	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
CCUS1	0.8	295	130	2.27	**4.1**	**8.1**	**14**
CCUS2	1	295	130	2.27	**5.1**	**10.2**	**17**
CCUS3	1	310	170	1.82	**4.8**	**9.7**	**16**
CCUS4	0.8	300	170	1.76	**4.0**	**8.0**	**13**
CCUS5	0.1	282	-	-	0.5	1.1	2
CCUS6	1	295	170	1.74	**5.1**	**10.2**	**17**
CCUS7	0.1	280	-	-	0.5	1.1	2
CCUS8	0.1	280	-	-	0.5	1.1	2
CCUS9	0.1	303	-	-	0.5	1.0	2
CCUS10	0.1	290	-	-	0.5	1.0	2
CCUS12	0.1	365	-	-	0.4	0.8	1
CCUS13	0.1	345	-	-	0.4	0.9	1
CCUS14	0.1	285	130	2.19	0.5	1.1	2
CCUS15	0.5	335	-	-	**2.2**	**4.5**	**7**
CCUS16	0.1	310	-	-	0.5	1.0	2
CCUS17	0.3	335	-	-	**1.3**	**2.7**	**4**
CCUS18	0.1	335	-	-	0.4	0.9	1
CCUS19	0.1	335	-	-	0.4	0.9	1
CCUS20	1	300	170	1.76	**5.0**	**10.0**	**17**
CCUS21	1	290	170	1.71	**5.2**	**10.3**	**17**
CCUS22	0.1	327	-	-	0.5	0.9	2
CCUS23	1	320	170	1.88	**4.7**	**9.4**	**16**
CRUS1	0.1	310	-	-	0.5	1.0	2
CRUS2	0.1	220	-	-	**0.7**	1.4	2
CRUS3	0.1	305	-	-	0.5	1.0	2
BCUS1	0.1	280	-	-	0.5	1.1	2
BCUS2	0.1	295	-	-	0.5	1.0	2
BCUS3	0.1	275	-	-	0.5	1.1	2
BCUS4	0.1	305	-	-	0.5	1.0	2
BCUS5	0.1	283	-	-	0.5	1.1	2
BCUS6	0.1	318	-	-	0.5	0.9	2
BCUS11	0.1	345	-	-	0.4	0.9	1

Subsidence data for upland swamps in the study area from extraction of the Bulli and Balgownie seams indicates that all upland swamps in the study area, except CCUS13, CCUS18, CCUS19 and BCUS6, have been subject to subsidence criteria sufficient to have placed these upland swamps at risk of negative environmental consequences, according to criteria outlined in DoP (2010) and OEH (2012).

This assessment of past mining in the Wonga East area indicates that natural features in the study area have been subject to subsidence resulting from extraction of the Bulli and Balgownie Seams sufficient to have placed the majority of upland swamps in the study area at risk of negative environmental consequences. This data provides a baseline against which assessments of potential impacts resulting from extraction of the Wongawilli Seam, as part of the preferred project, must be assessed.

Two pertinent examples are provided in CCUS4 and CCUS1. Through the extraction of the Bulli and Balgownie seams, upland swamp CCUS4, recognised as a 'wet swamp' containing MU44c Cyperoid Heath and MU43 Tea-tree Thicket, has previously been subject to:

- 900 mm of subsidence
- 4.7 mm / m of tensile strain
- 9.3 mm / m of compressive strain
- 16 mm / m of tilt

Upland swamp CCUS1, which contains a mix of all upland swamp vegetation communities, has previously been subject to:

- 2000 mm of subsidence
- 10.5 mm / m of tensile strain
- 21.1 mm / m of compressive strain
- 35 mm / m of tilt

Due to a lack of quantitative monitoring of these upland swamps during extraction of the Bulli and Balgownie seams we cannot determine with any degree of certainty what primary or secondary impacts, if any, did or did not result from this historic mining. However, these two swamps continue to support a wide range of vegetation communities, and provide an illustration of how subsidence criteria from DoP and OEH cannot be used alone to determine the impacts to upland swamps.

Following on from the swamp impact assessment undertaken by Biosis for the EA, a recommendation was made suggesting a number of changes to the original mine plan with the objective of avoiding and mitigating impacts to upland swamps. NRE have now redesigned the mine plan for Wonga East and have removed Wonga West from the project application. This revised impact assessment follows the methodology outlined in Biosis' EA report and is based on the revised mine plan and revised subsidence predictions.

Table 29 - Initial Risk Assessment for Wonga East in Preferred Project (Swamp names in italics indicate 'special significance'

Figures in bold are greater than criteria outlined by OEH ; subsidence predictions in red indicate predictions greater than in Biosis EA report; subsidence predictions in green indicate predictions lower than in Biosis' EA report

Swamp	Maximum subsidence within swamp boundary (m)	Adjacent subsidence used to calculate strains and tilts (m)	Overburden Depth (m)	Longwall panel width (m)	Ratio of Overburden to Panel Width	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)
BCUS1	< 0.1	1	270	-	-	0.5	1	2
BCUS2	< 0.1	0.5	285	-	-	0.5	0.9	2
BCUS3	< 0.1	0.5	265	-	-	0.5	1	2
BCUS4	1	0.5	295	140	2.11	**6.8**	**13.6**	**23**
BCUS5	< 0.1	0.5	273	-	-	0.5	1	2
BCUS6	< 0.1	< 0.1	308	-	-	0.4	0.9	1
BCUS11	1.4	0.5	335	145	2.31	**6.1**	**12.2**	**20**
CCUS1	0.6	0.7	285	-	-	**7**	**14.1**	**23**
CCUS2	2	< 0.1	285	120	2.38	**9.4**	**18.8**	**31**
CCUS3	1	1	300	125	2.40	**6.7**	**13.4**	**22**
CCUS4	1.4	< 0.1	290	125	2.32	**9.2**	**18.5**	**31**
CCUS5	1.2	0.5	272	125	2.18	**7.3**	**14.7**	**24**
CCUS6	2	1	285	125	2.28	**9.4**	**18.8**	**31**
CCUS7	< 0.1	1	270	-	-	0.5	1	2
CCUS8	< 0.1	< 0.1	270	-	-	0.5	1	2
CCUS9	< 0.1	< 0.1	293	-	-	0.5	0.9	2
CCUS10	0.8	0.5	280	145	1.93	**3.8**	**7.6**	**13**
CCUS11	1.8	1	340	145	2.34	**8.8**	**18**	**29**
CCUS12	1	0.5	355	145	2.45	**5.8**	**11.5**	**19**
CCUS13	< 0.1	< 0.1	335	-	-	0.4	0.8	1
CCUS14	< 0.1	1	275	-	-	0.5	1	2
CCUS15	< 0.1	< 0.1	325	-	-	0.4	0.8	1
CCUS16	< 0.1	0.5	300	-	-	0.4	0.9	1
CCUS17	< 0.1	< 0.1	325	-	-	0.4	0.8	1
CCUS18	< 0.1	< 0.1	325	-	-	0.4	0.8	1
CCUS19	< 0.1	< 0.1	325	-	-	0.4	0.8	1
CCUS20	< 0.1	1	290	-	-	0.5	0.9	2
CCUS21	< 0.1	1	280	-	-	**9.5**	**19**	**32**
CCUS22	< 0.1	0.5	317	-	-	0.4	0.9	1
CCUS23	0.2	< 0.1	310	125	2.48	**6.5**	**13**	**22**
CRUS1	1.4	0.5	300	125	2.40	**6.7**	**13.4**	**22**
CRUS2	< 0.1	0.5	210	-	-	**0.6**	1.2	2
CRUS3	< 0.1	0.4	295	-	-	0.5	0.9	2

Following assessment of a variety of risk factors **Table 30**, pg 83, provides an overall assessment of the potential for a significant impact to occur. Further detail of the analysis of these risk factors is located in **Attachment A**, pg 350. This final risk assessment assesses the overall risk of a primary impact based on the initial risk assessment and the consequent risk of a secondary impact based on factors such as groundwater data, reliance of vegetation communities on water availability, changes in flow accumulation and the position of water dependent communities within the upland swamp compared to areas of greatest tilt and strain.

This final risk assessment indicates that there is a risk of a significant secondary impact to upland swamps BCUS4 and CCUS4 from the proposed extraction of coal in Wonga East. Only CCUS4 is considered to be of special significance.

The revision of the mine plan for Wonga East has resulted in a reduction in risk to upland swamps of 'special significance' CRUS2 and CRUS3 due to these upland swamps now being situated outside of the predicted subsidence impact zone. Revision of the longwall layout has also resulted in a reduction in risk for CCUS5, as only the upper reaches of this upland swamp are now within the predicted subsidence impact zone.

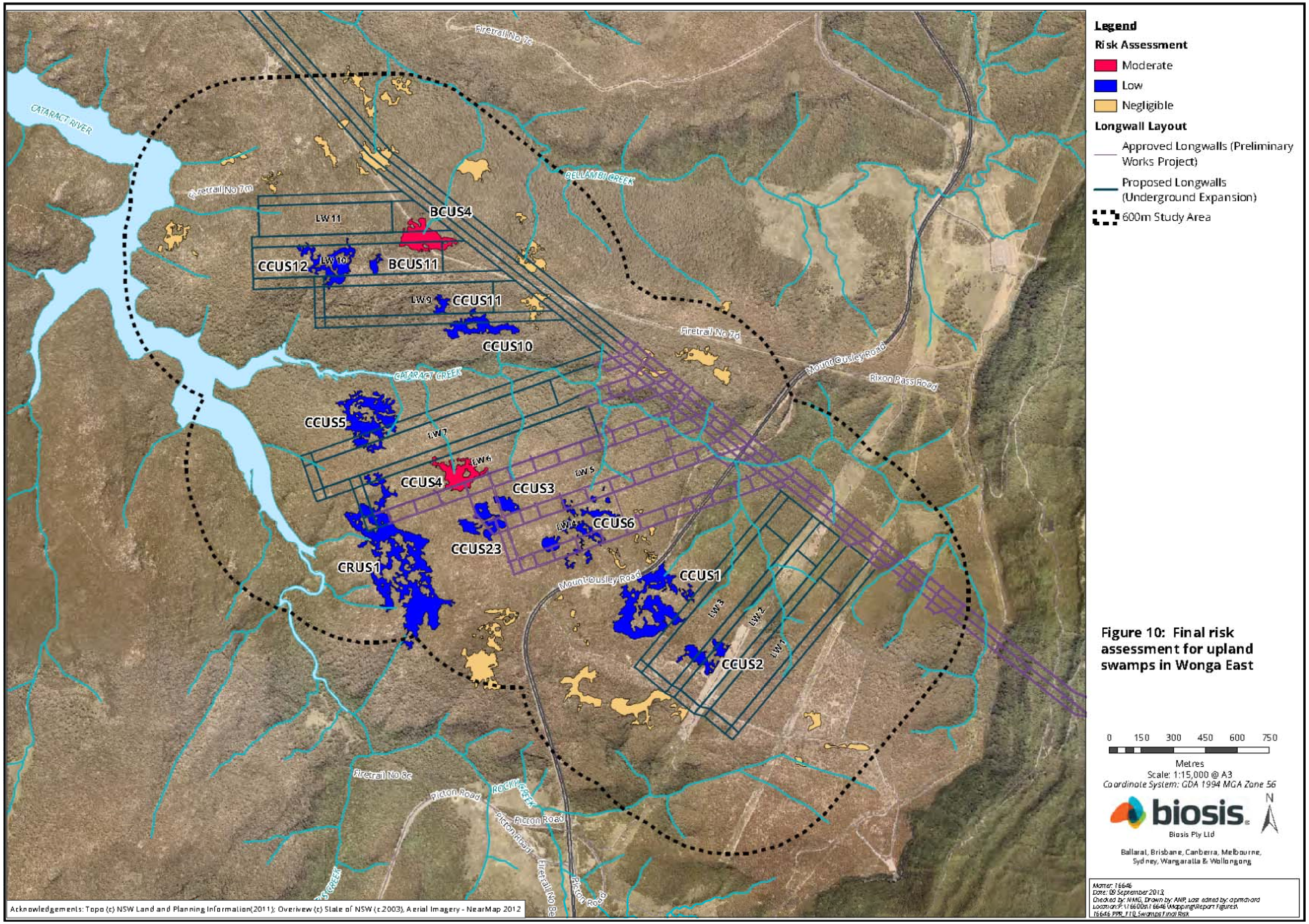
The changes in subsidence predictions and higher tilts and strains have resulted in an increase in risk level for CCUS4.

Table 30 - Final risk assessment for upland swamp sin the Wonga East area

Swamps of 'special significance' are shown in italics

Swamp	Initial risk assessment (risk of negative environmental consequences?)	Groundwater	Flow accumulation	Compressive tilts and strains	Final risk assessment
BCUS4	No	N/A	Moderate	Low	Moderate
BCUS11	Yes	N/A	Negligible	Low	Low
CCUS1	Yes	N/A	Low	Low	Low
CCUS2	Yes	Low	Low	Low	Low
CCUS3	Yes	Low	Low	Moderate	Low
CCUS4	Yes	Moderate	Moderate	Low	Moderate
CCUS5	Yes	High	Moderate	Low	Low
CCUS6	Yes	Low	Low	Low	Low
CCUS10	Yes	N/A	Low	Low	Low
CCUS11	Yes	N/A	Moderate	Low	Low
CCUS12	Yes	N/A	Negligible	Low	Low
CCUS23	Yes	N/A	Negligible	Low	Low
CRUS1	Yes	Low	Low	Low	Low

Figure 21 - Final risk assessment for upland swamps in Wonga East



2.2.1.4 Impact Management

Terrestrial Ecology

The majority of potential impacts to terrestrial biodiversity have been avoided as a result of the Preferred Project mine layout. Impact management will be broadly undertaken as outlined in *Section 24.6, pg 437- 441 of the EA,* as far as it pertains to the Preferred Project.

A monitoring plan as outlined in the Biodiversity Management Plan (BMP) for Longwalls LW4 and LW5 will be adopted and expanded for the Preferred Project. 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). The plan outlines measures for management of threatened species and ecological communities. Monitoring effort will 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. The BMP can be downloaded from the NRE website.

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 will be undertaken. Monitoring will be undertaken at annual intervals in appropriate seasonal timeframes for the detection of each individual species.

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 can be utilised as follows:

- if rock 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 rock 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 rock 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 (including humans) 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.

A Biodiversity Offset Strategy will be developed for impacts that are proven to be greater than allowable by any condition based performance indicators that form part of approved extraction.

Aquatic Ecology

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 and will be further managed through an adaptive mine plan, ongoing monitoring of subsidence, water quality, aquatic habitat, macro invertebrates and fish.

A monitoring plan as outlined in the BMP for Longwalls LW4 and LW5 will be adopted and expanded for the Preferred Project. Monitoring of water quality, aquatic habitat, macro invertebrates and fish during the same seasons as used for the baseline study will continue. There will be additional surveys of aquatic habitats and biota if fractures of the stream bed and associated loss of water from pools occur, fish or yabby kills are noted during routine surface monitoring or if significant changes in pH, dissolved oxygen, turbidity or metal concentrations are detected during routine surface monitoring.

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:

- 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.

A Biodiversity Offset Strategy will be developed for impacts that are proven to be greater than allowable by any condition based performance indicators that form part of approved extraction.

Upland Swamps

A swamp monitoring plan has been developed for the extraction of LW4 and LW5 in Wonga East as part of the BMP and the Subsidence Management Plan Monitoring Program for LW4 and LW5. These monitoring plans will be revised and updated for this application in liaison with SCA, OEH and to the approval of DPI. Copies of the existing management plans are available for download from the NRE website.

The existing shallow piezometers installed within the upland swamps in the Study Area will gauge any changes in standing water levels and swamp groundwater quality over the active mining area and all key water quality parameters on a regular basis for the duration and an appropriate time following mining.

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.

Water levels will be measured automatically, at least 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 in liaison with the OEH and SCA to ameliorate the situation until the water level or water quality recovers, if that is a likely outcome.

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 *Section 15 of Annex P to the EA*.

Any visual observation of surface impacts such as cracking of rock outcrops, erosion, slumping or changes in flow patters within the swamp that are detected during regular monitoring will be reported and a plan to remediate or repair the impact will be determined in liaison with OEH and SCA. As outlined in *Section 22.9, pgs 385-386 of the EA*, these measures can include:

- Installation of coir log dam erosion control structures at knick points in a swamp;
- Water spreading techniques;
- Sealing of minor surface cracks through the use of grouting products; and
- Curtain grouting

Adaptive management measures will be utilised in the context of ongoing mining in the Wonga East area. It is accepted by NRE that adaptive management based on groundwater levels is not rapid enough to prevent potential impacts to swamps as groundwater is a trailing indicator. If a swamp is impacted NRE will review the mine plan in liaison with DPI and DRE to determine options to prevent recurrence of impacts to future swamps affected by subsidence.

A Biodiversity Offset Strategy will be developed for impacts that are proven to be greater than allowable by any condition based performance indicators that form part of approved extraction.

2.2.1.5 Conclusion

Changes as a result of the Preferred Project have significantly reduced predicted impacts to terrestrial and aquatic biodiversity and upland swamps. A summary of the reduced impact predictions is provided below:

- Removal of Wonga West from the program has resulted in reduced impacts to cliffs, providing habitat for threatened bats, rocky outcrops, providing habitat for threatened flora species and the Broad-headed Snake, and habitat for threatened frogs. The risk assessment for each of these groups of species now indicates a low risk of potential impact.
- The revision of the mine plan to avoid undermining of Cataract Creek has resulted in a reduced risk of impact to Macquarie Perch, Murray Cod and Silver Perch, as well as habitat for the threatened Adam's Emerald Dragonfly.
- The revision of the mine plan has resulted in a reduction in risk for several upland swamps, including CRUS2, CRUS3 and CCUS5, and will result in low risk of impact for all upland swamps except BCUS4 and CCUS4.
- The revised mine plan and revised subsidence predictions have resulted in an increase in risk to one upland swamp, CCUS4.

2.2.2 Cliffs & Steep Slopes

2.2.2.1 Background

A number of issues were raised during the public exhibition period regarding what were considered significant issues in the EA with regard to the reliability of the subsidence model and resulting impact predictions.

Significant additional work has been undertaken to address these issues raised by use of an alternative mine subsidence modelling approach to the one used in the EA to form the basis of new impact assessments. Further field assessments of cliffs and steep slopes have been undertaken with regard to the combined potential impact on cliffs and steep slopes and any habitat for endangered species associated with them. This Section will provide an overview of the Cliffs and Steep Slopes of the Wonga East area with further detail, including the Figures used in this Section, available in **Attachment A**, pg 350, and **Attachment B**, pg 426 .

2.2.2.2 Significance Assessment

The Assessment Area has been defined as an area that extends to a horizontal distance of 600m from the outside edge of any of the proposed longwall panels including LW4 and LW5. A second far field assessment area extending to 1.5km outside the proposed longwall panels includes the Illawarra Escarpment which while some 800-900m east of proposed LW1is within the area where far-field horizontal movements may occur.

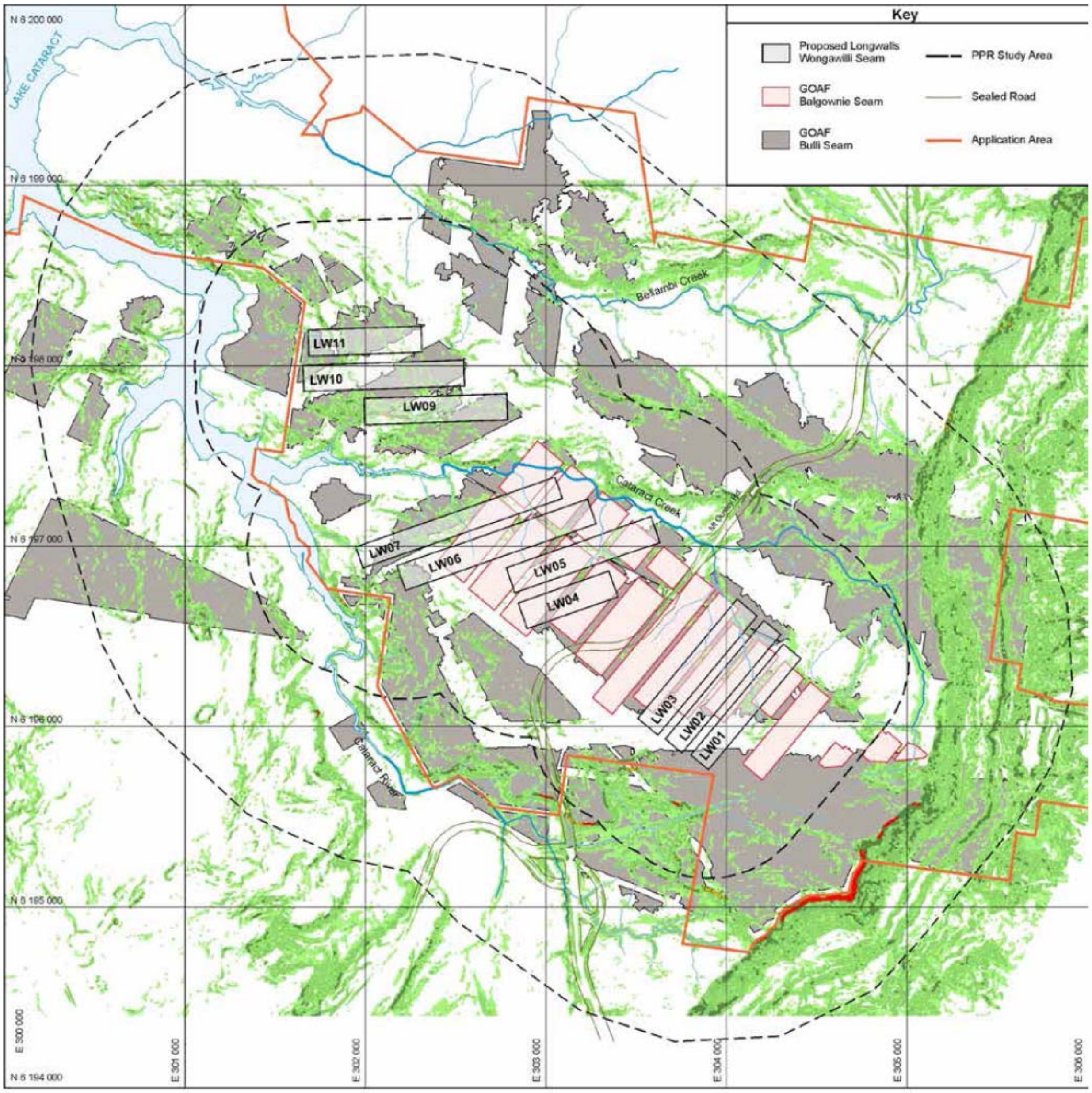
There are numerous sandstone cliff formations within the Assessment Area and many have previously been directly mined beneath and the impacts of this previous mining were assessed during site visits to inspect the surface area. All except for a few isolated sections are less than 5m high and none are considered to be significant using the significance criteria developed by the Planning Assessment Commission (PAC) in 2010 for the Bulli Seam Operations (BSO) PAC Report.

There are numerous sandstone cliff formations located within the Hawkesbury Sandstone outcrop in the Assessment Area. **Figure 22**, pg 89, shows the distribution of these cliff formations relative to the proposed longwall panels based on an interpretation of LiDAR data by Mine Subsidence Engineering Consultants (MSEC).

The most significant cliff formations are those associated with Brokers Nose on the Illawarra Escarpment located some 900m east of the southern end of LW1. Within the Assessment Area, there are several short sections of cliffs between 3m and 10m high located on the northern side of Cataract Creek and several short sections of slightly greater than 10m high cliff formations along the southern periphery of the Assessment Area.

Most of the sandstone cliff formations are less than 3m high and occur along the lower edge of the Hawkesbury Sandstone outcrop as a series of typically discontinuous outcrops and detached boulders. **Figure 23**, pg 90, shows a variety of photographs of typical sandstone cliff formations in the Assessment Area. Individual sandstone rock formations are typically less than 20m in length with sections of overhang in some of the formations and numerous isolated or toppled boulders scattered on the slopes immediately below.

Figure 22 – Locations of Cliffs and Steep Slopes



An inspection of cliff formations across the Assessment Area conducted during the subsidence assessment program indicates that there are several rock falls that could be attributable to mine subsidence from both Bulli Seam and Balgownie Seam mining activity. These rock falls are small in volume and are barely discernible from natural rock falls that have occurred in the general area over the period since mining was completed.

A length of cliff formation located above LW9 that includes archaeological site 52-2-3941 appears to have been subjected to fracturing and resultant rock falls which are likely to have been caused by subsidence associated with mining activity in the Bulli Seam. The nature of the fracturing and the age of the rock weathering appear consistent with the rock fall having occurred many decades ago.

Figure 23 – Examples of Cliff Formations in the Assessment Area

A small rock fall of only a few cubic metres of material was also observed above LW10 in the Balgownie Seam. The rock fall is located at the head of a small gully where the horizontal compression movements have been concentrated as the strata have subsided.

A rock fall located over the proposed LW11 in the Wongawilli Seam was observed during a recent surface inspection. This rock fall involving several tens of cubic metres appears to have occurred from natural causes over the last few years. The site is remote from recent mining activity and there is evidence of tree root invasion at the back of the fall.

There are numerous examples of much older natural rock falls along the slopes below most of the cliff formations across the site consistent with the natural processes of erosion.

The approach outlined in the NSW PAC (2010) is used as the basis for assessing significance. The categories of significance adopted are:

- Special significance – cliff formations that are longer than 200m, higher than 40m, and higher than 5m that constitute waterfalls.
- Minor environmental consequences – cliff formations where isolated rock falls of less than $30m^3$ are anticipated but where rock falls do not impact on Aboriginal heritage, endangered ecological communities, public safety and the like and rock falls and occur on less than 5% of the total length of cliff formations.
- Negligible environmental consequences – occasional displacement of boulders, hairline cracks, isolated dislodgement of overhanging rock slabs impacting less than 0.5% of the total length of a cliff formation.
- Nil environmental consequences – no mining impacts, although it is recognised that natural processes that cause ongoing erosion such as diurnal and seasonal thermal variations, high intensity rainfall, and the like continue to operate at a low level irrespective of mining activities.

Only the cliff formations associated with Brokers Nose are significant using the criteria outlined in the PAC (2010) based on their physical characteristics alone. However, Brokers Nose is remote from proposed mining and there is considered to be no potential for mining subsidence movements to impact the cliff formations along the Illawarra Escarpment.

There are a number of Aboriginal heritage sites located along cliff lines in the Assessment Area. These sites are dealt with separately in **Section 2.2.3**, pg 93. Impacts on Biodiversity are addressed in **Section 2.2.1**, pg 57.

2.2.2.3 Impact Assessment

The critical factor for the stability of sandstone cliff formations is horizontal compression along the line of the cliffs. Once this compression is greater than about 50-100mm per 20m length of cliff formation, rock falls become likely and their frequency increases as the compression increases, as the overhang increases, and as tree root invasion becomes more prevalent.

There is considered to be some potential for rock falls on up to 5% of the length of cliff formations directly mined under with potential for perceptible impacts such as tension cracking on up to 30% of the length of cliff formations directly mined under and extending outside the goaf edge to a distance of 0.4 times overburden depth (typically about 140m). A minor rock fall at approximately MGA 302600E, 6197000N on Hawkesbury Sandstone outcrop is considered likely to have been associated with mining activity in the Balgownie Seam and is typical of the impacts that are expected. This rock fall was difficult to detect, and was relatively minor in the context of ongoing natural erosion at the site.

Sites of archaeological significance located below sandstone cliff formations are considered separately in **Section 2.2.3**, pg 93**.**

The cliffs over LW9 have had specific predictions made as shown in **Table 31**, pg 92.

Table 31 – Subsidence Predictions for PPR Assessment Area

	Overburden Depth to Wongawilli Seam (m)	Bulli Seam & Balgownie Seam Subsidence (m)	Wongawilli Seam Predicted Subsidence (m) and Measured (in bold)	Balgownie Seam Tilt (mm/m)	Predicted Wongawilli Seam Tilt (mm/m) and Measured (in bold)	Balgownie Seam Max. Tensile Strain (mm/m) and Typical (in bold)	Predicted Wongawilli Seam Tensile Strain (mm/m) and Measured (in bold)	Balgownie Seam Max. Compressive Strain (mm/m) and Measured (in bold)	Predicted Wongawilli Seam Compressive Strain (mm/m) and Measured (in bold)
Cliffs over LW9	330	1	2.1	NA	32	NA	10	NA	19

Impacts on steep slopes are expected to be limited to the potential for subsidence cracks to develop at topographic high points that are directly mined under and at the start of longwall panels that commence mining in a downslope direction.

2.2.2.4 Impact Management

The environmental consequences of impacts on steep slopes are considered to be generally negligible although some cracks may need to be filled in where they are crossed by vehicle access tracks.

Impacts on cliffs are primarily of concern with regard to Aboriginal shelter sites and remediation and management options are discussed in **Section 2.2.3**, pg 93.

2.2.2.5 Conclusion

There are numerous sandstone cliff formations within the Assessment Area and many have previously been directly mined beneath and the impacts of this previous mining were assessed during site visits to inspect the surface area. All except for a few isolated sections are less than 5m high and none are considered to be significant using the significance criteria developed by the PAC for the BSO Report.

The most significant cliff formations are those associated with Brokers Nose on the Illawarra Escarpment located some 900m east of the southern end of LW1. Within the Assessment Area, there are several short sections of cliffs between 3m and 10m high located on the northern side of Cataract Creek and several short sections of slightly greater than 10m high cliff formations along the southern periphery of the Assessment Area

An inspection of cliff formations across the Assessment Area indicates that there are several rock falls that could be attributable to mine subsidence from both Bulli Seam and Balgownie Seam mining activity. These rock falls are small and barely discernible from natural rock falls that have occurred in the general area over the period since mining was completed.

If they are directly mined under, there is considered to be some potential for rock falls on up to 5% of the length of cliff formations and tension cracking on up to 30% of the length of cliff. There is no potential for mine subsidence impacts on Brokers Nose on the Illawarra Escarpment

2.2.3 Cultural Heritage

2.2.3.1 Background

A number of issues were raised during the public exhibition period regarding what were considered significant issues in the EA. These concerns broadly covered:

1. the requirement to relocate sites that were known to exist but were initially unable to be relocated;
2. the need for a complete reassessment of Aboriginal heritage impacts due to the EA subsidence modelling being considered unreliable;
3. concerns of broad destruction of Aboriginal heritage as a result of mine subsidence;
4. the need for more comprehensive monitoring plans; and
5. further Aboriginal consultation needing to be undertaken.

Significant additional work has been undertaken to address the issues raised in the EA, including the use of an alternative mine subsidence modelling approach to use as the basis of new impact assessments, relocation of a number of sites and further Aboriginal consultation. . This Section will provide an overview of the Cultural Heritage of the Wonga East area with further detail available in **Attachment C**, pg 536. Some Figures used in this Section can be found in **Attachment B**, pg 426

2.2.3.2 Consultation

ERM (2012) undertook Aboriginal stakeholder consultation in accordance with the OEH 2005 *Interim Community Consultation Requirements Guideline*. Consultation for the project commenced in October 2008 with five Aboriginal groups registered for the project. Section 2 and Annex U of ERM (2012) details the Aboriginal Community Consultation undertaken.

As part of this Preferred Project, and to address comments received from OEH in their submission, Biosis has continued consultation with the groups registered for the project. To facilitate an assessment of the cultural values associated with re-located and newly identified sites, Aboriginal stakeholders participated in a series of site visits conducted between 4 and 6 September 2013. These site visits were attended by representatives of the Northern Illawarra Aboriginal Collective (NIAC), Kullila Site Consultants (KSC), Peter Falk Consultancy (PFC), Illawarra Local Aboriginal Land Council (ILALC) and Wodi Wodi Elders Corporation (WWEC).

Copies of the NRE No. 1 Colliery – Underground Expansion Project: Preferred Project Report – Heritage will be sent to all registered Aboriginal groups for feedback on the content, assessment and recommendations. All comments received from these groups will be appended to that report when received and will inform future management plans should the Preferred Project be approved.

2.2.3.3 Site Identification

The changes to the Preferred Project and subsequent investigations have resulted in the following changes to predicted impacts to Aboriginal cultural heritage sites in the Wonga East area:

- Re-location of Aboriginal cultural heritage sites within Wonga East study area and revised locations in relation to impact footprint;
- Newly identified Aboriginal cultural heritage sites within the Wonga East study area not considered in ERM (2012) or ERM (2013);

- Changes in the location, orientation, length and width of long wall panels and reduction to the number of Aboriginal cultural heritage sites that will be undermined; and
- Changes in impacts to Aboriginal cultural heritage sites based on revised subsidence predictions.

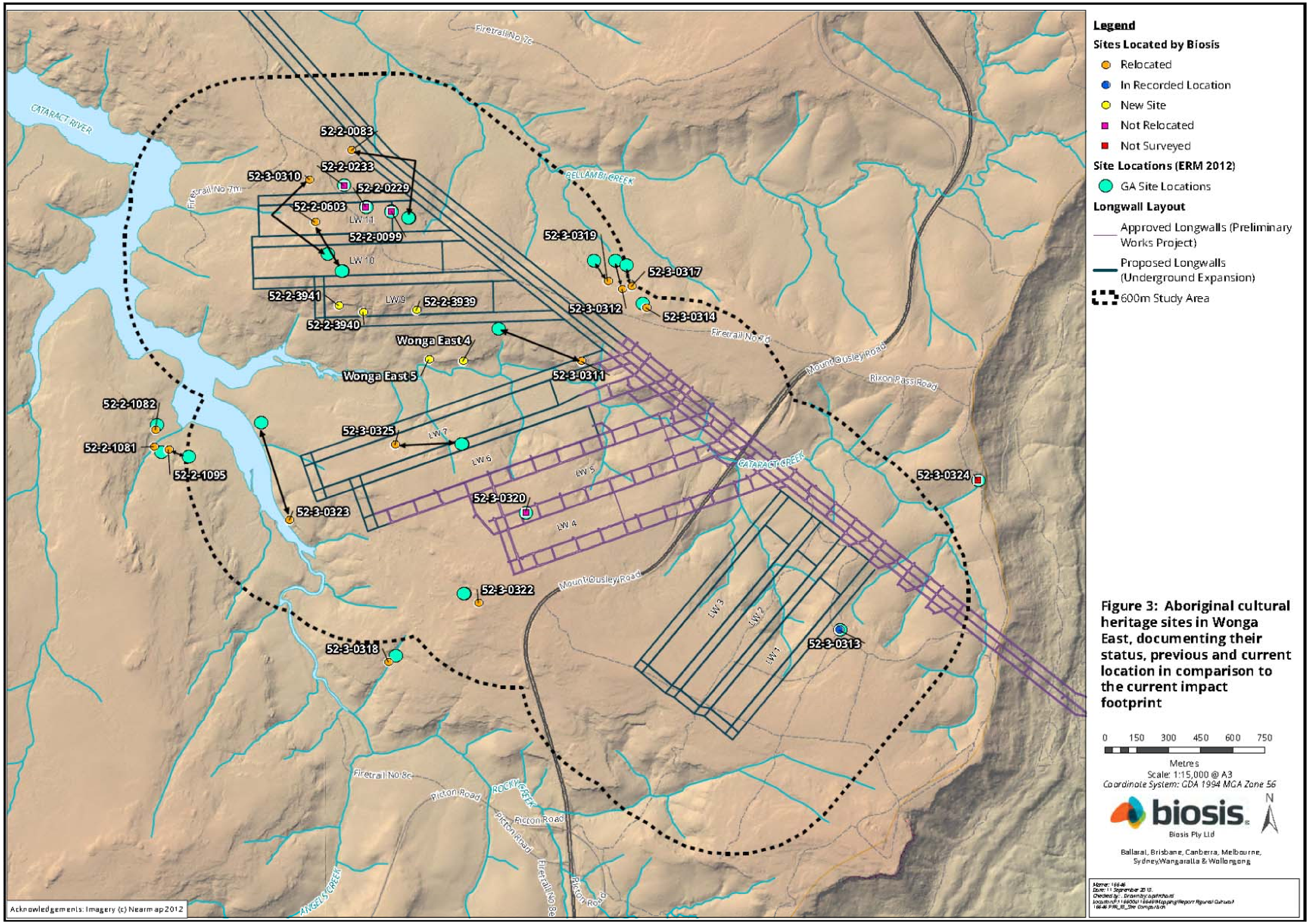
A summary of these changes is shown in **Table 32**, pg 94 and **Figure 24**, pg 96.

Table 32 - Aboriginal sites in Wonga East, showing their status (relocated or not) and previous and current location with regards to long wall layout

Site	Status	Previous location in relation to Longwalls	Current location in relation to Longwalls
All Aboriginal sites in Wonga West	-	Located within Wonga West area	No longer part of the project
52-2-0083	Relocated (current surveys)	Located above chain pillar of LW10	Located outside of longwalls, but within 600m study area
52-2-0099	Cannot be relocated	Located outside of longwalls, but within 600m study area	Located above LW10
52-2-0229	Cannot be relocated	Located outside of longwalls, but within 600m study area	Located above LW10
52-2-0233	Cannot be relocated	Located outside of longwalls, but within 600m study area	Located outside of longwalls, but within 600m study area
52-2-0603	Relocated (ERM 2012)	Located outside of longwalls, but within 600m study area	Located outside of longwalls, but within 600m study area
52-2-1081	Relocated (current surveys)	Located outside of longwalls, but within 600m study area	No longer located within 600m study area
52-2-1082	Relocated (current surveys)	Located outside of longwalls, but within 600m study area	No longer located within 600m study area
52-2-1095	Relocated (current surveys)	Located outside of longwalls, but within 600m study area	No longer located within 600m study area
52-2-3939	New site (Biosis 2012)	Located above LW10	Located above LW8
52-2-3940	New site (Biosis 2012)	Located above LW10	Located above LW8
52-2-3941	New site (Biosis 2012)	Located above LW10	Located above LW8
52-3-0310	Relocated (ERM 2012)	Located outside of longwalls, but within 600m study area	Located outside of longwalls, but within 600m study area
52-3-0311	Relocated (current surveys)	Located above LW9	Located outside of longwalls, but within 600m study area
52-3-0312	Relocated (ERM 2012)	Located outside of longwalls, but within 600m study area	Located outside of longwalls, but within 600m study area
52-3-0313	Relocated (ERM 2012)	Located above LW1	Located outside of longwalls, but within 600m study area

Site	Status	Previous location in relation to Longwalls	Current location in relation to Longwalls
52-3-0314	Relocated (ERM 2012)	Located outside of longwalls, but within 600m study area	Located outside of longwalls, but within 600m study area
52-3-0317	Relocated (Biosis 2012)	Located outside of longwalls, but within 600m study area	Located outside of longwalls, but within 600m study area
52-3-0318	Relocated (Biosis 2012)	Located outside of longwalls	No longer located within 600m study area
52-3-0319	Relocated (ERM 2012)	Located outside of longwalls, but within 600m study area	Located outside of longwalls, but within 600m study area
52-3-0320	Cannot be relocated	Located above chain pillar between LW4 and LW5	No change
52-3-0322	Relocated (Biosis 2012)	Located outside of longwalls, but within 600m study area	No change
52-3-0323	Relocated (current surveys)	Located above chain pillar between LW 7 and LW 8	Located outside of longwalls, but within 600m study area
52-3-0325	Relocated (current surveys)	Located above chain pillar between LW6 and LW7	Located above LW7
Wonga 4	New site (current surveys)	-	Located outside of longwalls, but within 600m study area
Wonga 5	New site (current surveys)		Located outside of longwalls, but within 600m study area

Figure 24 – Aboriginal cultural heritage sites in Wonga East, documenting their status, previous and current location in comparison to the current impact footprint

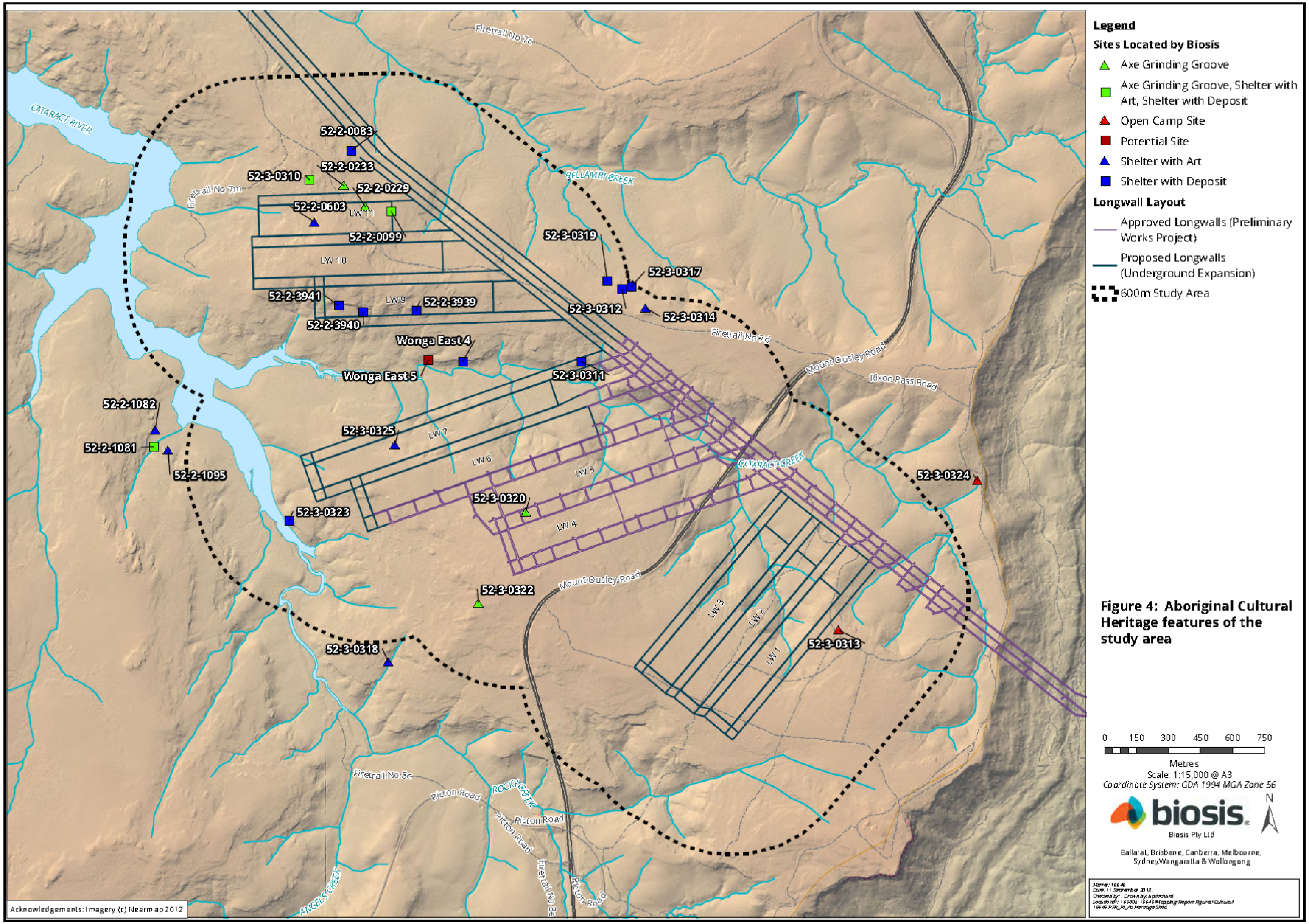


The EA and its Aboriginal heritage assessment report indicate a total of twenty-three sites are located in the Wonga East study area, seventeen of which would not be impacted by mine subsidence. ERM were able to relocate a total of nine sites within Wonga East. Since this time Biosis has undertaken an extensive relocation program and relocated an additional ten sites and identified five new sites; however four sites (all grinding grooves) remain unaccounted for (Biosis 2012, Biosis *in prep*). Four sites assessed by ERM are no longer located within the study area. A summary of the remaining twenty-one Aboriginal sites located within Wonga East study area Figure 1with site locations clearly displayed in **Figure 25**, pg 98.

Table 33 - Aboriginal sites within Wonga East

Site	Name	Context	Site Type
52-2-0083	Bulli Mine Shaft Site 7	Enclosed Shelter	Shelter with Deposit
52-2-0099	**Bulli Mine Shaft Site 8**	**Open Site**	**Axe grinding grooves**
52-2-0229	**Bulli Mine Shaft Site 12**	**Open Site**	**Axe grinding grooves**
52-2-0233	Bulli Mine Shaft Site 13	Open Site	Axe grinding grooves
52-2-0603	**Bulli Mine Shaft Site 19**	**Enclosed Shelter**	**Shelter with Art and Artefact**
52-2-3939	**Wonga East 1**	**Enclosed Shelter**	**Shelter with Deposit**
52-2-3940	**Wonga East 2**	**Enclosed Shelter**	**Shelter with Deposit**
52-2-3941	**Wonga East 3**	**Enclosed Shelter**	**Shelter with Deposit**
52-3-0310	Bulli Mine Shaft Site 18	Enclosed Shelter	Shelter with Art, Deposit and axe grinding grooves
52-3-0311	Bulli Mine Shaft Site 20	Enclosed Shelter	Shelter with Deposit
52-3-0312	Bulli Mine Shaft Site 23	Enclosed Shelter	Shelter with Deposit
52-3-0313	Bulli Mine Shaft Site 29	Open Site	Open Camp Site
52-3-0314	Bulli Mine Shaft Site 21	Enclosed Shelter	Shelter with Art
52-3-0317	Bulli Mine Shaft Site 22	Enclosed Shelter	Shelter with Deposit
52-3-0319	Bulli Mine Shaft Site 24	Enclosed Shelter	Shelter with Deposit
52-3-0320	**Bulli Mine Shaft Site 25**	**Open Site**	**Axe grinding grooves**
52-3-0322	Bulli Mine Shaft Site 31	Open Site	Axe grinding grooves
52-3-0323	Bulli Mine Shaft Site 26	Enclosed Shelter	Shelter with Deposit
52-3-0325	**Bulli Mine Shaft Site 27**	**Enclosed Shelter**	**Shelter with Art and Deposit**
n/a	Wonga East 4	Enclosed Shelter	Shelter with Deposit
n/a	Wonga East 5	Enclosed Shelter	Shelter with Stone Arrangement

Figure 25 - Aboriginal Cultural Heritage features of the study area



2.2.3.4 Significance Assessment

The high volume of re-identified and new sites has necessitated the re-assessment of scientific significance. The assessment of scientific significance for Aboriginal sites in the Study Area has used a different methodology from the ERM Aboriginal Heritage Assessment (2012) and, as a result, the scientific significance for all sites has been reassessed.

The two main values addressed when assessing the significance of Aboriginal sites are cultural values to the Aboriginal community and archaeological (scientific) values.

Heritage assessment criteria in NSW fall broadly within the significance values outlined in the Australia International Council on Monuments and Sites (ICOMOS) Burra Charter (Australia ICOMOS 1999). This approach to heritage has been adopted by cultural heritage managers and government agencies as the set of guidelines for best practice heritage management in Australia. These values are provided as a dot point outline below but are explained in detail in **Attachment C**, pg 536:

- Historical significance
- Aesthetic significance
- Social significance
- Scientific significance

The cultural and archaeological significance of Aboriginal and historic sites and places is assessed on the basis of the significance values outlined above. Other government agencies have developed criteria for assessing the significance of heritage places within NSW. Of primary interest are guidelines prepared by the Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA), the OEH and the Heritage Branch, NSW Department of Planning. These guidelines state that an area may contain evidence and associations which demonstrate one or any combination of the ICOMOS Burra Charter significance values outlined above in reference to Aboriginal heritage. Reference to each of the values should be made when evaluating archaeological and cultural significance for Aboriginal sites and places. In addition to the previously outlined heritage values, the OEH Guidelines (DECC 2006) also specify the importance of considering cultural given that 'the significance of individual features is derived from their inter-relatedness within the cultural landscape'.

Archaeological significance (also called scientific significance, as per the ICOMOS Burra Charter) refers to the value of archaeological objects or sites as they relate to research questions that are of importance to the archaeological community, including indigenous communities, heritage managers and academic archaeologists. Generally the value of this type of significance is determined on the basis of the potential for sites and objects to provide information regarding the past life-ways of people. The assessment of archaeological significance is constituted of two parts:

1. **Research Potential** – this consists of two ratings
    a. **Content Rating –** based on the volume of cultural materials or artefacts at the site; and
    b. **Condition Rating** - which ranges from 'site destroyed' through to 'excellent condition'; and
2. **Representativeness** – is a subjective assessment which refers to the regional distribution of a particular site type and ranges from 'common' to 'rare'.

Overall scientific significance ratings for sites, based on a cumulative score for site contents, site integrity and representativeness are:

- 1-3 low scientific significance
- 4-6 moderate scientific significance
- 7-9 high scientific significance

Each site is given a score on the basis of these criteria – the overall scientific significance is determined by the cumulative score. This scoring procedure has been applied to the Aboriginal archaeological sites identified during the sub-surface testing. The results are presented in **Table 34** pg 101.

Table 34 - Scientific significance assessment of archaeological sites recorded within the Study Area

Site	Site Type	Site Content	Site Condition	Representativeness	Scientific Significance	Statement of Significance
52-2-0083	Shelter with Deposit	2	2	1	5 - Moderate	52-2-0083 is a shelter with deposit site. Five artefacts were identified including chert, silcrete and quartz flakes. A yellowish sandy deposit with a depth of 30cm has accumulated in a 1 x 2m area of the shelter. The site is a typical example of a common site type in the region and is of moderate scientific significance due to its preservation and lack of disturbance.
52-2-0099	Axe grinding grooves	1	1	1	3 - Low	52-2-0099 is a grinding groove site. Three grinding grooves were located on a sandstone outcrop measuring 8m x 4m. The site is an example of a common site type in the region with poorly preserved features and is of low scientific significance.
52-2-0229	Axe grinding grooves	1	1	1	3 - Low	52-3-0229 is a grinding groove site. The site was recorded as a single grinding groove located within a sandstone outcrop measuring 18 x 2m. The site is recorded as being in reasonable condition. The site is an example of a common site type in the region with poorly preserved features and is of low scientific significance.
52-2-0233	Axe grinding grooves	1	1	1	3 - Low	52-3-0233 is a grinding groove site. The site was recorded as two grinding grooves located within a sandstone outcrop measuring approximately 18 x 4m. The site is recorded as being in reasonable condition. The site is an example of a common site type in the region with poorly preserved features and is of low scientific significance.
52-2-0603	Shelter with Art and Artefact	1	1	1	3 - Low	52-2-0603 is a shelter with art, no identified deposit and a single artefact. The art is located on two panels on the rear wall and consists of a single red ochre hand stencil and a separate indeterminate charcoal motif. A single silcrete core has previously been identified within the shelter. The art is faded and in a poor condition. The site is an example of a common site type in the region with poorly preserved features and is of low scientific significance.
52-2-3939	Shelter with Deposit	2	2	1	5 - Moderate	52-2-3939 is a shelter with deposit. Five surface artefacts consisting of quartz, chert and silcrete flakes have been recorded in the drip line at this site. A deposit of yellowish grey sand is present and is an intact and fair condition. The site is a typical example of a common site type in the region, and is of moderate scientific significance due to its preservation and lack of disturbance.
52-2-3940	Shelter with Deposit	2	2	1	5 - Moderate	52-2-3940 is a shelter with deposit. Six surface artefacts consisting of silcrete flakes and quartz angular fragments have been recorded in the drip line at this site. A deposit of yellowish grey sand is present and is an intact and fair condition. The site is a typical example of a common site type in the region, and is of moderate scientific significance due to its preservation and lack of disturbance.
52-2-3941	Shelter with Deposit	2	2	1	5 - Moderate	52-2-3941 is a shelter with deposit. Four surface artefacts consisting of quartz and silcrete flakes have been recorded in the drip line at this site. A deposit of yellowish grey sand is present and is an intact and fair condition. The site is a typical example of a common site type in the region, and is of moderate scientific significance due to its preservation and lack of disturbance.
52-3-0310	Shelter with Art, Deposit and axe grinding grooves	4	2	2	8 - High	52-2-0310 is a shelter site that has art, grinding grooves and an archaeological deposit. The deposit consists of over 100 stone artefacts on the shelter floor, suggesting a high potential for further material in the grey-brown sandy loam deposit, which has been partially disturbed through animal burrowing. The art assemblage contains 12 recognisable motifs including charcoal outline and infill anthropomorphic figures, macropods, fish and geometric lines and dots. The art is in good condition and is still easily recognisable. Three grinding grooves are located in the southern end of the shelter. The relatively large assemblage of big motifs, with multiple techniques affords rarity value, and the site is generally representative of charcoal and ochre motif art for the study area and region. This site is of high scientific significance.
52-3-0311	Shelter with Deposit	2	1	1	4 - Moderate	52-3-0311 is a shelter site with deposit. The deposit consists of yellowish-brown sand with quartz, silcrete and chert flakes. The deposit has been disturbed to some extent through wombat burrowing. The site is a typical example of a common site type in the region and is of moderate scientific significance due to its preservation and lack of disturbance.

Site	Site Type	Site Content	Site Condition	Representativeness	Scientific Significance	Statement of Significance
52-3-0312	Shelter with Deposit	2	2	1	5 - Moderate	52-3-0312 is a shelter site with deposit. The deposit consists of a yellowish-brown sand with high densities of artefacts located at two points in the drip line. The deposit is relatively undisturbed. The site is a typical example of a common site type in the region and is of moderate scientific significance due to its preservation and lack of disturbance.
52-3-0313	Open Camp Site	1	1	1	3 - Low	52-3-0313 is an open camp site. The site was recorded as containing nine stone artefacts with a range of raw material types including silcrete, chert and fossilized wood. The site has a shallow white sand overlaying a yellow clay, this has been extensively disturbed by erosion of the topsoil through flooding and fire train upgrades. The site is an example of a common site type in the region with poorly preserved features and is of low scientific significance.
52-3-0314	Shelter with Art	4	2	1	7 - High	52-3-0314 is a shelter with art and deposit. The shelter contains two art panels. The first panel contains 2 charcoal outline motifs of a lizard and indeterminate drawing. Nearby the second art panel contains a series of charcoal lines. The art is in good condition and is still easily recognisable. The small but unique motifs affords rarity value, and the site is generally representative of charcoal and ochre motif art for the study area and region. This site is of high scientific significance.
52-3-0317	Shelter with Deposit	2	1	1	4 - Moderate	52-3-0317 is a shelter site with deposit. The deposit consists of a yellowish-brown sand with a singe artefact identified. The deposit has been disturbed to some extent. The site is a typical example of a common site type in the region and is of moderate scientific significance due to its preservation and lack of disturbance.
52-3-0319	Shelter with Deposit	2	1	1	4 - Moderate	52-3-0319 is a shelter site with deposit. The deposit consists of a yellowish-clay loam with two artefacts consisting of a fossilized wood flake and a quartz flake identified. The deposit is in reasonable condition. The site is a typical example of a common site type in the region and is of moderate scientific significance due to its preservation and lack of disturbance.
52-3-0320	Axe grinding grooves	1	1	1	3 - Low	52-3-0320 is a grinding groove site. The site was recorded as a single grinding groove located within a sandstone outcrop measuring 22 x 2.5m. The site is recorded as being in reasonable condition. The site is an example of a common site type in the region with poorly preserved features and is of low scientific significance.
52-3-0322	Axe grinding grooves	1	1	1	3 - Low	52-3-0322 is a grinding groove site. The site was recorded as two grinding grooves located within a sandstone outcrop measuring approximately 11 x 20m. The site is recorded as being in reasonable condition. The site is an example of a common site type in the region with poorly preserved features and is of low scientific significance.
52-3-0323	Shelter with Deposit	2	2	1	5 - Moderate	52-3-0323 is a shelter with deposit. Three surface artefacts consisting of silcrete, chert and quartz flakes have been recorded in the drip line at this site. A deposit of yellowish grey sand is present with a depth of 20 cm and is an intact and fair condition. The site is a typical example of a common site type in the region, and is of moderate scientific significance due to its preservation and lack of disturbance.
52-3-0325	Shelter with Art and Deposit	2	1	1	4 - Moderate	52-3-0325 is a shelter with Art and deposit. Five surface artefacts consisting of silcrete, fossilized wood and quartz flakes and a quartz core have been recorded. A deposit of yellowish clayey sand is present but has been subject to wombat burrowing. A single art panel consisting of sprayed red ochre is present on the rear wall. The art is in poor condition and indiscernible. The site is a typical example of a common site type in the region, and is of moderate scientific significance due to the range of features present.
Wonga East 4	Shelter with Deposit	2	2	1	5 - Moderate	Wonga East 4 is a shelter with deposit. Four surface artefacts consisting of quartz and silcrete flakes have been recorded in the drip line at this site. A deposit of yellowish grey sand is present and is an intact and fair condition. The site is a typical example of a common site type in the region, and is of moderate scientific significance due to its preservation and lack of disturbance.
Wonga East 5	Shelter with Stone Arrangement	1	1	1	3 - Low	Wonga East 5 is a shelter with stone arrangement. The shelter is low with two piles of stones in the entrance. The lichen growing on the stones indicates that they were placed some time ago. The shelter does not contain a deposit, art or artefacts. Although this may have been a historical feature, consultation with Aboriginal stakeholders indicates that the site may have cultural significance. Given the condition of the site, limited range of site features the site is of low scientific significance.

2.2.3.5 Impact Assessment

During and following the extraction of coal via longwall mining methods, overlying rock strata are subject to varying degrees of subsidence, tilt and strain (SCT 2013). At the surface, the ground subsides vertically and also moves horizontally towards the centre of the mined ground. These movements can cause slumping of soils on poorly consolidated landform elements such as talus slopes and cracking of rigid areas such as sandstone platforms, ledges and cliffs. These ground surface changes can potentially impact on cultural heritage sites.

It is difficult to make precise statements of impact due to subsidence effects to Aboriginal shelter sites, and subsidence impact prediction modeling for Aboriginal shelter sites is still developing. Following on from Sefton's (2000) review of subsidence impacts in the Southern Coalfield, the majority of subsequent subsidence impact prediction modeling has been based on the identification of characteristics associated with the potential for subsidence effects to occur. To date, no single characteristic has been identified as the sole contributor to subsidence effects and risk assessments consider a combination of shelter, longwall and subsidence characteristics and parameters. In order to determine the level of risk of impacts to Aboriginal shelter sites from subsidence impacts in the Project Area, ratings and criteria have been developed considering the following:

- **Subsidence Impacts -** Changes to shelter conditions attributed to subsidence impacts include small movements along joints, tension cracking of strata, cliff collapse or block fall and increased water seepage of shelter sandstone surfaces. While subsidence impacts do not always have direct heritage values impacts, i.e. impacts to art panels, they can cause a change in shelter conditions that can then lead to a heritage values impact, such as altering water seepage patterns that subsequently adversely affects art panels. Thus the heritage values at a given Aboriginal shelter site, such as the presence or absence of art panels, will influence the occurrence risk of a heritage values impact due to subsidence impacts. Changes to site conditions of axe grinding grooves and engraving sites due to subsidence effects could include cracking of sandstone platforms, tree fall and change in drainage patterns.
- **Aboriginal shelter subsidence monitoring in the wider Southern Coalfield** - Subsidence monitoring data has been collected for 104 shelter sites in the Southern Coal Fields by Sefton, Biosis and Niche Environment and Heritage. Eleven of these sites, all having experienced greater than 300mm of subsidence, have had a change in condition due to subsidence impacts, however predicted tilt, tensile and compressive strains varied greatly across sites. A combination of large overhang size and presence of bedding planes with water seepage remains the most common shared characteristics in shelters to have a change in shelter conditions. Eight of the affected sites have water seepage and only one site has a shelter volume of less than 50 cubic metres. Other contributing characteristics distinguishable in the data as possibly contributing to the risk of impact resulting from subsidence impacts included maximum predicted subsidence movement and landform. A preliminary Discriminant Analysis of Southern Coalfield Aboriginal site subsidence monitoring data has been undertaken by Symbolix on behalf of Biosis. The analysis aimed to discriminate between sites that experienced subsidence effects and those that did not. While the results are only preliminary at this stage, trends indicate that larger, wet sites on ridge tops or valley bottoms are the features that best group into those that experience changes versus those that do not (Symbolix 2012).
- **Results of Aboriginal shelter subsidence monitoring in the Dendrobium and Delta (Elouera) Collieries** – Subsidence monitoring data has been collected for 17 shelter sites within the Dendrobium and Delta (Elouera) Colliery areas. These colliery areas share similar geological characteristics to the current Study Area, such as depth of coal

seams being mined, and are of direct relevance in assessing the risk of impact from subsidence impacts. Of these 17 sites, two sites have had impacts due to subsidence effects, a large dry shelter (52-2-2252) and as small wet shelter (52-5-0277) that had maximum predicted vertical movements of between 900mm to 1540mm and maximum predicted tensile strains of between 2.5mm/m and 7.4mm/m. Only one other site had similar subsidence predictions, 52-5-0278, but was not subject to subsidence impacts.

These reviews are discussed in detail in **Attachment C**, pg 536.

The development of an impact prediction methodology has attempted to provide reasonably accurate subsidence impact predictions to shelter sites, which, in combination with a cultural heritage significance assessment, is then used to provide appropriate avoidance and mitigation recommendations (generally subsidence monitoring). The risk of impact criteria adopted for the purposes of this assessment are shelter size (volume), the presence of water seepage, maximum predicted subsidence movement and the presence/absence of art. Risk categories are from moderate to negligible and reflect subsidence effect occurrence and actual impacts to heritage values from subsidence effects monitored to date.

A description of risk categories and criteria is provided in **Table 35**, pg 104. The subsidence impact assessment was made using the parameters in Sefton's PCA and in conjunction with the subsidence predictions provided by SCT for all 21 sites in Wonga East is found in **Table 36**, pg 109.

Table 35 - Subsidence Effect Risk Categories and Criteria

Category	Description	Criteria
Moderate	There is a moderate chance of subsidence effects occurring which may result in impacts to heritage values.	• The shelter has an art panel present; and • The shelter has a volume larger than 50 cubic metres; • The shelter has joints or bedding plans subject to water seepage; and • Maximum predicted subsidence is greater than 300mm.
Low	There is a low chance of subsidence effects occurring which may result in impacts to heritage values.	• The shelter has a volume larger than 50 cubic metres; and • Maximum predicted subsidence is greater than 300mm
Very Low	There is a very low chance of subsidence effects occurring which may result in impacts to heritage values.	• The shelter has a volume less than 50 cubic metres and maximum predicted subsidence is greater than 300mm; or • The shelter has a volume more than 50 cubic metres and maximum predicted subsidence is less than 300mm.
Negligible	Impacts to heritage values are unlikely and if they did occur would normally be indistinguishable from natural environmental effects; or The site is located outside of the predicted subsidence impact zone	• The shelter has a volume less than 50 cubic metres; • Maximum predicted subsidence is less than 300mm, tensile strain predictions are <0.5mm/m and compressive strain estimates are <0.01mm/m.

Site 52-2-3939 forms part of a 3-5m high sandstone cliff formation that protrudes from the general line of the cliffs with a 6m overhang as shown in **Figure 26**, pg 105. The site is estimated to have previously experienced approximately 0.2m of subsidence with horizontal compression of about 0.1m. Proposed mining of Longwall 9 in the Wongawilli Seam is expected to cause up to 0.8m of additional subsidence with 2m expected nearby, up to 350mm of additional compression at the site and tensile strains of about 9mm/m. The site is protected somewhat by being relatively short in length and protruding out from the general line of the cliffs in the area. The probability of rock falls at the site is assessed as being 2% which means that there is likely to be rock fall within the general area of the site i.e. somewhere along the 100-200m of cliff line that are located within a short distance of the site. Perceptible tensile cracking is assessed as having a 30% probability of being evident on rock surfaces in the general area including possibly through the site.

Figure 26 - Photograph of Archaeological Site 52-2-3939

Site 52-2-3940 is part of an extended (100m long) line of 4-6m high cliff formations, some of which have already fallen either naturally or as a result of previous mining in the Bulli Seam more than 50 years ago, and has a 5m overhang as shown in **Figure 27**, pg 106. The site is estimated to have previously experienced approximately 0.1m of subsidence with horizontal compression of about 0.1m. Proposed mining of Longwall 9 in the Wongawilli Seam is expected to cause up to 0.6m of additional subsidence with 1.5m expected nearby, up to 250mm of additional compression at the site, and tensile strains of about 7mm/m. The site is considered to be vulnerable to further rock falls because it is part of a long line of cliffs, some of which have already collapsed. The probability of rock falls at the site is assessed as being 5% which equates to a 5m rock fall being likely somewhere along the 100m section of cliff line adjacent to the site. Perceptible tensile cracking is assessed as having a 30% probability of being evident on rock surfaces in the general area including possibly through the site.

Figure 27 – Photograph of Archaeological Site 52-2-3940

Site 52-2-3941 is part of a 3-4m high cliff formation that been previously involved in a rock fall. The overhang that constitutes the site is located below a detached boulder and has an overhang of approximately 4m. **Figure 28**, pg 107, shows a photograph of the site including the fractured rock strata where the boulder has detached from the general cliff formation. There are several characteristics of the rock fall that indicate it is likely to have been associated with mining in the Bulli Seam more than 50 years ago. The site is estimated to have previously experienced approximately 0.2m of subsidence with horizontal compression of about 0.1m. Proposed mining of Longwall 9 in the Wongawilli Seam is expected to cause up to 1.2m of additional subsidence with 1.5m expected nearby, up to 250mm of additional compression at the site, and tensile strains of about 7mm/m. The site itself is not considered vulnerable to further rock falls because it is detached from the cliff line and is not large enough to experience significant lateral compression so the probability of a rock fall at the site is considered to be low (<1%). However, the probability of further rock falls in the general vicinity of the site along the standing cliff line is assessed as being 5%. This probability equates to a 5m length of the adjacent 100m of cliff formation likely to experience a rock fall. Perceptible tensile cracking is assessed as having a 30% probability of being evident on rock surfaces in the general area although a tension crack directly through the site is considered unlikely.

Figure 28 – Photograph of Archaeological Site 52-2-3941

Site 52-2-0603 is located high up on the ridge line. The cliff formation is estimated to be 50-70m long and the overhang where the rock art is located is approximately 4m deep and 3m high as shown in Figure 33. The rock in the roof of the overhang is only about 1-2m thick but relatively continuous. The site is estimated to have experienced up to 0.3m of subsidence as a result of previous Bulli Seam mining activity with horizontal movement of about 0.1m although it is possible that the geometry of the Bulli Seam mining was sufficiently narrow in this area to prevent significant subsidence movements at the site. Proposed mining of Longwall 11 is expected to cause up to 1.5m of additional subsidence and up to 250mm of horizontal compression. The site's location near the top of the ridge is likely to have reduced some of the horizontal compression because there is currently no evidence of a rock fall within the period of previous mining. There is a rock fall evident on a nearby formation, but this fall appears to be too recent (last few years) for it to have been directly associated with previous mining subsidence. The level of horizontal compression expected is assessed as being likely to cause perceptible cracking in the vicinity of the site with the probability of rock fall assessed as being 5-10%. The nature of the site is such that a rock fall anywhere along the 30-40m length of the overhang is likely to be considered as having impacted the site.

Grinding groove sites are located on bare rock areas in upland areas away from creeks. Perceptible cracking is expected in up to 30% of bare rock areas when these areas located directly above longwall panels. Outside the goaf edge, the frequency of cracking is expected to decrease in magnitude with distance from the goaf edge and become imperceptible beyond a distance of about 0.4 times the overburden depth or about 120-150m from the goaf edge. Within any given site where cracking occurs, individual cracks may be perceptible as tension cracks that cause the rock to move apart, usually on natural joints if these exist but also through intact rock, shear cracks that cause opening and lateral displacement of the two sides, and compression cracks that result in the rock surface popping up in slabs. Shear and tension cracks tend to be more prevalent in upland areas. The probability of one of the tension or shear cracks directly intersecting a grinding groove depends on the site characteristics, but is generally low because such cracks tend to be widely spaced (5-10m). However, the potential for a bare rock sites to be impacted generally is expected to up to about 30%. Compression fracturing tends to be more prevalent in topographic low points and the fracturing that occurs tends to affect a larger proportion of the site.

The **Wonga East 4, Wonga East 5, 52-3-0310, and 52-3-0311** sites are located beyond the footprint of the longwall panels and are not expected to be perceptibly impacted by mining subsidence because of their location.

Sites 52-2-0099, 52-2-0229, 52-3-0320 and 52-3-0325 are located within the boundaries of the longwall panels and some perceptible impacts are expected in the general area of these sites as a result. Those sites that are associated with detached boulders such as 52-3-0325 are considered unlikely to be significantly impacted.

Table 36 - Summary of the predicted risk of impact to Aboriginal Sites in Study Area

Site in bold are located within the 200 mm subsidence impact footprint; all other sites are located within the 600m study area buffer

Site Number	Site Name	Site Type	Scientific Significance	Cultural Significance	Risk of Impact
52-2-0083	Bulli Mine Shaft Site 7	Shelter with Deposit	Moderate	High	Negligible
52-2-0099	**Bulli Mine Shaft Site 8**	**Axe grinding grooves**	**Low**	**High**	**Very Low**
52-2-0229	**Bulli Mine Shaft Site 12**	**Axe grinding grooves**	**Low**	**High**	**Very Low**
52-2-0233	Bulli Mine Shaft Site 13	Axe grinding grooves	Low	High	Negligible
52-2-0603	**Bulli Mine Shaft Site 19**	**Shelter with Art and Artefact**	**Low**	**High**	**Moderate**
52-2-3939	**Wonga East 1**	**Shelter with Deposit**	**Moderate**	**High**	**Low**
52-2-3940	**Wonga East 2**	**Shelter with Deposit**	**Moderate**	**High**	**Low**
52-2-3941	**Wonga East 3**	**Shelter with Deposit**	**Moderate**	**High**	**Very Low**
52-3-0310	Bulli Mine Shaft Site 18	Shelter with Art, Deposit and axe grinding grooves	High	High	Negligible
52-3-0311	Bulli Mine Shaft Site 20	Shelter with Deposit	Moderate	High	Negligible
52-3-0312	Bulli Mine Shaft Site 23	Shelter with Deposit	Moderate	High	Negligible
52-3-0313	Bulli Mine Shaft Site 29	Open Camp Site	Low	High	Negligible
52-3-0314	Bulli Mine Shaft Site 21	Shelter with Art	High	High	Negligible
52-3-0317	Bulli Mine Shaft Site 22	Shelter with Deposit	Moderate	High	Negligible
52-3-0319	Bulli Mine Shaft Site 24	Shelter with Deposit	Moderate	High	Negligible
52-3-0320	**Bulli Mine Shaft Site 25**	**Axe grinding grooves**	**Low**	**High**	**Very Low**
52-3-0322	Bulli Mine Shaft Site 31	Axe grinding grooves	Low	High	Negligible
52-3-0323	Bulli Mine Shaft Site 26	Shelter with Deposit	Moderate	High	Negligible
52-3-0325	**Bulli Mine Shaft Site 27**	**Shelter with Art and Deposit**	**Moderate**	**High**	**Negligible**
n/a	Wonga East 4	Shelter with Deposit	Moderate	High	Negligible
n/a	Wonga East 5	Shelter with Stone Arrangement	Low	High	Negligible

2.2.3.6 Impact Management

The monitoring and management of the identified sites will be undertaken in generally in accordance with the principle's outlined in *Section 25.8.4, pgs 463 – 467, of the EA*. Of the 21 sites affected by the Preferred Project, only 8 are within the 20mm subsidence zone and of those only 1, Bulli Mine Shaft Site 19, is estimated to be at greater than low risk of impact. The potentially impacted sites are:

- Axe grinding grooves (52-2-0099, 52-2-0229, and 52-3-0320)
- Shelters with deposits (52-2-3939, 52-2-3940, and 52-2-3941)
- Shelter with art and deposit (52-3-0325)
- Shelter with art and artefact (52-2-0603)

Monitoring of axe grinding grooves will involve visual inspection and update to the AHIMS site card pre and post mining.

The monitoring program for shelters will include monitoring at the following times:

- pre mining;
- three months after mining beneath the shelter;
- six months after mining beneath the shelter; and
- post mining.

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.

2.2.3.7 Conclusion

Changes to the project have resulted in a significant reduction in predicted impacts to Aboriginal cultural heritage sites. A summary of the reduced impact predictions is provided below:

- Removal of Wonga West from the program has resulted in reduced impacts to Aboriginal cultural heritage sites;
- The revision of the mine plan has resulted in sites 52-03-0311 and 52-03-0313 no longer being undermined;
- Revised scientific and cultural significance assessments for all newly re-located and identified Aboriginal cultural heritage sites, this has confirmed the level of scientific and cultural significance attributed to sites which were not relocated by ERM (2012; 2013);
- Re-location of sites 52-2-0083 and 52-3-0310 which has lead to these sites being identified as outside of the proposed mine plan and being subject to a lower level of predicted impact to these sites;
- Revised subsidence impacts for sites 52-03-0320, 52-02-3939, 52-02-3940 and 52-03-3941; and
- The relocation of 52-2-0229 has resulted in the site being located within the mine plan and revised subsidence predictions have resulted in an increase in risk to this site.

In summary, site 52-2-0603 is considered to be at a moderate risk of impact. All other Aboriginal heritage sites in the study area are considered to be at low, very low or negligible risk of impact.

2.2.4 Geology

2.2.4.1 Background

A number of issues were raised during the public exhibition period regarding what were considered significant information gaps in the EA. These concerns broadly covered issues surrounding:

1. the potential for dykes, faults and other geological features to:
4. allow hydraulic connection between the mine workings and the base of the reservoir; and
5. allow hydraulic connection between the mine workings and surface streams;
2. the hydraulic performance of the geology above the workings with regard to the transmission of rainfall/stream recharged groundwater from the surface to the mine workings; and
3. the potential of dykes, faults and other geological features to exacerbate subsidence effects and impacts.

Significant additional work has been undertaken to address the issues identified in the EA in order to provide the best possible information for groundwater, surface water and subsidence modelling for the Preferred Project. This Section will provide an overview of the geology of the Wonga East area with further detail available in **Attachment D**, pg 579.

2.2.4.2 Regional Geology

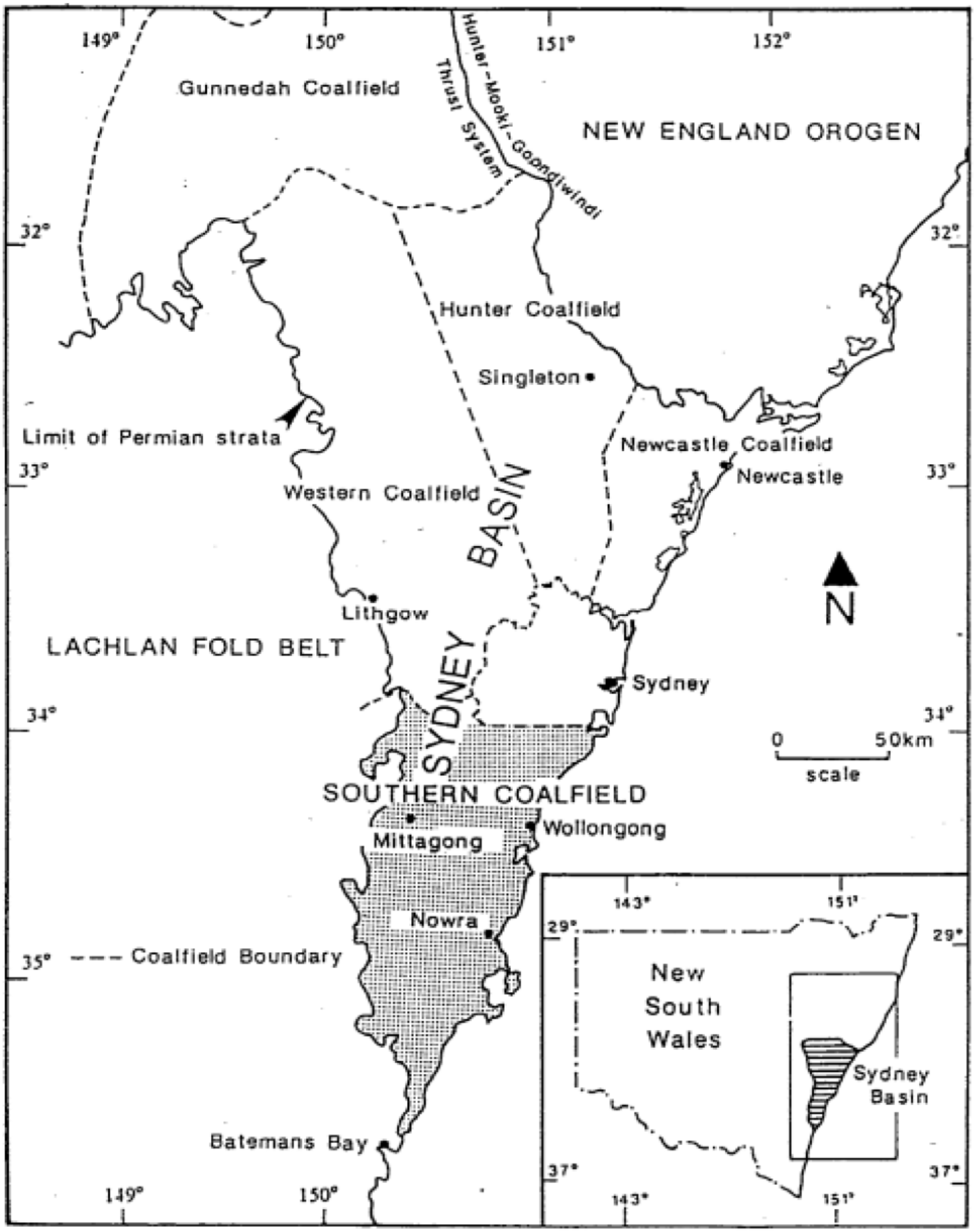
The NRE No.1 Colliery is located in the Southern Coalfield, which is the southern portion of the Permo-Triassic Sydney Basin, as shown in **Figure 29**, pg 112, and contains the Illawarra Coal Measures of Late Permian Age. Overlying the Illawarra Coal Measures are sandstones, shales and mudstones of the Narrabeen Group, which in turn are overlain by the Hawkesbury Sandstone, a massive quartzose sandstone unit. The Wianamatta Group, stratigraphically above the Hawkesbury Sandstone, is the topmost unit in the Southern Coalfield.

Within the Illawarra Coal Measures the Bulli Seam is the uppermost coal member and has been extensively mined across the Southern Coalfield. The Balgownie Seam, 9 to 10 metres below the Bulli Seam, was mined by the longwall method in the 1970's and in the 1990's by bord and pillar operations (Gibson's Colliery). There are currently no mining operations in the Balgownie Seam within the Southern Coalfield. The Wongawilli Seam lies below the Balgownie Seam and is around 24 to 35 metres below the Bulli Seam.

Although generally consistent in thickness across the Coalfield at 8 to 11 metres, the Wongawilli Seam deteriorates in quality to the north when compared to the southern part of the Coalfield where a basal section is mined at NRE's Wongawilli Colliery and BHPB's Dendrobium Colliery.

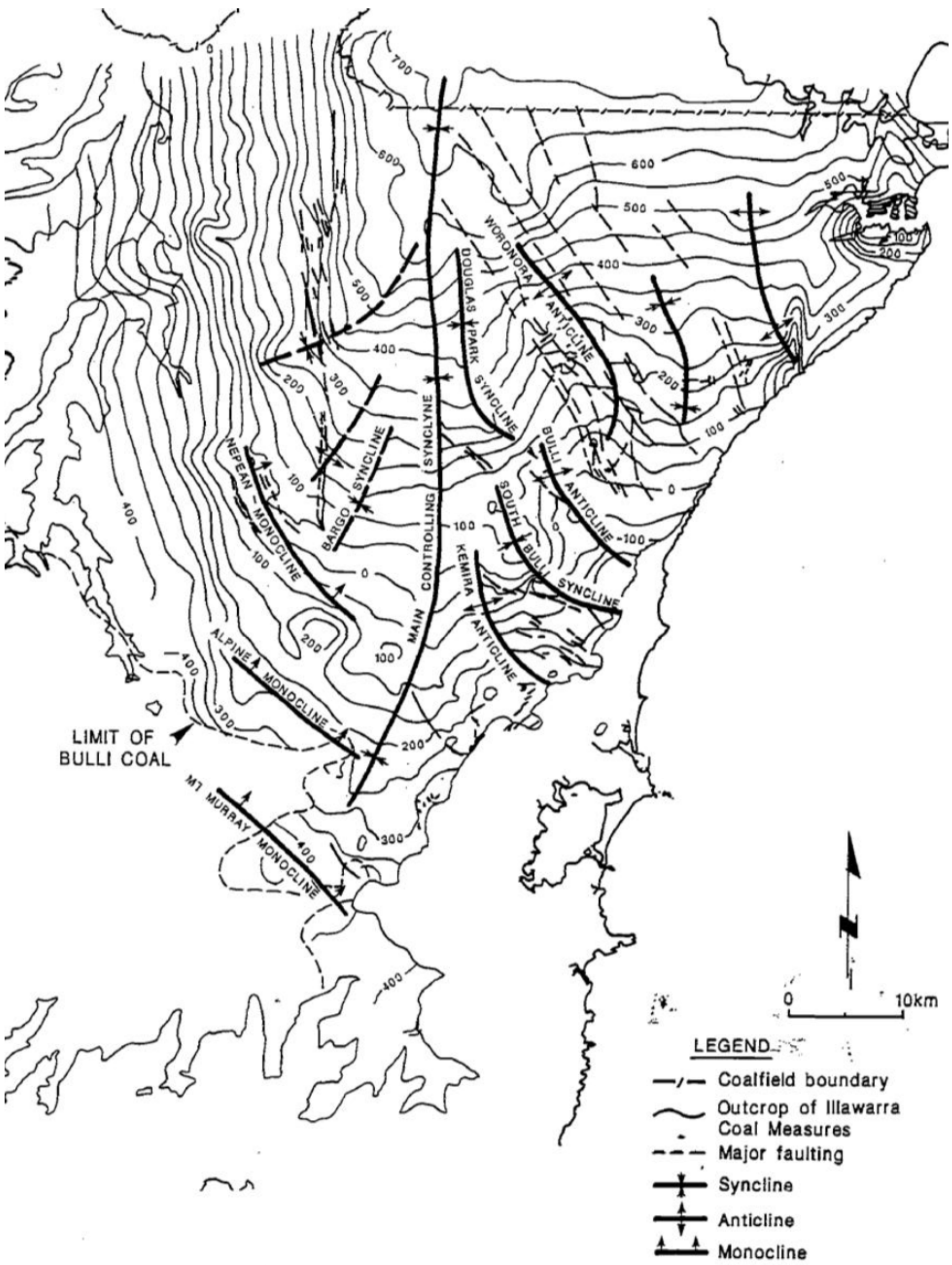
The Southern Coalfield is broadly dominated by a north plunging syncline with associated northwest trending synclines and anticlines, shown in **Figure 30**, pg 113. The overall structure of the Coalfield is based on the Bulli Seam, but the major structural trends of the Bulli Seam are considered representative of the coal measure sequence.

Figure 29 - Location of the Southern Coalfield



As can be seen in **Figure 30**, pg 113, large displacement faults in the Coalfield consist primarily of normal faults with dips of between 70 to 85 degrees, trending NW or NNW and are the primary set. The exceptions to this rule are faults found in a NE trending coastal fault zone. West of this zone, NE faults still occur but at a much wider spacing and as a secondary set (some of these are strike slip faults associated with dykes). The deformational history of the NW fault system is complex and the pattern is the sum of several events that appear to have started after the Permian although there is some evidence of growth faulting indicating structural activity during coal deposition.

Figure 30 - Structural Elements of the Southern Coalfield



2.2.4.3 Stratigraphy

Figure 31, pg 114, shows the stratigraphy of the Southern Coalfield and gives details of the coal seams present in the Illawarra Coal Measures.

Figure 31 - Generalised Stratigraphy of the Southern Coalfield

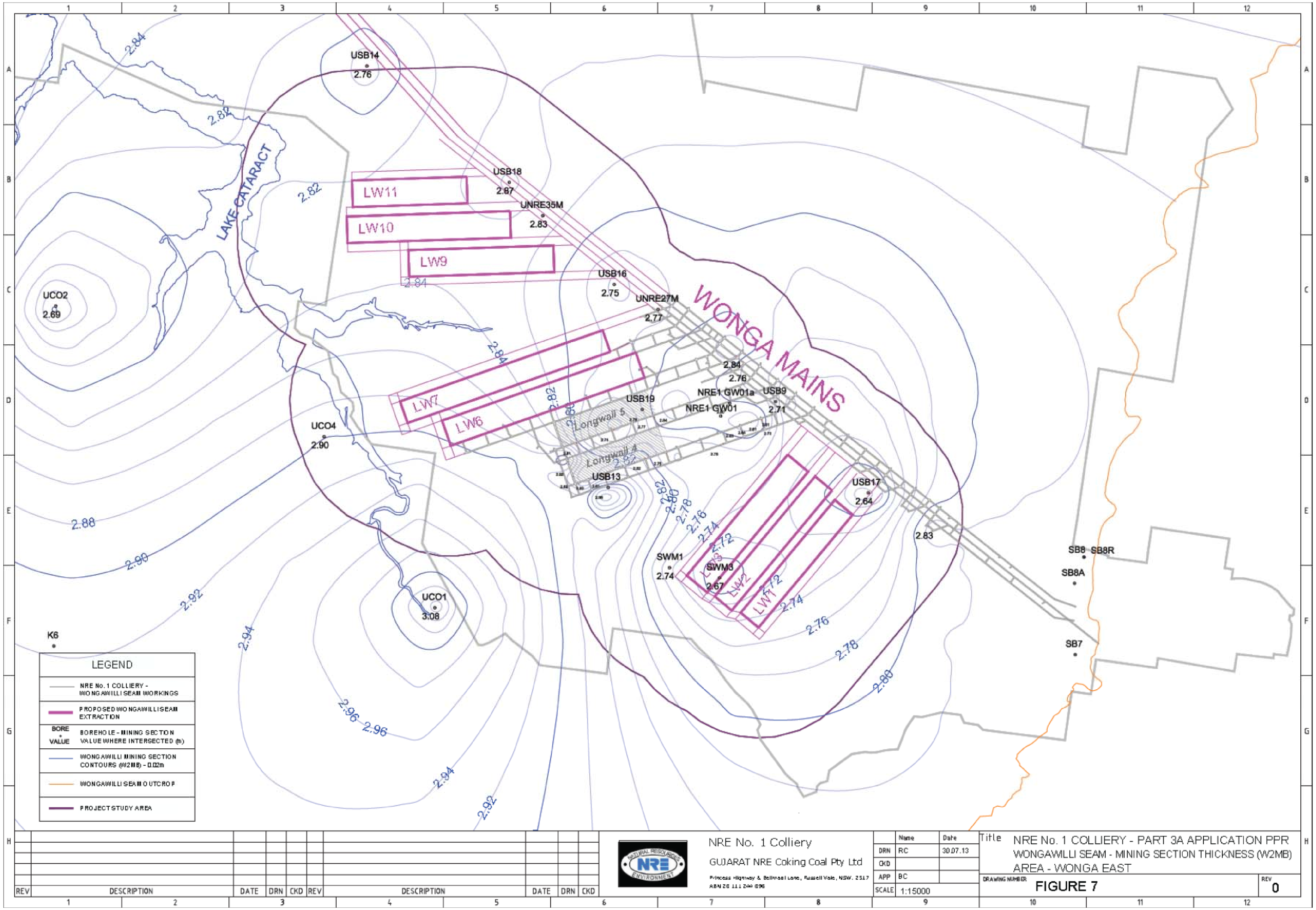
AGE	GROUP	SUB-GRP	CODE	FORMATION & MEMBERS	
TRIASSIC	WIANAMATTA GROUP		WMSH	BRINGELLY SHALE	
				MINCHINBURY SANDSTONE	
				ASHFIELD SHALE	
				MITTAGONG FORMATION	
			HBSS	HAWKSBURY SANDSTONE	
	NARRABEEN GROUP	GOSFORD	GRFM	NEWPORT FORMATION	
				GARIE FORMATION	
		CLIFTON	BACS	BALD HILL CLAYSTONE	
			BGSS	BULGO SANDSTONE	
			SPCS	STANWELL PARK CLAYSTONE	
			SBSS	SCARBOROUGH SANDSTONE	
			WBCS	WOMBARRA CLAYSTONE	
			CCSS	COAL CLIFF SANDSTONE	
PERMIAN	ILLAWARRA COAL MEASURES	SYDNEY	BUSM	BULLI COAL	
			UNM1	LODDON SANDSTONE	
			BASM	BALGOWNIE COAL	
			LRSS	LAWRENCE SANDSTONE	
				BURRAGORANG CLAYSTONE	
			CHSM	ECKERSLEY FORMATION	CAPE HORN
			UNM2		UNNAMED MEMBER 2
					HARGRAVE COAL
					WORONORA COAL
					NOVICE SANDSTONE
			WW01-11	WONGAWILLI COAL	
			KBSS	KEMBLA SANDSTONE	
			ACSM	ALLANS CREEK FORMATION	AMERICAN CK. COAL
			APFM	DARKES FOREST SANDSTONE (APPIN FORMATION)	
				BARGO CLAYSTONE	HUNTLEY CLAYST.
					AUSTIMER SANDST.
			TGSM	TONGARRA COAL	
			WTFM	WILTON FORMATION	
				WOONONA COAL MEMBER	
				ERINS VALE FORMATION	
		CUMBERLAND		PHEASANTS NEST FORMATION	FIGTREE COAL
					UNANDERRA COAL
					BERKELEY LATITE
					MINNAMURRA LATITE
					CALDERWOOD LATITE
					FIVE ISLANDS LATITE
	SHOALHAVEN GROUP			BROUGHTON FORMATION	
				BERRY SILTSTONE	
				NOWRA SANDSTONE	
				WANDRAWANDIAN SILTSTONE	
				SNAPPER POINT FORMATION	
				PEBBLEY BEACH FORMATION	
	TALATERANG			CLYDE COAL MEASURES	
UNDIFFERENTIATED PALAEOZOIC (DEVONIAN, SILURIAN & ORDOVICIAN) ROCKS OF THE BASIN BASEMENT					
Information Sourced From - "Geological Survey Report No. GS1998/277 - R.S. Moffitt"					

Table 37, pg 115, provides a brief summary of the stratigraphic units of the Southern Coalfield within the NRE No.1 Colliery holding. More detail is available in **Attachment D,** pg 579.

Table 37 - The Stratigraphic Units of the Southern Coalfield Within the No.1 Colliery Holdings

Group	Description
Wianamatta	• Only two boreholes (SR16 and WB8) in the western area of the NRE No.1 lease intersected the Wianamatta Shale. Its outcrop is restricted to a very small area and is well outside the Wonga East study Area.
Hawkesbury Sandstone	• The Hawkesbury Sandstone outcrops over most parts of the Coalfield and consists of thickly bedded or massive quartzose sandstone (with grey shale lenses up to several metres thick) with an average thickness of 154m in the lease area.
Narrabeen	• The **Gosford Formation**, consisting of the Newport Formation of interbedded grey shales and sandstones and the Garie Claystone, a generally hard, grey-brown "oolitic" clay stone, is about 12m thick across the lease area; • The **Bald Hill Claystone** displays characteristic brownish-red coloured "chocolate shale", a physically weak but lithologically stable unit about 20m thick; • The **Bulgo Sandstone**, averaging 162m thick, consists of strong, thickly bedded, and medium to coarse-grained lithic sandstone with occasional beds of conglomerate or shale; • The **Stanwell Park Claystone** averages 14m in thickness and consists of greenish-grey mudstones and sandstones. This "green shale" is very weak lithologically and frets easily on exposure; • The **Scarborough Sandstone**, averaging 36m in thickness, consists mainly of thickly bedded sandstone with shale and sandy shale lenses up to several metres thick; • The **Wombarra Shale** is on average 20m thick and consists of greenish-grey mudstones and sandstones. This "green shale" is also very weak lithologically and is prone to fretting on exposure; and • The **Coal Cliff Sandstone** averages 10m in thickness. In the coastal region of the Coalfield the Coal Cliff Sandstone is strong quartzose sandstone. Westward, away from the coast, dominance of the sandstone diminishes and in many areas the original roof strata of the Bulli Seam, a shale / mudstone unit, which can become laminated in places, is prominent.
Illawarra Coal Measures	• The **Bulli Seam** is the most extensively worked coal seam in the Southern Coalfield and produces a high quality hard coking coal that usually needs separation into a coking and energy fraction to obtain a marketable low ash coking coal. Resources of the Bulli Seam exist in the western portion of NRE No.1 Colliery. Average thickness is 2.2m and thickness variations across the project application area are shown in Figure 4 of **Attachment D**, pg 579. • The **Balgownie Seam** generally consists of medium to high ash coal with a transitional basal section of varying proportions of carbonaceous shale, mudstone and coal. Seam thickness averages 1.2m and thickness variations across the project application area are shown in Figure 5 of **Attachment D**, pg 579. The separation of the Balgownie Seam from the overlying Bulli Seam by the Loddon Sandstone averages 9.5m but varies from approximately 5.2m to 13.8m. Figure 6 of **Attachment D**, pg 579, shows the thickness variations of the Loddon Sandstone in the project application area. • The **Cape Horn Seam** is uneconomic and occurs about 9.5m below the Balgownie Seam with thickness varying between 0.06m and 0.8m. • The **Hargrave Seam** is uneconomic and occurs about 2.5m below the Cape Horn Seam with thickness varying from 0.1m to 0.50m. • The Wongawilli Seam varies in thickness from 7.7m to 11.9m across the Colliery and consists of interbedded bands of brown mudstone or grey shales and coal plies. In the NRE No.1 Wonga East Preferred Project application area there is a basal mining section varying between 2.6m to 2.8m that has been identified as the economic longwall mining section. **Figure 32**, pg 116, details the mining section thickness across the Wonga East area. The interval between the Bulli Seam and the roof of the Wongawilli mining section averages around 32m in the NRE No.1 lease area. Figure 8 of **Attachment D**, pg 579, details this interburden thickness. • The **American Creek Seam** is uneconomic and occurs about 10m below the Wongawilli Seam. It varies between 0.4m and 3.6m thick, • The **Tongarra Seam** is uneconomic and occurs about 33m below the American Creek Seam. It is about 1.8m thick. • The **Woonona, Figtree and Unanderra Seams** are uneconomic and are known to occur about 17m below the Tongarra Seam. The Woonona Seam is about 0.40m thick. Approximately 40m below the Woonona, the Figtree Seam is about 0.1m thick. The Unanderra Seam generally consists of numerous splits over an interval thickness of 9.5m and occurs some 17m below the Figtree Seam.

Figure 32 - Mining Section Thickness of the Wongawilli Seam



2.2.4.4 Depth of Cover

Topographic relief over the NRE No.1 Wonga East Study Area consists of a series of ridges and plateaux that slope down into the Cataract Reservoir and its tributaries that incise the landscape. Over the Study Area the depth of cover to the roof of the Bulli Seam varies from around 225m towards the escarpment to over 350m in the northwest of the Wonga East area as shown on **Figure 33**, pg 118.

The depth of cover to the lower seams has similar trends to the Bulli Seam with the roof of the Balgownie Seam some 11.7m deeper than the Bulli Seam floor. For the Wongawilli Seam, depth of cover is taken to the top of the planned longwall extraction height which is 2.8m. Depth to the mining roof for the Wongawilli Seam from the Bulli Seam floor averages 32.5m.

2.3.4.5 Surface Geology

Surface geology in the Wonga East project application area has been reviewed through ground proofing traverses, detailed Lidar topographic data at 1.0m contour intervals and aerial photography. **Figure 34**, pg 119, details the understanding of the surface geology to date.

The Hawkesbury Sandstone dominates the plateau and ridges forming prominent cliff lines in some areas. Descending into the Cataract Reservoir foreshore, the Hawkesbury Sandstone is still prominent on the eastern Reservoir shoreline where alluvium and colluvial deposits cover any outcrop of the lower stratigraphy. This colluvial deposit is still prominent toward Cataract Creek until the Gosford Formation, likely the lower Garie Formation, becomes evident. Further east along Cataract Creek the Bald Hill Claystone becomes evident in the creek bed until approximately 800m west of Mt. Ousley Road where the Bulgo Sandstone becomes evident in the creek bed. The Bulgo Sandstone appears to have only undergone a small amount of erosion given the proximity of the Bald Hill Claystone boundary.

The outcropping of Bulgo Sandstone remains east of Mt. Ousley Road within the base of Cataract Creek for about 500m, often covered by Bald Hill Claystone derived alluvium. East of Mt. Ousley Road the Bald Hill Claystone is again prominent in the main tributaries of Cataract Creek before ascending through the Gosford Formation to the Hawkesbury Sandstone.

Figure 35, pg 120, details two cross-sections within the Preferred Project Study Area and their traces are shown on **Figure 34**, pg 119, as section lines A – A and B – B. These cross-sections show consistency in strata thickness across the project application area with section B – B indicating a slight anticline across the northern section of the Preferred Project area.

Figure 33 - Wonga East Depth of Cover to the Roof of the Bulli Seam

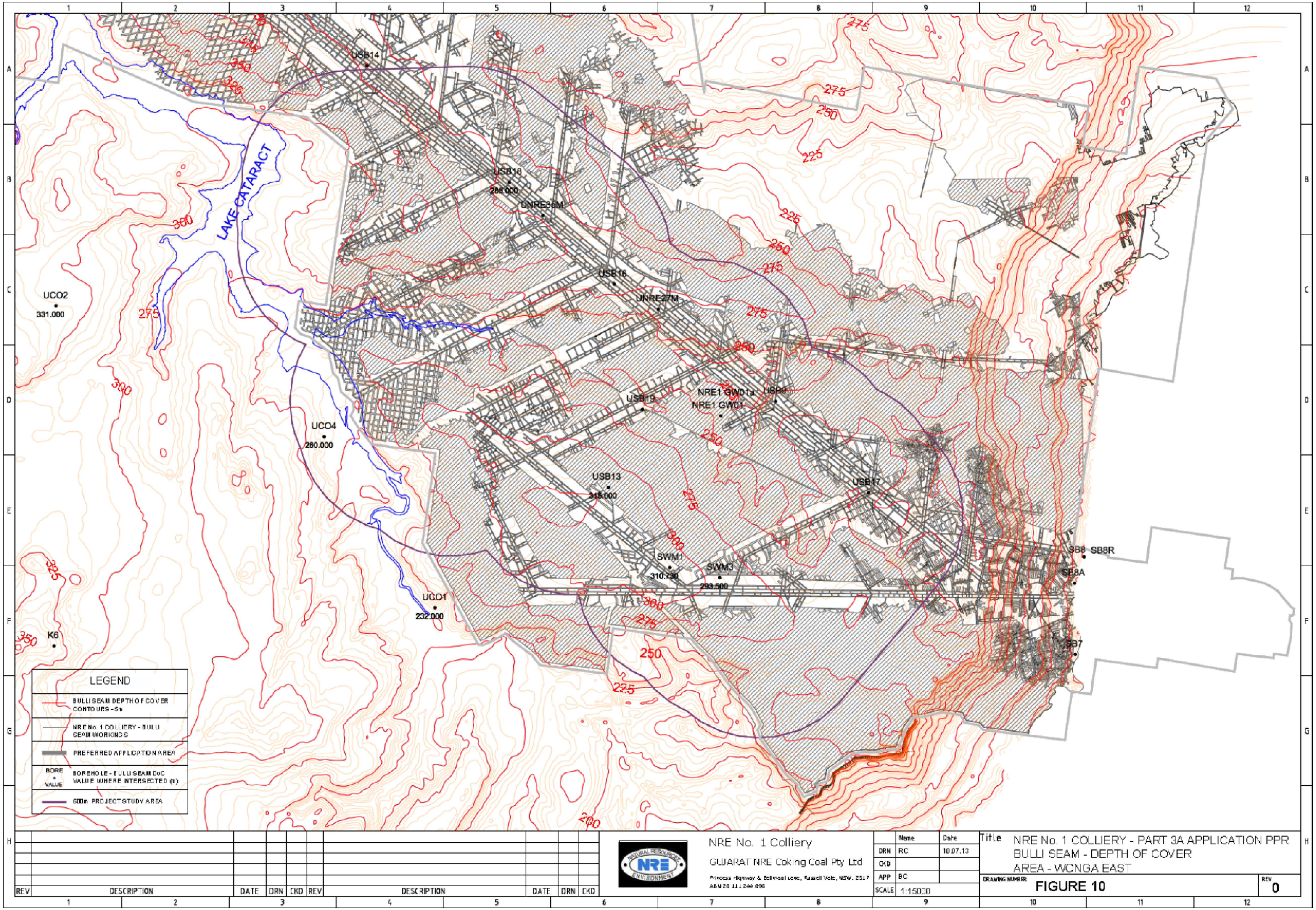


Figure 34 - Wonga East Topographic, Surface Features and Geological Details

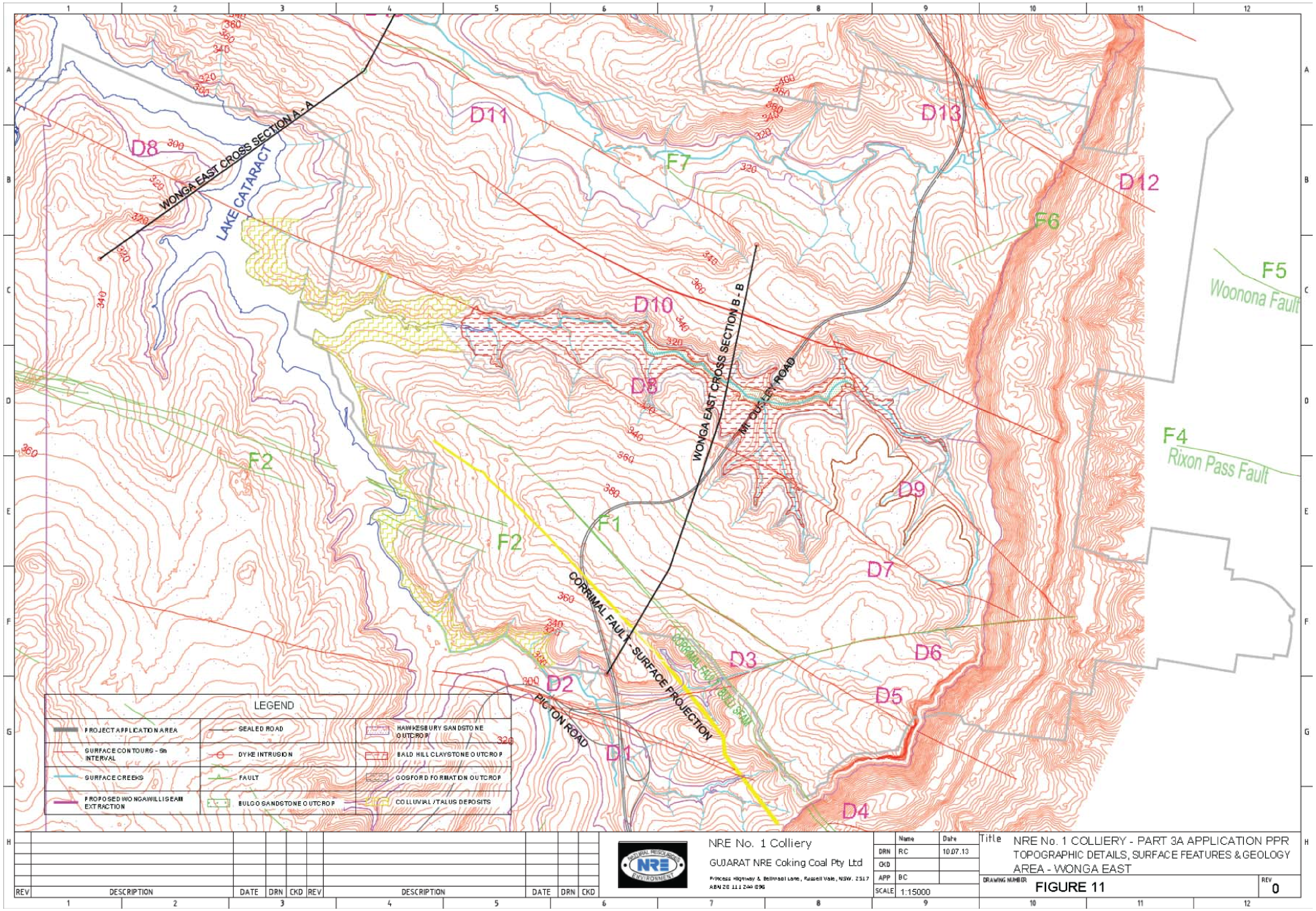
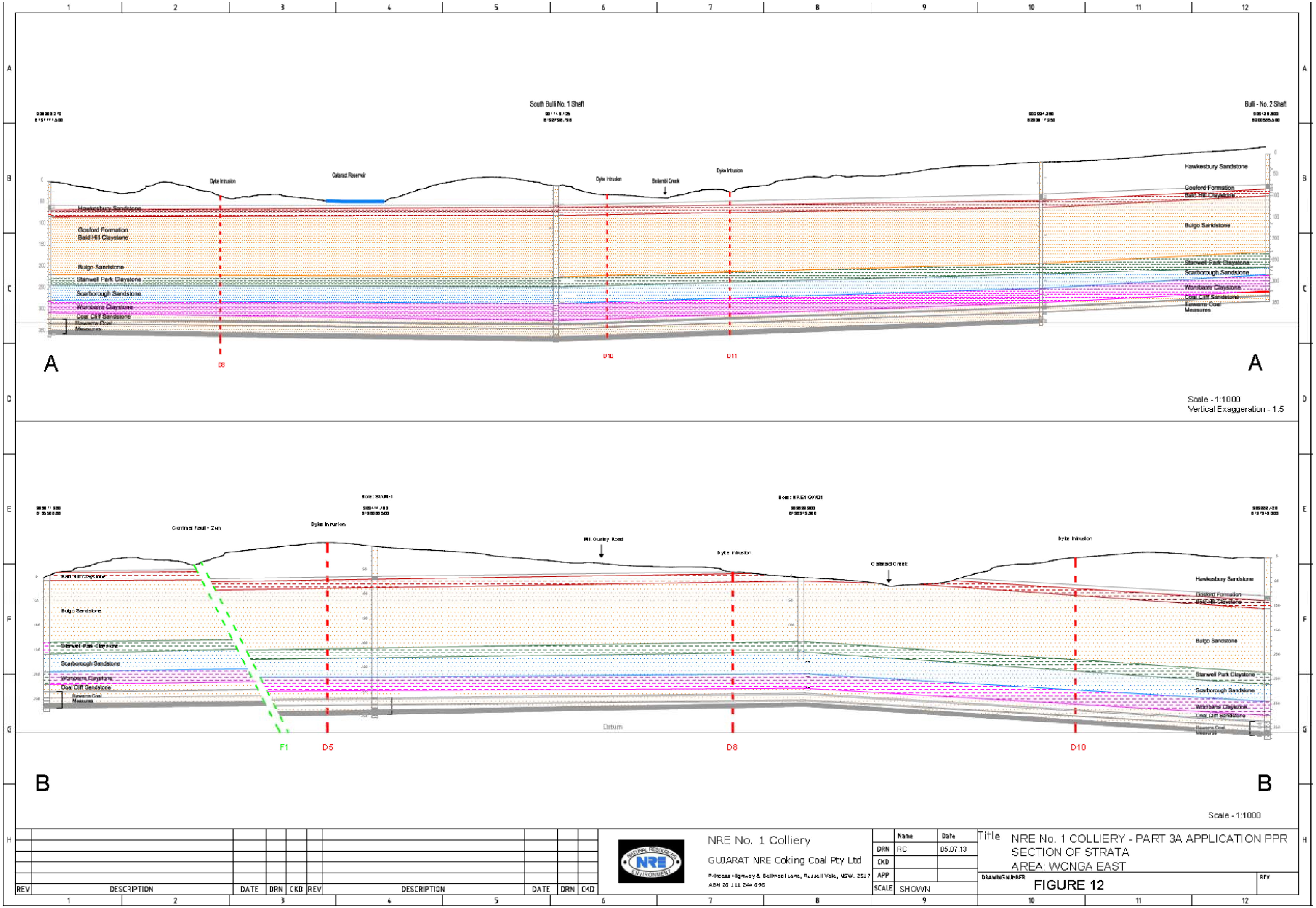


Figure 35 - Wonga East Strata Cross Sections



2.2.4.5 Coal Seam Structures

Bulli Seam

The extensive workings of the Bulli Seam and information from surrounding collieries (Bulli, Cordeaux and Corrimal) have been used to develop an understanding of the structural nature of the Bulli Seam in the NRE No.1 Wonga East Study Area. The Bulli Seam across this area dips to the west-nor-west from 1 in 25 to 1 in 30 and reflects the eastern section of a broad synclinal structure (South Bulli Syncline) and minor anticline structure toward the north of the Study Area. There are 7 known faults, 15 known dykes and various silling locations in the Wonga East area of NRE No.1 Colliery. The specific details of these structures are contained in **Table 38**, pg 123, and shown in **Figure 36**, pg 124**.**

Within the South Bulli Colliery mine workings of NRE No.1 Colliery Wonga East Preferred Project Study Area and surrounding collieries, igneous intrusions of dykes and sills have been intersected within the Bulli Seam. Dykes are the most common form of igneous intrusion and are generally oriented in a NE –SW direction within the project application area trending about 120 degrees.

Sills have a far greater impact on mine development than dykes. Their lateral intrusive nature often means that large areas of coal seams (often hectares) can be rendered uneconomic due to ingestion of the coal, cindering, alteration and loss of coking properties. Sills are erratic and the larger sills are often transgressive in nature and historically their definition other than in a general way has been difficult to define prior to mining. Within the Wonga East Study Area there is a significant sill event, the Bulli Sill Complex which has an area of over 13km^2. The sill complex is transgressive in nature, known to intrude the Bulli, Balgownie and Wongawilli seams in NRE No.1 Colliery and affecting other collieries to the north. Mine workings within the Bulli Seam at various collieries have enabled an accurate boundary definition of the Bulli Sill Complex to be established.

Balgownie Seam

Although faulting intersected by the Balgownie workings displays some correlation with known faulting in the overlying Bulli Seam the projection of faulting is not clear from the Bulli to Balgownie seams. Based on the above analysis and previous experience of multiple seam mining in Cordeaux and Kemira Collieries, minor faulting in one seam will not necessarily project through to other seams. Based on this generalization, faulting of less than approximately 0.4m occurring in one seam is not projected through to other seams. Faulting of greater than 0.4m is projected to other seams, the projection requiring an understanding of the hade of the faulting to improve accuracy. Where the hade is unknown projection at an angle of 80 degrees, dependent upon its sense of throw, is used as a “best” estimate of location. **Figure 37**, pg 125, details the known and predicted structural geology of the Balgownie Seam based on the above synopsis.

Balgownie Seam workings intersected 5 dykes. These dykes project through to the overlying Bulli Seam workings in almost the exact location, indicating the dykes have been injected in a near vertical plane through the Coal Measure strata.

Silling within the Balgownie Seam was intersected by workings driven during the late 1990’s. The silling initially appeared in the floor of the seam and has affected the quality of the coal. The extent of the sill where intersected by workings can be seen in **Figure 37**, pg 125. The northern extent of the silling is unknown due to a lack of data. The complexity of the silling can be seen from the location of the sill in the Balgownie Seam when compared to the Bulli Seam. In the Balgownie Seam the edge of the silling as defined by the workings varies between 450m to 750m further south than the edge of the silling in the Bulli Seam. Based on the above discussion and comparison of structures intersected in both the Bulli and Balgownie seams it is justifiable to assume dykes intersected in Bulli Seam workings will be in the Balgownie Seam at similar locations. Dyke thickness generally appears to be thinner in the Balgownie Seam than the Bulli Seam and may be a result of the thinner Balgownie Seam being more confined thus restricting expansion of the igneous material during injection when compared to the thicker Bulli Seam.

<u>Wongawilli Seam</u>

Within the mine workings of the Wongawilli Seam the Corrimal Fault (Fault F1 in the Bulli Seam) has been intersected. No other faulting of any significance has been intersected. The Corrimal Fault was intersected in Maingate 5 development and had displacement of 1.84m to 1.50m across the two headings, decreasing in displacement along its projected strike to the northwest. Characteristics of the fault are similar to those known from the Bulli and Balgownie seams, being a normal fault down thrown to the north. Where intersected, the fault had a measured dip of 35 degrees. The fault plane is offset approximately 24m to the north from its position in the Bulli Seam. Based on the decreasing displacement the fault is predicted to die out within a distance of less than 500m as shown in **Figure 38**, pg 126.

Only one dyke known from the Bulli Seam workings has been intersected by current Wongawilli Seam mine development. The Dyke is D8 and has been intersected in three sets of longwall gate road driveage. The dyke has a maximum measured thickness of 4.1m and is hard and dry. It has been mined through in the current LW5 and was highly fractured and blocky in nature. No evidence of water ingress about the dyke was evident. Silling within the basal 2.0m of the Wongawilli Seam on the northern side of the dyke has also been intersected. Of the other potential dykes projected from the Bulli Seam, Dyke D6 was not recognized in early development and this is most likely due to silling occurring in the Wongawilli Seam at the expected location of the dyke. Dyke D10 has not been intersected by mining but inseam drilling has detected the dyke approximately 75m ahead of current mine face location in C Heading, Wonga Mains. No details are available on its thickness but drilling indicated the dyke is soft.

Silling within the Wongawilli Seam was intersected early on in Mains driveage. The silling occurs in the roof on the northern most heading (C heading) and cuts across the seam to be in the floor in the southern most heading (A heading). The silling was intersected either in the mining section of the seam or determined to be above the mined roof by drilling and the sill extended over the first 745m of driveage. The sill was then not detected before reappearing again above the mining section in the roof at the 1600m mark and extended primarily above the mining horizon to the 2525m mark before no longer being detected. A significant aspect of silling within the Wongawilli Seam, rather than in the Bulli and Balgownie seams, is that due to the much thicker seam section the silling can, and does, occur in various sections within the seam. Thus the boundary of silling within the Wongawilli Seam as shown in **Figure 38**, pg 126, represents a best estimate of silling within all sections of the seam. It is therefore not inconceivable that successful mining can take place within the boundary of silling where the sill is some distance above the mining section and does not impact coal quality or mining conditions. The transgressive nature of the Bulli Sill Complex is again evident as the southern extent of the sill in the Wongawilli Seam is from between 800m to 1300m further south than the edge of the Sill Complex in the Bulli Seam and between 500m to 720m south of the sill edge in the Balgownie Seam.

.

Table 38 - Details of Geological Structures in the Wonga East Area

Structure	Structure Observed (✓✗)				Structure Details					
	Bulli Seam	Balgownie Seam	Wongawilli Seam	Surface	Length	Width	Displace-ment	Strike	Known Water Ingress	Description
Fault F1	✓	✓	✓	✓	3000m	20m	28.7m	320°	No	Known as the Corrimal Fault.
Fault F2	✓	✗	✗	✗	400m	170m	0.9m	110°	No	This fault zone is prominent in Corrimal Colliery and extends into NRE No.1 Colliery
Fault F3	✓	✓	✗	✗	610m	-	0.31m	300°	No	Associated with Dyke D5. Probably formed as a result of the forces associated with the injection of Dyke D5.
Fault F4	✗	✗	✗	✗	-	-	-	285°	NA	Known as the Rixons Pass Fault. Intersected clay quarry east of the escarpment. Doesn't intersect workings. Not in Project Application Area
Fault F5	✗	✗	✗	✗	-	-	-	290°-	NA	Known as the Woonona Fault. Doesn't intersect workings. Not in Project Application Area
Fault F6	✓	✗	✗	✗	500m	-	3.3m	60°	No	May be associated with the Bulli Sill Complex
Fault F7	✓	✗	✗	✗	830m	-	-	290°	No	Known from South Bulli Colliery workings but didn't interfere with mining
Dyke D1	✓	✗	✗	✗	1,500m	3.2m	NA	110°	No	Intersected in Corrimal Colliery. Not in Project Application Area
Dyke D2	✓	✗	✗	✗	1,500m	3.2m	NA	110°	No	Intersected in Corrimal Colliery. Not in Project Application Area
Dyke D3	✓	✗	✗	✓	650m	4.5m	NA	150°	No	Likely a continuation of Dyke D6 offset across the Corrimal Fault. Not in Project Application Area
Dyke D4	✓	✗	✗	✗	650m	3.3m	NA	110	No	Likely a continuation of Dykes D1 or D2 offset across the Corrimal Fault. Not in Project Application Area.
Dyke D5	✓	✓	✗	✓	2,300m	1.6m	NA	300	No	Extends from the escarpment and dies out near the Corrimal Fault. Didn't interfere with mining an assumed to be a soft clay dyke.
Dyke D6	✓	✓	✗	✓	1,890m	4.4m	NA	80°	No	Mine workings avoided the dyke so possibly made of hard material.
Dyke D7	✓	✓	✗	✗	1,500m	1.6m	NA	300°	No	Didn't interfere with mining
Dyke D8	✓	✓	✓	✓	7,000m	3.1m	NA	300°	No	Dyke is hard, possibly syenitic in nature
Dyke D9	✓	✓	✗	✗	1,900m	0.9m	NA	325°	No	Consists of soft clay material
Dyke D10	✓	✓	✓	✓	3,700m	3.1m	NA	290°-	No	Consists of soft material and dies out in the Wonga East area
Dyke D11	✓	✗	✗	✓	2,750m	2.7m	NA	300°	No	Dyke is soft and becomes thin and intermittent on its projection to the WNW.
Dyke D12	✓	✗	✗	✗	1,650m	-	NA	-	No	Dyke is soft and didn't affect mining. May be related to Corrimal Fault
Dyke D13	✓	✗	✗	✗	-	-	NA	180°	No	Swarm of thin intermittent dykes that didn't affect mining
Dyke D14	✓	✗	✗	✗	1,400m	-	NA	270°	No	On the northern Colliery boundary. Soft and thin and dies out to the west.
Dyke D15	✓	✗	✗	✗	1,400m	1.2m	NA	300°	No	Dyke appears soft and didn't affect mining

Figure 36 – Wonga East Bulli Seam Geological Plan

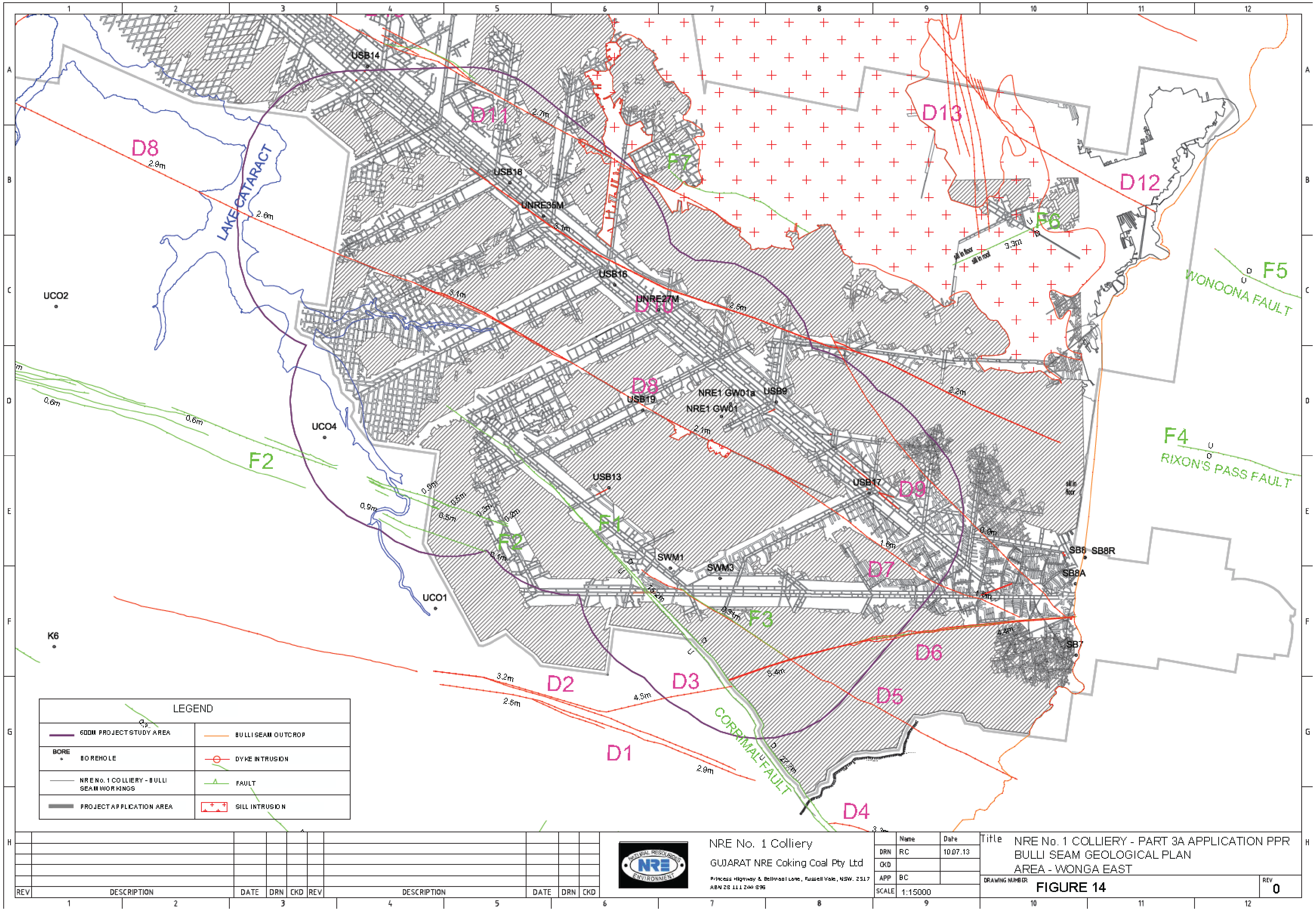


Figure 37 – Wonga East Balgownie Seam Geological Plan

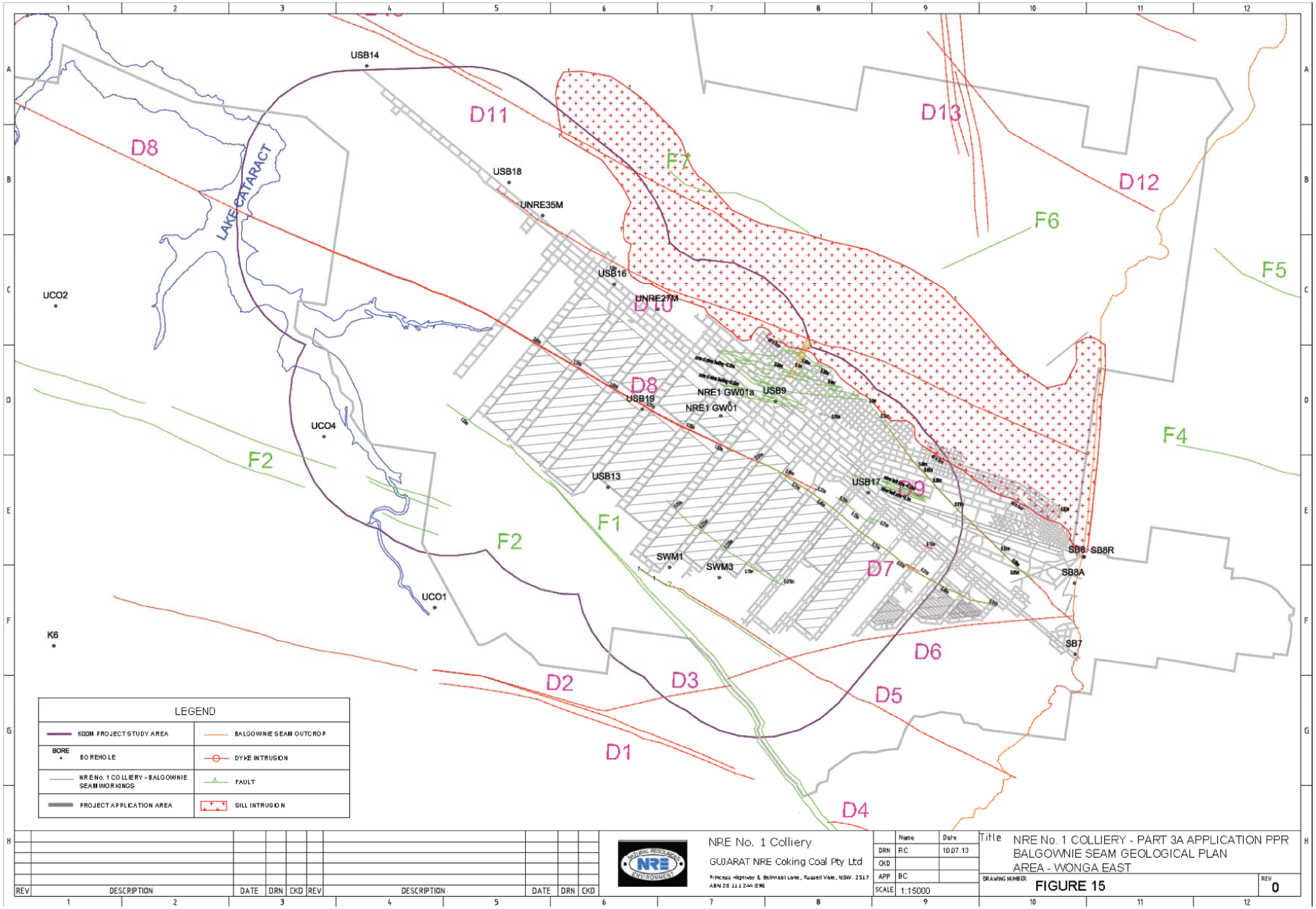
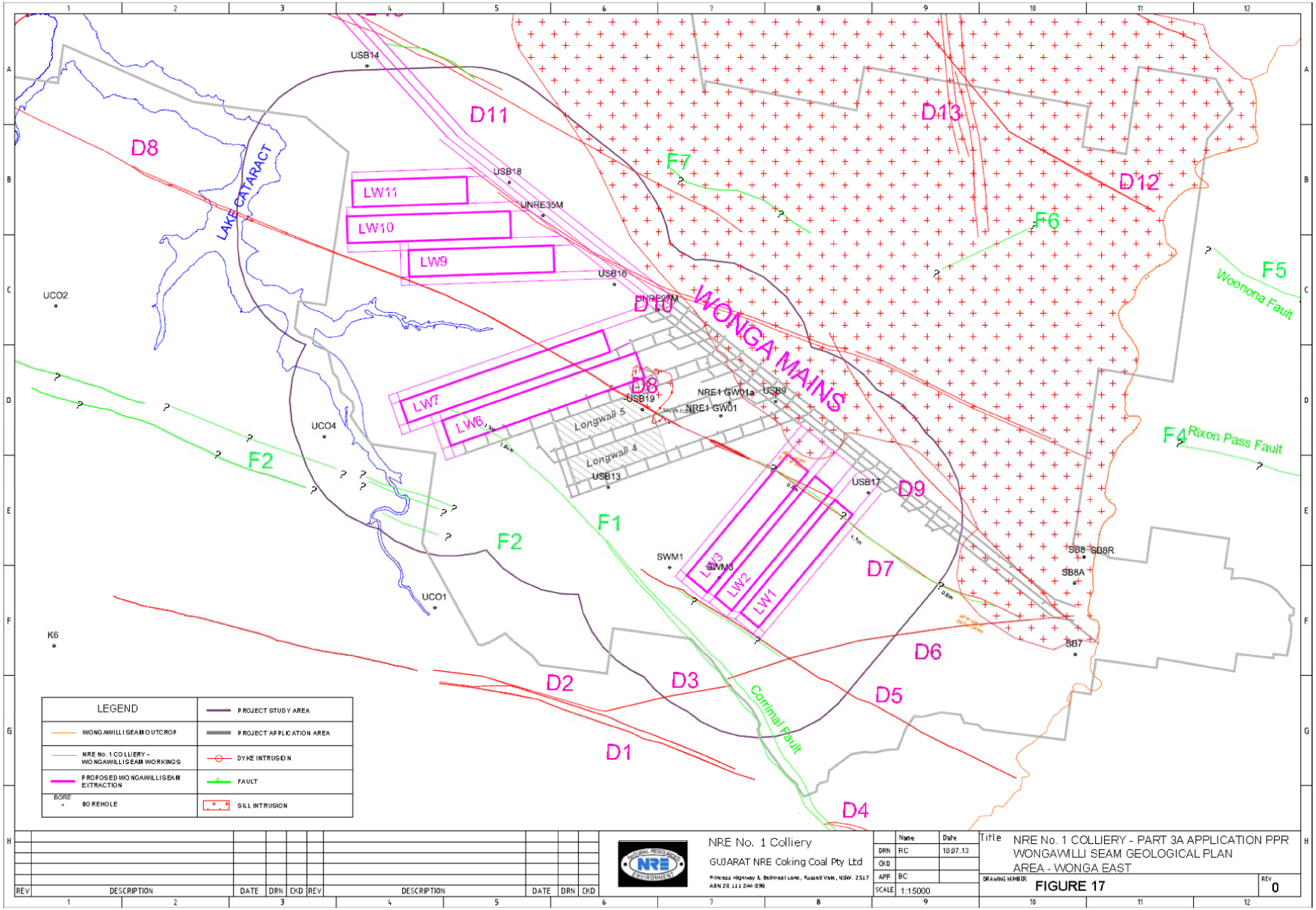


Figure 38 – Wonga East Wongawilli Seam Geological Plan



2.2.4.5 Conclusions

NRE has completed a detailed review of the geological structures in the Wonga East Study Area through comparison and analysis of coincident structures on mine plans between the Bulli, Balgownie and Wongawilli seams. The surface geology has been reviewed using ground truthing, Lidar topographic data and aerial photography.

There is no obvious surface expression of the Corrimal Fault (F1) and it is highly likely that the fault dies out in the Bulli Seam making surface connection with Cataract Reservoir impossible. The fault has been intersected by recent workings in Wonga East and no water make was noted nor is there any evidence of water make in the Bulli or Balgownie seams. No evidence of fault reactivation due to subsidence has been observed during the extraction of LW4 or LW5 in Wonga East. The fault swarm (F2) does not correspond with any surface feature and thus can be considered to not project to the surface. The Rixons Pass Fault (F4) doesn't extend west of the escarpment.

Dyke D3 correlates with a small tributary in the very upper drainage system for Cataract Creek and the upper most tributary of the Cataract River follows the strike of Dyke D6. Both streams are close to the escarpment and the dykes don't outcrop at the surface. Dyke D8 is exposed at the surface in an old bypassed section of Mt. Ousley Road and consists of soft puggy clay. Where dykes weather to soft, puggy clays they tend to act as seals to the movement of groundwater along their projections. The surface exposure disappears when following the strike to the northwest. There is no correlation with any surface feature in the Study Area but correlation does occur with a notch on the western shore Cataract Reservoir outside the Study Area in the old Corrimal Colliery. Corrimal Colliery records indicate that Dyke D8 was mined with no water ingress issues and there is no evidence of water make at all in the sections it has been mined through with both LW4 and LW5 in the Wongawilli Seam in Wonga East.

The chance either surface or Reservoir hydraulic connectivity as a result of the existence of fault or dyke structures in the Wonga East Study Area, or their reactivation as a result of subsidence is extremely unlikely.

2.2.5 Groundwater

2.2.5.1 Background

After extensive discussions with the DPI and Coffey Geotechnics Pty Ltd (Coffey) who reviewed the current groundwater study and model on behalf of DPI, it has been agreed that Golder Associates (Golders) will construct, run and interpret a new MODFLOW Surfact based groundwater model for the Preferred Project covering the proposed extraction of LW's 1 to 3 and LW's 6 to 11 in the Wongawilli Seam at the Wonga East project area. LW4 has been extracted and LW5 is being extracted from the Wongawilli Seam at the time of writing.

The new model will benefit from a significantly improved understanding of subsidence behaviour in Wonga East and better baseline data. This modelling process will take up to 3 months.

2.2.5.2 Modelling

The MODFLOW Surfact model has been deemed appropriate by Coffey to assess the impacts that may occur to the groundwater systems as a result of mine subsidence. However, it has been pointed out to DPI (and also highlighted in the Coffey review of the current body of work) that the proposed model will not be able to assess the hydraulic conductivity and associated water flow and water level changes within Upland Swamps over the proposed and existing workings.

All suggestions in the Coffey review will be incorporated into the new model, such as modified conductivity values, boundary conditions, height of fracturing etc. The model will be run and calibrated in transient mode using multiple parameters, and could be suitable, if required, for assessing the potential leakage from Cataract Reservoir using probabilistic assessment with a transiently calibrated model in the final stage of the modelling process.

In response to SCA comments, the proposed model is unable to assess creeks as ephemeral, intermittent or perennial on a catchment and sub catchment basis. The assessment will use observations from field monitoring that began in November 2010 in Cataract Creek and April 2012 in Cataract River.

Pertinent aspects of the Golders response to the Coffey review of the current body of work, and incorporation of their proposed MODFLOW Surfact modelling approach, is summarised below.

- The proposed MODFLOW Surfact groundwater model will be used to accommodate both saturated and unsaturated flow, although modelling unsaturated flow requires additional (and uncertain) parameters (up to 8 parameters) to represent the relative conductivity and capillary pressure relationships to be defined for each layer in the model. Severe impacts such as the voids of extracted workings can be applied as hydraulic head, pressure, seepage, saturation or moisture content boundary conditions.
- The proposed groundwater model will take into account the current and potential development of the depressurised (atmospheric pressure) zone that has developed / may develop above the workings based on the current accepted approach of using the longwall width / height ratio, with incorporation of the updated approach, which also incorporates the height of the rockhead above the workings (Tammetta, P., 2012).
- The model will not be able to assess the hydraulic impacts to the base of individual swamps.
- Conductivity values in the zones immediately above the goaf may potentially be modelled using values two to three orders of magnitude higher than the surrounding material, with conditions applied to allow water to be removed instantaneously from the model domain.

- Calibration of the model and predictive simulations will be conducted in transient mode, based on the response to mining and climatic conditions within the NRE No.1 lease area from data obtained in open standpipe and vibrating wire piezometer arrays that have been regularly monitored since November 2009 and mine inflows that have been monitored since December 2005.
- Determining the potential leakage from Cataract Reservoir using a probabilistic assessment of a transiently calibrated model is a new approach in groundwater models. Monte-Carlo simulations can be achieved using software such as PEST but this approach is very numerically intensive. Simulation runs are in the order of weeks for each stage resulting in months for multi-stage assessments. Due to the computational and time requirements, this assessment methodology is not proposed for the initial modelling study for the Preferred Project, but could be done at a later stage, if considered necessary.

The proposed MODFLOW Surfact model and associated reporting will also include where possible:

- improved geological structure data to account for potential linkage between the mine and Reservoir as a result of these structures;
- definition of boundary conditions along the Illawarra Escarpment as there may be a potential for pressure differentials between the Reservoir and the Illawarra Escarpment to drive water through the Bulgo Sandstone (BSS) and out the escarpment face;
- utilisation of horizontal packer test data for the area;
- potential changes to vertical permeability values as a result of past mining;
- all strata, hydrogeological data and known geological features that cut across the strata and the degree of confidence that the element exists;
- comparison of the NRE No. 1 results to other mines in the Southern Coalfields;
- sufficient meteorological data as well as the surface water and groundwater monitoring data collected since November 2009 will be used to set up and run the model;
- the cumulative impact from previous and adjacent man made hydrogeological elements such as mining and drill holes and incorporate an updated assessment of flooding within the current and future NRE No. 1 workings;
- drainage points outside the Cataract catchment;
- modelling of pre-mining conditions;
- comment on unknowns and their implications;
- comment of further work required to refine the model;
- comprehensive identification and assessment of the impacts of mining;
- evaluation of the risk of loss of storage from the Reservoir by comparison to the DSC risk acceptance criterion;
- assessment of the effectiveness of controls required to manage risks;
- a risk assessment undertaken to AS/NZ4360:2004 standards; and
- peer review of the model by Paul Tammetta from Coffey

The model and associated mining impacts and effects assessment on surface water and groundwater resources in the Preferred Project will be conducted with reference to the:

- 2012 Aquifer Interference Policy, issued by the NSW Office of Water (NOW); and
- 2012 Australian Groundwater Modelling Guidelines, issued by the National Water Commission

The 2012 Australian Groundwater Modelling Guidelines has classified groundwater models into three categories, defined by model confidence level. Applying these guidelines, Coffey indicates that Gujarat will require a Class 3 (highest confidence level) groundwater model. Class 3 models are required to satisfy the following criteria, and must be able to:

- predict groundwater responses to arbitrary changes in applied stress of hydrological conditions anywhere within the model domain;
- evaluate and manage potentially high-risk impacts;
- be used to design complex mine-dewatering schemes; and
- simulate the interaction between groundwater and surface water bodies to a level of reliability required for dynamic linkage to surface water models.

This places an increased emphasis on the quantity, quality and diversity of the dataset required for model development, requiring that:

- spatial and temporal distribution of groundwater head observations adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported;
- spatial distribution of bore logs and associated stratigraphic interpretations clearly define aquifer geometry;
- reliable metered groundwater extraction and injection data is available;
- rainfall and evaporation data is available;
- there is aquifer-testing data define key parameters;
- streamflow and stage measurements are available with reliable baseflow estimates at a number of points;
- reliable land-use and soil-mapping data is available;
- reliable irrigation application data (where relevant) is available; and
- there is good quality and adequate spatial coverage of a digital elevation model to define ground surfaces elevation.

It also places an increased emphasis on the quantity, quality and diversity of the dataset required for model calibration, requiring that:

- long-term trends are adequately replicated where these are important;
- seasonal fluctuations are adequately replicated where these are important;
- transient calibration is current, i.e. uses recent data;
- the model is calibrated to heads and fluxes;
- observations of the key modelling outcomes dataset is used in calibration;
- the model's predictive time frame is less than 3 times the duration of transient calibration;
- stresses are not more than 2 times greater than those included in calibration;
- temporal discretisation in the predictive model is the same as that used in calibration; and
- the mass balance closure error is less than 0.5% of total.

Current practice now (as opposed to the situation in 2010) requires a more thorough level of study. The 2012 Australian Groundwater Modelling Guidelines recommend that the quantities for which the model is being developed to predict (for example groundwater inflows to mine workings) be included in the calibration process.

Unlike the situation in 2010, more data has become available so it will be possible to conduct a transient calibration, with reference to water volumes extracted from and contained within the NRE1 mine workings and the best available data from mines outside the NRE No.1 lease area, as well as overburden groundwater level / pressure records and stream flow records within the

NRE No. 1 lease area. GW1 adjacent to LW5 is currently showing a good depressurisation response to the extraction of LW5. This information will be able to provide excellent calibration data for the remodelling of groundwater impacts for the PPR.

As the remodelling is currently underway there are no outcomes to report on. Given that the overall Preferred Project longwall dimensions are approximately 25% smaller in Wonga East than the original proposal and that the extension of the Wonga Mains and extraction of Wonga West no longer form part of this application. A very preliminary revision of the original mine water inflows has been undertaken using the same values for the Wonga East area.

2.2.5.3 Impacts

In order to provide some context while awaiting the new groundwater model results, it's assumed that the original groundwater modelling for the EA provides a reasonable groundwater mine inflow estimate for Wonga East. The original predictions for mine inflow from *Table 21.1, pg 342, of the EA* which are replicated in **Table 39**, pg 131, can be amended to remove post mining affects of extraction in Areas 3 and 4 in Wonga West.

Table 39 - Original 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

It can also be used to provide a comparison with the current Preferred Project layout as shown in **Table 40**, pg 131**.**

Table 40 - Preferred Project Predicted Mine Inflows at End of Mining Area 2

Stage	Current Inflow (ML/day)	Original Predicted Wongawilli Workings Inflow (ML/day) (1)	Modified Preferred Project Wongawilli Workings Inflow (ML/day)(2)	Modified Preferred Project Wongawilli Workings Inflow (ML/year)
Wonga East	0.2	1.4	1.4	511
Wonga West	0.9	1.7	0.9(3)	329
TOTAL	1.1	3.1	2	840

(1) Based on Wonga East longwalls and dimensions for LW 1-11 as per the original EA
(2) Uses the estimated EA mine groundwater inflows for Wonga East
(3) Assumes inflows from the existing Wonga West area remain constant

2.2.5.4 Management

Monitoring and management regimes are not currently anticipated to vary significantly from the regimes proposed in *Section 21.5, pgs 346-351, of the EA* or included in the site's SFWMP*.* However, any recommended modifications to the monitoring and management regime as a result of the outcomes of the revised model, as well as DPI and PAC assessments, will be considered and implemented if reasonable and achievable.

2.2.5.5 Conclusion

As a requirement of DPI, NRE is currently undertaking a remodelling of the groundwater effects and impacts from the Preferred Project on the Wonga East area.

Given the significantly reduced extent of the Preferred Project with the removal of the Wonga West extraction area, the impacts from the Preferred Project will be less than EA. However, in order to maintain a conservative approach in this PPR, Wonga East mine groundwater inflows from the Preferred Project are assumed to be the same as the original EA for comparative purposes only. The actual estimated mine groundwater inflows will be updated once remodelling of the groundwater impacts from the extraction of the Preferred Project Wonga East longwalls are complete.

Monitoring and management are not intended to vary significantly but will be reviewed on the basis of the revised groundwater model and assessment outcomes during the approvals process.

2.2.6 Infrastructure

2.2.6.1 Background

A number of submissions were received during the public exhibition period regarding what were considered significant issues in the EA. These concerns broadly covered impacts to:

1. Mt Ousley Rd;
2. Picton Rd bridge;
3. 4 high voltage electricity transmission towers; and
4. Cataract Reservoir;

Significant additional work has been undertaken to address the issues raised in the EA, primarily including extensive investigation of historical mining in the Bulli and Balgownie seams, improved understanding of the local geotechnical environmental and the use of an alternative mine subsidence modelling approach to use as the basis of new impact assessments. This Section will provide an overview of the likely subsidence effects on infrastructure in the Wonga East area with further detail available in **Attachment B**, pg 426**.**

The surface infrastructure located within the Assessment Area includes the Mount Ousley Road, four power transmission lines that run between Mount Ousley and the Illawarra Escarpment with two of these lines having pylons directly over the LW2 and the chain pillar between LW1 and LW2, and the storage of Lake Cataract. Other infrastructure within the extended assessment area includes the Picton Road Interchange and communications tower infrastructure near the top of Brokers Nose.

The Mount Ousley Road (recently renamed the M1 Princes Motorway) is a major four lane highway. This road is administered by Roads and Maritime Services (RMS). The interchange with the Picton Road is located to the south outside the Assessment Area but within the 1.5km far field assessment area. This interchange includes a concrete bridge and several drainage culverts.

The Mount Ousley Road was constructed as a defence route during 1942 with duplication of the highway commencing in 1965 reaching Picton Road from the south in 1979. A major deviation at Cataract Creek was opened in 1980. The northbound carriageway on Mount Ousley Road at Cataract Creek was last resurfaced in 2009 with the surface expected to last 10-12 years. The southbound carriageway was last resurfaced in 2003 and resurfacing of this section is expected within 5-6 years.

The four power lines include a 330kV transmission line owned and maintained by Transgrid, a 132kV transmission line located alongside that is owned and maintained by Endeavour Energy and two 33kV transmission lines and associated infrastructure owned and maintained by Endeavour Energy. There are also two more 33kV lines and sub-station infrastructure located outside the Assessment Area but within or just outside the 1.5km far field assessment area. One of these line services colliery infrastructure.

Infrastructure in the PPR Assessment Area are shown on **Figure 5**, pg 17.

2.2.6.2 Impact Assessment

Mt Ousley Rd

Mount Ousley Road is protected from direct mine subsidence by a horizontal distance from the nearest goaf edge equal to half overburden depth. Low levels of vertical subsidence of less than about 100mm in total are expected in the vicinity of Mount Ousley Road with approximately

30mm of this maximum having already occurred from mining LW4. These low level vertical movements are expected to be imperceptible for all practical purposes.

The ACARP method for predicting valley closure indicates horizontal movement in a downslope direction caused by mining below the slope on the southern side of Cataract Creek is likely to generate closure at the creek crossing as summarised in **Table 41**, pg 134.

Table 41 - Horizontal Closure across Cataract Creek at Mount Ousley Road

LW	Incremental Closure Expected (mm)	Cumulative Closure Expected (mm)
4	30	30
5	50	80
2	5	85
3	40	125

The 125mm of compression in the bottom of the valley expected at the completion of proposed mining is expected to be matched by up to 125mm of tensile cracking toward the top of the slope. Cracking is likely to continue to develop at the same location once a crack has formed. Some of this tensile cracking observed during LW4 appears to be continuing during mining of LW5.

Picton Road Interchange

The Picton Road Interchange is located on the opposite side of Cataract River and the opposite side of the tributary that joins Cataract River at the interchange. LWs 1-5 mine predominantly below the slope that leads down to Cataract Creek rather than the south facing slope that leads to Cataract River and its tributaries. As these longwall panels start below the ridge and mine away to the north, horizontal movements in a downslope direction are considered unlikely to develop on the south facing slopes leading down to Cataract River. The bridge on the Picton Road Interchange is further protected by being on the far side of the west flowing tributary to Cataract River.

There is considered to be no potential for significant horizontal movements to impact the Picton Road Interchange.

Power Transmission Lines

There are four power transmission lines located in two corridors between Mount Ousley Road and the Illawarra Escarpment. **Figure 39**, pg 135, shows photographs of the four different types of support structure used on these lines. The 330kV and 132kV lines are supported on trussed steel pylons. One of the 33kV lines is supported on single pole structures and the other one is supported on double pole structures that appear to have been replaced in the last few years.

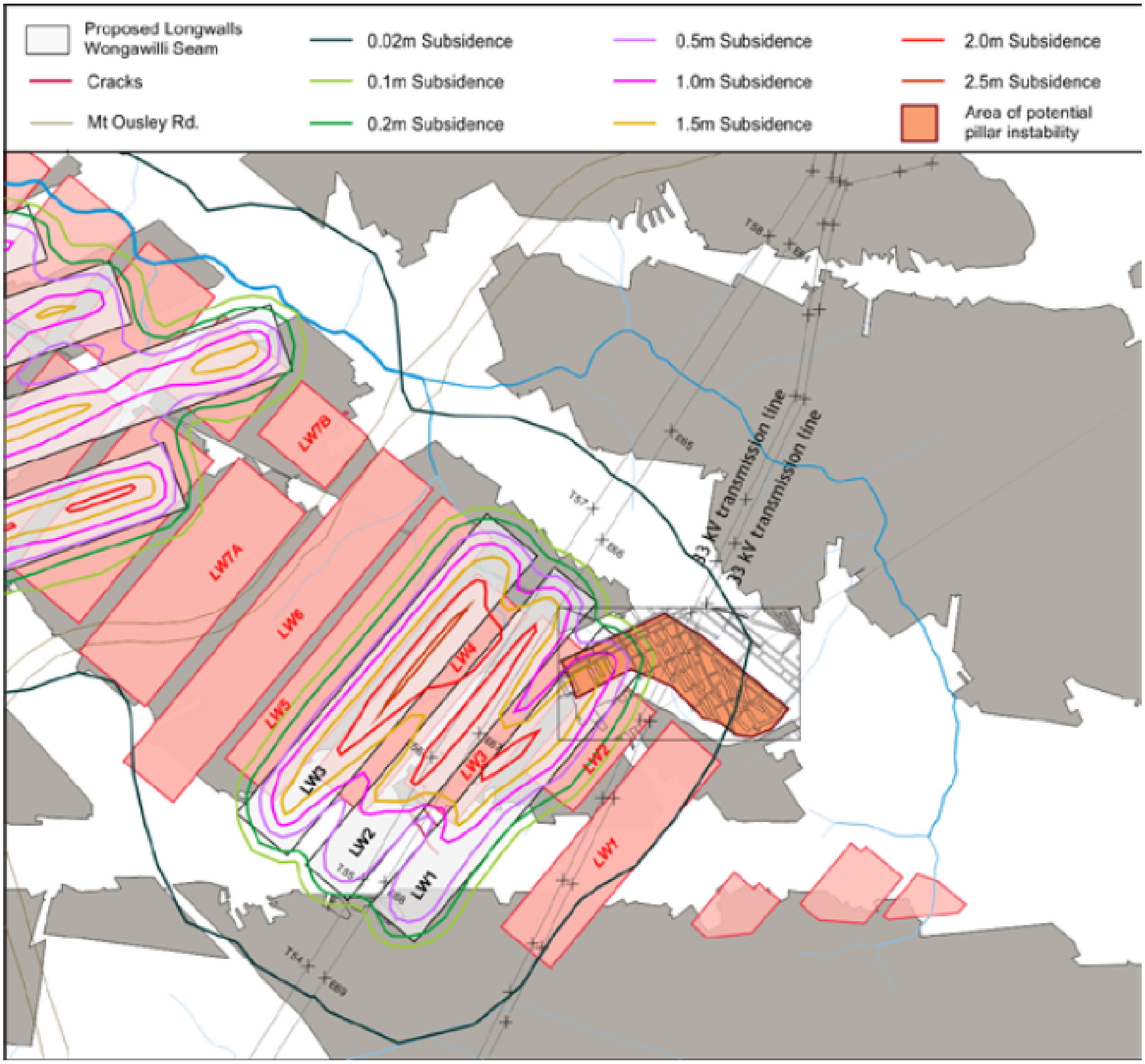
All four lines were mined under by LWs 1 and 3 in the Balgownie Seam and potentially by mining of main heading pillars in the Bulli Seam although this latter mining may have preceded construction of the lines.

The power transmission towers T56 (on the 330kV line) and E57 (on the 132kV line) are suspension towers located in an area where there was 1-1.2m of vertical subsidence measured during mining of the LW3 in the Balgownie Seam. The tower locations are noted on subsidence plans as T56 and T52 so it appears that they had been constructed prior to mining LW3 in 1975. Suspension towers are located on straight sections of line and the conductors are suspended from the tower structure on hanging insulators rather than fixed directly to the structure.

Figure 39 – Power Transmission Lines over LW1 and LW2

However, it is noted that T56 is located at a slight change of direction in the line. The side load associated with this slight change in direction is managed through rotation from vertical of the suspended insulators as can be seen in **Figure 40**, pg 136.

Figure 40 – Electrical Transmission Lines in Relation to Current and Historic Mining



In contrast, E57 is located on a straight section of line and the insulators hang vertically.

The towers T56 and E57 are also 100m and 200m respectively from the area of cracking at the topographic high point near the start of LW3. The tension cracking observed is consistent with expected ground movements. These towers do not appear to have been significantly impacted by previous mining possibly because they are located on Hawkesbury Sandstone. The structural integrity of pylons is sensitive to even small levels of differential displacement between the four legs. Fortuitously, it would appear that cracking did not occur through the sandstone strata between the tower legs and the tower foundations moved together as one unit allowing subsidence and tilting of the pylons without compromising the structural integrity of the towers themselves. Small tilting and horizontal movements are normally able to be accommodated by rotation of the suspended insulators that support the conductors. Realigning the insulators during subsequent maintenance allows any misalignment to be rectified.

The proposed mining is expected to cause levels of vertical subsidence, tilting, horizontal movement, and horizontal strains that would have potential to compromise the structural integrity of the towers if the movements occurred unfavourably between the tower legs. The predicted subsidence at the tower locations are detailed in **Table 42**, pg 137.

Table 42 - Subsidence Expected at Power Pylon Locations

Tower	Subs (m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)	Maximum Tilt (mm/m)	Differential movement over 10m (mm)	Horizontal Movement (m)
330kV T54	0.03	< 0.2	0	< 0.5	< 2	< 0.1 NE
330kV T55	0.5	4.6	9	15	50	0.3 NE
330kV T56	2.2	11.2	22	37	120	0.7 NE
330kV T57	0.05	< 0.2	0.0	< 0.5	< 2	<0.1 SW
132kV E66	0.07	< 0.2	0.0	< 0.5	< 2	<0.1 SW
132kV E67	1.8	11.8	0.0	39	120	0.3 NE
132kV E68	0.3	4.8	10	16	50	0.7 NE
132kV E69	0.03	< 0.2	0	< 0.5	< 2	<0.1 NE
33kV Lines	< 0.1	< 0.2	0	< 0.5	NA	<0.1 W

There is also an area where there is some potential for pillar collapse in the Bulli Seam. This area is shown in **Figure 40**, pg 136. Fortunately, the towers and poles are located outside the area likely to be affected by any pillar instability.

Permanent horizontal movement in the direction of mining is expected to occur at all the four towers located directly over the longwall panels. The horizontal movement is expected to range up to 700mm and is likely to be greatest on the two towers located directly over the goaf, T56 and E67.

The proposed mining is expected to cause ground movements that have potential to compromise the structural integrity of towers T55, T56, E67 and E68 if the movements occur differentially between the tower legs. Although there has been previous cracking nearby and such cracking is likely to continue to localise further ground movements, the risk of new cracking causing structural damage is considered too high without some form of mitigation.

The adjacent towers to the south T54 and E69 are considered to be sufficiently remote from mining for there to be no significant potential for ground movements. These towers are protected by an angle of draw of 30°. Both towers are located on ground that is sloping away from the direction of mining in an area where the slope the towers are on is not directly mined under.

The adjacent towers to the north T57 and E66 are protected by an angle of draw of 26° and 23° respectively, and they are therefore remote enough for systematic ground movements to be low. However, both towers are located on top of a ridgeline where tension cracks tend to be concentrated. While the direction of mining toward the ridge tends to lessen the potential for cracking on the ridge line, there is nevertheless considered to be a low level hazard associated with the potential for cracking between the tower legs with potential to compromise the structural integrity of the tower.

The 33kV lines are supported on single and double pole structures. The double pole structure appears to be relatively new. These structures are relatively tolerant to mine subsidence movements. Mining of LW1 in the Balgownie Seam caused subsidence of 0.8-1.2m below four of these pole locations and 0.4-0.6m on four others. It is considered unlikely that this mining caused any significant impact to these lines although they may need to have been straightened up at the completion of mining.

The 33kV single and double pole structures are more tolerant to subsidence movements and because these structures are located more than 60m outside of the footprint of the longwall panels, only low levels of subsidence and no significant impacts are expected.

Cataract Reservoir

No impacts are expected on Cataract Reservoir. The FSL, including the section that extends up Cataract Creek, is protected from the nearest longwall goaf by a horizontal distance greater than 0.7 times overburden depth (equivalent to an angle of draw of 35°). Vertical subsidence at the FSL is expected to be less than 20mm.

There is considered to be no potential for proposed mining to intersect the stored waters directly. There may be potential for flow along the dyke, but experience in the Southern Coalfield indicates that dykes are very rarely hydraulically conductive. A program of work to test the hydraulic conductivity of the dyke is recommended

As shown on **Figure 36**, pg 124, geological structures within the Assessment Area are relatively well defined because of the previous mining that has occurred in the overlying Bulli Seam over a large area and the overlying Balgownie Seam in a more limited area. The only geological structure that extends through to the proposed longwall panels in the Assessment Area and the reservoir is Dyke D8. The horizontal distance along the dyke from the end of LW10 to the FSL is approximately 560m at an overburden depth of 320m at the FSL.

The faults labelled F2 are apparent in the workings in Corrimal Colliery but become degraded in the Bulli Seam workings at South Bulli Colliery. These faults are not proposed to be directly intersected in the Wongawilli Seam but there is a flow pathway between the faults and the Wongawilli Seam mining horizon through the Bulli Seam mine workings that intersect both.

There is considered to be no potential for proposed mining to intersect the stored waters directly. There may be potential for flow along the dyke via the Bulli Seam, but experience in the Southern Coalfield indicates that dykes are very rarely hydraulically conductive and there does not appear to have been any significant inflow associated with mining the Bulli Seam on this dyke. Mining in the Wongawilli Seam 560m away from the reservoir is not expected to have any potential to increase hydraulic conductivity between the reservoir and the mine.

There are also a number of small pre-existing Bulli Seam goaf areas that are located within the 200m protection zone around the FSL. The largest width of any of these is 200m and it is located within 90m of the FSL at an overburden depth to the Bulli Seam of approximately 260m. It is considered unlikely that the proposed mining will interact with these pre-existing goaf areas and there does not appear to be any connection between the reservoir and the mining horizon. Nevertheless, the presence of these goafs reduces slightly the effective of the 0.7 times depth barrier between the FSL and the proposed mining, particularly of LW7 and LW9.

NRE has engaged a consultant to prepare a Mine Closure plan for the DSC to manage any uncontrolled inflow of water and prevent its egress from the mine workings. However, it should be recognised that there are limited options to control any significant inflow through sealing up the longwall panels or the mine portals. The Wongawilli Seam, the Balgownie Seam, and the Bulli Seam are all hydraulically connected through the intersecting goafs that are interconnected between all three seams and there is not considered to be any credible way to control inflow to the mine from Cataract Reservoir by preventing water egress from the mine. The Bulli Seam workings are in the shallow cover areas above the portals on the Illawarra Escarpment.

Telecommunications Infrastructure

There is a telecommunications tower located on Brokers Nose on the Illawarra Escarpment. Brokers Nose and the telecommunications infrastructure is protected by a horizontal distance of approximately 1km from the nearest point on Longwall 1. No ground movements are expected at this distance from the proposed mining because there is no potential for significant horizontal stress concentration along the escarpment and no potential for change in any of the other stress components.

2.2.6.3 Management

Mt Ousley Road

Management of the Mount Ousley Road and any subsidence impacts using a technical committee such as was used for LW4 and LW5 will continue for the ongoing management of subsidence impacts to the road, if considered necessary by RMS.

The half depth stand-off of mining from Mount Ousley Road is considered to significantly reduce the potential for significant impacts on the highway and this potential will reduce further as active mining moves away from the road. Some low level ground movements have been observed and surface cracking has also been observed on the road surface particularly around the crest of the ridge between Cataract Creek and Cataract River where stretching movements are expected. It is recommended that the observed surface cracks are filled from time to time to reduce ingress of surface water into the formation because unlike conventional road cracks that are likely to occur mainly in the surface layers, these subsidence cracks are likely to extend through the sub-grade. There is then potential for water ingress to cause damage to the road base and potential for particle migration into the cracks that eventually has potential to cause a pot hole.

Continued survey monitoring of the Mount Ousley Road at reduced frequency will form the basis to confirm the actual subsidence movements are consistent with those predicted.

A high level of monitoring of Mount Ousley Road has been appropriate during mining of LW4 and LW5 in close proximity to the highway. However, a reduction in the frequency of the survey monitoring is now considered appropriate given the low level of subsidence that has so far been observed. A management strategy based on regular visual inspections and mid panel and end of panel surveying unless otherwise triggered would appear to be sufficient to manage the levels of impacts expected once LW4 and LW5 have been completed. The frequency of monitoring, particularly of Mount Ousley Road may need to increase again during mining of LW2 and LW3.

The current program of monitoring and visual inspection for Mt Ousley Road is considered appropriate while mining is ongoing in LWs 2 to 5. A reduced survey frequency will be adopted during mining of the other longwall panels. Some localised resealing of the cracked sections of Mount Ousley Road is likely to be required at the completion of mining or whenever the tensile cracking becomes too wide to be considered serviceable. The cracking is expected to develop incrementally with mining and so a program of repairs can be scheduled based on forecast longwall retreat.

Picton Road Interchange

A high level of monitoring of Picton Road Interchange has been appropriate during mining of LW4 and LW5, however, a reduction in the frequency of the survey monitoring is now considered appropriate given the zero change observed during the extraction of the two longwalls. A management strategy based on regular visual inspections and mid panel and end of panel surveying unless otherwise triggered would appear to be sufficient to manage the levels of impacts expected once LW4 and LW5 have been completed. The frequency of monitoring may need to increase again during mining of LW2 and LW3.

Electrical Infrastructure

A technical committee comprising representatives from the colliery, the power utility companies, the Mine Subsidence Board, and government regulators is propsed to manage potential impacts on the power transmission towers. This forum provides all interested parties with understanding and control of the management processes.

Several of the power transmission towers are likely to require the construction of cruciform bases to allow them to remain structurally stable during mining. There is usually a significant lead time involved in getting cruciforms approved, financed, designed, and constructed.

Monitoring on the power transmission poles and towers will be designed in consultation with the power utility companies. It is envisaged that reflectors on the structures to capture tilt and high resolution surveying of the relative position of individual legs relative to each other and in three dimensions for the cruciforms would be appropriate.

Strain gauge monitoring of the steel structures and automatic regular logging of the changes transmitted back to a website portal is a practical solution for towers that are on the periphery of the mining area and do not have cruciforms.

Prior to the approach of LW1, a number of short survey lines will be located in the vicinity of the panel of small pillars at the northern end of the panel to confirm the nature and extent of any subsidence that occurs as a result of pillar destabilisation in this area.

All the monitoring points for the power transmission towers should be linked back into the distributed array of monitoring points and the control already established for Mount Ousley Road.

The proposed mining is expected to cause ground movements that have potential to compromise the structural integrity of towers T55, T56, E67 and E68 if the movements occur differentially between the tower legs. It is considered that all four towers require some mitigation works if they are to remain serviceable during the period of mining Longwalls 1, 2 and 3. The use of a cruciform foundation is considered likely to be effective to protect the structural integrity of the tower foundations. Some active realignment is likely to be required, particularly on Tower E67 where permanent tilts of up to 39mm/m are expected. Tilting of 39mm/m equates to a horizontal movement at 20m above the ground of about 800mm. This movement is likely to be able to be accommodated by rotation of the hanging insulators, but this needs to be checked in consultation with the tower owners. It may be necessary to suspend the conductor in roller sheaves during the active phase of mining below the structures.

A single point tie down may be required on the western leg of the cruciform for T56 to accommodate the lateral loads associated with the slight change in direction at this tower. However, the loads involved are expected to be able to be accommodated through appropriate design of the cruciform. Some monitoring of towers T54 and E69 is recommended, but there does not appear to be a compelling case to provide additional protection. The adjacent towers to the north T57 and E66 may require the cutting of a slot or confirmation that the tower will be protected by the local site conditions, but a site specific risk assessment is required to develop a mitigation strategy for this tower.

There is a significant change in direction on both the 330kV and 132kV transmission lines at a point approximately 1km north of the northern ends of LWs 1, 2 and 3. Some additional monitoring of these structures may be appropriate to monitor and manage any changes in conductor tension that results from the subsidence movements. Far-field movements are not expected to create any significant hazard in terms of the structural integrity of these towers because of the low levels of movement and even lower levels of differential movement expected at 1km from the goaf edge.

No protection measures are considered necessary for the 33kV single and double pole structures, although some before and after mining survey monitoring program is recommended to confirm the low levels of ground movement that are expected

Cataract Reservoir

The DSC is a statutory body with legal powers to manage mining to protect the stored waters in Cataract Reservoir. As is appropriate, the DSC takes a conservative view of the potential threats of mining to the stored waters because of the challenges of effectively remediating any leakage of water from the reservoir to the mine. The DSC also recognises that some minor loss is inevitable and is tolerable. The colliery has been working with the DSC for many years and it is considered that the management process that has been adopted in the past continues to be appropriate.

The management of potential impacts revolves around providing a sufficient standoff from the FSL, confirming that there are no geological structures with potential to provide elevated hydraulic conductivity between the reservoir and the mining horizon and that any such structures will not be adversely affected by mining, and monitoring the mine water balance to confirm the magnitude of any flows that occur. The 0.7 times depth (approximately 200m) stand-off from the FSL is considered to be the primary control for protecting the stored waters of Cataract Reservoir and this barrier is expected to provide a high level of protection to these stored water. The presence of existing pillar extraction areas within the barrier reduces the protection afforded by the barrier 80m from the FSL in some areas.

Geological structure in the area is well defined by the presence of previous mining. The D8 dyke is considered to be the only geological structure with potential for increased hydraulic conductivity but there is a separation between the reservoir and the mine along the dyke of approximately 500m horizontally and 360m vertically and exposures underground do not indicate a history of increased inflow despite previous mining adjacent to the dyke directly under Cataract Creek. A review of the integrity of the mine water balance will be undertaken to confirm that all sources of water are accounted for and that there is no unaccounted for loss of water into inaccessible storage deeper in the mine or into adjacent mines.

The piezometer monitoring network currently in place provides an indication of the changes in groundwater characteristics around the site. Further monitoring in areas where there are multiple goafs stacked above each other and in the area between the reservoir and the mine would increase confidence in and understanding of the impacts of mining on the groundwater system. The design of any required monitoring would need to be done in consultation with the DSC.

Although an uncontrolled inflow of water from the Reservoir is considered highly unlikely, there is no potential to control any sort of inflow by sealing up the longwall panels or the roadways. The Wongawilli Seam, the Balgownie Seam, and the Bulli Seam are all hydraulically connected through the intersecting goafs that are interconnected between all three seams. NRE has engaged a consultant to prepare a Mine Closure Plan in the event of an uncontrolled water flow from the Reservoir as part of its obligations under DSC approval requirements.

Telecommunications Infrastructure

No mining subsidence movements are expected at the site of the telecommunications infrastructure located on Brokers Nose. Nevertheless engagement with the owners of the infrastructure will occur. Monitoring of the infrastructure is not considered necessary. The only monitoring system that is likely to be effective would be in situ stress change monitoring. This equipment can be deployed in a borehole in the sandstone strata and remotely monitored to confirm that there have been no significant changes

A remotely logged borehole strain cell located in the rock strata between LW1 and the Illawarra Escarpment would provide confirmation of the level of any stress concentrations that may occur. These instruments are 10-100 times more sensitive than conventional survey monitoring.

2.2.6.4 Conclusion

Low levels of vertical subsidence of less than about 100mm in total are expected in the vicinity of Mount Ousley Road with approximately 30mm of this maximum having already occurred from mining LW4. These low level vertical movements are expected to be imperceptible although tensile cracking adjacent to the topographic high ground south of Cataract Creek and closure of up to a maximum of 125mm is expected at Cataract Creek. Ongoing management by a technical committee of Mount Ousley Road and any subsidence impacts, as for LW4 and LW5, is considered appropriate, if considered acceptable by the RMS. Some consideration to remedial work to prevent water ingress into minor tension cracks that have formed in the road pavement is recommended to protect the road sub-base.

There is considered to be no potential for significant horizontal movements to impact the Picton Road Interchange. As there are no impacts predicted for the Picton Rd Interchange, a low level monitoring strategy as outlined in the management is considered appropriate to confirm that subsidence movements are of low level and of no significance for the structures around the interchange.

All four transmission lines were mined under by LW1 and LW3 in the Balgownie Seam and potentially by late stage pillar extraction in the main heading pillars in the Bulli Seam. Subsidence movements predicted in the vicinity of four of the towers (two each on the 330kV and 132kV lines) are likely to require construction of cruciform bases to protect them from mining subsidence. T56 on the 330kV line will require a special design to accommodate the slight change in direction that occurs at this tower. The 33kV single and double pole structures are more tolerant to subsidence movements and are located more than 60m outside of the footprint of the longwall panels. As such, no protection measures are considered necessary but a monitoring regime will be implemented. A technical committee comprising representatives from the colliery, the power utility companies, the Mine Subsidence Board, and government regulators is proposed to manage potential impacts on the power transmission towers.

Cataract Reservoir is not expected to be impacted by the proposed mining. The FSL for the reservoir including the section that extends up Cataract Creek is protected from the nearest longwall goaf by a horizontal distance of greater than 203m at 290m overburden depth. Vertical subsidence at the FSL is expected to be less than about 20mm. Geological structures within the Assessment Area are relatively well defined because of the previous mining that has occurred in the overlying Bulli and Balgownie seams. The only geological structure that extends through to the proposed longwall panels in the Assessment Area and the reservoir is Dyke D8. There is considered to be no potential for proposed mining to intersect the stored waters directly. It is considered unlikely that the proposed mining will interact with these pre-existing goaf areas and currently there does not appear to be any connection between the reservoir and the mining horizon. The Colliery has been working with the DSC for many years and it is considered that the management process that has been adopted in the past continues to be appropriate. The 0.7 times depth (approximately 200m) stand-off from the FSL is considered to be the primary control for protecting the stored waters of Cataract Reservoir and this barrier is expected to provide a high level of protection.

The telecommunications tower located at Brokers Nose on the escarpment is protected by a horizontal distance of approximately 1km from the nearest point on LW1. No ground movements or any perceptible impacts are expected in this area as a result of the proposed mining.

2.2.7 Mine Subsidence

2.2.7.1 Summary

Coal has previously been mined in three seams at this site, the Bulli Seam, the Balgownie Seam 10m below, and the Wongawilli Seam a further 20m below that. The presence of this previous mining presents some challenges for future mining but also brings some advantages in terms of providing high confidence of the nature, location, and characteristics of geological structures, real measurements of the subsidence behaviour of the overburden strata during previous mining, and an extended baseline of up to 80 years to study the recovery of natural features from previous surface impacts.

The subsidence prediction methodology used in this assessment is based on previous subsidence monitoring experience at this site available from mining in the Bulli Seam (over longwall panels to 6-8km to the west) and the Balgownie and Wongawilli Seams in the Assessment Area. This data is considered to provide a strong basis for predicting subsidence above the proposed longwall panels, particularly when consideration is given to the mechanics of the subsidence processes involved, specifically the differences between sag subsidence over individual panels and elastic compression subsidence associated with the strata left between panels. Tilts and strains are predicted using incremental subsidence and the approach forwarded by Holla and Barclay. Maximum closure is predicted using the ACARP Method developed by Waddington and Kay.

The approach to predicting subsidence movements is considered to be appropriate in the relatively complex mining environment that exists within the Assessment Area especially now that there is actual subsidence data available from LW4 and LW5 to provide confirmation of behaviour when a third seam is mined. The experience available from mining LW4 and LW5 indicates that the subsidence behaviour in a multi-seam environment is different in respect of the overburden stiffness characteristics and therefore the bridging capacity across individual panels, but is otherwise essentially similar to the subsidence behaviour above single seam operations. Most importantly the experience from LW4 and LW5 indicates that the subsidence behaviour is still predictable.

Maximum subsidence over individual longwall panels in the Wongawilli Seam is predicted to range from 1.5m over the slightly narrower LW7 through to 2.6m over LW3 where the overburden depth is shallowest and there is overlying goaf in both seams. Previous mining in the Bulli and Balgownie Seams is estimated to have caused up to 1.9m of subsidence.

There is considered to be some potential for pillar instability in the Bulli Seam to cause additional surface subsidence when the proposed longwall panels are mined in the Wongawilli Seam, but the area likely to be affected at the northern end of LW1 is not expected to cause significant surface subsidence or significantly greater surface impacts.

Maximum tilts over individual longwall panels in the Wongawilli Seam are expected to range from peaks of 24mm/m over LW10 through to peaks of 51mm/m above LW3. The peak values predicted are expected to be the maximum anywhere in the panel, most likely at goaf edges in overlying seams and in areas of topographic change in gradient. More generally across the panel, systematic tilts are likely to be in the range 50-90% of the peak values.

Maximum strains over individual longwall panels in the Wongawilli Seam are expected to range from peaks of 14mm/m over LW10 to peaks of 31mm/m over LW3. The peak values predicted may occur anywhere within the panel but tensile peaks are most likely to occur at topographic high points and compression peaks are most likely to occur at topographic low points. More generally across the panel, systematic strains are likely to be 20-30% of the peak values.

The predicted closure ranges up to 400mm adjacent to the ends of LW6 and LW7 and up to 210mm at the end of LW5. These closure estimates are recognised as being upper limit values because they are based on experience in deep gorges at high stress levels. Monitoring so far indicates closure movements that are much less than the predicted maxima.

The following table summarises the subsidence that has occurred in the area of each longwall panel during mining in the Bulli Seam (estimated) and the Balgownie Seam (measured) as well as the subsidence that is predicted above each longwall panel from proposed mining in the Wongawilli Seam.

Table 43 – Summary of Historical and Predicted Subsidence

General Observations Above Individual Panels	Previous Bulli and Balgownie Seam Subsidence (m)	Predicted Subsidence for PPR Wongawilli Seam (m) and Measured (in bold)	Predicted Tilt for PPR Wongawilli Seam (mm/m) and Measured (in bold)	Predicted Tensile Strain for PPR Wongawilli Seam (mm/m) and Measured (in bold)	Predicted Compressive Strain for PPR Wongawilli Seam (mm/m) and Measured (in bold)	Predicted Maximum Closure on Cataract Creek (mm) (Southern Tributary in Brackets – LW1-3)
Longwall 1	1.3	2.1	40	12	24	N/A (650)
Longwall 2	1.1	2.1	40	12	24	N/A (610)
Longwall 3	1.3	2.6	51	15	31	N/A (350)
Longwall 4	1.9	2.1 (1.6)	35 (30)	10.5 (7.5)	21 (14)	N/A
Longwall 5	0.9	1.9 (1.5*)	36 (16*)	10.8 (4.5*)	22 (14*)	210 (20*)
Longwall 6	1.5	2.1	38	11	23	400
Longwall 7	1.2	1.5	28	8	17	400
Longwall 9	0.5	2.1	32	10	19	50
Longwall 10	0.6	1.6	24	7	14	30
Longwall 11	0.6	2.1	30	9	18	10

Movement outside the goaf edge are expected to be essentially similar to the movements observed so far during mining of LW4 and LW5. Vertical movements of greater than 20mm are expected to be limited to within a distance of 0.7 time overburden depth from the nearest goaf edge equivalent to an angle of draw of 35°. In areas where there has been previous mining in both the overlying seams, vertical subsidence at the goaf edge is expected to be up to 300-500mm and the goaf edge subsidence profile is expected to be generally softer than elsewhere. In areas where there is either solid coal or substantial coal pillars directly above the goaf edge, goaf edge subsidence is expected to be of the order of 100-200mm.

The impacts of mining subsidence on surface features are considered in detail in **Attachment B**, pg 426. These features include natural features such as Cataract Creek, Cataract River, Upland Swamps, and sandstone cliffs including the Illawarra Escarpment, archaeological heritage features, and surface infrastructure including Mount Ousley Road, four high power transmission lines, Cataract Reservoir, and a telecommunications installation on Brokers Nose.

Cataract Creek flows across the Assessment Area. The Preferred Project mine layout has been designed to avoid mining directly under the main channel of Cataract Creek and particularly the fourth order sections downstream of Mount Ousley Road. An adaptive management strategy based on closure monitoring and cessation of mining if there is a likelihood of significant perceptible impacts becoming apparent is considered to be an effective method of managing the potential for subsidence impacts on Cataract Creek.

Cataract River is remote from the proposed mining in an area where there are not expected to be any perceptible impacts.

Biosis has mapped and described 33 separate **Upland Swamps** within the Assessment Area. Many of these swamps have been previously mined under in both the Bulli Seam and Balgownie Seam. The proposed mining is not expected to cause significantly different impacts to those already experienced. It is considered that more work is required to determine the relationship between mining subsidence and the long term health of swamps. The extended baseline of subsidence impacts over 60-100 years in the Bulli Seam and 30-40 years in the Balgownie Seam provides a rare opportunity to study these effects. The development of a monitoring and review strategy involving relevant experts is recommended to manage mining impacts on these swamps. This process should include a review of the recovery of these features from previous impacts and the implication of this recovery for future swamp protection strategies.

There are numerous **sandstone cliff formations** located within the Hawkesbury Sandstone outcrop in the Assessment Area. Most of these are less than 5m high and none are considered to be significant based on the assessment criteria presented in PAC BSO report. Some perceptible cracking on hard rock surfaces is expected to be apparent as a result of the proposed mining. Minor rock falls are expected on up to 5% of the length of sandstone cliff formations that are mined directly under. It is noted that there are a number of rock falls present across the site that can be attributed to previous mining impacts and others that have occurred naturally.

Nineteen **Aboriginal heritage sites** have been identified within the Assessment Area. Some of these sites have potential to be impacted by rock falls caused by mining subsidence. A detailed assessment of these sites is presented in **Section 2.2.3**, pg 93, **Attachment B**, pg 426, and in **Attachment C**, pg 536.

Mount Ousley Road is protected from direct mine subsidence by a horizontal distance from the nearest goaf edge equal to half overburden depth. Low levels of vertical subsidence of less than about 100mm in total are expected in the vicinity of Mount Ousley Road with approximately 30mm of this maximum having already occurred from mining LW4. These low level vertical movements are expected to be imperceptible for all practical purposes although tensile cracking adjacent to the topographic high ground south of Cataract Creek and closure of up to a maximum of 125mm of closure predicted using the ACARP Method is expected at Cataract Creek. There is considered to be no potential for significant horizontal movements to impact the Picton Road Interchange. Ongoing management of the Mount Ousley Road and any subsidence impacts by a technical committee as for LW4 and LW5 is considered appropriate for the ongoing management of subsidence impacts to the road particularly given the half depth barrier to mining that has been used to substantially protect the road alignment. Some consideration to remedial work to prevent water ingress into minor tension cracks that have formed is recommended to protect the road sub-base.

There are four **power transmission lines** located in two corridors between Mount Ousley Road and the Illawarra Escarpment. All four lines were mined under by LW1 and LW3 in the Balgownie Seam and potentially by late stage pillar extraction in the main heading pillars in the Bulli Seam although this latter mining may have preceded their construction. Subsidence movements predicted in the vicinity of four of the towers (two each on the 330kV and 132kV lines) are expected to be sufficient to require construction of cruciform bases to protect them from mining subsidence. T56 on the 330kV line will require a special design to accommodate the slight change in direction that occurs at this tower. The 33kV single and double pole structures are more tolerant to subsidence movements and because these structures are located more than 60m outside of the footprint of the longwall panels no protection measures are considered necessary, although a monitoring regime is nevertheless required. A technical committee comprising representatives from the colliery, the power utility companies, the Mine Subsidence Board, and government regulators is proposed to manage potential impacts on the power transmission towers. This forum provides all interested parties with understanding and control of the management processes. Several of the power transmission towers are likely to require the construction of cruciform bases to allow them to remain structurally stable during mining. There is usually a significant lead time involved in getting cruciforms approved, financed, designed, and constructed.

The **Cataract Reservoir** is not expected to be impacted by the proposed mining. The Full Supply Level (FSL) for the reservoir including the section that extends up Cataract Creek is protected from the nearest longwall goaf by a horizontal distance of greater than 203m at 290m overburden depth (equivalent to 0.7 times overburden depth or an angle of draw of 35°). Vertical subsidence at the FSL is expected to be less than about 20mm. Geological structures within the Assessment Area are relatively well defined because of the previous mining that has occurred in the overlying Bulli Seam over a large area and the overlying Balgownie Seam in a more limited area. The only geological structure that extends through to the proposed longwall panels in the Assessment Area and the reservoir is Dyke D8. The horizontal distance along the dyke from the end of LW10 to the FSL is approximately 560m at an overburden depth of 320m at the FSL. There is considered to be no potential for proposed mining to intersect the stored waters directly. There are also a number of small pre-existing Bulli Seam goaf areas that are located within the 200m protection zone around the FSL. It is considered unlikely that the proposed mining will interact with these pre-existing goaf areas and currently there does not appear to be any connection between the reservoir and the mining horizon. Nevertheless, the presence of these goafs reduces slightly the effectiveness of the 0.7 times depth barrier between the FSL and the proposed mining, particularly for LW7 and LW9. DSC is a statutory body with legal powers to manage mining to protect the stored waters in Cataract Reservoir. The Colliery has been working with the DSC for many years and it is considered that the management process that has been adopted in the past continues to be appropriate. The 0.7 times depth (approximately 200m) stand-off from the FSL is considered to be the primary control for protecting the stored waters of Cataract Reservoir and this barrier is expected to provide a high level of protection.

There is a **telecommunications tower** located on Brokers Nose on the Illawarra Escarpment. The Illawarra Escarpment at Brokers Nose and the telecommunications infrastructure is protected by a horizontal distance of approximately 1km from the nearest point on LW1. No ground movements or any perceptible impacts are expected in this area as a result of the proposed mining.

The subsidence management strategies include continuation of the improvement to subsidence monitoring technique that has been ongoing since the start of LW4, such as moving from 2D to 3D surveying.

The detail of monitoring of swamps, heritage sites, and creek biota has been addressed in **Section 2.2.1**, pg 57, Section 2.2.3, pg 93, **Attachment A**, pg 350 and **Attachment C**, pg 536 . However, it is recommended that one or more technical committees are formed to design monitoring programs that not only review the changes that may be associated with proposed mining but also take the opportunity to review the longer term impacts from previous mining in the same area. These technical committees would include external expertise from the government agencies and respected community experts where appropriate so that monitoring programs are targeted, appropriate, and can be ongoing.

2.2.7.2 Background

A number of submissions were received during the public exhibition period regarding what were considered significant issues in the EA. These concerns broadly covered:

1. concern over the accuracy and specificity of the subsidence predictions for sensitive features;
2. inadequate geological understanding to estimate potential risk of reactivation of existing geological structures as a result of mine subsidence;
3. irregular subsidence/pillar run potential due to Bulli Seam pillars not being completely subsided prior to extraction of the Wongawilli Seam;
4. potential for and impacts of valley closure and upsidence not considered; and
5. requirements for improved subsidence monitoring and management.

Significant additional work has been undertaken to address the issues raised in the EA, including a full geological assessment of the Wonga East area, extensive research into historical subsidence and the extent of mine workings in the Bulli and Balgownie seams and the use of an alternative mine subsidence modelling approach as the basis of new impact assessments. This Section will provide an overview of both historical and predicted mine subsidence in the Wonga East area with further detail, including all Figures used in this Section, available in the **Attachment B**, pg 426**.**

2.2.7.3 Subsidence Assessment

Assessment Area

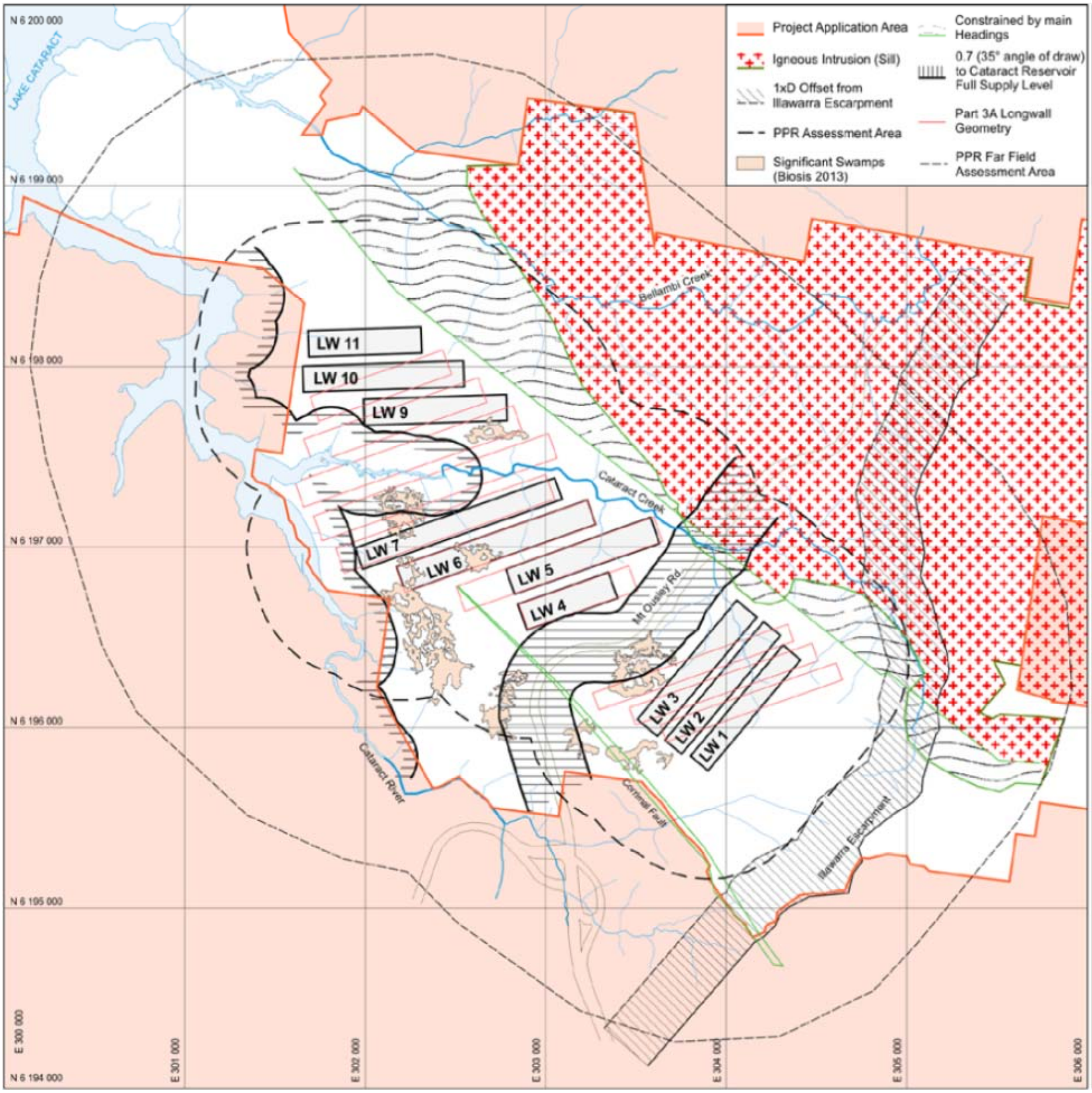
The longwall panels in the Preferred Project have been designed recognising the following constraints:

- the extent of the mine lease
- geological constraints including the Corrimal Fault in the south and silling (igneous intrusion) in the north,
- mining constraints associated with the need for main headings in the north
- surface subsidence constraints including:
    - avoiding longwall extraction within 0.7 times depth (equivalent of 35° angle of draw) of the full supply level of Cataract Reservoir including the section of the reservoir that extends up Cataract Creek,
    - avoiding mining directly under the fourth order section of Cataract Creek
- avoiding impacts on Mount Ousley Road by remaining beyond approximately half depth (equivalent to 26.5° angle of draw) from the road easement

These constraints are illustrated in **Figure 41**, pg 149, together with the Preferred Project layout and the original layout proposed for the Underground Expansion Project Pt3A application. In the Preferred Project, LW8 has been left out, most of the panels have been shortened, LW7 has been narrowed, and six of the panels (LWs 1-3 and 9-11) have been rotated in order to remain within the constraints described above.

The Assessment Area extends horizontally for 600m from the outside edge of any of the proposed longwall panels including LWs 4 and 5. A second far field assessment area extending to 1.5km outside the proposed longwall panels has been used to include significant features such as the Illawarra Escarpment and the bridges of the Picton Road Interchange that while remote from mining are within the area where far-field horizontal movements may occur.

Figure 41 – Preferred Project Design Constraints



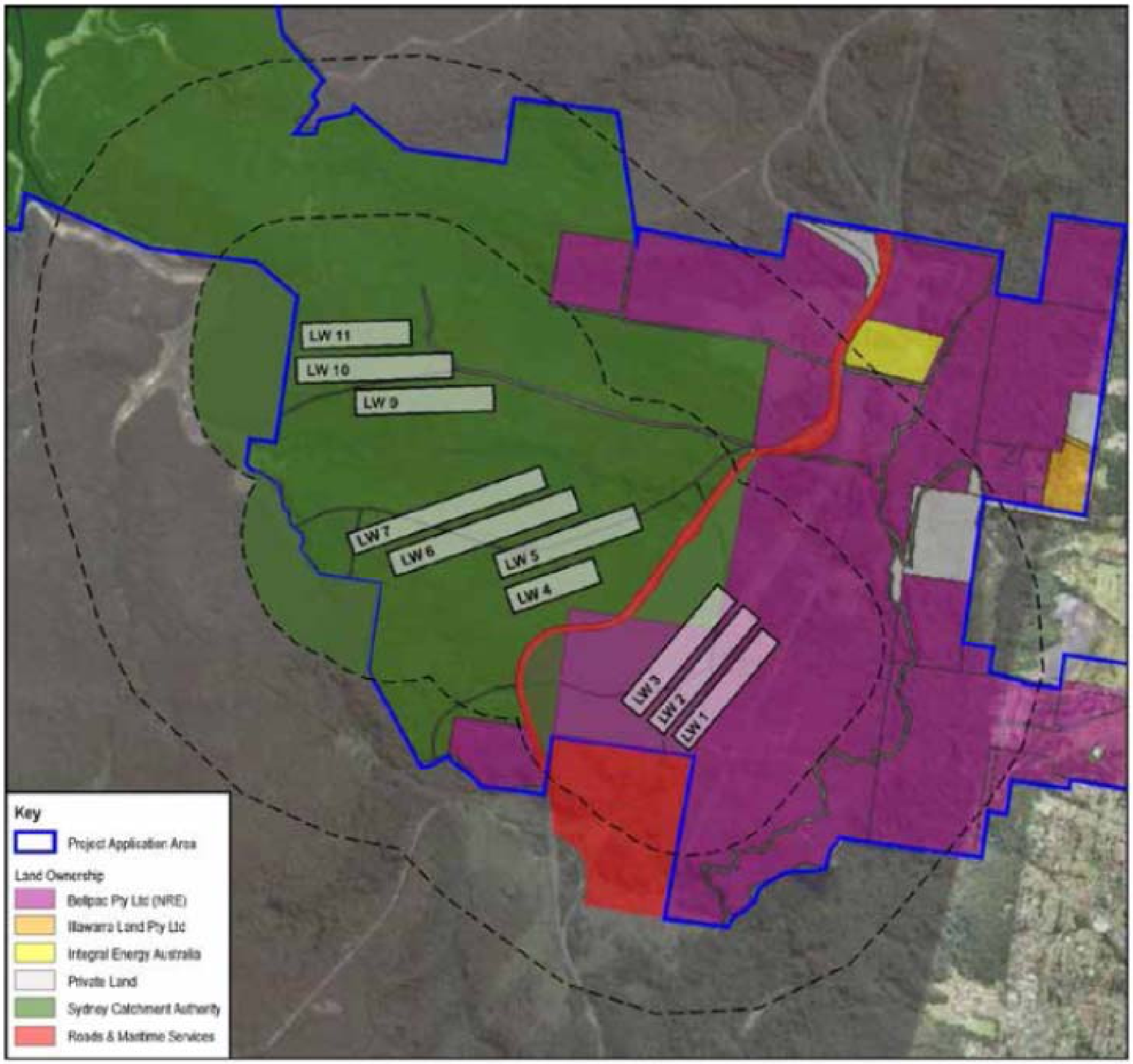
LW4 which has already been mined and LW5 which is currently in the process of being mined are included in the assessment area and this subsidence assessment because:

- although they have been mined under a different regulatory process, they are nevertheless within the purview of the current mining area and it is appropriate to assess their impacts in this context; and
- the levels of subsidence measured were significantly higher than predicted using the single seam subsidence prediction methodology used for the original assessments and therefore reassessment is considered appropriate.

Surface Ownership

Figure 42, pg 150, shows the surface ownership within the Assessment Area. Most of the area in the SCA Metropolitan Special Area set aside as a water catchment. Areas to the east and west of Mt Ousley Rd are owned by NRE. Mt Ousley Rd easement and a section of land to the northeast of the Picton Interchange are owned by the RMS.

Figure 42 – Land Ownership



Surface Features

The following features in **Table 44**, pg 151 are located in the 600m Assessment Area or the 1.5km far field area around the Preferred Project longwalls.

Table 44 – Summary of Infrastructure and Natural Features

Feature	Description	Assessed	
		In 600m Assessment Area	In 1.5km Far Field Area
Mt Ousley Rd	Recently renamed the M1 Princes Motorway is a major four lane highway connecting Sydney and Wollongong. This road is administered by RMS	✓	✘
Picton Road Interchange	Located to the south outside the Assessment Area but within the 1.5km far field assessment area. This interchange includes a concrete bridge and several drainage culverts	✘	✓
330kV Electricity Transmission Line	Owned and maintained by Transgrid and runs to the east of Mt Ousley Road and over the LW1-3 area.	✓	✘
132kV Electricity Transmission Line	Owned and maintained by Endeavour Energy and located adjacent to the Transgrid 330kV line.	✓	✘
33kV Electricity Transmission Lines	Two 33kV transmission lines and associated infrastructure owned and maintained by Endeavour Energy to the east of the 330kV line	✓	✘
Communications Infrastructure	Communications tower infrastructure located near the top of Brokers Nose around 900m east of LW1	✘	✓
Cataract Reservoir	Managed by the Sydney Catchment Authority to provide raw water to Sydney Water	✓	✘
Illawarra Escarpment	Located east of the mining area and outside the Assessment Area but within the 1.5km far field area	✘	✓
Cliffs	There are numerous cliffs and rocky outcrops across the Assessment Area. Brokers Nose on the Illawarra Escarpment is the only cliff that meets the PAC significance criteria and is located around 900m east of LW1	✓	✓
Upland Swamps	There are 33 separate upland swamps within the PPR Assessment Area	✓	✘
Cataract Creek	A 1st to 4th order stream located to the north of LW's 1-3 and 4-6 and passes between LS's 7 and 9 before entering the Cataract Reservoir.	✓	✘
Cataract River	Cataract River is located on the southern side of the ridge that runs below the start of LWs 4-7	✓	✓
Aboriginal Cultural Heritage	Six Aboriginal heritage sites have been identified within the PPR Assessment Area	✓	✘

Major natural features in the area include the Illawarra Escarpment located some 800-900m east of proposed LW1 and the upper parts of Lake Cataract that forms part of Sydney's water supply catchment. There are numerous natural creeks, swamps and small sandstone cliffs (less than 5m in height) within the Assessment Area.

Several Aboriginal heritage sites have been identified within the Assessment Area. These are sites are mainly associated with rock shelters in sandstone cliff formations and grinding grooves on rock outcrops.

Major infrastructure within the Assessment Area includes the Cataract Reservoir, Mount Ousley Road and four high voltage power lines to the east that cross the area.

Geological Setting

The geology of the Assessment Area is addressed in detail in **Section 2.2.4**, pg 111. Within the Assessment Area, the strata dip at between 1 in 25 and 1 in 30 to the west-north-west from outcrop on the Illawarra Escarpment. **Figure 43,** pg 153, provides good detail of the geological formations that outcrop at the surface and the geological structure that exists at the Wongawilli Seam level and at the surface. Hawkesbury Sandstone is present on the surface over most of the Assessment Area. The Bald Hill Claystone that underlies the Hawkesbury Sandstone outcrops in Cataract Creek and its tributaries. The Bulgo Sandstone that underlies the Bald Hill Claystone outcrops along the main channel of Cataract Creek either side of Mount Ousley Road.

Figure 35, pg 120, shows a cross-section through the Assessment Area extending from south to north in the vicinity of Mount Ousley Road drawn at natural scale. This section shows how Cataract Creek has cut down through the stratigraphy near the top of the anticlinal structure that exists in this area. An anticline is an upward or arch shaped fold in the geological strata.

Coal Seams

The three coal seams that have been mined at NRE No 1 Colliery are all located within the Illawarra Coal Measures. **Figure 36**, pg 124, shows layout and geology of the Bulli Seam which is the uppermost of the three seams and averages about 2.2m in thickness across the Assessment Area.

The Balgownie Seam is approximately 1.2m thick and located on average about 10m below the floor of the Bulli Seam ranging from 5m to 14m across the Assessment Area. Mining height may have been up to 1.5m depending on mining equipment used. **Figure 37**, pg 125 shows the layout of the Balgownie Seam workings and the geological structure in the Balgownie Seam.

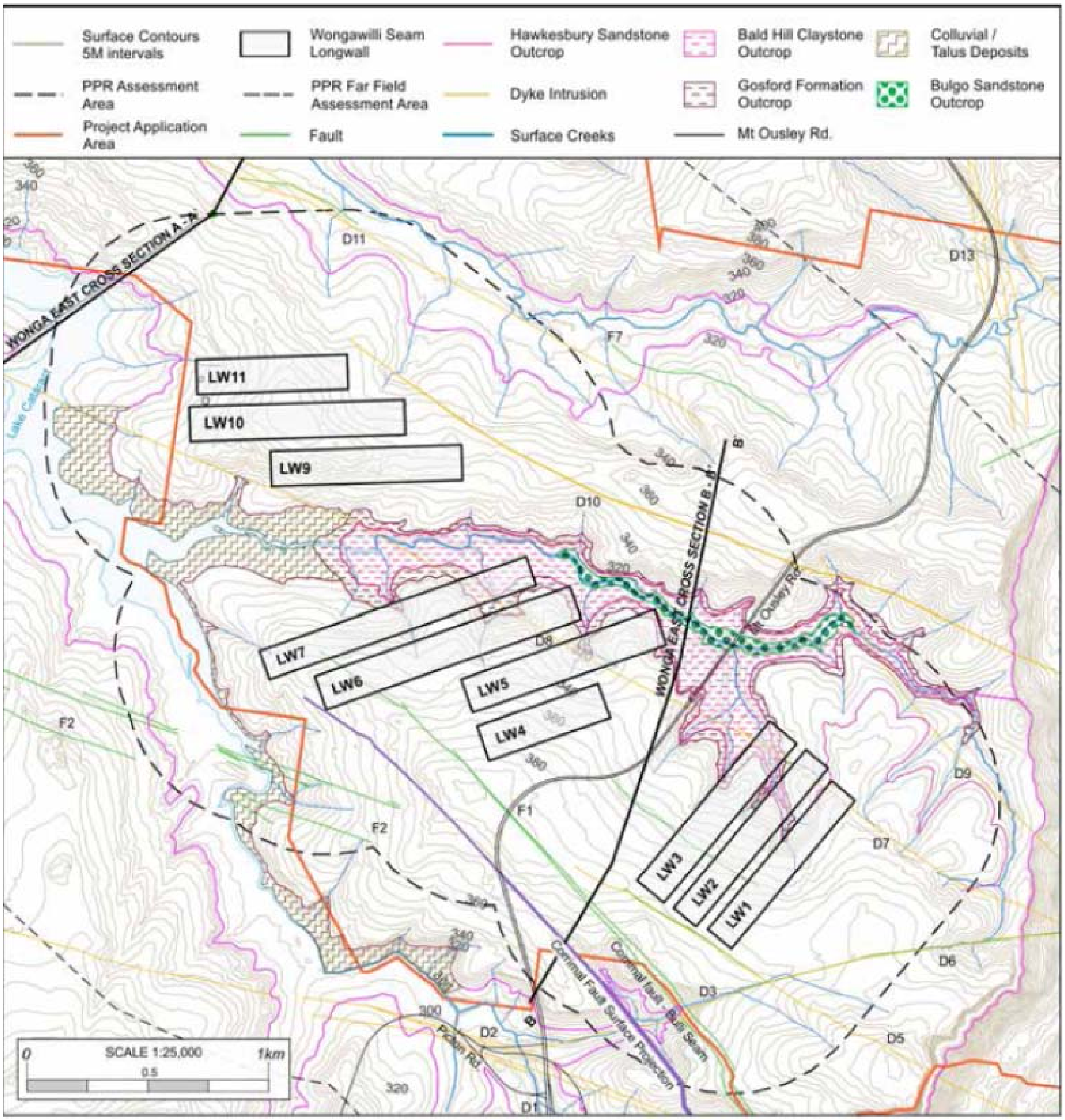
The Wongawilli Seam is located approximately 20m below the Balgownie Seam and ranges in thickness from 7.7m to 11.9m, but only the lower 2.6-2.8m is economic to mine and this section is planned to be targeted by proposed mining. **Figure 38**, pg 126, shows a plan of the geological structure at the Wongawilli Seam. The floor of the Wongawilli Seam has an elevation of approximately 80mAHD at the north eastern corner of LW1 and an elevation of approximately 25mAHD at north western corner of LW11. The dip of the seam between these two points is, for practical purposes, constant.

Geological Structures

The geological structure in each seam is shown in **Figure 36**, pg 124, **Figure 37**, pg 125, and **Figure 38**, pg 126. The major geological structures of interest in the area are igneous sills and dykes and the Corrimal fault. The vertically continuous structures are evident in the Bulli and Balgownie Seam and in the geomorphology on the surface and their positions are considered to be well defined.

An igneous sill has intruded into the Wongawilli Seam to the north of the main headings and the coal in this area is cindered and unsuitable for sale. Several dykes exist within the Assessment Area with most having a west-north-west east-south-east orientation. Dykes are the vertical equivalent of sills and in the Southern Coalfields are generally less than a few tens of centimetres thick but can be thicker in the coal seam and can also extend for many kilometres in length. Dykes are usually hard to mine, dilute the coal product, cause damage to the mining equipment, and tend to be avoided where possible.

Figure 43 – Geological Surface Outcrop and Longwall Layout in the Assessment Areas



The site constraints within the Assessment Area mean that several of the proposed longwall panels will need to mine through Dyke D8. This dyke has been previously encountered in the Bulli Seam and Balgownie Seam workings and its trace is apparent in the geomorphology on the surface indicating that it is vertically continuous to the surface.

Figure 44, pg 154, shows a photograph of Dyke D8 at Wongawilli Seam level where it was intersected on the longwall face at a shallow angle making it appear thicker than it actually is. Dyke D8 is approximately two metres thick in this area and fractured. Although the dyke appeared damp at the time of inspection on 21 June 2013, the coal seam to either side also appeared similarly damp. This dampness is considered likely to be a result of water sprays on the longwall shearer. There did not appear to be any significant seepage flow emanating from the dyke consistent with experience at almost all other dyke intersections in the Southern Coalfield.

The only major geological fault within the Assessment Area is the Corrimal Fault (F1) which extends in a north-west/south-east direction in the southern part of the Assessment Area. This fault was intersected in the overlying Bulli Seam but the longwall panels in the Balgownie Seam did not extend far enough south, although some of the headings extended to the fault or the associated dyke D5. The fault is also apparent in the surface geomorphology and so its location and characteristics are well defined. The fault diminishes to the northwest and has become insignificant where it is intersected by the gateroads for LW6.

Other faults in the general area, the Rixon's Pass Fault, the Woonona Fault, and F2 are remote from the proposed mining and are not considered likely to affect mining or to be affected in any significant way by the proposed mining.

Figure 44 - Photograph of Dyke D8 Exposed on LW5 Face

Overburden Depth

Figure 45, pg 155, shows a plan of the overburden depth to the Wongawilli Seam. The overburden depth ranges from 250m above LW2 and LW3 in the northern part below the southern tributary of Cataract Creek through to 390m above the central part of LW10 and LW11.

The overburden depth range for individual longwall panels is shown in **Table 45**, pg 156. The ratios of panel width to depth range from 0.37 to 0.60. In previously unmined terrain, low levels of subsidence would be expected above each individual panel with the overall maximum subsidence controlled by elastic compression of the chain pillar between panels. However, subsidence monitoring data from the recently mined LW4 and LW5 and from the Balgownie Seam longwall panels indicates that the presence of overlying mine workings has the effect of softening the overburden strata so that its bridging capacity (shear stiffness) is reduced thereby increasing the maximum subsidence above each individual panel to the higher magnitudes of subsidence that have been observed.

Figure 45 – Wongawilli Seam Overburden Depth

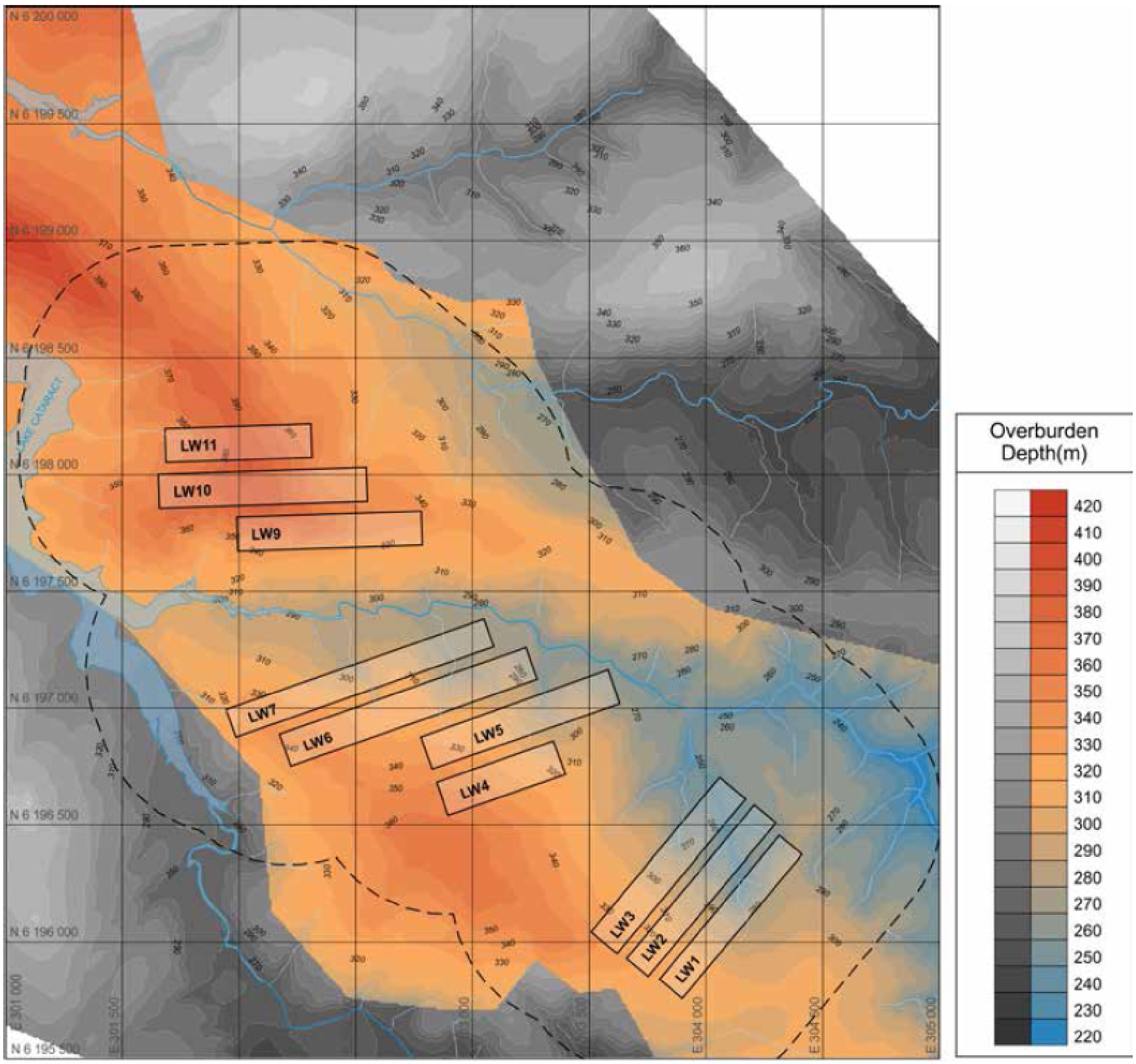


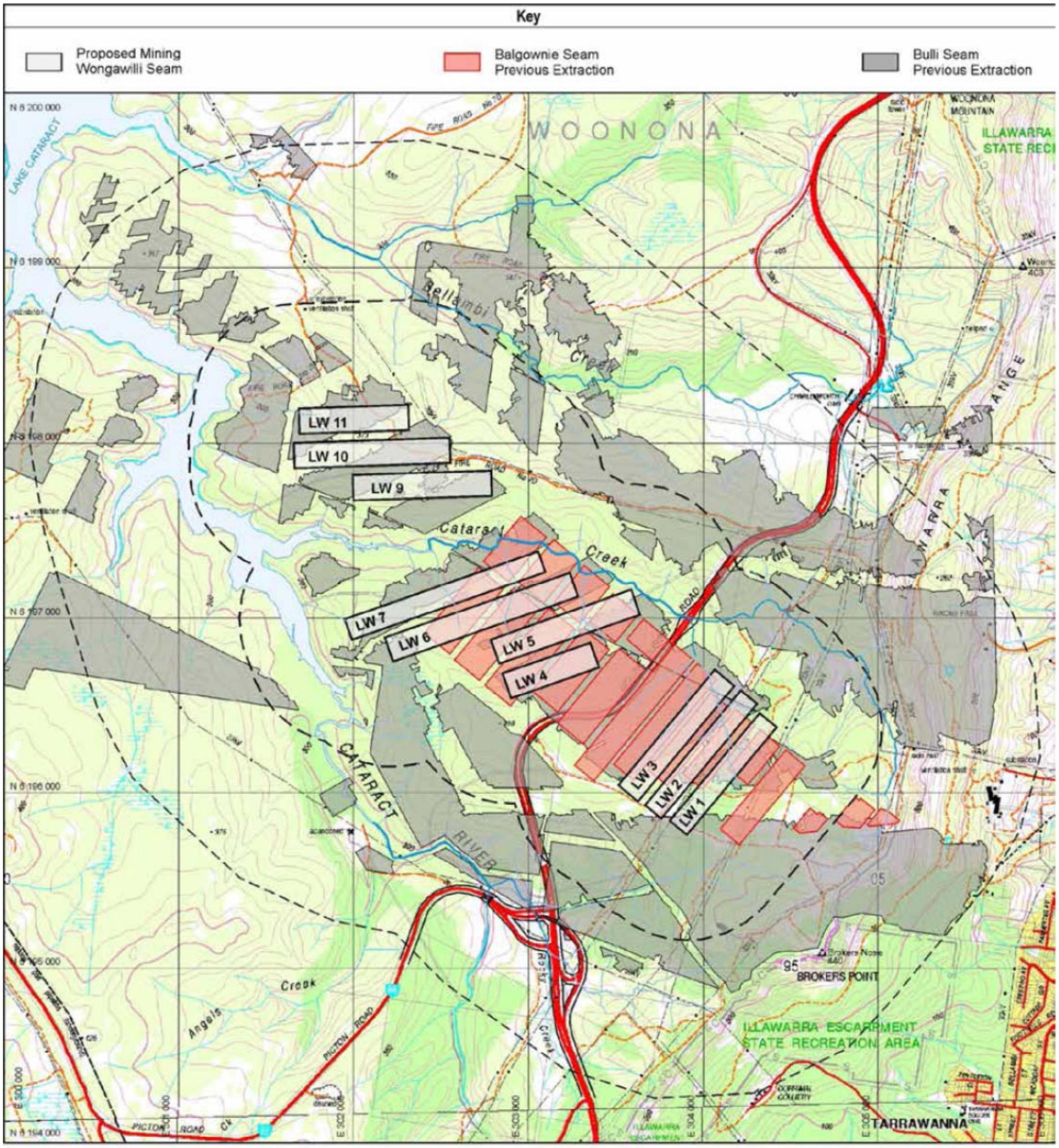
Table 45 - Overburden Depth Range

LW Panel	Panel Width (m)	Overburden Depth Range (m)	Width on Depth Ratio
1	131	255-320	0.41-0.51
2	125	255-330	0.37-0.49
3	150	250-340	0.44-0.60
4	150	300-360	0.42-0.50
5	150	265-345	0.43-0.57
6	150	270-345	0.43-0.55
7	131	270-340	0.39-0.49
9	150	330-380	0.39-0.45
10	150	335-390	0.38-0.45
11	150	350-385	0.39-0.43

Overview of Previous Mining Areas

The Assessment Area contains previous mining activity in two other seams unrelated to mining in the Wongawilli Seam. **Figure 36**, pg 124, **Figure 37**, pg 125, and **Figure 38**, pg 126, show the extent of previous mining in the Bulli Seam, Balgownie and Wongawilli seams. **Figure 46**, pg 157, shows the three seams superimposed over each other.

Figure 46 – Previous Mining in the Preferred Project Assessment Area



As a result of this previous mining, the geological structure and seam contour are much better known than would normally be possible for single seam mining. However, predicting subsidence behaviour in a multi-seam environment is more challenging. Previous mining activity provides an opportunity to examine the mining impacts over timeframes of 50-100 years for the Bulli Seam and 30-40 year for the Balgownie Seam mining. The subsidence movements associated with the earlier mining have been estimated for the Bulli Seam and those measured for the Balgownie Seam longwalls are presented to provide a baseline of impact experience and recovery that is not typically available.

The ongoing nature of the mining operation at NRE No.1 Colliery provides the opportunity to inspect the mine workings in the Bulli Seam and the Balgownie Seam to better understand the nature of the potential interactions between seams and the potential for pillar instability particularly in the Bulli Seam to cause unexpected additional subsidence.

Subsidence monitoring data available from mining in the Balgownie Seam and more recently from two longwall panels in the Wongawilli Seam provides a basis for predicting future subsidence behaviour. This data indicates that while there are some significant differences in behaviour compared to single seam mining, the multi-seam behaviour is essentially predictable and occurs mainly within the bounds of the panel being mined and the chain pillar to the previous panel. This data and observations of previous impacts indicate that the impacts of future mining are likely to be essentially similar in nature to the impacts that have already occurred. There is also some softening of the goaf edge subsidence in areas where overlying seams have been mined but the effect is a second order effect and of relatively little significance in terms of subsidence impacts.

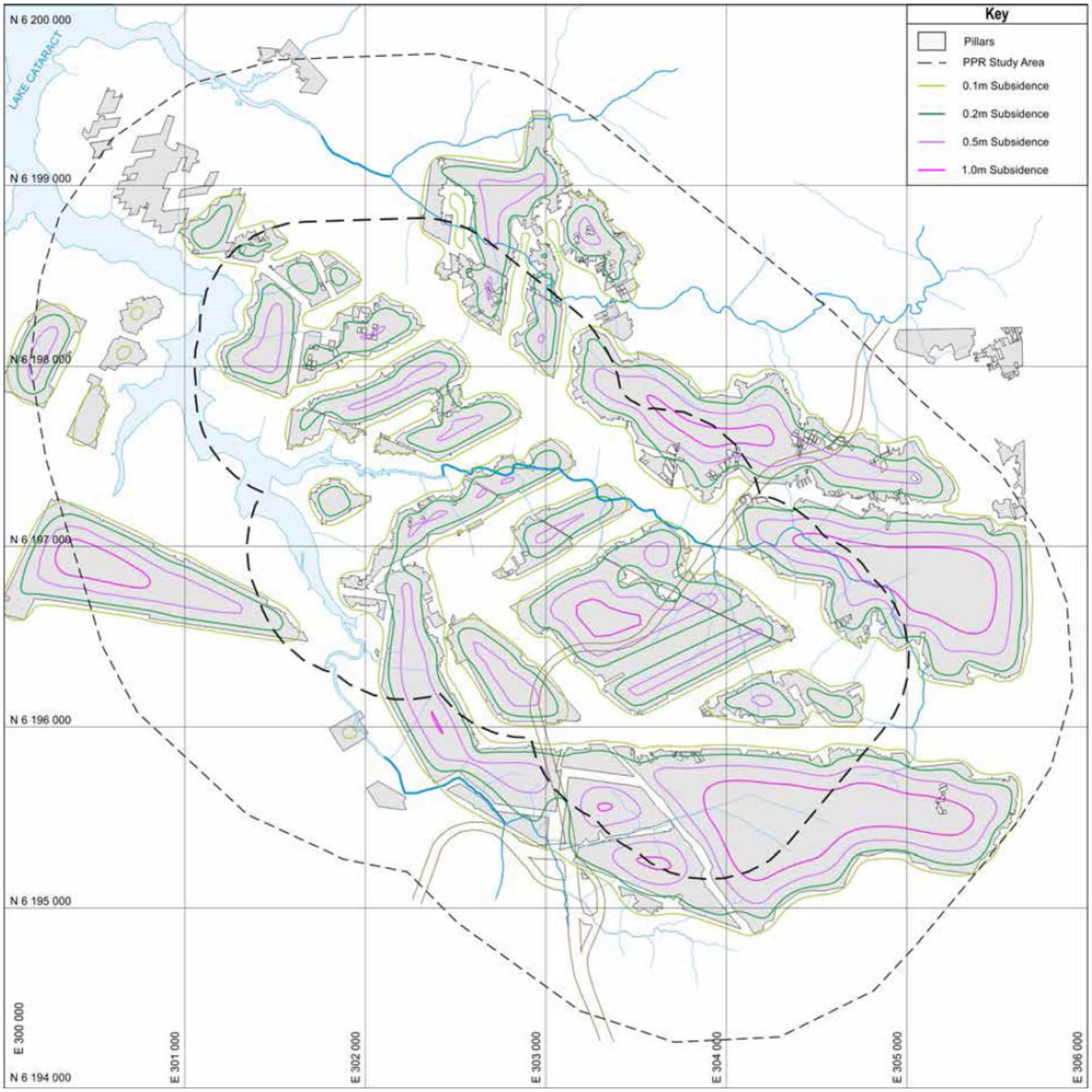
Prior Bulli Seam Mining and Subsidence

The Bulli Seam was mined initially using bord and pillar mining techniques from the 1890’s through until pillar extraction became possible with improvements in mining technique and the arrival of mechanised mining. Some of the standing pillars associated with the main headings and original mining were later extracted but mining in Bulli Seam within the Assessment Area had effectively finished by the 1950’s. Areas of pillar extraction in Corrimal Colliery immediately to the south are also included because they fall within the Assessment Area.

There are no subsidence records for the period of mining in the Bulli Seam. However, it is possible to estimate the levels of subsidence that are likely to have occurred given the geometry of the panels mined and estimating the likely extraction ratios. **Figure 47**, pg 159, shows the areas where subsidence is likely to have occurred as a result of the pillar extraction operations in the Bulli Seam and contours of the surface subsidence that has been estimated based on subsidence monitoring results and subsidence profiles from mining in the Bulli Seam further to the west above the T and W longwall panels at South Bulli and subsequent pillar extraction operations.

A site inspection conducted by SCT on 21 June 2013 showed that there are existing bord and pillar workings alongside the Bulli Seam main headings that are likely to be destabilised if mined directly under in the Wongawilli Seam. Similar workings were directly mined under by the Balgownie Seam longwall panels and it is clear from the underground inspection that these overlying pillars were destabilised in the area directly above the Balgownie Seam longwall goaf as shown in **Figure 48**, pg 161. There did not appear to be any evidence that the footprint of instability extended significantly beyond the footprint of the underlying goaf, but it is considered possible that this potential may exist in isolated areas.

Figure 47 – Estimated Bulli Seam Subsidence



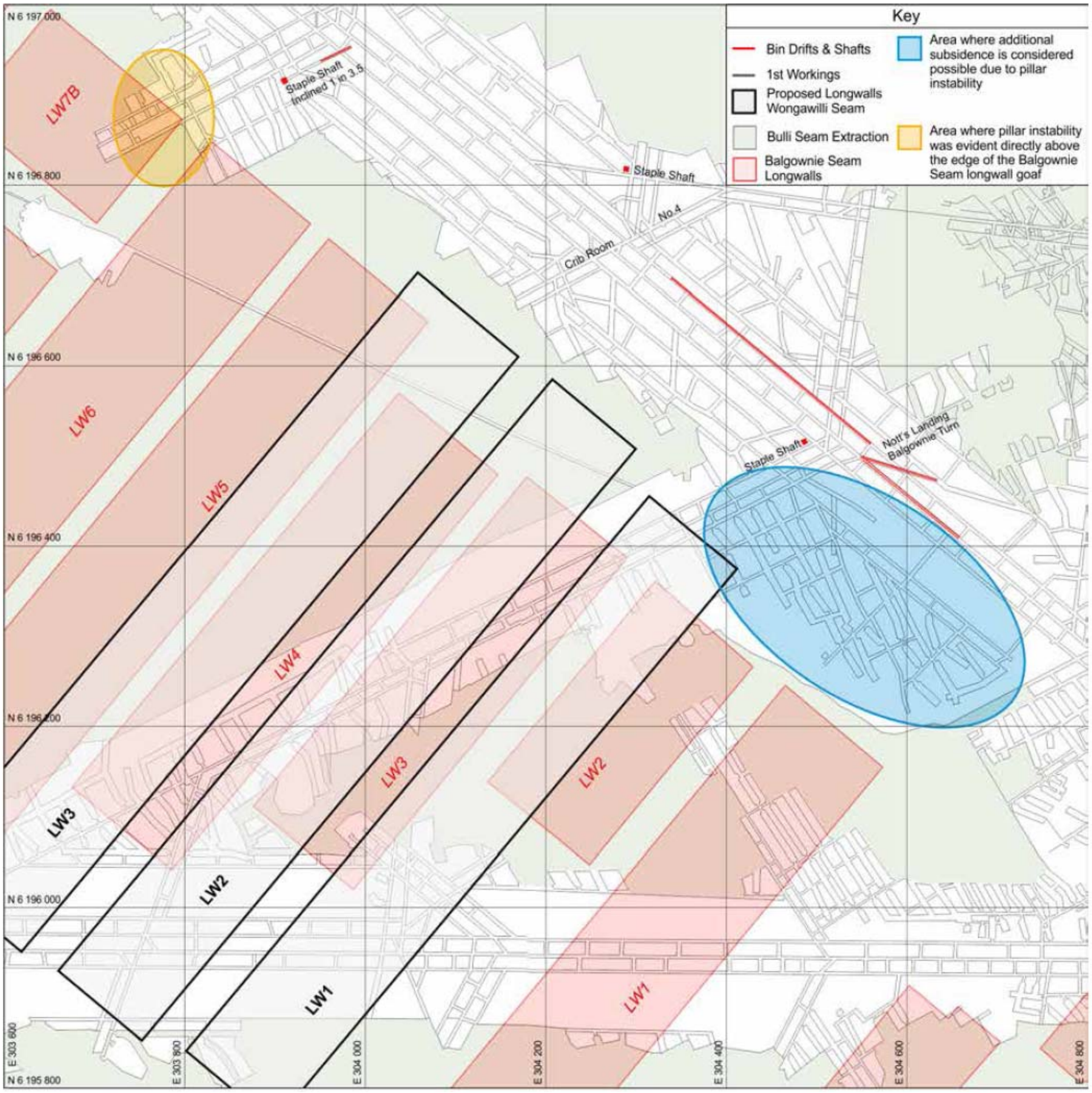
The detail of the Bulli Seam extraction is unavailable where large areas have simply been shaded in to represent the end of mining there. These areas will include different types of mining, ranging from solid coal, large standing pillars, standing pillars associated with Welsh bords, and goaf areas where there has been pillar extraction or the pillars have previously collapsed. The downward movements that occurred during Balgownie Seam mining provide a basis to differentiate these shaded areas where they have been directly mined under by the Balgownie Seam longwall panels. Small pillars that have been mined under by the Balgownie Seam longwall panels are considered almost certainly destabilised during the 1-1.5m downward movement that would have occurred as the pillars were mined under. Subsidence monitoring above the Balgownie Seam longwall panels shows areas where there has been some additional subsidence consistent with pillar instability, areas where there has been additional consolidation of an existing Bulli Seam goaf, and areas where there has been either no mining in the Bulli Seam or the Bulli Seam pillars are large enough to behave like solid coal.

The Bulli Seam subsidence estimates shown in **Figure 47**, pg 159, include refinements based on the ground behaviour observed during longwall mining in the Balgownie Seam. Although it is not possible to interpret the characteristics of some of the other large Bulli Seam goaf areas that have not been directly mined under in the Balgownie Seam, these other large goaf areas are remote from the areas where the PPR longwall panels are proposed. The detail of the Bulli Seam pillars is available in some areas close to the main headings as shown in **Figure 48**, pg 161. The site visit to this area indicated that additional subsidence due to pillar instability would be possible in the area shown if LW1 was extended to its full length although surface subsidence may be relatively small given the narrowness of the panel at an overburden depth of 270m. Any additional subsidence would have potential to impact on pylons on the two 33kV power transmission lines and this potential is addressed in the impact assessment for these structures.

The issue of a “pillar run” in the Bulli Seam has been raised in the Pt3A submissions. As indicated above, there is considered to be potential for a classical “pillar run” associated with pillar instability, but the geometries in the Bulli Seam and the evidence from previous mining in the Balgownie Seam make it unlikely that such an event would extend more than a few hundred metres from the goaf edge – i.e. the extent of the panel of standing pillars – and would be limited to only those areas where there are small standing pillars that have not previously been mined under in the Balgownie Seam.

However, the term “pillar run” may also be used to describe elastic stress redistribution and the relatively smaller ground movements that can be associated with this redistribution. As one area is subsided, pillars become more heavily loaded, and compress slightly causing lateral migration of low level subsidence movements well beyond the limits of subsidence normally associated with single seam mining. This phenomenon is particularly common where panels are relatively narrow compared with overburden depth and surface subsidence is controlled mainly by elastic compression of the pillars between panels. A similar process can also occur for horizontal movements as horizontal stresses are redistributed and dilation of subsiding strata causes horizontal movement in a downslope direction. Again the ground movements tend to be small second order movements that may cause perceptible low level cracking on hard surfaces such as sealed roads especially adjacent to topographic high points, but such movements are not usually significant because they tend to be of small magnitude and occur over large areas.

Figure 48 – Bulli Seam Pillar Instability



<u>Prior Balgownie Seam Mining and Subsidence</u>

There are eleven longwall panels in the Balgownie Seam extending to the south of the main headings. Longwall mining in the Balgownie Seam started in September 1970 at LW1 and finished on 27 May 1982 at LW11. The first six panels were located east of Mount Ousley Road and ranged in width from 141m to 145m. The last five panels were located west of Mount Ousley Road and ranged in width from 185m to 189m. These later panels were split into two parts either side of the D8 Dyke. **Figure 37**, pg 125, shows the extent of the Balgownie Seam workings. Apart from development headings, the remaining Balgownie Seam coal was recovered from three small areas of pillar extraction in the east and a panel of pillars formed up as stable first workings against the sill in the north.

Surface subsidence was monitored along the centreline of each of the eleven longwall panels and on three cross-lines. The vertical subsidence was monitored at regular intervals during panel retreat above the initial panels and less frequently during the last few panels. Surface strains were also measured during the last panel. **Figure 50**, pg 163, shows an example of the subsidence measured on the second cross-line that extends from the centre of LW5 to the solid coal west of LW11.

The characteristics of the subsidence measured that are of relevance to this assessment are:

- the chain pillars are clearly evident in the subsidence profile with 0.5m to 0.75m of subsidence;
- coal left in the Balgownie Seam around the dyke is clearly evident as reduced surface subsidence;
- the maximum sag subsidence in the centre of each panel is reduced (0.2m relative to the chain pillar subsidence) in areas where the panels are narrower compared to (0.5m above the wide panels);
- the sag subsidence is much less in areas where there are Bulli Seam main heading pillars;
- the subsidence is greatest (1.42m) over LW10 in an area on the fringe of Bulli Seam goaf where full subsidence was prevented by the presence of the Bulli Seam abutment or marginally stable pillars were destabilised;
- surface subsidence is essentially occurring within the geometry of the Balgownie Seam longwall panels; and
- the goaf edge subsidence is greater and extends further when there is overlying Bulli goaf, but the effect is a second order effect and the subsidence beyond the goaf edge is not significantly different to goaf edge subsidence that would be expected in a single seam operation.

These different characteristic behaviours have been considered for each of the subsidence lines and the maximum subsidence observed is able to be used to characterise the condition of the Bulli Seam goaf above. **Figure 49**, pg 163, shows the maximum subsidence observed for each of the longwall panels. The different areas can be differentiated as shown in **Table 46**, pg 162, based on where there are pillars and goaf in the two seams.

Table 46 - Subsidence Observed for the Balgownie Seam in Different Conditions

	Bulli Seam Pillars	**Bulli Seam Goaf**	**Unstable Bulli Pillars**
Balgownie Seam Pillars	Low level subsidence (<0.2m)	0.6-0.8m	Low level (<0.2m)
Balgownie Seam Goaf	0.6-0.8m	0.9-1.2m	1.4m

In areas where there are Balgownie chain pillars, the subsidence directly over the chain pillars is less than 0.2m if there are Bulli Seam pillars and between 0.6m and 0.8m if there is Bulli Seam goaf. In areas where there are Bulli Seam pillars, the same 0.6m to 0.8m level of subsidence is observed above the Balgownie goaf. When there are two goafs superimposed, the maximum incremental subsidence is in the range 0.9m to 1.2m – i.e. approaching 80% of the nominal mining height of the second seam mined.

Figure 49 – Maximum Observed Balgownie Seam Subsidence

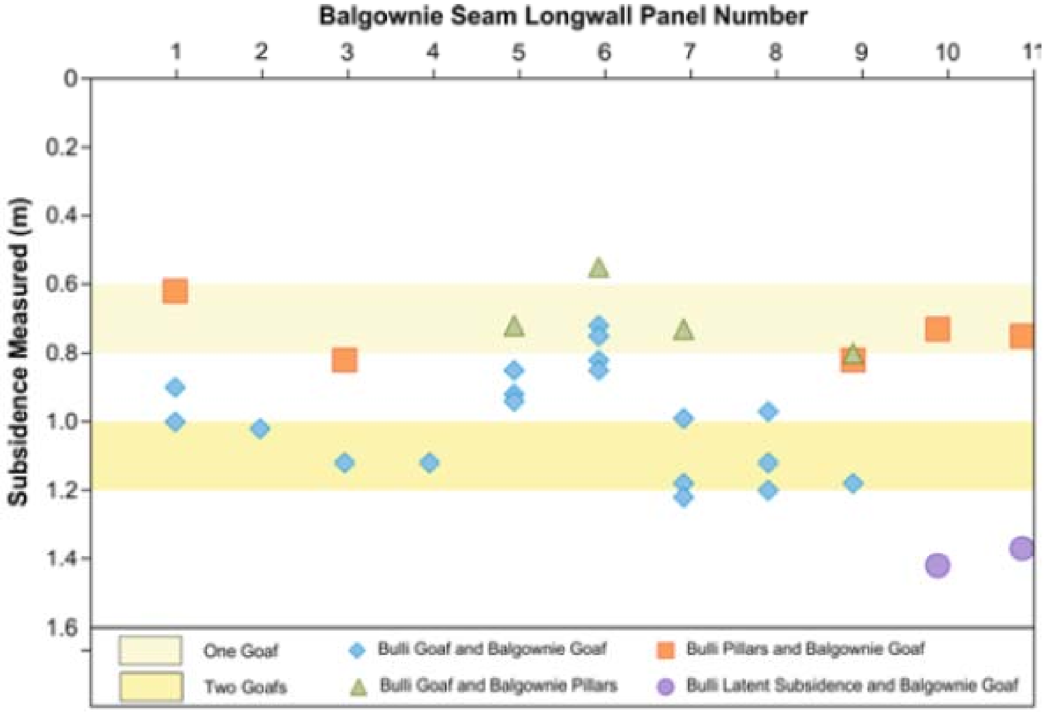
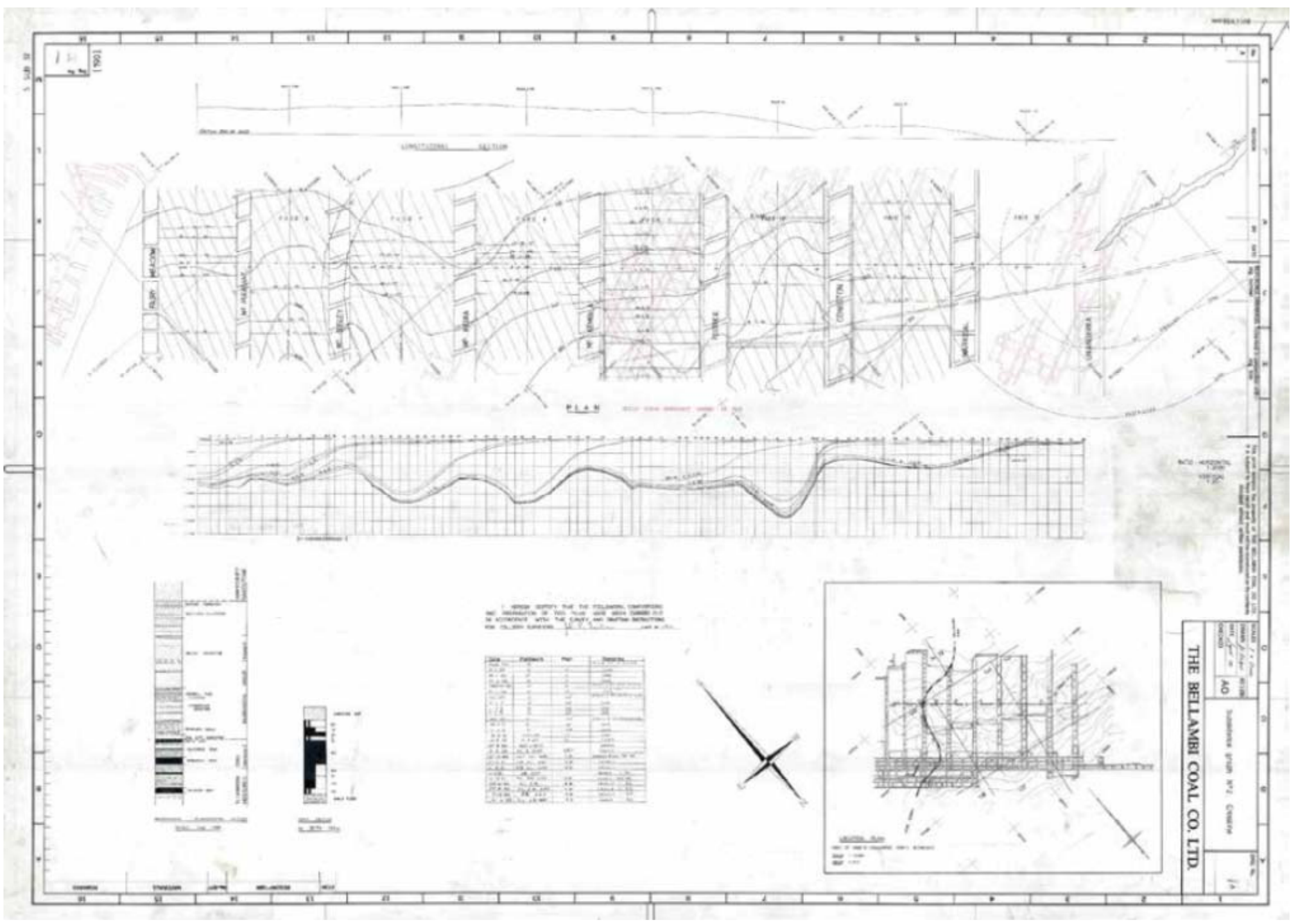


Figure 50 – Balgownie Seam Subsidence Monitoring

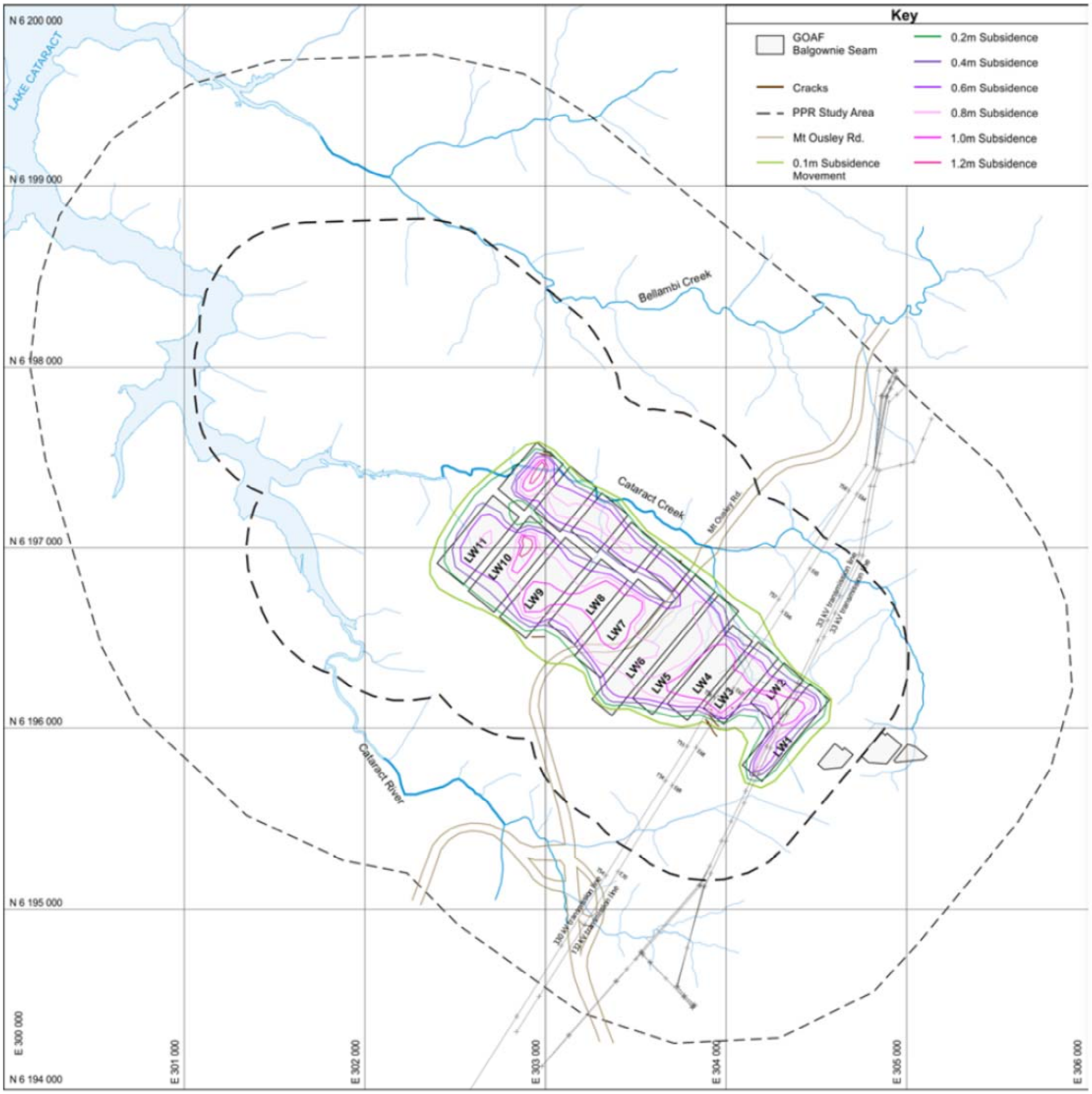


In areas where there is potential for either latent subsidence because the Bulli Seam goaf is narrow and bridging (such as in the high subsidence zone over LW11) or along a goaf edge where full subsidence has not been able to develop during mining the first seam (such as the high subsidence zone above LW10), the incremental subsidence reaches 1.4m and is of the order of 100% of the mining height of the second seam mined.

In the event that standing pillars in the Bulli Seam were destabilised by mining the Balgownie Seam, 0.4m of subsidence would be expected from mining below pillars in the Bulli Seam plus about 50% of the 2.2m mining height of the Bulli Seam given an extraction ratio of about 50% would be necessary for there to be standing pillars in the Bulli Seam. Thus it is also possible that the 1.4m of subsidence observed in the Balgownie Seam is a result of pillar destabilisation.

Figure 51, pg 165, shows the subsidence measured during mining the Balgownie Seam based on interpolation of the subsidence monitoring data. This data represents the incremental subsidence associated with mining the Balgownie Seam given that all the Bulli Seam subsidence had already occurred prior to the subsidence pegs being installed. Maximum subsidence is 1.42m and 1.33m over LWs 10 and 11 respectively but in most of the areas, subsidence over the longwall goafs is in the range 0.6m to 1.2m.

Figure 51 – Balgownie Seam Subsidence



Maximum strains measured over LW11 ranged from 3-4mm/m along the panel to peaks of 14mm/m in compression across the topographic low point of Cataract Creek and 9mm/m in tension on the slope beyond. For the maximum subsidence of 1.4m and an overburden depth to the Balgownie Seam at this location of 260m, the strain peaks measured indicate a relationship between maximum strain and maximum subsidence of:

- E_{max} = 500 S_{max} / D for systematic strains; and
- E_{max} = 1500-2500 S_{max} / D for non-systematic strains associated with valley closure and steep topography.

These compare reasonably with the peak strain subsidence relationships presented by Holla and Barclay (2000) for the Southern Coalfield which indicate:

- $E_{max\ tensile} = 1500\ S_{max} / D$
- $E_{max\ compressive} = 3000\ S_{max} / D$
- $Tilt_{max} = 5000\ S_{max} / D$

for peak strains and tilts that include non-systematic strains and tilts associated with valley closure and steep topography. The peak compressive strains tend to be apparent in topographic low points and the peak tensile strains tend to be apparent at the start of panels in ground sloping in the same direction as mining, and along topographic high points such as ridges.

The 14mm/m compressive strain peak measured across Cataract Creek on the centreline of LW11 as measured between pegs spaced 18m apart and the 4mm/m strain measured between the next two pegs spaced 15m apart imply a total closure across the creek of about 310mm. The ACARP method for estimating valley closure by Waddington and Kay (2003) indicates valley closure for this geometry and level of subsidence as being of the order of 200-300mm depending on assumptions about the somewhat irregular geometry associated with the short longwall panels. Valley closure at other locations is also evident as upsidence in the subsidence profiles that extend across Cataract Creek. The upsidence measured is summarised in **Table 47**, pg 166.

Table 47 - Comparison of Measured and Calculated Upsidence

Balgownie LW Panel	Distance from End of Panel (m) *(negative over goaf)*	Upsidence Indicated (mm) (not necessarily peak)	Overburden Depth (m)	Maximum Subsidence (m)	Calculated Upsidence (mm)
3	-170	130	230	1.1	70
4	-30	210	230	1.1	100
5	0	80	230	0.8	100
6	75	30	240	0.8	120
8	106	80	240	0.9	130
9	30	120	250	0.9	110
10	-20	100	260	0.9	100
11	-116	100	260	1.4	90

Upsidence measurements shown in **Table 47**, pg 166, are made at the peg locations. The pegs are 15-20m apart while the upsidence tends to peak over a distance of only a few metres. The location of the pegs may not necessarily coincide with the peak upsidence, so the measured upsidence is considered to be a lower bound estimate of the maximum upsidence that occurred. The measurements made during mining of the Balgownie Seam longwall panels indicate that Cataract Creek has already sustained upsidence in the range 100-300mm from this mining with some additional upsidence likely to have occurred during mining in the Bulli Seam.

The ACARP method for estimating upsidence for single seam mining operations indicates that upsidence from the Balgownie Seam longwall panels would have been in the range 70-130mm for each longwall panel. This method appears to still be relevant for estimating upsidence and valley closure for future mining activity in the Wongawilli Seam even in a multi-seam mining environment.

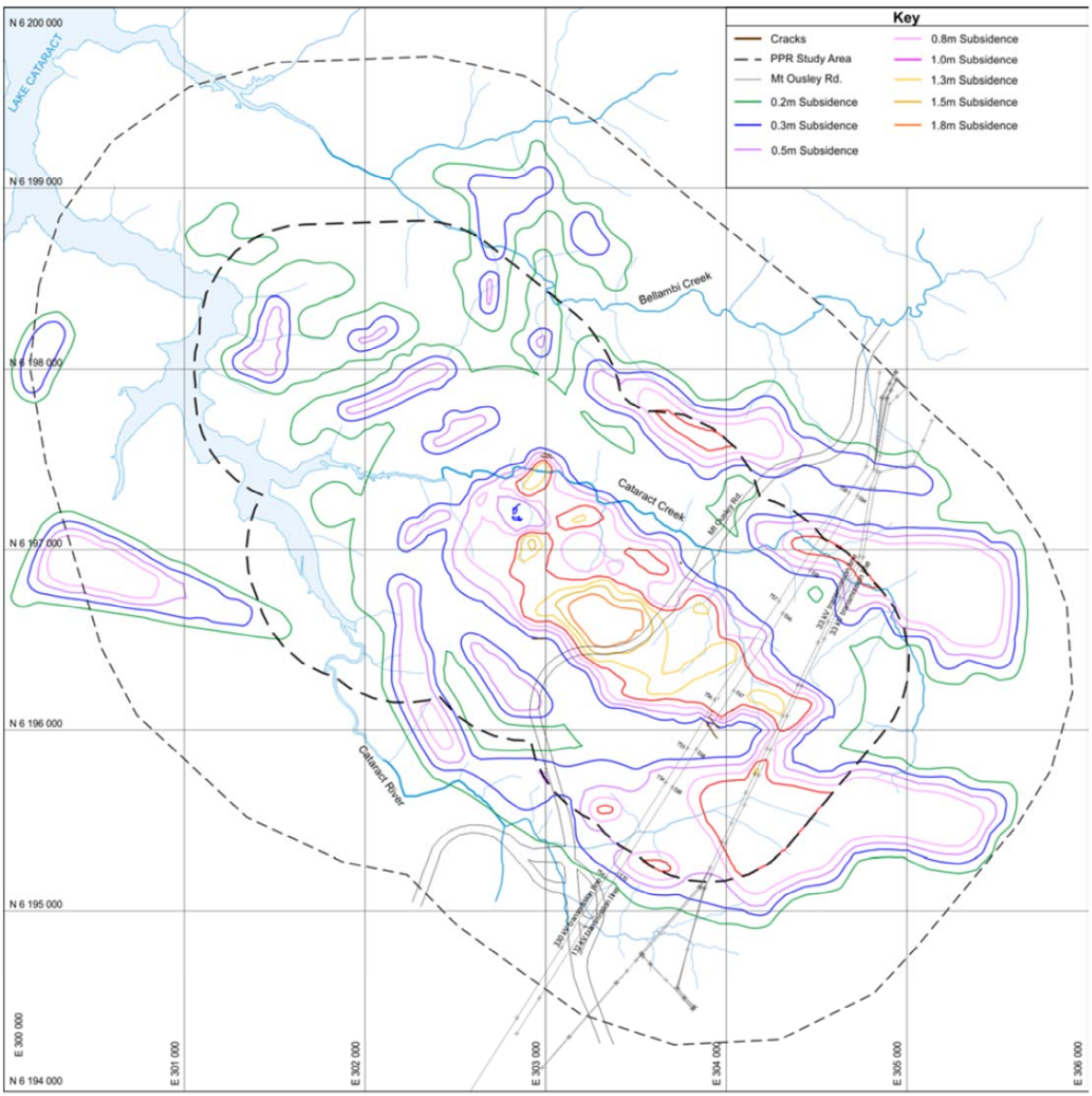
<u>Total Cumulative Subsidence</u>

The total cumulative subsidence associated with mining both the Bulli Seam and Balgownie Seam is an estimate because the Bulli Seam subsidence was not measured. The total subsidence can be used as an indicator of maximum subsidence when interpreting subsidence impacts from previous mining activity.

Figure 52, pg 167, shows the total cumulative subsidence estimated by adding together the estimated subsidence from the Bulli Seam and the measured subsidence from the Balgownie Seam using Surfer at a 10m by 10m grid spacing. The locations of surface features that have or may have been impacted by subsidence from this previous mining are also shown.

Maximum cumulative subsidence is approximately 1.9m in the area above LWs 7 and 8 in the Balgownie Seam just to the west of the Mount Ousley alignment on the slope to the south of Cataract Creek.

Figure 52 – Cumulative Subsidence for Bulli and Balgownie Seams



2.2.7.4 Subsidence Predictions

Surface subsidence is comprised of two aspects, sag subsidence and elastic strata compression which are discussed in more detail in **Attachment B**, pg 426. Sag subsidence results from the surface sagging into the gap left when the coal is removed and is essentially a measure of the capacity of the overlying rock strata to bridge the gap left by coal extraction. Elastic strata compression is the compression of the remaining coal pillar and the rock strata above and below it.

Multi-Seam Subsidence Behaviour

LW4 and LW5, both 150m wide, have recently been mined in the Wongawilli Seam. LW5 is still being extracted. Subsidence monitoring data for these longwalls has been used to provide insight into the incremental subsidence behaviour in a multi-seam environment, the magnitude of subsidence and subsidence impacts. **Figure 53** to **Figure 57**, pgs 169-173, show a summary of subsidence monitoring results for LW4 and LW5 along three cross-lines, two centre lines and the M-line which measures elastic chain pillar compression. LW4 experienced 1.3m of sag subsidence which increased to 1.6m when LW5 mined past it. This was due to an additional 0.3m subsidence in the centre of the panel from elastic compression of the chain pillars between the two longwall panels. The chain pillars actually compressed about 0.6m but only 0.3m of this was translated into the centre of LW4. The sag subsidence above LW5 was 1 to 1.2m but the measured subsidence of 1.3-1.5m was reflective of 0.3m of the total 0.6m of elastic chain pillar compression being translated to the centre of the panel.

Figure 52, pg 174, clearly shows the sag subsidence plotted as a function of the panel width for LW4 and LW5 and the sag subsidence that is commonly observed in undisturbed strata for a broad range of panel width to overburden depth ratios. LW4 was mined beneath both Bulli Seam and Balgownie Seam goaf whereas LW5 was mined beneath partly extracted Bulli Seam main heading pillars and Balgownie Seam goaf. Both longwalls experienced greater sag subsidence than in previously undisturbed strata, however LW4 experiences the greatest sag subsidence due to having the greatest disturbance of the overlying strata. This reduction of bridging capacity of the overlying strata has a significant effect on the maximum subsidence likely to be experienced from a given longwall. This is clearly observed in **Figure 59**, pg 174, that shows the goaf edge subsidence profiles that indicated the more seams extracted the lower the bridging capacity of the overburden.

Figure 53 – LW4 Subsidence Monitoring Summary

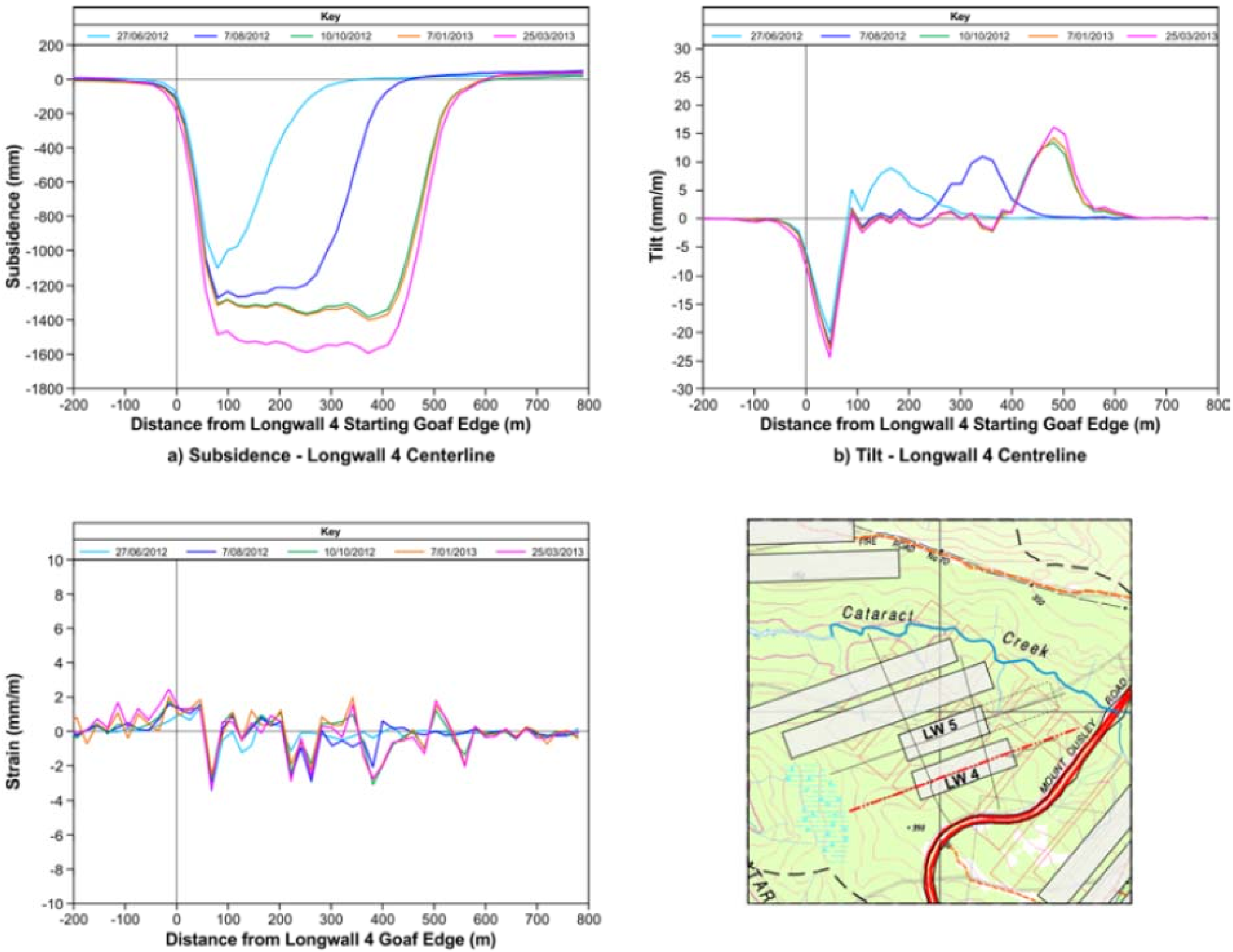


Figure 54 – LW5 Subsidence Monitoring Summary

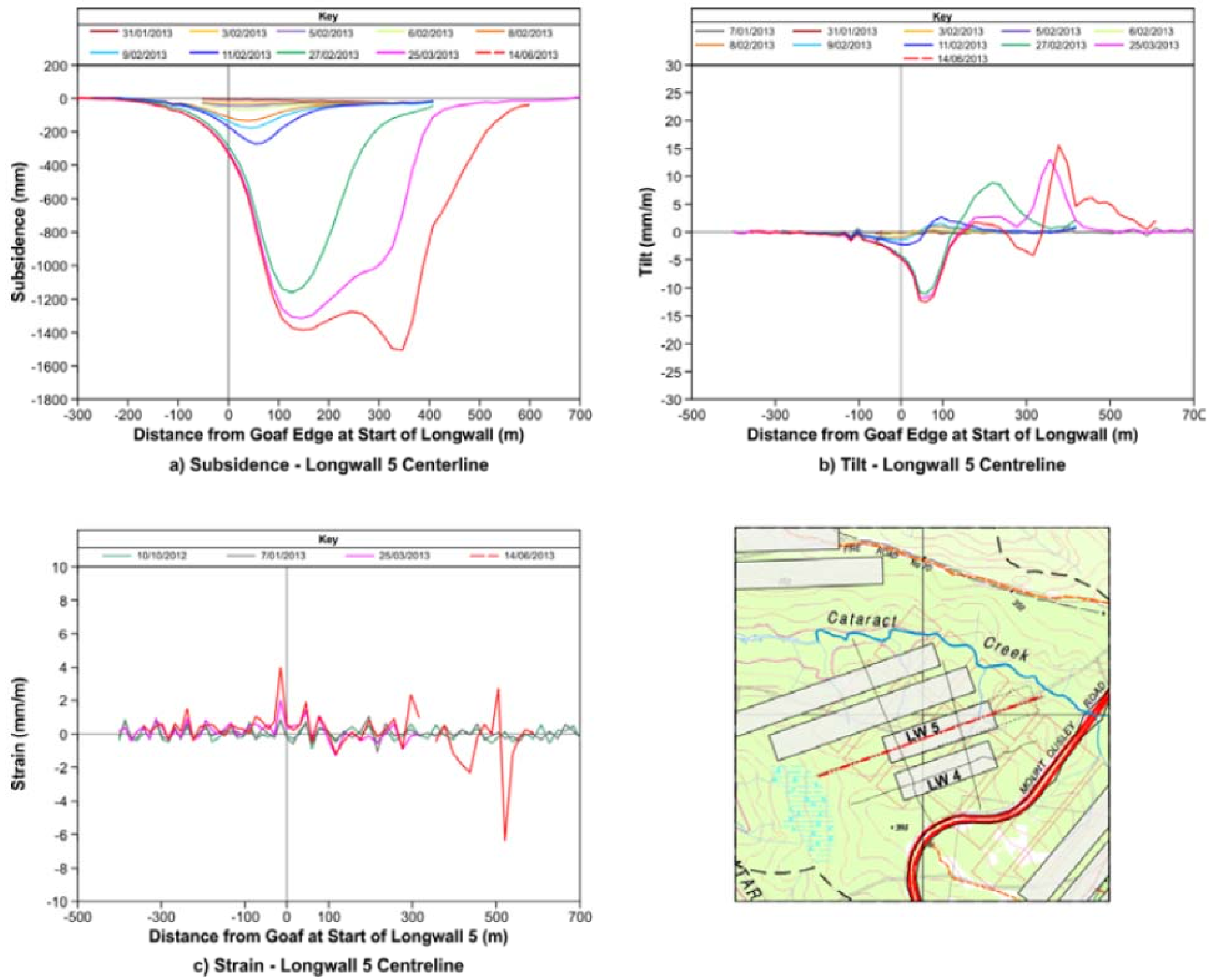
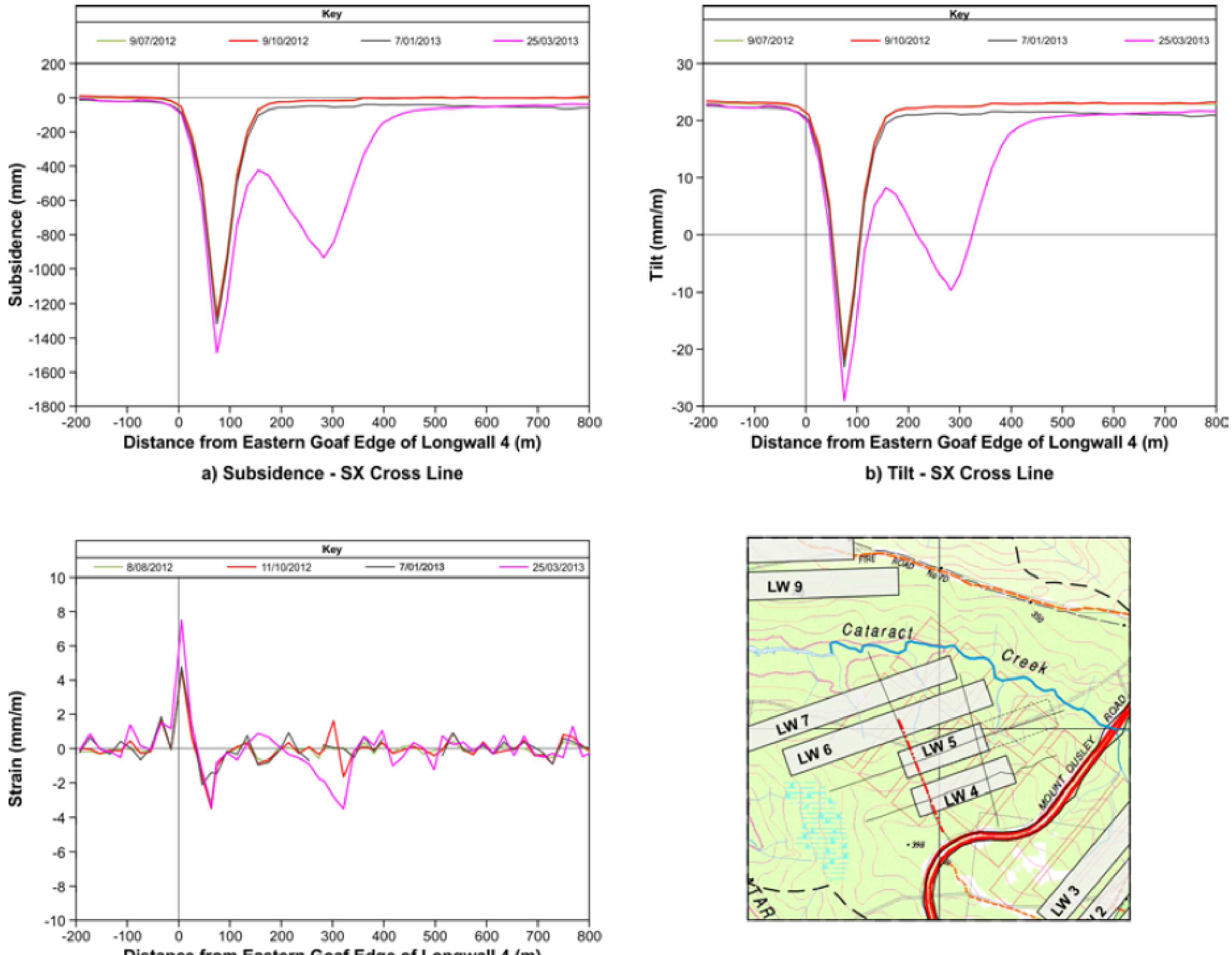


Figure 55 – LW4 and LW5 SX Line Subsidence Monitoring Summary



a) Subsidence - SX Cross Line

b) Tilt - SX Cross Line

c) Strain - SX Cross Section

Figure 56 - LW4 and LW5 SX Line Subsidence Monitoring Summary

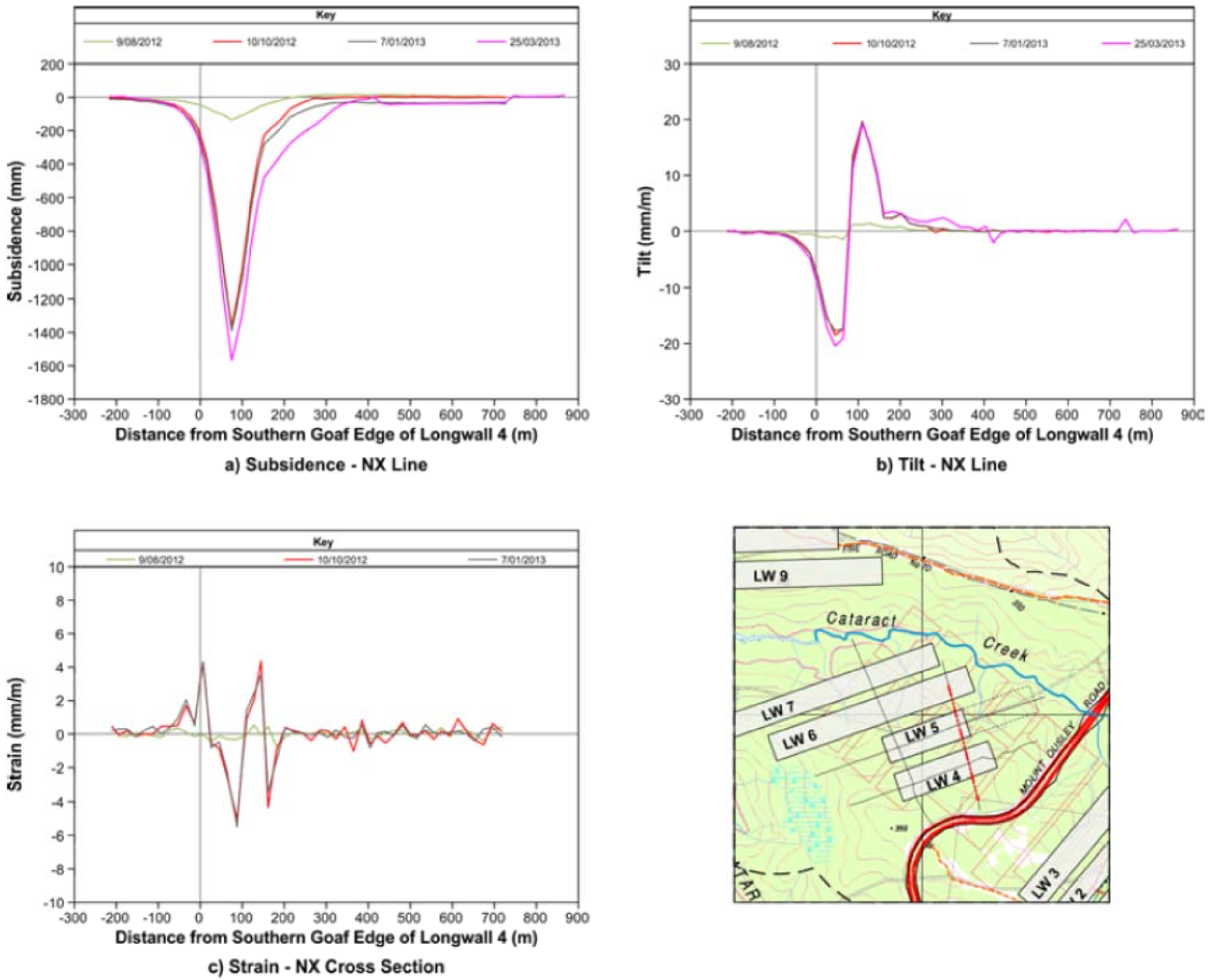
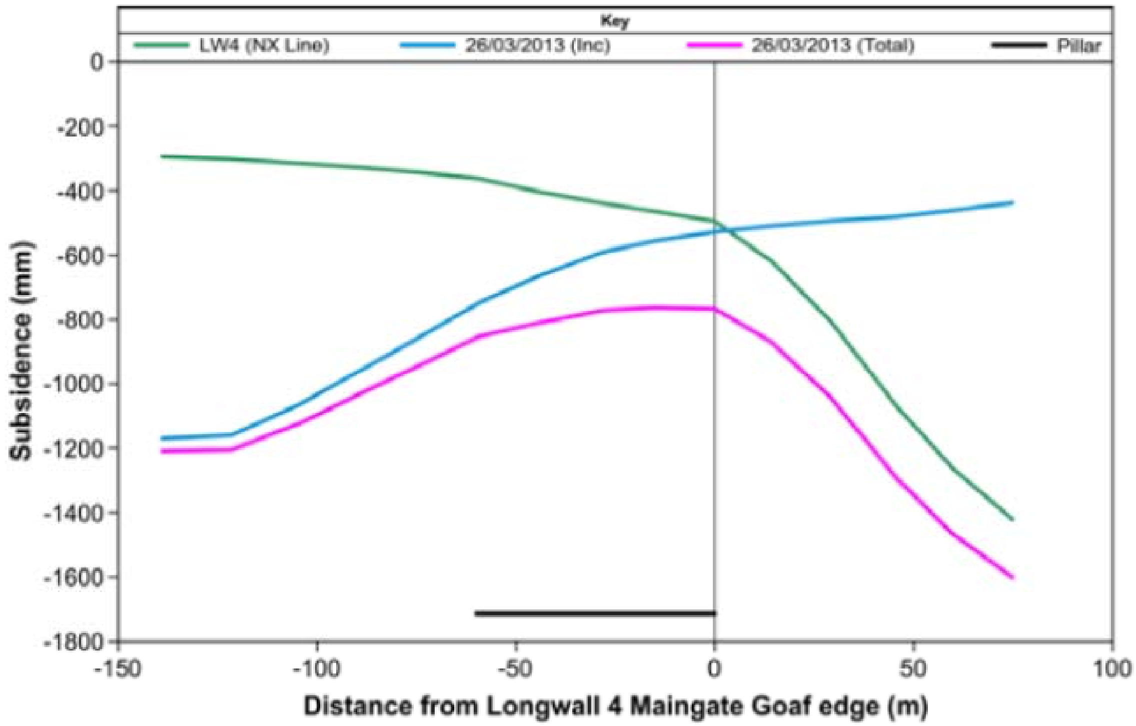


Figure 57 - LW4 and LW5 SX Line Subsidence Monitoring Summary



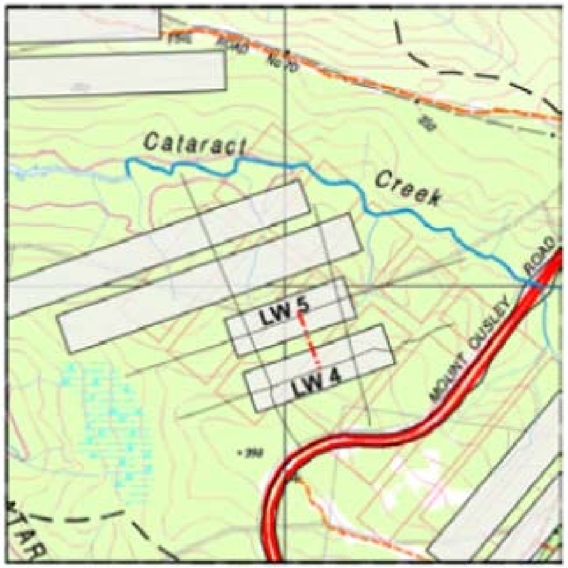


Figure 58 – Sag Subsidence Measured at the Start of LW4 and LW5

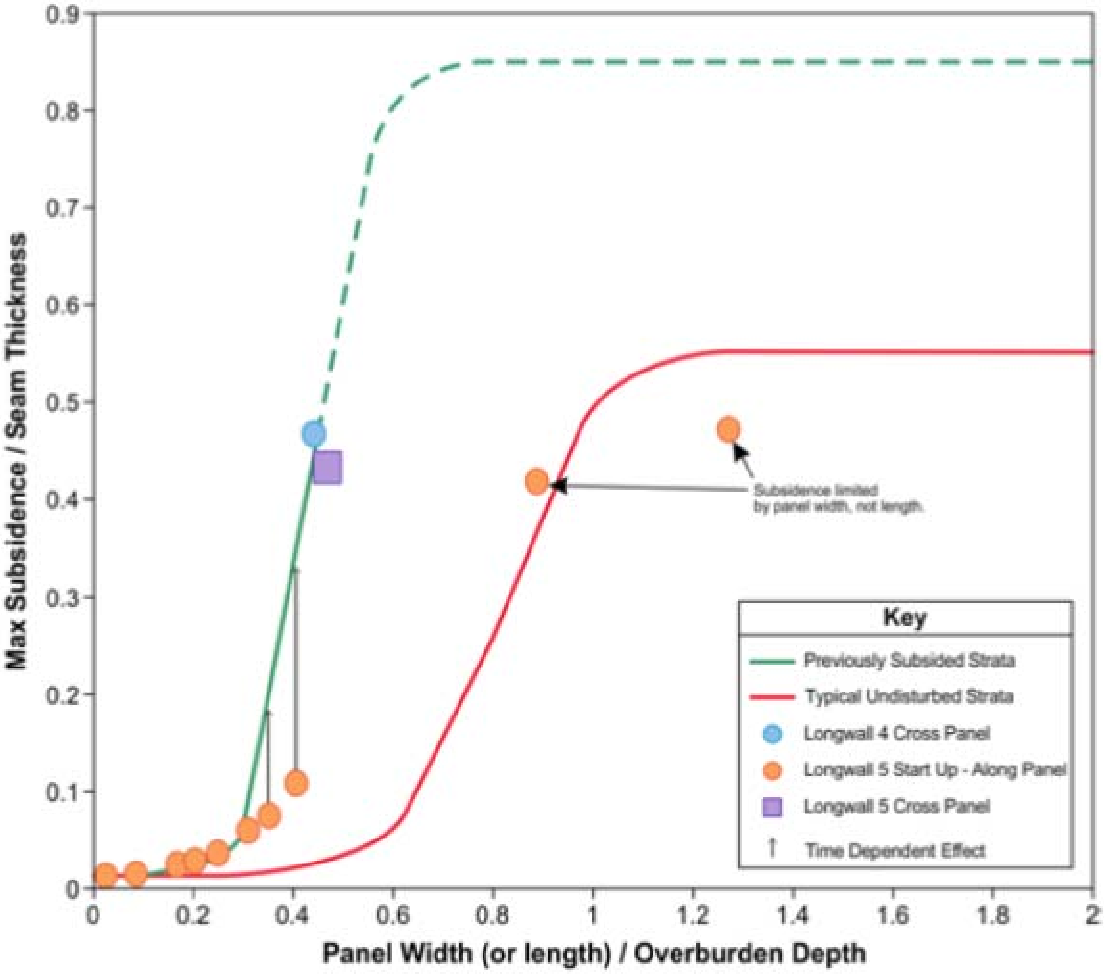
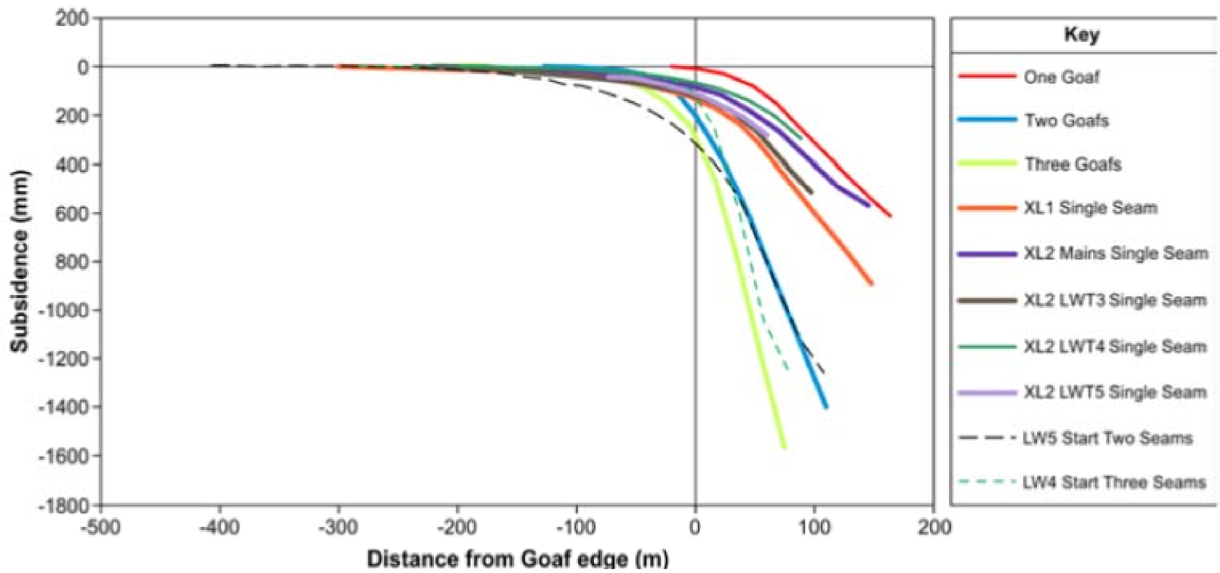


Figure 59 – Summary of Goaf Edge Profiles for Mining in One, Two and Three Seams

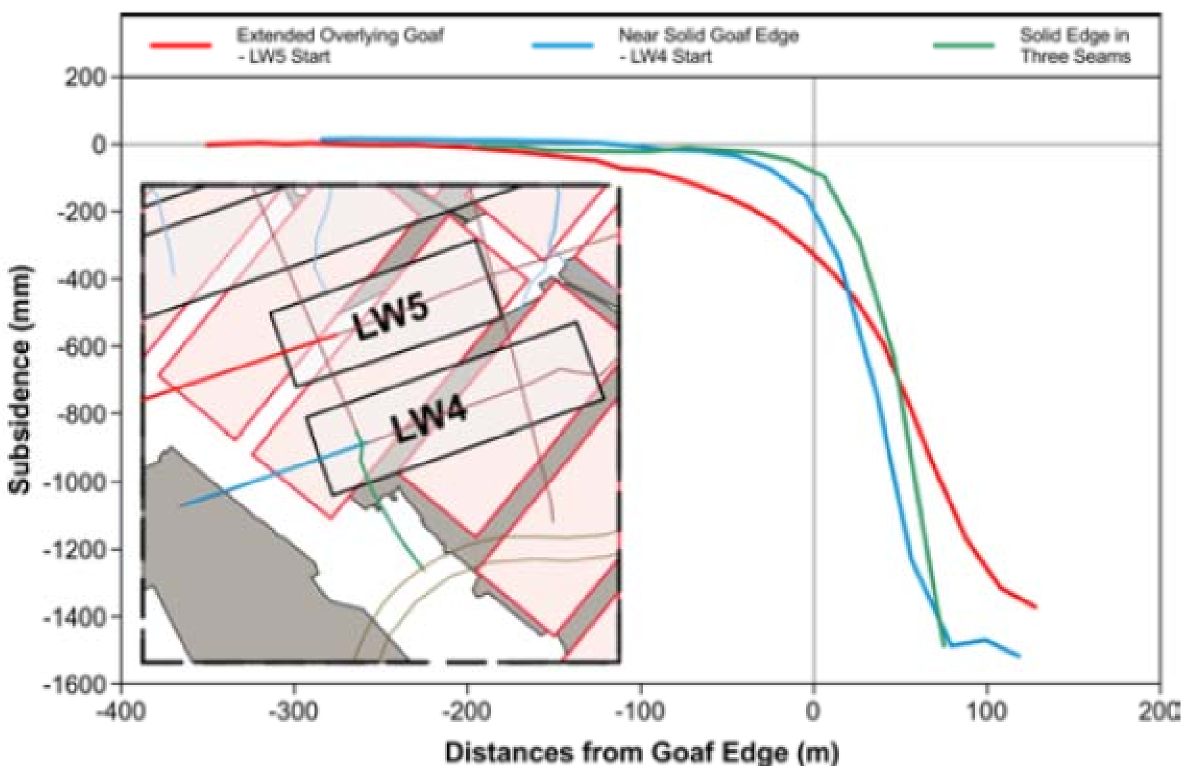


For a single seam extraction of a 150m wide longwall panel at between 300-360m depth the surface subsidence would be expected to range between 0-1-0.3m. In contrast LW4 experienced 1.3m of sag subsidence. This increased subsidence was also noted for the Balgownie Seam longwall extraction when it occurred below Bulli goaf compared to when it was mined beneath solid pillars. The elastic chain pillar compression on the 60m chian pillar between LW4 and LW5 was 0.6m and is considered to be consistent with a 340m depth of cover.

A significant characteristic of the subsidence observed over LW4 and LW5 is that the additional sag subsidence is essentially limited to the panel footprint. This is despite the variability of having two goafs, one goaf or one goaf and pillars over parts of LW4 and LW5. The cross panel subsidence profiles indicate that the maximum subsidence in the centre of panels is controlled by overburden bridging capacity and not strata recompression.

There are subtle variations outside the goaf edge compared to single seam mining operations. Softer subsidence profiles and greater goaf edge subsidence are evident where there are goaf areas in both the Bulli and Balgownie Seams as can be seen in **Figure 60**, pg 175. Where there are goaf areas directly above the goaf edge in only one of the overlying seams, the subsidence profile is sharper and shows less subsidence outside the goaf. When there are no overlying goaf areas, the subsidence profile is sharpest and the subsidence profile beyond the goaf edge is essentially the same as for single seam mining geometries.

Figure 60 – Goaf Edge Variations Over LW4 and LW5



Potential Pillar Run

In areas where there are small standing pillars in the Bulli Seam above the goaf edge, mining in the Wongawilli Seam below may cause these pillars to be destabilised. If the pillars were destabilised, the resulting subsidence from the pillar destabilisation could then extend outside the Wongawilli Seam goaf edge to the edge of the overlying pillar panel in the Bulli Seam.

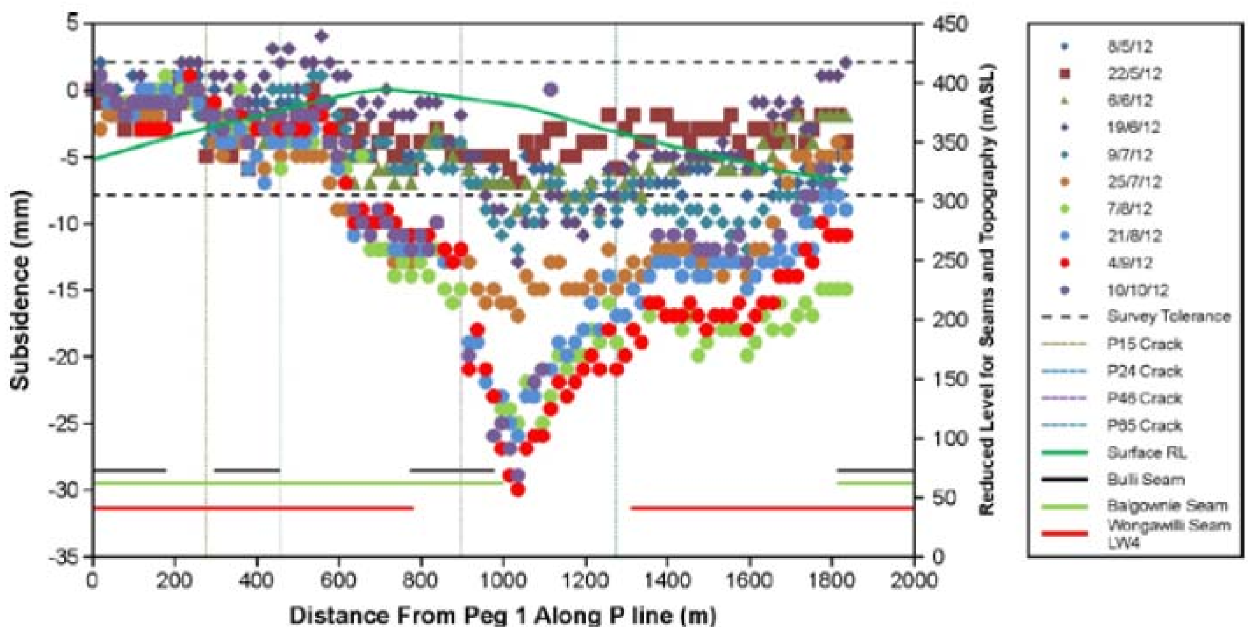
There has been no evidence of this type of behaviour so far from longwall mining in the Wongawilli Seam or in the Balgownie Seam but there is considered to be some opportunity for additional subsidence during mining of Longwall 1. A panel of Welsh bords was visited during the site inspection on 21 June 2012 in an area of the Bulli Seam immediately above and to the northeast of the end of Longwall 1 as shown in **Figure 48**, pg 161. If this area of pillars was destabilised, surface subsidence could extend some 100m to the northeast of the panel and up to 300m east of the eastern corner of Longwall 1, but this subsidence would only occur if Longwall 1 was mined full length and the pillars in the Bulli Seam were destabilised. Special consideration is required in this area to manage this potential.

<u>Observed Subsidence Extent</u>

Survey measurements conducted along the edge of the northbound lane of Mount Ousley Road have measured the effect of multi-seam mining based on the distance from the goaf edge providing evidence that vertical subsidence diminishes to low levels a short distance beyond the goaf edge.

Figure 61, pg 176, shows a summary of the vertical subsidence measured along Mount Ousley Road during mining of LW4. The projections of adjacent goaf areas in the Bulli, Balgownie, and Wongawilli Seams are also shown. The subsidence observed is of low level reaching a maximum of 31mm at the projected centre of LW4 some 180m from the goaf edge at an overburden depth of 350m.

Figure 61 – Subsidence Along Mt Ousley Rd



These measurements indicate the angle of draw to 20mm of subsidence is greater than 26.5° consistent with experience elsewhere in the Southern Coalfield at this overburden depth. At the projection of the north-eastern corner of Longwall 4 where both the Bulli Seam and the Balgownie Seam have been mined, subsidence at 230m from the goaf corner is 20mm at 320m deep indicates the angle of draw to 20mm off the corner of the panel is equal to 35°. At the south-eastern corner of Longwall 4, where the Balgownie Seam has not been mined but there are areas of mining in the Bulli Seam, the 14mm of subsidence at 225m at 360m overburden depth indicates an angle of draw off the corner of the panel of less than 32°. Other cross line measurements indicate the vertical subsidence is 50mm at between 20m and 100m from the goaf edge.

On the basis of these measurements, the angle of draw to 20mm of subsidence is considered likely to be slightly greater than 35° in areas where both overlying seams have been mined and slightly less than 35° where only one overlying seam has been mined. The angle of draw is therefore not significantly different to the angle of draw that would be expected for mining in a single seam at similar overburden depths. There does not appear to be any evidence of significant vertical subsidence outside the panel being mined associated with any type of pillar run.

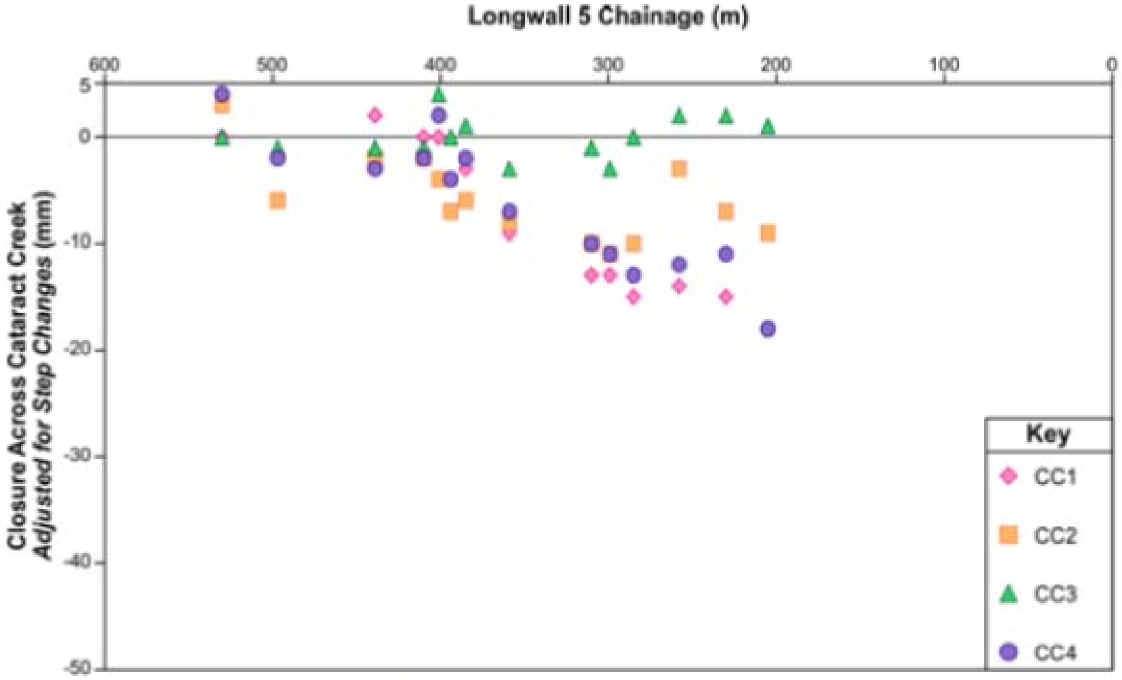
Observed Far Field Movements

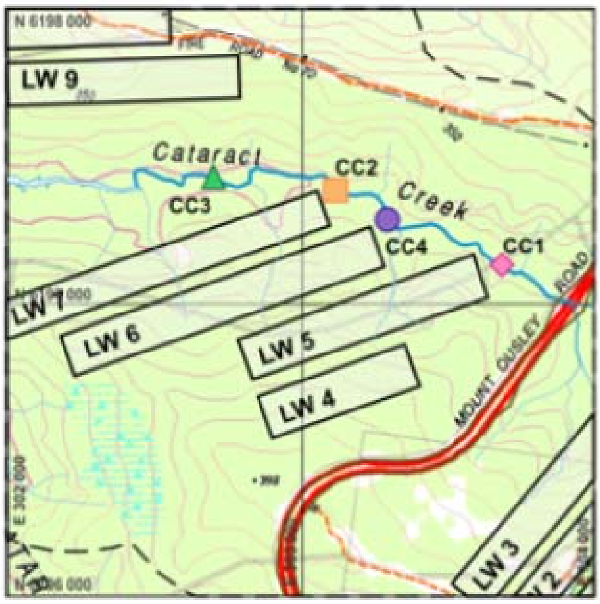
There are several sources of far-field horizontal subsidence measurements available from mining LW4 and LW5. The Mount Ousley Road P Line and Picton Road Interchange provide measurements of horizontal movements based on three dimensional GPS controlled surveying and the closure measurements across Cataract Creek provide an indication of the horizontal movement in the middle distance. Observations of cracks on Mount Ousley Road provide an indication of the horizontal distance that changes potentially associated with mining have been observed.

The GPS controlled surveying showed no convincing evidence of far-field horizontal movements. The survey tolerance of the systems being used is ±20mm. The monitoring at Picton Road Interchange is approximately 1300m from the southern end of LW4 and there is no evidence that there has been any differential or even total movement at the interchange associated with mining LW4 or LW5.

Figure 62, pg 178, shows the closure measurements on Cataract Creek up until the end of August 2013. Closure measurements across Cataract Creek first became evident at three of the four measurement points when LW5 was 450m from the finishing end of the panel (i.e. at longwall chainage CH450m). The longwall face at this position was approximately 320m from CC4, 420m from CC2, 530m from CC1, and 700m from CC3. At Cataract Creek where the measurement points are located, the overburden depth to the Wongawilli Seam is approximately 280m, so the horizontal closure movements have been observed out to a distance from the goaf edge equal to between 1.1 and 2.9 times depth.

Figure 62 – Cataract Creek Closure During Extraction of LW5





The closure measured on the Cataract Creek has steadily increased to about 20mm at CH205m (250m from CC1) as LW5 has continued to retreat. These measurements indicate that far-field downslope movements have been evident to a distance of between 530m and 700m from the approaching longwall panel but are of low magnitude at distances beyond 250m (0.9 times overburden depth). Relatively fresh cracks have appeared on Mount Ousley Road at P24 and P25 are approximately 500m from the southern end of Longwall 4 at an overburden depth of about 360m, so there is some evidence of small horizontal movements to a distance of about 1.4 times overburden depth.

Subsidence Prediction Methodology

The subsidence prediction methodology used in this assessment is based on consideration of the mechanics of the subsidence processes involved, particularly the differences between the two components of subsidence, sag subsidence and elastic compression subsidence and using measured subsidence profiles to characterise the subsidence behaviour and provide a basis for prediction of subsidence associated with future mining. This approach is considered to be appropriate in the relatively complex mining environment that exists within the PPR Assessment Area especially now that there is actual subsidence data available from LW4 and LW5.

As a result of mining in two other overlying seams, prediction methods such as the Incremental Profile Method which relies on repeatable elastic superposition of goaf edge profiles and the Influence Function Method which assumes essentially elastic strata behaviour become unreliable because of the complex and variable characteristics of the overburden strata when mining has occurred in multiple seams.

The method used to estimate subsidence in all three seams is primarily based on existing monitoring data. Contours of subsidence for the Bulli Seam mining operations have been estimated using subsidence profiles measured in the 1990's over the longwall panels at South Bulli Colliery (now owned by NRE). These profiles have been adjusted for overburden depth and contours of subsidence have been drawn in AutoCAD relative to the edges of goaf areas indicated on mine record tracings. The subsidence observed on the surface above the Balgownie Seam longwall panels also provides an indication of the status of the Bulli Seam mining. The Bulli Seam subsidence contours have been modified slightly to reflect this indicated status. The subsidence contours thus produced have then been converted into gridded model of subsidence values on a 10m by 10m grid using Golden Software's Surfer program.

Hard copies of measured subsidence from each of the Balgownie Seam longwall panels are available in the mine archives. These drawings have been scanned, scaled, and converted into a format that allows the final subsidence across all the panels to be contoured in AutoCAD. The contours have then been converted to a 10m x 10m grid of subsidence using the same approach described above for the Bulli Seam subsidence.

Subsidence predictions for mining in the Wongawilli Seam are based on measured subsidence profiles from LW4 and LW5. These profiles have been adjusted for panel width and overburden depth and allowances have been made for possible chain pillar interactions with the overlying Balgownie Seam longwall goafs above LWs1-3. The contour plots generated have again been drawn in AutoCAD and then gridded in Surfer onto a 10m by 10m grid. The combined subsidence from each seam or from combinations of seams has then been determined by adding together the components from each seam.

Contours of the surface topography have been generated from LiDAR data on the same 10m by 10m grid to allow the subsidence to be added and subtracted from the surface topography. Contours of the three coal seams have been developed from survey information of floor seam contours available in the Bulli Seam within the mine lease boundary. The Balgownie and

Wongawilli Seam floor contours have been estimated from the Bulli Seam floor contours assuming a separation of 10m and 30m to the Bulli Seam respectively. Overburden depth to the Wongawilli Seam has been determined as the difference in the Surfer model between the surface topography and the estimated Wongawilli Seam floor contours.

Estimates of strains and tilts presented in this assessment are based on measured values and the experience more broadly of monitoring in the Southern Coalfield reported by Holla and Barclay (2000). This broader experience is considered to provide a strong basis for predicting surface strains and tilts. Based on the subsidence measurements that have been made over LW4 and LW5 and previously above the Balgownie Seam longwall panels, the method described by Holla and Barclay (2000) appears to provide a reasonable and conservative basis to predict the incremental maximum strains and tilts even for multi-seam mining environments.

The strains and tilts are highly variable and are generally of a much more modest magnitude than the peak values. For prediction purposes, the peak values have been determined to be conservative and recognise that the exact position of the maximum values is difficult to determine accurately. Although the exact position of peak strains is difficult to determine, it is recognised that peak tensile strains are most likely to occur at topographic high points and the start of panels, particularly in areas where mining is proceeding in a downslope direction. Peak compressive strains are most likely to occur in topographic low points or near the finishing end of the panel particularly when mining in a downslope direction.

The measurements of incremental tilts and strains made so far indicate that the background values of tilts are more generally of the order of 50-80% of the peak values and background values of strains are more generally of the order of 20-30% of the peak values indicated by the approach presented by Holla and Barclay (2000).

Closures across Cataract Creek have been estimated using the ACARP method developed by Waddington, Kay and Associates (2003). This method is recognised to be an upper limit prediction method and an alternative approach has also been used based on the increment from only the nearest panel.

Prediction Accuracy

The subsidence monitoring data available from the eleven longwall panels in the Balgownie Seam mined 10m below the Bulli Seam and more recent subsidence data from LW4 mining under two levels of previous mining and from LW5 mining under Balgownie Seam goaf and Bulli Seam main heading pillars is considered to provide a strong basis to predict future subsidence. The accuracy of the subsidence predictions is limited by the uncertainties that exist in a natural environment combined with additional uncertainties about the detail of mining geometries in the Bulli Seam and some aspects of subsidence behaviour in a multi-seam mining environment.

Available subsidence monitoring data from mining in the PPR Assessment Area indicates that the subsidence associated with multi-seam subsidence in this area is essentially similar to the subsidence behaviour in a single seam mining environment except that the bridging capacity of the overburden strata is significantly reduced. This reduction in bridging capacity affects the magnitude of the maximum sag subsidence over the centre of each longwall panel. Importantly though, subsidence occurs predominantly within the footprint of the panel being mined and the panel width can still be used to control the magnitude of maximum subsidence. Also, elastic strata compression subsidence above the chain pillars between longwall panels appears to be similar to that which occurs in single seam mining operations.

Subsidence at the goaf edge is also somewhat softened by previous mining activity in overlying seams but this is of minor significance. The angle of draw to 20mm of subsidence appears to be of the order of 35° and consistent with experience in single seam mining operations.

The uncertainties that remain from predicting subsidence behaviour in a multi-seam environment are offset somewhat by the benefits of having previous subsidence monitoring experience and the opportunity to review the longer term recovery of surface impacts associated with earlier mining activity. The ability to inspect all three levels of underground mining also improves confidence in the understanding of the mechanics involved at this site.

There exists some potential in areas where there are small standing pillars in the Bulli Seam above the goaf edge for these pillars to be destabilised by mining in the Wongawilli Seam below similar to the destabilisation that is evident in the Bulli Seam beyond the end of Longwall 7 in the Balgownie Seam. If the pillars were destabilised, the resulting subsidence from the pillar destabilisation could then extend outside the Wongawilli Seam goaf edge to the edge of the overlying pillar panel in the Bulli Seam. The only place where this type of behaviour appears credible is in an area beyond the northeast corner of Longwall 1.

The monitoring data indicates that maximum sag subsidence is able to be controlled by the width of individual panels. It is nevertheless helpful to have an indication of the maximum credible subsidence that might result. Li et al (2010) provide a summary of the experience of multi-seam mining subsidence that indicates maximum subsidence of up to 83% of the cumulative mining height for all seams compared to 65% for single seam mining. The maximum subsidence indicated by this approach provides an upper limit to the maximum subsidence.

The combined mining height for all three seams ranges 5.4-6.9m depending on how much the thickness of the Bulli Seam is discounted to allow for the realistic recovery rates of pillar extraction and bord and pillar mining. The maximum subsidence using 85% of this thickness would be 4.6-5.8m.

Maximum subsidence of up to 1.4m has so far been observed above the Balgownie Seam with an additional 0.5m estimated for the Bulli Seam to give a maximum of 1.9m of subsidence from previous mining. Using the Li et al approach would indicate maximum subsidence from mining in the Wongawilli Seam would be likely to be in the range 2.7m (allowing for the 1.9m that may have already occurred) to 5.8m (in areas of small standing pillars in the Bulli Seam that may be destabilised by further mining and are coincident with the goaf edge of Balgownie Seam longwall panels).

Above LW4 and LW5, the maximum subsidence measured in the centre of the longwall panels ranges from 1.3-1.6m and is much less than the maximum subsidence that would be expected if these panels were wider. The subsidence observed above LW4 and LW5 is significantly reduced from this maximum by the bridging characteristics of the overburden strata albeit the bridging capacity is reduced compared to undisturbed strata. Although the bridging capacity of previously mined strata is less than the bridging capacity of undisturbed strata, the narrower panel widths of LW4 and LW5 and the remaining longwalls proposed within the Preferred Project are clearly still limiting maximum subsidence to well below the level that would be observed if the panels were wider and full subsidence could develop in the centre of each panel.

Strain and tilt values observed to date are within the range of predicted values using the approach presented by Holla and Barclay (2000). While it is possible that higher values of strain and tilt may be observed in isolated locations, the approach is considered unlikely to significantly underestimate strain and tilt values. Small errors or tolerances in the data used in the assessment are not considered likely to significantly influence the accuracy of the subsidence predictions. The LiDAR surface data is expected to be accurate to a few tens of centimeters across the entire Assessment Area. The Bulli Seam floor contours have been surveyed and are therefore likely to be accurate to a few tens of centimeters also. The Assessment Area extends beyond the mine lease boundary so the floor contours beyond the lease boundary have been extrapolated and are therefore of lower confidence, but are nevertheless considered suitable for the purposes of this assessment. There is potential for a 5-10m difference in seam separation across the Assessment Area that will slightly affect the calculation of overburden depth, but not significantly.

Subsidence Predictions

Figure 63, pg 183, shows the contours of subsidence predicted above the proposed longwall panels in the Preferred Project. The area is also shown where special consideration of the potential for pillar instability in the Bulli Seam is recommended.

Table 48, pg 184, presents a summary of the predicted subsidence movements for mining in the Wongawilli Seam, as well as estimated and measured subsidence in the Bulli Seam and Balgownie Seam in the area of each Wongawilli Seam longwall panel. Actual measurements from the Balgownie Seam longwalls and LW4 and LW5 in the Wongawilli Seam are shown in brackets as a basis for comparison with the predictions.

Maximum subsidence over individual longwall panels in the Wongawilli Seam is predicted to range from 1.5m over the slightly narrower LW7 through to 2.6m over LW3 where the overburden depth is shallowest and there is overlying goaf in both seams.

Figure 63 – Predicted Subsidence for the Wongawilli Seam

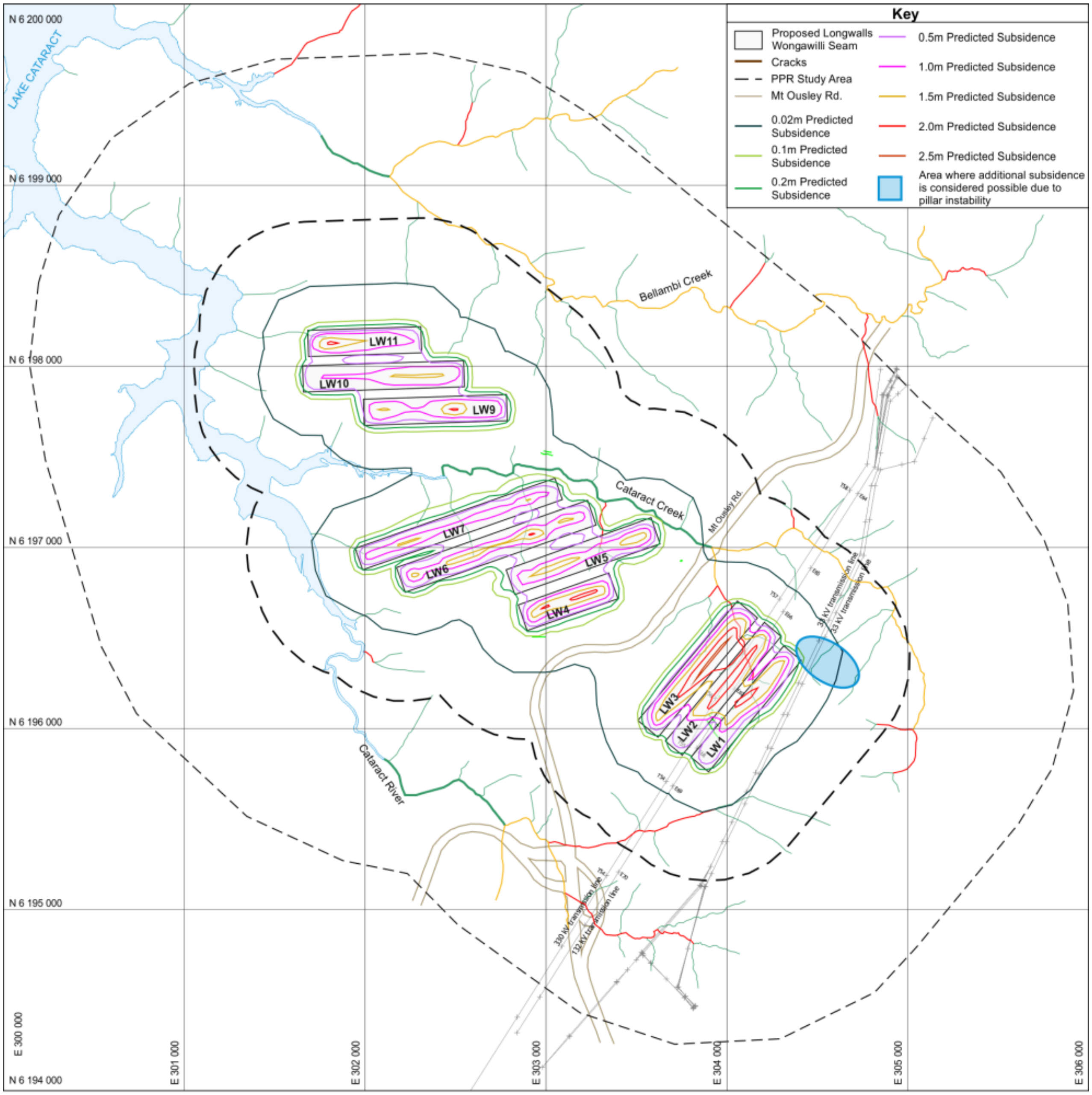


Table 48 – Subsidence Predictions for the Preferred Project Assessment Area

General Observations Above Individual Panels	Overburden Depth to WWSM (m)	BUSM and BASM Subsidence (m)	WWSM Subsidence Predicted (m) and Measured (in bold)	BASM Tilt (mm/m)	Predicted WWSM Tilt (mm/m) and Measured (in bold)	BASM Max Tensile Strain (mm/m) and Typical (in brackets)	Predicted WWSM Tensile Strain (mm/m) and Measured (in bold)	BASM Max Compressive Strain (mm/m) and Typical (in brackets)	Predicted WWSM Compressive Strain (mm/m) and Measured (in bold)	Closure on Cataract Creek Observed Directly and Inferred from Upsidence (mm)	Closure on Cataract Creek (mm) (Southern Tributary in Brackets)
Longwall 1	260	1	2.1	19	40	NA	12	NA	24	NA	NA (650)
Longwall 2	260	1	2.1	19	40	NA	12	NA	24	NA	NA (610)
Longwall 3	255	1	2.6	13	51	NA	15	NA	31	NA	NA (350)
Longwall 4	300	2	2.1 **(1.6)**	11	35 **(30*)**	NA	10.5 **(7.5)**	NA	21 **(14)**	100	NA
Longwall 5 *(in progress)*	265	1	1.9 **(1.5*)**	11	36 **(16*)**	NA	10.8 **(4.5*)**	NA	22 **(14*)**	130	210 **(20*)**
Longwall 6	280	2	2.1	18	38	7.5 (3)	11	14 (4)	23	310	400
Longwall 7	270	1	1.5	18	28	7.5 (3)	8	14 (4)	17	310	400
Longwall 9	330	1	2.1	NA	32	NA	10	NA	19	NA	50
Longwall 10	340	1	1.6	NA	24	NA	7	NA	14	NA	30
Longwall 11	350	1	2.1	NA	30	NA	9	NA	18	NA	10
Selected Natural Features											
Threatened frog habitat CRUS2 Trib	300	1	0	5 (est)	0	3	0	4	0		
Threatened frog habitat CRUS1 Trib1	320	1	0	5 (est)	0	3	0	4	0		
Threatened frog habitat CRUS1 Trib2	320	1	0.02	11 (est)	0	3	0	4	0		
CCUS4 Trib	270	1	1.5	18	28	7.5 (3)	8	14 (4)	17		
Cliffs over LW9	330	1	2.1	NA	32	NA	10	NA	19		
Cataract Creek	260	1	0.1	15 (est)	1	NA	0	NA	NA		

Maximum tilts over individual longwall panels in the Wongawilli Seam are expected to range from peaks of 24mm/m over LW10 through to peaks of 51mm/m above LW3. The peak values predicted are expected to be the maximum anywhere in the panel, most likely at goaf edges in overlying seams and in areas of topographic change in gradient. More generally across the panel, systematic tilts are likely to be in the range 50-90% of the peak values.

Maximum strains over individual longwall panels in the Wongawilli Seam are expected to range from peaks of 14mm/m over LW10 to peaks of 31mm/m over LW3. The peak values predicted are expected to be the maximum anywhere in the panel. More generally across the panel, systematic strains are likely to be 20-30% of the peak values.

The upper limit of valley closure across Cataract Creek downstream of the Mount Ousley Road has been estimated using the ACARP Method as being in the range up to 400mm adjacent to the ends of LW6 and LW7 and up to 210mm for LW5. These closure estimates are recognised as being upper limit values because they are based on experience in the deep gorges around Tower Colliery where the in situ stresses are much higher. The measurements made so far during mining of LW5 indicate closure values being measured are much lower than the maximums estimated using the ACARP method.

There is considered to be no potential for significant valley closure movements along the section of Cataract River adjacent to the start of LW6 and LW7. These longwall panels are located substantially on the northern side of the ridge and any downslope horizontal movements are expected to occur mainly on the northern slope toward Cataract Creek. There is also considered to be potential for valley closure across numerous first, second, and third order creeks in areas where longwall panels are located directly below the slopes that lead down to these creeks and the creeks are within about 300m of the longwall panel goaf edge.

Movements outside the goaf edge are expected to be similar to the movements observed so far during mining of LW4 and LW5. Vertical movements of greater than 20mm are expected to be limited to within a distance of 0.7 times overburden depth from the nearest goaf edge equivalent to an angle of draw of 35°. In areas where there has been previous mining in both the overlying seams, vertical subsidence at the goaf edge is expected to be up to 300-500mm and the goaf edge subsidence profile is expected to be general softer than elsewhere. In areas where there is either solid coal or substantial coal pillars directly above the goaf edge, goaf edge subsidence is expected to be of the order of 100-200mm.

The area of potential pillar instability adjacent to the end of Longwall 1 may cause additional vertical subsidence of up to about 0.7m over a limited area to a distance of about 300m from the goaf corner in an area where the overburden depth is about 270m.

Far field horizontal movements are also expected to be of low magnitude but may still be perceptible at up to 1.5-3 times overburden depth from the nearest goaf edge. These movements may be concentrated above previous goaf edges such as has been observed to date along the Mount Ousley Road. Horizontal downslope movements associated with valley closure have been observed to extend ahead of mining in a downslope direction to distances ranging from 1 times overburden depth to 2.9 time overburden depth when mining below the slope.

2.2.7.5 Subsidence Impacts

Historical Mining Impacts

It is difficult to separate Bulli Seam and Balgownie Seam subsidence impacts. The obvious impacts are rock falls, surface cracking of rock outcrops and changes to streams such as iron staining, upsidence cracking, and sediment infilling of subsided sections.

Surface cracking was recorded near the start of Balgownie LW3 in the vicinity of the electrical transmission lines was recorded during the Balgownie Seam extraction. The cracking occurred on a topographic where horizontal movement at the start of the extraction and downslope movement would be expected to occur. During the extraction of LW5 a linear depression that appears to be associated with surface cracking opened up at the southern corner of LW4. It was located on the top of a ridge between Cataract River and Cataract Creek where horizontal movements are likely to cause cracking and at a point where the goafs of all three seams were superimposed. Based on an assessment of subsidence data it is apparent that the crack was caused by prior mining and then infilled over time by sediment and other material.

There are several areas across the Assessment Area that show evidence of rock falls that occurred during prior mining. In particular a cliff above LW9 that contains archaeological site 52-2-3941 appears to have suffered fracturing and resultant rock falls as a result of Bulli Seam mining. There was a small rock fall located over Balgownie LW10 at the head of a small gully that is likely to have occurred as a result of the concentration of horizontal compression movements in the location. In both mined and non-mined areas are numerous natural rock falls, some reasonably recent, consistent with natural erosional processes.

Cataract Creek over Balgownie LW11 was subsidence by about 0.4m over a length of 400m and up to 1.3m over about a 40m length. This is on top of an estimated 0.2-0.4m of subsidence from Bulli Seam mining. Despite this subsidence and an indicated closure of up to 310mm across the creek, there is no evidence of significant physical disturbance. This level of closure would have caused cracking in Hawkesbury Sandstone. This may well be due to the exposure of the Bald Hill Claystone in the bed of the creek at this location. Iron precipitate from disturbed Hawkesbury Sandstone is evident as a result of prior mining and may be showing some signs of increase in CT1 as a result of LW4 and LW5 extraction.

The electrical transmission towers T56 and E57 appear to have been built prior to the extraction of Balgownie LW3. They are located directly over LW3 which experienced between 1 to 1.2m of subsidence and within about 200m of the surface cracking referred to above. There is no indication of any impact on the towers.

Mt Ousley Rd was realigned after mining had been completed in both Bulli and Balgownie seams in its vicinity. The extraction of LW4 caused some minor cracking of the road and coincided with goaf edges of old Bulli Seam mining indicating possible reactivation of historic subsidence cracking.

Cataract Creek Impact Predictions

Cataract Creek flows west across the Assessment Area and is the major creek system within the assessment area. The creek starts as first order creeks west of the Illawarra Escarpment and becomes a fourth order creek from where it flows under Mount Ousley Road to where it joins Cataract Reservoir. There is no mining proposed directly under the third and fourth order sections of Cataract Creek. Second order sections of the southern branch of Cataract Creek are mined under by LW2 and LW3 and a short section of another branch has been mined under by LW5. First order tributaries are mined under by all but three of the panels.

Almost all the second order and higher sections of Cataract Creek that are either directly mined under or are close to longwall panels are flowing within the outcrop of the Bald Hill Claystone. Previous experience of mining under the Bald Hill Claystone outcrop in Cataract Creek indicates that there have not been any significant long term effects on the bed of the creek or the character of the creek despite LW11 in the Balgownie Seam causing the creek bed to subside1.4m.

A management approach based on monitoring closure and stopping the longwall panels if these reach unacceptably high values will be used to manage the closures across Cataract Creek and this approach has been used as part of the LW5 SMP. Experience in Hawkesbury Sandstone river channels indicates that there has been not been total loss of surface flow in major river channels such as Cataract Creek where valley closure is less than 200mm. By adopting a TARP system based on maintaining closure to less than 200mm, it is anticipated that the potential for loss of surface flow can be managed.

Figure 64, pg 188, shows the profile of the southern branch of Cataract Creek located over LWs1-3 and its continuation downstream to Cataract Reservoir. This profile has been generated from the Surfer model derived from LiDAR imaging of the surface. The subsided profiles at the completion of mining in the Bulli Seam, Balgownie Seam, and Wongawilli Seam are shown. The vertical subsidence predicted mainly influences the creek profile in the second order section above LWs1-3. In this area there is potential for up to 2.6m of subsidence below the creek.

Although there is potential for water to pool in this area, valley closure effects are expected to increase the potential for sub-surface flow so pooling may only be short lived during periods of heavy rain. Valley closures are expected to cause perceptible cracking and surface flow diversion in the upper reaches of the southern branch of Cataract Creek, particularly where it flows across Hawkesbury Sandstone outcrop above LW1. Some loss of surface water and iron staining is expected from this area as a result.

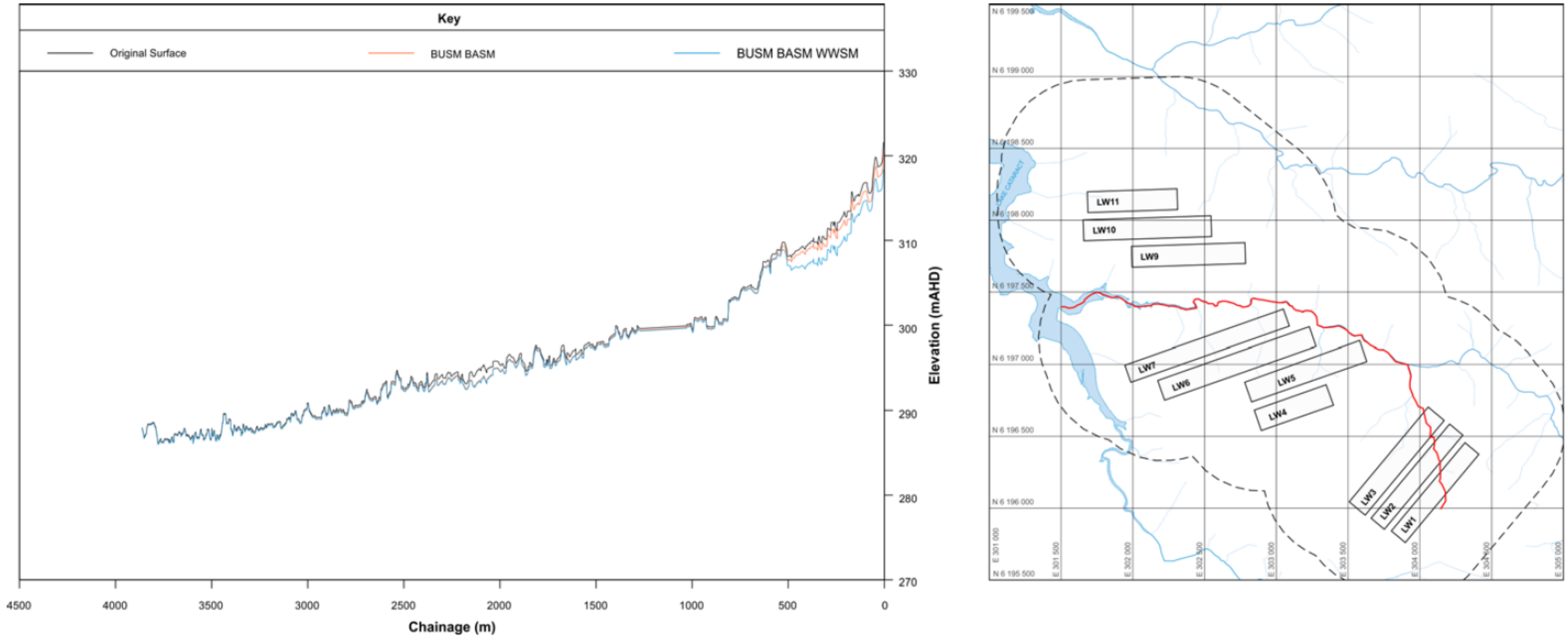
Further downstream above LW2 and LW3 and downstream of Mount Ousley Road where the creek will not be directly mined under, the bed of the stream is located mainly in Bald Hill Claystone and only low levels of perceptible impact are expected in this strata based on previous experience. Iron staining and flow diversion into the surface strata are not expected to be so apparent in Bald Hill Claystone because of its finer grained nature and high levels of natural fracturing.

A management strategy based on closure monitoring and cessation of mining if there is a likelihood of significant perceptible impacts becoming apparent is considered to be an effective method of managing the potential for subsidence impacts on Cataract Creek.

Cataract River

Cataract River is located on the southern side of the ridge that runs below the start of LWs4-7. Only the southern ends of LW6 and LW7 mine directly below the slopes that lead down to Cataract River and mining is in an upslope direction at the start of these panels as such only very low levels of valley closure are expected across Cataract River as a result. The maximum valley closure indicated by the ACARP method is approximately 30mm from LW6 and 40mm from LW7. These low levels of closure will have no perceptible impact on Cataract River or the surface flows.

Figure 64 – Cataract Creek Reach Profile



A second order tributary of Cataract River flows west-south-west and joins the Cataract river at the Picton Road Interchange. This tributary flows off the Hawkesbury Sandstone outcrop around 260m south of the start of LW1. No significant valley closure or perceptible impacts are expected along this section of creek because LWs1-3 don't mine under any significant part of the slope that leads down to this creek.

Upland Swamps

Biosis has mapped and described 33 separate upland swamps within the Assessment Area. Further detail of this assessment is available in **Section 2.2.1**, pg 57. **Figure 19**, pg 69, shows the location of these swamps. Different swamps are differentiated on the basis of the tributaries into which they flow and the nature of the swamp vegetation. Many of these swamps have been previously mined under in both the Bulli Seam and Balgownie Seam. The proposed mining is not expected to cause significantly different impacts to those already experienced. The estimated and measured subsidence for previous mining and predicted for proposed mining in the Wongawilli Seam are presented in **Appendix 1 of Attachment B**, pg 426.

Individual swamps can cover large areas and may be somewhat discontinuous in nature. The prediction of relevant subsidence parameters is challenging because of the large area of some swamps and the relatively large change in subsidence parameters such as strain and tilt over short distances. The approach taken has been to present the maximum subsidence parameters that are considered credible based on the experience presented in Holla and Barclay (2000) and recognise that these may only occur in one isolated area of a swamp, if at all. The subsidence parameters more likely to occur are in the order of 50-80% of the peak values for tilt and in the order of 20-30% of the peak values for horizontal strain.

Maximum subsidence within a swamp may not necessarily be a good indicator of the maximum subsidence parameters of strain and tilt, given that maximum strain and tilt typically occur on the fringes of a subsided area. The maximum strain and tilt values have been estimated based on the level of subsidence within the general proximity of a swamp that would contribute to maximum strains and tilts within the swamp boundary. When strains are greater than about 1-2mm/m in tension and 2-3mm/m in compression, perceptible fracturing of the sandstone strata below swamps are expected.

It is unclear how sensitive swamps are to mining subsidence. There is a clear association between mining and short term loss of piezometric pressure after rain within the surface layers of some swamps. However, the swamps located within the Assessment Area appear to be thriving despite having been previously subsided to levels that are of the same order as the subsidence expected above future longwall panels. This observation suggests that the drop in piezometric pressure observed when some swamps are mined under may not have a significant impact on their long term condition. It is considered that more work is required to determine the relationship between mining subsidence and the long term health of swamps. The extended baseline of subsidence impacts over 60-100 years in the Bulli Seam and 30-40 years in the Balgownie Seam provides a unique opportunity to study these effects. The changes that are expected from proposed mining are nominally sufficient to cause significant impacts to the rock strata and to surface and near surface water flows in the areas directly mined under, so it would be helpful to study how and if the wide range of swamps present above the site are significantly impacted by further mining.

Cliffs and Steep Slopes

Cliffs and Steep Slopes are dealt with in detail in **Section 2.2.2**, pg 88.

The most significant cliff formations are those associated with Brokers Nose on the Illawarra Escarpment located some 900m east of the southern end of LW1. Within the Assessment Area, there are several short sections of cliffs between 3m and 10m high located on the northern side of Cataract Creek and several short sections of slightly greater than 10m high cliff formations along the southern periphery of the Assessment Area. Most of the sandstone cliff formations are less than 3m high and occur along the lower edge of the Hawkesbury Sandstone outcrop as a series of typically discontinuous outcrops and detached boulders.

Only the cliff formations associated with Brokers Nose are significant using the criteria outlined in the PAC (2010) based on their physical characteristics alone. Brokers Nose is remote from proposed mining and there is considered to be no potential for mining subsidence movements to impact the cliff formations along the Illawarra Escarpment.

There is considered to be some potential for rock falls on up to 5% of the length of cliff formations directly mined under with potential for perceptible impacts such as tension cracking on up to 30% of the length of cliff formations directly mined under and extending outside the goaf edge to a distance of 0.4 times overburden depth (typically about 140m). A minor rock fall at approximately MGA 302600E, 6197000N on Hawkesbury Sandstone outcrop is considered likely to have been associated with mining activity in the Balgownie Seam and is typical of the impacts that are expected. This rock fall was difficult to detect, and was relatively minor in the context of ongoing natural erosion at the site.

Impacts on steep slopes are expected to be limited to the potential for subsidence cracks to develop at topographic high points that are directly mined under and at the start of longwall panels that commence mining in a downslope direction. The environmental consequences of impacts on steep slopes are considered to be generally negligible although some cracks may need to be filled in where they are crossed by vehicle access tracks.

Heritage Items

Nineteen Aboriginal heritage sites have been identified within the Assessment Area. These are described separately in **Section 2.2.3**, pg 93 and **Attachment C**, pg 536. The locations of these sites are shown in **Figure 25**, pg 98, relative to proposed mining and summarised in Table 5. There are two sites on the southern side of Cataract Creek that will be mined under or adjacent to. Three more sites are located over Longwall 9, another above Longwall 11, and the rest are located in areas that are unlikely to be significantly affected by mining subsidence.

Estimates and measurements of subsidence movements associated with past mining activity and predictions of subsidence movements for proposed mining activity are presented in **Appendix 1 of Attachment B**, pg 426. **Table 49**, pg 191, presents a summary of the subsidence parameters expected from mining in the Wongawilli Seam.

Table 49 - Subsidence Parameters Expected at Heritage Sites

Site ID	Subsidence at Site (m)	Adjacent Subsidence Used for Strain and Tilt Calculations (m)	Overburden Depth (m)	Max Tensile Strain (mm/m)	Max Comp Strain (mm/m)	Max Tilt (mm/m)	Compressive Horizontal Movement Along 20m Section of Cliff (m)
52-2-3939	0.8	2	340	8.8	18	29	350
52-2-3940	0.6	1.5	340	6.6	13	22	250
52-2-3941	1.2	1.5	340	6.6	13	22	250
52-2-0603	1.5	1.5	340	6.6	13	22	250
Wonga East 4	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
Wonga East 5	< 0.1	< 0.1	300	< 0.5	< 1	< 2	< 20
52-3-0320	0.7	2	340	8.8	18	29	350
52-3-0325	1.1	1.5	315	7.1	14	24	250
52-3-0311	< 0.1	< 0.1	285	< 0.5	< 1	< 2	< 20
52-3-0310	< 0.1	< 0.1	385	< 0.5	< 1	< 2	< 20
52-2-0099	0.4	1	355	4.2	8	14	150
52-2-0229	0.7	1	365	4.1	8	14	150

Cataract Reservoir

No impacts are expected on the Cataract Reservoir from the proposed mining. The FSL including the section that extends up Cataract Creek is protected from the nearest longwall goaf by a horizontal distance of greater than 203m at 290m overburden depth (equivalent to 0.7 times overburden depth or an angle of draw of 35°). Vertical subsidence at the FSL is expected to be less than about 20mm. Cataract Reservoir is addressed in more detail in **Section 2.2.6**, pg 133.

Telecommunications Infrastructure

There is a telecommunications tower located on Brokers Nose on the Illawarra Escarpment. Brokers Nose and the telecommunications infrastructure is protected by a horizontal distance of approximately 1km from the nearest point on Longwall 1. No ground movements are expected at this distance from the proposed mining because there is no potential for significant horizontal stress concentration along the escarpment and no potential for change in any of the other stress components.

2.2.7.6 Subsidence Management

Survey monitoring is expected to provide the primary basis for informing the processes used to manage subsidence impacts. This monitoring is discussed first because it underpins all the other processes.

Conventional subsidence monitoring using repeat surveys in three dimensions with far-field GPS control is considered to provide the industry best practice subsidence monitoring technique in steep terrain. This type of three dimensional surveying captures the full three dimensional ground movements independent of location to an accuracy that is suitable to characterise the nature of the ground movements. Strains and tilts are not necessarily captured to the same level of accuracy as is possible with levelling and peg to peg chaining but the reduced accuracy is offset by capturing all components of movement rather than just the components in the direction of the subsidence line. The existing survey lines over LWs4–7 are monitored in three dimensions using this approach.

Two cross lines across each panel and a centreline subsidence line are considered appropriate to monitor subsidence movements in the relatively complex subsidence environment above LWs1-11. The three dimensional movements on the active sections of these lines will be monitored regularly, particularly at the commencement of each longwall panel and during mining below or near significant infrastructure, and more widely at the midpoint and end of each longwall panel or every 2-3 months whichever occurs first.

A survey monitoring base line will be established in three dimensions with far field GPS control for a distributed array of monitoring points that are located at easily accessible locations across the area and around the periphery and out to around 3km from the mining area. This monitoring network can then be checked at any time and used to confirm the levels of movement that have occurred on all the monitoring lines and infrastructure in the area. This distributed array will provide an overview of any movements that are occurring. The array can also be used to provide confirmation of the accuracy of the survey control grid.

High resolution point to point measurement of valley closure across Cataract Creek will continue to occur at a number of crossing points. The four that are currently located across Cataract Creek are considered suitable locations. If possible, given the practical difficulties of surveying in a rainforest environment, these will be extended to increase the horizontal coverage so as not to miss any closure movements that occur beyond the ends of the convergence line.

Subsidence management actions are outlined in the sections related to the specific issue

2.2.7.7 Conclusions

The subsidence prediction methodology used in this assessment is based on previous subsidence monitoring experience at this site available from mining in the Bulli Seam (over longwall panels to the west) and the Balgownie and Wongawilli Seams in the Assessment Area. Tilts and strains are predicted using incremental subsidence and the approach forwarded by Holla and Barclay (2000). Maximum closure is predicted using the ACARP Method developed by Waddington and Kay (2003). The experience available from mining LW4 and LW5 indicates that the subsidence behaviour in a multi-seam environment is different in respect of the overburden stiffness and therefore the bridging capacity across individual panels, but is otherwise essentially similar to the subsidence behaviour above single seam operations. Most importantly the experience from Longwalls 4 and 5 indicates that the subsidence behaviour is still predictable.

Maximum subsidence over individual longwall panels in the Wongawilli Seam is predicted to range from 1.5m over the slightly narrower LW7 through to 2.6m over LW3 where the overburden depth is shallowest and there is overlying goaf in both seams. Previous mining in the Bulli and Balgownie Seams is estimated to have caused up to 1.9m of subsidence. Maximum tilts are expected to range from peaks of 24mm/m over LW10 through to peaks of 51mm/m above LW3. The peak values predicted are expected to be the maximum anywhere in the panel, most likely at goaf edges in overlying seams and in areas of topographic change in gradient. More generally across the panel, systematic tilts are likely to be in the range 50-90% of the peak values. The maximum predicted closure ranges up to 400mm adjacent to the ends of LW6 and LW7 and up to 210mm at the end of LW5. Monitoring so far indicates closure movements that are much less than predicted maxima.

There is considered to be some potential for pillar instability in the Bulli Seam at the northern end of LW1 but this is not expected to cause significant surface subsidence or significantly greater surface impacts

Movement outside the goaf edge are expected to be essentially similar to the movements observed so far during mining of Longwalls 4 and 5. Vertical movements of greater than 20mm are expected to be limited to within a distance of 0.7 time overburden depth from the nearest goaf edge equivalent to an angle of draw of 35°. In areas where there has been previous mining in both the overlying seams, vertical subsidence at the goaf edge is expected to be up to 300-500mm and the goaf edge subsidence profile is expected to be general softer than elsewhere. In areas where there is either solid coal or substantial coal pillars directly above the goaf edge, goaf edge subsidence is expected to be of the order of 100-200mm.

The main channel of **Cataract Creek** will not be undermined and particularly the fourth order sections downstream of Mount Ousley Road. An adaptive management strategy based on closure monitoring and cessation of mining if there is a likelihood of significant perceptible impacts becoming apparent is considered to be an effective method of managing the potential for subsidence impacts on Cataract Creek.

Cataract River is remote from the proposed mining in an area where there are not expected to be any perceptible impacts.

33 separate **Upland Swamps** are contained within the Assessment Area and many have been previously mined under in both the Bulli Seam and Balgownie Seam. The proposed mining is not expected to cause significantly different impacts to those already experienced. More work is required to determine the relationship between mining subsidence and the long term health of swamps and the extended baseline of subsidence impacts over the past 100 years offers a rare opportunity to study these effects. The development of a monitoring and review strategy involving relevant experts is recommended to manage mining impacts on these swamps and will include a review of the recovery of these features from previous impacts and the implication of this recovery for future swamp protection strategies.

Most **sandstone cliff formations** occur in the Hawkesbury Sandstone outcrop in the Assessment Area, are less than 5m high and none are considered to be significant based on the assessment criteria presented in PAC BSO report. Some perceptible cracking on hard rock surfaces is expected to be apparent as a result of the proposed mining. Minor rock falls are expected on up to 5% of the length of sandstone cliff formations that are mined directly beneath.

Nineteen **Aboriginal heritage sites** have been identified within the Assessment Area. Some of these sites have potential to be impacted by rock falls caused by mining subsidence. A detailed assessment of these sites is presented in **Section 2.2.3**, pg 93, **Attachment B**, pg 426, and in **Attachment C**, pg 536.

Mount Ousley Road will experience low levels of vertical subsidence of less than about 100mm in total with approximately 30mm of this having already occurred from mining LW4. Tensile cracking adjacent to the topographic high ground south of Cataract Creek and closure of up to a 125mm was predicted using the ACARP Method. Continuing impact management by a technical committee will be used as it was for LW4 and LW5.. Some consideration to remedial work to prevent water ingress into minor tension cracks that have formed is recommended to protect the road sub-base.

There is considered to be no potential for significant horizontal movements to impact the **Picton Road Interchange.**

There are four **power transmission lines** located in two corridors between Mount Ousley Road and the Illawarra Escarpment. Subsidence movements predicted in the vicinity of four of the towers (two each on the 330kV and 132kV lines) are expected to be sufficient to require construction of cruciform bases to protect them from mining subsidence. T56 on the 330kV line will require a special design to accommodate the slight change in direction that occurs at this tower. The 33kV single and double pole structures require no protection measures but will be monitored. A technical committee comprising representatives from the colliery, the power utility companies, the Mine Subsidence Board, and government regulators is proposed to manage potential impacts on the power transmission towers.

The **Cataract Water Storage Reservoir** is not expected to be impacted by the proposed mining as the FSL is over 203m from the longwall goaf (equivalent to 0.7 times overburden depth or an angle of draw of 35°), vertical subsidence at the FSL is expected to be less than 20mm, there is no potential for mining to intersect the stored waters directly, the proposed mining will not interact with pre-existing Bulli Seam goaf areas and currently there does not appear to be any connection between the reservoir and the mining horizon. The Colliery has been working with the DSC for many years and it is considered that the management process that has been adopted in the past continues to be appropriate. The 0.7 times depth (approximately 200m) stand-off from the FSL is considered to be the primary control for protecting the stored waters of Cataract Reservoir and this barrier is expected to provide a high level of protection.

There is a **telecommunications tower** located 1km from LW1 on Brokers Nose on the Illawarra Escarpment. No ground movements or any perceptible impacts are expected in this area as a result of the proposed mining.

The subsidence management strategies include continuation of the upgrade to subsidence monitoring technique that has been ongoing since the start of LW4.

The detail of monitoring of swamps, heritage sites, and creek biota has been addressed in **Section 2.2.1**, pg 57, Section 2.2.3, pg 93, **Attachment A**, pg 350 and **Attachment C**, pg 536 .

2.2.8 Rehabilitation

2.2.8.1 Background

The general rehabilitation and offset options available to manage impacts in the areas affected by mine subsidence were outlined in the relevant chapters of the EA. There have been no changes to the proposed options.

2.2.8.2 Management

Table 50, pg 195, provides an overview of the options that were included in the original EA to rehabilitate natural features that have been impacted by mine subsidence. Man-made features are not addressed in this section as the rehabilitation/remediation of mine subsidence impacts is an activity undertaken by the Mine Subsidence Board in association with the owner of the impacted feature.

Table 50 - Mine Subsidence Indicative Rehabilitation Options

Issue	Rehabilitation Options	Section of EA
Aquatic Ecology	• As for streams.	-
Cliffs and Steep Slopes	• Grouting of rock cracks; • Rock bolting or meshing; • Fill tension cracks; and • Stabilise slopes e.g. batter, bench, or other method.	*Section 26.5, pg 476*
Cultural Heritage	• Rehabilitation to be undertaken in liaison with Aboriginal stakeholders, an Aboriginal cultural heritage expert and OEH	*Section 25.8.2, pgs 463-465*
Groundwater	• No rehabilitation options are considered viable	-
Streams	• Natural stream remediation where sediment naturally seals cracks or fractures; • Stream hand mortaring; • Injection grouting of material to fill voids in small fractured areas; • Injection grouting of material in a series of boreholes in a pattern designed to cover larger fracture areas; • Permeation grouting where material is added to the stream and is drawn down cracks sealing them; • Curtain grouting which places grout in a curtain downstream of the fractures which acts like a dam causing the subsurface fractures to fill forcing water back into the stream bed. • Impermeable linings on the stream bed; • Filling or compaction of fractures in highly sedimentary stream beds; and • Offset if required.	*Section 16 & 16.1 of Annex O, pgs 116-118*
Swamps	• Installation of coir log dam erosion control structures at knick points; • Water spreading techniques to ‘dam’ and release water to maintain swamp moisture; • Sealing of surface cracks with grouting material in accessible areas such as exposed rock surfaces in stream beds and rock bars within swamp boundaries; • Injection grouting of material to fill voids in fractured containing rock bars; and • Offset if required	*Section 22.9, pgs 385-386*
Terrestrial Ecology	• As for swamps.	-

2.2.8.3 Conclusion

There have been no changes to proposed rehabilitation options. Any advances in rehabilitation options will be included in SMP's for extraction of the Wonga East longwalls

2.2.9 Surface Water

2.2.9.1 Background

NRE is currently remodelling the potential catchment area surface water effects from the Preferred Project in accordance with advice from the DPI's independent surface water review findings. The new model will benefit from significantly improved understanding of subsidence behaviour and better stream, swamp and groundwater monitoring baseline data. This modelling process will take up to 3 months..

2.2.9.2 Modelling

As the remodelling is currently underway there are no outcomes to report on. As a guide, the overall Preferred Project has changed as follows:

- longwall dimensions are approximately 25% smaller in Wonga East;
- longwalls no longer pass beneath Cataract Creek;
- longwalls no longer appear within a 35 degree angle of draw of the full supply level of the Cataract Reservoir;
- the Wonga Mains no longer extend beneath the Cataract Reservoir and the areas of concern expressed by DSC;
- the impacts on Cataract River will be reduced below already negligible levels;
- the impacts on Bellambi Creek will remain at similar negligible levels; and
- extraction of Wonga West no longer forms part of this application

2.2.9.3 Impacts

Extraction of LW4 and partial completion of LW5 at Wonga East in the Wongawilli Seam has not generated any observable impact or effect on stream flow in Cataract Creek. There will be no discernible change in Fe levels in Cataract Creek as they've remained high since NRE commenced monitoring in July 2008.

LW5 is currently mining beneath the Cataract Creek tributary CT1. NRE will continue to monitor CT1 tributary flow, water levels and water chemistry as LW5 passes beneath the tributary to clearly identify impacts that mine subsidence may have. There may be some effects on surface flow volumes but little impact on discharge into Cataract Creek. NRE is in the process of establishing monitoring points close to the mouth of CT1 and other tributaries along Cataract Creek to improve its understanding of the effects of mining on tributary discharge volumes.

There has been no observable impact to date on standing water levels in swamps CCUS6 over LW4, CCUS3 over LW5 or the shallow sandstone soil piezometers SP1 and SP2. This is attributed to the fact that the swamps / soil profile is relatively shallow and generally dry except after significant rainstorms.

Due to the relocation of longwalls away from the main channel of Cataract Creek and the complete removal of LW8 which has significantly reduced longwall areas in the Cataract River Catchment, subsidence or uplift cracking and stream flow transfers due to subsidence of the main stream channels is not anticipated.

Subsidence impacts on Upland Swamps and 1st and 2nd order tributaries are anticipated to have localised effects on the affected tributary stream flow and longevity and increased Fe, reduced DO, increased salinity and potentially increased metal concentrations in the downstream re-emergence and discharge zone.

It is not anticipated that overall stream discharge into Cataract Reservoir will be reduced by more than the regional groundwater depressurisation effect which is yet be quantified on the basis of the remodelling of catchment groundwater impacts. There is the possibility of connective fracturing from surface to seam but this hasn't yet been observed over LW4 or LW5 to date and is considered extremely unlikely.

There may be reductions in Upland Swamp shallow groundwater levels, surface water discharge and flow longevity as well as water quality following significant rainfall but to date this hasn't been identified as occurring over LW4 or LW5.

2.2.9.4 Management

Monitoring and management regimes are not currently anticipated to vary significantly from the regimes proposed in *Section 20.6, pgs 346-351, of the EA.* However, any modifications required to the monitoring and management regime as a result of the outcomes of the revised model as well as DPI and PAC assessments, will be considered and implemented if reasonable and achievable.

Due to the disagreement over the potential impacts of subsidence with regard to subsurface water flow and stream networks that is currently prevalent in the scientific and regulatory community, primarily due to inadequate data on both sides of the argument, a network monitoring methodology is being designed, based around CCUS4 and possibly CCUS5, to capture the total water balance of representative sections of surface waterways in order to determine the effects and impacts of subsidence on stream networks from Upland Swamps to Reservoir. This approach will be designed with input from specialists and agencies to ensure the monitoring is reasonable, effective and scientifically robust.

2.2.9.5 Conclusion

NRE is currently undertaking a remodelling of the surface water effects and impacts from the Preferred Project on the Wonga East area. This modelling will take up to 3 months.

Given the significantly reduced extent and layout of the Preferred Project, including 25% smaller longwall area in Wonga East, the overall subsidence impacts on stream flow, water levels, pool longevity and water quality are anticipated to be less than the predictions in the EA.

Monitoring and management are not intended to vary significantly but will be reviewed on the basis of the revised surface water model and assessment outcomes during the approvals process. A stream network monitoring program is being developed around CCUS4 and possibly CCUS5 and the Cataract Creek tributaries they feed to determine the actual impacts on surface and near surface water balances within a defined catchment area.

2.3 General Issues

2.3.1 Economic

2.3.1.1 Background

In order to progress the application through the NSW planning system the original longwall layout had to be revised due to general opposition to elements of the proposal. The necessity of the decision to amend the original EA proposal has been reinforced by recent precedents of refusal or the requirement for significant modifications of resource applications by the Planning Assessment Commission (PAC) as well as the overturning of prior PAC approvals by the NSW Land and Environment Court (LEC). The issues raised by agencies and special interest groups that have resulted in these PAC refusals and modifications or overturning of approvals by the LEC are overwhelmingly environmental in nature.

2.3.1.2 Coal Sterilisation and Royalties

The requirement to modify the original EA has resulted in significant financial impacts to both NRE and the NSW State Government as shown in **Table 52**, pg 199.

Table 51 - Comparison of Recovered ROM Coal

	ROM Coal Extracted		Reduction in PPR ROM Coal Production (Mt)	Sterilisation of ROM Coal in PPR
	Original EA (Mt)	Preferred Project (Mt)		
Wonga East ROM Coal Production	6.5	4.7	1.8	1.8
Total Project ROM Coal Production	31.1	4.7	26.4	1.8

Table 52 - Estimates of Economic Impact of PPR

	Estimated NRE Revenue		Estimated NRE Revenue Lost as a Result of PPR ($M)	Estimated Royalties		Estimated Royalties Lost as a Result of PPR ($M)
	Original EA ($M)[1]	Preferred Project ($M)[2]		Original EA ($M)[1]	Preferred Project[3]	
Wonga East	523	400	123	52	34	18
Total Project	2,504	400	2,104	250	34	216

1. From net present value calculations in Chapter 28 of EA
2. Based on 52.6% coking coal at $150/tonne and 28.6% thermal coal at $90/tonnes at an average of 934,000 tpa and adjusted by 7%pa over the 5 year project period to determine present value at the end of the project
3. Based on an average estimated royalty rate of 7.2% over the period of the project

When compared to the original EA, the Preferred Project redesign will result in the complete sterilisation of approximately 1.8Mt of ROM coal, no extraction of 26.4Mt of ROM coal, a revenue reduction to NRE of $2,104M and a reduction in royalties of $216M to the NSW State Government.

If the Wonga East area is compared in isolation, the Preferred Project redesign will result in the non-extraction and complete sterilisation of approximately 1.8Mt of ROM coal, a revenue reduction of $123M and a reduction in royalties of $18M to the NSW State Government. Added to this is a likely $0.5M reduction in Mine Rescue Station, Mine Subsidence and ACARP levies.

While this situation is obviously not a preferred outcome for either NRE or the NSW Government, NRE is aware that in both NSW as well as federally, the current political, regulatory and judicial climate places strong preference on environmental over economic outcomes.

2.3.1.3 Direct and Indirect Economic Benefits

As discussed in **Section 1**, pg 9, the Preferred Project layout has reduced the life of the project from 18 to 5 years and the volume of ROM coal available for extraction, and therefore potential income from sale, by approximately 85% compared to the EA. The current residential location of NRE employees was originally shown in *Table 28.2, pg 499, of the EA* but has been updated in **Table 57** of this report. With respect to estimating economic impacts of the Preferred Project, employee numbers are used based on actual numbers at NRE No.1 as of 4 April 2013:

- 92% of employees lived in directly neighbouring LGA's
- 90% resided in the Illawarra Statistical District
- 63% resided in the Wollongong LGA

As can be seen in **Table 53**, pg 200, the original project was estimated to increase regional output by $3,361 million and regional incomes by $1,981 million in net present value while raising regional employment by 2,137 full time equivalent employees over 18 years.

In contrast the Preferred Project is estimated to increase regional output by $580 million and regional incomes by $550 million in net present value while raising regional employment by 1,498 full time equivalent employees for a substantially shorter 5 year period.

Table 53 - Direct and Indirect Impact on the Regional Economy[1]

Project	Multiplier ($M)	Direct Effect	Indirect, Flow-on Effect	Total Effect
Original EA	Output	$2,504	$1,127	$3,631
	Multiplier	*1*	*0.45*	*1.45*
	Income	$627	$1,354	$1,981
	Multiplier	*1*	*2.16*	*3.16*
	Employment	409	1,727	2,137
	Multiplier	*1*	*4.22*	*5.22*
PPR	Output	$400[2]	$180	$580
	Multiplier	*1*	*0.45*	*1.45*
	Income	$125[3]	$376	$550
	Multiplier	*1*	*2.16*	*3.16*
	Employment	287[4]	1,211	1,498
	Multiplier	*1*	*4.22*	*5.22*

1. *Note that the multipliers are based on the Gillespie Economics (2009) analysis which was specific for the expenditure patters etc of that particular project. As such, the estimates in this assessment area considered approximations only but are considered valid due to the broad similarities between the Gillespie Economics (2009) and the proposed Project.*
2. *Estimated Preferred Project revenue from Table 52*
3 *Original EA Income adjusted for 28% fewer employees and reduced Preferred Project life of 5 years*
4 *NRE employees as of 4 April 2013*

Therefore, in terms of impact to regional economic output, the difference between the EA and the Preferred Project is $2,781 million less in regional output and $1,431 million less in regional incomes while producing 639 less full time equivalent positions.

Table 54 - Direct and Indirect Impact on the NSW Economy

Project	Multiplier ($M)	Direct Effect	Indirect, Flow-on Effect	Total Effect
Original EA	Output	$2,504	$2,429	$4,933
	Multiplier	*1*	*0.97*	*1.97*
	Value Added	$609	$445	$1,054
	Multiplier	*1*	*0.73*	*1.73*
	Income	$633	$2,830	3,463
	Multiplier	*1*	*4.47*	*5.47*
	Employment	409	1,727	2,137
	Multiplier	*1*	*4.22*	*5.22*
PPR	Output	$400[2]	$388	$788
	Multiplier	*1*	*0.97*	*1.97*
	Value Added	$120	$88	$208
	Multiplier	*1*	*0.73*	*1.73*
	Income	$125[3]	$559	$684
	Multiplier	*1*	*4.47*	*5.47*
	Employment	287[4]	2,348	2,635
	Multiplier	*1*	*8.18*	*9.18*

1. *Note that the multipliers are based on the Gillespie Economics (2009) analysis which was specific for the expenditure patters etc of that particular project. As such, the estimates in this assessment area considered approximations only but are considered valid due tot he broad similarities between the Gillespie Economics (2009) and the proposed Project.*
2. *Estimated Preferred Project revenue from Table 52*
3 *Original EA Income adjusted for 28% fewer employees and reduced Preferred Project life of 5 years*
4 *NRE employees as of 4 April 2013*

Table 54, pg 201, shows that the original project was estimated to increase State output by $4,933 million and value added by $1,054 million in net present value while raising regional employment by 3,795 full time equivalent employees over 18 years.

In contrast the Preferred Project is estimated to increase State output by only $788 million and value added by $208 million in net present value while raising regional employment by 2,635 full time equivalent employees for a substantially shorter 5 year period.

Therefore, in terms of impact to State's economic output, the difference between the EA and the Preferred Project is an estimated $4,145 million less in regional output and $846 million less in value added while producing 1,160 less full time equivalent positions.

2.3.1.4 External Costs

Section 28.2, pg 503-504, of the EA did not attempt to ascribe a value to external costs such as environmental and community impacts from the original project.

The economic valuation of potential impacts on environmental assets and services is an extremely difficult exercise with no accepted standard guidelines or methods to value these assets or services. This currently results in widely varying values being ascribed to the same element of the environment (e.g. endangered species) based on the techniques used or perspective of the person/s undertaking the valuation (i.e. a commercial interest or an environmental protection focus).

With regard to the Preferred Project there is one significant element that needs to be considered from an economic perspective which is the potential effects of subsidence on the Metropolitan Special Area with respect to impacts to Sydney's raw water supply.

As almost all potential significant mine subsidence related impacts that could occur are likely to occur in the Sydney Catchment Authority (SCA) Metropolitan Special Area, it appears reasonable to attempt to determine the value placed on the raw water resource by the NSW Government.

The role of the SCA is to capture, store and supply quality raw water from well managed catchments *(SCA Annual Report 2011/12)*. The Authority is responsible for managing approximately 370,000ha of catchment area and a total raw water storage capacity of 2,581,550 ML *(SCA Website)*. Of particular relevance to the Preferred Project, the SCA is responsible for managing the approximate 13,000ha catchment of the 94,300ML capacity Cataract Reservoir *(SCA Website)*.

The following financial records from the 2011/12 SCA Annual Report were used to try to gain an understanding of the value placed by the NSW Government of the provision of raw water to the 4.5 million people serviced by the SCA.

- Healthy Catchment Strategy Expenditure Budget $30,213,000 *(SCA Catchment Management Report 2011/12)*
- Profit $40,647,000 *(SCA Annual Report 2011/12)*
- Comprehensive Income $91,546,000 *(SCA Annual Report 2011/12)*
- Expenses $159,116,000 *(SCA Annual Report 2011/12)*
- Equity $779,558,000 *(SCA Annual Report 2011/12)*

Table 55 - Valuation of Catchment Areas from SCA Financial Information

Financial Value	Total for 2011/12 ($)	Average Value of All (370,000ha) SCA Catchment Areas ($/ha)	Value of the (13,000ha) Cataract Reservoir Catchment Area ($)	Average Water Storage Value of Total SCA Catchment Areas ($/L)	Water Storage Value for Cataract Reservoir Full Storage ($)
Environmental Expenditure	$30,213,000	$81.66	$1,061,538	$0.00001	$943,000
Profit	$40,647,000	$109.86	$1,428,180	$0.000016	$1,508,800
Income	$91,546,000	$247.42	$3,216,460	$0.000036	$3,394,800
Expenses	$159,116,000	$430.04	$5,590,520	$0.000062	$5.846,600
Equity	$779,558,000	$2,106.91	$27,389,830	$0.0003	$28,290,000

1. Total SCA catchment land area is 370,000ha (SCA Website July 2013)
2. Total potential water storage in SCA reservoir s is 2,581,550 ML (SCA Website July 2013)
3. Total Areas of Cataract Reservoir Catchment is 13,000ha (SCA Website July 2013)
4. Cataract Reservoir Capacity: 94,300 ML (SCA Website July 2013)
5. Total are of Cataract Creek Catchment is 520ha
6. Total area of Bellambi Creek Catchment is 930ha
7. Total area of Cataract River Catchment is 1,160ha
8. Total area inside Wonga West 600m Study Area is 860ha

Potentially subsidence affected land within the 600m Study Area around Wonga East covers approximately 860ha. The potentially affected areas are located in the catchments of Cataract Creek (~50% of catchment), Bellambi Creek (~1.5% of catchment) and Cataract River (~1.5% of catchment). Based on the 860ha of potentially affected area in the Cataract Reservoir catchment and the calculated $/ha financial values in **Table 55**, pg 202, it would appear that NSW currently values the 860ha area potentially affected by Wonga East at between $70,228 and $1,811,943.

There are 8 swamps that are completely or partially undermined by the Wonga East longwalls including gateroads. If the value of $2M/ha assigned to swamps, irrespective of special significance, by Gillespie Economics for the Bulli Seam Operations Pt3A application in 2009 are accepted, then the value of the swamps to be directly undermined by the Preferred Project can be calculated as shown in **Table 56**, pg 203.

Table 56 - Community Value of Upland Swamps

Swamp Identifier (% undermined)	Specially Significant	Total Area[1] (ha)	Area Affected (ha)	Value ($M)
CCUS2 (100%)		1.21	1.21	$2.42 million
CCUS3 (100%)		0.55	0.55	$1.10 million
CCUS5 (5%)	Y	3.45	0.17	$0.34 million
CCUS10 (1%)	Y	1.63	0.02	$0.04 million
CCUS11 (100%		0.34	0.34	$0.68 million
CCUS12 (100%)		1.84	1.84	$3.68 million
BCUS11 (100%)		0.26	0.26	$0.52 million
CRUS1 (5%)	Y	9.84	0.5	$1.00 million
TOTAL		**19.12**	**4.89**	**$9.78 million**
1. Data from Annex Q of the EA				

If the 4.89ha of swamp to be directly undermined replaces the average land values assumed from **Table 55**, pg 202, then NSW could be considered as valuing the 860ha of the Cataract Reservoir Catchment that potentially will be affected by mine subsidence from the Preferred Project at between $9.85M and $11.58M. This estimated value is only relevant in the case of the complete loss or significant degradation of the affected areas as result of Preferred Project which is highly improbable. The royalties alone from the extraction of the Preferred Project are estimated in **Table 52**, pg 199, at $18M.

2.3.1.5 Conclusion

In order to progress the application through the NSW planning system the original longwall layout was revised as a result of opposition to elements of the proposal. Recent PAC and LEC decisions have reinforced this decision.

The need for the Preferred Project has reduced the life of the project from 18 to 5 years and the volume of ROM coal available for extraction, and therefore potential income from sale, by approximately 85% compared to the EA, and resulted in the complete unrecoverable sterilisation of 1.8Mt of ROM coal.

As shown in **Figure 66**, pg 215, the Illawarra Statistical District, from which 90% of NRE's employees are drawn has the highest unemployment in Australia. Wollongong LGA from which 60% of NRE's employees are drawn on its own has the 9th highest unemployment in Australia. In the context of regional unemployment the impact to regional economic output, the difference between the EA and the Preferred Project, is $2,781 million less in regional output and $1,431 million less in regional incomes while producing 639 less full time equivalent positions.

The valuation of the key environmental impact of the Preferred Project in the Cataract Reservoir catchment would broadly indicate that the $18M in NSW State royalties alone would be greater than the value of complete destruction of the productive capacity of the area affected by the Preferred Project which is tentatively valued at a total of $11.6M.

Given that impacts from the Preferred Project are not going to destroy the productive capacity of the entire Study Area, it is more likely that the maximum impact would be in the vicinity of $1-2M. NRE will also be held accountable, where possible to remediate or offset impacts from the project which would bring the external costs down further.