REPORT: SUBSIDENCE PREDICTIONS AND IMPACT ASSESSMENTS

msec
mine subsidence
ENGINEERING CONSULTANTS

Austar Coal Mine:

Longwalls B1 to B3

Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Environmental Assessment for a Section 75W Modification Application for the Inclusion of the Proposed Longwalls B1 to B3 at the Austar Coal Mine

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MSEC417 (Revision C) – The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of the Proposed Longwall A5A in Stage 2 at the Austar Coal Mine (July 2010).

MSEC309 (Revision D) – The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of Proposed Austar Longwalls A6 to A17 in Support of a Part 3A Application (September 2008).

MSEC484 (Revision A) – Stage 3 – Longwalls A7 to A19 – Subsidence Predictions and Impact Assessments for Natural Features and Surface Infrastructure in Support of a Modification to the Development Consent (May 2011).

Background reports available at *www.minesubsidence.com*:-

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

Austar Coal Mine Pty Limited (Austar) has completed the extraction of Longwalls A1 and A2 in Stage 1, Longwalls A3 to A5A in Stage 2 and Longwalls A7 and A8 in Stage 3 of the Austar Coal Mine (the Mine) using Longwall Top Coal Caving (LTCC) mining techniques. Austar has approval to extract the future Longwalls A9 to A19 in Stage 3 at the Mine.

Austar is seeking approval to modify the existing Development Consent (DA 29/95) under Section 75W of the EP&A Act, to facilitate the extraction of three additional longwalls in the Greta Seam, referred to as Longwalls B1 to B3 (LWB1 to LWB3). The proposed longwalls are located to the south of the previously extracted Longwalls A3 to A5A in Stage 2 at the Mine and to the east of the existing Longwalls 1 to 12A at the Ellalong Colliery. The locations of the existing and the proposed longwalls are shown in Drawing No. MSEC769-01.

The predicted conventional subsidence parameters for the proposed longwalls have been obtained using the Incremental Profile Method. The subsidence model was calibrated and reviewed using the available ground monitoring data above the previously extracted longwalls at the Mine. The maximum predicted mine subsidence movements due to the extraction of the proposed Longwalls B1 to B3 are: 925 mm vertical subsidence; 3.5 mm/m tilt (i.e. 0.35 %, or 1 in 285); 0.03 km^{-1} hogging curvature (33 kilometre minimum radius) and 0.05 km^{-1} sagging curvature (20 kilometres minimum radius).

The Study Area has been defined, as a minimum, as the surface area enclosed by a 26.5 degree angle of draw line from the extents of the proposed Longwalls B1 to B3 and by the predicted 20 mm subsidence contour resulting from the extraction of these proposed longwalls. Other features which could be subjected to far-field or valley related movements and could be sensitive to such movements have also been assessed in this report.

A number of natural and built features have been identified within or in the vicinity of the Study Area including: Quorrobolong Creek and ephemeral drainage lines; Sandy Creek Road and Barraba Lane; a bridge, box culverts and circular culverts; 11 kV powerlines; copper telecommunications cables; rural structures; farm dams; archaeological sites; survey control marks; and houses.

The assessments provided in this report indicate that the levels of impact on the natural and built features can be managed by the preparation and implementation of subsidence management strategies. It should be noted that more detailed assessments of the impacts of mine subsidence on some features have been prepared by other consultants, experts in their fields, and the findings in this report should be read in conjunction with the findings in all other relevant reports.

Monitoring of ground movements is recommended, as subsidence occurs, to compare the observed ground movements with those predicted, and to periodically review the predictions and impact assessments in the light of measured data.

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Tables

Tables are prefixed by the number of the chapter or the letter of the appendix in which they are presented.

Figures

Figures are prefixed by the number of the chapter or the letter of the appendix in which they are presented.

Drawings

Drawings referred to in this report are included in Appendix E at the end of this report.

1.1. Background

Austar Coal Mine Pty Limited (Austar) has completed the extraction of Longwalls A1 and A2 in Stage 1, Longwalls A3 to A5A in Stage 2 and Longwalls A7 and A8 in Stage 3 of the Austar Coal Mine (the Mine) using Longwall Top Coal Caving (LTCC) mining techniques. Austar has approval to extract the future Longwalls A9 to A19 in Stage 3 at the Mine.

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Mine Subsidence Engineering Consultants (MSEC) has been commissioned by Austar to:-

- provide subsidence predictions for the proposed Longwalls B1 to B3 in the Greta Seam;
- identify the natural and built features located above and in the vicinity of the proposed longwalls;
- provide subsidence predictions for each of these natural and built features;
- provide impact assessments, in conjunction with other specialist consultants, for each of these natural and built features; and
- provide recommendations for any preventive measures and monitoring.

The proposed Longwalls B1 to B3 and the Study Area, as defined in Section 2.1, have been overlaid on an orthophoto of the area, which is shown in Fig. 1.1. The major natural features and surface infrastructure in the vicinity of the proposed longwalls can be seen in this figure.

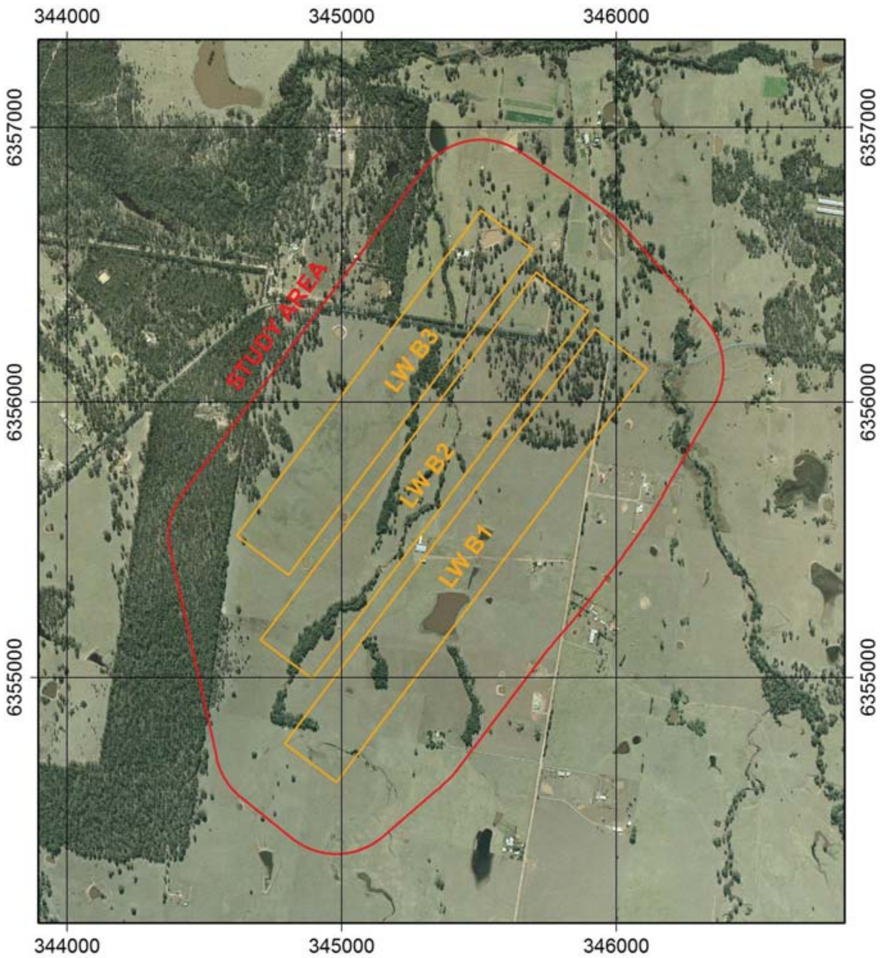

Fig. 1.1 Aerial Photograph Showing the Proposed Longwalls B1 to B3

This report has been prepared to support the Modification Application which will be submitted to the NSW Department of Planning and Environment. In some cases, this report will refer to other sources of information on specific natural features and items of surface infrastructure, and these reports should be read in conjunction with this report.

Chapter 1 of this report provides a general introduction to the study, which also includes a description of the mining geometry and geological details of the area.

Chapter 2 defines the Study Area and provides a summary of the natural and built features within this area.

Chapter 3 provides an overview of the mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the proposed longwalls.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of the proposed longwalls.

Chapters 5 and 6 provide the predictions and impact assessments for each of the natural and built features which have been identified within the Study Area. Recommendations for each of these features have also been provided, which have been based on the predictions and impact assessments.

1.2. Mining Geometry

The layout of the proposed Longwalls B1 to B3 in the Greta Seam is shown in Drawing Nos. MSEC769-01 and MSEC769-02. It is proposed that the longwalls would be extracted in order of LWB2, LWB3 and then LWB1. A summary of the dimensions of the proposed longwalls is provided in Table 1.1.

Table 1.1 Geometry of the Proposed Longwalls B1 to B3

Longwall	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
LWB2	1,670	237	-
LWB3	1,480	237	60
LWB1	1,880	237	60

The proposed width of the longwall extraction face (i.e. excluding the first workings) is 226 metres. The proposed longwall extracted lengths (i.e. excluding the installation headings) are 1,665 metres for Longwall B2, 1,475 metres for Longwall B3 and 1,875 for Longwall B1.

1.3. Surface and Seam Details

The surface level contours are shown in Drawing No. MSEC769-03.

There are two small ridgelines which partially cross above the western and eastern extents of the proposed mining area, having high points of approximately 157 metres above Australian Height Datum (mAHD) and 140 mAHD, respectively, directly above the longwalls. A drainage line is formed between the ridgelines, having a low point of approximately 125 mAHD above the longwalls. The drainage line flows in a northerly direction to where it drains into Quorrobolong Creek at a distance of approximately 1 kilometre from the proposed longwalls.

The seam floor contours, seam thickness contours and depth of cover contours for the Greta Seam are shown in Drawings Nos. MSEC769-04, MSEC769-05 and MSEC769-06, respectively.

The depth of cover to the Greta Seam directly above the proposed longwalls varies between a minimum of 480 metres above the maingate of Longwall B3 and a maximum of 555 metres above the north-eastern corner of Longwall B1. The seam floor within the proposed mining area dips from the north-west to the south-east, having an average gradient of around 6 %, or 1 in 17.

The thickness of the Greta Seam within the proposed mining area varies between 3.3 metres and 4.6 metres. It is proposed that a constant thickness of 3.4 metres will be extracted using conventional longwall mining techniques.

The surface and seam levels are illustrated along Cross-section 1 in Fig. 1.2, which has been taken transverse to the proposed longwalls near their mid-lengths (looking north-east). The location of this cross-section is shown in Drawing No. MSEC769-03 to MSEC769-06.

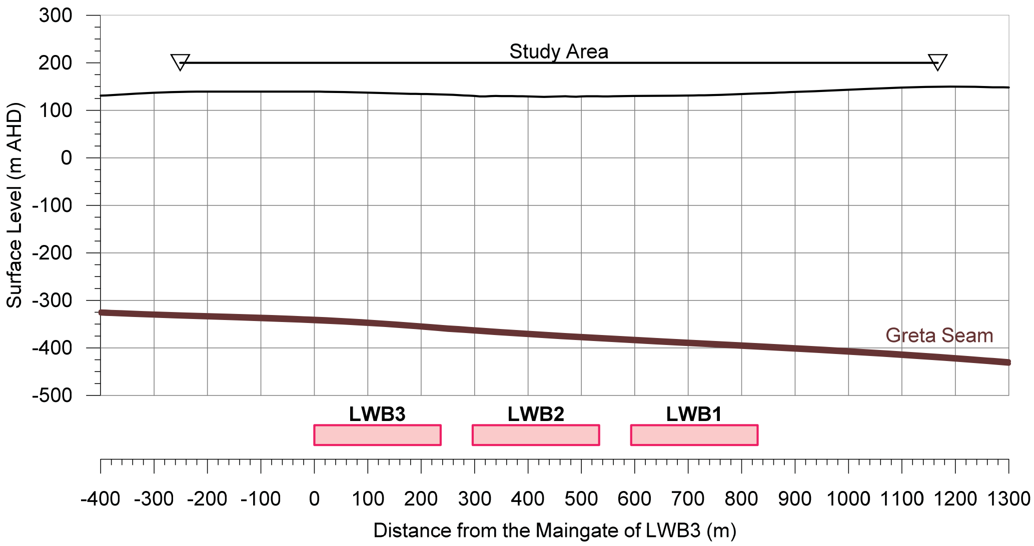

Fig. 1.2 Surface and Seam Levels along Cross-section 1

1.4. Geological Details

The Austar Coal Mine lies in the Newcastle Coalfield, within the Northern Sydney Basin. A typical stratigraphic section of the Newcastle Coalfield (after Ives et al, 1999, Moelle and Dean-Jones, 1995, Lohe and Dean-Jones, 1995, Sloan and Allman, 1995) is shown in Table 1.2. The strata shown in this table were laid down between the Early Permian and the Middle Triassic Periods.

Longwalls B1 to B3 are proposed to be extracted within the Greta Seam, which is located within the Kitchener Formation of the Greta Coal Measures. The overlying strata comprise the Paxton Formation, which consists of interbedded sandstone and siltstone layers up to 20 metres thick. The uppermost layer in the Greta Coal Measures is the Pelton Seam, which is less than 0.5 metres thick. The underlying strata comprise the Kurri Kurri Conglomerate and the Neath Sandstone. Strong and thick strata consisting of conglomerate and sandstone are typically observed within these formations.

The main sequence overlying the Greta Coal Measures is the Branxton Formation, which is part of the Maitland Group sediments from the mid Permian period. The Maitland Group comprises, in order of deposition, the Branxton Formation, Muree Sandstone and Mulbring Siltstone. The Branxton Formation immediately overlies the Greta Coal Measures and is made up of a substantial thickness of sedimentary rocks. The lithology of the Branxton Formation generally consists of the coarser sandstone and conglomerate rocks at the base of the formation, grading to finer deposits of silty sandstone and siltstone at the top of the formation. The upper part of the formation contains a unit known as *Fenestella Shale* that contains numerous fossils of marine invertebrate fauna.

The Newcastle region is characterised by a complex geological setting, with a great variety of rock types occurring over short lateral and vertical distances (Moelle and Dean-Jones, 1995). Folds, normal faults and dykes dominate the region and generally trend north-west to north-north-west (Lohe and Dean-Jones, 1995).

Table 1.2 Stratigraphy of the Newcastle Coalfield
(after Ives et al, 1999, Moelle & Dean-Jones, 1995, Lohe & Dean-Jones, 1995, Sloan & Allan, 1995)

Stratigraphy			Lithology
Group	**Formation**	**Coal Seams**	
Narrabeen Group	Clifton		Sandstone, siltstone, mudstone, claystone
Newcastle Coal Measures	Moon Island Beach	Vales Point Wallarah Great Northern	Sandstone, shale, conglomerate, claystone, coal
	Awaba Tuff		Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone, chert
	Boolaroo	Fassifern Upper Pilot Lower Pilot Hartley Hill	Conglomerate, sandstone, shale, claystone, coal
	Warners Bay Tuff		Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone, chert
	Adamstown	Australasian Montrose Wave Hill Fern Valley Victoria Tunnel	Conglomerate, sandstone, shale, claystone, coal
	Nobbys Tuff		Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone chert
	Lambton	Nobbys Dudley Yard Borehole	Sandstone, shale, minor conglomerate, claystone, coal
	Waratah Sandstone		Sandstone
Tomago Coal Measures	Dempsey		Shale, siltstone, fine sandstone, coal, and minor tuffaceous claystone
	Four Mile Creek		
	Wallis Creek		
Maitland Group	Mulbring Siltstone		Siltstone
	Muree Sandstone		Sandstone
	Branxton		Sandstone, and siltstone
Greta Coal Measures	Paxton	Pelton	Sandstone, conglomerate, and coal
	Kitchener	**Greta**	
	Kurri Kurri	Homeville	
	Neath Sandstone		Sandstone
Dalwood Group	Farley		Shale, siltstone, lithic sandstone, conglomerate, minor marl and coal, and interbedded basalts, volcanic breccia, and tuffs
	Rutherford		
	Allandale		
	Lochinvar		
Seaham Formation			

The surface lithology within the Study Area is shown in Fig. 1.3, which shows the proposed longwalls overlaid on Geological Series Sheet Quorrobolong 9132-2-S, which is published by Department of Mineral Resources (DMR, 1988), now known as the Department of Industry – Division of Resources and Energy. It can be seen from this figure, that the surface lithology within the Study Area comprises predominately of areas derived from the Branxton Formation (Pmbf) and Quaternary alluvium (Qa).

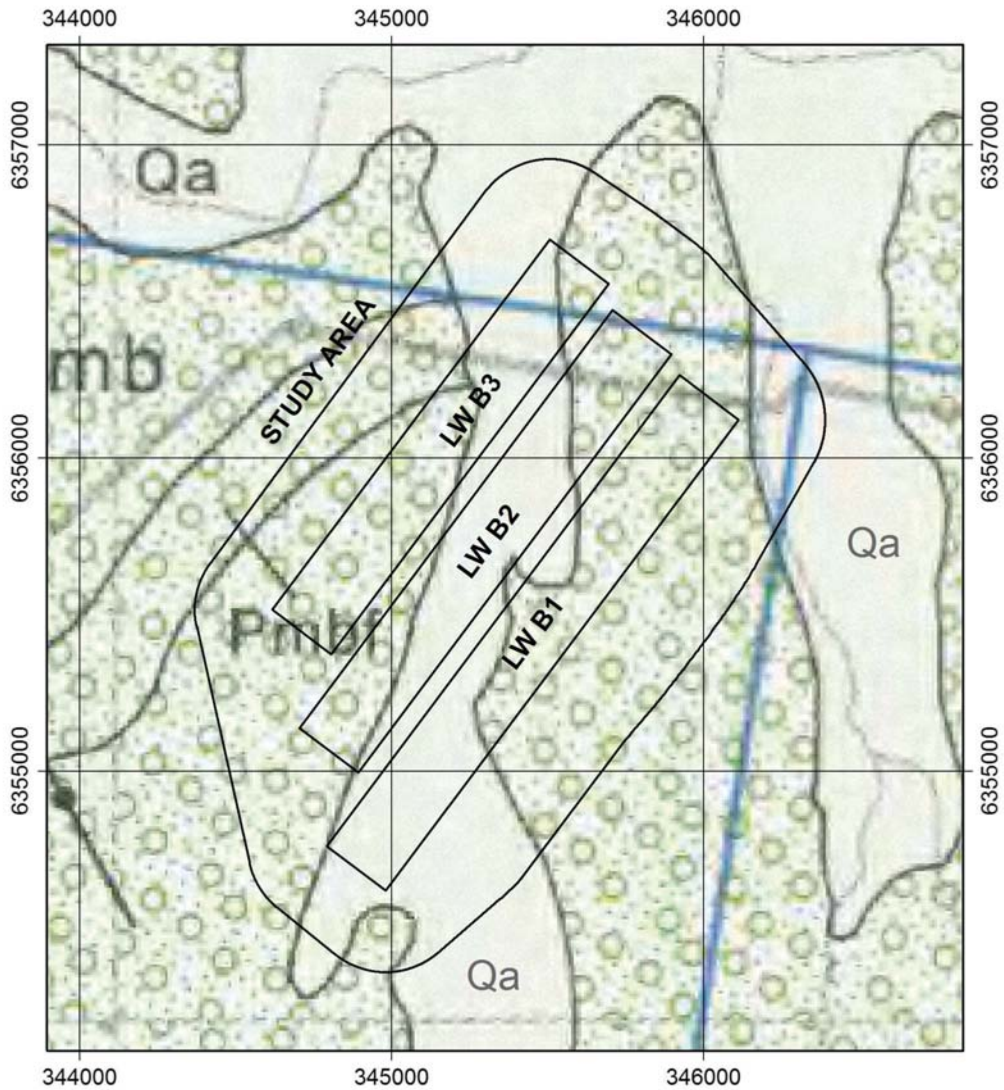

Fig. 1.3 Surface Lithology within the Study Area
Geological Series Sheet Quorrobolong 9132-2-S (DMR, 1988)

The major geological zones identified at seam level are shown in Drawings Nos. MSEC769-04 and MSEC769-05. The *Swamp Fault Zone* has been identified near the finishing (i.e. north-eastern) ends of the proposed longwalls. The *Barraba Fault Zone* has also been identified adjacent to the commencing (i.e. south-western) ends of the proposed longwalls. The nature and extents of these faulting zones will be better defined as further geological data is gathered during the development of the first workings and, if necessary, the extents of mining will be reviewed based on this information.

2.1. Definition of the Study Area

The *Study Area* is defined as the surface area that is likely to be affected by the proposed mining of Longwalls B1 to B3 in the Greta Seam at Austar Coal Mine. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:-

- The 26.5 degree angle of draw line from the proposed extents of Longwalls B1 to B3; and
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour resulting from the extraction of the proposed Longwalls B1 to B3.

The depth of cover contours are shown in Drawing No. MSEC769-06. It can be seen from this drawing, that the depth of cover varies between 480 metres and 555 metres directly above the proposed longwalls. The 26.5 degree angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 240 metres and 278 metres around the limits of the proposed extraction areas.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the Incremental Profile Method, which is described in further detail in Sections 3.5 and 3.6. The angle of draw to the predicted total 20 mm subsidence contour has been calibrated to 30 degrees adjacent to the maingates and tailgates of the proposed longwalls, in order to match those observed over the previously extracted longwalls at the Mine.

The predicted total 20 mm subsidence contour, therefore, is generally located outside the 26.5 degree angle of draw line adjacent to the longitudinal edges of the proposed longwalls, and is generally located inside the 26.5 degree angle of draw line adjacent to the commencing and finishing ends of the proposed longwalls. A line has therefore been drawn defining the Study Area, based upon the 26.5 degree angle of draw line and the predicted total 20 mm subsidence contour, whichever is furthest from the longwalls, and is shown in Drawings Nos. MSEC769-01 and MSEC769-02.

There are areas that lie outside the Study Area that are expected to experience either far-field movements, or valley related upsidence and closure movements. The surface features which are sensitive to such movements have been identified in this report and have been included in the assessments provided in this report.

2.2. Natural Features and Items of Surface Infrastructure within the Study Area

The major natural features and items of surface infrastructure within the Study Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), numbered QUORROBOLONG 9132-2-S. The proposed longwalls and the Study Area have been overlaid on an extract of this CMA Map and are shown in Fig. 2.1.

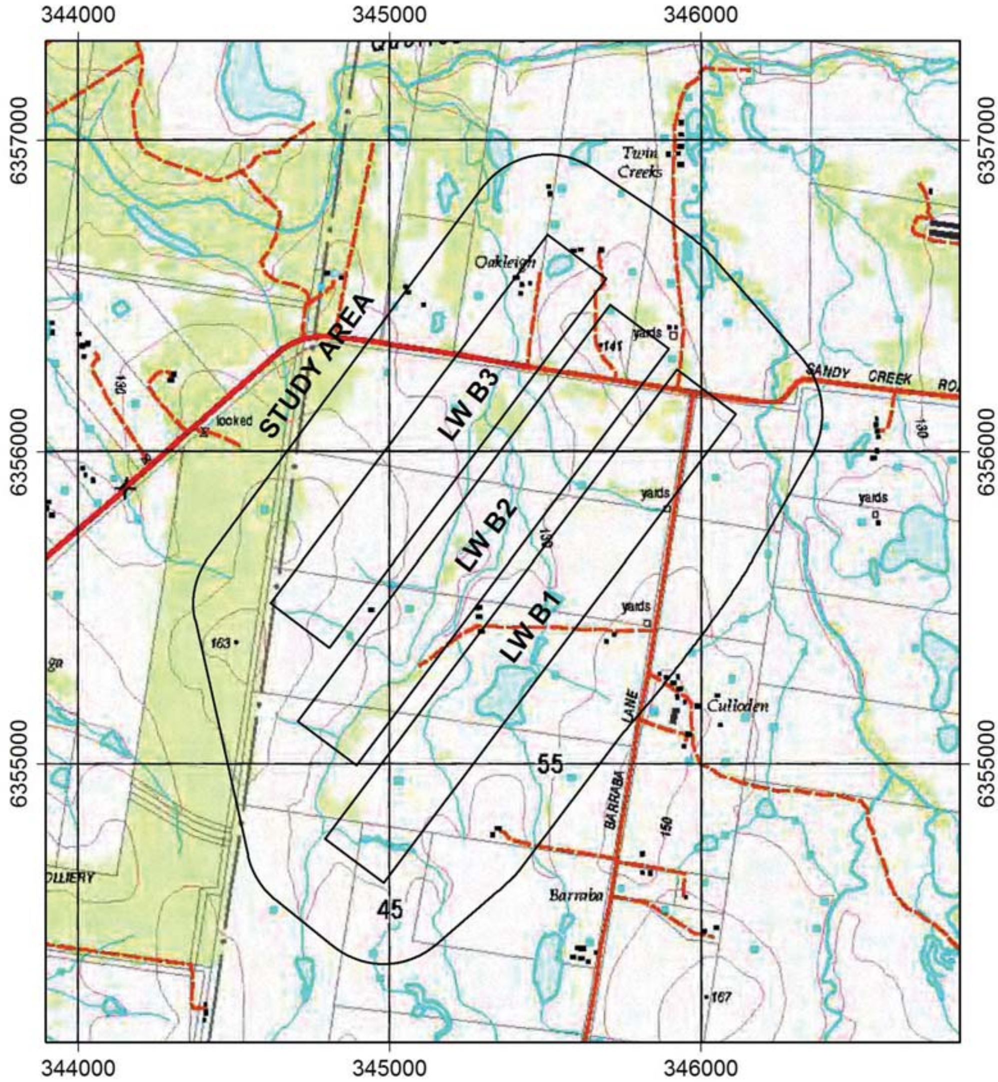

Fig. 2.1 Proposed Longwalls B1 to B3 and the Study Area Overlaid on CMA Map No. Quorrobolong 9132-2-S

A summary of the natural and built features within the Study Area is provided in Table 2.1. The locations of these features are shown in Drawings Nos. MSEC769-07 to MSEC769-09. The descriptions of these features are provided in Chapters 5 and 6, as indicated by the Section number in Table 2.1.

Table 2.1 Natural and Built Features

Item	Within Study Area	Section Number Reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	×	
Rivers or Creeks	✓	5.2
Aquifers or Known Groundwater Resources	✓	5.3
Springs	×	
Sea or Lake	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Pagodas	×	
Steep Slopes	✓	5.4
Escarpments	×	
Land Prone to Flooding or Inundation	✓	5.5
Swamps, Wetlands or Water Related Ecosystems	✓	5.6
Threatened or Protected Species	✓	5.7
National Parks	×	
State Forests	×	
State Conservation Areas	×	
Natural Vegetation	✓	5.7
Areas of Significant Geological Interest	×	
Any Other Natural Features Considered Significant	×	
PUBLIC UTILITIES	×	
Railways	×	
Roads (All Types)	✓	6.1
Bridges	✓	6.2
Tunnels	×	
Culverts	✓	6.3
Water, Gas or Sewerage Infrastructure	×	
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	✓	6.4
Telecommunication Lines or Associated Plants	✓	6.5
Water Tanks, Water or Sewage Treatment Works	×	
Dams, Reservoirs or Associated Works	×	
Air Strips	×	
Any Other Public Utilities	×	
	×	
PUBLIC AMENITIES	×	
Hospitals	×	
Places of Worship	×	
Schools	×	
Shopping Centres	×	
Community Centres	×	
Office Buildings	×	
Swimming Pools	×	
Bowling Greens	×	
Ovals or Cricket Grounds	×	
Race Courses	×	
Golf Courses	×	
Tennis Courts	×	
Any Other Public Amenities	×	
FARM LAND AND FACILITIES		
Agricultural Utilisation or Agricultural Suitability of Farm Land	✓	6.6
Farm Buildings or Sheds	✓	6.7
Tanks	✓	6.7
Gas or Fuel Storages	✓	6.8
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	✓	6.9
Farm Dams	✓	6.10
Wells or Bores	✓	6.11
Any Other Farm Features	×	
INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS		
Factories	×	
Workshops	×	
Business or Commercial Establishments or Improvements	×	
Gas or Fuel Storages or Associated Plants	×	
Waste Storages or Associated Plants	×	
Buildings, Equipment or Operations that are Sensitive to Surface Movements	×	
Surface Mining (Open Cut) Voids or Rehabilitated Areas	×	
Mine Infrastructure Including Tailings Dams or Emplacement Areas	×	
Any Other Industrial, Commercial or Business Features	×	
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓	6.12
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	✓	6.13
RESIDENTIAL ESTABLISHMENTS		
Houses	✓	6.14
Flats or Units	×	
Caravan Parks	×	
Retirement or Aged Care Villages	×	
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts	✓	6.15 and 6.16
Any Other Residential Features	×	
ANY OTHER ITEM OF SIGNIFICANCE	×	
ANY KNOWN FUTURE DEVELOPMENTS	×	

3.1. Introduction

This chapter provides an overview of the mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the proposed longwalls. Further details on methods of mine subsidence prediction are provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

3.2. Overview of Conventional Subsidence Parameters

The normal ground movements resulting from the extraction of pillars or longwalls are referred to as conventional or systematic subsidence movements. These movements are described by the following parameters:-

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements in some cases, where the subsidence is small beyond the longwall goaf edges, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *millimetres (mm)*.
- **Tilt** is the change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1,000.
- **Curvature** is the second derivative of subsidence, or the rate of change of tilt, and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres* (km^{-1}), but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*.
- **Strain** is the relative differential horizontal movements of the ground. **Normal strain** is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of *millimetres per metre (mm/m)*. **Tensile Strains** occur where the distance between two points increases and **Compressive Strains** occur when the distance between two points decreases. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

  Whilst mining induced normal strains are measured along monitoring lines, ground shearing can also occur both vertically and horizontally across the directions of monitoring lines. Most of the published mine subsidence literature discusses the differential ground movements that are measured along subsidence monitoring lines, however, differential ground movements can also be measured across monitoring lines using 3D survey monitoring techniques.
- **Horizontal shear deformation** across monitoring lines can be described by various parameters including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. It is not possible, however, to determine the horizontal shear strain across a monitoring line using traditional 2D or 3D monitoring techniques.

  High deformations along monitoring lines (i.e. normal strains) are generally measured where high deformations have been measured across the monitoring line (i.e. shear deformations). Conversely, high deformations across monitoring lines are also generally measured where high normal strains have been measured along the monitoring line.

The **incremental** subsidence, tilts, curvatures and strains are the additional parameters which result from the extraction of each longwall. The **cumulative** subsidence, tilts, curvatures and strains are the accumulated parameters which result from the extraction of a series of longwalls. The **total** subsidence, tilts, curvatures and strains are the final parameters at the completion of a series of longwalls. The **travelling** tilts, curvatures and strains are the transient movements as the longwall extraction face mines directly beneath a given point.

3.3. Far-field Movements

The measured horizontal movements at survey marks which are located beyond the longwall goaf edges and over solid unmined coal areas are often much greater than the observed vertical movements at those marks. These movements are often referred to as *far-field movements*.

Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain. These movements generally do not result in impacts on natural features or built environments, except where they are experienced by large structures which are very sensitive to differential horizontal movements.

In some cases, higher levels of far-field horizontal movements have been observed where steep slopes or surface incisions exist nearby, as these features influence both the magnitude and the direction of ground movement patterns. Similarly, increased horizontal movements are often observed around sudden changes in geology or where blocks of coal are left between longwalls or near other previously extracted series of longwalls. In these cases, the levels of observed subsidence can be slightly higher than normally predicted, but these increased movements are generally accompanied by very low levels of tilt, curvature and strain.

Far-field horizontal movements and the method used to predict such movements are described further in Section 4.5.

3.4. Overview of Non-Conventional Subsidence Movements

Conventional subsidence profiles are typically smooth in shape and can be explained by the expected caving mechanisms associated with overlying strata spanning the extracted void. Normal conventional subsidence movements due to longwall extraction are easy to identify where longwalls are regular in shape, the extracted coal seams are relatively uniform in thickness, the geological conditions are consistent and surface topography is relatively flat.

As a general rule, the smoothness of the profile is governed by the depth of cover and lithology of the overburden, particularly the near surface strata layers. Where the depth of cover is greater than 400 metres, such as is the case within the Study Area, the observed subsidence profiles along monitoring survey lines are generally smooth. Where the depth of cover is less than 100 metres, the observed subsidence profiles along monitoring lines are generally irregular. Very irregular subsidence movements are observed with much higher tilts and strains at very shallow depths of cover where the collapsed zone above the extracted longwalls extends up to or near to the surface.

Irregular subsidence movements are occasionally observed at the deeper depths of cover along an otherwise smooth subsidence profile. The cause of these irregular subsidence movements can be associated with:-

- issues related to the timing and the method of the installation of monitoring lines,
- sudden or abrupt changes in geological conditions,
- steep topography, and
- valley related mechanisms.

Non-conventional movements due to geological conditions and valley related movements are discussed in the following sections.

3.4.1. Non-conventional Subsidence Movements due to Changes in Geological Conditions

It is believed that most non-conventional ground movements are a result of the reaction of near surface strata to increased horizontal compressive stresses due to mining operations. Some of the geological conditions that are believed to influence these irregular subsidence movements are the blocky nature of near surface sedimentary strata layers and the possible presence of unknown faults, dykes or other geological structures, cross bedded strata, thin and brittle near surface strata layers and pre-existing natural joints. The presence of these geological features near the surface can result in a bump in an otherwise smooth subsidence profile and these bumps are usually accompanied by locally increased tilts, curvatures and strains.

Even though it may be possible to attribute a reason behind most observed non-conventional ground movements, there remain some observed irregular ground movements that still cannot be explained with the available geological information. The term “*anomaly*” is therefore reserved for those non-conventional ground movement cases that were not expected to occur and cannot be explained by any of the above possible causes.

It is not possible to predict the locations and magnitudes of non-conventional anomalous movements. In some cases, approximate predictions for the non-conventional ground movements can be made where the underlying geological or topographic conditions are known in advance. It is expected that these methods will improve as further knowledge is gained through ongoing research and investigation.

In this report, non-conventional ground movements are being included statistically in the predictions and impact assessments, by basing these on the frequency of past occurrence of both the conventional and non-conventional ground movements and impacts. The analysis of strains provided in Section 4.3 includes those resulting from both conventional and non-conventional anomalous movements. The impact assessments for the natural features and items of surface infrastructure, which are provided in Chapters 5 through to 9, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

3.4.2. Non-conventional Subsidence Movements due to Steep Topography

Non-conventional movements can also result from downslope movements where longwalls are extracted beneath steep slopes. In these cases, elevated tensile strains develop near the tops of the steep slopes and elevated compressive strains develop near the bases of the steep slopes. The potential impacts resulting from down slope movements include the development of tension cracks at the tops of the steep slopes and compression ridges at the bottoms of the steep slopes.

Further discussions on the potential for down slope movements for the steep slopes within the Study Area are provided in Section 5.3.

3.4.3. Valley Related Movements

The watercourses within the Study Area may also be subjected to valley related movements, which are commonly observed along river and creek alignments in the Southern Coalfield, but less commonly observed in the Newcastle Coalfield. The reason why valley related movements are less commonly observed in the Newcastle Coalfield could be that the conventional subsidence movements are typically much larger than those observed in the Southern Coalfield and tend to mask any smaller valley related movements which may occur.

Valley bulging movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.1. The potential for these natural movements are influenced by the geomorphology of the valley.

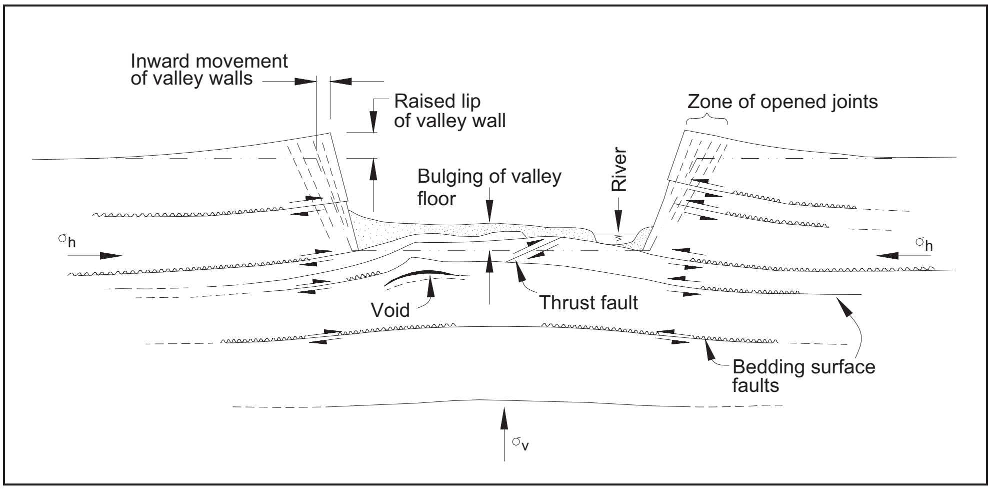

Fig. 3.1 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

Valley related movements can be caused by or accelerated by mine subsidence as the result of a number of factors, including the redistribution of horizontal in-situ stresses and down slope movements. Valley related movements are normally described by the following parameters:-

- **Upsidence** is the reduced subsidence, or the relative uplift within a valley which results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.

- **Closure** is the reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides.
- **Compressive Strains** occur within the bases of valleys as a result of valley closure and upsidence movements. **Tensile Strains** also occur in the sides and near the tops of the valleys as a result of valley closure movements. The magnitudes of these strains, which are typically expressed in the units of *millimetres per metre (mm/m)*, are calculated as the changes in horizontal distance over a standard bay length, divided by the original bay length.

The predicted valley related movements resulting from the extraction of the proposed longwalls were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*. There are other methods available to predict valley related movements, however, the ACARP method was adopted for this project as it is the most thoroughly used and tested method

3.5. The Incremental Profile Method

The Incremental Profile Method (IPM) was initially developed by Waddington Kay and Associates, now known as MSEC, as part of a study, in 1994 to assess the impacts of subsidence on particular surface infrastructure over a proposed series of longwall panels at Appin Colliery. The method evolved following detailed analyses of subsidence monitoring data from the Southern Coalfield, which was then extended to include detailed subsidence monitoring data from the Newcastle, Hunter and Western Coalfields.

The review of the detailed ground monitoring data from the NSW Coalfields showed that whilst the final subsidence profiles measured over a series of longwalls were irregular, the observed incremental subsidence profiles due to the extraction of individual longwalls were consistent in both magnitude and shape and varied according to local geology, depth of cover, panel width, seam thickness, the extent of adjacent previous mining, the pillar width and stability of the chain pillar and a time-related subsidence component.

MSEC developed a series of subsidence prediction curves for the Newcastle and Hunter Coalfields, in 1996 to 1998, after receiving extensive subsidence monitoring data from Centennial Coal for the Cooranbong Life Extension Project (Waddington and Kay, 1998). The subsidence monitoring data from many collieries in the Newcastle and Hunter Coalfields were reviewed and, it was found, that the incremental subsidence profiles resulting from the extraction of individual longwalls were consistent in shape and magnitude where the mining geometries and overburden geologies were similar.

Since this time, extensive monitoring data has been gathered from the Southern, Newcastle, Hunter and Western Coalfields of New South Wales and from the Bowen Basin in Queensland, including: Angus Place, Appin, Awaba, Baal Bone, Bellambi, Beltana, Blakefield South, Bulga, Bulli, Burwood, Carborough Downs, Chain Valley, Clarence, Coalcliff, Cook, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Donaldson, Eastern Main, Ellalong, Elouera, Fernbrook, Glennies Creek, Grasstree, Gretley, Invincible, John Darling, Kemira, Kestrel, Lambton, Liddell, Mandalong, Metropolitan, Moranbah North, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, NRE Wongawilli, Oaky Creek, Ravensworth, South Bulga, South Bulli, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend, and Wyee.

Based on the extensive empirical data, MSEC has developed standard subsidence prediction curves for the Southern, Newcastle, Hunter and Western Coalfields. The prediction curves can then be further refined, for the local geology and local conditions, based on the available monitoring data from the area. Discussions on the calibration and review of the Incremental Profile Method at the Mine are provided in Section 3.6.

The prediction of subsidence is a three stage process where, first, the magnitude of each increment is calculated, then, the shape of each incremental profile is determined and, finally, the total subsidence profile is derived by adding the incremental profiles from each longwall in the series. In this way, subsidence predictions can be made anywhere above or outside the extracted longwalls, based on the local surface and seam information.

For longwalls in the Newcastle and Hunter Coalfields, the maximum predicted incremental subsidence is initially determined, using the IPM subsidence prediction curves for a single isolated panel, based on the longwall void width (W) and the depth of cover (H). The incremental subsidence is then increased, using the IPM subsidence prediction curves for multiple panels, based on the longwall series, panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (W_{pi}/H). In this way, the influence of the panel width (W), depth of cover (H), as well as panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (W_{pi}/H) are each taken into account.

The shapes of the incremental subsidence profiles are then determined using the large empirical database of observed incremental subsidence profiles from the Newcastle and Hunter Coalfields. The profile shapes are derived from the normalised subsidence profiles for monitoring lines where the mining geometry and overburden geology are similar to that for the proposed longwalls. The profile shapes can be further refined, based on local monitoring data, which is discussed further in Section 3.6.

Finally, the total subsidence profiles resulting from the series of longwalls are derived by adding the predicted incremental profiles from each of the longwalls. Comparisons of the predicted total subsidence profiles, obtained using the Incremental Profile Method, with observed profiles indicates that the method provides reasonable, if not, slightly conservative predictions where the mining geometry and overburden geology are within the range of the empirical database. The method can also be further tailored to local conditions where observed monitoring data is available close to the mining area.

3.6. Calibration and Review of the Incremental Profile Method at Austar Coal Mine

The Incremental Profile Method was originally calibrated for the local conditions at the Mine during the preparation of the Subsidence Management Plan Application for Longwalls A3 to A5 in Stage 2, which was discussed in Section 3.4.1 of Report No. MSEC275.

The calibration was based on the available ground monitoring data at that time, which included: eight monitoring lines above Longwalls SL1 to SL4 and Longwalls 1 to 13A at Ellalong Colliery; and three monitoring lines above Longwalls A1 and A2 in Stage 1 of the Mine.

Initially, the magnitudes and shapes of the observed incremental subsidence profiles along each monitoring line were compared with the back-predicted subsidence profiles obtained using the standard Incremental Profile Method, which is based on the typical Newcastle Coalfield subsidence profiles. The standard Incremental Profile Method was not modified for the presence of any thick massive strata units, which can reduce the sag subsidence directly above the extracted longwalls.

It was found that the values of maximum observed incremental subsidence for the previously extracted longwalls along each of the monitoring lines were less than the values of maximum back-predicted incremental subsidence obtained using the standard Incremental Profile Method. It was also found that the observed incremental subsidence profiles along the monitoring lines were slightly wider, and that the points of maximum observed subsidence were located closer to the longwall tailgates, than for the back-predicted incremental subsidence profiles obtained using the standard Incremental Profile Method.

The reason that the observed subsidence profiles were wider or beamier than the predicted profiles and that the maximum observed subsidence was less than the maximum predicted subsidence was the result of the geology of the overburden. The massive sandstones in the overlying Branxton Formation were capable of spanning the extracted voids with minimal sag subsidence and, hence, the observed subsidence profiles and the magnitudes of the observed subsidence were governed, to a large extent, by pillar compression.

The shapes of the back-predicted incremental subsidence profiles along each monitoring line were adjusted to more closely match those observed. No adjustments were made to the magnitudes of the maximum back-predicted incremental subsidence for each longwall. The angle of draw to the predicted total 20 mm subsidence contour, obtained using the Incremental Profile Method, was also calibrated to 30 degrees adjacent to the longitudinal edges of the longwalls, to match those observed over the previously extracted longwalls at the colliery.

Subsequent to the calibration undertaken as part of Report No. MSEC275, Austar has extracted Longwalls A3 to A5A in Stage 2 and Longwalls A7 and A8 in Stage 3 at the Mine. The mine subsidence movements were monitored along four monitoring lines in above Longwalls A3 to A5A and four monitoring lines above Longwalls A7 and A8. The comparisons between the observed and predicted movements were provided in the End of Panel subsidence review reports for each of these longwalls.

The comparisons between the observed and predicted subsidence, tilt and strain have been provided for: Line 1B above Longwalls A1 and A2 in Fig. 3.2; Line A3X above Longwalls A3 to A5A in Fig. 3.3; and Line XL3 above Longwalls A7 and A8 in Fig. 3.4.

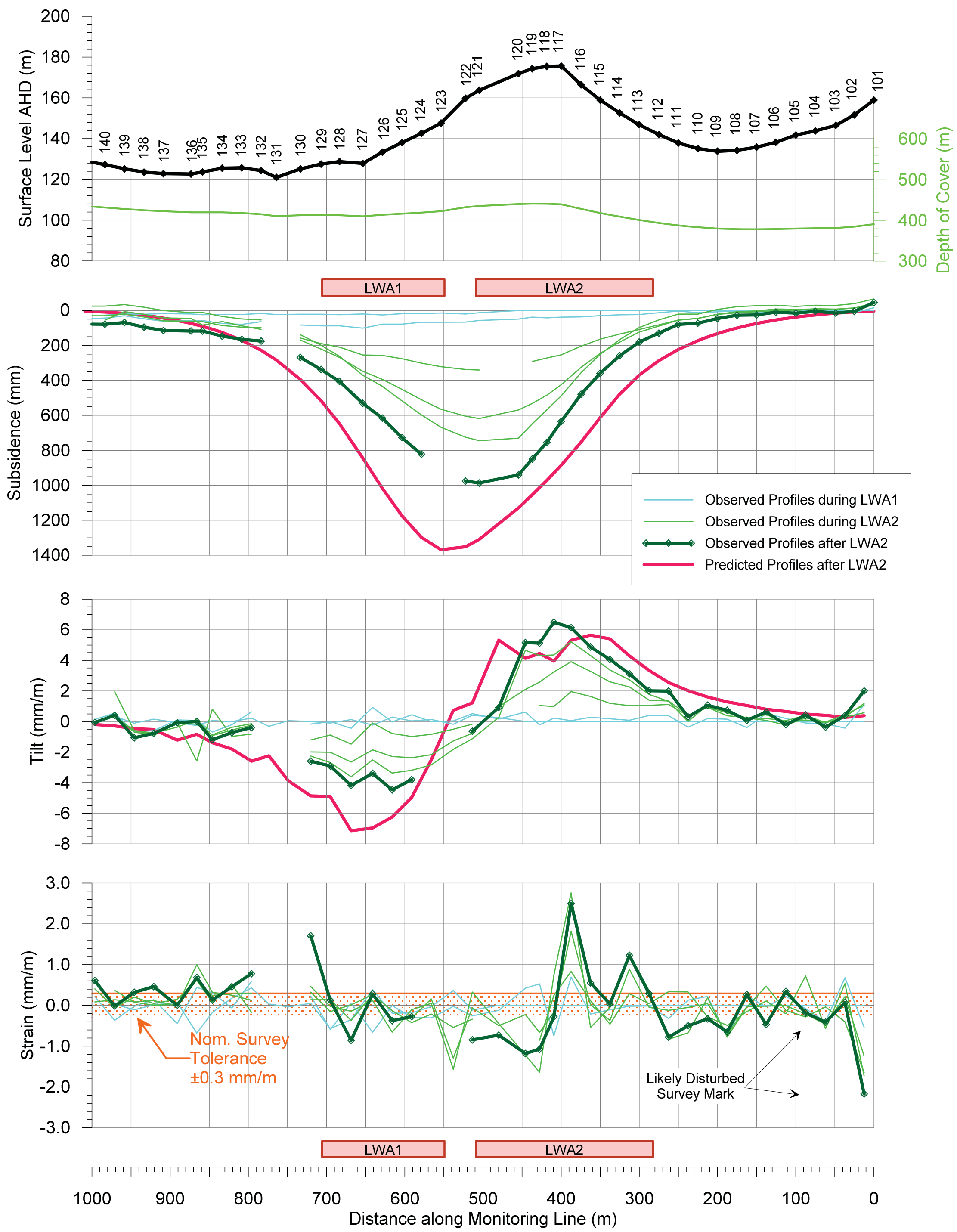

Fig. 3.2 Observed and Predicted Profiles of Subsidence, Tilt and Strain along Line 1B above Longwalls A1 and A2 in Stage 1

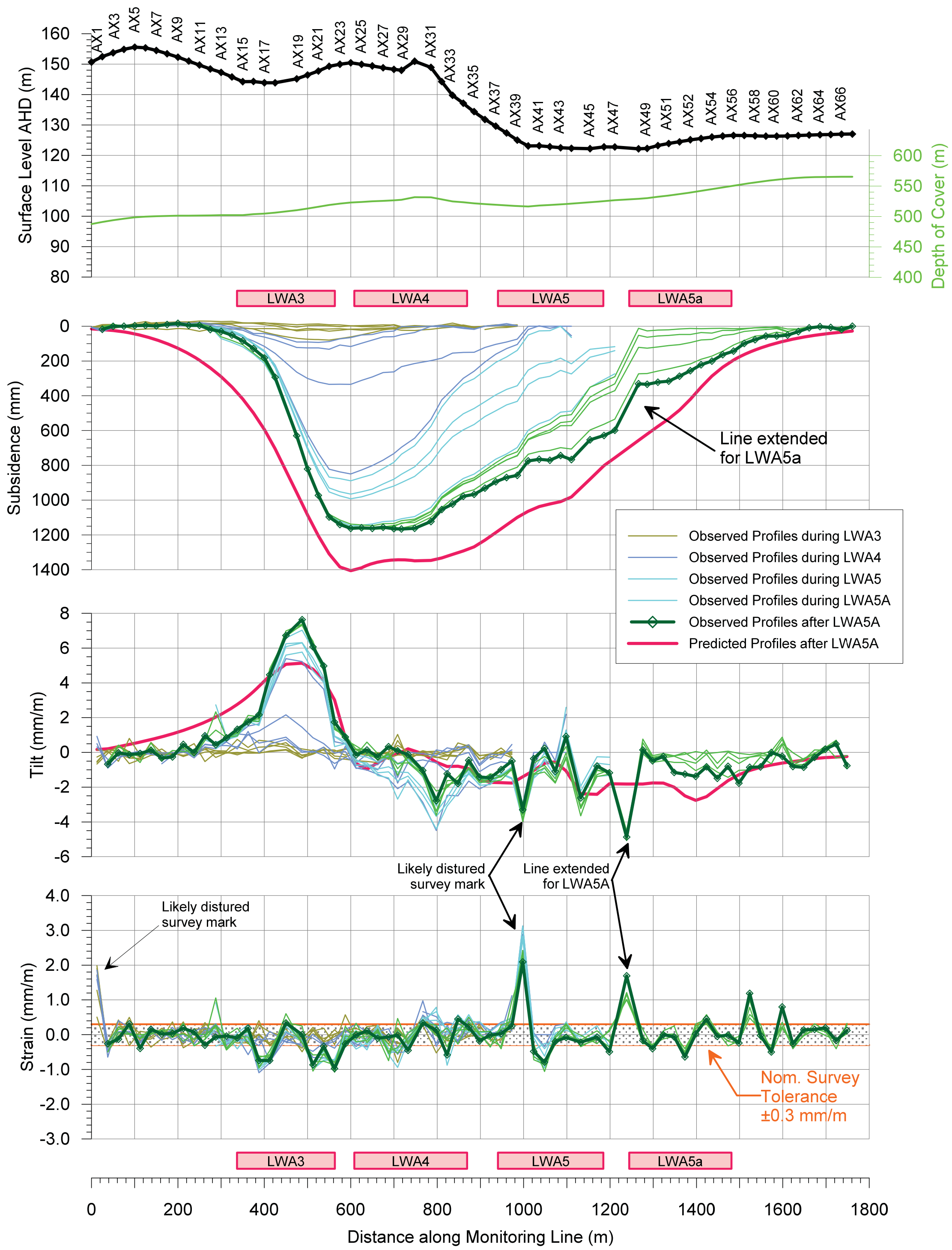

Fig. 3.3 Observed and Predicted Profiles of Subsidence, Tilt and Strain along Line A3X above Longwalls A3 and A5A in Stage 2

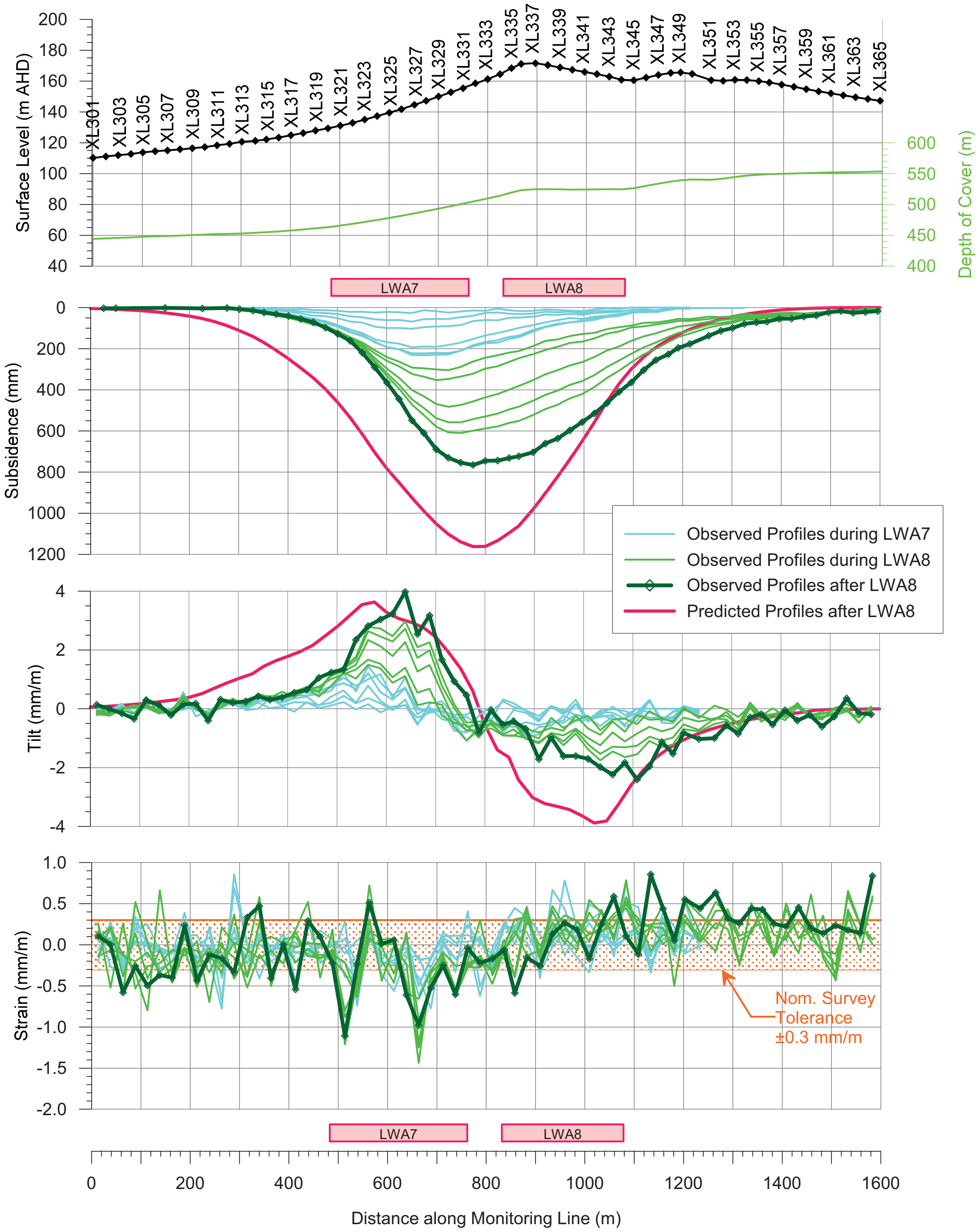

Fig. 3.4 Observed and Predicted Profiles of Subsidence, Tilt and Strain along Line XL3 above Longwalls A7 and A8 in Stage 3

It can be seen from Fig. 3.2 to Fig. 3.4, that the maximum observed subsidence were less than the maxima predicted using the calibrated Incremental Profile Method, representing 75 % for Line 1B, 83 % for Line A3X and 66 % for Line XL3. It is not unexpected that the Incremental Profile Method has provided conservative predictions of vertical subsidence, as no subsidence reduction factor has been applied due to the presence of the massive Branxton Formation within the overburden.

The observed vertical subsidence slightly exceeds the predicted subsidence outside the extents of the extracted longwalls adjacent to the tailgate of Longwall A1 (see Fig. 3.2) and adjacent to the maingate of Longwall A8 (see Fig. 3.4). This low level vertical subsidence, however, is not associated with any significant observed tilts, curvatures or strains and impacts are not anticipated at this distance from the extracted longwalls.

The shapes of the observed subsidence profiles reasonably match the predicted profiles. The maximum observed tilts are generally less than the maxima predicted. The exception to this is the maximum observed tilt of 7.6 mm/m adjacent to the tailgate of Longwall A3 which is greater than the maxima predicted of 5.1 mm/m (see Fig. 3.3). It was considered that the higher observed tilt was associated with the reduced subsidence above solid coal which may have been the result of stronger strata cantilevering and reducing the subsidence over the tailgate of Longwall A3. Localised and elevated tilts were also observed in some locations, which exceeded the predictions, however, it is likely that many of these have occurred as the result of disturbed survey marks, as they occurred outside of the extents of the longwalls.

The observed strains were typically less than those expected based on conventional ground movements, which are 1 mm/m tensile and 2 mm/m compressive. A localised tensile strain of 3.1 mm/m occurred along Line 1B (see Fig. 3.2) which is considered to have been influenced by top of hill effects. Localised tensile strains between 1 mm/m and 2 mm/m also occurred along Line A3X (see Fig. 3.3) which are likely the result of disturbed survey marks.

It is considered that the calibrated Incremental Profile Method has provided reasonable, if not, conservative predictions for the monitoring lines above the longwalls extracted in Stages 1 to 3 at the Mine. It has not been considered necessary to undertake any further refinement of the subsidence prediction model based on the available results. It is expected that the calibrated Incremental Profile Method would provide reasonable, if not, slightly conservative predictions for the proposed Longwalls B1 to B3.

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of the proposed Longwalls B1 to B3. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapters 5 and 6.

The predicted subsidence, tilt and curvature have been obtained using the Incremental Profile Method, which has been calibrated and reviewed based on the local mining conditions, as described in Sections 3.5 and 3.6. The predicted strains have been determined by analysing the strains measured at the Mine.

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report describe and show the conventional movements and do not include the valley related upsidence and closure movements, nor the effects of faults and other geological structures. Such effects have been addressed separately in the impact assessments for each feature provided in Chapters 5 and 6.

4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature

A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of each of the proposed longwalls, is provided in Table 4.1. It is proposed that the longwalls would be extracted in order of LWB2, LWB3 and then LWB1.

Table 4.1 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature due to the Extraction of Each of the Proposed Longwalls

Longwall	Maximum Predicted Incremental Conventional Subsidence (mm)	Maximum Predicted Incremental Conventional Tilt (mm/m)	Maximum Predicted Incremental Conventional Hogging Curvature (km^{-1})	Maximum Predicted Incremental Conventional Sagging Curvature (km^{-1})
LWB2	250	1.0	0.01	0.02
LWB3	525	2.5	0.02	0.05
LWB1	500	2.0	0.03	0.05

The predicted total conventional subsidence contours, after the completion of each of the proposed Longwalls B2, B3 and B1, are shown in Drawings Nos. MSEC769-10 to MSEC769-12. The predicted total subsidence contours including the adjacent existing and approved longwalls at Ellalong and Austar Mines are shown in Drawing No. MSEC769-13. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature within the Study Area is provided in Table 4.2.

Table 4.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature after the Extraction of Each of the Proposed Longwalls

Longwalls	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
LWB2	250	1.0	0.01	0.02
LWB3	700	2.5	0.02	0.05
LWB1	925	3.5	0.03	0.05

The maximum predicted total subsidence resulting from the extraction of the proposed longwalls is 925 mm, which represents 27 % of the proposed extraction height of 3.4 metres. The maximum predicted subsidence occurs directly above the proposed Longwall B2.

The maximum predicted total conventional tilt is 3.5 mm/m (i.e. 0.35 %), which represents a change in grade of 1 in 285. The maximum predicted total conventional curvatures are 0.03 km^{-1} hogging and 0.05 km^{-1} sagging, which represent minimum radii of curvatures of 33 kilometres and 20 kilometres, respectively.

If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the maximum predicted subsidence parameters resulting from the proposed mining would not be expected to change significantly. The locations of these maxima would move, however, depending on the locations of the slightly shifted longwall boundaries.

The predicted conventional subsidence parameters vary across the Study Area as the result of, amongst other factors, variations in the depths of cover, seam thickness and overburden geology. To illustrate this variation, the predicted profiles of conventional subsidence, tilt and curvature have been determined along Prediction Line 1, the location of which is shown in Drawings Nos. MSEC769-10 to MSEC769-13. The predicted profiles of conventional subsidence, tilt and curvature along this prediction line, resulting from the extraction of the proposed longwalls, are shown in Fig. C.01, in Appendix C.

4.3. Predicted Strains

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including ground curvature and horizontal movement, as well as local variations in the near surface geology, the locations of pre-existing natural joints at bedrock and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

In previous MSEC subsidence reports, predictions of conventional strain were provided based on the best estimate of the average relationship between curvature and strain. Similar relationships have been proposed by other authors. The reliability of the strain predictions was highlighted in these reports, where it was stated that measured strains can vary considerably from the predicted conventional values.

Adopting a linear relationship between curvature and strain provides a reasonable estimate for the conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones.

In the Newcastle Coalfield a factor of 10 is generally used to determine the conventional strains from curvatures. It has been found, however, that a factor of 15 provides a better prediction of the conventional strains at Austar Coal Mine based on reviews of the available ground monitoring data. The maximum predicted conventional strains for the proposed longwalls, adopting a factor of 15, are 0.5 mm/m tensile and 1 mm/m compressive.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature. In this report, therefore, we have provided a statistical approach to account for the variability, instead of just providing a single predicted conventional strain.

The range of potential strains for the proposed longwalls has been determined using monitoring data from the previously extracted longwalls at the Mine. Longwalls A1 and A2 in Stage 1, Longwalls A3 to A5A in Stage 2 and Longwalls A7 and A8 in Stage 3 were extracted using LTCC mining techniques. A summary of the overall void widths, depths of cover, width-to-depth ratios and seam thicknesses for these previously extracted longwalls is provided in Table 4.3.

Table 4.3 Mine Geometry for Previously Extracted Longwalls at the Austar Coal Mine

Stage	Longwall	Void Width (m)	Depth of Cover (m)	Width-to-depth Ratio	Seam Thickness (m)
Stage 1	LWA1	157	395 ~ 470	0.33 ~ 0.40	6.4 ~ 6.9
	LWA2	227	385 ~ 450	0.50 ~ 0.59	6.5 ~ 6.9
Stage 2	LWA3	227	485 ~ 535	0.42 ~ 0.47	5.0 ~ 6.8
	LWA4	237	500 ~ 535	0.44 ~ 0.47	5.0 ~ 6.6
	LWA5	237	510 ~ 535	0.44 ~ 0.46	5.3 ~ 6.5
	LWA5A	237	530 ~ 555	0.43 ~ 0.45	5.5 ~ 6.0
Stage 3	LWA7	237	455 ~ 520	0.46 ~ 0.52	6.0 ~ 6.5
	LWA8	237	490 ~ 555	0.43 ~ 0.48	6.0 ~ 6.5

The width-to-depth ratios for the previously extracted longwalls at the Mine typically vary between 0.4 and 0.5, with the ratios varying between 0.33 and 0.59 for the longwalls in Stage 1. The width-to-depth ratios for the proposed longwalls vary between 0.4 and 0.5 and, therefore, are within the range of those for the previously extracted longwalls.

The thickness of the Greta Seam within the extents of the previously extracted longwalls varied between 5.0 metres and 6.9 metres, which were extracted using LTCC techniques. The LTCC mining cuts the bottom 3 metres of coal and recovers approximately 85% of the top coal. The seam thickness within the extents of the proposed longwalls varies between 3.3 metres and 4.6 metres, with a constant thickness of 3.4 metres proposed to be extracted using conventional longwall mining techniques.

The range of strains measured during the extraction of the previous longwalls in Stages 1 to 3 at the Mine should provide a good, if not, slightly conservative indication of the range of potential strains for the proposed longwalls. The mine subsidence movements were measured along 11 monitoring lines during the extraction of the previous longwalls at the Mine, which were: Line 1A, Line 1B and Line 2 in Stage 1; Line A3, Line A3X, Line A4 and Line A5A in Stage 2; and Line XL3, Line A7, Line A8 and Quorrobolong Road in Stage 3.

In order to improve the strain analysis, the monitoring lines above the previously extracted Longwalls SL1 to SL4 and Longwalls 1 to 13A at the adjacent Ellalong Colliery were also included. These longwalls were extracted using conventional longwall mining techniques, where the width-to-depth ratios typically varied between 0.4 and 0.5 and the seam thickness typically varied between 3.0 metres and 3.5 metres, which are similar to the ranges for the proposed longwalls.

The data used in the analysis of observed strains included those resulting from both conventional and non-conventional anomalous movements, but did not include those resulting from valley related movements, which are addressed separately in this report. The strains resulting from damaged or disturbed survey marks have also been excluded.

4.3.1. Analysis of Strains Measured in Survey Bays

For features that are in discrete locations, such as building structures, farm dams and archaeological sites, it is appropriate to assess the frequency of the observed maximum strains for individual survey bays.

The monitoring lines have been analysed to extract the maximum tensile and compressive strains that have been measured at any time during mining, for survey bays that were located directly above the goaf or the chain pillars that are located between the extracted longwalls. A number of probability distribution functions were fitted to the empirical data and, it was found, that a *Generalised Pareto Distribution* (GPD) provided good fits to the raw strain data.

The histogram of the maximum observed tensile and compressive strains measured in survey bays located above goaf is provided in Fig. 4.1. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

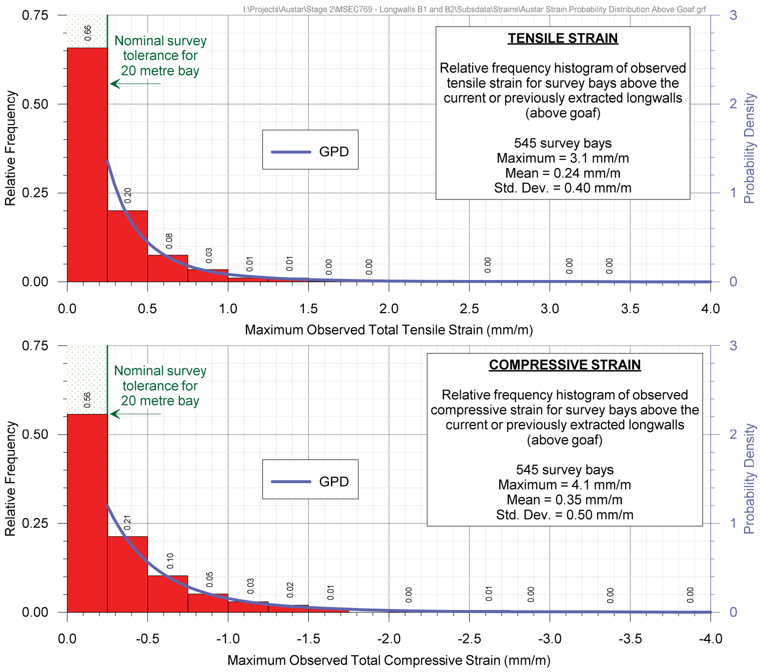

Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls for Survey Bays Located Above Goaf

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during the longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay). A summary of the predicted strains directly above the proposed longwalls (i.e. above goaf) is provided in Table 4.4.

Table 4.4 Predicted Strains Directly Above the Proposed Longwalls (i.e. Above Goaf)

Location	Confidence Level	Predicted Tensile Strain (mm/m)	Predicted Compressive Strain (mm/m)
Above Goaf	95 %	0.9	1.2
	99%	1.7	2.3

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during mining, for survey bays that were located directly above solid coal and within 250 metres of the nearest longwall goaf edge. Solid coal is defined as the surface area above where the coal that has not been extracted by longwalls.

The histogram of the maximum observed tensile and compressive strains measured in survey bays above solid coal is provided in Fig. 4.2. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

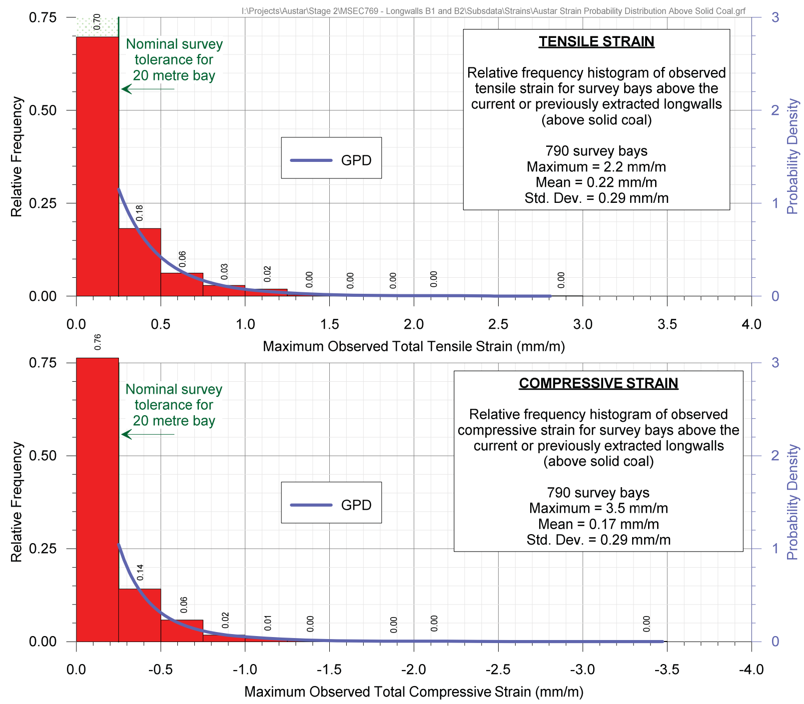

Fig. 4.2 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls for Survey Bays Located Above Solid Coal

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during the longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay). A summary of the predicted strains outside but within 250 metres of the proposed longwalls (i.e. above solid coal) is provided in Table 4.5.

Table 4.5 Predicted Strains outside the Proposed Longwalls (i.e. Above Solid Coal)

Location	Confidence Level	Predicted Tensile Strain (mm/m)	Predicted Compressive Strain (mm/m)
Above Solid Coal	95 %	0.8	0.7
	99%	1.4	1.3

4.3.2. Analysis of Strains Measured Along Whole Monitoring Lines

For linear features such as roads, cables and pipelines, it is more appropriate to assess the frequency of observed maximum strains along whole monitoring lines, rather than for individual survey bays. That is, an analysis of the maximum strains anywhere along the monitoring lines, regardless of where the strain actually occurs.

The histogram of maximum observed tensile and compressive strains measured anywhere along the monitoring lines is provided in Fig. 4.3.

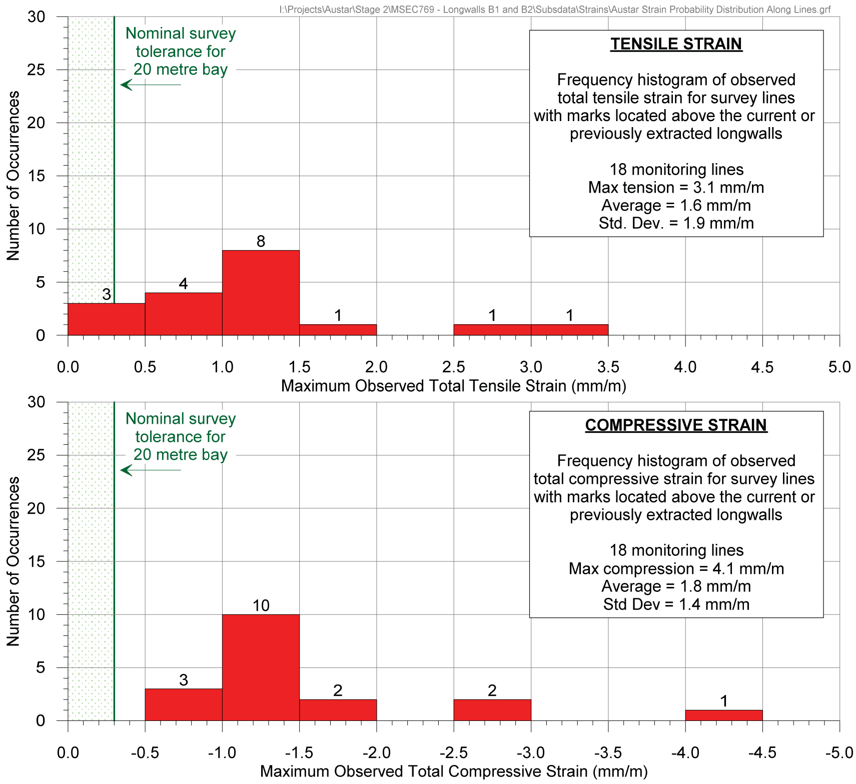

Fig. 4.3 Distributions of Measured Maximum Tensile and Compressive Strains along the Monitoring Lines during the Extraction of Previous Longwalls

It can be seen from Fig. 4.3, that 16 of the 18 monitoring lines (i.e. 89 % of the total) have recorded maximum total tensile strains of 2 mm/m or less. It can also be seen, that 15 of the 18 monitoring lines (i.e. 83 % of the total) also have recorded maximum compressive strains of 2 mm/m or less. The maximum observed strains along the monitoring lines, excluding the survey bays which appear to have been disturbed, were 3.1 mm/m tensile and 4.1 mm/m compressive.

4.4. Predicted Conventional Horizontal Movements

The predicted conventional horizontal movements over the proposed longwalls are calculated by applying a factor to the predicted conventional tilt values. In the Newcastle Coalfield a factor of 10 is generally adopted, being the same factor as that used to determine the conventional strains from curvatures, and this has been found to give a reasonable correlation with measured data.

The comparisons between observed and back-predicted strains along the monitoring lines above the previously extracted longwalls at the Mine, as described in Sections 3.5 and 3.6, indicates that a factor of 15 provides a better correlation for the prediction of conventional horizontal movements at Austar Coal Mine. This factor will in fact vary and will be higher at low tilt values and lower at high tilt values. The application of this factor will therefore lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the movements where the tilts are low.

The maximum predicted conventional tilt within the Study Area, at any time during or after the extraction of the proposed longwalls, is 3.5 mm/m, which occurs adjacent to the maingate of Longwall B3. This area will experience the greatest predicted conventional horizontal movement towards the centre of the overall goaf area resulting from the extraction of the proposed longwalls. The maximum predicted conventional horizontal movement is, therefore, approximately 50 mm, i.e. 3.5 mm/m multiplied by a factor of 15.

Conventional horizontal movements do not directly impact on natural and built features, rather impacts occur as the result of differential horizontal movements. Strain is the rate of change of horizontal movement. The impacts of strain on the natural and built features are addressed in the impact assessments provided in Chapters 5 and 6.

4.5. Predicted Far-field Horizontal Movements

In addition to the vertical subsidence movements that have been predicted above and adjacent to the proposed longwalls, it is also likely that far-field horizontal movements will be experienced during the extraction of these longwalls.

An empirical database of observed incremental far-field horizontal movements has been compiled using monitoring data from the NSW Coalfields, but predominately from the Southern Coalfield. The far-field horizontal movements resulting from longwall mining were generally observed to be orientated towards the extracted longwall. At very low levels of far-field horizontal movements, however, there was a high scatter in the orientation of the observed movements.

The observed incremental far-field horizontal movements, resulting from the extraction of a single longwall, are provided in Fig. 4.4. The confidence levels, based on fitted *Generalised Pareto Distributions* (GPDs), have also been shown in this figure to illustrate the spread of the data.

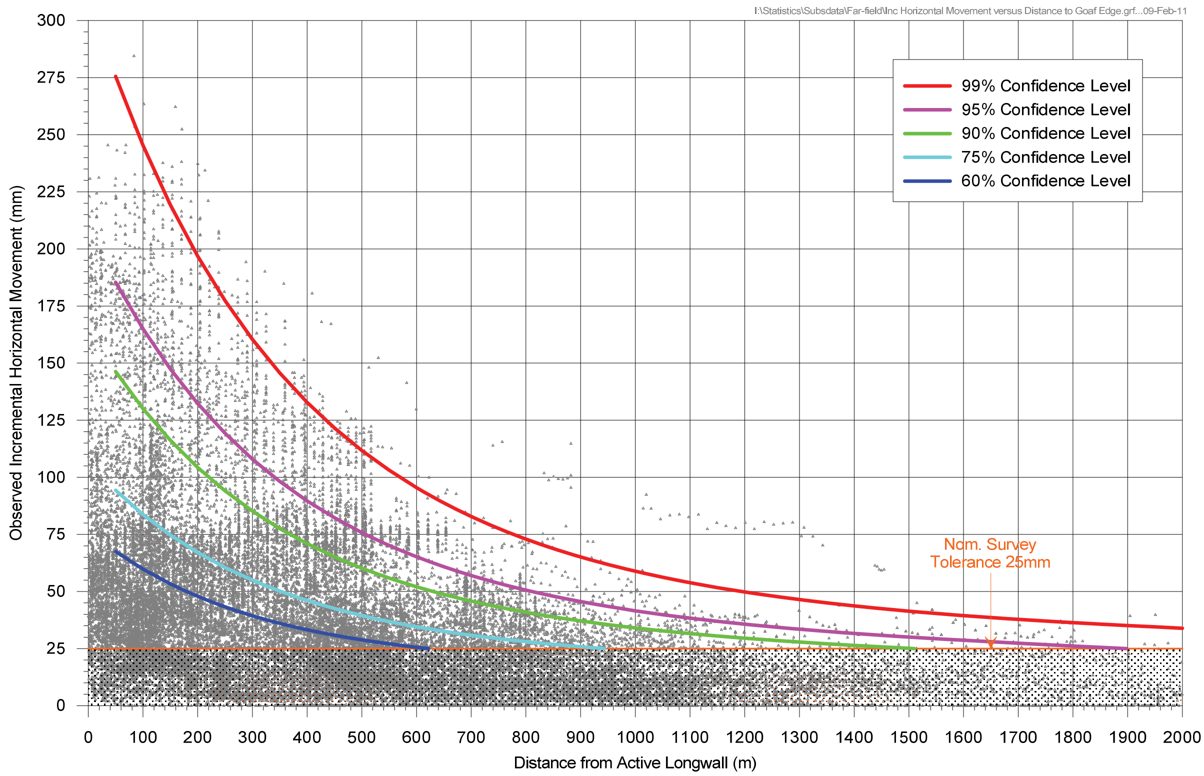

Fig. 4.4 Observed Incremental Far-Field Horizontal Movements

As successive longwalls within a series of longwalls are mined, the magnitudes of the incremental far-field horizontal movements decrease. This is possibly due to the fact that once the in situ stresses within the strata have been redistributed around the collapsed zones above the first few extracted longwalls, the potential for further movement is reduced. The total far-field horizontal movement is not, therefore, the sum of the incremental far-field horizontal movements for the individual longwalls.

The predicted far-field horizontal movements resulting from the extraction of the proposed longwalls are very small and could only be detected by ground surveys. Such movements tend to be bodily movements towards the extracted goaf area, and are accompanied by very low levels of strain, which are generally less than the order of survey tolerance (i.e. less than 0.3 mm/m).

The potential impacts of far-field horizontal movements on the natural and built features within the vicinity of the proposed longwall are not expected to be significant. It is not considered necessary, therefore, that monitoring be established to measure the far-field horizontal movements resulting from the proposed mining.

4.6. General Discussion on Mining Induced Ground Deformations

Longwall mining can result in surface cracking, heaving, buckling, humping and stepping at the surface. The extent and severity of these mining induced ground deformations are dependent on a number of factors, including the mine geometry, depth of cover, overburden geology, locations of natural jointing in the bedrock and the presence of near surface geological structures.

Faults and joints in bedrock develop during the formation of the strata and from subsequent distressing associated with movement of the strata. Longwall mining can result in additional fracturing in the bedrock, which tends to occur in the tensile zones, but fractures can also occur due to buckling of the surface beds in the compressive zones. The incidence of visible cracking at the surface is dependent on the pre-existing jointing patterns in the bedrock as well as the thickness and inherent plasticity of the soils that overlie the bedrock.

Surface cracking in soils as the result of conventional subsidence movements is not commonly observed where the depths of cover are greater than 400 metres, such as is the case at Austar Coal Mine, and any cracking that has been observed has generally been isolated and of a minor nature.

Cracking is found more often in the bases of stream valleys due to the compressive strains associated with upsidence and closure movements. The likelihood and extent of cracking along the creeks within the Study Area are discussed in Section 5.2. Cracking can also occur at the tops of steep slopes as the result of downslope movements, which is discussed in Section 5.4.

Surface cracks are more readily observed in built infrastructure such as road pavements. In the majority of these cases no visible ground deformations can be seen in the natural ground adjacent to the cracks in the road pavements. In rare instances more noticeable ground deformations, such as humping or stepping of the ground can be observed at thrust faults.

There has been no significant or visible surface cracking above the previously extracted Longwalls A3 to A8 at the Mine. The surface cracking, if any, resulting from the extraction of the proposed longwalls is expected to be of a minor nature, which can be easily remedied by infilling with soil or other suitable materials, or by locally regrading and recompacting the surface.

Examples of surface tensile cracking and compression buckling from elsewhere in the NSW Coalfields are provided in the photographs in Fig. 4.5 and Fig. 4.6, respectively. These ground deformations were observed in the Southern Coalfield, where the depths of cover were similar to those within the Study Area.

Fig. 4.5 Example of Surface Tensile Cracking in the Natural Ground Surface (Observed in the Southern Coalfield at a Similar Depth of Cover as the Study Area)

Fig. 4.6 Example of Surface Compression Buckling Observed in Road Pavement (Observed in the Southern Coalfield at a Similar Depth of Cover as the Study Area)

Localised ground buckling and shearing can occur wherever faults, dykes and abrupt changes in geology occur near the ground surface. The identified geological structures within the Study Area are discussed in Section 1.4.

4.7. Estimated Height of the Fractured Zone

The extraction of longwalls results in deformation throughout the overburden strata. The terminology used by different authors to describe the strata deformation zones above extracted longwalls varies considerably and caution should be taken when comparing the recommendations from differing authors. Forster (1995) noted that most studies have recognised four separate zones, as shown in Fig. 4.7, with some variations in the definitions of each zone.

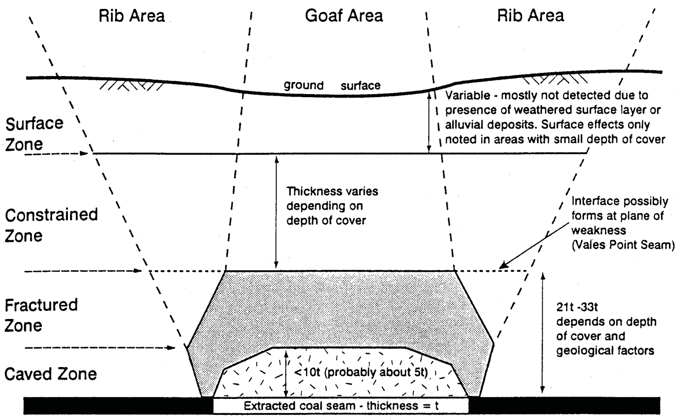

Fig. 4.7 Zones in the Overburden according to Forster (1995)

Peng and Chiang (1984) recognised only three zones as reproduced in Fig. 4.8.

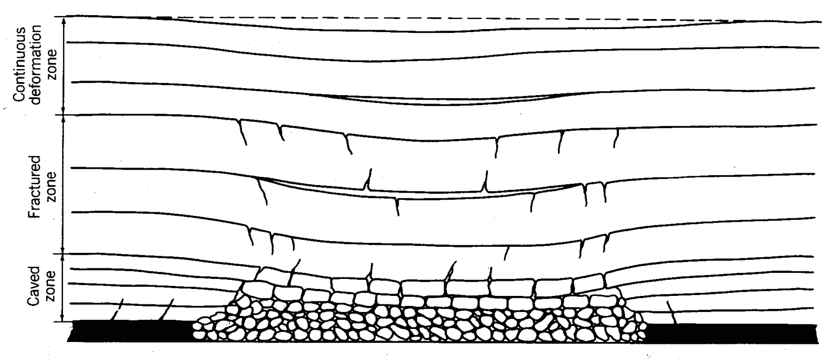

Fig. 4.8 Zones in the Overburden According to Peng and Chiang (1984)

McNally et al (1996) also recognised three zones, which they referred to as the caved zone, the fractured zone and the elastic zone. Kratzsch (1983) identified four zones, but he named them the immediate roof, the main roof, the intermediate zone and the surface zone.

For the purpose of these discussions, the following zones, as described by Singh and Kendorski (1981) and proposed by Forster (1995), as shown in Fig. 4.7, have been adopted:-

- *Caved* or *Collapsed Zone* comprises loose blocks of rock detached from the roof and occupying the cavity formed by mining. This zone can contain large voids. It should be noted, that some authors note primary and secondary caving zones.
- *Disturbed* or *Fractured Zone* comprises in situ material lying immediately above the caved zone which have sagged downwards and consequently suffered significant bending, fracturing, joint opening and bed separation. It should be noted, that some authors include the secondary caving zone in this zone.
- *Constrained* or *Aquiclude Zone* comprises confined rock strata above the disturbed zone which have sagged slightly but, because they are constrained, have absorbed most of the strain energy without suffering significant fracturing or alteration to the original physical properties. Some bed separation or slippage can be present as well as some discontinuous vertical cracks, usually on the underside of thick strong beds, but not of a degree or nature which would result in connective cracking or significant increases in vertical permeability. Some increases in horizontal permeability can be found. Weak or soft beds in this zone may suffer plastic deformation.
- *Surface Zone* comprises unconfined strata at the ground surface in which mining induced tensile and compressive strains may result in the formation of surface cracking or ground heaving.

Just as the terminology differs between authors, the means of determining the extents of each of these zones also varies. Some of the difficulties in establishing the heights of the various zones of disturbance above extracted longwalls stem from the imprecise definitions of the fractured and constrained zones, the differing zone names, and the use of different testing methods and differing interpretations of monitoring data, such as extensometer readings.

Some authors interpret the collapsed and fractured zones to be the zone from which groundwater or water in boreholes would flow freely into the mine and, hence, look for the existence of aquiclude or aquitard layers above this height to confirm whether surface water would or would not be lost into the mine.

The heights of the collapsed and fractured zones above extracted longwalls are affected by a number of factors, which include the:-

- widths of extraction;
- heights of extraction;
- depths of cover;
- types of previous workings, if any, above the current extractions;
- interburden thicknesses to previous workings;
- presence of pre-existing natural joints within each strata layer;
- thickness, geology, geomechanical properties and permeability of each strata layer;
- angle of break of each strata layer;
- spanning capacity of each strata layer, particularly those layers immediately above the collapsed and fractured zones;
- bulking ratios of each strata layer within the collapsed zone; and the
- presence of aquiclude or aquitard zones.

Some authors have suggested simple equations to estimate the heights of the collapsed and fractured zones based solely on the extracted seam height, others have suggested equations based solely on the widths of extraction, whilst others have suggested equations based on the width-to-depth ratios of the extractions. As this is a complex issue comprising the above factors, MSEC understand that no simple geometrical equation can properly estimate the heights of the collapsed and fractured zones and a more thorough analysis is required, which should include other properties, such as geology and permeability, of the overburden strata.

At the Austar Coal Mine, the massive sandstones in the Branxton Formation are capable of spanning the extracted voids with minimal sag subsidence, with the observed subsidence governed, to a large extent, by pillar compression. The combination of low width-to-depth ratios of the extracted longwalls and the properties of the overburden at the Mine limit the heights of vertical fracturing above the seam.

Two extensometers were installed above Longwalls A1 and A2 in Stage 1 at the Mine. The measured heights of vertical fracturing above the seam in these locations were: 86 metres for Extensometer AQD1074 after Longwall A1; and 150 metres for Extensometer AQD1085 after Longwall A2.

The height of the discontinuous fracturing (i.e. the Discontinuous Fracture Zone, or Zone B) can extend 1 to 1.5 times the longwall void width above the extracted seam. The overall void widths of the proposed longwalls are 236 metres and, therefore, the height of the discontinuous fracturing could extend 235 metres to 355 metres above the seam.

The depth of cover above the proposed Longwalls B1 to B3 varies between 480 metres and 555 metres. It is expected, therefore, that a constrained zone would develop in the upper section of the overburden, due to the high depths of cover, where vertical fracturing is generally discontinuous and unlikely, therefore, to result in significantly increased vertical hydraulic conductivity.

Further discussions on the effects of mining on the overburden and groundwater are provided by the specialist groundwater consultant in the report by Dundon Consulting (2015). Further details on sub-surface strata movements are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

5.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES

The following sections provide the descriptions, predictions and impact assessments for the natural features within the Study Area, as identified in Chapter 2. The impact assessments are based on the predicted movements due to the extraction of the proposed Longwalls B1 to B3, as well as the predicted movements due to the previously extracted longwalls at Ellalong Colliery and Austar Coal Mine (i.e. cumulative movements due to the existing and proposed longwalls).

All significant natural features located outside the Study Area, which may be subjected to valley related or far-field horizontal movements due to the proposed longwalls and may be sensitive to these movements, have also been included as part of these assessments.

5.1. Natural Features

As listed in Table 2.1, the following natural features were not identified within the Study Area nor in the immediate surrounds:-

- drinking water catchment areas or declared special areas;
- known springs or groundwater seeps;
- seas or lakes;
- shorelines;
- natural dams;
- cliffs or pagodas;
- escarpments;
- lands declared as critical habitat under the *Threatened Species Conservation Act 1995*;
- National Parks or State Forests;
- State Recreation Areas or State Conservation Areas;
- areas of significant geological interest; and
- other significant natural features.

The following sections provide the descriptions, predictions and impact assessments for the natural features which have been identified within or in the vicinity of the Study Area.

5.2. Watercourses

The locations of the watercourses within the Study Area are shown in Drawing No. MSEC769-07. The descriptions, predictions and impact assessments for these watercourses are provided in the following sections.

5.2.1. Descriptions of the Watercourses

Quorrobolong Creek is located outside and adjacent to the finishing (i.e. north-eastern) end of the proposed Longwall B1. The centreline of the creek channel is located at a minimum distance of 65 metres from the proposed longwalls. The total length of creek within the Study Area is around 0.7 kilometres. Quorrobolong Creek is ephemeral and has a shallow incision into the natural surface soils, with an average natural gradient less than 1 mm/m within the Study Area.

The creek generally flows in a northerly direction, to where it joins Cony Creek approximately 1 kilometre from the proposed longwalls, and then generally continues in a westerly direction to where it drains into Ellalong Lagoon, which is located more than 5 kilometres from the Study Area. Quorrobolong Creek has been previously directly mined beneath by Longwalls SL1 and 1 to 5 at Ellalong Colliery and by Longwalls A3 to A5A at the Austar Coal Mine, with a total length of approximately 4 kilometres located directly above these previously extracted longwalls.

Photograph of Quorrobolong Creek taken from Sandy Creek Road are provided in Fig. 5.1.

 

Fig. 5.1 Quorrobolong Creek Looking North (Left) and South (Right) from Sandy Creek Road

There are also ephemeral drainage lines located on and between the two small ridgelines located within the Study Area, which are also shown in Drawing No. MSEC769-07. The drainage lines within the Study Area flow into Quorrobolong Creek to the north of the proposed longwalls.

5.2.2. Predictions for the Watercourses

A summary of the maximum predicted values of total subsidence, tilt and curvature for Quorrobolong Creek, resulting from the extraction of the proposed longwalls, is provided in Table 5.1. The predictions are the maxima within the Study Area, i.e. do not include the sections of creek located above the previously extracted longwalls at Ellalong Colliery and Austar Coal Mine, but include the predicted movements resulting from these previous longwalls.

Table 5.1 Maximum Predicted Total Subsidence, Tilt and Curvature for Quorrobolong Creek

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Quorrobolong Creek	After LWB2	< 20	< 0.5	< 0.01	< 0.01
	After LWB3	< 20	< 0.5	< 0.01	< 0.01
	After LWB1	25	< 0.5	< 0.01	< 0.01

The predicted profiles of conventional subsidence, tilt and curvature along the alignment of the Unnamed Drainage Line 1 are shown in Fig. C.02, in Appendix C. The location of this drainage line is shown in Drawing No. MSEC769-07. A summary of the maximum predicted values of total subsidence, tilt and curvature for the Unnamed Drainage Line 1, after the completion of each of the proposed longwalls, is provided in, is provided in Table 5.2.

Table 5.2 Maximum Predicted Total Subsidence, Tilt and Curvature for Unnamed Drainage Line 1

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Unnamed Drainage Line 1	After LWB2	250	1.0	0.01	0.02
	After LWB3	650	2.0	0.02	0.05
	After LWB1	925	2.5	0.02	0.05

The tilts provided in the above table are the maxima predicted along the alignment of the drainage line after the completion of each of the proposed longwalls. The curvatures are the maxima predicted in any direction at any time during or after the extraction of each of the proposed longwalls.

The drainage line is a linear feature and, therefore, the most relevant distributions of strain are the maximum strains measured along whole monitoring lines. The analysis of strain along whole monitoring lines during the extraction of the previous longwalls at the Mine is discussed in Section 4.3.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The remaining drainage lines are located across the Study Area and, therefore, could experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence parameters within the Study Area is provided in Chapter 4. If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the overall levels of predicted movement for the drainage lines within the Study Area would not be expected to change significantly.

Quorrobolong Creek and the drainage lines located within the Study Area have shallow incisions into the natural surface soils. It is unlikely, therefore, that these watercourses would experience any significant valley related movements resulting from the extraction of the proposed longwalls.

5.2.3. Impact Assessments for Quorrobolong Creek

Quorrobolong Creek is located at distance of 65 metres east of the finishing (i.e. north-eastern) end of Longwall B1, at its closest point to the proposed longwalls. At this distance, this creek is predicted to experience around 25 mm of vertical subsidence. While the creek could experience low levels of vertical subsidence, it is not expected to experience any significant tilts, curvatures or ground strains.

It is unlikely, therefore, that Quorrobolong Creek would experience adverse impacts, as a result of the proposed longwalls, even if the predictions were extended by a factor of 2 times. This is supported by the fact that downstream sections of the creek have been previously directly mined beneath by Longwalls SL1 and 1 to 5 at Ellalong Colliery and by Longwalls A3 to A5A at the Austar Coal Mine and no adverse impacts have been reported.

5.2.4. Impact Assessments for the Drainage Lines

The extraction of the proposed longwalls could potentially affect the surface water flows along the drainage lines which are located directly above the proposed longwalls. It is possible that locally increased ponding could occur if the mining induced tilts oppose and are greater than the natural gradients that exist before mining. The natural surface levels and grades and the predicted post mining surface levels and grades along the Unnamed Drainage Line 1 are illustrated in Fig. 5.2.

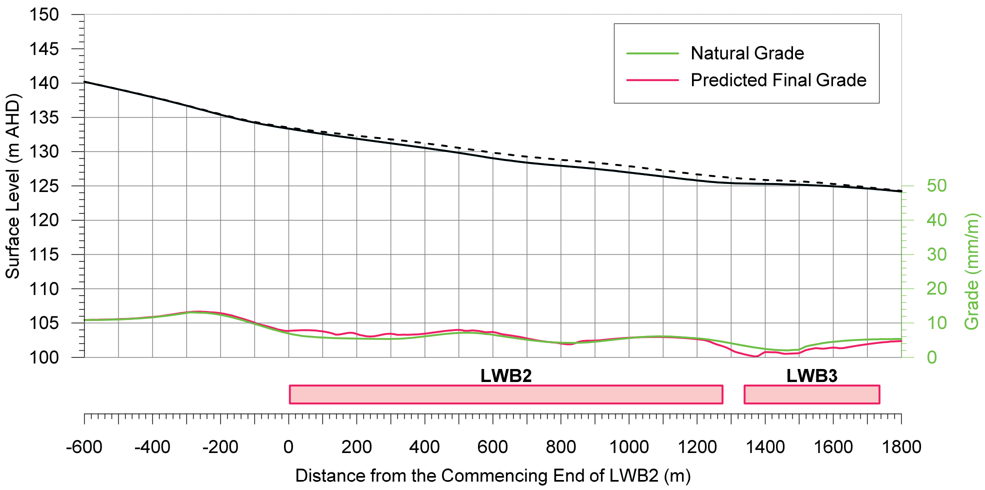

Fig. 5.2 Natural and Predicted Post-Mining Levels and Grades along Unnamed Drainage Line 1

Unnamed Drainage Line 1 has a natural grade of approximately 5 mm/m (i.e. 0.5 %, or 1 in 200) directly above the proposed longwalls. It can be seen from Fig. 5.2, that the there are no predicted reversals in stream grade as a result of the proposed mining. The post mining grade above the chain pillar between Longwalls B2 and B3 is small and it is possible that minor and localised increased ponding could develop in this location.

The other drainage lines within the Study Area are located on the sides of the small ridgelines and, therefore, have greater natural grades. It is unlikely, therefore, that any significantly increased ponding would develop along these drainage lines as a result of the proposed mining.

A detailed flood model of the watercourses has been developed by Umwelt, using the predicted subsidence movements resulting from the extraction of the proposed longwalls, which were provided by MSEC. The increased likelihoods of ponding and flooding along the watercourses have been assessed in the flood study and are provided in the report by *Umwelt* (2015b).

The maximum predicted curvatures for the drainage lines located directly above the proposed longwalls are 0.03 km^{-1} hogging and 0.05 km^{-1} sagging, which represent minimum radii of curvatures of 33 kilometres and 20 kilometres, respectively. The drainage lines could also experience the full range of predicted ground strains which is discussed in Section 4.3.2.

It is likely that compressive buckling and dilation of the uppermost bedrock would occur beneath the natural surface soil beds along the drainage lines which are located directly above the proposed longwalls. Surface cracking can potentially occur in the locations where the uppermost bedrock fractures or buckles and where the depths of cover to bedrock are shallow.

The Cessnock Sandstone forms the upper section of the overburden, which is relatively homogeneous and contains relatively thick beds. A constrained zone is expected to develop in the upper section of the overburden, due to the high depths of cover, where vertical fracturing is generally discontinuous and unlikely, therefore, to result in increased vertical hydraulic conductivity. It is unlikely, therefore, that there would be any net loss of water from the drainage lines resulting from the extraction of the proposed longwalls.

The previously extracted longwalls in Stages 2 and 3 at the Mine have extracted beneath approximately 2.4 kilometres of creeks and no significant surface cracking or loss of surface water flows have been observed.

Any surface cracking above the proposed longwalls would tend to be naturally filled with the natural surface soils during subsequent flow events, especially during times of heavy rainfall. If any surface cracks were found not to seal naturally, some remedial measures may be required at the completion of mining. Where necessary, any significant surface cracks in the drainage line beds could be easily remediated by infilling with the natural surface soils or other suitable materials, or by locally regrading and recompacting the surface.

Further discussion on the potential impacts on the changes in surface water flows are provided in the reports by *Umwelt* (2015a and 2015b).

5.2.5. Recommendations for the Watercourses

It is recommended that the beds of the drainage lines are periodically visually monitored during the extraction of the proposed longwalls, and that any significant surface tensile cracking is remediated by infilling with the natural surface soils or other suitable materials, or by locally regrading and recompacting the surface, as required. With these management strategies in place, it is unlikely that there would be any significant long term impact on the watercourses resulting from the extraction of the proposed longwalls

5.3. Aquifers and Known Groundwater Resources

The groundwater resources within the Study Area occur in the shallow alluvial aquifers associated with Quorrobolong Creek and within the deeper Newcastle Coal Measures. Further descriptions of the aquifers within the Study Area are provided in the report by Dundon Consulting (2015).

5.4. Steep Slopes

The locations of the steep slopes within the Study Area are shown in Drawing No. MSEC769-07. The descriptions, predictions and impact assessments for the steep slopes are provided in the following sections.

5.4.1. Descriptions of the Steep Slopes

The definition of a steep slope provided in the NSW Department of Planning and Environment Standard and Model Conditions for Underground Mining (DP&E, 2012) is: "*An area of land having a gradient between 1 in 3 (33% or 18.3º) and 2 in 1 (200% or 63.4º)*". The locations of any steep slopes were identified from the 1 metre surface level contours which were generated from the Light Detection and Ranging (LiDAR) survey of the area.

There were no broad areas comprising steep slopes identified within the Study Area, that is, the natural grades are typically less than 1 in 3. The surface grades are locally greater than 1 in 3, in some isolated locations, such as along the banks of Quorrobolong Creek and the drainage lines. These areas could experience mining inducing cracking, as a result of the proposed longwalls, which is discussed in Section 5.2.

5.5. Land Prone to Flooding and Inundation

The natural gradients along the alignments of Quorrobolong Creek and the associated drainage lines are relatively flat and could be prone to flooding and inundation. A detailed flood study of the area has been undertaken and is described in the report by *Umwelt* (2015b).

5.6. Swamps, Wetlands and Water Related Ecosystems

A soak has also been identified within the Study Area which is shown in Drawing No. MSEC769-07. The soak is located 100 metres east of the maingate of Longwall B1, at its closest point to the proposed longwalls. A summary of the maximum predicted values of total subsidence, tilt and curvature for the soak, after the completion of each of the proposed longwalls, is provided in, is provided in Table 5.3.

Table 5.3 Maximum Predicted Total Subsidence, Tilt and Curvature for the Soak

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Soak	After LWB2	< 20	< 0.5	< 0.01	< 0.01
	After LWB3	< 20	< 0.5	< 0.01	< 0.01
	After LWB1	60	0.5	< 0.01	< 0.01

The maximum predicted hogging and sagging curvatures for the soak are less than 0.01 km^{-1}, which represents a minimum radius of curvature greater than 100 kilometres. It is expected that the strains would be less than 0.5 mm/m at the distance of the soak from the proposed longwalls

Whilst the soak could experience low level vertical subsidence, it is not expected to experience any significant tilts, curvatures or strains, even if the predictions were exceeded by a factor of 2 times. It is unlikely, therefore, that the soak would experience adverse impacts resulting from the proposed longwalls.

There are also a number of ponding areas along the alignment of Quorrobolong Creek within the Study Area, which are described in the report by *Umwelt* (2015b). The predictions and impact assessments for this creek are provided in Section 5.2.

5.7. Natural Vegetation

The land within the Study Area has generally been cleared for agricultural and light residential uses. There are pockets of native vegetation, however, primarily along the alignments of Quorrobolong Creek and the associated drainage lines. Threatened and protected species that have been identified within the Study Area which are described by the specialist ecology consultant (Umwelt, 2015c).

The potential for impacts on the natural vegetation are dependent on the: surface cracking; changes in surface water; and changes in ground water. It is unlikely that significant surface cracking would occur as a result of the proposed longwalls, as none has been observed at Austar Coal Mine to date. Also, as described in Section 5.2, the watercourses within the Study Area are ephemeral and it is unlikely that the mining induced tilts would have a significant impact on the surface water flows. Further discussions on the potential impacts on the surface water are provided by *Umwelt* (2015b).

The following sections provide the descriptions, predictions and impact assessments for the built features which have been identified within or in the vicinity of the Study Area, as identified in Chapter 2. The impact assessments are based on the predicted movements due to the extraction of the proposed longwalls, as well as the predicted movements due to the previously extracted longwalls at Ellalong Colliery and Austar Coal Mine (i.e. cumulative movements due to the existing and proposed longwalls).

6.1. Public Roads

The locations of public roads within the Study Area are shown in Drawing No. MSEC769-08. The descriptions, predictions and impact assessments for the roads within the Study Area are provided in the following sections.

6.1.1. Descriptions of the Roads

Sandy Creek Road crosses directly above the finishing (i.e. north-eastern) ends of the proposed longwalls. The total length of this road located directly above these longwalls is around 0.9 kilometres. Sandy Creek Road has also been previously directly mined beneath by Longwalls 1 to 9 at Ellalong Colliery, to the west of the Study Area, with a total length of approximately 2 kilometres located directly above these previously extracted longwalls.

Sandy Creek Road provides access between the township of Ellalong, which is located to the west of the Study Area, and Freemans Drive and Lake Road, which are located east of the Study Area. The section of road within the Study Area has a single carriageway with a bitumen seal and grass verges (i.e. no kerb and guttering, however, there are concrete v-channels adjacent to the road on the hill to the west of Barraba Lane).

A bridge is located where Sandy Creek Road crosses Quorrobolong Creek, which is discussed in Section 6.2. Concrete drainage culverts are also located where the road crosses the drainage lines, which are discussed in Section 6.3.

Barraba Lane crosses directly above the finishing (i.e. north-eastern) end of the proposed Longwall B1. This unsealed road provides access to the private properties which are located to the south of Sandy Creek Road.

Photographs of Sandy Creek Road (left side) and Barraba Lane (right side) are provided in Fig. 6.1.

Fig. 6.1 Sandy Creek Road (left side) and Barraba Lane (right side)

The roads are owned and maintained by the Cessnock City Council.

6.1.2. Predictions for the Roads

The predicted profiles of conventional subsidence, tilt and curvature along the alignments of Sandy Creek Road and Barraba Lane are shown in Figs. C.03 and C.04, respectively, in Appendix C. A summary of the maximum predicted values of total subsidence, tilt and curvature for these roads, after the completion of each of the proposed longwalls, is provided in, is provided in Table 6.1.

Table 6.1 Maximum Predicted Total Subsidence, Tilt and Curvature for the Public Roads

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Sandy Creek Road	After LWB2	150	0.5	0.01	0.01
	After LWB3	650	2.5	0.02	0.05
	After LWB1	850	2.5	0.02	0.05
Barraba Lane	After LWB2	40	< 0.5	< 0.01	< 0.01
	After LWB3	50	< 0.5	< 0.01	< 0.01
	After LWB1	275	1.0	0.02	0.01

The tilts provided in the above table are the maxima predicted along the alignments of the roads after the completion of each of the proposed longwalls. The curvatures are the maxima predicted in any direction at any time during or after the extraction of each of the proposed longwalls. If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the overall levels of predicted movement for the public roads within the Study Area would not be expected to change significantly.

The roads are linear features and, therefore, the most relevant distributions of strain are the maximum strains measured along whole monitoring lines. The analysis of strain along whole monitoring lines during the extraction of the previous longwalls at the Mine is discussed in Section 4.3.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.1.3. Impact Assessments for the Roads

The maximum predicted conventional tilt for the roads is 2.5 mm/m (i.e. 0.25 %), which represents a change in grade of 1 in 400. The predicted tilts are less than 1 % and are unlikely, therefore, to result in any significant impacts on the serviceability or surface water drainage of these roads. If any additional ponding or adverse changes in surface water drainage were to occur as a result of mining, the roads could be repaired using normal road maintenance techniques.

The maximum predicted conventional curvatures for the roads are 0.02 km^{-1} hogging and 0.05 km^{-1} sagging, which equate to minimum radii of curvatures of 50 kilometres and 20 kilometres, respectively. The maximum predicted ground curvatures and the range of potential strains for these roads are similar to or less than those predicted where: Longwalls A3 and A4 were extracted directly beneath Nash Lane (unsealed); and where Longwalls A7 and A8 were extracted beneath Quorrobolong Road (bitumen seal), Big Hill Road (unsealed) and a number of unsealed fire trails.

The previously extracted longwalls in Stages 2 and 3 at the Mine have extracted beneath approximately 1 kilometre of public roads, which were maintained in safe and serviceable conditions at all times. Only isolated and minor impacts to the road surfaces have been observed, which were remediated using normal road maintenance techniques.

The predicted mine subsidence movements for the public roads within the Study Area are also less than those typically experienced in the Southern Coalfield. The most extensive experience comes from Tahmoor Colliery, where Longwalls 22 to 27 have been extracted directly beneath approximately 24.5 kilometres of local roads. A total of 46 impacts have been observed, to date, which equates to an average of one impact for every 533 metres of pavement. The impacts were minor and did not present a public safety risk.

It is expected that any impacts on the public roads within the Study Area could be repaired using normal road maintenance techniques. With the necessary remedial measures implemented, it is expected that the roads would be maintained in safe and serviceable conditions throughout the mining period.

6.1.4. Recommendations for the Roads

Management strategies have previously been developed for the public roads which have already been directly extracted beneath at the Mine. It is recommended that the existing management strategies for the roads be reviewed in consultation with Cessnock City Council and, where required, are revised to include the effects of the proposed longwalls.

It is recommended that the roads should be periodically visually monitored as each of the proposed longwalls are mined beneath them, such that any impacts can be identified and remediated accordingly. With the implementation of the necessary management strategies, it is expected that the roads can be maintained in safe and serviceable conditions at all times.

6.2. Road Bridges

The *Quorrobolong Creek Forbes Bridge* (Ref. SCR-B1) is located within the Study Area where Sandy Creek Road crosses Quorrobolong Creek, which is shown in Drawing No. MSEC769-08. The bridge is located 100 metres east of the finishing (i.e. north-eastern) end of Longwall B1, at its closest point to the proposed longwalls.

The bridge comprises a concrete deck supported on three concrete box culverts and concrete wingwalls. The 3 metre wide box culverts are spaced evenly along the 15 metre deck span, with one adjacent to each of the wingwalls and one at mid-span. A photograph of the bridge is provided in Fig. 6.2. The bridge is owned and maintained by the Cessnock City Council.

Fig. 6.2 Bridge SCR-B1 along Sandy Creek Road

Bridge SCR-B1is predicted to experience around 20 mm vertical subsidence due to the extraction of the proposed longwalls. Whilst the bridge could experience low level vertical subsidence, it is not expected to experience any measurable tilts, curvatures or strains, even if the predictions were exceeded by a factor of 2 times. It is unlikely, therefore, that Bridge SCR-B1 would experience adverse impacts resulting from the proposed longwalls.

It is recommended that Bridge SCR-B1 is incorporated into the management strategies for the roads developed in consultation with Cessnock City Council. Periodic visual inspection of the bridge should be undertaken during the later stages of extraction of the proposed longwalls.

6.3. Road Drainage Culverts

The locations of the road drainage culverts within the Study Area are shown in Drawing No. MSEC769-08. The descriptions, predictions and impact assessments for the culverts within the Study Area are provided in the following sections.

6.3.1. Descriptions of the Road Drainage Culverts

There are two concrete box culverts (Refs. SCR-C1 and SCR-C2) within the Study Area, where Sandy Creek Road crosses two drainage lines, which are located directly above the proposed Longwall B3. Photographs of these box culverts are provided in Fig. 6.3.

Fig. 6.3 Box Culverts SCR-C1 (Left) and SCR-C2 (Right)

Dual 300 mm diameter circular concrete culverts (Ref. BL-C1) are located on Barraba Lane, near the intersection with Sandy Creek Road, which are directly above the proposed Longwall B1. There are also other drainage culverts along Sandy Creek Road and Barraba Lane which are located inside the Study Area but outside the extents of the proposed longwalls.

6.3.2. Predictions for the Road Drainage Culverts

A summary of the maximum predicted values of total subsidence, tilt and curvature for the box culverts SCR-C1 and SCR-C2, after the completion of each of the proposed longwalls, is provided in, is provided in Table 6.2.

Table 6.2 Maximum Predicted Total Subsidence, Tilt and Curvature for the Box Culverts

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
SCR-C1	After LWB2	70	0.5	< 0.01	< 0.01
	After LWB3	475	2.0	0.01	0.01
	After LWB1	600	2.5	0.01	0.01
SCR-C2	After LWB2	50	0.5	< 0.01	< 0.01
	After LWB3	400	2.5	0.01	0.01
	After LWB1	500	2.5	0.01	0.01

The tilts and curvatures are the maxima predicted in any direction at any time during or after the extraction of each of the proposed longwalls. If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the overall levels of predicted movement for the box culverts could increase or decrease, but would be less than the maxima presented in Chapter 4.

The maximum predicted subsidence parameters for the dual circular culverts BL-C1 are: 200 mm vertical subsidence, 2.0 mm/m tilt, 0.02 km^{-1} hogging curvature and less than 0.01 km^{-1} sagging curvature. The other culverts located outside the extents of the proposed longwalls could also experience vertical subsidence up to around 100 mm.

The culverts are point features and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays. The analysis of strain measured in individual survey bays during the extraction of the previous longwalls at the Mine is discussed in Section 4.3.1.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.3.3. Impact Assessments for the Road Drainage Culverts

The predicted curvatures and strains could be of sufficient magnitudes to result in cracking in the box culverts or the dual circular culverts which are located directly above the proposed longwalls. It is unlikely, however, that these movements would adversely impact on the stability or structural integrity of the culverts. The potential impacts on the drainage culverts could be managed by visual inspection and, if required, any affected sections of the culvert repaired or replaced.

Previous experience of mining beneath culverts in the NSW Coalfields, at similar depths of cover, indicates that the incidence of impacts is very low. Impacts have generally been limited to cracking in the concrete headwalls which can be more readily remediated. In some cases, however, cracking in the culvert pipes occurred which required the culverts to be replaced

6.3.4. Recommendations for the Road Drainage Culverts

It is recommended that the road drainage culverts are incorporated into the management strategies for the roads developed in consultation with Cessnock City Council. Periodic visual inspections should be undertaken for the culverts that are located directly above the proposed longwalls during active subsidence.

6.4. Electrical Infrastructure

The locations of the electrical infrastructure within the Study Area are shown in Drawing No. MSEC769-08. The descriptions, predictions and impact assessments for the electrical infrastructure are provided in the following sections.

6.4.1. Descriptions of the Electrical Infrastructure

The electrical services comprise above ground 11 kV powerlines supported by timber poles. There are also low voltage powerlines which supply power to the rural properties within the Study Area. Photographs of the 11 kV powerlines within the Study Area are provided in Fig. 6.4.

Fig. 6.4 11 kV Powerlines adjacent to Sandy Creek Road (Left) and Barraba Lane (Right)

The powerlines are owned and maintained by *Ausgrid*.

6.4.2. Predictions for the Electrical Infrastructure

The powerlines will not be directly affected by the ground strains, as the cables are supported by poles above ground level. The cables may, however, be affected by changes in the bay lengths, i.e. the distances between the poles at the levels of the cables, resulting from differential subsidence, horizontal movements, and tilt at the pole locations. The stabilities of the poles may also be affected by conventional tilts, and by changes in the catenary profiles of the cables.

The predicted profiles of conventional subsidence, tilt along and tilt across the alignments of the 11 kV Powerline Branch 1 (adjacent to Sandy Creek Road) and 11 kV Powerline Branch 2 (Adjacent to Barraba Lane) are shown in Figs. C.05 and C.06, respectively, in Appendix C.

A summary of the maximum predicted values of total subsidence and tilt for these powerlines, after the completion of each of the proposed longwalls, is provided in, is provided in Table 6.3. The values provided in this table are the maxima anywhere along the powerlines, i.e. not just at the pole locations.

Table 6.3 Maximum Predicted Total Subsidence and Tilt for the Powerlines

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt Along the Alignment (mm/m)	Maximum Predicted Total Tilt Across the Alignment (mm/m)
11 kV Powerline Branch 1	After LWB2	175	0.5	< 0.5
	After LWB3	650	2.5	1.0
	After LWB1	875	2.5	1.5
11 kV Powerline Branch 2	After LWB2	40	< 0.5	< 0.5
	After LWB3	50	< 0.5	0.5
	After LWB1	275	1.0	2.0

The maximum predicted tilt in any direction at the powerpole locations is 3.0 mm/m (i.e. 0.3 %, or 1 in 335). The maximum predicted horizontal movement at the tops of the powerpoles, based on a pole height of 15 metres, is 90 mm. If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the overall levels of predicted movement for the powerlines within the Study Area would not be expected to change significantly.

6.4.3. Impact Assessments for the Electrical Infrastructure

A rule of thumb used by some electrical engineers is that the tops of the poles may displace up to 2 pole diameters horizontally before remediation works are considered necessary. Based on pole heights of 15 metres and pole diameters of 250 mm, the maximum tolerable tilt at the pole locations is in the order of 33 mm/m. It is unlikely, therefore, that the powerlines within the Study Area would experience adverse impacts as a result of the proposed longwalls, even if the predictions were exceeded by a factor of 2 times.

Longwalls at the Mine and elsewhere in the New South Wales Coalfields have successfully been mined directly beneath powerlines in the past, where the magnitudes of the predicted mine subsidence movements were similar to or greater than those predicted within the Study Area. This includes approximately 4 kilometres of powerlines located above Longwalls 1 to 12A at Ellalong Colliery and approximately 4.5 kilometres of powerlines located above the Longwalls A3 to A5A and Longwalls A7 and A8 at the Austar Coal Mine and no adverse impacts have been reported.

Whilst adverse impacts generally do not result, where the magnitudes of the predicted mine subsidence movements are similar to those predicted within the Study Area, there are some cases where tension adjustments have been required to some aerial connections to houses. This is understandable as the overhead cables are typically pulled tight between each house and the power pole.

The incidence of impacts on the powerlines within the Study Area, resulting from the extraction of the proposed longwalls, is expected to be low and it is anticipated that any impacts would be relatively very minor and easily repaired.

6.4.4. Recommendations for the Electrical Infrastructure

Management strategies have previously been developed for the 11 kV and consumer powerlines which have already been directly extracted beneath at the Mine. It is recommended that the existing management strategies for the powerlines be reviewed in consultation with *Ausgrid* and, where required, are revised to include the effects of the proposed longwalls.

It is recommended that the powerlines should be inspected by a suitably qualified person prior to being mined beneath, to assess the existing conditions of the powerlines and to determine whether any preventive measures are required. The powerlines should be periodically visually monitored as each longwall is mined beneath them, so that any impacts can be identified and rectified immediately. With the implementation of the necessary management strategies, it is expected that the powerlines can be maintained in safe and serviceable conditions at all times.

6.5. Telecommunications Infrastructure

The locations of the telecommunications infrastructure within the Study Area are shown in Drawing No. MSEC769-08. The descriptions, predictions and impact assessments for the telecommunications infrastructure are provided in the following sections.

6.5.1. Description of the Telecommunications Infrastructure

The telecommunication infrastructure within the Study Area are owned by Telstra and comprise direct buried copper cables with some aerial connections to the houses. The cables generally follow the alignments and Sandy Creek Road and Barraba Lane and service the rural properties within the Study Area. The total length of copper telecommunications cables located directly above the proposed longwalls is approximately 2 kilometres. There were no optical fibre cables identified within the Study Area.

6.5.2. Predictions for the Telecommunications Infrastructure

The copper telecommunications cables within the Study Area generally follow the alignments of the public roads. The predicted profiles of subsidence, tilt and curvature for these copper cables, therefore, are similar to those predicted along Sandy Creek Road and Barraba Lane which are shown in Figs. C.03 and C.04, respectively, in Appendix C.

A summary of the maximum predicted values of total subsidence, tilt and curvature for the copper telecommunications cable, after the completion of each of the proposed longwalls, is provided in, is provided in Table 6.4.

Table 6.4 Maximum Predicted Total Subsidence, Tilt and Curvature for the Copper Telecommunications Cables

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Copper Telecommunications Cables	After LWB2	150	0.5	0.01	0.01
	After LWB3	650	2.5	0.02	0.05
	After LWB1	850	2.5	0.02	0.05

The tilts provided in the above table are the maxima predicted along the alignments of the cables after the completion of each of the proposed longwalls. The curvatures are the maxima predicted in any direction at any time during or after the extraction of each of the proposed longwalls. If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the overall levels of predicted movement for the copper telecommunications cables within the Study Area would not be expected to change significantly.

The cables are linear features and, therefore, the most relevant distributions of strain are the maximum strains measured along whole monitoring lines. The analysis of strain along whole monitoring lines during the extraction of the previous longwalls at the Mine is discussed in Section 4.3.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.5.3. Impact Assessments for the Telecommunications Infrastructure

The direct buried copper telecommunications cables are not directly affected by vertical subsidence or tilt. The maximum predicted curvature for the cables is 0.02 km^{-1} hogging and 0.05 km^{-1} sagging, which represent minimum radii of curvatures of 50 kilometres and 20 kilometres, respectively. The copper cables are reasonably flexible and, therefore, are also unlikely to experience adverse impacts based on the magnitudes of the predicted conventional curvatures.

The direct buried copper cables could, however, be affected by the ground strains resulting from the extraction of the proposed longwalls. The copper cables are more likely to be impacted by tensile strains rather than compressive strains. It is possible, that the direct buried cables could experience higher tensile strains where they are anchored to the ground by associated infrastructure, or by tree roots.

Aerial copper telecommunications cables are generally not affected by ground strains, as they are supported by the poles above ground level. The aerial cables, however, could be affected by the changes in bay lengths, i.e. the distances between the poles at the levels of the cables, which result from mining induced differential subsidence, horizontal ground movements and lateral movements at the tops of the poles due to tilting of the poles. The stabilities of the poles can also be affected by mining induced tilts and by changes in the catenary profiles of the cables.

Longwalls at the Mine and elsewhere in the New South Wales Coalfields have successfully been mined directly beneath buried and aerial copper telecommunications cables in the past, where the magnitudes of the predicted mine subsidence movements were similar to or greater than those predicted within the Study Area. This includes approximately 0.8 kilometres of cables located above Longwalls 1 to 12A at Ellalong Colliery and approximately 1.2 kilometres of cables located above the Longwalls A3 to A5A and Longwalls A7 and A8 at the Austar Coal Mine and no adverse impacts have been reported.

It is also understood, that there have been no significant impacts on direct buried copper telecommunications cables elsewhere in the NSW Coalfields, where the depths of cover were greater than 400 metres, such as is the case above the proposed longwalls. In some cases, there have been some minor impacts on aerial copper telecommunications cables, such as the aerial connections to houses. This is understandable as the overhead cables are typically pulled tight between each house and the power pole. The incidence of these impacts, however, was very low.

Based on this experience, it is unlikely that the extraction of the proposed longwalls would result in any significant impacts on the direct buried or aerial copper telecommunications cables within the Study Area. Any minor impacts on these cables would be expected to be relatively infrequent and easily repaired.

6.5.4. Recommendations for Telecommunications Infrastructure

Management strategies have previously been developed for the copper telecommunications cables which have already been directly extracted beneath at the Mine. It is recommended that the existing management strategies for the powerlines be reviewed in consultation with Telstra and, where required, are revised to include the effects of the proposed longwalls.

With the implementation of the necessary management strategies, it is expected that the copper telecommunications cables can be maintained in safe and serviceable conditions at all times.

6.6. Agricultural Utilisation

The land within the Study Area has predominately been cleared for agricultural and light residential use. The descriptions, predictions and impact assessments for the built features on these rural properties are provided in the following sections.

The potential for impacts on the land use result from the: surface cracking; changes in surface water; and changes in ground water. It is unlikely that significant surface cracking would occur as a result of the proposed longwalls, as none has been observed at Austar Coal Mine to date. Also, as described in Section 5.2, the watercourses within the Study Area are ephemeral and it is unlikely that the mining induced tilts would have a significant impact on the surface water flows. Further discussions on the potential impacts on the surface water drainage are provided by *Umwelt* (2015b).

6.7. Rural Structures

6.7.1. Descriptions of the Rural Structures

The rural structures (Structure Type R) are shown in Drawing No. MSEC769-09. The locations, sizes and details of the rural structures were determined from the aerial photograph of the area and from kerb side inspections.

There are 54 rural structures which have been identified within the Study Area, of which: eight are located directly above the chain pillar between the proposed Longwalls B1 and B2 (Refs. B03r07 to B03r14 on Property B03); and two are located directly above the proposed Longwall B3 (Refs. A02d and A02f on Property A02). The rural structures within the Study Area are generally of lightweight construction and include farm sheds, garages, tanks and other non-residential structures.

6.7.2. Predictions for the Rural Structures

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at the vertices of each rural building structure, as well as at eight equally spaced points placed radially around the centroid and vertices at a distance of 20 metres. In the case of a rectangular shaped structure, predictions have been made at a minimum of 45 points within and around the structure.

The predicted total conventional subsidence, tilts and curvatures for the rural structures within the Study Area are provided in Table D.01, in Appendix D. A summary of the maximum predicted subsidence parameters for the rural structures on each of the properties within the Study Area is provided in Table 6.5. The values include the predicted movements resulting from the previous extraction of the adjacent longwalls at Ellalong Colliery and Austar Coal Mine (i.e. cumulative movements).

Table 6.5 Maximum Predicted Total Subsidence, Tilt and Curvature for the Rural Structures

Property	Number of Rural Structures	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
A01	2	150	1.5	0.02	< 0.01
A02	9	200	2.0	0.02	< 0.01
A06	3	100	1.0	0.01	< 0.01
B03	14	850	2.0	0.01	0.04
B04	6	70	0.5	< 0.01	< 0.01
B09	3	100	0.5	< 0.01	< 0.01
B10	4	50	< 0.5	< 0.01	< 0.01
B11	3	30	< 0.5	< 0.01	< 0.01
B12	5	70	< 0.5	< 0.01	< 0.01
B13	3	30	< 0.5	< 0.01	< 0.01
C01	2	< 20	< 0.5	< 0.01	< 0.01

The tilts provided in the above table are the maxima predicted in any directions at the completion of the proposed longwalls. The curvatures are the maxima predicted in any direction at any time during or after the extraction of each of the proposed longwalls. If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the individual rural structures would be predicted to experience greater or lesser movements depending on their locations relative to the longwalls, but the overall levels of predicted movement for these structures within the Study Area would not be expected to change significantly.

The rural structures are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays. The analysis of strain in survey bays during the extraction of the previous longwalls at the Mine is discussed in Section 4.3.1.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.7.3. Impact Assessments for the Rural Structures

There are eight rural structures on Property B03 (Refs. B03r07 to B03r14) and two rural structures on Property A02 (Refs. A02d and A02f) which are located directly above the proposed longwalls. The maximum predicted movements for these structures are: 850 mm vertical subsidence; 2.0 mm/m tilt, 0.02 km^{-1} hogging curvature and 0.04 km^{-1} sagging curvature.

The remaining 44 rural structures within the Study Area are located outside the extents of the proposed longwalls and the maximum predicted movements for these structures are: 150 mm vertical subsidence; 1.5 mm/m tilt; 0.02 km^{-1} hogging curvature; and less than 0.01 km^{-1} sagging curvature.

It has been found from previous longwall mining experience, that tilts of the magnitudes predicted within the Study Area generally do not result in any significant impacts on rural structures. Some very minor serviceability impacts could occur at the rural structures located directly above the longwalls, including door swings and minor issues with roof and pavement drainage, all of which can be repaired using normal building maintenance techniques.

The maximum predicted curvatures for the rural structures within the Study Area are less than the maxima predicted for these types of structures which were located above the previously extracted longwalls at the Mine. There were 18 rural structures located directly above Longwalls A3 to A5A in Stage 2 and Longwalls A7 and A8 in Stage 3 and there were no reported mining related impacts.

There is also extensive experience of mining directly beneath rural structures in the Southern Coalfield, where the maximum predicted subsidence parameters are similar to or greater than the maxima predicted for the proposed longwalls. This incidence of impacts on these types of structures is very low, with adverse impacts generally reported for the larger industrial type sheds. This is not surprising as rural structures are generally small in size and being of light-weight construction they are less susceptible to impact than houses which are typically more rigid. In all cases, the rural structures remained in safe and serviceable conditions.

It is expected, therefore, that all the rural structures within the Study Area would remain safe and serviceable during the mining period, provided that they are in sound existing condition. The risk of impact is clearly greater if the structures are in poor condition, though the chances of there being a public safety risk remains very low. A number of rural structures, which were in poor condition prior to mining, have been directly mined beneath and these structures have not experienced impacts during mining.

Any impacts on the rural structures that occur as a result of the extraction of the proposed longwalls could be repaired using well established building techniques. With these remedial measures available, it is unlikely that there would be any significant long term impacts on rural structures resulting from the extraction of the proposed longwalls.

6.7.4. Recommendations for the Rural Structures

It is recommended that the rural structures located above the proposed longwalls should be inspected, prior to being mined beneath, to assess the existing conditions and to determine whether any preventive measures may be required. It is also recommended that the rural structures located directly above the proposed longwalls are periodically visually monitored during active subsidence. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the rural structures.

6.8. Gas and Fuel Storages

There are domestic gas and fuel storages on the rural properties within the Study Area and, therefore, could experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4. If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the individual storage tanks would be predicted to experience greater or lesser movements depending on their locations relative to the longwalls, but the overall levels of predicted movement for these structures within the Study Area would not be expected to change significantly.

The storage tanks are generally elevated above ground level and, therefore, are not susceptible to mine subsidence movements. It is possible, however, that any buried gas pipelines associated with the storage tanks within the Study Area could be impacted by the ground strains, if they are anchored by the storage tanks, or by other structures in the ground. Any impacts would be expected to be of a minor nature, including minor gas leaks, which could be easily repaired. It is unlikely that there would be any significant impacts on the pipelines associated with the gas and fuel storage tanks.

6.9. Farm Fences

There are a number of fences within the Study Area which are constructed in a variety of ways, generally using either timber or metal materials. Wire fences could be affected by tilting of the fence posts and changes of tension in the fence wires due to strain as mining occurs. Wire fences are generally flexible in construction and can usually tolerate tilts of up to 10 mm/m and strains of up to 5 mm/m without any significant impact.

The fences are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4. If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the overall levels of predicted movement for the fences within the Study Area would not be expected to change significantly.

The fences are linear features and, therefore, the most relevant distributions of strain are the maximum strains measured along whole monitoring lines. The analysis of strain along whole monitoring lines during the extraction of the previous longwalls at the Mine is discussed in Section 4.3.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

It is possible that some of the wire fences within the Study Area would be impacted as a result of the extraction of the proposed longwalls. Any impacts on the wire fences are likely to be of a minor nature and relatively easy to remediate by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

Colorbond and timber paling fences are more rigid than wire fences and, therefore, are more susceptible to impacts resulting from mine subsidence movements. It is possible that these types of fences could be impacted as the result of the extraction of the proposed longwalls. Any impacts on Colorbond or timber paling fences are expected to be of a minor nature and relatively easy to remediate or, where necessary, to replace.

6.10. Farm Dams

6.10.1. Descriptions of the Farm Dams

The farm dams (Structure Type D) are shown in Drawing No. MSEC769-09. The locations and sizes of the dams were determined from the aerial photograph of the area. There are 20 farm dams which have been identified within the Study Area, of which, only six are located directly above the proposed longwalls.

The farm dams are typically of earthen construction and have been established by localised cut and fill operations along the natural drainage lines. The heights of the dam walls are typically less than 5 metres. The farm dams within the Study Area have surface areas ranging between 30 m^2 and 2,970 m^2 and maximum plan dimensions ranging between 8 metres and 190 metres.

6.10.2. Predictions for the Farm Dams

The predicted total conventional subsidence, tilts and curvatures for the farm dams within the Study Area are provided in Table D.02, in Appendix D. A summary of the maximum predicted subsidence parameters for the farm dams on each of the properties within the Study Area is provided in Table 6.6. The values include the predicted movements resulting from the previous extraction of the adjacent longwalls at Ellalong Colliery and Austar Coal Mine (i.e. cumulative movements).

Table 6.6 Maximum Predicted Total Subsidence, Tilt and Curvature for the Farm Dams

Property	Number of Farm Dams	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
A01	3	250	2.5	0.03	< 0.01
A02	1	70	0.5	< 0.01	< 0.01
A04	1	375	3.5	0.03	< 0.01
A06	4	400	3.0	0.03	0.03
B01	3	800	3.0	0.02	0.04
B02	2	825	2.5	0.01	0.03

Property	Number of Farm Dams	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
B03	5	825	2.5	0.02	0.02
B04	2	375	2.5	0.02	0.01
B07	1	30	< 0.5	< 0.01	< 0.01
B08	1	125	1.0	0.01	< 0.01
B09	1	60	< 0.5	< 0.01	< 0.01
B12	1	50	< 0.5	< 0.01	< 0.01
B13	1	20	< 0.5	< 0.01	< 0.01
C01	1	80	0.5	< 0.01	< 0.01

The tilts provided in the above table are the maxima predicted in any directions at the completion of the proposed longwalls. The curvatures are the maxima predicted in any direction at any time during or after the extraction of each of the proposed longwalls. If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the individual farm dams would be predicted to experience greater or lesser movements depending on their locations relative to the longwalls, but the overall levels of predicted movement for these features within the Study Area would not be expected to change significantly.

The farm dams are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays. The analysis of strain in survey bays during the extraction of the previous longwalls at the Mine is discussed in Section 4.3.1.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.10.3. Impact Assessments for the Farm Dams

The maximum predicted tilt for the farm dams within the Study Area 3.5 mm/m (i.e. 0.35 %), which represents a change in grade of 1 in 285. Mining induced tilts can affect the water levels around the perimeters of farm dams, with the freeboard increasing on one side, and decreasing on the other. Tilt can potentially reduce the storage capacity of farm dams, by causing them to overflow.

The predicted changes in freeboard at the farm dams within the Study Area were determined by taking the difference between the maximum predicted subsidence and the minimum predicted subsidence anywhere around the perimeter of each farm dam. The predicted maximum changes in freeboard at the farm dams within the Study Area, after the completion of the proposed longwalls, are provided in Table D.02, in Appendix D.

The maximum predicted change in freeboard is 300 mm at Dam Ref B03d01, which are located near the maingate of the proposed Longwall B1. The predicted maximum changes in freeboard at the remaining farm dams within the Study Area are all 150 mm or less and are unlikely, therefore, to have a significant impact on the storage capacities.

The maximum predicted curvatures at Dam B03d01, the largest farm dam located directly above the proposed longwalls, are 0.02 km^{-1} hogging and less than 0.01 km^{-1} sagging, which equates to minimum radii of curvatures of 50 kilometres and greater than 100 kilometres, respectively. This dam is located adjacent to the maingate through to the middle of the proposed Longwall B1 (i.e. the third panel in the series). The strains measured in similar locations above the previously extracted longwalls at the Mine were 1.3 mm/m tensile and 1.6 mm/m compressive.

The maximum predicted curvatures for the remaining farm dams are 0.03 km^{-1} hogging and 0.05 km^{-1} sagging, which equate to minimum radii of curvatures of 33 kilometres and 20 kilometres, respectively. These dams could experience the full range of the predicted strains, which is discussed in Section 4.3.

The dam walls are constructed with cohesive materials which would be expected to tolerate tensile strains of up to 3 mm/m without adverse impact, because of their inherent elasticity. The maximum predicted curvatures for the farm dams within the Study Area are less than the maxima predicted for the farm dams which were located above the previously extracted longwalls at the Mine. There were 14 farm dams located directly above Longwalls A3 to A5A in Stage 2 and Longwalls A7 and A8 in Stage 3 and there were no reported mining related impacts.

There is also extensive experience of mining directly beneath farm dams in the Southern Coalfield, where the maximum predicted subsidence parameters are similar to or greater than the maxima predicted for the proposed longwalls. This incidence of impacts on farm dams is very low, being less than 0.5 %.

It is expected, therefore, that the incidence of impacts on the farm dams within the Study Area, resulting from the extraction of the proposed longwalls, will be extremely low. If cracking or leakage of water were to occur in the farm dam walls, it is expected that this could be easily identified and repaired as required. It is not expected that any significant loss of water will occur from the farm dams, and any loss that did occur would flow into the tributary in which the dam was formed.

6.10.4. Recommendations for the Farm Dams

It is recommended that all water retaining structures located directly above the proposed longwalls be periodically visually monitored during active subsidence. With the necessary management strategies in place, it is unlikely that there would be any significant long term impacts on the farm dams.

6.11. Groundwater Bores

The locations of the groundwater bores in the vicinity of the proposed longwalls are shown in Drawing No. MSEC769-09. The locations and details of the registered groundwater bores were obtained from the *Natural Resource Atlas* website (NRAtlas, 2015).

There were three bores (Refs. GW080973, GW080974 and GW054676) identified within the Study Area which are located above and north-west of the maingate of the proposed Longwall B3. The authorised purposes for bores GW080973 and GW080974 are for monitoring and for bore GW054676 is for stock.

It is possible that the groundwater bores could experience some impacts as a result of mining the longwalls. Impacts could include temporary lowering of the piezometric surface, blockage of the bore due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality.

Such impacts on the groundwater bores can be readily managed, by repairing or replacing the bores at the completion of mining. If required, temporary alternative supplies of water could be provided by the Mine during the mining period.

6.12. Archaeological Sites

There was one archaeological site identified within the Study Area, which comprises an artefact scatter consisting of two small stone artefacts (Ref. ACM35). The site is located directly above the proposed Longwall B2 as shown in Drawing No. MSEC769-09.

This site could potentially be affected by cracking of the surface soils as a result of the proposed mining. It is expected that only isolated and minor cracking of the surface soils would develop, as a result of mining, which is discussed in Section 4.6. It is unlikely, however, that the scattered artefacts themselves would be impacted by any surface cracking.

Management strategies should be developed to remediate any surface cracking, if required, in the vicinity of the open site. Further assessments of the potential impacts on the open artefact site are provided in a report by *Umwelt* (2015d).

6.13. Survey Control Marks

The locations of the survey control marks in the vicinity of the proposed longwalls are shown in Drawing No. MSEC769-09. The locations and details of the state survey control marks were obtained from the *Land and Property Management Authority* using the *Six Viewer* (2015).

There are two survey control marks which are located above the proposed longwalls, which could experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The survey control marks located in the area could be affected by far-field horizontal movements, up to 3 kilometres outside the extents of the proposed longwalls. Far-field horizontal movements and the methods used to predict such movements are described further in Section 4.5.

It will be necessary on the completion of the proposed longwalls, when the ground has stabilised, to re-establish any survey control marks that are required for future use. Consultation between Austar and the Department of Lands will be required to ensure that these survey control marks are reinstated at the appropriate time, as required.

6.14. Houses

6.14.1. Descriptions of the Houses

There are nine houses (Structure Type H) which have been identified within the Study Area, which are shown in Drawing No. MSEC769-09 and details provided in Table D.03, in Appendix D. House Ref. A02c is located above the northern end of the proposed Longwall B3. The remaining houses are located outside the extents of the proposed longwalls, at distances between 100 metres and 300 metres. The locations and sizes of the houses were determined from the aerial photograph of the area. The types of construction of the houses were determined, where possible, from kerb side inspections.

6.14.2. Predictions for the Houses

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at the vertices of each house, as well as at eight equally spaced points placed radially around the centroid and vertices at a distance of 20 metres. In the case of a rectangular shaped structure, predictions have been made at a minimum of 45 points within and around the structure.

The predicted total conventional subsidence, tilts and curvatures for the houses within the Study Area are provided in Table D.03, in Appendix D. A summary of the maximum predicted subsidence parameters for the houses is provided in Table 6.7. The values include the predicted movements resulting from the previous extraction of the adjacent longwalls at Ellalong Colliery and Austar Coal Mine (i.e. cumulative movements).

Table 6.7 Maximum Predicted Total Subsidence, Tilt and Curvature for the Houses

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Houses (9 total)	After LWB2	50	< 0.5	< 0.01	< 0.01
	After LWB3	150	1.5	0.01	< 0.01
	After LWB1	175	1.5	0.01	< 0.01

If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the individual houses would be predicted to experience greater or lesser movements depending on their locations relative to the longwalls, but the overall levels of predicted movement for these structures within the Study Area would not be expected to change significantly.

The houses are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays. The analysis of strain in survey bays during the extraction of the previous longwalls at the Mine is discussed in Section 4.3.1. The houses are all located outside the extents of the proposed longwalls (i.e. above solid coal) and, hence, the relevant distribution of strain is shown in Fig. 4.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.14.3. Impact Assessments for the Houses

The following sections provide the impact assessments for the houses within the Study Area.

Potential Impacts Resulting from Vertical Subsidence

Vertical subsidence does not directly affect the stability or serviceability of houses. The potential impacts on houses are affected by differential subsidence, which includes tilt, curvature and ground strain, and the impact assessments based on these parameters are described in the following sections.

Vertical subsidence in this case, however, could affect the heights of the houses above the flood level. The potential impacts on the houses resulting from the changes in flood level from the proposed mining is assessed as part of the flood study, which is described in the report by *Umwelt* (2015b).

Potential Impacts Resulting from Tilt

It has been found from past longwall mining experience that tilts of less than 7 mm/m generally do not result in any significant impacts on houses. Some minor serviceability impacts can occur at these levels of tilt, including door swings and issues with roof gutter and wet area drainage, all of which can be remediated using normal building maintenance techniques. Tilts greater than 7 mm/m can result in greater serviceability impacts which may require more substantial remediation measures, including the relevelling of wet areas or, in some cases, the relevelling of the building structure.

The maximum predicted tilt for the houses is 1.5 mm/m (i.e. 0.15 %), which represents a change in grade of 1 in 1665. It is expected, therefore, that only minor serviceability impacts would occur at the houses within the Study Area, as the result of tilt, which could be remediated using normal building techniques. It is expected that the houses within the Study Area will remain in safe conditions as the result of the mining induced tilts.

Potential Impacts Resulting from Curvature and Strain

There is only one house (Ref. A02c) which is located directly above the proposed longwalls. The maximum predicted curvatures for this house are 0.01 km^{-1} hogging and less than 0.01 km^{-1} sagging, which represent minimum radii of curvatures of 100 kilometres and greater than 100 kilometres, respectively. This house is also predicted to experience maximum strains of 0.9 mm/m tensile and 1.7 mm/m compressive, based on the 95 % confidence level.

The remaining houses are located outside the extents of the proposed longwalls, at distances between 100 metres and 300 metres. These houses are predicted to experience hogging and sagging curvatures less than 0.01 km^{-1} and are predicted to experience tensile and compressive strains typically less than 0.5 mm/m.

The maximum predicted subsidence parameters for the houses within the Study Area are less than the maxima predicted for the houses located above the previously extracted longwalls in Stages 2 at the Mine. Longwalls A3 to A5a were extracted directly beneath seven houses and no substantial impacts were reported.

It is unlikely, therefore, that the houses within the Study Area would experience any substantial impacts as a result of the proposed mining. It is possible that some houses could experience some minor impacts, such as cracking in the internal plasterboard linings or cornices. It would be expected that any such impacts could be remediated using normal building maintenance techniques. All houses within the Study Area are expected to remain safe, serviceable and repairable throughout the mining period.

6.14.4. Recommendations for the Houses

It is recommended that the houses are periodically visually monitored during the extraction of the proposed longwalls. It is also recommended that Built Features Management Plans are developed in consultation with the owners.

6.15. Swimming Pools

There is one privately owned swimming pool (Structure Ref. B12r05) which has been identified within the Study Area, which is located 200 metres east of Longwall B1, i.e. outside the extents of the proposed longwalls. The location of this pool is shown in Drawing No. MSEC769-09.

Mining-induced tilts are more noticeable in pools than other structures due to the presence of the water line and small gaps to the edge coping, particularly when the pool lining has been tiled. Skimmer boxes are also susceptible to being lifted above the water line due to mining induced tilt. The Australian Standard AS2783-1992 (Use of reinforced concrete for small swimming pools) requires that pools be constructed level ± 15 mm from one end to the other. This represents a tilt of approximately 3 mm/m for pools that are 10 metres in length. Australian Standard AS/NZS 1839:1994 (Swimming pools – Pre-moulded fibre-reinforced plastics – Installation) also requires that pools be constructed with a tilt of 3 mm/m or less.

The maximum predicted tilt for the pool is less than 0.5 mm/m (i.e. less than 0.05 % or 1 in 2,000), which is considerably less than the Australian Standard. The mining induced tilt is very small and unlikely to adversely impact on the pool.

The maximum predicted hogging and sagging curvatures for the pool are less than 0.01 km^{-1}, which represents a minimum radius of curvature greater than 100 kilometres. It is expected that the strains would be less than 0.5 mm/m at the distance of the pool from the proposed longwalls. The predicted curvatures and strains at the pool are very small and are unlikely to be measurable, i.e. in the order of survey tolerance. It is unlikely, therefore, that the pool would experience adverse impacts as a result of the proposed longwalls.

6.16. On-Site Waste Water Systems

The residences on the rural properties within the Study Area have on-site waste water systems. The systems are located near the houses and, therefore, are expected to experience similar mine subsidence movements as the houses which are provided in Table D.03, in Appendix D. If the proposed longwalls were slightly shifted, rotated, the lengths slightly modified, or the mining sequence reversed, the individual waste water systems would be predicted to experience greater or lesser movements depending on their locations relative to the longwalls, but the overall levels of predicted movement for these structures within the Study Area would not be expected to change significantly.

The on-site waste water systems are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays. The analysis of strain in survey bays during the extraction of the previous longwalls at the Mine is discussed in Section 4.3.1.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted change in grade for the on-site waste water systems within the Study Area are less than 1 %. It is unlikely, therefore, that the maximum predicted tilts would result in any significant impacts on the systems. The maximum predicted conventional tilts could, however, be of sufficient magnitude to affect the serviceability of the buried pipes between the houses and the on-site waste water systems, if the existing grades of these pipes are very small, say less than 1 %.

The on-site waste water system tanks are generally small, typically less than 3 metres in diameter, are constructed from reinforced concrete, and are usually bedded in sand and backfilled. It is unlikely, therefore, that the maximum predicted curvatures and ground strains would be fully transferred into the tank structures.

It is possible, however, that the buried pipelines associated with the on-site waste water tanks could be impacted by the ground strains if they are anchored by the tanks or other structures in the ground. Any impacts are expected to be of a minor nature, including leaking pipe joints, and could be easily repaired. With the implementation of these remedial measures, it would be unlikely that there would be any significant impacts on the pipelines associated with the on-site waste water systems.

APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

Glossary of Terms and Definitions

Some of the more common mining terms used in the report are defined below:-

Angle of draw	The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence).
Chain pillar	A block of coal left unmined between the longwall extraction panels.
Cover depth (H)	The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel.
Closure	**T**he reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill movements and other possible strata mechanisms.
Critical area	The area of extraction at which the maximum possible subsidence of one point on the surface occurs.
Curvature	The change in tilt between two adjacent sections of the tilt profile divided by the average horizontal length of those sections, i.e. curvature is the second derivative of subsidence. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres (km-1)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*. Curvature can be either **hogging** (i.e. convex) or **sagging** (i.e. concave).
Extracted seam	The thickness of coal that is extracted. The extracted seam thickness is thickness normally given as an average over the area of the panel.
Effective extracted seam thickness (T)	The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel.
Face length	The width of the coalface measured across the longwall panel.
Far-field movements	The measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain.
Goaf	The void created by the extraction of the coal into which the immediate roof layers collapse.
Goaf end factor	A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.
Horizontal displacement	The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.
Inflection point	The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max.
Incremental subsidence	The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.
Panel	The plan area of coal extraction.
Panel length (L)	The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib.
Panel width (Wv)	The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.
Panel centre line	An imaginary line drawn down the middle of the panel.
Pillar	A block of coal left unmined.
Pillar width (Wpi)	The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.

Shear deformations	The horizontal displacements that are measured across monitoring lines and these can be described by various parameters including; horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index.
Strain	The change in the horizontal distance between two points divided by the original horizontal distance between the points, i.e. strain is the relative differential displacement of the ground along or across a subsidence monitoring line. Strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation. **Tensile Strains** are measured where the distance between two points or survey pegs increases and **Compressive Strains** where the distance between two points decreases. Whilst mining induced **strains** are measured **along** monitoring lines, ground **shearing** can occur both vertically, and horizontally **across** the directions of the monitoring lines.
Sub-critical area	An area of panel smaller than the critical area.
Subsidence	The vertical movement of a point on the surface of the ground as it settles above an extracted panel, but, 'subsidence of the ground' in some references can include both a vertical and horizontal movement component. The vertical component of subsidence is measured by determining the change in surface level of a peg that is fixed in the ground before mining commenced and this vertical subsidence is usually expressed in units of *millimetres (mm)*. Sometimes the horizontal component of a peg's movement is not measured, but in these cases, the horizontal distances between a particular peg and the adjacent pegs are measured.
Super-critical area	An area of panel greater than the critical area.
Tilt	The change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the horizontal distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.
Uplift	An increase in the level of a point relative to its original position.
Upsidence	Upsidence results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.

APPENDIX B. REFERENCES

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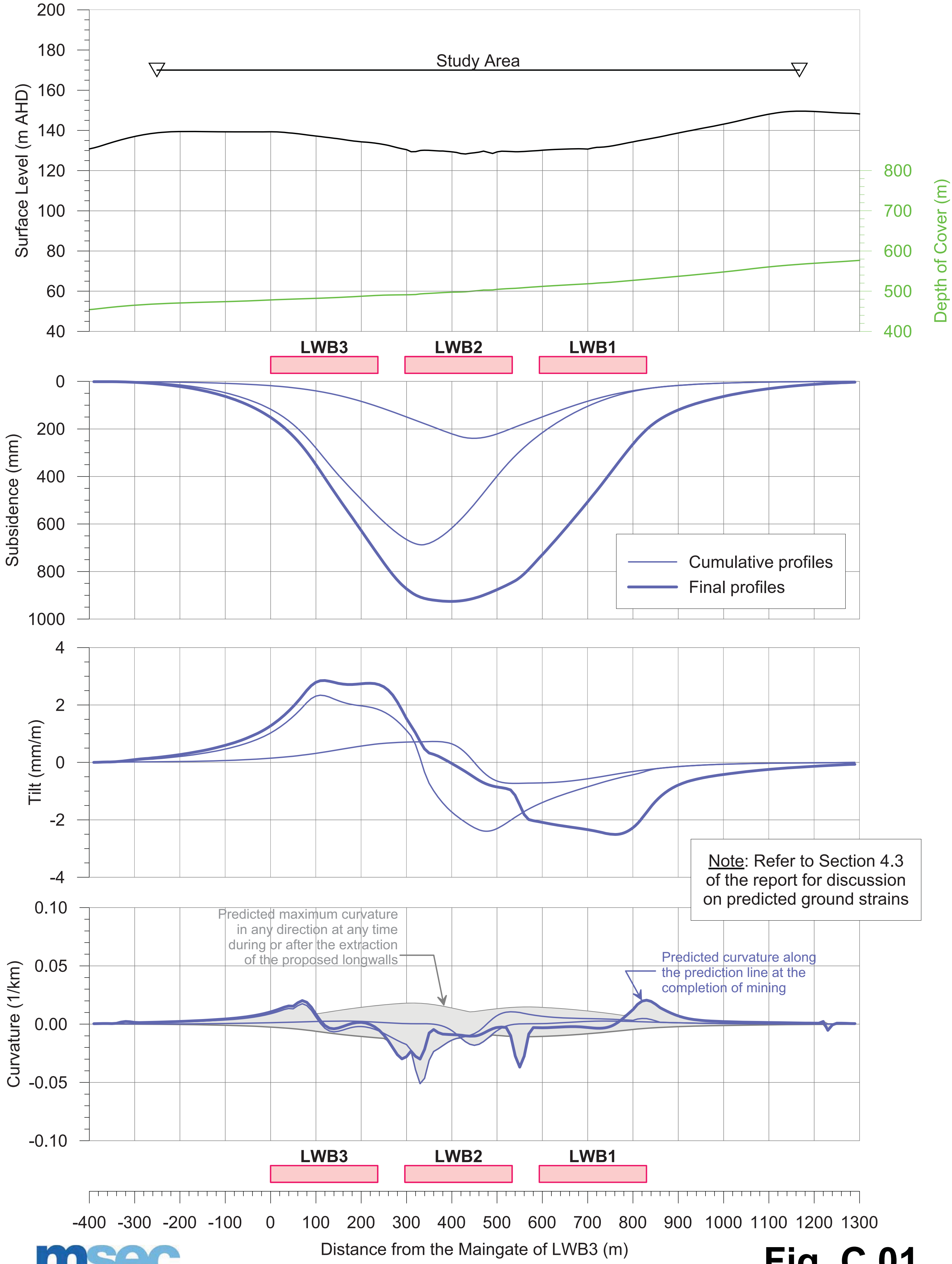
APPENDIX C. FIGURES

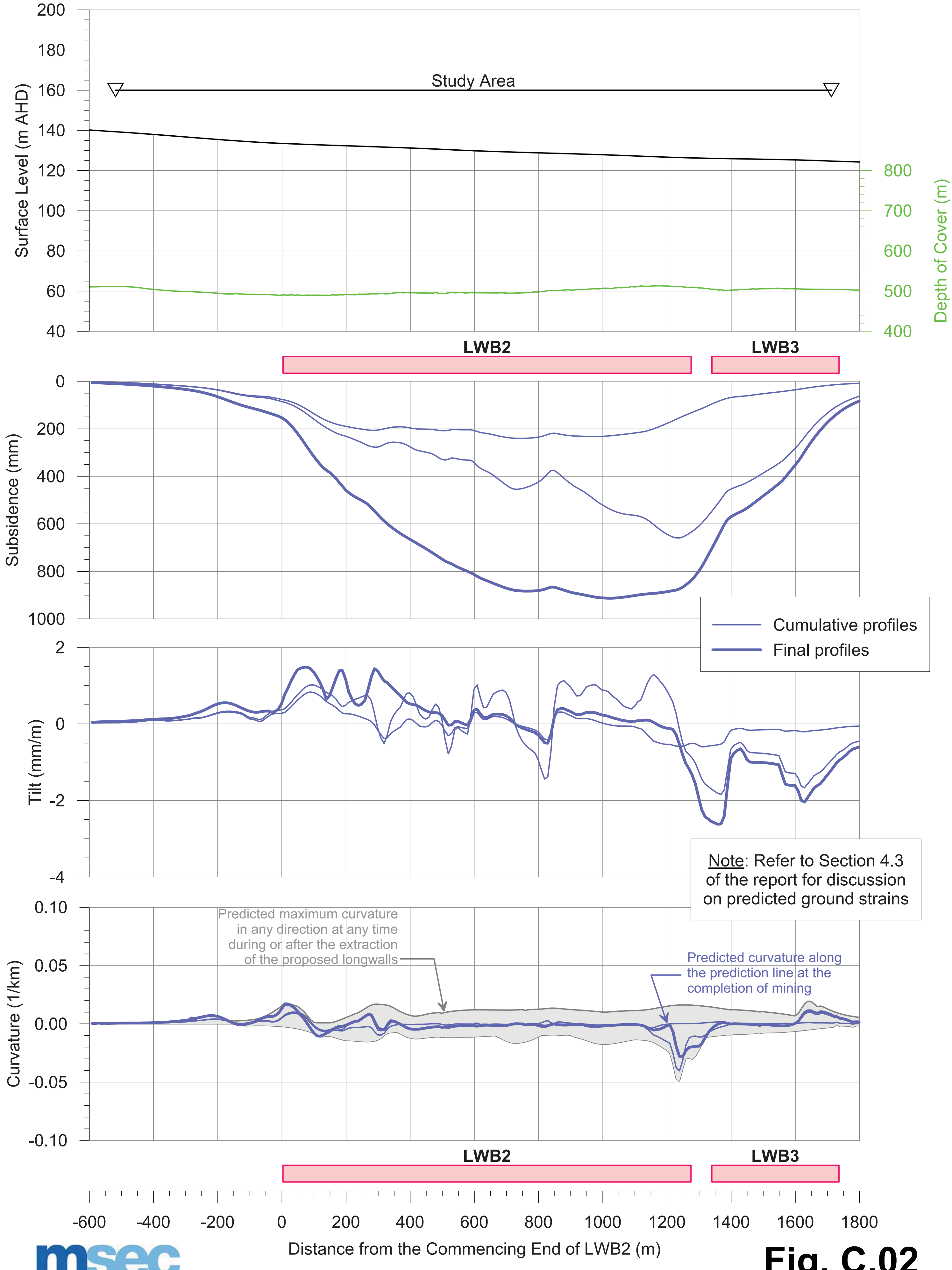
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 Resulting from the Extraction of Longwalls B1 to B3



msec

Fig. C.01

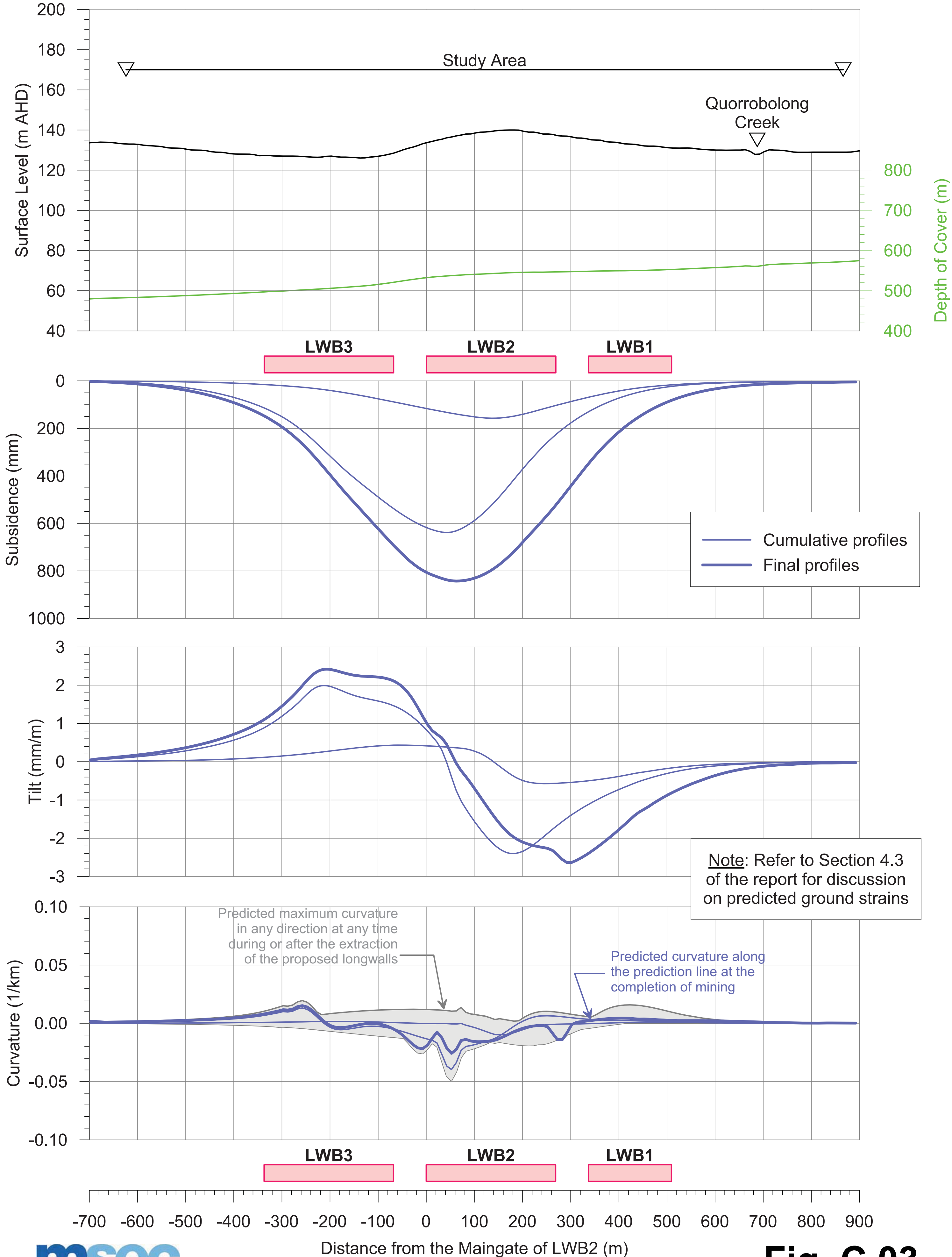
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along the Unnamed Drainage Line 1 Resulting from the Extraction of Longwalls B1 to B3



msec

Fig. C.02

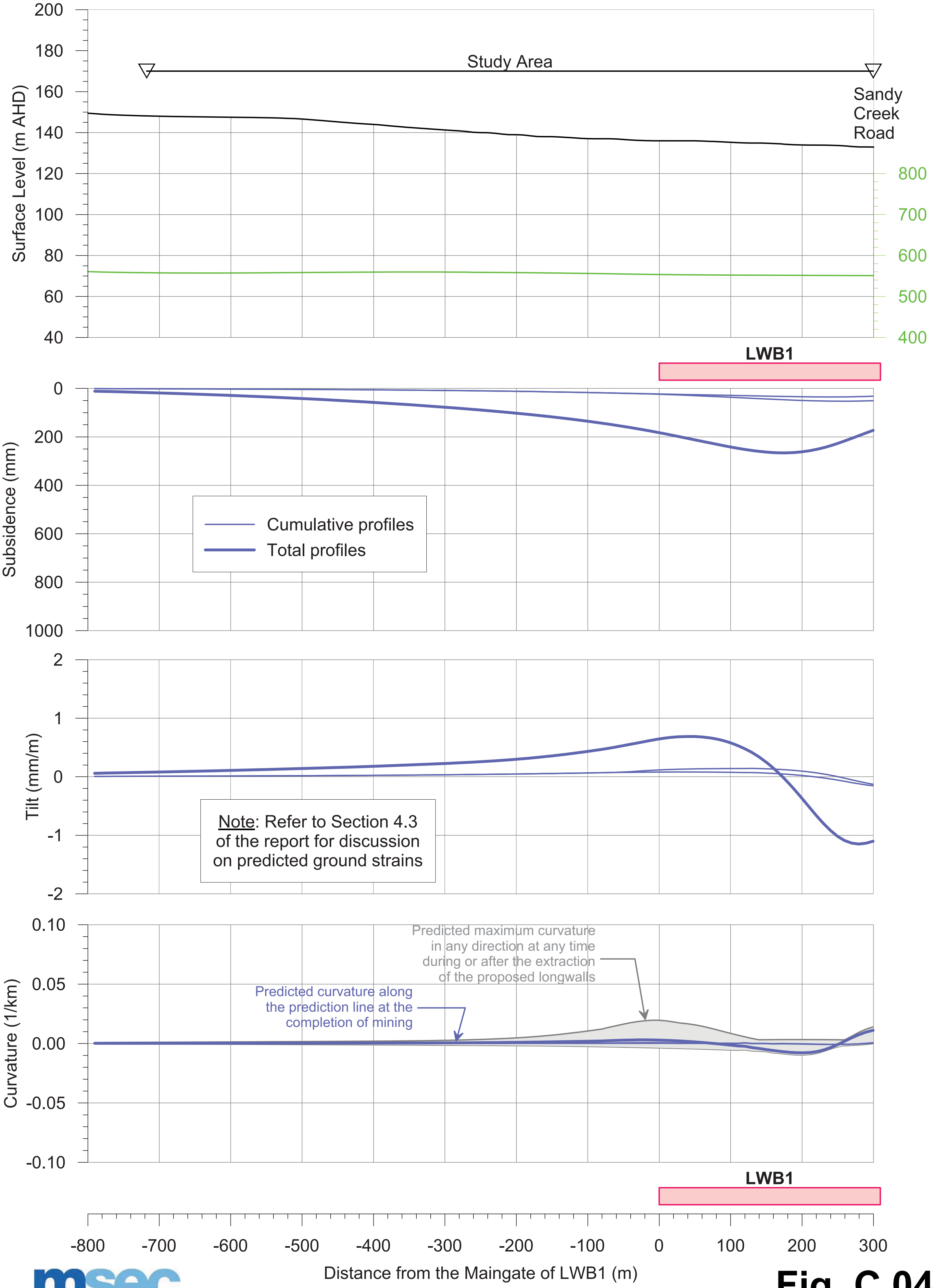
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Sandy Creek Road Resulting from the Extraction of Longwalls B1 to B3



msec

Fig. C.03

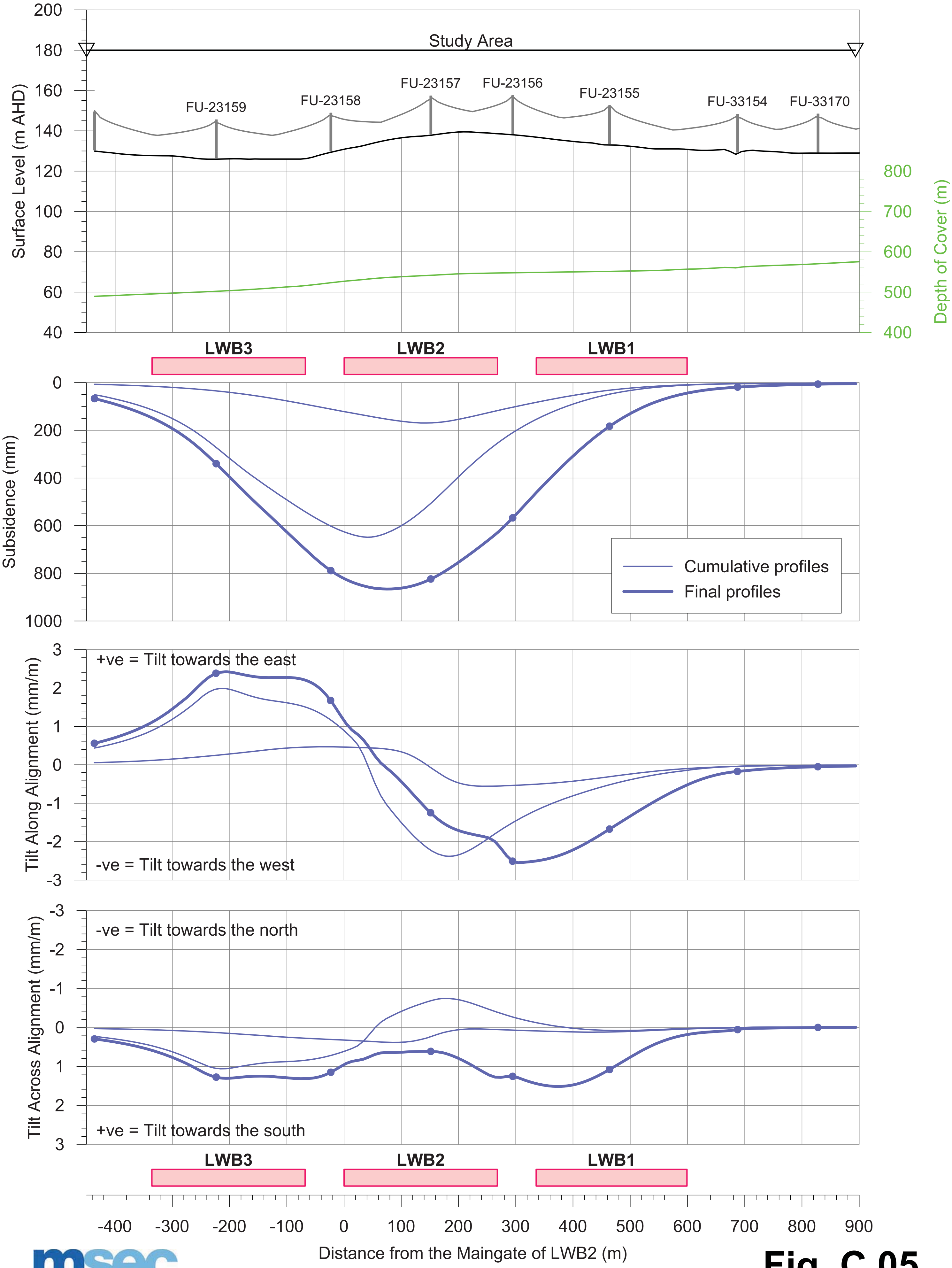
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Barraba Lane Resulting from the Extraction of Longwalls B1 to B3



msec

Fig. C.04

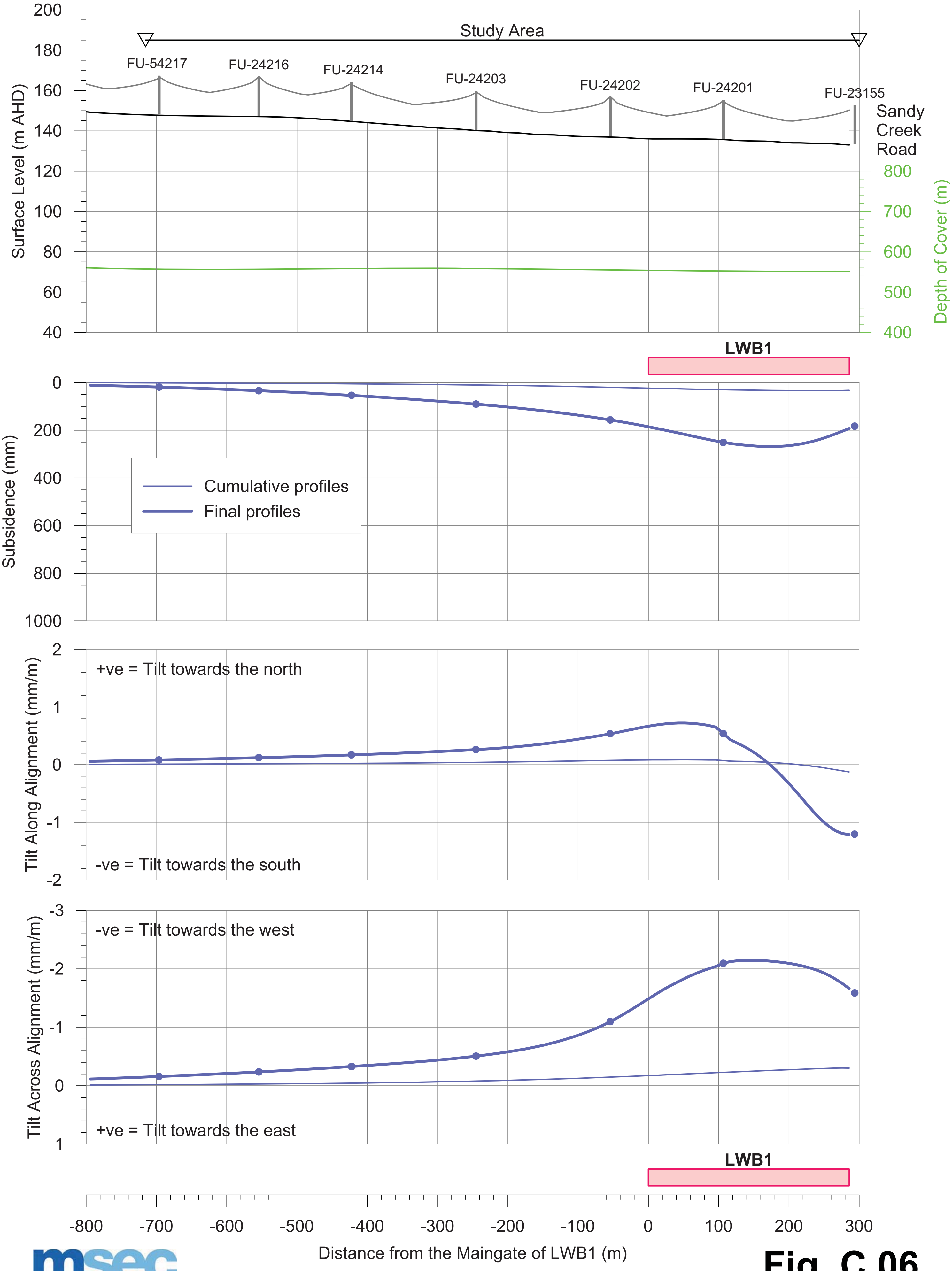
Predicted Profiles of Conventional Subsidence, Tilt Along and Tilt Across the Alignment of the 11 kV Powerline Branch 1 Resulting from the Extraction of Longwalls B1 to B3



msec

Fig. C.05

Predicted Profiles of Conventional Subsidence, Tilt Along and Tilt Across the Alignment of the 11 kV Powerline Branch 2 Resulting from the Extraction of Longwalls B1 to B3



msec

Fig. C.06

APPENDIX D. TABLES

Table D.01 - Maximum Predicted Subsidence Parameters for the Rural Structures within the Study Area

Structure Reference	Type	Predicted Total Subsidence after LWB2 (mm)	Predicted Total Subsidence after LWB3 (mm)	Predicted Total Subsidence after LWB1 (mm)	Predicted Total Tilt after Longwall B2 (mm/m)	Predicted Total Tilt after Longwall B3 (mm/m)	Predicted Total Tilt after Longwall B1 (mm/m)	Predicted Total Hogging Curvature after Longwall B2 (1/km)	Predicted Total Hogging Curvature after Longwall B3 (1/km)	Predicted Total Hogging Curvature after Longwall B1 (1/km)	Predicted Total Sagging Curvature after Longwall B2 (1/km)	Predicted Total Sagging Curvature after Longwall B3 (1/km)	Predicted Total Sagging Curvature after Longwall B1 (1/km)
A01j	Shed	30	90	150	< 0.5	1	1.5	< 0.01	0.01	0.02	< 0.01	< 0.01	< 0.01
A01k	Tank	30	90	150	< 0.5	1	1.5	< 0.01	0.01	0.02	< 0.01	< 0.01	< 0.01
A02a	Shed	70	80	80	0.5	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
A02b	Shed	60	70	70	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
A02d	Shed	< 20	175	200	< 0.5	1.5	2	< 0.01	0.01	0.02	< 0.01	< 0.01	< 0.01
A02e	Shed	< 20	125	150	< 0.5	1	1.5	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01
A02f	Shed	< 20	150	200	< 0.5	1.5	1.5	< 0.01	0.01	0.01	< 0.01	< 0.01	< 0.01
A02g	Shed	< 20	80	90	< 0.5	0.5	1	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
A02h	Tank	< 20	100	125	< 0.5	1	1	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01
A02i	Tank	< 20	100	125	< 0.5	1	1.5	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01
A02j	Tank	< 20	125	150	< 0.5	1	1.5	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01
A06b	Shed	40	80	100	< 0.5	0.5	0.5	< 0.01	0.01	0.01	< 0.01	< 0.01	< 0.01
A06c	Shed	30	80	100	< 0.5	0.5	0.5	< 0.01	0.01	0.01	< 0.01	< 0.01	< 0.01
A06d	Shed	30	80	100	< 0.5	0.5	1	< 0.01	0.01	0.01	< 0.01	< 0.01	< 0.01
B03r01	Shed	< 20	< 20	90	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B03r02	Shed	< 20	< 20	100	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B03r03	Tank	< 20	< 20	100	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B03r04	Shed	< 20	< 20	125	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B03r05	Shed	< 20	< 20	125	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B03r06	Shed	< 20	< 20	100	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B03r07	Shed	175	250	775	0.5	1.5	2	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.01
B03r08	Shed	200	325	825	0.5	2	2	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.04
B03r09	Shed	225	350	850	0.5	2	2	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.04
B03r10	Tank	200	300	800	0.5	1.5	2	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.04
B03r11	Tank	175	275	775	0.5	1.5	2	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.02
B03r12	Tank	200	300	800	0.5	2	2	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.04
B03r13	Shed	200	325	825	0.5	2	2	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.04
B03r14	Shed	100	125	525	0.5	1	2	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01
B04r01	Tank	< 20	< 20	< 20	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B04r02	Tank	< 20	< 20	< 20	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B04r03	Shed	< 20	< 20	50	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B04r04	Shed	< 20	< 20	70	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B04r05	Shed	< 20	< 20	70	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B04r06	Tank	< 20	< 20	60	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B09r01	Shed	< 20	< 20	100	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B09r02	Tank	< 20	< 20	100	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B09r03	Tank	< 20	< 20	100	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B10r01	Shed	< 20	< 20	50	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B10r02	Tank	< 20	< 20	40	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B10r03	Tank	< 20	< 20	40	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B10r04	Tank	< 20	< 20	50	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B11r01	Shed	< 20	< 20	30	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B11r02	Tank	< 20	< 20	30	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B11r03	Tank	< 20	< 20	30	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B12r01	Shed	< 20	< 20	70	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B12r02	Tank	< 20	< 20	70	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B12r03	Tank	< 20	< 20	70	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B12r04	Shed	< 20	< 20	60	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B12r05	Pool	< 20	< 20	60	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B13r01	Shed	< 20	< 20	30	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B13r02	Shed	< 20	< 20	20	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B13r03	Shed	< 20	< 20	20	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
C01r01	Shed	< 20	< 20	< 20	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
C01r02	Tank	< 20	< 20	< 20	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	Maximum	**225**	**350**	**850**	**0.5**	**2.0**	**2.0**	**< 0.01**	**0.01**	**0.02**	**< 0.01**	**< 0.01**	**0.04**

Table D.02 - Maximum Predicted Subsidence Parameters for the Farm Dams within the Study Area

Reference	Maximum Planar Dimension (m)	Surface Area (m^2)	Predicted Total Subsidence after LWB2 (mm)	Predicted Total Subsidence after LWB3 (mm)	Predicted Total Subsidence after LWB1 (mm)	Predicted Total Tilt after Longwall B2 (mm/m)	Predicted Total Tilt after Longwall B3 (mm/m)	Predicted Total Tilt after Longwall B1 (mm/m)	Predicted Total Hogging Curvature after Longwall B2 (1/km)	Predicted Total Hogging Curvature after Longwall B3 (1/km)	Predicted Total Hogging Curvature after Longwall B1 (1/km)	Predicted Total Sagging Curvature after Longwall B2 (1/km)	Predicted Total Sagging Curvature after Longwall B3 (1/km)	Predicted Total Sagging Curvature after Longwall B1 (1/km)	Predicted Total Change in Freeboard (mm)
A01d05	164	9125	200	200	200	2	2	2	0.03	0.03	0.03	< 0.01	< 0.01	< 0.01	100
A01d06	71	1467	50	125	250	0.5	1.5	2.5	< 0.01	0.01	0.02	< 0.01	< 0.01	< 0.01	50
A01d07	23	406	60	90	100	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 50
A02d01	133	6223	70	70	70	0.5	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 50
A04d06	83	1806	375	375	375	3.5	3.5	3.5	0.03	0.03	0.03	< 0.01	< 0.01	< 0.01	150
A06d01	81	2968	30	175	200	< 0.5	2	2	< 0.01	0.02	0.02	< 0.01	< 0.01	< 0.01	100
A06d02	28	480	50	100	125	< 0.5	< 0.5	0.5	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 50
A06d03	60	968	50	350	400	< 0.5	2.5	3	< 0.01	0.02	0.03	< 0.01	0.03	0.03	100
A06d04	9	52	40	50	60	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 50
B01d01	40	956	175	300	800	0.5	2	2	< 0.01	0.01	0.01	< 0.01	< 0.01	0.04	50
B01d02	47	879	50	350	425	< 0.5	2.5	3	< 0.01	0.02	0.02	< 0.01	< 0.01	< 0.01	100
B01d03	35	1044	< 20	40	50	< 0.5	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 50
B02d01	63	1714	100	125	550	0.5	1	2.5	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	100
B02d02	34	718	150	625	825	0.5	1.5	2.5	< 0.01	0.01	0.01	< 0.01	0.03	0.03	50
B03d01	193	1449	80	100	475	0.5	1	2.5	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	300
B03d02	25	442	30	30	175	< 0.5	< 0.5	1.5	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 50
B03d03	82	806	70	80	400	< 0.5	0.5	2.5	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	100
B03d04	41	955	150	375	525	0.5	2	2.5	< 0.01	0.02	0.02	< 0.01	0.01	0.02	100
B03d05	8	29	200	600	825	0.5	1.5	0.5	< 0.01	0.01	0.01	< 0.01	0.02	0.02	< 50
B04d01	29	603	< 20	< 20	30	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 50
B04d02	31	417	40	50	375	0.5	0.5	2.5	< 0.01	< 0.01	0.02	< 0.01	< 0.01	0.01	< 50
B07d01	24	178	20	20	30	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 50
B08d01	26	392	< 20	< 20	125	< 0.5	< 0.5	1	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 50
B09d01	15	136	< 20	< 20	60	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 50
B12d01	25	391	< 20	< 20	50	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 50
B13d01	30	532	< 20	< 20	20	< 0.5	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 50
C01d01	63	1695	< 20	60	80	< 0.5	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 50
		Maximum	**375**	**625**	**825**	**3.5**	**3.5**	**3.5**	**0.03**	**0.03**	**0.03**	**< 0.01**	**0.03**	**0.04**	**300**

Table D.03 - Maximum Predicted Subsidence Parameters for the Houses within the Study Area

Structure Reference	Maximum Planar Dimension (m)	Number of Storeys	Wall Construction	Footing Construction	Roof Construction	Predicted Total Subsidence after LWB2 (mm)	Predicted Total Subsidence after LWB3 (mm)	Predicted Total Subsidence after LWB1 (mm)	Predicted Total Tilt after Longwall B2 (mm/m)	Predicted Total Tilt after Longwall B3 (mm/m)	Predicted Total Tilt after Longwall B1 (mm/m)
A02c	13	Single	Timber Frame	Piers	Metal	< 20	150	175	< 0.5	1.5	1.5
A06a	16	Single	Timber Frame	Slab on Ground	Metal	50	90	100	< 0.5	< 0.5	< 0.5
B03h01	13	Single	Timber Frame	Piers	Metal	< 20	< 20	100	< 0.5	< 0.5	0.5
B04h01	21	Single	Brick	Slab on Ground	Tiles	< 20	< 20	20	< 0.5	< 0.5	< 0.5
B04h03	16	Single	Brick	Slab on Ground	Metal	< 20	< 20	60	< 0.5	< 0.5	0.5
B09h01	28	Single	Brick	Slab on Ground	Metal	< 20	< 20	100	< 0.5	< 0.5	0.5
B10h01	29	Single	Brick	Slab on Ground	Metal	< 20	< 20	40	< 0.5	< 0.5	< 0.5
B11h01	20	Single	Brick	Slab on Ground	Tiles	< 20	< 20	30	< 0.5	< 0.5	< 0.5
B12h01	20	Double	Brick	Slab on Ground	Tiles	< 20	< 20	70	< 0.5	< 0.5	< 0.5
					Maximum	**50**	**150**	**175**	**< 0.5**	**1.5**	**1.5**

Table D.03 - Maximum Predicted Subsidence Parameters for the Houses within the Study Area

Structure Reference	Predicted Total Hogging Curvature after Longwall B2 (1/km)	Predicted Total Hogging Curvature after Longwall B3 (1/km)	Predicted Total Hogging Curvature after Longwall B1 (1/km)	Predicted Total Sagging Curvature after Longwall B2 (1/km)	Predicted Total Sagging Curvature after Longwall B3 (1/km)	Predicted Total Sagging Curvature after Longwall B1 (1/km)
A02c	< 0.01	0.01	0.01	< 0.01	< 0.01	< 0.01
A06a	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B03h01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B04h01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B04h03	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B09h01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B10h01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B11h01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B12h01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	< 0.01	**0.01**	**0.01**	**< 0.01**	**< 0.01**	**< 0.01**

APPENDIX E. DRAWINGS

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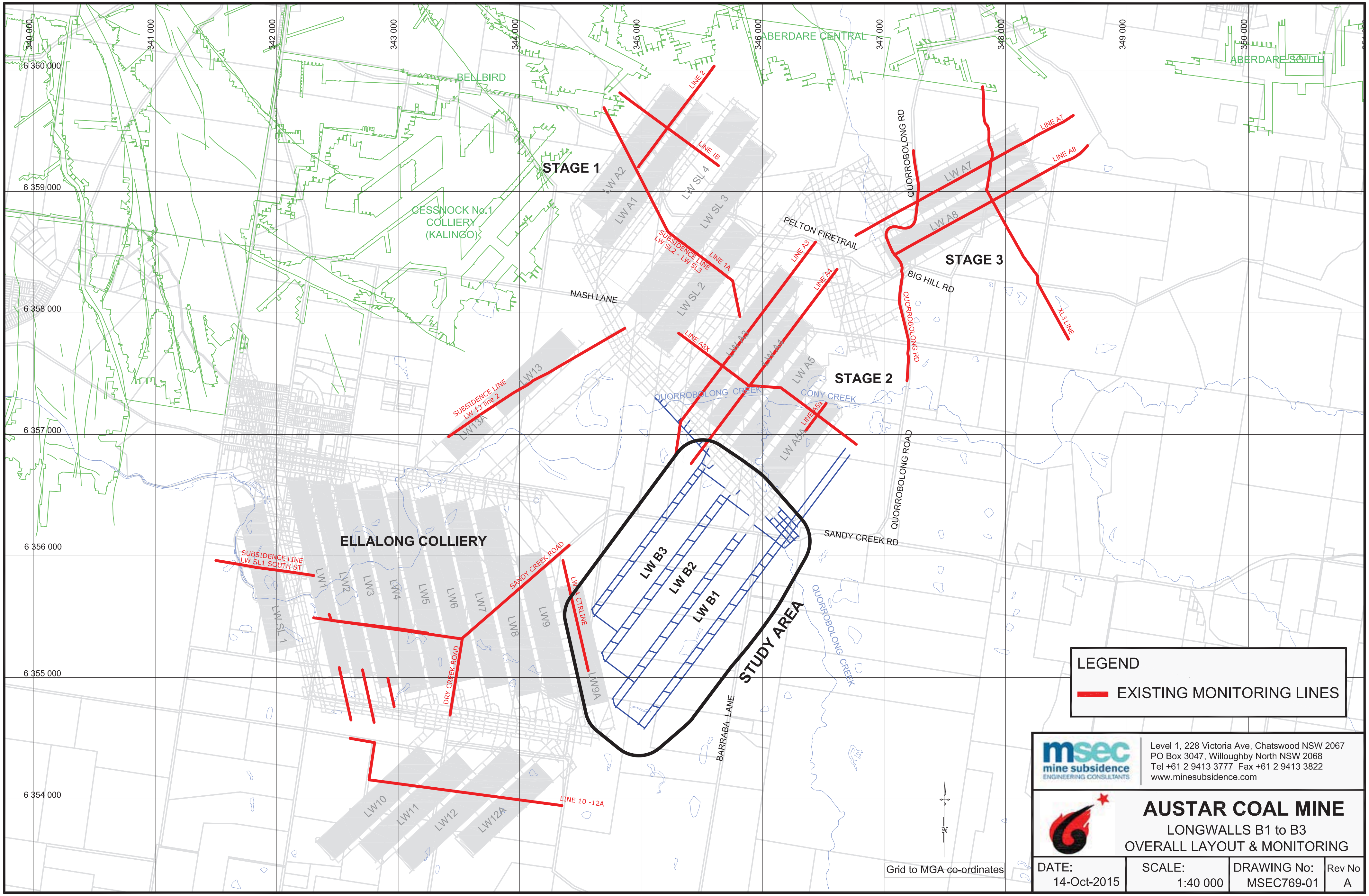

LEGEND

EXISTING MONITORING LINES

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AUSTAR COAL MINE

LONGWALLS B1 to B3
OVERALL LAYOUT & MONITORING

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14-Oct-2015	1:40 000	MSEC769-01	A

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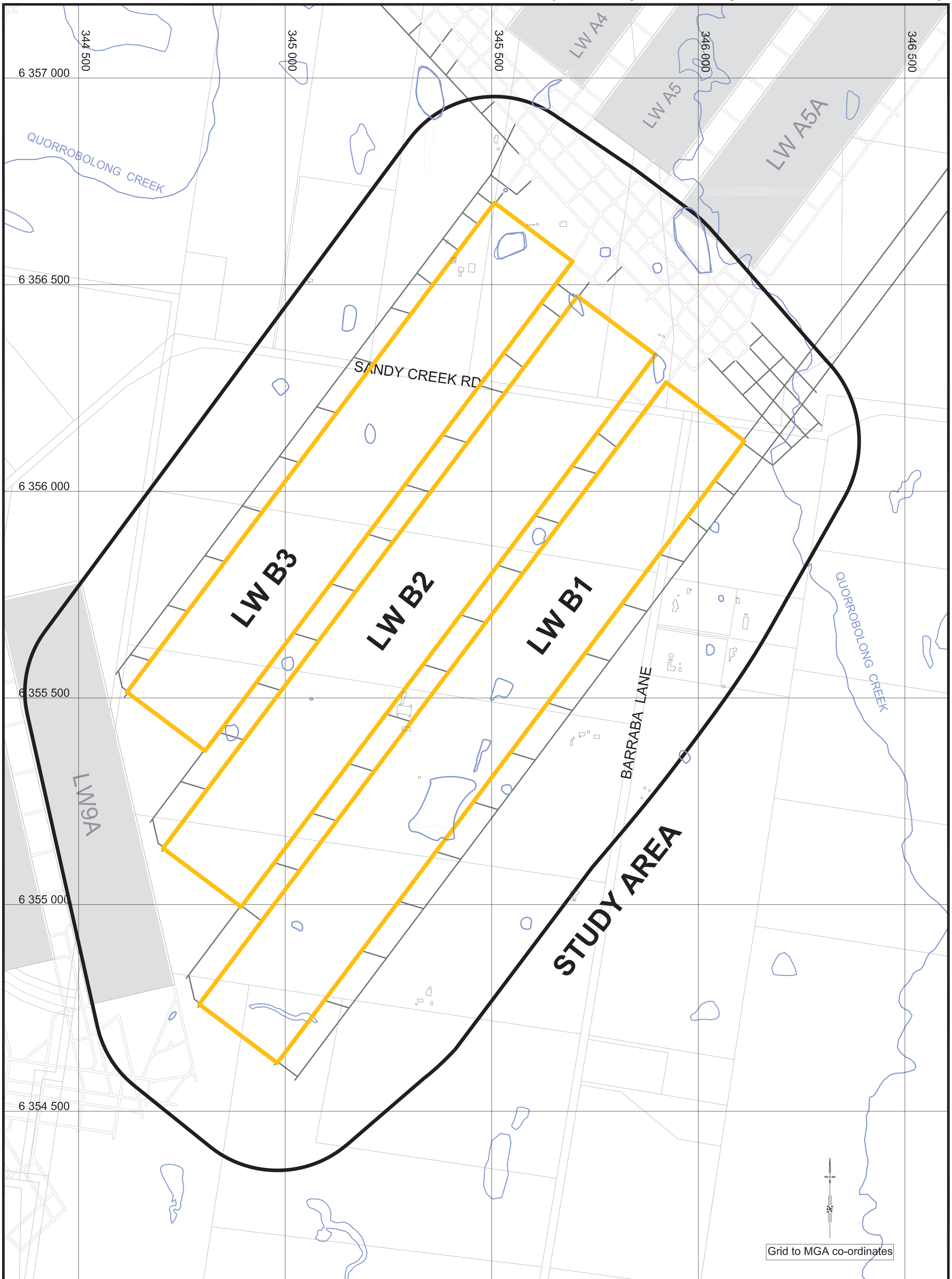

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LAYOUT OF
LONGWALLS B1 TO B3

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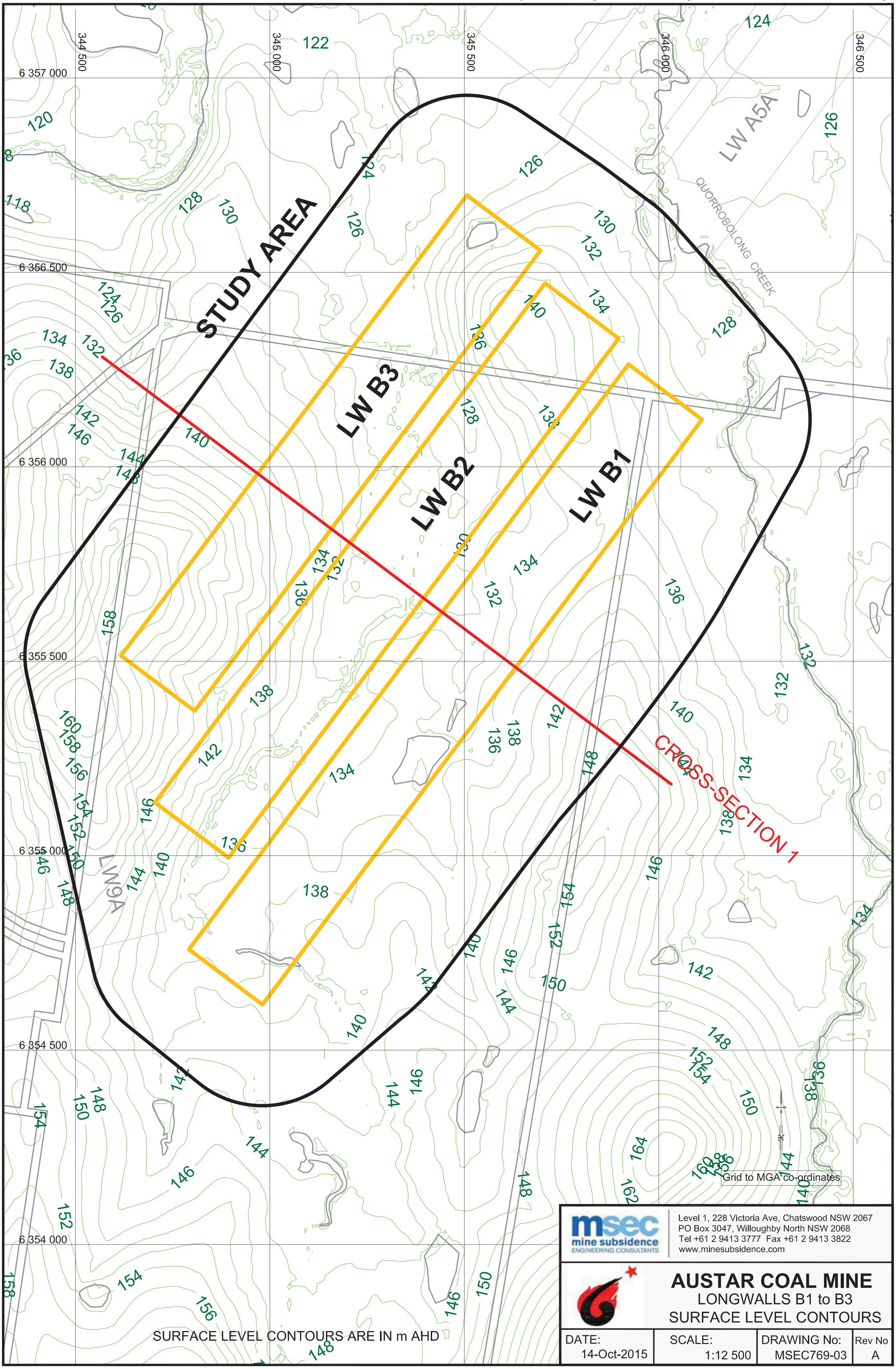

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AUSTAR COAL MINE
LONGWALLS B1 to B3
SURFACE LEVEL CONTOURS

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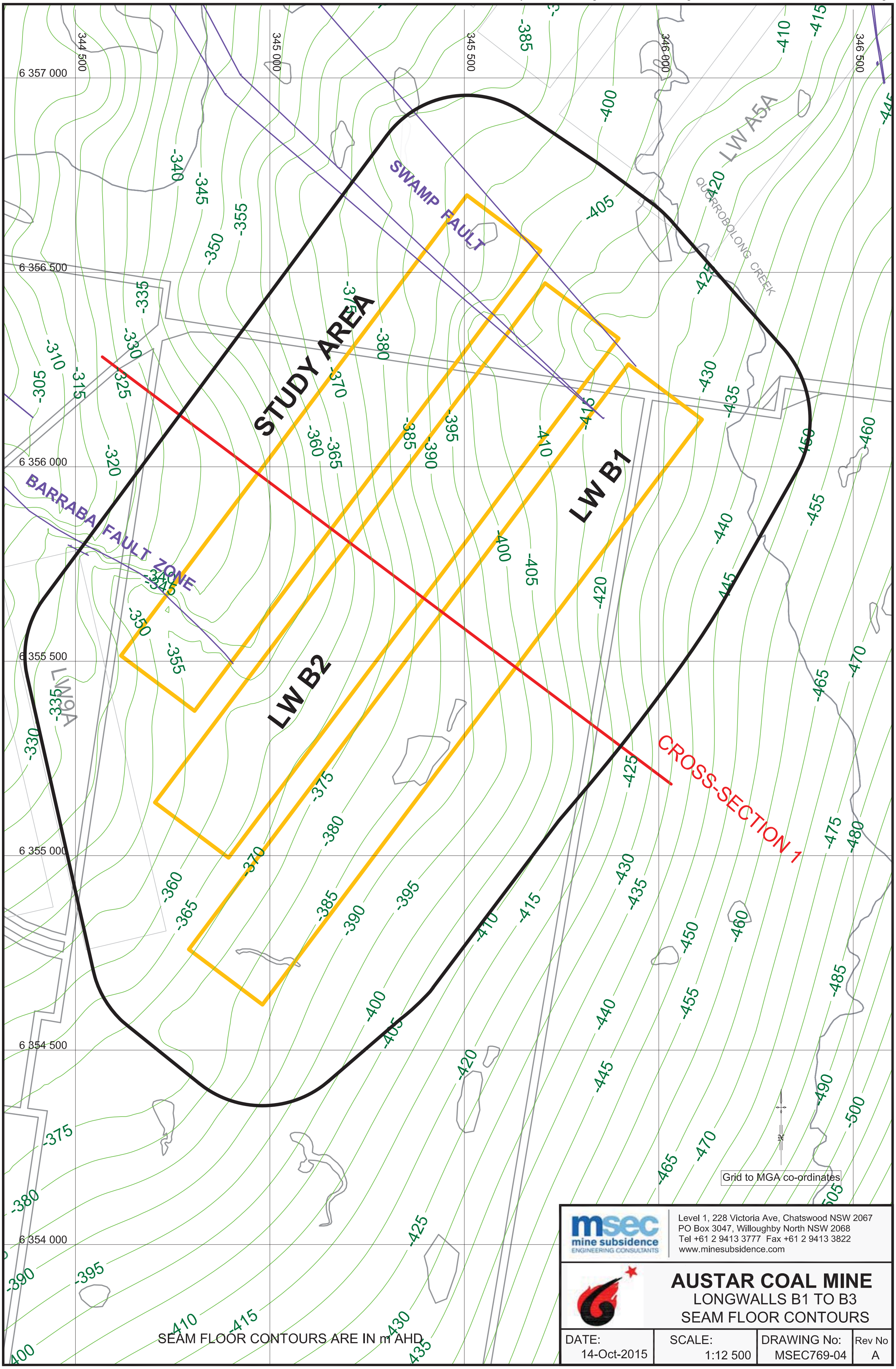

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LONGWALLS B1 TO B3
SEAM FLOOR CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
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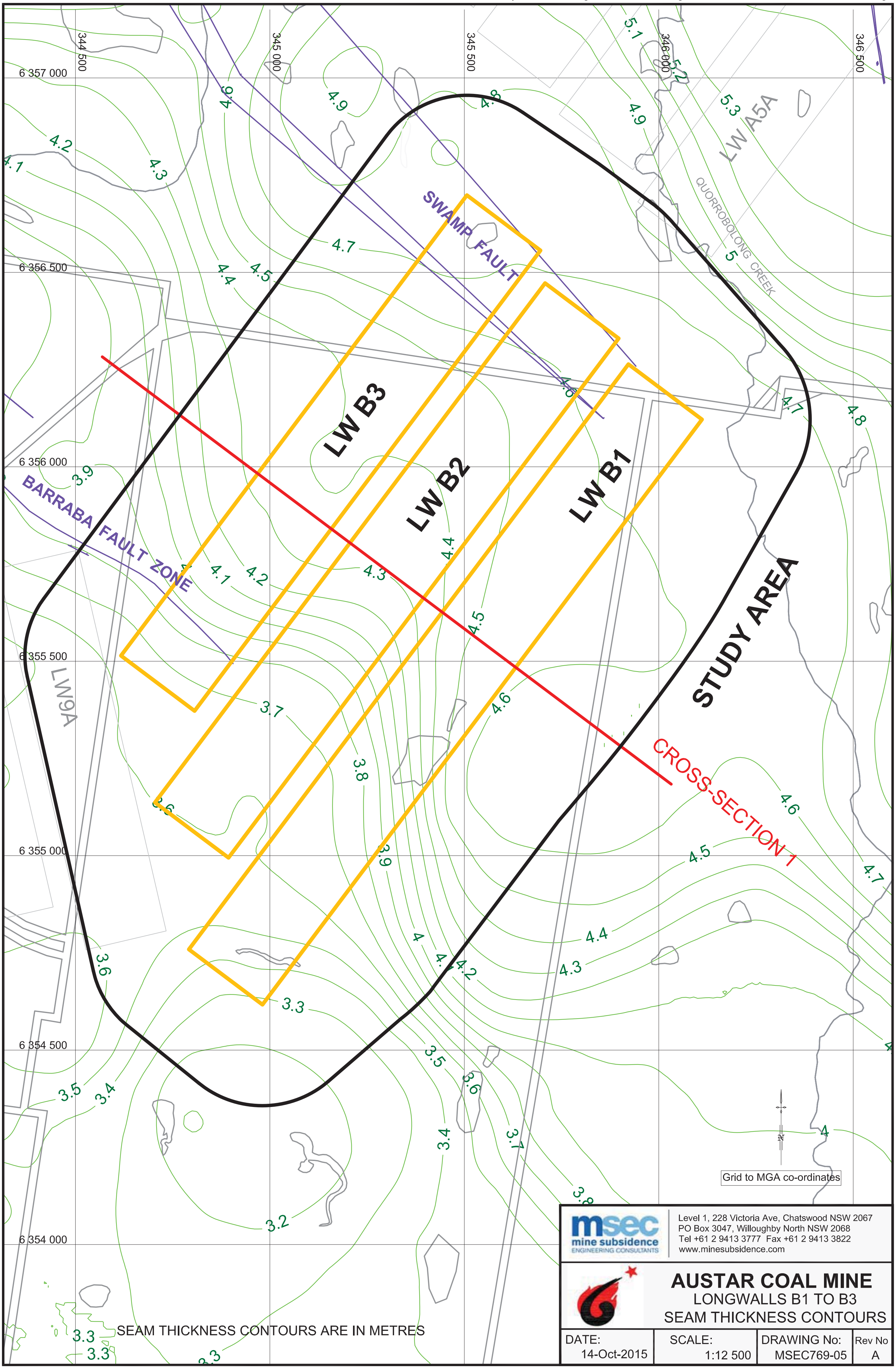

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LONGWALLS B1 TO B3
SEAM THICKNESS CONTOURS

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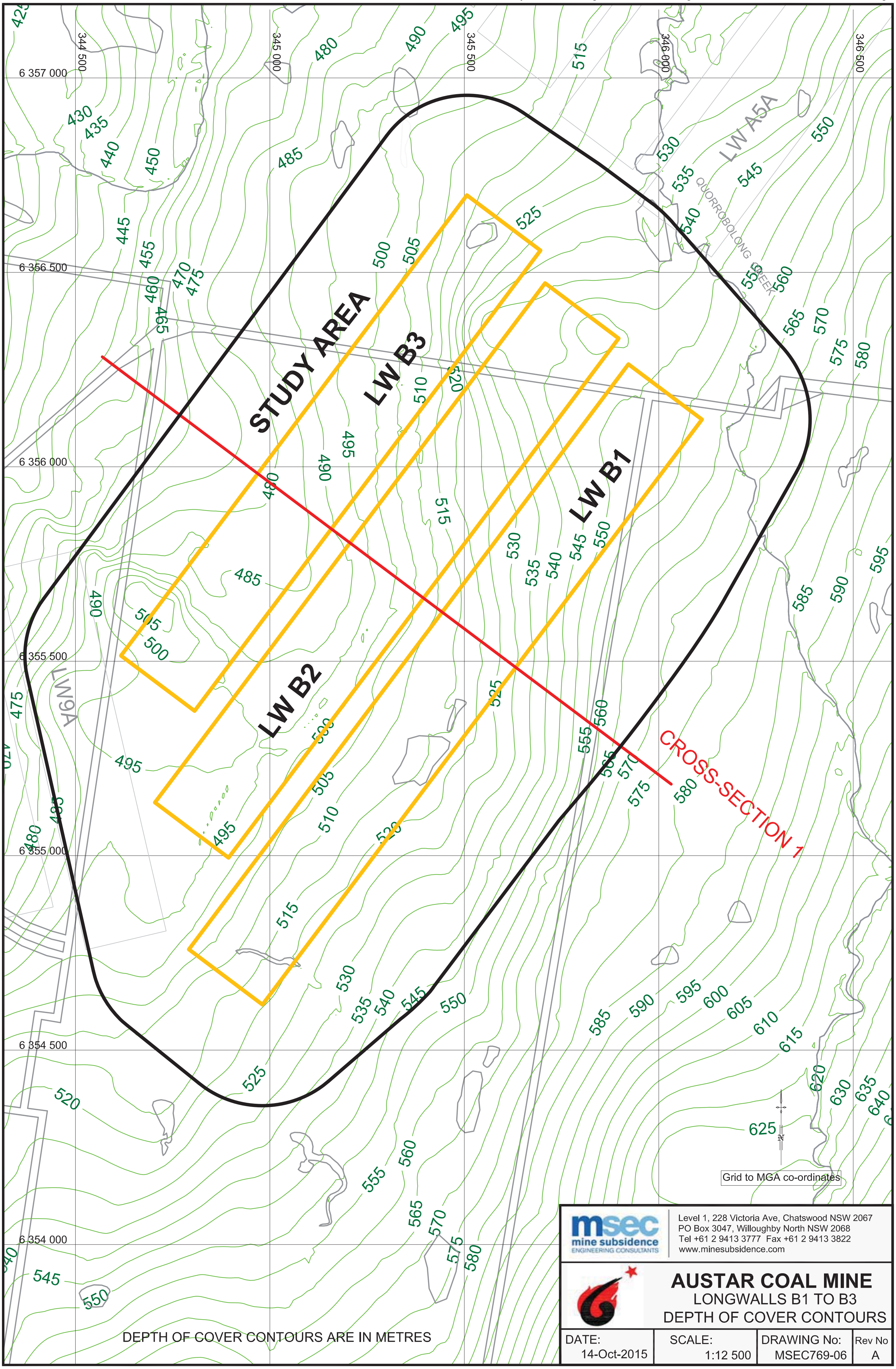

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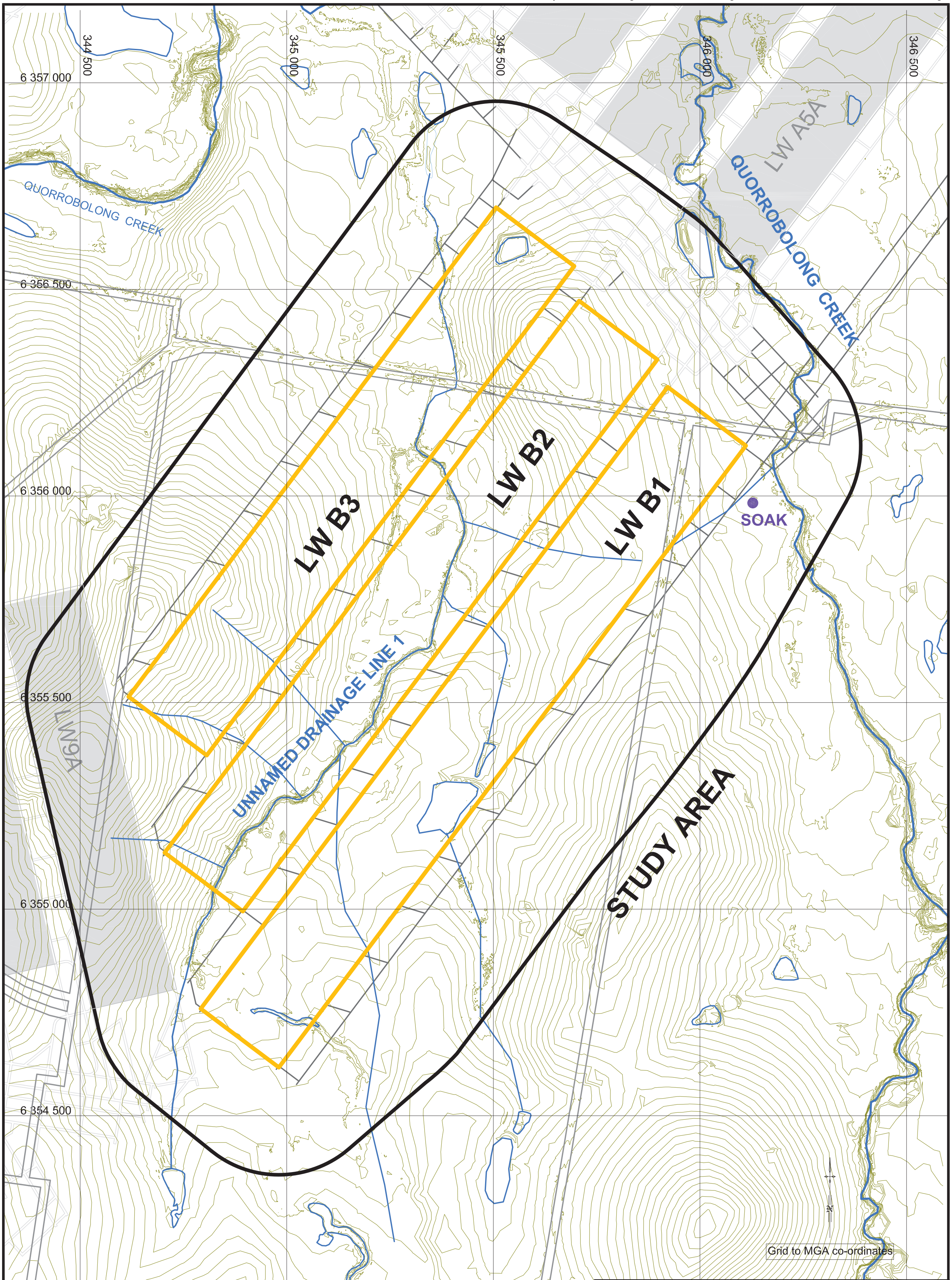

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AUSTAR COAL MINE
LONGWALLS B1 TO B3
NATURAL FEATURES

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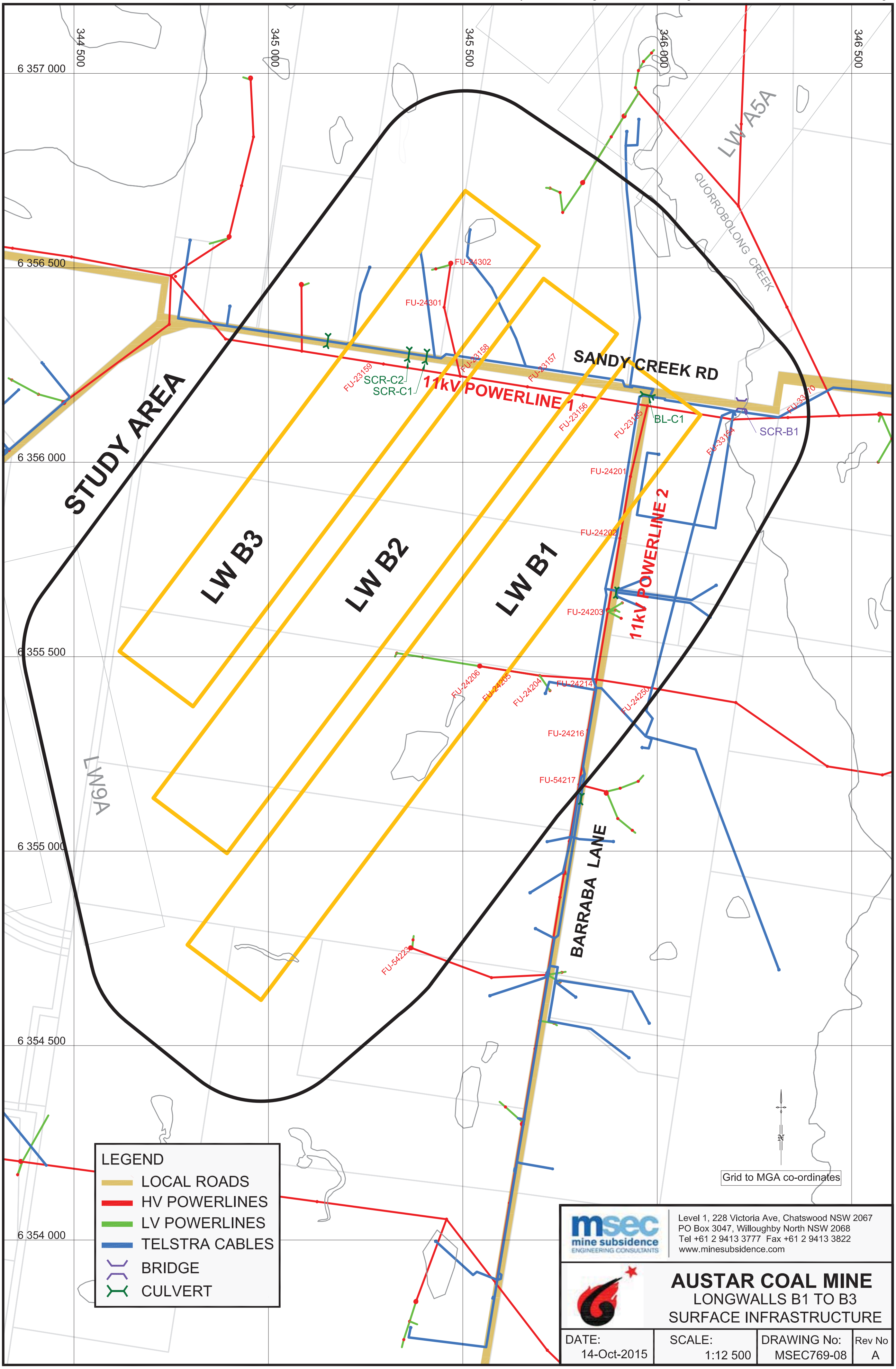

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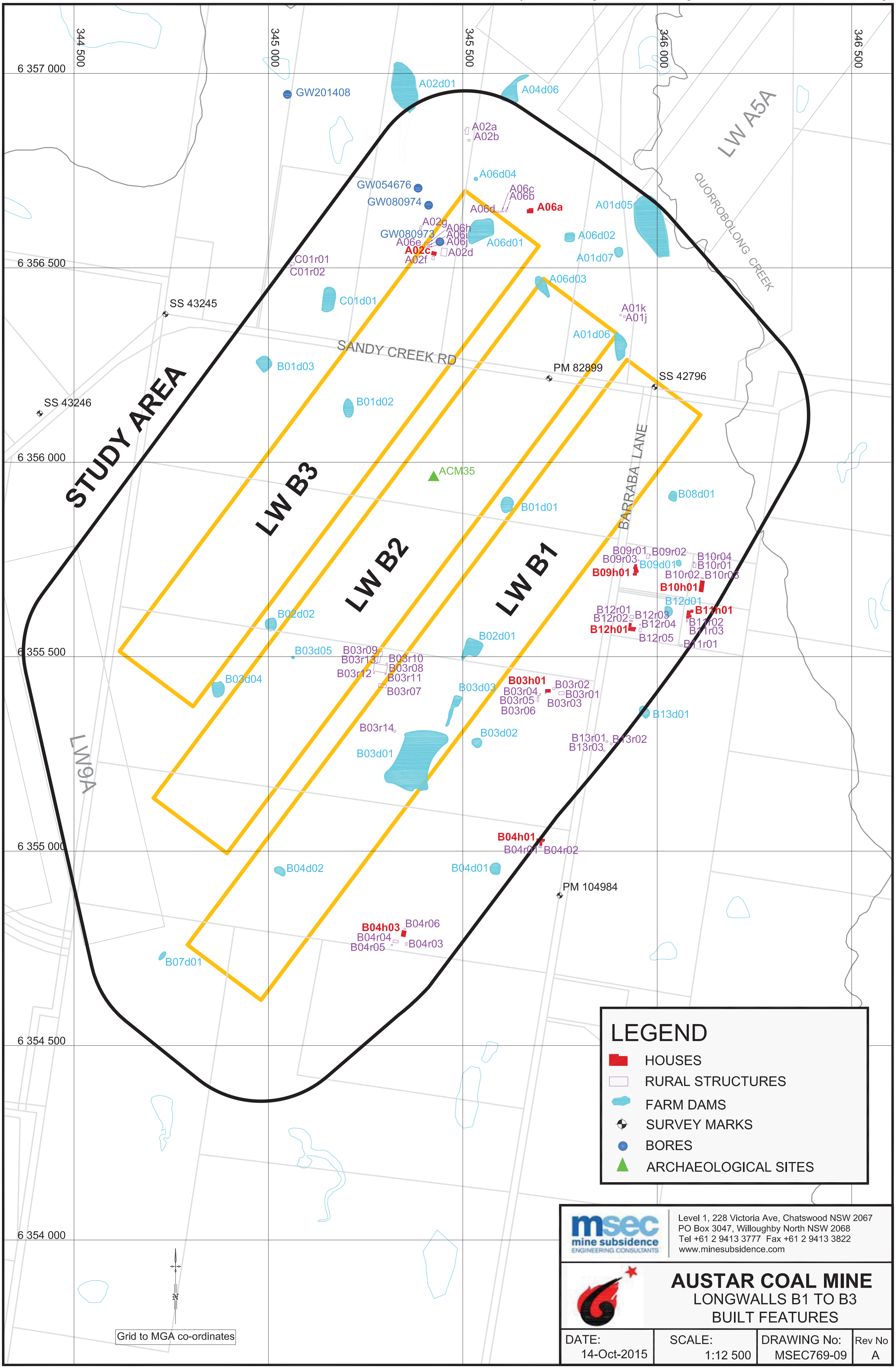

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AUSTAR COAL MINE
LONGWALLS B1 TO B3
BUILT FEATURES

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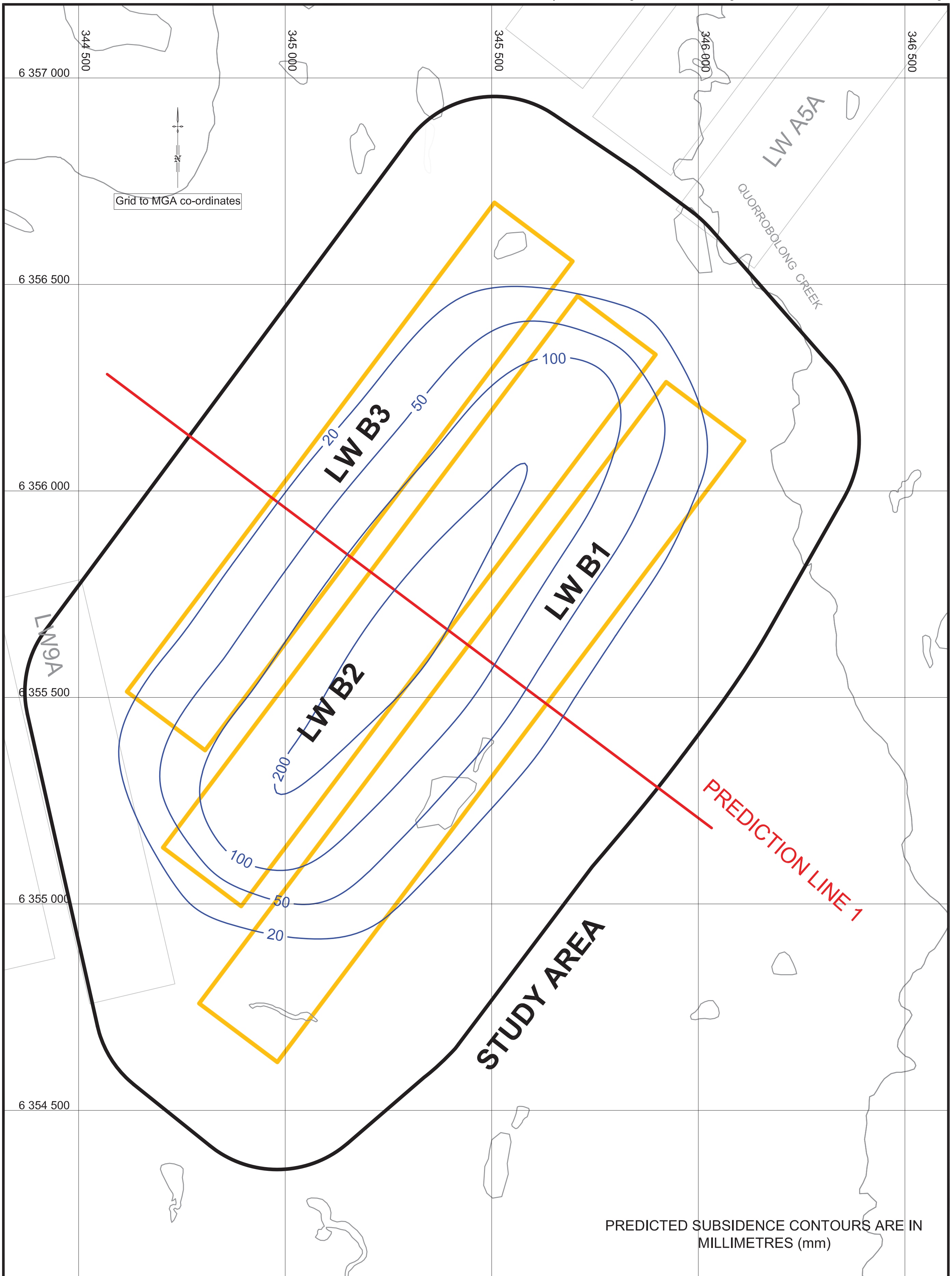

Note: Contours show the predicted vertical subsidence due to LWB1 & LWB2 only, hence do not include the movements due to previously extracted longwalls at Ellalong Colliery or Austar Coal Mine.

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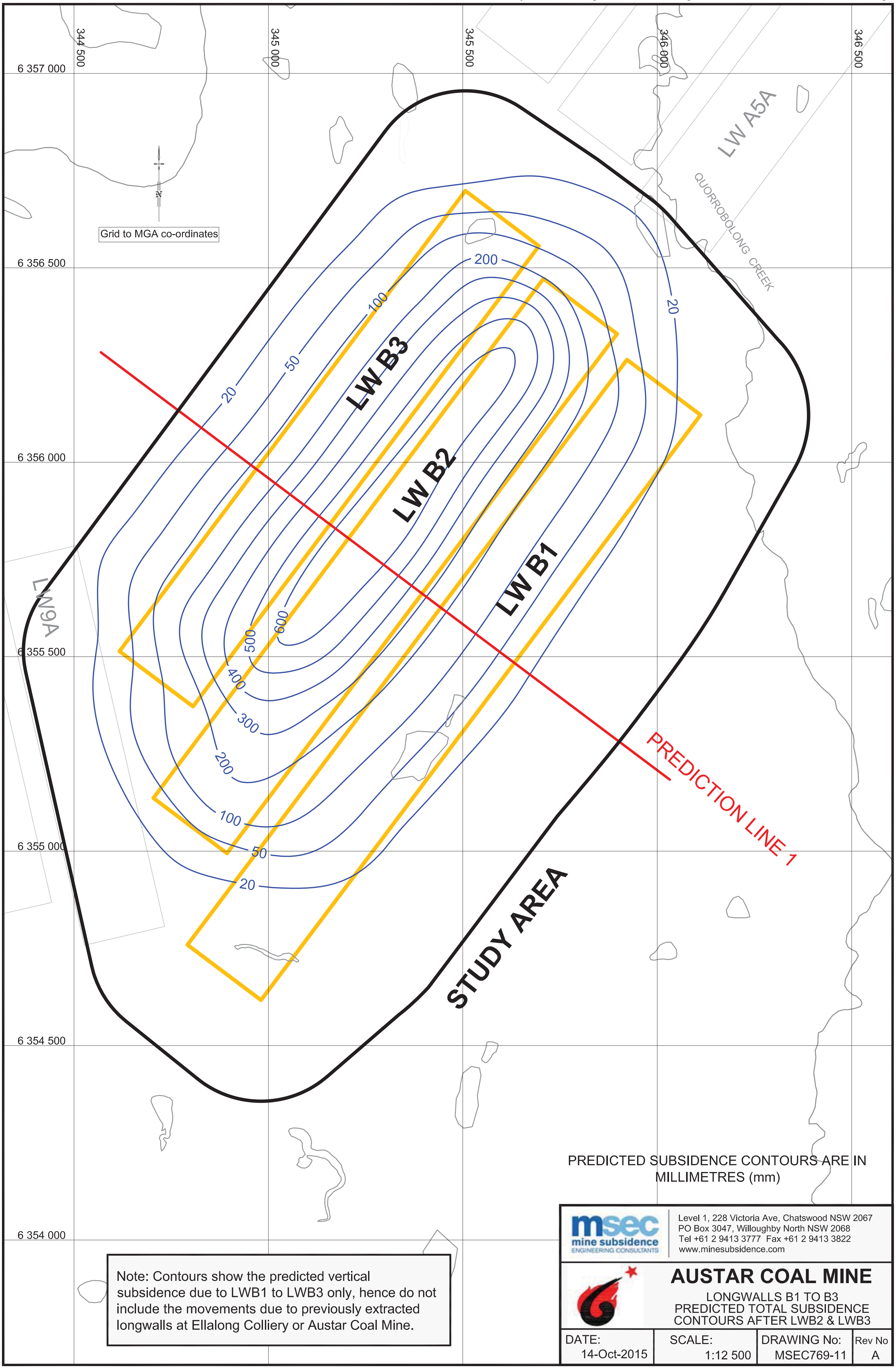
AUSTAR COAL MINE

LONGWALLS B1 TO B3
PREDICTED SUBSIDENCE CONTOURS
AFTER LWB2

DATE:	SCALE:	DRAWING No:	Rev No
14-Oct-2015	1:12 500	MSEC769-10	A



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AUSTAR COAL MINE

LONGWALLS B1 TO B3
PREDICTED TOTAL SUBSIDENCE
CONTOURS AFTER LWB2 & LWB3

DATE:	SCALE:	DRAWING No:	Rev No
14-Oct-2015	1:12 500	MSEC769-11	A

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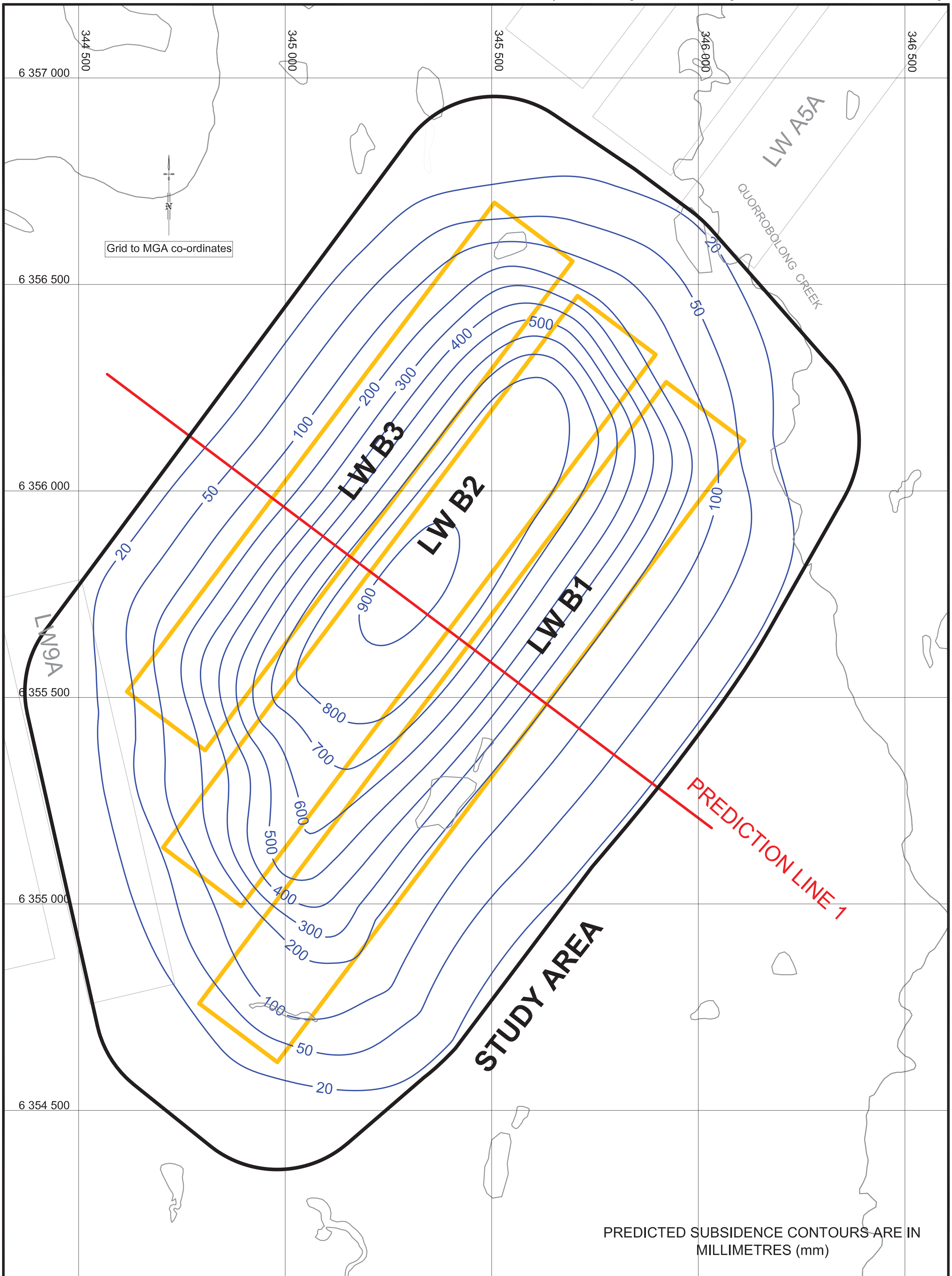

Note: Contours show the predicted vertical subsidence due to LWB1 to LWB3 only, hence do not include the movements due to previously extracted longwalls at Ellalong Colliery or Austar Coal Mine.

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AUSTAR COAL MINE

LONGWALLS B1 TO B3
PREDICTED TOTAL SUBSIDENCE
CONTOURS AFTER LWB2, LWB3 & LWB1

DATE:	SCALE:	DRAWING No:	Rev No
14-Oct-2015	1:12 500	MSEC769-12	A

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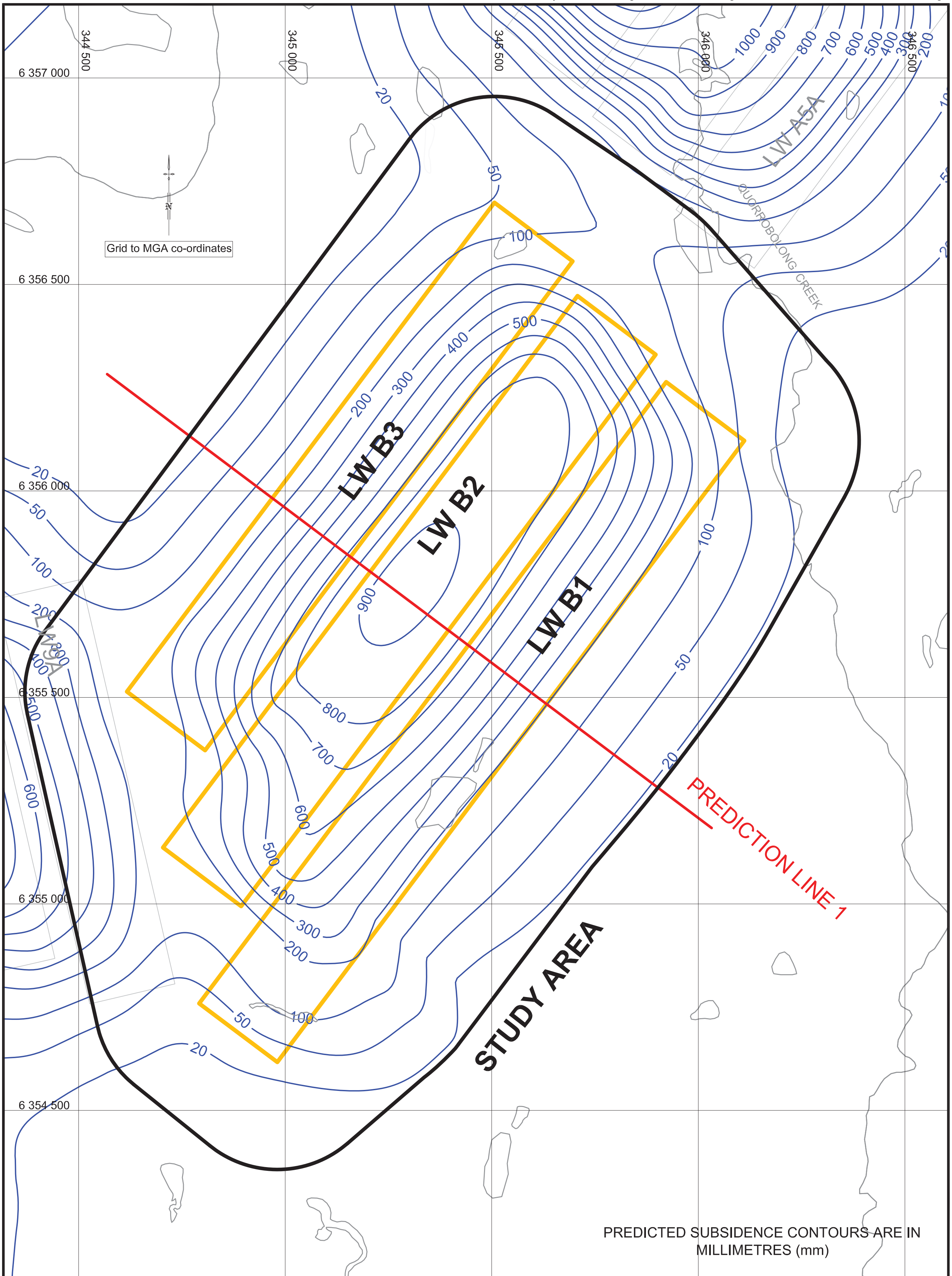

Note: Contours show the predicted vertical subsidence due to LWB1 to LWB3 only, hence do not include the movements due to previously extracted longwalls at Ellalong Colliery or Austar Coal Mine.

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AUSTAR COAL MINE

LONGWALLS B1 TO B3
PREDICTED TOTAL SUBSIDENCE CONTOURS
AFTER LWB2, LWB3 & LWB1
AND EXISTING LONGWALLS

DATE:	SCALE:	DRAWING No:	Rev No
14-Oct-2015	1:12 500	MSEC769-13	A