APPENDIX 5

Subsidence Impact Assessment

Austar Coal Mine Pty Limited

REPORT

on

THE PREDICTION OF SUBSIDENCE PARAMETERS AND THE ASSESSMENT OF MINE SUBSIDENCE IMPACTS ON THE NATURAL FEATURES AND SURFACE INFRASTRUCTURE RESULTING FROM THE EXTRACTION OF THE PROPOSED LONGWALL A5A IN STAGE 2 AT THE AUSTAR COAL MINE

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Associated reports:- MSEC275 (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 Proposed Austar Longwalls A3 to A5 in Support of a SMP Application (February 2007).

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).

MSEC380 (Letter Report) – Proposed Modification to the Commencing End of Longwall A4 (October 2008).

MSEC389 (Revision B) – End of Panel Subsidence Monitoring Report for Austar Longwalls A1 and A2 (January 2009).

MSEC391 (Revision B) **-** The Effects of the Proposed Modifications to Longwalls A4 and A5 in Stage 2 at Austar Mine on the Subsidence Predictions and Impact Assessments (February 2009).

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)

EXECUTIVE SUMMARY

Austar Coal Mine (Austar) is currently extracting Longwall A3 in Stage 2 at the Colliery using Longwall Top Coal Caving (LTCC) mining techniques. Austar then proposes to extract Longwalls A4 and A5, which were the subject of a previous application. The predictions and impact assessments for Longwalls A3 to A5 were provided in Report No. MSEC275 (Revision C), which was issued in February 2007, in support of the SMP Application. The overall lengths, void widths and chain pillar widths have since been modified, as described in Reports Nos. MSEC380 and MSEC391, which were issued in October 2008 and February 2009, respectively, in support of these modifications.

Austar now proposes to extract an additional longwall in Stage 2, referred to as Longwall A5a, which is located immediately to the south-east of Longwalls A3 to A5. The locations of these longwalls are shown in Drawing No. MSEC417-01 in Appendix C. Longwall A5a is proposed to be extracted from within the Greta Seam using Longwall Top Coal Caving mining techniques.

There are a number of natural features and items of surface infrastructure in the vicinity of the proposed Longwall A5a, including Quorrobolong and Cony Creeks, steep slopes, 11 kV powerlines and consumer lines, aerial and direct buried copper telecommunications cables, farm dams, houses and non-residential structures.

The assessed impacts on the natural features and items of surface infrastructure, resulting from the extraction of the proposed Longwall A5a, could be managed with the implementation of suitable management strategies. It is expected that the management strategies which have been developed for Longwalls A3 to A5 could be extended to include the proposed Longwall A5a.

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Drawings

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

CHAPTER 1. INTRODUCTION

1.1. Background

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by Austar Coal Mine (Austar) to undertake subsidence predictions and impact assessments for Longwalls A3 to A5, in support of the SMP Application. Report No. MSEC275 (Revision C) was issued on the 2nd February 2007 on completion of that work. The Department of Primary Industries, now called the Department of Industry and Investment (DII), gave Austar first workings approval for Longwall A3 on the 3rd March 2008 and approval to mine Longwall A3 on the 3rd February 2009. The extraction of Longwall A3 commenced on the 16th February 2009.

Austar previously proposed to modify the length of Longwall A4 by extending the commencing (north-eastern) end by 20 metres. A letter report was issued by MSEC on the 13th October 2008 to support the proposed modification of Longwall A4. The DII gave Austar approval for the modification of the first workings for Longwall A4 on the 26th May 2009.

Austar then proposed to modify Longwalls A4 and A5 by increasing the longwall void widths, by increasing the chain pillar width between these longwalls and by slightly shortening the overall length of Longwall A5. Report No. MSEC391 (Revision B) was issued on the 13th February 2009 in support of these modifications. The Department of Planning gave Austar approval for the modification of DA 29/95 in accordance with this application on the 28th May 2009.

Austar now proposes to extract an additional longwall in Stage 2, referred to Longwall A5a, which is located immediately to the south-east of Longwalls A3 to A5. The locations of these longwalls are shown in Drawing No. MSEC417-01 in Appendix C. The longwall is proposed to be extracted within the Greta Seam using Longwall Top Coal Caving (LTCC) mining techniques.

MSEC has been commissioned by Austar to study the mining proposals, identify all natural features and surface infrastructure above the proposed longwall, and to prepare subsidence predictions and impact assessments for the features that could be affected by the extraction of the proposed longwall.

1.2. Mining Geometry

The location of the proposed Longwall A5a is shown in Drawing No. MSEC417-01 in Appendix C. A summary of the dimensions of the proposed Longwall A5a, as well as the previous Longwalls A3 to A5, is provided in Table 1.1.

Table 1.1 Summary the Proposed and Previous Longwall Dimensions

Longwall	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
A3 to A5	950 ~ 1330	225 ~ 235	45 ~ 60
A5a	735	235	60

The depth of cover to the Greta Seam directly above Longwall A5a varies between a minimum of 530 metres, at the northern corner, and a maximum of 560 metres, at the southern corner of the proposed longwall. The depth of cover above Longwalls A3 to A5 varies between 485 metres and 530 metres. The seam floor within Stage 2 generally dips from the north-west to the south-east.

The seam thickness within the proposed mining area of Longwall A5a varies between a minimum of 5.5 metres, at the finishing (south-western) end, and a maximum of 6.0 metres, at the commencing (north-eastern) end of the proposed longwall. The seam thickness within the proposed mining areas of Longwalls A3 to A5 varies between 4.8 metres and 6.8 metres. It is proposed that the LTCC equipment will be used to extract the bottom 3 metres of the seam and recover approximately 85 % of the remaining top coal.

1.3. Geological Details

The Stage 2 longwalls lie in the Newcastle Coalfield within the Northern Sydney Basin. The 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 to Middle Triassic Periods.

The longwalls 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 consist 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).

The major geological features within the vicinity of the proposed longwall are shown in Drawing No. MSEC417-01. No major faults or dykes have been identified within the proposed extraction area of Longwall A5a. The *Central Dyke* is located immediately to the east of the Stage 2 longwalls. The *Swamp Fault Zone* is located to the west of the Stage 2 longwalls, which is at a distance of approximately 250 metres from the proposed Longwall A5a at its nearest point.

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

<table>
<tr><th colspan="3">STRATIGRAPHY</th><th rowspan="2">LITHOLOGY</th></tr>
<tr><th>Group</th><th>Formation</th><th>Coal Seams</th></tr>
<tr><td>Narrabeen Group</td><td>Clifton</td><td></td><td>Sandstone, siltstone, mudstone, claystone</td></tr>
<tr><td rowspan="9">Newcastle Coal Measures</td><td>Moon Island Beach</td><td>Vales Point
Wallarah
Great Northern</td><td>Sandstone, shale, conglomerate, claystone, coal</td></tr>
<tr><td colspan="2">Awaba Tuff</td><td>Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone, chert</td></tr>
<tr><td>Boolaroo</td><td>Fassifern
Upper Pilot
Lower Pilot
Hartley Hill</td><td>Conglomerate, sandstone, shale, claystone, coal</td></tr>
<tr><td colspan="2">Warners Bay Tuff</td><td>Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone, chert</td></tr>
<tr><td>Adamstown</td><td>Australasian
Montrose
Wave Hill
Fern Valley
Victoria Tunnel</td><td>Conglomerate, sandstone, shale, claystone, coal</td></tr>
<tr><td colspan="2">Nobbys Tuff</td><td>Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone chert</td></tr>
<tr><td>Lambton</td><td>Nobbys
Dudley
Yard
Borehole</td><td>Sandstone, shale, minor conglomerate, claystone, coal</td></tr>
<tr><td colspan="2">Waratah Sandstone</td><td>Sandstone</td></tr>
<tr style="display:none"><td></td></tr>
<tr><td rowspan="3">Tomago Coal Measures</td><td>Dempsey</td><td></td><td rowspan="3">Shale, siltstone, fine sandstone, coal, and minor tuffaceous claystone</td></tr>
<tr><td>Four Mile Creek</td><td></td></tr>
<tr><td>Wallis Creek</td><td></td></tr>
<tr><td rowspan="3">Maitland Group</td><td colspan="2">Mulbring Siltstone</td><td>Siltstone</td></tr>
<tr><td colspan="2">Muree Sandstone</td><td>Sandstone</td></tr>
<tr><td>Braxton</td><td></td><td>Sandstone, and siltstone</td></tr>
<tr><td rowspan="4">Greta Coal Measures</td><td>Paxton</td><td>Pelton</td><td rowspan="3">Sandstone, conglomerate, and coal</td></tr>
<tr><td>Kitchener</td><td>Greta</td></tr>
<tr><td>Kurri Kurri</td><td>Homeville</td></tr>
<tr><td colspan="2">Neath Sandstone</td><td>Sandstone</td></tr>
<tr><td rowspan="4">Dalwood Group</td><td>Farley</td><td></td><td rowspan="4">Shale, siltstone, lithic sandstone, conglomerate, minor marl and coal, and interbedded basalts, volcanic breccia, and tuffs</td></tr>
<tr><td>Rutherford</td><td></td></tr>
<tr><td>Allandale</td><td></td></tr>
<tr><td>Lochinvar</td><td></td></tr>
<tr><td colspan="4">Seaham Formation</td></tr>
</table>

CHAPTER 2. IDENTIFICATION OF SURFACE FEATURES

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 Longwall A5a 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 26½ degree angle of draw line from the proposed extents of Longwall A5a,
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour resulting from the extraction of the proposed Longwall A5a, and
- Features sensitive to far-field movements.

The 26½ degree angle of draw line is described as the "surface area defined by the cover depths, angle of draw of 26½ degrees, and the limit of the proposed extraction area in mining leases of (the Newcastle Coalfield)", as stated in Section 6.2 of the Department of Primary Industries (now the DII) SMP Guideline 2003. Given that the depth of cover above the proposed longwall varies between 530 metres and 560 metres, the 26½ degree angle of draw line has been determined by drawing a line that is a horizontal distance varying between 265 metres and 280 metres around the limit of the proposed extraction area.

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

The predicted 20 mm subsidence contour is, therefore, located outside the 26½ degree angle of draw line adjacent to the longitudinal edges of the proposed longwall, and is located inside the 26½ degree angle of draw line adjacent to the commencing and finishing ends of the proposed longwall. A line has therefore been drawn defining the general Study Area, based upon the 26½ degree angle of draw line and the predicted 20 mm subsidence contour, and is shown in Drawing No. MSEC417-01.

There are areas that lie outside the general 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

A summary of the natural features and items of surface infrastructure within the general Study Area is provided below:-

- Watercourses including Quorrobolong and Cony Creeks,
- Steep slopes,
- Electrical infrastructure comprising 11 kV powerlines and consumer lines,
- Telecommunications infrastructure comprising aerial and underground copper cables,
- Farm dams, and
- Houses and non-residential structures.

A summary of the features that are located outside the general Study Area and that are expected to experience far-field movements and may be sensitive to these movements is provided below:-

- Sections of Quorrobolong and Cony Creeks outside the general Study Area but within the predicted limits of the valley related movements, and
- Survey Control Marks.

The locations of the natural features and items of surface infrastructure are shown in Drawings Nos. MSEC417-02 and MSEC417-03, respectively, in Appendix C.

CHAPTER 3. OVERVIEW OF LONGWALL TOP COAL CAVING, THE DEVELOPMENT OF SUBSIDENCE, AND THE METHOD USED TO PREDICT THE MINE SUBSIDENCE PARAMETERS FOR THE PROPOSED LONGWALL

3.1. Introduction

This chapter provides a brief overview of longwall top coal caving, the development of mine subsidence, and the method that has been used to predict the subsidence movements for the proposed longwall. Further details 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*.

The maximum predicted conventional subsidence parameters within the Study Area, resulting from the extraction of the proposed longwall, are provided in Chapter 4. The predicted subsidence parameters and impact assessments for the natural features and items of surface infrastructure within the Study Area are provided in Chapter 5.

3.1.1. Overview of Longwall Top Coal Caving

Longwall Top Coal Caving (LTCC) has been developed in China over the past 20 years, and is capable of extracting seam thicknesses between 4.5 and 12.5 metres. Austar Longwalls A1 and A2 in Stage 1 have been extracted using LTCC mining techniques and Longwall A3 in Stage 2 is currently being extracted using LTCC mining techniques.

The Stage 2 longwalls are to be extracted from the Greta Seam, where the seam thickness locally varies between 5.0 and 6.8 metres within the proposed extents of the longwalls. A typical cross-section through one of the Stage 2 longwalls is shown in Fig. 3.1.

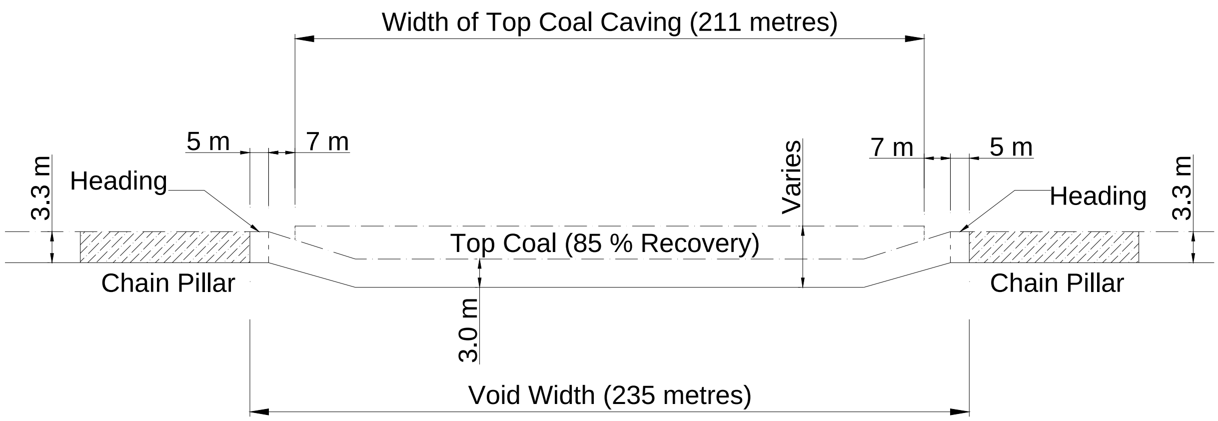

Fig. 3.1 Cross-Section through a Typical Stage 2 Longwall

The development headings are initially extracted using continuous miners, and are 5 metres wide and 3.3 metres high. The headings are extracted above the seam floor, so that the floor of the longwall panel can be tapered down, as shown in the above figure, having a 1.3 metre drop over a horizontal distance of 23 metres from the headings.

The LTCC equipment uses a conventional longwall shearer to extract the bottom 3 metres of the coal seam, which is transported from the coal face by a face conveyor. The LTCC equipment uses specially designed shields with retractable flippers to allow the coal in the roof to cave behind the shields, which is transported by a second conveyor located behind the shields. A recovery of approximately 85 % of the top coal is generally achieved within the void width which is 12 metres clear of each chain pillar. Although the seam thickness varies between 5.0 and 6.8 metres within the proposed extents of the Stage 2 longwalls, the extracted seam thickness adjacent to the proposed chain pillars is only 3.3 metres.

The strata behind the shields, immediately above the coal seam, is allowed to collapse into the void that is left as the coal face retreats. The collapsed zone comprises loose blocks and can contain large voids. Immediately above the collapsed zone, the strata remains relatively intact and bends into the void, resulting in new vertical fractures, opening up of existing vertical fractures, and bed separation. The amount of strata sagging, fracturing, and bed separation reduces towards the surface.

The Stage 2 longwalls width-to-depth ratios vary between 0.4 and 0.5, which are subcritical and, therefore, the depths of cover are sufficiently thick to allow the upper levels of strata to span between the chain pillars. The subsidence above these longwalls, therefore, will develop primarily as the result of pillar squashing, rather than as the result of sag subsidence.

At the surface, the ground subsides vertically as well as moves horizontally towards the centre of the mined goaf area. The maximum subsidence at the surface varies, depends on a number of factors including longwall geometry, depth of cover, extracted seam thickness and overburden geology. The maximum achievable subsidence in the Newcastle Coalfield is typically between 55 % to 65 % of the extracted seam thickness. The maximum predicted subsidence resulting from the extraction of the Stage 2 longwalls is less than this maximum achievable subsidence, since the proposed longwalls are subcritical.

3.2. Overview of Conventional Subsidence Parameters

The *conventional* or *systematic* mine subsidence movements resulting from the extraction of longwalls are typically described by the following parameters:-

- **Subsidence** usually refers to the 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, 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 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.

- **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 horizontal 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 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.

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.

A cross-section through a typical single longwall panel showing typical profiles of subsidence, tilt, curvature and strain is provided in Fig. 3.2.

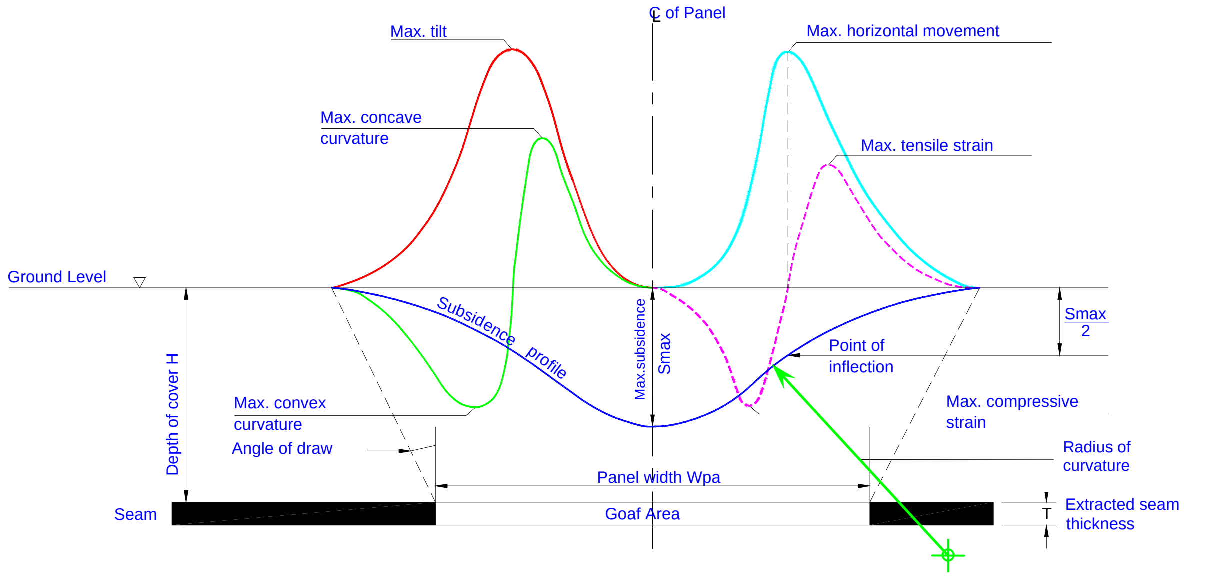

Fig. 3.2 Typical Profiles of Conventional Subsidence Parameters for a Single Longwall Panel

3.3. Far-field Horizontal Movements

In addition to the conventional horizontal movements which occur above and adjacent to extracted longwalls, far-field horizontal movements have been observed at considerable distances from extracted longwalls. Such movements are predictable and occur whenever significant excavations occur at the surface or underground.

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 significant impacts, except where they occur at large structures which are very sensitive to differential horizontal movements.

3.4. Overview of Non-Conventional Subsidence Movements

Non-conventional subsidence movements include irregular subsidence movements and valley related movements. These movements are briefly described below and further details are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

3.4.1. Irregular Subsidence Movements

Irregular subsidence movements can result from near surface geological structures, including faults, dykes and abrupt changes in geology. The presence of these features near the surface can result in a bump in the subsidence profile, which is accompanied by locally higher tilts, curvatures and strains.

In many cases it is possible to determine the cause of observed irregular ground movements, but there remain some observed irregular ground movements that cannot be explained with the available geological information. The term *anomalous movement* refers to irregular ground movements that cannot be explained with by the available geological information.

The non-conventional tilts and strains resulting from irregular subsidence movements can be much greater than those resulting from the normal conventional subsidence movements. Irregular subsidence movements, and the impacts resulting from such movements, are described further in Section 5.12.4.

3.4.2. Valley Related Movements

The creeks and tributaries 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. 3.3. The potential for these natural movements are influenced by the geomorphology of the valley.

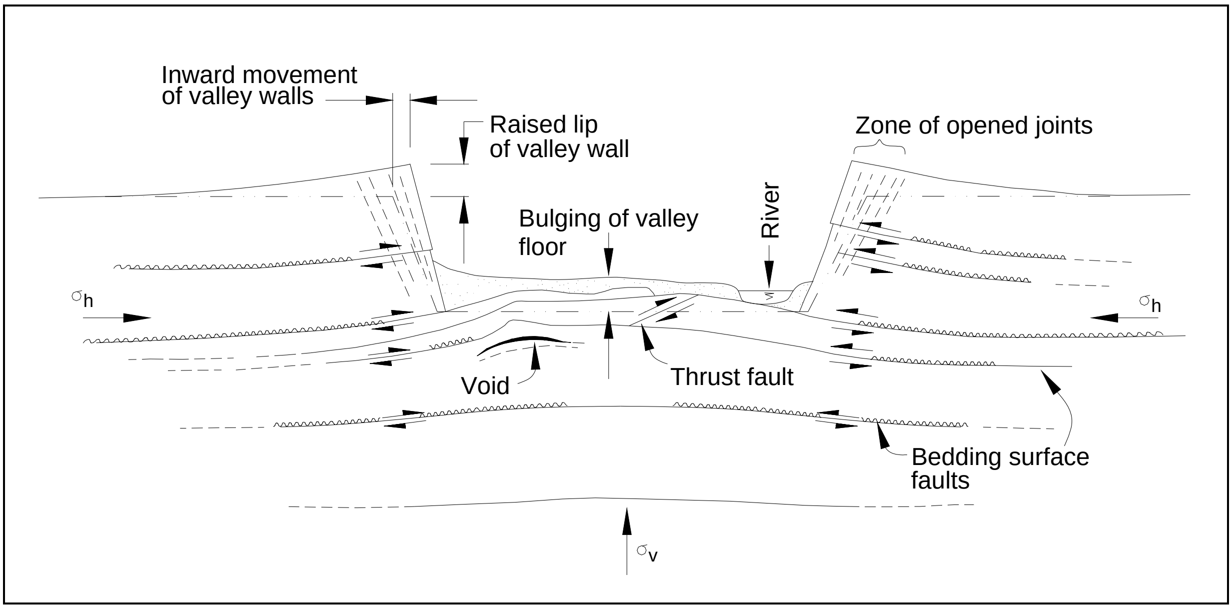

Fig. 3.3 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

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 the result of valley closure and upsidence movements. **Tensile Strains** also occur at the tops of the valleys as the 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. 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.

The predicted valley related movements resulting from the extraction of the Stage 2 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 predicted conventional subsidence parameters for the Stage 2 longwalls were determined using the calibrated Incremental Profile Method. The Incremental Profile Method is an empirical model which was developed by MSEC, when previously trading as Waddington Kay and Associates. The standard Incremental Profile Method is briefly described below and further details can be obtained from 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*.

The standard Incremental Profile Method is based on a large database of observed monitoring data from previously extracted longwalls within the Southern, Newcastle, Hunter and Western Coalfields of New South Wales. The database consists of detailed subsidence monitoring data from Collieries including: Angus Place, Appin, Baal Bone, Bellambi, Beltana, Bulli, Chain Valley, Clarence, Coalcliff, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong (now Austar), Fernbrook, Glennies Creek, Gretley, Invincible, John Darling, Kemira, Lambton, Liddell, Metropolitan, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, South Bulga, South Bulli, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, West Cliff, West Wallsend and Wyee.

The empirical database includes the subsidence profiles measured from conventional longwall mining, having extraction heights varying from less than 2 metres up to 5 metres. Of these observed subsidence profiles, 7 % are for cases having seam extraction heights of less than 2 metres, 74 % are for cases having seam extraction heights between 2 and 3 metres, 15 % are for cases having seam extraction heights between 3 and 4 metres, and 4 % are for cases having seam extraction heights between 4 and 5 metres.

The Incremental Profile Method was calibrated to local conditions using monitoring data from the previously extracted longwalls at the Colliery, which included Longwalls SL1 to SL4 and Longwalls 1 to 13A. The model was also calibrated for LTCC mining, which has a greater extraction height when compared to the previously extracted longwalls at the Colliery and when compared to the previously extracted longwalls elsewhere in the NSW Coalfields. Details of the calibration method are provided in Report No. MSEC275 (Revision C), which supported the SMP Application for Longwalls A3 to A5.

Subsequent to the issue of Report No. MSEC275, the extraction of Austar Stage 1 Longwalls A1 and A2 were completed using LTCC mining techniques. The comparisons between the observed movements and those predicted using the Incremental Profile Method were provided in Report No. MSEC389 (Revision B), which was issued in January 2009. A brief overview of these comparisons is provided below.

The mine subsidence movements were monitored during the extraction of Austar Stage 1 Longwalls A1 and A2. The comparisons between the observed and predicted movements along Line 1A, Line 1B and Line 2 are provided in Fig. 3.4, Fig. 3.5 and Fig. 3.6, respectively.

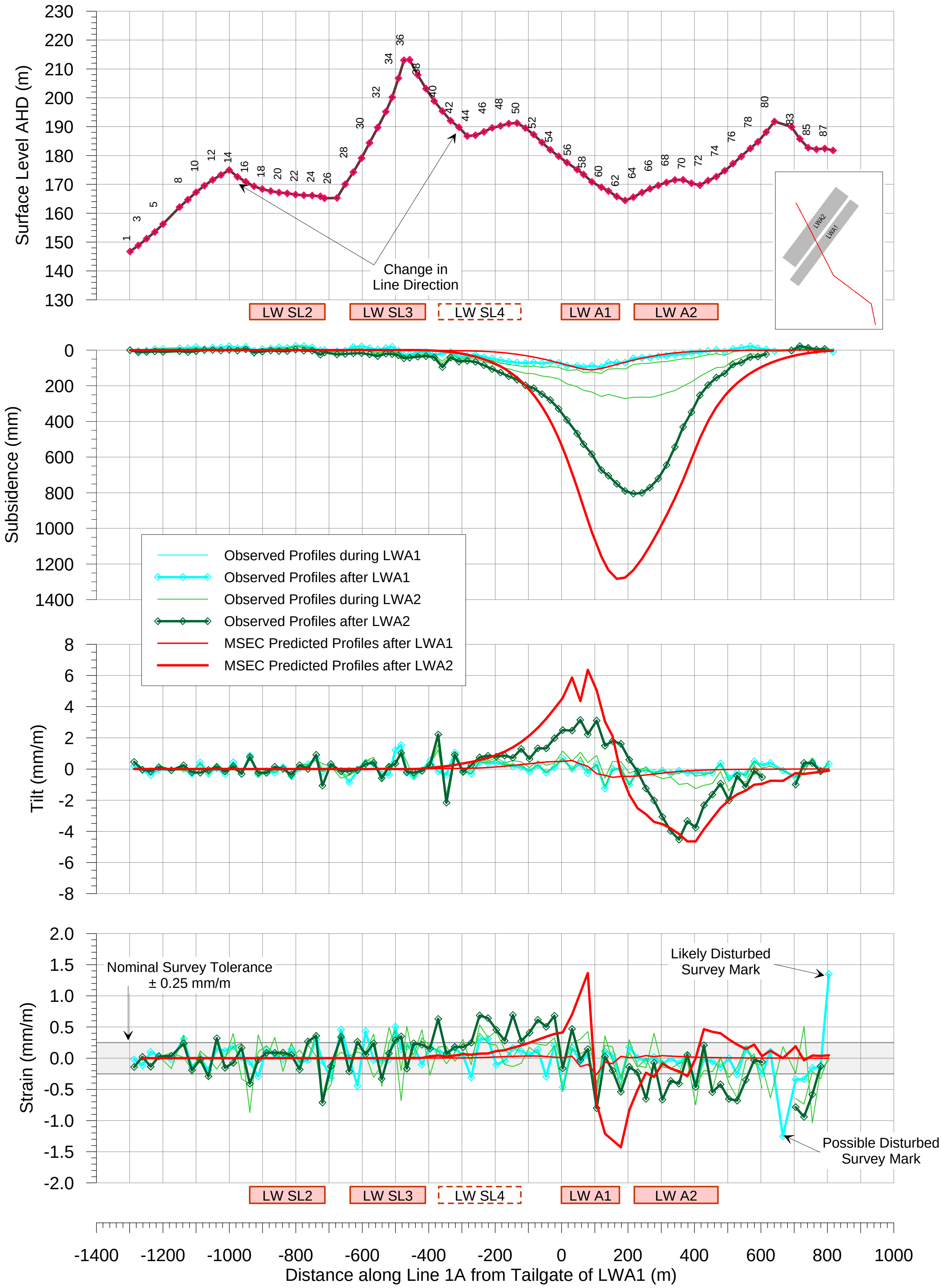

Fig. 3.4 Comparisons between the Observed and Predicted Subsidence, Tilt and Strain along Line 1A Resulting from the Extraction of Longwall A1

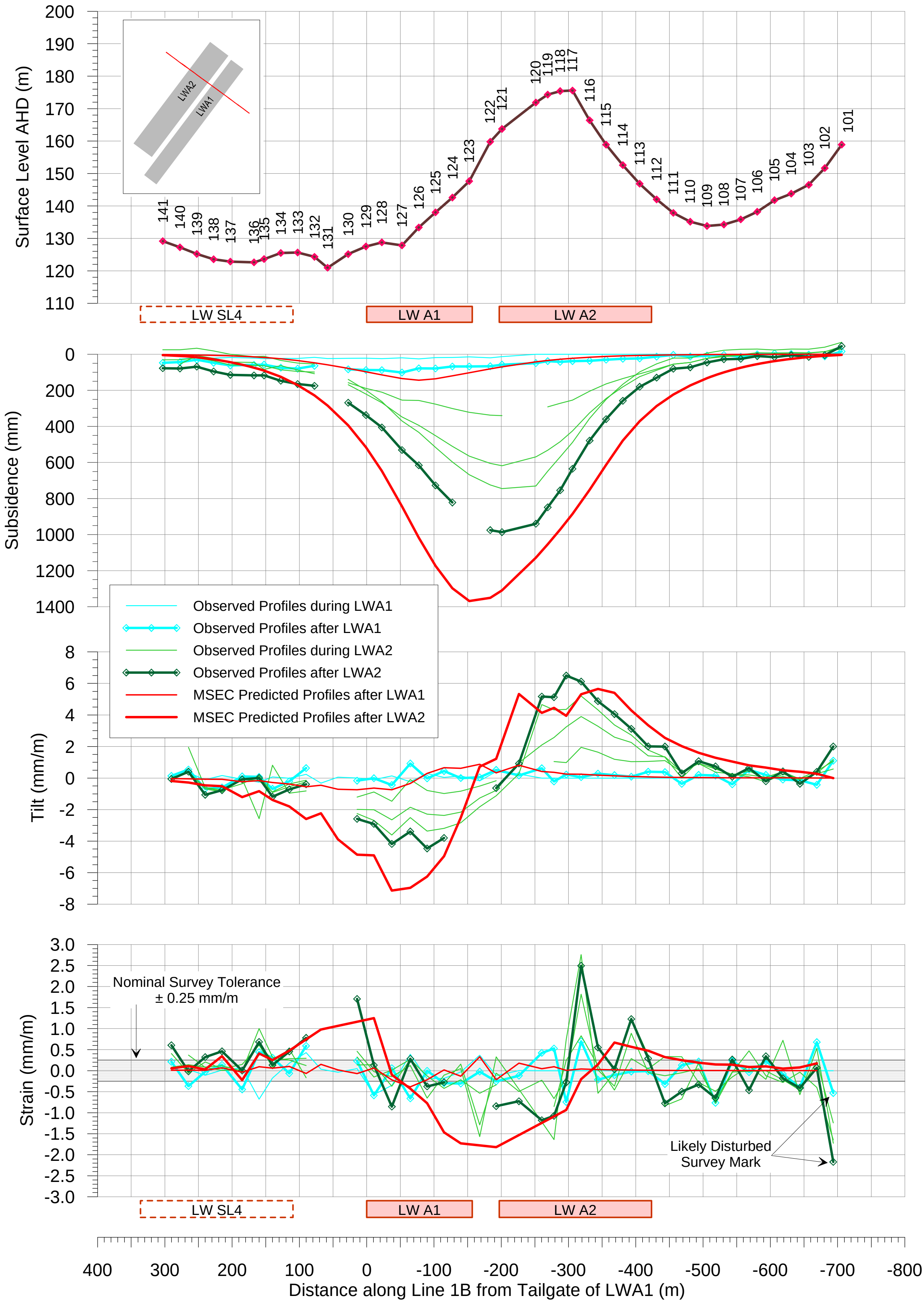

Fig. 3.5 Comparisons between the Observed and Predicted Subsidence, Tilt and Strain along Line 1B Resulting from the Extraction of Longwall A1

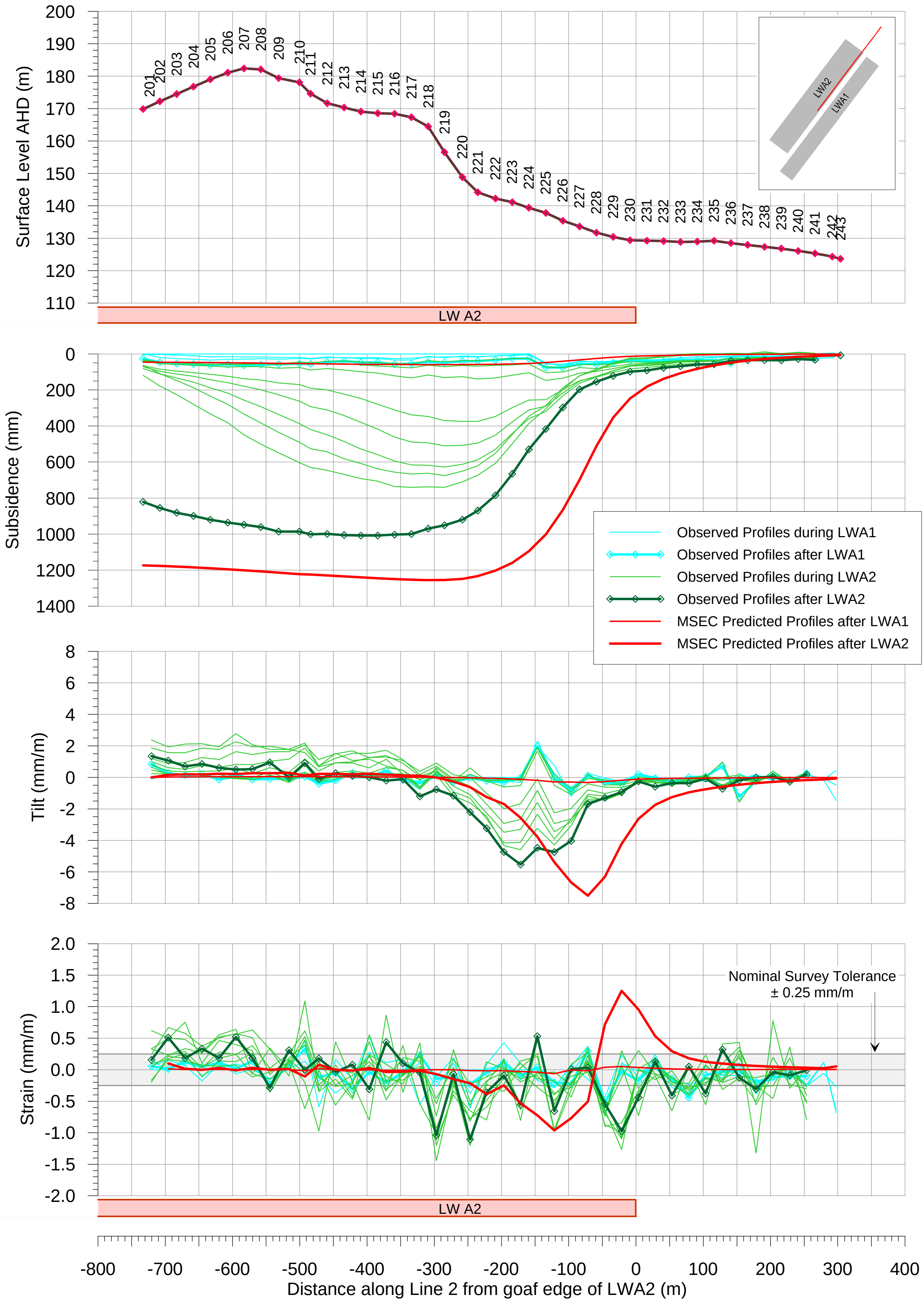

Fig. 3.6 Comparisons between the Observed and Predicted Subsidence, Tilt and Strain along Line 2 Resulting from the Extraction of Longwall A1

It can be seen from the above figures, that the maximum observed subsidence along the monitoring lines were typically less than those predicted using the calibrated Incremental Profile Method. The only exception was the maximum observed subsidence along Line 2, after the extraction of Longwall A1, of 75 mm which was slightly greater than the maximum prediction of 60 mm. As described in Section 5.22 of Report No. MSEC275, "*where subsidence is predicted at points beyond the goaf edge, which are likely to experience very low values of subsidence, the predictions should generally be accurate to within 50 mm of subsidence*".

The observed tilts, tensile strains and compressive strains along the monitoring lines, after the extraction of Longwall A1, were typically in the order of survey tolerance. There were a number of spikes in the observed profiles which appear to have resulted from disturbed survey marks.

The maximum observed tilts, tensile strains and compressive strains along the monitoring lines, after the extraction of Longwall A2, were typically less than or similar to those predicted using the calibrated Incremental Profile Method. The only exceptions were the maximum observed tensile and compressive strains along Line 1B of 2.5 mm/m and 2.2 mm/m, respectively, which were greater than the predictions of 1.3 mm/m and 1.8 mm/m, respectively. It is noted, however, that the maximum observed tensile strain occurred at the top of a ridge line and, therefore, could have been influenced by down slope movements. It is also noted, that the maximum observed compressive strain occurred approximately 250 metres north of the active longwall and, therefore, was likely to be the result of a disturbed survey mark.

CHAPTER 4. MAXIMUM PREDICTED CONVENTIONAL SUBSIDENCE PARAMETERS FOR THE PROPOSED LONGWALL

4.1. Introduction

The following sections provide the maximum predicted incremental conventional subsidence parameters due to the extraction of the proposed Longwall A5a, as well as the maximum predicted total conventional subsidence parameters after the extraction of Longwall A5a, which includes the movements resulting from the earlier Longwalls A3 to A5.

The subsidence predictions are based on the latest available surface level contours, seam floor contours and seam thickness contours, which were provided by Austar, and are shown in Drawings Nos. MSEC417-02, MSEC417-03 and MSEC417-04, respectively, in Appendix C. The predicted subsidence parameters are based on the LTCC equipment extracting the bottom 3 metres of the seam and recovering approximately 85 % of the remaining top coal.

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report 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 Chapter 5.

4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature

The predicted incremental conventional subsidence contours, resulting from the extraction of Longwall A5a only, are shown in Drawing No. MSEC417-09. A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of the proposed Longwall A5a only, is provided in Table 4.1.

Table 4.1 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature Resulting from the Extraction of Longwall A5a Only

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})
LWA5a	650	3.0	0.03	0.06

The predicted total conventional subsidence contours, resulting from the extraction of Longwalls A3 to A5a, are shown in Drawing No. MSEC417-10. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature resulting from the extraction of Longwalls A3 to A5a, is provided in Table 4.2.

Table 4.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature Resulting from the Extraction of Longwalls A3 to A5a

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})
LWA3 to LWA5	1400	5.7	0.05	0.12
LWA3 to LWA5a	1450	5.7	0.05	0.12

It should be noted, that the predicted conventional subsidence parameters for Longwalls A3 to A5 include the effects of the modified lengths and widths of these longwalls, which were subject to separate modification applications and were described in Reports Nos. MSEC380 and MSEC391. The predicted total conventional subsidence contours, resulting from the extraction of Longwalls A3 to A5a plus the approved Stage 3 longwalls, are shown in Drawing No. MSEC417-11.

4.3. Maximum Upperbound Conventional Subsidence, Tilt and Curvature

The predicted conventional subsidence parameters for a second case, referred to as the *Upperbound Case*, were previously provided for Longwalls A3 to A5 in Report No. MSEC275. The Upperbound Case, which was used for risk assessment purposes only, was determined by scaling up the predicted conventional subsidence parameters such that a maximum total subsidence of 65 % of the extracted seam thickness was achieved above the proposed longwalls. Details of the method used to determine the Upperbound Case subsidence parameters were provided in Section 3.6 in Report No. MSEC275.

A summary of the maximum upperbound values of incremental conventional subsidence, tilt and curvature, due to the extraction of the proposed Longwall A5a only, is provided in Table 4.3. A summary of the maximum upperbound values of total conventional subsidence, tilt and curvature resulting from the extraction of Longwalls A3 to A5a, is provided in Table 4.4.

Table 4.3 Maximum Upperbound Incremental Conventional Subsidence, Tilt and Curvature Resulting from the Extraction of Longwall A5a Only

Longwall	Maximum Upperbound Incremental Conventional Subsidence (mm)	Maximum Upperbound Incremental Conventional Tilt (mm/m)	Maximum Upperbound Incremental Conventional Hogging Curvature (km^{-1})	Maximum Upperbound Incremental Conventional Sagging Curvature (km^{-1})
LWA5a	1300	6.0	0.06	0.12

Table 4.4 Maximum Upperbound Total Conventional Subsidence, Tilt and Curvature Resulting from the Extraction of Longwalls A3 to A5a

Longwalls	Maximum Upperbound Total Conventional Subsidence (mm)	Maximum Upperbound Total Conventional Tilt (mm/m)	Maximum Upperbound Total Conventional Hogging Curvature (km^{-1})	Maximum Upperbound Total Conventional Sagging Curvature (km^{-1})
LWA3 to LWA5	2950	11	0.08	0.25
LWA3 to LWA5a	3000	12	0.08	0.25

It can be seen from Table 4.1 and Table 4.3, that the upperbound incremental conventional subsidence parameters, due to the extraction of Longwall A5a only, are twice the predicted incremental conventional subsidence parameters. It can also be seen from Table 4.4, that the upperbound total conventional subsidence parameters, after the extraction of Longwall A5a, are similar to but slightly greater than those after the extraction of Longwall A5.

The impact assessments based on increased predictions for the natural features and surface infrastructure, provided in Chapter 5, have been based on the upperbound subsidence parameters. That is, the impact assessments based on increased predictions have considered the case where the actual subsidence parameters exceed those predicted by a factor of up to 2 times.

4.4. Predicted Strains

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reasons for this are 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 joints at bedrock, and the depth of bedrock. Survey tolerance also represents a substantial portion of the measured strain is some cases. The profiles of observed strain can, therefore, be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

In previous MSEC subsidence reports, predictions of conventional strain have been 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 experience hogging curvature are more likely to experience tensile strains and locations that experience sagging curvature are more likely to experience compressive strains.

There is, however, considerable variation from the linear relationship. When expressed as a percentage, observed strains can be many times greater than the linear relationship for low curvatures. In this report, therefore, a statistical approach has been used to account for the variability, instead of providing a single predicted conventional strain.

The range of potential strains above the proposed longwall has been determined using monitoring data from the previously extracted longwalls at the Colliery. Longwalls A1 and A2 were extracted using LTCC mining techniques and have slightly shallower depths of cover and slightly higher seam thicknesses than the proposed longwall. The range of strains measured during the extraction of these longwalls should, therefore, provide a good indication of the range of potential strains for the proposed longwall.

The mine subsidence movements were measured along three monitoring lines during the extraction of Longwalls A1 and A2, being the Line 1A, Line 1B and Line 2. Unfortunately, three monitoring lines do not provide a sufficient sample to undertake a statistical analysis of strain.

The monitoring lines above the previously extracted Longwalls SL1 to SL4 and Longwalls 1 to 13A at the Colliery were also included in the analysis. These longwalls were extracted using conventional longwall mining techniques, where the mined seam thickness varied between 3 metres and 3.5 metres. The seam thickness for the proposed Longwall A5a varies between 5.5 metres and 6 metres, of which only 85 % of the top coal is recovered and, hence, the effective extracted seam thickness is likely to range between 5.1 metres and 5.6 metres.

Although the extracted seam thickness for Longwalls S1 to SL4 and Longwalls 1 to 13A were less than the likely effective extracted seam thickness for the proposed longwall, these previously extracted longwalls were mined at shallower depths of cover, typically ranging between 350 metres and 400 metres for Longwall SL1 and Longwalls 1 to 4, between 400 metres and 450 metres for Longwalls 5 to 9, and between 450 metres and 500 metres for Longwall 9A, Longwalls 10 to 12A and Longwalls SL2 and SL3.

The overall ground curvatures measured along the monitoring lines above Longwalls SL1 to SL4 and Longwalls 1 to 13A are similar to those predicted above the proposed longwall. In addition to this, there were a number of elevated strains measured along the monitoring lines above these longwalls, due to the presence of dykes and other geological structures. The range of strains measured during the extraction of these longwalls should, therefore, provide a reasonable indication of the range of potential strains for the proposed longwall.

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.

4.4.1. Assessment 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 survey database has been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls at the Colliery, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls.

The frequency distribution of the maximum observed tensile and compressive strains measured in survey bays above goaf is provided in Fig. 4.1. A gamma probability distribution function has been fitted to the data which is also shown in this figure.

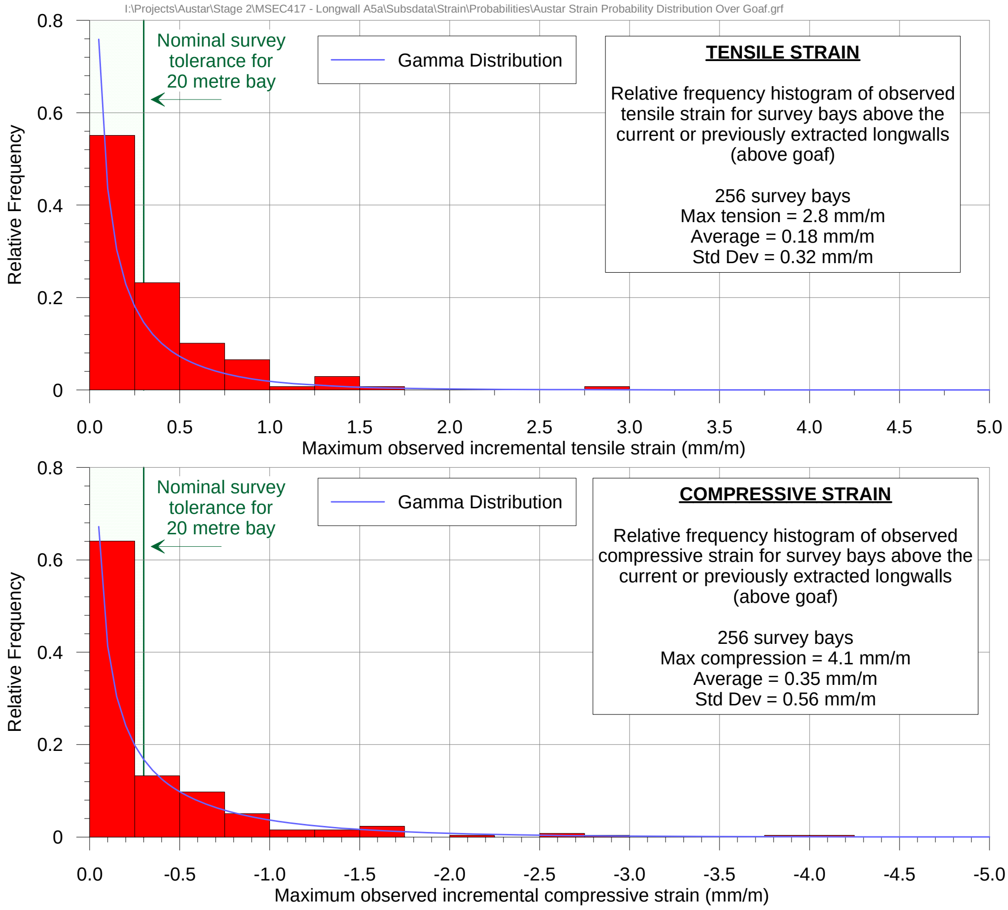

Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains at Any Time during the Extraction of Previous Longwalls at the Colliery for Marks Located Above Goaf

A summary of the probabilities of exceedance for tensile and compressive strains for survey bays located above goaf, based on these gamma probability distributions, is provided in Table 4.5.

Table 4.5 Probabilities of Exceedance for Strain for Survey Bays above Goaf

Strain (mm/m)		Probability of Exceedance
Compression	-5.0	1 in 1,500
	-4.0	1 in 500
	-3.0	1 in 150
	-2.5	1 in 80
	-2.0	1 in 40
	-1.5	1 in 20
	-1.0	1 in 10
	-0.75	1 in 7
	-0.5	1 in 5
	-0.25	1 in 3
Tension	0.25	1 in 4
	0.5	1 in 9
	0.75	1 in 15
	1.0	1 in 30
	1.5	1 in 90
	2.0	1 in 250
	2.5	1 in 700
	3.0	1 in 2,000

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls at the Colliery, 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 coal that has not been extracted by longwalls.

The frequency distribution of the maximum observed tensile and compressive strains measured in survey bays above solid coal is provided in Fig. 4.2. A gamma probability distribution function has been fitted to the data which is also shown in this figure.

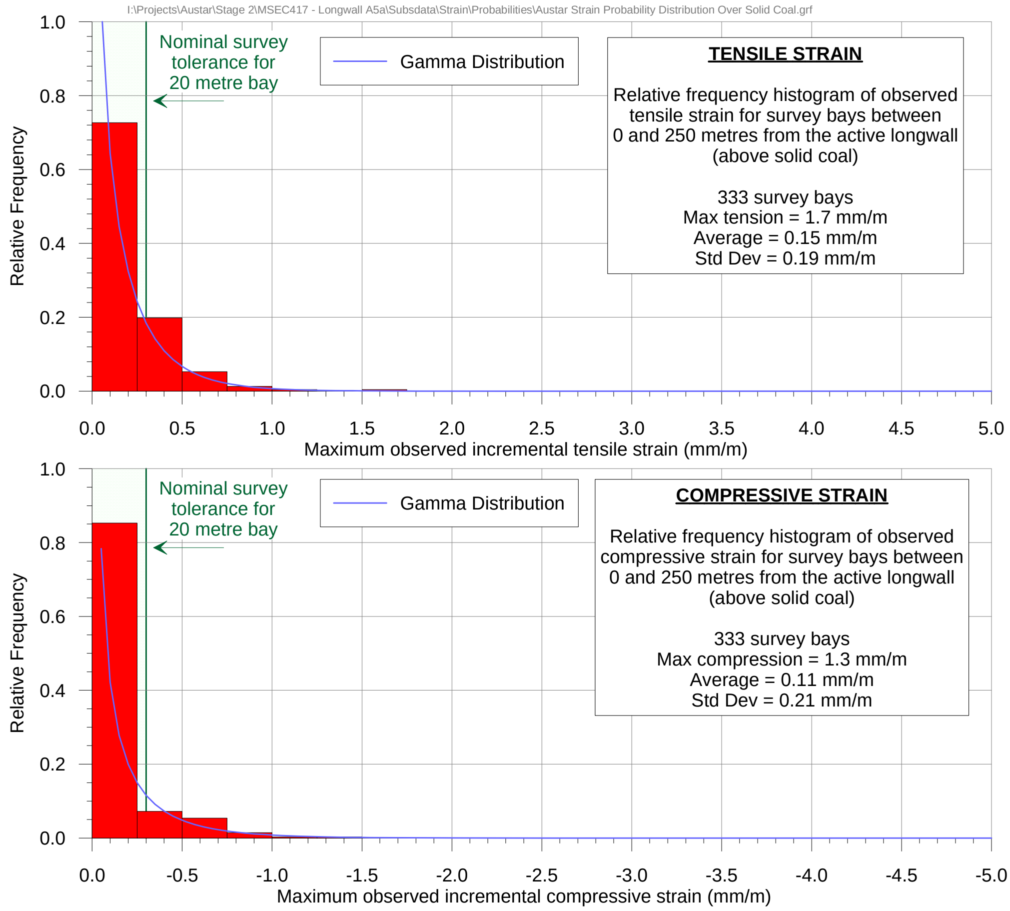

Fig. 4.2 Distributions of the Measured Maximum Tensile and Compressive Strains at Any Time during the Extraction of Previous Longwalls at the Colliery for Marks Located Above Solid Coal

A summary of the probabilities of exceedance for tensile and compressive strains for survey bays above solid coal, based these gamma probability distributions, is provided in Table 4.6.

Table 4.6 Probabilities of Exceedance for Strain for Survey Bays above Solid Coal

Strain (mm/m)		Probability of Exceedance
Compression	-1.5	1 in 400
	-1.0	1 in 100
	-0.75	1 in 40
	-0.5	1 in 20
	-0.25	1 in 7
Tension	0.25	1 in 5
	0.5	1 in 15
	0.75	1 in 50
	1.0	1 in 150
	1.5	1 in 1,300

4.4.2. 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 frequency distribution of maximum observed tensile and compressive strains measured anywhere along the monitoring lines, at any time during or after the extraction of the previous longwalls at the Colliery, is provided in Fig. 4.3.

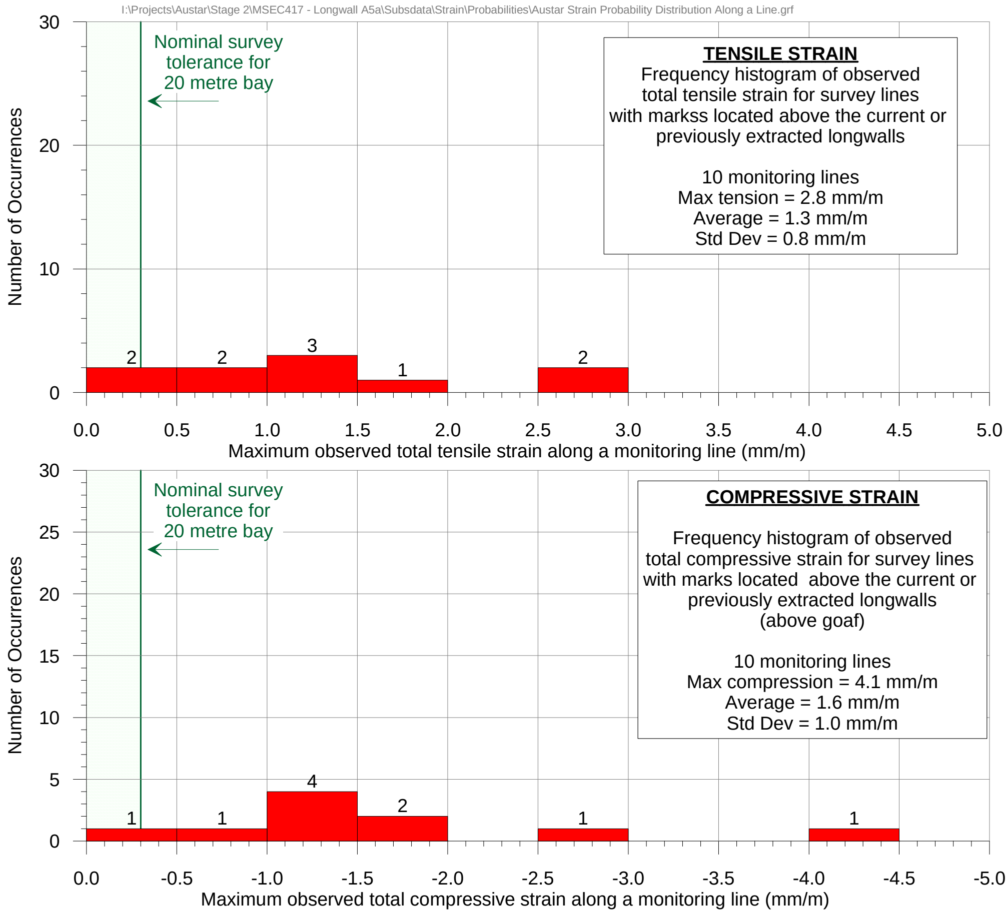

Fig. 4.3 Distributions of Measured Maximum Tensile and Compressive Strains along the Monitoring Lines at Any Time during the Extraction of Previous Longwalls at the Colliery

It can be seen from Fig. 4.3, that 7 of the 10 monitoring lines have recorded maximum total tensile strains of 1.5 mm/m or less. It can also be seen, that 6 of the 10 monitoring lines have recorded maximum compressive strains of 1.5 mm/m or less. The maximum observed tensile strain was 2.8 mm/m and the maximum observed compressive strain was 4.1 mm/m.

4.5. Predicted Subsidence Parameters due to the Future Stage 3 Longwalls

Austar are also proposing to extract the future Longwalls A6 to A17 in Stage 3, which were the subject of a separate Part 3A Application. The closest Stage 3 longwall to the Study Area is Longwall A6, which is located at a distance of approximately 220 metres east of the proposed Longwall A5a, at its closest point. The location of this longwall is shown in Drawing No. MSEC417-01. The remaining Stage 3 longwalls are located at distances of 1.4 kilometres or greater from the proposed Longwall A5a. The predicted total conventional subsidence contours, resulting from the extraction of Longwalls A3 to A5a plus the approved Stage 3 longwalls, are shown in Drawing No. MSEC417-11.

The predictions and impact assessments for the future Stage 3 longwalls were provided in Report No. MSEC309 (Revision D), which was issued in September 2008, in support of the Part 3A Application. The predictions and impact assessments for the Stage 3 longwalls also included the predicted movements resulting from the extraction of the Stage 2 Longwalls A3 to A5.

The predicted subsidence contours, resulting from the extraction of the future Stage 3 Longwall A6, are shown illustrated in Fig. 4.4 below.

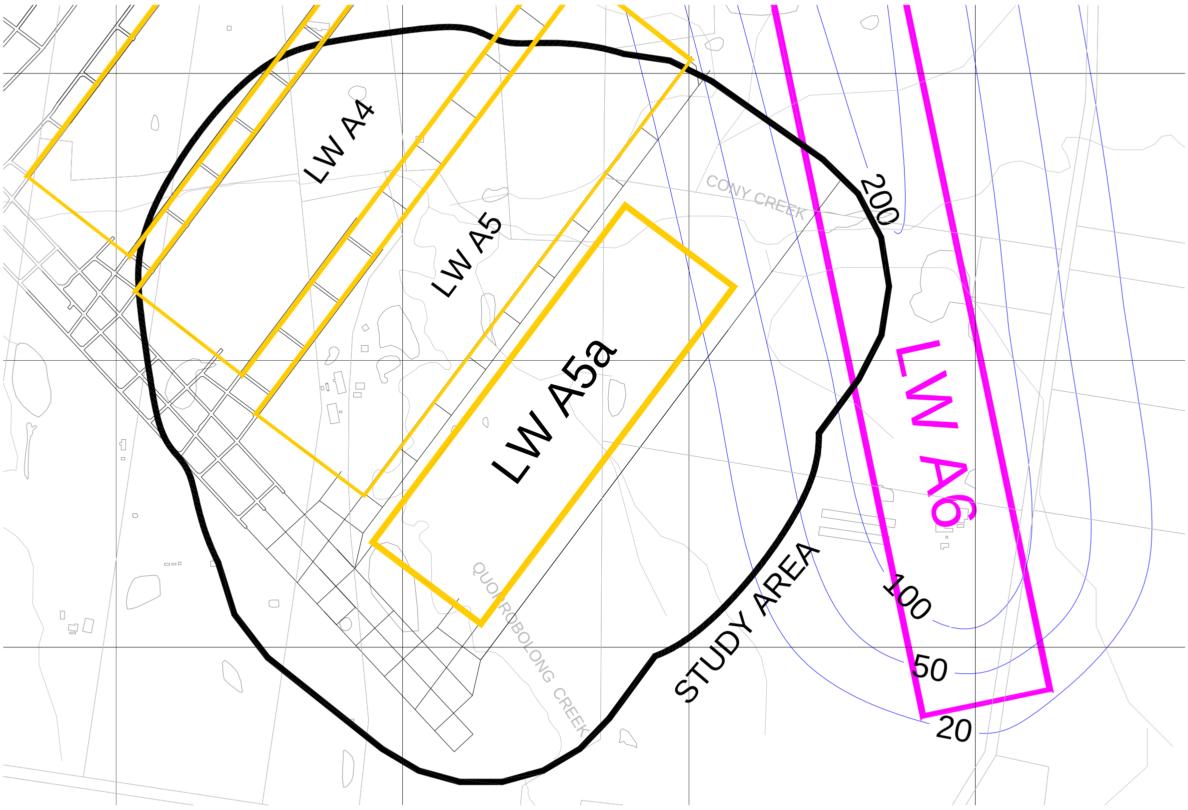

Fig. 4.4 Predicted Conventional Subsidence Contours Resulting from the Extraction of the Future Stage 3 Longwall A6

It can be seen from the above figure, that the extraction of the future Longwall A6 is predicted to result in an additional subsidence of 200 mm at the eastern extent of the Study Area, and an additional subsidence of 40 mm above the commencing (north-eastern) end of the proposed Longwall A5a. The predictions and impact assessments provided in this report, for the features located in the eastern part of the Study Area, include discussions on the additional subsidence movements resulting from the extraction of the future Longwall A6.

The predicted conventional subsidence movements, resulting from the remaining Stage 3 Longwalls A7 to A17, are negligible within the Study Area. The extraction of these future longwalls are unlikely, therefore, to result in any significant impacts on the natural features and items of surface infrastructure located within the Study Area.

4.6. Reliability of the Predicted Conventional Subsidence Parameters

The Incremental Profile Method is based upon a large database of observed subsidence movements in the Newcastle Coalfield and has been found to give good, if rather conservative results in most cases. In this case, the model has been calibrated to local conditions using monitoring data from the previously extracted longwalls at the Colliery, which included Longwalls SL1 to SL4 and Longwalls 1 to 13A. The model was also calibrated for LTCC mining, which has a greater extraction height when compared to the previously extracted longwalls at the Colliery and elsewhere in the NSW Coalfields.

The comparisons between the observed mine subsidence movements during the extraction of Stage 1 Longwalls A1 and A2, which were extracted using LTCC mining techniques, with those predicted using the calibrated Incremental Profile Method were provided in Section 3.5. It can be seen from these comparisons, that the calibrated Incremental Profile Method provided reasonable, if not slightly conservative predictions for these longwalls.

The calibrated Incremental Profile Method should, therefore, generally provide realistic and possibly conservative predictions of subsidence, tilt and curvature for the proposed longwall. The predicted profiles obtained using this method also reflect the way in which each parameter varies over the mined area and indicate the movements that are likely to occur at any point on the surface.

Empirical methods of subsidence prediction are generally accepted as providing predictions of maximum subsidence to an accuracy of ±10 % to ±15 %. It was indicated by Dr Lax Holla (1991), in his paper entitled, "Reliability of Subsidence Prediction Methods for use in Mining Decisions in New South Wales", that the accuracy of predictions of maximum subsidence, made using the Department's Empirical Method, generally ranged from +8 % to -11 %. Of the 14 examples, referred to in the paper, from longwalls at seven different collieries in the Southern and Newcastle Coalfields, the predicted maximum subsidence was less than the measured maximum subsidence in only four cases. Where empirical models have been calibrated to local data, even greater accuracies have been found to be possible in predicting the maximum values of the subsidence parameters.

The prediction of conventional subsidence parameters at a specific point is more difficult, but, based upon a large number of comparative analyses, it is concluded that the vertical subsidence predictions at any point, using the Incremental Profile Method, should generally be accurate within ±15%, where the longwall and mining geometries are within the range of the empirical database, and where the model has been calibrated to local data. Where subsidence is predicted at points beyond the goaf edge, which are likely to experience very low values of subsidence, the predictions should generally be accurate to within 50 mm of subsidence.

The comparison between predicted and observed tilts and conventional curvatures show that the Incremental Profile Method provides reasonable results. It is likely, however, that the predicted conventional tilts and curvatures will be exceeded at the watercourses, as a result of valley related movements. A separate method of predicting valley closure, upsidence and strain is provided in this report and the reliability of the predictions is provided in Section 4.7.

Observations of strain show that there is a trend of increasing average tensile strain with increasing hogging curvature and an increasing average compressive strain with increasing sagging curvature. As discussed in Section 4.4, applying a linear relationship between curvature and strain provides a reasonable estimate for the conventional tensile and compressive strains. However, there is a considerable variability in strain observations. When expressed as a percentage, observed strains can be many times greater than the linear relationship for low curvatures.

The predictions of strain provided in this report have therefore adopted a statistical approach to account for the variability, rather than providing a single predicted conventional strain. The variation in strain occurs for the following reasons:-

- Variations in local geology can affect the way in which the near surface rocks are displaced as subsidence occurs. In the compression zone, the surface strata can buckle upwards or can fail by shearing and sliding over their neighbours. If localised cross bedding exists, this shearing can occur at relatively low values of stress. This can result in fluctuations in the local strains, which can range from tensile to compressive. In the tensile zone, existing joints can be opened up and new fractures can be formed at random, leading to localised concentrations of tensile strain.
- Where a thick surface layer of soil, clay or rock exists, the underlying movements in the bedrock are often transferred to the surface at reduced levels and the measured strains are, therefore, more evenly distributed and hence more conventional in nature than they would be if they were measured at rockhead.

- Strain measurements can sometimes give a false impression of the state of stress in the ground. For example:-
  - buckling of the near-surface strata can result in localised cracking and apparent tensile strain in areas where overall, the ground is in fact being compressed, because the actual values of the measured strains are dependent on the locations of the survey pegs.
  - where joints open up or cracks develop in the tensile phase and fail to close in the compressive phase, as they sometimes do if they are subsequently filled, the ground can appear to be in tension when it is actually in compression.
- Sometimes, survey errors can also affect the measured strain values and these can result from movement in the benchmarks, inaccurate instrument readings, or disturbed survey pegs.
- In sandstone dominated environments, much of the earlier ground movements can be concentrated at the existing natural joints, which have been found to be at an average spacing of 7 to 15 metres.

It is also recognised that the ground movements above a longwall panel can be affected by the gradient of the coal seam and the direction of mining, which can cause a lateral shift in the subsidence profile. While an adjustment for seam dip has been included in the predictions, the assessments at isolated features have, been based upon the highest predicted values of subsidence, tilt and curvature within a radius of 20 metres of each feature, rather than the predicted values at the points.

4.7. Reliability of Predictions of Upsidence and Closure Movements

The development of the predictive methods for upsidence and closure are the result of recent research and the methods do not, at this stage, have the same confidence level as conventional subsidence prediction techniques. As further case histories are studied, the method will be improved, but it can be used in the meantime, so long as suitable factors of safety are applied. This is particularly important where the predicted levels of movement are small, and the potential errors, expressed as percentages, can be higher.

Whilst the major factors that determine the levels of movement have been identified, there are some factors that are difficult to isolate. One factor that is thought to influence the upsidence and closure movements is the level of in-situ horizontal stress that exists within the strata. In-situ stresses are difficult to obtain and not regularly measured and the limited availability of data makes it impossible to be definitive about the influence of the in-situ stress on the upsidence and closure values. The methods are, however, based predominantly upon the measured data from Tower Colliery, where the in situ stresses are high. The methods will, therefore, tend to over-predict the movements in areas of lower stress.

Another factor that is thought to influence the movements is the characteristics of near surface geology, particularly in stream beds. Upsidence in particular is considered to be sensitive to the way in which the bedrock responds, since thin strata layers may respond differently to thicker ones. The location of the point of maximum upsidence is also considered to be strongly influenced by the characteristics of near surface geology.

Another factor that is thought to influence upsidence and closure movements is the presence of geomorphological features. Recent monitoring along a deeper and more incised valley has shown variable measurements around bends. There tended to be less movement at the apex of the bend than in the straight sections.

CHAPTER 5. PREDICTED SUBSIDENCE PARAMETERS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES AND ITEMS OF SURFACE INFRASTRUCTURE DUE TO THE EXTRACTION OF LONGWALL A5A

5.1. Introduction

The following sections provide the predicted subsidence parameters for the natural features and items of surface infrastructure within the Study Area. All significant natural features and items of surface infrastructure located outside the general Study Area, which may be subjected to far-field movements or valley related movements and may be sensitive to these movements, have also been included as part of these assessments.

The predicted conventional subsidence parameters provided in the following sections for Longwalls A3 to A5 include the effects of the modified lengths and widths of these longwalls, which were subject of separate modification applications and were presented in Reports Nos. MSEC380 and MSEC391. The predictions for the future Stage 3 Longwall A6 are based on the layout provided in the Part 3A Application and were presented in Report No. MSEC309.

5.2. Watercourses

The locations of the watercourses within the Study Area are shown in Drawing No. MSEC417-06. The descriptions, predictions and impact assessments for the major watercourses are provided in the following sections.

5.2.1. Descriptions of the Watercourses

The major watercourses within the Study Area are Quorrobolong and Cony Creeks.

Quorrobolong Creek crosses above the finishing (south-western) end of Longwall A5a and generally flows in a northerly direction, to where it joins Cony Creek above Longwall A5, and then generally flows in a westerly direction above Longwalls A3 and A4. Quorrobolong Creek drains into Ellalong Lagoon, which is located more than 5 kilometres west of the Study Area.

Cony Creek crosses partly above the commencing (north-eastern) end of Longwall A5a and generally flows in a westerly direction, to where it drains into Quorrobolong Creek above Longwall A5.

Quorrobolong and Cony Creeks are alluvial based ephemeral creeks, having average natural gradients of less than 1 mm/m (i.e. < 0.1 %) within the Study Area.

There are also a number of ephemeral drainage lines around and between the hills within the Study Area, which are also shown in Drawing No. MSEC417-06. The drainage lines within the Study Area flow into Quorrobolong and Cony Creeks.

5.2.2. Predictions for the Watercourses

The predicted profiles of conventional subsidence, upsidence and closure along Quorrobolong Creek, resulting from the extraction of Longwalls A3 to A5a, are shown in Fig. B.02 in Appendix B. A summary of the maximum predicted values of the total conventional subsidence, upsidence and closure at the creek is provided in Table 5.1.

Table 5.1 Maximum Predicted Total Subsidence, Upsidence and Closure at Quorrobolong Creek Resulting from the Extraction of Longwalls A3 to A5a

Longwalls	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
LWA3 to LWA5	1065	185	120
LWA3 to LWA5a	1250	205	135

The predicted profiles of conventional subsidence, upsidence and closure along Cony Creek, resulting from the extraction of Longwalls A3 to A5a, are shown in Fig. B.03 in Appendix B. A summary of the maximum predicted values of the total conventional subsidence, upsidence and closure at the creek is provided in Table 5.2.

Table 5.2 Maximum Predicted Total Subsidence, Upsidence and Closure at Cony Creek Resulting from the Extraction of Longwalls A3 to A5a

Longwalls	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
LWA3 to LWA5	825	105	90
LWA3 to LWA5a	1050	155	100

The extraction of the future Stage 3 Longwall A6 is expected to result in additional mine subsidence movements along Cony Creek. The predicted additional movements along the creek within the Study Area, resulting from the extraction of the future Longwall A6, are 180 mm subsidence, 20 mm upsidence and 10 mm closure.

The other drainage lines within the Study Area are located across the extents of the longwalls and, therefore, are expected to experience the full range of predicted movements. The maximum predicted conventional subsidence parameters within the Study Area are provided in Section 4.2.

5.2.3. Impact Assessments for the Watercourses

The extraction of the proposed Longwall A5a will result in longer sections of Quorrobolong and Cony Creeks being affected by mine subsidence movements. A summary of the lengths of these creeks within the predicted limits of vertical subsidence, taken as the 20 mm total subsidence contour, and within the predicted limits of valley related movements, taken as 20 mm total upsidence and 20 mm total closure, is provided in Table 5.3 below.

Table 5.3 Extents of Creeks within the Predicted Limits of Vertical Subsidence and Valley Related Movements Resulting from the Extraction of Longwalls A3 to A5a

Creek	Longwalls	Length of Creek within Predicted Limits of Vertical Subsidence (km)	Length of Creek within Predicted Limits of Valley Related Movements (km)
Quorrobolong Creek	A3 to A5	1.9	1.0
	A3 to A5a	2.3	1.3
Cony Creek	A3 to A5	0.7	0.4
	A3 to A5a	0.8	0.6

It can be seen from the above table, that the extraction of the proposed Longwall A5a would result in an additional 0.4 kilometres of Quorrobolong Creek and additional 0.2 kilometres of Cony Creek experiencing mine subsidence movements, compared to those predicted based on the extraction of Longwalls A3 to A5.

The maximum predicted change in grade along Quorrobolong Creek, resulting from the extraction of Longwalls A3 to A5a, is 5 mm/m (i.e. 0.5 %), or a change in grade of 1 in 200. The maximum predicted change in grade along Cony Creek, resulting from the extraction of Longwalls A3 to A5a, is 4 mm/m (i.e. 0.4 %), or a change in grade of 1 in 250. The extraction of the future Longwall A6 is not expected to result in any significant changes in grade along Cony Creek.

The predicted maximum changes in grade along the creeks, after the extraction of Longwall A5a, are similar to those predicted after the extraction of Longwalls A3 to A5. The locations of these maximum changes in grade, however, occur further upstream as a result of the extraction of Longwall A5a.

A detailed flood model of the creeks has been undertaken by Umwelt using the predicted and the upperbound subsidence movements resulting from the extraction of Longwalls A3 to A5a. The effects of the proposed Longwall A5a are discussed further in the report by Umwelt (2009).

The maximum predicted hogging and sagging curvatures along Quorrobolong Creek, resulting from the extraction of Longwalls A3 to A5a, are 0.03 km^{-1} and 0.05 km^{-1}, respectively, which equate to minimum radii of curvature of 30 kilometres and 20 kilometres, respectively. The maximum predicted hogging and sagging curvatures along Cony Creek, resulting from the extraction of Longwalls A3 to A5a, are 0.03 km^{-1} and 0.01 km^{-1}, respectively, which equate to minimum radii of curvature of 30 kilometres and 100 kilometres, respectively. The extraction of the future Longwall A6 is not expected to result in any significant curvatures along Cony Creek.

The range of potential strains above the Stage 2 longwalls is expected to be similar to the range of strains measured during the previously extracted longwalls at the Colliery, which is described in Section 4.4.2. It is also likely, that the creeks will experience elevated compressive strains as the result of valley closure movements.

The compressive strains resulting from valley related movements are more difficult to predict than conventional strains. It has been observed in the past, however, that compressive strains greater than 2 mm/m have occurred where the magnitudes of closure and upsidence are similar to those predicted along Quorrobolong and Cony Creeks.

It is possible, therefore, that some compressive buckling and dilation of the uppermost bedrock could occur beneath the alluvial beds of Quorrobolong and Cony Creeks, above and within 250 metres of the longwalls. It has been observed in the past, that the depth of buckling and dilation of the uppermost bedrock, resulting from valley related movements, is generally less than 10 to 15 metres.

Surface cracking can potentially occur in the locations where the uppermost bedrock buckles and where the depths of bedrock are shallow. Any surface cracking that occurs as the result of the extraction of the proposed longwall is likely to be filled with alluvial materials during subsequent flow events.

In times of heavy rainfall, any dilated bedrock beneath the creek beds would become water charged, and the surface water would flow over any surface cracks. Surface water that is diverted into the dilated bedrock beneath the creeks, during times of rainfall, is unlikely to significantly affect the overall quality or quantity of the surface water flow, as the cross-sectional area of dilated bedrock is very small when compared to the cross-sectional area of the creek channels.

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

As described in Section 5.12.5, the likely height of the fractured zone is estimated to be between 235 metres to 275 metres above the proposed longwall. The depths of cover directly above the proposed longwall varies between 530 and 560 metres and, therefore, the depth of the constrained zone, which is located above the fractured zone, is estimated to be between 255 metres and 325 metres.

The constrained zone, also known as the continuous deformation zone, is illustrated in Fig. 5.11 and Fig. 5.12. The constrained zone contains confined rock strata above the fractured zone which has 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 discontinuous vertical cracks, usually on the underside of thick strong beds. Weak or soft beds in this zone may suffer plastic deformation.

The Cessnock Sandstone forms the upper section of the constrained zone, which is relatively homogeneous and contains relatively thick beds. Vertical fracturing within the constrained zone is generally discontinuous and is unlikely, therefore, to result in increased hydraulic conductivity. It is unlikely, therefore, that there would be any net loss of water from the creeks resulting from the extraction of the proposed longwall.

Where Quorrobolong Creek was previously mined beneath by Longwalls 1 to 6 and Longwall SL1 at the Colliery, where the depths of cover vary between 310 and 370 metres, there was no reported loss of water from the creek and no reported surface cracking in the creek bed.

Further discussion on the potential impacts of surface cracking and changes in surface water flows are provided in the report by Umwelt (2009).

5.2.4. Impact Assessments for the Watercourses Based on Increased Predictions

If the maximum predicted conventional subsidence parameters were to be increased by factors of up to 2 times, the predicted parameters would be similar to the upperbound parameters. It is unlikely that the maximum upperbound conventional subsidence parameters within the Study Area would be exceeded, as these parameters are based on achieving a maximum total subsidence of 65 % of effective extracted seam thickness above the Stage 2 longwalls, as discussed in Section 4.3.

If the maximum upperbound conventional tilt anywhere within the Study Area of 12 mm/m were to occur at the creeks, increased ponding, flooding and scouring would occur along the creeks. The flood model has considered the upperbound subsidence movements and further discussions are provided in the report by Umwelt (2009).

If the maximum upperbound conventional curvatures anywhere within the Study Area of 0.08 km^{-1} hogging and 0.25 km^{-1} sagging were to occur at the creeks, the likelihood and extent of fracturing, buckling and dilation of the underlying bedrock would increase accordingly. Surface cracking could potentially occur in the locations where the depths of bedrock are shallow. Any surface cracking that occurs as the result of the extraction of the proposed longwall is likely to be filled with alluvial materials during subsequent flow events. It is still expected, however, that any surface cracking could be remediated by infilling with alluvial or other suitable materials, or by locally regrading and recompacting the surface.

5.2.5. Recommendations for the Watercourses

The assessed impacts on Quorrobolong and Cony Creeks, resulting from the extraction of the proposed Longwall A5a, could be managed with the implementation of suitable management strategies. It is expected that the management strategies which have been developed for the creeks for Longwalls A3 to A5 could be extended to include Longwall A5a.

It is recommended that the creek beds are visually monitored during the extraction of the proposed longwall, and that any significant surface cracking is remediated by infilling with alluvial or other suitable materials, or by locally regrading and recompacting the surface. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the creeks resulting from the extraction of the proposed longwall.

5.3. Steep Slopes

The locations of the steep slopes within the Study Area are shown in Drawing No. MSEC417-06. The descriptions, predictions and impact assessments for the steep slopes are provided in the following sections.

5.3.1. Descriptions of the Steep Slopes

For the purposes of this report, a steep slope has been defined as an area of land having a natural gradient greater than 1 in 3 (i.e. a grade of 33 %, or an angle to the horizontal of 18°). The extents of the steep slopes were determined from the surface level contours generated from an airborne laser scan of the area.

It can be seen from Drawing No. MSEC417-02, that there are steep slopes located on the southern side of the hill above Longwall A4. The steep slopes are located at a distance of 325 metres north-west of the tailgate of Longwall A5a, at their closest point to this longwall.

5.3.2. Predictions for the Steep Slopes

A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature at the steep slopes, due to the extraction of Longwall A5a only, is provided in Table 5.4.

Table 5.4 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature at the Steep Slopes Resulting from the Extraction of Longwall A5a Only

Location	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})
Steep Slopes	50	0.3	< 0.01	< 0.01

5.3.3. Impact Assessments for the Steep Slopes

The predicted additional subsidence at the steep slopes, due to the extraction of Longwall A5a only, is 50 mm, which is small when compared to the predicted total subsidence after the extraction of the earlier Longwalls A3 to A5 of 1200 mm. The predicted additional tilt is 0.3 mm/m (i.e. < 0.1 %), or a predicted change in grade of 1 in 3000. The predicted additional curvatures and strains at the steep slopes, resulting from the extraction of Longwall A5a only, are in the order of survey tolerance.

It is unlikely, therefore, that the extraction of Longwall A5a would result in any significant impacts to the steep slopes. It is expected, therefore, that the management strategies which have been developed for the steep slopes for Longwalls A3 to A5 can be extended to include Longwall A5a. With these management strategies in place, it is unlikely that there would be any significant impacts on the steep slopes.

5.3.4. Impact Assessments for the Steep Slopes Based on Increased Predictions

If the maximum predicted conventional subsidence parameters were to be increased by factors of up to 2 times, the predicted parameters would be similar to the upperbound parameters. It is unlikely that the maximum upperbound conventional subsidence parameters within the Study Area would be exceeded, as these parameters are based on achieving a maximum total subsidence of 65 % of effective extracted seam thickness above the proposed longwalls, as discussed in Section 4.3.

If the maximum upperbound conventional tilt anywhere within the Study Area of 12 mm/m were to occur at the steep slopes, it would still be unlikely to result in any significant impacts, as the maximum change in the natural surface gradients would be around 1 %, or 1 in 100, which is small when compared to the natural surface gradients of the steep slopes.

If the maximum upperbound conventional curvatures anywhere within the Study Area of 0.08 km^{-1} hogging and 0.25 km^{-1} sagging were to occur at the steep slopes, the likelihood and extent of surface cracking would increase accordingly. Similarly, if the maximum ground strains measured above the previously extracted longwalls at the Colliery, which are described in Section 4.4.2, were to occur at the steep slopes, the likelihood and extent of surface cracking would also increase accordingly. Any surface cracking would still be expected to be of a minor nature and could be remediated by infilling the cracks with soil or other suitable materials, or by locally regrading and recompacting the surface.

5.3.5. Recommendations for the Steep Slopes

The assessed impacts on the steep slopes, resulting from the extraction of the proposed Longwall A5a, could be managed with the implementation of suitable management strategies. It is expected that the management strategies which have been developed for the steep slopes for Longwalls A3 to A5 could be extended to include Longwall A5a.

It is recommended that the steep slopes are visually monitored during the extraction of the Stage 2 longwalls, such that any significant surface cracking can be identified and remediated, as required. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the steep slopes resulting from the extraction of the proposed longwall.

5.4. Electrical Infrastructure

The locations of the electrical infrastructure within the Study Area are shown in Drawing No. MSEC417-07. The descriptions, predictions and impact assessments for the electrical infrastructure are provided in the following sections.

5.4.1. Descriptions of the Electrical Infrastructure

There are two branches of an 11 kV powerline within the Study Area, referred to as Branch 1 and Branch 2, the locations of which shown in Drawing No. MSEC417-07. There are also consumer lines within the Study Area which connect the rural properties with these powerlines.

5.4.2. Predictions and Impact Assessments for the Electrical Infrastructure

The aerial cables will not be directly affected by the ground strains, as they are supported by the 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, conventional horizontal movements, and conventional tilt at the pole locations. The stabilities of the poles may also be affected by conventional tilt, and by the changes in the centenary profiles of the cables.

The powerlines cross directly above Longwall A5a and, therefore, are expected to experience the full range of predicted subsidence movements resulting from the extraction of this longwall, which are summarised in Section 4.2.

The maximum predicted incremental tilt, due to the extraction of Longwall A5a only, is 3.0 mm/m (i.e. 0.3 %), or a change in verticality of 1 in 300. The maximum predicted total tilt, resulting from the extraction of Longwalls A3 to A5a, is 5.7 mm/m (i.e. 0.6 %), or a change in verticality of 1 in175.

Low voltage powerlines have been successfully mined beneath in the past at the Colliery and elsewhere in the NSW Coalfields, where the magnitudes of the predicted mine subsidence movements were similar to those predicted within the Study Area. This includes approximately 4 kilometres of low voltage powerlines which were directly mined beneath by Longwalls 1 to 12A at the Colliery. In addition to this, Tahmoor Colliery Longwalls 22 to 24A have mined directly beneath approximately 17 kilometres of electrical cables and 380 power poles and no significant impacts have been reported.

Whilst significant 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 longwall, are expected to be low and any impacts would be expected to be relatively minor and easily repairable.

5.4.3. Impact Assessments for the Electrical Infrastructure Based on Increased Predictions

If the maximum predicted conventional subsidence parameters were to be increased by factors of up to 2 times, the predicted parameters would be similar to the upperbound parameters. It is unlikely that the maximum upperbound conventional subsidence parameters within the Study Area would be exceeded, as these parameters are based on achieving a maximum total subsidence of 65 % of effective extracted seam thickness above the proposed longwalls, as discussed in Section 4.3.

If the maximum upperbound conventional tilt anywhere within the Study Area of 12 mm/m were to occur at the powerlines, it is possible that some poles would require additional support, including the installation of guy wires, and that some cable catenaries would need to be adjusted. It would still be expected that these potential impacts could be managed with the implementation of suitable management strategies.

5.4.4. Recommendations for the Electrical Infrastructure

The assessed impacts on the 11 kV powerlines and consumer lines, resulting from the extraction of the proposed Longwall A5a, could be managed with the implementation of suitable management strategies. It is expected that the management strategies which have been developed for the powerlines for Longwalls A3 to A5 could be extended to include Longwall A5a.

It is recommended that the powerlines are visually monitored as each longwall mines beneath them, so that any impacts can be identified and rectified accordingly. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the powerlines.

5.5. Telecommunications Infrastructure

The locations of the telecommunications infrastructure within the Study Area are shown in Drawing No. MSEC417-07. The descriptions, predictions and impact assessments for the telecommunications infrastructure are provided in the following sections.

5.5.1. Descriptions of the Telecommunications Infrastructure

There are overhead copper telecommunications cables within the Study Area which follow the same alignments as the low voltage powerlines, the locations of which shown in Drawing No. MSEC417-07. There are also underground copper telecommunications cables within the Study Area, which are also shown in this drawing. It can be seen that the underground cables are located to the south-west of the proposed Longwall A5a and are not directly mined beneath by this longwall.

5.5.2. Predictions and Impact Assessments for the Telecommunications Infrastructure

The predictions and impact assessments for aerial telecommunications cables are the same as those for the aerial powerlines, which were provided in Section 5.4.

The underground copper telecommunications cables are unlikely to be impacted by tilt. The copper cables, however, could experience curvatures and ground strains resulting from the extraction of the proposed longwall. A summary of the maximum predicted values of incremental conventional subsidence and curvature at the underground cables, due to the extraction of Longwall A5a only, is provided in Table 5.5.

Table 5.5 Maximum Predicted Incremental Conventional Subsidence and Curvature at the Telecommunications Cables Resulting from the Extraction of Longwall A5a Only

Location	Maximum Predicted Incremental Conventional Subsidence (mm)	Maximum Predicted Incremental Conventional Hogging Curvature (km^{-1})	Maximum Predicted Incremental Conventional Sagging Curvature (km^{-1})
Underground Copper Telecommunications Cables	125	0.01	< 0.01

The maximum predicted conventional curvature at the underground copper telecommunications cables, resulting from the extraction of Longwall A5a only, is 0.01 km^{-1}, or a minimum radius of curvature of 100 kilometres. Copper cables are very flexible and would be expected to tolerate curvatures of these magnitudes without any significant impacts.

The underground copper telecommunications cables are located outside the extents of the Stage 2 longwalls and, therefore, the most relevant distribution of strain are the maximum observed strains in survey bays above solid coal, which is illustrated in Fig. 4.2. The cables are predicted to experience hogging curvature and, therefore, it is more likely that these cables would experience tensile strains. It can be seen from Fig. 4.2, that the strains along the underground telecommunications cables, resulting from the extraction of Longwall A5a, are expected to be in the order of survey tolerance.

Underground copper telecommunications cables have been successfully mined beneath in the past at the Colliery and elsewhere in the NSW Coalfields, where the magnitudes of the predicted mine subsidence movements are greater than those predicted at the cables within the Study Area. This includes the underground cables which were directly mined beneath by Longwalls 1 to 9A at the Colliery. In addition to this, Tahmoor Colliery Longwalls 22 to 24A have mined directly beneath approximately 19 kilometres of underground cables and there were no reported significant impacts to the modern cables, but some minor impacts were reported for the older lead sheathed copper cables.

It is unlikely, therefore, that there will be any significant impacts on the underground copper telecommunications cables within the Study Area resulting from the extraction of the proposed Longwall A5a.

5.5.3. Impact Assessments for Telecommunications Infrastructure Based on Increased Predictions

If the maximum predicted conventional subsidence parameters were to be increased by factors of up to 2 times, the predicted parameters would be similar to the upperbound parameters. It is unlikely that the maximum upperbound conventional subsidence parameters within the Study Area would be exceeded, as these parameters are based on achieving a maximum total subsidence of 65 % of effective extracted seam thickness above the proposed longwalls, as discussed in Section 4.3.

If the predicted curvatures and strains at the underground copper telecommunications cables were increased by factors of up to two times, the curvatures and strains would still be less than those predicted to occur where underground cables have been previously mined beneath at the Colliery and elsewhere in the NSW Coalfields.

It is unlikely, therefore, that there will be any significant impacts on the underground copper telecommunications cables within the Study Area, even if the predicted movements were increased by factors of up to 2 times.

5.5.4. Recommendations for Telecommunications Infrastructure

The assessed impacts on the aerial and underground and telecommunications cables, resulting from the extraction of the proposed Longwall A5a, could be managed with the implementation of suitable management strategies. It is expected that the management strategies which have been developed for the telecommunications cables for Longwalls A3 to A5 could be extended to include Longwall A5a.

It is recommended that the aerial telecommunications cables are visually monitored as each longwall mines beneath them, so that any impacts can be identified and rectified accordingly. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the telecommunications cables.

5.6. Rural Building Structures

The locations of the rural building structures within the Study Area are shown in Drawing No. MSEC417-08. The descriptions, predictions and impact assessments for these structures are provided in the following sections.

5.6.1. Description of the Rural Building Structures

There are nine rural building structures (Structure Type R) that have been identified within the Study Area, which include sheds, garages, and other non-residential building structures. There are no rural building structures located directly above the proposed Longwall A5a.

A summary of the lengths and heights of the rural building structures within the Study Area is provided in Table 5.6. The locations, sizes, and details of the rural building structures were determined from an aerial photograph of the area and from site investigations.

Table 5.6 Locations, Lengths and Heights of the Rural Building Structures within the Study Area

Label	Centroid Easting (m)	Centroid Northing (m)	Maximum Length (m)	Structure Height (m)
A01b	345860	6356950	7	3
A01c	345925	6356955	15	3
A01d	345920	6356940	14	3
A01e	345935	6357020	12	3
A01f	345890	6356910	4	3
A01g	345935	6357055	9	3
A01j	345915	6356375	5	3
A01k	345905	6356375	5	3
A04d	346030	6357385	13	3

The rural building structures within the Study Area are typically of light-weight construction.

5.6.2. Predictions for the Rural Building 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 eight equally spaced points radially placed 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.

A summary of the maximum predicted conventional subsidence parameters at the rural building structures, resulting from the extraction of the earlier Longwalls A3 to A5, is provided in Table 5.7. A summary of the maximum predicted conventional subsidence parameters at the rural building structures, resulting from the extraction of all Longwalls A3 to A5a, is provided in Table 5.8.

Table 5.7 Maximum Predicted Conventional Subsidence, Tilt and Curvature for the Rural Building Structures Resulting from the Extraction of Longwalls A3 to A5

Structure ID	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})
A01b	425	3.4	0.01	0.02
A01c	450	2.8	0.01	0.02
A01d	400	2.9	0.01	0.02
A01e	600	2.6	0.01	0.02
A01f	325	2.9	0.02	0.01
A01g	675	2.5	0.01	0.01
A01j	< 20	< 0.2	< 0.01	< 0.01
A01k	< 20	< 0.2	< 0.01	< 0.01
A04d	1100	2.7	0.03	0.04

Table 5.8 Maximum Predicted Conventional Subsidence, Tilt and Curvature for the Rural Building Structures Resulting from the Extraction of Longwalls A3 to A5a

Structure ID	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})
A01b	650	4.0	0.02	0.02
A01c	775	3.3	0.01	0.02
A01d	725	3.6	0.01	0.02
A01e	875	2.2	0.03	0.02
A01f	600	3.8	0.02	0.02
A01g	925	2.0	0.03	0.02
A01j	< 20	< 0.2	0.00	< 0.01
A01k	< 20	< 0.2	0.00	< 0.01
A04d	1200	2.3	0.03	0.04

It is noted, that the predicted conventional subsidence parameters at the rural building structures, resulting from the extraction of Longwalls A3 to A5, include the modified lengths, void widths and chain pillar widths, which were the subject of separate modification applications. The predicted additional subsidence movements at these structures, resulting from the extraction of the future Longwall A6, are negligible.

The rural building structures are located at discrete locations and, therefore, the most relevant distributions of strain are the maximum observed strains in survey bays. Analysis of strains in survey bays during the mining of previous longwalls at the Colliery is discussed in Section 4.4.1.

5.6.3. Impact Assessments for the Rural Building Structures

There are no rural building structures located directly above the proposed Longwall A5a. The closest rural building structures are on Property A01, which are located at a minimum distance of 170 metres from the proposed Longwall A5a.

The maximum predicted total conventional tilt at the rural building structures within the Study Area, resulting from the extraction of Longwalls A3 to A5a, is 4.0 mm/m (i.e. 0.4 %) at Structure Ref. A01b, which equates to a change in grade of 1 in 250. The maximum predicted additional tilt at the rural building structures, resulting from the extraction of Longwall A5a only, is 0.9 mm/m (i.e. < 0.1 %) at Structure Ref. A01f. The predicted tilts at the rural building structures are small and are not expected to result in any significant impacts.

The maximum predicted hogging and sagging curvatures at the rural building structures, resulting from the extraction of Longwalls A3 to A5a, are 0.03 km^{-1} and 0.04 km^{-1}, respectively, which equate to minimum radii of curvatures of 30 kilometres and 25 kilometres, respectively. The range of potential strains above the longwalls is expected to be similar to the range of strains measured during the previously extracted longwalls at the Colliery, which is described in Section 4.4.1.

The predicted maximum curvatures and the range of potential strains at the rural building structures within the Study Area are similar to those measured during the extraction of the previous Longwalls SL1 to SL4 and Longwalls 1 to 13A at the Colliery. These longwalls mined directly beneath 98 rural building structures and, in all cases, these structures remained safe, serviceably and repairable.

The predicted maximum curvatures and the range of potential strains are also similar to those typically measured in the Southern Coalfield, where the depths of cover are greater than 400 metres. Numerous rural building structures have been directly mined beneath in the Southern Coalfield and the incidence of impacts on these types of structures is extremely low where the magnitudes of the subsidence movements are similar to those within the Study Area.

This includes Tahmoor Longwalls 22 to 24A which have mined directly beneath approximately 79 rural building structures and impacts have been reported at only three (i.e. 4 %) of these structures. Illawarra Coal has mined directly beneath approximately 275 rural building structures in Appin Areas 3, 4 and 7 and at West Cliff Colliery and there have been no reported impacts on the domestic rural building structures.

It is expected, therefore, that all the rural building structures within the Study Area would remain safe, serviceable and repairable throughout the mining period. Any impacts that occur to the rural building structures are expected to be minor and easily repaired using well established building techniques. With these remediation measures in place, it is unlikely that there would be any significant long term impacts on rural building structures resulting from the extraction of the proposed longwall.

The rural building structures located outside the Study Area, including those above the future Longwall A6, are predicted to experience less than 20 mm of subsidence as the result of the extraction of the proposed Longwall A5a. It is unlikely, therefore, that the structures located outside the Study Area would experience any significant impacts resulting from the extraction of the proposed Longwall A5a.

5.6.4. Impact Assessments for the Rural Building Structures Based on Increased Predictions

If the maximum predicted conventional subsidence parameters were to be increased by factors of up to 2 times, the predicted parameters would be similar to the upperbound parameters. It is unlikely that the maximum upperbound conventional subsidence parameters within the Study Area would be exceeded, as these parameters are based on achieving a maximum total subsidence of 65 % of effective extracted seam thickness above the proposed longwalls, as discussed in Section 4.3.

If the maximum upperbound conventional tilt anywhere within the Study Area of 12 mm/m were to occur at the rural building structures, it is possible that these structures would experience minor serviceability impacts, including door swings and issues with roof gutter and pavement drainage. It would still be unlikely that stabilities of these rural building structures would be affected at this magnitude of tilt.

If the maximum upperbound conventional curvatures anywhere within the Study Area of 0.08 km^{-1} hogging and 0.25 km^{-1} sagging were to occur at the rural building structures, it is likely that some of these structures would experience slight or moderate impacts. It would still be expected, however, that all rural building structures would remain in safe conditions throughout the mining period and that any impacts could be remediated using well established building techniques.

5.6.5. Recommendations for the Rural Building Structures

The assessed impacts on the rural building structures within the Study Area, resulting from the extraction of the proposed Longwall A5a, could be managed with the implementation of suitable management strategies. It is expected that the management strategies which have been developed for the rural building structures for Longwalls A3 to A5 could be extended to include Longwall A5a.

It is recommended that the rural building structures located above the Stage 2 longwalls should be inspected, prior to being mined beneath, to assess the existing conditions and whether any preventive measures may be required. It is also recommended that the rural building structures are visually monitored during the extraction of the Stage 2 longwalls. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the rural building structures.

5.7. Farm Dams

The locations of the farm dams within the Study Area are shown in Drawing No. MSEC417-08. The descriptions, predictions and impact assessments for these features are provided in the following sections.

5.7.1. Description of the Farm Dams

There are 14 farm dams (Structure Type D) that have been identified within the Study Area. There are three dams which are located directly above the proposed Longwall A5a, being Dams Refs. A01d04, A01d07 and A10d01. There is one dam which is located above and adjacent to the future Stage 3 Longwall A6, being Dam A10d04.

The maximum lengths of the farm dams vary between 13 metres and 165 metres and the surface areas of the farm dams vary between 70 and 9,300 m^2. The farm dams are generally of earthen construction, and have been established by localised cut and fill operations within the natural drainage lines. The farm dams are generally shallow, with the dam wall heights generally being less than 3 metres.

5.7.2. Predictions for the Farm Dams

Predictions of conventional subsidence, tilt and strain have been made at the centroid and around the perimeters of each farm dam, as well as eight equally spaced points placed radially around the centroid and around points on the dam perimeters at a distance of 20 metres.

A summary of the maximum predicted conventional subsidence parameters at the farm dams, resulting from the extraction of the earlier Longwalls A3 to A5, is provided in Table 5.9. A summary of the maximum predicted conventional subsidence parameters at the farm dams, resulting from the extraction of all Longwalls A3 to A5a, is provided in Table 5.10.

Table 5.9 Maximum Predicted Conventional Subsidence, Tilt and Curvature for the Farm Dams Resulting from the Extraction of Longwalls A3 to A5

Structure ID	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})
A01d01	525	2.7	0.01	0.01
A01d02	700	2.8	0.02	0.01
A01d03	425	3.0	0.02	0.01
A01d04	125	0.9	0.01	< 0.01
A01d05	25	0.3	< 0.01	< 0.01
A01d07	150	1.2	0.01	< 0.01
A01d08	< 20	0.1	< 0.01	< 0.01
A01d09	625	3.4	0.01	0.02
A04d04	1300	1.1	0.02	0.02
A04d05	725	3.1	0.02	0.01
A04d06	275	3.1	0.04	< 0.01
A06d02	< 20	0.1	< 0.01	< 0.01
A10d01	75	0.4	< 0.01	< 0.01
A10d04	< 20	0.2	0.01	< 0.01

Table 5.10 Maximum Predicted Conventional Subsidence, Tilt and Curvature for the Farm Dams Resulting from the Extraction of Longwalls A3 to A5a

Structure ID	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})
A01d01	875	2.4	0.01	0.02
A01d02	950	1.7	0.03	0.02
A01d03	925	1.8	0.02	0.04
A01d04	750	2.0	0.01	0.01
A01d05	175	2.0	0.02	< 0.01
A01d07	750	2.1	0.01	0.03
A01d08	50	0.4	< 0.01	< 0.01
A01d09	850	3.7	0.03	0.02
A04d04	1325	0.9	0.02	0.02
A04d05	925	2.9	0.02	0.01
A04d06	350	3.7	0.04	0.01
A06d02	50	0.3	< 0.01	< 0.01
A10d01	475	2.8	0.02	0.01
A10d04	25	0.3	0.01	< 0.01

It is noted, that the predicted conventional subsidence parameters at the farm dams, resulting from the extraction of Longwalls A3 to A5, include the modified lengths, void widths and chain pillar widths, which were the subject of separate modification applications. The predicted additional subsidence movements at Dam A10d04, resulting from the extraction of the future Longwall A6, are 200 mm subsidence, 0.7 mm/m tilt and 0.02 km^{-1} hogging curvature.

The farm dams are located at discrete locations and, therefore, the most relevant distributions of strain are the maximum observed strains in survey bays. Analysis of strains in survey bays during the mining of previous longwalls at the Colliery is discussed in Section 4.4.1.

5.7.3. Impact Assessments for the Farm Dams

The predicted maximum tilt at the farm dams within the Study Area, resulting from the extraction of Longwalls A3 to A5a, is 3.7 mm/m (i.e. 0.4 %) at Dam Ref. A01d09, which equates to a change in grade of 1 in 270. The maximum additional tilt at the farm dams, resulting from the extraction of Longwall A5a only, is 2.4 mm/m (i.e. 0.2 %) at Dam Ref. A10d01.

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, or can affect the stability of the dam walls.

The predicted changes in freeboard at the farm dams within the Study Area were conservatively 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 changes in freeboard at the farm dams within the Study Area, after the extraction of Longwalls A3 to A5a, are illustrated in Fig. 5.1.

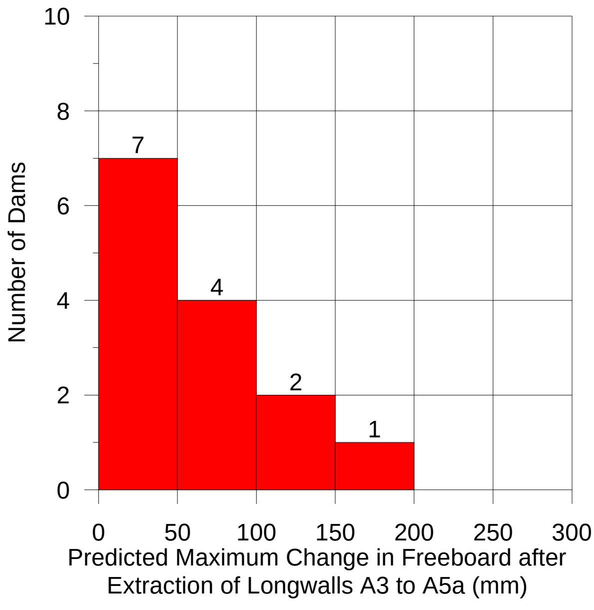

Fig. 5.1 Predicted Changes in Freeboards for the Farm Dams within the Study Area

The predicted maximum changes in freeboard at the farm dams are less than 200 mm and are unlikely, therefore, to have a significant impact on the stability of the dam walls or the overall capacities of the farm dams.

The maximum predicted hogging and sagging curvatures at the farm dams within the Study Area, resulting from the extraction of Longwalls A3 to A5a, are both 0.04 km^{-1}, which equates to a minimum radius of curvature of 25 kilometres. The predicted maximum curvature at the farm dams does not change as a result of the extraction of the future Stage 3 Longwall A6. The range of potential strains above the Stage 2 longwalls is expected to be similar to the range of strains measured during the previously extracted longwalls at the Colliery, which is described in Section 4.4.1.

The predicted maximum curvatures and the range of potential strains at the farm dams within the Study Area are similar to those measured during the extraction of the previous Longwalls SL1 to SL4 and Longwalls 1 to 13A at the Colliery. These longwalls mined directly beneath 59 farm dams and no significant impacts have been reported.

The predicted maximum curvatures and the range of potential strains are similar to those measured in the Southern Coalfield, where the depths of cover are greater than 400 metres. Numerous farm dams have been directly mined beneath in the Southern Coalfield and the incidence of impacts on these types of features is extremely low where the magnitudes of the subsidence movements are similar to those within the Study Area.

This includes Tahmoor Longwalls 22 to 24A which have mined directly beneath approximately 16 farm dams and there have been no reported impacts. Illawarra Coal has mined beneath approximately 105 farm dams in Appin Areas 3, 4 and 7 and at West Cliff Colliery and there has been only one reported case where the farm dam has drained. The farm dam reported to drain was of poor, shallow construction and seepage was observed at the base of the dam wall prior to mining.

It is expected, therefore, that the incidence of impacts on the farm dams within the Study Area, resulting from the extraction of Longwall A5a, 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.

The farm dams located outside the Study Area, including those above the future Longwall A6, are predicted to experience less than 20 mm of subsidence as the result of the extraction of the proposed Longwall A5a. It is unlikely, therefore, that the dams located outside the Study Area would experience any significant impacts resulting from the extraction of the proposed Longwall A5a.

5.7.4. Impact Assessments for the Farm Dams Based on Increased Predictions

If the maximum predicted conventional subsidence parameters were to be increased by factors of up to 2 times, the predicted parameters would be similar to the upperbound parameters. It is unlikely that the maximum upperbound conventional subsidence parameters within the Study Area would be exceeded, as these parameters are based on achieving a maximum total subsidence of 65 % of effective extracted seam thickness above the proposed longwalls, as discussed in Section 4.3.

If the maximum upperbound conventional tilt anywhere within the Study Area of 12 mm/m were to occur at the farm dams, the changes in freeboard would still be less than 500 mm and unlikely, therefore, to result in any instabilities of the farm dam walls or any significant reductions in the farm dam capacities.

If the maximum upperbound curvatures anywhere within the Study Area of 0.08 km^{-1} hogging and 0.25 km^{-1} sagging were to occur at the farm dams, the likelihood and extent of surface cracking would increase accordingly. Similarly, if the maximum ground strains measured above the previously extracted longwalls at the Colliery, which are described in Section 4.4.2, were to occur at the farm dams, the likelihood and extent of surface cracking would also increase accordingly.

Any surface cracking would still be expected to be of a minor nature and could be easily repaired. With any necessary remediation measures implemented, it is unlikely that any significant impact on the farm dams would occur resulting from the extraction of the proposed longwall.

5.7.5. Recommendations for the Farm Dams

The assessed impacts on the farm dams, resulting from the extraction of the proposed Longwall A5a, can be managed with the implementation of suitable management strategies. It is expected that the management strategies which have been developed for the farm dams for Longwalls A3 to A5 could be extended to include Longwall A5a.

It is recommended that all water retaining structures be visually monitored during the extraction of the proposed longwall, to ensure that they remain in a safe and serviceable condition. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the farm dams.

5.8. Houses

The locations of the houses within the Study Area are shown in Drawing No. MSEC417-08. The descriptions, predictions and impact assessments for these structures are provided in the following sections.

5.8.1. Description of the Houses

There are two houses that have been identified within the Study Area.

House Ref. A01a is located above Longwall A5, near the finishing (south-western) end, and is at a distance of approximately 190 metres from the proposed Longwall A5a. This structure is a single-storey weatherboard house with a Colorbond roof. The maximum dimension of the house is 37 metres.

House A06a is located west of the Stage 2 longwalls and is at a distance of 270 metres from the commencing (south-western) end of Longwall A5a. This structure is a single-storey fibro cottage with a tiled roof. The maximum dimension of the house is 16 metres.

5.8.2. 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 eight equally spaced points radially placed 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.

A summary of the maximum predicted conventional subsidence parameters at the houses, resulting from the extraction of the earlier Longwalls A3 to A5, is provided in Table 5.11. A summary of the maximum predicted conventional subsidence parameters at the houses, resulting from the extraction of the all Longwalls A3 to A5a, is provided in Table 5.12.

Table 5.11 Maximum Predicted Conventional Subsidence, Tilt and Curvature for the Houses Resulting from the Extraction of Longwalls A3 to A5

Structure ID	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})
A01a	500	3.2	0.01	0.02
A06a	< 20	0.2	< 0.01	< 0.01

Table 5.12 Maximum Predicted Conventional Subsidence, Tilt and Curvature for the Houses Resulting from the Extraction of Longwalls A3 to A5a

Structure ID	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})
A01a	750	3.8	0.03	0.02
A06a	50	0.3	< 0.01	< 0.01

It is noted, that the predicted conventional subsidence parameters at the houses, resulting from the extraction of Longwalls A3 to A5, include the modified lengths, void widths and chain pillar widths, which were the subject of separate modification applications. The predicted additional subsidence movements at these structures, resulting from the extraction of the future Longwall A6, are negligible.

The houses are located at discrete locations and, therefore, the most relevant distributions of strain are the maximum observed strains in survey bays. Analysis of strains in survey bays during the mining of previous longwalls at the Colliery is discussed in Section 4.4.1.

5.8.3. Impact Assessments for the Houses

The predicted maximum tilt at the houses within the Study Area, resulting from the extraction of Longwalls A3 to A5a, is 3.8 mm/m (i.e. 0.4 %) at Structure Ref. A01a, which equates to a change in grade of 1 in 260. The additional tilt at this structure, resulting from the extraction of Longwall A5a only, is 0.6 mm/m (i.e. < 0.1 %).

It has been found from past longwall mining experience, that tilts less than 7 mm/m generally do not result in any significant impacts on houses. It is possible, however, that Structure Ref. A01a could experience some minor serviceability impacts, including door swings and issues with gutter and wet area drainage, which may require some remediation measures during or after the mining period. The predicted tilts at Structure Ref. A06a are very small and unlikely, therefore, to result in any serviceability impacts.

The maximum predicted hogging and sagging curvatures at Structure Ref. A01a, resulting from the extraction of Longwalls A3 to A5a, are 0.03 km^{-1} and 0.02 km^{-1}, respectively, which equate to minimum radii of curvature of 30 kilometres and 50 kilometres, respectively. The range of potential strains above the Stage 2 longwalls is expected to be similar to the range of strains measured during the previously extracted longwalls at the Colliery, which is described in Section 4.4.1.

The assessed impacts for the houses, resulting from the extraction of Longwalls A3 to A5, were previously classified in accordance with Table C1 of the Australian Standard 2870-1996. This method of assessment was described in Appendix E of Report No. MSEC275, which supported the SMP Application for these longwalls. Using this method, the assessed impacts for the houses, resulting from the extraction of Longwalls A3 to A5a, are Category 1 for Structure Ref. A01a and Category 0 for Structure A06a. These categories represent minor impacts, where only fine cracking less than 1 mm in width, is expected to occur as the result of normal conventional subsidence movements.

It is possible, however, that Structure Ref. A01a could experience curvatures or ground strains greater than those predicted as the result of non-conventional anomalous movements, due to near surface geological features, the locations of which cannot be predicted prior to mining. The likelihood of impacts resulting from non-conventional movements can only be assessed by considering past longwall mining experience.

The most extensive data has come from the extraction of Tahmoor Longwalls 22 to 25, where over 1000 residential and significant civil structures have experienced subsidence movements. The predicted maximum curvatures and the range of potential strains within the Study Area are similar to those measured at Tahmoor Colliery.

The impacts to houses at Tahmoor Colliery were last analysed in detail following the completion of Longwall 24A. At this time, a total of the 699 structures had been directly mined beneath. Impacts have been reported at 123 of these structures (i.e. 18 %), the majority of which have been assessed as very slight or slight, which consisted of sticky doors and minor impacts to external or internal walls, ceilings or floor finishes.

About 1 % of all houses at Tahmoor Colliery had reported impacts that were assessed as moderate or greater (i.e. Category 3 or greater). In all of these cases, however, the impacts were considered to have occurred as a result of non-conventional anomalous movements, due to near surface geological features, the locations of which cannot be predicted prior to mining. In three of these cases (i.e. 0.4 % of the building structures directly mined beneath), the impacts were substantial and the costs to repair these structures were deemed to be greater than the costs to rebuild these structures. There were no claims made on the remaining 80 % of the building structures which were directly mined beneath by Tahmoor Longwalls 22 to 24A.

The predicted maximum curvatures at Structure Ref. A01a are also similar to those measured during the extraction of the previous Longwalls SL1 to SL4 and Longwalls 1 to 13A at the Colliery. These longwalls mined directly beneath 64 houses and, in all cases, these structures remained in safe, serviceable and repairable conditions.

Based on the experience at Tahmoor Colliery and the previously extracted longwalls at the Colliery, it is assessed that the houses within the Study Area will remain safe and serviceable throughout the mining period. It is estimated that there is a 20 % probability that Structure Ref. A01a would experience impacts, resulting from the extraction of the Stage 2 longwalls, but these impacts are likely to be minor and could be repaired using normal building maintenance techniques. There is a small chance, less than 1 %, that Structure Ref. A01a could experience moderate or severe impacts as the result of anomalous non-conventional movements.

The predicted movements at Structure Ref. A06a are very small and unlikely to result in any significant impacts.

The houses located outside the Study Area, including those above the future Longwall A6, are predicted to experience less than 20 mm of subsidence as the result of the extraction of the proposed Longwall A5a. It is unlikely, therefore, that the structures located outside the Study Area would experience any significant impacts resulting from the extraction of the proposed Longwall A5a.

5.8.4. Impact Assessments for the Houses Based on Increased Predictions

If the maximum predicted conventional subsidence parameters were to be increased by factors of up to 2 times, the predicted parameters would be similar to the upperbound parameters. It is unlikely that the maximum upperbound conventional subsidence parameters within the Study Area would be exceeded, as these parameters are based on achieving a maximum total subsidence of 65 % of effective extracted seam thickness above the proposed longwalls, as discussed in Section 4.3.

If the maximum upperbound conventional tilt anywhere within the Study Area of 12 mm/m were to occur at Structure Ref. A01a, it is likely that this structure would experience serviceability impacts, including door swings and issues with gutter and wet area drainage, which would require remediation. It is also possible that the house would need to be relevelled. It would be unlikely, however, that the structural stability of this house would be affected by this magnitude of tilt.

If the maximum upperbound conventional curvatures anywhere within the Study Area of 0.08 km^{-1} hogging and 0.25 km^{-1} sagging were to occur at Structure Ref. A01a, it is likely that this structure would experience moderate impacts (i.e. Category 3 or greater). It would still be expected, that the likelihood of impact resulting from an anomalous non-conventional movement would still be less than 1 % for this structure.

If the predicted conventional subsidence movements at Structure Ref. A06a were increased by factors of up to 2 times, this structure could experience very slight or slight impacts (i.e. Category 0 or 1), which would consist of sticky doors or minor impacts to external or internal walls, ceilings or floor finishes.

Based on the experience at Tahmoor Colliery, it would still be expected, that the houses would remain in safe conditions throughout the mining period and that the impacts resulting from the mine subsidence movements could be remediated using well established building techniques.

5.8.5. Recommendations for the Houses

The assessed impacts on the houses within the Study Area, resulting from the extraction of the proposed Longwall A5a, could be managed with the implementation of suitable management strategies. It is expected that the management strategies which have been developed for the houses for Longwalls A3 to A5 could be extended to include Longwall A5a.

It is recommended that the houses located above the Stage 2 longwalls should be inspected, prior to being mined beneath, to assess the existing structural conditions and whether any preventive measures are required. It is also recommended that the houses are visually monitored during the extraction of the Stage 2 longwalls. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the houses.

5.9. Pools

There is one inground pool which has been identified within the Study Area, being Structure Ref. A01h, which is located above Longwall A5, near the finishing (south-western) end. The pool is located at a distance of approximately 220 metres from the proposed Longwall A5a.

Predictions of systematic subsidence, tilt and curvature have been made at the centroid and at the corners of the pool, as well as eight equally spaced points radially placed around the centroid and corners at a distance of 20 metres. A summary of the maximum predicted conventional subsidence parameters at the pool, resulting from the extraction of Longwalls A3 to A5a, is provided in Table 5.13.

Table 5.13 Maximum Predicted Conventional Subsidence, Tilt and Curvature for the Pool A01h Resulting from the Extraction of Longwalls A3 to A5a

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})
LWA3 to LWA5	450	3.3	0.01	0.02
LWA3 to LWA5a	670	3.9	0.02	0.02

The pool is located at a discrete location and, therefore, the most relevant distributions of strain are the maximum observed strains in survey bays. Analysis of strains in survey bays during the mining of previous longwalls at the Colliery is discussed in Section 4.4.1.

The maximum predicted tilt at the pool, after the extraction of Longwall A5a, is 3.9 mm/m (i.e. 0.4 %), which represents a change in grade of 1 in 250. While the maximum predicted tilt is not expected to result in a loss of capacity for the pool, it is noted that tilts are more readily noticeable to property owners, particularly if the walls of the pools are tiled, as the height of the freeboard will vary along the length of the pool. Skimmer boxes are also susceptible of being lifted above the water line due to mining 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 3.3 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 hogging and sagging curvatures at the pool, resulting from the extraction of Longwalls A3 to A5a, are both 0.02 km^{-1}, which equates to a minimum radius of curvature of 50 kilometres. The range of potential strains above the Stage 2 longwalls is expected to be similar to the range of strains measured during the previously extracted longwalls at the Colliery, which is described in Section 4.4.1.

The predicted maximum curvatures and the range of potential strains within the Study Area are similar to those measured at Tahmoor Colliery. Observations during the mining of Tahmoor Colliery Longwalls 22 to 25 have shown that pools, particularly in-ground pools, are more susceptible to severe impacts than houses and other structures. Pools cannot be easily repaired and most of the impacted pools will need to be replaced in order to restore them to pre-mining condition or better.

As of May 2009, a total of 108 pools have experienced mine subsidence movements during the mining of Tahmoor Colliery Longwalls 22 to 25, of which 80 are located directly above the extracted longwalls. A total of 14 pools have reported impacts, all of which are located directly above the extracted longwalls. This represents an impact rate of approximately 18 %. A higher proportion of impacts have been observed for in-ground pools, particularly fibreglass pools. The majority of the impacts related to tilt or cracking, though in a small number of cases the impacts are limited to damage to skimmer boxes or the edge coping.

While not strictly related to the pool structure, a number of pool gates have been impacted as the result of the previous extraction of longwalls beneath pools. While the gates can be easily repaired, the consequence of breaching pool fence integrity is considered to be severe. As a result, it is recommended that regular inspections of the integrity of pool fences during the active subsidence period be included in the development of any Management Plan for properties that have pools or are planning to construct a pool during the mining period.

The pools located outside the Study Area are predicted to experience less than 20 mm of subsidence as the result of the extraction of the proposed Longwall A5a. It is unlikely, therefore, that the pools located outside the Study Area would experience any significant impacts resulting from the extraction of the proposed Longwall A5a.

5.10. Tennis Courts

There is one tennis court which has been identified within the Study Area, being Structure Ref. A01i, which is located above Longwall A5, near the finishing (south-western) end. The tennis court is located at a distance of approximately 170 metres from the proposed Longwall A5a.

Predictions of systematic subsidence, tilt and curvature have been made at the centroid and at the corners of the tennis court, as well as eight equally spaced points radially placed around the centroid and corners at a distance of 20 metres. A summary of the maximum predicted conventional subsidence parameters at the tennis court, resulting from the extraction of Longwalls A3 to A5a, is provided in Table 5.14.

Table 5.14 Maximum Predicted Conventional Subsidence, Tilt and Curvature for the Tennis Court A01i Resulting from the Extraction of Longwalls A3 to A5a

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})
LWA3 to LWA5	350	3.1	0.02	0.01
LWA3 to LWA5a	625	3.9	0.03	0.02

The tennis court is located at a discrete location and, therefore, the most relevant distributions of strain are the maximum observed strains in survey bays. Analysis of strains in survey bays during the mining of previous longwalls at the Colliery is discussed in Section 4.4.1.

The maximum predicted tilt at the tennis court is 3.9 mm/m (i.e. 0.4 %), or a change in grade of 1 in 250, which represents a change in grade of less than 1 % and is unlikely, therefore, to result in any significant impact on the serviceability of the tennis court.

The maximum predicted hogging and sagging curvatures at the tennis court, resulting from the extraction of Longwalls A3 to A5a, are 0.03 km^{-1} and 0.02 km^{-1}, respectively, which equate to minimum radii of curvatures 33 kilometres and 50 kilometres, respectively. The range of potential strains above the Stage 2 longwalls is expected to be similar to the range of strains measured during the previously extracted longwalls at the Colliery, which is described in Section 4.4.1.

The predicted maximum curvatures and the range of potential strains could result in ripping of the tennis court surface. Any impacts on the surface are expected to be of a minor nature and easily repaired. The fence surrounding the tennis court would be considered reasonably flexible and unlikely, therefore, to experience any significant impacts.

The tennis courts located outside the Study Area are predicted to experience less than 20 mm of subsidence as the result of the extraction of the proposed Longwall A5a. It is unlikely, therefore, that the tennis courts located outside the Study Area would experience any significant impacts resulting from the extraction of the proposed Longwall A5a.

5.11. Survey Control Marks

The locations of the survey control marks in the vicinity of the proposed longwall are shown in Drawing No. MSEC417-07. It can be seen from this drawing, that there are no survey control marks within the Study Area. There are, however, a number of survey control marks located along Sandy Creek Road which are just outside the Study Area.

The survey control marks in the vicinity of the proposed longwalls may experience either small amounts of subsidence and / or some small far-field horizontal movements as the proposed longwall is mined. It is possible that other marks outside the immediate area could also be affected by far-field horizontal movements, up to 3 kilometres outside the general Study Area.

It will be necessary on completion of the proposed longwall, when the ground has stabilised, to re-establish these marks. Consultation between Austar and the Department of Lands will be required throughout the mining period to ensure that these survey marks are reinstated at an appropriate time, as required.

5.12. Other Potential Subsidence Movements and Impacts

The following sections provide discussions on other potential subsidence movements and impacts resulting from the extraction of the proposed Longwalls A5a.

5.12.1. Predicted Conventional Horizontal Movements

The predicted conventional horizontal movements over the proposed longwall 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 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 Colliery, as described in Section 3.5, indicates that a factor of 15 provides a better correlation for the prediction of conventional horizontal movements. 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 5.7 mm/m, which occurs adjacent maingate of Longwall A5a. This area will experience the greatest predicted conventional horizontal movement towards the centre of the overall goaf area resulting from the extraction of the Stage 2 longwalls. The maximum predicted conventional horizontal movement is, therefore, approximately 90 mm, i.e. 5.7 mm/m multiplied by a factor of 15.

Conventional horizontal movements do not directly impact on natural features or items of surface infrastructure, 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 features and items of surface infrastructure are addressed in the impact assessments for each feature, which have been provided in Sections 5.2 to 5.11.

5.12.2. Predicted Far-Field Horizontal Movements

In addition to the conventional subsidence movements that have been predicted above and adjacent to the longwall, and the predicted valley related movements along the creeks, it is also likely that some far-field horizontal movements will be experienced during the extraction of the longwall.

Far-field horizontal movements result from the redistribution of horizontal in-situ stresses in the strata around the collapsed and fractured zones above longwall extractions. Such movements are to some extent predictable and occur whenever significant excavations occur at the surface or underground.

The horizontal in-situ stresses in the strata within the Study Area have already been affected by the previously extracted Longwalls SL2 to SL4 and Longwalls A1 and A2 to the north of the proposed longwall, and by the previously extracted Longwalls SL1 and 1 to 13A to the west of the proposed longwall. It is also likely that the in-situ stresses in the strata will be affected by the mining of earlier Longwalls A3 to A5 immediately north of the proposed longwall. As the proposed Longwall A5a is mined, it is likely that further redistribution of the horizontal in-situ stresses would result in far-field horizontal movements towards the new goaf area.

An empirical database of observed incremental far-field horizontal movements has been compiled using monitoring data primarily from the Southern Coalfield, from Collieries including Appin, Bellambi, Dendrobium, Douglas, Newstan, Tower and West Cliff. 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, for all monitoring points within the database, is provided in Fig. 5.2. The observed incremental far-field horizontal movements, resulting from the extraction of a single longwall, for monitoring points within the database where there was solid coal between the longwall and monitoring points, is provided in Fig. 5.3.

It can be seen from these figures, that incremental far-field horizontal movements of up to 20 mm have been observed at distances of 2000 metres from extracted longwalls. 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 in the collapsed zones above the first few extracted longwalls has been redistributed, 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 longwall are very small and could only be detected by precise 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 0.1 mm/m. The impacts of far-field horizontal movements on the natural features and items of surface infrastructure within the vicinity of the Study Area is not expected to be significant.

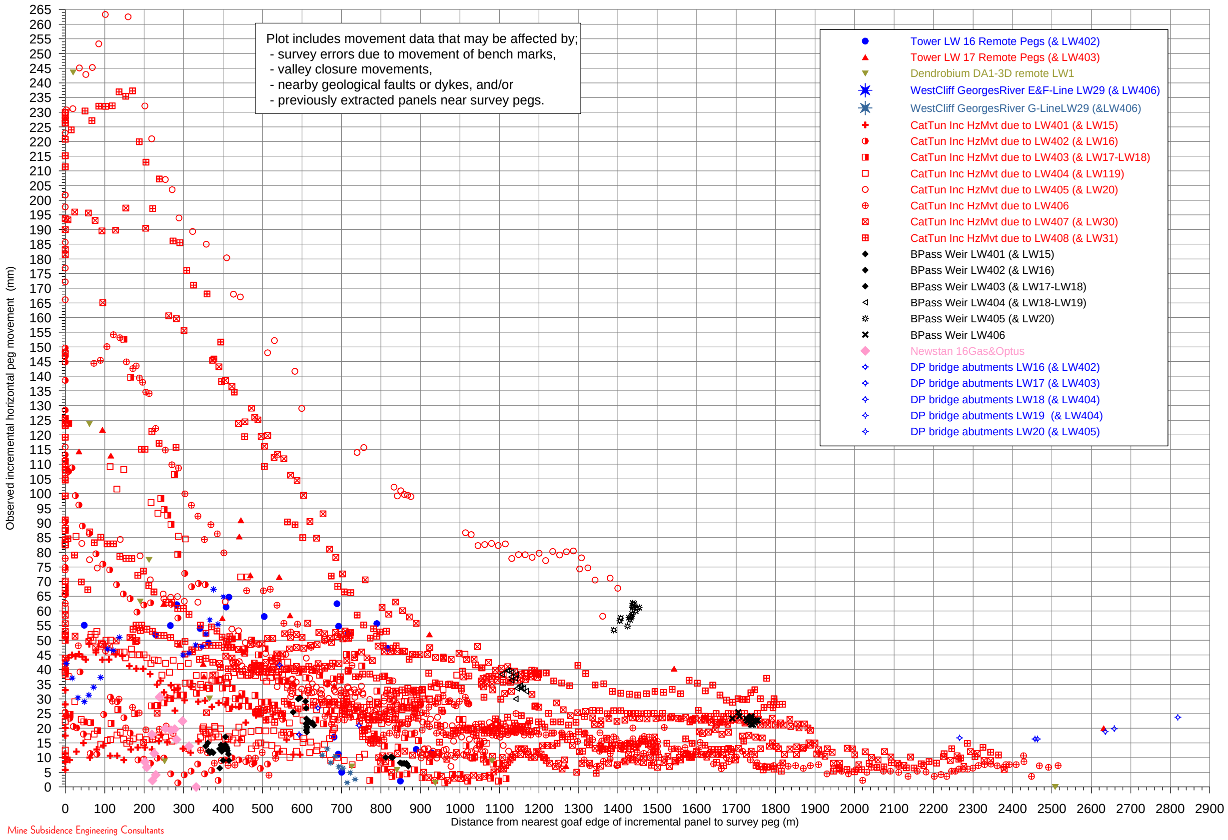

Fig. 5.2 Observed Incremental Far-Field Horizontal Movements

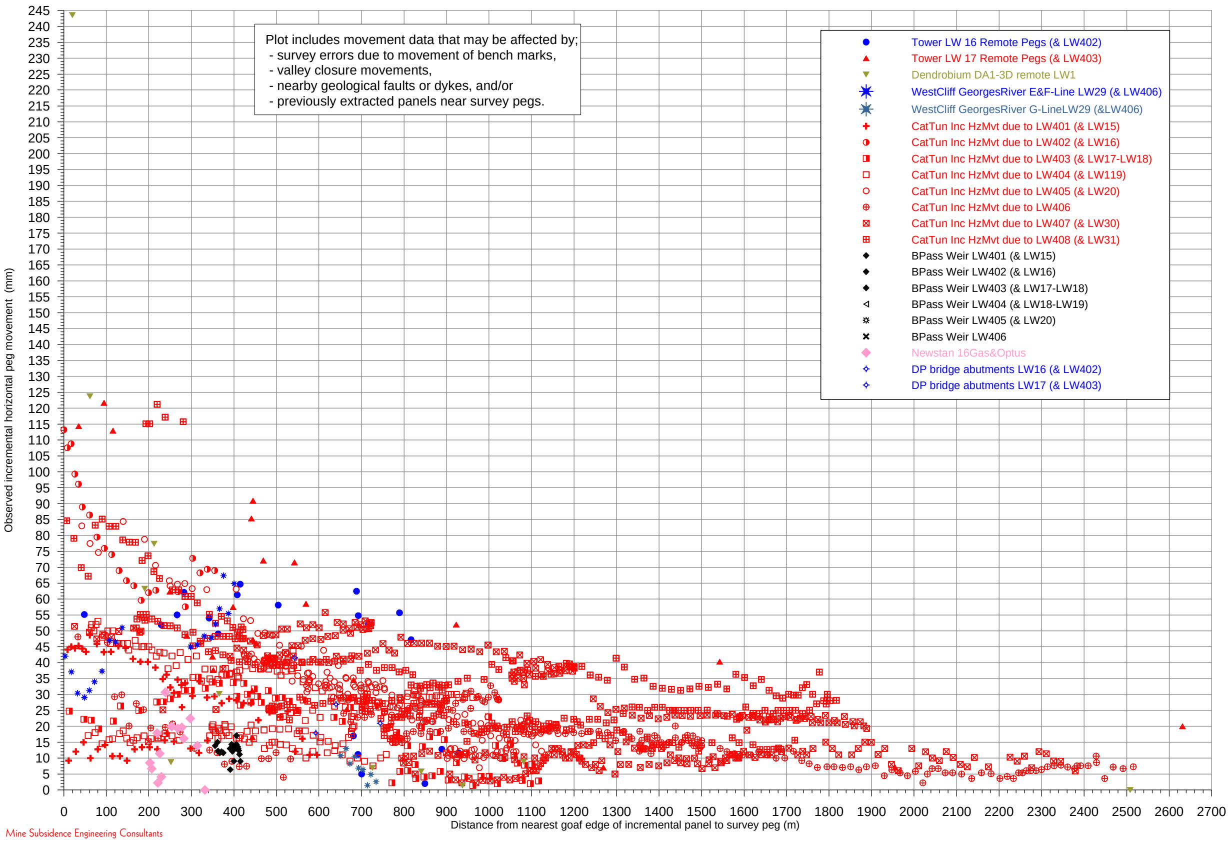

Fig. 5.3 Observed Incremental Far-Field Horizontal Movements with Solid Coal between the Monitoring Points and Mined Longwall

5.12.3. The Likelihood of Surface Cracking in Soils and Fracturing of Bedrock

As subsidence occurs, surface cracks will generally appear in the tensile zone, i.e. within 0.1 to 0.4 times the depth of cover from the longwall perimeter. Most of the cracks will occur within a radius of approximately 0.1 times the depth of cover from the longwall perimeter. The residual cracks will generally be above and parallel to the longitudinal edges of the longwalls.

It is also possible that surface cracks could occur above and parallel to the moving longwall extraction faces, i.e. at right angles to the longitudinal edges of the longwalls, as the subsidence trough develops. This cracking is, however, likely to be transient, since the tensile phase, which causes the cracks to open up, is generally followed by a compressive phase, that partially closes them.

Fracturing of exposed sandstone or near surface bedrock is likely to occur coincident with the maximum tensile strains, but open fractures could also occur due to buckling of surface beds that are subject to compressive strains. Fracture widths tend to increase as the depth of cover reduces, and only minor fracturing is expected for the proposed longwall, where the depth of cover exceeds 500 metres.

Fractures are less likely to be observed in exposed bedrock where the conventional strain levels are low, typically less than 2 mm/m, as has been predicted within the Study Area. A joint spacing of ten metres is not unusual for sandstone and, therefore, fractures at joints could be as wide as 10 mm, based on an estimate conventional tensile strain of 1 mm/m resulting from the extraction of the proposed longwall.

The incidence of cracks on the surface due to mine subsidence is additionally dependent on the thickness and inherent plasticity of the soils that overlie the bedrock. Surface soils above the proposed longwalls are generally weathered to some degree. The widths and frequencies of any cracks are also dependent upon the pre-existing jointing patterns in the bedrock. Large joint spacing can lead to concentrations of strain and possibly the development of fissures at rockhead, which are not necessarily coincident with the joints.

The relationship between the depth of cover and the width of surface cracks, based upon measured data in the NSW Coalfields and observations over mines in the United Kingdom is shown in Fig. 5.4. The line on the graph represents the upperbound limit of the data in flat terrain. It can be seen that the typical crack width at a depth of cover of 500 metres, due to normal subsidence movements, would generally be expected to be around 20 mm to 30 mm. If a reasonable thickness of surface soil exists, it is more likely that the surface soil would exhibit a number of narrower cracks, rather than a single larger crack.

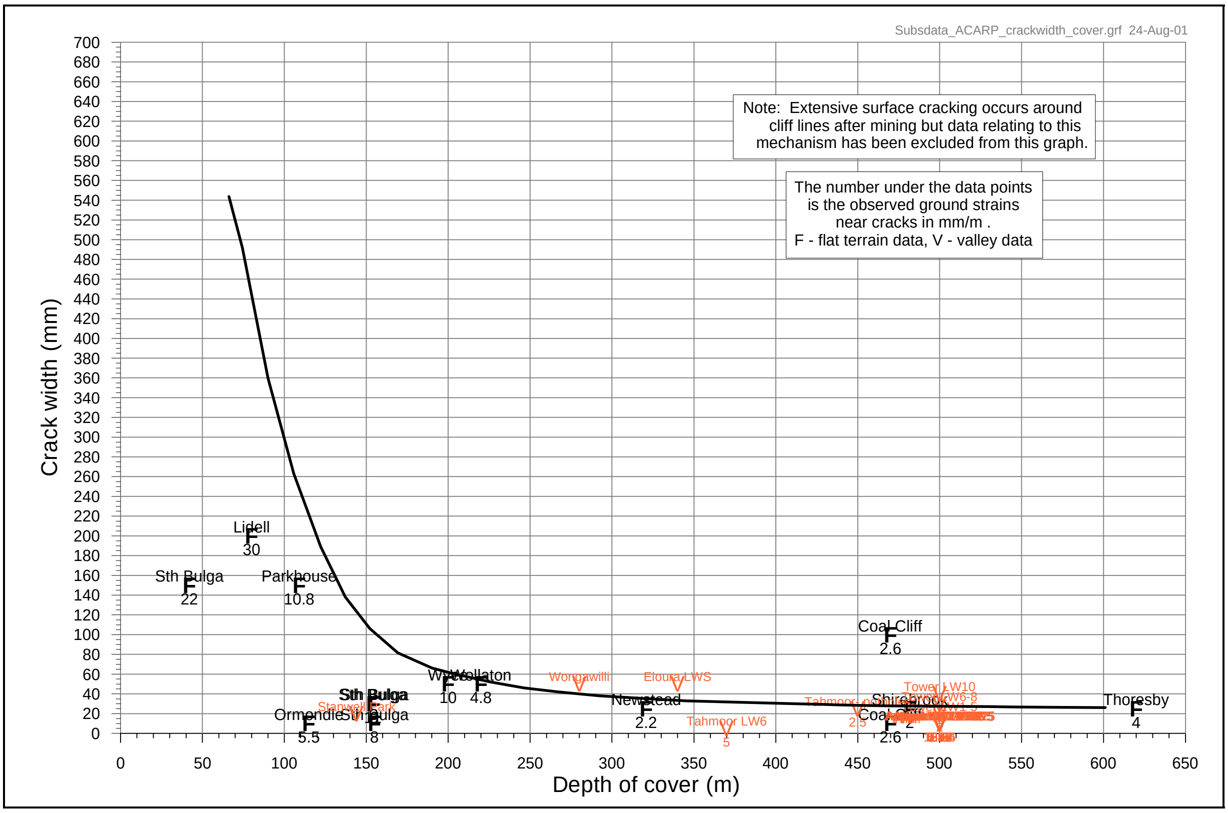

Fig. 5.4 Relationship between Crack Width and Depth of Cover

Surface cracking in soils as the result of conventional subsidence movements is not commonly seen at depths of cover greater than 500 metres, such as at Austar, 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 creek and river 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 Sections 5.2.

Surface cracks are also more readily observed in built infrastructure such as road pavements. In many 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.

The surface cracking resulting from the extraction of the proposed longwall is expected to be of a minor nature, which can be easily remediated by infilling with soil or other suitable materials, or by locally regrading and recompacting the surface.

Examples of surface tensile cracking and compression buckling are provided in the photographs in Fig. 5.5 and Fig. 5.6, respectively. These ground deformations were observed in the Southern Coalfield, where the depths of cover were similar to, but slightly less than those within the Study Area.

Fig. 5.5 Example of Surface Tensile Cracking in the Natural Ground Surface

Fig. 5.6 Example of Surface Compression Buckling Observed in Road Pavement

5.12.4. The Likelihood of Irregular Profiles

Wherever faults, dykes, or abrupt changes in geology are present at the surface, it is possible that irregularities in the subsidence profiles could occur. Similarly, where surface rocks are thinly bedded, and where cross-bedded strata exist close to the surface, it is possible for surface buckling to occur, leading to irregular movements. Most irregularities in subsidence profiles, however, can be explained by the presence of surface incisions such as gorges, river valleys, and creeks.

The major geological features within the vicinity of the proposed longwall are shown in Drawing No. MSEC417-01. There are no identified major faults or dykes within the proposed extraction area of Longwall A5a. The *Central Dyke* is located immediately to the east of the Stage 2 longwalls. The *Swamp Fault Zone* is located to the west of the Stage 2 longwalls, which is at a distance of approximately 250 metres from the proposed Longwall A5a at its nearest point

Irregularities also occur in shallow mining situations, where the collapsed zone, which develops above the extracted seam, extends near to the surface. This type of irregularity is generally only seen where the depth of cover is less than 100 metres, and is unlikely to occur above the proposed longwall, where the depth of cover exceeds 500 metres.

Irregular subsidence profiles can also occur where longwall mining is carried out beneath previous workings, especially beneath bord and pillar extractions which have extensive stooks preventing immediate subsidence. In such situations, the pillars or stooks left in the upper seam can collapse, when mining occurs beneath them, leading to local increased subsidence and irregular subsidence profiles. There are no existing workings above the proposed longwalls, and this kind of irregularity will not occur in this case.

It is also possible that anomalous movements could occur at unknown geological structures above the proposed longwall. These have occurred in the past within the NSW Coalfields. Given the relatively low density of surface features within the Study Area, the probability of an anomalous movement coinciding with a surface feature is assessed as low.

Examples of these rarely observed anomalous ground movements are provided in the photographs in Fig. 5.7 and Fig. 5.8. These ground deformations occurred along a low angle thrust fault in the Southern Coalfield. No such thrust faults have been identified within the Study Area.

Fig. 5.7 Example of Surface Compression Humping due to Low Angle Thrust Fault

Fig. 5.8 Example of Surface Compression Humping due to Low Angle Thrust Fault

5.12.5. Likely Height of the Fractured Zone

The background to sub-surface strata movements is provided in the report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com,* and the following conclusions should be read in that context.

The height of the collapsed zone, which forms immediately above extracted longwalls, is generally between 21 to 33 times the extracted seam thickness. The effective extracted seam thickness for the proposed Longwall A5a varies between 5.1 and 5.6 metres and, therefore, the predicted height of the collapsed zone above the proposed longwall varies between 100 and 185 metres.

The height of the fractured zone is dependent upon the angle of break (a), the width of the panel (W) and the spanning capacity of a competent stratum at the top of the fracture zone, span (w). These are illustrated in Fig. 5.9. From the mining geometry it can be shown that the height of the fractured zone equals the panel width (W) minus the span (w) divided by twice the tangent of the angle of break.

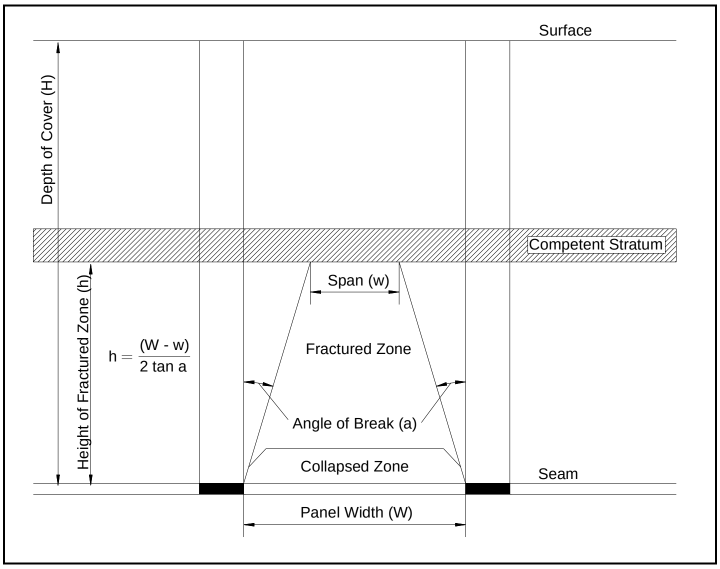

Fig. 5.9 Theoretical Model illustrating the Development and Limit of the Fractured Zone

Using this relationship, the theoretical height of the fractured zone, as a proportion of the width of the extracted panel, has been determined for a range of panel width-to-depth ratios. These values have been plotted in the graph shown in Fig. 5.10, together with the values that have been reported in literature. The red data points are those which have been reported in literature whilst the theoretical values are shown in green, magenta and blue for angles of break of 17°, 20° and 23°, respectively.

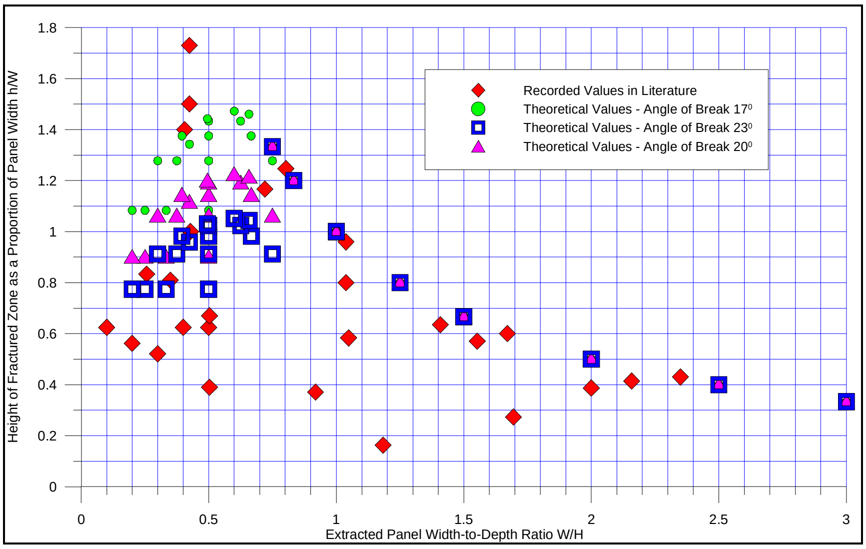

Fig. 5.10 Graph showing Height of Fractured Zone as a Proportion of Panel Width for different Width-to-Depth Ratios

It can be seen that the height of the fractured zone in the database is reasonably represented by the theoretical model using an angle of draw of 20°. Only three red data points appear above the magenta data points and these are the heights of the fractured zone over Longwall 2 at Ellalong Colliery (now Austar), and over Longwall 3 at Tahmoor Colliery, which were given by Holla (1986) and Holla and Buizen (1991).

In both of these cases, the apparent heights of the fractured zone were determined from extensometer readings which could have included horizontal shear as well as vertical dilation. The stated heights of the fractured zone at Tahmoor, which are the highest data points in the graph, are not supported by the measured vertical strains, which averaged only 0.6 mm/m in the top 160 metres of the overburden. A more realistic assessment is that the fractured zone extended only to the Bald Hill Claystone.

In some cases, it is likely that the upwards progression of the fractured zone was limited by the levels of vertical strain that could be developed, which is dependent upon the extracted seam thickness, the surface subsidence and the depth of cover.

The upper limit of the fractured zone will be reached when the strata above that zone are sufficiently strong to span the goaf area without significant bending or shear strains being developed. In the Newcastle Coalfield, the upper layers in the overburden strata are relatively strong sandstones. These sandstone strata are particularly strong and would be expected to be capable of spanning at least 35 metres. If an average angle of break of 20° is assumed, with an extracted panel width of 235 metres, then a height of 275 metres would be required above the seam to reduce the effective span to 35 metres. If an angle of break of 23° is assumed, then a height of 235 metres would be required above the seam to reduce the effective span to 35 metres.

The depth of cover above the proposed longwall varies between 530 and 560 metres and it is unlikely, therefore, that the fractured zone would extend up to the surface. It is expected that a *Constrained Zone*, also called a *Continuous Deformation Zone*, would occur between the fractured zone and the surface, which is illustrated in Fig. 5.11 and Fig. 5.12.

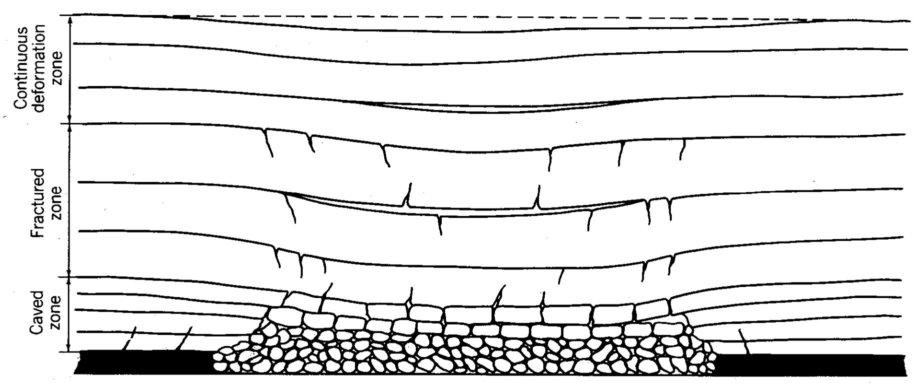

Fig. 5.11 Zones in the Overburden According to Peng and Chiang (1984)

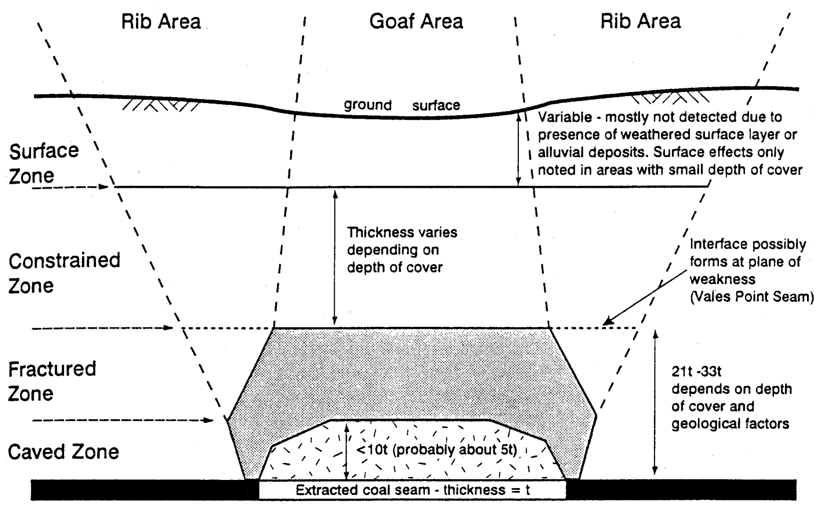

Fig. 5.12 Zones in the Overburden according to Forster (1995)

The constrained zone comprises confined rock strata 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 discontinuous vertical cracks (usually on the underside of thick strong beds). Weak or soft beds in this zone may suffer plastic deformation.

APPENDIX A. REFERENCES

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APPENDIX B.   FIGURES

Predicted Profiles of Conventional Subsidence, Tilt and Strain along Prediction Line A Resulting from the Extraction of Longwalls A3 to A5a

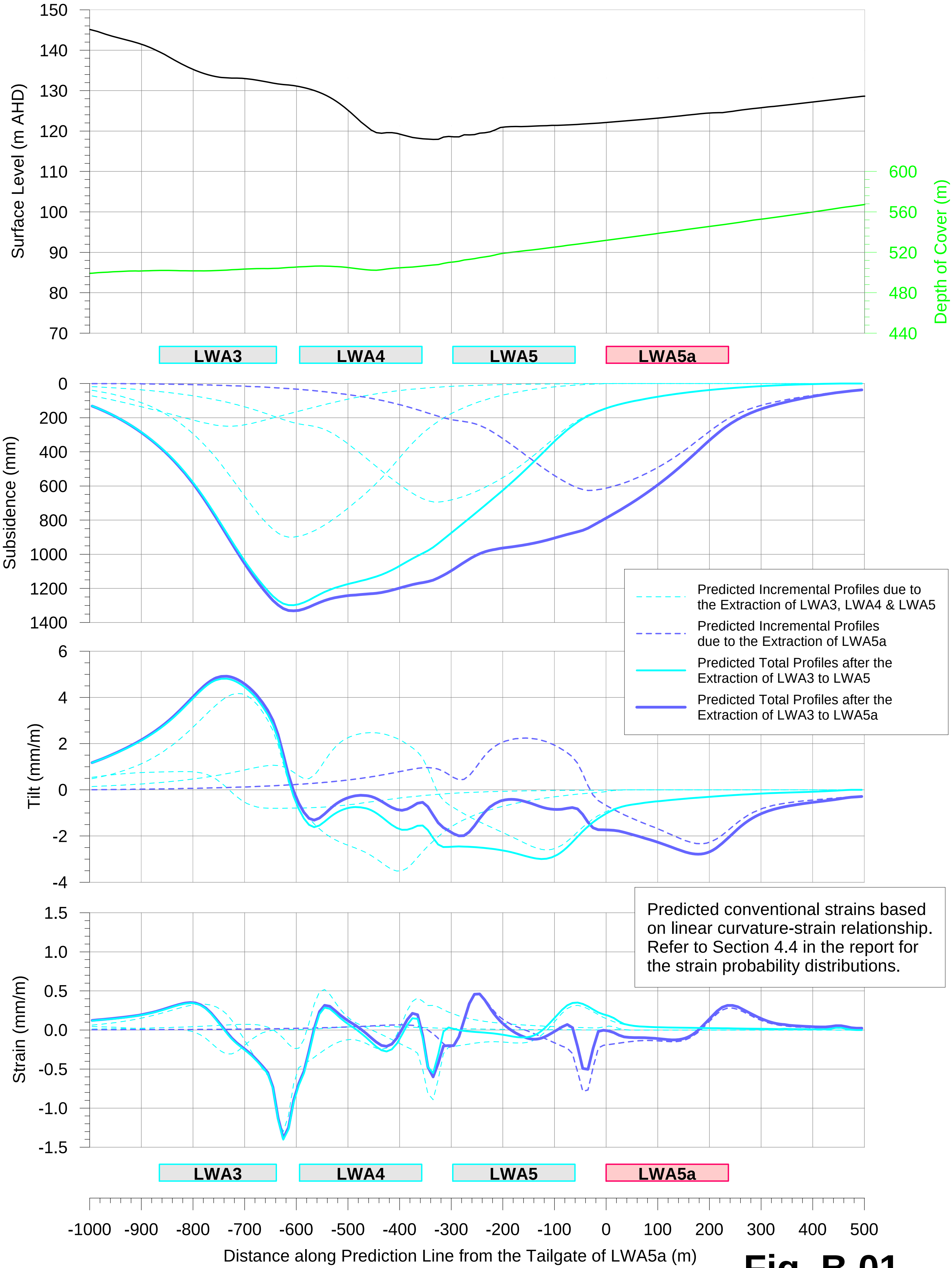

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Fig. B.01

Predicted Profiles of Conventional Subsidence, Upsidence and Closure along Quorrobolong Creek Resulting from the Extraction of Longwalls A3 to A5a

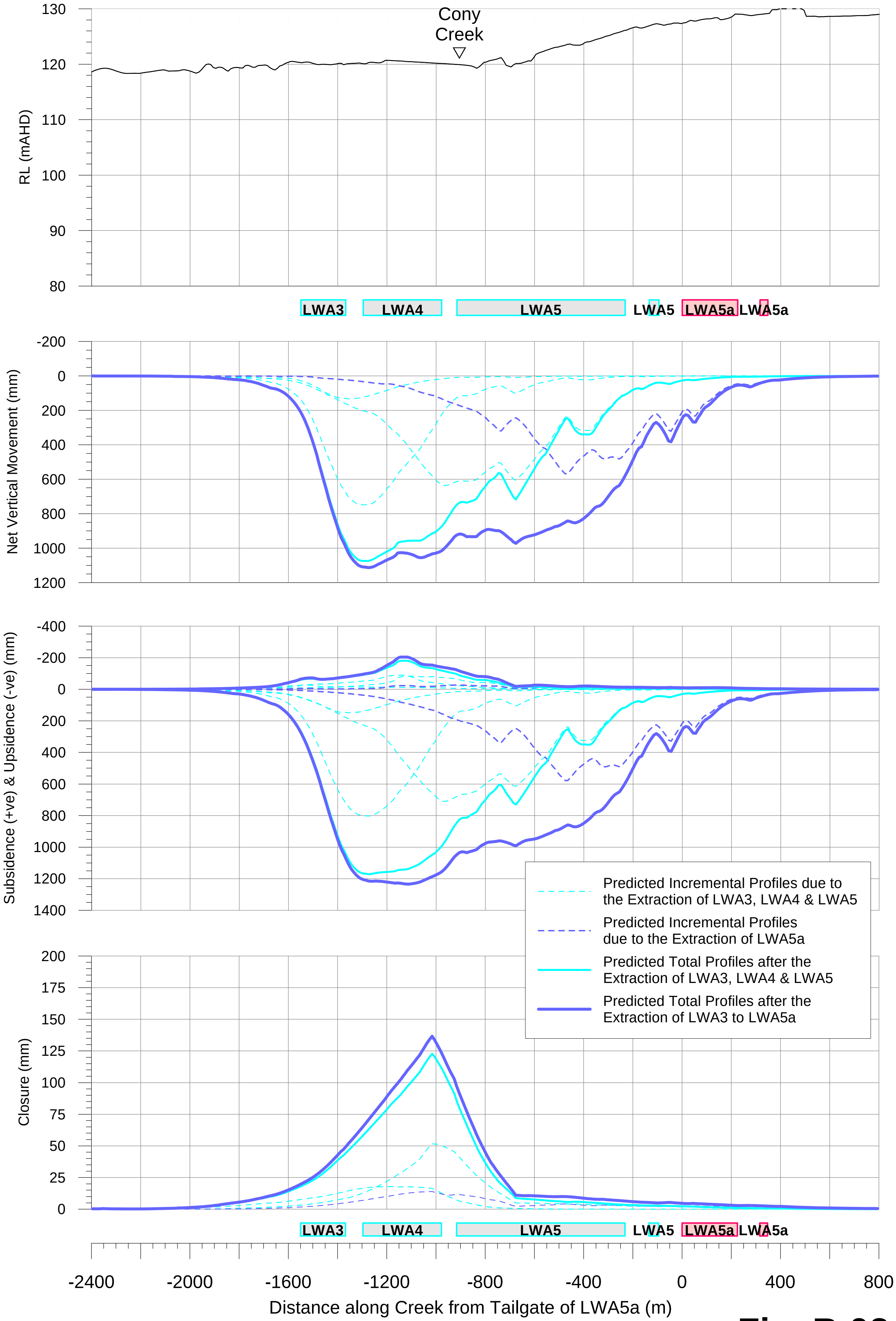
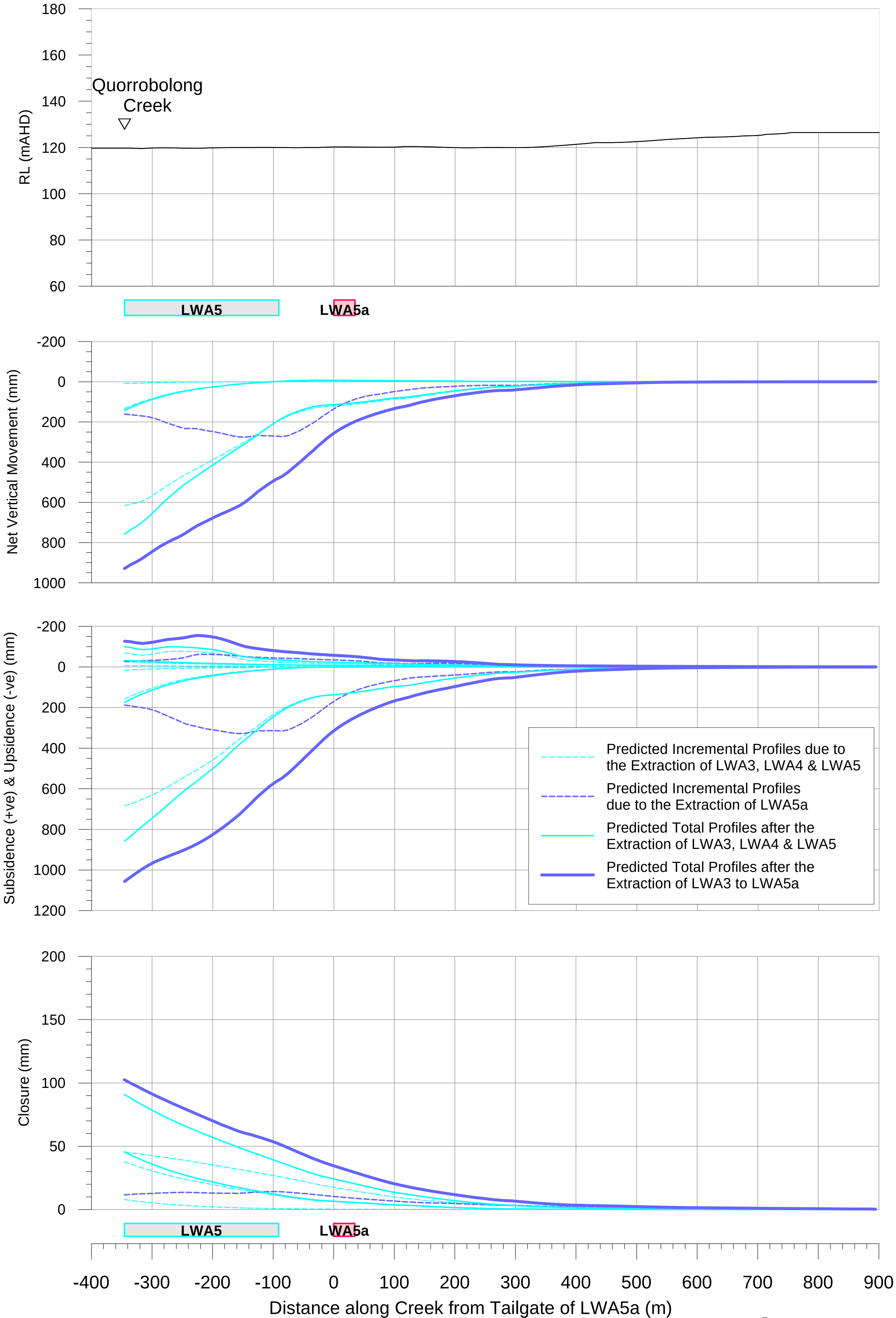


Fig. B.02

Predicted Profiles of Conventional Subsidence, Upsidence and Closure along Cony Creek Resulting from the Extraction of Longwalls A3 to A5a



APPENDIX C. DRAWINGS

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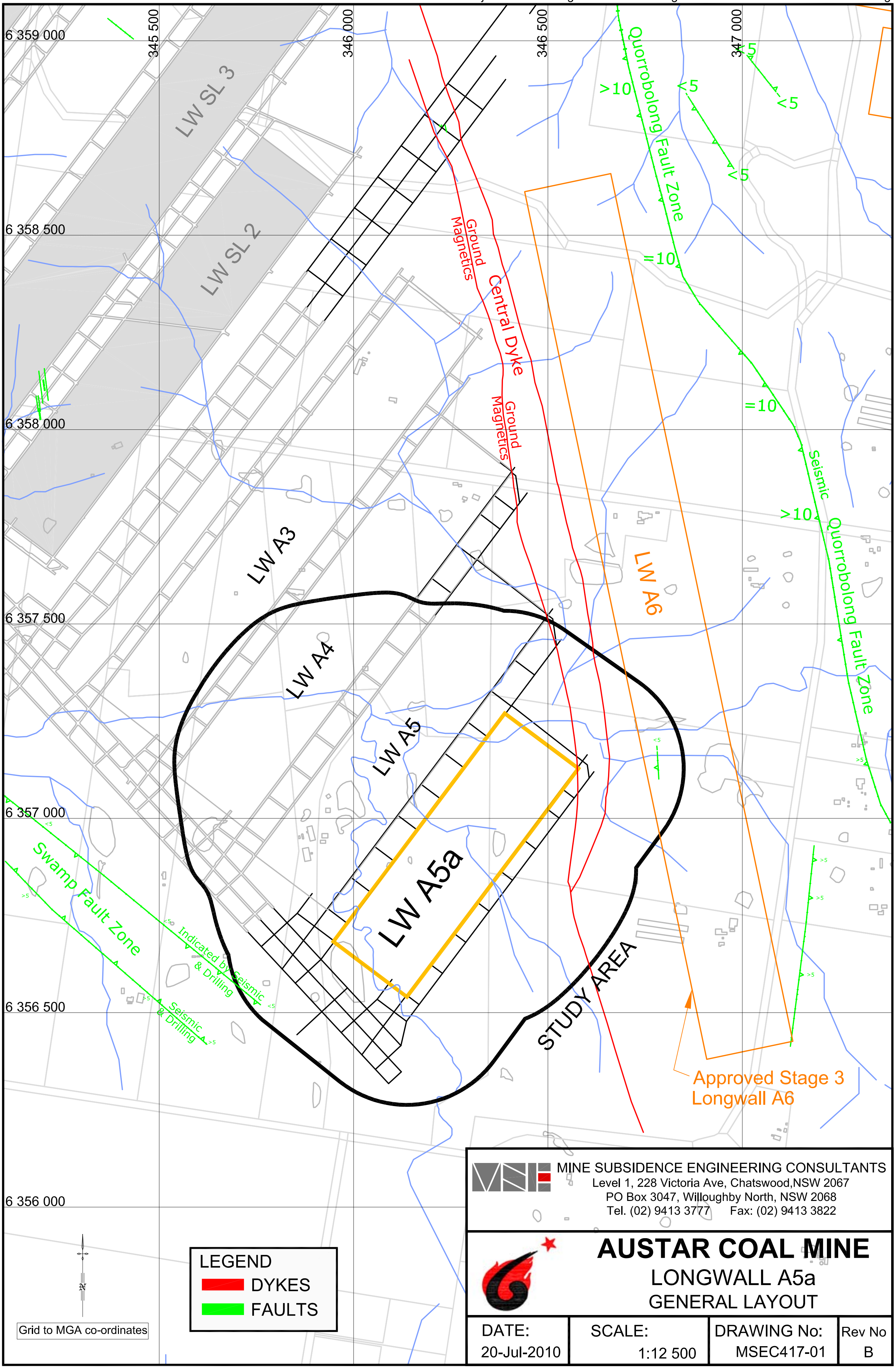

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AUSTAR COAL MINE
LONGWALL A5a
GENERAL LAYOUT

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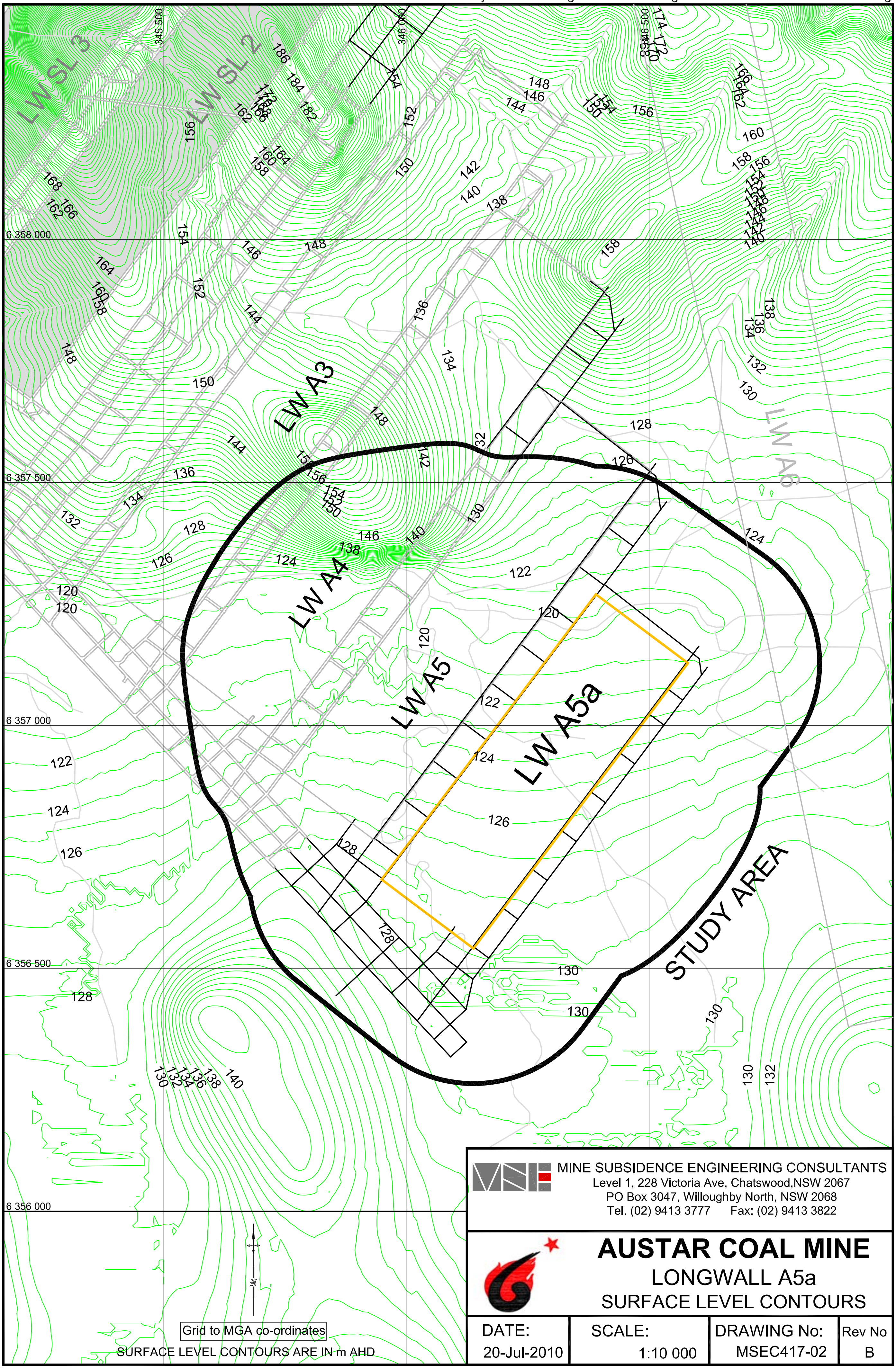

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LONGWALL A5a
SURFACE LEVEL CONTOURS

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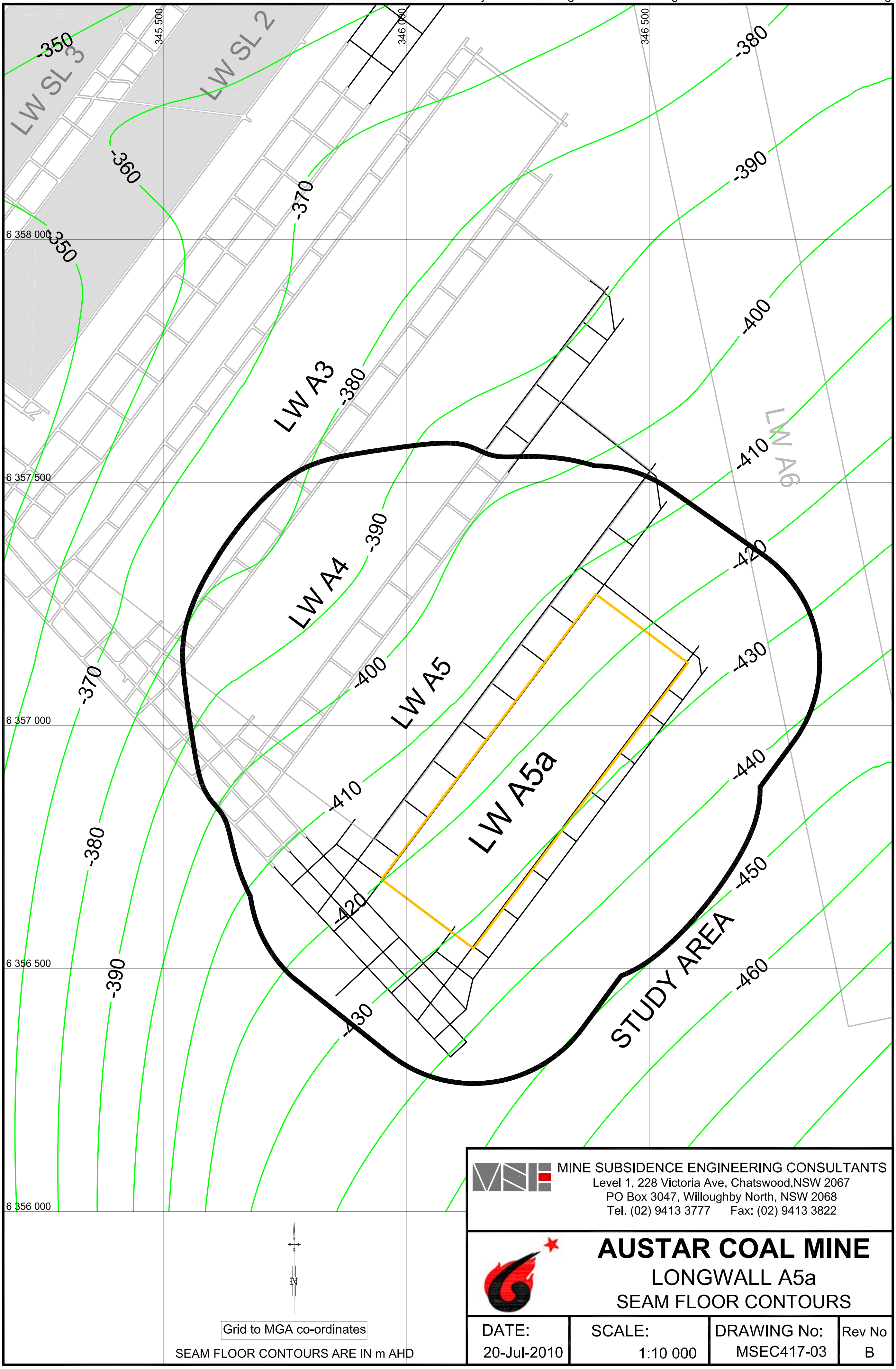

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LONGWALL A5a
SEAM FLOOR CONTOURS

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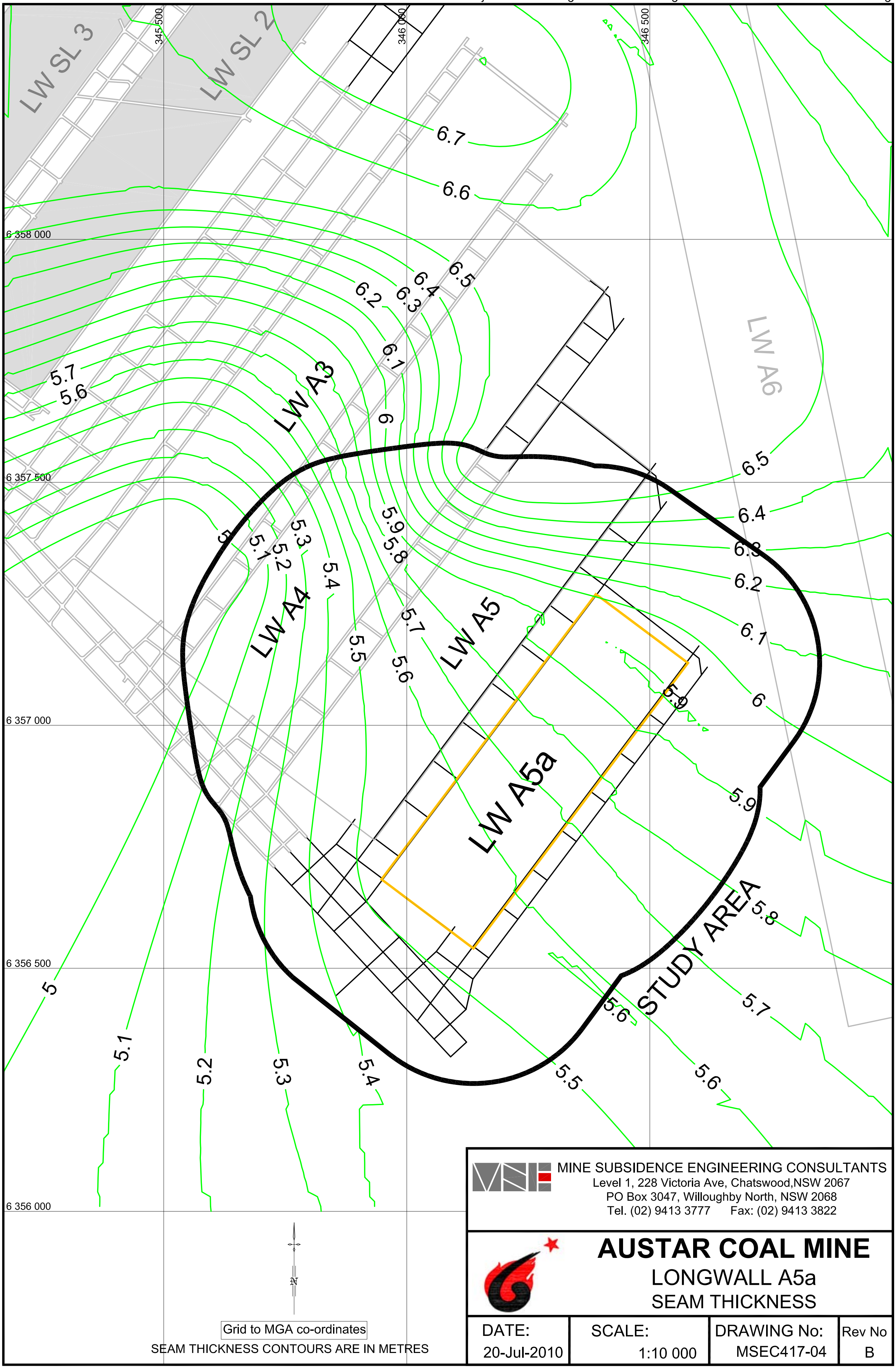

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LONGWALL A5a

SEAM THICKNESS

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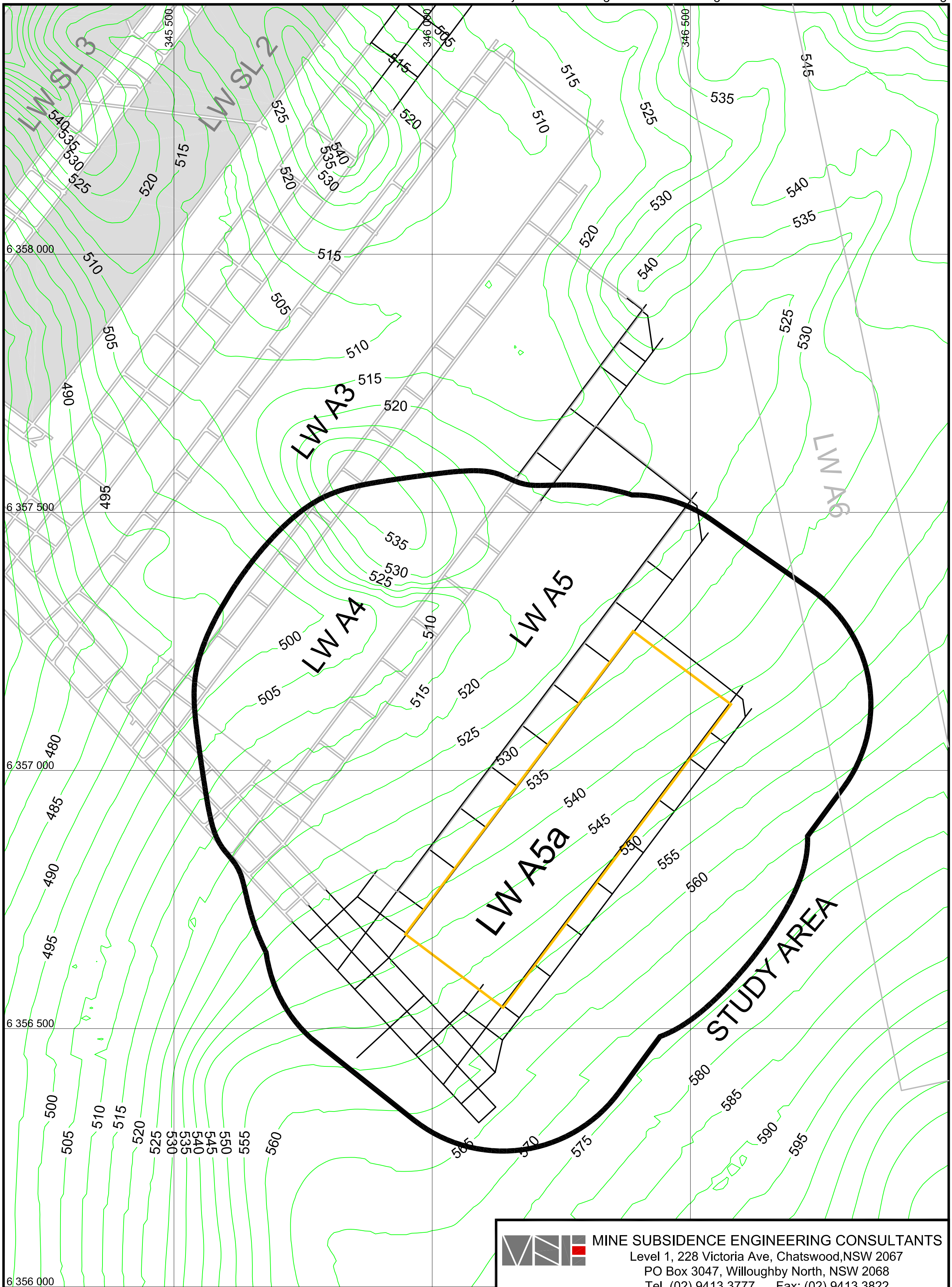

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AUSTAR COAL MINE

LONGWALL A5a

DEPTH OF COVER CONTOURS

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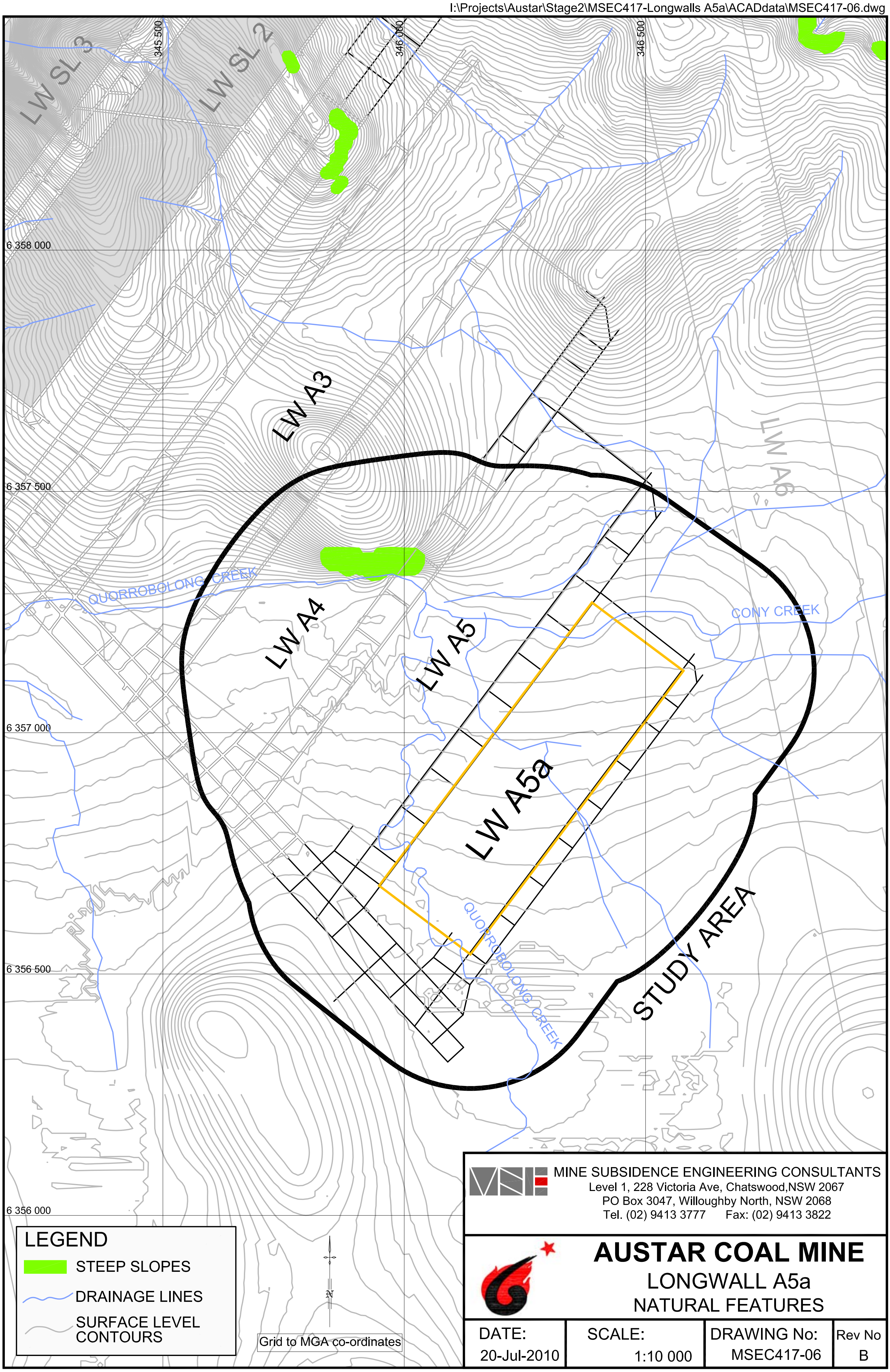

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AUSTAR COAL MINE
LONGWALL A5a
NATURAL FEATURES

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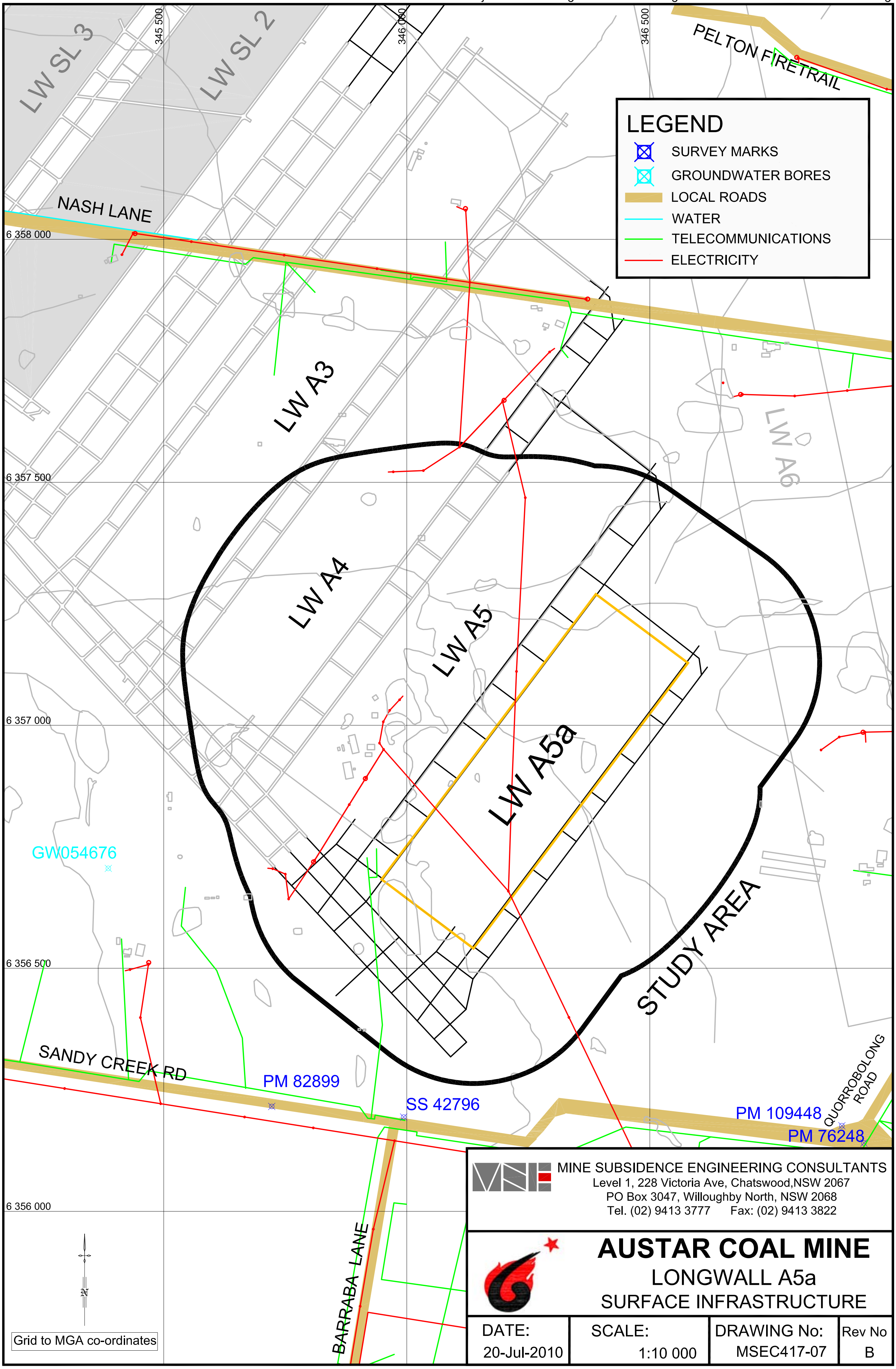

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AUSTAR COAL MINE

LONGWALL A5a

SURFACE INFRASTRUCTURE

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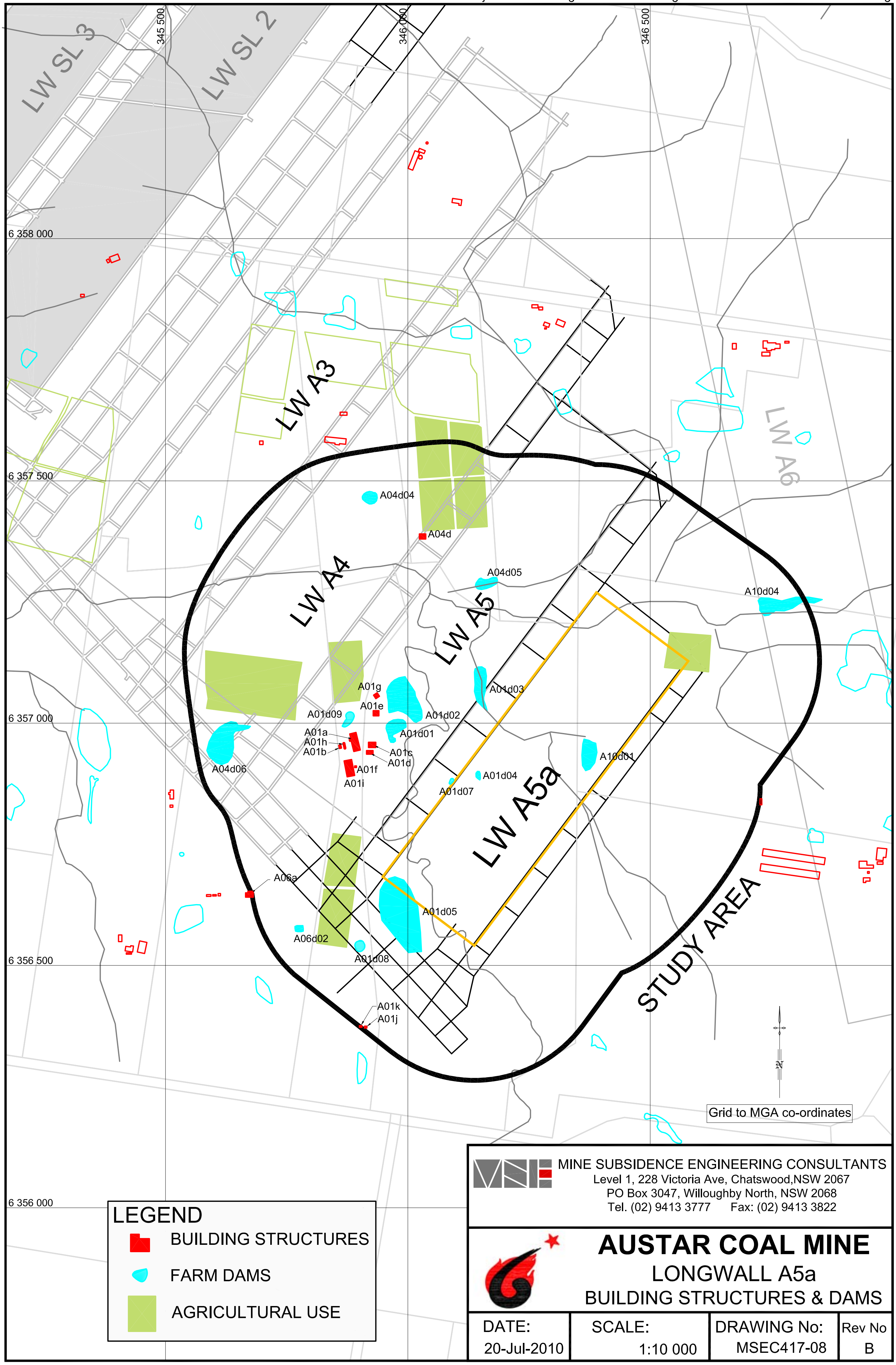

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AUSTAR COAL MINE
LONGWALL A5a
BUILDING STRUCTURES & DAMS

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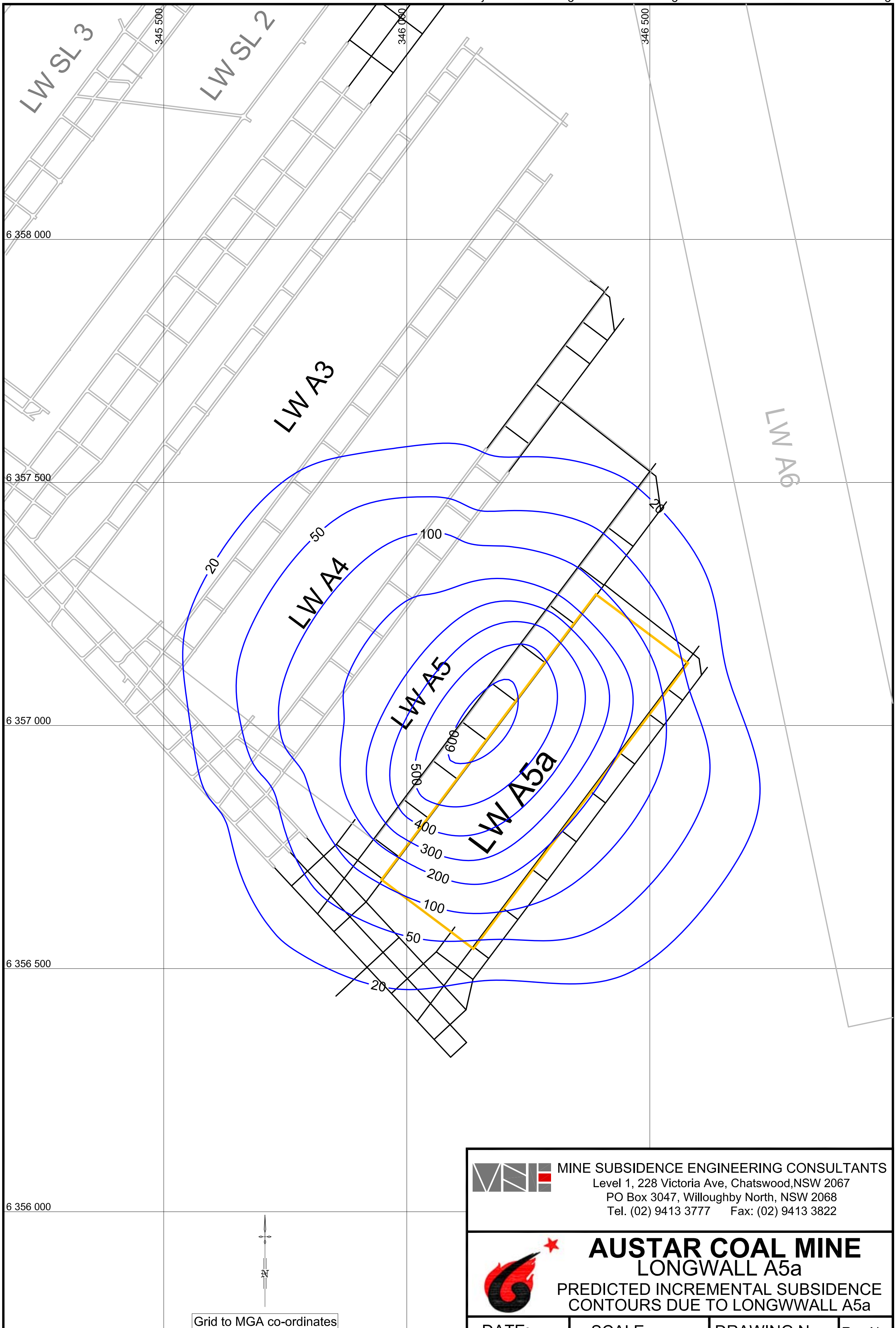

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AUSTAR COAL MINE
LONGWALL A5a
PREDICTED INCREMENTAL SUBSIDENCE CONTOURS DUE TO LONGWWALL A5a

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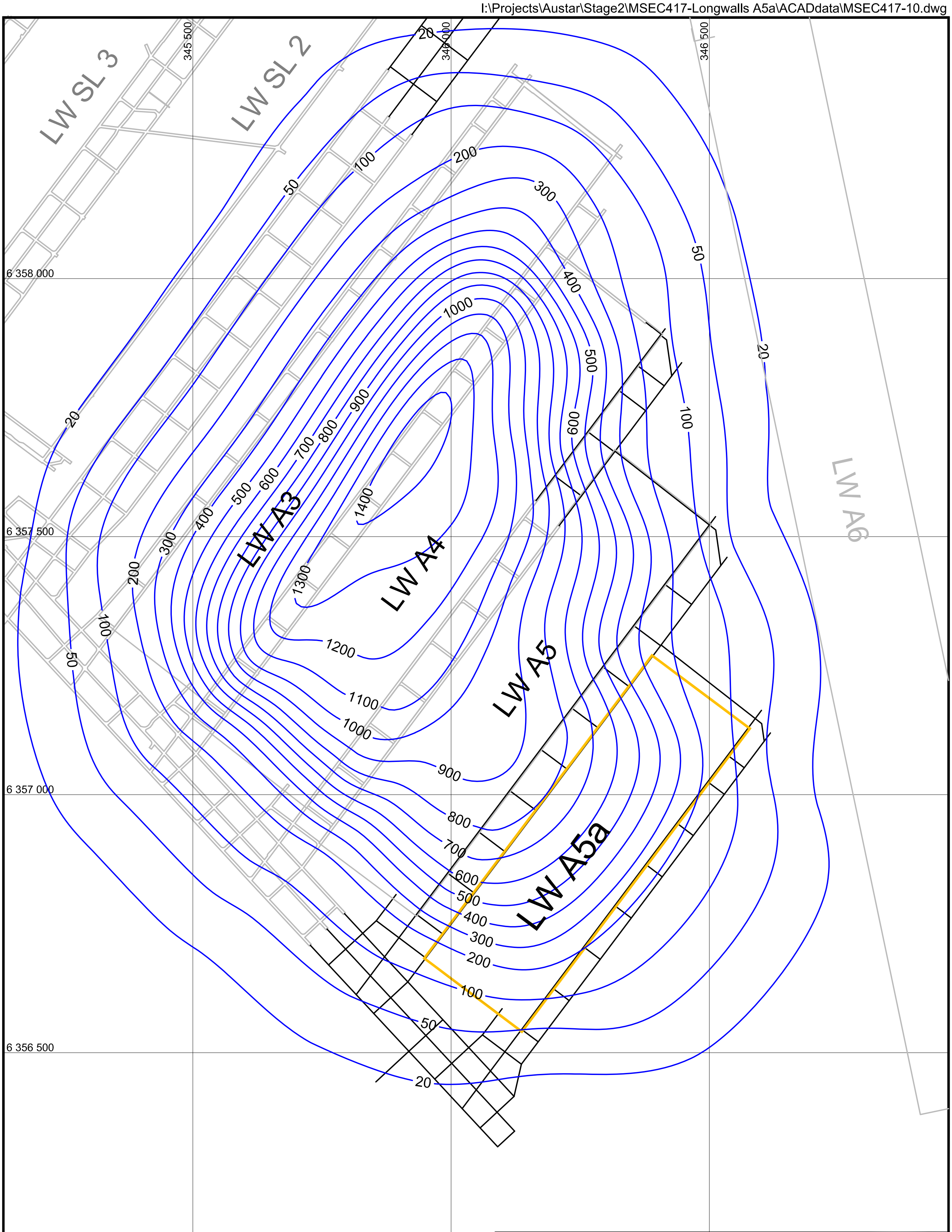

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AUSTAR COAL MINE
LONGWALL A5a
PREDICTED TOTAL SUBSIDENCE
CONTOURS AFTER LONGWALL A5a

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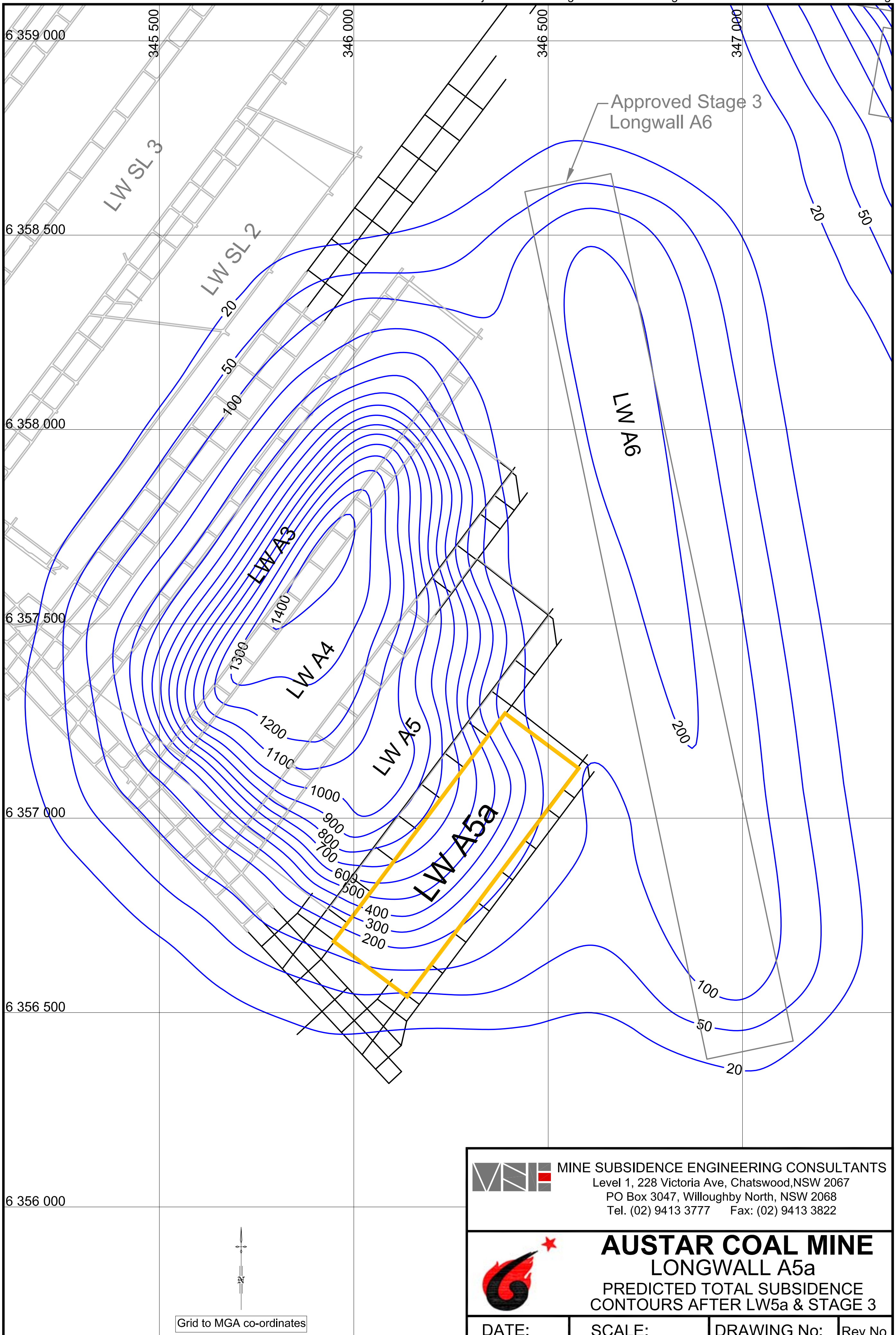

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AUSTAR COAL MINE
LONGWALL A5a
PREDICTED TOTAL SUBSIDENCE
CONTOURS AFTER LW5a & STAGE 3

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