MOOLARBEN COAL COMPLEX:

# Moolarben Project Stage 1 – Longwalls 409 to 414

Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan

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Report produced to:- Support the Extraction Plan for submission to the Department of Planning and Environment (DP&E).

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

Moolarben Coal Operations Pty Limited (MCO) operates the Moolarben Coal Complex (MCC), which is located approximately 40 kilometres north east of Mudgee in New South Wales (NSW). MCO has been granted approval to develop Stages 1 and 2 of the Moolarben Coal Project (MCP) under the *Environmental Planning and Assessment Act 1979*. Approval for Stage 1 of the MCP (05_0117) was granted by the Minister for Planning on 6 September 2007. Approval for Stage 2 of the MCP (08_0135) was granted on 30 January 2015.

The MCC includes four approved open cut mines, (known as Open Cut 1 mine (OC1), Open Cut 2 mine (OC2), Open Cut 3 mine (OC3) and Open Cut 4 mine (OC4)), and three approved underground mines, (known as Underground Area 1 (UG1), Underground Area 2 (UG2) and Underground Area 4 (UG4)) and the associated infrastructure.

The locations of the approved MCC open cut mines and underground mines, including UG4, are shown in Drawing No. MSEC138101, which together with all other drawings is included in Appendix E.

MCO has completed underground mining at UG1 and is currently extracting Longwall 405 within UG4 under an approved Extraction Plan for UG4 Longwalls 401 to 408.

This Extraction Plan has been prepared for UG4 Longwalls 409 to 414. The proposed *Extraction Plan Layout* for Longwalls 409 to 414 incorporates shortening of Longwalls 413 and 414, and a reduced extraction height to 3.0m.

Mine Subsidence Engineering Consultants (MSEC) has prepared this subsidence report to support the Extraction Plan for Longwalls 409 to 414. The predictions and impact assessments provided in this report are based on the *Extraction Plan Layout*, as shown in Drawing No. MSEC1381-02. The report includes a comparison to the subsidence predictions of the *Approved Layout*. The *Approved Layout* is the current approved layout under 05_0117 which remains unchanged from original approval in 2007.

The Study Area has been defined, as a minimum, as the surface area enclosed by a 26.5° angle of draw line from the extents of secondary extraction and by the predicted total 20 mm subsidence contour based on the Extraction Plan Layout and Approved Layout. Other features which could be subjected to far-field or valley related movements and could be sensitive to such movements have also been assessed in this report.

A number of natural and built features have been identified within or in the vicinity of the Study Area including: Goulburn River and ephemeral drainage lines; cliffs including The Drip and Goulburn River Gorge; the Goulburn River National Park; roads; unsealed tracks and trails; telecommunications infrastructure; dams; bores; mine infrastructure; exploration drill holes; archaeological sites; and survey control marks.

The maximum predicted total conventional subsidence based on the Extraction Plan Layout is 1,900 mm. The maximum predicted total conventional tilt based on the Extraction Plan Layout is 40 mm/m. The maximum predicted total conventional curvature based on the Extraction Plan Layout is 2.0 $km^{-1}$ hogging and 1.6 $km^{-1}$ sagging. The maximum predicted conventional subsidence parameters based on the Extraction Plan Layout are the same as those based on the Approved Layout.

The predicted levels of subsidence, tilt, curvature and strain that are expected to be experienced at the natural features and items of surface infrastructure vary depending on their positions in relation to the Extraction Plan Layout and Approved Layout. The proposed panel and pillar widths for the Extraction Plan Layout and Approved Layout are unchanged. Longwall 413 has been shortened at the finishing end and Longwall 414 has been shortened at the commencing end, hence there are some locations near the shortened lengths where reduced levels of subsidence, tilt, curvature and strain are now expected and some locations where slightly increased levels of subsidence, tilt, curvature and strain are expected. Generally, the maximum predicted subsidence parameters at the surface features are similar for the Extraction Plan Layout and Approved Layout.

The majority of the built features are located outside the Study Area and the predictions and impact assessments generally do not change based on the Extraction Plan Layout.

This report is structured as follows:

Chapter 1 provides an introduction and information on the mine layout, surface topography, seam and geological information.

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

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

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of the Approved Layout and Extraction Plan Layout.

Chapters 5 to 10 provide the descriptions, predictions and impact assessments for each of the natural and built features which have been identified within the Study Area. Recommendations for each of these features are also provided, which have been based on the predictions and impact assessments.

The overall findings of the subsidence predictions and impact assessments that have been undertaken by MSEC for this report due to the Extraction Plan Layout are that the levels of ground movements, and any potential impacts to the identified natural features and built infrastructure can be managed to comply with the subsidence performance measures in 05_0117 including maintaining safety and serviceability..

Monitoring and management strategies will be developed for the identified natural features as part of the Extraction Plan process for Longwalls 409 to 414 based on the Extraction Plan Layout.

The monitoring and management strategies for built features would aim to achieve the performance measure of safe, serviceable and repairable.

It should also be noted that more detailed assessments on some natural features and items of surface infrastructure have been undertaken by other consultants, and the findings in this report should be read in conjunction with the findings in all other relevant reports.

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## LIST OF TABLES, FIGURES AND DRAWINGS

### Tables

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

**Figures**

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

**Drawings**

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

## 1.1. Background

Moolarben Coal Operations Pty Limited (MCO) operates the Moolarben Coal Complex (MCC), which is located approximately 40 kilometres north east of Mudgee in New South Wales (NSW). MCO has been granted approval to develop Stages 1 and 2 of the Moolarben Coal Project (MCP) under the *Environmental Planning and Assessment Act 1979*. Approval for Stage 1 of the MCP (05_0117) was granted by the Minister for Planning on 6 September 2007. Approval for Stage 2 of the MCP (08_0135) was granted on 30 January 2015.

The MCC includes four approved open cut mines, (known as Open Cut 1 mine (OC1), Open Cut 2 mine (OC2), Open Cut 3 mine (OC3) and Open Cut 4 mine (OC4)), and three approved underground mines, (known as Underground Area 1 (UG1), Underground Area 2 (UG2) and Underground Area 4 (UG4)) and the associated infrastructure.

The locations of the approved MCC open cut mines and underground mines, including UG4, are shown in Drawing No. MSEC1381-01, which together with all other drawings is included in Appendix E.

MCO has completed underground mining at UG1 and is currently extracting Longwall 405 within UG4 under an approved Extraction Plan for UG4 Longwalls 401 to 408.

This Extraction Plan has been prepared for UG4 Longwalls 409 to 414. The proposed *Extraction Plan Layout* for Longwalls 409 to 414 incorporates shortening of Longwalls 413 and 414, and a reduced extraction height to 3.0m.

The locations of the approved MCC open cut mines and underground mines, including the UG4, are shown in Drawing No. MSEC1381-01, which together with all other drawings is included in Appendix E. This regional drawing also shows the locations of the adjoining Ulan Coal Mine (UCM), Wilpinjong Coal Mine, Goulburn River National Park, Munghorn Gap Nature Reserve and Sandy Hollow Gulgong Railway Line.

The following subsidence reports were prepared to provide the necessary mine subsidence predictions and subsidence impact assessments for the project approval for Stage 1 of the MCP:

- Strata Engineering, Mine Subsidence Impact Assessment for the Proposed Longwall Panels LWs 1 to 14, No. 4 Underground Area, Moolarben Coal Project, Report No. 04-001-WHT/1 Rev D, 7th September 2006, Moolarben Coal Project Appendix 8 Subsidence Impact Assessment (Strata Engineering 2006-1);
- Strata Engineering, Preferred Project Report for the Proposed Longwalls 1 to 14 in the No. 4 Underground Area, Moolarben (Stage 1), Report No. 06-002-WHT/1, 1st December 2006, Moolarben Coal Project Response to Submissions Appendix A8 Subsidence Response (Strata Engineering 2006-2); and
- Mine Subsidence Engineering Consultants, Supplementary Notes on Predictions of Subsidence, Valley Upsidence and Closure and Impacts of Subsidence, Upsidence and Closure on the Goulburn River and Cliff Lines, Based on the Preferred Project Mine Layout, Report No. MSEC287 Rev D, November 2006, Moolarben Coal Project Response to Submissions Appendix A9 Upsidence and Valley Closure (MSEC 2006-2).

Mine Subsidence Engineering Consultants (MSEC) has prepared this subsidence report to support the Extraction Plan for Longwalls 409 to 414. The predictions and impact assessments provided in this report are based on the Extraction Plan Layout, as shown in Drawing No. MSEC1381-02. The report includes a comparison to the subsidence predictions of the *Approved Layout*. The *Approved Layout* is the current approved layout under 05_0117 which remains unchanged from original approval in 2007.

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

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

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of the Approved Layout and Extraction Plan Layout.

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

The Extraction Plan Layout and Study Area Boundary, as defined in Section 2.1, have been overlaid on an orthophoto of the area, which is shown in Fig. 1.1.

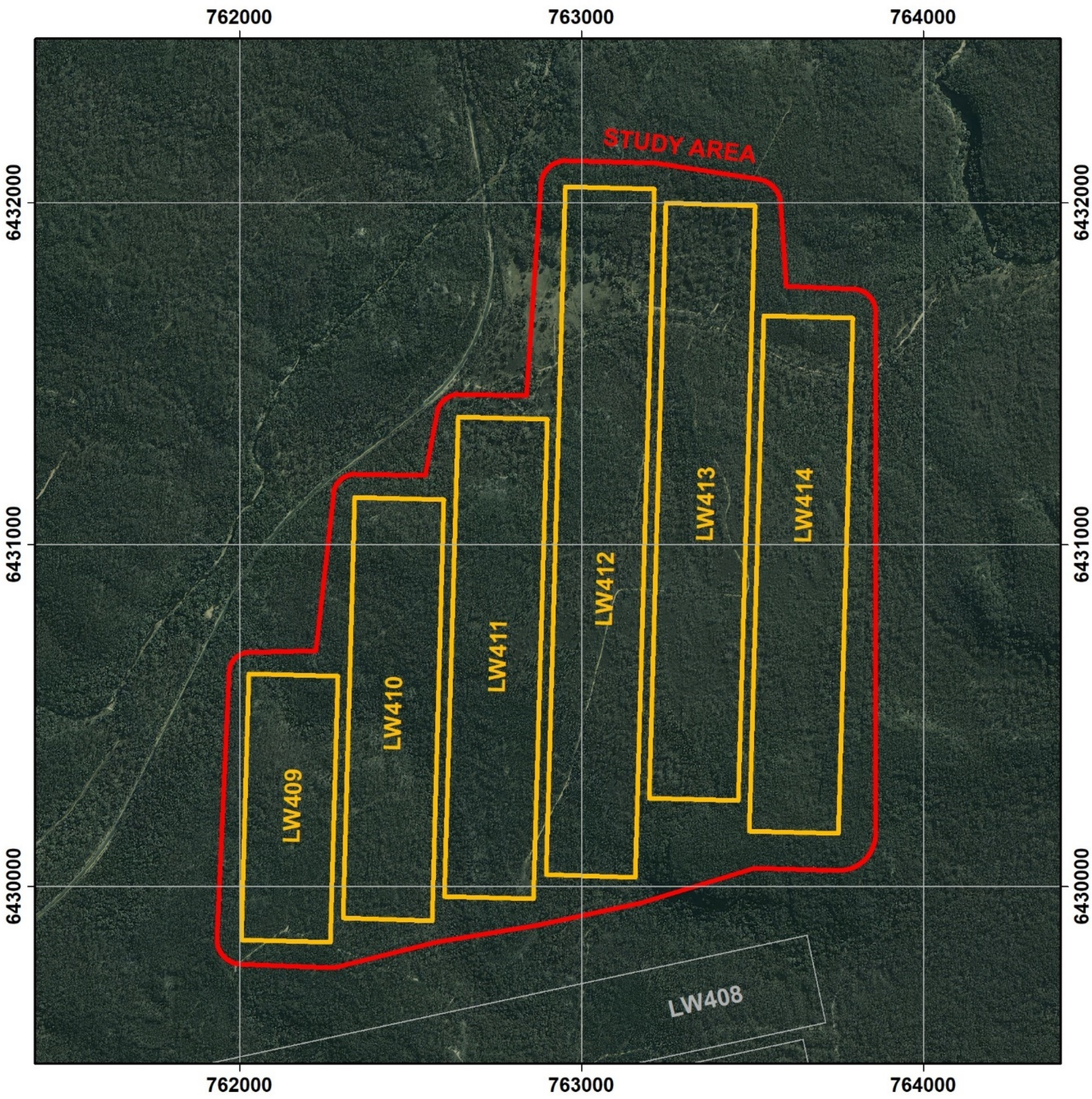


**Fig. 1.1 Aerial Photograph Showing Location of Extraction Plan Layout and the Study Area**

## 1.2. Mining Geometry

The Extraction Plan Layout of Longwalls 409 to 414 is shown in Drawing No. MSEC1381-01 in Appendix E. The longwall geometry for the Extraction Plan Layout is the same as that for the Approved Layout with the exception of Longwall 413 which was shortened at the southern end by 125 m, and Longwall 414 which was shortened at the northern end by 20 m. A summary of the longwall dimensions is provided in Table 1.1.

**Table 1.1 Geometry of the Longwalls 409 to 414 based on the Extraction Plan Layout**

| Longwall | Overall Void Length Including Installation Heading (m) | Overall Void Width Including First Workings (m) | Overall Tailgate Chain Pillar Width (m) |
|---|---|---|---|
| LW409 | 787 | 260 | - |
| LW410 | 1241 | 260 | 35 |
| LW411 | 1411 | 260 | 35 |
| LW412 | 2022 | 260 | 35 |
| LW413 | 1750 | 260 | 35 |
| LW414 | 1509 | 260 | 35 |

## 1.3. Surface Topography and Seam Information

The surface level contours are shown in Drawing No. MSEC1381-03. The surface levels directly above the proposed longwalls in the Extraction Plan Layout vary from a high point of 495 m above Australian Height Datum (mAHD) above finishing (southern) end of Longwall 414 to a low point of 395 mAHD near the commencing (northern) end of Longwall 412.

The seam floor contours, seam thickness contours and depth of cover contours for the Ulan Seam (DWS) are shown in Drawings Nos. MSEC1381-04, MSEC1381-05, and MSEC1381-06, respectively. The contours are based on the latest seam information provided by MCO.

The depth of cover to the Ulan Seam above these longwalls varies between a minimum of 120 near the commencing end of LW412, and a maximum of 215 m above the finishing end of LW414.

The seam floor within the mining area generally dips from the south-west towards the north-east. The average dip of the seam within the extents of the proposed longwalls is around 1.6 %. The thickness of the Ulan Seam (DWS) within the extents of the proposed longwalls varies between 2.8 m and 3.1 m. The proposed mining height for the longwalls is 3.0 m.

The variations in the surface and seam levels across the mining area are illustrated along Prediction Line 1 in Fig. 1.2 and Prediction Line 2 in Fig. 1.3. The locations of the prediction lines are shown in Drawing No. MSEC1381-09.

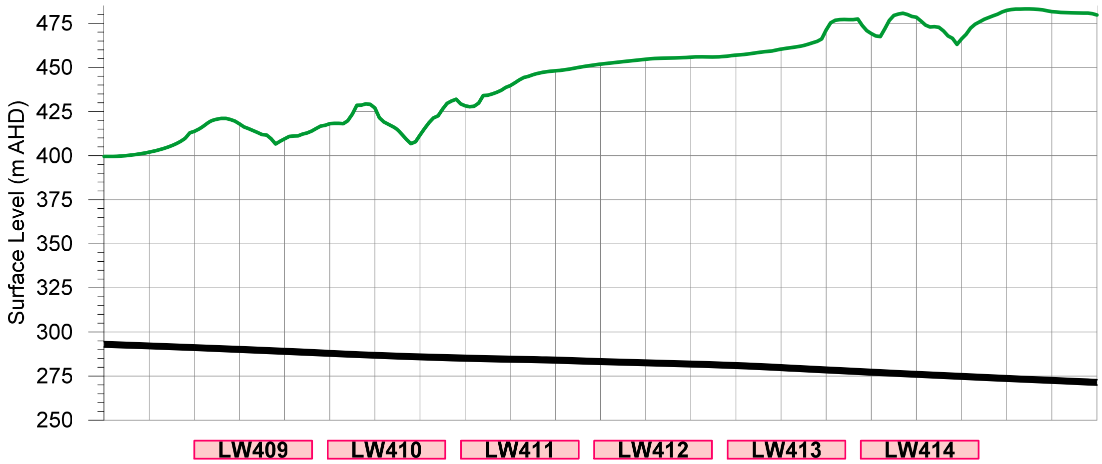


**Fig. 1.2 Surface and Seam Levels along Prediction Line 1**

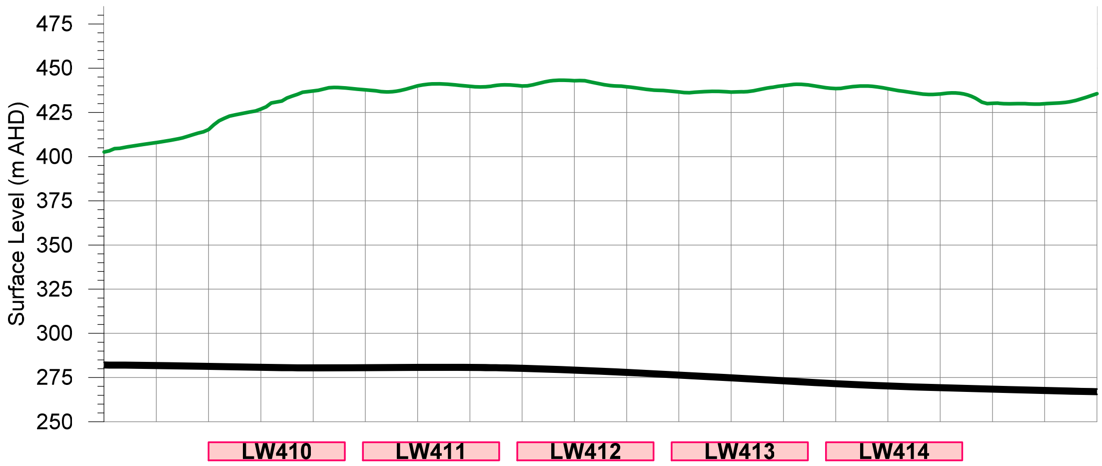


**Fig. 1.3 Surface and Seam Levels along Prediction Line 2**

## 1.4. Geological Details

The surface lithology in the vicinity of the UG4 is shown in Fig. 1.4.

This figure was produced from a geological coalfield map that was downloaded from the Geological Survey of the Department of Primary Industries' website called Western Coalfield Regional Geology (Northern Part) Geological Sheet 1 1998 -1:100000 Western Coalfield Map.

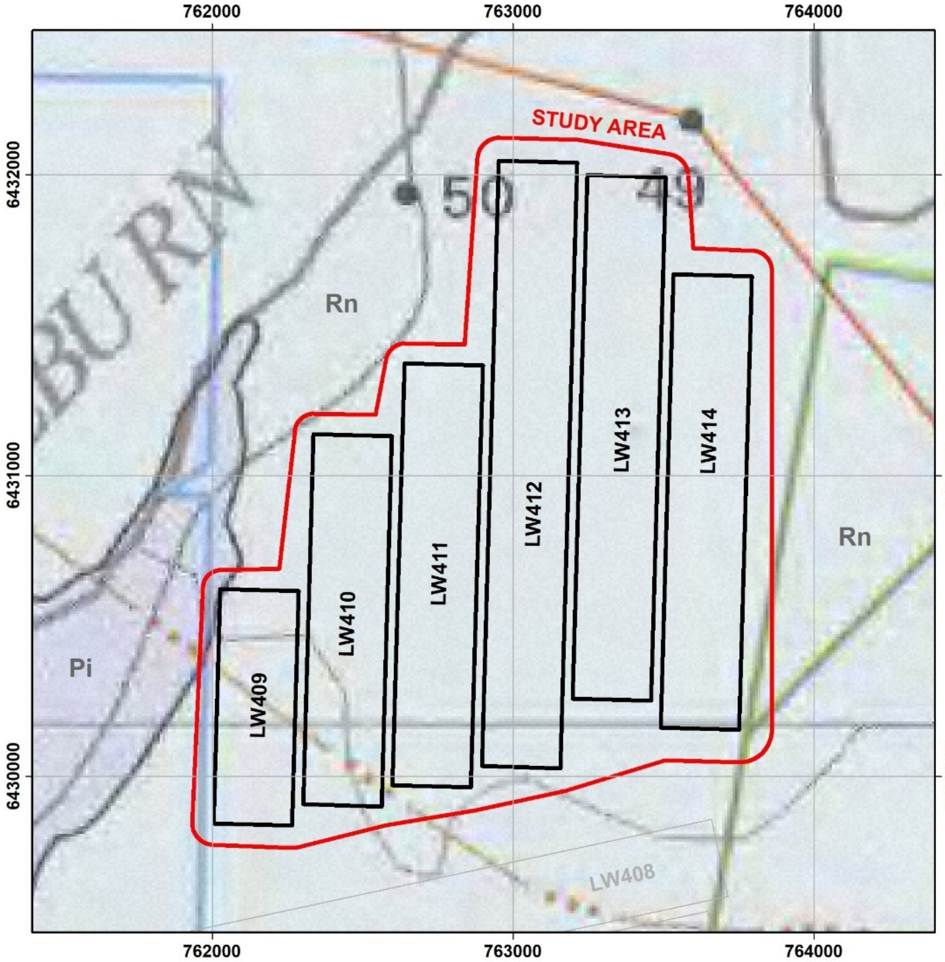


**Fig. 1.4 Surface Geological Map Showing Longwall 409 to 414 and the Study Area**
(Source-1:100000 Western Coalfield Map)

As can be seen in this figure the surface geology of most of the areas over the UG4 is predominantly units from the Narrabeen Group Sandstones and Conglomerates, (Rn), which are coloured in a light green hatching. These units overlie areas, which are hatched in a violet colour, that indicate the surface geology around the longwalls is from the Illawarra Coal Measures (Pi).

A typical stratigraphic section for the area, which was provided by Minerva Geological Services Pty Ltd, is shown in Fig. 1.5. A discussion of the geological units is provided below in Section 1.4.1.

### 1.4.1. Lithology

The major geological units in the UG4 Study Area are, from the youngest to oldest:-

- Triassic aged sandstones and conglomerates of the Narrabeen Group;
- Permian aged Illawarra Coal Measures, including the Ulan Seam; and
- Carboniferous aged Ulan Granite.

The Triassic sandstone, known as Wollar Sandstone, is part of the Narrabeen Group and this sandstone unit is the main outcropping rock formation over the UG4 Study Area. Where present, the sandstones are between 14 metres and 70 metres thick and normally about 60 m with both massive and strongly cross-bedded units of individual thickness in the range of 1.5 metres to 3 metres.

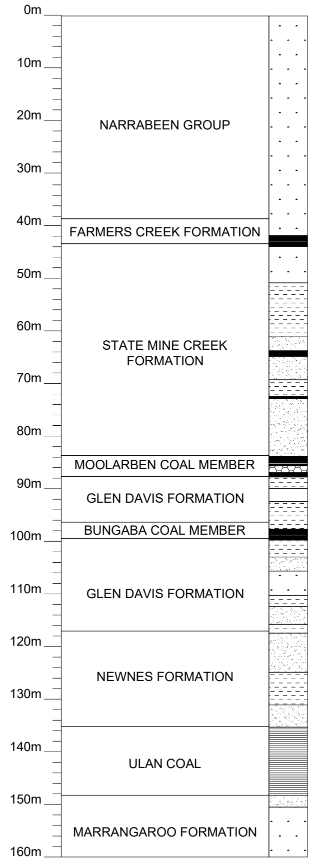


**Fig. 1.5 Stratigraphic Column (based on WMLB117)**

Permian Illawarra Coal Measures consist of up to six formations that include conglomerate, claystone, mudstone, siltstone, tuff, sandstone and coal with a general northwest strike direction and dip of 1 to 2 degrees to the northeast. A brief description of each formation, provided in Minerva Geological Services, (February 2007), is as follows;

- Farmers Creek Formation: between 6 metres to 10 metres of siltstone, sandstone, and white cherty claystone;
- State Mine Creek Formation: up to 30 metres of interbedded sandstone, siltstone and claystone. The Moolarben Coal Member occurs at the base of the State Mine Creek Formation and is between 2 metres and 4 metres thick, consisting of tuffaceous mudstone and claystone. The Middle River Coal Member occurs at the top of the State Mine Creek Formation and is generally less than 2 metres thick, consisting of stony coal and claystone;
- Cockabutta Creek Sandstone Member: up to 9 metres of predominantly medium to very coarse-grained quartzose sandstone, similar to the Marrangaroo Conglomerate;
- Newnes and Glen Davis Formations: up to 20 metres thickness of laminated mudstones, siltstones and find-grained sandstones;
- Ulan Coal: the major coal development in the licence area. The seam thickness varies from approximately 6 metres to 15 metres and is divided into 2 units – Upper (comprising, from top down, ULA, UB1, UB2, UC1, UC2) and Lower (comprising from top down, UCL, DTP, DWS, ETP, EBT and ELR). CMK defines the boundary between upper and lower units; and
- Marrangaroo Conglomerate: Generally between 2 metres and 6 metres thick. The conglomerate is quartzose, commonly porous, and has a “gritty” sucrosic texture.

The Carboniferous Ulan Granite forms the basement below the Illawarra Coal Measures. There are four regional structural features, none of which intersect the proposed underground mining areas. The four regional structural features are the Spring Gully Fault Zone, Curra and Greenhill’s Fault, Flat Dip Domain, and Ulan Hinge Line. A detailed description of the surface and subsurface geological features in the lease area is contained in a report by Minerva Geological Services, (February 2007).

## 2.1. Definition of the Study Area

The Study Area is defined as the surface area that is likely to be affected by the proposed mining of Longwalls 409 to 414 (*Extraction Plan Layout*) in the Ulan Seam by MCO. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:-

- The 26.5° angle of draw line;
- The predicted vertical limit of subsidence, taken as the 20 mm subsidence contour; and
- Features sensitive to far-field movements.

As the depth of cover above the longwalls varies between 120 and 215 m, the 26.5° angle of draw line has been conservatively determined by drawing a line around the outer edge of the longwall voids at a horizontal distance that varies between 60 and 108 m.

The predicted limit of vertical subsidence has been taken as the predicted total 20 mm subsidence contour as determined using the Incremental Profile Method, which is described in Section 3.5. A detailed discussion of the Incremental Profile Method can also be found at http://www.minesubsidence.com in Background Reports in the report titled 'General Discussion of Mine Subsidence Ground Movements'.

The line defining the Study Area, based on the further extent of the 26.5° angle of draw and the predicted 20 mm subsidence contour is shown in Drawing No. MSEC1381-01. The predicted total 20 mm subsidence contour line resulting from the extraction of Longwalls 409 to 414 was found to be located entirely within the area bounded by the 26.5° angle of draw line.

There are additional features that lie outside or partly outside the Study Area that are expected to experience minor far-field horizontal movements. The surface features which may be sensitive to such movements have been identified in this report and, hence, these features, which are listed below, have been included as part of this study.

- Ulan Road;
- Goulburn River Bridge;
- Survey Control Marks;
- Cliff Line 3; and
- The Drip and Goulburn River Gorge.

## 2.2. Natural and Built Features within the Study Area

A number of the natural and built features within the Study Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), numbered Durridgere 88331S. The proposed longwalls and the Study Area have been overlaid on an extract of this CMA map in Fig. 2.1.

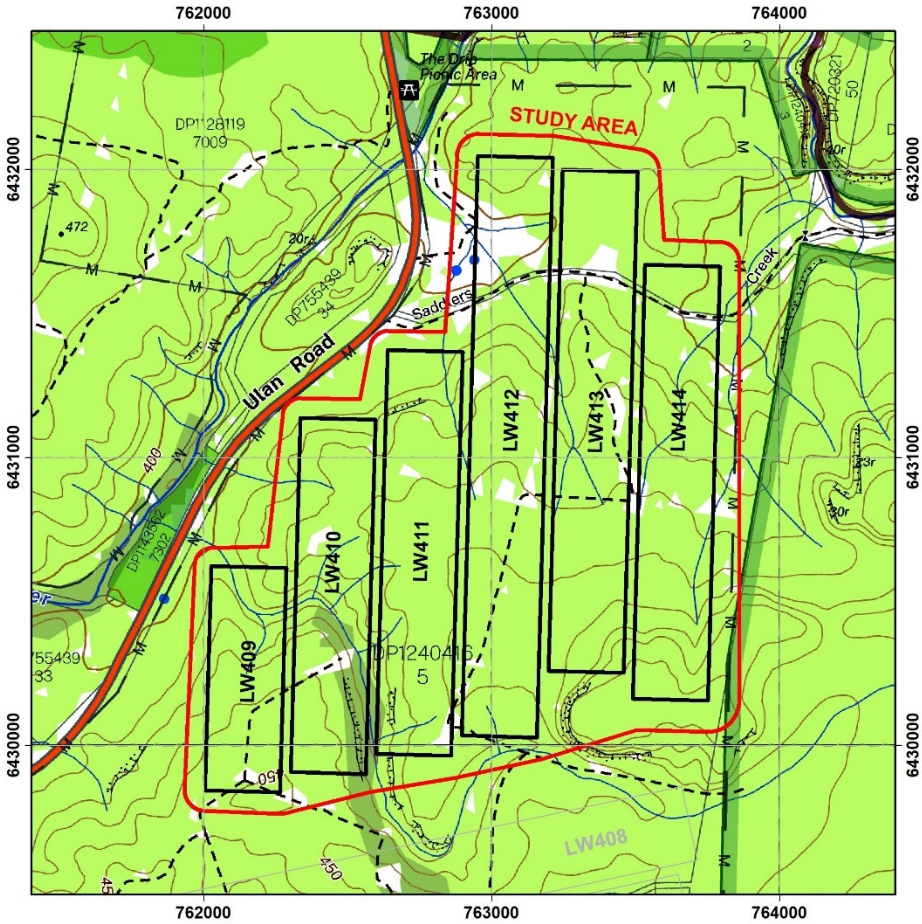


**Fig. 2.1 Topographic Map Showing Longwalls 409 to 414 and the Study Area (source: CMA Map No. Durridgere 88331S)**

A summary of the natural and built features within the Study Area, or relevant to this report with respect to potential far-field movements, is provided in Table 2.1. The locations of these features are shown in Drawings Nos. MSEC1381-07 and MSEC1381-08, in Appendix E.

The descriptions, predictions and impact assessments for the natural and built features are provided in Chapters 5 through to 11. The section number references are provided in Table 2.1.

## Table 2.1 Natural and Built Features

| Item | Within Study Area | Section Number |
|---|---|---|
| **NATURAL FEATURES** | | |
| Catchment Areas or Declared Special Areas | × | |
| Streams | ✓ | 5.2 & 5.3 |
| Aquifers or Known Groundwater Resources | ✓ | 5.5 |
| Springs or Groundwater Seeps | × | |
| Sea or Lake | × | |
| Shorelines | × | |
| Natural Dams | × | |
| Cliffs or Pagodas | ✓ | 5.4 & 5.6 |
| Steep Slopes | ✓ | 5.7 |
| Escarpments | × | |
| Land Prone to Flooding or Inundation | × | 5.8 |
| Swamps or Wetlands | × | |
| Water Related Ecosystems | × | |
| Threatened or Protected Species | ✓ | 5.9 |
| Lands Defined as Critical Habitat | × | |
| National Parks | ✓ | 5.10 |
| State Forests | × | |
| State Recreation or Conservation Areas | ✓ | 5.11 |
| Natural Vegetation | ✓ | 5.12 |
| Areas of Significant Geological Interest | × | |
| Any Other Natural Features Considered Significant | × | |
| | | |
| **PUBLIC UTILITIES** | | |
| Railways | × | |
| Roads (All Types) | ✓ | 6.1 & 6.2 |
| Bridges | ✓ | 6.1 |
| Tunnels | × | |
| Culverts | ✓ | 6.1 |
| Water, Gas or Sewerage Infrastructure | × | |
| Liquid Fuel Pipelines | × | |
| Electricity Transmission Lines or Associated Plants | × | |
| Telecommunication Lines or Associated Plants | ✓ | 6.4 |
| Water Tanks, Water or Sewage Treatment Works | × | |
| Dams, Reservoirs or Associated Works | × | |
| Air Strips | × | |
| Any Other Public Utilities | × | |
| | | |
| **PUBLIC AMENITIES** | | |
| Hospitals | × | |
| Places of Worship | × | |
| Schools | × | |
| Shopping Centres | × | |
| Community Centres | × | |
| Office Buildings | × | |
| Swimming Pools | × | |
| Bowling Greens | × | |
| Ovals or Cricket Grounds | × | |
| Race Courses | × | |
| Golf Courses | × | |
| Tennis Courts | × | |
| Any Other Public Amenities | × | |

| Item | Within Study Area | Section Number |
|---|---|---|
| **FARM LAND AND FACILITIES** | | |
| Agricultural Utilisation or Agricultural Suitability of Farm Land | × | |
| Farm Buildings or Sheds | × | |
| Tanks | × | |
| Gas or Fuel Storages | × | |
| Poultry Sheds | × | |
| Glass Houses | × | |
| Hydroponic Systems | × | |
| Irrigation Systems | × | |
| Fences | ✓ | 8.1 |
| Farm Dams | ✓ | 8.2 |
| Wells or Bores | ✓ | 9.1 |
| Any Other Farm Features | × | |
| | | |
| **INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS** | | |
| Factories | × | |
| Workshops | × | |
| Business or Commercial Establishments or Improvements | × | |
| Gas or Fuel Storages or Associated Plants | × | |
| Waste Storages or Associated Plants | × | |
| Buildings, Equipment or Operations that are Sensitive to Surface Movements | × | |
| Surface Mining (Open Cut) Voids or Rehabilitated Areas | × | |
| Mine Related Infrastructure Including Exploration Bores and Gas Wells | ✓ | 9.1 & 9.2 |
| Any Other Industrial, Commercial or Business Features | × | |
| | | |
| **AREAS OF ARCHAEOLOGICAL SIGNIFICANCE** | ✓ | 10.1 |
| | | |
| **AREAS OF HISTORICAL SIGNIFICANCE** | × | |
| | | |
| **ITEMS OF ARCHITECTURAL SIGNIFICANCE** | × | |
| | | |
| **PERMANENT SURVEY CONTROL MARKS** | ✓ | 10.3 |
| | | |
| **RESIDENTIAL ESTABLISHMENTS** | | |
| Houses | × | |
| Flats or Units | × | |
| Caravan Parks | × | |
| Retirement or Aged Care Villages | × | |
| Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts | × | |
| Any Other Residential Features | × | |
| | | |
| **ANY OTHER ITEM OF SIGNIFICANCE** | × | |
| | | |
| **ANY KNOWN FUTURE DEVELOPMENTS** | × | |

# 3.0 OVERVIEW OF MINE SUBSIDENCE PARAMETERS AND THE METHOD USED TO PREDICT THE MINE SUBSIDENCE MOVEMENTS FOR THE LONGWALLS

## 3.1. Introduction

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

## 3.2. Overview of Conventional Subsidence Parameters

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

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

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

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

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

## 3.3. Far-field Movements

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

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

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

As successive longwalls within a series of longwall panels 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 in the strata within 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.

## 3.4. Overview of Non-Conventional Subsidence Movements

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

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

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

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

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

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

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

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

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

In this report, non-conventional ground movements are being included statistically in the predictions and impact assessments, by basing these on the frequency of past occurrence of both the conventional and non-conventional ground movements and impacts. The analysis of strains provided in Section 4.4 includes those resulting from both conventional and non-conventional anomalous movements. The impact assessments for the natural and built features, which are provided in Chapters 5 through to 11, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

### 3.4.2. Non-conventional Subsidence Movements due to Steep Topography

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

### 3.4.3. Valley Related Movements

The watercourses may be subjected to valley related movements, which are commonly observed along river and creek alignments in the Southern Coalfield, but are less commonly observed in the Hunter and Western Coalfields, which typically have much shallower depths of cover. The reason that valley related movements are less commonly observed in the Hunter and Western Coalfields could be that the systematic subsidence movements are typically much larger than those observed in the Southern Coalfield, which 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 conceptually illustrated in Fig. 3.1. The potential for these natural movements are influenced by the geomorphology of the valley.

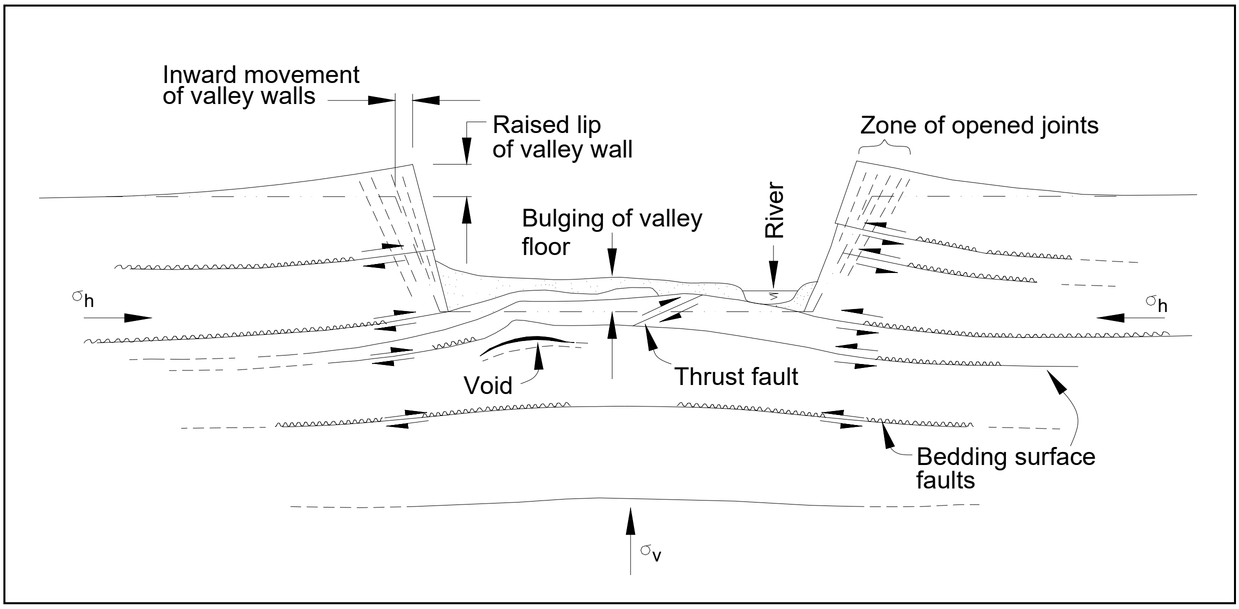


**Fig. 3.1** Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

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

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

- **Closure** is the reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides.

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

Valley related movements are 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*.

The drainage lines above the Approved and Extraction Plan Layouts are unlikely to experience noticeable mining induced valley related movements, (valley closure movements and upsidence in the floors of valleys), because of the relatively shallow depths of cover over these longwalls.

## 3.5. The Incremental Profile Method

The predicted conventional subsidence parameters for the longwalls were determined using the Incremental Profile Method, which was developed by MSEC, formally known as Waddington Kay and Associates. The method is an empirical model based on a large database of observed monitoring data from previous mining within the Southern, Newcastle, Hunter and Western Coalfields of New South Wales and from mining in the Bowen Basin in Queensland. Empirical models are a common and accepted method of subsidence prediction in NSW.

The database consists of detailed subsidence monitoring data from many mines and collieries in NSW and QLD including: Angus Place, Appin, Baal Bone, Bellambi, Beltana, Blakefield South, Bulli, Carborough Downs, Chain Valley, Clarence, Coalcliff, Cook, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Fernbrook, Glennies Creek, Grasstree, Gretley, Invincible, John Darling, Kemira, Kestrel, Lambton, Liddell, Mandalong, Metropolitan, Mt. Kembla, Moranbah, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, South Bulga, South Bulli, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend, and Wyee.

The database consists of the observed incremental subsidence profiles, which are the additional subsidence profiles resulting from the extraction of each longwall within a series of longwalls. It can be seen from the normalised incremental subsidence profiles within the database, that the observed shapes and magnitudes are reasonably consistent where the mining geometry and local geology are similar.

Subsidence predictions made using the Incremental Profile Method use the database of observed incremental subsidence profiles, the longwall geometries, local surface and seam information and geology. The method has a tendency to over-predict the conventional subsidence parameters (i.e. is slightly conservative) where the mining geometry and geology are within the range of the empirical database. The predictions can be further tailored to local conditions where observed monitoring data is available close to the mining area.

Further details on the Incremental Profile Method can be obtained from *www.minesubsidence.com*.

## 3.6. Calibration and Testing of the Incremental Profile Method

Initial predicted conventional subsidence parameters that were provided in previous reports for MCC longwalls at Moolarben in 2009 were determined based on the standard IPM model for the Hunter, Newcastle and Western Coalfields, after applying some local calibrations that were determined to suit the particular geological and the overburden depth conditions at MCC. The IPM model for MCC was adjusted to predict a maximum subsidence factor value of 60% of the extracted seam thickness for supercritical panels in single seam conditions. The model for UG1 was subsequently increased to allow a maximum vertical subsidence of 65% based a review of the overburden geology above the proposed UG1 longwall panels.

After the commencement of longwall mining operations, annual reviews have been completed since 2017 to assess the observed monitoring data due to the extraction of UG1 Longwalls 101 to 105 and UG4 Longwalls 401 to 403. The ground movements measured during the annual review were similar to or less than those predicted in Report No. MSEC867 and MSEC1084, which supported the Extraction Plan for Longwalls 101 to 105, and Report No MSEC1165 which supported the Extraction Plan for Longwalls 401 to 408. Monitoring within UG1 showed maximum observed subsidence of between approximately 55% and 65% of the modelled seam thickness for a single panel. Graphs showing predicted and observed subsidence, tilt and strain across Longwalls 101 to 105 in UG1 are shown in Fig. 3.2 and Fig. 3.3. A graph showing predicted and observed subsidence, tilt and strain across Longwalls 401 to 403 in UG4 is shown in Fig. 3.4.

Borehole logs for the MCC indicate the presence of thicker or massive units with UG4. The units vary in thickness from less than 10m to greater than 30 m and are likely to be absent in some locations. The thicker units have a greater potential to bulk and span and hence reduce the magnitude of subsidence above the mined panels. Given the broader extent of thicker or massive units, it is considered that a maximum incremental subsidence of 60% of the extracted seam thickness is appropriate for modelling and assessment of subsidence parameters for UG4. Monitoring within UG4 showed a maximum observed subsidence of 1778mm (near the end of Longwall 402) which represents approximately 60% of the modelled seam thickness for a single panel.

It should also be noted that, when the maximum incremental subsidence for each panel is limited to 60% of the extracted seam thickness, the maximum total subsidence over a series of longwall panels can still accumulate to be as high as 65% of the extracted seam thickness due to the overlapping effects from adjacent longwalls.

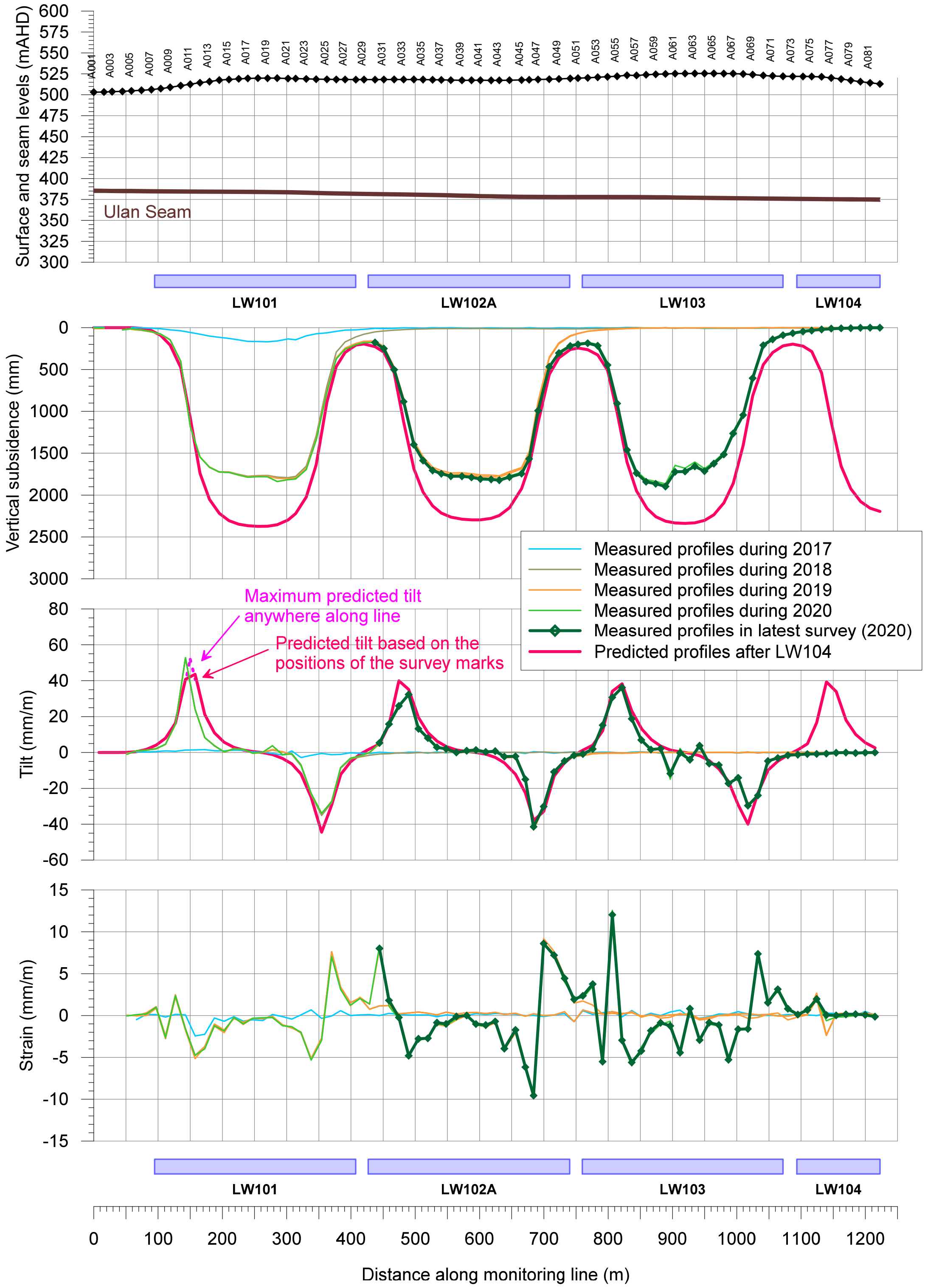


Fig. 3.2 Measured and predicted vertical subsidence, tilt and strain along the A Line in UG1

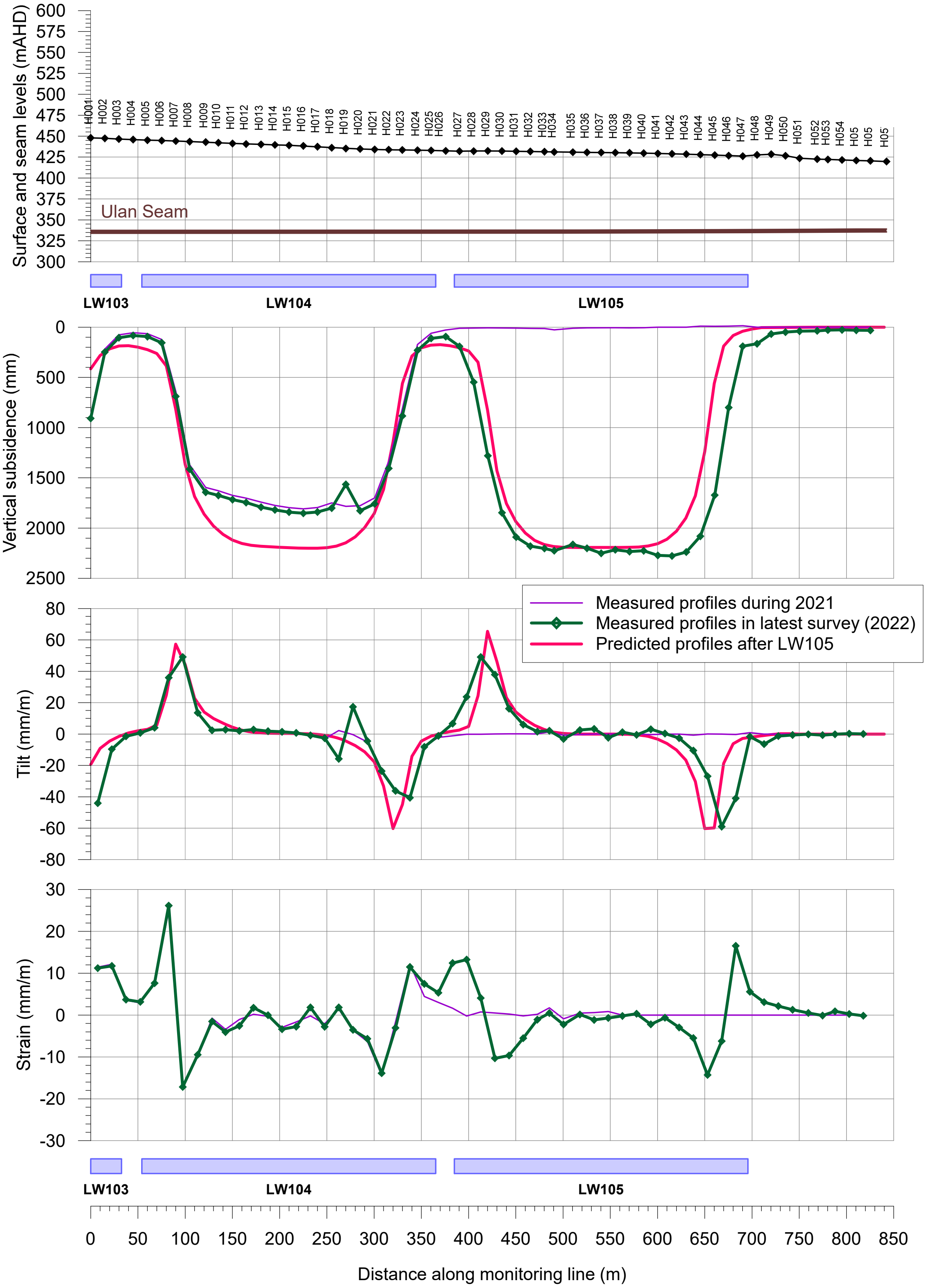


Fig. 3.3 Measured and predicted vertical subsidence, tilt and strain along the H Line in UG1

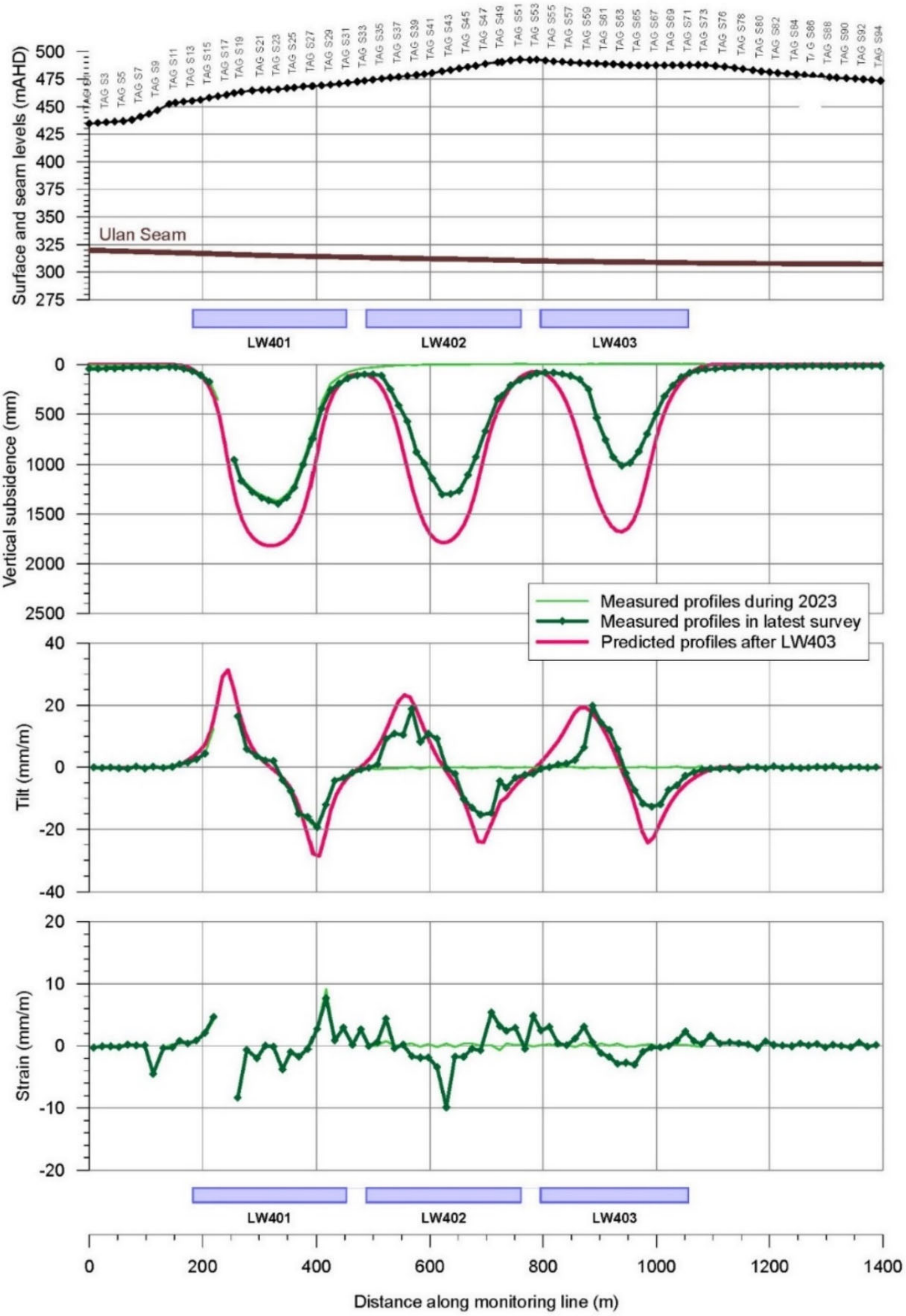


Fig. 3.4 Measured and predicted vertical subsidence, tilt and strain along the S Line in UG4

## 3.7. GNSS Survey Mark Stability

Global Navigation Satellite System (GNSS) is an established method of three dimensional positioning using global satellites including:

- Galileo (EU)
- GPS (USA)
- GLONASS (Russia)
- BeiDou (China)

The high degree of accuracy of local GNSS monitoring units is achieved using a fixed local GNSS reference mark. The positioning of the local GNSS reference mark is established and periodically checked using the NSW network of Continuously Operating Reference Stations (CORSnet).

The reference mark at MCO is located to the east of UG1 and is positioned using surrounding CORSnet marks at Mudgee, Merriwa and Dunedoo, which are shown in Fig. 3.5. The positional accuracy of the reference mark at MCO was validated on 12 June 2024 by Geomatix. The check processing, over a period of approximately 1 year and 9 months, identified normal variation with typical reversion to mean and no trending movement.

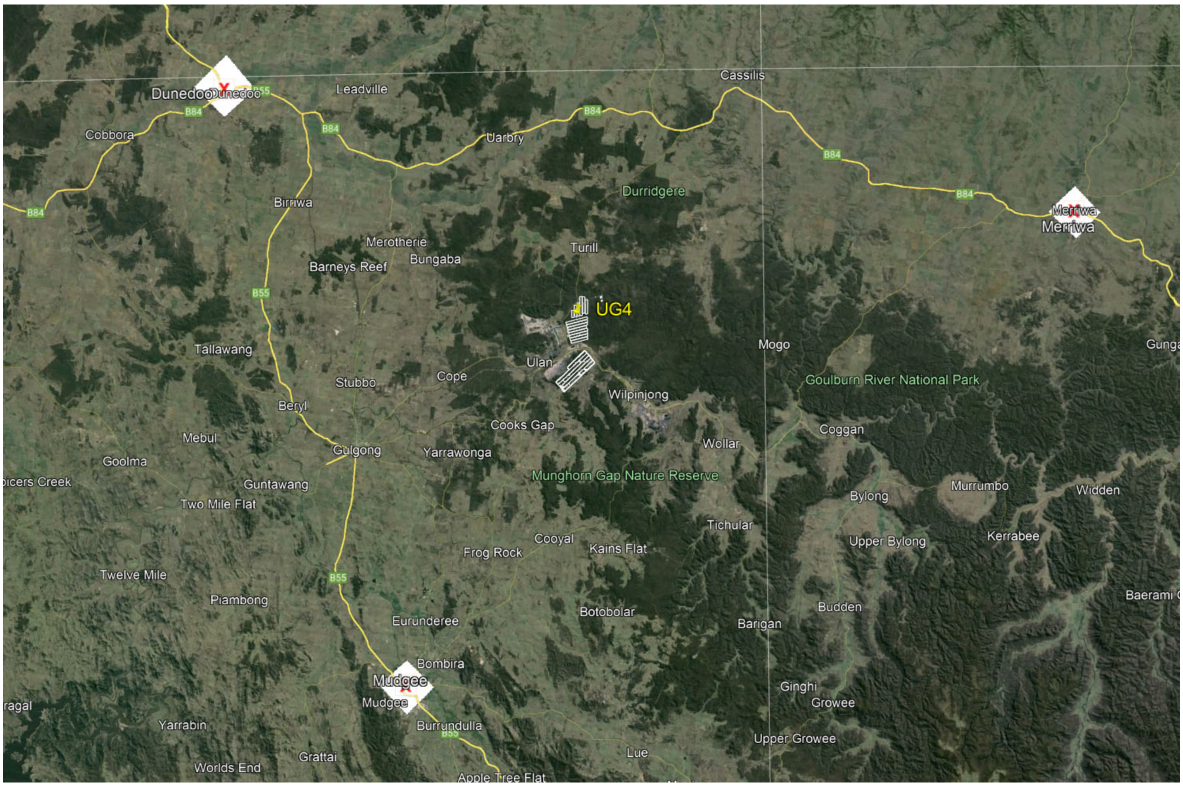


Fig. 3.5 CORSnet locations

Variations in the observed GNSS data occur regularly as a result seasonal and environmental effects and atmospheric conditions, including solar activity. The variation in observed data at the surrounding CORSnet marks is shown below in Fig. 3.6, Fig. 3.7, and Fig. 3.8. These graphs show an uncertainty of typically ±9 mm for horizontal positioning and ±20mm for vertical positioning.

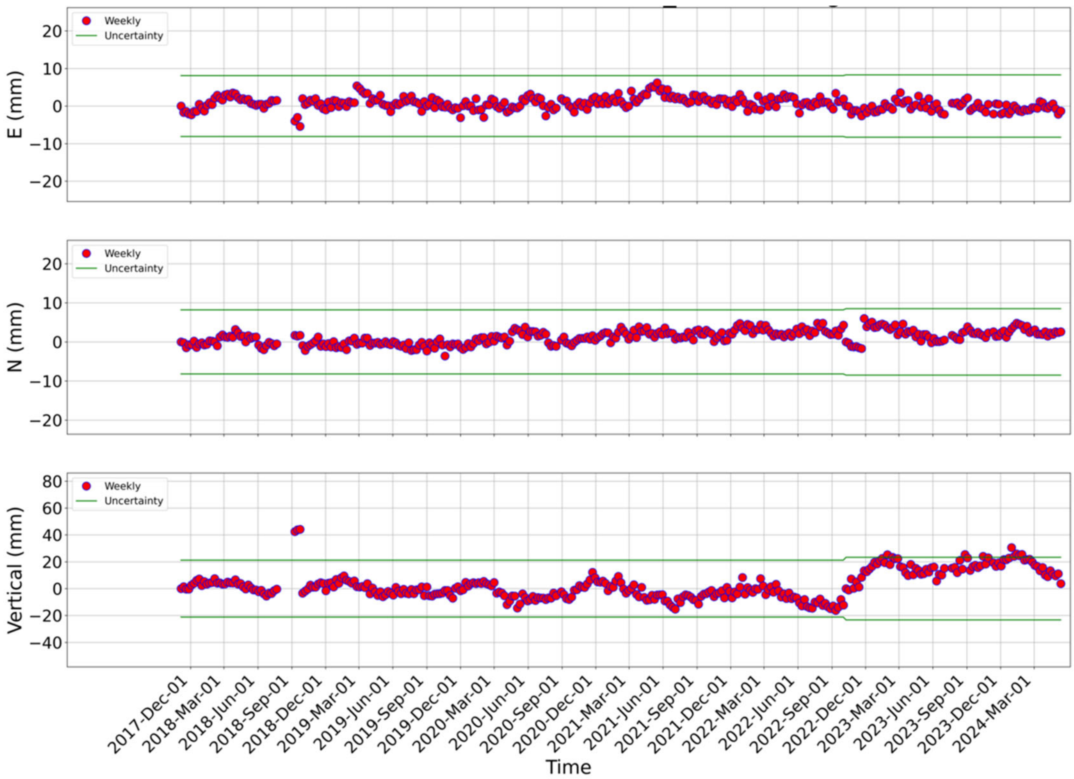


Fig. 3.6 CORSnet Mudgee

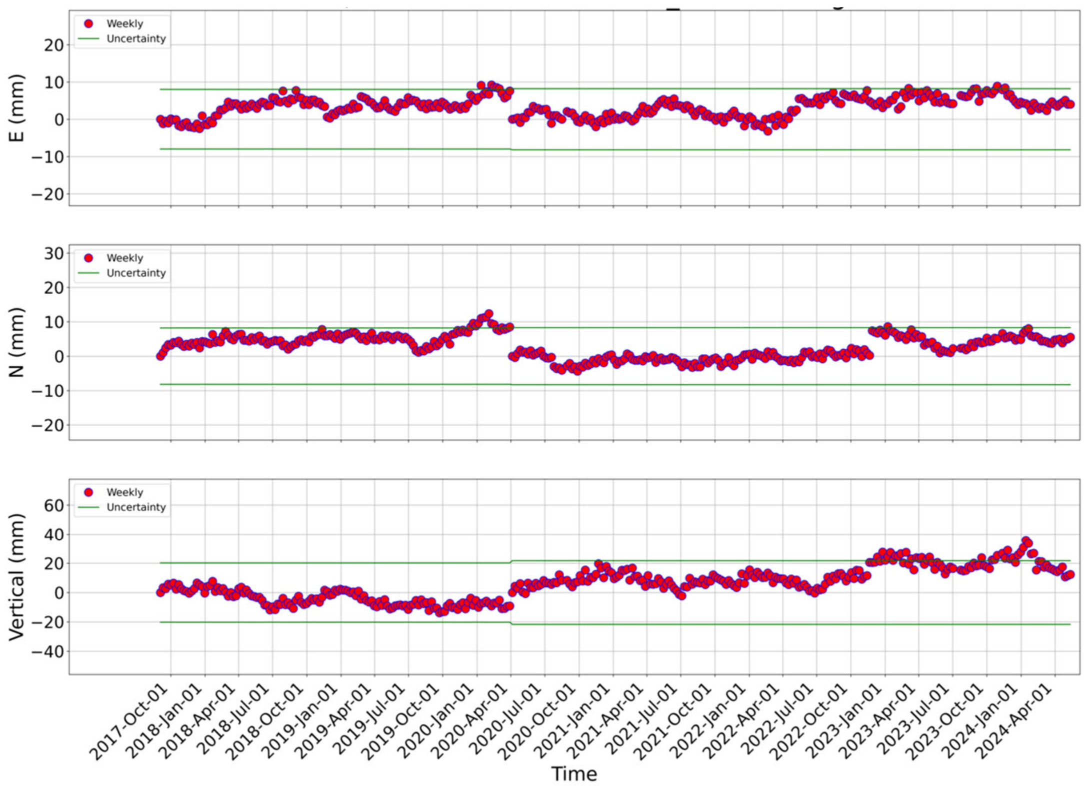


Fig. 3.7 CORSnet Dunedoo

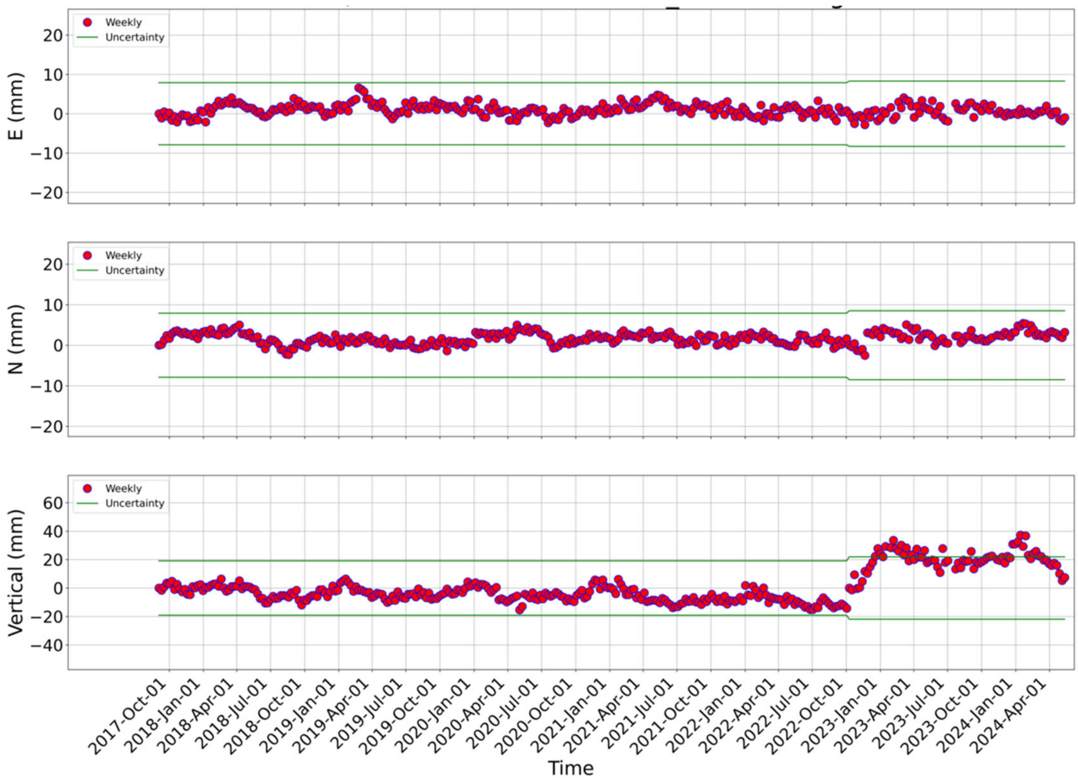


Fig. 3.8 CORSnet Merriwa

The use of a local GNSS reference mark improves the accuracy of local positioning during longwall extraction, however some variation due to natural effects will still occur. An example of variations over an approximate 4.5 year monitoring period is shown below in Fig. 3.9 for a site in the southern coalfield. The site was initially located approximately 2.2km from the longwall mining area with longwall extraction progressing towards the mark. Following a period of stable measurements with no apparent mine related movement, the gradual development of far-field horizontal movement can be observed prior to the development of vertical subsidence, commencing when the longwall was approximately 1.8km from the monitoring site. However it can be seen that regular variation occurs in both the horizontal and vertical directions, typically with reversion to the trending mean. It is also noted in this figure that reduced scatter in the data occurs with time, which is the result of improvements in hardware and processing developed by Geomatix.

The magnitude of variation of the GNSS units is likely to differ between locations due to differences in geology, topography and local climate. It is therefore considered important, where features may be susceptible to small movements, to establish baseline monitoring prior to mining to establish the typical variations in observed monitoring data and enable identification of trends in ground movement that deviate from the baseline.

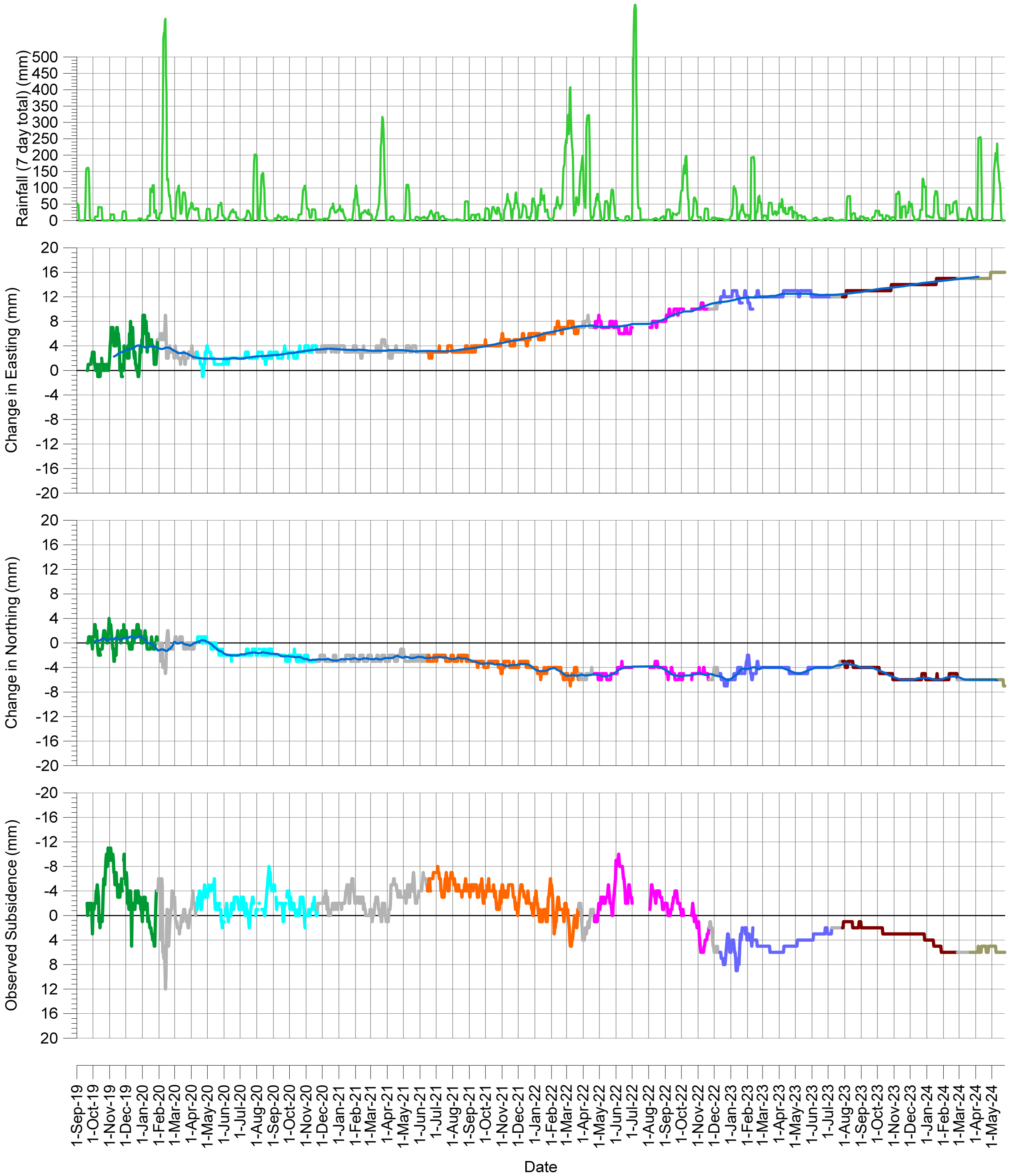


Fig. 3.9 GNSS monitoring example from Southern Coalfield

## 4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of Longwalls 409 to 414. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapters 5 to 11.

It should be noted that the predicted conventional subsidence parameters were obtained using the Incremental Profile Method, which was calibrated to local conditions based on the available monitoring data as discussed in Section 3.6.

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report describe and show the conventional movements and do not include the valley related upsidence and closure movements, nor the effects of faults and other geological structures. Such effects have been addressed separately in the impact assessments for each feature provided in Chapters 5 to 11.

## 4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature

The maximum predicted conventional subsidence parameters resulting from the extraction of Longwalls 409 to 414 were determined using the calibrated Incremental Profile Method. The predicted subsidence contours are irregular due to the shallow depths of cover. The maximum predicted tilts and curvatures are very localised and therefore do not necessarily represent the overall (i.e. macro) ground movements. Revised standards for reporting adopted by MSEC may result in slight differences in reported values compared with previous reports.

A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of each of the longwalls based on the Extraction Plan Layout, is provided in Table 4.1.

**Table 4.1 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature Resulting from the Extraction of Each of the Longwalls 409 to 414**

| 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 ($km^{-1}$) |
|---|---|---|---|---|
| LW409 | 1800 | 40 | 2.0 | 1.6 |
| LW410 | 1800 | 35 | 1.7 | 1.1 |
| LW411 | 1800 | 30 | 1.1 | 0.8 |
| LW412 | 1800 | 40 | 1.8 | 1.4 |
| LW413 | 1800 | 35 | 1.5 | 1.1 |
| LW414 | 1800 | 35 | 1.5 | 1.1 |

The predicted total conventional subsidence contours, resulting from the extraction of Longwalls 409 to 414 are shown in Drawing No. MSEC1381-09. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature, after the extraction of each of the longwalls based on the Extraction Plan Layout, is provided in Table 4.2. The predicted tilts provided in this table are the maxima after the completion of each of the longwalls. The predicted curvatures are the maxima at any time during or after the extraction of each of the longwalls.

**Table 4.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature after the Extraction of Each of the Longwalls 409 to 414**

| 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 ($km^{-1}$) |
|---|---|---|---|---|
| LW409 | 1800 | 40 | 2.0 | 1.6 |
| LW410 | 1900 | 40 | 2.0 | 1.6 |
| LW411 | 1900 | 40 | 2.0 | 1.6 |
| LW412 | 1900 | 40 | 2.0 | 1.6 |
| LW413 | 1900 | 40 | 2.0 | 1.6 |
| LW414 | 1900 | 40 | 2.0 | 1.6 |

The maximum predicted total conventional tilt is 40 mm/m (i.e. > 4 %), which represents a change in grade greater than 1 in 25. The maximum predicted total conventional curvatures are 2.0 $km^{-1}$ hogging and 1.6 $km^{-1}$ sagging, which represent minimum radii of curvature of less than 0.5 km and 0.63 km respectively.

The predicted profiles of conventional subsidence, tilt and curvature have been determined along Prediction Line 1 and Prediction Line 2, the locations of which are shown in Drawing No. MSEC1381-09. The predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 1 and Prediction Line 2, resulting from the extraction of Longwalls 409 to 414, are shown in Fig. C.01 and Fig. C.02 in Appendix C. The predicted incremental profiles along the prediction lines, due to the extraction of each of the longwalls, are shown as dashed black lines. The predicted total profiles along the prediction line, after the extraction of each of the longwalls based on the Extraction Plan Layout, are shown as solid blue lines. The predicted total profiles based on the Approved Layout are the same as those shown for the Extraction Plan Layout.

## 4.3. Comparison of Maximum Predicted Conventional Subsidence, Tilt and Curvature

A comparison of the maximum predicted subsidence parameters resulting from the extraction of Longwalls 409 to 414, based on the Extraction Plan Layout, with those based on the Approved Layout with a 3 m cutting height is provided in Table 4.3. The values are the maxima anywhere above the longwall layouts.

**Table 4.3 Comparison of Maximum Predicted Conventional Subsidence Parameters based on the Approved Layout and the Extraction Plan Layout**

| Layout | 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 ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout | 1900 | 40 | 2.0 | 1.6 |
| Extraction Plan Layout | 1900 | 40 | 2.0 | 1.6 |

It can be seen from the above table, that the maximum predicted total subsidence parameters based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 409 to 414.

## 4.4. Predicted Strains

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

For this reason, the predicted strains provided in this report have been based on statistical analyses of strains measured in the NSW Coalfields to account for this variability.

It has been found, for single-seam mining conditions, that applying a constant factor to the predicted maximum curvatures provides a reasonable prediction for the maximum normal or conventional strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Newcastle, Hunter and Western Coalfields, it has been found that a factor of 10 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains, for single-seam mining conditions.

The maximum predicted conventional curvatures resulting from the extraction of the longwalls are 2.0 $km^{-1}$ hogging and 1.6 $km^{-1}$ sagging. Adopting a factor of 10, the maximum predicted conventional strains, due to the proposed mining are 20 mm/m tensile and 16 mm/m compressive. Localised and elevated strains greater than the predicted conventional strains can also occur, as the result of non-conventional movements, which was discussed in Section 3.4.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature.

The range of potential strains above the longwalls has been assessed using monitoring data from previously extracted panels in the Hunter, Newcastle and Western Coalfields, for single-seam conditions, where the longwall width-to-depth ratios and extraction heights were similar to those of the longwalls. Comparisons of the void widths, depths of cover, width-to-depth ratios and extraction heights for the longwalls with those for the historical cases are provided in Table 4.4.

**Table 4.4 Comparison of the Mine Geometry for the Longwalls 409 to 414 with Longwalls in the Hunter, Newcastle and Western Coalfields used in the Strain Analysis**

| Parameter | Longwalls 409 to 414 | | Longwalls Used in Strain Analysis | |
|---|---|---|---|---|
| | Range | Average | Range | Average |
| Width | 260 | 260 | 210 ~ 410 | 285 |
| Depth of Cover | 120 ~ 215 | 150 | 40 ~ 239 | 130 |
| W/H Ratio | 1.2 ~ 2.2 | 1.7 | 1.7 ~ 6.4 | 2.5 |
| Extraction Height | 3.0 | 3.0 | 2.2 ~ 4.2 | 3.0 |

It can be seen from the above table that the range of the panel width-to-depth ratios used in the strain analysis are between 1.7 and 6.4, with an average ratio of 2.5, which is slightly more than the range for Longwalls 409 to 414. The range of extraction heights for the longwalls used in the strain analysis are between 2.2 m and 4.2 m, with an average of 3.0 m, which is the same as the average extraction height for Longwalls 409 to 414. The strain analysis, therefore, should provide a reasonable indication of the range of potential strains for the longwalls.

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

A number of probability distribution functions were fitted to the empirical monitored strain data. It was found that a *Generalised Pareto Distribution (GPD)* provided a good fit to the raw strain data. Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

### 4.4.1. Analysis of Strains Measured in Survey Bays

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

***Predictions of Strain Above Goaf***

The survey database has been analysed to extract the maximum tensile and compressive strains that have been measured at any time during mining, for survey bays that were located directly above 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. The probability distribution functions, based on the fitted GPDs, are also shown in this figure.

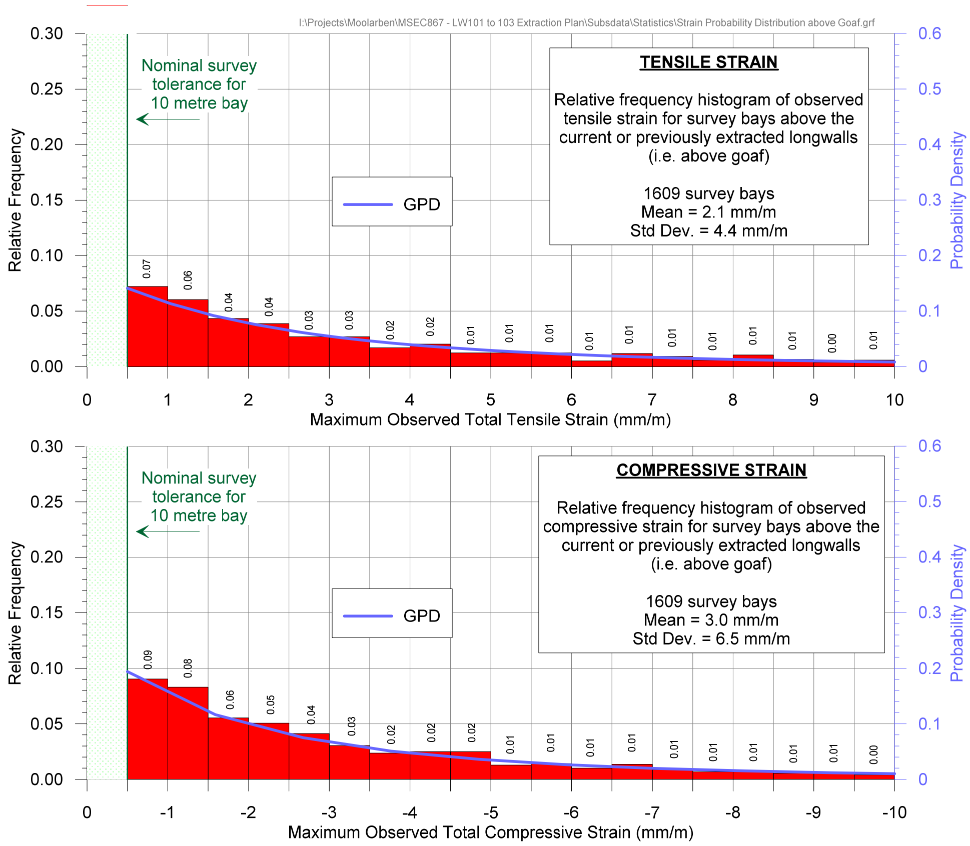


**Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains in the Hunter, Newcastle and Western Coalfields for Longwalls having W/H Ratios between 1.7 and 6.4**

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

The 95 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining are 10 mm/m tensile and 13 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining are 22 mm/m tensile and 31 mm/m compressive. The maximum strains measured along the monitoring lines were greater than 50 mm/m tensile and 100 mm/m compressive. These maximum strains represent very localised movements in the locations of large surface deformations.

By comparison, from monitoring undertaken at UG4, the 95 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining are 9 mm/m tensile and 12 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining are 14 mm/m tensile and 18 mm/m compressive.

The predicted conventional strains are greater than the predicted 95 and 99 % confidence levels for the strains that include non-conventional movements, as the irregular strains are isolated and extreme events. This is demonstrated by the maximum observed strains that are considerably greater than the predicted confidence levels and the conventional strains.

It is noted, that these strains are based on monitoring data having an average width-to-depth ratio of 2.5 and, therefore, the strains above the longwalls are expected to be greater, on average, where the width-to-depth ratios are greater than 2.5 (i.e. depths of cover less than 105 m) and are expected to be less, on average, where the width-to-depth ratios are less than 2.5 (i.e. depths of cover greater than 105 m).

### *Predictions of Strain Above Solid Coal*

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during mining for survey bays that were located beyond the goaf edges of the mined panels and positioned on unmined areas of coal, i.e. outside the longwall panels, but within 200 m of the nearest longwall goaf edge.

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

The 95 % confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced at any time during mining are 3.3 mm/m tensile and 3.0 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 9.2 mm/m tensile and 14.4 mm/m compressive.

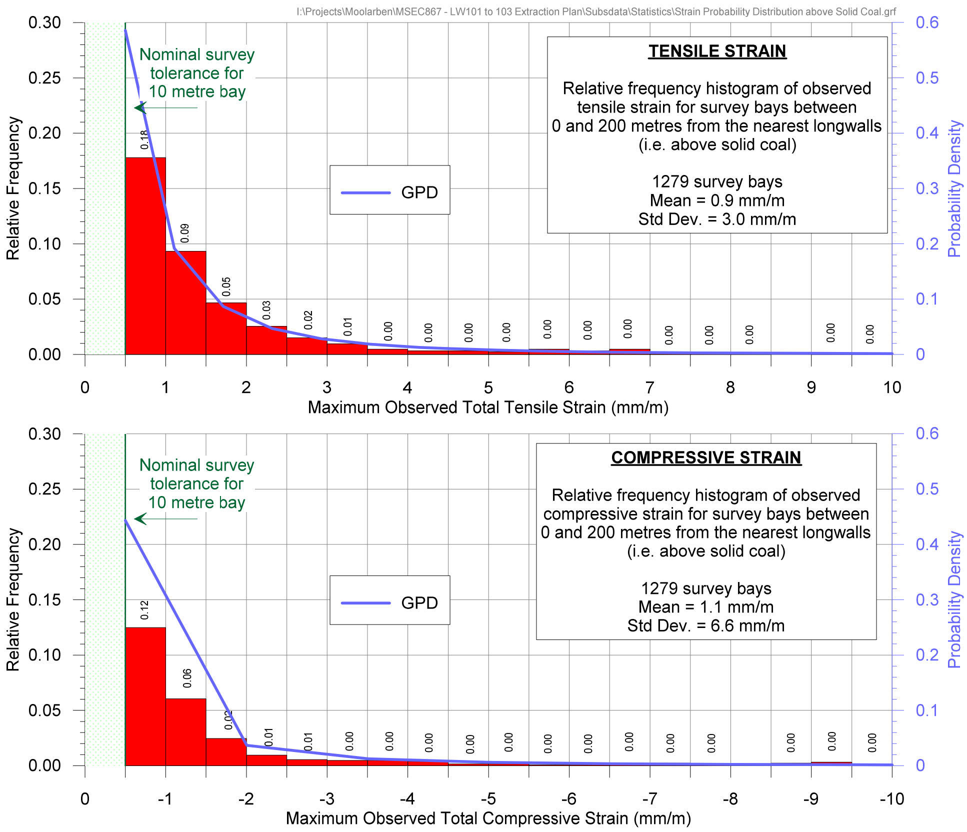


**Fig. 4.2 Distributions of the Measured Maximum Tensile and Compressive Strains in the Hunter, Newcastle and Western Coalfields for Survey Bays located above Solid Coal within 200 m of the nearest longwall**

Further assessment of observed strain data was carried out using monitoring data from the extraction of Longwalls 401 to 403 in UG4. Survey marks along monitoring lines within UG4 are nominally spaced at approximately 15 m. A plot of the observed tensile and compressive strains from UG4 monitoring lines versus distance from the extracted longwalls is shown in Fig. 4.3. It can be seen from Fig. 4.3 that observed tensile and compressive strains are predominantly less than 0.5 mm/m. Based on Fig. 4.3, the 95 % confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced within 200m of the extracted longwalls at any time during mining are 0.8 mm/m tensile and 0.3 mm/m compressive. The 95 % confidence levels for the maximum total strains that the individual survey bays above solid coal between 200 m and 600 m from extracted goaf experienced at any time during mining are 0.5 mm/m tensile and 0.3 mm/m compressive.

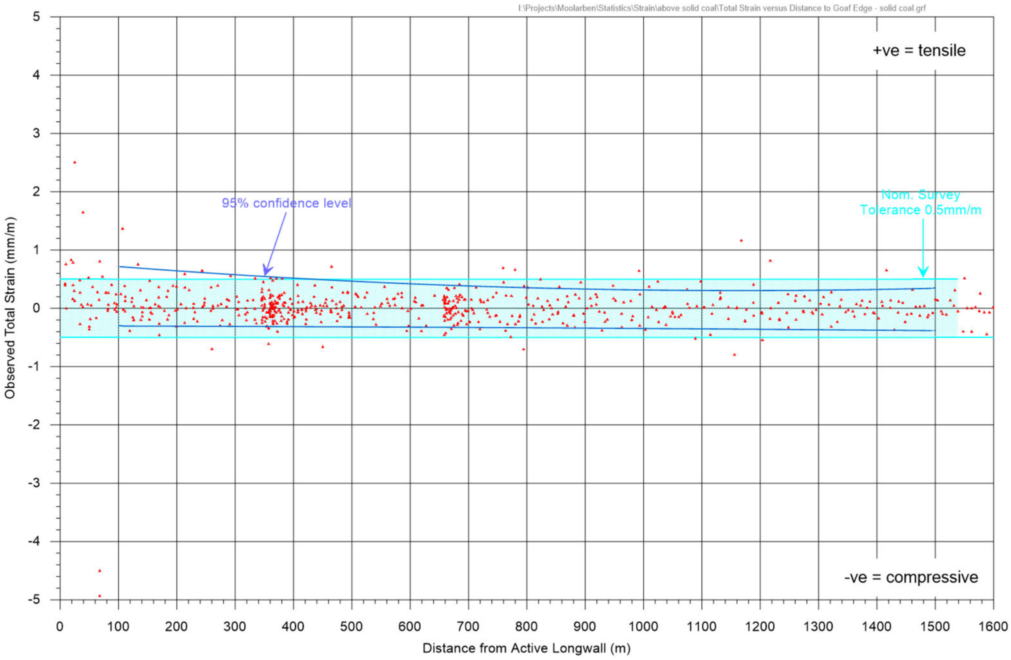


**Fig. 4.3 Observed Total Strain Versus the Distance to the Nearest Edge of the Mined Panel for UG4**

### 4.4.2. Analysis of Strains Measured Along Whole Monitoring Lines

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

The histogram of maximum observed total tensile and compressive strains measured anywhere along the monitoring lines, at any time during or after mining, is provided in Fig. 4.4.

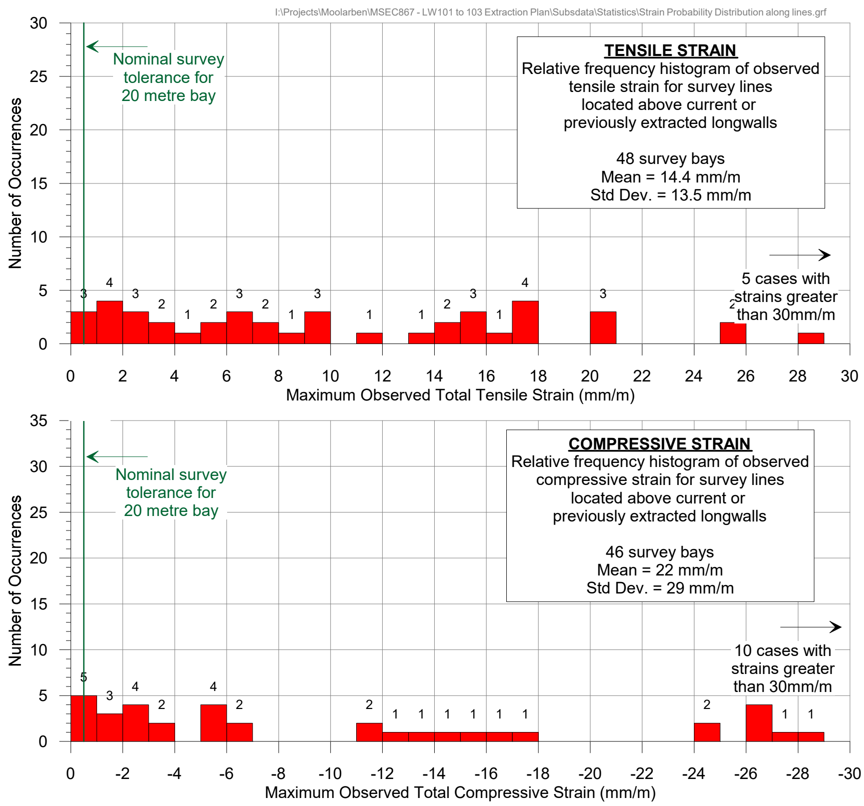


**Fig. 4.4 Distributions of Measured Maximum Tensile and Compressive Strains Anywhere along the Monitoring Lines in the Hunter, Newcastle and Western Coalfields**

It can be seen from the above figure, that 24 of the 48 monitoring lines (i.e. 50 %) have recorded maximum total tensile strains of 10 mm/m, or less, and that 36 monitoring lines (i.e. 75 %) have recorded maximum total tensile strains of 20 mm/m, or less. Also, 20 of the 46 monitoring lines (i.e. 43 %) have recorded maximum compressive strains of 10 mm/m, or less, and that 28 of the monitoring lines (i.e. 60 %) have recorded maximum compressive strains of 20 mm/m, or less.

## 4.5. Horizontal Movements

The predicted conventional horizontal movements over the longwalls are calculated by applying a factor to the predicted conventional tilt values. A factor of 10 is generally adopted for the Western Coalfield, 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. 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 total conventional tilt within the Study Area, at any time during or after the extraction of the longwalls, is greater than 40 mm/m. The application of the factor of 10 is likely to be conservative at this high magnitude of predicted tilt. The maximum predicted conventional horizontal movement is, therefore, greater than 400 mm, i.e. 40 mm/m multiplied by a factor of 10. This prediction is considered to be conservative, with the actual horizontal movements expected to be generally less than 400 mm.

Conventional horizontal movements do not directly impact on natural or built features, rather impacts occur as a result of differential horizontal movements. Strain is the rate of change of horizontal movement. The impacts of strain on the natural and built features are addressed in the impact assessments for each feature, which have been provided in Chapters 5 to 11.

## 4.6. Predicted Far-field Horizontal Movements

In addition to the conventional subsidence movements that have been predicted above and adjacent to Longwalls 409 to 414, it is also likely that far-field horizontal movements will be experienced during the extraction of the longwalls.

An empirical database of observed incremental far-field horizontal movements has been compiled using available monitoring data from the NSW Coalfields This database predominately includes measurements from the Southern Coalfield. The far-field horizontal movements are generally observed to be orientated towards the extracted longwall. At very low levels of far-field horizontal movements, however, there is a higher scatter in the orientation of the observed movements.

This database includes available observed far-field horizontal movements that have been measured at Ulan Coal Mine, Moolarben Mine and observed data from other regions where the depths of cover are also relatively shallow compared to the Southern Coalfield of NSW. The observed far-field horizontal movements in the database represent large variations in depth of cover from less than 50 m to greater than 600 m. In order to utilise the observed far-field horizontal data at the Moolarben Coal Complex where depth of cover is relatively shallow, the data has been plotted, as shown in Fig. 4.5, against the distances from the nearest edge of the incremental panel divided by the depth of cover. This plot excludes those cases where higher movements occurred because of multi-seam mining and valley closure effects.

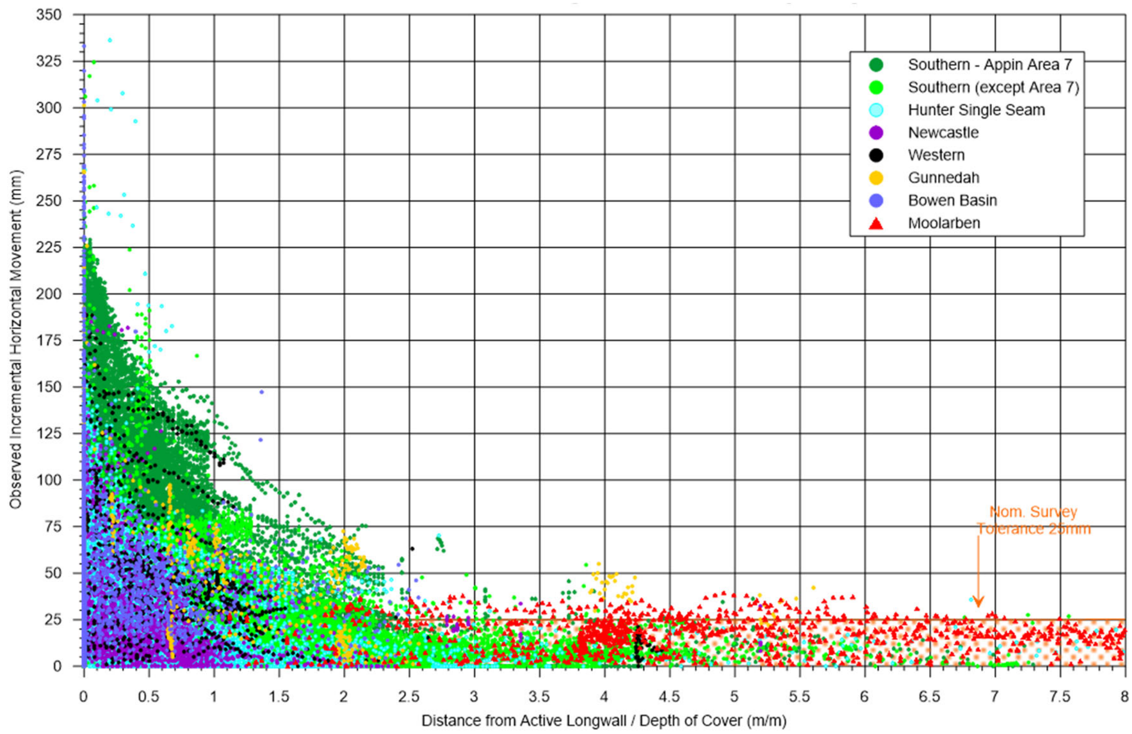


**Fig. 4.5 Observed Incremental Far-Field Horizontal Movements (mm) from many regions in NSW versus the distance to the nearest edge of the mined panel divided by the depth of cover (m/m)**

As successive longwalls within a series of longwall panels 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 in the strata within 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 far-field horizontal movements presented in Fig. 4.5 include monitoring carried out during underground mining of Longwalls 101 to 105 in UG1. Since commencement of underground mining at UG4, three longwall panels have been extracted. In addition to conventional terrestrial survey monitoring lines, MCO have installed several continuous Global Navigation Satellite Systems (GNSS) monitoring sites across the UG4 area. Additional GNSS units will also be installed for future longwall extraction within UG4. The GNSS units provide continuous positioning with a typical output of one positional data point per day. The result is a much higher positional accuracy compared to conventional terrestrial survey. The quoted accuracy of GNSS positioning is ±5mm. The current monitoring GNSS monitoring locations within the Study Area are shown in Fig. 4.6.

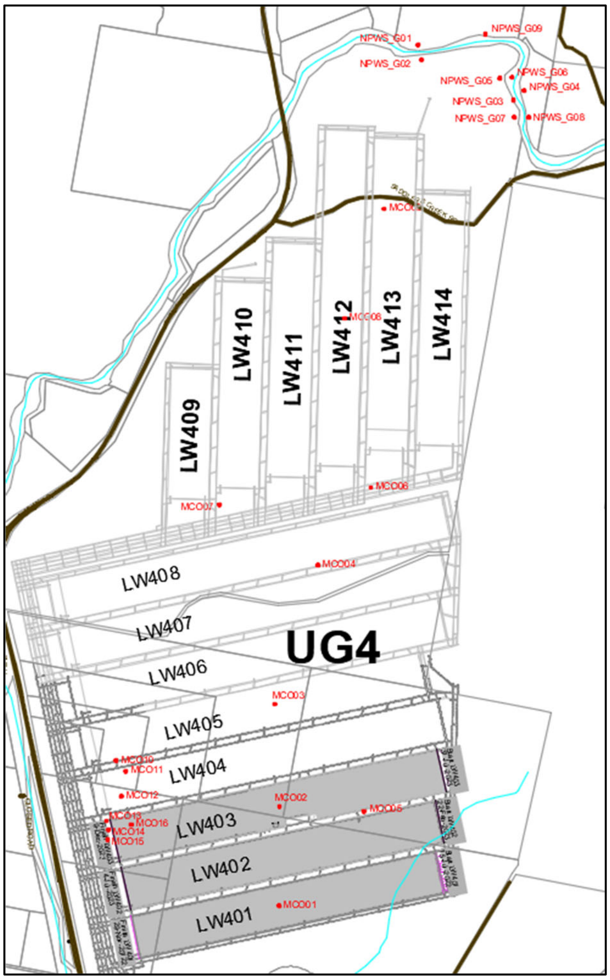


**Fig. 4.6 GNSS monitoring locations**

An updated plot of observed incremental far-field horizontal movements with monitoring data from UG4 is presented in Fig. 4.7.

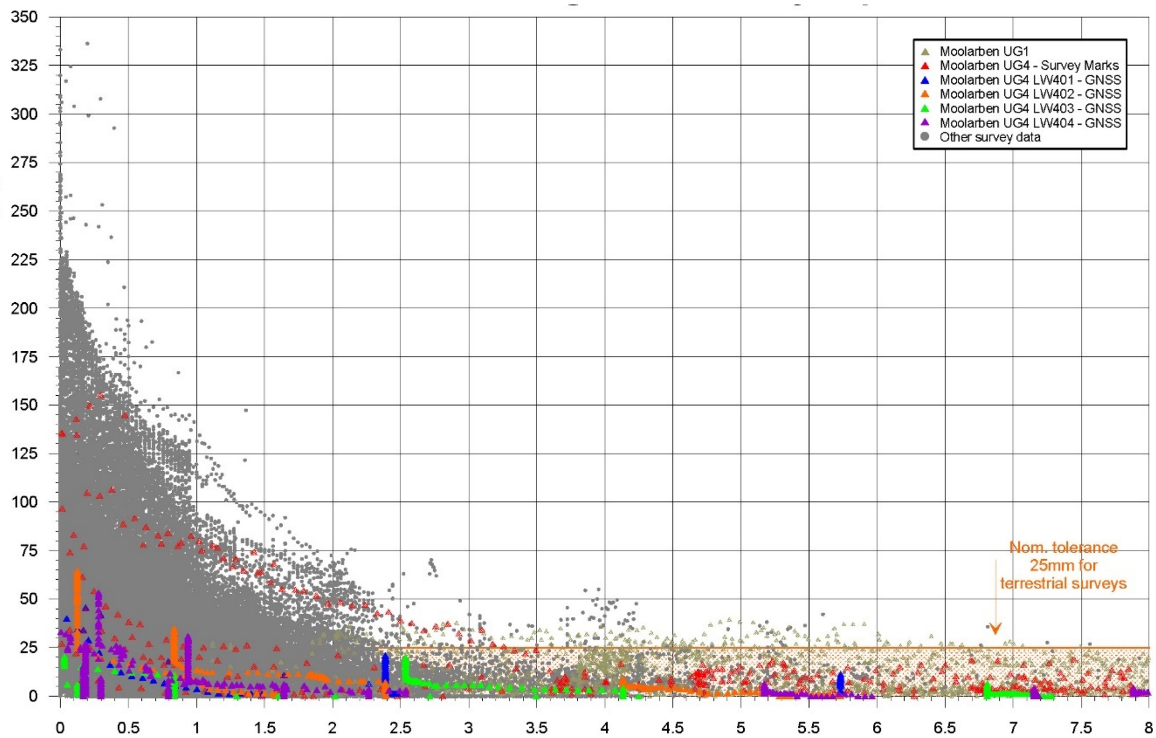


**Fig. 4.7 Observed Incremental Far-Field Horizontal Movements (mm) from many regions in NSW with MCO monitoring included**

It can be seen in Fig. 4.7 that MCO survey data is generally within the range of data from other regions in NSW. The majority of the GNSS monitoring data points indicates horizontal movements significantly less than the upper limits of the observed data.

It is considered that the observed GNSS monitoring data from MCO provides a more accurate representation of potential horizontal movements within and surrounding the UG4 underground mining area for future longwall extraction.

A plot of the GNSS monitoring data as total horizontal movement versus distance from extracted longwalls is presented in Fig. 4.8. An upper bound line has been included above the observed maxima.

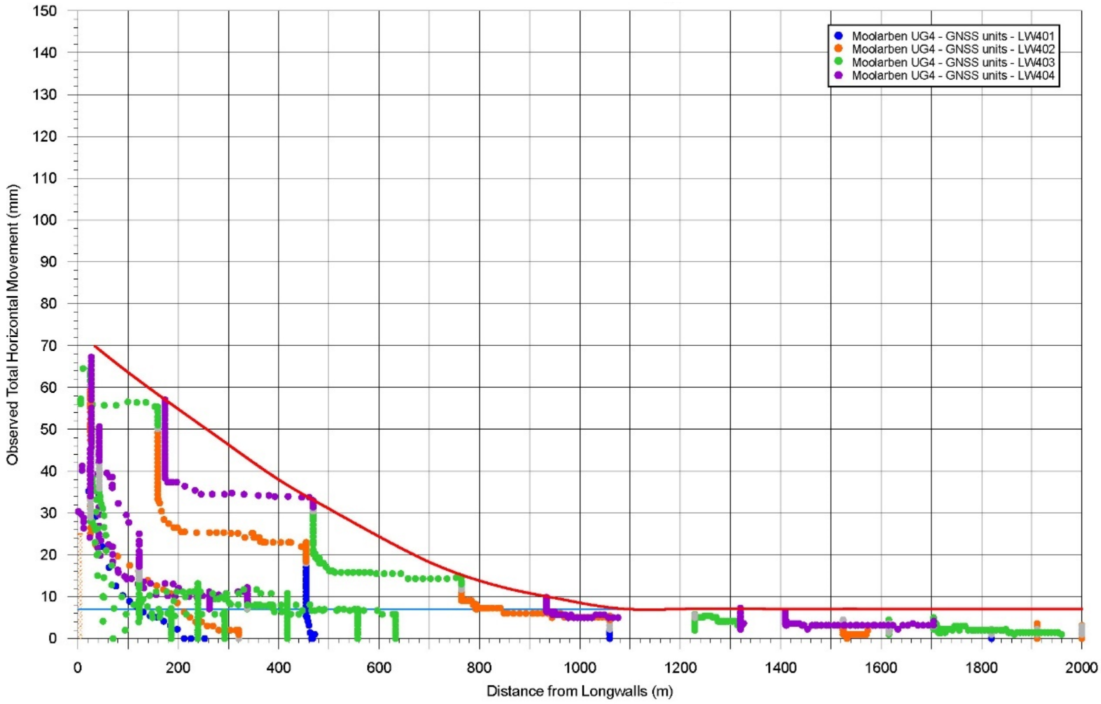


**Fig. 4.8 Observed total far-field horizontal movements (mm) within UG4 mining area versus distance from extracted longwalls (m)**

It can be seen from Fig. 4.8 that horizontal movements are less than 7mm beyond approximately 1,100 m from the extracted longwalls, gradually increasing with reduced distance from the longwalls. The movement range of up to 7mm is slightly greater than the typical ±5mm accuracy discussed above however observation of the movement trends for the GNSS units identified some variation which may be related to seasonal changes, rainfall, and/or atmospheric conditions. With ongoing longwall extraction, additional GNSS monitoring data will be added to Fig. 4.8 to form a comprehensive database of total horizontal movement at UG4. Additional data will also allow formulation of statistical distribution of far-field horizontal movements.

The impacts of far-field horizontal movements on the natural features and items of surface infrastructure within the vicinity of the Extraction Plan Layout are expected to be insignificant, except where they occur at large built features, such as roads and bridges, which may be sensitive to small differential movements and may require monitoring and maintenance to remain in a safe and serviceable condition.

The effects of natural variation in the GNSS monitoring data can be observed in the graphical plot of each GNSS monitoring unit against time. Plots showing the observed horizontal and vertical movements at GNSS units MCO03, MCO04, and MCO06 to MCO09 are shown below in Fig. 4.9 to Fig. 4.14. These units are located to the north of the LW401 to 408 series of longwalls and have been recording movements for approximately 12 to 18 months since installation. In each graph, variations in horizontal easting and northing of up to about ±4mm can be observed, which equates to approximately ±5mm to 6mm horizontal movement in any direction.

Minor increases are observed in a southerly direction, towards the extracted longwalls in MC06 and 07 which are 1300 m to 1400 m from the nearest longwall. Minor southerly increase can be observed in MCO08, which is located over 2300 m from the nearest longwall, however further data would be required to confirm the increase. The magnitude of southerly movements increases in the GNSS units as they get closer to the extracted longwalls, as expected. The horizontal movements towards the longwalls do not generally increase to greater than 5 mm until the units are within about 1400 m of the nearest longwall.

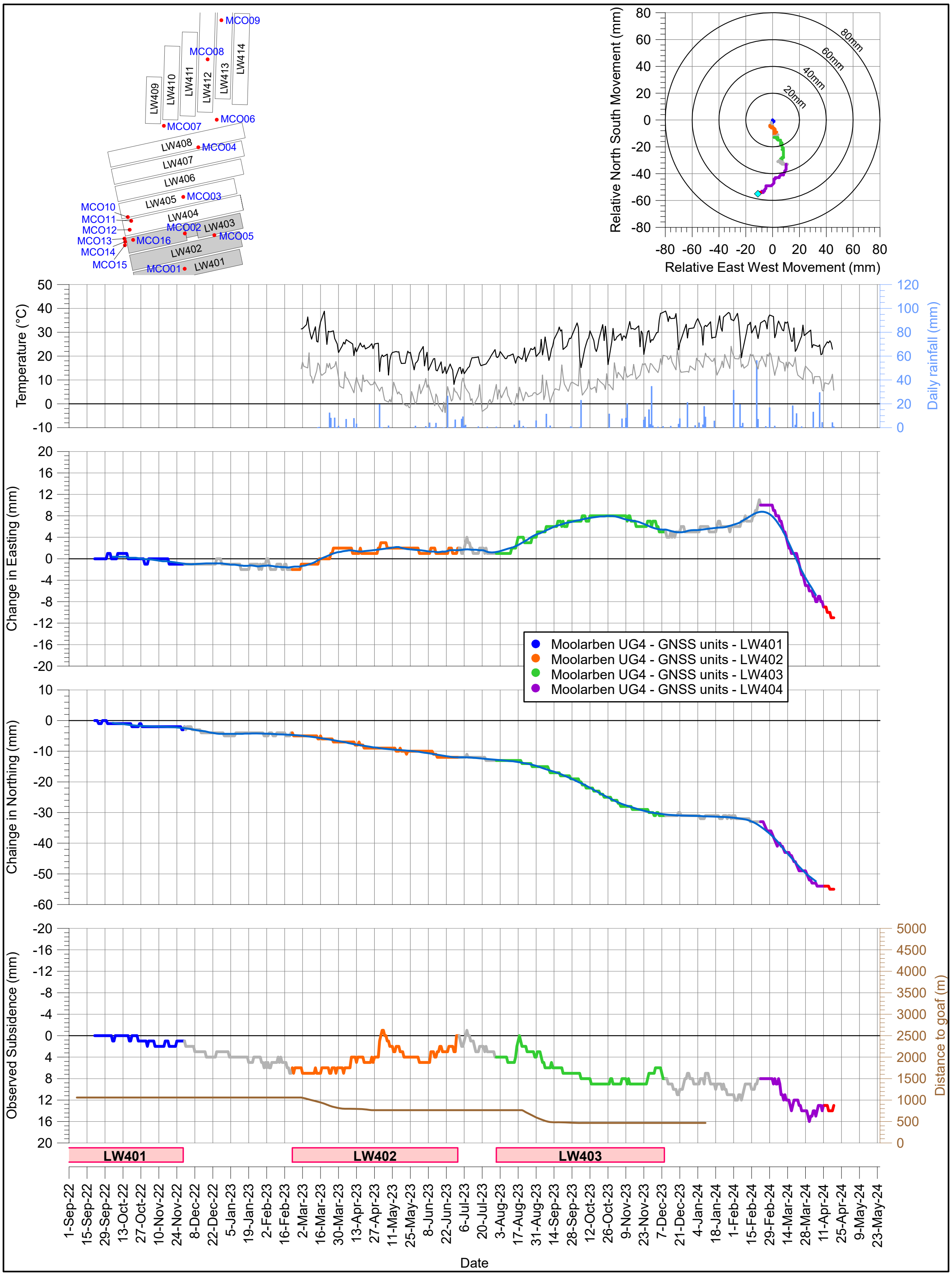


**Fig. 4.9 Total horizontal movement and vertical subsidence at GNSS MCO03**

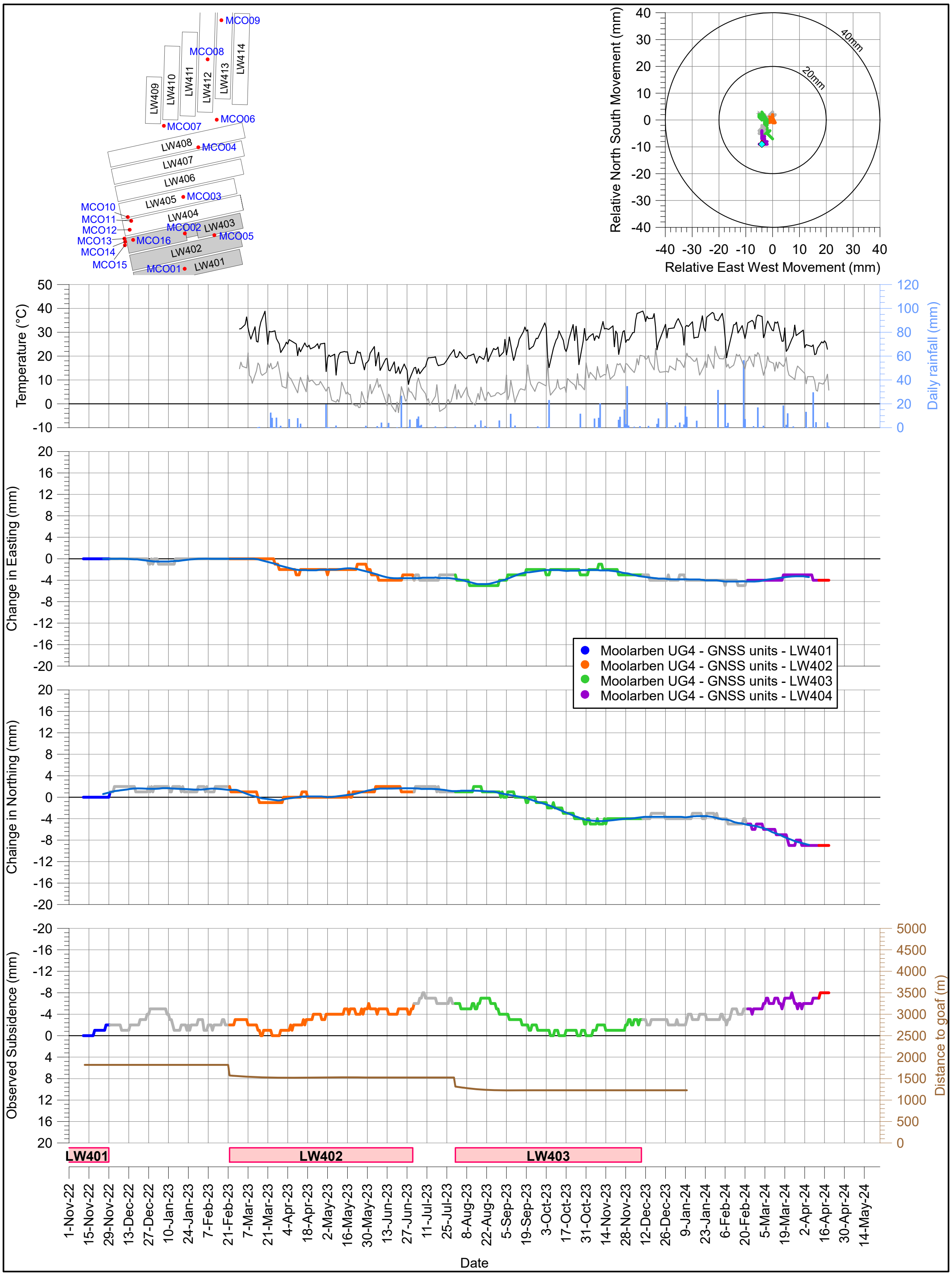


**Fig. 4.10 Total horizontal movement and vertical subsidence at GNSS MCO04**

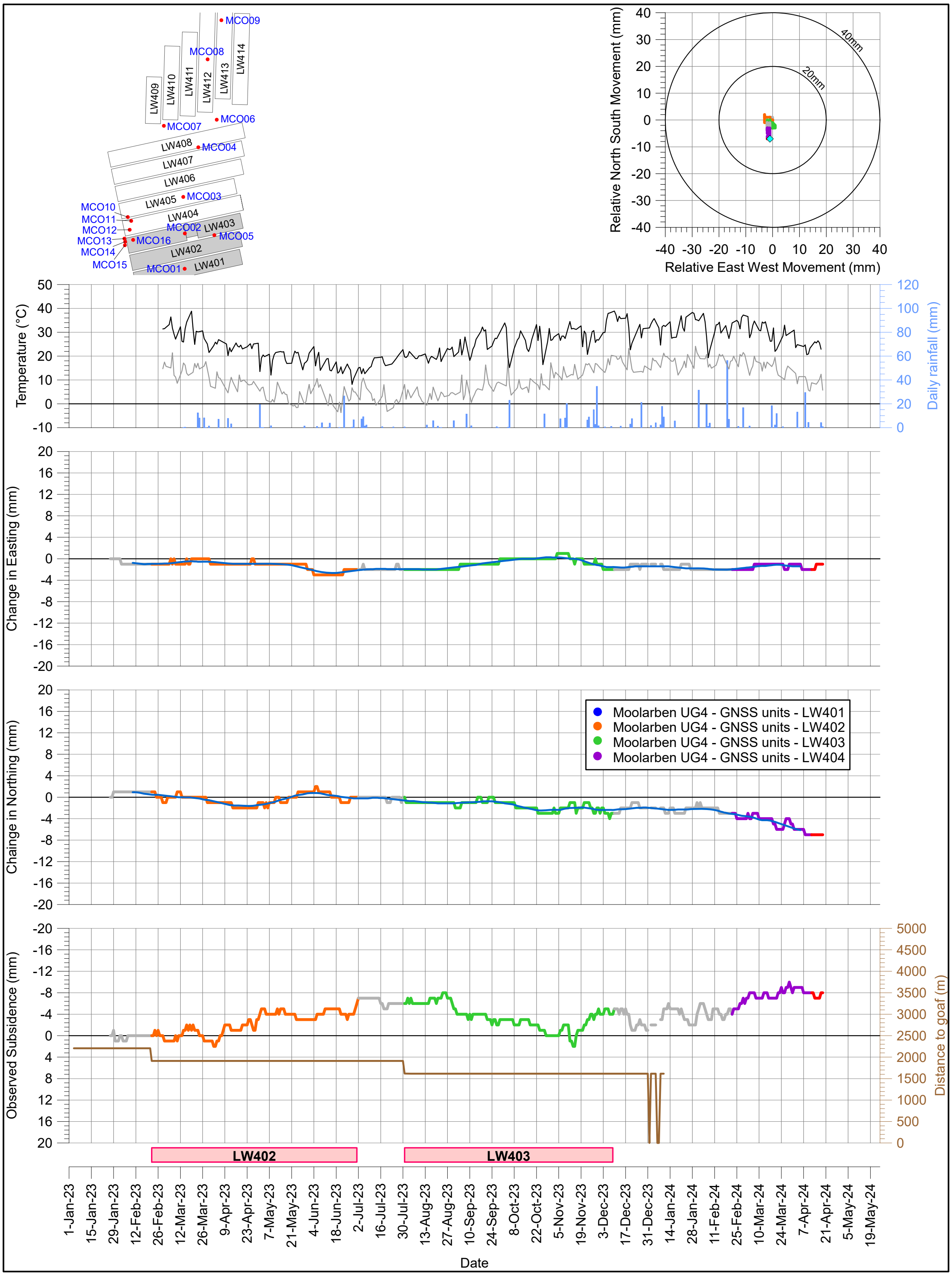


**Fig. 4.11 Total horizontal movement and vertical subsidence at GNSS MCO06**

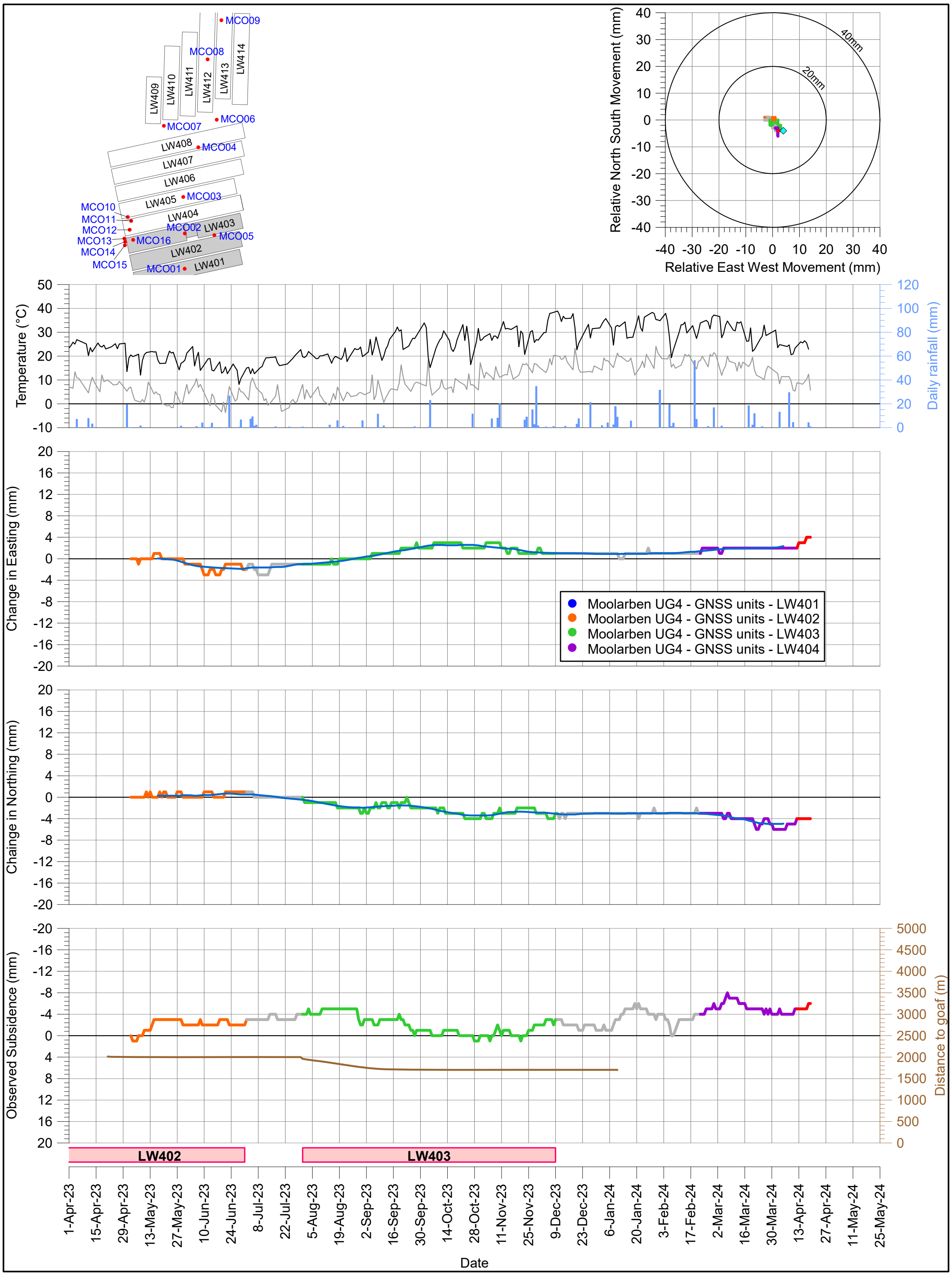


**Fig. 4.12 Total horizontal movement and vertical subsidence at GNSS MCO07**

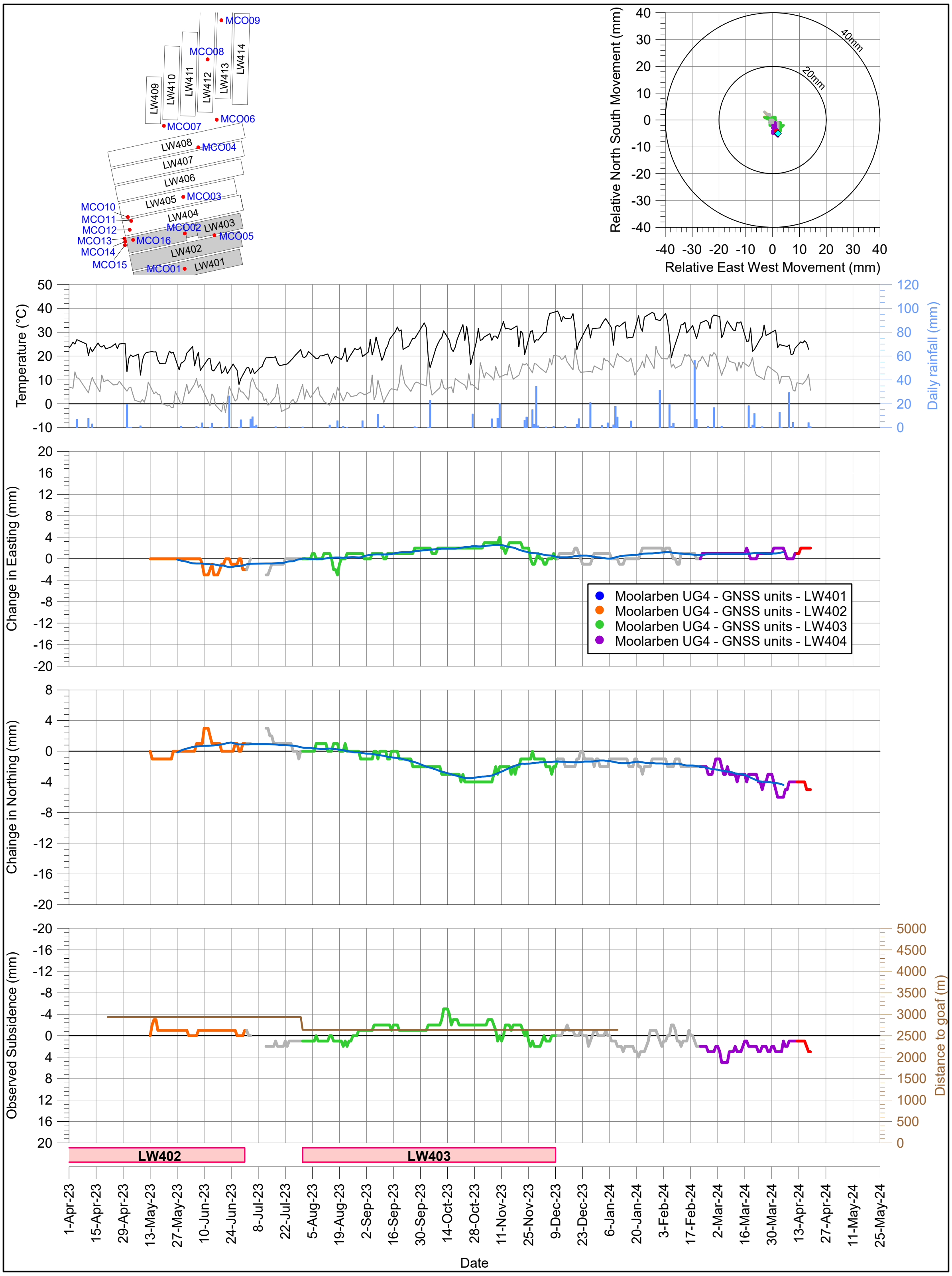


**Fig. 4.13 Total horizontal movement and vertical subsidence at GNSS MCO08**

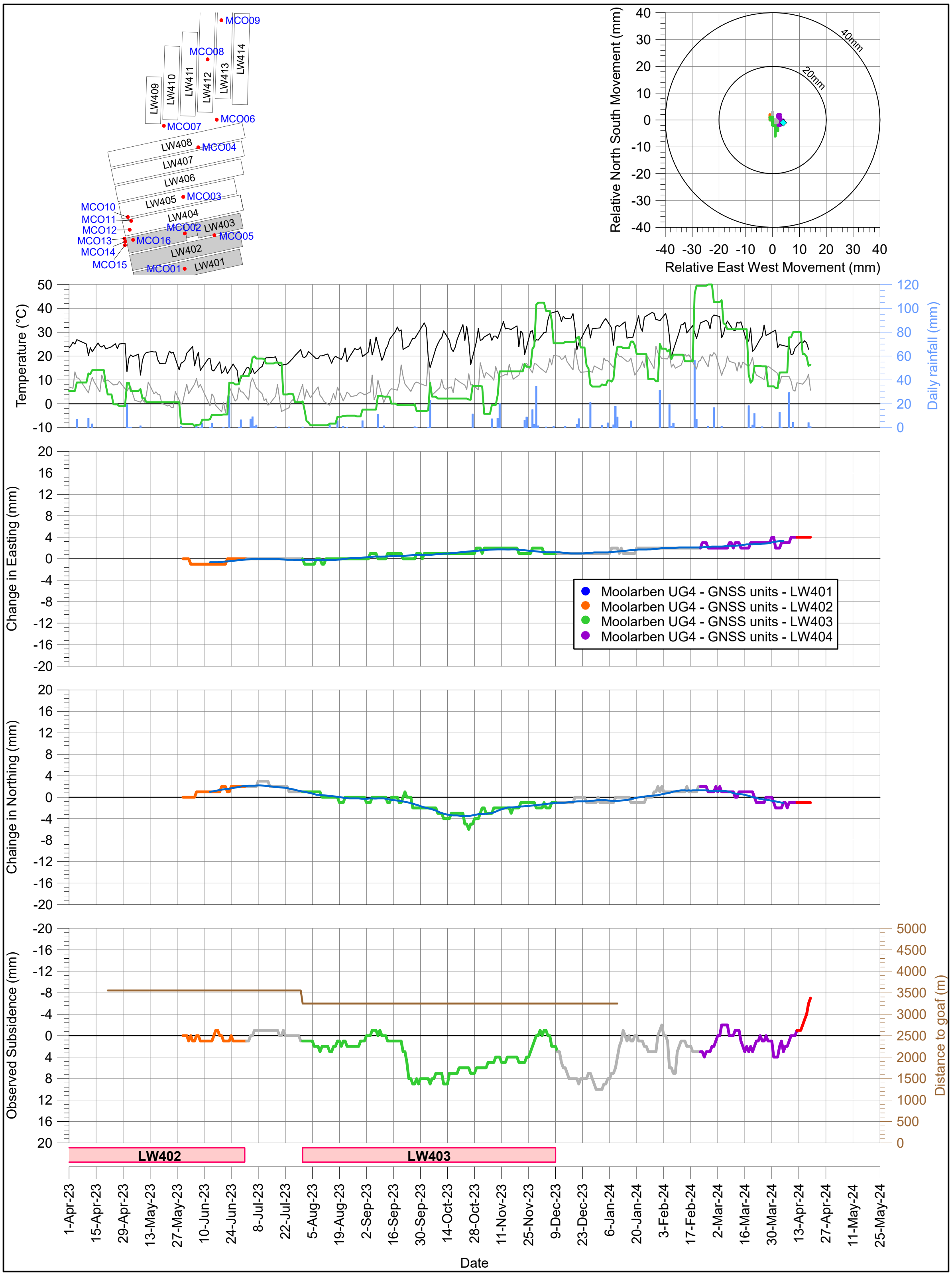


**Fig. 4.14 Total horizontal movement and vertical subsidence at GNSS MCO09**

## 4.7. Non-Conventional Ground Movements

It is likely non-conventional ground movements will occur within the Study Area, due to near surface geological conditions and steep topography, which were discussed in Section 3.4. These non-conventional movements are often accompanied by elevated tilts and curvatures which are likely to exceed the conventional predictions in places.

In most cases, it is not possible to predict the exact locations or magnitudes of the non-conventional anomalous movements due to near surface geological conditions. For this reason, the strain predictions provided in this report are based on a statistical analysis of measured strains, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4. In addition to this, the impact assessments for the natural and built features, which are provided in Chapters 5 to 11, include historical impacts resulting from previous longwall mining which have occurred as a result of both conventional and non-conventional subsidence movements.

## 4.8. General Discussion on Mining Induced Ground Deformations

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

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

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 perimeters. Most of the cracks will occur within a radius of approximately 0.1 times the depth of cover from the longwall perimeters. The cracks will generally be parallel to the longitudinal edges or the ends of the longwalls. Surface cracking normally develops behind the extraction face up to a horizontal distance equal to around half the depth of cover and, hence, the cracking in any location normally develops over a period of around two to four weeks.

At shallow depths of cover, it is also likely that transient surface cracks will occur above and parallel to the moving extraction face, i.e. at right angles to the longitudinal edges of the longwall, as the subsidence trough develops. The larger and more permanent cracks, however, are usually located in the final tensile zones around the perimeters of the longwalls. Open fractures and heaving, however, can also occur due to the buckling of surface beds that are subject to compressive strains. An example of crack patterns that develop in shallow depths of cover is shown in Fig. 4.15 below.

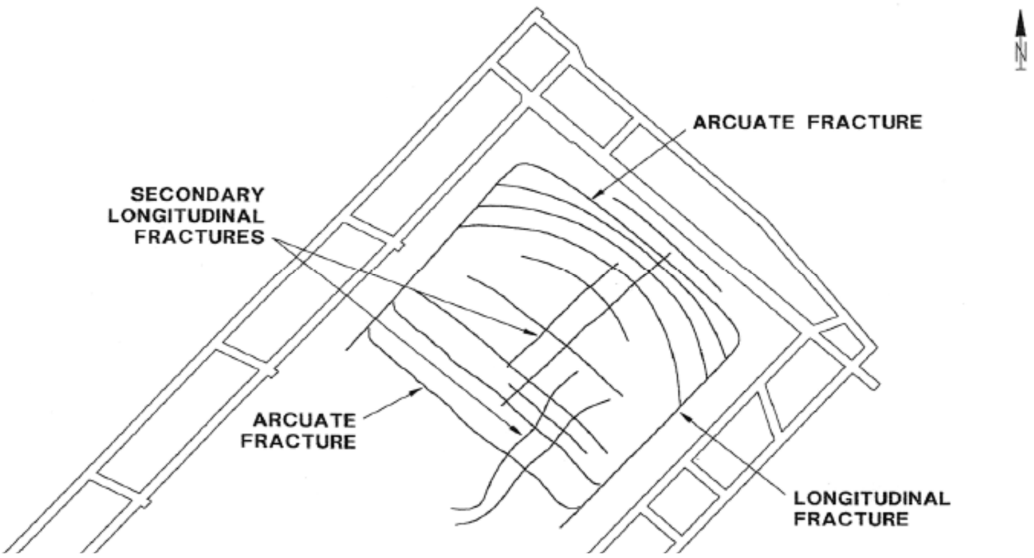


**Fig. 4.15 Survey of Major Fracture Pattern at Approx. 110m Cover (Source: Klenowski, ACARP C5016, 2000)**

Over previously mined longwalls, typical surface crack widths in the order of 100 mm and step heights in the order of 100 mm have been commonly observed at shallow depths of cover, say less than 200 m. Larger crack widths have been observed with shallow depths of cover where thicker seams are extracted, where mining occurs near or beneath steep terrain, where thick massive strata beams are present, or where multiple cracks join to form a broader surface deformation.

Localised cracking and stepping greater than 500 mm have been observed at other collieries with similar depths of cover in the NSW Coalfields. These larger tensile cracks tend to be isolated and located above and around the perimeters of the longwalls and along the tops of steep slopes, due to down slope movements resulting from the extraction of the longwalls. The typical surface cracks and these larger isolated cracks can normally be easily identified and remediated – Klenowski (ACARP C5016, 2000).

Experience in NSW has found that the severity and frequency of surface cracking reduces as the depth of cover to the extraction increases.

Crack mapping was undertaken during the extraction of Longwalls 101 to 103. Crack widths were generally less than 100 mm in 78 % of cases. Crack widths were measured between 100 mm and 200 mm in 18 % of cases, and between 200 mm and 300 mm in 4 % of cases. A small number of larger isolated cracks up to approximately 500 mm were also identified.

The depths of cover over the Longwalls 409 to 414 underground mining areas vary from 120 m to 215 m. At the shallow depths of cover, surface cracking is expected to be typically in the order of 150 to 200 mm wide, however in some instances could be up to 500 mm wide where the depths of cover are the shallowest. Where the depths of cover are greater, the surface crack widths are expected to be typically in the order of 100 to 150 mm wide. The surface crack widths are likely to be smaller where the depths of cover are greater, or where the surface cracks result from the travelling wave.

The surface cracking and deformation could result in safety issues (i.e. trip hazards), affect vehicle access (i.e. large deformations in access tracks), or result in increased erosion (especially along the drainage lines and the steeper slopes).

Management strategies and remediation measures developed for UG4 Longwalls 401 to 408 for the surface cracking and deformations should continue to be implemented for Longwalls 409 to 414. These include visual monitoring of the surface in the active subsidence zone, to identify the larger surface cracking and deformations which could affect safety, access, or increased erosion. In some cases, remediation may be required and could include infilling, regrading or erosion protection measures.

# 5.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES WITHIN THE STUDY AREA

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the natural features located within the Study Area for Longwalls 409 to 414. The predicted parameters for each of the natural features have been compared to the predicted parameters based on the Approved Layout. Supporting impact assessments for the natural features have also been undertaken by other specialist consultants for the Extraction Plan Layout.

## 5.1. Natural Features

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

- drinking water catchment areas or declared special areas;
- seas or lakes;
- escarpments;
- shorelines;
- natural dams;
- water related ecosystems;
- lands declared as critical habitat under the *Threatened Species Conservation Act 1995*;
- State Recreation Areas or State Conservation Areas;
- State Forests;
- areas of significant geological interest; and
- other significant natural features.

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

## 5.2. Drainage Lines

### 5.2.1. Description of the Drainage Lines

There are no perennial drainage lines within the Study Area. The Goulburn River is the nearest major drainage line, located on the western side of the Study Area and is 180 m from the finishing end of Longwall 412 at its nearest point. A number of other small ephemeral drainage lines have been identified above the longwalls and within the Study Area. The drainage lines are shown in Drawing No. MSEC1381-07. The main drainage line flowing through the Study Area has been labelled in Drawing No. MSEC1381-07 (Drainage Line 2).

The drainage lines within the Study Area flow to the Goulburn River. The predictions and impact assessments for the drainage lines within the Study Area are provided in the following sections.

The drainage lines within the Study Area comprise a rounded gravel to sandy and silty base. There is also debris along sections of the drainage lines, including boulders, tree branches and other vegetation. The valley profiles of the drainage lines are predominantly broad and shallow with some incised sections as shown in Fig. 5.1.

**Fig. 5.1 Drainage Line 2**

The natural grades of the main drainage lines within the Study Area typically vary between 5 mm/m (i.e. 0.5 % or 1 in 200) and 100 mm/m (i.e. 10 % or 1 in 10), with average natural grades of approximately 20 mm/m (i.e. 2 % or 1 in 50).

### 5.2.2. Predictions for the Drainage Lines

The drainage lines are located across the Study Area and are likely, therefore, to be subjected to the full range of predicted systematic subsidence and valley related movements, as discussed in Section 4.2. The predicted profiles of conventional subsidence, tilt and curvature along Drainage Line 2 are shown in Fig. C.03 in Appendix C. The predicted total profiles along the Drainage Line 2, after the extraction of each of the proposed longwalls, are shown as blue lines.

A summary of the maximum predicted total conventional subsidence parameters along Drainage Line 2, after the extraction of Longwalls 409 to 414, is provided in Table 5.1.

**Table 5.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for Drainage Line 2 after the Extraction of Longwalls 409 to 414**

| Drainage Line | 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 ($km^{-1}$) |
|---|---|---|---|---|
| Drainage Line 2 | 1900 | 40 | 1.9 | 1.6 |

The maximum predicted conventional tilt for the drainage lines is 40 mm/m (i.e. 4 %, or 1 in 25). The maximum predicted conventional curvatures are greater than 1.9 $km^{-1}$ hogging and 1.6 $km^{-1}$sagging, which equate to minimum radii of curvature of 0.53 km and 0.63 km respectively.

The predicted strains for the Drainage Line 2 are provided in Table 5.2. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4).

**Table 5.2 Predicted Strains for the Drainage Lines based on Conventional and Non-Conventional Anomalous Movements**

| Drainage Line | Conventional tensile strain based on 10 times Curvature (mm/m) | Conventional compressive strain based on 10 times Curvature (mm/m) | Tensile strain based on the 95 % Confidence Level (mm/m) | Compressive strain based on the 95 % Confidence Level (mm/m) |
|---|---|---|---|---|
| Drainage Line 2 | 19 | 16 | 10 | 13 |

The drainage lines could also experience higher strains due to non-conventional ground movements. The distribution of strain along linear features shown in Fig. 4.4 includes those resulting from both conventional and non-conventional anomalous movements.

It is also possible that the drainage lines could experience some valley related movements resulting from the extraction of Longwalls 409 to 414, however the magnitudes of these upsidence and closure movements are expected to be much lower than the conventional movements and hence may not be significant.

### 5.2.3. Comparison of the Predictions for Drainage Lines

A comparison of the maximum predicted subsidence parameters for Drainage Line 2, resulting from the extraction of Longwalls 409 to 414, with those based on the Approved Layout is provided in Table 5.3. The values are the maxima along the section of the drainage lines located within the Study Area.

**Table 5.3 Maximum Predicted Systematic Subsidence Parameters along the Alignments of the Drainage Line 2 Resulting from the Extraction of the Approved Layout and Extraction Plan Layout**

| Layout | Drainage Line | 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 ($km^{-1}$) |
|---|---|---|---|---|---|
| Approved Layout | Drainage Line 2 | 1900 | 40 | 1.9 | 1.6 |
| Extraction Plan Layout | Drainage Line 2 | 1900 | 40 | 1.9 | 1.6 |

The predicted total subsidence parameters for the drainage lines based on the Extraction Plan Layout are the same as those for the Approved Layout.

### 5.2.4. Impact Assessments and Recommendations for the Drainage Lines

The maximum predicted total subsidence parameters for the drainage lines based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 409 to 414. The potential impacts for the drainage lines, based on the Extraction Plan Layout are the same as those assessed based on the Approved Layout. The following summary outlines the potential impacts to the drainage lines:

- The drainage lines within the Study Area are ephemeral as water only flows during and for short periods after each rain event. Ponding naturally develops along some sections of the drainage lines, for short periods of time, after major rain events. The predicted changes in grade along the drainage lines after the completion of the longwalls are generally less than most of the natural grades, however the magnitudes of tilt will result in increases and decreases in grade and reversal of grade at some locations. Additional ponding may occur along the drainage lines resulting from the extraction of Longwalls 409 to 414, predominantly upstream of the chain pillars.

  A plot of pre-mining and predicted post-mining grade along Drainage Line 2 is provided below in Fig. 5.2. It can be seen that a predicted reversal of grade (negative grade) occurs near the commencing end of Longwall 409 and the maingate of Longwall 410.

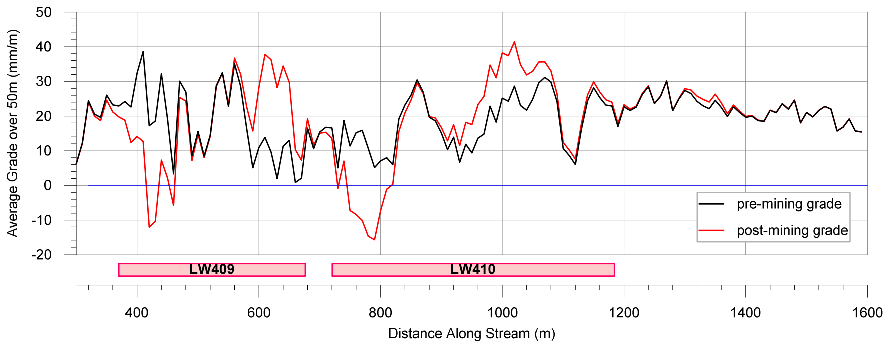


**Fig. 5.2 Average Grade along Drainage Line 2**

- Sections of beds downstream of the additional ponding areas may erode during subsequent rain events, especially during times of high flow. It is expected that, over time, the gradients along the drainage lines would approach grades similar to those that existed before mining. The extent of additional ponding along the drainage lines would, therefore, be expected to decrease with time.
- Fracturing, dilation and buckling of the bedrock would occur as a result of the extraction of these longwalls. Some surface cracking is expected to develop in the bases of the drainage lines as outlined in Section 4.8.
- In times of heavy rainfall, the majority of the surface water runoff would be expected to flow over the surface cracking in the beds and only a small proportion of the flow would be diverted into the fractured and dilated strata below. In times of low flow, however, a larger proportion of the surface water flow could be diverted into the strata below the beds and this could affect the quality and quantity of this water flowing through the cracked strata beds. Nevertheless, during high flow or low flow times, this small quantity is expected to have little impact on the overall quality of water flowing out of the drainage lines.

If adverse impacts were to develop as the result of increased ponding along the drainage lines, these could be remediated by locally regrading the beds, so as to re-establish the natural gradients. It would be expected that the majority of fracturing in the underlying bedrock would gradually be filled with the surface soils during subsequent flow events, especially during times of heavy rainfall. If the surface cracks were found not to fill naturally, some remedial measures may be required at the completion of mining. Where necessary, any significant surface cracks in the drainage line beds could be remediated by infilling with the surface soil or other suitable materials, or by locally regrading and recompacting the surface.

Specialist input may be required to determine when remediation works are required. Drainage lines above the previously extracted longwalls in UG1 and UG4 have not required remediation works.

The shallow depth of cover will result in the development of a network of fractures in the overburden above the extracted longwalls. The changes in permeability and the potential hydrogeological impacts above proposed longwalls are discussed by the specialist groundwater consultant in the report by *Australasian Groundwater & Environmental Consultants* (2024). The hydrogeological modelling indicates that continuous fracturing is not predicted to occur at the land surface with the zone of continuous fracturing being 16 m or more below the ground surface.

### 5.2.5. Recommendations for the Drainage Lines

It is recommended that the drainage lines are visually monitored as the longwall mines beneath them and that management strategies currently developed for UG4 Longwalls 401 to 408 would remain appropriate for Longwalls 409 to 414, such that the impacts can be identified and remediated if and as they are required. Management strategies based on the Extraction Plan Layout are the same as those for the Approved Layout.

## 5.3. The Goulburn River

The Goulburn River is located on the north western side of Longwalls 409 to 412 at distances of 180 m to 440 m from the commencing ends of these longwalls, and to the north and north east of Longwalls 412 to 414 at distances of 460 m to 500 m. The location of the Goulburn River is shown in Drawing No. MSEC1381-07. The river flows in a general north easterly direction. A picture of the Goulburn River approximately 350m to 400m from Longwalls 409 and 410 is shown in Fig. 5.3.

**Fig. 5.3 Goulburn River**

The Stage 1 Project Approval 05_0117 has the following Impact Performance Measure in Table 14.

| *Water Resources* | |
|---|---|
| *Goulburn River and the bed of the Goulburn River (see Appendix 7)* | *Negligible impact or environmental consequences*<br>*Remain outside the zone of recorded subsidence damage for longwall mining* |

The Goulburn River is located outside the Study Area boundary. At its nearest point of 180 m from the longwalls, the distance to the Goulburn River represents about 1.3 times the depth of cover from the longwalls. Elsewhere, the Goulburn River is two or more times the depth of cover from the longwalls.

At distances of 180 m to over 440 m between the longwalls and the Goulburn River, the maximum expected incremental horizontal movement is 75 mm based on Moolarben Coal monitoring data in Fig. 4.7 and 40 mm to 50 mm total horizontal movement based on the Moolarben Coal GNSS monitoring data in Fig. 4.8. Based on Fig. 4.3, the 95% confidence levels for the maximum total strains at 180 m from the extracted longwalls is 0.8 mm/m tensile and 0.3 mm/m compressive.

It is possible that where horizontal movement is observed at a valley location then valley related closure movement could be observed. A prediction of valley closure at the nearest location of the Goulburn River indicates a potential valley closure of 20 mm, which is below the limit of accuracy for the survey data used in the valley closure prediction model.

The impact assessments for the Goulburn River based on the Approved Layout do not change based on the Extraction Plan Layout. It is considered unlikely that fracturing of the bed of the Goulburn River would occur due to the Extraction Plan Layout based on the magnitude of expected movements discussed above and the offset distances of the Extraction Plan Layout from the Goulburn River. If fracturing were to occur, it is likely that the fractures will be localised in nature and minor in size, and represent no greater than negligible impact. It is expected that the majority of the bedrock in the bed of the river will be covered with alluvial deposits. Minor fractures that potentially develop outside extracted longwalls are not generally associated with any increased rate of diversion of surface water into near-surface substrata. Therefore, it is expected the performance measure of negligible impact or environmental consequences will be achieved.

It is recommended that the river is visually monitored for any visible indications of mining related impact during the extraction of Longwalls 409 to 412.

## 5.4. The Drip and Goulburn River Gorge

### 5.4.1. Description of The Drip and Goulburn River Gorge

The Drip and Goulburn River Gorge (also called Corner Gorge) are natural cliff features located on the Goulburn River. The locations of The Drip and Goulburn River Gorge are shown in Drawing No. MSEC1381-07.

The Drip is the more prominent feature comprising a south facing cliff with sheer to sub-vertical faces up to approximately 25 m high and approximately 300 m long. The Drip is located approximately 645 m from the commencing end of Longwall 413 and is 770 m from the commencing end of Longwall 412. An image of The Drip is shown below in Fig. 5.4.

The Goulburn River Gorge comprises east and west facing cliffs along the Goulburn River. The western cliff is approximately 380 m long with a maximum height of approximately 25 m. The eastern cliff is approximately 600 m long with a maximum height of approximately 30 m. The Goulburn River Gorge is located 450 m from Longwall 414 and is 575 m from Longwall 413.

Surface profiles through The Drip and Goulburn River Gorge are shown in Fig. 5.6 and Fig. 5.7.

**Fig. 5.4 The Drip**

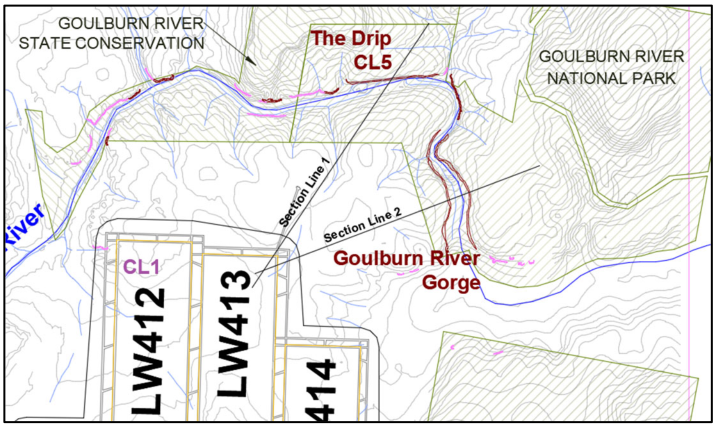


**Fig. 5.5 Cross Section Lines**

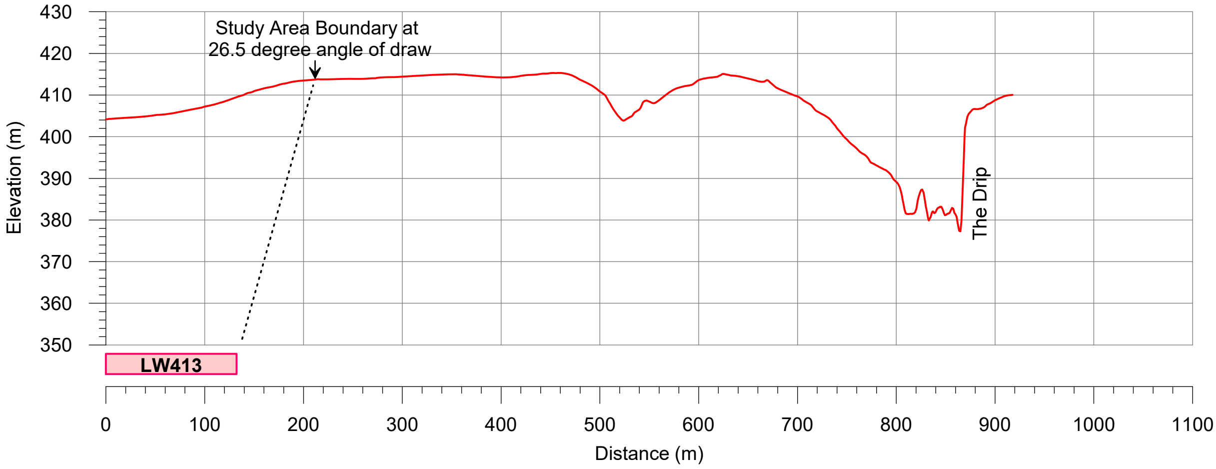


**Fig. 5.6 Section Line 1 - The Drip**

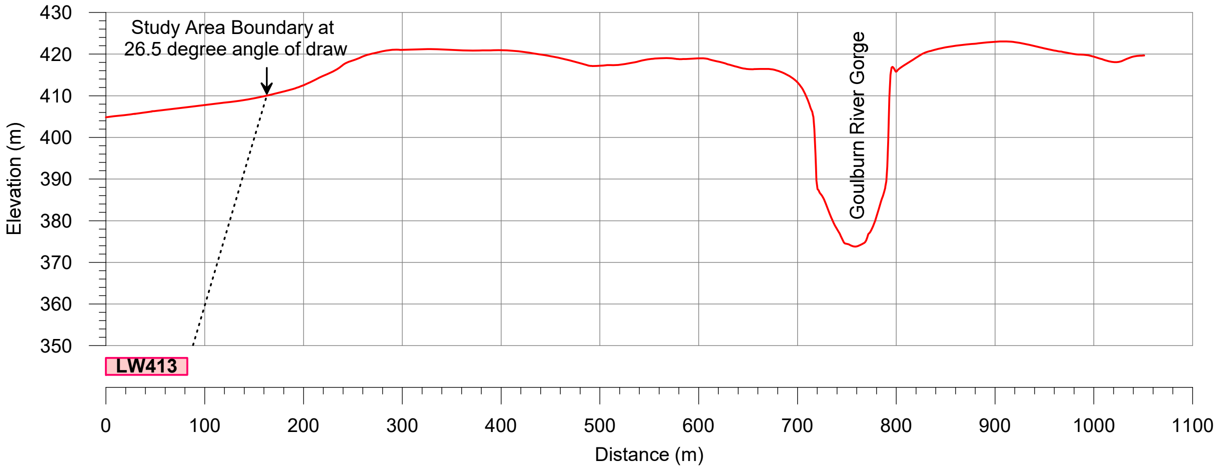


**Fig. 5.7 Section Line 2 - Goulburn River Gorge**

The original Moolarben Stage 1 Environmental Assessment (MCM, 2006) (Stage 1 EA) proposed a longwall layout for UG4 where mining of LW412-414 would occur at a distance of 250 m to 450 m from The Drip.

In response to comments received on the Stage 1 EA by the Independent Hearing and Assessment Panel (IHAP), MCO revised the UG4 mine plan to increase the minimum setback from the Drip to 645 m. The revised layout also incorporates a setback from the Goulburn River Gorge of 450 m.

The IHAP review of the revised underground mining layout concluded "the revised mine plan incorporates important mitigation measures that significantly reduce the level of risk of subsidence related damage to several important features, with The Drip, Corner Gorge and Goulburn River now being 'well outside the recorded subsidence damage from longwall mining'".

The *Director General's Environmental Assessment Report* on the Stage 1 Project concluded (NSW Department of Planning, 2007):

> *Both the Department and DPI concur with the Panel's findings, and are satisfied that the revised mine plan has reduced the residual subsidence impacts of the project to an acceptable level, and that these impacts can be suitably managed through the current subsidence management plan process.*

It is noted that in their determination of the Moolarben Stage 2 Project in 2014, the then Planning and Assessment Commission strengthened the Subsidence Impact Performance Measure for The Drip and Corner Gorge from 'negligible impact' to 'nil impact'. There was no change to the UG4 mine plan (i.e. the Approved Layout) or the proposed setbacks during this process.

Therefore, the Stage 1 Project Approval 05_0117 has the following Subsidence Impact Performance Measure for The Drip and Corner Gorge.

| *Special Feature* | |
|---|---|
| *The Drip and Goulburn River Gorge* | *Nil impact or environmental consequences* |

### 5.4.2. Predictions for The Drip and Goulburn River Gorge

*Setback Distance*

The distance of 645 m to The Drip represents approximately 4.5 times the depth of cover of 145 m from Longwall 413. The distance of 450 m to The Goulburn River Gorge represents approximately 3.5 times the depth of cover of 130 m from Longwall 414.

The setback distance for the Approved Layout established in response to the IHAP remains outside of the extent of expected subsidence damage from longwall mining based on a review of available data to 2024.

That is, there have been no known cases of mining-related physical impacts to cliff lines at distances of 450 m and 3.5 times the depth of cover from extracted longwalls. Case studies supporting this are provided in Appendix F. A summary of the comparative geometries for the case studies is provided in Table 5.4

**Table 5.4 Summary of Case Study Geometries**

| Location | Feature | Distance from extracted Longwall(s) (m) | Ratio of distance to longwall divided by depth of cover (m/m) |
|---|---|---|---|
| Dendrobium Mine | Sandy Creek Waterfall | 290 to 330 | 1.2 to 1.7 |
| Wambo Coal Mine | Wollemi escarpment | >230 | > 0.9 |
| Appin Colliery | Razorback range and Nepean River | 310 to 780 | 0.6 to 1.5 |
| Ulan | Brokenback Conservation Area | 420 current | 0.5 (future longwalls) |
| MCO | The Drip | 645 | 4.5 |
| MCO | Goulburn River Gorge | 450 | 3.5 |

With no known significant geological features located near the longwalls, the risk of impact from anomalous movements at The Drip and Goulburn River Gorge is considered remote. Due to the significant distance and low magnitude of expected far-field movement at the cliffs, mining related impacts to The Drip and Goulburn River Gorge due to the extraction of Longwall 409 to 414 are considered unlikely to occur. Therefore, it is expected the performance measure of nil impact or environmental consequences will be achieved.

*Conventional Subsidence*

At distances of over 450 m, The Drip and Goulburn River Gorge will not experience measurable conventional tilts, curvatures or strains from the extraction of Longwalls 409 to 414.

*Far-field Movement*

Far-field horizontal movements at the setback distance of longwalls from The Drip and Corner Gorge are expected to be very small. Monitoring devices comprising nine GNSS units have been installed at selected locations along the Goulburn River (Fig. 5.8). Two units are located to the west of The Drip and six units are located along the Goulburn River Gorge cliffs. A single unit is located at the top of The Drip. The units were installed in December 2023.

The total far-field horizontal GNSS data in Fig. 4.8 shows a maximum observed total horizontal movement of 35mm at a distance of 450 m from the longwalls. At over 450 m from the extracted longwalls, potential differential movements and ground strain are expected to be negligible. Differential horizontal movements are also expected to be very small and predominantly within observational limits of the survey methods being used.

The amount of site-specific empirical data of far-field horizontal and differential movements at cliff features at similar distances from current longwall mining as The Drip and Goulburn River Gorge is limited at this stage. It is recommended to review and refine predictions of expected far-field movements as additional monitoring is obtained from current mining in LW401-408 to establish baseline (natural) movement to refine predictions.

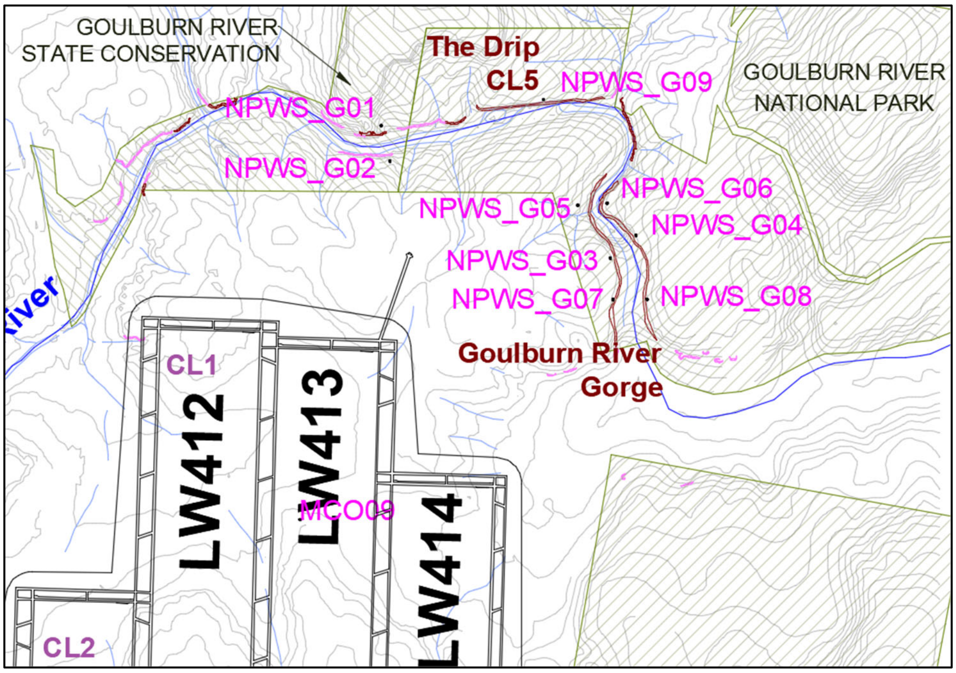


**Fig. 5.8 Monitoring locations at The Drip and Goulburn River Gorge**

#### 5.4.3. Impact Assessments and Recommendations for The Drip and Goulburn River Gorge

As described above, due to the significant distance and low magnitude of expected far-field movement at the cliffs, mining related impacts to The Drip and Goulburn River Gorge due to the extraction of Longwall 409 to 414 are considered unlikely to occur. Therefore, it is expected the performance measure of nil impact or environmental consequences will be achieved.

The existing GNSS monitoring network at The Drip and Goulburn River Gorge is considered sufficient to undertake recommended monitoring prior to and during mining.

It is recommended that the existing monitoring is continued for The Drip and Goulburn River Gorge to establish baseline natural movements prior to the commencement of mining.

As described above, the amount of site-specific empirical data of far-field horizontal and differential movements at cliff features at similar distances from current longwall mining as The Drip and Goulburn River Gorge is limited at this stage. Therefore, it is also recommended that the existing GNSS monitoring array for UG4 be extended to include additional monitoring of cliff features or other similar features at similar distances from mining to those for The Drip and Goulburn River Gorge. Data from these GNSS monitoring locations would be used to observe movements and refine predictions of expected far-field movements for The Drip and Goulburn River Gorge.

Cliff CL3 is a large cliff formation located over 165 m from Longwall 408 and 466 m from Longwall 407 and is considered to provide a good opportunity to observe movements at similar distance to those for The Drip and Goulburn River Gorge.

Management strategies for the Drip and Corner Gorge should include monitoring to confirm that observed far-field movements do not exceed predictions, and also a visual monitoring program of the cliffs including photographic records at periods prior to, during and after completion of longwall extraction.

In addition to ongoing GNSS monitoring in proximity to the Drip and Corner Gorge, additional management strategies should be developed, including visual inspections and a Trigger Action Response Plan.

### 5.5. Aquifers and Known Ground Water Resources

The descriptions, predictions and the assessment of potential impacts on the aquifers and groundwater resources within the Study Area are provided in the Groundwater Assessment report prepared by *Australasian Groundwater & Environmental Consultants* (2024).

There are no *Ground Water Management Areas*, within the Study Area.

## 5.6. Cliffs

### 5.6.1. Descriptions of the Cliffs

The subsidence impact assessments for the Approved Layout in 2006 were based on 8 defined areas containing a range of cliffs.

The definitions of cliffs and minor cliffs provided in the NSW DP&E *Standard and Model Conditions for Underground Mining* (DP&E, 2012) are:

*"Cliff* — *Continuous rock face, including overhangs, having a minimum length of 20 metres, a minimum height of 10 metres and a minimum slope of 2 to 1 (>63.4º)*

*Minor Cliff* — *A continuous rock face, including overhangs, having a minimum length of 20 metres, heights between 5 metres and 10 metres and a minimum slope of 2 to 1 (>63.4º); or a rock face having a maximum length of 20 metres and a minimum height of 10 metres"*

A detailed assessment of cliffs and minor cliffs was carried out using 1 m surface level contours generated from a Light Detection and Ranging (LiDAR) survey and from site investigations. A summary of the cliffs and minor cliffs at each of the Cliff Line areas within or near the Study Area (including The Drip) is provided in Table 5.5. Only cliff areas CL3 and CL5 (The Drip) meet the definitions of cliffs provided in the NSW DP&E *Standard and Model Conditions for Underground Mining* (DP&E, 2012). The locations of the cliff areas are shown in Drawing No. MSEC1381-07.

**Table 5.5 Cliff areas assessed for the Approved Layout**

| Cliff Line Area ID | Maximum Height (m) | Maximum Length (m) | Classification |
|---|---|---|---|
| CL1 | 10 | 60 | Minor Cliff |
| CL2 | 8 | 30 | Minor Cliff |
| CL3 | 15 | 500 | Cliff |
| CL4 | 10 | 30 | Minor Cliff |
| CL5 (The Drip) | 25 | 330 | Cliff |

Cliff CL5 (The Drip) is unlikely to experience subsidence related movements due to the extraction of Longwalls 409 to 414 as discussed in Section 5.4. Cliff CL3 is located adjacent to the finishing end of Longwall 413 and is over 165 m to the north of Longwall 408.

The assessment of cliffs and minor cliffs also included identification of cliffs and minor cliffs within the Goulburn River National Park and Goulburn River State Conservation Area, within approximately 600 m of the longwalls. Within the Goulburn River State Conservation Area, the nearest cliff is 330 m from Longwall 412 and the nearest minor cliff is 300 m from Longwall 412. Within the Goulburn River National Park the nearest cliff is the Goulburn River Gorge which is located 450 m from Longwall 414 and the nearest minor cliff is 313 m from Longwall 414.

The locations of the cliffs and minor cliffs are shown in Drawing No. MSEC1381-07.

### 5.6.2. Predictions for the Cliffs

The cliffs located outside the Study Area will not be subjected to measurable tilts, curvatures or strains, however, they may experience far-field horizontal movements. Further discussion of the cliffs and minor cliffs within the Goulburn River National Park and Goulburn River State Conservation Area are discussed in Section 5.10 and 5.11.

Cliff Line CL3 is located adjacent to the southern end of Longwall 413, which has been shortened (in the Extraction Plan Layout relative to the Approved Layout) to reduce the predicted subsidence parameters and potential impacts at CL3.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for CL3, resulting from the extraction of Longwalls 409 to 414 for the Extraction Plan Layout, is provided in Table 5.6. The predicted tilts provided in this table are the maxima after the completion of all the longwalls. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.

**Table 5.6 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Cliffs within the Study Area Resulting from the Extraction of Longwalls 409 to 414**

| 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 ($km^{-1}$) |
|---|---|---|---|---|
| CL3 | 90 | 2.5 | 0.09 | 0.01 |

The predicted strains for the Cliffs are provided in Table 5.7. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4).

**Table 5.7 Predicted Strains for the Cliffs based on Conventional and Non-Conventional Anomalous Movements**

| Type | Conventional based on 10 times Curvature | Non-conventional based on the 95 % Confidence Level | Non-conventional based on the 99 % Confidence Level |
|---|---|---|---|
| Tension | < 0.5 | 3.3 | 9.2 |
| Compression | < 0.5 | 3.0 | 14.4 |

### 5.6.3. Comparison of the Predictions for the Cliffs

A comparison of the maximum predicted subsidence parameters for the cliffs within the Study Area, resulting from the extraction of Longwalls 409 to 414, with those based on the Approved Layout is provided in Table 5.8.

**Table 5.8 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Cliffs based on the Extraction Plan Layout and the Approved Layout**

| Layout | 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 ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout | 1700 | 30 | 0.85 | 0.85 |
| Extraction Plan Layout | 90 | 2.5 | 0.09 | 0.01 |

It can be seen from Table 5.8, that the maximum predicted conventional subsidence parameters based on the Extraction Plan Layout are less than those for the Approved Layout.

The minor cliffs are located across the Study Area and will be subjected to the full range of predicted subsidence movements which are outlined in Section 4.2.

### 5.6.4. Impact Assessments and Recommendations for the Cliffs

***Cliff Line 3***

The Stage 1 Project Approval lists the following Subsidence Impact Performance Measures in Table 14:

| *Land* | |
|---|---|
| *Cliff Line 3* | *Minimise subsidence damage* |

To reduce subsidence impacts at CL3 MCO has adopted a reduced length for Longwall 413 that will not mine directly beneath CL3. The risk of impact to Cliff line CL3 is significantly reduced by reducing the length of Longwall 413.

The risk of cliff falls are generally greatly reduced for cliffs located outside the footprints of extracted longwalls. Where impacts to cliffs occur outside extracted longwalls, they are often the result of mining beneath another section of cliff line. An assessment of the risk of impact to CL3 must therefore take into consideration the possibility of impact to the minor cliff adjoining the northern end of CL3.

The predicted subsidence parameters for the minor cliff adjoining the northern end of CL3 include predicted tilt of 19mm/m, and based on a 10 times curvature relationship for conventional strain, predicted strains of 7.5 mm/m tensile and 1.1mm/m compressive. These parameters are greater at the northern end of the minor cliff and reduce closer to CL3. The magnitude of these predicted subsidence parameters are expected to be sufficient to result in impacts to the minor cliff, and could result in associated minor impact to CL3.

There is no definition for the performance measure of "minimise subsidence damage". It is considered reasonable to assume that minimal damage to CL3 would constitute a mine layout that reduces the risk of impact to minimal or minor impacts. The project approval defines Minor as "Not very large, important or serious". Impact to a cliff such as cracking, minor rock fall or minor spalling that occur at isolated locations are considered minor impacts.

It is therefore considered that the reduced length of Longwall 413 would be sufficient to minimise subsidence damage to CL3.

***Other minor cliffs***

The minor cliffs located above the proposed longwalls are predicted to experience the full range of predicted subsidence movements which include up to 1900 mm vertical subsidence. These movements are predicted to be associated with conventional tilt of up to 40 mm/m, or 1 in 25, and maximum curvature of 2 $km^{-1}$ hogging and 1.6 $km^{-1}$ sagging.

It is extremely difficult to assess the likelihood of instabilities for the cliffs based upon predicted ground movements. The likelihood of the cliffs becoming unstable is dependent on a number of factors which are difficult to fully quantify. These factors include jointing, inclusions, weaknesses within the rockmass, groundwater pressure and seepage flow behind the rockface. Even if these factors could be determined, it would still be difficult to quantify the extent to which these factors may influence the stability of the cliff naturally or when it is exposed to mine subsidence movements.

Some of the minor cliffs are located within the Study Area and are outside the extents of the longwalls. There is extensive experience of mining adjacent to (i.e. not directly beneath) cliffs in the NSW Coalfields which indicates that the likelihood of impacts is very low. Whilst minor and isolated rockfalls have occurred at some cliffs which are located outside the extents of active longwalls, there have been no large cliff instabilities where the cliffs have been wholly located outside the extents of mining.

It is expected that the minor cliffs located above the extracted longwalls and chain pillars will experience impacts including fracturing and rockfalls. The percentage of the length of each minor cliff likely to experience rockfalls is likely to vary considerably due to the variability in geological and geometric factors. It is, however, expected that minor cliffs that have greater height and continuous length, are considered to be more susceptible to impacts.

The overall assessed impacts to the minor cliff lines located above the extracted longwalls does not change for the Extraction Plan Layout compared with the Approved Layout.

The mine plan has been modified by shortening Longwall 413 with the objective of achieving the performance measure for CL3 of 'minimise subsidence damage'. The subsidence damage can be measured through visual monitoring of CL3. Baseline monitoring of the cliff CL3 should be established prior to nearby longwall extraction for identification and reporting of mining related impacts.

It is recommended that monitoring and management strategies developed for UG4 Longwalls 401 to 408 are updated to manage the hazards associated with potential impacts to the cliffs and minor cliffs resulting from the extraction of Longwalls 409 to 414. Management strategies should be developed for CL3 and cover site access control, safety, visual inspections, and mitigation/remediation.

## 5.7. Steep Slopes

The definition of a steep slope provided in the NSW DP&E Standard and Model Conditions for Underground Mining (DP&E, 2012) is: "An area of land having a gradient between 1 in 3 (33% or 18.3º) and 2 in 1 (200% or 63.4º)". Steep slopes are present at various locations within the Study Area.

The steep slopes within the Study Area could experience the full range of predicted subsidence movements, as summarised in Section 4.2. The maximum predicted subsidence parameters for the steep slopes, based on the Extraction Plan Layout, are the same as those based on the Approved Layout.

The longwall panel extraction is supercritical and magnitudes of differential movements are high for both the Extraction Plan Layout and Approved Layout. The overall assessed impacts to the steep slopes located above the extracted longwalls does not change for the Extraction Plan Layout compared with the Approved Layout. The potential for ground surface cracking, is discussed in Section 4.8.

It has been observed that down slope movements occur on slopes that are located over or near extracted longwalls. Sometimes these movements are observed to be directed down the hill slope rather than towards the extracted goaf area. Where such movements occur on steep slopes, there is a higher likelihood that surface tension cracking can occur near the tops of the slopes. It is unlikely that mine subsidence would result in large-scale slope failure, since such failures have not been observed elsewhere as the result of longwall mining. Management strategies should be developed to manage the hazards associated with potential impacts to steep slopes resulting from the extraction of Longwalls 409 to 414.

## 5.8. Land Prone to Flooding or Inundation

There are no major natural flood prone areas identified within the Study Area. The subsided surface levels are expected to result in increased ponding along the drainage lines as discussed in Section 5.2.4 and at other localised areas where natural grades are shallow.

## 5.9. Threatened, Protected Species or Critical Habitats

An investigation of the flora and fauna within the Study Area was undertaken by Niche Environment and Heritage (2024-1).

Flora and fauna surveys within these areas were undertaken and identified one threatened flora species under the *Biodiversity Conservation Act, 2016*. There is known and potential habitat for a number of threatened fauna species within the Study Area as described in Niche Environment and Heritage (2024-1). There are no endangered ecological communities located within the Study Area.

There is no change in subsidence impacts expected to threatened flora or fauna species based on the Extraction Plan Layout.

The effects of subsidence on flora and fauna within the Study Area are considered in the report by Niche Environment and Heritage (2024-1), which states "that secondary extraction at LW 409-414 will not significantly impact the biodiversity values within the Study Area".

## 5.10. National Parks or Wilderness Areas

The Goulburn River National Park boundary is located to the east and north east of the Extraction Plan Layout and is over 75 m from the nearest longwall, Longwall 414, which equates to 0.3 times the depth of cover at this location. The location of the National Park is shown in Drawings Nos. MSEC1381-01 and MSEC1381-07. A small area of the national park is located within the Study Area boundary near the finishing end of Longwall 414. The area is approximately 390 m in length with an average width of approximately 20 m.

The land within the National Park is wholly located outside the predicted 20 mm subsidence contour and is therefore predicted to experience less than 20 mm vertical subsidence resulting from the extraction of the Approved Layout and Extraction Plan Layout. The magnitude of the predicted vertical subsidence is similar to the natural vertical movements that occur due to seasonal and environmental changes in the surface soils. Whilst the National Park could experience very low levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains.

The Goulburn River National Park is over 75 m from the longwalls. At distances of 75 m or 0.3 times the depth of cover between the longwalls and the Goulburn River National Park, the maximum expected far-field horizontal movements based on Moolarben Coal monitoring data in Fig. 4.7 is 160 mm. The maximum expected far-field horizontal movements based on GNSS monitoring data in Fig. 4.8 is 65 mm.

These far-field horizontal movements generally do not result in impacts at surface features unless they are very sensitive to differential horizontal movements. The predicted maximum far-field horizontal movements at the Goulburn River National Park are expected to be bodily movements and should be accompanied by very low levels of strain. Ground strains within 200 m of the extracted longwalls based on the 95 % confidence levels as discussed in Section 4.4.1 are 3.3 mm/m tensile and 3.0 mm/m compressive. At these magnitudes of strain, it is possible for minor ground fractures to develop. If fracturing does occur, it is likely that the fractures will be localised in nature and relatively minor in size, less than say 50 mm. Minor fractures that potentially develop outside extracted longwalls are not generally associated with any impact such as erosion, rockfall, or impact to flora and fauna. The likelihood of ground fractures reduces with distance away from the extracted longwalls.

An assessment of surface features carried out for the Goulburn River National Park identified minor cliffs and cliffs, which are discussed in Section 5.6 and shown in Drawing No. MSEC1381-07. The nearest minor cliff within the Goulburn River National Park is located 313 m from the commencing end of Longwall 414. There are no other cliffs or minor cliffs within the Goulburn River National Park within 400 m of the longwalls. The nearest cliff in Goulburn River National Park is Goulburn River Gorge which is 450 m from Longwall 414. The impact assessment for the Goulburn River Gorge is provided in Section 5.4.

At 313 m or greater from the nearest longwall, the cliffs and minor cliffs are located 2.5 times the depth cover or greater from the longwalls. At distances of 313 m or 2.5 times the depth of cover between the longwalls and the minor cliffs, the maximum expected incremental horizontal movements based on Moolarben Coal monitoring data in Fig. 4.7 is 40 mm. The maximum expected total horizontal movements based on GNSS monitoring data in Fig. 4.8 is 45 mm. Based on Fig. 4.3, the 95% confidence levels for the maximum total strains at 313 m from the extracted longwalls is 0.6 mm/m tensile and 0.3 mm/m compressive.

There is extensive experience of mining adjacent to (i.e. not directly beneath) cliffs in the NSW Coalfields which indicates that the likelihood of impacts is very low. There have been no large cliff instabilities where the cliffs have been wholly located outside the extents of mining. It is unlikely, therefore, that the cliffs and minor cliffs within the Goulburn River National Park would be adversely impacted by the far-field horizontal movements.

It is recommended that monitoring and management strategies developed for UG4 Longwalls 401 to 408 are updated for Longwalls 409 to 414.

## 5.11. State Recreation or Conservation Areas

The Goulburn River State Conservation Area is located along the Goulburn River, to the north of the Extraction Plan Layout and is 180 m from the nearest longwall, Longwall 412. The location of the Goulburn River State Conservation Area is shown in Drawings Nos. MSEC1381-01 and MSEC1381-07.

The land within the Goulburn River State Conservation Area is outside the Study Area boundary. Whilst the Goulburn River State Conservation Area could experience very low levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains.

At distances of 180 m or more between the longwalls and the State Conservation Area, the maximum expected incremental far-field horizontal movement is 75 mm based on Moolarben Coal monitoring data in Fig. 4.7 and 60 mm total far-field horizontal movement based on the Moolarben Coal GNSS monitoring data in Fig. 4.8. Based on Fig. 4.3, the 95% confidence levels for the maximum total strains at 180 m from the extracted longwalls are 0.8 mm/m tensile and 0.3 mm/m compressive.

An assessment of surface features carried out for the State Conservation Area identified minor cliffs and cliffs, which are discussed in Section 5.6 and shown in Drawing No. MSEC1381-07. The nearest minor cliff within the State Conservation Area is located 300 m from the commencing end of Longwall 412. The nearest cliff within the State Conservation Area is located 330 m from the commencing end of Longwall 412. There is one cliff and three minor cliffs within the State Conservation Area within 400 m of the longwalls.

At 330 m or greater from the nearest longwall, the cliffs and minor cliffs are located 2.4 times the depth cover or greater from the longwalls. At distances of 330 m or 2.4 times the depth of cover between the longwalls and the minor cliffs, the maximum expected incremental horizontal movements based on Moolarben Coal monitoring data in Fig. 4.7 is 45 mm. The maximum expected total horizontal movements based on GNSS monitoring data in Fig. 4.8 is 45 mm. Based on Fig. 4.3, the 95% confidence levels for the maximum total strains at 330 m from the extracted longwalls are 0.6 mm/m tensile and 0.3 mm/m compressive.

There is extensive experience of mining adjacent to (i.e. not directly beneath) cliffs in the NSW Coalfields which indicates that the likelihood of impacts is very low. There have been no large cliff instabilities where the cliffs have been wholly located outside the extents of mining. It is unlikely, therefore, that the cliffs and minor cliffs within the Goulburn River State Conservation Area would be adversely impacted by the far-field horizontal movements.

At over 180 m or more from the nearest longwalls to the Goulburn River State Conservation Area, impacts to other natural features within the State Conservation Area are considered unlikely to occur.

It is recommended that monitoring and management strategies developed for UG4 Longwalls 401 to 408 are updated for Longwalls 409 to 414.

## 5.12. Natural Vegetation

There is natural vegetation located throughout the Study Area, as can be seen from the aerial photograph in Fig. 1.1. A detailed survey of the natural vegetation has been undertaken and is described and assessed in the report prepared by Niche Environment and Heritage (2024-1). The natural vegetation could, therefore, experience the full range of predicted subsidence movements, as summarised in Section 4.0 . The maximum predicted subsidence parameters for the natural vegetation, based on the Extraction Plan Layout, are the same as the maxima based on the Approved Layout. The potential impacts on the natural vegetation, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Approved Layout.

The assessment of mine subsidence impacts by Niche Environment and Heritage (2024-1) indicates that the extraction of Longwalls 409 to 414 will not significantly impact the biodiversity values within the Study Area.

## 5.13. Areas of Significant Geological Interest

A brief description of the geology within the Study Area is provided in Section 1.4. There are no areas of significant geological interest within the Study Area.

# 6.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE PUBLIC UTILITIES

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the public utilities located within the Study Area for Longwalls 409 to 414. The predicted parameters for each of the built features have been compared to the predicted parameters based on the Approved Layout.

As listed in Table 2.1, the following public utilities were not identified within the Study Area nor in the immediate surrounds:

- Railways;
- Tunnels;
- Gas pipelines;
- Liquid fuel pipelines;
- Electricity Transmission Lines or Associated Plants;
- Water and sewage treatment works;
- Dams, Reservoirs or Associated works; and
- Air strips.

## 6.1. Roads

### 6.1.1. Descriptions of the Roads

The locations of the roads maintained by Mid-Western Regional Council (MWRC) are shown in Drawing No. MSEC1381-08. The roads within or in the vicinity of the Study Area include:

- Saddlers Creek Road;
- Ulan Road; and
- Ulan Road bridge (over Goulburn River).

MWRC also own infrastructure associated with these roads, such as the road pavement, embankments and culverts.

Ulan Road is a sealed bitumen pavement with no kerb and gutter located to the west of the Study Area. The road passes along the north western side of Longwalls 409 to 412 and is 65 m from the commencing end of Longwall 410 at its nearest point, which equates to approximately 0.5 times the depth of cover at this location. The road is wholly outside the Study Area Boundary but is close to the boundary at the commencing ends of Longwalls 409 to 411. Features along the road include three cuttings in sandstone with approximate heights up to 3m at 400 m west of Longwall 409, 2 m at 175 m west of Longwall 412, and 5 m at 250 m north west of Longwall 412. Culverts beneath Ulan Road are typically 400 mm to 800 mm diameter concrete pipes.

The Ulan Road bridge over the Goulburn River, is 210 m or 1.5 times the depth of cover from Longwall 412. The bridge is a two span simply supported structure on concrete abutments and a central headstock supported on three cast piers. The bridge dimensions are approximately 26 m to 30 m long, 7 m wide and the pavement surface is approximately 4 m above the bed of the Goulburn River.

Saddlers Creek road is a unsealed dirt road that crosses the northern ends of Longwalls 412 to 414. Images of Ulan Road bridge and Saddlers Creek Road are shown in Fig. 6.1 and Fig. 6.2.

**Fig. 6.1 Ulan Road bridge over Goulburn River**

**Fig. 6.2 Saddlers Creek Road**

### 6.1.2. Predictions for the Roads

Ulan Road, the cuttings and Goulburn River bridge are all located outside the Study Area Boundary and will not be subjected to measurable conventional subsidence, tilts, curvatures; however, the road, cuttings and bridge may experience far-field horizontal movements which are discussed in Section 3.3 and 4.6.
The maximum potential far-field horizontal movements based on MCO monitoring data in Fig. 4.7 for Ulan Road, the road cuttings and Goulburn River bridge are summarised in Table 6.1.

**Table 6.1 Maximum predicted horizontal movements at Ulan Road features resulting from the extraction of longwalls 409 to 414**

| Feature | Minimum distance to longwalls (m) | Distance on Depth of Cover (m/m) | Maximum predicted horizontal movement (mm) |
|---|---|---|---|
| Ulan Road | 65 | 0.5 | 150 |
| Ulan Road Cuttings | 175 | 1.2 | 75 |
| Goulburn River Bridge | 210 | 1.5 | 75 |

Ulan Road is located to the west of the Extraction Plan Layout. The minimum distances to Ulan road occur at the north west corners of Longwalls 409 (130 m), 410 (65 m), and 411 (75 m). There is the potential for measurable ground strains to occur along the sections of Ulan Road nearest to the longwalls, particularly those sections within 100 m of the extracted longwalls, however the risk of adverse impacts to the road and culverts is considered to be low. Based on observed strains discussed in Section 4.4, predicted ground strains within 100 m of the extracted longwalls are 3.3 mm/m tensile and 3.0 mm/m compressive and ground strains for the remainder of the road (to within approximately 1km of the Study Area) are 0.5 mm/m tensile and 0.3 mm/m compressive.

Saddlers Creek Road will be mined beneath by Longwalls 412 to 414. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for Saddlers Creek Road, resulting from the extraction of Longwalls 409 to 414 for the Extraction Plan Layout, is provided in Table 6.2. The predicted tilts provided in this table are the maxima after the completion of all the longwalls. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.

The predicted profiles of vertical subsidence, tilt and curvature along Saddlers Creek Road, resulting from the extraction of Longwalls 409 to 414, are shown in Fig. C.04 in Appendix C. The predicted incremental profiles along the prediction line, due to the extraction of each of the longwalls, are shown as dashed black lines. The predicted total profiles along the road, after the extraction of each of the longwalls based on the Extraction Plan Layout, are shown as solid blue lines. The predicted profiles based on the Extraction Plan Layout are the same as those based on the approved layout.

**Table 6.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Saddlers Creek Road Resulting from the Extraction of Longwalls 409 to 414**

| 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 ($km^{-1}$) |
|---|---|---|---|
| 1900 | 40 | 2.0 | 1.6 |

The predicted strains along Saddlers Creek Road are provided in Table 6.3. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4).

**Table 6.3 Predicted Strains for the Saddlers Creek Road based on Conventional and Non-Conventional Anomalous Movements**

| Type | Conventional based on 10 times Curvature | Non-conventional |
|---|---|---|
| Tension | 20 | 20 |
| Compression | 16 | 20 |

### 6.1.3. Comparison of the Predictions for Saddlers Creek Road

A comparison of the maximum predicted subsidence parameters for Saddlers Creek Road, resulting from the extraction of Longwalls 409 to 414, with those based on the Approved Layout is provided in Table 6.4.

**Table 6.4 Comparison of Maximum Predicted Conventional Subsidence Parameters for Saddlers Creek Road based on the Extraction Plan Layout and the Approved Layout**

| Layout | 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 ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout | 1900 | 40 | 2.0 | 1.6 |
| Extraction Plan Layout | 1900 | 40 | 2.0 | 1.6 |

It can be seen from Table 6.4, that the maximum predicted conventional subsidence parameters based on the Extraction Plan Layout are the same as those for the Approved Layout.

### 6.1.4. Impact Assessments and Recommendations for the Roads

*Ulan Road*

Ulan Road is located to the west of the Extraction Plan Layout. The distance from Ulan Road to the Extraction Plan Layout is the same as that for the Approved Layout. The potential subsidence movements and impacts based on the Extraction Plan Layout are therefore the same as those based on the Approved Layout.

The minimum distances to Ulan Road occur at the north west corners of Longwalls 409, 410, and 411 due to the staggered location of these longwalls. The majority of the road is greater than 200 m from the Extraction Plan layout and impacts to the road due to far-field horizontal movements are considered unlikely to occur. There is the potential for measurable ground strains to occur along the sections of Ulan Road nearest to the longwalls, however the risk of adverse impacts to the road and culverts outside the Study Area boundary is considered to be low.

Ground monitoring and visual monitoring is recommended for Ulan Road during the extraction of Longwalls 409 to 412 to check for the potential development of strain or irregular subsidence movements.

It is expected that the potential impacts on the MWRC infrastructure can be managed with the implementation of the necessary monitoring and management strategies. It is recommended that monitoring and management strategies developed for UG4 Longwalls 401 to 408 are updated for the extraction of Longwalls 409 to 414.

*Bridge over Goulburn River*

The bridge over the Goulburn River is located 210 m from the nearest longwall. The maximum expected incremental horizontal movements at this distance (1.5 times depth of cover) based on based on horizontal movement data at MCO in Fig. 4.7 is 75 mm. From Fig. 4.3, the 95 % confidence levels for the maximum total strains observed at UG4 at 200 m from extracted goaf are 0.6 mm/m tensile and 0.3 mm/m compressive. At a distance of over 200 m from the nearest longwall and a small valley height, the development of valley related movement due to the extraction of the longwalls is not expected.

Minor movements within the bridge structure are expected at this distance however the potential for significant differential movement within the bridge structure elements is considered to be low. Based on a ground strain of 0.6 mm/m and span lengths of approximately 15 m, it is recommended that potential differential movement (longitudinal and transverse) of 10 mm between span supports is adopted.

It is expected that the potential impacts on the bridge can be managed with the implementation of the necessary monitoring and management strategies. It is recommended that an assessment of the bridge is carried out by a bridge engineer to identify movement tolerances within the bridge elements and abutments. Development of a monitoring program for key structural elements is recommended to monitor movement of the bridge during the extraction of at least Longwalls 411 to 413. It is recommended to monitor absolute horizontal movements at or near the location of the bridge and differential movement between bridge abutments. Monitoring of key structural elements within the bridge structure should be carried out in consultation with the bridge engineer.

*Cuttings*

The Ulan Road cuttings are located 175 m or more from the nearest longwall. The cuttings south of the bridge over Goulburn River are formed as gentle batters in weathered sandstone, away from the road pavement and show significant erosion. The cuttings immediately to the north of the bridge over Goulburn River are steeper and closer to the road pavement. The maximum expected incremental horizontal movements at this distance (1.2 times depth of cover) based on Fig. 4.7 is 75 mm. From Fig. 4.3, the 95 % confidence levels for the maximum total strains observed at UG4 at 175 m from extracted goaf are 0.6 mm/m tensile and 0.3 mm/m compressive. At these magnitudes of horizontal movement and strain, adverse impacts to the cuttings are considered unlikely to occur.

Baseline monitoring and visual monitoring is recommended for the cuttings during the extraction of Longwalls 409 to 412 to check for the potential development of irregular subsidence movements and impacts.

It is expected that the potential impacts on the cuttings can be managed with the implementation of the necessary monitoring and management strategies. It is recommended that monitoring and management strategies developed for UG4 Longwalls 401 to 408 are updated for the extraction of Longwalls 409 to 412.

*Saddlers Creek Road*

The predicted subsidence parameters due to the Extraction Plan Layout are the same as those for the Approved Layout. The potential subsidence movements and impacts based on the Extraction Plan Layout are therefore the same as those based on the Approved Layout.

Saddlers Creek Road will experience subsidence movements from the extraction of Longwalls 412, 413 and 414 as shown in Fig. C.04 in Appendix C. The potential impacts on Saddlers Creek Road, are expected to include cracking, stepping and rippling of the road surfaces. The road may also experience ponding and redirection of surface flow. Plots of pre-mining and predicted post-mining surface levels and grades along Saddlers Creek Road is provided below in Fig. 6.3 and Fig. 6.4. It can be seen that the maximum changes in grade along the road will occur near the edges of the extracted longwalls.. There is an increased likelihood of ponding where post-mining grades are reversed or near zero grade.

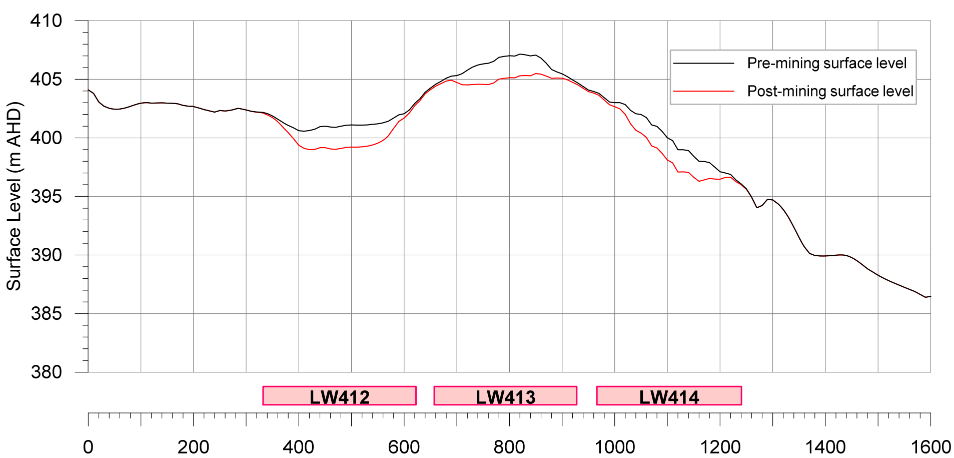


**Fig. 6.3 Surface Levels along Saddlers Creek Road**

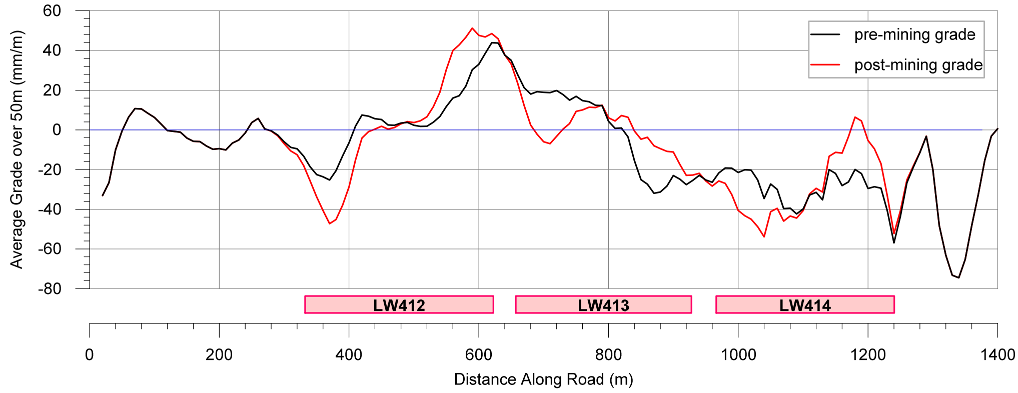


**Fig. 6.4 Average Grade along Saddlers Creek Road**

Saddlers Creek Road is an unsealed track. Impacts to the road can be remediated with earthwork, regrading and relevelling the road using standard road maintenance techniques.

Traffic volumes along Saddlers Creek Road are relatively low given the road is only used for access to the property and rental accommodation to the east of the longwalls.

The management approach for maintaining Saddlers Creek Road in a safe and serviceable condition will include an active maintenance program to address impacts during the periods of active subsidence for each of the Longwalls 412, 413 and 414. Alternatives to an active maintenance program could include alternate routes and/or periods of temporary road closure.

The expected duration of active subsidence beneath Saddlers Creek Road with the extraction of each longwall panel is dependent on the rate of extraction, however based on rates of extraction at MCO the most active period of vertical subsidence is approximately 2 weeks at a single location. A monitoring site above previously extracted Longwall 401 provides an example of the expected duration of active subsidence, since panel geometry and depth of cover are similar to those beneath Saddlers Creek Road. A plot of the development of vertical subsidence and the distance to the longwall face at GNSS MC01 during the extraction of Longwall 401 is shown in Fig. 6.5. The plot shows the most active subsidence period to be approximately 2 weeks, with additional minor subsidence occurring from approximately 100 m prior to the face passing beneath GNSS MC01, to approximately 300 m beyond GNSS MC01, over a total of about 4 weeks.

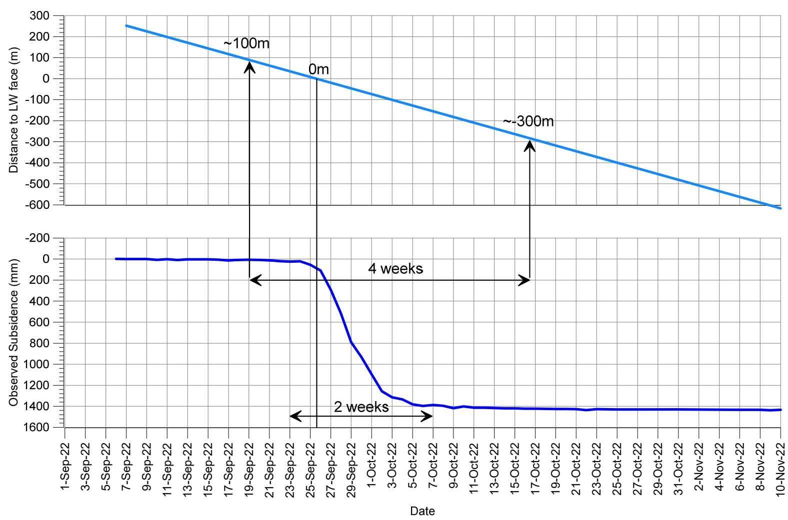


**Fig. 6.5 Development of vertical subsidence at GNSS MC01 during Longwall 401**

It is noted that the estimated duration of 4 weeks is based on a single location. Saddlers Creek Road follows a curved route and is angled to the longwall alignment, therefore the duration would be longer since the longwall face will extract for some distance directly beneath the road. The management period should be implemented from when the longwall face is approximately 100 m before the road, to approximately 300 m beyond the road.

It is expected that the potential impacts to Saddlers Creek Road can be managed with the implementation of the necessary monitoring and management strategies in consultation with MWRC.

## 6.2. Four Wheel Drive Tracks

There are a number of four wheel drive tracks through the Study Area, some of which are shown on Drawing No. MSEC1381-08. These tracks are not publicly accessible.

The tracks could experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence parameters for these tracks, based on the Extraction Plan Layout, therefore, are the same as the maxima based on the Approved Layout, as summarised in Table 4.3.

The potential impacts on the tracks, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Approved Layout. Impacts are expected to include cracking, stepping and rippling of the track surfaces. The tracks may also experience ponding, however, the impacts of increased levels of ponding along these tracks can be remediated by regrading and relevelling the surface using standard road maintenance techniques. Alternatives to an active maintenance program could include alternate routes and temporary track closure.

## 6.3. Road Drainage Culverts

No drainage culverts were identified within the Study Area; however, drainage culverts are located along Ulan Road and are discussed in Section 6.1.

## 6.4. Telecommunications Infrastructure

### 6.4.1. Descriptions of the Telecommunications Infrastructure

The locations of the telecommunications infrastructure are shown in Drawing No. MSEC1381-08.

The telecommunications infrastructure in the vicinity of Longwalls 409 to 414 comprises Telstra owned copper cables that follow the general alignments of Ulan Road and Saddlers Creek Road. It is understood that the cables are in use.

### 6.4.2. Predictions for the Telecommunications Infrastructure

The copper cables along Ulan Road will not be subjected to measurable conventional mine subsidence ground movements (i.e. less than limits of survey accuracy); however, the cables may experience far-field horizontal movements. At a minimum distance of 80 m between the longwalls and the Telstra cables, the maximum expected horizontal movements based on Fig. 4.7 is 150 mm. From Section 4.4, the 95 % confidence levels for total strains within 200 m of the extracted longwalls are 3.3 mm/m tensile and 3.0 mm/m compressive.

The copper cables along Saddlers Creek Road will be mined beneath by Longwalls 412 to 414. The profiles of predicted subsidence, tilt and curvature along the copper cables will be similar to those predicted for Saddlers Creek Road as shown in Fig. C.04 in Appendix C.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for copper cable along Saddlers Creek Road, resulting from the extraction of Longwalls 409 to 414 for the Extraction Plan Layout, is provided in Table 6.5. The predicted tilts provided in this table are the maxima after the completion of all the longwalls. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.

**Table 6.5 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Saddlers Creek Road Copper Cables Resulting from the Extraction of Longwalls 409 to 414**

| 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 ($km^{-1}$) |
|---|---|---|---|
| 1900 | 40 | 2.0 | 1.6 |

The predicted strains along the copper cables are provided in Table 6.6. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4).

**Table 6.6 Predicted Strains for the Saddlers Creek Road copper cables based on Conventional and Non-Conventional Anomalous Movements**

| Type | Conventional based on 10 times Curvature | Non-conventional |
|---|---|---|
| Tension | 20 | 20 |
| Compression | 16 | 20 |

### 6.4.3. Impact Assessment and Recommendations for the Telecommunications Infrastructure

Copper telecommunications cables can typically tolerate significant tensile strains of up to 20 mm/m without adverse impacts. The maximum predicted strains along the Saddlers Creek Road alignment are 20 mm/m but irregular strains are expected to occur and is it possible that the copper cables along Saddlers Creek Road could be impacted as a result of the proposed mining.

Extensive experience of mining beneath copper telecommunications cables in the NSW Coalfields, where the mine subsidence movements were similar to those predicted for the proposed mining, indicates that incidences of impacts are generally low and of a minor nature.

Based on this experience, it is unlikely that the proposed mining would result in any significant impacts on the copper telecommunications cables within the Study Area. Any impacts on these cables would be expected to be relatively infrequent and readily repairable.

The copper cables located outside the Study Area boundary are not expected to be subjected to measurable conventional vertical subsidence, tilt, curvature or strain. Based on the low magnitude of mine subsidence movements outside the Study Area boundary the development of adverse impacts to the copper cables due to extraction of Longwalls 409 to 414 is considered to be unlikely to occur.

It is recommended that monitoring and management strategies are developed, in consultation with Telstra, to manage the copper cables for potential irregular ground movements. It is expected that the cables can be maintained in serviceable condition with the implementation of the appropriate monitoring and management strategies.

## 6.5. Tilt Renewables Infrastructure

### 6.5.1. Descriptions of the Tilt Renewables Infrastructure

A proposed development by Tilt Renewables for future electrical infrastructure for renewable energy transmission is located to the west of the Extraction Plan Layout. The location of the proposed Tilt Renewables infrastructure is shown in the attached Drawing No. MSEC1381-08.

The proposed Tilt Renewables infrastructure in the vicinity of Longwalls 409 to 414 comprises a proposed powerline to be located along the western side of Ulan Road, at distances of 600 m from Longwall 409 to 840 m from Longwall 411. Specific construction details of the powerline are not known. It is assumed for the purposes of this report, that the power line is constructed prior to the extraction of Longwalls 409 to 414 in UG4.

The depth of cover along the western side of Longwalls 409 to 414 varies from approximately 115 m at Longwall 409 to 125 m at Longwall 411 and the distances to the proposed powerline from these longwalls equates to 5.2 to 6.7 times the depth of cover.

### 6.5.2. Predictions for the Tilt Renewables Infrastructure

At distances of over 600 m between the longwalls and the proposed powerline, the powerline is not expected to experience measurable subsidence, tilts, curvatures or strains; however, the powerline may experience low level far-field horizontal movements.

Based on Fig. 4.7, at greater than 5 times the depth of cover from the mined panels, the upper limit of previously observed absolute incremental far-field horizontal movements is less than 40 mm. Measured total far-field horizontal movements based on monitoring data from UG4 indicates maximum total far-field horizontal movement at 600 m from the longwalls is 25 mm

The powerline, therefore, is predicted to experience maximum incremental far-field horizontal movements in the order of 25 mm due to the extraction of Longwalls 409 to 414. These low-level horizontal movements are not expected to be associated with measurable tilts, curvatures or strains.

The predicted far-field horizontal movements at the Tilt Renewables powerline are expected to be bodily movements that are directed across the general alignment of the powerline towards the extracted goaf area and should be accompanied by very low levels of strain that are in the order of survey tolerance. Relative movement between poles is expected to be negligible. Adverse impact to the powerline resulting from these potential far-field horizontal movements is considered unlikely.

With the location of the yet to be constructed Tilt Renewables powerline outside the longwall footprint and the low probability of significant observed strains developing, the development of adverse impacts to the proposed Tilt Renewables powerline due to the extraction of Longwalls 409 to 414 is considered unlikely.

Unless greater than predicted, or anomalous movements, are observed at monitoring sites for other features located nearer to the Longwalls 409 to 414, regular monitoring of the Tilt Renewables alignment is not considered necessary.

# 7.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE PUBLIC AMENITIES

As listed in Table 2.1, the following public amenities were not identified within the Study Area nor in the immediate surrounds:

- Hospitals;
- Places of worship;
- Schools;
- Shopping centres;
- Community centres;
- Office buildings;
- Swimming pools;
- Bowling greens;
- Ovals or cricket grounds;
- Racecourses;
- Golf courses; and
- Tennis courts.

# 8.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE FARM LAND AND FARM FACILITIES

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the farm land and facilities located within the Study Area for Longwalls 409 to 414.

As listed in Table 2.1, the following farm land facilities were not identified within the Study Area nor in the immediate surrounds:

- Agricultural utilisation or agricultural suitability of farm land;
- Farm buildings or sheds;
- Tanks;
- Gas or fuel storages;
- Poultry sheds;
- Glass houses;
- Hydroponic systems;
- Irrigation systems; and
- Wells or Bores.

## 8.1. Fences

Fences are located within the Study Area and are constructed in a variety of ways, generally using either timber or metal materials.

The fences could experience the full range of predicted subsidence movements, as summarised in Section 4.2. The maximum predicted subsidence parameters for the fences, based on the Extraction Plan Layout, therefore, are the same as the maxima based on the Approved Layout, as summarised in Table 4.3.

Fences can be affected by tilting of the fence posts and by changes of tension in the fence wires due to strain as mining occurs. Fences are generally flexible in construction and can usually tolerate significant tilts and strains.

Any impacts on the fences are likely to be of a minor nature and relatively easy to remediate by re-tensioning fencing wire, straightening fence posts, and if necessary, replacing some sections of fencing.

It is recommended that management strategies be developed to manage potential impacts on fences during the mining of the longwalls.

## 8.2. Farm Dams

### 8.2.1. Descriptions of the Farm Dams

There are three farm dams that have been identified within the Study Area (D1, D3 and D4) and their locations are shown in Drawing No. MSEC1381-08. The dams are shallow with maximum dimensions of approximately 10 m to 20 m and were understood to be previously used for livestock watering but are no longer in use.

The farm dams are located on land owned by MCO.

### 8.2.2. Predictions for the Farm Dams

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the farm dams, resulting from the extraction of Longwalls 409 to 414 for the Extraction Plan Layout, is provided in Table 8.1. The predicted tilts provided in this table are the maxima after the completion of all the longwalls. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.

Table 8.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Farm Dams within the Study Area Resulting from the Extraction of Longwalls 409 to 414

| 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 ($km^{-1}$) |
|---|---|---|---|---|
| D1 | < 20 | < 0.5 | < 0.01 | < 0.01 |
| D3 | < 20 | < 0.5 | < 0.01 | < 0.01 |
| D4 | 325 | 17 | > 3.0 | 0.40 |

The predicted strains for the farm dam are provided in Table 8.2. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4).

Table 8.2 Predicted Strains for the Farm Dams based on Conventional and Non-Conventional Anomalous Movements

| Type | Conventional based on 10 times Curvature | Non-conventional based on the 95 % Confidence Level | Non-conventional based on the 99 % Confidence Level |
|---|---|---|---|
| Tension | >30 | 10 | 22 |
| Compression | 4.0 | 13 | 31 |

### 8.2.3. Comparison of the Predictions for the Farm Dams

A comparison of the maximum predicted subsidence parameters for the farm dams within the Study Area, resulting from the extraction of Longwalls 409 to 414, with those based on the Approved Layout is provided in Table 8.3.

Table 8.3 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Farm Dam based on the Extraction Plan Layout and the Approved Layout

| Layout | 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 ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout | 325 | 17 | > 3.0 | 0.4 |
| Extraction Plan Layout | 325 | 17 | > 3.0 | 0.4 |

It can be seen from Table 8.3, that the maximum predicted conventional subsidence parameters based on the Extraction Plan Layout are the same as those for the Approved Layout.

### 8.2.4. Impact Assessments and Recommendations for the Farm Dams

The maximum predicted total subsidence parameters for the farm dams within the Study Area based on the Extraction Plan Layout are the same as those for the Approved Layout for Longwalls 409 to 414. The changes to the predicted subsidence parameters for the dams do not change the impact assessments for the dams.

Dams D1 and D3 are located outside the longwall footprints and are expected to experience negligible predicted subsidence movements. Impacts to these dams are not expected.

The following summary outlines the potential impacts to farm dam (D4) located above the longwalls:

- Change in freeboard of up to 200 mm for the farm dams located above the extracted longwalls.
- Farm dams are typically constructed of cohesive soils with reasonably high clay contents, and are likely to be capable of withstanding tensile ground strains up to 3 mm/m without impact. The predicted strains based on the Extraction Plan Layout are greater than 3 mm/m.
- The farm dam located above the extracted longwalls is expected to experience cracking and leakage of water. Any loss of water from the farm dams would flow into the drainage line in which the dam was formed.

It is recommended that farm dams, where not decommissioned, are visually monitored as the longwalls are extracted, such that any impacts can be identified and remediated accordingly. In this way the farm dams within the Study Area can be maintained in a safe condition throughout the mining period.

# 9.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE INDUSTRIAL, COMMERICAL AND BUSINESS ESTABLISHMENTS

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the industrial, commercial and business establishments located within the Study Area for Longwalls 409 to 414. The predicted parameters for each of the built features have been compared to the predicted parameters based on the Approved Layout.

As listed in Table 2.1, the following Industrial, Commercial and Business Establishments were not identified within the Study Area nor in the immediate surrounds:

- Factories;
- Workshops;
- Business or commercial establishments or improvements;
- Gas or fuel storages and associated plant;
- Waste storages and associated plant;
- Buildings, Equipment or Operations that are Sensitive to Surface Movements; and
- Surface Mining (Open Cut) Voids or Rehabilitated Areas;

## 9.1. Exploration Drill Holes

The locations of the exploration drill holes within the Study Area are shown in Drawing No. MSEC1381-08. The drill holes are located directly above and adjacent to the proposed longwalls and, therefore, could experience the full range of predicted subsidence movements, which are described in Chapter 4. It is likely, therefore, that fracturing and shearing would occur in the drill holes as the result of mining. It is recommended that the exploration drill holes are capped (if not already completed) prior to being directly mined beneath.

## 9.2. Mine Infrastructure Including Tailings Dams or Emplacement Areas

Dewatering infrastructure owned and operated by MCO is located above the Extraction Plan Layout as shown in Drawing MSEC1381-08. The dewatering infrastructure includes dewatering bores, water pipelines and electrical cables. The polyethylene pipelines and cables are flexible and laid on the ground surface.

The dewatering infrastructure is located above the longwalls and will therefore experience the full range of predicted subsidence movements as outlined in Section 4.0 . The pipelines and electrical cables are flexible and laid on the ground surface and are therefore able to tolerate significant ground movements. It is considered unlikely that the pipelines and electrical cables would experience impacts due to conventional ground movements. Potential impacts could occur as a result of irregular movements such as ground heave, stepping, large cracks, rockfalls or tree falls. It is expected that impacts to the pipelines and cables could be readily remediated if they occur. Where dewatering bores are located above the extracted panels, it is likely, that fracturing and shearing would occur in the drill holes as the result of mining. It is recommended that the bores are capped prior to being directly mined beneath.

Visual monitoring and management strategies should be developed for the dewatering infrastructure. It is expected that the dewatering infrastructure can be maintained in serviceable condition with the implementation of the appropriate monitoring and management strategies.

# 10.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR AREAS OF ARCHAEOLOGICAL AND HERITAGE SIGNIFICANCE

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the archaeological and heritage sites located within the Study Area for Longwalls 409 to 414. The predicted parameters for each of the features have been compared to the predicted parameters based on the Approved Layout.

## 10.1. Aboriginal Heritage Sites

### 10.1.1. Descriptions of the Aboriginal Heritage Sites

There are 33 Aboriginal heritage sites identified within and in proximity (100 m) to the Study Area which include rock shelters, isolated finds, artefacts, PADs, grinding grooves and art. The locations of the Aboriginal heritage sites within and in proximity to the Study Area are shown in Drawing No. MSEC1381-08.

Five sites within and in proximity to the Study Area have been salvaged under existing approvals, and one site is partially managed. Therefore, revised subsidence predictions and impact assessments have been provided for the 28 in situ sites.

Detailed descriptions of the Aboriginal heritage sites are provided in the report by Niche Environment and Heritage (2024-2).

### 10.1.2. Predictions for the Aboriginal Heritage Sites

The maximum predicted subsidence parameters for each of the Aboriginal heritage sites located within and in proximity to the Study Area is provided in Table D.01, in Appendix D. The predictions have been provided based on the Extraction Plan Layout, as well as for the Approved Layout for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the Aboriginal heritage sites, resulting from the extraction of Longwalls 409 to 414 for the Extraction Plan Layout, is provided in Table 10.1. The predicted tilts provided in this table are the maxima after the completion of all the longwalls. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.

**Table 10.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Aboriginal Heritage Sites within and in proximity to the Study Area due to the Extraction of Longwalls 409 to 414**

| Site Type | 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 ($km^{-1}$) |
|---|---|---|---|---|
| Artefacts | 1900 | 7.5 | 1.30 | 0.35 |
| Isolated Find | 1900 | 12 | 1.30 | 0.35 |
| Shelter with/without Artefacts and/or PAD and/or Art | 1900 | 40 | 1.30 | 1.30 |
| Grinding Grooves, Artefacts and PAD | < 20 | < 0.5 | < 0.01 | < 0.01 |

The maximum predicted conventional tilt for the Aboriginal heritage sites is 40 mm/m (i.e. 4.0 %, or 1 in 25). The maximum predicted conventional curvatures for these sites are greater than 1.3 $km^{-1}$ hogging and sagging, which represents minimum radii of curvature of 760 m.

The predicted strains for the Aboriginal heritage sites is provided in Table 10.2. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis above solid coal provided in Section 4.4).

**Table 10.2 Predicted Strains for the Aboriginal Heritage Sites within and in proximity to the Study Area based on Conventional and Non-Conventional Anomalous Movements**

| Type | Conventional based on 10 times Curvature (mm/m) | Non-conventional based on the 95 % Confidence Level (mm/m) | Non-conventional based on the 99 % Confidence Level (mm/m) |
|---|---|---|---|
| Tension | 13 | 10 | 22 |
| Compression | 11 | 13 | 31 |

### 10.1.3. Comparisons of the Predictions for the Aboriginal Heritage Sites

Comparisons of the maximum predicted conventional subsidence parameters for the Aboriginal heritage sites within and in proximity to the Study Area, resulting from the extraction of Longwalls 409 to 414, with those based on the Approved Layout are provided in Table 10.3. A comparison of the maximum predicted subsidence parameters for each of the Aboriginal heritage sites located within and in proximity to the Study Area is also provided in Table D.01, in Appendix D.

**Table 10.3 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Aboriginal Heritage Sites within and in proximity to the Study Area based on the Approved Layout and the Extraction Plan Layout**

| Layout | 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 ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout | 1900 | 40 | 1.30 | 1.10 |
| Extraction Plan Layout | 1900 | 40 | 1.30 | 1.30 |

It can be seen from Table D.01 in Appendix D that the majority of the predicted subsidence parameters based on the Extraction Plan Layout are the same as those based on the Approved Layout. The maximum predicted subsidence, tilt and hogging curvature in Table 10.3 are unchanged for the Extraction Plan Layout and sagging curvature increases slightly. Based on the similar magnitudes of predicted subsidence parameters, the potential impacts for the Aboriginal heritage sites based on the Extraction Plan Layout are the same as those based on the Approved Layout.

### 10.1.4. Impact Assessments and Recommendations for the Aboriginal Heritage Sites

The Stage 1 Project Approval lists the following Subsidence Impact Performance Measures in Table 14 for the Aboriginal Heritage Sites:

| *Heritage Sites* | |
|---|---|
| *Aboriginal heritage sites 264, 282, 283, 286 and 287 (see Appendix 7)* | *Reduce the likelihood of subsidence damage to low* |
| *Aboriginal heritage site 280 (see Appendix 7)* | *Reduce the likelihood of subsidence damage to moderate* |

Aboriginal heritage site 280 is located between Longwalls 402 and 403 and has been successfully managed during mining of these longwalls.

Sites 264, 282, 283, and 286 are located outside the Study Area at 80 m to 180 m from the nearest longwalls. Site 264 has grinding grooves and artefacts and is located approximately 80 m from the commencing end of Longwall 409. The grinding grooves are located within alignment of Drainage Line 2. The location is at the downstream end of Drainage Line 2 where there is no significant valley profile and therefore impact to the grinding grooves as a result of valley closure is considered to be unlikely. The artefacts at these sites are not predicted to experience conventional subsidence movements but are expected to experience far-field horizontal movements. Based on MCO monitoring data in Fig. 4.7, the maximum observed incremental horizontal movements within 80 m (0.7 times depth of cover) to 180 m (1.3 times depth of cover) of the extracted longwalls are 150 mm to 75 mm. Based on observed strains discussed in Section 4.4, potential ground strains within 200 m of the extracted longwalls are 3.3 mm/m tensile and 3.0 mm/m compressive based on a 95% confidence level.

Based on the magnitudes of potential ground strains, it is possible for sites 264, 282, 283, and 286 to experience ground strain and associated ground cracking. The incidences of cracking outside the Study

Area are expected to be minor and isolated and it is considered unlikely that ground cracking would impact the artefacts and grinding grooves. Sites 283 and 286 are located within or near rock shelters. The rock shelters at these locations are small isolated features and impacts to the shelters located in proximity to the Study Area are considered to be unlikely.

Site 287 has artefacts within a rock shelter and is located immediately downslope of CL3 outside the 20 mm subsidence contour. The site is located 80 m from Longwall 412. Predicted subsidence parameters at this site are negligible, less than typical limits of survey accuracy, and impact to this shelter is considered unlikely to occur.

Site 284 is not listed as performance measures in Table 14 of the Stage 1 Project Approval. However, in consideration of the features associated with S1MC284 (i.e. rock shelter with art and artefacts) and the scientific significance (moderate), it is proposed that the performance measure of *reduce the likelihood of subsidence damage to low* is voluntarily applied to S1MC284. S1MC284 is located in proximity to the LW409-414 Study Area. The site is located approximately 100 m to the north west of Longwall 412. Predicted subsidence parameters at this site are negligible, less than typical limits of survey accuracy, and impact to this shelter is considered unlikely to occur.

Therefore, it is expected the performance measure of reduce the likelihood of subsidence damage to low for sites 264, 282, 283, 286,287 and 284 will be achieved.

Impacts to open sites containing artefacts and isolated finds and rock shelters located outside the Study Area are considered to be unlikely.

Open sites inside the Study Area containing artefacts and isolated finds can potentially be affected by cracking of the surface soils as a result of mine subsidence movements. It is unlikely that the artefacts and isolated finds themselves would be impacted by surface cracking.

Whilst it is unlikely that the artefacts and isolated finds themselves would be impacted by mine subsidence, it is possible that, if remediation works to the surface areas around the Aboriginal heritage sites was required after mining, these works could potentially impact on the Aboriginal heritage sites. All remediation works would be subject to MCO's ground disturbance permit process. A discussion on surface cracking resulting from the extraction of Longwalls 409 to 414 is provided in Section 4.8.

Rock shelters and overhangs inside the Study Area are predicted to be subject to similar impacts as described for minor cliffs in Section 5.6 (i.e. potential for fracturing of sandstone and subsequent rockfalls). These sites could therefore be impacted by rockfalls associated with the rock shelter.

Further details and discussions on the potential impacts on the archaeological sites resulting from the extraction of the Extraction Plan Layout are provided in the report by Niche Environment and Heritage (2024-2). Management of Aboriginal heritage sites will be outlined in a Heritage Management Plan.

## 10.2. Items of Architectural Significance

There are no items of architectural significance within the Study Area.

## 10.3. Survey Control Marks

There are no survey control marks identified within the Study Area. The locations of survey marks outside the Study Area are shown in Drawing No. MSEC1381-08. The survey marks are predominantly located along road easements.

At these locations the survey marks will not be subjected to measurable conventional mine subsidence ground movements due to the Extraction Plan Layout; however, they are expected to experience far-field horizontal movements as discussed in Section 4.6. The potential impacts on the survey marks based on the Extraction Plan Layout, are the same as those based on the Approved Layout.

It will be necessary on the completion of the longwalls, i.e. when the ground has stabilised, to re-establish the exact location of the survey marks. Consultation between MCO and Land and Property Information (LPI) NSW will be required throughout the mining period to ensure that the survey marks near the Study Area are not used for detailed surveying purposes by others and that they are reinstated at an appropriate time, as required.

It is recommended that management strategies are developed, in consultation with LPI NSW, as required by the *Surveyor General's Directions No.11 Preservation of Survey Infrastructure*."

# 11.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE RESIDENTIAL BUILDING STRUCTURES

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

- Flats or Units;
- Caravan Parks;
- Retirement or aged care villages;
- Associated structures such as workshops, garages, water or gas tanks, tennis courts, and swimming pools.

## 11.1. Building Structures

Former building structures located at the northern end of Longwall 411 and 412 have been demolished and most building materials have been removed from site.

A private property is located outside the Study Area boundary, to the east of Longwall 414. The property consists of rental cottages (Goulburn River Stone Cottages) comprising three cottages (River Cottage, Saddlers Cottage and Barbara's Cottage) of stone and brick construction. The cottages are accessed via Saddler's Creek Road and power supply is by an onsite solar powered system.

River Cottage is located 970 m from Longwall 414, and Saddlers Cottage and Barbara's Cottage are greater than 1.5 km from Longwall 414. At these distances the building structures are not expected to experience measurable conventional mine subsidence ground movements. However, the structures may experience low level far-field horizontal movements, which are discussed in Sections 3.3 and 4.6. The potential far-field horizontal movements are expected to be within the range of accuracy and baseline variation and not expected to result in any impacts to the cottages.

# APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

# Glossary of Terms and Definitions

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

| | |
|---|---|
| **Angle of draw** | The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence). |
| **Approved Layout** | Secondary extraction footprint consistent with the Project Approval (05_0117), as modified, with an extraction height of 3.0m. |
| **Chain pillar** | A block of coal left unmined between the longwall extraction panels. |
| **Cover depth (H)** | The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel. |
| **Closure** | 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. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill movements and other possible strata mechanisms. |
| **Critical area** | The area of extraction at which the maximum possible subsidence of one point on the surface occurs. |
| **Curvature** | The change in tilt between two adjacent sections of the tilt profile divided by the average horizontal length of those sections, i.e. curvature is the second derivative of subsidence. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/km (km-1)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*. Curvature can be either **hogging** (i.e. convex) or **sagging** (i.e. concave). |
| **Extracted seam** | The thickness of coal that is extracted. The extracted seam thickness is thickness normally given as an average over the area of the panel. |
| **Effective extracted seam thickness (T)** | The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel. |
| **Extraction Plan Layout** | Secondary extraction footprint of the extraction plan |
| **Face length** | The width of the coalface measured across the longwall panel. |
| **Far-field movements** | The measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain. |
| **Goaf** | The void created by the extraction of the coal into which the immediate roof layers collapse. |
| **Goaf end factor** | A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel. |
| **Horizontal displacement** | The horizontal movement of a point on the surface of the ground as it settles above an extracted panel. |
| **Inflection point** | The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max. |
| **Incremental subsidence** | The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel. |
| **Panel** | The plan area of coal extraction. |
| **Panel length (L)** | The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib. |
| **Panel width (Wv)** | The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side. |
| **Panel centre line** | An imaginary line drawn down the middle of the panel. |
| **Pillar** | A block of coal left unmined. |

**Pillar width (Wpi)** The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.

**Shear deformations** The horizontal displacements that are measured across monitoring lines and these can be described by various parameters including; horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index.

**Strain** The change in the horizontal distance between two points divided by the original horizontal distance between the points, i.e. strain is the relative differential displacement of the ground along or across a subsidence monitoring line. Strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation.

**Tensile Strains** are measured where the distance between two points or survey pegs increases and **Compressive Strains** where the distance between two points decreases. Whilst mining induced **strains** are measured **along** monitoring lines, ground **shearing** can occur both vertically, and horizontally **across** the directions of the monitoring lines.

**Sub-critical area** An area of panel smaller than the critical area.

**Subsidence** The vertical movement of a point on the surface of the ground as it settles above an extracted panel, but, 'subsidence of the ground' in some references can include both a vertical and horizontal movement component. The vertical component of subsidence is measured by determining the change in surface level of a peg that is fixed in the ground before mining commenced and this vertical subsidence is usually expressed in units of *millimetres (mm)*. Sometimes the horizontal component of a peg's movement is not measured, but in these cases, the horizontal distances between a particular peg and the adjacent pegs are measured.

**Super-critical area** An area of panel greater than the critical area.

**Tilt** The change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the horizontal distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.

**Uplift** An increase in the level of a point relative to its original position.

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

# APPENDIX B. REFERENCES

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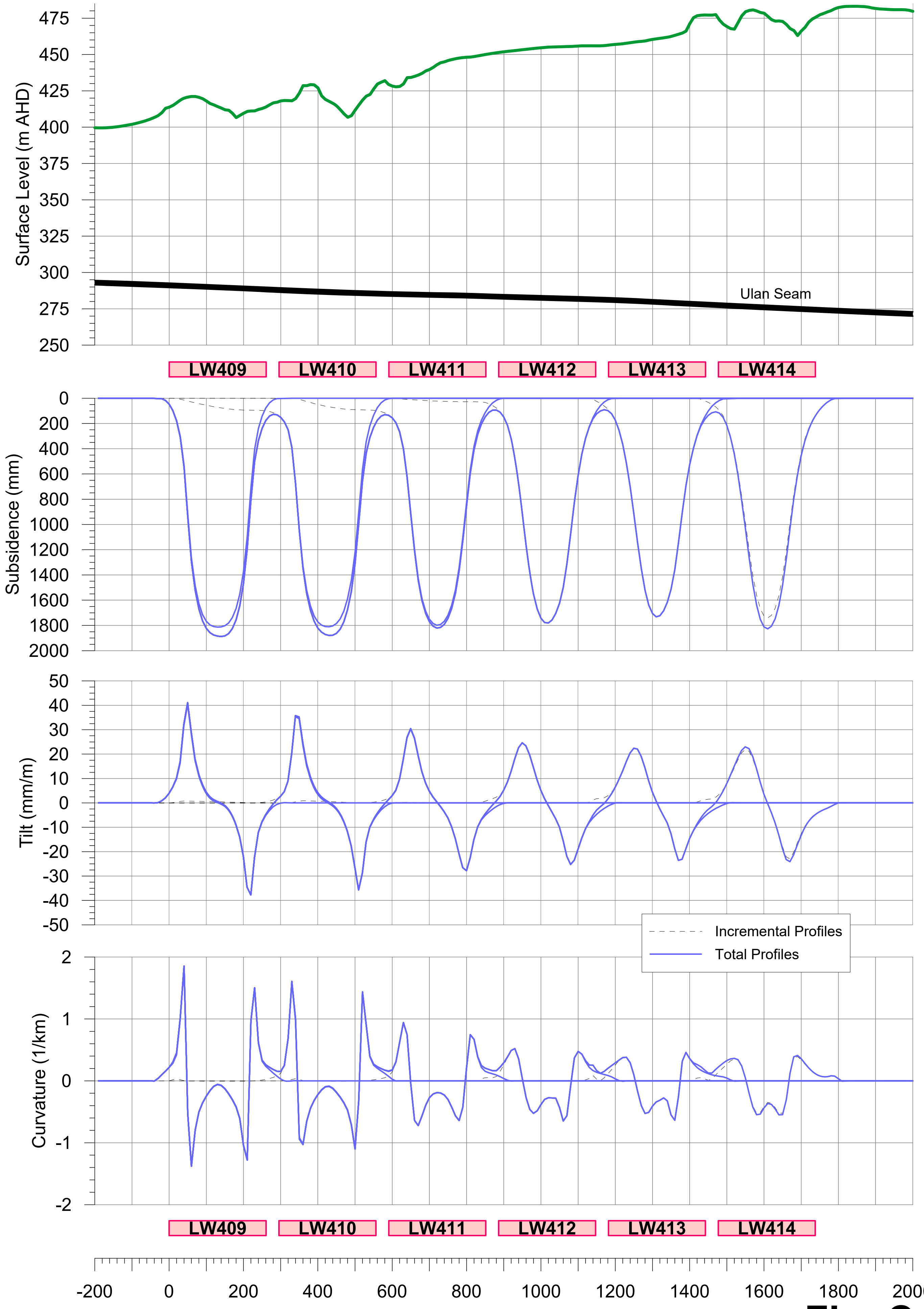
# APPENDIX C. FIGURES

# Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 resulting from the Extraction of Longwalls 409 to 414




msec

**Fig. C.01**

# Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 resulting from the Extraction of Longwalls 409 to 414

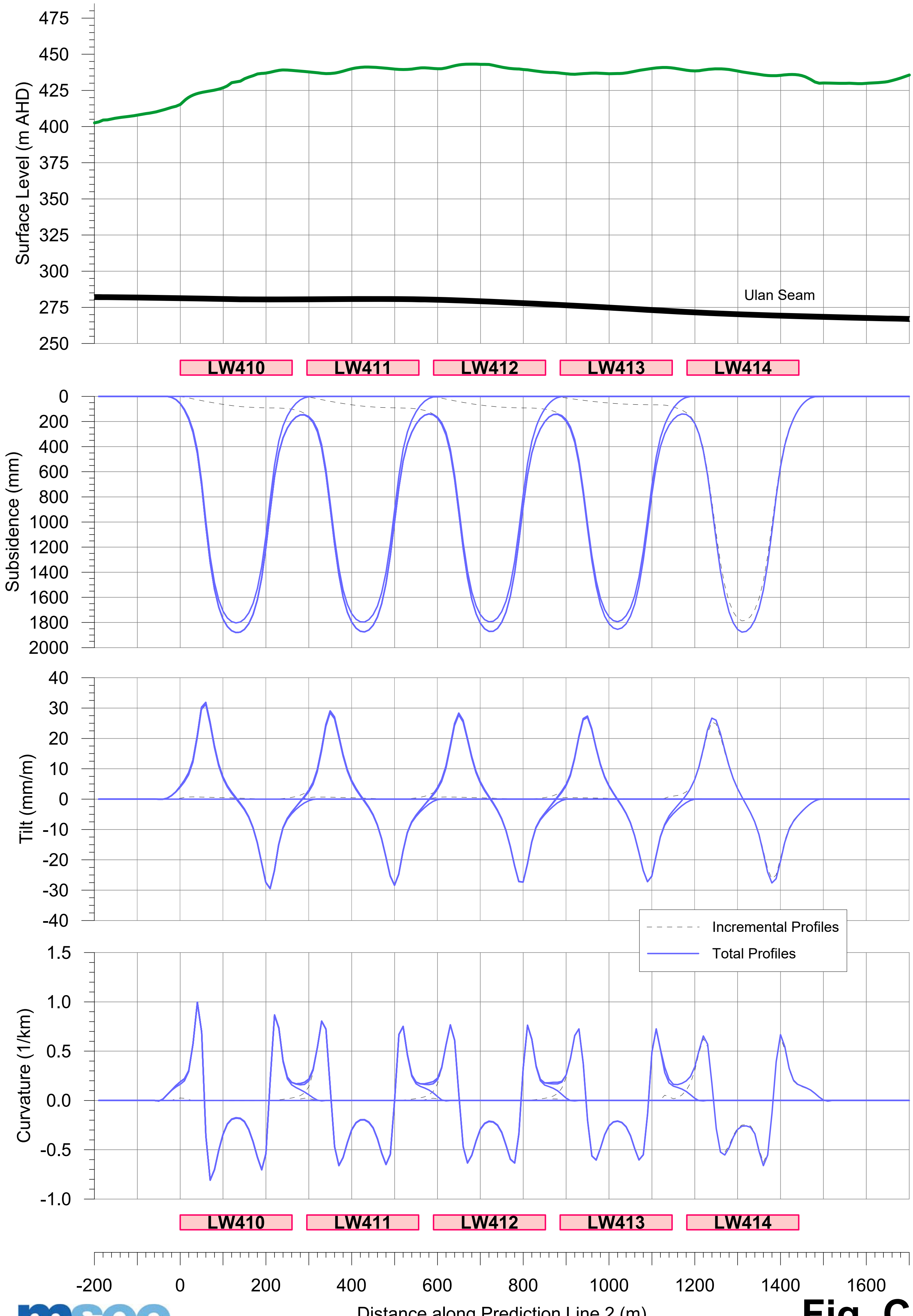



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**Fig. C.02**

# Predicted Profiles of Subsidence, Tilt and Curvature along Drainage Line 2 due to LW409 to 414

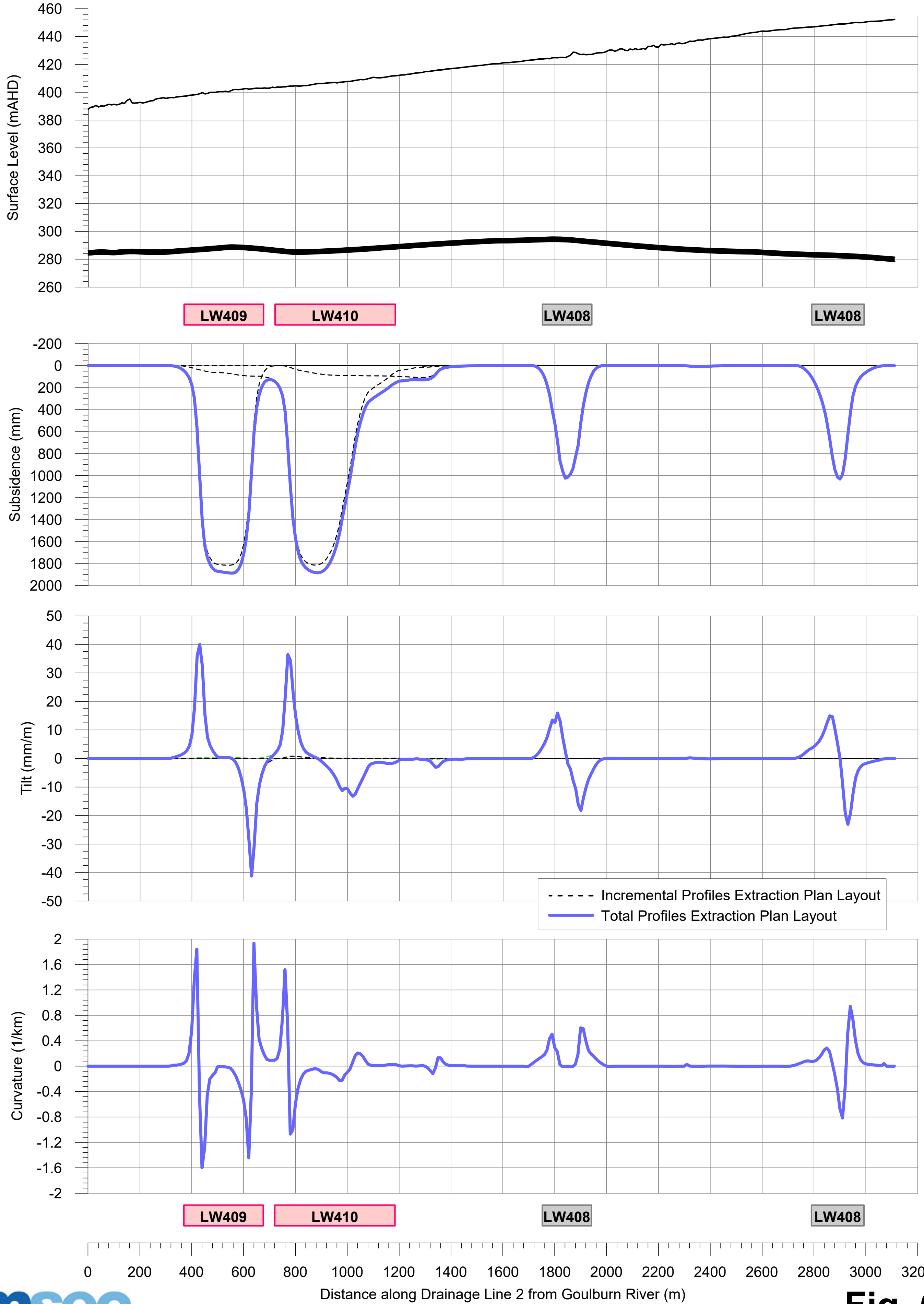


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Fig. C.03

# Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Saddlers Creek Rd resulting from the Extraction of Longwalls 409 to 414

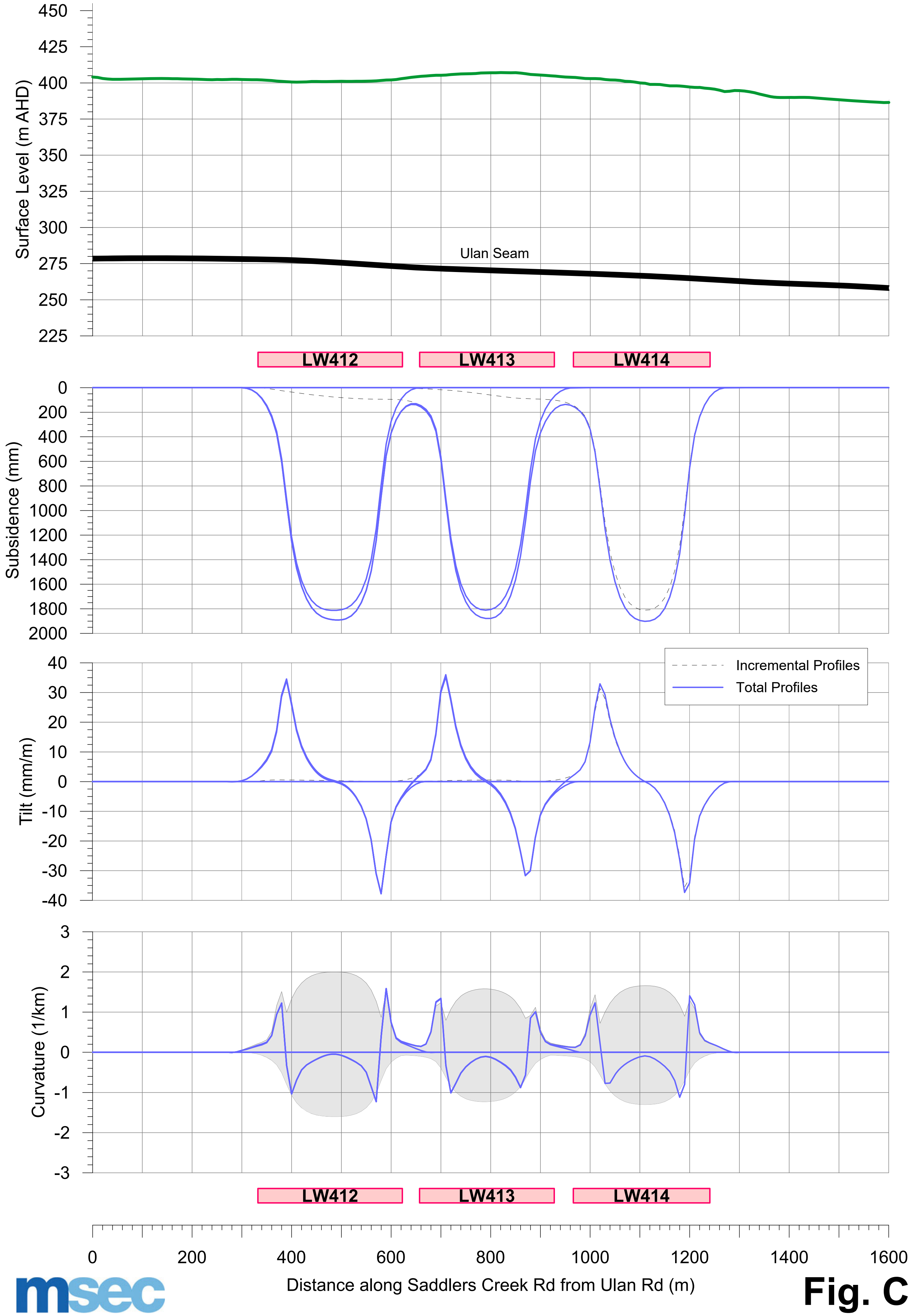


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Fig. C.04

# APPENDIX D. TABLES

# Table D.01 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

| ID | Description | *Maximum Predicted Subsidence based on the Approved Layout after (after LW414) (mm)* | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW409 (mm) | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW410 (mm) | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW411 (mm) | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW412 (mm) | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW413 (mm) | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW414 (mm) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| S1MC263 | Isolated Find | *1900* | 1800 | 1900 | 1900 | 1900 | 1900 | 1900 |
| S1MC264 / Curra Creek; Goulburn River | Grinding Grooves, Artefacts and PAD | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC265 | Shelter with Artefacts | *775* | 900 | 975 | 975 | 975 | 975 | 975 |
| S1MC266 | Shelter with Artefacts | *1750* | < 20 | < 20 | < 20 | 1700 | 1750 | 1750 |
| S1MC267 | Shelter with Artefacts | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC268 | Shelter with Artefacts | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC269 | Shelter with Artefacts | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC270 | Isolated Find | *250* | 225 | 250 | 250 | 250 | 250 | 250 |
| S1MC282 | Artefacts | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC283 | Shelter with Artefacts | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC284 | Shelter with Art and Artefacts | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC285 | Shelter with Artefacts | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC286 | Shelter with Artefacts and PAD | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC287 | Shelter with Artefacts and PAD | *90* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC288 | Shelter with Artefacts and PAD | *1650* | < 20 | < 20 | < 20 | < 20 | 50 | 50 |
| S1MC295 | Isolated Find | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |

# Table D.01 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

| ID | Description | *Maximum Predicted Subsidence based on the Approved Layout after (after LW414) (mm)* | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW409 (mm) | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW410 (mm) | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW411 (mm) | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW412 (mm) | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW413 (mm) | Maximum Predicted Subsidence based on the Extraction Plan Layout after LW414 (mm) |
|---|---|---|---|---|---|---|---|---|
| S1MC296 | Shelter with Artefacts and PAD | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC297 | Shelter with Artefacts and PAD | *1450* | < 20 | < 20 | < 20 | < 20 | 1050 | 1050 |
| S1MC432 | Artefacts | *40* | < 20 | < 20 | < 20 | 40 | 40 | 40 |
| S1MC466 | Shelter with Artefacts and PAD | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC467 | Shelter with PAD | *375* | 300 | 375 | 375 | 375 | 375 | 375 |
| S1MC470 | Shelter with PAD | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC480 | Shelter with PAD | *70* | < 20 | < 20 | < 20 | < 20 | < 20 | 70 |
| S1MC481 | Shelter with PAD | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC482 | Shelter with Artefacts and PAD | *< 20* | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| S1MC492 | Artefacts | *1900* | < 20 | < 20 | < 20 | < 20 | < 20 | 1900 |
| S1MC493 | Shelter with Artefacts and PAD | *1900* | < 20 | < 20 | < 20 | 1800 | 1900 | 1900 |
| S1MC541 | Isolated find | *1900* | < 20 | < 20 | 1800 | 1900 | 1900 | 1900 |
| | | | | | | | | |

# Table D.01 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

| ID | Description | *Maximum Predicted Tilt based on the Approved Layout (after LW414) (mm/m)* | Maximum Predicted Tilt based on the Extraction Plan Layout (mm/m) LW414 | *Maximum Predicted Hogging Curvature based on the Approved Layout (after LW414) (1/km)* | Maximum Predicted Hogging Curvature based on the Extraction Plan Layout (mm/m) LW414 | *Maximum Predicted Sagging Curvature based on the Approved Layout (after LW414) (1/km)* | Maximum Predicted Sagging Curvature based on the Extraction Plan Layout (mm/m) LW414 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| S1MC263 | Isolated Find | *6.5* | 6.5 | *1.30* | 1.30 | *0.35* | 0.35 |
| S1MC264 / Curra Creek; Goulburn River | Grinding Grooves, Artefacts and PAD | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC265 | Shelter with Artefacts | *40.0* | 40.0 | *0.50* | 0.65 | *0.45* | 1.30 |
| S1MC266 | Shelter with Artefacts | *35.0* | 35.0 | *1.20* | 1.20 | *1.10* | 1.10 |
| S1MC267 | Shelter with Artefacts | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC268 | Shelter with Artefacts | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC269 | Shelter with Artefacts | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC270 | Isolated Find | *12.0* | 12.0 | *0.15* | 0.15 | *< 0.01* | < 0.01 |
| S1MC282 | Artefacts | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC283 | Shelter with Artefacts | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC284 | Shelter with Art and Artefacts | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC285 | Shelter with Artefacts and PAD | *1.0* | 1.0 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC286 | Shelter with Artefacts and PAD | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC287 | Shelter with Artefacts and PAD | *3.0* | < 0.5 | *0.06* | < 0.01 | *0.02* | < 0.01 |
| S1MC288 | Shelter with Artefacts and PAD | *30.0* | 1.5 | *1.10* | 0.04 | *0.80* | < 0.01 |
| S1MC295 | Isolated Find | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |

# Table D.01 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

| ID | Description | *Maximum Predicted Tilt based on the Approved Layout (after LW414) (mm/m)* | Maximum Predicted Tilt based on the Extraction Plan Layout (mm/m) LW414 | *Maximum Predicted Hogging Curvature based on the Approved Layout (after LW414) (1/km)* | Maximum Predicted Hogging Curvature based on the Extraction Plan Layout (mm/m) LW414 | *Maximum Predicted Sagging Curvature based on the Approved Layout (after LW414) (1/km)* | Maximum Predicted Sagging Curvature based on the Extraction Plan Layout (mm/m) LW414 |
|---|---|---|---|---|---|---|---|
| S1MC296 | Shelter with Artefacts and PAD | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC297 | Shelter with Artefacts and PAD | *25.0* | 30.0 | *0.95* | 0.70 | *0.65* | 0.80 |
| S1MC432 | Artefacts | *3.5* | 3.5 | *0.02* | 0.02 | *< 0.01* | < 0.01 |
| S1MC466 | Shelter with Artefacts and PAD | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC467 | Shelter with PAD | *14.0* | 14.0 | *0.25* | 0.25 | *< 0.01* | < 0.01 |
| S1MC470 | Shelter with PAD | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC480 | Shelter with PAD | *4.5* | 4.5 | *0.05* | 0.05 | *< 0.01* | < 0.01 |
| S1MC481 | Shelter with PAD | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC482 | Shelter with Artefacts and PAD | *< 0.5* | < 0.5 | *< 0.01* | < 0.01 | *< 0.01* | < 0.01 |
| S1MC492 | Artefacts | *7.5* | 7.5 | *1.30* | 1.30 | *0.35* | 0.35 |
| S1MC493 | Shelter with Artefacts and PAD | *7.0* | 7.0 | *1.30* | 1.30 | *0.35* | 0.35 |
| S1MC541 | Isolated find | *7.0* | 7.0 | *1.20* | 1.20 | *0.35* | 0.35 |
| | | | | | | | |

# Table D.01 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

| ID | Description | *Predicted Conventional Tensile Strain based on the Approved Layout (after LW414) (mm/m)* | Maximum Predicted Tensile Strain based on the Extraction Plan Layout (mm/m) LW414 | *Predicted Conventional Comp. Strain based on the Approved Layout (after LW414) (mm/m)* | Maximum Predicted Comp. Strain based on the Extraction Plan Layout (mm/m) LW414 |
|---|---|---|---|---|---|
| | | | | | |
| S1MC263 | Isolated Find | *13.0* | 13.0 | *3.5* | 3.5 |
| S1MC264 / Curra Creek; Goulburn River | Grinding Grooves, Artefacts and PAD | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC265 | Shelter with Artefacts | *5.0* | 6.5 | *4.5* | 13.0 |
| S1MC266 | Shelter with Artefacts | *12.0* | 12.0 | *11.0* | 11.0 |
| S1MC267 | Shelter with Artefacts | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC268 | Shelter with Artefacts | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC269 | Shelter with Artefacts | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC270 | Isolated Find | *1.5* | 1.5 | *< 0.5* | < 0.5 |
| S1MC282 | Artefacts | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC283 | Shelter with Artefacts | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC284 | Shelter with Art and Artefacts | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC285 | Shelter with Artefacts and PAD | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC286 | Shelter with Artefacts and PAD | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC287 | Shelter with Artefacts and PAD | *0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC288 | Shelter with Artefacts and PAD | *11.0* | < 0.5 | *8.0* | < 0.5 |
| S1MC295 | Isolated Find | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |

# Table D.01 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

| ID | Description | *Predicted Conventional Tensile Strain based on the Approved Layout (after LW414) (mm/m)* | Maximum Predicted Tensile Strain based on the Extraction Plan Layout (mm/m) LW414 | *Predicted Conventional Comp. Strain based on the Approved Layout (after LW414) (mm/m)* | Maximum Predicted Comp. Strain based on the Extraction Plan Layout (mm/m) LW414 |
|---|---|---|---|---|---|
| S1MC296 | Shelter with Artefacts and PAD | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC297 | Shelter with Artefacts and PAD | *9.5* | 7.0 | *6.5* | 8.0 |
| S1MC432 | Artefacts | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC466 | Shelter with Artefacts and PAD | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC467 | Shelter with PAD | *2.5* | 2.5 | *< 0.5* | < 0.5 |
| S1MC470 | Shelter with PAD | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC480 | Shelter with PAD | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC481 | Shelter with PAD | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC482 | Shelter with Artefacts and PAD | *< 0.5* | < 0.5 | *< 0.5* | < 0.5 |
| S1MC492 | Artefacts | *13.0* | 13.0 | *3.5* | 3.5 |
| S1MC493 | Shelter with Artefacts and PAD | *13.0* | 13.0 | *3.5* | 3.5 |
| S1MC541 | Isolated find | *12.0* | 12.0 | *3.5* | 3.5 |
| | | | | | |

Note: Predicted conventional strains are based on 10 times curvature

# APPENDIX E.   DRAWINGS

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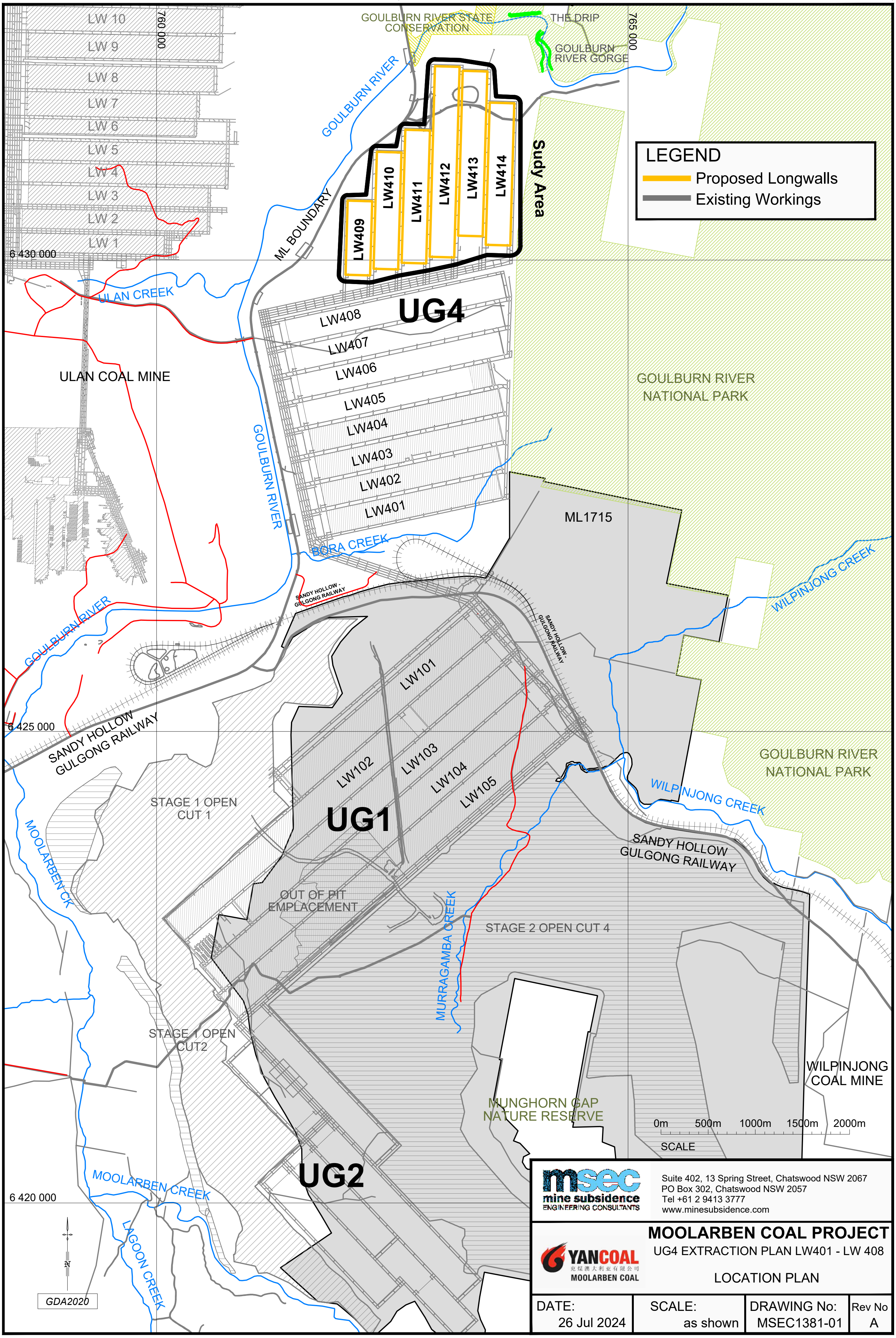

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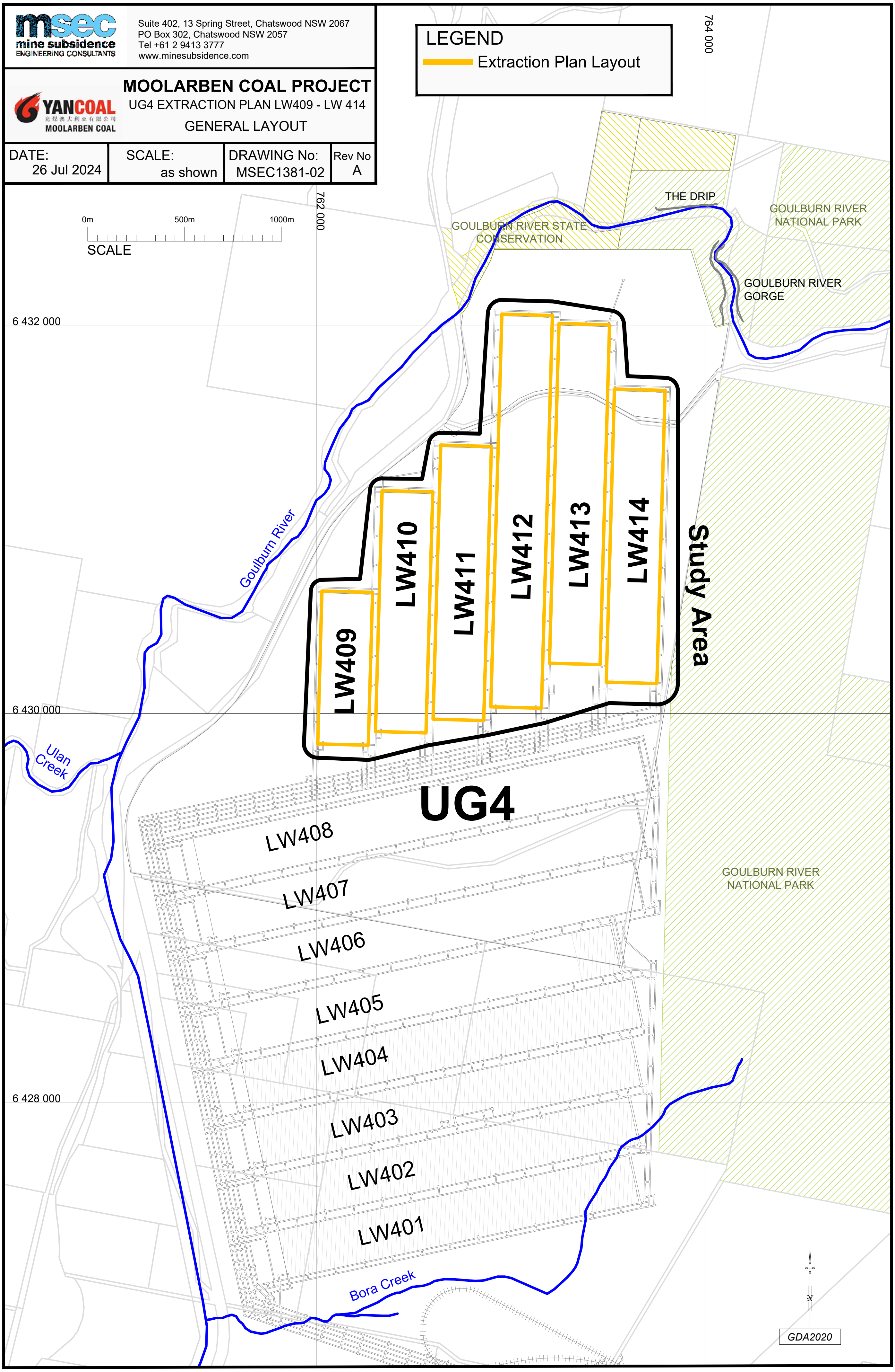
**MOOLARBEN COAL PROJECT**

UG4 EXTRACTION PLAN LW409 - LW 414

GENERAL LAYOUT

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 26 Jul 2024 | as shown | MSEC1381-02 | A |



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SURFACE LEVEL CONTOURS

| DATE: | SCALE: | DRAWING No: | Rev No |
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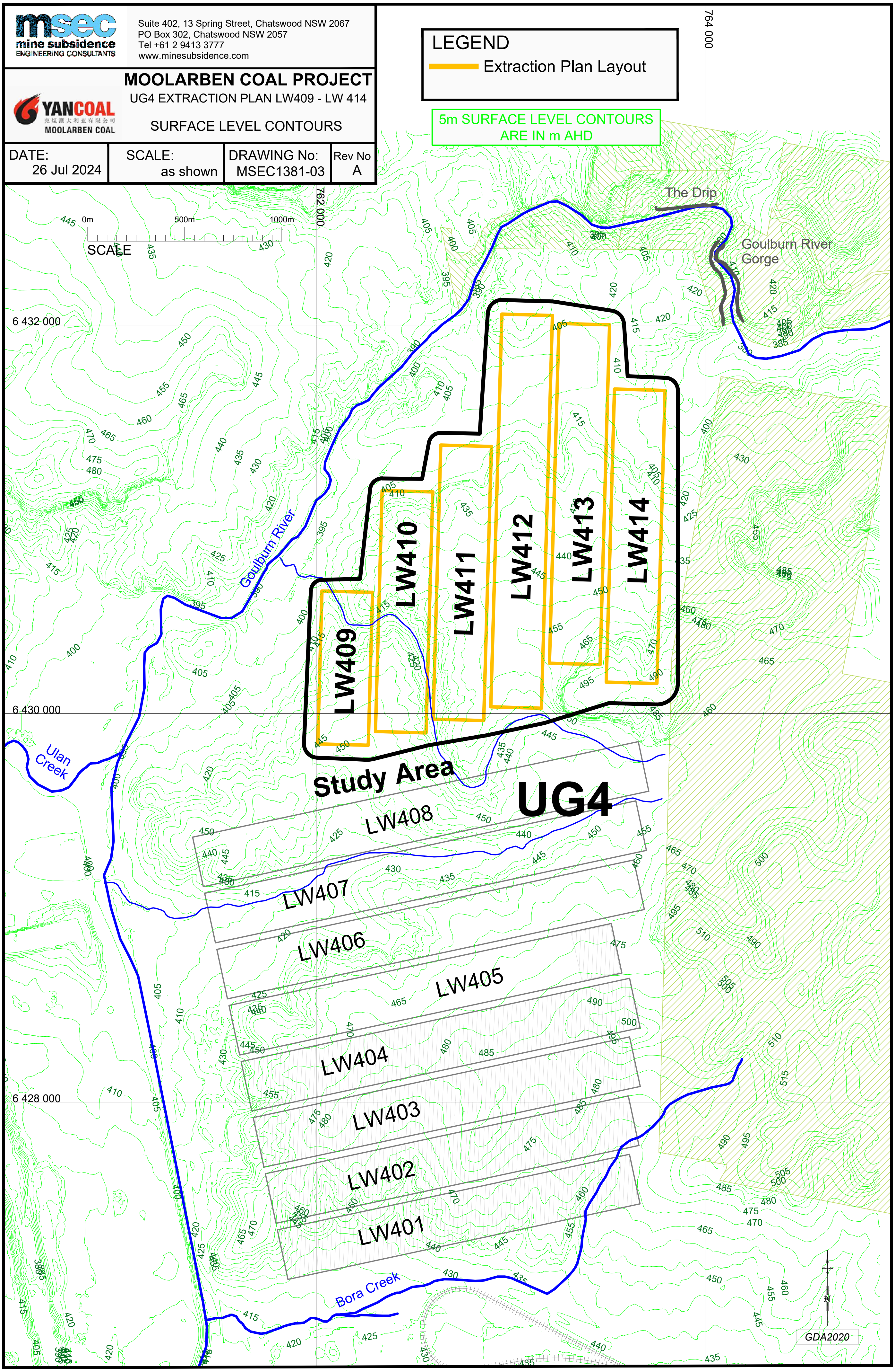

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UG4 EXTRACTION PLAN LW409 - LW 414

DWS SEAM FLOOR CONTOURS

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
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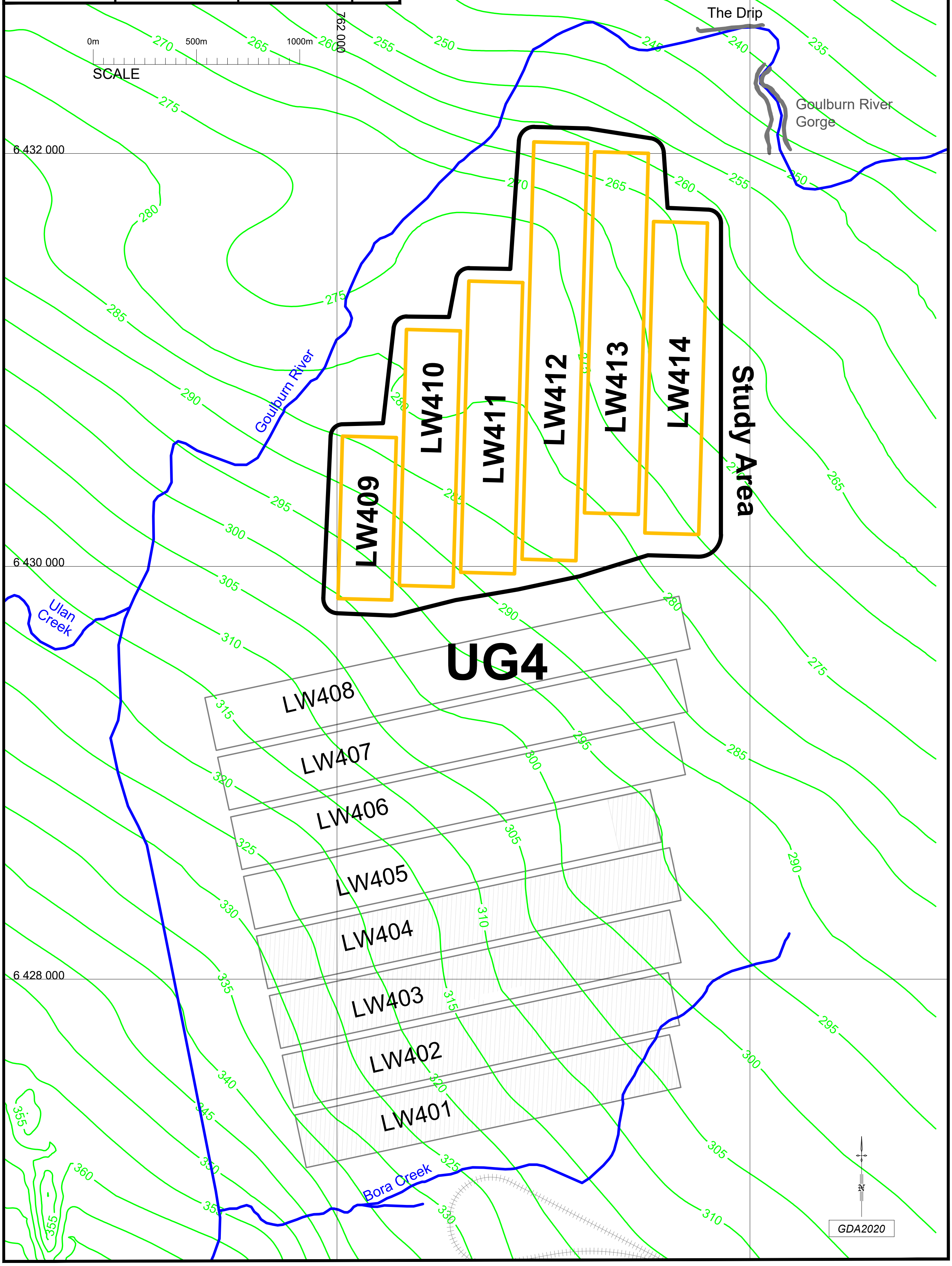

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UG4 EXTRACTION PLAN LW409 - LW 414
DWS SEAM THICKNESS CONTOURS

| DATE: | SCALE: | DRAWING No: | Rev No |
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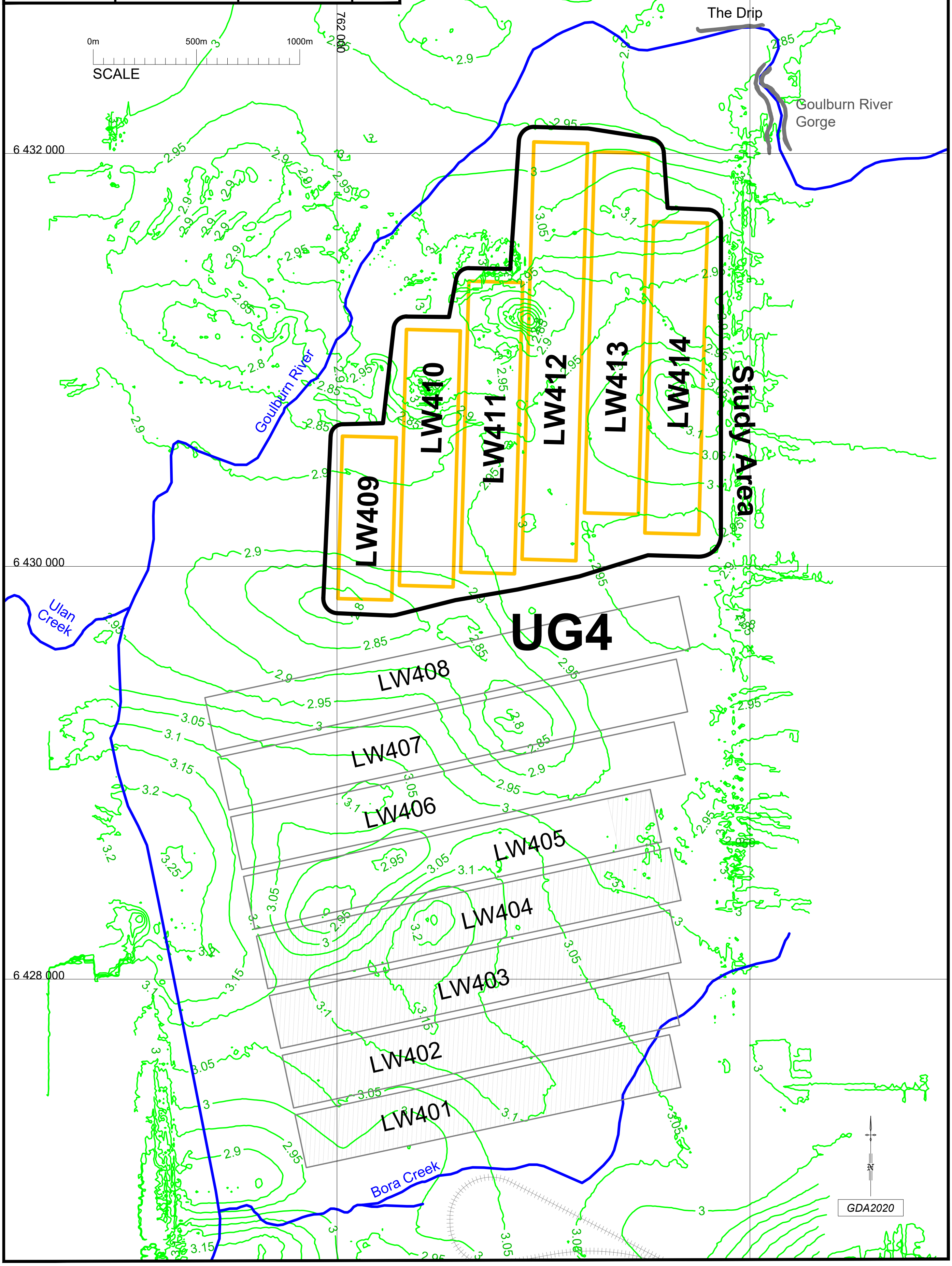

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## UG4 EXTRACTION PLAN LW409 - LW 414 DWS DEPTH OF COVER CONTOURS AT DTP SEAM

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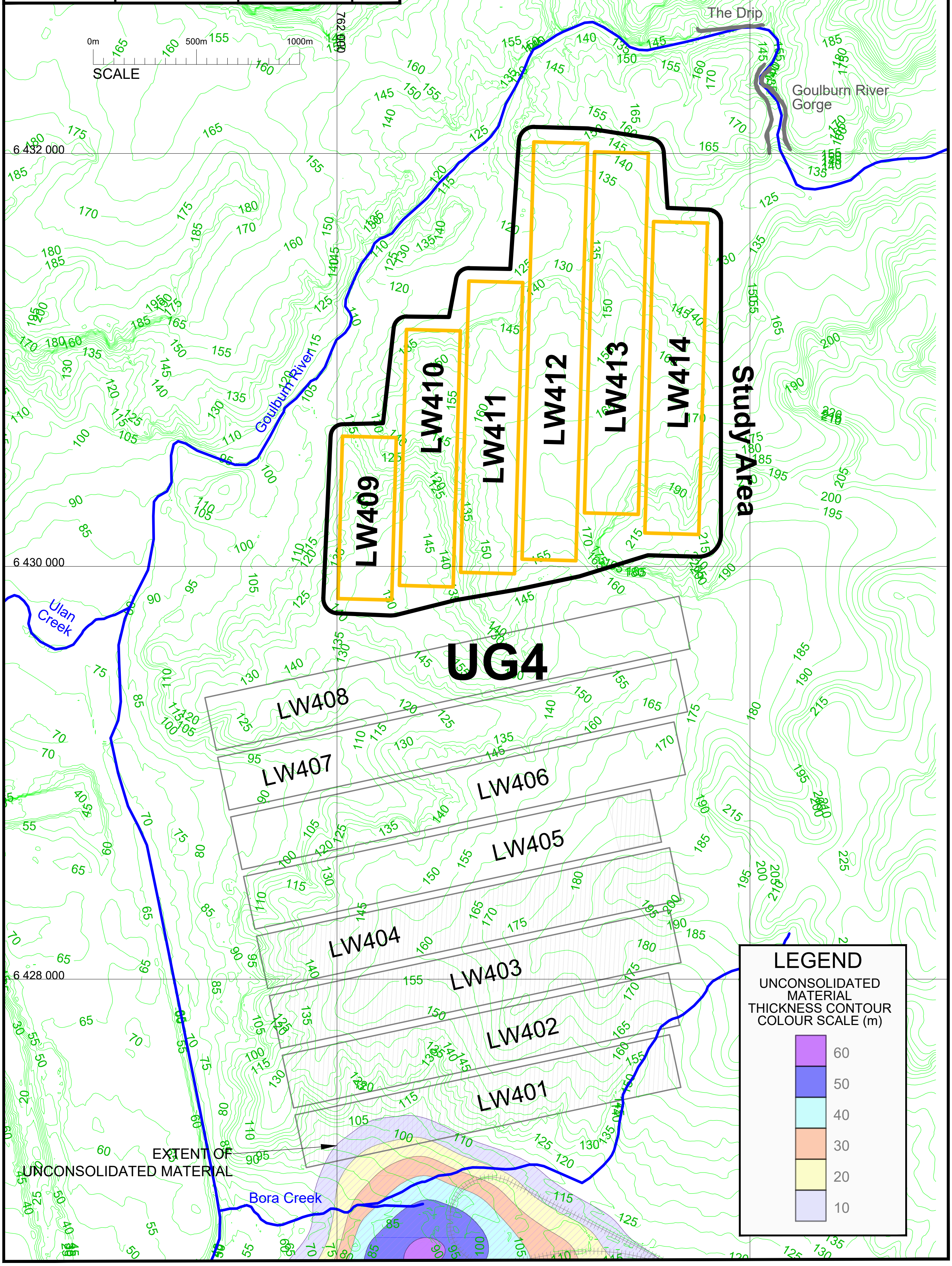
| 26 Jul 2024 | as shown | MSEC1381-06 | A |



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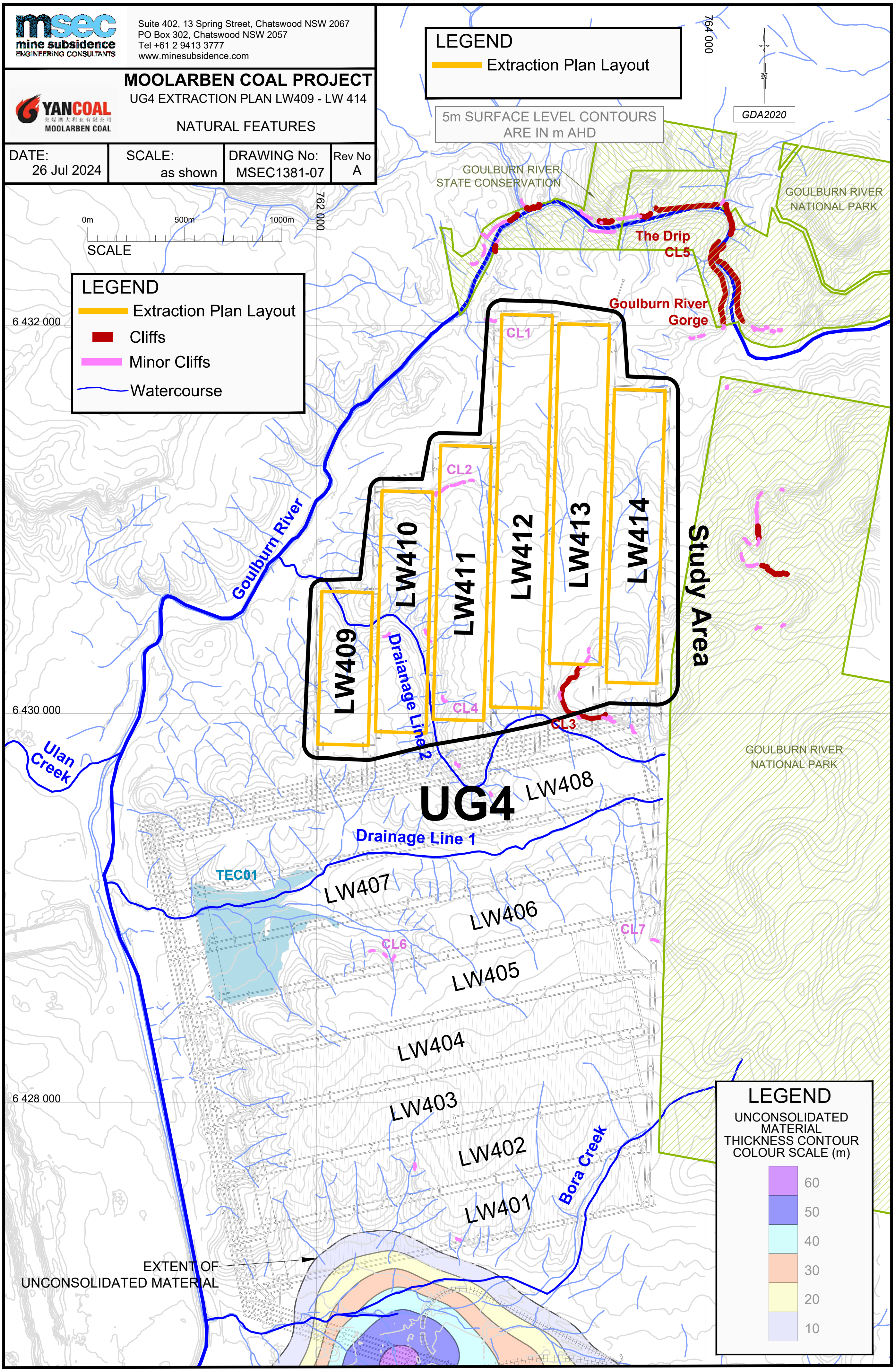

I:\Projects\Moolarben\MSEC1381 - UG4 Extraction Plan - LW409 to 414\AcadData\MSEC1381-08 Built Features.dwg


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UG4 EXTRACTION PLAN LW409 - LW 414

BUILT FEATURES

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
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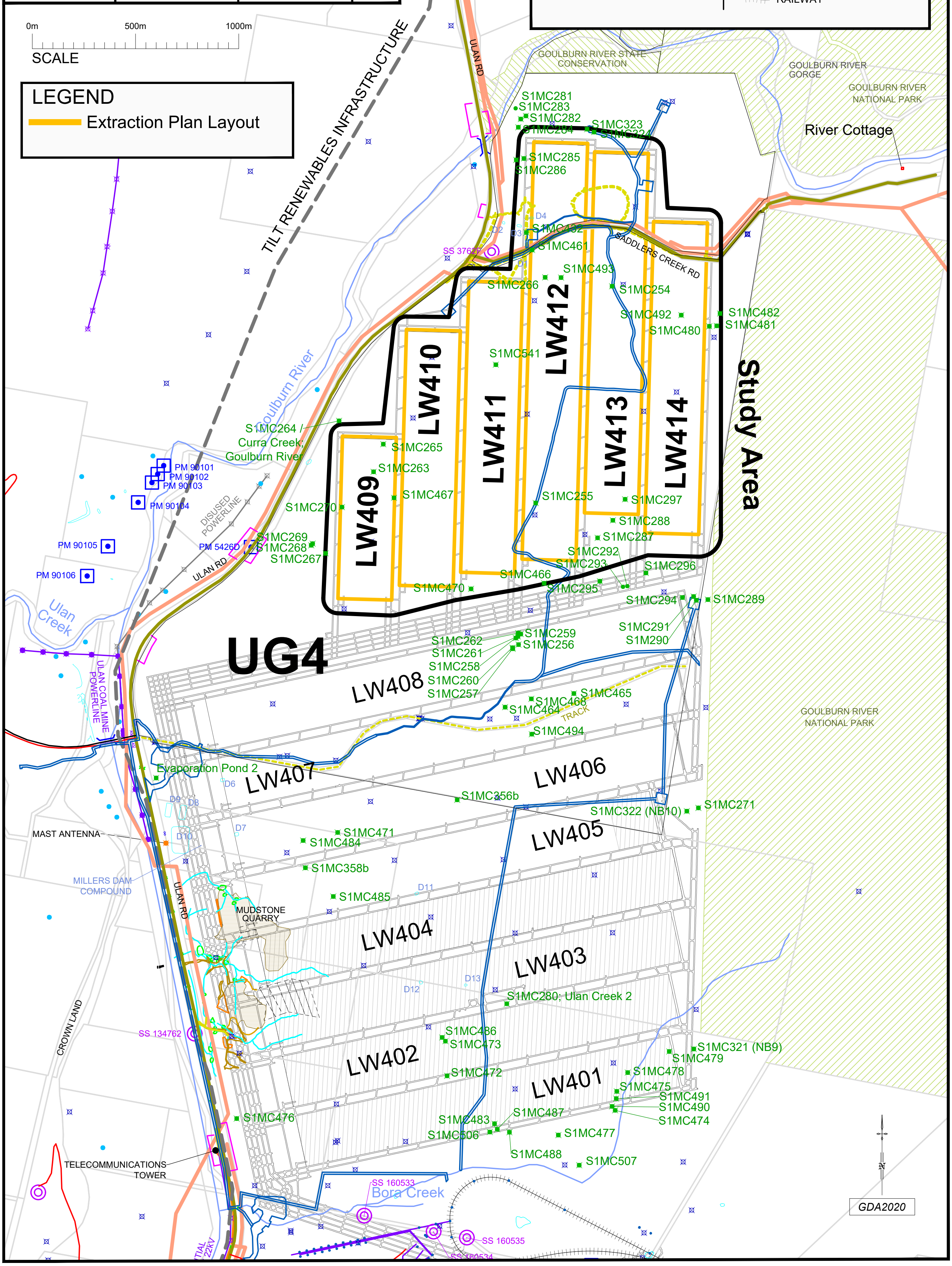

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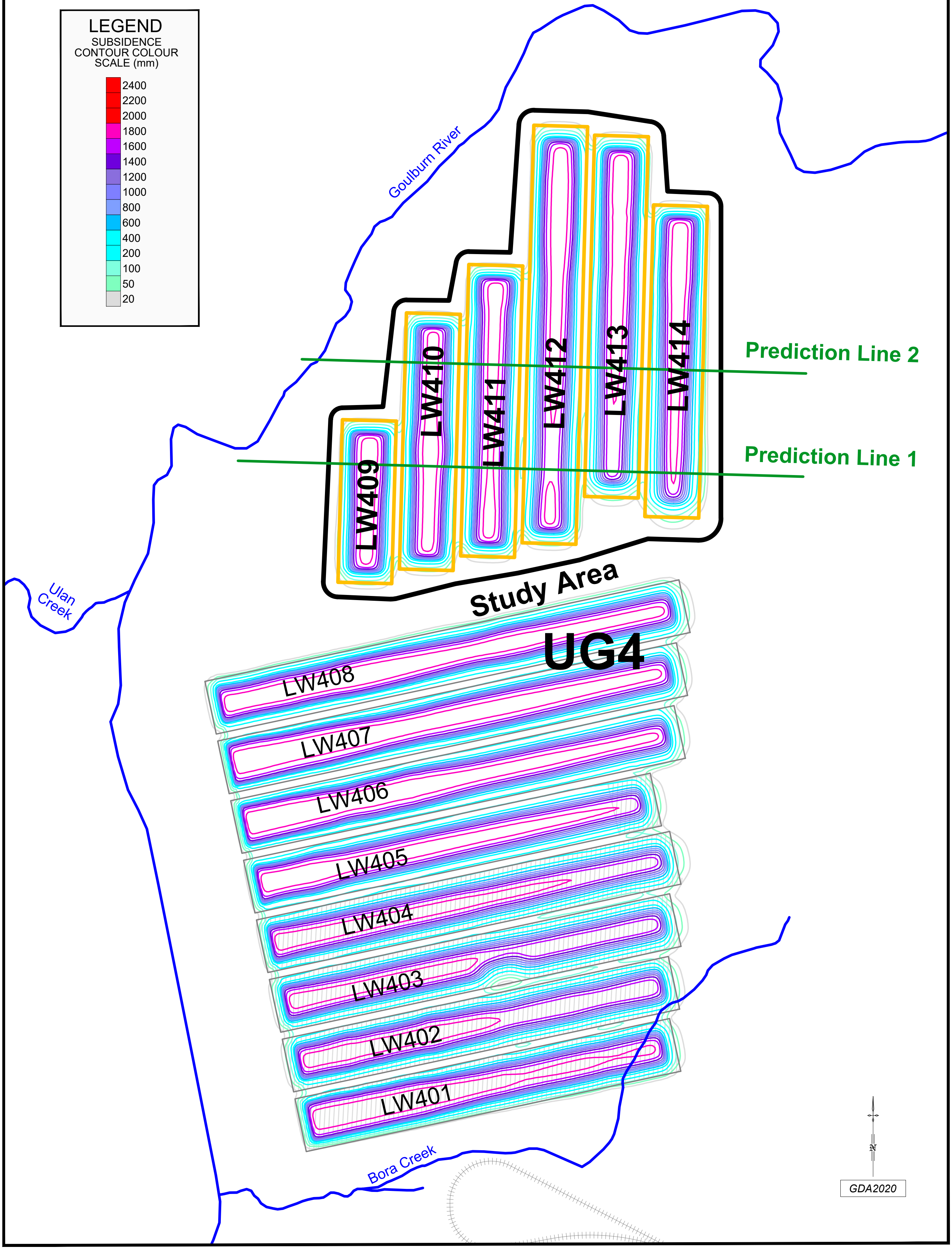
UG4 EXTRACTION PLAN LW409 - LW 414
PREDICTED TOTAL SUBSIDENCE
CONTOURS AFTER LW414

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 26 Jul 2024 | as shown | MSEC1381-09 | A |

NOTE:
The value of the Subsidence Contours, from the outside to the inside of the panels, are 20mm, 50mm, 100mm, 200mm, and so forth, in 100mm increments.

LEGEND
SUBSIDENCE CONTOUR COLOUR SCALE (mm)

2400, 2200, 2000, 1800, 1600, 1400, 1200, 1000, 800, 600, 400, 200, 100, 50, 20



# APPENDIX F. CASE STUDIES

The following cases outline other longwall mining operations that have extracted second workings longwall panels within the proximity of cliff lines.

***Sandy Creek Waterfall***

Sandy Creek Waterfall is a sensitive overhanging natural rock feature near Dendrobium Mine in the NSW Southern Coalfield. The overhang feature is approximately 20 m high, 75 m long and 21 m deep and has a minimum thickness of less than 1m. Illawarra Coal carried out a comprehensive monitoring programme for the extraction of four adjacent longwall panels. Details of the feature and monitoring are outlined in Mine Subsidence Technological Society papers Walsh et al (2014-1 and 2014-2). Longwall panels were extracted up to 390 m to 500 m from the waterfall and actively managed to determine a position to cease mining each longwall. With depths of cover of 290 m to 330 m, the waterfall was located at 1.2 to 1.7 times the depth of cover from the extracted longwalls. Measured total horizontal movements at the waterfall were 20mm to 32mm. The outcome was compliance with the development consent with no impacts to the waterfall occurred following extraction of the four longwall panels.

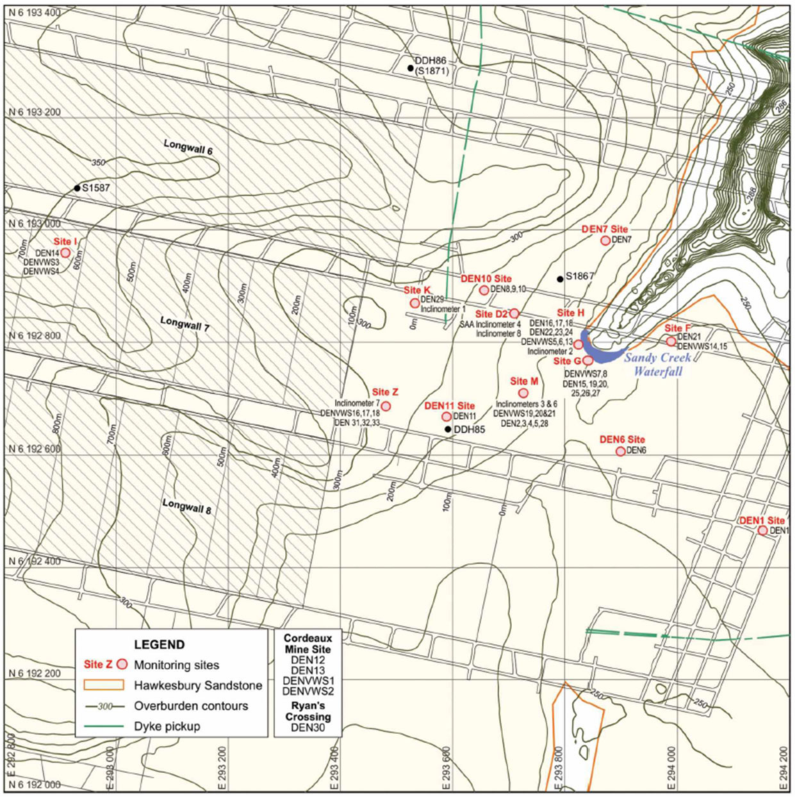



**Fig. 11.1 Site plan showing the location of Sandy Creek Waterfall and extracted longwalls (Walsh et al 2014-1)**

***Wollemi Escarpment***

Wambo Coal Mine has extracted several longwalls adjacent to the Wollemi escarpment in the NSW Hunter Coalfield. The extraction plan subsidence assessment for Longwalls WYLW21 to WYLW24 (MSEC 2020) outlines cliffs within the escarpment ranging from 10 m to 40 m height. The longwalls alignments are perpendicular to the escarpment and extraction direction is away from the escarpment. The longwalls are 230 m or more from the escarpment, representing a minimum of 0.9 times the depth of cover from the longwalls. Monitoring of the cliff lines within the escarpment is carried out by visual drone survey. The 2022 annual review report (Wambo 2022) states that no cliff instabilities have been identified along the escarpment. Two rockfalls, comprising fallen boulders and associated vegetation damage, have been identified that were attributed to heavy rainfall events.

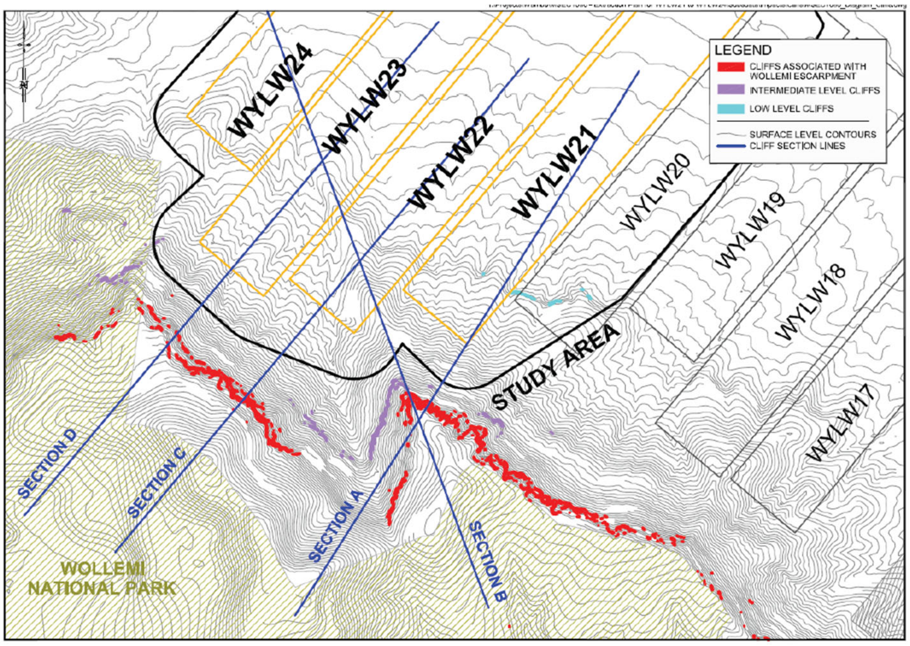



**Fig. 11.2 Site plan showing the location of Wollemi escarpment and extracted longwalls (MSEC 2020)**

### *Nepean River and Razorback Range Cliff Lines*

Appin Colliery has extracted Longwalls 901 to 905 at distances of 310 m to 780 m from a series of cliff lines ranging from 10 m to 25 m height and 30 m to 140 m length. The distances equate to 0.6 to 1.5 times the depth of cover from the longwalls. The end of panel subsidence assessment report for Longwall 905 (MSEC 2023) notes that no mining related impacts to the cliffs have been observed. The report notes that *"Impacts not related to mining included minor rockfalls along Harris Creek Cliff Line and Razorback Range and several shallow slides along Razorback Range which occurred after heavy rainfall periods and are associated with existing or natural instabilities".* Total horizontal movements of 124 to 168mm were measured at the base razorback range. Incremental horizontal movements of 50mm to 60mm were measured at 400 to 600m from the longwalls.

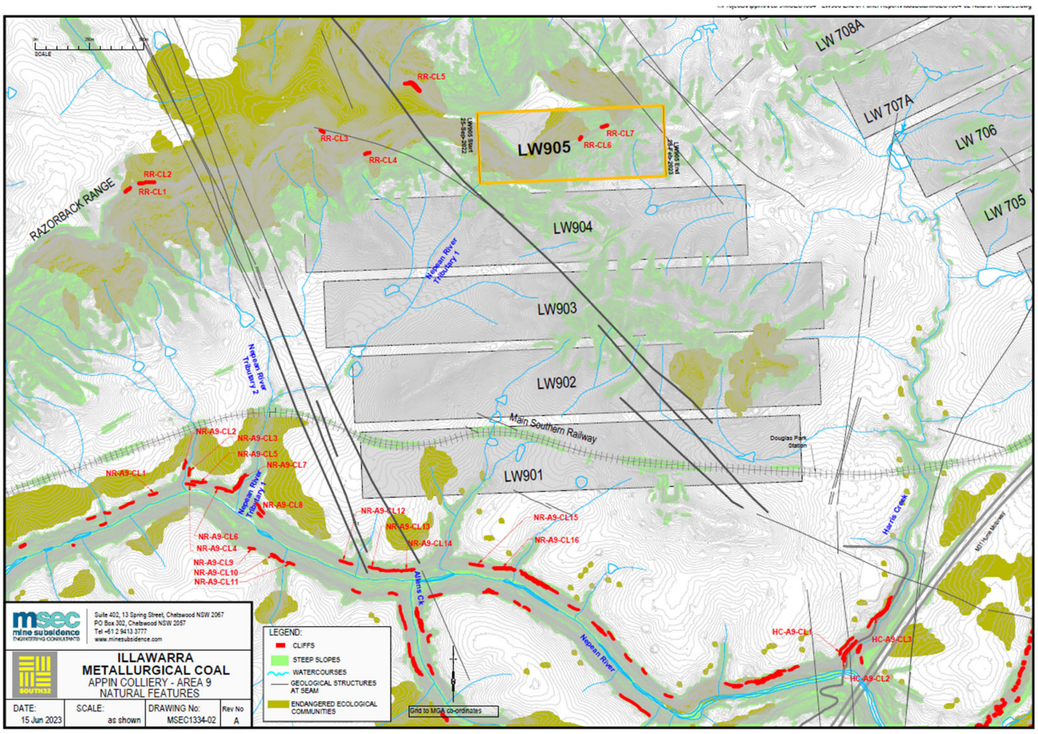



**Fig. 11.3 Site plan showing the location of Nepean River and Razorback Range cliff lines and extracted longwalls (MSEC2023)**

### *Brokenback Conservation Area*

The extraction plan for Ulan West Longwalls LW1 to LW8 (Glencore 2022) outlines a performance measure of nil environmental consequences for the Brokenback Conservation Area. The longwall layout has been modified to set back longwall panels by 0.5 times the depth of cover from the cliffs within the Brokenback Conservation Area. A cliff monitoring report (Pacific Environmental 2023) outlines cliff inspections following the extraction of Longwall LW5. The report notes that no impacts have been observed to the cliffs within the Brokenback Conservation Area. Longwall 5 is estimated to be located about 420 m from the Brokenback Conservation Area.

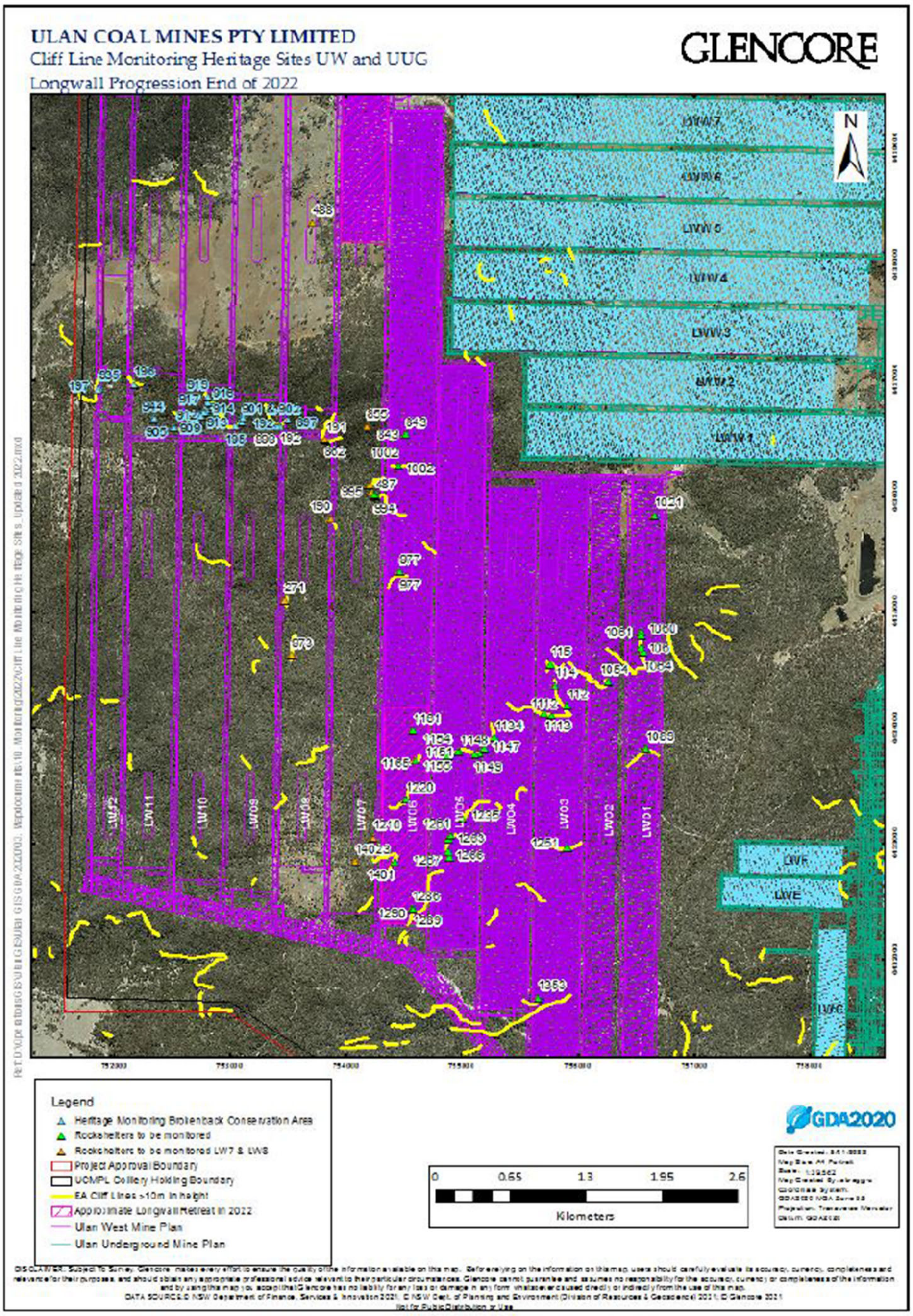



**Fig. 11.4 Site plan showing the location of Brokenback Conservation Area cliff lines and longwalls (Glencore 2022)**