Mandalong Mine

Longwall 22 & 23
First Workings Modification

Statement of Environmental Effects

August 2016

Executive Summary

Mandalong Mine is an existing underground longwall coal mining operation producing thermal coal that is supplied to domestic and export markets.

Mandalong Mine operates under Development Consent SSD-5144 which was granted on 12 October 2015 by the NSW Planning Assessment Commission under Part 4, Division 4.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). Mandalong Mine is owned and operated by Centennial Mandalong Pty Limited (Centennial Mandalong), a wholly owned subsidiary of Centennial Coal Company Limited (Centennial Coal). Centennial Mandalong is seeking to modify Development Consent SSD-5144 to allow for the extended development of first workings associated with maingates for longwall panels 22 and 23 beyond the approved mine plan.

An igneous sill exists to the west of approved longwall panels 22 to 23. Due to historic uncertainty associated with the extent of the igneous sill, longwall panels 22 to 23 were shortened as a conservative measure to mitigate the sill's impact on the mine's production. In recent times through ongoing geological exploration and the successful extraction of adjacent longwall panels below the igneous sill its extent and condition has become better understood. This has resulted in the proposed extension of maingates for longwall panels 22 and 23 within the Project Application Area of SSD-5144.

First workings development of longwall panels occurs in advance of secondary longwall extraction. This modification is seeking approval of extended first workings only to enable development continuity at Mandalong Mine ahead of longwall extraction. Based on the Mandalong Mine schedule, first workings to form longwall panel 22 are expected to extend beyond the approved mine plan in late October 2016.

The predicted deformations for the 37 m chain pillars during maingate development are in the range of 6 mm to 11 mm. Based on the pillar deformations recorded to date and the minor changes in pillar stress that result from the reduction in pillar width, it is assessed that the 37 m wide chain pillars will be long-term stable during maingate development and the associated surface deformations will be undetectable with standard survey tools.

The proposed modification is not predicted to have any impacts on the natural or built surface environment. The existing Mandalong Mine Environmental Management Strategy and associated environmental management plans are considered adequate to monitor and identify any impacts should they occur. No specific management measures are proposed as a result of this proposed modification.

The proposed modification to SSD-5144 is of minimal environmental impact and will remain substantially the same development as the originally approved. As such it is considered the modification can be approved pursuant to Section 96(1A) of the EP&A Act.

Any subsequent secondary extraction of the extended longwalls will be subject to a separate modification application.

Abbreviations

Authorisation	A
Aboriginal Heritage Information Management System	AHIMS
Australian Height Datum	AHD
Community Consultative Committee	CCC
Centennial Mandalong Pty Limited	Centennial Mandalong
Consolidated Coal Lease	CCL
Department of the Environment	DoE
Department of Primary Industries	DPI
Electrical Conductivity	EC
Environment Protection Authority	EPA
Environment Protection Licence	EPL
Environmental Planning and Assessment Act 1979	EP&A Act
Environment Protection Biodiversity Conservation Act 1999	EPBC Act
Exploration Licence	EL
Licenced Discharge Point	LDP
Lake Macquarie City Council	CCC
Mandalong South Surface Site	MSSS
Million tonnes per annum	Mtpa
Mining Lease	ML
Mining Lease Application	MLA
Mining Purpose Lease	MPL
Office of Environment and Heritage	OEH
Plant Community Types	PCTs
Protection of the Environment Operations Act 1997	POEO Act
Run of Mine	ROM
State Significant Development	SSD
Statement of Environmental Effects	SEE
Threatened Species Conservation Act 1995	TSC Act

Table of Contents

Tables

Figures

Appendices

1. Introduction

Mandalong Mine is an existing underground longwall coal mining operation producing thermal coal that is supplied to domestic and export markets. It is located approximately 35 kilometres south-west of Newcastle near Morisset in New South Wales in the Lake Macquarie Local Government Area (**Figure 1**).

Mandalong Mine operates under Development Consent SSD-5144 which was granted on 12 October 2015 by the NSW Planning Assessment Commission under Part 4, Division 4.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act), and provided for extension of the mining area with a production limit of 6 million tonnes per annum of thermal coal from the West Wallarah and Wallarah-Great Northern Seams.

The currently approved Mandalong Mine comprises the underground workings and surface infrastructure of the following:

- The Mandalong Mine Access Site, encompassing underground workings and associated surface infrastructure near Morisset;
- Delivery of run-of-mine coal from the underground workings to the Cooranbong Entry Site. The coal handling and processing facilities are approved under the Northern Coal Logistic Project (SSD-5145);
- Delivery of run-of-mine coal from underground workings to the Delta Entry Site, located near Wyee at the Vales Point Rail Unloader Facility. The coal handling facility is approved under DA35-2-2004; and
- Mandalong South Surface Site (MSSS), which is yet to be constructed, encompassing ventilation shafts, ventilation fans and underground delivery boreholes located approximately 6 kilometres south-west of the Mandalong Mine Access Site.

2. The Applicant

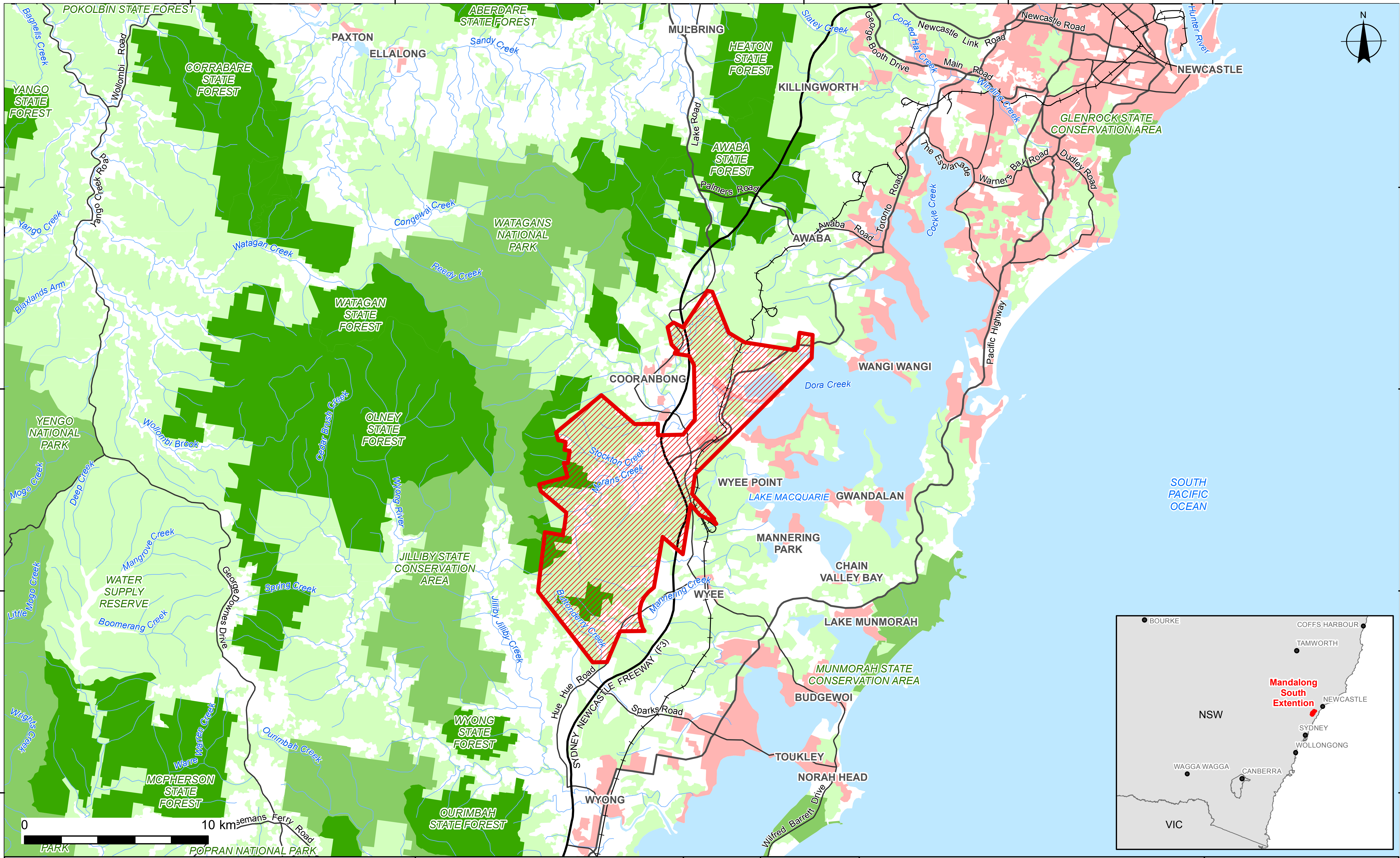
Mandalong Mine is owned and operated by Centennial Mandalong Pty Limited (Centennial Mandalong), a wholly owned subsidiary of Centennial Coal Company Limited (Centennial Coal). Centennial Coal is a wholly owned subsidiary of Banpu Public Company Limited. Mandalong Mine is one of the largest underground coal producers in NSW.

Centennial Mandalong is the applicant for the Project. The relevant address is:

Centennial Mandalong Pty Limited
Level 18, BT Tower
1 Market Street
Sydney NSW 2000

3. Existing and Approved Operations

Underground longwall mining operations commenced at Mandalong Mine in January 2005. Since this time, Centennial Mandalong has extracted up to 6 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal from the West Wallarah Seam utilising a combination of longwall and continuous mining methods.



LEGEND

- Mandalong South Extension Project Development Consent Boundary
- Existing rail
- Freeway
- Principal road
- Secondary road
- Watercourse
- Watercourse area
- Built up area
- Nature conservation
- State forest
- Forest or shrub

LOCATION	MANDALONG
SEAM	WEST WALLARAH
DRAWN	K.S.
CHECKED	
APRROVED	

SCALE 1:200000

Centennial Coal
Mandalong

MANDALONG MINE MODIFICATION
LOCALITY PLAN

CONTRACT	
PLOTFILE	
A3	Figure 1
DRAWING REVISION	18/08/16

Document Path: G:\22\01050001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\MOD\2218510_MOD001_Locality_B.mxd

3.1. Development Consents

The primary activities authorised under SSD-5144 are as follows:

- Continue to operate the Mandalong Mine, with the exception of the infrastructure and operations at the surface of the Cooranbong Entry Site (however the mine ventilation shaft, ventilation fan and Borehole Dam at the surface of the Cooranbong Entry Site are part of the Project).
- Extend Mandalong Mine's underground mining operations into the area covered by ML1722 (Southern Extension Area) using a combination of continuous miner and longwall mining methods.
- Extract up to 6 Mtpa of ROM coal from the West Wallarah and Wallarah-Great Northern Seams within the current mining lease areas.
- Deliver ROM coal from the underground workings to the Cooranbong Entry Site at a rate of up to 6 Mtpa and to the Delta Entry Site at a rate of up to 6 Mtpa.
- Continue to utilise the existing surface infrastructure of the Mandalong Mine Access Site.
- Install and operate surface infrastructure at the proposed MSSS to service the extended underground mining operation.
- Increase manning to 420 full-time employees and up to 50 contractors during longwall relocations.
- Undertake on-going exploration drilling activities within the bounds of Centennial Mandalong's mining leases and exploration licences.
- Continue to operate 24 hours per day, seven days per week.

SSD-5144 was modified on 14 June 2016 to allow for the Mandalong Transmission Line TL24 Relocation Project.

In addition to SSD 5144, Development Consent DA 35/2/2004 was granted in July 2004 by the Minister for Planning, approving the construction and operation of the coal handling and clearance system at the Delta Entry Site. This Statement of Environmental Effects only relates to the proposed modification of SSD-5144.

3.2. Environment Protection Licence

Mandalong Mine is a premises-based activity under Schedule 1 of the *Protection of the Environment Operations Act 1997* (POEO Act). On this basis, the occupier of the premises must hold an Environment Protection Licence (EPL) administered by the Environment Protection Authority (EPA) under Section 43(b) of the POEO Act. Mandalong Mine operates under EPL 365, which covers coal mining to a scale of greater than 5 million tonnes produced per annum and coal works to a scale of greater than 5 million tonnes handled per annum.

3.3. Water Licencing

Centennial Mandalong currently holds several groundwater monitoring licences under the provisions of the Water Act 1912 for the purposes of monitoring groundwater levels in the Mandalong Mine Development Consent Boundary. A groundwater dewatering licence (licence number 20BL173524) is also held by Centennial Mandalong under the Water Act 1912 permitting the extraction of up to 1,825 megalitres per year of groundwater from the coal seam as part of the process of mining (dewatering).

3.4. Mineral Authorities

As listed in **Table 1**, exploration, mining and mining-related operations at Mandalong Mine occur under the provisions of various mineral authorities.

Table 1 – Mandalong Mine's Mineral Authorities

Reference	Title	Description	Expiry Date
CCL 762	Consolidated Coal Lease 762	Title of Cooranbong workings, includes some surface land.	13 Oct 2022
CCL 746	Consolidated Coal Lease 746 (sublease)	Title of Cooranbong workings, includes some surface land.	31 Dec 2028
ML 1722	Mining Lease 1722	Title for Mandalong Mine workings, includes surface land for MSSS.	17 Dec 2036
ML 1443	Mining Lease 1443	Title for Mandalong Mine workings, includes Mandalong Mine Access Site.	1 Mar 2020
ML 1431	Mining Lease 1431	Title to surface land for proposed shaft at the back of Morisset.	27 May 2019
ML 1543	Mining Lease 1543	Title for Mandalong Mine workings.	25 Nov 2024
ML 1553	Mining Lease 1553	Title for Delta Link Project.	7 Sept 2025
MPL 191	Mining Purposes Lease 191	Title to surface land for water tanks at Cooranbong.	24 Feb 2023
MLA 457	Mining Lease Application 457	Subsurface lease for part of Mandalong Southern Extension Area	Pending
EL 6317	Exploration Licence 6317	Title for exploration activities in the Southern Extension Area	8 Aug 2019
EL 4443	Exploration Licence 4443	Title for exploration activities over the former Cooranbong Colliery.	23 Oct 2017
EL 4968	Exploration Licence 4968	Title for exploration activities over part of Mandalong Mine.	31 July 2017
EL 4969	Exploration Licence 4969	Title for exploration activities over part of Mandalong Mine.	31 July 2017
EL 5892	Exploration Licence 5892	Title for exploration activities over part of Mandalong Mine.	31 July 2017
A 404	Authorisation 404	Title for exploration activities over part of Mandalong Mine.	31 July 2017

4. Proposed Modification

The proposed modification is for the extended development of first workings associated with maingates for longwall panels 22 and 23 that extend beyond the current approved mine plan within the SSD 5144 Development Consent boundary and ML1443. The proposed extraction of the extended longwalls will be subject to a separate modification. Should secondary extraction for the extended longwall panels 22 and 23 not be approved, the extraction of these two longwalls will remain within the approved mine plan.

In addition to the extension of first workings for longwalls 22 and 23 beyond the current approved mine plan, this modification is seeking amendments to the SSD 5144 conditions of consent to allow the development to be carried out 'generally in accordance' with the Development Layout provided as Appendix 2. Currently condition 2, Schedule 2 of SSD 5144 requires the development to be undertaken 'in accordance' with the Development Layout. This wording provides no flexibility to Centennial Mandalong being able to adaptively manage the operations at Mandalong Mine in consideration of geological, mine safety and other factors that may necessitate the Development Layout to be altered whilst still ensuring compliance with the performance criteria. Centennial Mandalong also requests the reference to the 'Approved Mine Plan' throughout the conditions of consent be removed from the Development Consent definitions, Condition 6 of Schedule 2, Condition 1 (Table 6) of Schedule 4 and from the title of Figure 2 Appendix 2. Reference to the 'Approved Mine Plan' should be replaced with 'Conceptual Mine Plan', where appropriate, to provide clarity around the proposed changes to Condition 2, Schedule 2 as detailed above. A summary of the proposed changes to the Development Consent conditions is provided in **Appendix C**.

5. Modification Justification

An igneous sill exists to the west of approved longwall panels 22 to 23. Due to historic uncertainty associated with the extent of the igneous sill, longwall panels 22 to 23 were shortened as a conservative measure to mitigate the sill's impact on the mine's production. In recent times through ongoing geological exploration and the successful extraction of adjacent longwall panels below the igneous sill, its extent and condition has become better understood. This has resulted in the proposed extension of longwall panels 22 and 23 within the Project Application Area of SSD-5144. **Figure 2** and **Appendix D** illustrate the proposed maximum extent of maingate development within longwall panels 22 and 23 beyond the approved mine plan. Depending on the actual sill location, which will be identified during maingate development, the actual extent of maingate development may be anywhere between the current approved mine plan boundary and the proposed maximum extent as shown on **Figure 2**.

First workings development of longwall panels occurs in advance of secondary longwall extraction. This modification is seeking approval of extended first workings only to enable development continuity at Mandalong Mine ahead of longwall extraction. Based on the Mandalong Mine schedule, first workings to form longwall panel 22 are expected to extend beyond the approved mine plan in late October 2016. Centennial Mandalong acknowledges that further approval is required to undertake secondary extraction of longwall panels 22 and 23 as extended.

If approved, the proposed modification will result in an increase in coal recovery from maingate development of approximately 84,402 tonnes above the coal that would be recovered from development of these maingates if they were to remain within the current approved mine plan footprint. Should approval for secondary extraction of these longwalls be received (subject to a separate modification application), the extended development of these maingates will facilitate additional coal resource to be recovered from within the existing Mandalong Mine Lease that would otherwise be sterilised.

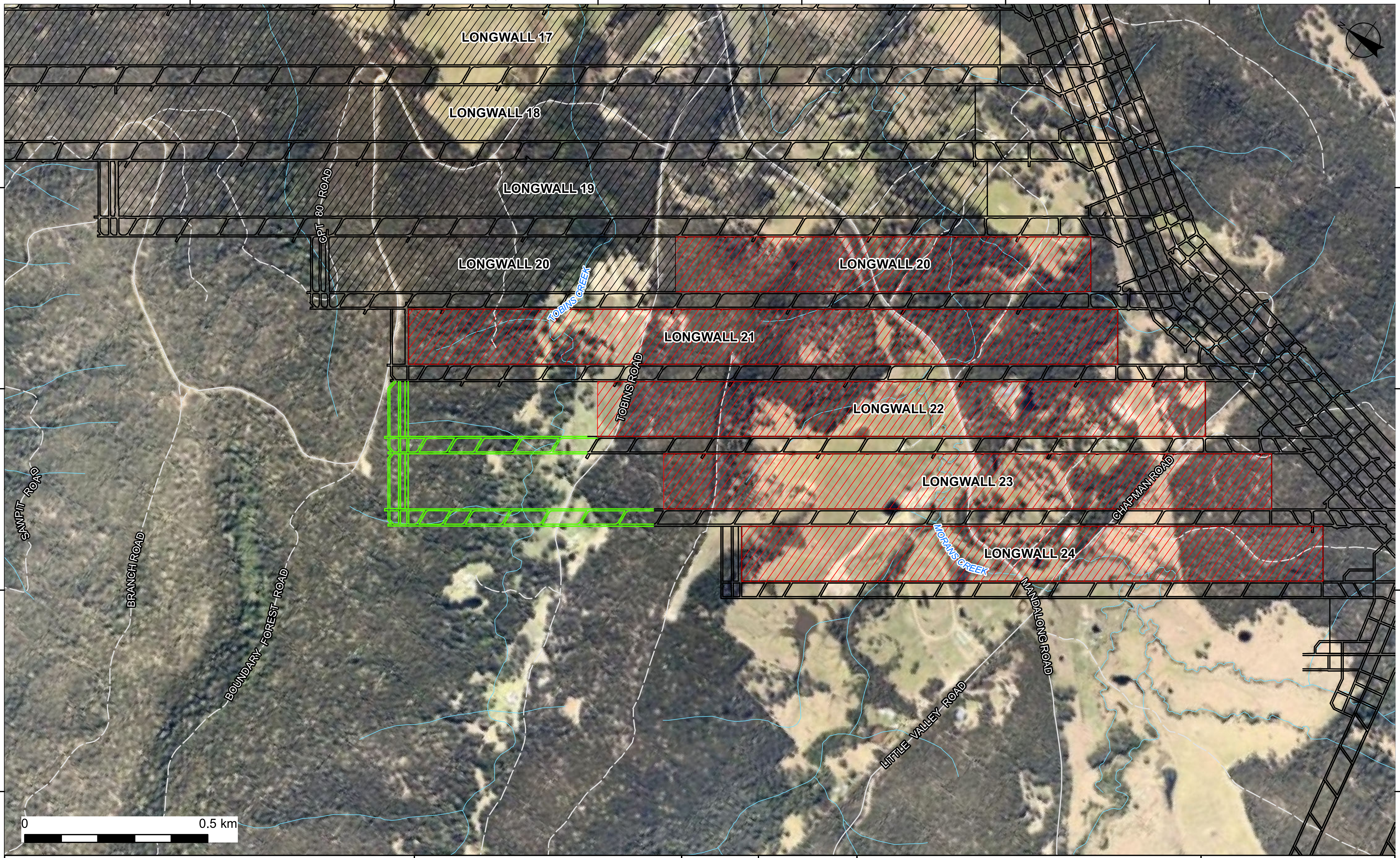
The proposed changes to SSD 5144 Development Consent condition will provide flexibility to Centennial Mandalong and enable the operations to adaptively manage the development at Mandalong Mine in consideration of geological, mine safety and other factors that may necessitate the Development Layout to be altered whilst still ensuring compliance with the performance criteria.

6. Study Area

The study area for this modification encompasses the extent of maingate development associated with longwall panels 22 and 23 that extend beyond the current approved mine plan boundary.

The Study Area is located in the south-western part of the Newcastle Coalfield, which occupies the north-eastern portion of the Sydney Basin. The coal seams found here are the Wallarah Seam and the Great Northern Seam, which together form the upper part of the Permian Newcastle Coal Measures.

Above the Wallarah and Great Northern Seams lies the Narrabeen Group, which are comprised of variable sequences of interbedded claystones, siltstones and fine to coarse-grained sandstones. The Munmorah Conglomerate is a sandstone-dominated formation within the Narrabeen Group, which typically occurs between 60 and 140 metres above the Newcastle Coal Measures.



LEGEND

- Proposed Modification
- Approved Secondary Extraction Area
- Current extraction area
- Approved Mine Workings
- Watercourse
- Road
- Track

CENTENNIAL MANDALONG PTY LTD ©

LOCATION	MANDALONG
SEAM	WEST WALLARAH
DRAWN	K.S.
CHECKED	
APPROVED	
SCALE 1:10000	

Centennial Coal
Mandalong

MANDALONG MINE
PROPOSED FIRST WORKINGS

CONTRACT	
PLOTFILE	
A3	Figure 2
DRAWING REVISION	18/08/16

7. Landownership

As shown on **Figure 3**, land ownership within the Study Area consists of privately owned land and land associated with the Olney State Forest managed by the Forestry Corporation of NSW.

8. Consultation

Mandalong Mine has consulted with both the landowners and stakeholders within the area of the proposed first workings modification for Maingate 22 and 23. Landowners were provided with a mining notification in early September 2015, advising that an Extraction Plan would be developed over the following 12 months. The notification document outlined the application and mining process, typical impacts from subsidence and the process for the development of individual Property Subsidence Management Plans (PSMP) as required by Mandalong's Development Consent.

Structural inspections and assessment of the dwellings within the Study Area have been completed by a qualified structural/civil engineer and soil sampling and flora and fauna surveys has also been conducted on various private properties within the Study Area.

Centennial Mandalong has undertaken extensive consultation with the Forestry Corporation of NSW (FCNSW) since mining beneath FCNSW land associated with Longwall 17. Consultation with FCNSW about mining and mining related activities is ongoing. FCNSW has not raised any concerns or issues during previous or current mining activities.

Centennial Mandalong has developed and implemented a Public Roads Management Plan. This Management Plan was originally developed and implemented prior to the extraction of the first longwall at Mandalong Mine in 2005. The Public Roads Management Plan has been developed in consultation with Lake Macquarie City Council (LMCC) who manages the public roads located within the Study Area. The Public Roads Management Plan is updated for each subsequent Subsidence Management Plan or Extraction Plan in consultation with LMCC. Impacts to the public roads is limited and typically limited to possible hairline cracking not requiring repairs. Centennial Mandalong are currently revising the Public Roads Management Plan associated with the future extraction of Longwalls 22 and 23 in consultation with LMCC.

Telstra copper cables are located along the Tobins Road easement. Telstra have been consulted and have been provided with an assessment report for mining impacts up to Longwall 24. The Telstra Management Plan is currently being reviewed by Telstra for impacts associated with future extraction within Longwalls 22 and 23. The Telstra Management Plan is revised for each subsequent Subsidence Management Plan or Extraction Plan. There has been no impact to any copper cables since mining commenced in 2005.

Similarly, a Powerline Management Plan has been established with Ausgrid for mining up to LW21. A revision of the Powerline Management Plan is currently being developed in consultation with Ausgrid for subsidence to powerlines, associated with the future extraction of Longwalls 22 and 23, located along the Tobins Road easement. There has not been any recorded or observed impact to any the Ausgrid powerline network since mining commenced at Mandalong Mine in 2005 due to the low levels of subsidence observed.

Centennial Mandalong operates a Community Consultative Committee (CCC). The CCC are kept informed of all current and future mining activities. The next CCC meeting is scheduled for October 2016.

9. Legislative Framework and Permissibility

Development Consent SSD-5144 was granted on 12 October 2015 by the NSW Planning Assessment Commission under Part 4 Division 4.1 of the EP&A Act. Centennial Mandalong is now proposing to modify SSD-5144 for the extended first workings maingate development associated with the Mandalong Longwall Panels 22 and 23.

SSD consents may be modified under Section 96 of the EP&A Act provided that the development as modified will be substantially the same development as the development for which consent was originally granted.

Section 96(1A) relates to Modifications involving minimal environmental and includes the following provisions:

> *A consent authority may, on application being made by the applicant or any other person entitled to act on a consent granted by the consent authority and subject to and in accordance with the regulations, modify the consent if:*
>
> *(a) it is satisfied that the proposed modification is of minimal environmental impact, and*
>
> *(b) it is satisfied that the development to which the consent as modified relates is substantially the same development as the development for which consent was originally granted and before that consent as originally granted was modified (if at all), and…*

In relation to Section 96(1A) (a) and (b) as set out above, it is considered that the proposed modification to Development Consent SSD-5144 for extended first workings associated with longwall panels 22 and 23 is:

(a) of minimal environmental impact as the chain pillars will be long-term stable during maingate development and the associated surface deformations will be undetectable with standard survey tools, and

(b) the proposed modifications will result in substantially the same development as the development for which consent was originally granted being an underground longwall coal mine.

As such, it is considered the modification can be modified pursuant to Section 96(1A) of the EP&A Act.

10. Subsidence Predictions

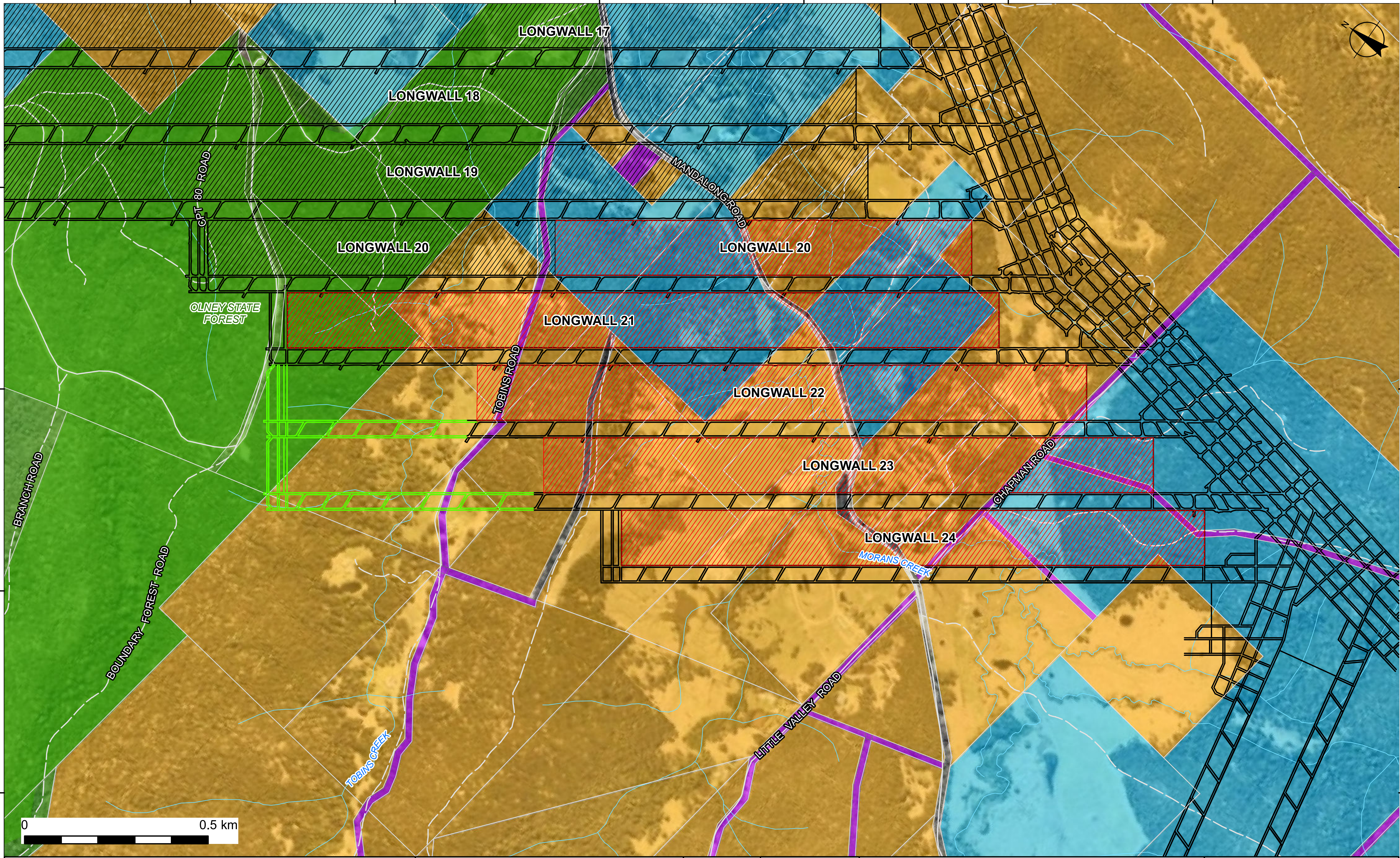
Subsidence predictions have been prepared by Seedsman Geotechnics Pty Ltd to review the proposed pillar design for longwalls 22 and 23 in the context of their stability and deformation during first workings to support this application to modify SSD-5144. A copy of the Subsidence Predictions Report is provided as **Appendix A**.

Deformations of the surface above mains pillars and maingates prior to longwall extraction at Mandalong Mine have previously been less than the detection limits of 20 mm for subsidence surveys. This is assessed to be because the mining-induced displacements are very small, and in fact less than the shrink/swell of the surface related to rainfall events and in some case the precision of the survey tools.

The pillar design for maingate development associated with longwall panels 22 and 23 are proposed to be 37 m in width. This is narrower than the 46 m pillars used previously but the increase in pillar stress is assessed to be negligible.

The predicted deformations for the 37 m chain pillars during maingate development are in the range of 6 mm to 11 mm. Based on the pillar deformations recorded to date and the minor changes in pillar stress that result from the reduction in pillar width, it is assessed that the 37 m wide chain pillars will be long-term stable during maingate development and the associated surface deformations will be undetectable with standard survey tools.

The assessment of subsidence associated with the secondary extraction of these extended longwall panels will be subject to a separate modification application currently being prepared.



LEGEND

- Proposed Modification
- Approved Secondary Extraction Area
- Current extraction area
- Approved Mine Workings
- Private
- Centennial Owned
- State Forest
- Crown Land
- Cadastre
- Watercourse
- Road
- Track

LOCATION	MANDALONG
SEAM	WEST WALLARAH
DRAWN	K.S.
CHECKED	
APRROVED	
SCALE 1:10000	

Centennial Coal
Mandalong

MANDALONG MINE MODIFICATION
LAND OWNERSHIP

CONTRACT	
PLOTFILE	
A3	Figure 3
DRAWING REVISION	19/08/16

Document Path: G:\22\01050001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\MOD\2218510_MOD004_Ownership_B.mxd

11. Environmental Assessment

11.1. Ecology

11.1.1. Existing Environment

Preliminary ecological surveys were undertaken by Hunter Eco in July 2016. Surveys were limited to threatened flora searches, vegetation community delineation and opportunistic fauna observations. Four vegetation communities occur within the Study Area as illustrated in **Figure 4**. Mapped vegetation communities comprise of:

- MU1 Coastal Wet Gully Forest
- MU5 Alluvial Tall Moist Forest
- MU15 Coastal Foothills Spotted Gum - Ironbark Forest
- MU12C Hunter Valley Moist Spotted gum – Ironbark Forest

The vegetation type MU1 – Coastal Wet Gully Forest is potentially commensurate with the *Threatened Species Conservation Act 1995* (TSC Act) listed *Lowland Rainforest in NSW North Coast and Sydney Basin Bioregion*. MU5 – Alluvial Tall Moist Forest is potentially commensurate with the TSC Act listed *River-Flat Eucalypt Forest on Coastal Floodplains* Endangered Ecological Community.

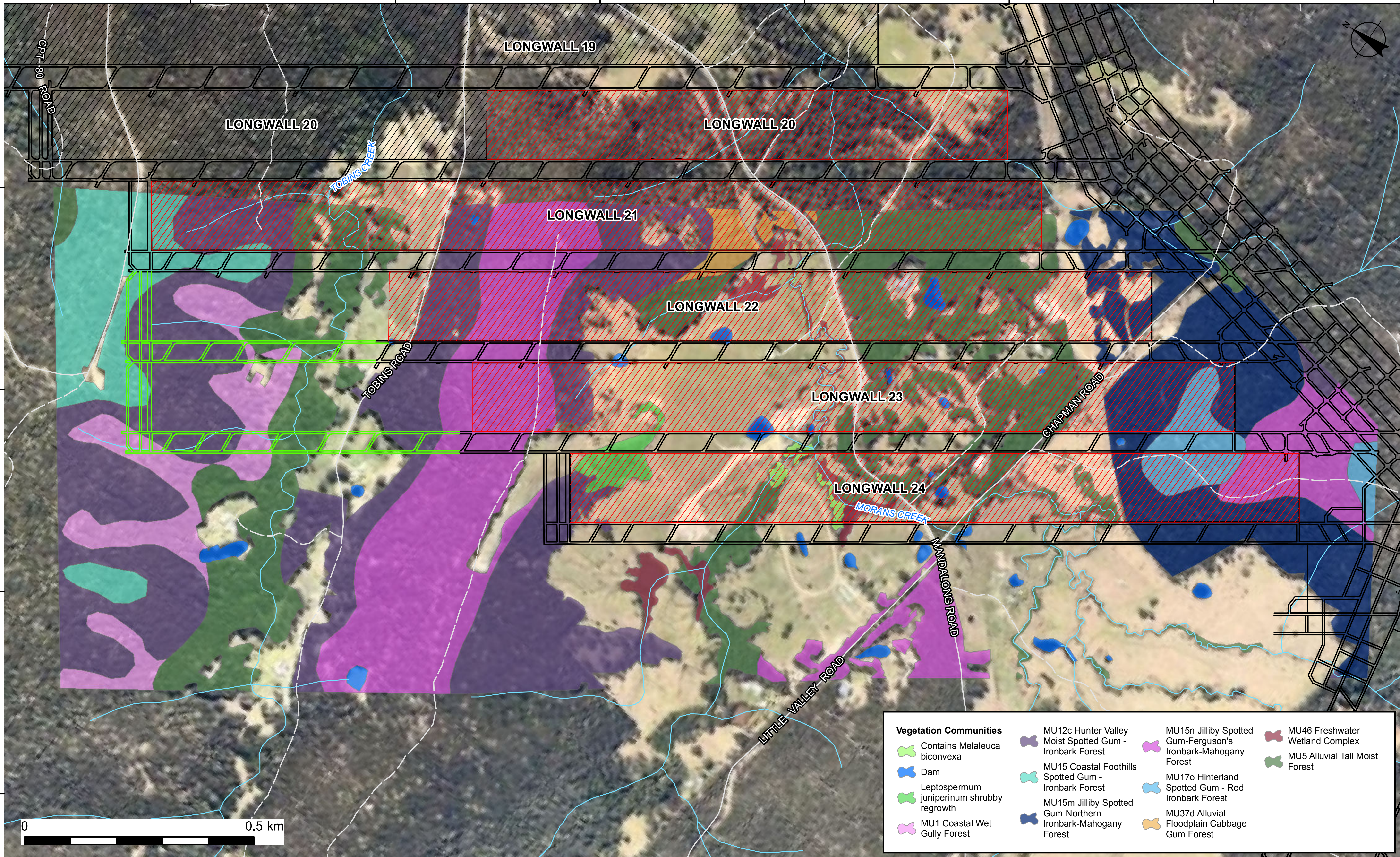
No threatened flora species were identified within the Study Area during field surveys.

In addition to the field surveys, a review of relevant information was performed to identify any other ecological values occurring or potentially occurring within the Study Area. Information sources reviewed for a 10 km radius of the Study Area included:

- Fauna and flora records contained in the Office of Environment and Heritage (OEH) Atlas of NSW Wildlife that may occur within the locality (OEH 2016); and
- Fauna and flora records contained in the Department of the Environment (DoE) Protected Matters Search tool that may occur within the locality (DoE 2016).

The results of these database searches formed the basis for a 'likelihood of occurrence' assessment that has been provided as **Appendix B**. Threatened flora and fauna species (listed under the TSC Act and/or *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)) that have been gazetted and recorded within a 10 km radius of the Study Area were considered within this assessment. Additional species that were known from the region that did not arise in searches were also considered. Each species was considered for its potential to occur within the Study Area based on the Plant Community Types (PCTs) and habitats present.

Eight flora species and 25 fauna species listed under the TSC Act and/or EPBC Act were identified as occurring or potentially occurring within the Study Area. **Table 2** below summarises the TSC and EPBC listed flora and fauna occurring or likely to occur within the Study Area.



LEGEND

- Proposed Modification
- Approved Secondary Extraction Area
- Current extraction area
- Approved Mine Workings
- Watercourse
- Road
- Track

LOCATION	MANDALONG
SEAM	WEST WALLARAH
DRAWN	K.S.
CHECKED	
APRROVED	
SCALE 1:8000	

Centennial Coal
Mandalong

MANDALONG MINE MODIFICATION
VEGETATION COMMUNITIES

CONTRACT	
PLOTFILE	
A3	Figure 4
DRAWING REVISION	18/08/16

Document Path: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\MOD\2218510_MOD005_VegetationComms_B.mxd

Table 2 – Threatened Flora and Fauna Likelihood of Occurrence

Flora Species	TSC Act listing	EPBC Act listing
Angophora inopina	V	V
Grevillea parviflora subsp. Parviflora (Small-flowered Grevillea)	V	V
Melaleuca biconvexa (Biconvex Paperbark)	V	V
Persicaria elatior	V	V
Pterostylis gibbosa (Illawarra Greenhood)	E	E
Rutidosis heterogama	V	V
Syzygium paniculatum (Magenta Lilly Pilly)	E	V
Tetratheca juncea (Black-eyed Susan)	V	V
Fauna Species	**TSC Act listing**	**EPBC Act listing**
Anthochaera Phrygia (Regent Honeyeater)	CE	E,M
Callocephalon fimbriatum (Gang-gang Cockatoo)	V	-
Calyptorhynchus lathami (Glossy Black-Cockatoo)	V	-
Climacteris picumnus victoriae (Brown Treecreeper (eastern subspecies))	V	-
Daphoenositta chrysoptera (Varied Sittella)	V	-
Glossopsitta pusilla (Little Lorikeet)	V	-
Ninox strenua (Powerful Owl)	V	-
Tyto tenebricosa (Sooty Owl)	V	-
Chalinolobus dwyeri (Large-eared Pied Bat)	V	V
Dasyurus maculatus maculatus (Spotted-tailed Quoll)	V	E
Falsistrellus tasmaniensis (Eastern False Pipistrelle)	V	-
Kerivoula papuensis (Golden-tipped Bat)	V	-

Fauna Species	TSC Act listing	EPBC Act listing
Miniopterus schreibersii oceanensis (Eastern Bentwing-bat)	V	-
Mormopterus norfolkensis (Eastern Freetail-bat)	V	-
Myotis macropus (Southern Myotis)	V	-
Petauroides Volans (Greater Glider population in the Eurobodalla local government area)	EP	-
Petaurus australis (Yellow-bellied Glider)	V	-
Petaurus norfolcensis (Squirrel Glider)	V	-
Phascogale tapoatafa (Brush-tailed Phascogale)	V	-
Phascolarctos cinereus (Koala)	V	V
Pteropus poliocephalus (Grey-headed Flying-fox)	V	V
Scoteanax rueppellii (Greater Broad-nosed Bat)	V	-
Litoria brevipalmata (Green-thighed Frog)	V	-
Pseudophryne australis (Red-crowned Toadlet)	V	-
Hoplocephalus stephensii (Stephens' Banded Snake)	V	-

11.1.2. Impact Assessment

Based on the predicted pillar deformations being undetectable (Seedsman Geotechnics, 2016) for the maingate development associated with longwall panels 22 and 23, no impacts to vegetation communities, threatened flora, threatened fauna or their habitats are predicted as a result of the proposed modification.

11.2. Aboriginal and Historic Heritage

11.2.1. Existing Environment

A search was undertaken of the Aboriginal Heritage Information Management System (AHIMS) on 31 May 2016. One Aboriginal site has been previously recorded in close proximity to the Study Area (**Table 3**).

Table 3 – AHIMS Sites

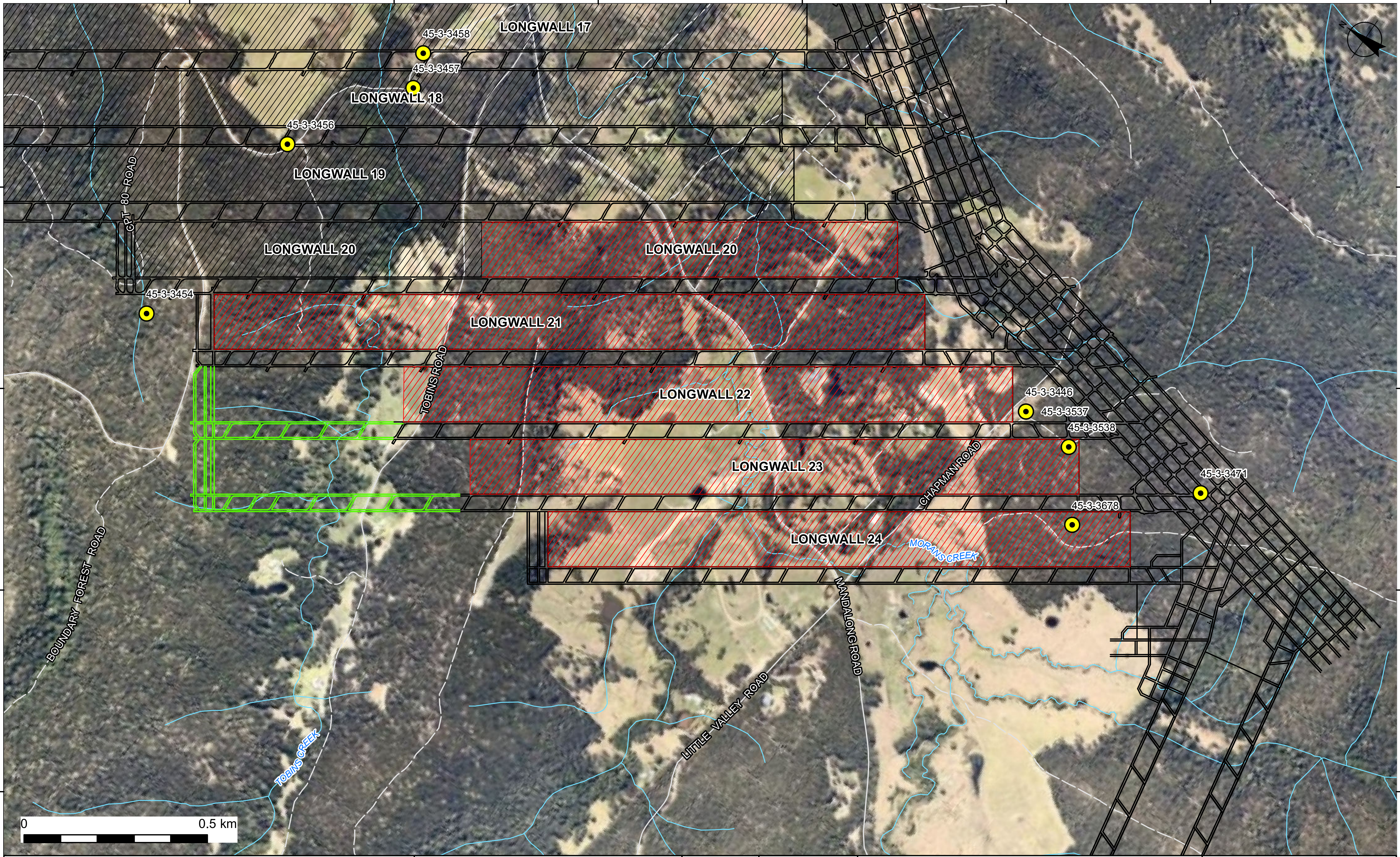
AHIMS Number	Site Type	Easting	Northing
45-3-3454	Grinding Groove	351812	6333662

In addition to the AHIMS search, a survey was undertaken by Archeologists from RPS Australia East Pty Ltd on 14 and 15 June 2016 in and around the Study Area. The survey was conducted in accordance with the requirements set out in the Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales (OEH 2010). The survey was conducted on foot (pedestrian) and targeted all accessible areas in and around the Study Area.

No Aboriginal heritage sites were identified in the Study Area. All Aboriginal heritage sites identified within the vicinity of the Study Area are shown on **Figure 5**.

11.2.2. Impact Assessment

No Aboriginal heritage sites were identified within the Study Area. Based on the predicted pillar deformations being undetectable (Seedsman Geotechnics, 2016) for the maingate development associated with longwall panels 22 and 23, no impacts to identified Aboriginal heritage sites within the vicinity of the Study Area are predicted as a result of the proposed modification.



LEGEND

- Proposed Modification
- Approved Secondary Extraction Area
- Current extraction area
- Approved Mine Workings
- Aboriginal Heritage Site
- Watercourse
- Road
- Track

LOCATION	MANDALONG
SEAM	WEST WALLARAH
DRAWN	K.S.
CHECKED	
APRROVED	
SCALE	1:10000

Centennial Coal
Mandalong

MANDALONG MINE MODIFICATION
HERITAGE

CONTRACT	
PLOTFILE	
A3	Figure 5
DRAWING REVISION	18/08/16

Document Path: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\MOD\2218510_MOD006_AHIMS_B.mxd

11.3. Surface Water

11.3.1. Existing Environment

Tobins Creek is a second order creek that flows in a north-easterly direction through the Study Area (**Figure 6**). Tobins Creek is considered as an intermittent watercourse with limited or zero flow during low rainfall periods suggesting that the number of users dependent on flows from this watercourse, would be limited.

11.3.2. Impact Assessment

Based on the predicted pillar deformations being undetectable (Seedsman Geotechnics, 2016) for the maingate development associated with longwall panels 22 and 23, no impacts to watercourse stability, surface water quality, or surface water flows are predicted as a result of the proposed modification.

11.4. Groundwater

11.4.1. Existing Environment

The groundwater sources in the vicinity of the Study Area are generally low yielding and predominantly weathered and/or fractured sandstone, coal seams with some clayey quaternary alluvium. Groundwater sources in the area would be classified as 'less productive', in accordance with the NSW Aquifer Interference Policy (NSW DPI Water 2012).

Alluvial Water Sources

The alluvium in the vicinity of the Study Area forms an unconfined shallow aquifer with a water table typically ranging in depth from less than 1 m and up to about 3 m below ground level, and aquifer thickness less than 20 m. The alluvial groundwater is moderately acidic to slightly alkaline, brackish to saline, extremely hard and of sodium chloride type (GHD 2013). Groundwater EC varies considerably within alluvium across the mining area, ranging from less than 1,000 µS/cm to over 10,000 µS/cm. Due to the relatively high silt and clay content of the alluvium, the groundwater yields are relatively low (typically less than 1 L/s). As a result of the low yield and relatively poor water quality, there are very few registered private alluvial groundwater bores throughout in the vicinity of the Study Area. The environmental value of the alluvial groundwater is considered to be 'primary industry' (specifically stock watering), with the saline groundwater only suitable for stock watering (GHD 2013).

Porous and Fractured Rock Water Sources

The piezometric head within the Permian coal seams tends to reflect the natural topography and the orientation and dip of the seams, with reduced pressures at major surface drainage areas and in areas of coal extraction. Where coal seam groundwater has not been depressurised, the groundwater head generally tends to be in the order of 0 m AHD due to the coastal environment. Groundwater within the porous and fractured rock groundwater sources is slightly alkaline and brackish to saline with EC typically ranging from about 6,000 µS/cm to over 10,000 µS/cm (GHD 2016).

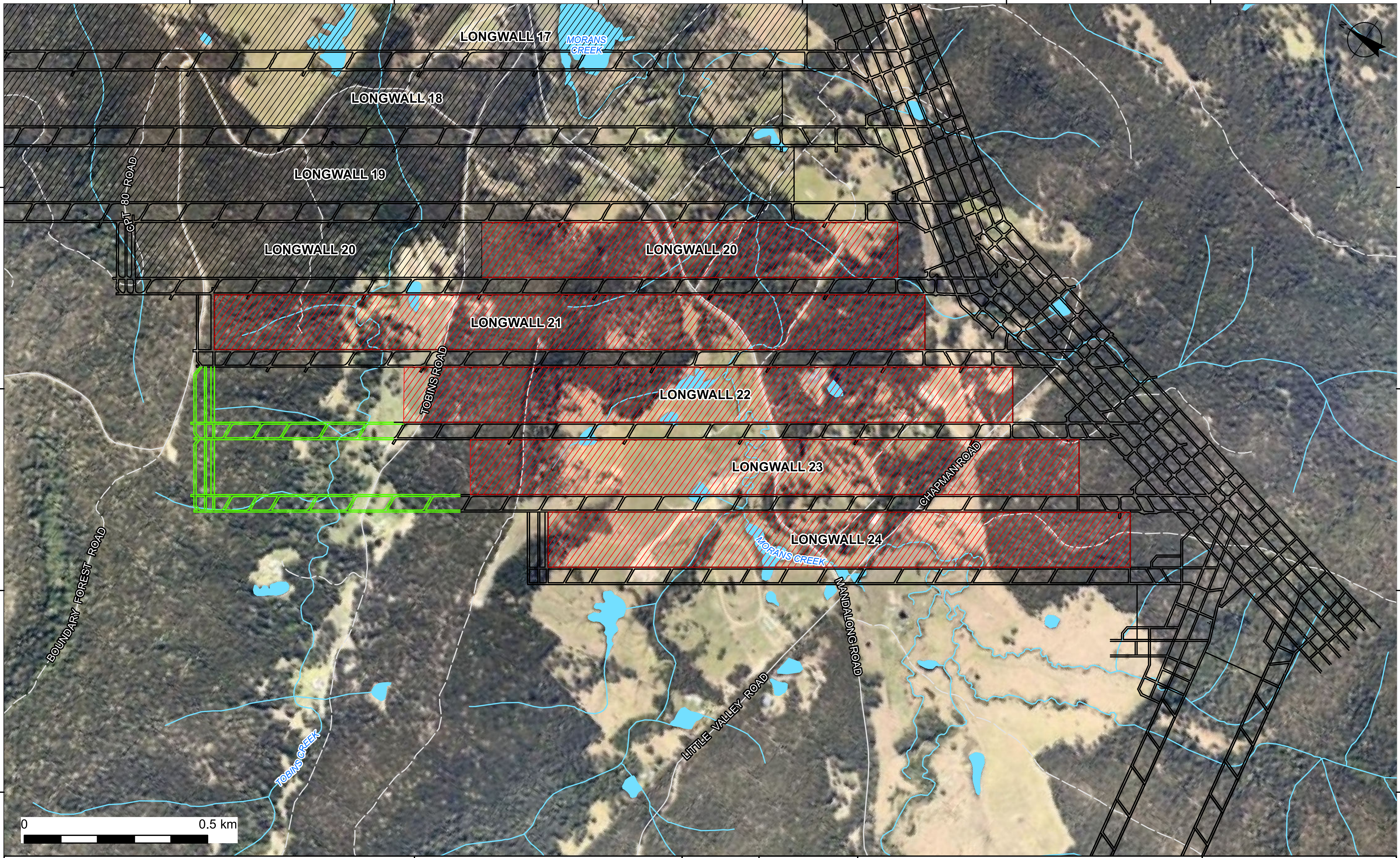
Groundwater Management

Groundwater inflows into the existing Cooranbong and Mandalong workings from the coal seam and adjacent strata are relatively low. Groundwater inflows to the mine are dewatered to the Cooranbong underground water storage area at the Cooranbong Entry Site and subsequently discharged through licenced discharge point (LDP001) in accordance with EPL 365. Discharges from Cooranbong Entry Site are managed under the Northern Coal Logistics Project (SSD-5145). Monitoring is undertaken on the water level held within the Cooranbong underground storage and discharge rate from LDP001.

11.4.2. Impact Assessment

Based on the predicted pillar deformations being undetectable (Seedsman Geotechnics, 2016) for the maingate development associated with longwall panels 22 and 23, no impacts to alluvial groundwater sources or groundwater users within the locality are predicted as a result of the proposed modification.

Groundwater inflows into the mine workings associated with the maingate development for longwalls 22 and 23 will be managed by the existing underground water management system. The additional groundwater inflows into the mine will be managed within the capacity constraints of the existing water management system.



LEGEND

- Proposed Modification
- Approved Secondary Extraction Area
- Current extraction area
- Approved Mine Workings
- Watercourse
- Waterbody

LOCATION	MANDALONG
SEAM	WEST WALLARAH
DRAWN	K.S.
CHECKED	
APPROVED	
SCALE 1:10000	

Centennial Coal
Mandalong

MANDALONG MINE MODIFICATION
WATERCOURSES

CONTRACT	
PLOTFILE	
A3	Figure 6
DRAWING REVISION	18/08/16

Document Path: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\MOD\2218510_MOD006_Watercourses_B.mxd

11.6. Soils and Agriculture

11.6.1. Existing Environment

The Soil Landscapes Units within the Study Area have been mapped by the former NSW Department of Land and Water Conservation, incorporating the NSW Soil Conservation Service (now part of NSW Department of Primary Industries (DPI)), on the Soil Landscapes of the Gosford – Lake Macquarie Sheet 1:100 000 Sheet (Murphy, 1993) and shown in **Figure 7**. Three soil landscapes occur in the Study Area being:

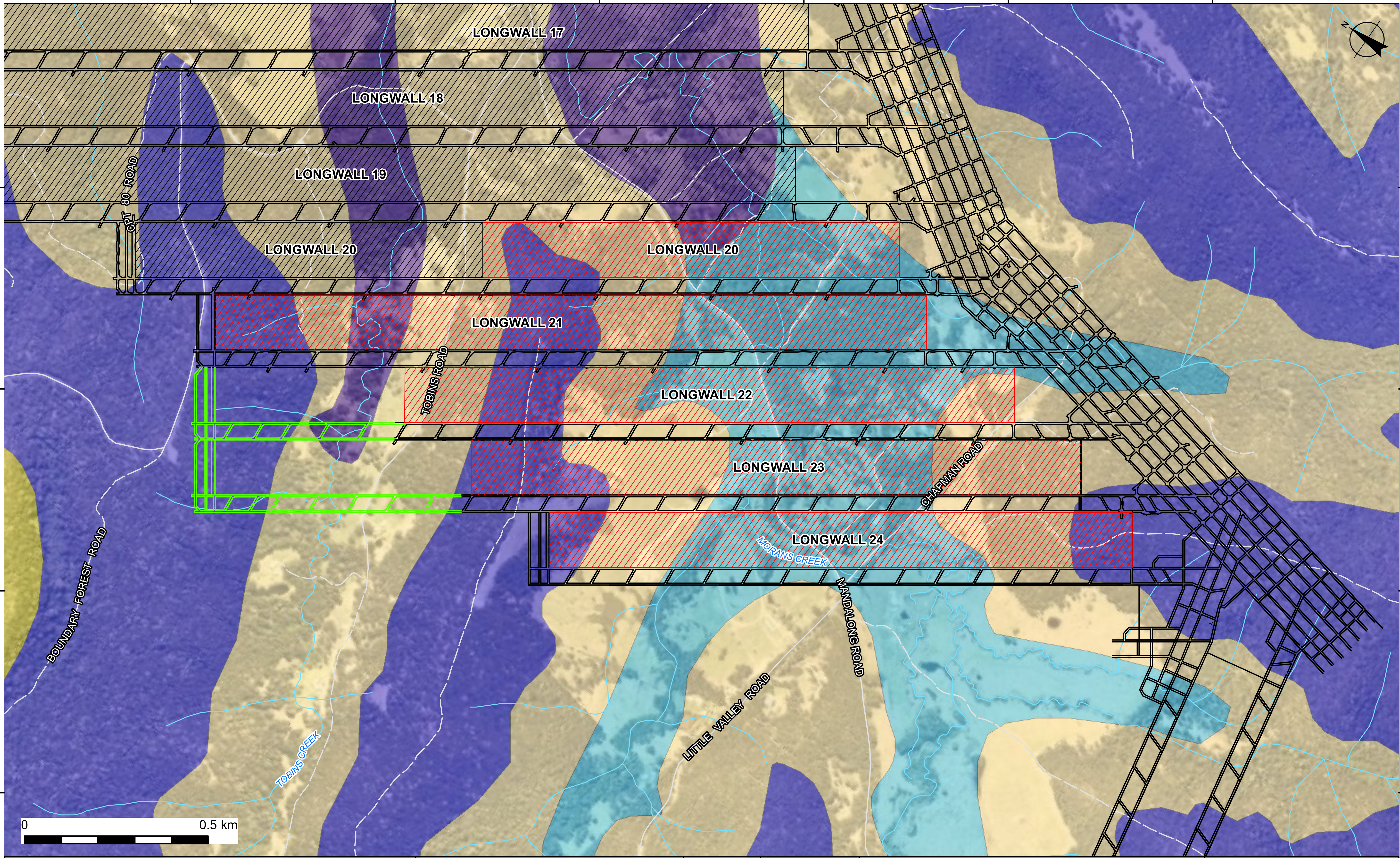
- Mandalong;
- Wyong; and
- Gorokan.

Topsoil in the Wyong soil landscape is generally 0 - 40 cm thick. Topsoils in the Gorokan soil landscape are generally 0 - 150 cm thick and topsoil in the Mandalong soil landscape is generally 0 - 10 cm thick.

The majority of the Study Area remains under native vegetation. The remainder is land that has been previously cleared and may be suitable for agricultural enterprises. Within and surrounding the Study Area, agricultural enterprises have traditionally been small farm enterprises conducted in pockets of cleared native bushland, reliant upon off-farm income to be sustainable. Cattle grazing, pleasure horse agistment and small orchard areas are the main agricultural activities in the area.

11.6.2. Impact Assessment

Based on the predicted pillar deformations being undetectable (Seedsman Geotechnics, 2016) for the maingate development associated with longwall panels 22 and 23, no impacts to soil landscapes or agricultural enterprises are predicted to occur as a result of the proposed modification.



LEGEND

- Proposed Modification
- Approved Secondary Extraction Area
- Current extraction area
- Approved Mine Workings
- Watercourse
- Road
- Track

LANDSCAPE, NAME

- ALwy - Wyong
- ALya - Yarramalong
- COml - Mandalong
- COwn - Watagan
- ERgk - Gorokan

LOCATION	MANDALONG
SEAM	WEST WALLARAH
DRAWN	K.S.
CHECKED	
APRROVED	
SCALE 1:10000	

Centennial Coal
Mandalong

MANDALONG MINE MODIFICATION
SOIL LANDSCAPE UNITS

CONTRACT	
PLOTFILE	
A3	Figure 7
DRAWING REVISION	18/08/16

Document Path: G:\22\0105001\GIS\Maps\Deliverables\Hunter\Mandalong\2218510\MOD\2218510_MOD008_SoilLandscapes_B.mxd

13. Monitoring and Management

The proposed modification is not predicted to have any impacts on the natural or built surface environment. The existing Mandalong Mine Environmental Management Strategy and associated environmental management plans are considered adequate to monitor and identify any impacts should they occur. No specific management measures are proposed as a result of this proposed modification.

14. Conclusion

The proposed modification, which is seeking approval to extend the first workings of longwall panels 22 and 23, has been adequately assessed with regard to subsidence impacts on the built and natural environment in addition to groundwater resources. Based on the pillar deformations recorded to date and the minor changes in pillar stress that result from the reduction in pillar width, it is concluded that the 37 m wide chain pillars will be long-term stable during maingate development and the associated surface deformations will be undetectable with standard survey tools. The modification will therefore not have any impacts on the natural or built surface environment. Groundwater inflows are predicted to remain low yielding and are to be managed within the confines of the existing water management system.

As no impacts are predicted, the existing Mandalong Mine Environmental Management Strategy and associated environmental management plans are considered adequate to monitor and identify any impacts should they occur. Consequently no specific management measures are proposed as a result of this proposed modification.

This modification is seeking approval of extended first workings only to enable development continuity at Mandalong Mine ahead of longwall extraction. Based on the Mandalong Mine schedule, first workings to form longwall panel 22 are expected to extend beyond the approved mine plan in late October 2016. The increase in coal recovery from the extended maingate development of approximately 84,402 tonnes optimises the coal resource within the existing SSD-5144 Project Application Area. Centennial Mandalong acknowledges that further approval is required to undertake secondary extraction of longwall panels 22 and 23 as extended.

The Modification is considered to be consistent with the relevant objectives of the EP&A Act and will not change the nature of the development originally approved. On this basis Section 96(1A) is considered an appropriate approval mechanism. On considering the balance of the proposed negligible impacts it is considered reasonable to conclude that the benefits of the modification outweigh the impacts. Based on the findings of this report, it is recommended that the modification be approved subject to conditions.

15. References

GHD (2016) Mandalong Mine Water Management Plan, prepared by GHD Pty Ltd for Centennial Mandalong Pty Limited.

GHD (2013) Mandalong Southern Extension Project: Groundwater Impact Assessment, prepared by GHD Pty Ltd for Centennial Mandalong Pty Limited.

Murphy, C.L. (1993) Soil Landscapes of the Gosford – Lake Macquarie Sheet 1:100 000 Sheet Soil Conservation Service of NSW, Sydney.

NSW Department of Primary Industries, Office of Water (2012) NSW Aquifer Interference Policy: NSW Government policy for the licencing and assessment of aquifer interference activities.

Seedsman Geotechnics (2016) Centennial Mandalong Pty Ltd – Pillar Design for LW22 – 23.

Appendix A – Subsidence Assessment (Seedsman Geotechnics Pty Limited)

SEEDSMAN GEOTECHNICS PTY LTD

ACN 082 109 082
Telephone 0417279556
Facsimile 0242712220

CENTENNIAL MANDALONG PTY LTD

PILLAR DESIGN FOR LW22 – LW23

MAND16-08   AUGUST 2016

SEEDSMAN GEOTECHNICS PTY LTD

ACN 082 109 082
Telephone 0417279556
Facsimile 0242712220

Tuesday, 9 August 2016

REF: MAND16-08

Mr P Enright
Mining Approvals Coordinator
Centennial Coal Company Limited | Mandalong
12 Kerry Anderson Drive
Mandalong NSW 2264

Dear Phil,

RE: Pillar design for LW22 – LW23

This report reviews the design of the chain pillars in LW22 and LW23 in the context of their stability and deformation during first workings.

Please contact the undersigned if you require further details

Yours truly

Ross Seedsman
FAusIMM (CP)

EXECUTIVE SUMMARY

Deformations of the surface above mains pillars and maingates before longwall extraction at Mandalong Mine have been less than the detection limits of 20 mm for subsidence surveys. This is assessed to be because the mining-induced displacements are very small, and in fact less than the shrink/swell of the surface related to rainfall events and in some case the precision of the survey tools.

For LW22 and LW23 the chain pillars are proposed to be 37 m in width. This is narrower than the 46 m pillars used previously but the increase in pillar stress is assessed to be negligible. The predicted deformations for the 37 m chain pillars during maingate driveage are in the range of 6 mm to 11 mm.

Based on the pillar deformations recorded to date and the minor changes in pillar stress that result from the reduction in pillar width, it is assessed that the 37 m wide chain pillars will be long-term stable during maingate driveage and the associated surface deformations will be undetectable with standard survey tools.

TABLE OF CONTENTS

LIST OF FIGURES

1 INTRODUCTION

Mandalong Mine operates under Development Consent SSD-5144 which was granted on 12 October 2015 by the NSW Planning Assessment Commission under Part 4, Division 4.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act), and provided for extension of the mining area with a production limit of 6 million tonnes per annum of thermal coal from the West Wallarah and Wallarah-Great Northern Seams.

Centennial Mandalong, as the operator of Mandalong Mine, is currently preparing a Statement of Environmental Effects to support an application seeking to modify Development Consent SSD-5144 under Part 4 of the EP&A Act. The modification is seeking to extend the chain pillars associated with longwall panels 22 and 23 within the Project Application Area of SSD-5144. Figure 1 provides a comparison of the approved development layout and proposed modifications.

This Subsidence Report reviews the design of the chain pillars in LW22 and LW23 in the context of their stability and deformation during first workings to support the application to modify SSD-5144. In addition this Subsidence Report addresses Schedule 4, Condition 12 of SSD-5144 which is reproduced below:

> *The Applicant may carry out first workings on site, other than in accordance with an approved Extraction Plan, provided that DRE is satisfied that the first workings are designed to remain stable and non-subsiding, except insofar as they may be impacted by approved second workings.*

The portion of MG 22 impacted by this condition is shown in Figure 1 shows the proposed mine plan for Mandalong up to LW24. Close inspection will reveal that there has been no change in the dimension of the Main heading pillars (27.8 m solids and 5.2 m roadways). From MG20 onwards the chain pillar width has decreased from 46 m to 37 m. The longwall extraction voids are 160 m wide. The development roadway height is 3.4 m and the depth of cover ranges between 250 m and 330 m (Figure 2).

There has been extensive monitoring of surface subsidence at Mandalong Mine since the beginning of operations in 2003. The surface deformations above the Main Headings and chain pillars are within the anticipated range of elastic deformation of the roof/pillar/floor system and do not indicate the onset of unstable conditions. This is consistent with underground observations in the longwall tailgates and long-term ventilation roadways.

This report assesses the pillar designs for the first workings based on considerations of performance to date and a review of the design process used to justify the change in chain pillar width.

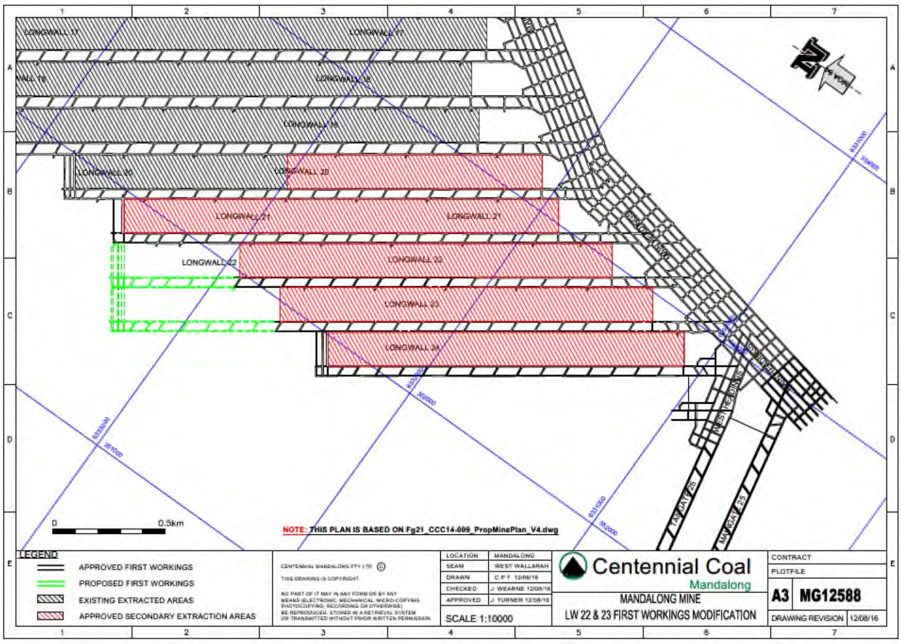


Figure 1 Detail of the proposed modification for MG22 and MG23 outside the Mandalong South approved plan (shown in green)

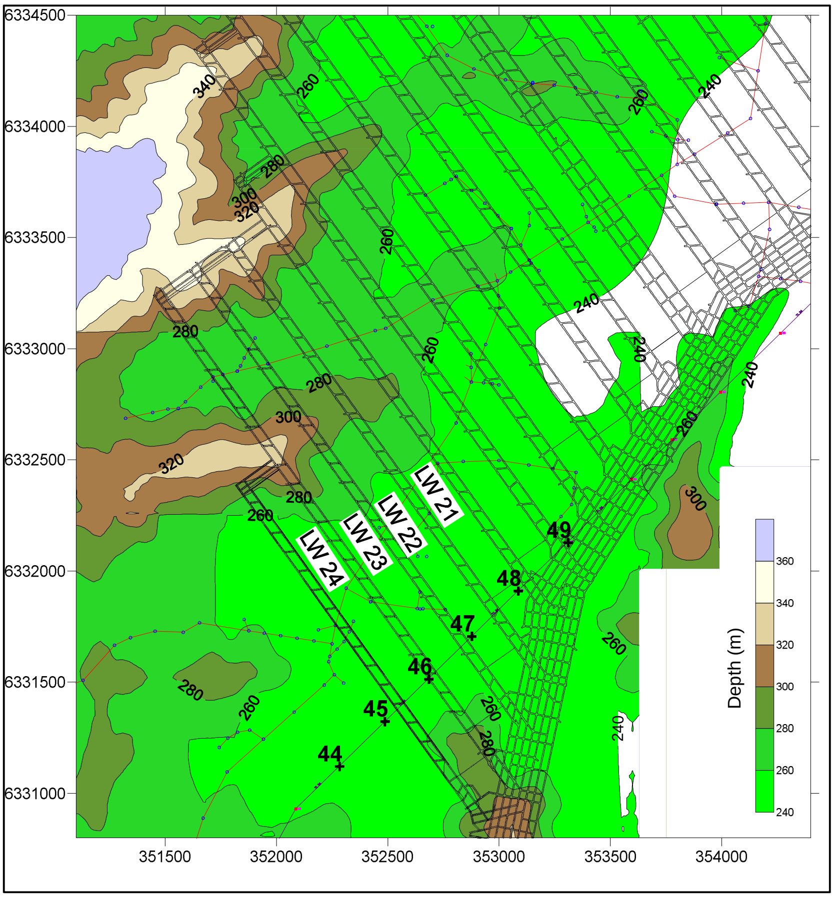


Figure 2 Mine plan and depth of cover

2 REVIEW OF PILLAR PERFORMANCE TO DATE

In this section the subsidence monitoring from three survey lines (Figure 3) are discussed CL14 which is along the centreline of LW14, and two cross lines - CS18 and CS2.

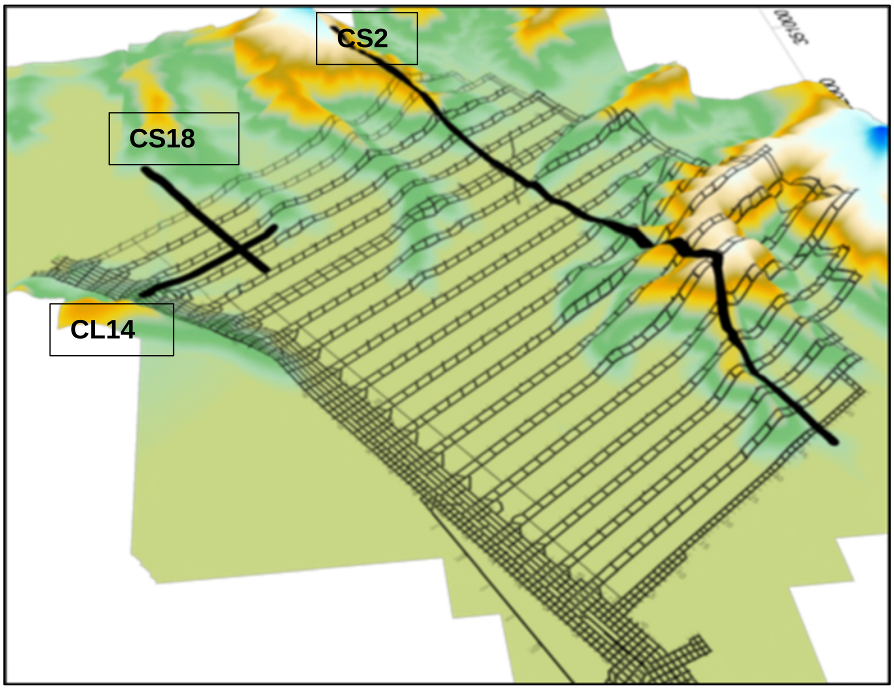


Figure 3 Three survey lines discussed in this report

The subsidence survey along the centreline of LW17 in early 2016 (Figure 4) indicates that there has been typically less than 10 mm of recorded movement above the Main Headings, noting that the reproducibility of the survey method is in the order of +/-20 mm as controlled by soil shrink and swell.

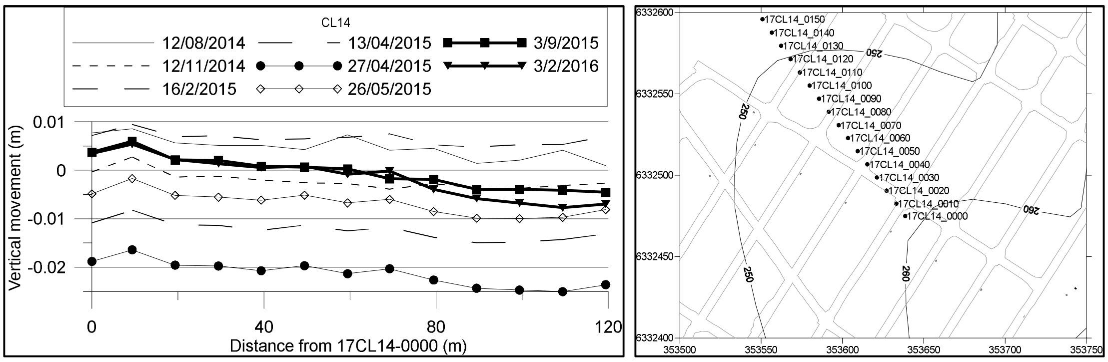


Figure 4 Survey data above the Main Headings along the centreline line down LW17

The surveys along subsidence cross lines that extend out to the west above the maingates and beyond the longwall extraction have revealed movements of less than 10 mm (Figure 5). This scale of movement is less than the detection limit for mining induced movement.

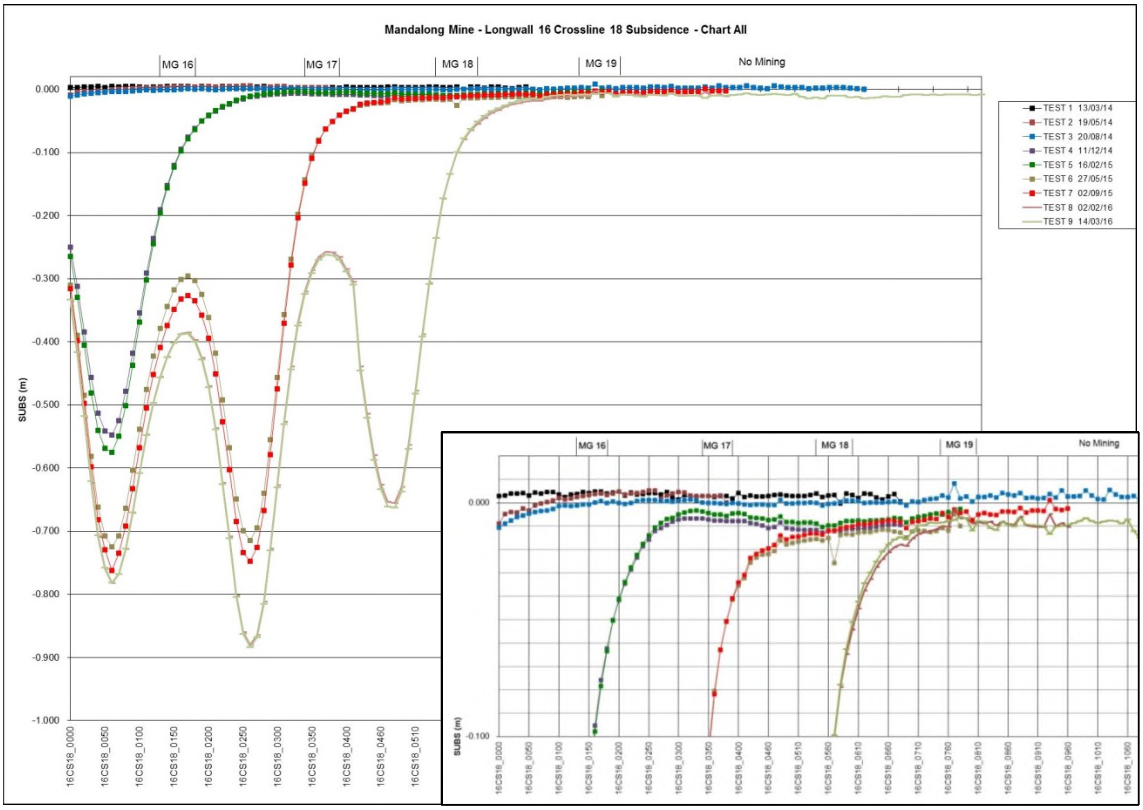


Figure 5 Subsidence associated with the driveage of maingates based on data from CS18

Since longwall extraction began in 2005 there has been no evidence that the chain pillars have collapsed. Certainly there is deformation of the surface above the chain pillars, for example along crossline line CS2 (Figure 6), which can be adequately explained by the compression of the roof and floor strata and the West Wallarah coal seam itself. A compilation of the data on the depth of cover and the minimum subsidence deformation above chain pillars (Figure 7) shows a strong relationship.

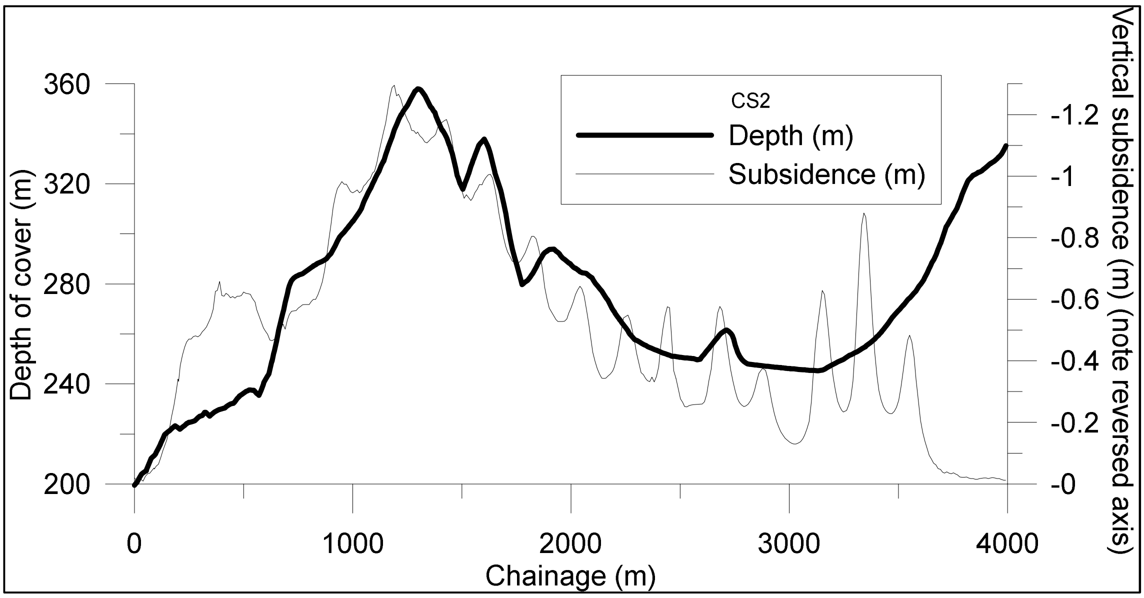


Figure 6 CS2 subsidence survey data from test 54 conducted in 2016 (n.b. subsidence axis inverted to emphasise relationship with depth of cover

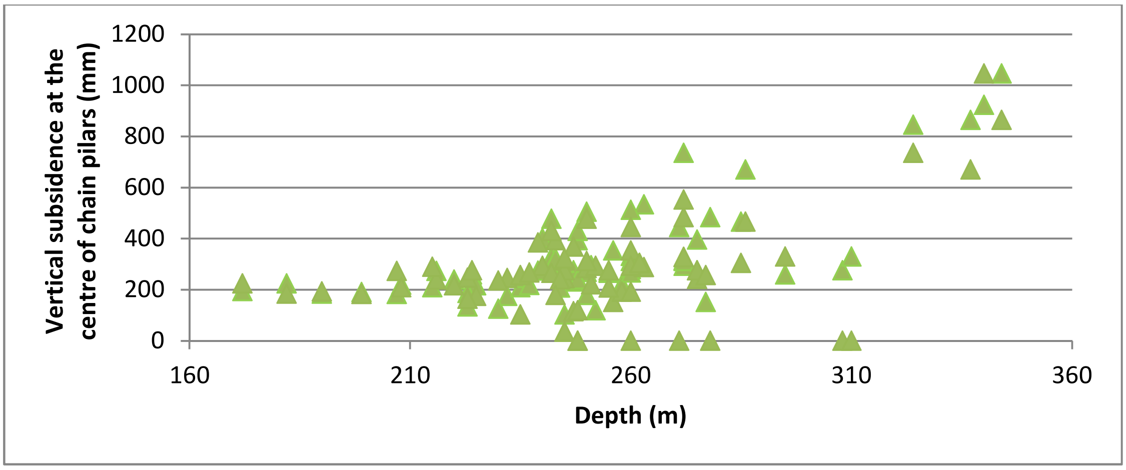


Figure 7 Vertical subsidence measured directly above chain pillars at Mandalong

3 PREDICTION FOR MG22 AND MG23

The width of the chain pillars for MG22 and MG23 is 37 m compared to the 46 m used previously. As yet, there has been no longwall extraction on both sides of 37 m wide chain pillars. An appendix to this report outlines the design methods adopted to make predictions on the future behaviour of the chain pillars.

The analysis of pillar stability and deformation for a two-heading gateroad is somewhat constrained by the lack of a method to calculate pillar stresses. For wide expanses of pillars the tributary area stress method can be used – this is equivalent to an assumption of zero stiffness in the overburden which is not a sustainable assumption for two roadways 37 m apart at in excess of 250 m depth. Galvin[1] quotes an example where the stress applied to a small pillar between two roadways is only 50% of the tributary area loading – a lower proportion would apply to two roadways and a wider pillar such as the 37 m pillars under consideration.

The change in the pillar width from 46 m to 37 m results in a minor change in the pillar stresses. Using a 50% reduction factor for tributary area loading implies an increase in pillar stress of only 1.1 % so the difference in behaviour will be very small.

Using a 50% reduction factor for the tributary area stress, the deformation of the pillar system and hence the associated surface subsidence can be calculated to be in the range of 6 mm to 11 mm over a depth range of 200 m to 350 m. Since this is below the detection limit for surface surveys the validity of this prediction cannot be assessed. The stability factors against yield of the pillars are calculated to be in the range of 3.0 to 5.2. By comparison, the corresponding ranges for 46 m pillars are 6 mm to 10 mm and 3.6 to 6.3.

4 CONCLUSION

Based on the pillar deformations recorded to date and the minor changes in pillar stress that result from the reduction in pillar width, it is assessed that the 37 m wide chain pillars will be long-term stable during maingate driveage and the associated surface deformations will be undetectable with standard survey tools.

[1] Galvin 2016 Ground Engineering - Principles and Practice for Underground Coal Mining. Springer.

APPENDIX

CHAIN PILLARS FOR MG20 AND MG21
MAND14-04

SEEDSMAN GEOTECHNICS PTY LTD

ACN 082 109 082
Telephone 0417279556
Facsimile 0242712220

CENTENNIAL MANDALONG PTY LTD

CHAIN PILLARS FOR MG2O AND MG21

MAND14-04 pillars.docx OCTOBER 2014

SEEDSMAN GEOTECHNICS PTY LTD

ACN 082 109 082
Telephone 0417279556
Facsimile 0242712220

Monday, 27 October 2014

REF: MAND14-04 pillars.docx

Mr P Enright
Mining Approvals Coordinator
Centennial Coal Company Limited | Mandalong
12 Kerry Anderson Drive
Mandalong NSW 2264

Dear Phil,

RE: Chain pillars for MG 20 and MG 21

This report reviews the various assumptions used in the dimensioning of the chain pillars in the light of monitoring results and advances in the state of the art in pillar design. It concludes that a chain pillar width of 37m is suitable for MG 20 and MG 21.

Please contact the undersigned if you require further details

Yours truly

Ross Seedsman
FAusIMM (CP)

EXECUTIVE SUMMARY

Currently at Mandalong the chain pillars are 46 m in width for the 160 m wide extraction panels. This represents a width to height ratio of 13.1. Subsidence above the chain pillars at Mandalong has ranged between less than 100 mm to about 1 m depending on the depth of cover. There is no evidence that there has been any pillar collapse.

A key aspect of the pillar design adopted in 2003 needs a review. The strength equation that was used previously cannot be applied to pillars with a width to height ratio greater than 4.8. When the pillar design argument is formatted in terms of pillar yield instead of ultimate collapse, a linear strength equation should be used. From a yield perspective, the key design issue becomes stability of the face/tailgate corner. A 37 m wide chain pillar is indicated.

A more rigorous pillar subsidence prediction tool has been developed by considering both the width and the length of each pillar and the role of layering in the roof and floor strata. An examination of the subsidence above MG14 has provided evidence that each pillar acts in isolation and does not form an infinite strip footing.

For LW20 and LW21, the revised design method should be applied to limiting subsidence at depths less than 260m. A 37m wide pillar is indicated. Compared to the 46 m wide pillars, the new pillar width will give an additional 14 % vertical subsidence. This is well within the variability in outcomes recorded to date and should result in only a marginal increase in the risk of exceeding consents.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

When Mandalong Mine was initially planned in 2003 the method used to determine the width of the chain pillars was based on the need to have a very conservative pillar design so that the focus of the regulators would be on the arguments regarding panel width. Reflecting the knowledge base at that time, it was decided to adopt the following:

1. pillar height given by roadway height
2. minimum pillar width used (not effective width)
3. pillar strength given by Uni NSW squat pillar equation applied to width of chain pillar:
4. $$\text{Strength} = 19.24\ (0.2373[\{w/5/h\}^{2.5}-1]+1)/(w^{0.1334}h^{0.0667})^{1} \qquad \text{Equation 1}$$
   where w is minimum pillar width, and h = pillar height
5. pillar load given by abutment angle approach assuming 21^{o} and double goaf loading.
6. overburden density of 2.5 MN/m^{2}
7. factor of safety of 2.23
8. uniaxial compression of coal pillar develops
9. coal modulus of 1.5 GPa applied to coal seam of thickness equal to roadway height
10. roof and floor compression given by rigid circular footing on an elastic half space
11. stone modulus of 15 GPa
12. Awaba Tuff modulus of 300-400 MPa
13. Awaba Tuff thickness of 3.5 m to 6.3 m

In consultation with Mandalong concerning the improvements on the surfaces and the flood study, it was decided to base the chain pillars width on the vertical stresses acting at 260 m depth of cover. At that stage the overall objective was to limit the vertical subsidence to less than 500 mm under the flood plain with the greatest depth under the plain being approximately 260 m. For the initial panels, the immediate maximum subsidence goal was 250 mm until the mine design approach was validated. The result was a 41 m pillar (width to height ratio of 12.8) for the initial 125 m wide extraction voids.

When the panels were extended to 160 m width, the pillar width was modified so that the same factor of safety applied and this resulted in a pillar width of 46m. The 160 m wide panels/ 46 m wide pillars have been used since LW5.

2 REVIEW OF PILLAR STABILITY

It is noted that the 1999 effective width formulation of the NSW pillar design method was not used. By using the earlier 1995 minimum width equation, we were introducing some additional level of conservativeness.

In the early mine planning stages, the roadway height was originally nominated to be 3.2 m, and over time this has increased to 3.4 m.

There was some controversy about the selection of the pillar height to be equal to the roadway height. One expert (Prof Hebblewhite) proposed that the effective pillar height may need to be the extraction height (5 m) because of the shape of the chain pillars, particularly

[1] Galvin, J.M. and Hebblewhite, B.K. 1995. UNSW pillar design methodology. University of New South Wales, School of Mining Engineering, Research Release No 1.

on the tailgate side (Figure 1). In reply, Mandalong argued that the amount of coal left around the base of the coal pillar would prevent a reduction in the strength of the pillar and hence a pillar height equal to the roadway height was valid. Centennial Mandalong commissioned further work by the University of NSW and it is understood that no report has yet been submitted.

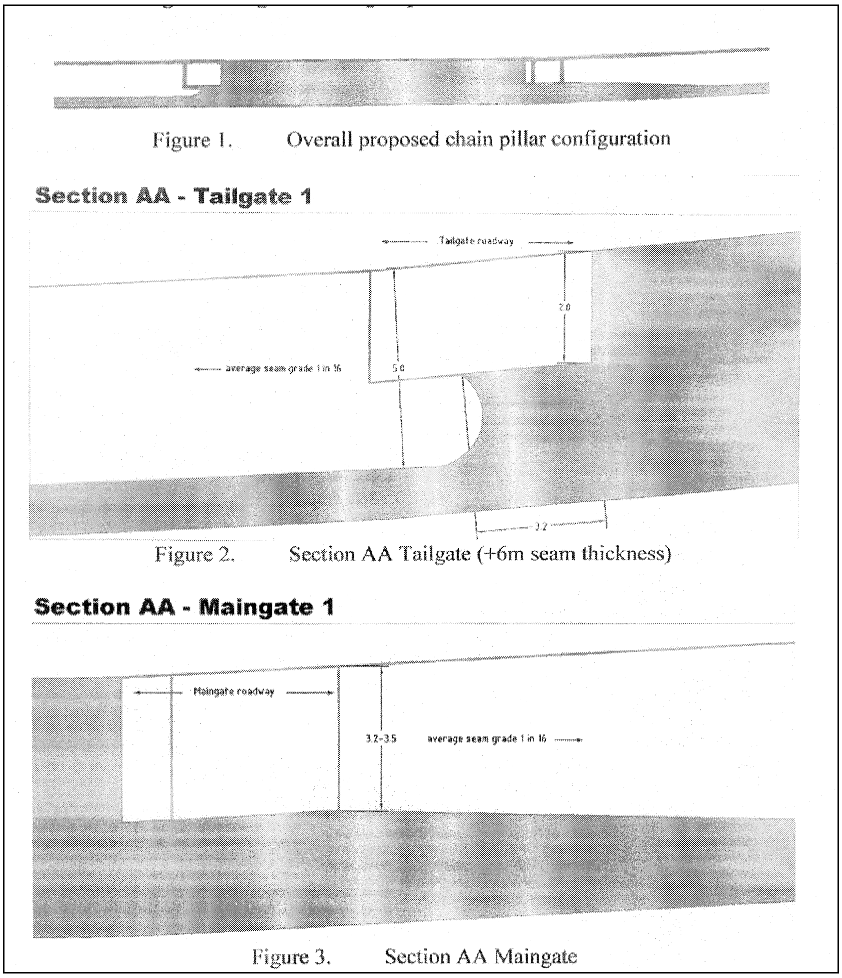


Figure 1 Natural scale cross sections of the chain pillars showing how the maingate and tailgate sides differ

Since longwall extraction began in 2005 there has been no evidence that the chain pillar have collapsed. Certainly there is deformation of the surface above the chain pillars (Figure 2) which can be adequately explained by the compression of the roof and floor strata and the West Wallarah coal seam itself (as discussed later in this report).

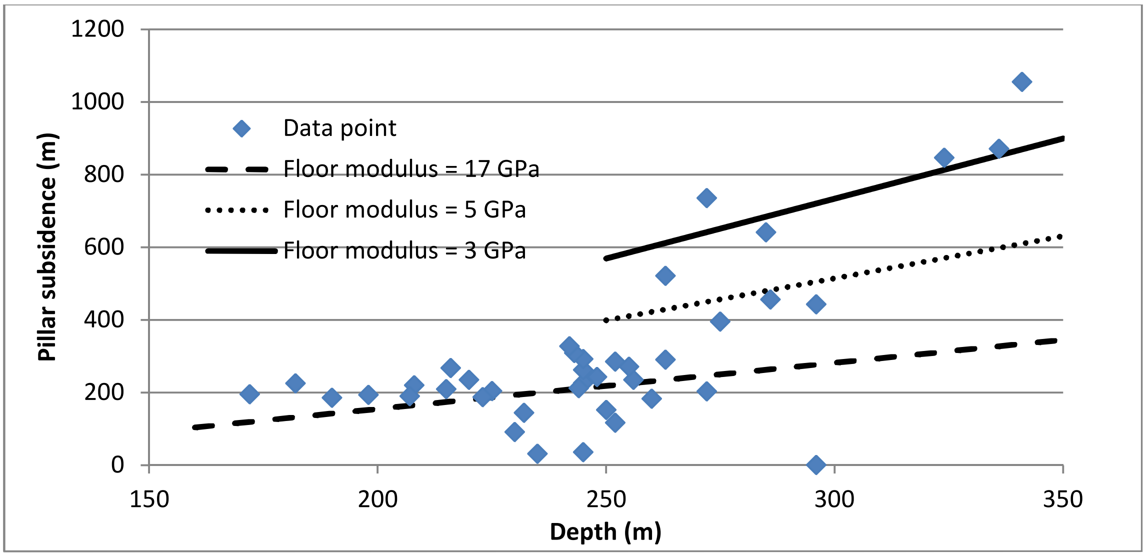


Figure 2 Vertical subsidence measured directly above chain pillars at Mandalong along with some prediction lines.

3 REVIEW OF THE PILLAR SUBSIDENCE MODEL

The subsidence above a series of extraction panels is considered to be a combination of the sag above the panels and the subsidence that develops above the intervening pillars (Figure 3). This pillar subsidence is the result of the compression of the coal pillar and the enclosing roof and floor strata as a result of the increase in the vertical stresses acting on the pillar.

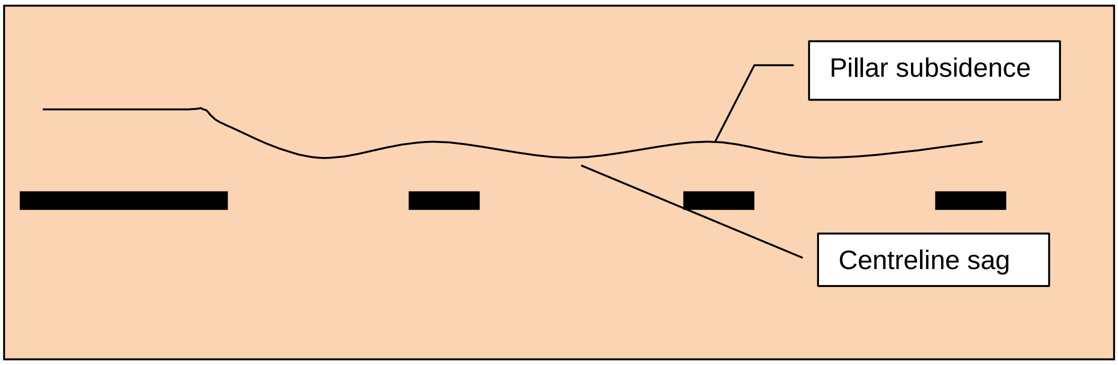


Figure 3 Definition of centreline sag and pillar subsidence

It is proposed that the compression of the pillar itself can be calculated with simple elastic theory with a modulus of the coal being set at 1.5 GPa; this value being at the low end of the range for large sized coal samples[2] .

The floor at Mandalong Mine consists of the Awaba Tuff geological formation which has been associated with unplanned subsidence events elsewhere in the Newcastle area. The floor strata at Mandalong/Cooranbong Extended had been extensively studied by Coffey Partners. Coffey reported that there were a few areas where there was a substantial thickness of very low strength Awaba Tuff (i.e. more than 0.5m of material less than 3 MPa strength) which

[2] Medhurst, T.P. and Brown, E.T. 1998. A Study of the Mechanical Behaviour of Coal for Pillar Design. Int J Rock Mech Min Sci, 35, (8), 1087-1105

may undergo time-dependent consolidation as well as simple elastic compression. Time-dependent consolidation of the Awaba Tuff was included in the initial model proposed for subsidence prediction.

The compression of the roof and floor was assumed to be the result of the settlement of a rigid footing (Poulos and Davis, 1976)[3], with the roof and floor modulus being assumed to 15 GPa. The calculation of compression of the roof and floor required estimates of the imposed stresses (q, Equation 2), the deformation moduli (E) of the various materials in the roof and floor, and geometric factors (Ip) related to pillar width (B), pillar length (L) and thickness of deformable material (H).

$$\text{Settlement (S)} = q*B*(1-v^2)*\ Ip/E \qquad \text{Equation 2}$$

For typical values of v (Poisson's ratio) of 0.2 - 0.3, the $1-v^2$ term can be ignored.

A major concern for the initial predictions was the inapplicability of methods to allocate values to the deformation moduli of the roof and floor strata.

3.1 Pillar load

The pillar vertical stresses were estimated using the industry standard ALPS/ALTS loading model – our 2003 reports investigated the sensitivity of the pillars stresses to changes in the caving assumptions. It is noted that the method provides maximum credible vertical pillar stresses and does not rely on any possible arching of the overburden to the unmined abutments.

The expert for the Department of Planning (Prof Galvin) maintained that four or five longwall panels needed to be extracted before the risk of a "global instability" could be dismissed. This risk appeared to be related to the presumption that the overburden strata could be spanning and hence not fully loading the pillars. However, it is worth emphasising that the assumptions regarding pillar stresses did not rely on spanning. Thirteen panels have been extracted and there has been no global instability. At shallow depth of cover the subsidence above the chain pillars does not significantly increase once extraction is completed on both sides of the pillars. At higher depth of cover, there is some minor additional movement when the next subsequent wall is extracted – so it is accepted there is some arching of vertical stresses but at levels below the design stresses (2 subsequent walls need to be extracted before the applied stresses approach the values used in the design).

3.2 Awaba Tuff

Over most of the area the Awaba Tuff has been found to be a high strength rock that does not exhibit time-dependent consolidation behaviour. A focus of the early subsidence monitoring was to establish if there was any time-dependent subsidence over the solid coal to the east of LW 1. No such movement was detected and to date there has been no movement above any of the chain pillars monitored that can be attributed to this mechanism.

We maintain our view that there is no evidence that the Awaba Tuff is undergoing long-term consolidation. It is somewhat fortunate that this mechanism was included in the initial analysis as it provided necessary "contingency" against the higher subsidence that was found to be associated with the roof and floor compression.

[3] Poulos,H.G. and Davis,E. 1974 Elastic solutions for soil and rock mechanics. WILEY

3.3 Reducing the modulus

Reducing the laboratory modulus values to represent field behaviour is standard practice in rock engineering. In 2003 the engineering literature on estimating the deformation modulus of a rock mass (E_{rm}) was not extensive and was difficult to apply to bedded sedimentary rocks. At that time, the state of the art was the 1999 paper by Hoek and Brown[4] which stated:

$$E_{rm}\ (GPa) = \sqrt{(UCS/100)} \times 10^{((GSI-10)/40)} \qquad \text{Equation 3}$$

where GSI is the Geological Strength Index (see Figure 4).

It is noted that the relationship is not based on a reduction of the laboratory modulus values. Using a GSI estimate of 60, and a UCS of 70 MPa, this equation suggests that the deformation modulus of a rock mass would be 14.9 GPa. This value is within the range of laboratory values (Modulus/UCS ratio of 250, or 17.5 GPa) and hence the use of this equation would suggest that there would be little mass reduction effect.

Later, Hoek and Diederichs (2005)[5] provided the following equation to estimate the deformation modulus of rock masses from the laboratory values (Ei):

$$E_{rm}(MPa) = E_i\left(0.02 + \frac{1 - D/2}{1 + e^{\left(\frac{60+15D-GSI}{11}\right)}}\right) \qquad \text{Equation 4}$$

where D is disturbance factor (set at 0 for this application), and GSI is given by Hoek et al[6] for various rock types (Figure 4).

A difficulty with the GSI system is the lack of guidance on what is appropriate for sedimentary rocks – good or smooth surface conditions? For a blocky rock mass and good to fair surface conditions, a GSI value of 60 could be appropriate, although values as low as 35 could also be selected (flysch or fissile molasse). The reduction factors are in the range of 0.52 to 0.11 respectively are indicated, with the observation that a difference in GSI between 60 and 35 represent a nearly 5-fold difference in the mass modulus (Figure 5) (and hence a 5 fold increase in deformation).

The GSI values and rock mass deformation moduli for the key materials in the 2006 predictions are presented in Table 1. For the Mandalong project, allocation of GSI values has been based on the coal joints being rough, stone joints being smooth, and the West Wallarah coal and the roof sandstone being considered blocky and the other materials being very blocky. It is noted that these selections are based, in part, on a calibration to the subsidence outcomes to date.

[4] Hoek E and Brown, E.T. 1999. Practical estimates of rock mass strength. Int J Rock Mech Min Sci, 34(8), 1165-1186.
[5] Hoek, E and Diederichs, M.S. 2005 Empirical estimation of rock mass modulus. Int J Rock Mech Min Sci, 43(2), 203-215.
[6] Hoek E, Marinos PG, and Marinos VP, 2005. Characterisation and engineering properties of tectonically undisturbed but lithologically varied sedimentary rock masses. International Journal of Rock Mechanics and Mining Sciences, 42, 277-285.

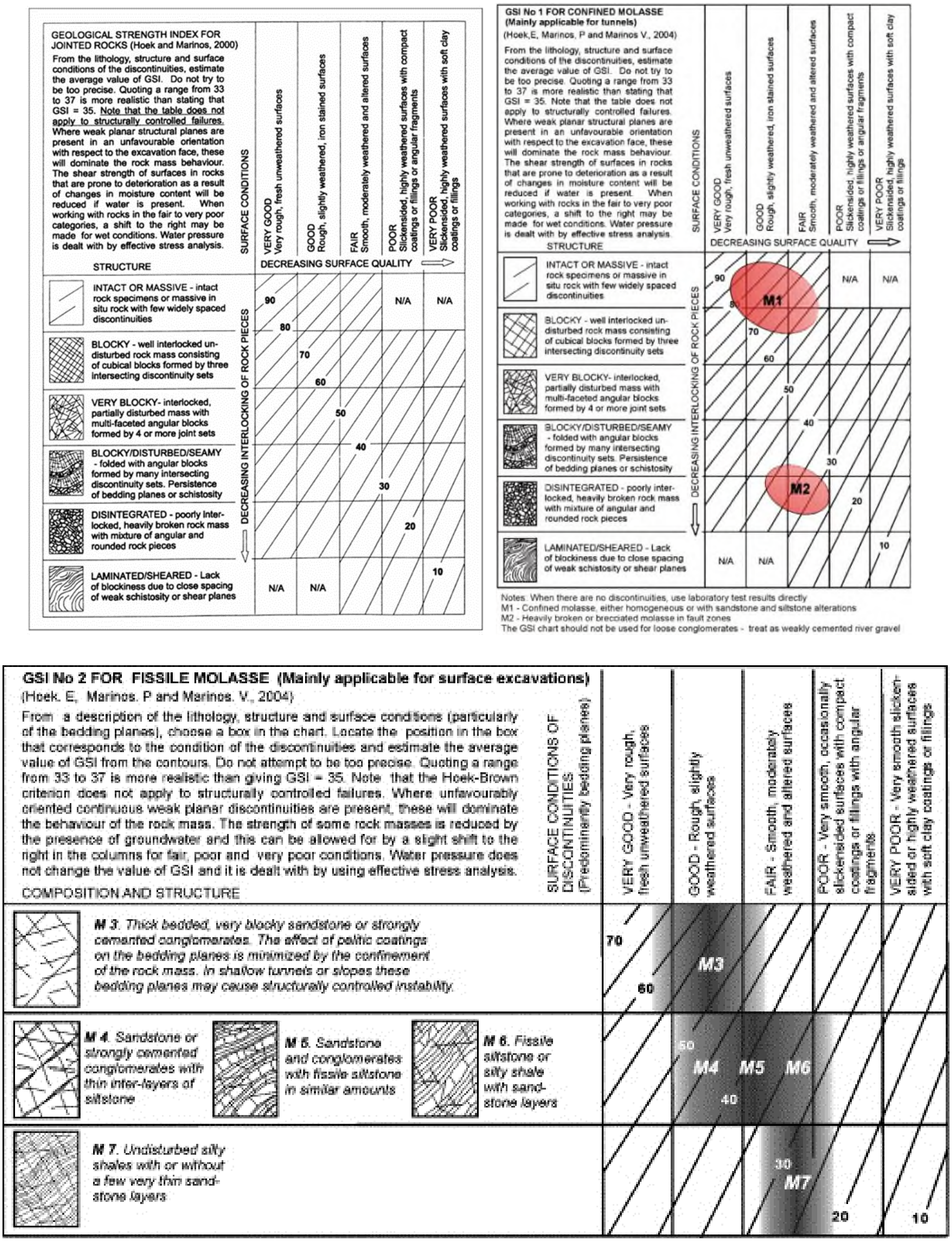


Figure 4 Nomograms to determine the Geologic Strength Index of various rock types

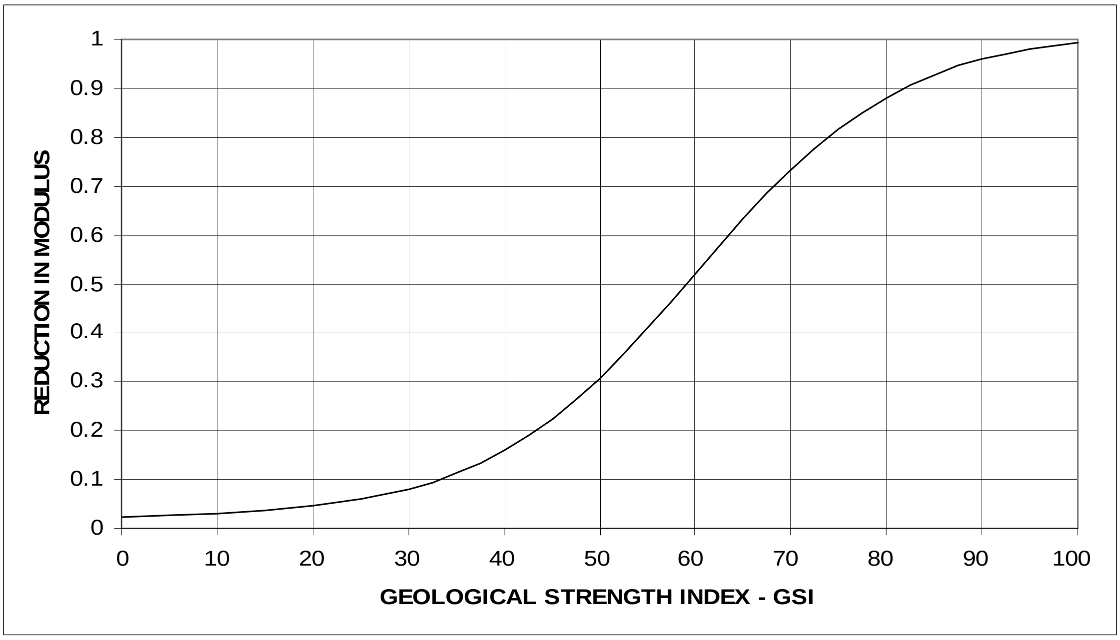


Figure 5 Reduction of modulus as a function of Geological Strength Index

Table 1 Modulus and GSI values derived in 2006

	Ei	RSI	Erm
West Wallarah Seam	3	60	1.5
Fassifern and Pilot Seams	2	45	0.4
Floor stone	10	43	1.8
Roof sandstone	15	60	7.5
Roof mudstones	15	49	4
Mandalong Conglomerate	22.8	95	22.8[7]

3.4 Layering

Implicit in the 2003 analysis of the compression of the strata beneath the chain pillars was the assumption that the strata beneath the Awaba Tuff were the same in all locations. This assumption was necessary because of the lack of deeper drilling. Subsequently, a geological model has been developed for the floor – albeit with relatively little drilling data. At the inbye end of LW6, the base of the Newcastle Coal Measures is 60m below the floor of the West Wallarah Seam compared to about 110m near the main headings. In addition, the lower split of the Fassifern Seam is closer to the West Wallarah Seam at the inbye ends (Figures 6 and 7).

The implication of this layering is that greater compression of the floor strata per unit of pillar load will be generated at the inbye end (north west) of the chain pillars. Coincidently, this is also the deeper part of the mine so the subsidence will tend to be greater due to both the more compressible floor and the higher pillar loads.

[7] Correction factor is 0.98, so modulus left unchanged for consistency with previous reports

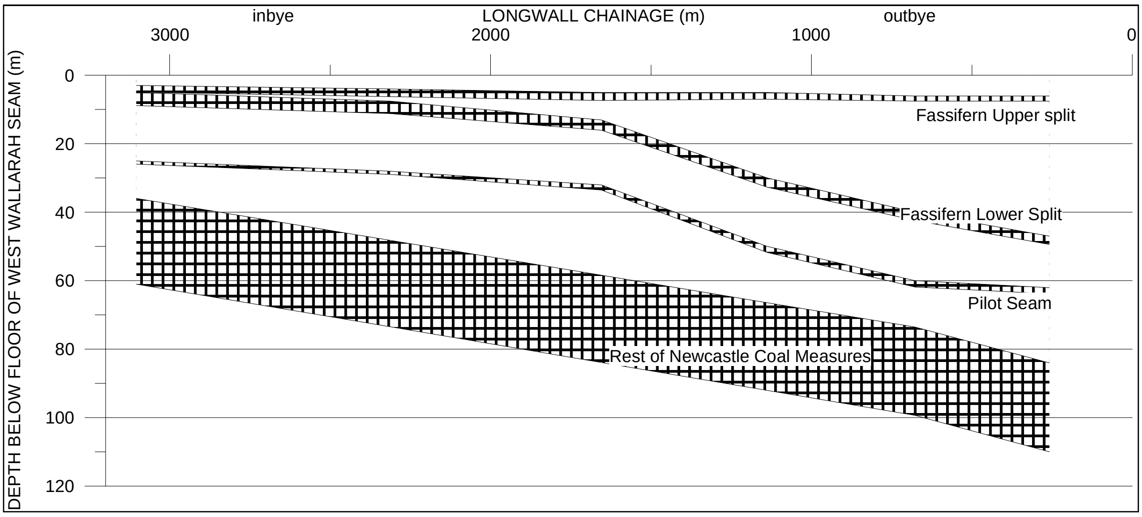


Figure 6 Indicative long section of the floor of the West Wallarah Seam along Maingate 6.

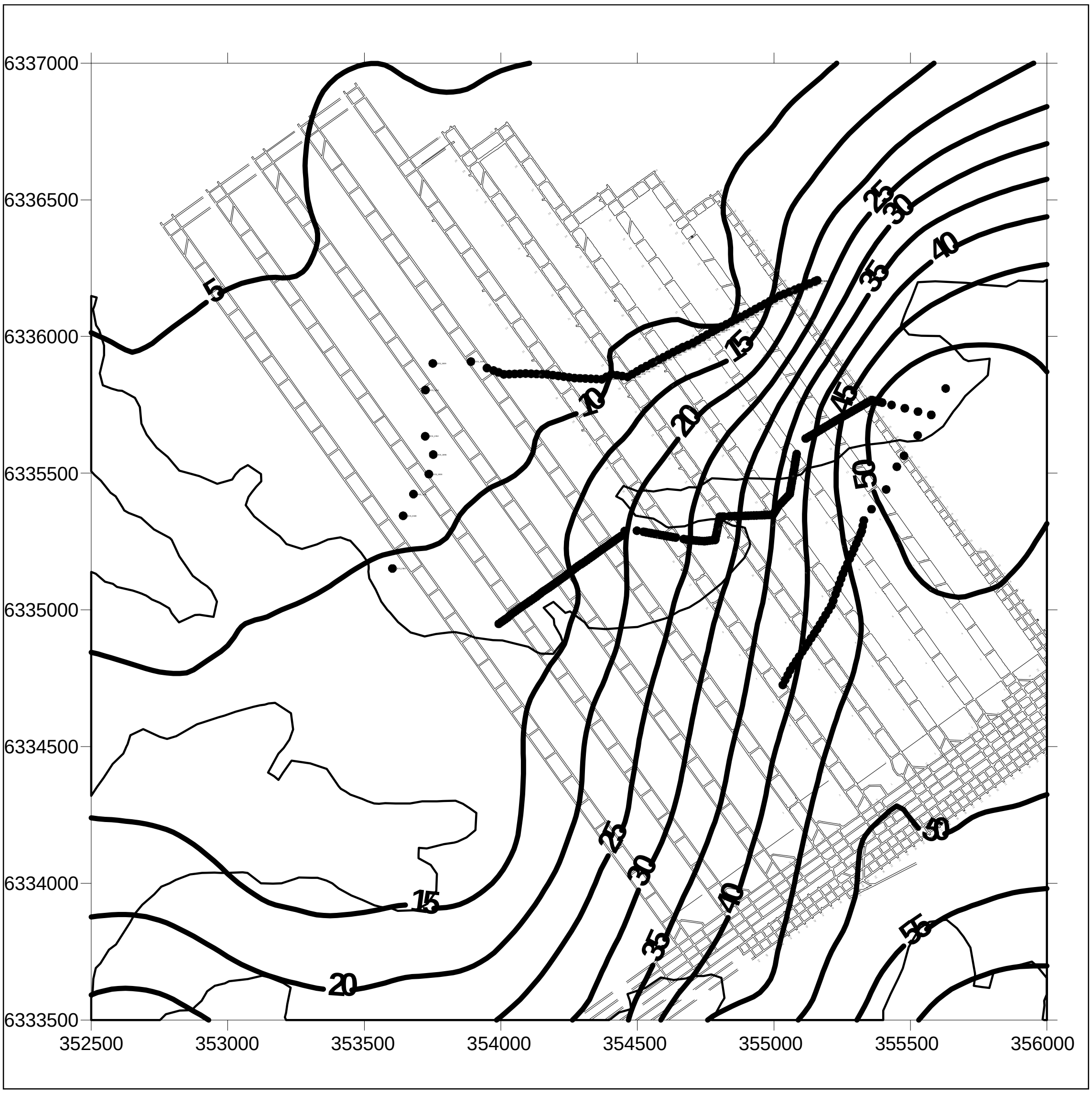


Figure 7 Distance from floor of West Wallarah Seam to the floor of Lower Fassifern Seam

3.5 Influence factor (I_P)

The calculation of the pillar compression has been based on the application of the standard settlement equation from foundation engineering (Equation 2) where the geometric components are addressed by the influence factor (Ip). Values for Ip are tabulated in the literature for finite and infinite layer thickness, and for circular, rectangular and infinite strip footings (Table 2). For chain pillar dimensions, there was a degree of uncertainty as to which Ip value to use. For the sake of simplicity we elected to use a rigid circle (Ip=0.74) at the beginning of the Mandalong project, recognising that a better value would become apparent as monitoring data was collected. Partial justification of the circle assumption was the concept of the pillar being loaded progressively as the longwall face retreats.

More appropriate influence factors are discussed in the next section of this report.

Table 2 Influence factors for rigid footings in the technical literature

Footing	Circle	Square	Rectangle L/B=2	Rectangle L/B=10	Strip
H/B=2.5	0.740	0.800	1.119	1.256	1.323
H/B=∞	0.846	0.946	1.527	2.246	∞

3.6 Pragmatic empirical design

Once longwall extraction commenced, the availability of pillar compression data reduced the need to use the analytical calculations – it was possible to develop an empirical model that implicitly addressed the uncertainty in the analytical model. We developed a simple empirical model to calculate an equivalent modulus based not only on the GSI but also on the presence of coal and stone layers.

Figure 8 presents the equivalent roof and floor modulus determined from a trial and error fit to the pillar subsidence data obtained up to the end of LW 4. The equivalent roof modulus ranged from 7.5 GPa to 4 GPa and floor modulus from 2.2 GPa to 1.4 GPa. Graphical representation of the calibration is presented in Figure 9 with the GSI values given earlier in Table 1.

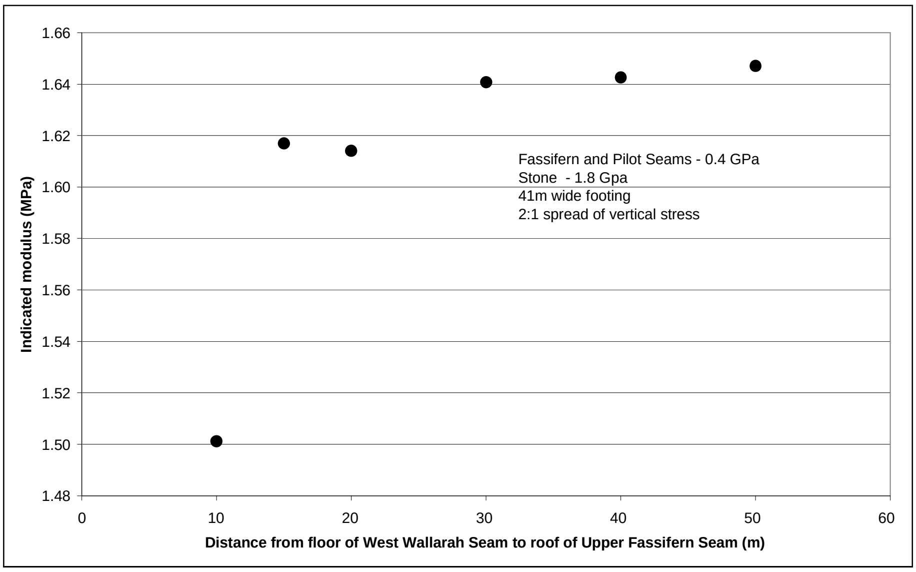


Figure 8 Variation in the equivalent floor modulus based on a back analysis in 2006.

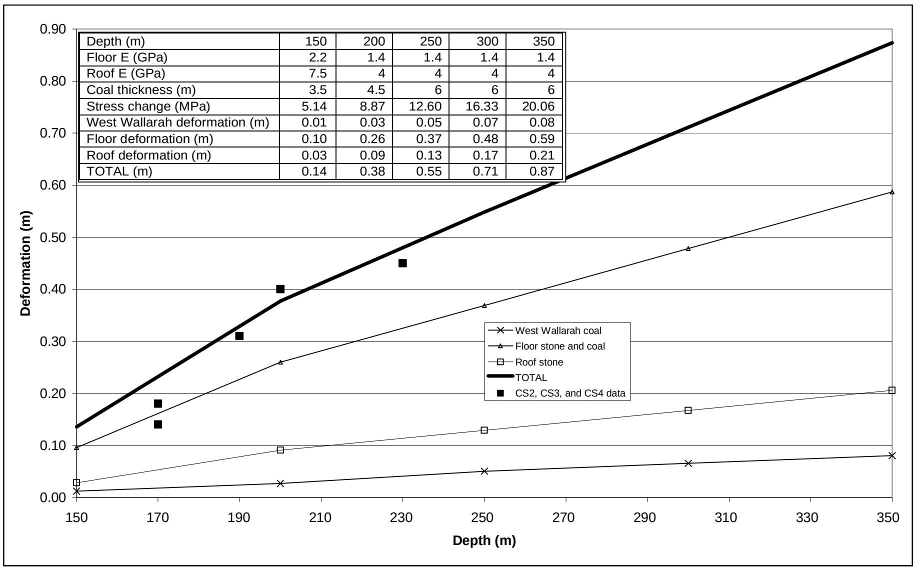


Figure 9 Calibration of pillar subsidence based on data in 2006.

4 2013 - 2014 REVISION TO PILLAR MODEL

4.1 PILLAR STRENGTH

A 46 m wide, 3.5 m high pillar has a width to height ratio of 13:1, and if 5 m high the width to height ratio is 9.2.

In 2010 Prof Galvin[8] published a note which clarified to some extent the status of the only reported pillar collapse with a width to height greater than 5. Whilst the UNSW's confidential database has been destroyed, the available evidence together with the Galvin note suggests that this one point was in fact drawn from Wyee Colliery in the Great Northern Seam J and K panel. A cored borehole adjacent to the site reveals low strength Awaba Tuff in the floor (Figure 10) and it is highly likely that the pillar did not collapse but merely punched into the floor.

The appropriate technical response to the Galvin note has been to remove the data point from the data base. Once amended, the Australian pillar failure data base has no pillar collapse with a pillar width to height ratio greater than 4.8, and for the South African database[9] no pillar collapse at a width to height ratio greater than 4.3. Any statistical analysis of the corrected database must acknowledge than the database is truncated and that the probability of failure of a pillar with a width to height ratio greater than 4.8 should be zero. Certainly, the UNSW relationship between factor of safety and probability of failure cannot be validly applied for width to height ratios greater than 4.8.

[8] Galvin, J.M. 2010. Clarifications and Corrections Related to UNSW Pillar Design Methodology. Notes issued to attendees of a workshop associated with the 2nd Australasian Ground Control in Mining Conference, AusIMM. Sydney.
[9] Van der Merwe J.N. 2006. South African coal pillar database. J South African Institute of Mining and Metallurgy, 106, 115-128.

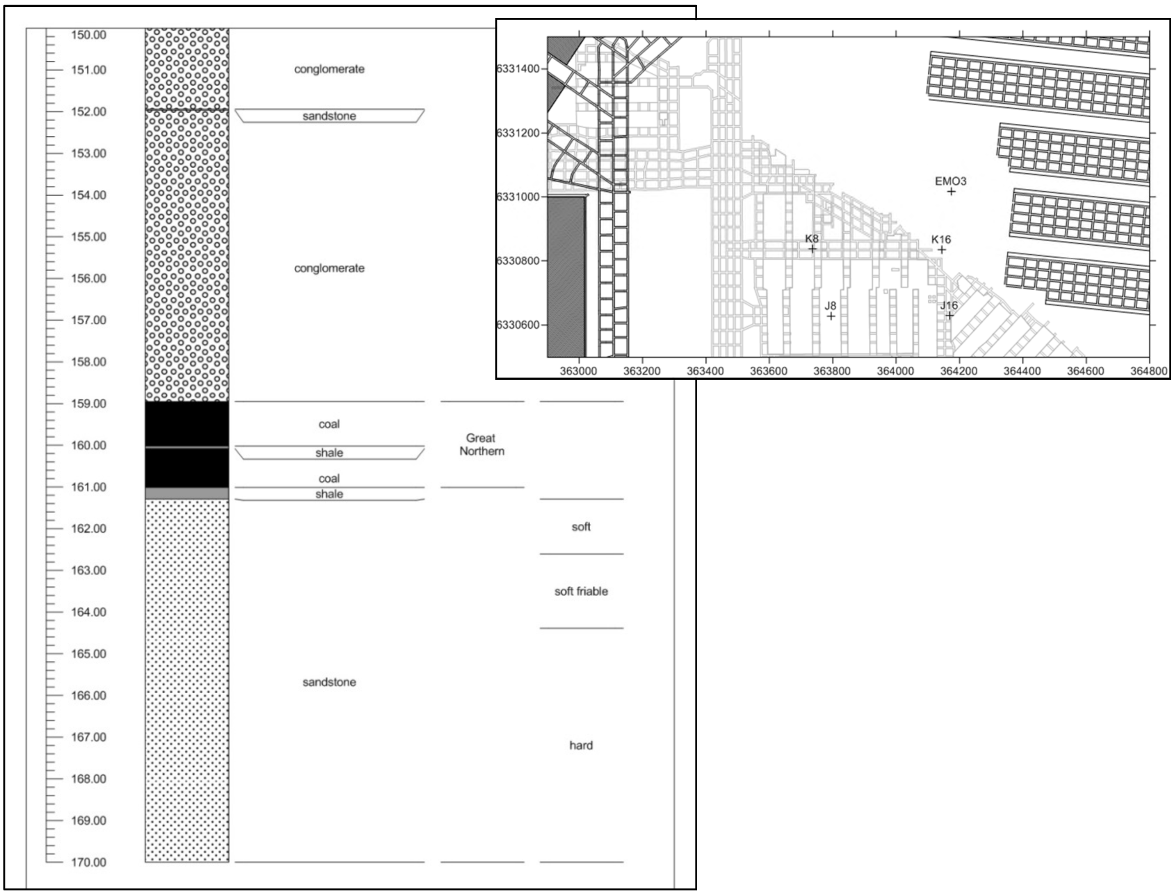


Figure 10 The strength log from borehole EM03 adjacent to J and K panel at Wyee

Seedsman[10] proposed that the kinematics of pillar collapse requires the onset of shear diagonally through the pillar and hence such a shear surface must be inclined at greater than the friction angle of coal. A width to height ratio of 4.8 would require the friction angle of coal to be less than 11.8°, which is a value less than that implied by other researchers[11].

Colwell et al[12] proposed a relationship between pillar performance and tailgate serviceability with all their data are drawn from pillars with width to height ratios in excess of 6.0 (Figure 11). In their work, they determined pillar strength by a linear strength equation:

$$\text{Strength (MPa)} = 6.2*(0.64+0.36*w/h) \qquad \text{Equation 5}$$

Based on the previous discussion about kinematics, Equation 5 cannot be reflecting pillar collapse. Seedsman[13] proposed that a decrease in tailgate serviceability is related to the onset of yield in the chain pillar and that the linear strength equation used by Colwell et al represents yield strength (Figure 12); pillar yield leads to a distressing of the immediate roof

10 Seedsman, R.W. 2012. The strength of the pillar-floor system. Coal 2012 - 12th Australasian Coal Operators' Conference, Wollongong,

11 Medhurst and Brown, op cit

12 Colwell, M., Frith, R. and Mark, M. 1999. Analysis of Longwall Tailgate Serviceability (ALTS): A chain pillar design methodology for Australian conditions. In Proceedings of the Second International Workshop on Coal Pillar Mechanics and Design, Colorado. NIOSH IC 9448.

13 Seedsman, R.W. 2001. The stress and failure paths followed by coal mine roofs during longwall extraction and implications to tailgate support. In Proceedings of the 20th International Conference on Ground Control in Mining, 42-49. (West Virginia University).

and the mobilisation of joint-bounded blocks and it is this that determines tailgate serviceability.

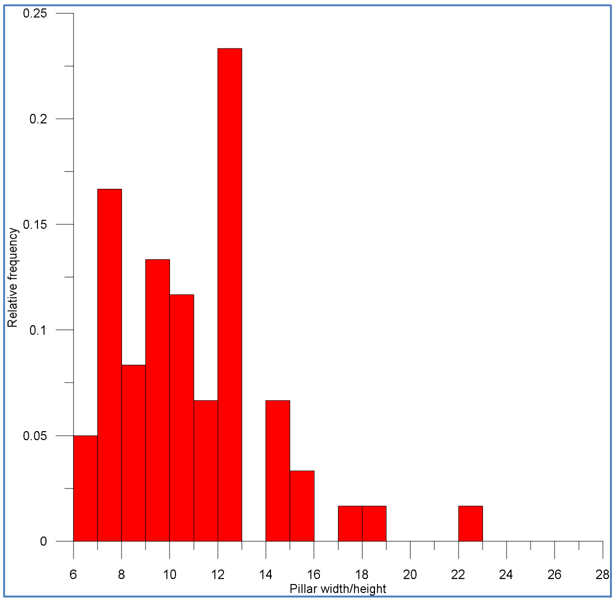


Figure 11 Pillar width to height ratios in the ALTS database

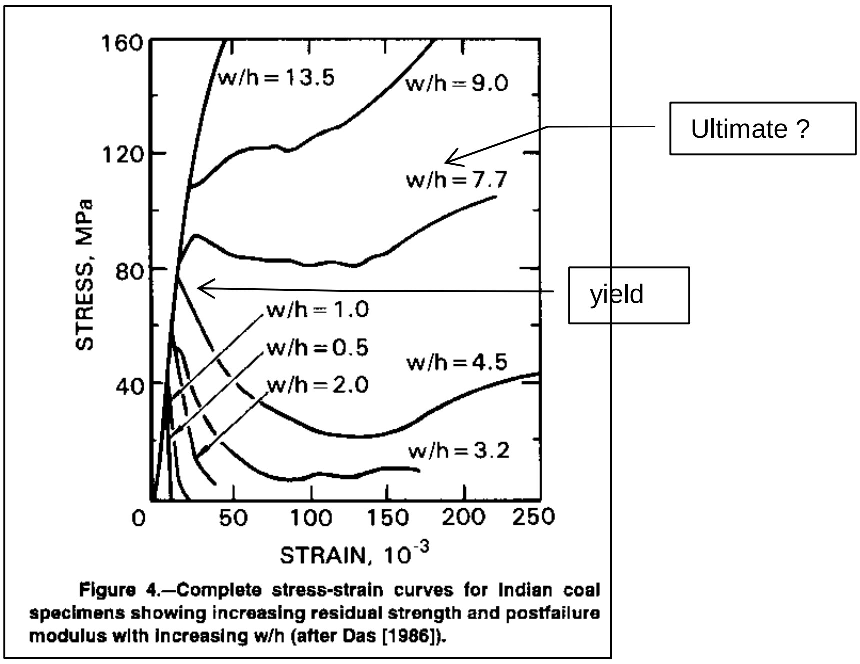


Figure 12 Model pillar studies showing yield and ultimate strengths

In terms of subsidence, the impact of yield in a chain pillar is that there will be greater incremental deformation at stresses beyond yield (equivalent to a lower secant modulus). Based on Figure 12, as the width to height ratio increases the secant modulus after yield will also increase and eventually be very similar to the elastic modulus before yield (compare w/h of 9.0 to w/h = 13.5).

Based on this discussion, an appropriate pillar stability criterion for critical surface features at Mandalong is to design pillars with a width that is the greater of either (i) a factor of safety against yield greater than 1.1 using the Equation 5 and full pillar loading (double goaf loading) or (ii) a width to height ratio in excess of 6.0, or (iii) an acceptable subsidence deformation outcome.

4.2 ROCK MASS MODULUS AND THE INFLUENCE FACTOR (I_P)

The modulus values that have been used recently (Table 2) have been empirically derived and their use in any analytical predictions depends on the assumed Ip value. Until now we have used an Ip of 0.74 which corresponds to a circular rigid footing. The back-calculated modulus values are consistent with reasonable values of the GSI.

We have used Settle3D (www.rocscience.com) to investigate the variation of the Ip with different pillar width/length ratios (L/W) for rectangular rigid footings (Figure 13). If the chain pillar is considered to be 46 m by 100 m, the indicated influence factor would be 1.1, or if it is an infinite strip (46 m by 3000 m) the value would be 2.2. These values are in general agreement with those in Table 2. Settle3D is limited to isotropic materials and hence cannot consider transverse isotropic (bedded?) materials.

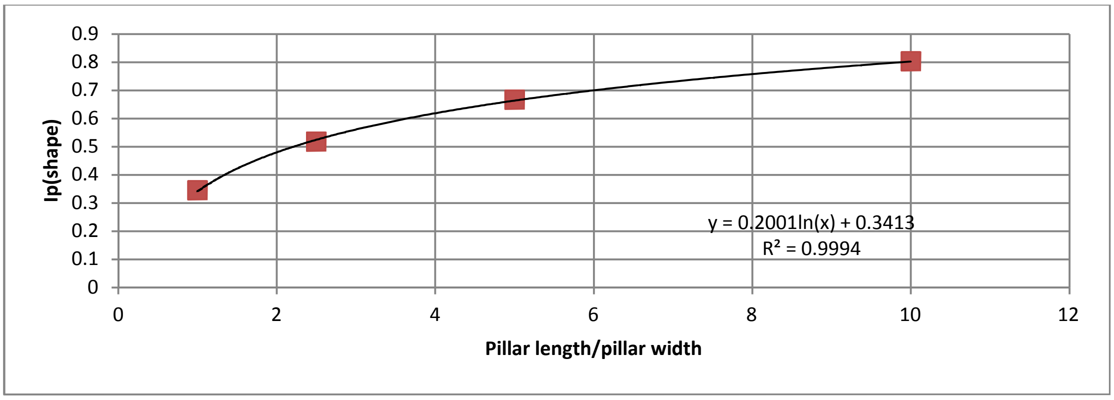


Figure 13 A shape based influence factor for different L/B ratios

Recently there have been concerns raised in the technical literature about the application of the GSI to laminated rock. The GSI is used to determine the strength of rock masses using the Hoek Brown failure criterion based on the concept that there are sufficient discontinuities sets and densities that the rock mass is isotropic – this is clearly not the case for laminated rocks such as undisturbed coal measures where bedding is always the dominant textural element.

We have conducted some simple two dimensional finite element analyses (Phase2) to investigate the role of bedding in modifying the settlement of a rigid infinite strip footing. Bedding has been simulated by modelling the rock mass as a transversely isotropic material with a relatively low independent shear modulus (G), as also recently done by others for multiple seam longwalls[14]. Figure 14 shows how the influence factor associated with transverse isotropy (Ip(ti)) increases (greater settlement) with increasing E/G ratios: separately I have found that for roof falls an E/G ratio of 15 may be applicable to typical coal

[14] A.M. Suchowerska, R.M. Merifield, J.P. Carter 2012 effects of transverse isotropy on vertical stresses under supercritical longwall panels. 31st International Conference on Ground Control in Mining, Morgantown , WV.

measure rocks[15]. It is noteworthy that the percentage increase in the influence factor is of a similar order of magnitude as the percentage decrease in modulus associated with varying the GSI.

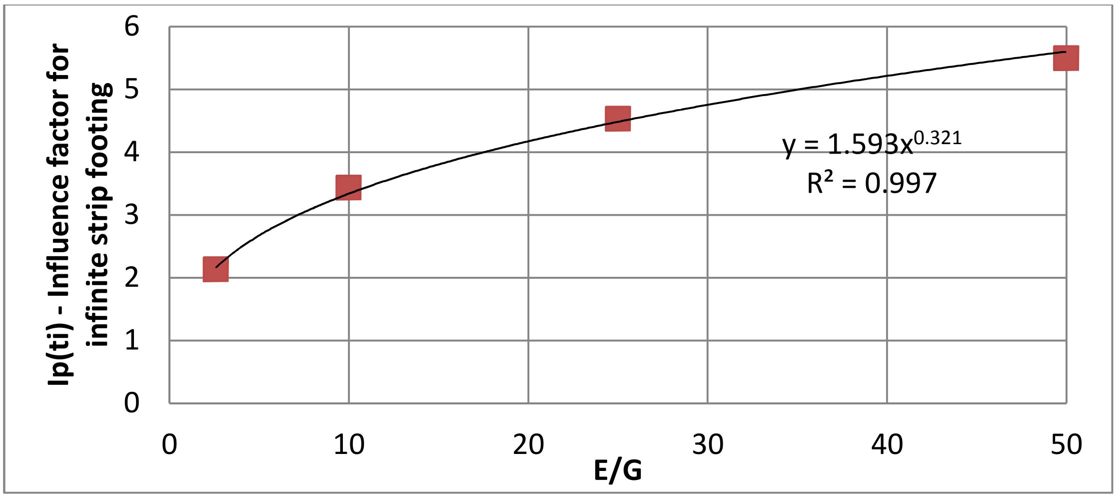


Figure 14 Increases in the influence factor for settlement of a infinte rigid strip footing increases with the E/G ratio

By combining Figures 13 and 14, Equation 6 gives a revised simplified method for assessing the influence factor to be applied to the estimation of settlement of an individual chain pillar into the roof and floor using the laboratory values for the deformation modulus.

Deflection = vertical pillar stress*pillar width*Ip(shape)*Ip(ti)/E   Equation 6

We have also used Settle3D to examine the distribution of elastic settlement within the immediate floor of a pillar. Figure 15 indicates that half of the total settlement will be generated within a depth equal to 1.5 times the pillar width and 85 % is developed within a depth equal to 5 times the pillar width. This provides the technical basis to the discussion in Section 3.4 regarding the proximity of the Fassifern Seam increasing the pillar settlement.

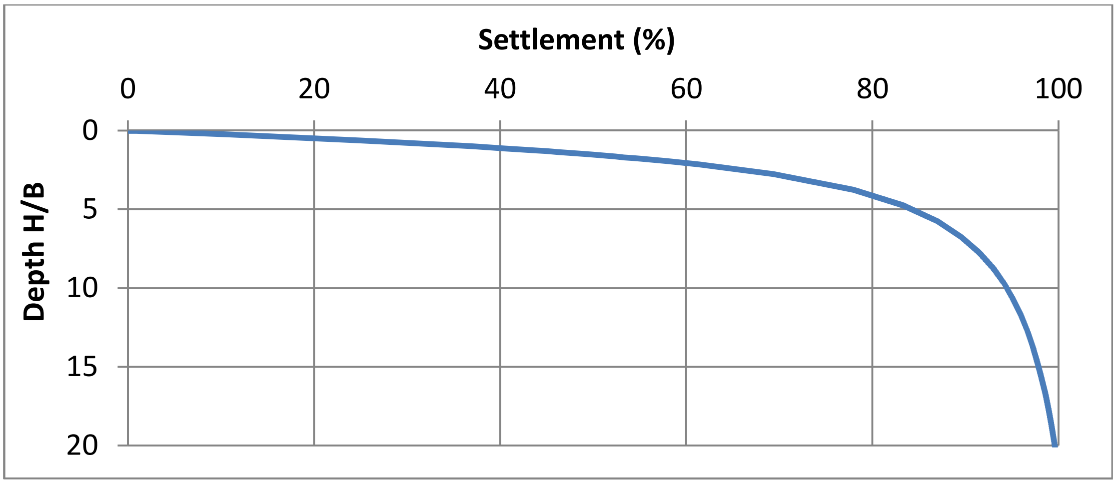


Figure 15 Depth of influence for pillar settlement

[15] Seedsman, R.W. 2011. Application of the brittle failure criterion to the design of roof support in the soft rocks of coal mines. Coal 2011 - 11th Australasian Coal Operators' Conference, Wollongong.

4.3 PILLAR SUBSIDENCE UP TO LW 15

Figure 2 shows three pillar subsidence prediction lines based on Equation 6 using three different assumptions for the overall floor modulus. The reduction in the modulus has been as a calibration and in recognition of the variation in the floor geology shown in Figures 6 and 7.

The subsidence data over MG 14 is of particular value as it represents a major change in the mine geometry. The subsidence developed above MG 14 is 109 mm and 118mm for LW1CS2 and LW3CS3EX respectively, which is about 50 % lower than for MG13 and MG15 (Figures 16 and 17, Table 3) .

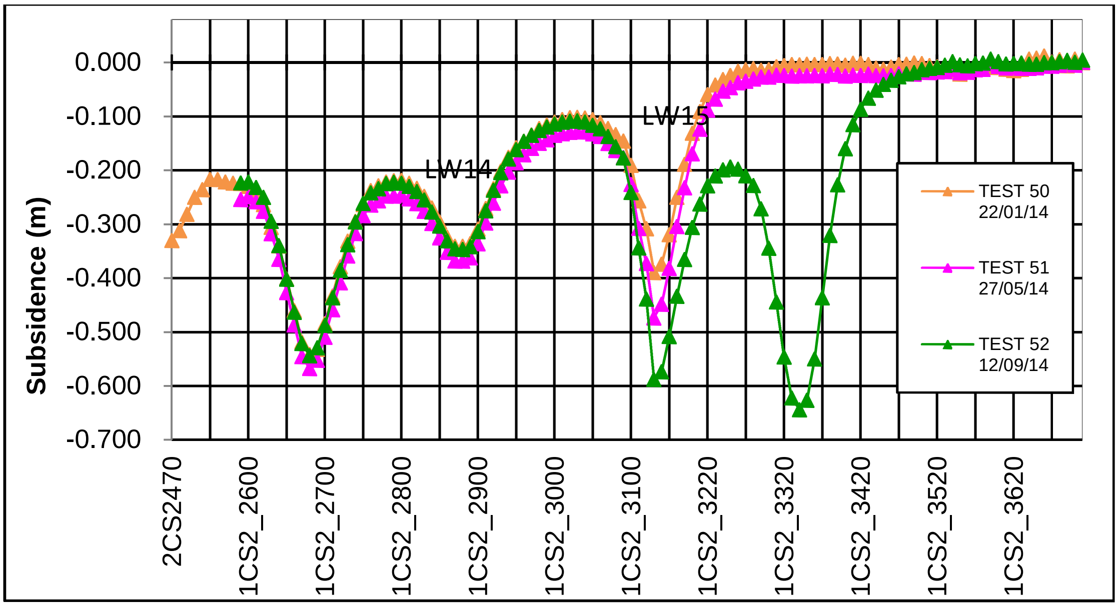


Figure 16 LW1CS2 subsidence survey data

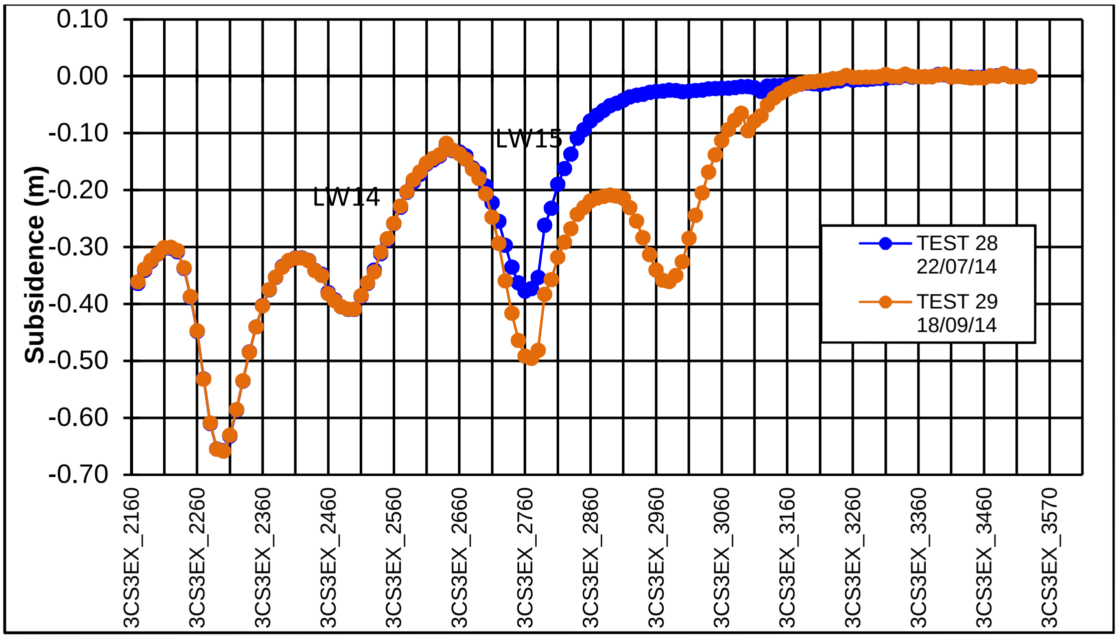


Figure 17 LW3 CS3EX subsidence survey data

Table 3 Summary of vertical subsidence above MG 13 to MG15

	MG13	MG14	MG15	Depth
LW1CS2	225 mm	109 mm	194 mm	250 m
LW3CS3EX	320 mm	118 mm	209 mm	275 m

This data has been used to validate/calibrate the pillar subsidence prediction equation (Equation 6) using an assumption of the roof and floor "laboratory" modulus of 17 GPa (Table 4). It can be seen that the match is quite good. The observation that the subsidence above MG 14 was about half that of the other pillars was a key factor in the recognition that each pillar behaves in isolation and not as part of an infinite strip.

Table 4 New prediction model applied to the larger pillar between LW14 and LW15

Parameter		LW1CS2		LW3CS3EX	
Coal modulus	MPa	1500	1500	1500	1500
Floor modulus	GPa	17	17	17	17
Roof modulus	GPa	17	17	17	17
E/G		15.00	15.00	15.00	15.00
Strip footing		3.80	3.80	3.80	3.80
Reciprocal of shape factor		2.01	2.01	2.01	2.01
Extraction thick	m	3.4	3.4	3.4	3.4
Coal thickness	m	7	7	7	7
Depth	m	250	250	275	275
Length	m	97.5	97.5	97.5	97.5
Pillar width (solids)	m	46	46	46	46
Panel 1 width (ribs)	m	160	160	160	160
Panel 2 width (ribs)	m	160	5.5	160	5.5
Goaf angle		21	21	21	21
Interburden		104	104	104	104
CALCULATIONS					
Pillar stress		6.13	6.13	6.74	6.74
Design stress		20.78	14.77	23.52	16.49
stress change		15	9	17	10
OUTPUT					
Pillar stability	linear	1.64	2.31	1.45	2.07
Pillar stability	squat	1.85	2.61	1.64	2.34
Coal compression	mm	68	40	78	45
Floor compression	mm	75	44	86	50
Roof compression	mm	75	44	86	50
TOTAL COMPRESSION	mm	219	129	250	145
AS MEASURED (Table 3)	mm	225,194	109	320, 209	118

5 IMPLICATION TO MINE DESIGN

Based on the new information about pillar strength and the deformation of rock masses as discussed above, it is now considered that the method to dimension the chain pillars should change. The method should be:

1. pillar height (h) given by roadway height
2. minimum pillar width used
3. pillar yield strength given by: Strength = 6.2 * (0.64 + 0.36 w/h), where w is minimum pillar width, and h = pillar height
4. pillar load given by abutment angle approach assuming 21^{o} and double goaf loading.
5. overburden density of 2.5 MN/m^2
6. pillar width to height ratio greater than 6.0
7. factor of safety of greater than 1.1 under key surface features
8. uniaxial compression of coal pillar develops
9. coal modulus of 1.5 GPa applied to coal seam of thickness equal to roadway height

10. roof and floor compression given by rigid strip footing, an E/G ratio of 15, and influence factors for the length/width ratio and transverse isotropy in the bedded rocks (Figures 13 and 14, and Equation 6).
11. roof and floor modulus values based on laboratory sized samples and consideration of the proximity of lower coal seams.
12. no specific consideration of the Awaba Tuff unless logging indicates strengths less than 20MPa.

With this revised method, Figure 18 indicates that a change in pillar width from 46 m to 37 m will result in a 14 % increase in pillar subsidence.

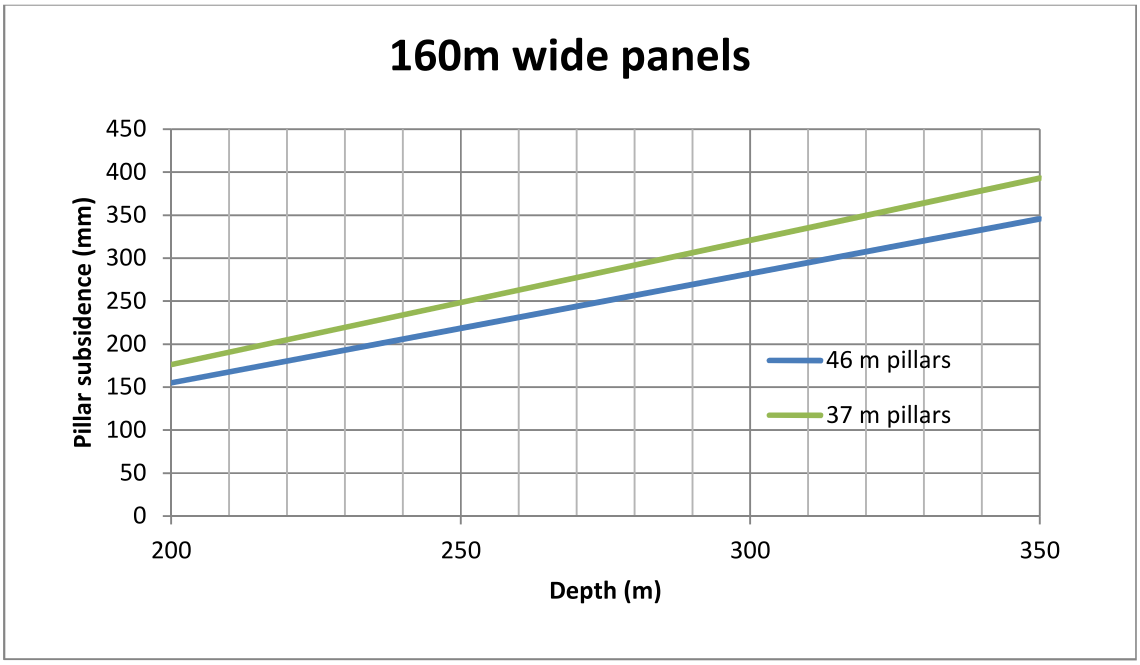


Figure 18 37 m wide pillars result in 14% more pillar subsidence

6 RECOMMENDATIONS

In the context of subsidence constraints for LW18 to LW21, the key features are the presence of numerous dwellings and the continuation of the alluvial deposits associated with the drainage patterns. By inspection of Figure 19, a continuation of the 260m depth of cover is justified as the depth at which the chain pillars should be dimensioned.

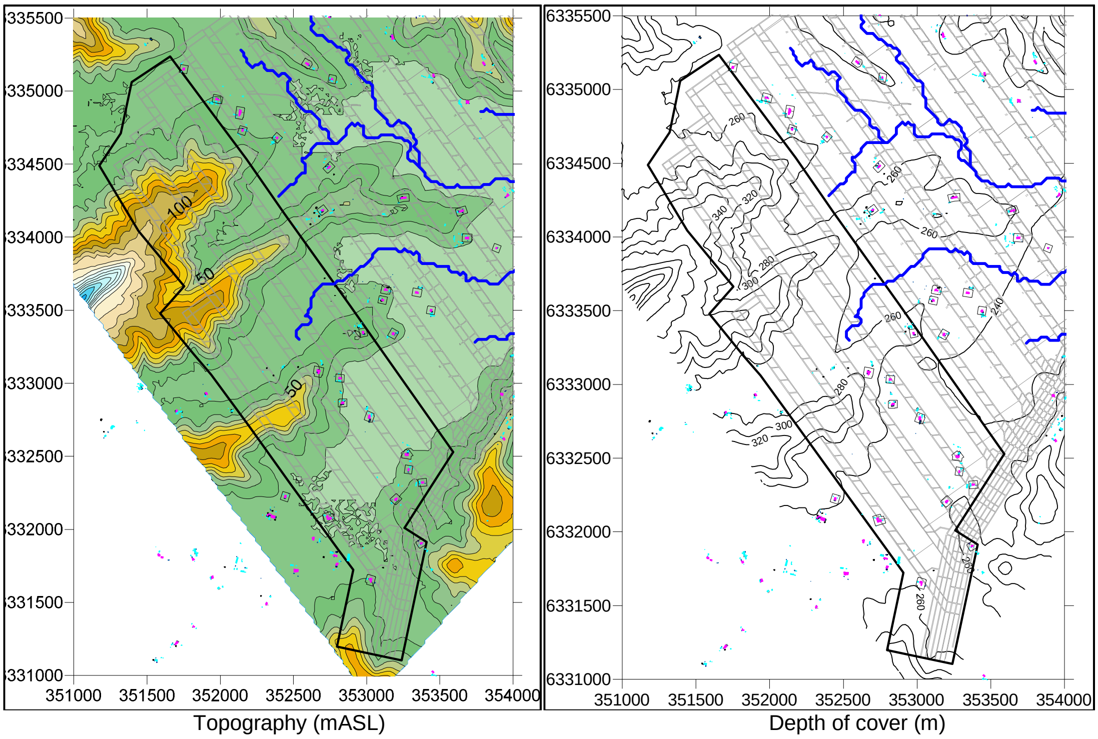


Figure 19 Topography and depth of cover for LW18 to LW21

Figure 20 shows how the predicted stability and pillar subsidence varies as a function of pillar width for the case of 260 m depth, a 3.4 m high roadway, an E/G ratio of 15, an assumption of 7 m of coal, and the roof and floor modulus values being 17 GPa. A 37 m pillar will have a stability factor against yield of 1.1 and a pillar subsidence of 263 mm, compared to 231 mm for a 46 m pillar (a 32 mm increase).

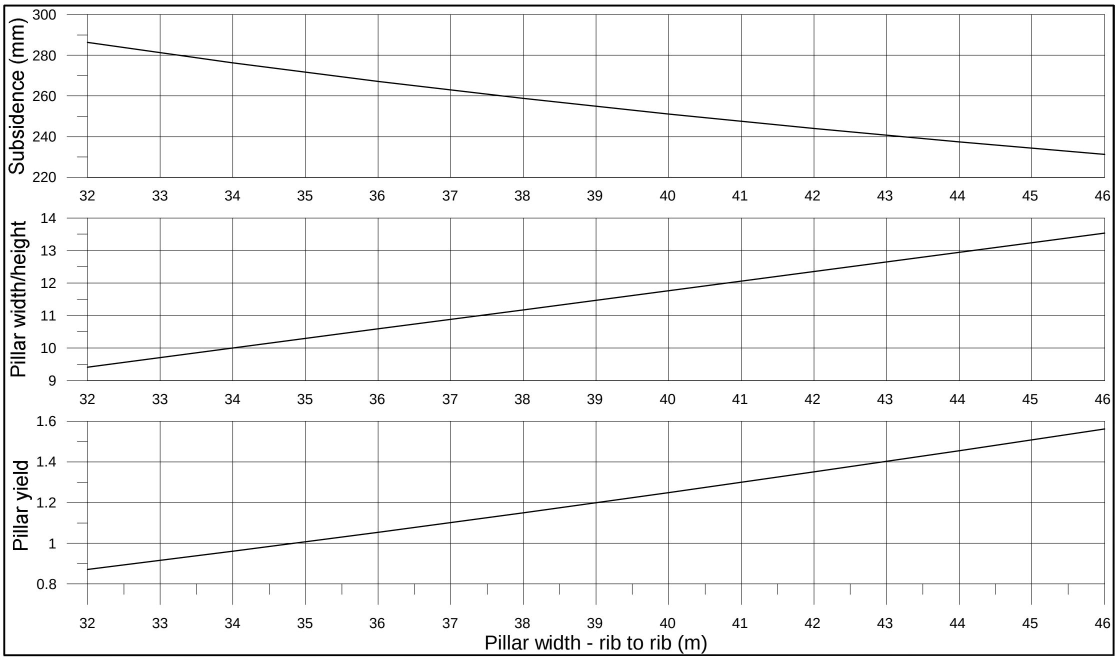


Figure 20 260m deep, 3.4m pillar height, 7m of coal, E=17 GPa, E/G=15, 160m wide panel

The minor difference in subsidence may seem anomalous but it is direct result of the reduction in the depth of influence as the pillar width decrease. The key aspect of the reduced pillar width is the perception of stability. Figure 21 presents the visualisation of vertical subsidence with smaller MG20 and MG21 chain pillars, and tilts and strains are presented in Figure 22. Electronic files (as dwg) have been forwarded separately.

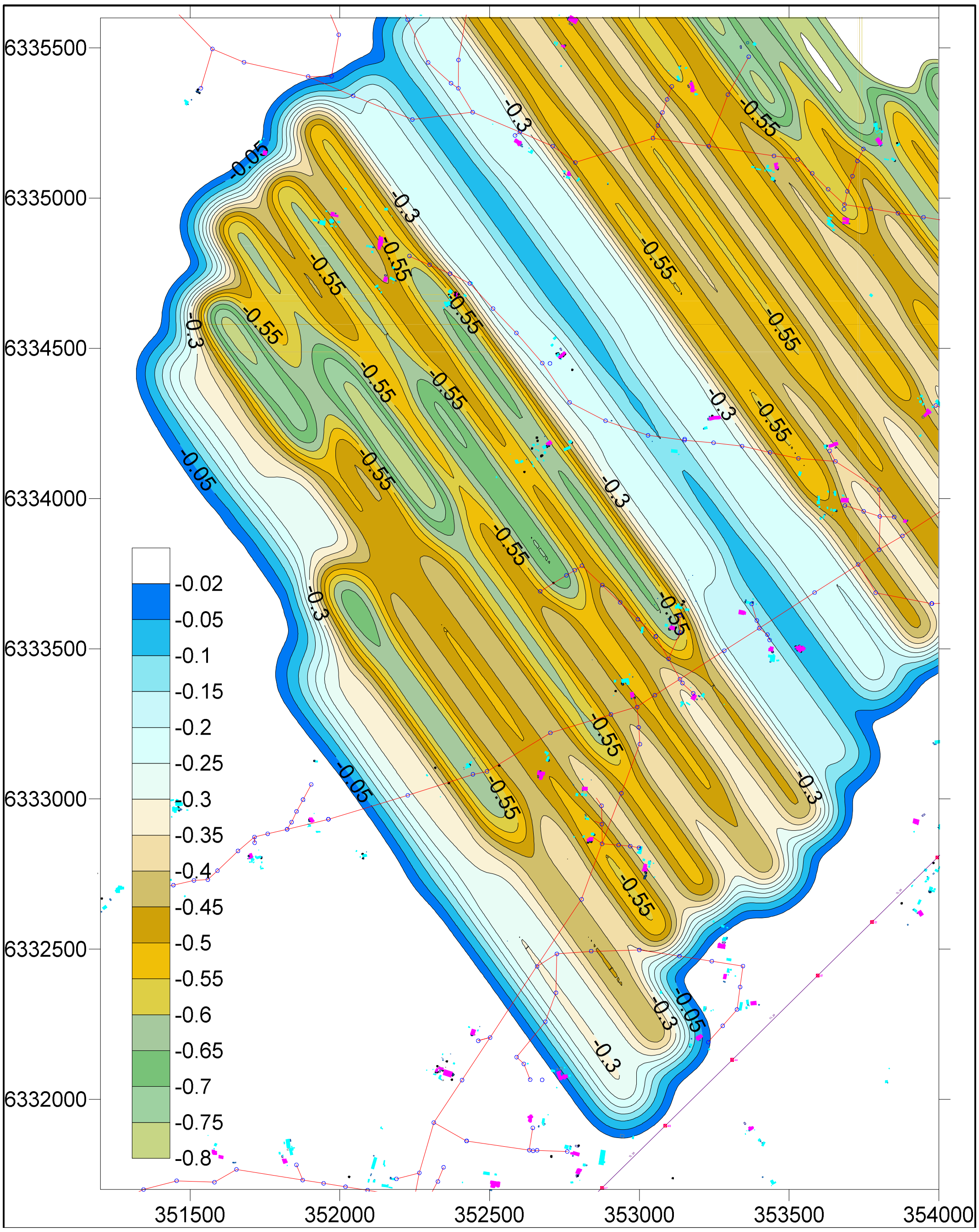


Figure 21 Visualisation of vertical subsidence

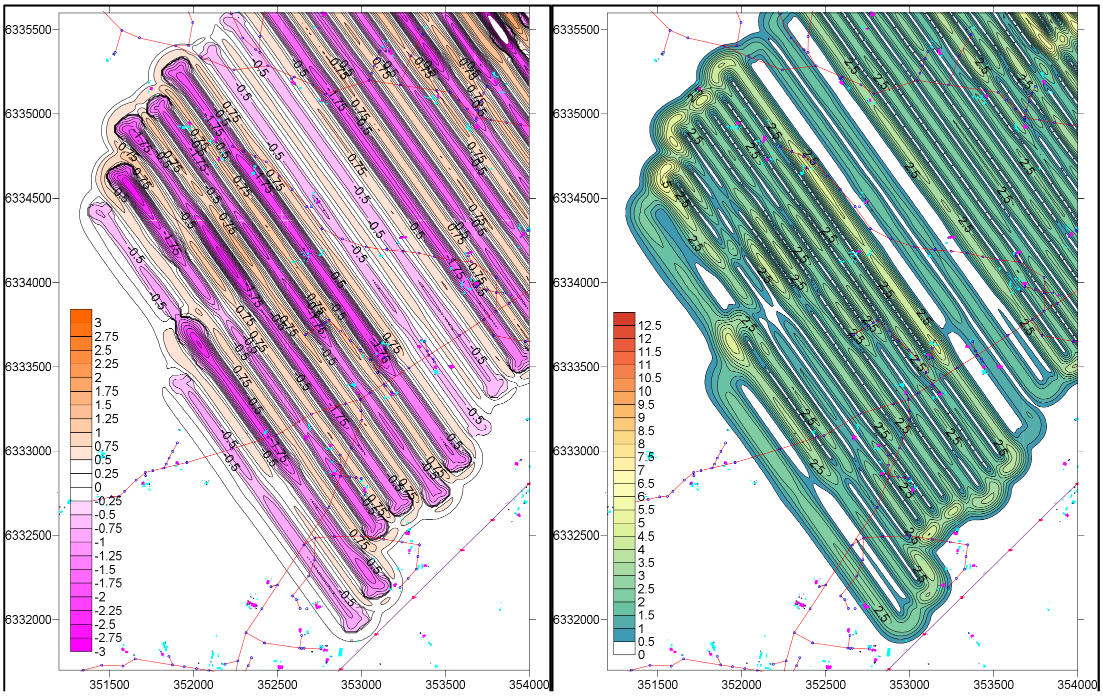


Figure 22 Visualisation of tilts and strains

Reducing the pillar width will also impact on tailgate stability (Figure 23). For the 46 m wide pillars the onset of yield and hence changes in the confining stresses in the tailgate roof has been unlikely. For 37 m wide chain pillars, there is a possibility that there will be some deterioration in tailgate conditions at depth in excess of about 310 m. There is only a small portion of the LW18-LW21 area where such depths apply. Deterioration could be anticipated and some preventative steps taken – standing support or some truss cabling. It is noted that the orientation of the gate roads is not ideal for tailgate pillar yield (gates sub parallel to the dominant joint set) so this hazard should not be under-rated.

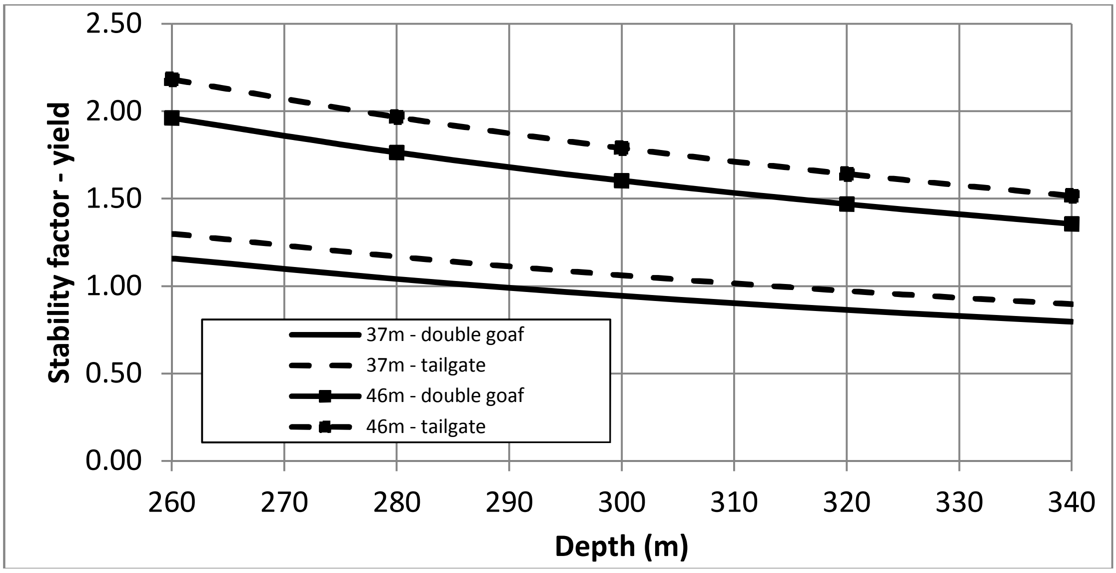


Figure 23 Tailgate stability

Appendix B – Threatened Flora and Fauna Likelihood of Occurrence Assessment

RPS

MEMORANDUM

Date:	12/08/2016
To:	James Wearne
From:	Arne Bishop
Subject:	Likelihood of Occurrence Table – Mandalong LW 22-24a

Desktop Assessment

A review of relevant information was performed to gain an understanding of ecological values occurring or potentially occurring within the site. Information sources reviewed for a 10 km radius of the site (i.e. locality) included:

- Fauna and flora records contained in the Office of Environment and Heritage (OEH) Atlas of NSW Wildlife that may occur within the locality (OEH 2016); and
- Fauna and flora records contained in the Department of the Environment (DoE) Protected Matters Search tool that may occur within the locality (DoE 2016).

The results of these database searches formed the basis for a preliminary 'likelihood of occurrence' assessment. This assessment was used as a framework for determining investigation methods necessary for performing adequate site investigation (i.e. determine target species and appropriate investigation methods).

Likelihood of Occurrence

Threatened flora and fauna species (listed under the *TSC Act 1995* and/or *EPBC Act 1999*) that have been gazetted and recorded within a 10 km radius of the Study Area have been considered within this assessment. Additional species that were known from the region that did not arise in searches were also considered. Each species is considered for its potential to occur within the Study Area based on the Plant Community Types (PCTs) and habitats present. Four 'likelihood of occurrence' categories were attributed to threatened biodiversity as outlined in **Table 1**.

Table 1 Likelihood of Occurrence Criteria

Likelihood Rating	Threatened Flora Criteria	Threatened and Migratory Fauna Criteria
Known	The species was observed within the Study Area.	The species was observed within the Study Area.
Likely	PCT and micro-habitat conditions present. Habitat condition moderate to high. Species recorded within locality.	PCT and micro-habitat conditions present. Habitat condition moderate to high and likely to support important lifecycle processes such as breeding. Species recorded within locality.
May	Based on broad habitat predictor (i.e. PCT). Habitat condition low (i.e. micro-habitat conditions either disturbed or of limited suitability). Species records may not occur within locality.	Based on broad habitat predictor (i.e. PCT). Habitat condition low (i.e. micro-habitat conditions either disturbed or of limited suitability). Species records may not occur within locality. If present, the species would likely be a transient visitor and unlikely to rely on habitat for important lifecycle processes.
Unlikely	Habitat unsuitable for the species.	Habitat unsuitable for the species.

Habitat descriptions for each species were generally obtained from the online Threatened Species Profile Database (OEH 2016).

RPS

MEMORANDUM

Table 2 Likelihood of Occurrence of Threatened Species

Species	TSC Act listing	EPBC Act listing	Habitat requirements	Likelihood of Occurrence
Acacia bynoeana (Bynoe's Wattle)	E	V	Grows mainly in heath and dry sclerophyll forest in sandy soils. Mainly south of Dora Creek-Morisset area to Berrima and the Illawarra region, west to the Blue Mountains, also recorded from near Kurri Kurri in the Hunter Valley and from Morton National Park.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Angophora inopina	V	V	Endemic to the Central Coast region of NSW. The known northern limit is near Karuah where a disjunct population occurs; to the south populations extend from Toronto to Charmhaven with the main population occurring between Charmhaven and Morisset. Occurs most frequently in red bloodwood – scribbly gum woodland, wet heath, red mahogany – paperbark sedge woodland and stringybark – red bloodwood forest.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Asterolasia elegans	E	E	Occurs north of Sydney, in the Baulkham Hills, Hawkesbury and Hornsby local government areas. Also likely to occur in the western part of Gosford local government area. Known from only seven populations, only one of which is wholly within a conservation reserve. Occurs on Hawkesbury sandstone in sheltered forests on mid- to lower slopes and valleys, e.g. in or adjacent to gullies which support sheltered forest.	The habitat of this species does not exist within the site. Not observed and unlikely to occur.
Caladenia tessellata (Thick-lip Spider Orchid)	E	V	The Tessellated Spider Orchid is found in grassy sclerophyll woodland on clay loam or sandy soils, though the population near Braidwood is in low woodland with stony soil. Known from the Sydney area (old records), Wyong, Ulladulla and Braidwood in NSW. Populations in Kiama and Queanbeyan are presumed extinct.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Genoplesium insignis (Variable Midge Orchid)	E	-	Grows in patches of kangaroo grass amongst shrubs and sedges in heathland and forest. Associated vegetation at Chain Valley Bay is described as dry sclerophyll woodland dominated by scribbly gum, red bloodwood, smooth-barked apple and black she-oak.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Eucalyptus camfieldii	V	V	Restricted distribution in a narrow band with the most northerly records in the Raymond Terrace Area south to Waterfall. Localised and scattered distribution includes sites at Norah Head (Tuggerah Lakes), Peats Ridge, Mt Colah, Elvina Bay Trail (West Head), Terrey Hills, Killara, North Head, Menai, Wattamolla and a few other sites in Royal National Park. Poor coastal country in shallow sandy soils overlying Hawkesbury sandstone. Coastal heath mostly on exposed sandy ridges. Occurs mostly in small scattered stands near the boundary of tall coastal heaths and low open woodland of the slightly more fertile inland areas.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Genoplesium baueri (Bauer\'s Midge Orchid)	E	E	Grows in dry sclerophyll forest and moss gardens over sandstone. Flowers February to March. Has been recorded between Ulladulla and Port Stephens. Currently the species is known from just over 200 plants across 13 sites. The species has been recorded in Berowra Valley Regional Park, Royal National Park and Lane Cove National Park and may also occur in the Woronora, O'Hares, Metropolitan and Warragamba Catchments.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Grevillea parviflora subsp. parviflora (Small-flowered Grevillea)	V	V	Grows in sandy or light clay soils usually over thin shales. Occurs in a range of vegetation types from heath and shrubby woodland to open forest. Found over a range of altitudes from flat, low-lying areas to upper slopes and ridge crests. Often occurs in open, slightly disturbed sites such as along tracks.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Maundia triglochinoides	V	-	Grows in swamps, creeks or shallow freshwater 30 - 60 cm deep on heavy clay, low nutrients. Flowering occurs during warmer months. Diaspore is the seed and root tubers, which are probably dispersed by water.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Melaleuca biconvexa (Biconvex Paperbark)	V	V	Grows in damp places, often near streams or low-lying areas on alluvial soils of low slopes or sheltered aspects. Scattered and dispersed populations found in the Jervis Bay area in the south and the Gosford-Wyong area in the north.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. Species known to occur.
Persicaria elatior	V	V	This species normally grows in damp places, especially beside streams and lakes. Occasionally in swamp forest or associated with disturbance.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Pterostylis gibbosa (Illawarra Greenhood)	E	E	Grows in open forest or woodland, on flat or gently sloping land with poor drainage. Known from a small number of populations in the Hunter region (Milbrodale), the Illawarra region (Albion Park and Yallah) and the Shoalhaven region (near Nowra).	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Rhizanthella slateri	V, EP (Great Lakes)	E	Habitat requirements are poorly understood and no particular vegetation type has been associated with the species, although it is known to occur in sclerophyll forest.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Rutidosis heterogama	V	V	Grows in heath on sandy soils and moist areas in open forest, and has been recorded along disturbed roadsides.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Syzygium paniculatum (Magenta Lilly Pilly)	E	V	Found only in NSW, in a narrow, linear coastal strip from Bulahdelah to Conjola State forest. On the south coast the species occurs on grey soils over sandstone, restricted mainly to remnant stands of littoral rainforest. On the central coast it occurs on gravels, sands, silts and clays in riverside gallery rainforests and remnant littoral rainforest communities	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Tetratheca juncea	V	V	Confined to the northern portion of the Sydney Basin bioregion and the southern portion of the North	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are

Species	TSC Act listing	EPBC Act listing	Habitat requirements	Likelihood of Occurrence
(Black-eyed Susan)			Coast bioregion in the local government areas of Wyong, Lake Macquarie, Newcastle, Port Stephens, Great Lakes and Cessnock. It is usually found in low open forest-woodland with a mixed shrub understorey and grassy groundcover. The majority of populations occur on low nutrient soils associated with the Awaba Soil Landscape. Cryptic species that requires survey in September-October.	present within the site. While not observed the species may occur.
Thelymitra sp. *adorata*	CE	-	Occurs from 10-40 m a.s.l. in grassy woodland or occasionally derived grassland in well-drained clay loam or shale derived soils. The vegetation type in which the majority of populations occur (including the largest colony) is a spotted gum - ironbark forest with a diverse grassy understorey and occasional scattered shrubs.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Thesium australe (Austral Toadflax)	V	V	Grows in very small populations scattered across eastern NSW, along the coast, and from the Northern to Southern Tablelands. It is also found in Tasmania and Queensland and in eastern Asia. Occurs in grassland or grassy woodland. Grows on kangaroo grass tussocks but has also been recorded within the exotic coolatai grass.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Anthochaera phrygia (Regent Honeyeater)	CE	E,M	The Regent Honeyeater mainly inhabits temperate woodlands and open forests of the inland slopes of south-east Australia. Birds are also found in drier coastal woodlands and forests in some years. The distribution of the species has contracted dramatically in the last 30 years to between north-eastern Victoria and south-eastern Queensland. There are only three known key breeding regions remaining: north-east Victoria (Chiltern-Albury), and in NSW at Capertee Valley and the Bundarra-Barraba region. In NSW the distribution is very patchy and mainly confined to the two main breeding areas and surrounding fragmented woodlands. In some years flocks converge on flowering coastal woodlands and forests.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Artamus cyanopterus (Dusky Woodswallow)	V	-	The Dusky Woodswallow is often reported in woodlands and dry open sclerophyll forests, usually dominated by eucalypts, including mallee associations. It has also been recorded in shrublands and heathlands and various modified habitats, including regenerating forests; very occasionally in moist forests or rainforests. At sites where Dusky Woodswallows are recorded the understorey is typically open with sparse eucalypt saplings, acacias and other shrubs, including heath. The ground cover may consist of grasses, sedges or open ground, often with coarse woody debris. Birds are also often observed in farm land, usually at the edges of forest or woodland or in roadside remnants or wind breaks with dead timber	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Botaurus poiciloptilus (Australasian Bittern)	E	E	The Australasian Bitterns is widespread but uncommon over south-eastern Australia. In NSW they may be found over most of the state except for the far north-west. Favours permanent freshwater wetlands with tall, dense vegetation, particularly bullrushes and spikerushes.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Burhinus grallarius (Bush Stone-curlew)	E	-	The Bush Stone-curlew is found throughout Australia except for the central southern coast and inland, the far south-east corner, and Tasmania. Only in northern Australia is it still common however and in the south-east it is either rare or extinct throughout its former range. Inhabits open forests and woodlands with a sparse grassy groundlayer and fallen timber. Largely nocturnal, being especially active on moonlit nights.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Callocephalon fimbriatum (Gang-gang Cockatoo)	V	-	In summer, occupies tall montane forests and woodlands, particularly in heavily timbered and mature wet sclerophyll forests. Also occur in subalpine snow gum woodland and occasionally in temperate or regenerating forest. In winter, occurs at lower altitudes in drier, more open eucalypt forests and woodlands, particularly in box-ironbark assemblages, or in dry forest in coastal areas. It requires tree hollows in which to breed.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. Species likely to occur.
Calyptorhynchus lathami (Glossy Black-Cockatoo)	V	-	Inhabits forest with low nutrients, characteristically with key Allocasuarina spp. Tends to prefer drier forest types with a middle stratum of Allocasuarina below Eucalyptus or Angophora. Often confined to remnant patches in hills and gullies. Breed in hollows stumps or limbs, either living or dead. Endangered population in the Riverina.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. Species likely to occur.
Climacteris picumnus victoriae (Brown Treecreeper (eastern subspecies))	V	-	Found in eucalypt woodlands (including box-gum woodland) and dry open forest of the inland slopes and plains inland of the Great Dividing Range; mainly inhabits woodlands dominated by stringybarks or other rough-barked eucalypts, usually with an open grassy understorey, sometimes with one or more shrub species; also found in mallee and river red gum forest bordering wetlands with an open understorey of acacias, saltbush, lignum, cumbungi and grasses; usually not found in woodlands with a dense shrub layer; fallen timber is an important habitat component for foraging; also recorded, though less commonly, in similar woodland habitats on the coastal ranges and plains.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Daphoenositta chrysoptera (Varied Sittella)	V	-	Inhabits wide variety of dry eucalypt forests and woodlands, usually with either shrubby under storey or grassy ground cover or both, in all climatic zones of Australia. Usually in areas with rough-barked trees, such as stringybarks or ironbarks, but also in paperbarks or mature Eucalypts with hollows.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. Species likely to occur.
Dasyornis brachypterus (Eastern Bristlebird)	E	E	Found in coastal woodlands, dense scrub and heathlands, particularly where it borders taller woodlands.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Ephippiorhynchus asiaticus	E	-	Mainly found on shallow, permanent, freshwater terrestrial wetlands, and surrounding marginal vegetation, including swamps, floodplains, watercourses and billabongs, freshwater meadows, wet	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.

MEMORANDUM

Species	TSC Act listing	EPBC Act listing	Habitat requirements	Likelihood of Occurrence
(Black-necked Stork)			heathland, farm dams and shallow floodwaters, as well as extending into adjacent grasslands, paddocks and open savannah woodlands. They also forage within or around estuaries and along intertidal shorelines, such as saltmarshes, mudflats and sandflats, and mangrove vegetation.	
Glossopsitta pusilla (Little Lorikeet)	V	-	Distributed in forests and woodlands from the coast to the western slopes of the Great Dividing Range in NSW, extending westwards to the vicinity of Albury, Parkes, Dubbo and Narrabri. Mostly occur in dry, open eucalypt forests and woodlands. They feed primarily on nectar and pollen in the tree canopy. Nest hollows are located at heights of between 2 m and 15 m, mostly in living, smooth-barked eucalypts. Most breeding records come from the western slopes.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. Species likely to occur.
Grantiella picta (Painted Honeyeater)	V	-	The Painted Honeyeater is nomadic and occurs at low densities throughout its range. The greatest concentrations of the bird, and almost all breeding occurs on the inland slopes of the Great Dividing Range in NSW, Victoria and southern Queensland. During the winter it is more likely to be found in the north of its distribution. Inhabits boree, brigalow and box-gum woodlands and box-ironbark forests.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Irediparra gallinacea (Comb-crested Jacana)	V	-	Inhabits permanent wetlands with a good surface cover of floating vegetation, especially water-lilies.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Lathamus discolor (Swift Parrot)	E	CE	The Swift Parrot occurs in woodlands and forests of NSW from May to August, where it feeds on eucalypt nectar, pollen and associated insects. The Swift Parrot is dependent on flowering resources across a wide range of habitats in its wintering grounds in NSW. This species is migratory, breeding in Tasmania and also nomadic, moving about in response to changing food availability.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Limosa lapponica (Bar-tailed Godwit)	-	M	Bar-tailed Godwits are strongly migratory, breeding along the Arctic littoral of eastern Eurasia and spending the non-breeding season in South East Asia and Australasia as far south as Tasmania and New Zealand. They are rare vagrants to western Europe. They are often seen in western Alaska and occasionally elsewhere in the Americas.	The habitat of this species does not exist within the site. Not observed and unlikely to occur.
Ninox strenua (Powerful Owl)	V	-	Occupies wet and dry eucalypt forests and rainforests. Can occupy both un-logged and lightly logged forests as well as undisturbed forests where it usually roosts on the limbs of dense trees in gully areas. It is most commonly recorded within red turpentine in tall open forests and black she-oak within open forests. Large mature trees with hollows at least 0.5 m deep are required for nesting. Tree hollows are particularly important for the Powerful Owl because a large proportion of the diet is made up of hollow-dependent arboreal marsupials. Nest trees for this species are usually emergent with a diameter at breast height of at least 100 cm.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Numenius madagascariensis (Eastern Curlew)	-	CE	The Eastern curlew spends its breeding season in northeastern Asia, including Siberia to Kamchatka, and Mongolia. Its breeding habitat is composed of marshy and swampy wetlands and lakeshores. Most individuals winter in coastal Australia, with a few heading to South Korea, Thailand, Philippines and New Zealand, where they stay at estuaries, beaches, and salt marshes. It uses its long, decurved bill to probe for invertebrates in the mud. It may feed in solitary but it generally congregates in large flocks to migrate or roost. Its call is a sharp, clear whistle, cuuue-reee, often repeated.	The habitat of this species does not exist within the site. Not observed and unlikely to occur.
Pachyptila turtur subantarctica (Fairy Prion)	-	V	The fairy prion is the smallest prion and it measures between 23 and 28 cm (9.1–11.0 in) long.[2] Its plumage is blue-grey on its upperparts, and white underneath. They have a dark "M" on their upperparts extending to their wingtips, and their tail is wedge-shaped with a dark tip. They have a blue bill and feet. The diet consists mainly of planktonic crustaceans and other tiny sea animals, which they feed at night from the water's surface. They breed colonially and prefer small islands. The nest is situated in soil, hidden by vegetation and is dug with the bill or feet, or it is in a hollow in a crevice. When coming back to their nest at night, they will coo softly and listen for their mate. The fairy prion is found throughout oceans and coastal areas in the Southern Hemisphere. Their colonies can be found on Chatham, Snares and Antipodes Islands of New Zealand, Bass Strait Islands of Australia, Falkland Islands, Marion Island, the Crozet Islands and Macquarie Island.	The habitat of this species does not exist within the site. Not observed and unlikely to occur.
Pelargonium sp. *Striatellum* (Omeo's Stork's-bill)	E	E	Flowering occurs from October to March. Occurs in habitat usually located just above the high water level of irregularly inundated or ephemeral lakes. During dry periods, the species is known to colonise exposed lake beds. The species is known to form clonal colonies by rhizomatous propagation.	The habitat of this species does not exist within the site. Not observed and unlikely to occur.
Rostratula australis (Australian Painted Snipe)	E	E, M	In NSW, this species has been recorded at the Paroo wetlands, Lake Cowell, Macquarie Marshes and Hexham Swamp. Most common in the Murray-Darling Basin. Prefers fringes of swamps, dams and nearby marshy areas where there is a cover of grasses, lignum, low scrub or open timber. Nests on the ground amongst tall vegetation, such as grasses, tussocks or reeds.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Tyto novaehollandiae (Masked Owl)	V	-	Inhabits a diverse range of wooded habitat that provide tall or dense mature trees with hollows suitable for nesting and roosting. Mostly recorded in open forest and woodlands adjacent to cleared lands. Nest in hollows, in trunks and in near vertical spouts or large trees, usually living but sometimes dead. Nest hollows are usually located within dense forests or woodlands. Masked owls prey upon hollow-dependent arboreal marsupials, but terrestrial mammals make up the largest proportion of the diet.	The habitat of this species does not exist within the site. Not observed and unlikely to occur.
Tyto tenebricosa (Sooty Owl)	V	-	Often found in tall old-growth forests, including temperate and subtropical rainforests. In NSW mostly found on escarpments with a mean altitude less than 500 metres. Nests and roosts in hollows of tall emergent trees, mainly eucalypts often located in gullies. Nests have been located in trees 125 to 161	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.

Species	TSC Act listing	EPBC Act listing	Habitat requirements	Likelihood of Occurrence
			centimetres in diameter.	
Chalinolobus dwyeri (Large-eared Pied Bat)	V	V	Located in a variety of drier habitats, including the dry sclerophyll forests and woodlands to the east and west of the Great Dividing Range. Can also be found on the edges of rainforests and in wet sclerophyll forests. This species roosts in caves and mines in groups of between 3 and 37 individuals.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Dasyurus maculatus maculatus (Spotted-tailed Quoll)	V	E	Spotted-tailed Quoll are found on the east coast of NSW, Tasmania, eastern Victoria and north-eastern Queensland. Only in Tasmania is it still considered common. Recorded across a range of habitat types, including rainforest, open forest, woodland, coastal heath and inland riparian forest, from the sub-alpine zone to the coastline.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Falsistrellus tasmaniensis (Eastern False Pipistrelle)	V	-	Inhabit sclerophyll forests, preferring wet habitats where trees are more than 20 m high. Two observations have been made of roosts in stem holes of living eucalypts. There is debate about whether or not this species moves to lower altitudes during winter, or whether they remain sedentary but enter torpor . This species also appears to be highly mobile and records showing movements of up to 12 km between roosting and foraging sites.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Kerivoula papuensis (Golden-tipped Bat)	V	-	Distributed along the east coast of Australia in scattered locations from Cape York Peninsula in Queensland to Bega in southern NSW. Found in rainforest and adjacent sclerophyll forest. Roost in abandoned hanging Yellow-throated Scrubwren and Brown Gerygone nests located in rainforest gullies on small first- and second-order streams.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Macropus parma (Parma Wallaby)	V	-	Once occurred from north-eastern NSW to the Bega area in the southeast. Their range is now confined to the coast and ranges of central and northern NSW from the Gosford district to the Queensland border. Preferred habitat is moist eucalypt forest with thick, shrubby understorey, often with nearby grassy areas, rainforest margins and occasionally drier eucalypt forest.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Miniopterus australis (Little Bentwing-bat)	V	-	Coastal north-eastern NSW and eastern Queensland. Little Bent-wing Bat is an insectivorous bat that roost in caves, in old mines, in tunnels, under bridges, or in similar structures. They breed in large aggregations in a small number of known caves and may travel 100s km from feeding home ranges to breeding sites. Little Bent-wing Bat has a preference for moist eucalypt forest, rainforest or dense coastal banksia scrub where it forages below the canopy for insects.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Miniopterus schreibersii oceanensis (Eastern Bentwing-bat)	V	-	Eastern Bent-wing Bats occur along the east and north-west coasts of Australia. Caves are the primary roosting habitat, but also use derelict mines, storm-water tunnels, buildings and other man-made structures. Form discrete populations centred on a maternity cave that is used annually in spring and summer for the birth and rearing of young.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. Species likely to occur.
Mormopterus norfolkensis (Eastern Freetail-bat)	V	-	Most records are from dry eucalypt forests and woodlands to the east of the Great Dividing Range. Appears to roost in trees, but little is known of this species' habits.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Myotis macropus (Southern Myotis)	V	-	The Large-footed Myotis is found in the coastal band from the north-west of Australia, across the top-end and south to western Victoria. Generally roost in groups of 10 - 15 close to water in caves, mine shafts, hollow-bearing trees, storm water channels, buildings, under bridges and in dense foliage.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Petauroides volans (Greater Glider population in the Eurobodalla local government area)	EP	-	This population of Greater Gliders on the south coast of NSW is bounded by the Moruya River to the north, Coila Lake to the south and the Princes Highway and cleared land exceeding 700 m in width to the west. The Greater Glider occurs in eucalypt forests and woodlands.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Petaurus australis (Yellow-bellied Glider)	V	-	Occur in tall mature eucalypt forest generally in areas with high rainfall and nutrient rich soils. forest type preferences vary with latitude and elevation; mixed coastal forests to dry escarpment forests in the north; moist coastal gullies and creek flats to tall montane forests in the south. Found along the eastern coast to the western slopes of the Great Dividing Range, from southern Queensland to Victoria.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. Species likely to occur.
Petaurus norfolcensis (Squirrel Glider)	V	-	Generally occurs in dry sclerophyll forests and woodlands but is absent from dense coastal ranges in the southern part of its range. Requires abundant hollow bearing trees and a mix of eucalypts, banksias and acacias. There is only limited information available on den tree use by Squirrel gliders, but it has been observed using both living and dead trees as well as hollow stumps. Within a suitable vegetation community at least one species should flower heavily in winter and one species of eucalypt should be smooth barked. Endangered population in the Wagga Wagga LGA.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. Species likely to occur.
Petrogale penicillata (Brush-tailed Rock-wallaby)	E	V	Found in rocky areas in a wide variety of habitats including rainforest gullies, wet and dry sclerophyll forest, open woodland and rocky outcrops in semi-arid country. Commonly sites have a northerly aspect with numerous ledges, caves and crevices.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Phascogale tapoatafa (Brush-tailed Phascogale)	V	-	The Brush-tailed Phascogale has a patchy distribution around the coast of Australia. In NSW it is mainly found east of the Great Dividing Range although there are occasional records west to the divide. Prefer dry sclerophyll open forest with sparse groundcover of herbs, grasses, shrubs or leaf litter. Also inhabit heath, swamps, rainforest and wet sclerophyll forest.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.

Species	TSC Act listing	EPBC Act listing	Habitat requirements	Likelihood of Occurrence
Phascolarctos cinereus (Koala)	V	V	Inhabits eucalypt forests and woodlands. The suitability of these forests for habitation depends on the size and species of trees present, soil nutrients, climate and rainfall.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Potorous tridactylus tridactylus (Long-nosed Potoroo)	V	V	Inhabits coastal heath and wet and dry sclerophyll forests. Generally found in areas with rainfall greater than 760 mm. Requires relatively thick ground cover where the soil is light and sandy.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Pseudomys novaehollandiae (New Holland Mouse)	-	V	The New Holland Mouse currently has a disjunct, fragmented distribution across Tasmania, Victoria, New South Wales and Queensland. Across the species' range the New Holland Mouse is known to inhabit open heathlands, open woodlands with a heathland understorey, and vegetated sand dunes.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Pteropus poliocephalus (Grey-headed Flying-fox)	V	V	This species is a canopy-feeding frugivore and nectarivore of rainforests, open forests, woodlands, melaleuca swamps and Banksia woodlands. Bats commute daily to foraging areas, usually within 15 km of the day roost although some individuals may travel up to 70 km.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. Species likely to occur.
Scoteanax rueppellii (Greater Broad-nosed Bat)	V	-	Prefer moist gullies in mature coastal forests and rainforests, between the Great Dividing Range and the coast. They are only found at low altitudes below 500 m. In dense environments they utilise natural and human-made opening in the forest for flight paths. Creeks and small rivers are favoured foraging habitat. This species roosts in hollow tree trunks and branches.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Heleioporus australiacus (Giant Burrowing Frog)	V	V	The Giant Burrowing Frog has been recorded breeding in a range of water bodies associated with more sandy environments of the coast and adjacent ranges from the Sydney Basin south the eastern Victoria. It breeds in hanging swamps, perennial non-flooding creeks and occasionally permanent pools, but permanent water must be present to allow its large tadpoles time to reach metamorphosis.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Litoria aurea (Green and Golden Bell Frog)	E	V	Inhabits a very wide range of water bodies including marshes, dams and streams, particularly those containing emergent vegetation such as bullrushes or spikerushes. It also inhabits numerous types of man-made water bodies including quarries and sand extraction sites. Optimum habitat includes water-bodies that are un-shaded, free of predatory fish such as Plague Minnow, have a grassy area nearby and diurnal sheltering sites available.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Litoria brevipalmata (Green-thighed Frog)	V	-	This species is distributed from south-east Queensland to the NSW Central Coast. It occurs in a range of habitat types including rainforest, moist eucalypt forest, dry eucalypt forest and heath, but is most closely associated with wetter forest types in the southern part of its range. Calling and breeding is highly correlated with heavy rainfalls that lead to the formation of large ephemeral pools in a range of sites, but always in association with some native vegetation. Calling occurring only for one or two nights at a time anywhere between September and May.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Litoria littlejohni (Littlejohn's Tree Frog)	V	V	Occurs in wet and dry sclerophyll forests and heathland associated with sandstone outcrops between 280 and 1000 m on the eastern slopes of the Great Dividing Range from the Central Coast down into Victoria. Individuals have been collected from a wide range of water bodies that includes semi-permanent dams, permanent ponds, temporary pools and permanent streams, with calling occurring from fringing vegeation or on the banks. Individuals have been observed sheltering under rocks on high exposed ridges during summer and within deep leaf litter adjacent to the breeding site. Calling occurs in all months of the year, often in association with heavy rains. The tadpoles are distinctive, being large and very dark in colouration.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Mixophyes balbus (Stuttering Frog)	E	V	Associated with streams in dry sclerophyll and wet sclerophyll forests and rainforests of more upland areas of the Great Dividing Range of NSW and down into Victoria. Breeding occurs along forest streams with permanent water where eggs are deposited within nests excavated in riffle zones by the females and the tadpoles swim free into the stream when large enough to do so. Outside of breeding, individuals range widely across the forest floor and can be found hundres of metres from water	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Mixophyes iteratus (Giant Barred Frog)	E	E	This species is found along larger streams of the coast and adjacent ranges of NSW and SE QLD. It inhabits rainforest and wet sclerophyll forest, but is also found within cleared farmland where fringing vegetation is retained, including lantana beds. Many sites where the Giant Barred Frog is known to occur are the lower reaches of streams which have been affected by major disturbances such as clearing, timber harvesting and urban development in their headwaters.	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.
Pseudophryne australis (Red-crowned Toadlet)	V	-	Occurs on wetter ridge tops and upper slopes of sandstone formations on which the predominant vegetation is dry open forests and heaths. This species typically breeds within small ephemeral creeks that feed into larger semi-perennial streams. After rain these creeks are characterised by a series of shallow pools lined by dense grasses, ferns and low shrubs and usually contain leaf litter for shelter. Eggs are terrestrial and laid under litter, vegetation or rocks where the tadpoles inside will reach a relatively late stage of development before waiting for flooding waters before hatching will occur.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.
Hoplocephalus bungaroides (Broad-headed Snake)	E	V	Occurs almost exclusively in association with communities occurring on Triassic sandstone within the Sydney Basin. Typically found among exposed sandstone outcrops with vegetation types ranging from woodland to heath. Within these habitats they spend most of the year sheltering in and under rock crevices and exfoliating rock. However, some individuals will migrate to tree hollows to find shelter	Habitat at a PCT level exists. However, micro-habitat conditions necessary for incidence are absent from the site. Species not observed and unlikely to occur.

Species	TSC Act listing	EPBC Act listing	Habitat requirements	Likelihood of Occurrence
			during hotter parts of summer.	
Hoplocephalus stephensii (Stephens' Banded Snake)	V	-	The Stephens Banded Snake is found through the coast and adjacent ranges of NSW from the Central Coast northwards and into SE Queensland. It is most commonly found living in wet sclerophyll and rainforest areas, but can be found in taller dry forest areas and even in some areas of dry forest where there is significant rock outcropping. They spend the majority of the time in tree tops, either in large hollows or in dense vegetation, coming to the ground for forage for a range of vertebrates.	Habitat at a PCT level exists. Micro-habitat conditions necessary for incidence are present within the site. While not observed the species may occur.

References

DoE (2016) EPBC Protected Matters Search Tool, accessed 11 August 2016, http://www.environment.gov.au/epbc/pmst/index.html

OEH (2016). BioNet Atlas of NSW Wildlife. , accessed 11 August 2016 http://www.environment.nsw.gov.au/atlaspublicapp/UI_Modules/ATLAS_/AtlasSearch.aspx

Appendix C – Proposed Amendments to Development Consent Conditions

Proposed Amendments to Development Consent SSD-5144 Conditions

Definitions

~~Approved~~ Conceptual mine plan	The conceptual ~~approved~~ mine plan for the development, as shown in Figure 2 of Appendix 2

Schedule 2 Condition 2(c)

Generally in accordance with the Development Layout and Statement of Commitments; and

Schedule 2 Condition 6

The Applicant may only carry out underground mining operations within the area covered by the ~~approved~~ conceptual mine plan.

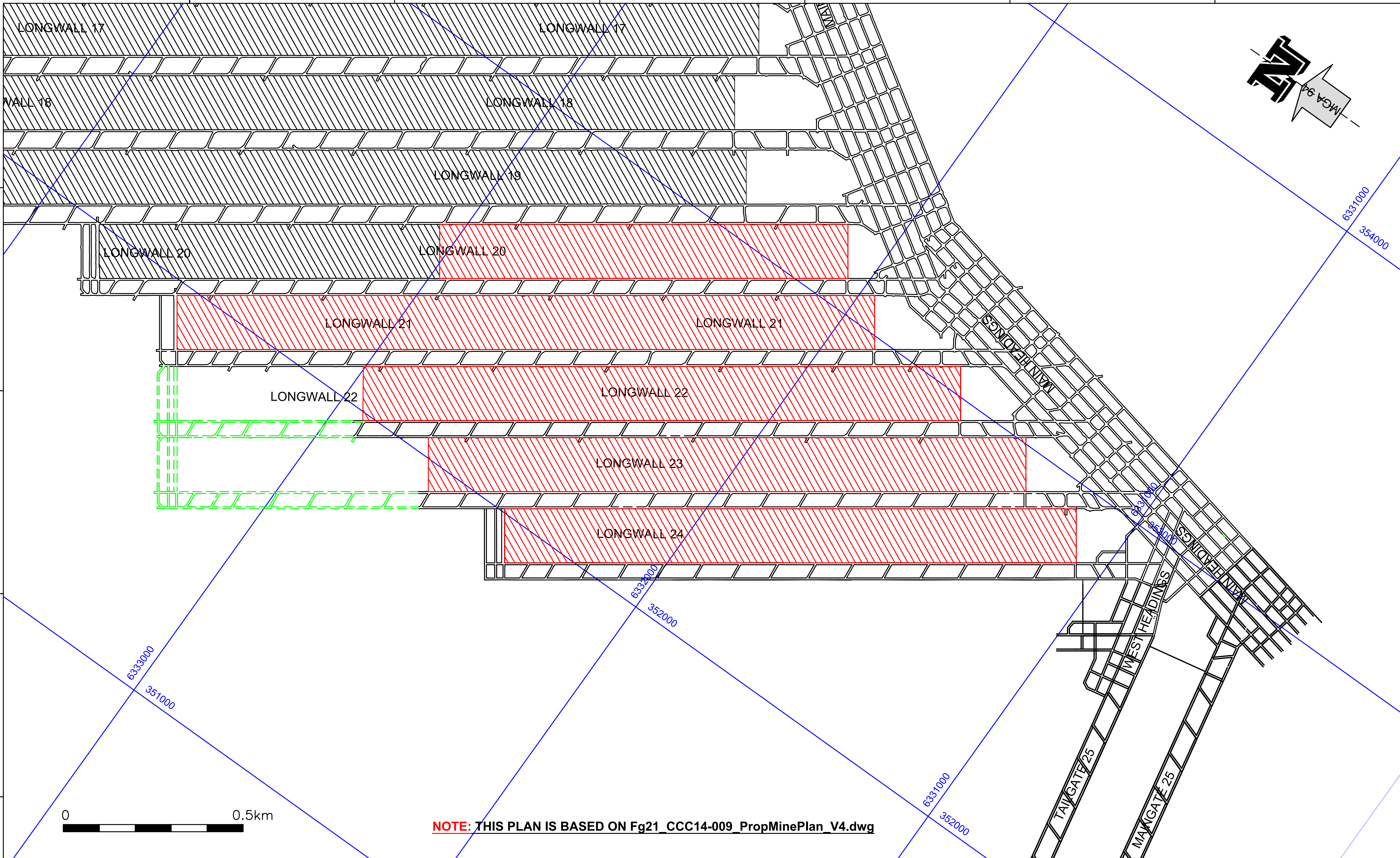
Schedule 4 Condition 1 Table 6

Mine Workings	
Second workings	To be carried out only ~~within the approved mine plan,~~ in accordance only with an approved Extraction Plan.

Appendix 2 Figure 2

Figure 2: ~~Approved~~ Conceptual Mine Plan

Appendix D - Plan MG12588 Mandalong Mine LW22 & 23 First Workings Modification



LEGEND

- APPROVED FIRST WORKINGS
- PROPOSED FIRST WORKINGS
- EXISTING EXTRACTED AREAS
- APPROVED SECONDARY EXTRACTION AREAS

LOCATION	MANDALONG
SEAM	WEST WALLARAH
DRAWN	C.P.T. 12/08/16
CHECKED	J. WEARNE 12/08/16
APPROVED	J. TURNER 12/08/16

SCALE 1:10000

Centennial Coal
Mandalong

MANDALONG MINE

LW 22 & 23 FIRST WORKINGS MODIFICATION

CONTRACT	
PLOTFILE	
A3	MG12588
DRAWING REVISION	12/08/16