METROPOLITAN COAL LONGWALL 304

SUBSIDENCE REPORT




Peabody

METROPOLITAN COAL

REPORT: SUBSIDENCE PREDICTIONS AND IMPACT ASSESSMENTS

METROPOLITAN COAL PROJECT:

Metropolitan Mine – Longwall 304

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

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Associated reports:-

MSEC285 (Revision C) – Metropolitan Colliery - The Prediction of Subsidence Parameters and the Assessment of Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Proposed Extraction of Longwalls 20 to 44 at Metropolitan Colliery in Support of a Part 3A Application.

MSEC403 (May 2009) – Metropolitan Colliery – Preferred Project Layout (Longwalls 20 to 27 and 301 to 317) Technical discussion on Proposed Modification of Longwall Layout Orientation.

MSEC487 (Revision A, August 2013) – Metropolitan Mine – Longwalls 23 to 27 Subsidence Predictions and Impact Assessments for the Natural and Built Features in support of the Extraction Plan.

MSEC736-02 (Revision A, April 2015) – Metropolitan Colliery – Proposed Longwalls 301 to 317 – Technical Discussion on Proposed Modification of Preferred Project Layout.

MSEC846 (Revision A, October 2016) – Metropolitan Mine – Longwalls 301 to 303 – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan.

MSEC984 (Revision A, September 2018) – Metropolitan Mine – Longwalls 301 to 303 – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan.

MSEC958 (Revision C, October 2018) – Metropolitan Coal – Report on Subsidence Predictions and Impact Assessments in support of a Request for a Revised Longwall 304 to 306 Layout.

MSEC1020-02 (February 2019) – Metropolitan LW303 – Updated Predictions and Trigger Action Response Plan for the Eastern Tributary

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)

Metropolitan Coal proposes to continue its underground coal mining operations within the Bulli Seam at Metropolitan Colliery, which is located in the Southern Coalfield of New South Wales. Metropolitan Coal proposes to extract the next longwall in the current series, referred to as Longwall 304.

Metropolitan Coal was granted Project Approval 08_0149 by the Minister for Planning on the 22nd June 2009. The Project Approval included a layout for Longwalls 301 to 317 referred to as the Preferred Project Layout. Longwall 304 based on the *Preferred Project Layout* comprised a 163 m panel width (void) with 45 m pillars (solid) beyond 500 m from the Woronora Reservoir, and a 138 m panel width (void) with 70 m pillars (solid) within 500 m of the Woronora Reservoir.

In April 2015, Metropolitan Coal received approval from the Department of Planning and Environment (DP&E) for changes to Longwalls 301 to 317, by rotating them in an anti-clockwise direction by approximately six degrees.

The Metropolitan Coal Longwalls 301-303 Extraction Plan (September 2018) describes the amendments that have been made to the Longwalls 301-303 layout from 2016 to 2018. In particular, the Longwalls 301-303 Extraction Plan (September 2018) sought approval for the secondary extraction of Longwall 303 at a length of 1,600 m, which included shortening of the finishing end of Longwall 303 by 98 m adjacent to the Eastern Tributary. In November 2018, the DP&E approved secondary extraction of the first 1,143 m of Longwall 303. Metropolitan Coal has applied for approval for an additional 182 m of secondary extraction in Longwall 303 for a total length of 1,325 m. MSEC prepared the letter Report No. MSEC1020-02 (February 2019) in support of the application.

In October 2018, Metropolitan Coal submitted an application to the DP&E to amend the first workings layout of Longwalls 304-306. The amended longwall layout included:

- uniform void panel width of 163 m and uniform solid tailgate pillar width of 45 m for Longwall 304 with a void panel length of 1,438 m;
- uniform void panel width of 138 m and uniform solid tailgate pillar width of 45 m for Longwall 305; and
- uniform void panel width of 138 m and uniform solid tailgate pillar width of 70 m for Longwalls 306.

DP&E's approval of the first workings application (granted in November 2018) requires Metropolitan Coal to commit to an appropriate setback of Longwall 304 from the Eastern Tributary and a detailed cumulative subsidence assessment of valley closure including Longwalls 304 to 308 for the Eastern Tributary.

MSEC has prepared this report to support the Longwall 304 Extraction Plan. The predictions and impact assessments provided in this report are based on the Extraction Plan Layout, defined as:

- the approved Longwalls 301 to 303 layout incorporating the proposed additional 182 m of secondary extraction of Longwall 303 (i.e. a longwall length of 1,325 m); and
- uniform void panel width of 163 m and uniform solid tailgate pillar widths of 45 m for Longwall 304 with a void panel length of 1,286 m.

A comparison of predicted subsidence predictions and impact assessments has been made for the natural and built features resulting from extraction of Longwall 304 (including the effects of the previous LW301 to LW303), based on the Extraction Plan Layout, with the Preferred Project Layout for these longwalls at Metropolitan Colliery.

The main changes made to the longwalls for the Extraction Plan Layout compared with the Preferred Project Layout include an approximate 6 degree anti-clockwise rotation, a reduction in longwall lengths and a narrowing of the pillar widths of Longwalls 301-304.

The changes from the Preferred Project Layout generally result in a reduction in predicted subsidence parameters where the longwalls have been shortened, and an increase in predicted subsidence parameters where pillar widths have been reduced. Where there is an increase in the predicted subsidence parameters, based on the Extraction Plan Layout, the magnitudes of the maximum predicted subsidence parameters are similar to the maxima predicted elsewhere above the Preferred Project Layout. As a result, the overall impact assessments for the natural and built features based on the Extraction Plan Layout are unchanged, or reduce compared to those based on the Preferred Project Layout.

The management and monitoring plans that have been developed for natural and built features have been updated for Longwall 304.

Monitoring and management strategies have been revised for the following built features as part of the Extraction Plan process for Longwall 304, in consideration of the results of additional assessments and consultation with the infrastructure owners:

- NSW Health - Garrawarra;
- Sydney Water – water and sewer pipelines;
- Roads and Maritime Services - M1 Princes Motorway and bridges;
- Wollongong City Council - Old Princes Highway;
- Wollongong City Council - Waterfall Cemetery;
- Nextgen - telecommunication infrastructure;
- Telstra - telecommunication infrastructure;
- Optus - telecommunication infrastructure;
- Vocus - telecommunication infrastructure;
- Axicom - telecommunication infrastructure;
- Sydney Trains - Illawarra Railway and infrastructure;
- TransGrid – 330 kV transmission line infrastructure; and
- Endeavour Energy – 132 kV transmission line infrastructure and other high voltage powerline infrastructure.

The monitoring and management strategies for built features aim to achieve the performance measure of safe, serviceable and repairable (unless the owner, authority and the Mine Subsidence Board agree otherwise in writing).

CONTENTS

Tables

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

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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

Metropolitan Coal is a wholly owned subsidiary of Peabody Energy Pty Limited (Peabody) and operates Metropolitan Colliery (the Colliery), which is located in the Southern Coalfield of New South Wales (NSW). Metropolitan Coal has extracted Longwalls 1 to 27, 301 and 302 at the Colliery and, at the time of this report, was extracting Longwall 303.

Metropolitan Coal submitted the Metropolitan Coal Project Environmental Assessment for the extraction of Longwalls 20 to 44 at the Colliery in 2008 (Helensburgh Coal Pty Ltd, 2008). Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC285 (Rev. C) that provided the subsidence predictions and impact assessments for these longwalls in support of the Environmental Assessment.

Metropolitan Coal submitted the Metropolitan Coal Project Preferred Project Report (Helensburgh Coal, 2009), with changes to the layout used in the Environmental Assessment. MSEC prepared Report No. MSEC403 that provided an assessment of the Preferred Project Layout in support of the Preferred Project Report. The longwalls based on the *Preferred Project Layout* comprised 163 m panel widths (void) with 45 m pillars (solid) beyond 500 m from the Woronora Reservoir, and 138 m panel widths (void) with 70 m pillars (solid) within 500 m of the Woronora Reservoir. The Minister for Planning granted Peabody approval for Preferred Project Layout on the 22nd June 2009 (Project Approval 08_0149).

Metropolitan Coal subsequently modified the northern series of longwalls, now referred to as Longwalls 301 to 317, by rotating them in an anti-clockwise direction by approximately six degrees. MSEC prepared the letter Report No. MSEC736-02 (Rev. A) that provided the updated subsidence predictions and impact assessments in support of the application. Metropolitan Coal received approval from the Department of Planning and Environment (DP&E) for the orientation change in April 2015.

The Metropolitan Coal Longwalls 301-303 Extraction Plan (September 2018) describes the amendments that have been made to the Longwalls 301-303 layout from 2016 to 2018. In particular, the Longwalls 301-303 Extraction Plan (September 2018) sought approval for the secondary extraction of Longwall 303 at a length of 1,600 m, which included shortening of the finishing end of Longwall 303 by 98 m adjacent to the Eastern Tributary. In November 2018, the DP&E approved secondary extraction of the first 1,143 m of Longwall 303. This approval allows Metropolitan Coal to seek further approval for any additional secondary extraction beyond 1,143 m in Longwall 303. Metropolitan Coal has applied for approval for an additional 182 m of secondary extraction in Longwall 303 for a total length of 1,325 m. MSEC prepared the letter Report No. MSEC1020-02 (February 2019) in support of the application.

In October 2018, Metropolitan Coal submitted an application to the DP&E to amend the first workings layout of Longwalls 304-306. The amended longwall layout included:

- uniform void panel width of 163 m and uniform solid tailgate pillar width of 45 m for Longwall 304 with a void panel length of 1,438 m;
- uniform void panel width of 138 m and uniform solid tailgate pillar width of 45 m for Longwall 305; and
- uniform void panel width of 138 m and uniform solid tailgate pillar width of 70 m for Longwalls 306.

DP&E's approval of the first workings application (granted in November 2018) requires Metropolitan Coal to commit to an appropriate setback of Longwall 304 from the Eastern Tributary and a detailed cumulative subsidence assessment including Longwalls 304 to 308 for the Eastern Tributary.

MSEC has prepared this report to support the Longwall 304 Extraction Plan. The predictions and impact assessments provided in this report are based on the Extraction Plan Layout, defined as:

- the approved Longwalls 301 to 303 layout incorporating the proposed additional 182 m of secondary extraction of Longwall 303 (i.e. a longwall length of 1,325 m); and
- uniform void panel width of 163 m and uniform solid tailgate pillar widths of 45 m for Longwall 304 with a void panel length of 1,286 m.

Section 5.4 of this report provides predictions for the Eastern Tributary for the Extraction Plan Layout (which includes the proposed additional 182 m of secondary extraction in Longwall 303) as well as an Alternative Layout. The Alternative Layout is based on the proposed additional 182 m of Longwall 303 not being approved, as well as a 58 m reduction in the length of Longwall 304 compared to the Extraction Plan Layout. Predicted impacts for other surface features for the Alternative Layout would be similar to or less than the predicted impacts for the Extraction Plan Layout.

Subsidence predictions for the Eastern Tributary based on the Alternative Layout, including Longwalls 304 to 308, is provided in Attachment 1.

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

Chapter 3 includes overviews of the mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the longwalls.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of Longwall 304 (including the effects of the previous LW301 to LW303) based on the Extraction Plan Layout. Comparisons of these predictions with the maxima based on the Preferred Project Layout are also provided in this chapter.

Chapters 5 through 11 provide the descriptions, predictions and impact assessments for each of the natural and built features within the Study Area based on the Extraction Plan Layout. Comparisons of the predictions for each of these features with those based on the Preferred Project Layout are provided in these chapters. The impact assessments and recommendations have also been provided based on the Extraction Plan Layout.

The comparisons of the Extraction Plan Layout with the Preferred Project Layout is provided in Fig. 1.1.

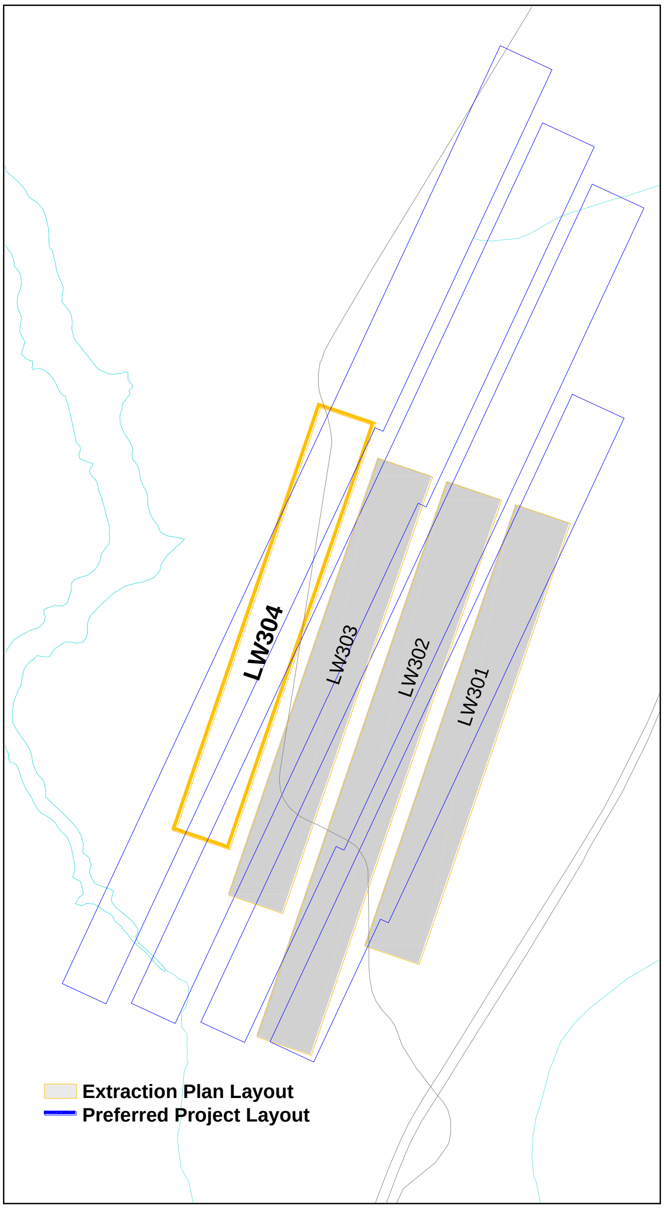

Fig. 1.1 Comparison of the Extraction Plan Layout with the Preferred Project Layout

1.2. Mining Geometry

The layout of Longwall 304 is shown in Drawing No. MSEC1009-01 in Appendix E. The void length of Longwall 304 including installation headings is 1,286 m and the overall void width including first workings is 163 m. The overall tailgate chain pillar width (i.e. solid width) is 45 m. The mining direction of Longwall 304 is north to south.

The length of the longwall has been shortened at the northern and southern ends from that adopted in the Preferred Project Report. The overall length of Longwall 304 adopted in the Preferred Project Report for the Preferred Project Layout (MSEC403) is 2,971 m.

The proposed extraction void width for Longwall 304 is 163 m for the full length of the longwall. The void width adopted for Longwall 304 in the Preferred Project Report was narrowed to 138 m at the southern end over a length of 1,826 m.

1.3. Surface Topography

The surface level contours in the vicinity of the proposed Longwall 304 are shown in Drawing No. MSEC1009-02, which were generated from an airborne laser scan of the area.

A topographical high point is located within the Study Area and to the north east of Longwall 304, with a surface level of 300 m AHD. Surface levels above Longwall 304 vary from 285 m AHD at the north east corner to 215 m AHD at the longwall maingate. The natural surface generally slopes down to the west towards the Woronora Reservoir.

1.4. Seam Information

The surface level contours, seam floor contours, seam thickness contours and depth of cover contours are shown in Drawings Nos. MSEC1009-02, MSEC1009-03, MSEC1009-04 and MSEC1009-05, respectively.

The depth of cover to the Bulli Seam within the Study Area varies between a minimum of 395 m, in the south of the Study Area, and a maximum of 555 m, near the northern commencing end of Longwall 304. The depth of cover above Longwall 304 varies from 450 m to 535 m.

The seam floor within the Study Area generally dips from the south east to the north west. The seam thickness within the Longwall 304 footprint varies between approximately 2.7 m at the northern end and less than 2.9 m at the southern end. The proposed longwall will extract the full height of the seam with a minimum extraction height of 2.8 m.

The variations in the surface and seam levels across the mining area are illustrated along Cross section 1 Fig. 1.2. The locations of these sections are shown in Drawings Nos. MSEC1009-02 to MSEC1009-04.

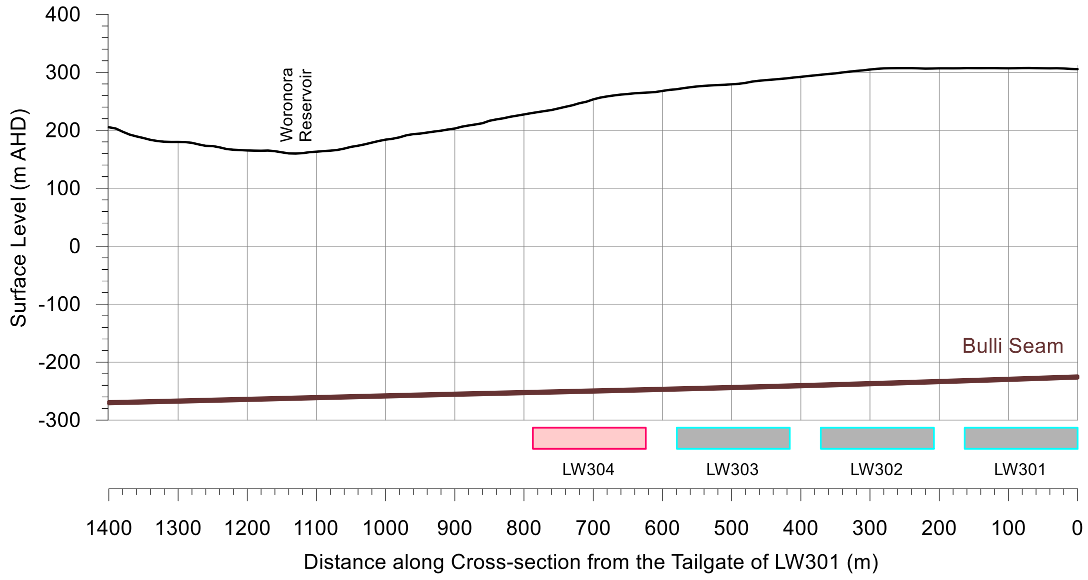

Fig. 1.2 Surface and Seam Levels along Cross-section 1

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1.5. Geological Details

The overburden geology mainly comprises sedimentary sandstones, shales and claystones of the Permian and Triassic Periods, which have in some places been intruded by igneous sills. The main geological features mapped at seam level in the area of the longwalls are shown in Drawing No. MSEC1009-06.

Minor discontinuous faulting is located within the Study Area to the south of Longwall 304 with one probable fault (F-0008) extending into the southern half of the Longwall 304 footprint at the same approximate orientation as the centreline of Longwall 304. Fault F0008 is associated with a surface linear that aligns with the Eastern Tributary. Longwalls 20 to 27 extracted through this feature directly under the Eastern Tributary. A strike slip fault, F-0027, has been mapped in the Longwall 304 maingate roadway. There are no mapped faults located within the Study Area that extend beneath the surface infrastructure.

The commencing end of Longwall 304 is approximately 900 m from the Metropolitan Fault. The Metropolitan Fault has a north west to south east strike and dips to the north east.

The stratigraphic section at one borehole location within the Study Area, which was provided by Metropolitan Coal, is shown in Fig. 1.3. The location of the borehole is shown in Drawing No. MSEC1009-09.

The sandstone and shale units vary in thickness from a few metres to over 160 m. The major sandstone units are interbedded with other rocks and, though shales and claystones are quite extensive in places, the sandstone predominates.

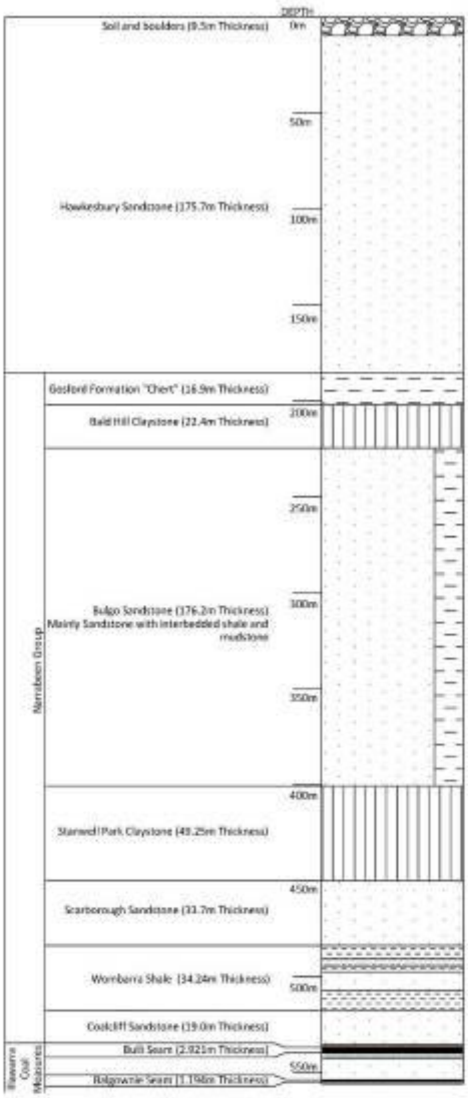

Fig. 1.3 Stratigraphic Section at Borehole S225

The major sedimentary units in the Metropolitan area are, from the top down:-

- Hawkesbury Sandstone; and
- the Narrabeen Group.

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The Narrabeen Group contains the Newport Formation (sometimes referred to as the Gosford Formation), the Bald Hill Claystone (also referred to as Chocolate Shale), the Bulgo Sandstone, the Stanwell Park Claystone/Shale, the Scarborough Sandstone, the Wombarra Shale and the Coal Cliff Sandstone.

The surface geology within the Study Area can be seen in Fig. 1.4, which shows the proposed longwalls overlaid on Geological Series Sheet 9029-9129, which is published by the Department of Industry – Division of Resources and Energy (DRE).

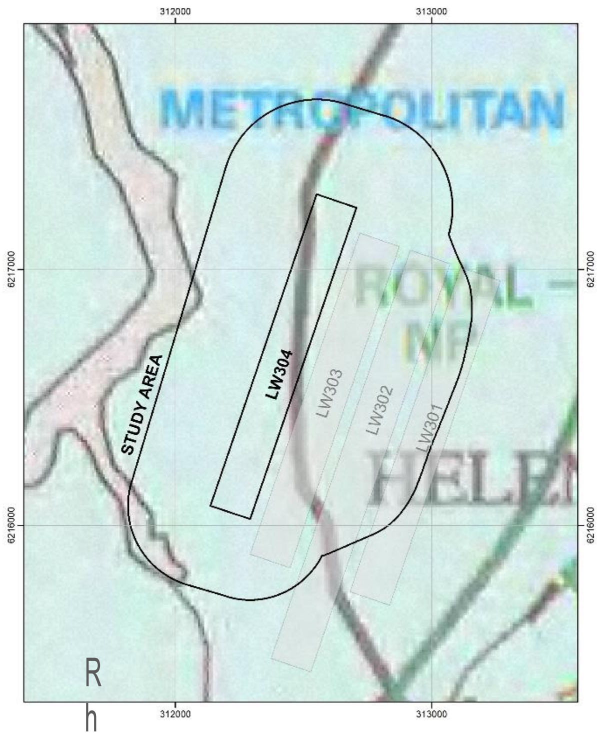

Fig. 1.4 Surface Lithology within the Study Area (DRE Geological Series Sheet 9029-9129)

It can be seen from the above Fig. 1.4 that the surface lithology in the vicinity of the proposed Longwall 304 comprises Hawkesbury Sandstone Group (Rh).

2.1. Definition of the Study Area

The Study Area is defined as the surface area that is likely to be affected by the proposed mining of Longwall 304 at Metropolitan Colliery. The surface features included in the Study Area are those features within areas bounded by the following limits:-

- A 35° angle of draw line from the proposed extent of Longwall 304; and
- The predicted limit of vertical subsidence, taken as the predicted incremental 20 mm subsidence contour resulting from the extraction of the proposed Longwall 304.

The depth of cover contours are shown in Drawing No. MSEC1009-05. It can be seen from this drawing that the depth of cover directly above the proposed Longwall 304 varies between a minimum of 450 m and a maximum of 535 m. The 35° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 315 m and 375 m from Longwall 304.

The predicted limit of vertical subsidence, taken as the predicted incremental 20 mm subsidence contour, has been determined using the calibrated Incremental Profile Method, which is described in Chapter 3.

The line defining the Study Area, based on the further extent of the 35° angle of draw and the predicted incremental 20 mm subsidence contour is shown in Drawing No. MSEC1009-01.

There are features that lie outside the Study Area that are expected to experience either far-field movements, or valley related movements. The surface features which are sensitive to such movements have been identified and have been included in the assessments provided in this report. These features are listed below and details of these are provided in later sections of the report:-

- Eastern Tributary;
- M1 Princes Motorway bridges at Old Princes Highway (bridge 2) and Cawleys Road;
- Garrawarra Complex;
- Illawarra Railway;
- Exploration bores; and
- Survey control marks.

The natural features within 600 m of the proposed Longwall 304 are also considered in this report.

2.2. Natural and Built Features within the Study Area

Many 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 APPIN 9029-1S. The proposed Longwall 304 has been overlaid on an extract of this CMA map in Fig. 2.1.

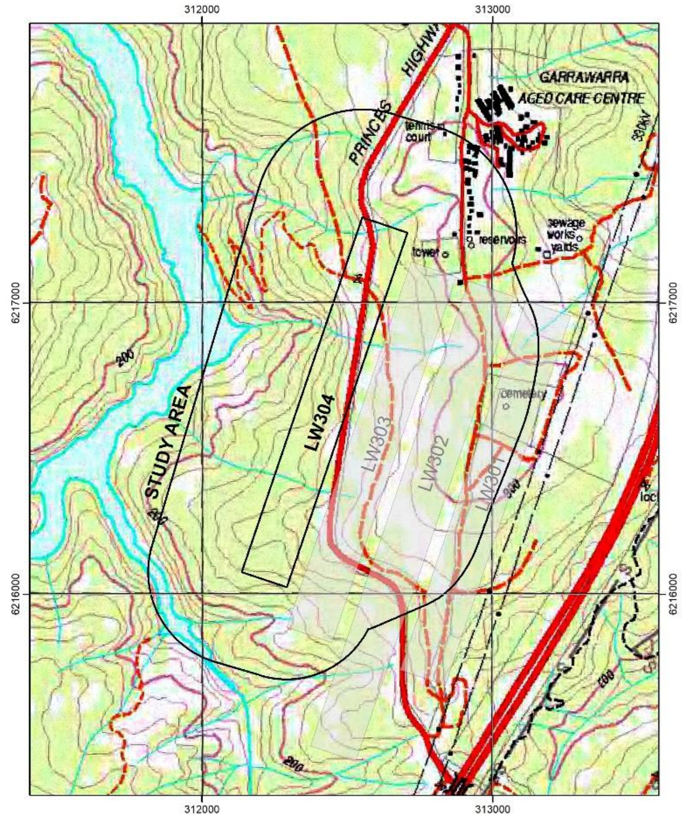

Fig. 2.1 The Proposed Longwall 304 Overlaid on CMA Map No. Appin 9029-1S

A summary of the natural and built features within the Study Area is provided in Table 2.1. The locations of these features are shown in Drawings Nos. MSEC1009-07 to MSEC1009-10, 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 Reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	✓	5.2
Rivers or Creeks	✓	5.3 to 5.6
Aquifers or Known Groundwater Resources	✓	5.7
Springs	×	
Sea or Lake	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Pagodas	✓	5.9 & 5.10
Steep Slopes	✓	5.11
Escarpments	×	
Land Prone to Flooding or Inundation	×	
Swamps, Wetlands or Water Related Ecosystems	✓	5.13
Threatened or Protected Species	✓	5.14
National Parks	×	
State Forests	×	
State Conservation Areas	×	
Natural Vegetation	✓	5.15
Areas of Significant Geological Interest	×	
Any Other Natural Features Considered Significant	×	
PUBLIC UTILITIES		
Railways	×	6.1
Roads (All Types)	✓	6.2 to 6.4
Bridges	✓	6.5
Tunnels	×	
Culverts	✓	6.6
Water, Gas or Sewerage Infrastructure	✓	6.7
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	✓	6.8
Telecommunication Lines or Associated Plants	✓	6.9
Water Tanks, Water or Sewage Treatment Works	✓	6.7
Dams, Reservoirs or Associated Works	✓	6.11
Air Strips	×	
Any Other Public Utilities	×	
PUBLIC AMENITIES		
Hospitals	×	
Places of Worship	×	
Schools	×	
Shopping Centres	×	
Community Centres	×	
Office Buildings	✓	11.1
Swimming Pools	×	
Bowling Greens	×	
Ovals or Cricket Grounds	×	
Race Courses	×	
Golf Courses	×	
Tennis Courts	×	
Any Other Public Amenities	×	

Item	Within Study Area	Section Number Reference
FARM LAND AND FACILITIES		
Agricultural Utilisation or Agricultural Suitability of Farm Land	✓	8.1
Farm Buildings or Sheds	×	
Tanks	×	
Gas or Fuel Storages	×	
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	✓	8.2
Farm Dams	×	
Wells or Bores	×	
Any Other Farm Features	×	
INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS		
Factories	×	
Workshops	×	
Business or Commercial Establishments or Improvements	×	
Gas or Fuel Storages or Associated Plants	×	
Waste Storages or Associated Plants	×	
Buildings, Equipment or Operations that are Sensitive to Surface Movements	×	
Surface Mining (Open Cut) Voids or Rehabilitated Areas	×	
Mine Infrastructure Including Tailings Dams or Emplacement Areas	✓	9.1
Any Other Industrial, Commercial or Business Features	×	
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓	10.1 & 10.2
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	✓	10.4
RESIDENTIAL ESTABLISHMENTS		
Houses	✓	11.1
Flats or Units	×	
Caravan Parks	×	
Retirement or Aged Care Villages	✓	11.1
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts	✓	11.1
Any Other Residential Features	×	
ANY OTHER ITEM OF SIGNIFICANCE	×	
ANY KNOWN FUTURE DEVELOPMENTS	×	

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 proposed Longwall 304. 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.

Far-field horizontal movements and the method used to predict such movements are described further in Section 4.6.

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, such as the case within the Study Area, the observed subsidence profiles along monitoring survey lines are generally smooth. Where the depth of cover is less than 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 possible that surface features located above the longwalls could experience localised and elevated strains due to unknown geological structures (i.e. anomalies). Non-conventional or anomalous movements have not been identified during the extraction of Longwalls 301 and 302 and part extraction of Longwall 303. 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 downslope movements 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 down slope movements 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.

Further discussions on the potential for down slope movements for the steep slopes within the Study Area are provided in Section 5.11.

3.4.3. Valley Related Movements

Watercourses may be subjected to valley related movements, which are commonly observed along river and creek alignments in the Southern Coalfield. Valley bulging movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.1. The potential for these natural movements are influenced by the geomorphology of the valley.

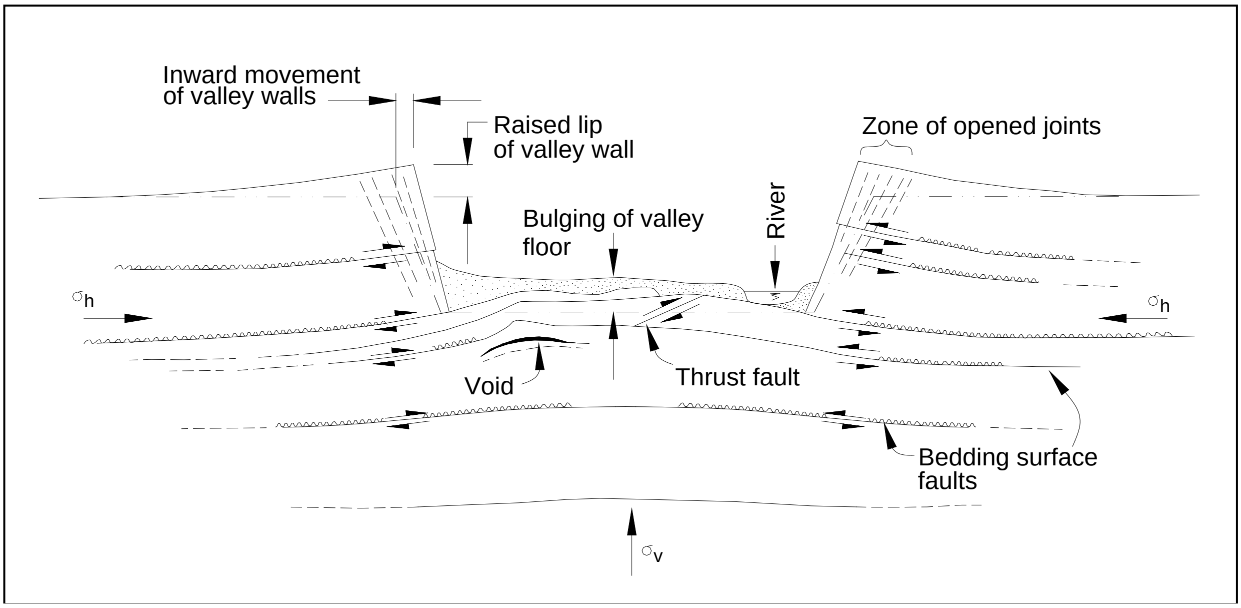

Fig. 3.1 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

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

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

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

The predicted valley related movements resulting from the extraction of the proposed longwalls were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

The reliability of the predicted valley related upsidence and closure movements is discussed in Section 3.8.

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.

The database consists of detailed subsidence monitoring data from many mines and collieries in NSW 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 of the Incremental Profile Method

The standard Incremental Profile Method as used for the Southern Coalfield was calibrated to local conditions using observed monitoring data above the previously extracted longwalls at the Colliery. The calibration of the Incremental Profile Method is outlined in detail in the MSEC285 report. The calibrated model predicts subsidence greater than the standard model so as to account for the local geology at Metropolitan Colliery.

An adjustment was made to the model for the prediction of the magnitude of subsidence for the first panel in a longwall series. Following the completion of Longwall 301 it was found from several monitoring lines, that the predicted magnitude of vertical subsidence was less than the observed subsidence. The magnitude of the predicted vertical subsidence has been increased for the prediction of subsidence parameters for Longwall 304 and subsequent longwalls. A plot of the predicted and observed vertical subsidence for the 300XL line at Metropolitan Colliery is shown in Fig. 3.2 for the extraction of Longwall 301 and in Fig. 3.3 for the extraction of Longwalls 301 and 302. The predicted profiles of vertical subsidence prior to the adjustment is shown as red lines and the predicted profile of vertical subsidence after the adjustment is shown as blue lines.

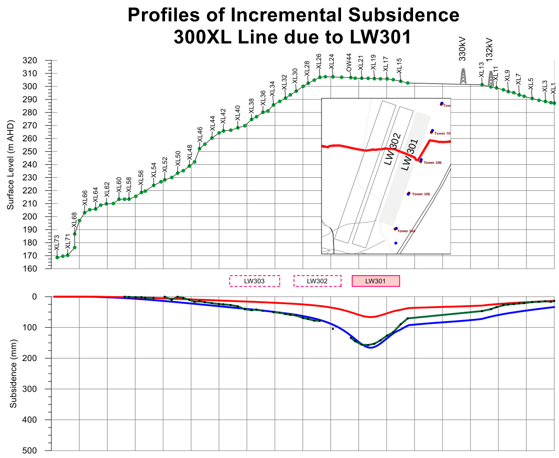

Fig. 3.2 Predicted Vertical Subsidence due to the Extraction of Longwall 301

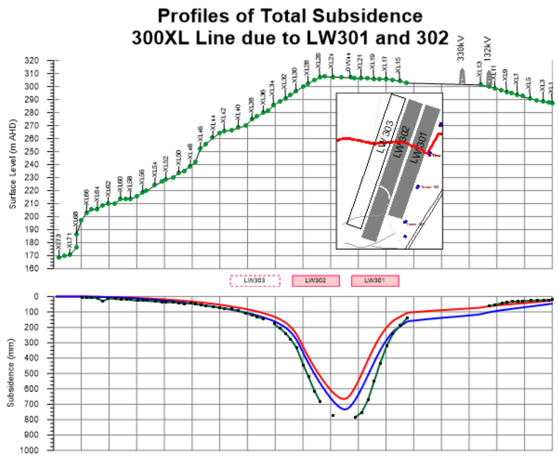

Fig. 3.3 Predicted Vertical Subsidence due to the Extraction of Longwall 301 and 302

3.7. Reliability of the Predicted Conventional Subsidence Parameters

The Incremental Profile Method is based upon a large database of observed subsidence movements in the Southern Coalfield and has been found, in most cases, to give reasonable, if not, conservative predictions of maximum subsidence, tilt and curvature. The predicted profiles obtained using this method also reflect the way in which each parameter varies over the mined area and indicate the movements that are likely to occur at any point on the surface.

The following findings have been previously documented in relation to the Incremental Profile Method:

- The observed subsidence profiles reasonably match those predicted using the standard or calibrated prediction curves. While there is reasonable correlation, it is highlighted that in some locations away from the points of maxima and, in particular beyond the longwall goaf edges, that the observed subsidence can exceed that predicted. In these locations, however, the magnitude of subsidence is low and there were no associated significant tilts, curvatures and strains.

- In some cases, however, the observed subsidence has exceeded those predicted. It is highlighted, that in one rare case in the Southern Coalfield, the maximum observed subsidence substantially exceeded that predicted above Longwall 24A and parts of Longwall 25 to 27 at Tahmoor Colliery. In the Tahmoor cases, the maximum observed subsidence of 1169 mm and 1216 mm, or 54 % and 55 % of the extracted seam thicknesses, were more than double the predicted amounts of 500 mm and 600 mm, or 23 % and 27 % of the extracted seam thickness. This was a very unusual and rare event for the Southern Coalfield and geotechnical advice indicates the cause was unusual geology (Gale W, *Investigation into Abnormal Increased Subsidence above Longwall Panels at Tahmoor Colliery NSW*, MSTS Conference, 2011). The abnormal subsidence was found to be associated with the localised weathering of joint and bedding planes above a depressed water table adjacent to the incised Bargo River Gorge. Similar increased subsidence has not been observed beside other incised gorges. To put this in perspective, the surface area that was affected by increased subsidence at Tahmoor represents less than 1 % of the total surface area affected by longwall mining in the Southern Coalfield.

- The observed tilt and curvature profiles also reasonably matched the predicted profiles using the standard or calibrated prediction curves. The observed curvatures were derived from the smoothed subsidence profiles, so as to obtain overall levels of curvature, rather than the localised curvatures at each survey mark.
- The maximum observed tilts and curvatures were, in most cases, similar to the maximums predicted using the standard or calibrated prediction curves. The observed tilts and curvatures exceeded those predicted at the tributary crossings, at the locations of the upsidence movements, as the predicted profiles did not include non-conventional valley related movements. There was also some scatter in the observed tilt and curvature profiles.

The prediction of the conventional subsidence parameters at a specific point is more difficult. Variations between predicted and observed parameters at a point can occur where there is a lateral shift between the predicted and observed subsidence profiles, which can result from seam dip or variations in topography. In these situations, the lateral shift can result in the observed parameters being greater than those predicted in some locations, whilst the observed parameters being less than those predicted in other locations.

The prediction of strain at a point is even more difficult as there tends to be a large scatter in observed strain profiles. It has been found that measured strains can vary considerably from those predicted at a point, not only in magnitude, but also in sign, that is, the tensile strains have been observed where compressive strains were predicted, and vice versa. For this reason, the prediction of strain in this report has been based on a statistical approach, which is discussed in Section 4.4.

The tilts, curvatures and strains observed at the streams are likely to be greater than the predicted conventional movements, as a result of valley related movements, which is discussed in Section 3.4.3. Specific predictions of upsidence, closure and compressive strain due to the valley related movements are provided for the streams in Sections 5.3 to 5.6. The impact assessments for the streams are based on both the conventional and valley related movements.

It is also likely that some localised irregularities will occur in the subsidence profiles due to near surface geological features. The irregular movements are accompanied by elevated tilts, curvatures and strains, which often exceed the conventional predictions. In most cases, it is not possible to predict the locations or magnitudes of these irregular movements. For this reason, the strain predictions provided in this report are based on a statistical analysis of measured strains in the Southern Coalfield, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4. Further discussions on irregular movements are provided in Section 4.7.

The Incremental Profile Method approach allows site specific predictions for each natural and built feature and hence provides a more realistic assessment of the subsidence impacts than by applying the maximum predicted parameters at every point, which would be overly conservative and would yield an excessively overstated assessment of the potential subsidence impacts.

It is expected, therefore, that the calibrated Incremental Profile Method should generally provide reasonable, if not, slightly conservative predictions for conventional subsidence, tilt and curvature resulting from the extraction of the proposed longwalls. Allowance should, however, be made for the possibility of observed movements exceeding those predicted as the result of anomalous or non-conventional movements, or for greater subsidence, to occur in some places.

The reliability of the predictions obtained using the standard Incremental Profile Method is illustrated by comparing the magnitudes of observed movements with those predicted for previously extracted longwalls in the Southern Coalfield. The comparisons have been made for monitoring lines at Metropolitan Colliery and the nearby Appin Colliery (Areas 3, 4 and 7), Tower Colliery and West Cliff Colliery (Area 5).

The comparison between the maximum observed incremental subsidence and the maximum predicted incremental subsidence for the monitoring lines is illustrated in Fig. 3.4. The results shown in this figure are the maximum observed and predicted subsidence for each monitoring line at the completion of each longwall. The results for Metropolitan Colliery have been presented as red data points.

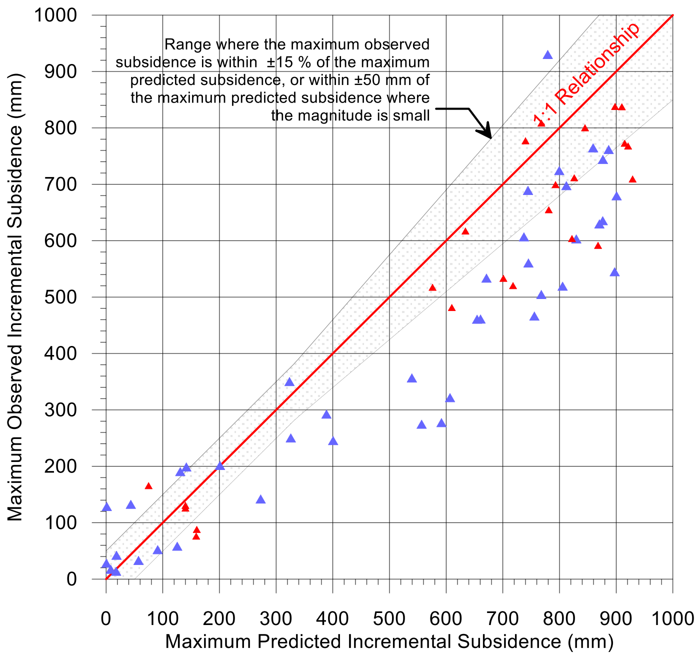

Fig. 3.4 Comparisons between Maximum Observed Incremental Subsidence and Maximum Predicted Incremental Subsidence for the Previously Extracted Longwalls in the Southern Coalfield

It can be seen from the above figure, that in most cases the observed subsidence was typically less than that predicted. The observed subsidence exceeded that predicted in some cases, but was typically within +15 % or +50 mm of the prediction. In the locations where the magnitude of subsidence was small (i.e. beyond the limits of the active longwall), the observed subsidence was typically within ±100 mm of the prediction.

The distribution of the ratio of the maximum observed to maximum predicted incremental subsidence for the monitoring lines is illustrated in Fig. 3.5 (Left). A gamma distribution has been fitted to the results and is also shown in this figure.

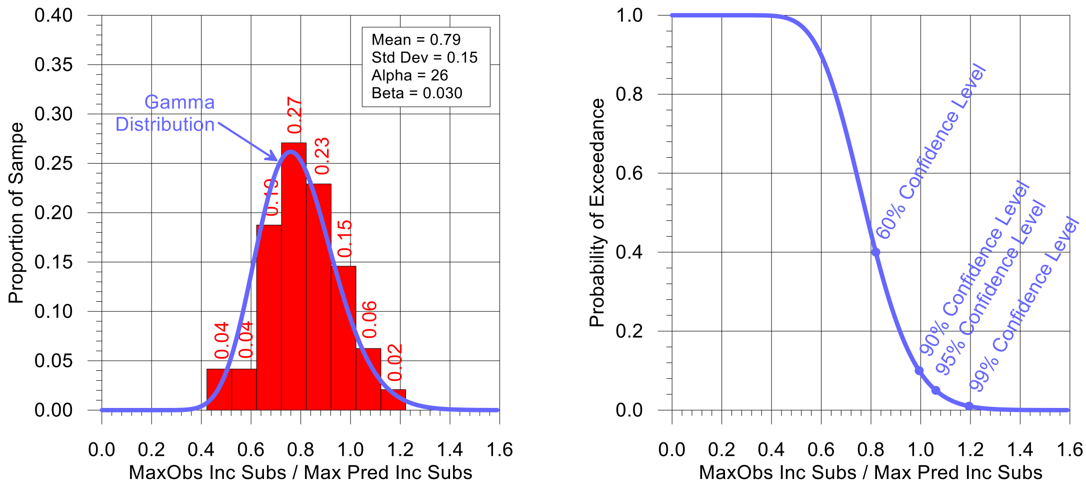

Fig. 3.5 Distribution of the Ratio of the Maximum Observed to Maximum Predicted Incremental Subsidence for Previously Extracted Longwalls in the Southern Coalfield

The probabilities of exceedance have been determined, based on the gamma distribution, which is shown in Fig. 3.5 (right). It can be seen from this figure that, based on the monitoring data from the Southern Coalfield, there is an approximate 90 % confidence level that the maximum observed incremental subsidence will be less than the maximum predicted incremental subsidence using the standard model.

3.8. Reliability of the Predicted Upsidence and Closure Movements

The predicted valley related movements resulting from the extraction of the proposed Longwall 304 were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled *General Discussion on*

Mine Subsidence Ground Movements which can be obtained at *www.minesubsidence.com*. Discussions on the reliability of the method of prediction were provided in the EA report No. MSEC285.

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

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

Variations in local geology can affect the way in which the near surface rocks are displaced as subsidence occurs. In the compression zone, the surface strata can buckle upwards or can fail by shearing and sliding over their neighbours. If localised cross bedding exists, this shearing can occur at relatively low values of stress. This can result in fluctuations in the local strains, which can range from tensile to compressive. In the tensile zone, existing joints can be opened up and new fractures can be formed at random, leading to localised concentrations of tensile strain.

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

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

The 2002 ACARP prediction method was developed by drawing upper bound curves over the majority of the available monitoring data and, therefore, it is expected to be generally conservative in most cases.

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of Longwall 304. 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 Model for the Southern Coalfield, which was calibrated to local conditions based on the available monitoring data from Metropolitan Colliery.

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. 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 Longwall 304 were determined using the calibrated Incremental Profile Method, which was described in Chapter 3. A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of Longwall 304 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 Longwall 304

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})
Due to LW304	625	4	0.04	0.06

The predicted total conventional subsidence contours after the extraction of Longwall 304 are shown in Drawing No. MSEC1009-11. The predicted total conventional subsidence contours include predictions for longwalls extracted prior to Longwall 304. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature, within the Study Area after the extraction of Longwall 304 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 Longwall 304. The predicted curvatures are the maxima at any time during or after the extraction of Longwall 304.

Table 4.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature after the Extraction of Longwall 304

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})
After LW304	1050	5	0.05	0.13

The maximum predicted total subsidence resulting from the extraction of Longwall 304 is 1050 mm, which represents around 38 % of the seam thickness. The maximum predicted total conventional tilt is 5 mm/m (i.e. 0.5 %), which represents a change in grade of 1 in 200. The maximum predicted total conventional curvatures are 0.05 km^{-1} hogging and 0.13 km^{-1} sagging, which represent minimum radii of curvature of 14 km and 7 km, respectively.

The predicted conventional subsidence parameters vary across the Study Area as the result of, amongst other factors, variations in the depths of cover, and extraction heights. To illustrate this variation, the predicted profiles of conventional subsidence, tilt and curvature have been determined along Prediction Line 1, the location of which is shown in Drawing No. MSEC1009-11.

The predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 1, resulting from the extraction of Longwall 304, is shown in Fig. C.01, in Appendix C. The predicted incremental profiles along the prediction line, due to the extraction of Longwall 304, are shown as dashed black lines. The predicted total profiles along the prediction line, after the extraction of Longwall 304, are shown as solid blue lines. The range of predicted curvatures in any direction to the prediction lines, at any time during or after the extraction of the longwalls, are shown by the grey shading. The predicted total profiles based on the Preferred Project Layout are shown as the red lines for comparison.

The reliability of the predictions of subsidence, tilt and curvature, obtained using the Incremental Profile Method, is discussed in Section 3.7.

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

The comparison of the maximum predicted subsidence parameters resulting from the extraction of Longwall 304 with those based on the Preferred Project Layout for Longwall 304 and the Preferred Project Layout for Longwalls 301 to 317 is provided in Table 4.3. The values are the maxima anywhere above longwall layouts.

Table 4.3 Comparison of Maximum Predicted Conventional Subsidence Parameters based on the Preferred Project 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})
Preferred Project Layout (LW301-317) (Report No. MSEC403)	1300	6.0	0.07	0.14
Preferred Project Layout (LW304) (Report No. MSEC403)	1150	5.5	0.05	0.14
Extraction Plan Layout (Report No. MSEC1009)	1050	5.0	0.05	0.13

In previous MSEC subsidence reports (including MSEC285 report for the EA and MSEC403 for the Preferred Project Layout) predictions were provided for strain rather than curvature. The predicted conventional strains were provided based on the best estimate of the average relationship between curvature and strain. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains and this factor was used for the Preferred Project Layout. In order to provide a suitable comparison of predicted subsidence parameters for the Preferred Project Layout and the currently proposed Longwall 304, the predicted curvatures have been derived back from the predicted conventional strains presented in the MSEC403 report using the strain-curvature relationship factor of 15.

It can be seen from the above table, that the maximum predicted total subsidence, tilt and curvature based on the Extraction Plan Layout for Longwall 304 are similar to or less than the maxima predicted based on the Preferred Project Layout for Longwall 304.

A feature of the Preferred Project Layout is increased pillar widths beneath and in close proximity to the Woronora Reservoir. As a result, the maxima based on the Preferred Project Layout, occur at the northern ends of Longwall 304 and this area has been left unmined by the shortening of Longwall 304 based on the Extraction Plan Layout. The location of Prediction Line 1 is at the southern end of Longwall 304 of the Preferred Project Layout where pillar widths are greater and therefore, the predicted subsidence parameters are less than those based on the Extraction Plan Layout as shown in Fig C.01, in Appendix C.

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.

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

Adopting a linear relationship between curvature and strain provides a reasonable prediction for the maximum conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains. Predicted strains using this relationship are rounded to 0.5 mm/m.

The maximum predicted conventional strains resulting from the extraction of Longwall 304 for the Extraction Plan Layout, based on applying a factor of 15 to the maximum predicted total curvatures, are 1.0 mm/m tensile and 2.0 mm/m compressive.

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

The range of potential strains above the proposed Longwall 304 has been determined using monitoring data from the previously extracted longwalls in the Southern Coalfield. The monitoring data was used from the nearby Appin, Tower, West Cliff and Tahmoor Collieries, where the overburden geology and depths of cover are reasonably similar to the proposed longwalls. The panel widths at these collieries are greater than those at Metropolitan Colliery and, therefore, the statistical analyses should provide a reasonable, if not, conservative indication of the range of potential strains for the proposed longwalls.

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

4.4.1. 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.

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

The strain distributions were analysed with the assistance of the centre of Excellence for Mathematics and Statistics of Complex Systems (MASCOS). A number of probability distribution functions were fitted to the empirical data. It was found that a *Generalised Pareto Distribution (GPD)* provided the best fit to the raw strain data.

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

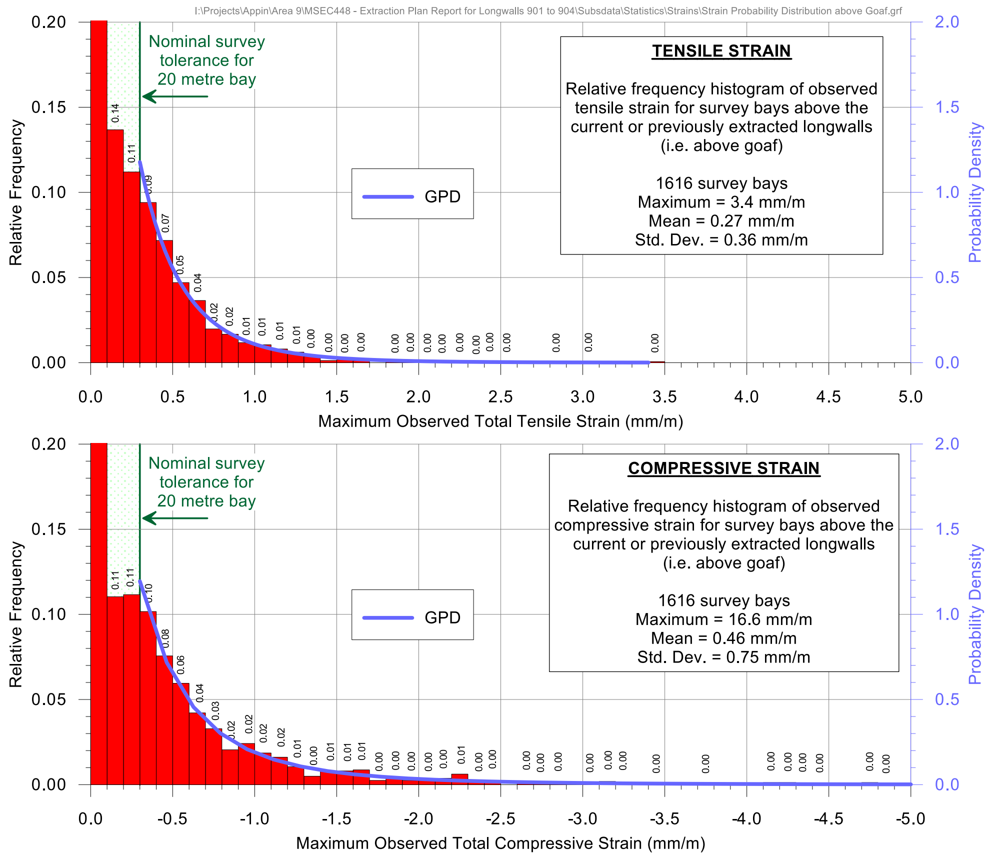

Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield for Bays Located Above Goaf

Confidence levels have been determined from the empirical strain data using the GPD. 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 per longwall).

A summary of the probabilities of exceedance for tensile and compressive strains for survey bays located above goaf, based on the fitted GPDs, is provided in Table 4.4.

Table 4.4 Probabilities of Exceedance for Strain for Survey Bays above Goaf

Strain (mm/m)		Probability of Exceedance
Compression	-6.0	1 in 500
	-4.0	1 in 175
	-2.0	1 in 35
	-1.0	1 in 10
	-0.5	1 in 3
	-0.3	1 in 2
Tension	+0.3	1 in 3
	+0.5	1 in 6
	+1.0	1 in 25
	+2.0	1 in 200
	+3.0	1 in 1,100

The 95 % confidence levels for the maximum total strains that the individual survey bays above goaf experienced at any time during mining were 0.9 mm/m tensile and 1.6 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays above goaf experienced at any time during mining were 1.6 mm/m tensile and 3.2 mm/m compressive.

It is noted, that the maximum observed compressive strain of 16.6 mm/m, which occurred along the T-Line at the surface above Appin Longwall 408, was the result of movements along a low angle thrust fault which daylighted above the Cataract Tunnel. All remaining compressive strains were less than 7 mm/m. The inclusion of the strain at the fault above Appin Longwall 408 has a substantial influence on the probabilities of exceeding the strains provided in Table 4.4, particularly at the high magnitudes of strain.

The probabilities for survey bays located above goaf are based on the strains measured anywhere above the previously extracted longwalls in the Southern Coalfield. As described previously, tensile strains are more likely to develop in the locations of hogging curvature and compressive strains are more likely to develop in the locations of sagging curvature.

This is illustrated in Fig. 4.2, which shows the distribution of incremental strains measured above previously extracted longwalls in the Southern Coalfield. The distances have been normalised, so that the locations of the measured strains are shown relative to the longwall maingate and tailgate sides. The approximate confidence levels for the incremental tensile and compressive strains are also shown in this figure, to help illustrate the variation in the data.

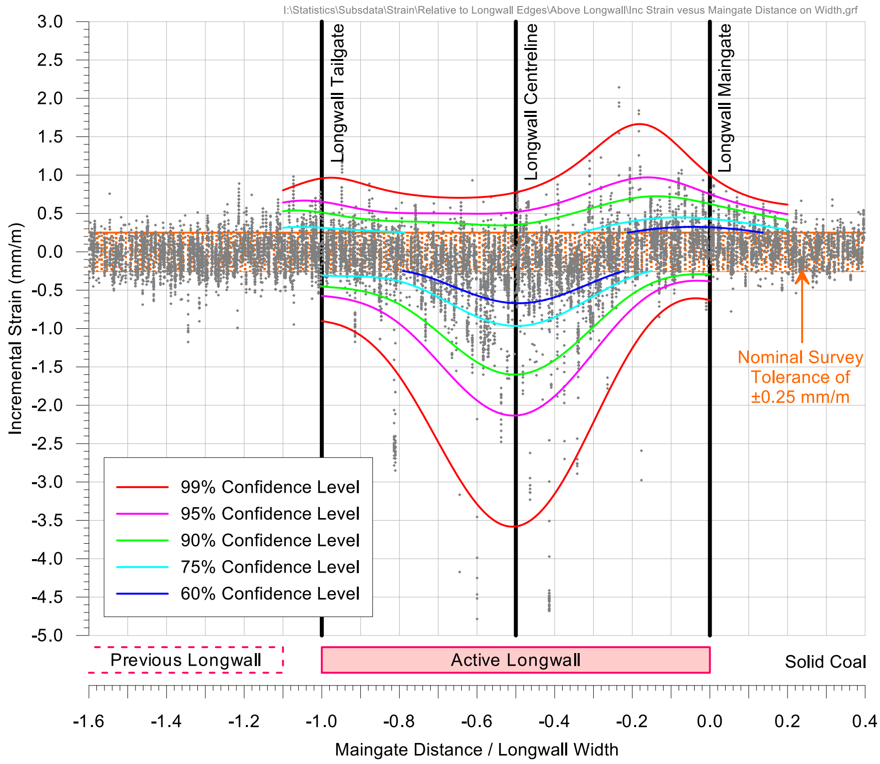

Fig. 4.2 Observed Incremental Strains versus Normalised Distance from the Longwall Maingate for Previously Extracted Longwalls in the Southern Coalfield

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls in the Southern Coalfield, for survey bays that were located outside and within 250 m of the nearest longwall goaf edge, which has been referred to as "*above solid coal*".

The histogram of the maximum observed tensile and compressive strains measured in survey bays above solid coal, for monitoring lines in the Southern Coalfield, is provided in Fig. 4.3. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

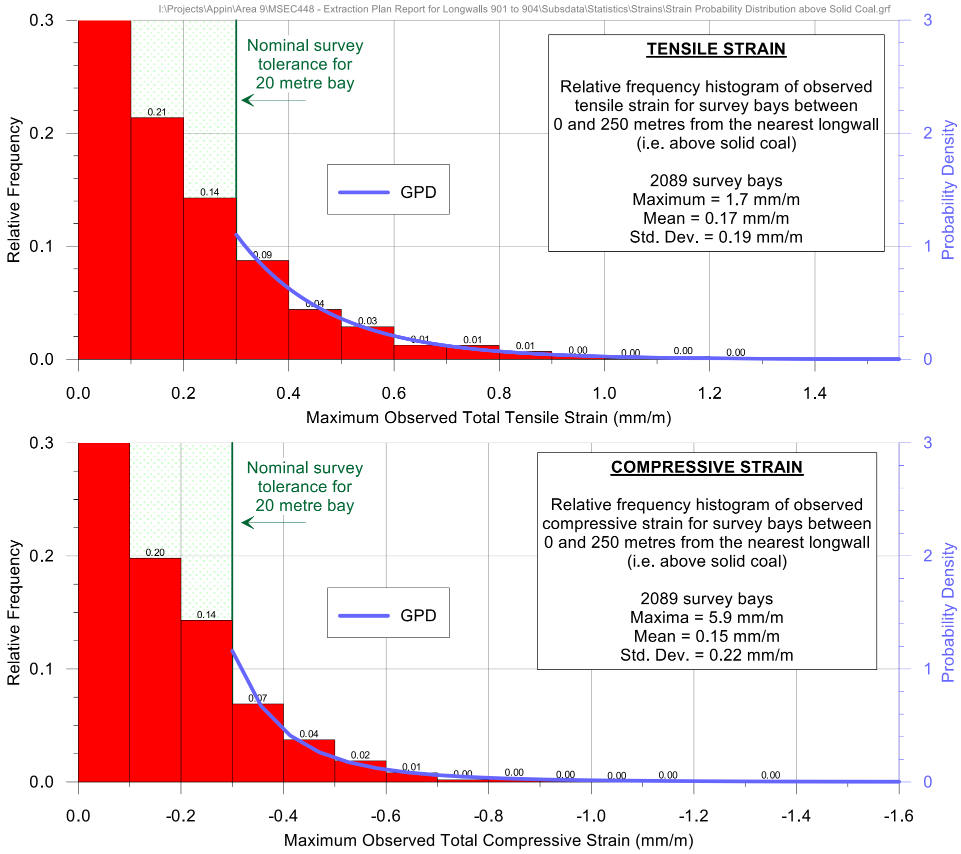

Fig. 4.3 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield for Bays Located Above Solid Coal

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during 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).

A summary of the probabilities of exceedance for tensile and compressive strains for survey bays located above solid coal, based the fitted GPDs, is provided in Table 4.5.

Table 4.5 Probabilities of Exceedance for Strain for Survey Bays Located above Solid Coal

Strain (mm/m)		Probability of Exceedance
Compression	-2.0	1 in 2,000
	-1.5	1 in 800
	-1.0	1 in 200
	-0.5	1 in 25
	-0.3	1 in 7
Tension	+0.3	1 in 5
	+0.5	1 in 15
	+1.0	1 in 200
	+1.5	1 in 2,500

The 95 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining were 0.6 mm/m tensile and 0.5 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 were 0.9 mm/m tensile and 0.8 mm/m compressive.

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 observed maximum strains along whole monitoring lines, rather than for individual survey bays. That is, an analysis of the maximum strains anywhere along the monitoring lines, regardless of where the strain actually occurs.

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

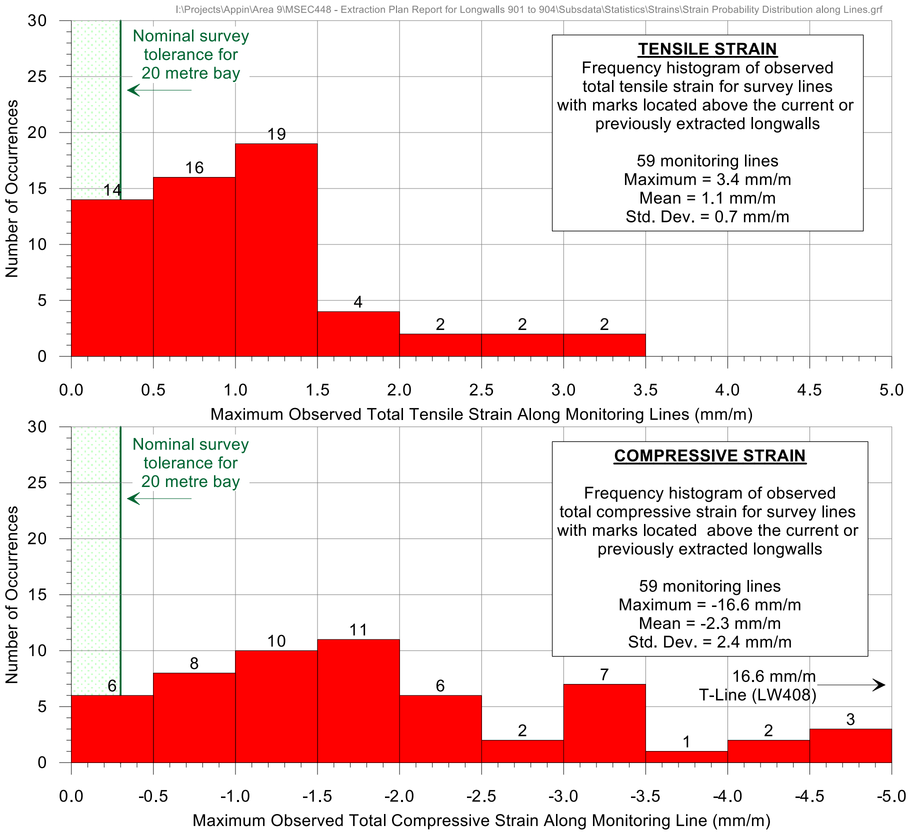

Fig. 4.4 Distributions of Measured Maximum Tensile and Compressive Strains along the Monitoring Lines during the Extraction of Previous Longwalls in the Southern Coalfield

It can be seen from Fig. 4.4, that 30 of the 59 monitoring lines (i.e. 51 %) have recorded maximum total tensile strains of 1.0 mm/m, or less, and that 53 monitoring lines (i.e. 89 %) have recorded maximum total tensile strains of 2.0 mm/m, or less. It can also be seen, that 35 of the 59 monitoring lines (i.e. 59 %) have recorded maximum compressive strains of 2.0 mm/m, or less, and that 51 of the monitoring lines (i.e. 86 %) have recorded maximum compressive strains of 4.0 mm/m, or less.

4.4.3. Analysis of Strains Resulting from Valley Closure Movements

The streams within the Study Area are expected to experience localised and elevated compressive strains resulting from valley related movements. The strains resulting from valley related movements are more difficult to predict than strains in flatter terrain, as they are dependent on many additional factors, including the valley shape and valley height, the valley geomorphology and the local geology in the valley base.

The predicted strains resulting from valley related movements, for the streams located directly above the proposed longwalls, have been determined using the monitoring data for longwalls which have previously mined directly beneath streams in the Southern Coalfield.

The relationship between total closure strain and total closure movement, based on monitoring data for longwalls which have previously mined directly beneath streams in the Southern Coalfield, is provided in Fig. 4.5. The confidence levels, based on the fitted GPDs, have also been shown in this figure.

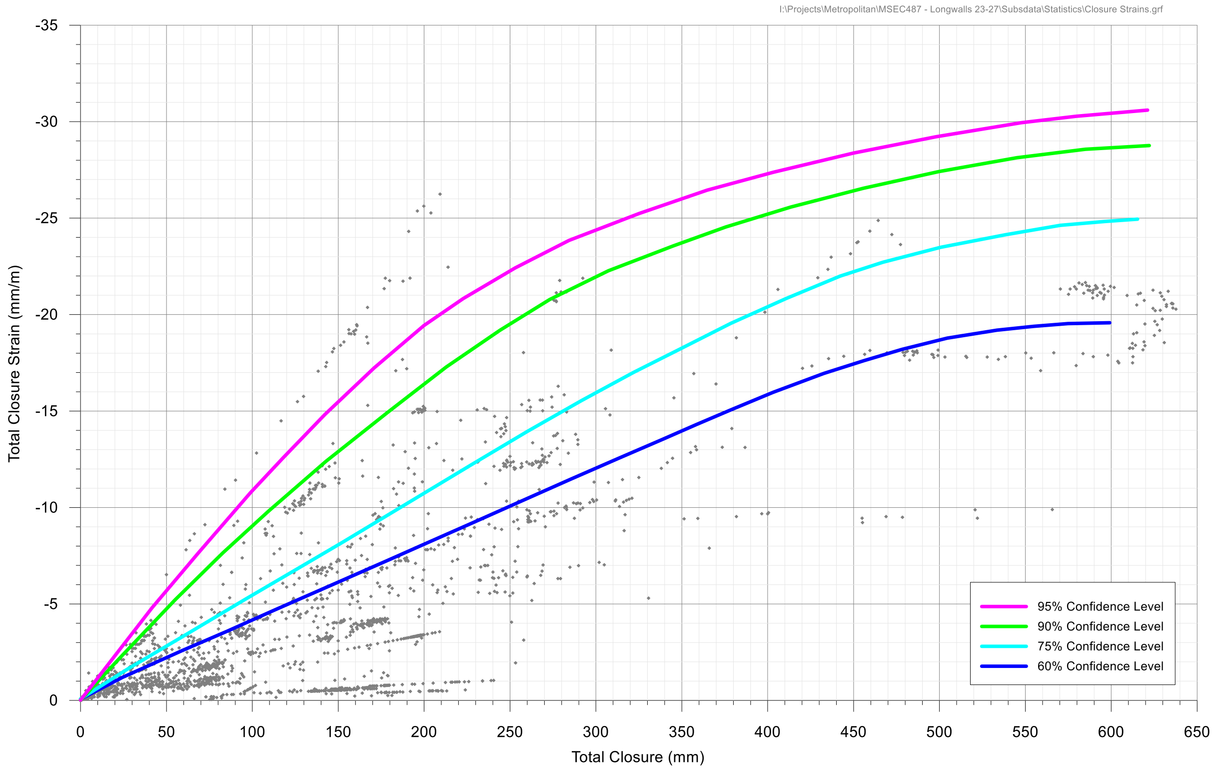

Fig. 4.5 Total Closure Strain versus Total Closure Movement Based on Monitoring Data for Streams Located Directly Above Longwalls in the Southern Coalfield

It can be seen from Fig. 4.5 that total compressive strains up to approximately 20 mm/m to 25 mm/m have been measured for total closures varying between approximately 150 mm to 650 mm. It should be noted, however, that the measured compressive strain is dependent on the length of the survey bay in which the strain was measured. Typical measurements and predictions of conventional strain are based on an approximate survey bay length of 20 m in the Southern Coalfield. Where survey lines are established across streams, for the purposes of measuring valley closure movements, they are often established with survey bay lengths shorter than 20 m in order to provide greater detail and these should not be compared to strain measurements and predictions based on 20 m bay lengths. The bay lengths for the data presented in Fig. 4.5 have been plotted below in a graph of bay length versus total closure and Fig. 4.6 has been reproduced to show the distribution of bay lengths.

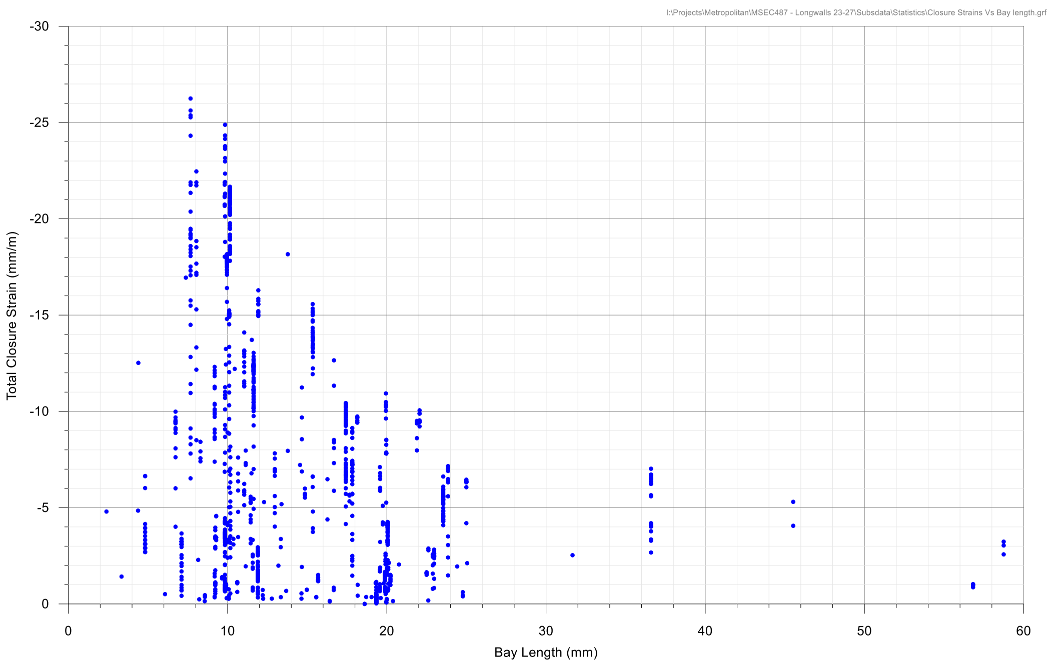

Fig. 4.6 Total Closure Strain versus Bay Length Based on Monitoring Data for Streams Located Directly Above Longwalls in the Southern Coalfield

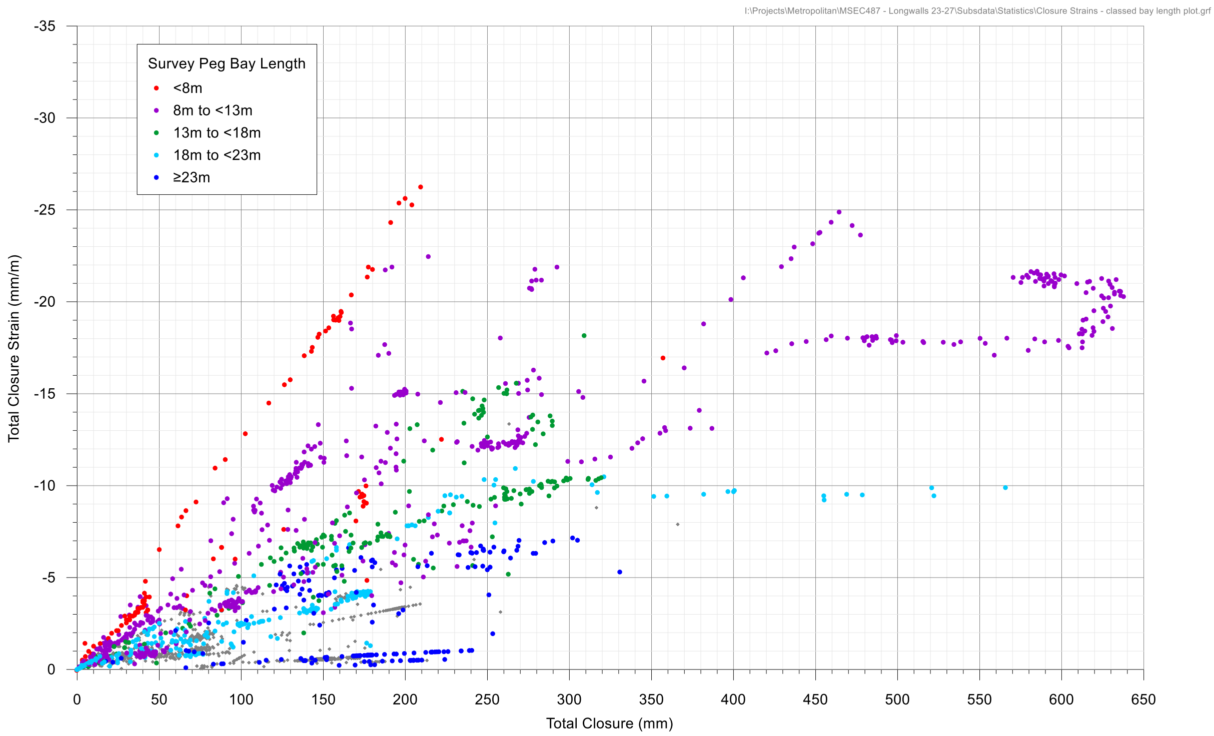

Fig. 4.7 Total Closure Strain versus Total Closure Movement Based on Monitoring Data for Streams Located Directly Above Longwalls in the Southern Coalfield

It can be seen from Fig. 4.6 and Fig. 4.7 that the majority of the data with high compressive strains has been measured over bay lengths much less than 20 m. The maximum measured compressive strain for an approximate 20 m bay length is 11 mm/m as indicated by the cyan coloured points in Fig. 4.7.

The reliability of the predicted valley related upsidence and closure movements is discussed in Section 3.8.

4.4.4. Analysis of Shear Strains

As described in Section 3.2, ground strain comprises two components, being normal strain and shear strain, which can be interrelated using Mohr's Circle. The magnitudes of the normal strain and shear strain components are, therefore, dependant on the orientation in which they are measured. The maximum normal strains, referred to as the principal strains, are those in the direction where the corresponding shear strain is zero.

Normal strains along monitoring lines can be measured using 2D and 3D techniques, by taking the change in horizontal distance between two points on the ground and dividing by the original horizontal distance between them. This provides the magnitude of normal strain along the orientation of the monitoring line and, therefore, this strain may not necessarily be the maximum (i.e. principal) normal strain.

Shear deformations are more difficult to measure, as they are the relative horizontal movements perpendicular to the direction of measurement. However, 3D monitoring techniques provide data on the direction and the absolute displacement of survey pegs and, therefore, the shear deformations perpendicular to the monitoring line can be determined. But, in accordance with rigorous definitions and the principles of continuum mechanics, (e.g. Jaeger, 1969), it is not possible to determine horizontal shear strains in any direction relative to the monitoring line using 3D monitoring data from a straight line of survey marks.

As described in Section 3.2, shear deformations perpendicular to monitoring lines can be described using various parameters, including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. In this report, mid-ordinate deviation has been used as the measure for shear deformation, which is defined as the differential horizontal movement of each survey mark, perpendicular to a line drawn between two adjacent survey marks.

The frequency distribution of the maximum mid-ordinate deviation measured at survey marks above goaf, for previously extracted longwalls in the Southern Coalfield, is provided in Fig. 4.8. As the typical bay length was 20 m, the calculated mid-ordinate deviations were over a chord length of 40 m. The probability distribution function, based on the fitted GPD, has also been shown in this figure.

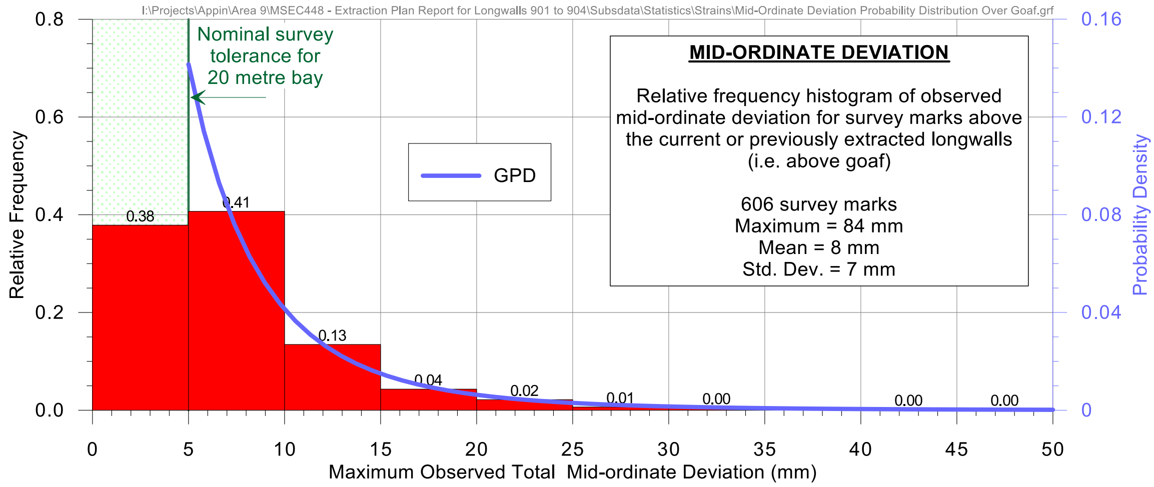

Fig. 4.8 Distribution of Measured Maximum Mid-ordinate Deviation during the Extraction of Previous Longwalls in the Southern Coalfield for Marks Located Above Goaf

A summary of the probabilities of exceedance for horizontal mid-ordinate deviation for survey bays located above goaf, based the fitted GPD, is provided in Table 4.6.

Table 4.6 Probabilities of Exceedance for Mid-Ordinate Deviation for Survey Marks above Goaf for Monitoring Lines in the Southern Coalfield

Horizontal Mid-ordinate Deviation (mm)		Probability of Exceedance
Mid-ordinate Deviation over 40 m Chord Length	10	1 in 4
	20	1 in 20
	30	1 in 70
	40	1 in 175
	50	1 in 400
	60	1 in 800
	70	1 in 1,400
	80	1 in 2,300

The 95 % and 99 % confidence levels for the maximum total horizontal mid-ordinate deviation that the individual survey marks located above goaf experienced at any time during mining were 20 mm and 35 mm, respectively.

4.5. Predicted Conventional Horizontal Movements

The predicted conventional horizontal movements over the proposed Longwall 304 are calculated by applying a factor to the predicted conventional tilt values. In the Southern Coalfield a factor of 15 is generally adopted, being the same factor as that used to determine conventional strains from curvatures, and this has been found to give a reasonable correlation with measured data. 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 proposed Longwall 304, is 5.0 mm/m. The maximum predicted conventional horizontal movement is, therefore, approximately 75 mm, i.e. 5 mm/m multiplied by a factor of 15.

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 the proposed longwalls, and the predicted valley related movements along the streams, it is also likely that far-field horizontal movements will be experienced during the extraction of the proposed longwalls.

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

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The data is based on survey marks located outside of the mining area (i.e. above solid coal). The confidence levels, based on fitted GPDs, have also been shown in this figure to illustrate the spread of the data.

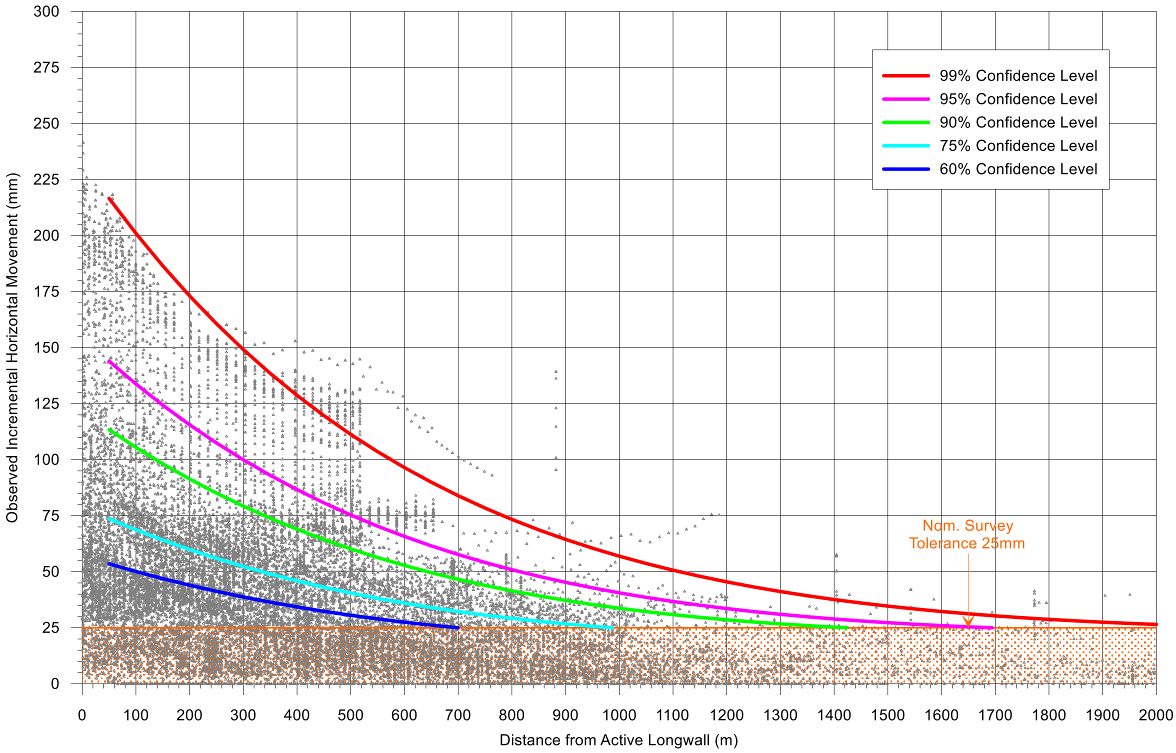

Fig. 4.9 Observed Incremental Far-Field Horizontal Movements from the Southern Coalfield (Solid Coal)

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

The predicted far-field horizontal movements resulting from the extraction of the proposed longwalls are small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area, and are accompanied by very low levels of strain, which are generally less than the order of survey tolerance. While the impacts of far-field horizontal movements on the natural and built features within the vicinity of the Study Area are not expected to be significant, there are structures which are sensitive to small differential movements, including the transmission towers and road bridges to the east of the proposed longwalls. These features are discussed further in Section 6.5 and Section 6.8.

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, steep topography and valley related movements, 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.

Specific predictions of upsidence, closure and compressive strain due to the valley related movements are provided for the streams in Sections 5.3 to 5.6. The impact assessments for the streams are based on both the conventional and valley related movements. The potential for non-conventional movements associated with steep topography is discussed in the impact assessments for the steep slopes provided in Section 5.11.

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 in the Southern Coalfield, 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.

The largest known case of non-conventional movement in the Southern Coalfield occurred above Appin Longwall 408. In this case, a low angle thrust fault was re-activated in response to mine subsidence movements, resulting in differential vertical and horizontal movements across the fault. Observations at the site showed that the non-conventional movements developed gradually and over a period of time. Regular ground monitoring across the fault indicated that the rate of differential movement was less than 0.5 mm per day at the time non-conventional movements could first be detected. Subsequently as mining progressed, the rate of differential movement increased to a maximum of 28 mm per week.

The development of strain at the low angle thrust fault, as measured along the T-Line during the extraction of Longwall 408, is illustrated in Fig. 4.10. Photographs of the anomalous ground movements associated with this fault are provided in the photographs in Fig. 4.11 and Fig. 4.12.

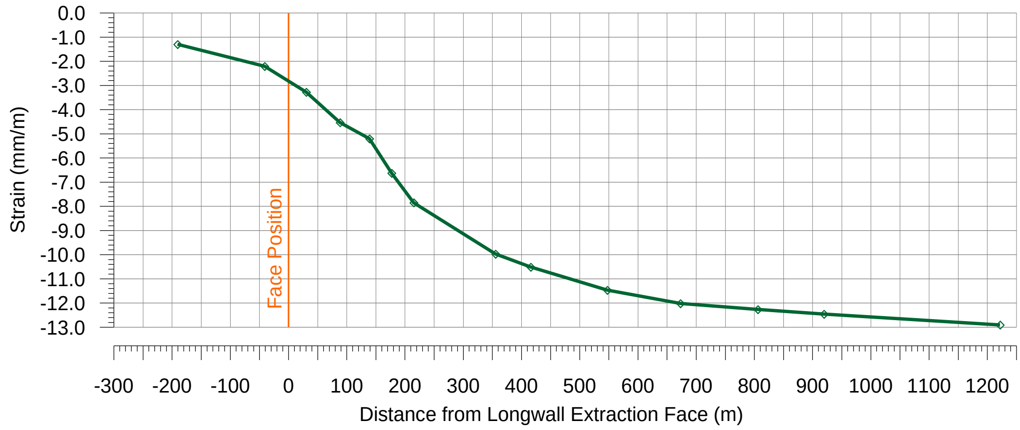

Fig. 4.10 Development of Strain at the Low Angle Thrust Fault Measured along the T-Line during the Extraction of Appin Longwall 408

Fig. 4.11 Surface Compression Humping due to Low Angle Thrust Fault

Fig. 4.12 Surface Compression Humping due to Low Angle Thrust Fault

The developments of strain at anomalies identified in the Southern Coalfield and elsewhere, excluding the low angle thrust fault discussed previously, are illustrated in Fig. 4.13. It can be seen from this figure, that the non-conventional movements develop gradually. For these cases, the maximum rate of development of anomalous strain was 2 mm/m per week. Based on the previous experience of longwall mining in the Southern Coalfield and elsewhere, it has been found that non-conventional anomalous movements can be detected early by regular ground monitoring and visual inspections.

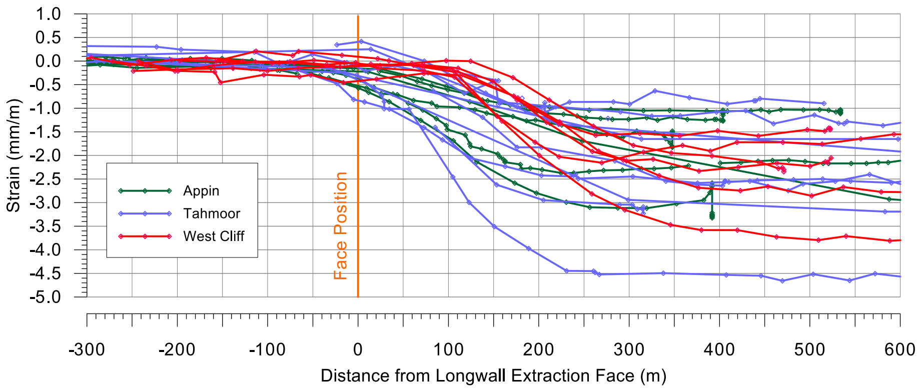

Fig. 4.13 Development of Non-Conventional Anomalous Strains in the Southern Coalfield

A study of anomalies for the majority of ground survey data within the Southern Coalfield was undertaken in 2006 by MSEC. Forty-one (41) monitoring lines were examined for anomalies, which represent a total of 58.2 km of monitoring lines, and approximately 2,980 survey pegs. The monitoring lines crossed over 75 longwalls. The selected lines represented all the major lines over the subsided areas, and contained comprehensive information on subsidence, tilt and strain measurements. A total of 20 anomalies were detected, of which 4 were considered to be significant. The observed anomalies affected 41 of the approximately 2,980 survey pegs monitored. This represented a frequency of 1.4 %.

The above estimates are based on ground survey data that crossed only a small proportion of the total surface area affected by mine subsidence. Recent mining beneath urban and semi-rural areas at Tahmoor and Thirlmere by Tahmoor Colliery Longwalls 22 to 25 provides valuable “whole of panel” information. A total of approximately 35 locations (not including valleys) have been identified over the four extracted longwalls. The surface area directly above the longwalls is approximately 2.56 km^2. This equates to a frequency of 14 sites per square kilometre or one site for every 7 hectares.

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 jointing in the bedrock and the presence of near surface geological structures.

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

Surface cracking in soils as a result of conventional subsidence movements is not commonly observed where the depths of cover are greater than say 400 m, and any cracking that has been observed has generally been isolated and of a minor nature.

Cracking is found more often in the bases of stream valleys due to the compressive strains associated with upsidence and closure movements. The likelihood and extent of cracking along the streams within the Study Area are discussed in Sections 5.3 to 5.6. Cracking can also occur at the tops and on the sides of steep slopes as a result of downslope movements.

Surface cracks are more readily observed in built features such as road pavements. In the majority of these cases no visible ground deformations can be seen in the natural ground adjacent to the cracks in the road pavements. In rare instances more noticeable ground deformations, such as humping or stepping of the ground can be observed at thrust faults. Examples of ground deformations previously observed in the Southern Coalfield, where the depths of cover exceed 400 m, are provided in the photographs in Fig. 4.14 to Fig. 4.17 below.

Fig. 4.14 Surface Compression Buckling Observed in a Pavement

Fig. 4.15 Surface Tension Cracking along the Top of a Steep Slope

Fig. 4.16 Surface Tension Cracking along the Top of a Steep Slope

Fig. 4.17 Fracturing and Bedding Plane Slippage in Sandstone Bedrock in the Base of a Stream

Localised ground buckling and shearing can occur wherever faults, dykes and abrupt changes in geology occur near the ground surface. The identified geological structures at seam level within the Study Area are discussed in Section 1.5. Discussions on irregular ground movements are provided in Section 4.7.

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The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the natural features located within the Study Area for Longwall 304 and selected features located outside the Study Area. The predicted parameters for each of the natural features have been compared to the predicted parameters based on the Preferred Project 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:

- springs;
- seas or lakes;
- shorelines;
- natural dams;
- escarpments;
- national parks;
- state forests;
- state recreation or conservation areas;
- areas of significant geological interest; and
- other significant natural features.

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

5.2. Catchment Areas and Declared Special Areas

The Study Area lies within the Woronora Special Area, which is controlled by WaterNSW. The Study Area also lies partly within the Dams Safety Committee (DSC) Notification Area for the Woronora Reservoir, which is also known as Lake Woronora.

The boundary of the DSC Notification Area is shown in Drawing No. MSEC1009-07. The proposed Longwall 304 is located within the DSC Notification Area. The Woronora Special Area provides the main water supply for the Sutherland region, via the Woronora Reservoir.

The Woronora Reservoir full supply level occurs within the Study Area and the main body of the Woronora Reservoir is located to the west and south-west of Longwall 304. Longwall 304 does not extend beneath the Woronora Reservoir. Subsidence predictions and impact assessments for the Woronora Reservoir full supply level are provided in Section 5.5.

5.3. Waratah Rivulet

The Waratah Rivulet is located over 1.1 km south west of Longwall 304, at its closest point.

At this distance, the rivulet is outside the 35° angle of draw and is not predicted to experience measurable conventional subsidence resulting from the extraction of Longwall 304. The predicted valley related movements resulting from these longwalls are less than 20 mm upsidence and less than 20 mm closure. The strains due to the valley related effects are not expected to be measurable.

It is unlikely, therefore, that the Waratah Rivulet would experience adverse impacts resulting from the extraction of Longwall 304, even if the predictions were exceeded by a factor of two times.

5.4. The Eastern Tributary

5.4.1. Description of the Eastern Tributary

The Eastern Tributary flows in an approximate south to north direction into the Full Supply Level of the Woronora Reservoir to the south of the Study Area.

The Eastern Tributary flows into the Woronora Reservoir Full Supply Level approximately 390 m to the south of Longwall 304.

5.4.2. Predictions for the Eastern Tributary

As described in Section 1, Metropolitan Coal has applied for approval for an additional 182 m of secondary extraction in Longwall 303 (i.e. a Longwall 303 void length of 1,325 m). Predictions are provided for the Eastern Tributary for the Extraction Plan Layout (which includes the proposed additional 182 m of secondary extraction in Longwall 303) as well as an Alternative Layout. The Alternative Layout is based on the proposed additional 182 m of Longwall 303 not being approved, as well as a 58 m reduction in the length of Longwall 304 compared to the Extraction Plan Layout.

The predicted profiles of vertical subsidence, upsidence and closure along the Eastern Tributary (to the Woronora Reservoir Full Supply Level), resulting from the extraction of Longwall 304 (based on the Extraction Plan Layout), are shown in Fig. C.02a, in Appendix C. Fig. C.02b shows the predicted profiles along the Eastern Tributary, based on the extraction of the Alternative Layout. The predicted incremental profiles along the Eastern Tributary/Woronora Reservoir Full Supply Level, due to the extraction of Longwall 304, are shown as dashed black lines. The predicted total profiles are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as the solid red lines for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the Eastern Tributary, resulting from the Extraction Plan and Alternative Layouts, is provided in Table 5.1. The values are the predicted maxima at the location where the Eastern Tributary meets the Woronora Reservoir Full Supply Level, which is located immediately south of the Study Area. Subsidence predictions for the Extraction Plan and Alternative Layouts for extraction of Longwalls 304 to 308 are presented in Attachment 1.

Table 5.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Eastern Tributary Resulting from the Extraction of Longwall 304

Longwall	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})
LW304 Extraction Plan Layout				
After LW303	40	< 0.5	< 0.01	< 0.01
After LW304	40	< 0.5	< 0.01	< 0.01
Alternative Layout[1]				
After LW303	35	< 0.5	< 0.01	< 0.01
After LW304	35	< 0.5	< 0.01	< 0.01

[1] Longwall 303 length of 1,143 m and Longwall 304 length of 1,227 m.

The maximum predicted conventional tilt for the Eastern Tributary based on the Extraction Plan Layout is less than 0.5 mm/m (i.e. 0.05 %, or 1 in 2,000), which is orientated across its alignment (i.e. towards Longwall 304). The maximum predicted conventional curvatures are less than 0.01 km^{-1} hogging and sagging, which equate to minimum radii of curvature of greater than 100 km. The predicted conventional strains for the Eastern Tributary based on the Extraction Plan Layout (based on 15 times the curvature) are less than 0.5 mm/m tensile and compressive.

A summary of the maximum predicted values of total upsidence and closure for the Eastern Tributary at the location where the Eastern Tributary meets the Woronora Reservoir Full Supply Level, resulting from the Extraction Plan and Alternative Layouts, is provided in Table 5.2. The compressive strains due to valley closure effects have also been provided (based on Section 4.4.3). Cumulative subsidence predictions for the Extraction Plan and Alternative Layouts for extraction of Longwalls 304 to 308 are presented in Attachment 1.

Table 5.2 Maximum Predicted Total Upsidence, Closure and Compressive Strain for the Eastern Tributary Resulting from the Extraction of Longwalls 303 and 304

Longwall	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Closure Strain based on the 90 % Confidence Level (mm/m)	Maximum Predicted Closure Strain based on the 95 % Confidence Level (mm/m)
LW304 Extraction Plan Layout				
After LW303	30	50	5	6
After LW304	50	70	7	8
Alternative Layout				
After LW303	< 20	20	3	3
After LW304	30	50	5	6

The method used to predict the valley related compressive strains is based on the measured strains for streams that were located directly above the longwalls. The Eastern Tributary is located above solid coal therefore actual valley related compressive strains are expected to be less than those provided in Table 5.2.

A summary of the predicted valley closure for Pools ETAS/ETAT and ETAU resulting from the Extraction Plan and Alternative Layouts is provided in Table 5.3. Subsidence predictions for the Extraction Plan and Alternative Layouts for extraction of Longwalls 304 to 308 are presented in Attachment 1.

Table 5.3 Maximum Predicted Total Closure at Rockbars Downstream of Pools ETAS/ETAT and ETAU

Rockbar	Maximum Predicted Total Closure after LW303 (mm)	Maximum Predicted Total Closure after LW304 (mm)
LW304 Extraction Plan Layout		
ETAS/ETAT	50	70
ETAU	40	70
Alternative Layout		
ETAS/ETAT	40	60
ETAU	30	50

The additional predicted total closure due to the extraction of Longwall 304 based on the Extraction Plan layout at Pools ETAS/ETAT and ETAU is 20 mm and 30 mm respectively.

5.4.3. Comparison of the Predictions for the Eastern Tributary

The comparison of the maximum predicted subsidence parameters for the Eastern Tributary, resulting from the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.4. The values are the predicted maxima at the location where the Eastern Tributary meets the Woronora Reservoir Full Supply Level, to the immediate south of the Study Area.

Table 5.4 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Eastern Tributary based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Vertical Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Preferred Project Layout (After LW304) (Report No. MSEC403)	325	300	200
Extraction Plan Layout (Report No. MSEC1009)	40	50	70

The maximum predicted vertical subsidence, upsidence and closure for the Eastern Tributary, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

The comparison of the maximum predicted closure for Pools ETAS/ETAT and ETAU, resulting from the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.5.

Table 5.5 Comparison of Maximum Predicted Closure for the Eastern Tributary Pools based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Closure (mm)	
	Pools ETAS/ETAU	Pool ETAU
Preferred Project Layout (After LW304) (Report No. MSEC403)	200	200
Extraction Plan Layout (Report No. MSEC1009)	70	70

The maximum predicted closure for Pools ETAS/ETAT and ETAU, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

5.4.4. Impact Assessments and Recommendations for the Eastern Tributary

The maximum predicted subsidence parameters for the Eastern Tributary, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

Previous assessments of stream impacts for the Waratah Rivulet, Eastern Tributary and other tributaries at Metropolitan Colliery have used a relationship between predicted total closure at rock bars and proportion of impacted pools for streams in the Southern Coalfield. The relationship identified approximately 10% of pools were impacted at a predicted total valley closure of up to 200mm. Impacts to some pools along the Eastern Tributary have occurred at predicted values of total valley closure of less than 200 mm resulting in a higher proportion of impacted pools at lower magnitudes of predicted total valley closure. The predicted valley closure impact relationship is not used for the extraction of Longwall 304 and an adaptive management approach will instead be adopted as described below.

As a result of the observed impacts to the Eastern Tributary, the finishing ends of Longwalls 303 and 304 have been set back to minimise predicted valley closure at the Eastern Tributary. Metropolitan Colliery have established a comprehensive monitoring and adaptive management program to identify subsidence related movements at the Eastern Tributary during the extraction of Longwall 303 and the same monitoring and adaptive management program will be used for the extraction of Longwall 304. Similar monitoring of subsidence movements using high resolution survey methods has been successfully implemented for the Sandy Creek Waterfall at the Dendrobium Coal Mine by South32.

To implement the monitoring and adaptive management approach, Metropolitan Coal has substantially increased the terrestrial subsidence survey monitoring measures for the Eastern Tributary. Subsidence survey monitoring for the Eastern Tributary TARP includes the following:

- Cross lines across rockbars downstream of Pools ETAQ, ETAR, ETAT and ETAU, with expected accuracy of closure measurement of ±2 mm.
- Three high resolution fixed lines, A Line, B Line and C Line, using prisms attached to sandstone across the base of the Eastern Tributary Valley near Pool ETAU. The lines are surveyed using a high precision total station. Expected accuracy for these lines is ±1 mm.
- Three real time Global Navigation Satellite System, GNSS, monitoring stations providing real time closure monitoring around Pool ETAU, with telemetry and trend monitoring. The expected accuracy of measurement between GNSS stations is ±10 mm.

In addition, a high accuracy Leica total station has been commissioned to improve the accuracy and repeatability of surveyed data.

A Technical Committee will review the results of the monitoring program and report to the Colliery in accordance with a Trigger Action Response Plan for decisions by the Colliery on adaptive management for Longwall 304.

5.5. Woronora Reservoir

5.5.1. Description of the Woronora Reservoir

The Woronora Reservoir Full Supply Level is located inside the Study Area to the west and south west of Longwall 304. The area of the Full Supply Level to the south west and immediately downstream of the Eastern Tributary is referred to as an inundation area. When the Woronora Reservoir is at full capacity, this area is flooded. When the water level is below the Full Supply Level, portions of the inundation area form temporary pools above exposed rock bars that would normally be covered at the Full Supply Level. Longwall 304 does not extend beneath the Woronora Reservoir Full Supply Level.

5.5.2. Predictions for the Woronora Reservoir

The predicted profiles of vertical subsidence, upsidence and closure for the Woronora Reservoir Full Supply Level, resulting from the extraction of Longwall 304 (based on the Extraction Plan Layout), are shown in Fig. C.02a, in Appendix C. Fig. C.02b shows the predicted profiles for the Woronora Reservoir Full Supply Level, based on the extraction of the Alternative Layout. The predicted incremental profiles along the Eastern Tributary/Woronora Reservoir Full Supply Level, due to the extraction of Longwall 304, are shown as dashed black lines. The predicted total profiles are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as the solid red lines for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the Woronora Reservoir Full Supply Level, resulting from the Extraction Plan Layout is provided in Table 5.6. The values are the predicted maxima within the Study Area.

Table 5.6 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Woronora Reservoir Full Supply Level Resulting from the Extraction of Longwall 304

Longwall	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})
LW304 Extraction Plan Layout				
After LW303	40	< 0.5	< 0.01	< 0.01
After LW304	40	< 0.5	< 0.01	< 0.01

The maximum predicted conventional tilt for the Woronora Reservoir Full Supply Level based on the Extraction Plan Layout is less than 0.5 mm/m (i.e. 0.05 %, or 1 in 2,000). The maximum predicted conventional curvatures are less than 0.01 km^{-1} hogging and sagging, which equate to minimum radii of curvature of greater than 100 km. The predicted conventional strains for the Woronora Reservoir Full Supply Level based on the Extraction Plan Layout (based on 15 times the curvature) are less than 0.5 mm/m tensile and compressive.

A summary of the maximum predicted values of total upsidence and closure for the Woronora Reservoir Full Supply Level, resulting from the Extraction Plan Layout, is provided in Table 5.7. The compressive strains due to valley closure effects have also been provided (based on Section 4.4.3).

Table 5.7 Maximum Predicted Total Upsidence, Closure and Compressive Strain for the Woronora Reservoir Full Supply Level Resulting from the Extraction of Longwalls 303 and 304

Longwall	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Closure Strain based on the 90 % Confidence Level (mm/m)	Maximum Predicted Closure Strain based on the 95 % Confidence Level (mm/m)
LW304 Extraction Plan Layout				
After LW303	20	30	3	4
After LW304	50	90	8	10

The method used to predict the valley related compressive strains is based on the measured strains for streams that were located directly above the longwalls. The Woronora Reservoir Full Supply Level is located above solid coal therefore actual valley related compressive strains are expected to be less than those provided in Table 5.7.

5.5.3. Comparison of the Predictions for the Woronora Reservoir

The comparison of the maximum predicted subsidence parameters for the Woronora Reservoir Full Supply Level, resulting from the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.8. The values are the predicted maxima within the Study Area.

Table 5.8 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Woronora Reservoir Full Supply Level based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Vertical Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Preferred Project Layout (After LW304) (Report No. MSEC403)	475	800	825
Extraction Plan Layout (Report No. MSEC1009)	40	50	90

The maximum predicted vertical subsidence, upsidence and closure for the Woronora Reservoir Full Supply Level, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

5.5.4. Impact Assessments and Recommendations for the Woronora Reservoir

The maximum predicted subsidence parameters for the Woronora Reservoir Full Supply Level, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

The longwalls for the Preferred Project Layout extended beneath the Woronora Reservoir as shown in Fig. 1.1. With the modifications to Longwalls 301 to 304, longwall extraction does not extend beneath the Woronora Reservoir and there is a significant reduction in the predicted subsidence parameters as shown in in Fig. C.02a and Table 5.8. As a result, there is a much lower likelihood of impacts due to the Extraction Plan Layout compared to impacts assessed for the Preferred Project Layout.

5.6. Other Tributaries

There are three watercourses located above Longwall 304, as shown in Drawing No. MSEC1009-07. These watercourses consist of shallow drainage lines from the topographical high point above Longwalls 301-303, forming tributaries where valley heights increase and drain into the Woronora Reservoir to the west of the longwalls.

The three watercourses are located directly above Longwall 304 and could, therefore, experience the full range of predicted subsidence movements, as summarised in Table 4.1. The maximum predicted subsidence parameters, based on the Extraction Plan Layout, therefore, are similar to the maxima based on the Preferred Project Layout, as summarised in Table 4.3.

The shallow drainage lines above the northern and southern ends of Longwall 304 have small valley heights of generally less than 10 m and are predicted to experience small magnitudes of predicted upsidence and closure. The valley heights increase at the lower reaches. The largest valley height is located above the middle of Longwall 304. This drainage line is predicted to experience maximum total closure due to Longwall 304 of 350 mm near the Longwall 304 maingate for the Extraction Plan Layout.

The overall potential impacts on the tributaries above Longwall 304, based on the Extraction Plan Layout, are the same as those assessed for the Preferred Project Layout. A summary of potential impacts to the tributaries is provided below:

- Cracking in the bedrock along base of the tributaries and fracturing and dilation of the underlying strata above and immediately adjacent to the proposed longwalls;
- Leakage from pools where cracking in the bedrock occurs; and
- Potential loss of surface water flow by diversion through subsurface fractures.

The total length of tributaries affected by subsidence, based on the Extraction Plan Layout, is less than that based on the Preferred Project Layout. This reduction is due to the shortened overall lengths of the longwalls.

5.7. Aquifers and Known Groundwater Resources

The aquifers and groundwater resources within the vicinity of the proposed longwalls have been described in the Groundwater Assessment report by Dr Noel Merrick (Heritage Computing) (2008) in Appendix B of the Metropolitan Coal Project EA.

Descriptions of the aquifers and known groundwater resources within the study area are provided in the Metropolitan Coal Longwall 304 Water Management Plan.

5.8. Natural Dams

There are no natural dams within the Study Area. There are natural pools in the Eastern Tributary and streams described in Sections 5.4 and 5.6.

5.9. Cliffs and Overhangs

The locations of the cliffs and overhangs within the Study Area and surrounds are shown in Drawing No. MSEC1009-07. There is one cliff identified within the Study Area (COH17), located approximately 280 m to the south of Longwall 304. The descriptions, predictions and impact assessments for cliff COH17 is provided in the following sections.

5.9.1. Descriptions of the Cliffs and Overhangs

Consistent with the Project Approval, cliffs have been defined as a continuous rock face, including overhangs, having a minimum height of 10 metres and a slope of greater than 66° (2 to 1). The locations of the cliffs were determined from site inspections and from an aerial laser scan of the area. The cliffs and overhangs have formed within the Hawkesbury Sandstone.

Cliff COH17 is approximately 80 m in length and varies in height from 8 m to 11 m, with overhangs up to approximately 7 m in depth.

5.9.2. Predictions for the Cliffs

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for Cliff COH17, resulting from the Extraction Plan Layout, is provided in Table 5.9. The predicted tilts provided in this table are the maxima after the completion of Longwall 304. The predicted curvatures are the maxima at any time during or after the extraction of Longwall 304.

Table 5.9 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Cliff COH17 Resulting from the Extraction of Longwall 304

Location	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})
COH17	40	< 0.5	< 0.01	< 0.01

The predicted strains for Cliff COH17 is provided in Table 5.10. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 5.10 Predicted Strains for Cliff COH17 based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature	Non-conventional based on the 95 % Confidence Level	Non-conventional based on the 99 % Confidence Level
Tension	< 0.5	0.6	0.9
Compression	< 0.5	0.5	0.8

5.9.3. Comparison of the Predictions for the Cliffs

A summary of the maximum predicted vertical subsidence, tilt and curvature for Cliff COH17 is provided in Table 5.11.

Table 5.11 Comparison of Maximum Predicted Conventional Subsidence Parameters for Cliff COH17 based on the Extraction Plan Layout and the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	500	1.0	0.01	0.03
Preferred Project Layout (After LW304) (Report No. MSEC403)	350	2.5	0.01	0.03
Extraction Plan Layout (Report No. MSEC1009)	40	< 0.5	< 0.01	< 0.01

It can be seen from Table 5.11, that the maximum predicted conventional subsidence, tilt and curvature for Cliff COH17, based on the Extraction Plan Layout, are less than the maxima based on the Preferred Project Layout.

5.9.4. Impact Assessments for the Cliffs

The predicted subsidence parameters at Cliff COH17 due to the extraction of Longwall 304 based on the Extraction Plan Layout are lower than those based on the Preferred Project Layout. The reduction is due to the shortening of Longwall 304 at the finishing end. The cliff is predicted to experience low magnitudes of subsidence and tilt and curvatures less than typical survey accuracy.

Although isolated rock falls have been observed over solid coal outside the extracted goaf areas of longwall mining in the Southern Coalfield, there have been no recorded cliff instabilities outside the extracted goaf areas of longwall mining in the Southern Coalfield. It is possible that isolated rock falls could occur as a result of the extraction of the proposed longwalls. It is not expected, however, that any large cliff instabilities would occur as a result of the extraction of the longwalls, as the longwalls are not proposed to be extracted directly beneath the cliffs and overhangs.

5.10. Rock Ledges

There are rock ledges, also called rock outcrops and minor cliffs, located across the Study Area.

The rock ledges will experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence parameters for the rock ledges, based on the Extraction Plan Layout, therefore, are similar to the maxima based on the Preferred Project Layout, as summarised in Table 4.3.

The potential impacts on the rock ledges, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Preferred Project Layout, specifically, the potential for fracturing of sandstone and subsequent rockfalls, particularly where the rocks ledges are marginally stable.

5.11. Steep Slopes

The locations of steep slopes are shown on Drawing No. MSEC1009-07. Steep slopes are presented based on the definition used in the subsidence assessment for the EA and MSEC285 Report (a natural gradient between 18° and 63°) and also based on the definition in the Project Approval 08_0149 (a natural gradient between 33° and 66°).

There are steep slopes located above Longwall 304. The natural gradients for the steep slopes within the Study Area are typically up to 1 in 2, with some isolated areas with natural gradients up to 1 in 1.5.

The steep slopes 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 the steep slopes, based on the Extraction Plan Layout, therefore, are similar to the maxima based on the Preferred Project Layout, as summarised in Table 4.3.

The potential impacts on the steep slopes, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Preferred Project Layout. The potential for ground surface cracking, is discussed in Section 4.8. The size and extent of surface cracking at the steep slopes is expected to be similar to that observed during the extraction of earlier longwalls at Metropolitan Coal.

5.12. Land Prone to Flooding and Inundation

No major natural flood prone areas have been identified within the Study Area.

An area was defined in Sections 2.3.12 and 5.4 in the MSEC285 report between the Woronora Reservoir surface water level, and the full supply level as land prone to inundation. Photographs of the inundation area are shown in Fig. 5.1. When the Woronora Reservoir is at full capacity the inundation area is flooded. When the water level is below the full supply level, portions of the inundation area form temporary pools above exposed rock bars that would normally be covered when the reservoir is at full supply.

Fig. 5.1 Woronora Reservoir Inundation Area

The Woronora Reservoir full supply level is shown in Drawing No. MSEC1009-07. It can be seen from this drawing that a section of the full supply level is within the Study Area, measuring approximately 405 m in length. The full supply level is 250 m to the south west of Longwall 304 at its nearest point.

Predictions of subsidence, upsidence and closure for this section of the full supply level for the Extraction Plan Layout are shown Fig. C.02a and discussed in Section 5.5.

5.13. Swamps, Wetlands and Water Related Ecosystems

5.13.1. Descriptions of the Swamps

The locations of the swamps are shown in Drawing No. MSEC1009-07. The mapped extents of these swamps is based on field inspections and validation by Eco Logical Australia. There are 11 swamps located within the Study Area. There are a further four swamps that are located outside the Study Area and within 600 m of Longwall 304.

Detailed descriptions of the swamps within the study area are provided in the Metropolitan Coal Longwall 304 Biodiversity Management Plan.

5.13.2. Predictions for the Swamps

The maximum predicted subsidence parameters for each of the swamps located within the Study Area and within 600m of the Longwall 304 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 Preferred Project Layout (After LW304) and the Preferred Project Layout (After LW317), for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the swamps, resulting from the Extraction Plan Layout, is provided in Table 5.12. The predicted tilts provided in this table are the maxima after the completion of Longwall 304. The predicted curvatures are the maxima at any time during or after the extraction of Longwall 304.

Table 5.12 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Swamps within the Study Area Resulting from the Extraction of Longwall 304

Location	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})
S40	925	4.5	0.05	0.06
S41	1050	5.0	0.04	0.12
S46	1050	1.0	0.05	0.06
S47	850	4.0	0.03	0.03
S48	175	1.5	0.02	< 0.01
S49	450	4.5	0.05	< 0.01
S50	700	4.5	0.04	0.03
S51/S52	1000	3.5	0.04	0.04
S53	1050	3.0	0.05	0.05
S58	90	1.0	< 0.01	< 0.01
S69	< 20	< 0.5	< 0.01	< 0.01
S70	< 20	< 0.5	< 0.01	< 0.01
S71a	< 20	< 0.5	< 0.01	< 0.01
S71b	< 20	< 0.5	< 0.01	< 0.01
S72	< 20	< 0.5	< 0.01	< 0.01

The maximum predicted strains for the swamps located directly above Longwall 304 is provided in Table 5.13. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1). The compressive strains due to valley closure effects are provided separately.

Table 5.13 Maximum Predicted Strains for the Swamps Located directly above Longwall 304 based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature	Non-conventional based on the 95 % Confidence Level	Non-conventional based on the 99 % Confidence Level
Tension	1.0	0.9	1.6
Compression	2.0	1.6	3.2

A number of the swamps within the Study Area are located along the alignments of tributaries (shallow drainage lines) (based on Department of Lands mapping) and, therefore, could experience valley related effects. A summary of the maximum predicted upsidence and closure for these swamps, resulting from the extraction of Longwall 304, is provided in Table 5.14. The compressive strains due to valley closure effects have also been provided (based on Section 4.4.3).

Table 5.14 Maximum Predicted Total Upsidence, Closure and Valley Related Strain for the Swamps within the Study Area Resulting from the Extraction of Longwall 304

Location	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Closure Strain based on the 90 % Confidence Level (mm/m)	Maximum Predicted Closure Strain based on the 95 % Confidence Level (mm/m)
S51/S52	90	40	4	5
S53	90	40	4	5
S58	< 20	< 20	< 2	< 2

5.13.3. Comparison of the Predictions for the Swamps

The comparison of the maximum predicted subsidence parameters for the swamps within the Study Area and within 600m of Longwall 304, with those based on the Preferred Project Layout is provided in Table D.01, in Appendix D.

It can be seen from Table D.01 that the maximum predicted subsidence based on the Extraction Plan Layout is similar to or less than that based on the Preferred Project Layout at 7 of the 15 swamps. The increases in maximum predicted subsidence (at 8 of the 15 swamps) occur predominantly at the swamps located in the areas where pillar widths have been narrowed for the Extraction Plan Layout. The maximum predicted tilt is reduced or remains the same for 9 of the 15 swamps based on the Extraction Plan Layout. The maximum predicted total tilt increases at swamps S40, S47, S49, S50, S51/S52, and S53. The predicted hogging and sagging curvatures are reduced or unchanged for the majority of the swamps based on the Extraction Plan Layout (hogging curvature increases slightly at three swamps and sagging curvature increases at one swamp).

A summary of the maximum predicted vertical subsidence, tilt and curvature for the swamps within the Study Area is provided in Table 5.15. A summary of the maximum predicted upsidence and closure for the swamps within the Study Area is provided in Table 5.16.

Table 5.15 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Swamps based on the Extraction Plan Layout and the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1150	5.0	0.07	0.10
Preferred Project Layout (After LW304) (Report No. MSEC403)	825	5.0	0.06	0.10
Extraction Plan Layout (Report No. MSEC1009)	1050	5.0	0.05	0.12

Table 5.16 Comparison of Maximum Predicted Upsidence and Closure for the Swamps based on the Extraction Plan Layout and the Preferred Project Layout

Layout	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Preferred Project Layout (After LW317) (Report No. MSEC403)	100	40
Preferred Project Layout (After LW304) (Report No. MSEC403)	90	40
Extraction Plan Layout (Report No. MSEC1009)	90	40

It can be seen from Table 5.15, that the maximum predicted conventional tilt and hogging curvature for the swamps, based on the Extraction Plan Layout, are similar to, or less than the maxima based on the Preferred Project Layout after Longwall 304. The maximum predicted subsidence and sagging curvature for the Extraction Plan Layout is slightly greater than the maximum predicted based on the Preferred Project Layout after Longwall 304, however sagging curvature is greater for one swamp only (S41, Table D.01). The predicted parameters for the individual swamps increase or decrease, depending on their locations relative to Longwall 304.

It can be seen from Table 5.16, that the maximum predicted upsidence and closure for the swamps, based on the Extraction Plan Layout, are the same as the maxima predicted based on the Preferred Project Layout after Longwall 304.

5.13.4. Impact Assessments and Recommendations for the Swamps

Whilst the predicted subsidence parameters increase at a small number of swamps the maxima are similar to the maxima predicted for other swamps located above the previously extracted longwalls at the Colliery. The potential impacts for the swamps, based on the Extraction Plan Layout, therefore, are similar to those assessed based on the Preferred Project Layout.

Cracking of the bedrock within upland swamps is expected to be isolated and of a minor nature, due to the relatively low magnitudes of the predicted curvatures and strains and the relatively high depths of cover. The minor cracking within the swamps would generally not be expected to propagate through swamp soil profiles.

Whilst swamp grades vary naturally, the predicted maximum mining-induced tilts are generally an order of magnitude lower than the existing natural grades within the swamps. The predicted tilts would not be expected to have a significant effect on the localised or overall gradient of the swamps or the flow of surface water.

The three swamps listed in the performance measures in the Project Approval 08_0149 (Swamps 76, 77 and 92) are located greater than 1.5 km to the west of Longwall 304 and on the western side of the Woronora Reservoir. At this distance, these swamps are not predicted to experience measurable subsidence or valley related movements due to the extraction of Longwall 304.

5.14. Threatened, Protected Species or Critical Habitats

There are no lands within the Study Area that have been declared as critical habitat under the *Biodiversity Conservation Act 2016*. However, threatened and protected species and their habitats occur within the Study Area as described in the Longwall 304 Biodiversity Management Plan.

5.15. Natural Vegetation

The vegetation within the Study Area generally consists of native bushland. A detailed survey of the natural vegetation has been undertaken and is described in the Baseline Flora Survey report (Bangalay Botanical Surveys, April 2008) in Appendix E of the Metropolitan Coal Project EA.

Natural vegetation covers the majority of the Study Area. The natural vegetation could, therefore, experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence parameters for the natural vegetation, based on the Extraction Plan Layout, therefore, are similar to the maxima based on the Preferred Project Layout, as summarised in Table 4.3.

The potential impacts on the natural vegetation, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Preferred Project Layout.

5.16. Areas of Significant Geological Interest

There are no areas of significant geological interest within the Study Area. A brief description of the geology within the Study Area is provided in Section 1.5.

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 Longwall 304. The predicted parameters for each of the built features have been compared to the predicted parameters based on the Preferred Project Layout.

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

- Tunnels;
- Gas pipelines;
- Liquid fuel pipelines;
- Water and sewage treatment works; and
- Air strips.

6.1. Railways

There are no railways located within the Study Area. The Illawarra Railway is located at a minimum distance of 1.9 km to the north east of Longwall 304.

At this distance, the railway is not expected to experience measurable conventional vertical subsidence, tilts or curvatures. The railway could experience low level far-field horizontal movement. The far-field horizontal movements are expected to be similar to those observed for previous longwall mining in the Southern Coalfield.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The absolute horizontal movements measured at distances greater than 1.9 km from mining are in the order of survey tolerance of 25 mm based on the 95 % confidence level. Far-field horizontal movements tend to be bodily movements orientated towards the mining area. The strains associated with these low level horizontal movement are not expected to be measurable.

Whilst the railway could experience low level far-field horizontal movements, the associated tilts, curvatures or strains are not expected to be measurable. It is unlikely that the railway and associated infrastructure would experience adverse impacts as a result of Longwall 304.

The potential for impacts on the Illawarra Railway and associated infrastructure, based on the Extraction Plan Layout, are the same as those based on the Preferred Project Layout. It is expected that the Illawarra Railway would be maintained in a safe and serviceable condition during and after mining.

6.2. M1 Princes Motorway

The M1 Princes Motorway is located to the east of Longwall 304 and is shown on Drawing No. MSEC1009-08. The distance of the M1 Princes Motorway from Longwall 304 varies from 850 m near the finishing (southern) end to 930 m near the commencing (northern) end.

At this distance, the M1 Princes Motorway is not expected to experience measurable conventional vertical subsidence, tilts or curvatures. The M1 Princes Motorway could experience low level far-field horizontal movement. The far-field horizontal movements are expected to be similar to those observed for previous longwall mining in the Southern Coalfield.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The absolute horizontal movements measured at distances greater than 850 m from mining are in the order of 50 mm based on the 95% confidence level. Far-field horizontal movements tend to be bodily movements orientated towards the mining area. The strains associated with these low level horizontal movement are not expected to be measurable.

Whilst the M1 Princes Motorway could experience low level far-field horizontal movements, the associated tilts, curvatures or strains are not expected to be measurable. It is unlikely that the M1 Princes Motorway and associated infrastructure would experience adverse impacts as a result of Longwall 304.

The potential for impacts on the M1 Princes Motorway and associated infrastructure, based on the Extraction Plan Layout, are the same as those based on the Preferred Project Layout. It is expected that the M1 Princes Motorway would be maintained in a safe and serviceable condition during and after mining.

6.3. Old Princes Highway

6.3.1. Description of the Old Princes Highway

The Old Princes Highway is a regional road that crosses directly above Longwall 304. The location of the highway is shown in Drawing No. MSEC1009-08.

The Old Princes Highway is often referred to as Princes Highway and is referred to as such in other reports including previous reports prepared by MSEC. The section of Princes Highway located within the Study Area was renamed as Old Princes Highway in October 2002 (NSW Government Gazette No. 189, 25th October 2002).

The section of the Old Princes Highway located within the Study Area comprises a single carriageway with a flexible asphalt pavement and grass verges. A photograph of the highway is provided in Fig. 6.1.

Fig. 6.1 Old Princes Highway

The total length of the Old Princes Highway that is located within the Study Area is approximately 1.9 km. The total length of the highway located directly above Longwall 304 is approximately 660 m.

6.3.2. Predictions for the Old Princes Highway

The predicted profiles of vertical subsidence, tilt and curvature along the alignment of the Old Princes Highway, resulting from the extraction of Longwall 304, are shown in Fig. C.03, in Appendix C. The predicted incremental profiles for the highway, due to the extraction of Longwall 304, are shown as dashed black lines. The predicted total profiles for the highway, after the extraction of each of the longwalls, are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as red lines for comparison.

A summary of the maximum predicted values of total subsidence, tilt and curvature for the Old Princes Highway, resulting from the extraction of Longwall 304, is provided in Table 6.1. The values are the maxima anywhere along the section of the highway located within the Study Area.

Table 6.1 Predicted Total Subsidence, Tilt and Curvature for the Old Princes Highway Resulting from the Extraction of Longwall 304

Longwall	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})
After LW303	950	3.0	0.05	0.05
After LW304	1,000	2.5	0.05	0.05

The maximum predicted conventional tilt for the highway is 2.5 mm/m after the extraction of Longwall 304 (i.e. 0.25 %, or 1 in 400). The maximum predicted conventional curvatures are 0.05 km^{-1} hogging and sagging, which equate to minimum radii of curvature of 20 km.

The predicted strains for the section of the Old Princes Highway located directly above Longwall 304 is provided in Table 6.2. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 6.2 Predicted Strains for the Section of the Old Princes Highway Located directly above Longwall 304 based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 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	1.0	0.9	1.6
Compression	1.0	1.6	3.2

The Old Princes Highway does not cross any major streams within the Study Area. The highway, therefore, is not expected to experience valley closure effects.

6.3.3. Comparison of the Predictions for the Old Princes Highway

The comparison of the maximum predicted subsidence parameters for the Old Princes Highway with those based on the Preferred Project Layout is provided in Table 6.3. The values are the maxima anywhere along the section of the highway located within the Study Area.

Table 6.3 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Old Princes Highway based on the Extraction Plan Layout and the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1150	5.0	0.05	0.07
Preferred Project Layout (After LW304) (Report No. MSEC403)	700	2.5	0.05	0.07
Extraction Plan Layout (Report No. MSEC1009)	1000	2.5	0.05	0.05

The maximum predicted vertical subsidence based on the Extraction Plan Layout is greater than the maxima based on the Preferred Project Layout (After LW304). However, the potential for impact does not result from absolute vertical subsidence, but rather from the differential movements (i.e. tilt, curvature and strain).

The maximum predicted tilt, curvatures and strains based on the Extraction Plan Layout are the same of less than the maxima predicted based on the Preferred Project Layout. The potential impacts on the Old Princes Highway based on the Extraction Plan Layout, therefore, are similar to those based on the Preferred Project Layout. The impact assessments for the highway are provided in the following section.

6.3.4. Impact Assessments and Recommendations for the Old Princes Highway

The maximum predicted conventional tilt for the Old Princes Highway is 2.5 mm/m (i.e. 0.25 %, or 1 in 400). The predicted changes in grade are small, less than 1 %, and therefore are unlikely to result in adverse impacts on the serviceability or surface water drainage for the highway. If additional localised ponding or adverse changes in surface water drainage were to occur as the result of mining, the highway could be repaired using normal road maintenance techniques.

The maximum predicted curvatures and the range of potential strains for the Old Princes Highway are similar to those typically experienced elsewhere in the Southern Coalfield. Longwalls in the Southern Coalfield have been successfully mined directly beneath roads with bitumen and asphaltic pavements.

For example, at Tahmoor Colliery, Longwalls 22 to 27 have mined beneath approximately 24.5 km of local roads. A total of 46 impact sites have been observed and, therefore, this equates to an average of one impact for every 533 m of pavement. The impacts were minor and did not present a public safety risk. The potential impacts due to conventional subsidence movements include minor cracking, rippling, bumps and stepping in the road surface. The nature of potential impacts to the pavement are also affected by the type of construction of the road pavement.

The potential impacts on the Old Princes Highway could be managed using monitoring (visual and/or ground survey lines) during active subsidence and remediation of impacts using normal road maintenance techniques. The road was successfully maintained in safe and serviceable conditions during the extraction of Longwall 302 directly beneath it.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301-303 are updated and continued, in consultation with Wollongong City Council, to manage the potential impacts on the Old Princes Highway. It is expected that the highway can be maintained in safe and serviceable conditions with the implementation of the appropriate monitoring and management strategies.

6.4. Fire Trails and Four Wheel Drive Tracks

The locations of the unsealed four wheel drive tracks and fire roads within and adjacent to the Study Area are shown in Drawing No. MSEC1009-08. Tracks are located directly above Longwall 304 and previously extracted longwalls. The tracks would therefore experience the full range of subsidence movements during the extraction of Longwall 304, which are provided in Chapter 4.

The maximum predicted subsidence parameters for the unsealed four wheel drive tracks and fire roads, based on the Extraction Plan Layout, are similar to the maxima predicted based on the Preferred Project Layout. The potential impacts for the unsealed four wheel drive tracks and fire roads, based on the Extraction Plan Layout, therefore, are similar to those assessed based on the Preferred Project Layout. Impact assessments for the fire trails and four wheel drive tracks are provided in Section 5.13 of the MSEC285 Report.

It is possible that the four wheel drive tracks and fire roads could experience surface cracking during the mining period, particularly where the tracks and roads are located near the tops of existing slopes. The size and extent of surface tension cracking on slopes is expected to be minor and similar to that observed during the extraction of previous longwalls at the Metropolitan Colliery. Further discussion on mining induced ground deformations is provided in Section 4.8.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301-303 are updated and continued to manage the potential impacts on the fire trails and four wheel drive tracks. It is expected that the fire trails and four wheel drive tracks can be maintained in safe and serviceable conditions with the implementation of the appropriate monitoring and management strategies.

6.5. Bridges

Bridge 2 (RMS reference BN616-southbound and BN617-northbound) is located approximately 880 m to the south east of Longwall 304 as shown in Drawing No. MSEC1009-08. A photograph of Bridge 2 is shown in Fig. 6.2 below.

Fig. 6.2 Bridge 2

The next nearest bridge is Cawleys Rd overpass (RMS reference BN615), located approximately 1.67 km from Longwall 304.

At these distances Bridge 2 and Cawleys Rd overpass are not expected to experience measurable conventional vertical subsidence, tilts or curvatures. The bridges could experience low level far-field horizontal movement. The far-field horizontal movements are expected to be similar to those observed for previous longwall mining in the Southern Coalfield.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The absolute horizontal movements measured at distances greater than 880 m from mining are in the order of 45 mm based on the 95% confidence level. Far-field horizontal movements tend to be bodily movements orientated towards the mining area. The strains associated with these low level horizontal movement are not expected to be measurable.

The potential for differential horizontal movement was assessed by analysing the far-field horizontal movement data discussed in Section 4.6. The data set was analysed to determine incremental relative opening and closing and incremental mid ordinate deviation.

Relative opening and closing movement is calculated as the change in the distance between two survey marks (either positive opening, or negative closing) over two survey epochs.

A plot of the calculated incremental relative opening and closing movement for the current database of observed far-field horizontal movements that were used for this assessment is provided in Fig. 6.3. The incremental relative opening and closing movement was calculated for pegs with a spacing of 20 m ±10 m.

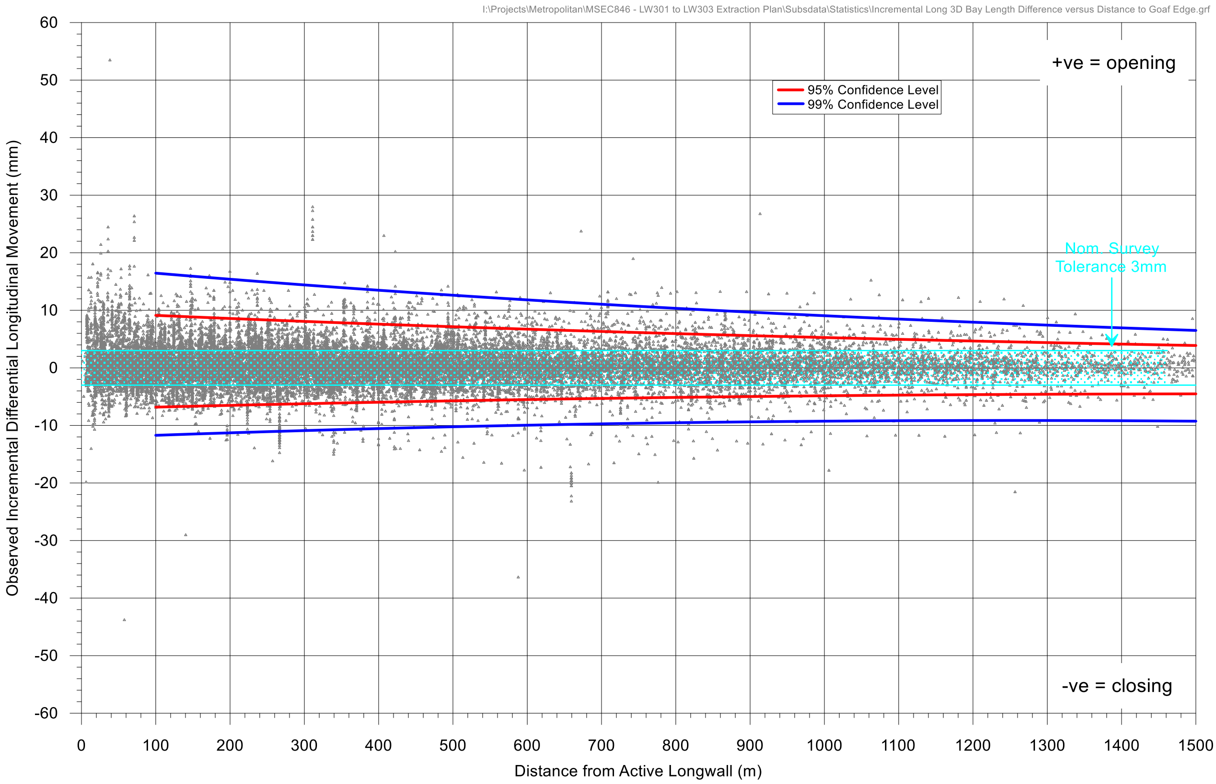

Fig. 6.3 Incremental Differential Horizontal Movements versus Distance from Active Longwall for Marks Spaced at 20 m ±10 m

Mid ordinate deviation provides a measure of out of plane movement or horizontal bending by calculating the mid ordinate deviation between three survey pegs. The mid ordinate deviation is the change in perpendicular horizontal distance from a point to a chord formed by points on either side. A schematic sketch of the mid ordinate deviation is provided in, Fig. 6.4.

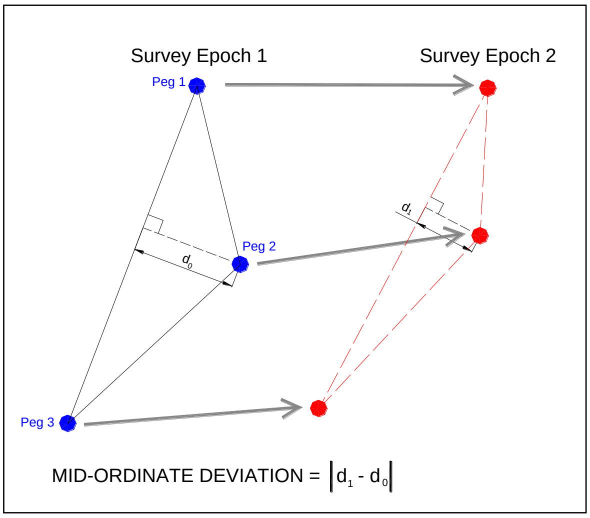

Fig. 6.4 Schematic Representation of Mid Ordinate Deviation

A plot of the calculated incremental mid-ordinate deviation for the current database of observed far-field horizontal movements that were used for this assessment is provided in Fig. 6.5. The mid ordinate deviation was calculated for pegs with a spacing of 20 m ±10 m, or an approximate spacing of 40 m over the three pegs.

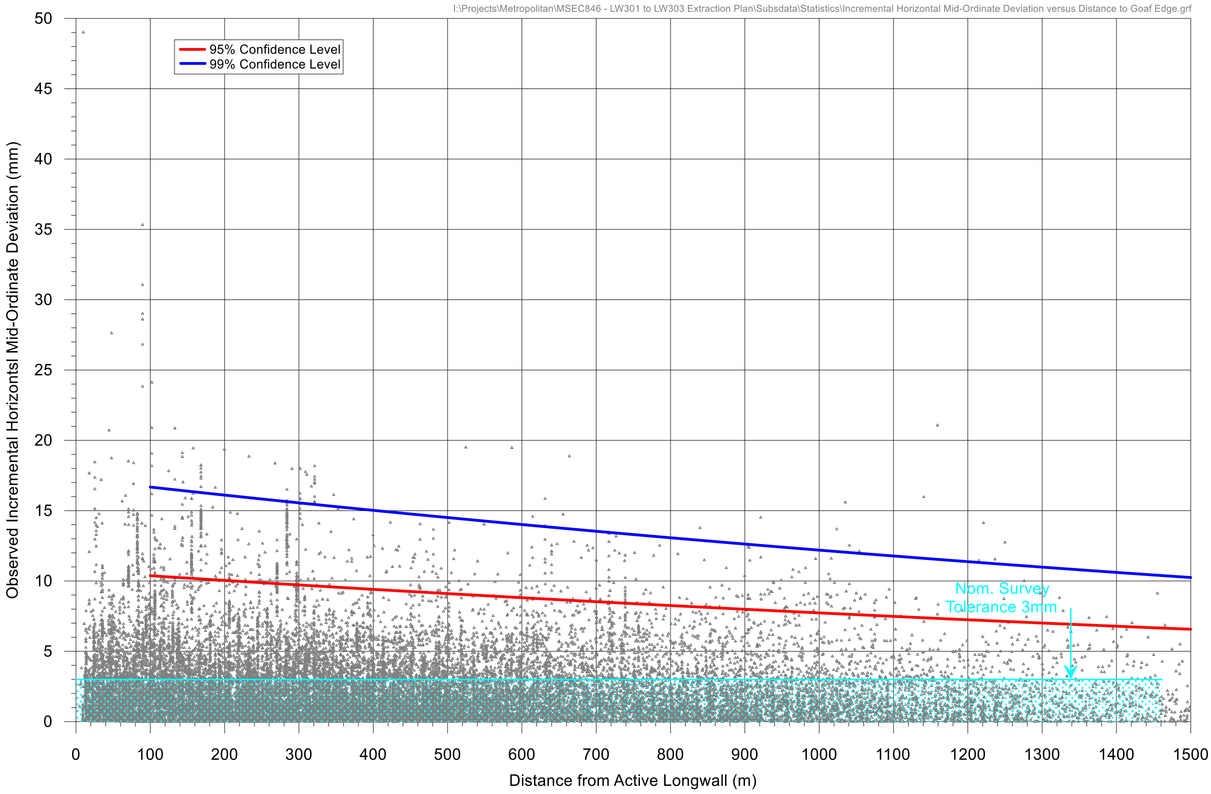

Fig. 6.5 Observed Incremental Mid-Ordinate Deviation versus Distance from Active Longwall for Marks Spaced at 20 m ±10 m

A detailed assessment of Bridge 2 by Cardno indicated that the bridge is sensitive to small differential movements. Given the low magnitude of predicted movements and sensitivity of the bridge to small movements, a high accuracy monitoring system, using fibre optic monitoring, will continue to be implemented by the RMS technical committee to monitor movements at Bridge 2. Details of the monitoring system will be outlined in the Built Features Management Plan for RMS infrastructure.

Cawleys Road Overpass is located at 1.43 km from Longwall 301 at its nearest point to the mining area. At this distance, observed far-field movements are close to nominal survey tolerance and observed differential movement data is predominantly within survey tolerance. At this distance, adverse impact to Cawleys Road Overpass resulting from the extraction of Longwall 304 is considered unlikely. It is recommended assessment of the Cawleys Road Overpass be undertaken by the RMS technical committee to assess the sensitivity of this structure to potential differential movements as a result of Longwall 304.

6.6. Road Drainage Culverts

A series of culverts cross the M1 Princes Motorway. The culverts comprise pipes of varying diameters from 375 mm to 1800 mm. The pipe materials comprise asbestos cement (pipes up to 600 mm diameter) and steel reinforced concrete (pipes up to 1800 mm diameter). In addition to the culverts, there are also a number of other drainage structures, such as kerbs, gutters, pits and drainage pipes. The largest culvert comprises two 1800 mm pipes located to the north east of the longwalls at Cawleys Creek.

Since the drainage culverts are located along the M1 Princes Motorway, the predicted movements at the culverts resulting from the extraction of the proposed Longwall 304 are the same as those discussed in Section 6.2 for the M1 Princes Motorway and the potential impacts on the culverts based on the Extraction Plan Layout, therefore, are the same as those based on the Preferred Project Layout.

It is considered unlikely that impacts to the culverts would occur as a result of the extraction of Longwall 304. Should impacts occur, they are expected to be isolated and of a minor nature and easily repairable.

6.7. Water Infrastructure

6.7.1. Descriptions of the Water Infrastructure

The locations of the water infrastructure within the Study Area are shown in Drawing Nos. MSEC1009-08 to MSEC1009-10.

There are two potable water supply pipelines owned by Sydney Water that cross through the Study Area. Water Main 1 is a 300 mm diameter Cast Iron Cement Lined (CICL) pipeline and Water Main 2 is a 300 mm diameter CICL pipeline. There is also a 150 mm diameter CICL pipeline between Water Main 2 and the water storage tanks in the Garrawarra Complex. Water Main 1 crosses above Longwall 304. The water storage tanks in the Garrawarra Complex are discussed in Section 11.1.

A sewer main is located in the Garrawarra Complex to the north of the Study Area. This pipeline is 150 mm PVC pressure main. There are also networks of potable water and sewer pipelines located outside and in the vicinity of the Study Area, within the township of Helensburgh to the south-east of the longwalls. These networks are located at a minimum distance of approximately 0.9 km from Longwall 301 and 1.5 km from Longwall 304.

6.7.2. Predictions for the Water Infrastructure

The predicted profiles of vertical subsidence, tilt and curvature along the alignments of Water Main 1 and Water Main 2, resulting from the extraction of Longwall 304, are shown in Figs. C.04 and C.05, respectively, in Appendix C. The predicted incremental profiles for the pipelines, due to the extraction of Longwall 304, are shown as dashed black lines. The predicted total profiles for the pipelines, after the extraction of Longwalls 303 and 304, are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as red lines for comparison.

Summaries of the maximum predicted values of total subsidence, tilt and curvature for the Water Main 1 and Water Main 2, resulting from the extraction of Longwall 304, are provided in Table 6.4, respectively. The values are the maxima anywhere along the sections of the pipelines located within the Study Area.

Table 6.4 Predicted Total Subsidence, Tilt and Curvature for Water Main 1 and 2 Resulting from the Extraction of Longwall 304

Pipeline	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})
Water Main 1	1050	3.5	0.05	0.09
Water Main 2	1000	3.5	0.04	0.13

The maximum predicted conventional tilt for the water mains is 3.5 mm/m (i.e. 0.4 %, or 1 in 250). It is noted, that the maximum tilt occurs after the extraction of Longwall 302 and reduces after the extraction of

Longwall 303. The maximum predicted conventional curvatures are 0.05 km^{-1} hogging and 0.13 km^{-1} sagging, which equate to minimum radii of curvature of 20 km and 8 km, respectively.

The predicted strains for the sections of the water mains located directly above Longwall 304 is provided in Table 6.5. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 6.5 Predicted Strains for the Sections of the Water Mains Located directly above Longwall 304 based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 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	1.0	0.9	1.6
Compression	2.0	1.6	3.2

The water mains do not cross any major streams within the Study Area. The pipelines, therefore, are not expected to experience valley closure effects.

The sewer main to the north of the Study Area is not expected to experience measurable tilts, curvatures or strains. Similarly, the networks of water and sewerage pipelines located within the township of Helensburgh are not expected to experience any measurable vertical subsidence, tilts, curvatures or strains. The pipelines could experience low level far-field horizontal movements. However, these absolute horizontal movements tend to be bodily movements that are not associated with measurable strains.

6.7.3. Comparison of the Predictions for the Water Infrastructure

The comparison of the maximum predicted subsidence parameters for Water Main 1 and Water Main 2 with those based on the Preferred Project Layout is provided in Table 6.6. The values are the maxima anywhere along the sections of the pipelines located within the Study Area.

Table 6.6 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Water Mains based on the Extraction Plan Layout and the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	975	4.0	0.07	0.13
Preferred Project Layout (After LW304) (Report No. MSEC403)	875	4.0	0.06	0.13
Extraction Plan Layout (Report No. MSEC1009)	1050	3.5	0.05	0.13

The maximum predicted vertical subsidence for the water mains based on the Extraction Plan Layout is slightly greater than the maximum based on the Preferred Project Layout. However, the potential for impact does not result from absolute vertical subsidence, but rather from the differential movements (i.e. tilt, curvature and strain).

The maximum predicted tilt, curvatures and strains for the water mains based on the Extraction Plan Layout are similar to or less than the maxima predicted based on the Preferred Project Layout. The potential impacts based on the Extraction Plan Layout, therefore, are similar to those based on the Preferred Project Layout. The impact assessments for the water mains are provided in the following section.

6.7.4. Impact Assessment and Recommendations for Water Infrastructure

Water Mains 1 and 2 are pressure mains and, therefore, are unlikely to be adversely impacted by the mining induced vertical subsidence or tilt. These pipelines are direct buried and are likely to experience the curvatures and ground strains resulting from the extraction of Longwall 304.

The maximum predicted conventional curvatures for the water mains are 0.05 km^{-1} hogging and 0.13 km^{-1} sagging, which equate to minimum radii of curvature of 20 km and 8 km, respectively. Localised and elevated curvatures could develop along the pipelines due to non-conventional movements resulting from near surface geological structures (i.e. anomalies).

The predicted curvatures and strains for the water mains are similar to those where longwalls in the Southern Coalfield have previously mined directly beneath similar pipelines. It has been found from this previous experience that the impacts on CICL pipelines in the Southern Coalfield are rare and generally of a minor nature. Some examples of mining beneath water mains in the Southern Coalfield are provided in Table 6.7.

Table 6.7 Examples of Mining Beneath Water Mains in the Southern Coalfield

Colliery and Longwalls	Pipelines	Observed Movements	Observed Impacts
Appin LW301 and LW302	0.6 km of 150 dia DICL 0.6 km of 300 dia CICL 0.6 km of 1200 dia SCL	650 mm Subsidence 4.5 mm/m Tilt 1 mm/m Tensile Strain 3 mm/m Comp. Strain (Measured M & N-Lines)	Leakage of the 150 mm DICL and 300 mm CICL pipelines at a creek crossing, elsewhere no other reported impacts
Tahmoor LW22 to LW25	2.7 km DICL pipes 7.3 km CICL pipes	1200 mm Subsidence 6 mm/m Tilt 1.5 mm Tensile Strain 2 mm (typ.) and up to 5 mm/m Comp. Strain (Extensive street monitoring)	One reported impact to the distribution network and a very small number of minor leaks in the consumer connection pipes
West Cliff LW5A3, LW5A4 & LW29 to LW34	2.8 km of 100 dia CICL pipe directly mined beneath	1100 mm Subsidence 10 mm/m Tilt 1 mm/m Tensile Strain 5.5 mm/m Comp. Strain (Measured B-Line)	No reported impacts

Based on this experience, it is possible that some minor leakages of the water mains could occur as the result of the extraction of Longwall 304. However, the incidence of impacts is likely to be very low and of a minor nature. It is expected that any impacts could be remediated by locally exposing the pipeline and repairing or replacing the affected section.

The water mains were previously mined beneath by Longwalls 301 to 303. No adverse impacts were observed due to the extraction of these longwalls.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301-303 are updated and continued, in consultation with Sydney Water, to manage the potential impacts on the water mains that are located directly above Longwall 304. It is expected that these pipelines can be maintained in serviceable conditions with the implementation of the appropriate monitoring and management strategies.

The sewer main to the north of the Study Area and the networks of water and sewer pipelines located within the township of Helensburgh are all located outside of the predicted 20 mm subsidence contour. It is unlikely that these pipelines would experience adverse impacts as a result of Longwall 304.

6.8. Electrical Infrastructure

6.8.1. Descriptions of the Electrical Infrastructure

The locations of the electrical infrastructure are shown in Drawing No. MSEC1009-08. The infrastructure comprises a 132 kV transmission line owned by Endeavour Energy, a 330 kV transmission line owned by TransGrid and 11 kV distribution lines owned by Endeavour Energy.

The 132 kV and 330 kV transmission lines are located to the east of Longwall 301 and are located outside the Study Area. The 132 kV transmission line towers are located over 730 m from Longwall 304. The 330 kV transmission line towers are located over 670 m from Longwall 304. An 11 kV distribution line runs between the township of Helensburgh and the Garrawarra Complex to the north east of Longwall 304 and outside the Study Area, referred to as Powerline 1.

Powerlines within the Study Area comprise 11 kV powerlines servicing the Garrawarra Complex in the northern part of the Study Area. The powerlines comprise aerial conductors supported on timber poles. Underground powerlines are also present within the Garrawarra Complex and are understood to be private lines. There are no powerlines above Longwall 304.

6.8.2. Predictions for the Electrical Infrastructure

The transmission lines are located over 670 m from Longwall 304. Powerline 1 is located over 460 m from Longwall 304. At these distances, the transmission lines and Powerline 1 are not expected to experience measurable conventional vertical subsidence, tilts or curvatures due to the extraction of Longwall 304. The transmission towers and power poles could experience low level far-field horizontal movement. The far-field horizontal movements are expected to be similar to those observed for previous longwall mining in the Southern Coalfield.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The absolute horizontal movements measured at distances greater than 670 m from mining are in the order of 60 mm based on the 95% confidence level. The absolute horizontal movements measured at distances greater than 460 m from mining are in the order of 85 mm based on the 95% confidence level. Far-field horizontal movements tend to be bodily movements orientated towards the mining area. The strains associated with these low level horizontal movement are not expected to be measurable.

The range of potential ground strains at the transmission towers was assessed statistically using the monitoring data from Metropolitan Colliery and other nearby collieries. 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.

The transmission towers are located at distances of 100 m or greater from Longwall 301. The database has therefore been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls in the Southern Coalfield, for survey bays that were located outside and within 100 m to 250 m of the nearest longwall goaf edge, which has been referred to as "*above solid coal*".

A histogram of the maximum observed tensile and compressive strains measured in survey bays located above solid coal, for monitoring lines in the Southern Coalfield, is provided in Fig. 6.6. The probability distribution functions, based on a fitted *Generalised Pareto Distribution (GPD)*, have also been shown in this figure.

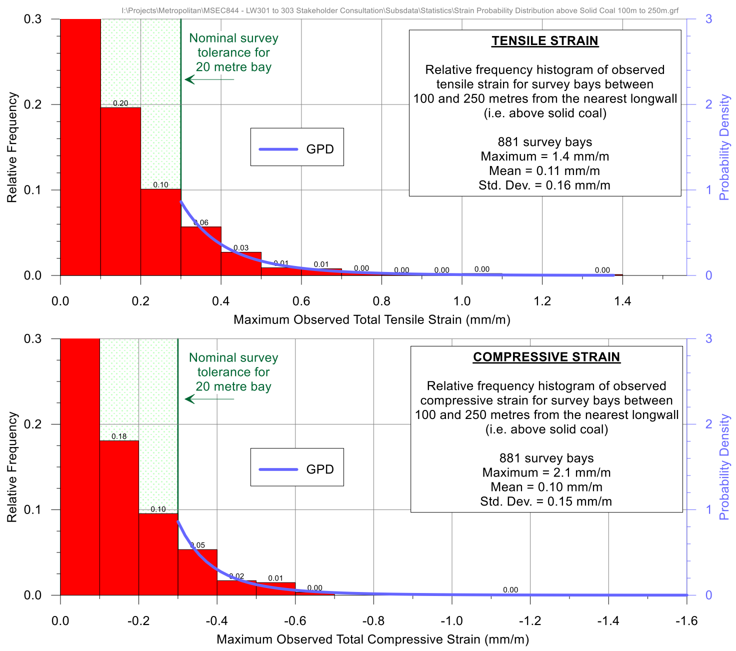

Fig. 6.6 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield Above Solid Coal (100 to 250 m)

The 95 % confidence levels for the maximum total strains that the individual survey bays above solid coal (100 to 250 m) experienced at any time during mining are 0.4 mm/m tensile and 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 0.7 mm/m tensile and 0.6 mm/m compressive.

The predicted profiles of vertical subsidence, tilt along and tilt across the alignment of Powerline 1, resulting from the extraction of Longwall 304, are shown in Fig. C.06, in Appendix C. The predicted incremental profiles for the powerline, due to the extraction of Longwall 304, are shown as dashed black lines. The predicted total profiles for the powerline, after Longwalls 303 and 304, are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as red lines for comparison.

A summary of the maximum predicted values of total subsidence, tilt and curvature for the 11 kV powerlines on the Garrawarra Complex, resulting from the extraction of Longwall 304 for the Extraction Plan Layout, is provided in Table 6.8. The values are the maxima anywhere within this network.

Table 6.8 Predicted Total Subsidence, Tilt and Curvature for the 11 kV Powerlines on the Garrawarra Complex Resulting from the Extraction of Longwall 304

Longwall	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})
After LW303	200	2.0	0.03	< 0.01
After LW304	300	3.0	0.03	< 0.01

The maximum predicted total subsidence is 300 mm. The maximum predicted conventional tilt is 3.0 mm/m (i.e. 0.3 %, or 1 in 330). The maximum predicted conventional curvatures are 0.03 km^{-1} hogging and < 0.01 sagging, which equate to minimum radii of curvature of 33 km and 100 km respectively.

The predicted strains for the 11 kV powerlines located to the north east of Longwall 304 is provided in Table 6.9. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 6.9 Predicted Strains for the 11 kV Powerlines due to Longwall 304 based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 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	< 0.5	0.5	0.8
Compression	< 0.5	0.6	0.9

There are no streams in the locations of the power poles within the Study Area. The 11 kV powerlines, therefore, are not expected to experience valley closure effects.

6.8.3. Comparisons of the Predictions for the Electrical Infrastructure

The comparisons of the maximum predicted subsidence parameters for the 11 kV powerlines based on the Extraction Plan Layout, with those based on the Preferred Project Layout, are provided in Table 6.10, respectively. The values for the transmission lines are the maxima at the tower locations and the values for the 11 kV powerlines and the maxima anywhere along their alignments within the Study Area.

Table 6.10 Comparison of Maximum Predicted Conventional Subsidence Parameters for the 11 kV Voltage Powerlines based on the Extraction Plan Layout and the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1200	5.5	0.05	0.14
Preferred Project Layout (After LW304) (Report No. MSEC403)	1200	5.5	0.05	0.14
Extraction Plan Layout (Report No. MSEC1009)	300	3.0	0.03	< 0.01

The maximum predicted subsidence parameters for the 11 kV powerlines, based on the Extraction Plan Layout, are less than the maxima based on the Preferred Project Layout. The predicted subsidence parameters reduce due to the shortened commencing (i.e. northern) ends of Longwalls 302, 303 and 304.

6.8.4. Impact Assessments and Recommendations for the Electrical Infrastructure

Whilst the 132 kV and 330 kV transmission lines and Powerline 1 could experience low level far-field horizontal movements, the associated tilts, curvatures or strains are not expected to be measurable. It is unlikely that the transmission lines would experience adverse impacts as a result of Longwall 304.

The potential for impacts on the transmission lines, based on the Extraction Plan Layout, are the same as those based on the Preferred Project Layout. It is expected that the transmission lines would be maintained in a safe and serviceable condition during and after mining.

The 11 kV powerlines comprise aerial conductors supported on timber poles and buried cables. Experience from the Southern Coalfield indicates that the potential impacts on these types of powerlines are rare and generally of a minor nature. Some remedial measures have been required, which include adjustments to cable catenaries, pole tilts and consumer cables which connect between the poles and building structures. The incidence of these impacts, however, was very low.

It is expected that the 11kV powerlines can be maintained in safe and serviceable conditions with the development of the appropriate monitoring and management plans.

6.9. Telecommunications Infrastructure

6.9.1. Descriptions of the Telecommunications Infrastructure

The locations of the telecommunications infrastructure are shown in Drawing No. MSEC1009-08.

There are two optical fibre cables within the Study Area: on optical fibre cable owned by Telstra crosses above the northern end of Longwall 303 and a second optical fibre cable owned by Optus crosses above the northern end of Longwall 303 and above Longwalls 302 and 301. There are no optical fibre cables above Longwall 304. Copper telecommunications cables owned by Telstra are also located above Longwall 304 and to the north of Longwalls 302 and 303 and these cables service the Garrawarra Complex.

There are a number of telecommunications towers and compounds that are located to the north of Longwall 303. These installations are owned by Telstra, Axicom and Sydney Trains. Photographs of the towers and compounds for three of these installations are provided in Fig. 6.7 to Fig. 6.9.

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Fig. 6.7 Telecommunications Tower and Compound owned by Telstra

Fig. 6.8 Telecommunications Tower and Compound owned by Sydney Trains

Fig. 6.9 Telecommunications Tower and Compound owned by Axicom

6.9.2. Predictions for the Telecommunications Infrastructure

The predicted profiles of vertical subsidence, tilt and curvature along the alignments of the optical fibre cables owned by Telstra and Optus resulting from the extraction of Longwall 304, are shown in Figs. C.07 and C.08, respectively, in Appendix C. The predicted incremental profiles for the cables, due to the extraction of Longwall 304, are shown as dashed black lines. The predicted total profiles for the cables, after the extraction of Longwalls 303 and 304, are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as the red lines for comparison.

Summaries of the maximum predicted values of total subsidence, tilt and curvature for the optical fibre cables, resulting from the extraction of Longwall 304, are provided in Table 6.11 to Table 6.12. The values are the maxima anywhere along the sections of the cables located within the Study Area.

Table 6.11 Predicted Total Subsidence, Tilt and Curvature for the Telstra Optical Fibre Cable Resulting from the Extraction of Longwall 304

Longwall	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})
After LW303	150	1.0	0.02	< 0.01
After LW304	300	2.5	0.02	< 0.01

Table 6.12 Predicted Total Subsidence, Tilt and Curvature for the Optus Optical Fibre Cable Resulting from the Extraction of Longwall 304

Longwall	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})
After LW303	925	4.5	0.03	0.13
After LW304	1000	4.5	0.04	0.13

The maximum predicted conventional tilt for the optical fibre cables is 4.5 mm/m (i.e. 0.45 %, or 1 in 225). The maximum predicted conventional curvatures are 0.04 km^{-1} hogging and 0.13 km^{-1} sagging, which equate to minimum radii of curvature of 25 km and 8 km, respectively.

A summary of the maximum predicted values of total subsidence, tilt and curvature for the copper telecommunications cables, resulting from the extraction of Longwall 304, are provided in Table 6.13. The values are the maxima anywhere within the network located within the Study Area.

Table 6.13 Predicted Total Subsidence, Tilt and Curvature for the Copper Telecommunications Cables Resulting from the Extraction of Longwall 304

Longwall	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})
After LW303	175	2.0	0.03	< 0.01
After LW304	650	3.5	0.03	0.03

The maximum predicted conventional tilt for the copper telecommunications cables is 3.5 mm/m (i.e. 0.35 %, or 1 in 290). The maximum predicted conventional curvatures are 0.03 km^{-1} hogging and sagging, which equate to minimum radii of curvature of 33 km.

The maximum predicted strains for the optical fibre cables and copper telecommunications cables within the Study Area is provided in Table 6.14. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 6.14 Predicted Strains for the Sections of the Optical Fibre Cables and Copper Telecommunications Cables Located within the Study Area based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 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	0.5	0.9	1.6
Compression	2.0	1.6	3.2

The optical fibre cables and the copper telecommunications cables do not cross any major streams within the Study Area. The cables, therefore, are not expected to experience valley closure effects.

The telecommunications towers and compounds are located to the east of Longwall 304. A summary of the maximum predicted values of total subsidence, tilt and curvature for these installations, resulting from the extraction of Longwall 304, is provided in Table 6.15.

Table 6.15 Maximum Predicted Total Subsidence, Tilt and Curvature for the Telecommunications Towers and Compounds Resulting from the Extraction of Longwall 304

Location	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Site 1 Axicom Optus	125	1.0	0.01	< 0.01
Site 2 Axicom Vodafone	150	1.5	0.02	< 0.01
Site 3 Telstra	175	2.0	0.02	< 0.01
Site 4 Sydney Trains	400	3.5	0.03	< 0.01
Site 5 Garrawarra radio tower	50	< 0.5	<0.01	< 0.01

The maximum predicted conventional tilt for the telecommunications towers and compounds is 3.5 mm/m (i.e. 0.35 %, or 1 in 286). The maximum predicted conventional curvatures are 0.03 km^{-1} hogging and < 0.01 km^{-1} sagging, which equate to minimum radii of curvature of 33 km and greater than 100 km, respectively.

The predicted strains for telecommunications towers and compounds are provided in Table 6.16. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 6.16 Predicted Strains for the Telecommunications Towers and Compounds based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 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	0.5	0.9	1.6
Compression	0.5	1.6	3.2

The telecommunications towers and compounds are not located near any major streams. These installations, therefore, are not expected to experience valley closure effects.

6.9.3. Comparison of the Predictions for the Telecommunications Infrastructure

The comparisons of the maximum predicted subsidence parameters for optical fibre cables and the copper telecommunications cables with those based on the Preferred Project Layout are provided in Table 6.17 and Table 6.18. The values are the maxima anywhere along the sections of the cables located within the Study Area.

Table 6.17 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Optical Fibre Cables based on the Extraction Plan Layout and the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1000	3.5	0.05	0.13
Preferred Project Layout (After LW304) (Report No. MSEC403)	950	3.5	0.05	0.13
Extraction Plan Layout (Report No. MSEC1009)	1000	4.5	0.04	0.13

Table 6.18 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Copper Cables based on the Extraction Plan Layout and the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1200	5.5	0.05	0.14
Preferred Project Layout (After LW304) (Report No. MSEC403)	1150	5.0	0.05	0.14
Extraction Plan Layout (Report No. MSEC1009)	650	3.5	0.03	0.03

The maximum predicted subsidence and tilt for the optical fibre telecommunications cables, based on the Extraction Plan Layout, are slightly greater than the maxima based on the Preferred Project Layout. However, as discussed in the following section, the potential for impacts on these cables are due to curvature and strain, rather than due to vertical subsidence and tilt. The maximum predicted hogging and sagging curvature based on the Extraction Plan Layout, are similar to or less than the maxima based on the Preferred Project Layout.

The maximum predicted subsidence parameters for the copper telecommunications cables, based on the Extraction Plan Layout, are less than the maxima based on the Preferred Project Layout.

The comparison of the maximum predicted subsidence parameters for the telecommunications towers and compounds with those based on the Preferred Project Layout is provided in Table 6.19. The values are the maxima at any time during or after the extraction of the longwalls.

Table 6.19 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Telecommunications Towers based on the Extraction Plan Layout and the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1150	1.0	0.03	0.07
Preferred Project Layout (After LW304) (Report No. MSEC403)	1100	1.5	0.04	0.07
Extraction Plan Layout (Report No. MSEC1009)	400	3.5	0.03	< 0.01

The maximum predicted tilt for the telecommunications towers and compounds, based on the Extraction Plan Layout, are greater than the maxima based on the Preferred Project Layout. The maximum predicted vertical subsidence, hogging curvature and tensile strain for the telecommunications towers and compounds, based on the Extraction Plan Layout, are similar to or less than the maxima predicted based on the Preferred Project Layout. The impact assessments for the telecommunications towers and compounds are provided in the following section.

6.9.4. Impact Assessment and Recommendations for Optical Fibre Cables

The optical fibre cables within the Study Area are buried in conduits of various diameters. The cables will not be impacted by the subsidence and tilt resulting from the extraction of Longwall 304. The cables, however, are likely to experience the curvatures and ground strains resulting from the extraction of Longwall 304. There is also the potential for localised curvatures and strains due to non-conventional ground movements. The conduit surrounding the cables reduces the potential for direct transfer of ground strain to the cables.

The tensile strains in the optical fibre cables can be higher than predicted where the cables connect to the support structures, which may act as anchor points, preventing any differential movements that may have been allowed to occur within the ground. Tree roots have also been known to anchor cables to the ground. The extent to which the anchor points affect the ability of the cable to tolerate the mine subsidence movements depends on the cable size, type, age, installation method and ground conditions.

In addition to this, optical fibre cables contain additional fibre lengths over the sheath lengths, where the individual fibres are loosely contained within tubes. Compression of the sheaths can transfer to the loose tubes and fibres and result in 'micro-bending' of the fibres constrained within the tubes, leading to higher attenuation of the transmitted signal. If the maximum predicted compressive strains were to be fully transferred into the optical fibre cables, they could be of sufficient magnitude to result in the reduction in capacities of the cables or transmission loss.

Localised and elevated curvatures could develop along the optical fibre cables due to non-conventional movements resulting from near surface geological structures (i.e. anomalies). It is possible that these non-conventional movements could be sufficient to result in the attenuation of signal.

The predicted curvatures and strains for the optical fibre cables are similar to those where longwalls in the Southern Coalfield have previously mined directly beneath similar cables. It has been found from this previous experience that the potential impacts on optical fibre cables in the Southern Coalfield can be managed with the implementation of suitable monitoring and management strategies.

Some examples of mining beneath optical fibre cables in the Southern Coalfield are provided in Table 6.20.

Table 6.20 Examples of Mining Beneath Optical Fibre Cables in the Southern Coalfield

Colliery and Longwalls	Length of Optical Fibre Cables Directly Mined Beneath (km)	Observed Maximum Movements at Optical Fibre Cables	Pre-Mining Mitigation, Monitoring and Observed Impacts
Appin LW301 and LW302	0.8	650 mm Subsidence 1 mm/m Tensile Strain 3 mm/m Comp. Strain (Measured M & N-Lines)	600 metre aerial cable on standby. Ground survey, visual, OTDR. No reported impacts.
Appin LW703 to LW706	12.7 total for eight cables	1,200 mm Subsidence 2.1 mm/m Tensile Strain 4.5 mm/m Comp. Strain (Measured HW2, ARTC and MPR Lines)	New cable redirection to avoid potential impacts to old optical fibre cable. Ground survey, visual, OTDR. Strain concentrations detected in three cables, attenuation losses were relieved by locally exposing the cables or by building a bypass cable.
Tahmoor LW22 to LW29	1.9	775 mm Subsidence 0.8 mm/m Tensile Strain 3.9 mm/m Comp. Strain	Ground survey, visual, OTDR, SBS. No reported impacts.
Tower LW1 to LW10	1.7	400 mm Subsidence 3 mm/m Tilt 0.5 mm/m Tensile Strain 1 mm/m Comp. Strain	No reported impacts
West Cliff LW5A3, LW5A4 and LW29 to LW38	3.4	1,300 mm Subsidence 1.3 mm/m Tensile Strain 5.5 mm/m Comp. Strain (Measured B-Line)	Survey, visual, OTDR, SBS. No reported impacts.
Metropolitan LW301 to 302	2.3	800 mm Subsidence 0.6 mm/m Tensile Strain 0.7 mm/m Comp. Strain (Measured Optic Water Line)	Ground survey, visual, OTDR. No reported impacts.

The strains transferred into the optical fibre cables can be monitored using Optical Time Domain Reflectometry (OTDR). The ground movements can also be monitored using traditional survey lines and visual inspections. These monitoring methods can be used to identify the development of irregular ground movements. If non-conventional movements or signal attenuation are detected during active subsidence, then the cable can be relieved by locally exposing and then reburying the affected section of cable.

The optical fibre cables have been directly mined beneath by Longwalls 301 and 302. There were no adverse impacts on these cables due to the extraction of these longwalls.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301 to 303 are updated and continued, in consultation with Telstra and Optus, to manage the optical fibre cables for potential irregular ground movements. It is expected that these cables can be maintained in serviceable condition with the implementation of the appropriate monitoring and management strategies.

6.9.5. Impact Assessment and Recommendations for Copper Telecommunications Cables

The copper telecommunications cables within the Study Area include both buried and aerial cables. The buried cables can be affected by curvatures and ground strains and the aerial cables can be affected by the changes in cable catenaries. Copper telecommunications cables are flexible and it has been found that these types of cables can typically tolerate strains up to 20 mm/m without adverse impacts.

Extensive experience of mining beneath copper telecommunications cables in the NSW Coalfields, where the observed strains were similar or greater than those predicted for the longwalls, indicates that incidences of impacts is very low and generally of a minor nature. Some remedial measures have been required,

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which include adjustments to cable catenaries, pole tilts and consumer cables which connect between the poles and building structures. The incidence of these impacts, however, was very low.

The copper telecommunications cables are predominantly located to the north-east of Longwall 304. It is unlikely that the copper telecommunications cables would experience adverse impacts as a result of the extraction of Longwall 304.

6.9.6. Impact Assessment and Recommendations for Telecommunications Towers and Compounds

The maximum predicted tilts for the telecommunications towers and compounds vary up to 3.5 mm/m (i.e. 0.35 %, or 1 in 286). The magnitudes of tilt are very small (i.e. less than 1 %) and therefore are unlikely to adversely impact on the towers or compounds. Tilt can potentially effect directional antennas (i.e. microwave dishes) and therefore it is recommended that the infrastructure owners (e.g. radio engineers) review the predicted changes in alignment.

The maximum predicted conventional curvatures for these installations are 0.03 km^{-1} hogging and < 0.01 km^{-1} sagging, which equate to minimum radii of curvature of 33 km and 100 km, respectively. The predicted strains are 0.9 mm/m tensile and 1.6 mm/m compressive based on the 95 % confidence level and 1.6 mm/m tensile and 3.2 mm/m compressive based on the 99 % confidence level.

The steel framed building enclosures are supported on piers above concrete ground slabs. It is unlikely that these structures would experience adverse impacts due to their lightweight constructions and their elevation above natural ground. The brick building enclosures could potentially experience adverse impacts such as cracking of the brickwork or sticky entry doors. It is expected that these enclosures would remain in safe and serviceable conditions during and after mining. Adverse impacts could be remediated using normal building maintenance techniques.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301 to 303 are updated and continued, in consultation with Optus, Axicom and Sydney Trains, to manage the towers for potential irregular ground movements.

6.10. Water Tanks, Water and Sewage Treatment Works

The discussions on the water storage tanks in the Garrawarra Complex are provided in Section 11.1.

6.11. Dams, Reservoirs or Associated Works

The full supply level of the Woronora Reservoir is located inside the Study Area and is discussed in Section 5.5.

The Woronora Dam wall is located approximately 7.0 km to the commencing end of Longwall 304 and the distance from the labyrinth spillway, which is to the south of the dam wall, is approximately 6.6 km.

The dam wall and spillway are located at large distances from Longwall 304. It is not expected, therefore, that measurable conventional subsidence movements would occur at the dam wall and spillway.

Far-field horizontal movements have been measured up to distances of approximately 3.9 km from active longwalls, however, almost all of the measured data beyond approximately 2.5 km is within the order of survey tolerance or accuracy. A discussion of far-field horizontal movements in provided in Section 4.6.

It is unlikely that far-field movements would be observed at the distances of the dam wall and spillway from Longwall 304.

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;
- Swimming pools;
- Bowling greens;
- Ovals or cricket grounds;
- Racecourses;
- Golf courses; and
- Tennis courts.

7.1. Office Buildings

Office buildings are located within the Garrawarra Complex, which is discussed in Section 11.1.

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 Longwall 304.

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

- Farm buildings or sheds;
- Tanks;
- Gas or fuel storages;
- Poultry sheds;
- Glass houses;
- Hydroponic systems;
- Irrigation systems;
- Farm Dams; and
- Wells or Bores.

8.1. Agricultural Utilisation

The agricultural land classification types in the vicinity of the proposed Longwall 304 are illustrated in Fig. 8.1.

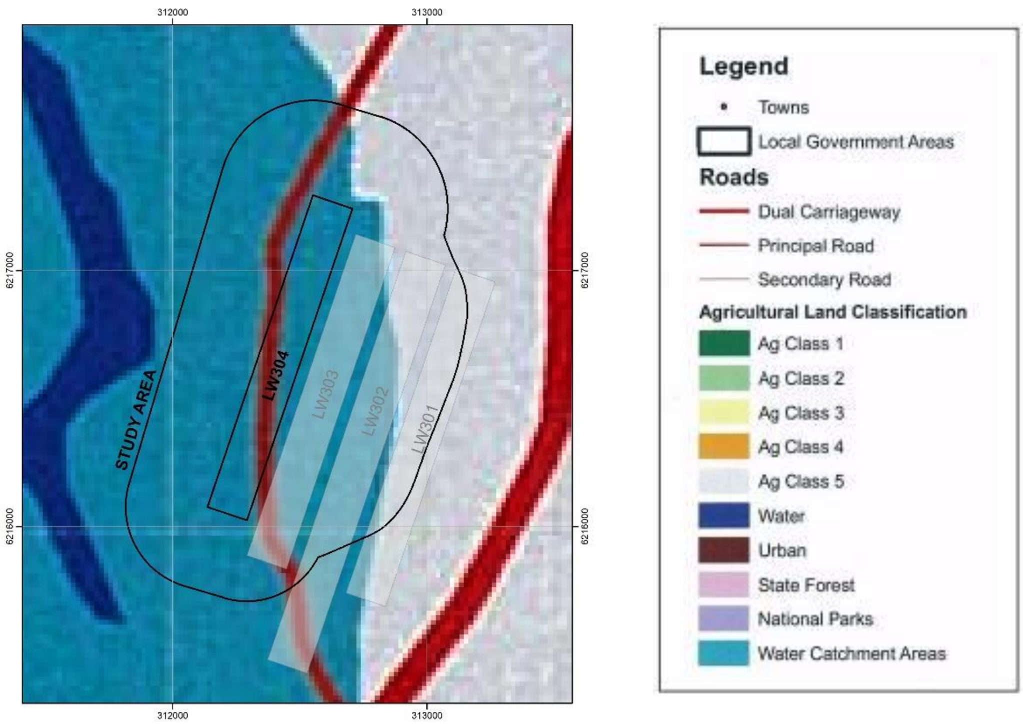


Fig. 8.1 Agricultural Land Classification within the Study Area (Source NSW DII November 2008)

It can be seen from the above figure, that the main land classification types in the vicinity of the proposed Longwall 304 are Water Catchment on the south western side and Agricultural Class 5 on the north eastern side. There are no known agricultural activities within the Study Area.

8.2. Fences

Fences are located within the Study Area associated with the Garrawarra Complex and cadastral boundaries.

The fences 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 the fences, based on the

Extraction Plan Layout, therefore, are similar to the maxima based on the Preferred Project 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 plans be developed to manage potential impacts on fences during the mining of Longwall 304.

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 Longwall 304. The predicted parameters for each of the built features have been compared to the predicted parameters based on the Preferred Project 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 and rehabilitated areas.

Gas supply tanks are located within the Garrawarra Complex and are discussed in Section 11.1.

9.1. Mine Infrastructure Including Tailings Dams or Emplacement Areas

There is one exploration drill hole (boreholes) within the Study Area, S225, the location of which is shown in Drawing No. MSEC1009-09.

9.1.1. Predictions for the Exploration Boreholes

There is one exploration bore within the Study Area, S225. The maximum predicted subsidence parameters for the borehole located within the Study Area is provided in Table 9.1. The predicted tilts provided in this table are the maxima after the completion of Longwall 304. The predicted curvatures are the maxima at any time during or after the extraction of Longwall 304.

Table 9.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for Exploration Borehole S225 within the Study Area Resulting from the Extraction of Longwall 304

Location	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})
S225 (drilled in 1962)	1000	2.7	0.02	0.11

The predicted strains for borehole S225 is provided in Table 9.2. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 9.2 Predicted Strains for Exploration Borehole S225 based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature	Non-conventional based on the 95 % Confidence Level	Non-conventional based on the 99 % Confidence Level
Tension	0.5	0.9	1.6
Compression	2.0	1.6	3.2

9.1.2. Comparison of the Predictions for the Exploration Boreholes

The comparison of the maximum predicted subsidence parameters for borehole S225 within the Study Area, resulting from the extraction of Longwall 304, with those based on the Preferred Project Layout is provided in Table 9.3.

Table 9.3 Comparison of Maximum Predicted Conventional Subsidence Parameters for Exploration Borehole S225 based on the Extraction Plan Layout and the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	800	5.0	0.02	0.08
Preferred Project Layout (After LW304) (Report No. MSEC403)	800	5.0	0.02	0.08
Extraction Plan Layout (Report No. MSEC1009)	1000	2.7	0.02	0.11

It can be seen from Table 9.3, that the maximum predicted conventional subsidence and sagging curvature for borehole S225, based on the Extraction Plan Layout, are greater than those for the Preferred Project Layout. However, these parameters are less than the maxima predicted above the previously extracted Longwalls 20 to 27. The maximum predicted conventional tilt based on the Extraction Plan Layout is less than that for the Preferred Project Layout.

9.1.3. Impact Assessments and Recommendations for Exploration Borehole S225

The potential impacts for borehole S225 includes shearing at different horizons within the strata. It is recommended that the borehole be grouted and capped, if not already done so, prior to active subsidence.

9.2. Any Other Industrial, Commercial or Business Features

There are no other industrial, or commercial, or business features within the Study Area.

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 Longwall 304. The predicted parameters for each of the features have been compared to the predicted parameters based on the Preferred Project Layout.

10.1. Aboriginal Heritage Sites

10.1.1. Descriptions of the Aboriginal Heritage Sites

The detailed descriptions of the Aboriginal heritage sites are provided in the baseline reports prepared by Niche Environment and Heritage. There are 12 Aboriginal heritage sites that have been identified within the Study Area. The locations of these sites are shown in Drawing No. MSEC1009-09.

The descriptions of the Aboriginal heritage sites within the Study Area are provided in Table D.02, in Appendix D. All 12 sites have sandstone overhangs, of which six have art only, and six have art and/or artefacts and/or deposits.

10.1.2. Predictions for the Aboriginal Heritage Sites

The maximum predicted subsidence parameters for each of the Aboriginal heritage sites located within the Study Area is provided in Table D.02, in Appendix D. The predictions have been provided based on the Extraction Plan Layout, as well as for the Preferred Project Layout (After LW304) and the Preferred Project Layout (After LW317), 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 Plan Layout, is provided in Table 10.1. The predicted tilts provided in this table are the maxima after the completion of Longwall 304. The predicted curvatures are the maxima at any time during or after the extraction of Longwall 304.

Table 10.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Aboriginal Heritage Sites within the Study Area due to the Extraction of Longwall 304

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})
Overhangs	700	4.5	0.03	0.03

The maximum predicted conventional tilt for the overhang sites is 4.5 mm/m (i.e. 0.45 %, or 1 in 220). The maximum predicted conventional curvatures for these sites are 0.03 km^{-1} hogging and sagging, which equate to minimum radii of curvature of greater than 33 km.

The predicted strains for the overhang sites located above solid coal is provided in Table 10.2. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis above solid coal provided in Section 4.4.1).

Table 10.2 Predicted Strains for the Overhang Sites above solid coal based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 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	0.5	0.5	0.8
Compression	0.5	0.6	0.9

The predicted strains for the overhang sites located above longwall panels (including those above Longwalls 301 to 303) is provided in Table 10.3. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis above goaf provided in Section 4.4.1).

Table 10.3 Predicted Strains for the Overhang Sites above goaf based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 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	0.5	0.9	1.6
Compression	0.5	1.6	3.2

10.1.3. Comparisons of the Predictions for the Aboriginal Heritage Sites

The comparisons of the maximum predicted conventional subsidence parameters for the Aboriginal heritage sites within the Study Area, resulting from the extraction of Longwall 304, with those based on the Preferred Project Layout (After LW304) and the Preferred Project Layout (After LW317) are provided in Table 10.4. A comparison of the maximum predicted subsidence parameters for each of the Aboriginal heritage sites located within the Study Area is provided in Table D.02, in Appendix D.

Table 10.4 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Overhang Sites based on the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	600	1.0	0.03	0.04
Preferred Project Layout (After LW304) (Report No. MSEC403)	425	2.5	0.03	0.03
Extraction Plan Layout (Report No. MSEC1009)	700	4.5	0.03	0.03

It can be seen from Table D.02 in Appendix D that there is an increase in the predicted vertical subsidence at five of the Aboriginal Heritage sites based on the Extraction Plan Layout when compared to the Preferred Project Layout after Longwall 304. The potential for impacts on these sites do not result from absolute vertical subsidence, but rather the differential movements (i.e. tilt, curvature and strain). The predicted tilt increases at five of the Aboriginal Heritage sites based on the Extraction Plan Layout and curvatures based on the Extraction Plan Layout are generally similar to or less than those predicted based on the Preferred Project Layout.

Whilst the predicted subsidence parameters increase at a small number of Aboriginal heritage sites the maxima are similar to or less than the maxima predicted for other Aboriginal heritage sites located above the previously extracted longwalls at the Colliery. The potential impacts for these sites based on the Extraction Plan Layout, therefore, are similar to those assessed based on the Preferred Project Layout.

10.1.4. Impact Assessments and Recommendations for the Aboriginal Heritage Sites

The potential impacts for the Aboriginal heritage sites, based on the Extraction Plan Layout, are similar to or less than those assessed for this Extraction Plan layout or other Aboriginal heritage sites assessed for previous Metropolitan Coal Extraction Plans, based on the Preferred Project Layout. The assessments of the potential impacts for the Aboriginal heritage sites were provided in Section 5.24.2 of Report No. MSEC285, which supported the Project EA and Preferred Project Layout.

The majority of the Aboriginal heritage sites are located above solid coal and based on the low magnitudes of the predicted subsidence parameters, impacts to these sites resulting from the extraction of Longwall 304 are considered unlikely. Surface fracturing of the bedrock can occur outside the longwall layouts, as discussed in Section 4.8. However such fracturing is minor and isolated and the likelihood of fracturing impacting the Aboriginal Heritage Sites outside the longwall layouts is considered to be low. Site FRC76 is located above Longwall 304 and potential impacts to this site are similar to those assessed based on the Preferred Project Layout, including potential for fracturing and rock falls within overhangs.

The recommendations and management strategies for the Aboriginal heritage sites are the same as those based on the Preferred Project Layout.

10.2. European Heritage Sites

The Garrawarra Hospital is listed as local heritage significance in the *Wollongong Local Environmental Plan, 2009* with a number of items of heritage significance. Predictions and impact assessments for the Garrawarra Complex are provided in Section 11.1.

The Waterfall General (Garrawarra) Cemetery (the Cemetery) is located above Longwall 301 as shown in the attached Drawing No. MSEC1009-09.

The Wollongong City Council (WCC) LEP 2009 identifies the cemetery as an item of heritage significance (Item 6486 within Schedule 5 Part 1. A Conservation Plan for the Garrawarra Centre for Aged Care (Howard Tanner & Associates, 1993) provides the following information on the cemetery:

- The cemetery was closed when the Sanatorium closed (i.e. now the Garrawarra Complex), which was in 1957;
- No maintenance has been carried out since it closed;
- The cemetery has been recolonised by neighbouring bushland;
- The cemetery is described as "Mounds in ground, some broken pieces of marble. Overgrown with Eucalyptus haemastoma and other indigenous vegetation";
- The condition is described as "poor – little remains to identify this area as the Cemetery"

In 1967, Wollongong City Council was handed responsibility for maintenance and control of the Cemetery. Details of the cemetery and future recommendations are outlined in a report published in the Wollongong City Council minutes of ordinary meeting on Monday 27 August 2012. A summary of points from the report is as follows:

- The Cemetery is understood to have received some 2000 burials between 1909 and mid 1950's
- Little maintenance of the cemetery has occurred since the hand over in 1967
- Surrounding bush has encroached onto the site making it unrecognisable as a cemetery
- A site inspection was undertaken by WCC in March 2012 which found:
    - Many graves were damaged by overgrown vegetation, vandalism and grave subsidence.
    - Bush fires are believed to have resulted in the loss of much of the evidence of the Cemetery including timber grave markers
    - 43 identifiable graves were located during the site inspection
    - Clearing of the site would likely reveal further evidence of burials
    - Some evidence of fencing, roadways and entry gates remains on site
- A staged process is proposed for working towards further options for the future management, conservation and potential public accessibility

The cemetery is located in an area of relatively flat topography at a topographical high point. The area is approximately 22 hectares and has average dimensions of approximately 156 m by 142 m.

10.2.1. Predictions for the Cemetery

A summary of the maximum predicted values of total subsidence, tilt and curvature for the Cemetery, resulting from the extraction of Longwall 304, is provided in Table 10.5. The values are the maxima anywhere within the Cemetery and within 20 m of the cemetery boundary at any time during or after the extraction of each longwall.

Table 10.5 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Cemetery Resulting from the Extraction of Longwall 304

Location	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})
After LW303	750	5.0	0.03	0.03
After LW304	800	5.0	0.04	0.03

The maximum predicted total subsidence for the Cemetery, resulting from the extraction of Longwall 304, is 800 mm. The maximum predicted conventional tilt for the Cemetery is 5.0 mm/m (i.e. 0.5 %, or 1 in 200). The maximum predicted conventional curvatures are 0.04 km^{-1} hogging and 0.03 km^{-1} sagging, which equate to minimum radii of curvature of 25 km and 33 km, respectively.

The predicted strains for the cemetery are provided in Table 10.6. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 10.6 Predicted Strains for the Cemetery based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature	Non-conventional based on the 95 % Confidence Level	Non-conventional based on the 99 % Confidence Level
Tension	0.5	0.9	1.6
Compression	1.5	1.6	3.2

10.2.2. Comparison of the Predictions for the Cemetery

The comparison of the maximum predicted subsidence parameters for the Cemetery with those based on the Preferred Project Layout is provided in Table 10.7.

Table 10.7 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Cemetery based on the Extraction Plan Layout and the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	700	5.0	0.04	0.04
Preferred Project Layout (After LW304) (Report No. MSEC403)	700	5.0	0.04	0.04
Extraction Plan Layout (Report No. MSEC1009)	800	5.0	0.04	0.03

It can be seen from Table 10.7, that the maximum predicted conventional subsidence for the Cemetery, based on the Extraction Plan Layout, is greater than that for the Preferred Project Layout after Longwall 304. The potential for surface cracking does not depend on the vertical subsidence, but rather the differential movements (i.e. curvature and strain). The maximum predicted conventional tilt and hogging and sagging curvature based on the Extraction Plan Layout are the same or less than those for the Preferred Project Layout after Longwall 304.

10.2.3. Impact Assessments and Recommendations for the Cemetery

The maximum predicted conventional tilt for the Cemetery is 5.0 mm/m (i.e. 0.5 %, or 1 in 200). The predicted changes in grade are small, less than 1 %, and therefore are unlikely to result in adverse impacts on the Cemetery features including headstones or fencing.

The maximum predicted conventional curvatures for the Cemetery are 0.04 km^{-1} hogging and 0.03 km^{-1} sagging, which equate to minimum radii of curvature of 25 km and 33 km, respectively. The predicted strains are 0.9 mm/m tensile and 1.6 mm/m compressive based on the 95 % confidence level and 1.6 mm/m tensile and 3.2 mm/m compressive based on the 99 % confidence level.

The maximum predicted curvatures and the range of potential strains for the Cemetery are similar to those typically experienced elsewhere in the Southern Coalfield.

The cemetery is located above Longwall 301 and, it can be seen from Table 10.5, that the increase in predicted subsidence parameters due to Longwall 304 are very small. The likelihood of impact to the cemetery due to the extraction of Longwall 304 is considered to be low. It is possible but unlikely that minor surface cracking would occur at the cemetery due to Longwall 304. The identification of cracking may be difficult given the overgrown nature of the Cemetery. If these cracks eventuate and can be identified, they can be readily repaired by infilling with soil or other suitable materials.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301-303 are updated, in consultation with Wollongong City Council, to manage the potential impacts on the Cemetery.

10.3. Items of Architectural Significance

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

10.4. Survey Control Marks

The locations of the survey control marks within and immediately adjacent to the Study Area are shown in Drawing No. MSEC1009-09. The locations and details of the survey control marks were obtained from the *Land and Property Management Authority* using the *SCIMS Online* website (SCIMS, 2016).

The survey control marks within the Study Area 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 the survey control marks, based on the Extraction Plan Layout, therefore, are similar to the maxima based on the Preferred Project Layout, as summarised in Table 4.3. There are survey control marks that are located outside the Study Area that are likely to experience either small amounts of subsidence or far-field horizontal movements as the longwalls are mined. Far-field horizontal movements have been measured up to distances of approximately 3.9 km from active longwalls, however, almost all of the measured data beyond approximately 2.5 km is within the order of survey tolerance or accuracy. A discussion of far-field horizontal movements in provided in Section 4.6.

The potential impacts on the survey control marks, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Preferred Project Layout. It would be necessary on the completion of Longwall 304, when the ground has stabilised, to re-establish the coordinates for marks. The survey control network would be re-established following the completion of mining activities in consultation with Land and Property Information (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;
- Tennis courts;
- Swimming pools; and
- On-site water systems.

11.1. Garrawarra Complex

11.1.1. Descriptions of the Garrawarra Complex

The location of the Garrawarra Complex is shown in Drawing No. MSEC1009-09. The locations of the building structures and other built features and services on this complex are shown in Drawing Nos. MSEC1009-09 and MSEC1009-10.

The type and size of the building structures are shown in Table D.03, in Appendix D. There are a total of 86 building structures on the complex, comprising 57 residential or hospital buildings and 29 ancillary structures. There are also nine water storage tanks and a number of telecommunications towers located within the complex. All structures are located outside and to the north of the longwalls.

The *hospital* building structures are Refs. A01a to A01k and B03a to B03l. These structures are located outside the Study Area at a minimum distance of 470 m from Longwall 304. The buildings are not currently in use and have been fenced off. Photographs of the main hospital building structures are provided in Fig. 11.1 and Fig. 11.2.

Fig. 11.1 Hospital Building Structure (Ref. A01a)

Fig. 11.2 Hospital Building Structure (Ref. B03a)

The main *aged care* building structures are Refs. B01a to B01j and B02a to B02h. The other buildings associated with the aged care are Refs. B01k to B01q, B02i and B02j.

Structure Refs. B01a to B01d are located over 250 m to the north of Longwall 304. These buildings comprise single storey structures founded on a combination of ground slabs, strip footings and pad footings. The external walls are brick-veneer and the internal walls are of lightweight construction. The roofs are steel framed with metal sheeting. Photographs of these structures are provided in Fig. 11.3.

Fig. 11.3 Aged Care Building Structure Refs. B01a to B01d

Structure Ref. B01e is located 350 m to the north of Longwall 304. This building is a double storey brick structure founded on a ground slab with a tiled roof. Photographs of this structure are provided in Fig. 11.4.

Fig. 11.4 Aged Care Building Structure Ref. B01e

Structure Refs. B02a to B02h are located outside the Study Area. These buildings comprise one and two storey structures founded on strip footings and ground slabs. The perimeter walls are double brick, but in some cases the upper levels have timber framed walls. The suspended floors are timber framed and in some cases are supported on steel frames. The tiled roofs are supported by timber frames. Photographs of two of these structures are provided in Fig. 11.5.

Fig. 11.5 Aged Care Building Structure Refs. B02a and B02b

The *houses* are Refs. A01m, A02a to A09a and B04a to B09a. The other buildings associated with the houses are Refs. A01l, A02b, A03b to A03d, A06b, and A08b to A08f.

Structure Refs. A01m, A02a to A09a are located outside the Study Area. Only Structure Ref. A09a is located within the Study Area boundary. This building is a two storey double brick structure on strip footings with timber floor and a tiled roof. Photographs of this house and the associated structure are provided in Fig. 11.6.

Fig. 11.6 House Structure Ref. A09a (left side) and A09b (right side)

Structure Refs. B04a to B09a are located 200 m to 240 m to the north east of Longwall 304. These houses are one storey structures founded on brick piers and low level perimeter brick walls with timber floors, fibro walls and tiled roofs. Photographs of two of these houses are provided in Fig. 11.7. The houses are currently vacant and have been fenced off in preparation for demolition.

Fig. 11.7 Houses Structure Refs. B06a (left side) and B08a (right side)

The other main structures on the complex include water storage tanks (Refs. B14t01, B14t02, B16t01 to B16t03, B17t01, and B18t01), above ground gas storage tank (Ref. B01t03), and trickle filter tank B15t01. Photographs of these features are provided in Fig. 11.8 to Fig. 11.11.

Fig. 11.8 Water Storage Tanks Refs. B14t01 and B14t02 (left side) and Refs. B16t01 to B16t03 (right side)

Fig. 11.9 Water Storage Tanks Refs. B17t01 (poly tank) and B18t01 (steel tank)

Fig. 11.10 Gas Storage Tank B01t03

Fig. 11.11 Trickle Filter Tank B15t01

Other structures on the complex include telecommunications towers and compounds (Refs. B06b and B10a to B12a), potable water and sewer pipelines, powerlines and telecommunications cables. These built features and services are discussed in Sections 6.7 to 6.9.

11.1.2. Predictions for the Garrawarra Complex

The maximum predicted subsidence, tilt and curvature for each of the building structures and tanks, resulting from the extraction of Longwall 304 for the Extraction Plan Layout, are provided in Table D.03, in Appendix D. The values are the maxima within a distance of 20 m from the mapped extents of these features.

Summaries of the maximum predicted values of total subsidence, tilt and curvature after the extraction of Longwall 304 are provided in Table 11.1.

Table 11.1 Maximum Predicted Total Subsidence, Tilt and Curvature after the Extraction of Longwall 304

Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Hospital Building Structures (Refs. A01a to A01k and B03a to B03l)	< 20	< 0.5	< 0.01	< 0.01
Aged Care Building Structures (Refs. B01a to B01q and B02a to B02j)After LW302	< 20	< 0.5	< 0.01	< 0.01
Northern Houses (Refs. A01m and A02a to A09a)	< 20	< 0.5	< 0.01	< 0.01
Southern Houses (Refs. B04a to B09a)	90	0.5	< 0.01	< 0.01
Water Tanks and Trickle Filter Tank (Refs. B14t01, B14t02, B15t01, B16t01 to B16t03, B17t01 B18t01)	125	1.0	0.01	< 0.01
Gas Storage Tank (Ref. B01t03)	< 20	< 0.5	< 0.01	< 0.01

The majority of the building structure are outside the predicted 20 mm subsidence contour for Longwall 304 or outside the Study Area. The predicted subsidence parameters for these structures are therefore less than the expected limits of survey tolerance.

The private roads and the services directly associated with the hospital and residential building structures are located outside the footprint of Longwall 304 and are therefore expected to experience low levels of predicted movements, consistent with the above tables. A summary of the maximum predicted subsidence, tilt and curvature for the services located above Longwall 304, resulting from the extraction of Longwall 304, is provided in Table 11.2.

Table 11.2 Maximum Predicted Total Subsidence, Tilt and Curvature for the Private Roads and Services on the Garrawarra Complex

Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
After LW303	200	2.0	0.03	< 0.01
After LW304	300	3.0	0.03	< 0.01

The maximum predicted total subsidence for the private roads and services is 300 mm. The maximum predicted conventional tilt is 3.0 mm/m (i.e. 0.3 %, or 1 in 330). The maximum predicted conventional curvatures are 0.03 km^{-1} hogging and < 0.01 sagging, which equate to minimum radii of curvature of 33 km and 100 km respectively.

11.1.3. Comparisons of the Predictions for the Garrawarra Complex

The comparisons of the maximum predicted subsidence parameters for the building structures with those based on the Preferred Project Layout are provided in Table 11.3 to Table 11.6. The values are the maxima are the maxima at any time during or after the extraction of the longwalls.

Table 11.3 Comparison of Maximum Predicted Conventional Subsidence Parameters for the **Hospital Building Structures (Refs. A01a to A01k and B03a to B03l)**

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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1250	6.0	0.06	0.14
Preferred Project Layout (After LW304) (Report No. MSEC403)	950	5.5	0.05	0.14
Extraction Plan Layout (Report No. MSEC1009)	< 20	< 0.5	< 0.01	< 0.01

Table 11.4 Comparison of Maximum Predicted Conventional Subsidence Parameters for the **Aged Care Building Structures (Refs. B01a to B01q and B02a to B02j)**

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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1200	2.5	0.05	0.14
Preferred Project Layout (After LW304) (Report No. MSEC403)	1100	4.0	0.05	0.14
Extraction Plan Layout (Report No. MSEC1009)	< 20	< 0.5	< 0.01	< 0.01

Table 11.5 Comparison of Maximum Predicted Conventional Subsidence Parameters for the **Northern Houses (Refs. A01m and A02a to A09a)**

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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1300	2.5	0.05	0.13
Preferred Project Layout (After LW304) (Report No. MSEC403)	750	4.0	0.04	0.03
Extraction Plan Layout (Report No. MSEC1009)	< 20	< 0.5	< 0.01	< 0.01

Table 11.6 Comparison of Maximum Predicted Conventional Subsidence Parameters for the **Southern Houses (Refs. B04a to B09a)**

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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1200	1.0	0.03	0.10
Preferred Project Layout (After LW304) (Report No. MSEC403)	1100	2.0	0.03	0.10
Extraction Plan Layout (Report No. MSEC1009)	90	0.5	< 0.01	< 0.01

The maximum predicted subsidence parameters for the building structures, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout. The subsidence parameters have reduced due to the shortened commencing (i.e. northern) ends of Longwalls 302, 303 and 304.

The comparison of the maximum predicted subsidence parameters for the water storage tanks and trickle filter tank with those based on the Preferred Project Layout is provided in Table 11.7. The values are the maxima at any time during or after the extraction of the longwalls.

Table 11.7 Comparison of Maximum Predicted Conventional Subsidence Parameters for the **Water Storage Tanks and Trickle Filter Tank** based on the Extraction Plan Layout and the Preferred Project 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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1150	4.5	0.05	0.08
Preferred Project Layout (After LW304) (Report No. MSEC403)	1150	4.5	0.05	0.08
Extraction Plan Layout (Report No. MSEC1009)	125	1.0	0.01	< 0.01

The maximum predicted subsidence parameters for the water storage tanks and trickle filter tank based on the Extraction Plan Layout are less than the maxima predicted based on the Preferred Project Layout.

The comparison of the maximum predicted subsidence parameters for the private roads and services on the Garrawarra Complex with those based on the Preferred Project Layout are provided in Table 11.8. The values are the maxima are the maxima at any time during or after the extraction of the longwalls.

Table 11.8 Comparison of Maximum Predicted Conventional Subsidence Parameters for the **Private Roads and Services on the Garrawarra Complex**

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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1200	5.5	0.05	0.14
Preferred Project Layout (After LW304) (Report No. MSEC403)	1200	5.5	0.05	0.14
Extraction Plan Layout (Report No. MSEC1009)	300	3.0	0.03	< 0.01

The maximum predicted subsidence parameters for the private roads and services, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

11.1.4. Impact Assessments and Recommendations for the Garrawarra Complex

Impact Assessments for the Building Structures

Longwall layouts have been modified in order to minimise predicted subsidence movements at the Garrawarra building structures B01a to B01e, which house aged care patients and administrative support.

A structural assessment of the building structures within the Garrawarra Complex was undertaken by John Matheson and Associates Pty Ltd (JMA 2016). A summary of the results of the structural inspection is provided in Table 3 of JMA (2016). The assessment is based on predicted subsidence parameters for Longwall 301 to 303 and indicates that the likelihood of greater than negligible damage developing in the building structures is low, with an assessed probability of exceedance for Category 1 damage (i.e. fine cracks of less than 1mm) of 1% or less for all buildings with the exception of Building B02c. The abandoned building B02c has a probability of exceedance of 10% for Category 1 damage and a probability of exceedance of 1% for a 2 mm crack in Category 2.

The assessed probability exceedance of 1% is generally associated with large masonry structures. The assessed probability exceedance for the smaller building structures is generally unlikely to remote. A detailed discussion of the structural assessments is provided in the report by JMA (2016). Since the preparation of the structural assessment report, the Longwalls 301 to 303 were shortened by 90 m. The predicted subsidence parameters for the structures after Longwall 304 are generally unchanged or similar to those assessed in the report by JMA (2016) and the resulting assessments for the structures do not change for the EP Layout. The buildings are expected to remain safe and serviceable and potential impacts could be repaired using normal building maintenance techniques.

No adverse impacts on the building structures were observed due to the extraction of Longwalls 301 to 303.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301-303 are updated, in consultation with the infrastructure owner, to manage the potential impacts on the building structures. It is expected that these structures can be maintained in safe and serviceable conditions with the implementation of the appropriate monitoring and management strategies.

Impact Assessments for the Water Tanks and Trickle Filter Tank

The maximum predicted tilt for the water tanks and trickle filter tank is 1.0 mm/m (i.e. 0.1 %, or 1 in 1000). The magnitude of tilt is very small (i.e. less than 1 %) and therefore unlikely to adversely impact on these structures. Tilt can potentially affect the stored water levels within these tanks. It is recommended that infrastructure owner reviews the potential changes in freeboard resulting from the mining induced tilt.

The maximum predicted conventional curvatures are 0.01 km^{-1} hogging and less than 0.01 km^{-1} sagging, which equate to minimum radii of curvature of 50 km and greater than 100 km, respectively.

The tanks are located at distances of 200 m or greater from Longwall 304. The 95 % confidence intervals for the maximum total strains that the individual survey bays above solid coal (100 to 250 m as outlined in Section 6.8.2) experienced at any time during mining are 0.4 mm/m tensile and compressive. The 99 % confidence intervals for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 0.7 mm/m tensile and 0.6 mm/m compressive.

As assessment of the tanks was undertaken by John Matheson and Associates Pty Ltd (JMA 2016). A summary of the results of the structural inspection is provided in Table 3 of JMA (2016). The assessment is based on predicted subsidence parameters for Longwall 301 to 303 and indicates that the likelihood of greater than negligible damage developing in the water storage tanks is 20% for Category 1 damage (i.e. fine cracks of less than 1mm) of 1% or less.). Since the preparation of the structural assessment report, the Longwalls 301 to 303 were shortened by 90 m. The predicted subsidence parameters for the structures after Longwall 304 are unchanged or less than those assessed in the report by JMA (2016) and the resulting assessments for the structures do not change for the EP Layout. The tanks are expected to remain safe and serviceable and potential impacts could be repaired using normal building maintenance techniques.

No adverse impacts on the tanks were observed due to the extraction of Longwalls 301 to 303.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301-303 are updated, in consultation with the infrastructure owner, to manage the potential impacts on the water storage tanks and trickle filter tank. It is expected that these tanks can be maintained in safe and serviceable conditions with the implementation of the appropriate monitoring and management strategies.

Impact Assessments for the Gas Storage Tank

The gas storage tank is located more than 330 m from Longwall 304. The maximum predicted subsidence parameters are negligible and therefore unlikely to adversely impact on this tank.

The maximum predicted conventional curvatures are less than 0.01 km^{-1} for both hogging and sagging curvature, which equate to minimum radii of curvature of greater than 100 km. The predicted strains are less than 0.5 mm/m tensile and compressive based on the 95 % confidence level.

The gas storage tank is supported on a concrete slab above the ground and therefore is unlikely to experience the mining induced curvatures and strains.

At this distance, it is unlikely that the storage tank and pipework would experience adverse impacts as a result of the extraction of Longwall 304. No adverse impacts were observed due to the extraction of Longwalls 301 to 303.

Impact Assessments for the Private Roads and Services

The private roads in the complex with bitumen seals and private services within the complex are located outside Longwall 304. Experience from the Southern Coalfield indicates that the impacts on these roads and services are unlikely.

Short lengths of road comprising chip seal or gravel surface are located above Longwall 302. The roads are not well maintained. Potential impacts to these roads may include minor and isolated cracks. The impacts can be managed using monitoring (visual or ground survey lines) during active subsidence and remediation of impacts using normal road maintenance techniques.

It is expected that the private roads and services can be maintained in safe and serviceable conditions with the development of the appropriate monitoring and management plans. No adverse impacts were observed due to the extraction of Longwalls 301 to 303.

The predicted subsidence parameters for the built features and services on the Garrawarra Complex, based on the Extraction Plan Layout, are similar to or less than the maxima predicted based on the Preferred Project Layout. Longwall 304 has been set back a considerable distance from the majority of the structures in the Garrawarra Complex. The recommendations and management strategies for the Garrawarra Complex, therefore, are significantly less than those based on the Preferred Project Layout.

11.2. Any Other Residential Feature

There are no other residential features within the Study Area.

APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

Glossary of Terms and Definitions

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

Angle of draw	The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence).
Chain pillar	A block of coal left unmined between the longwall extraction panels.
Cover depth (H)	The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel.
Closure	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 *km (km)*. Curvature can be either **hogging** (i.e. convex) or **sagging** (i.e. concave).
Extracted seam	The thickness of coal that is extracted. The extracted seam thickness is thickness normally given as an average over the area of the panel.
Effective extracted seam thickness (T)	The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel.
Face length	The width of the coalface measured across the longwall panel.
Far-field movements	The measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain.
Goaf	The void created by the extraction of the coal into which the immediate roof layers collapse.
Goaf end factor	A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.
Horizontal displacement	The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.
Inflection point	The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max.
Incremental subsidence	The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.
Panel	The plan area of coal extraction.
Panel length (L)	The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib.
Panel width (Wv)	The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.
Panel centre line	An imaginary line drawn down the middle of the panel.
Pillar	A block of coal left unmined.
Pillar width (Wpi)	The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.

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

APPENDIX B. REFERENCES

References

Bangalay Botanical Surveys (2008). *Metropolitan Coal Project Baseline Flora Survey – Proposed Longwall Mining Area.* Bangalay Botanical Surveys, April 2008.

Cardno Report No.3 (July 2009) *Bridges Near Proposed Longwalls 20 to 22 at Metropolitan Colliery - Investigation of Potential Effects on Bridges of Ground Movement Due to Mining. (Cardno Report 607126 Report No. 3, 20 July 2009)*

Helensburgh Coal Pty Ltd (2008), *Metropolitan Coal Project Environmental Assessment,* 5 September 2008.

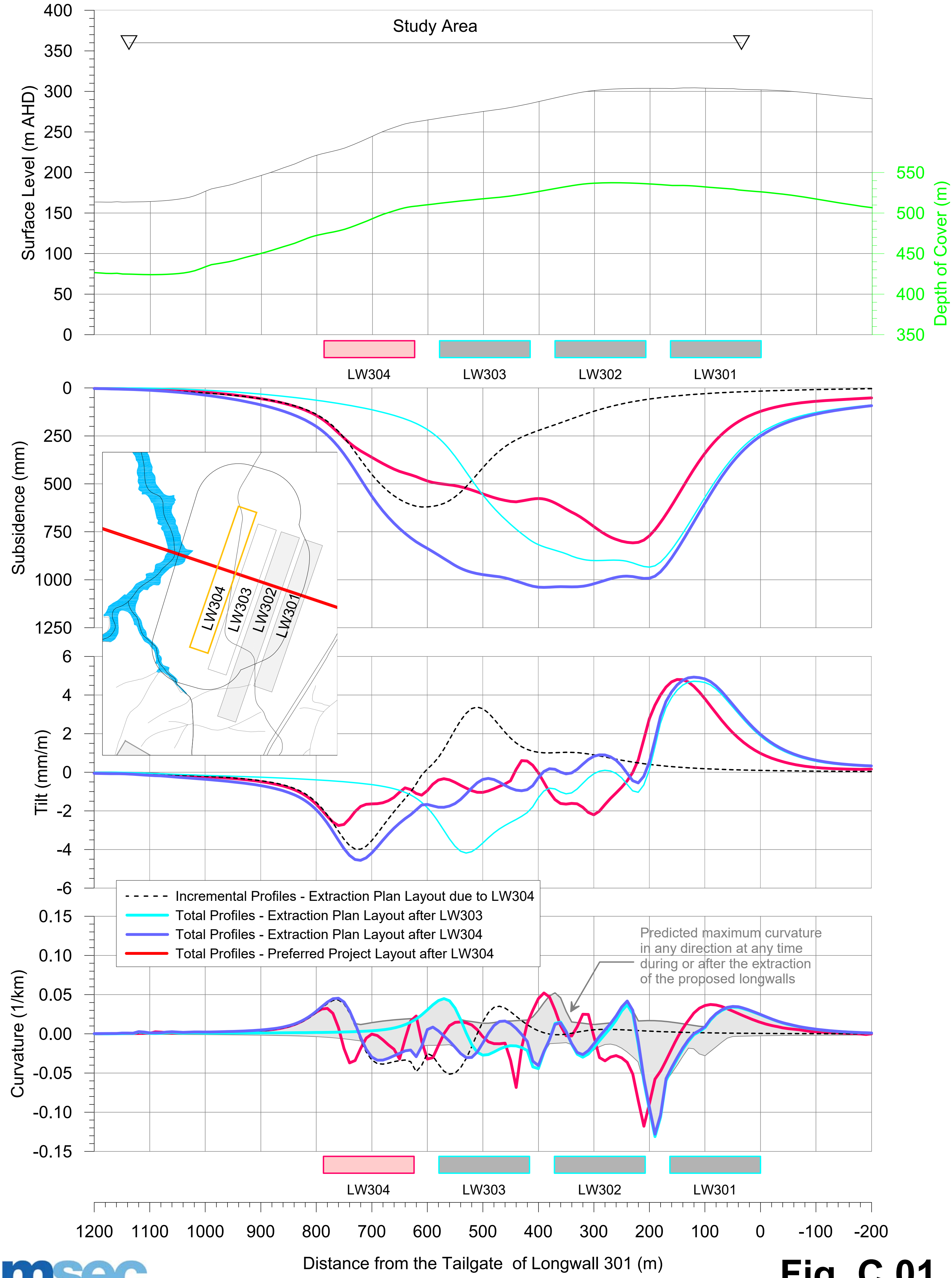
Heritage Computing (2008). *Hydrogeological Assessment in Support of Metropolitan Colliery Longwalls 20 to 22 Environmental Assessment.* June 2008.

JMA (2016). *Preliminary Structural Assessment Report*. John Matheson and Associates Pty Ltd, October 2016.

Waddington, A.A. and Kay, D.R., (2002). *Research into the Impacts of Mine Subsidence on the Strata and Hydrology of River Valleys and Development of Management Guidelines for Undermining Cliffs, Gorges and River Systems*. Report on ACARP Research Project C9067, June 2002.

APPENDIX C. FIGURES

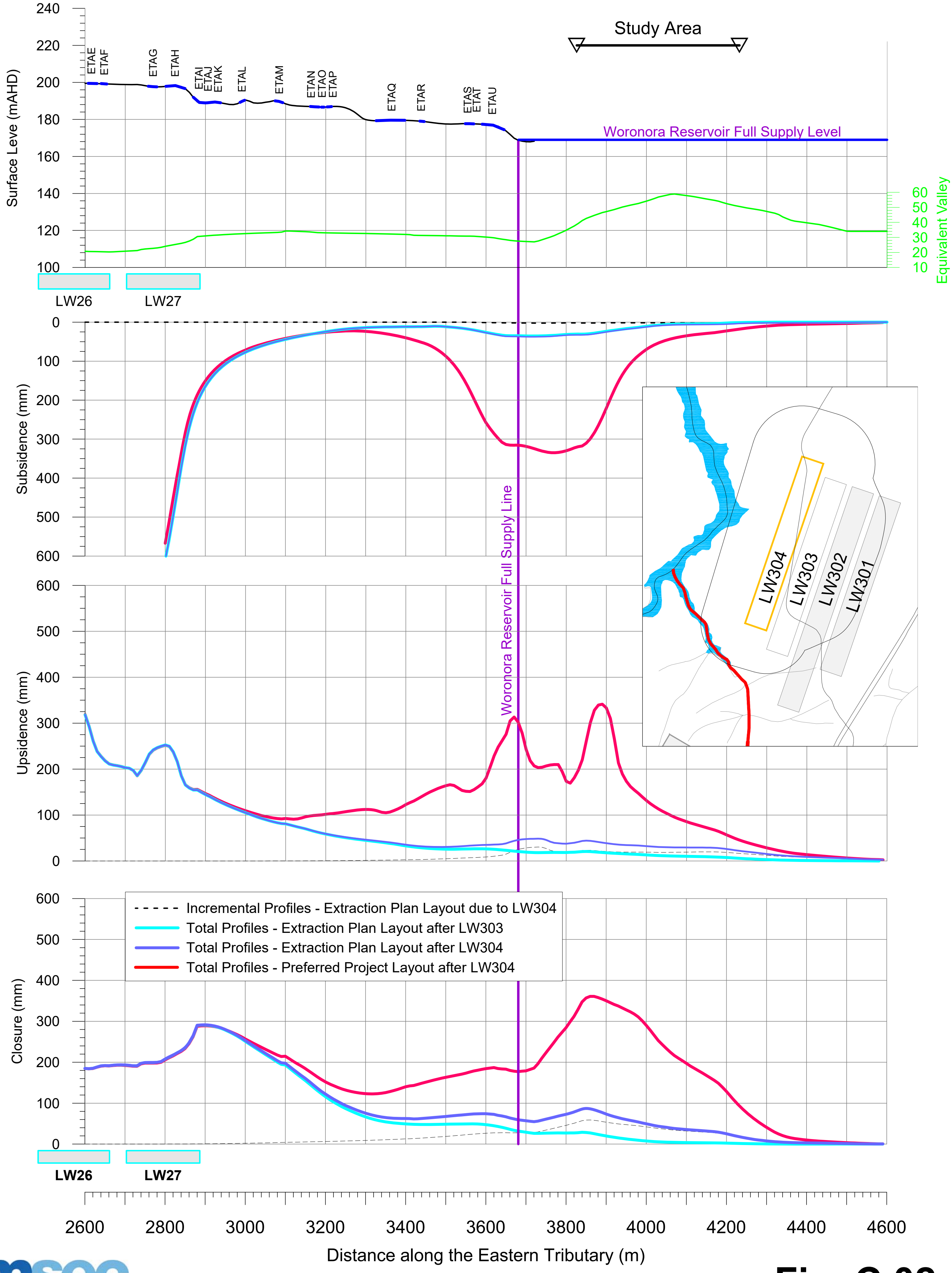
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 due to LW304



msec

Fig. C.01

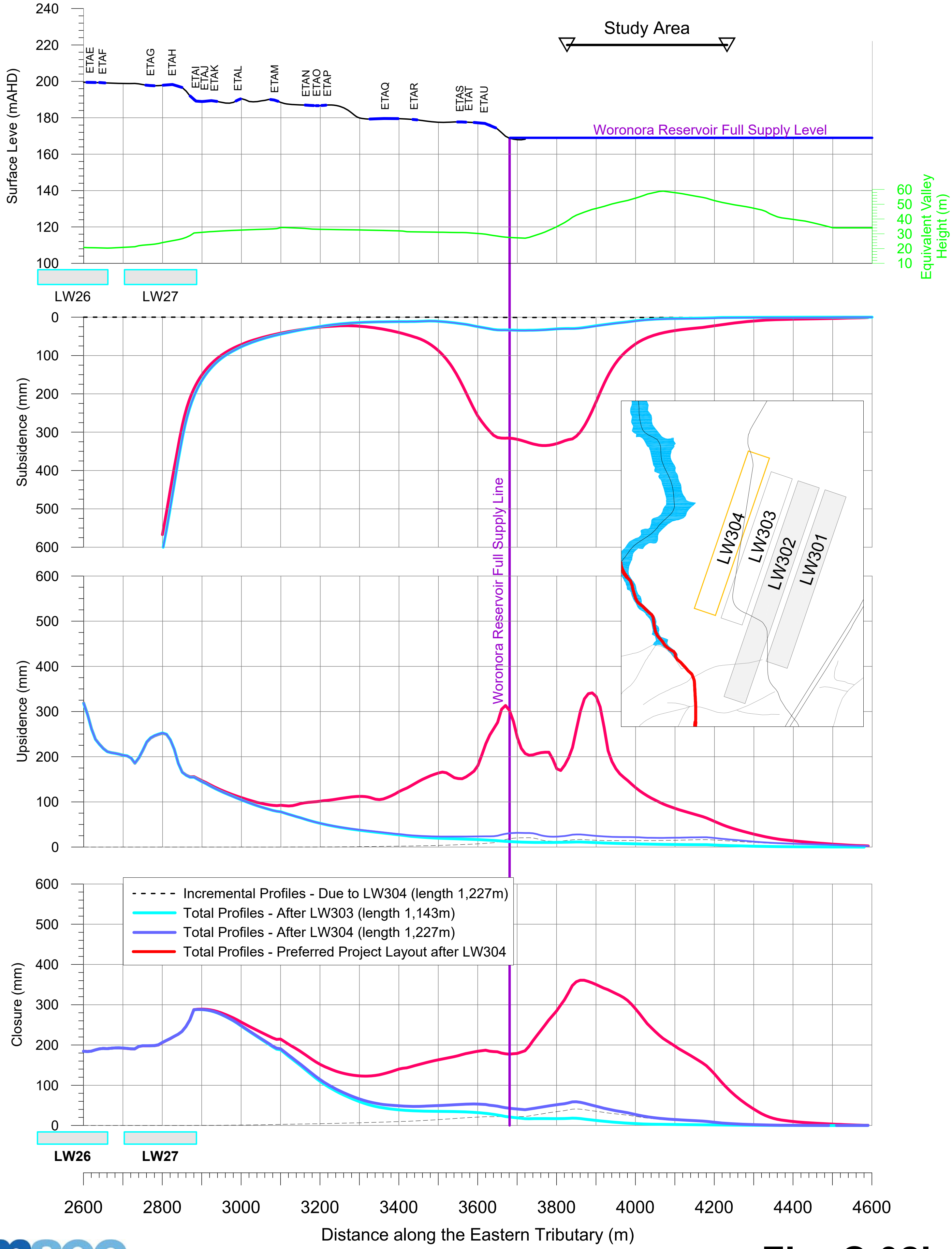
Predicted Profiles of Subsidence, Upsidence and Closure along the Eastern Tributary and Woronora Reservoir due to LW304 Extraction Plan Layout



msec

Fig. C.02a

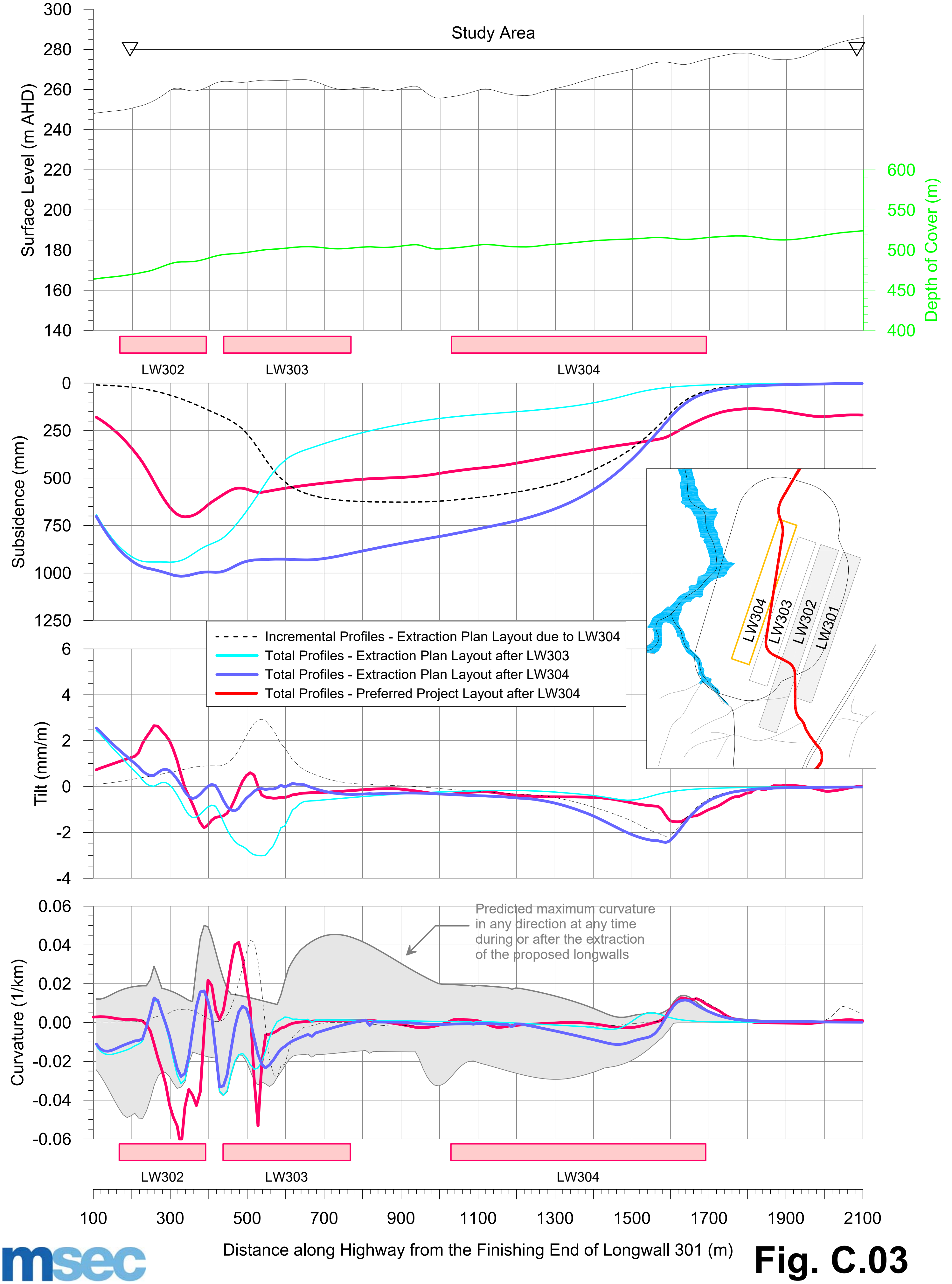
Predicted Profiles of Subsidence, Upsidence and Closure along the Eastern Tributary and Woronora Reservoir due to LW304 Alternative Layout



msec

Fig. C.02b

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along the Old Princes Highway due to LW304



msec

Fig. C.03

I:\Projects\Metropolitan\MSEC1009 - LW304 Extraction Plan\Subsdata\Impacts\Water\Fig. C.04 - Water Main 1.grf.....25-Jan-19

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Water Main 1 due to LW304

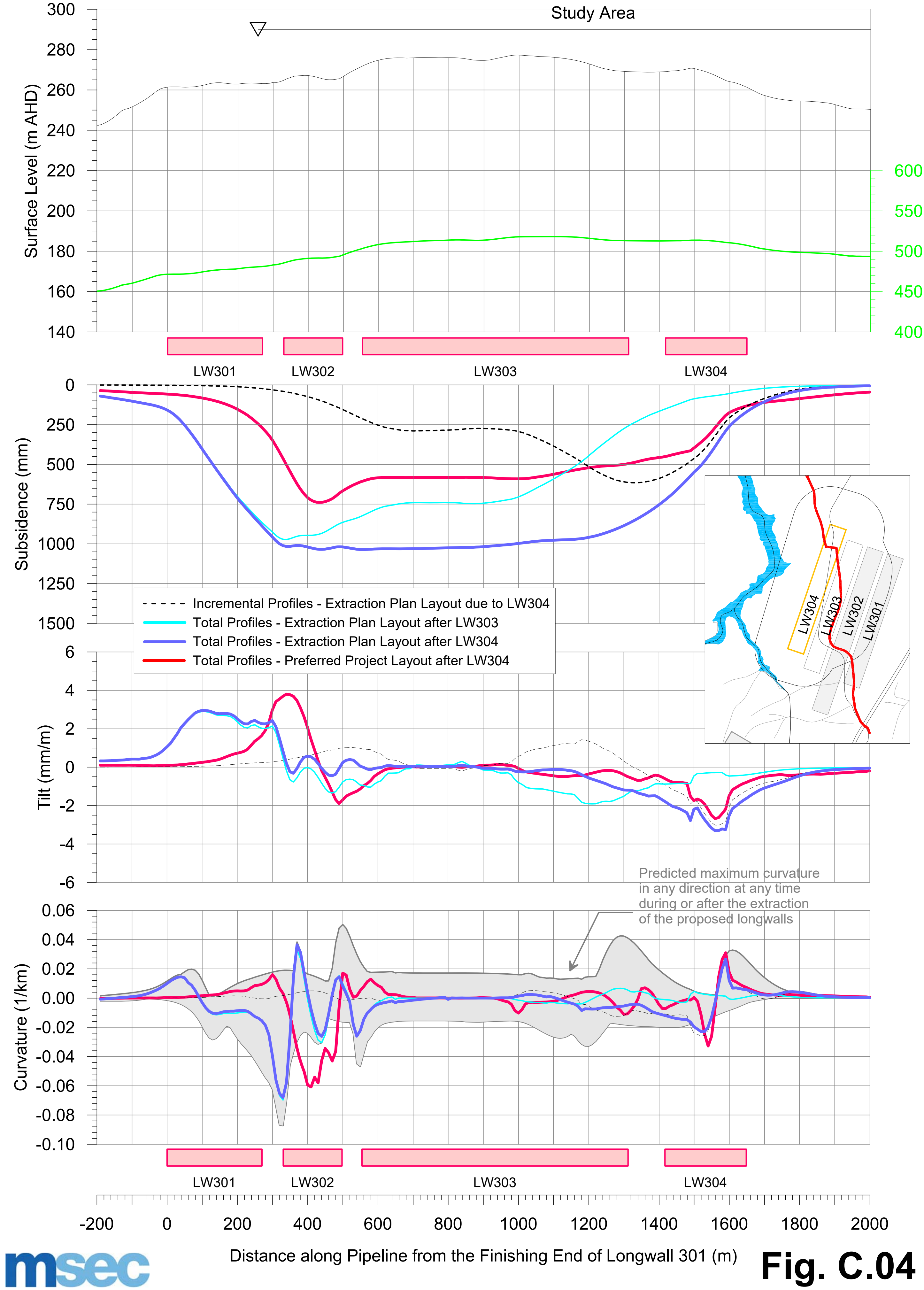
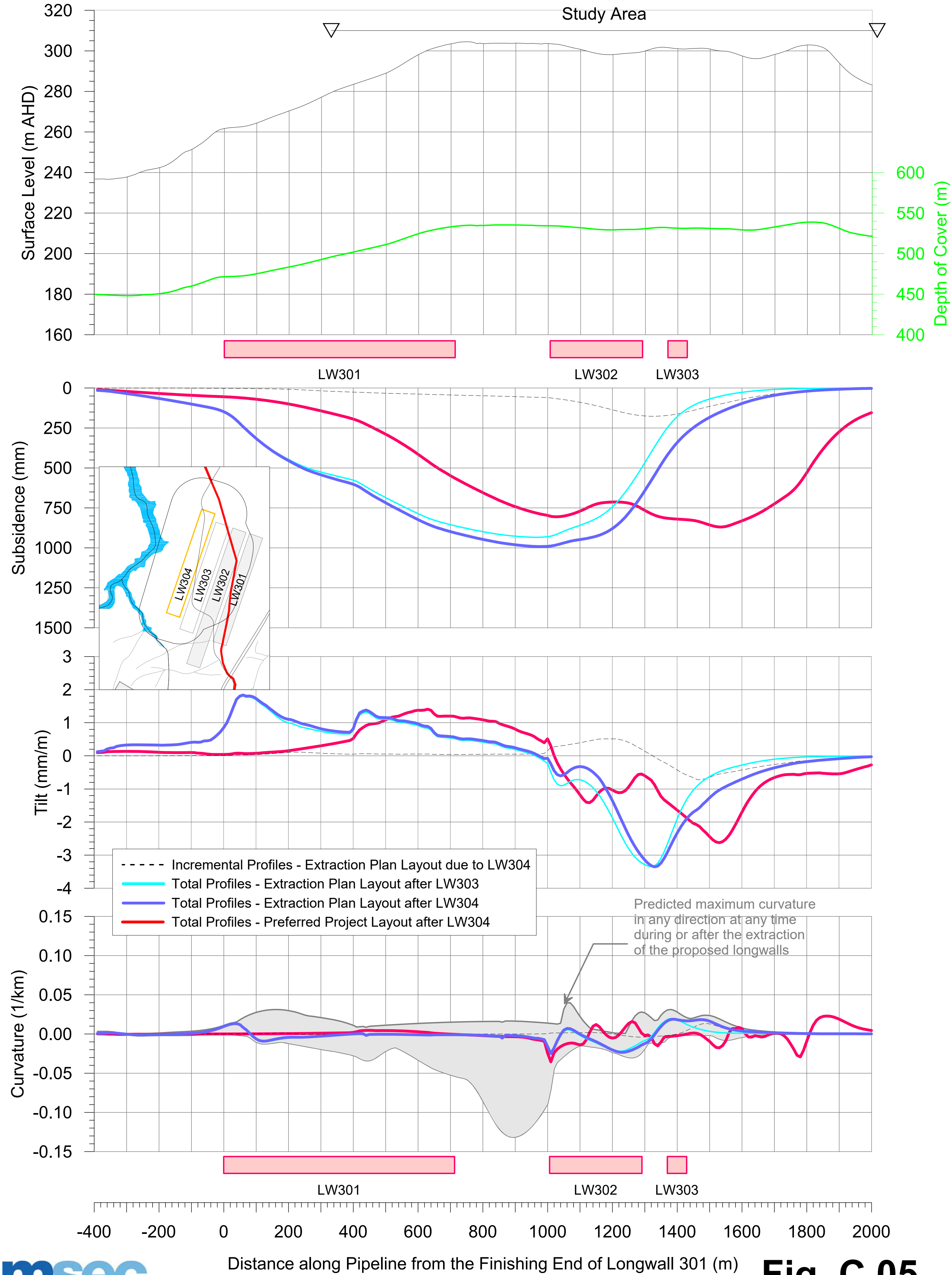


Fig. C.04

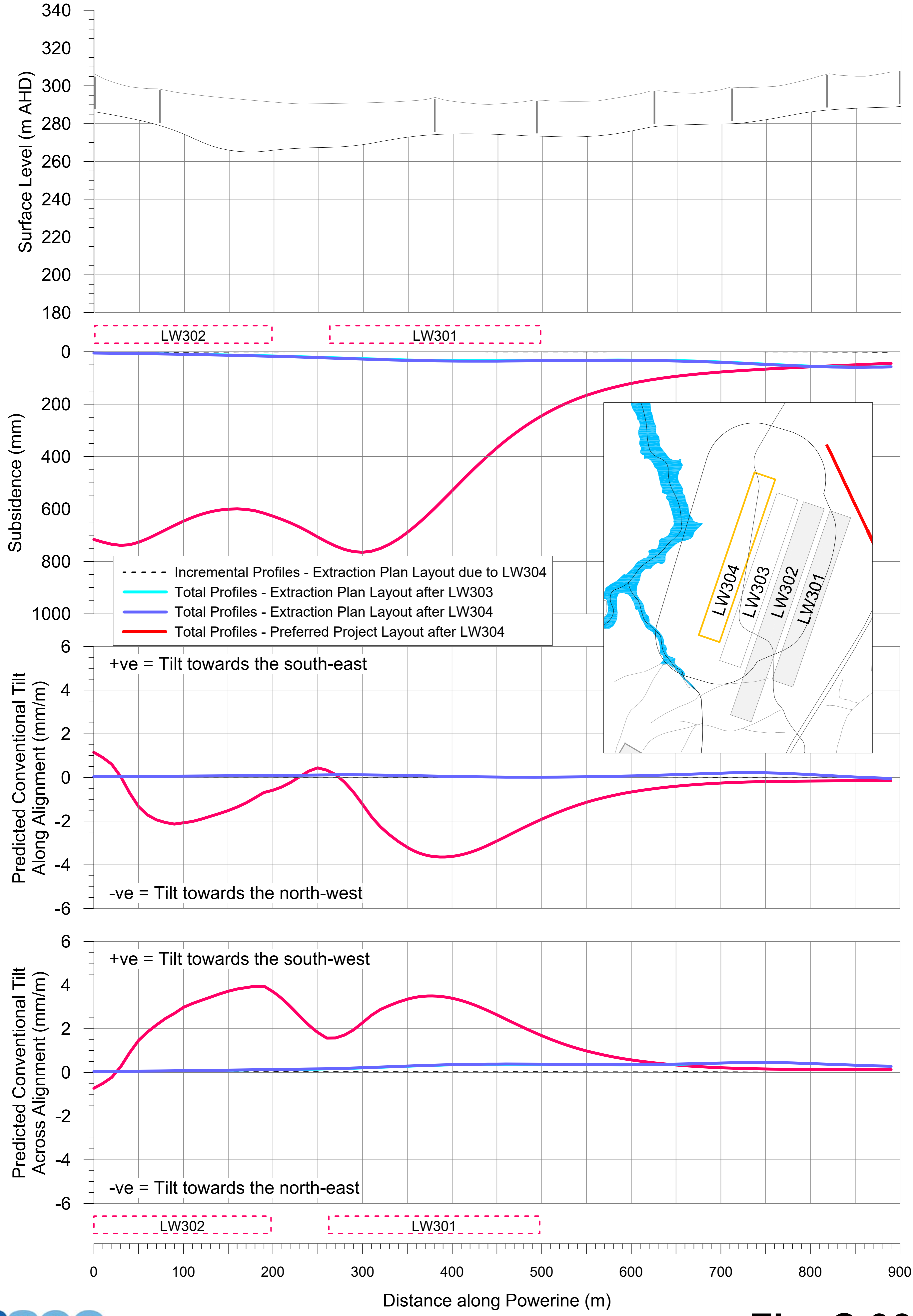
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Water Main 2 due to LW304



msec

Fig. C.05

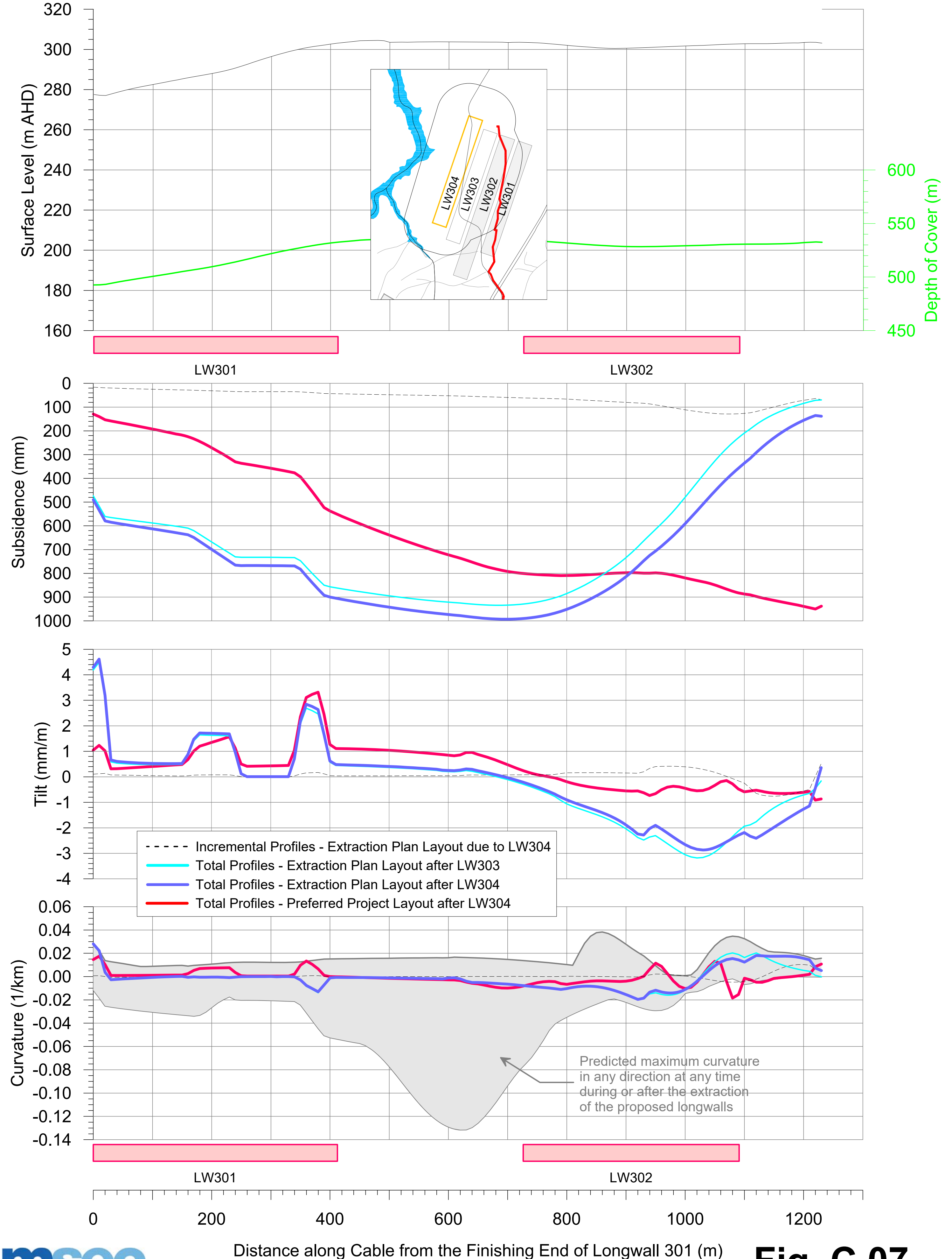
Predicted Profiles of Conventional Subsidence, Tilt Along and Tilt Across the Alignment of Powerline 1 due to LW304



msec

Fig. C.06

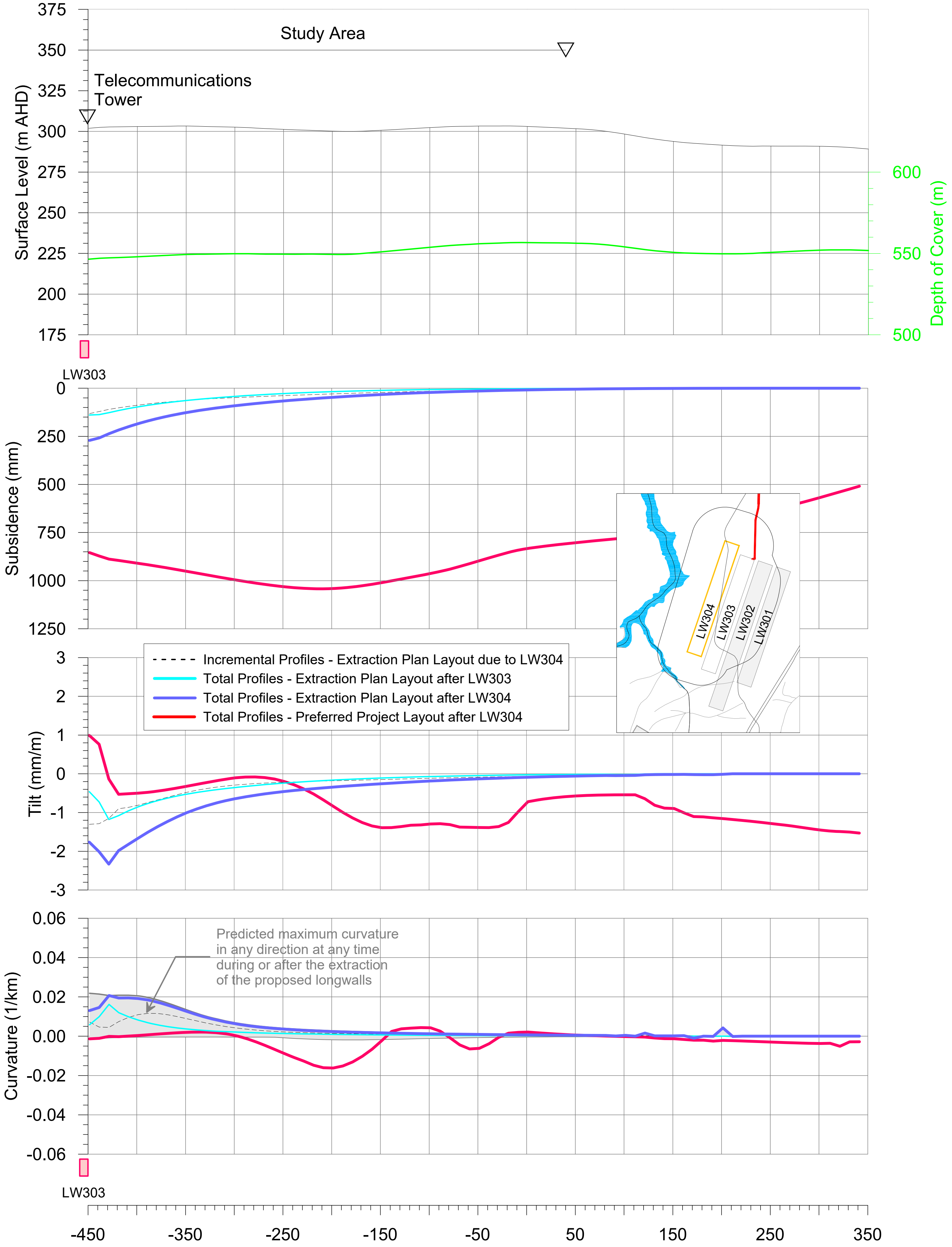
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along the Optus Optical Fibre Cable due to LW304



msec

Fig. C.07

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along the Telstra Optical Fibre Cable due to LW304



msec

Fig. C.08

APPENDIX D. TABLES

Table D.01 - Maximum Predicted Subsidence Parameters for the Swamps

Swamp ID	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW304 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW304 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW304 (mm/m)*	Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW304 (mm/m)	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW317 (1/km)*	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW304 (1/km)*	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW304 (1/km)
S40	*550*	*550*	925	3.0	*3.0*	4.5	0.04	*0.04*	0.05
S41	*825*	*800*	1050	5.0	*5.0*	5.0	0.04	*0.04*	0.04
S46	*775*	*750*	1050	2.5	*2.5*	1.0	0.06	*0.06*	0.05
S47	*575*	*500*	850	0.5	*1.5*	4.0	0.03	*0.03*	0.03
S48	*500*	*200*	175	0.5	*2.5*	1.5	0.03	*0.03*	0.02
S49	*500*	*350*	450	0.5	*2.5*	4.5	0.04	*0.03*	0.05
S50	*550*	*400*	700	1.0	*3.0*	4.5	0.04	*0.03*	0.04
S51/S52	*650*	*625*	1000	1.0	*2.0*	3.5	0.04	*0.04*	0.04
S53	*750*	*725*	1050	1.5	*1.5*	3.0	0.06	*0.06*	0.05
S58	*975*	*825*	90	2.0	*4.5*	1.0	0.05	*0.04*	< 0.01
S69	*1150*	*150*	< 20	2.0	*1.0*	< 0.5	0.05	*< 0.01*	< 0.01
S70	*1150*	*175*	< 20	1.0	*1.0*	< 0.5	0.05	*0.01*	< 0.01
S71a	*975*	*125*	< 20	2.0	*0.5*	< 0.5	0.05	*< 0.01*	< 0.01
S71b	*725*	*30*	< 20	2.5	*< 0.5*	< 0.5	0.07	*< 0.01*	< 0.01
S72	*525*	*< 20*	< 20	1.0	*< 0.5*	< 0.5	0.05	*< 0.01*	< 0.01

Table D.01 - Maximum Predicted Subsidence Parameters for the Swamps

Swamp ID	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW317 (1/km)*	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW304 (1/km)*	Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW304 (1/km)	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW304 (mm/m)*	Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW304 (mm/m)	*Maximum Predicted Total Compressive Strain based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Compressive Strain based on the Preferred Project Layout after LW304 (mm/m)*	Predicted Total Conventional Comp. Strain based on the Extraction Plan Layout after LW304 (mm/m)
S40	0.09	*0.09*	0.06	1.00	1.00	1.00	1.50	1.50	1.00
S41	0.10	*0.10*	0.12	1.00	1.00	1.00	2.00	2.00	2.00
S46	0.07	*0.07*	0.06	1.00	1.00	1.00	1.50	1.50	1.00
S47	0.04	*0.04*	0.03	1.00	1.00	1.00	1.00	1.00	1.00
S48	0.03	*< 0.01*	< 0.01	< 0.5	< 0.5	< 0.5	1.00	< 0.5	< 0.5
S49	0.04	*0.04*	< 0.01	1.00	< 0.5	1.00	1.00	1.00	< 0.5
S50	0.04	*0.04*	0.03	1.00	< 0.5	1.00	1.00	1.00	1.00
S51/S52	0.07	*0.07*	0.04	1.00	1.00	1.00	1.50	1.50	1.00
S53	0.07	*0.07*	0.05	1.00	1.00	1.00	1.50	1.50	1.00
S58	0.05	*0.05*	< 0.01	1.00	1.00	< 0.5	1.00	1.00	< 0.5
S69	0.06	*< 0.01*	< 0.01	1.00	< 0.5	< 0.5	1.00	< 0.5	< 0.5
S70	0.07	*< 0.01*	< 0.01	1.00	< 0.5	< 0.5	1.00	< 0.5	< 0.5
S71a	0.05	*< 0.01*	< 0.01	1.00	< 0.5	< 0.5	1.00	< 0.5	< 0.5
S71b	0.06	*< 0.01*	< 0.01	1.00	< 0.5	< 0.5	1.00	< 0.5	< 0.5
S72	0.06	*< 0.01*	< 0.01	1.00	< 0.5	< 0.5	1.00	< 0.5	< 0.5

Table D.01 - Maximum Predicted Subsidence Parameters for the Swamps

Swamp ID	*Maximum Predicted Total Upsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Upsidence based on the Preferred Project Layout after LW304 (mm)*	Maximum Predicted Total Upsidence based on the Extraction Plan Layout after LW304 (mm)	*Maximum Predicted Total Closure based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Closure based on the Preferred Project Layout after LW304 (mm)*	Maximum Predicted Total Closure based on the Extraction Plan Layout after LW304 (mm)
S40	-	-	-	-	-	-
S41	-	-	-	-	-	-
S46	-	-	-	-	-	-
S47	-	-	-	-	-	-
S48	-	-	-	-	-	-
S49	-	-	-	-	-	-
S50	-	-	-	-	-	-
S51/S52	80	*70*	90	*40*	*40*	*40*
S53	100	*90*	90	*40*	*40*	*40*
S58	40	*30*	< 20	*30*	*30*	*< 20*
S69	-	-	-	-	-	-
S70	-	-	-	-	-	-
S71a	-	-	-	-	-	-
S71b	-	-	-	-	-	-
S72	-	-	-	-	-	-

Table D.02 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

Site	Description	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW304 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW304 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW304 (mm/m)*	Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW304 (mm/m)
FRC 71	Sandstone overhang with art only	*450*	*30*	< 20	*< 0.5*	*< 0.5*	< 0.5
FRC 76	Sandstone overhang with art only	*550*	*425*	700	*1.0*	*1.5*	4.5
FRC 77	Sandstone overhang with art, artefacts and deposit	*525*	*125*	200	*< 0.5*	*1.5*	2.0
FRC 78	Sandstone overhang with art only	*525*	*125*	175	*0.5*	*1.0*	1.5
FRC 85	Sandstone overhang with art, artefacts and deposit	*550*	*90*	< 20	*0.5*	*0.5*	< 0.5
FRC 86	Sandstone overhang with art only	*575*	*175*	225	*0.5*	*2.0*	2.5
FRC 87	Sandstone overhang with art, artefacts and deposit	*450*	*< 20*	< 20	*0.5*	*< 0.5*	< 0.5
FRC 90	Sandstone overhang with artefacts and deposit	*575*	*125*	80	*1.0*	*1.0*	1.0
FRC 91	Sandstone overhang with art, artefacts and deposit	*600*	*125*	< 20	*1.0*	*1.0*	< 0.5
FRC 309	Sandstone overhang with artefacts and deposit	*475*	*60*	100	*1.0*	*0.5*	1.0
FRC 310	Sandstone overhang with art only	*500*	*20*	< 20	*0.5*	*< 0.5*	< 0.5
FRC 325	Sandstone overhang with art only	*450*	*225*	30	*< 0.5*	*2.5*	< 0.5

Table D.02 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

Site	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW317 (1/km)*	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW304 (1/km)*	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW304 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW317 (1/km)*	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW304 (1/km)*	Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW304 (1/km)
FRC 71	0.03	< 0.01	< 0.01	0.01	< 0.01	< 0.01
FRC 76	0.01	0.01	0.02	0.03	0.03	0.03
FRC 77	0.02	0.02	0.03	0.03	< 0.01	< 0.01
FRC 78	0.02	0.02	0.02	0.03	< 0.01	< 0.01
FRC 85	0.03	< 0.01	< 0.01	0.03	< 0.01	< 0.01
FRC 86	0.03	0.03	0.03	0.04	< 0.01	< 0.01
FRC 87	0.03	< 0.01	< 0.01	0.01	< 0.01	< 0.01
FRC 90	0.01	0.01	0.01	0.01	< 0.01	< 0.01
FRC 91	0.01	< 0.01	< 0.01	0.03	< 0.01	< 0.01
FRC 309	0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01
FRC 310	< 0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01
FRC 325	0.03	0.03	< 0.01	0.01	0.01	< 0.01

Table D.02 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

Site	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW304 (mm/m)*	Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW304 (mm/m)	*Maximum Predicted Total Compressive Strain based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Compressive Strain based on the Preferred Project Layout after LW304 (mm/m)*	Predicted Total Conventional Comp. Strain based on the Extraction Plan Layout after LW304 (mm/m)
FRC 71	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 76	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 77	*< 0.5*	*< 0.5*	< 0.5	*1.0*	*< 0.5*	< 0.5
FRC 78	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 85	*1.0*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 86	*< 0.5*	*< 0.5*	< 0.5	*1.0*	*< 0.5*	< 0.5
FRC 87	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 90	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 91	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 309	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 310	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 325	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5

Note: Predicted conventional strains are based on 15 times curvature

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	Description	Maximum Dimension (m)	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW304 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW304 (mm)	Maximum Predicted Total Tilt based on the Preferred Project Layout after LW317 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW304 (mm)*	*Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW304 (mm/m)*
A01a	Hospital	38	1250	925	< 20	2.0	2.5	< 0.5
A01b	Hospital	17	1200	925	< 20	1.5	1.0	< 0.5
A01c	Hospital	5	1150	925	< 20	2.0	1.0	< 0.5
A01d	Hospital	5	1150	925	< 20	2.0	0.5	< 0.5
A01e	Hospital	34	1200	950	< 20	2.0	1.0	< 0.5
A01f	Hospital	5	1200	900	< 20	1.0	2.5	< 0.5
A01g	Hospital	5	1250	900	< 20	1.0	2.5	< 0.5
A01h	Hospital	7	1250	900	< 20	1.0	2.5	< 0.5
A01i	Hospital	5	1250	900	< 20	1.0	2.5	< 0.5
A01j	Hospital	5	1250	875	< 20	< 0.5	2.5	< 0.5
A01k	Hospital	5	1250	850	< 20	< 0.5	2.5	< 0.5
A01l	Shed	4	1200	850	< 20	< 0.5	2.5	< 0.5
A01m	House	18	1300	675	< 20	2.0	4.0	< 0.5
A02a	House	11	1300	525	< 20	2.5	4.0	< 0.5
A02b	Shed	6	1300	425	< 20	2.5	4.0	< 0.5
A03a	House	16	1300	575	< 20	2.5	4.0	< 0.5
A03b	Shed	10	1300	525	< 20	2.5	4.0	< 0.5
A03c	Shed	5	1300	475	< 20	2.5	4.0	< 0.5
A03d	Shed	2	1300	475	< 20	2.5	4.0	< 0.5
A04a	House	14	1300	625	< 20	2.0	4.0	< 0.5
A05a	House	12	1300	650	< 20	1.5	4.0	< 0.5
A06a	House	11	1300	675	< 20	1.5	4.0	< 0.5
A06b	Shed	4	1300	625	< 20	1.5	4.0	< 0.5
A07a	House	16	1250	700	< 20	1.5	4.0	< 0.5
A08a	House	17	1250	750	< 20	1.5	3.5	< 0.5
A08b	Shed	13	1250	700	< 20	1.5	4.0	< 0.5
A08c	Shed	3	1250	725	< 20	1.5	3.5	< 0.5
A08d	Shed	3	1250	700	< 20	1.5	3.5	< 0.5
A08e	Shed	2	1250	600	< 20	1.5	4.0	< 0.5
A08f	Shed	2	1200	550	< 20	2.5	4.0	< 0.5
A09a	House	15	1200	725	< 20	1.0	4.0	< 0.5
A09b	Shed	10	1150	675	< 20	1.0	4.0	< 0.5
B01a	Retirement Home	14	1150	825	< 20	1.5	4.0	< 0.5
B01b	Retirement Home	14	1150	925	< 20	1.5	3.0	< 0.5

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	Description	Maximum Dimension (m)	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW304 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW304 (mm)	Maximum Predicted Total Tilt based on the Preferred Project Layout after LW317 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW304 (mm)*	*Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW304 (mm/m)*
B01c	Retirement Home	14	*1200*	*1050*	20	*2.0*	*3.0*	< 0.5
B01d	Retirement Home	15	*1200*	*1100*	30	*2.0*	*3.0*	< 0.5
B01e	Retirement Home	19	*1150*	*975*	< 20	*1.0*	*2.5*	< 0.5
B01f	Retirement Home	11	*1150*	*950*	< 20	*1.5*	*2.5*	< 0.5
B01g	Retirement Home	21	*1150*	*1000*	< 20	*1.0*	*2.5*	< 0.5
B01h	Retirement Home	19	*1150*	*950*	< 20	*1.5*	*2.5*	< 0.5
B01i	Retirement Home	12	*1150*	*975*	< 20	*1.0*	*2.5*	< 0.5
B01j	Retirement Home	6	*1100*	*850*	< 20	*1.5*	*3.0*	< 0.5
B01k	Shed	3	*1150*	*950*	< 20	*1.0*	*2.5*	< 0.5
B01l	Shed	5	*1150*	*950*	< 20	*1.0*	*2.0*	< 0.5
B01m	Shed	3	*1150*	*975*	< 20	*1.5*	*1.5*	< 0.5
B01n	Shed	7	*1200*	*1050*	< 20	*1.5*	*2.0*	< 0.5
B01o	Shed	5	*1200*	*1050*	< 20	*1.5*	*2.0*	< 0.5
B01p	Shed	7	*1200*	*1100*	30	*1.5*	*1.0*	< 0.5
B01q	Shed	5	*1200*	*1100*	20	*1.5*	*1.0*	< 0.5
B01t01	Tank	4	*1150*	*925*	< 20	*1.0*	*2.5*	< 0.5
B01t02	Tank	4	*1150*	*925*	< 20	*1.0*	*2.5*	< 0.5
B01t03	Tank	6	*1150*	*925*	< 20	*1.0*	*2.5*	< 0.5
B02a	Retirement Home	40	*1200*	*950*	< 20	*2.0*	*1.0*	< 0.5
B02b	Retirement Home	21	*1200*	*950*	< 20	*1.5*	*1.5*	< 0.5
B02c	Retirement Home	83	*1100*	*1050*	< 20	*2.0*	*1.5*	< 0.5
B02d	Retirement Home	25	*1100*	*975*	< 20	*1.5*	*1.0*	< 0.5
B02e	Retirement Home	15	*1100*	*925*	< 20	*2.0*	*1.0*	< 0.5
B02f	Retirement Home	18	*1100*	*950*	< 20	*1.5*	*1.0*	< 0.5
B02g	Retirement Home	9	*1100*	*950*	< 20	*1.5*	*1.0*	< 0.5
B02h	Retirement Home	8	*1100*	*925*	< 20	*1.5*	*1.0*	< 0.5
B02i	Shed	5	*1050*	*975*	< 20	*1.5*	*1.0*	< 0.5
B02j	Shed	5	*1050*	*975*	< 20	*2.5*	*2.0*	< 0.5
B03a	Hospital	41	*1050*	*950*	< 20	*3.5*	*3.0*	< 0.5
B03b	Hospital	11	*1050*	*950*	< 20	*1.5*	*1.0*	< 0.5
B03c	Hospital	8	*1050*	*950*	< 20	*1.0*	*1.0*	< 0.5
B03d	Hospital	23	*1050*	*950*	< 20	*4.0*	*3.5*	< 0.5
B03e	Hospital	25	*1050*	*950*	< 20	*1.5*	*1.0*	< 0.5
B03f	Hospital	28	*1050*	*950*	< 20	*1.5*	*1.0*	< 0.5
B03g	Hospital	8	*1050*	*950*	< 20	*1.5*	*1.0*	< 0.5

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	Description	Maximum Dimension (m)	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW304 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW304 (mm)	Maximum Predicted Total Tilt based on the Preferred Project Layout after LW317 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW304 (mm)*	*Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW304 (mm/m)*
B03h	Hospital	28	*1050*	*950*	< 20	*3.5*	*3.0*	< 0.5
B03i	Hospital	5	*1050*	*950*	< 20	*2.0*	*1.0*	< 0.5
B03j	Hospital	14	*950*	*875*	< 20	*6.0*	*5.5*	< 0.5
B03k	Hospital	15	*1000*	*925*	< 20	*5.5*	*5.0*	< 0.5
B03l	Hospital	11	*1050*	*950*	< 20	*4.5*	*4.0*	< 0.5
B04a	House	14	*1200*	*1100*	40	*1.0*	*2.0*	< 0.5
B05a	House	11	*1200*	*1100*	50	*1.0*	*1.0*	< 0.5
B06a	House	14	*1150*	*1050*	60	*1.0*	*0.5*	< 0.5
B06b	Shed	5	*1150*	*1100*	50	*1.0*	*1.0*	< 0.5
B07a	House	11	*1150*	*1050*	70	*0.5*	*1.0*	0.5
B08a	House	11	*1100*	*1050*	80	*0.5*	*1.0*	0.5
B09a	House	14	*1100*	*1050*	90	*1.0*	*1.0*	0.5
B09b	Shed	14	*1150*	*1100*	90	*1.0*	*1.0*	0.5
B10a	Shed	6	*1100*	*1000*	125	*1.0*	*1.5*	1.0
B10b	Shed	3	*1050*	*1000*	125	*1.0*	*1.5*	1.0
B11a	Shed	7	*1000*	*975*	175	*1.0*	*1.0*	2.0
B11b	Shed	5	*975*	*925*	225	*1.0*	*1.5*	2.5
B11c	Shed	3	*1050*	*975*	150	*1.0*	*1.0*	1.5
B12a	Shed	14	*950*	*925*	400	*1.0*	*1.5*	3.5
B14t01	Reservoir	12	*1100*	*1050*	100	*1.0*	*1.0*	1.0
B14t02	Reservoir	8	*1100*	*1050*	125	*1.0*	*1.0*	1.0
B15t01	Tank	13	*525*	*500*	20	*4.5*	*4.5*	< 0.5
B16t01	Tank	9	*1150*	*1100*	60	*1.0*	*1.0*	< 0.5
B16t02	Tank	9	*1150*	*1150*	60	*1.0*	*1.0*	< 0.5
B16t03	Tank	9	*1150*	*1150*	60	*1.0*	*1.0*	0.5
B17a	Pump house	4	*1150*	*1100*	50	*1.0*	*1.0*	< 0.5
B17t01	Fire water tank	3	*1150*	*1100*	50	*1.0*	*1.0*	< 0.5
B18t01	Tank	5	*1150*	*1100*	50	*1.0*	*1.0*	< 0.5
F01b	Kiln	3	*1100*	*1100*	100	*1.5*	*1.0*	1.0

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW317 (mm)	Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW304 (mm)	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW304 (1/km)	Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW317 (mm)	Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW304 (mm)	Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW304 (1/km)	Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW317 (mm)	Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW304 (mm)	Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW304 (mm/m)
A01a	0.05	0.05	< 0.01	0.08	0.08	< 0.01	1.0	1.0	< 0.5
A01b	0.04	0.04	< 0.01	0.04	0.04	< 0.01	0.5	0.5	< 0.5
A01c	0.01	0.01	< 0.01	0.04	0.04	< 0.01	< 0.5	< 0.5	< 0.5
A01d	0.01	0.01	< 0.01	0.04	0.04	< 0.01	< 0.5	< 0.5	< 0.5
A01e	0.05	0.05	< 0.01	0.03	0.03	< 0.01	0.5	0.5	< 0.5
A01f	0.05	0.05	< 0.01	0.08	0.08	< 0.01	1.0	1.0	< 0.5
A01g	0.05	0.05	< 0.01	0.08	0.08	< 0.01	1.0	1.0	< 0.5
A01h	0.05	0.05	< 0.01	0.08	0.08	< 0.01	1.0	1.0	< 0.5
A01i	0.05	0.05	< 0.01	0.08	0.08	< 0.01	1.0	1.0	< 0.5
A01j	0.05	0.05	< 0.01	0.08	0.08	< 0.01	0.5	0.5	< 0.5
A01k	0.04	0.04	< 0.01	0.04	0.04	< 0.01	0.5	0.5	< 0.5
A01l	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
A01m	0.04	0.01	< 0.01	0.13	0.02	< 0.01	0.5	< 0.5	< 0.5
A02a	0.05	0.04	< 0.01	0.13	0.02	< 0.01	0.5	0.5	< 0.5
A02b	0.05	0.04	< 0.01	0.09	< 0.01	< 0.01	0.5	0.5	< 0.5
A03a	0.03	0.03	< 0.01	0.13	0.02	< 0.01	0.5	< 0.5	< 0.5
A03b	0.04	0.04	< 0.01	0.13	0.02	< 0.01	0.5	0.5	< 0.5
A03c	0.05	0.04	< 0.01	0.12	< 0.01	< 0.01	0.5	0.5	< 0.5
A03d	0.05	0.04	< 0.01	0.12	< 0.01	< 0.01	0.5	0.5	< 0.5
A04a	0.02	0.01	< 0.01	0.12	0.02	< 0.01	< 0.5	< 0.5	< 0.5
A05a	0.04	0.01	< 0.01	0.12	0.02	< 0.01	0.5	< 0.5	< 0.5
A06a	0.04	0.01	< 0.01	0.11	0.02	< 0.01	0.5	< 0.5	< 0.5
A06b	0.03	0.01	< 0.01	0.12	0.02	< 0.01	< 0.5	< 0.5	< 0.5
A07a	0.04	0.01	< 0.01	0.11	0.02	< 0.01	0.5	< 0.5	< 0.5
A08a	0.04	0.01	< 0.01	0.04	0.02	< 0.01	0.5	< 0.5	< 0.5
A08b	0.04	0.01	< 0.01	0.09	0.02	< 0.01	0.5	< 0.5	< 0.5
A08c	0.04	0.01	< 0.01	0.03	0.02	< 0.01	0.5	< 0.5	< 0.5
A08d	0.04	0.01	< 0.01	0.05	0.02	< 0.01	0.5	< 0.5	< 0.5
A08e	0.02	0.01	< 0.01	0.12	0.02	< 0.01	< 0.5	< 0.5	< 0.5
A08f	0.02	0.02	< 0.01	0.11	0.02	< 0.01	< 0.5	< 0.5	< 0.5
A09a	0.03	0.02	< 0.01	0.06	0.03	< 0.01	< 0.5	< 0.5	< 0.5
A09b	0.03	0.02	< 0.01	0.07	0.03	< 0.01	< 0.5	< 0.5	< 0.5
B01a	0.03	0.02	< 0.01	0.05	0.04	< 0.01	< 0.5	< 0.5	< 0.5
B01b	0.05	0.05	< 0.01	0.06	0.06	< 0.01	0.5	0.5	< 0.5

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW304 (mm)*	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW304 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW317 (mm)*	Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW304 (mm)	*Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW304 (1/km)*	Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW317 (mm)	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW304 (mm)*	*Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW304 (mm/m)*
B01c	*0.05*	*0.05*	< 0.01	*0.09*	*0.09*	< 0.01	*0.5*	*0.5*	< 0.5
B01d	*0.05*	*0.05*	< 0.01	*0.10*	*0.10*	< 0.01	*0.5*	*0.5*	< 0.5
B01e	*0.05*	*0.05*	< 0.01	*0.07*	*0.07*	< 0.01	*1.0*	*1.0*	< 0.5
B01f	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01g	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*1.0*	*1.0*	< 0.5
B01h	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01i	*0.05*	*0.05*	< 0.01	*0.05*	*0.05*	< 0.01	*0.5*	*0.5*	< 0.5
B01j	*0.03*	*0.02*	< 0.01	*0.01*	*0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01k	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01l	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01m	*0.03*	*0.03*	< 0.01	*0.06*	*0.06*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01n	*0.03*	*0.03*	< 0.01	*0.07*	*0.07*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01o	*0.02*	*0.02*	< 0.01	*0.07*	*0.07*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01p	*0.03*	*0.02*	< 0.01	*0.08*	*0.08*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01q	*0.03*	*0.03*	< 0.01	*0.06*	*0.06*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01t01	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01t02	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01t03	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*1.0*	*1.0*	< 0.5
B02a	*0.04*	*0.04*	< 0.01	*0.05*	*0.05*	< 0.01	*0.5*	*0.5*	< 0.5
B02b	*0.05*	*0.05*	< 0.01	*0.05*	*0.05*	< 0.01	*1.0*	*1.0*	< 0.5
B02c	*0.05*	*0.04*	< 0.01	*0.13*	*0.13*	< 0.01	*1.0*	*0.5*	< 0.5
B02d	*0.05*	*0.04*	< 0.01	*0.03*	*0.03*	< 0.01	*0.5*	*0.5*	< 0.5
B02e	*0.05*	*0.04*	< 0.01	*0.03*	*0.03*	< 0.01	*1.0*	*0.5*	< 0.5
B02f	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*1.0*	*0.5*	< 0.5
B02g	*0.05*	*0.04*	< 0.01	*0.03*	*0.03*	< 0.01	*1.0*	*0.5*	< 0.5
B02h	*0.05*	*0.04*	< 0.01	*0.03*	*0.03*	< 0.01	*1.0*	*0.5*	< 0.5
B02i	*0.05*	*0.04*	< 0.01	*0.11*	*0.11*	< 0.01	*0.5*	*0.5*	< 0.5
B02j	*0.03*	*0.02*	< 0.01	*0.14*	*0.14*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B03a	*0.05*	*0.05*	< 0.01	*0.14*	*0.14*	< 0.01	*1.0*	*0.5*	< 0.5
B03b	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*1.0*	*0.5*	< 0.5
B03c	*0.05*	*0.05*	< 0.01	*0.07*	*0.07*	< 0.01	*1.0*	*0.5*	< 0.5
B03d	*0.05*	*0.04*	< 0.01	*0.14*	*0.14*	< 0.01	*0.5*	*0.5*	< 0.5
B03e	*0.05*	*0.05*	< 0.01	*0.09*	*0.09*	< 0.01	*1.0*	*0.5*	< 0.5
B03f	*0.06*	*0.05*	< 0.01	*0.11*	*0.11*	< 0.01	*1.0*	*0.5*	< 0.5
B03g	*0.06*	*0.05*	< 0.01	*0.08*	*0.08*	< 0.01	*1.0*	*0.5*	< 0.5

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW304 (mm)*	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW304 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW317 (mm)*	Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW304 (mm)	*Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW304 (1/km)*	Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW317 (mm)	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW304 (mm)*	*Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW304 (mm/m)*
B03h	0.06	0.05	< 0.01	0.14	0.14	< 0.01	1.0	0.5	< 0.5
B03i	0.05	0.05	< 0.01	0.11	0.11	< 0.01	1.0	0.5	< 0.5
B03j	0.02	0.02	< 0.01	0.09	0.09	< 0.01	< 0.5	< 0.5	< 0.5
B03k	0.02	0.02	< 0.01	0.14	0.14	< 0.01	< 0.5	< 0.5	< 0.5
B03l	0.02	0.02	< 0.01	0.14	0.14	< 0.01	< 0.5	< 0.5	< 0.5
B04a	0.03	0.03	< 0.01	0.10	0.10	< 0.01	< 0.5	< 0.5	< 0.5
B05a	0.03	0.03	< 0.01	0.08	0.08	< 0.01	0.5	< 0.5	< 0.5
B06a	0.03	0.03	< 0.01	0.05	0.05	< 0.01	< 0.5	< 0.5	< 0.5
B06b	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B07a	0.03	0.03	< 0.01	0.03	0.03	< 0.01	< 0.5	< 0.5	< 0.5
B08a	0.03	0.03	< 0.01	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B09a	0.03	0.02	< 0.01	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B09b	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B10a	0.02	0.02	0.01	0.07	0.07	< 0.01	< 0.5	< 0.5	< 0.5
B10b	0.02	0.01	0.01	0.07	0.07	< 0.01	< 0.5	< 0.5	< 0.5
B11a	0.02	0.01	0.02	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B11b	0.01	0.01	0.03	0.03	0.03	< 0.01	< 0.5	< 0.5	< 0.5
B11c	0.02	0.02	0.02	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B12a	0.05	0.05	0.03	0.05	0.05	< 0.01	0.5	0.5	0.5
B14t01	0.03	0.02	< 0.01	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B14t02	0.02	0.02	0.01	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B15t01	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B16t01	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B16t02	0.04	0.04	< 0.01	0.05	0.05	< 0.01	0.5	0.5	< 0.5
B16t03	0.05	0.05	< 0.01	0.08	0.08	< 0.01	0.5	0.5	< 0.5
B17a	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B17t01	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B18t01	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
F01b	0.02	0.02	< 0.01	0.04	0.04	< 0.01	< 0.5	< 0.5	< 0.5

Note: Predicted conventional strains are based on 15 times curvature

APPENDIX E. DRAWINGS

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METROPOLITAN COLLIERY
LONGWALL 304
GENERAL LAYOUT

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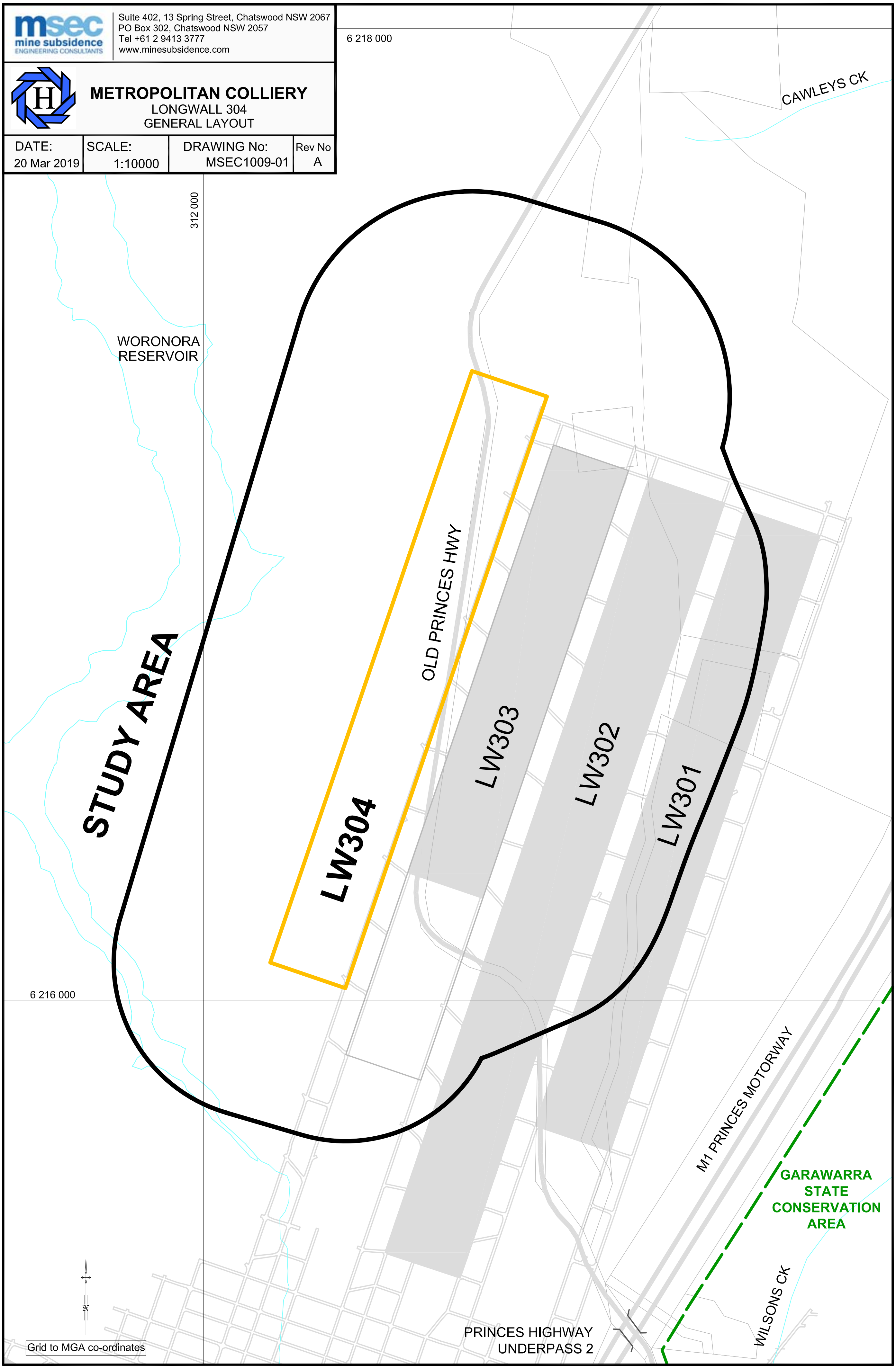
20 Mar 2019	1:10000	MSEC1009-01	A



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METROPOLITAN COLLIERY
LONGWALL 304
SURFACE LEVEL CONTOURS

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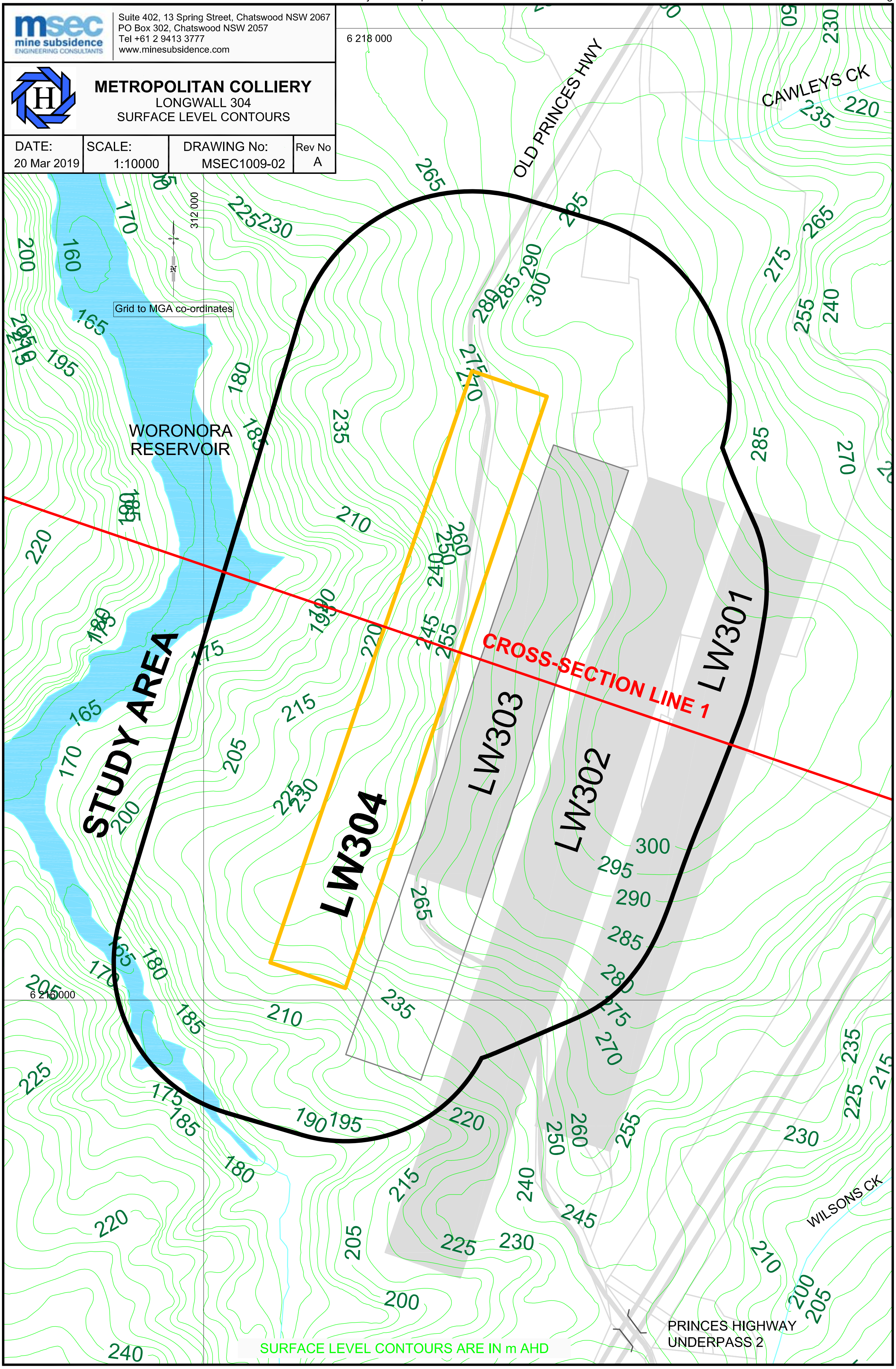

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METROPOLITAN COLLIERY
LONGWALL 304
SEAM FLOOR CONTOURS

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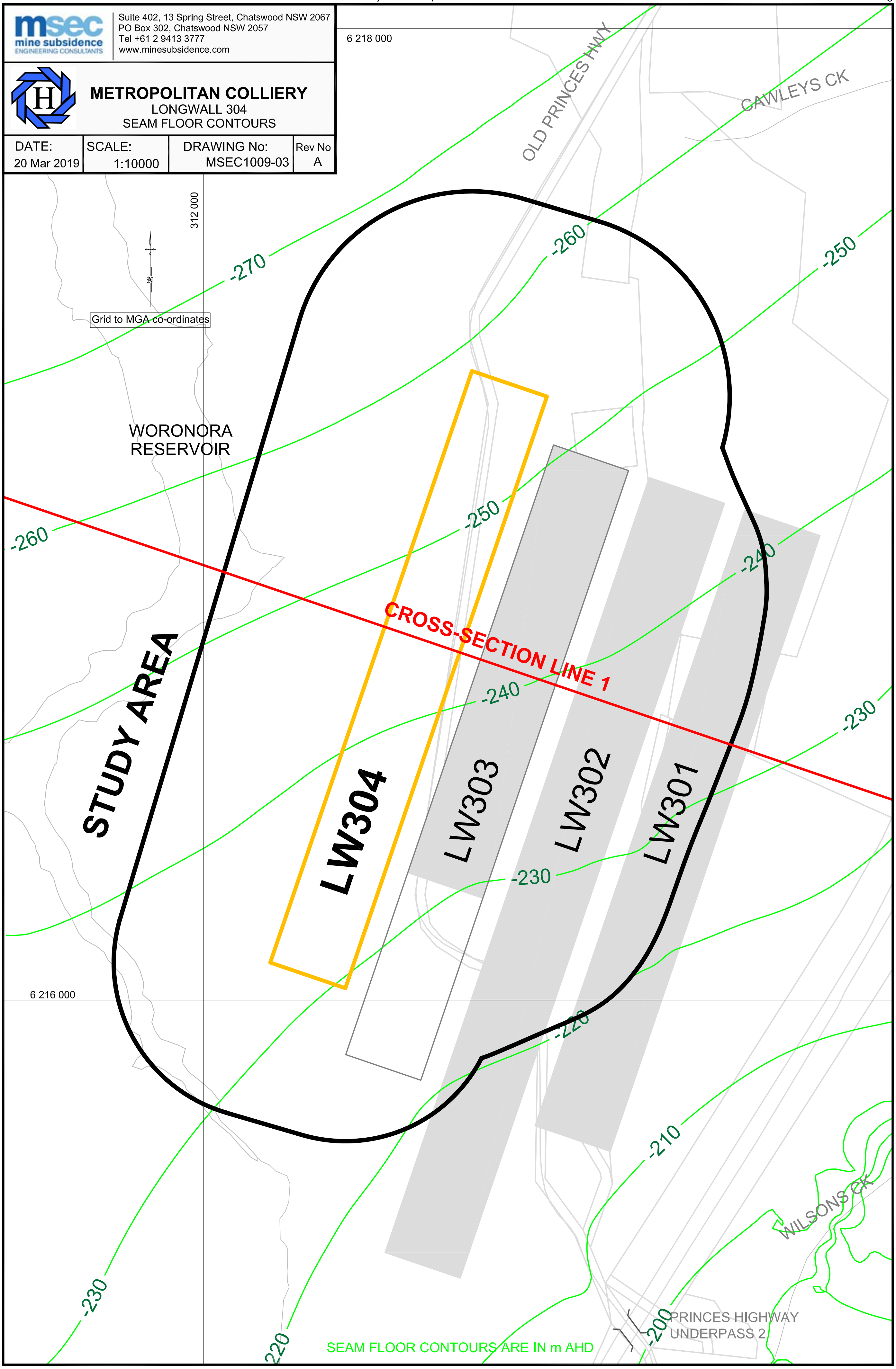

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METROPOLITAN COLLIERY
LONGWALLS 304
SEAM THICKNESS CONTOURS

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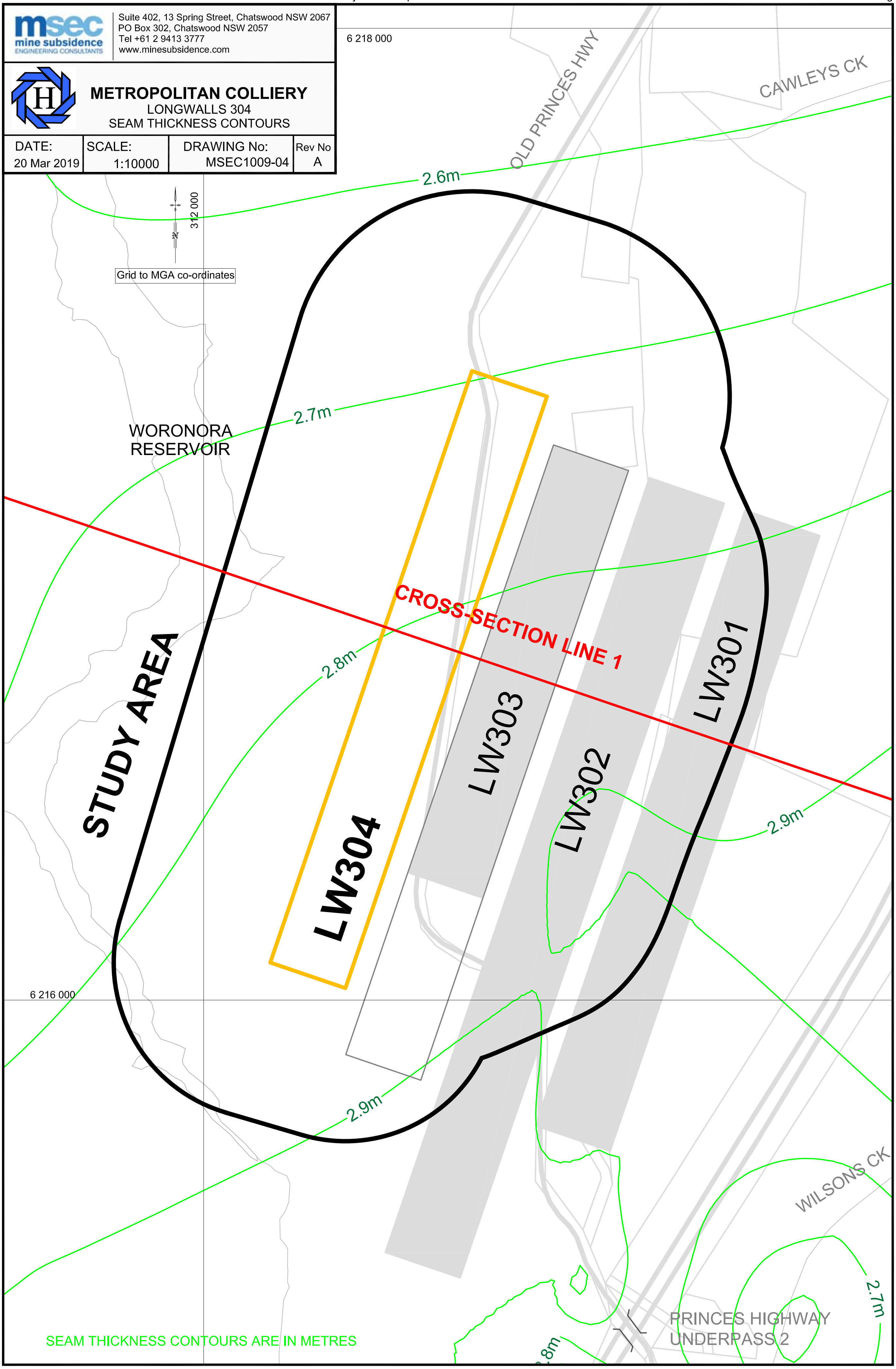
20 Mar 2019	1:10000	MSEC1009-04	A



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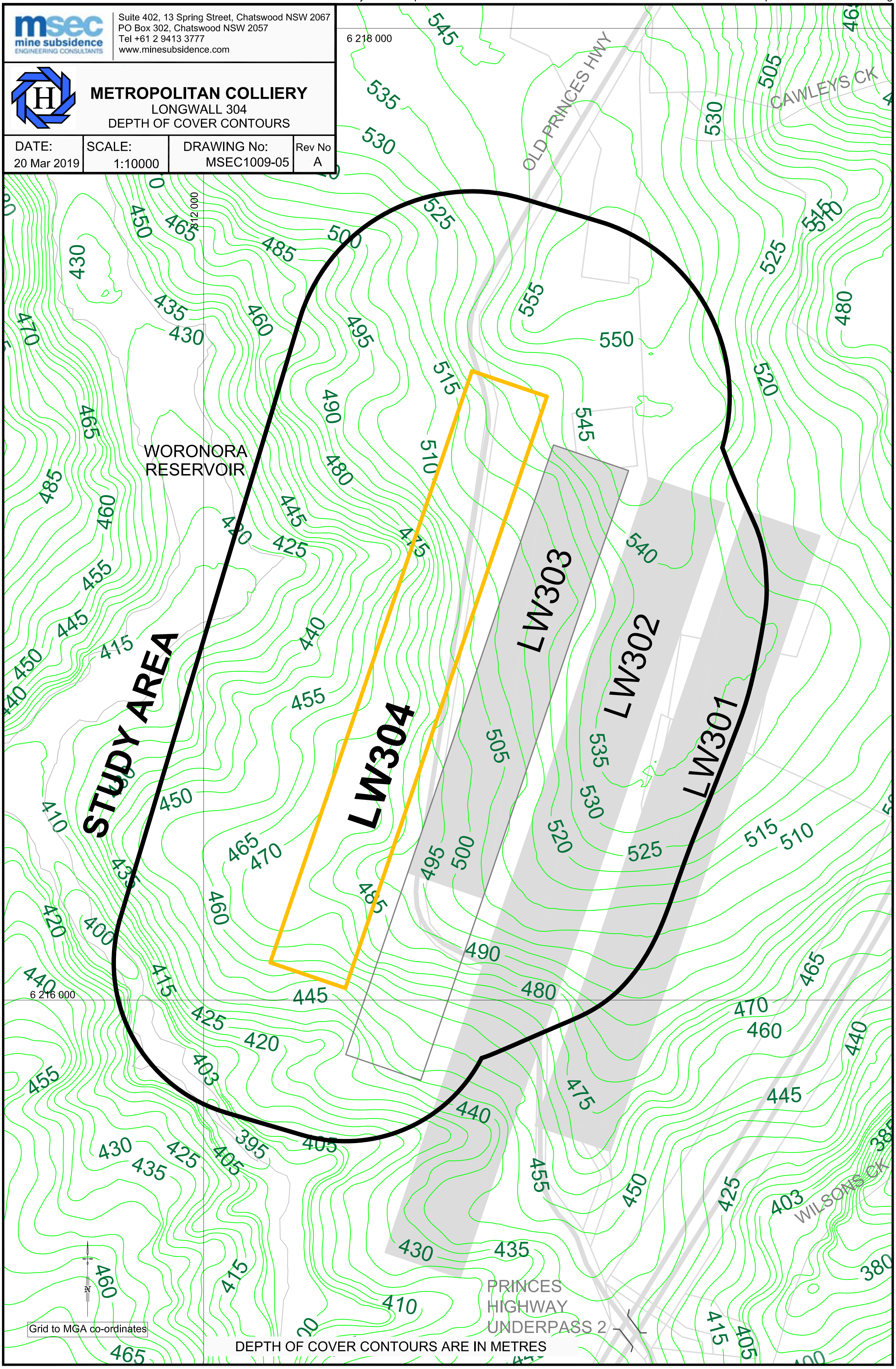
METROPOLITAN COLLIERY
LONGWALL 304
DEPTH OF COVER CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
20 Mar 2019	1:10000	MSEC1009-05	A



DEPTH OF COVER CONTOURS ARE IN METRES

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METROPOLITAN COLLIERY
LONGWALL 304
GEOLOGICAL STRUCTURES
IDENTIFIED AT SEAM LEVEL

DATE:	SCALE:	DRAWING No:	Rev No
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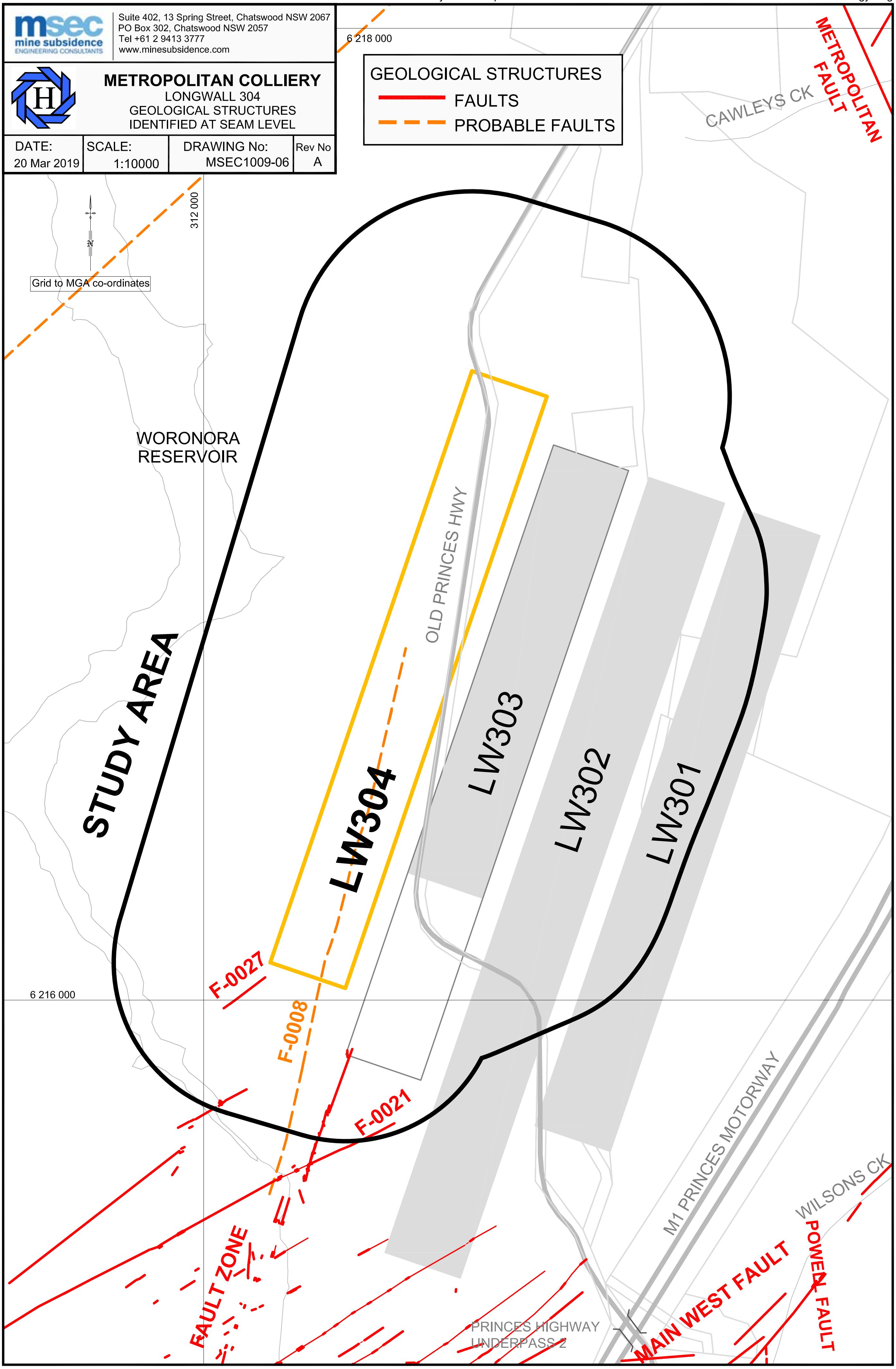

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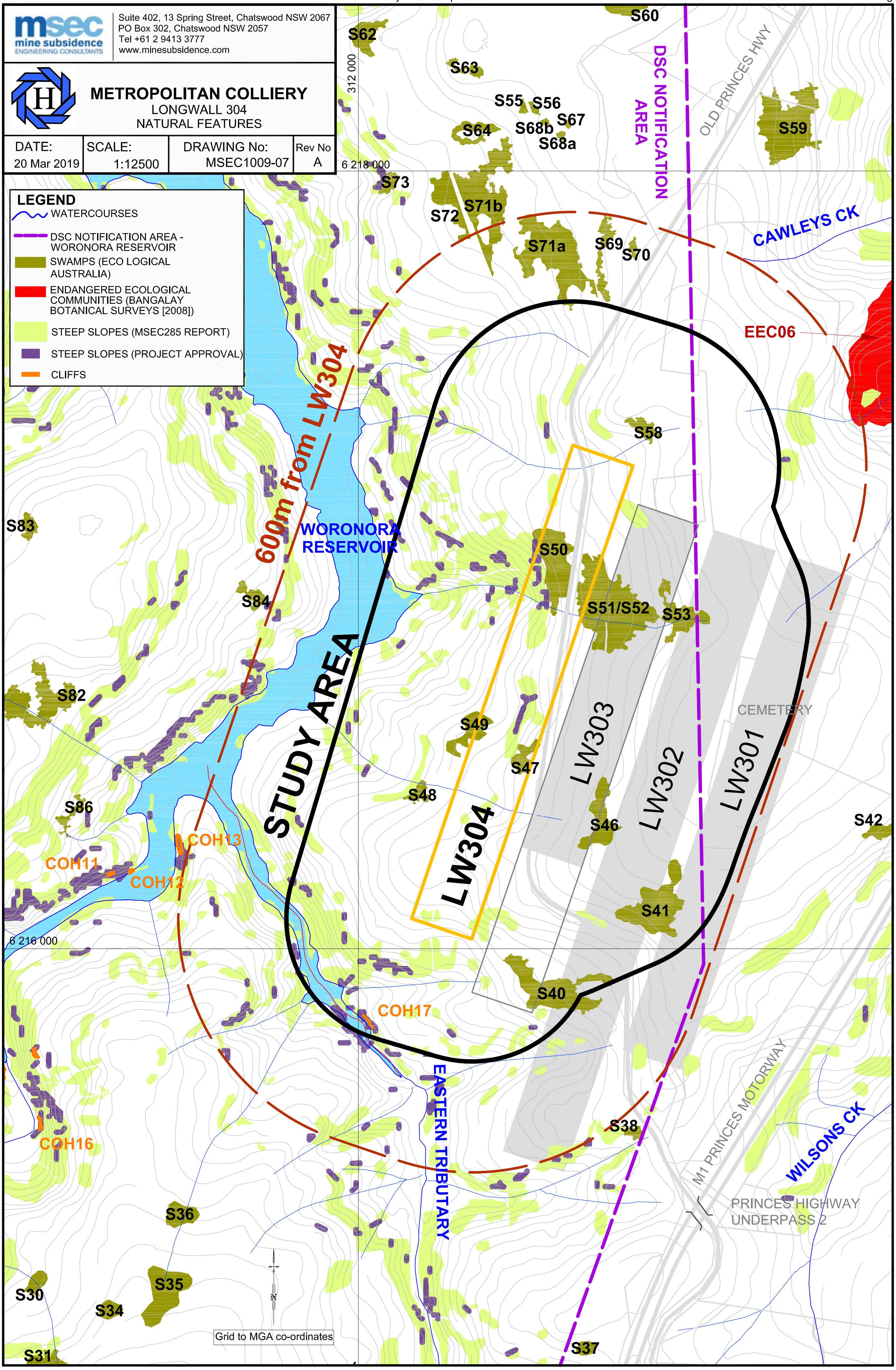

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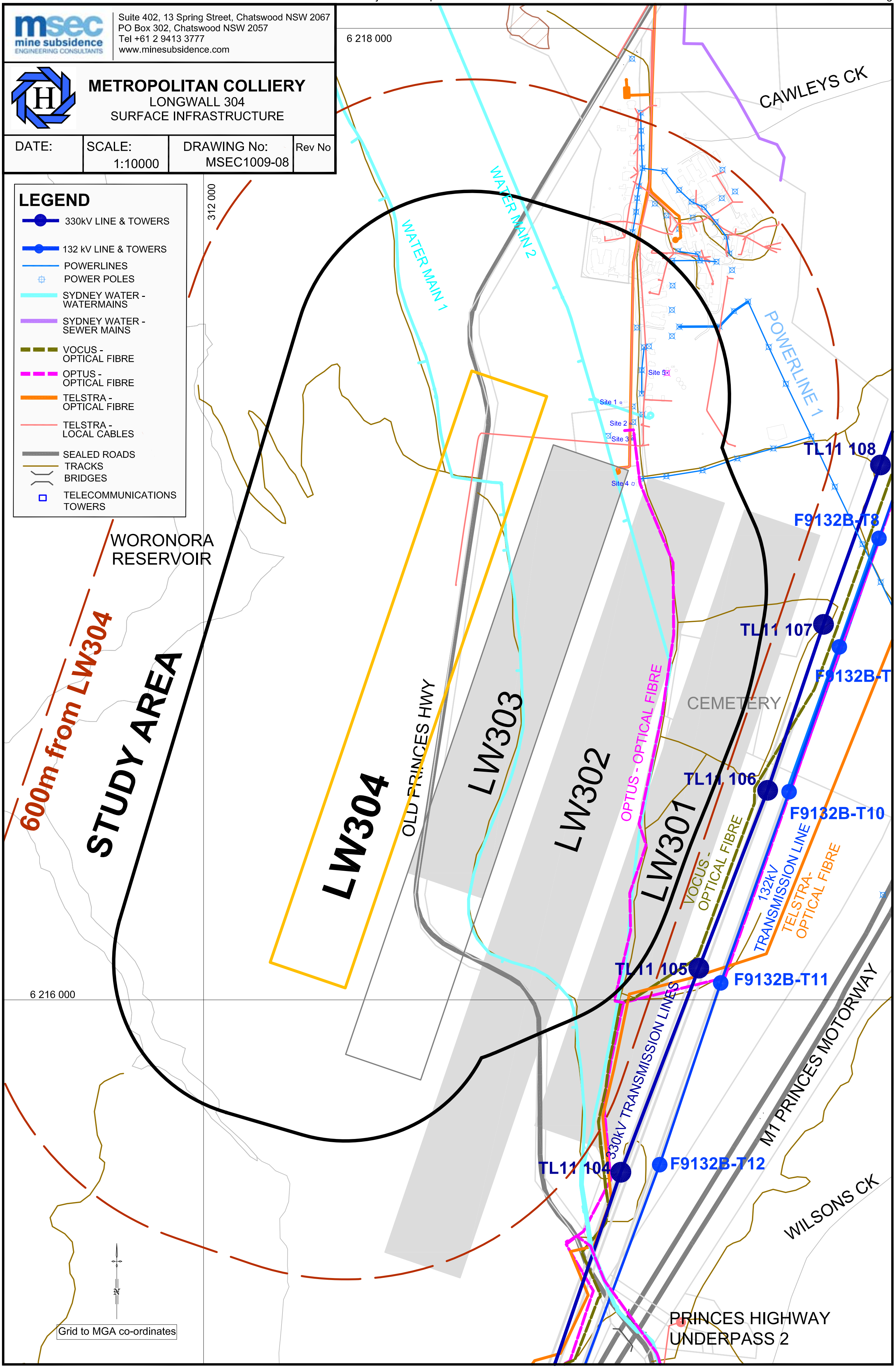

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METROPOLITAN COLLIERY
LONGWALL 304
BUILT FEATURES - LOCATION PLAN

DATE:	SCALE:	DRAWING No:	Rev No
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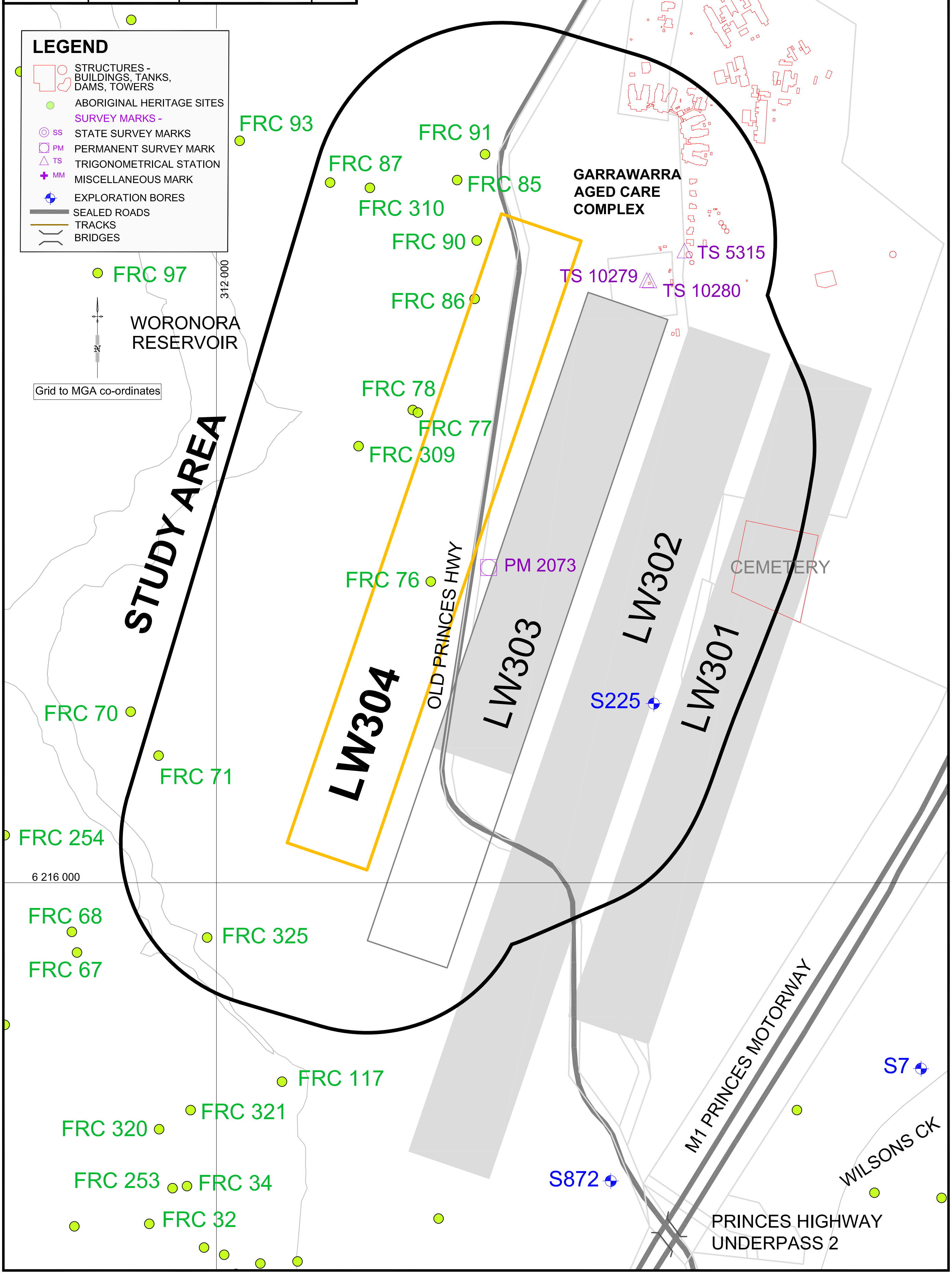

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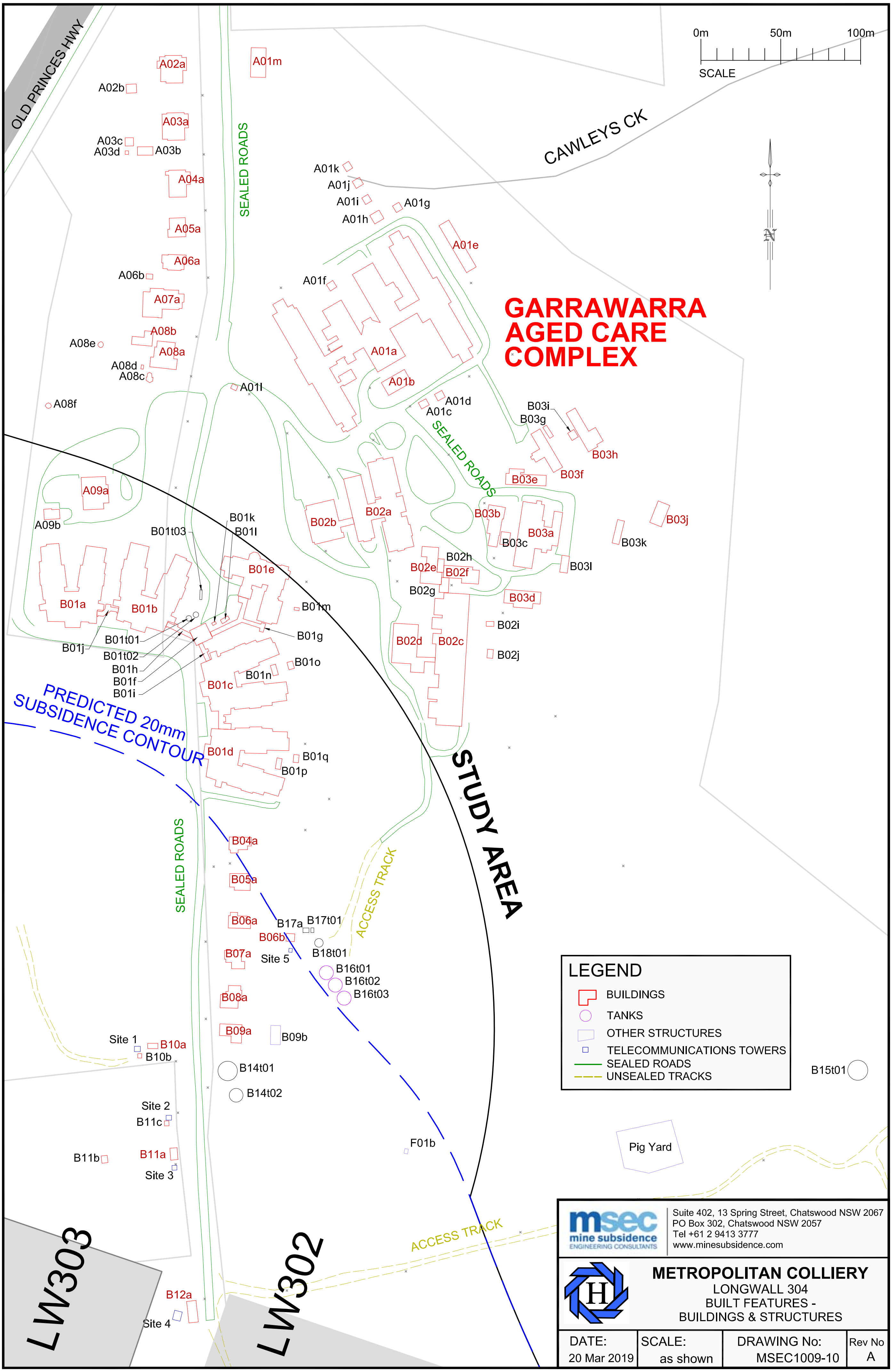

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METROPOLITAN COLLIERY
LONGWALL 304
PREDICTED TOTAL SUBSIDENCE CONTOURS AFTER LONGWALL 304

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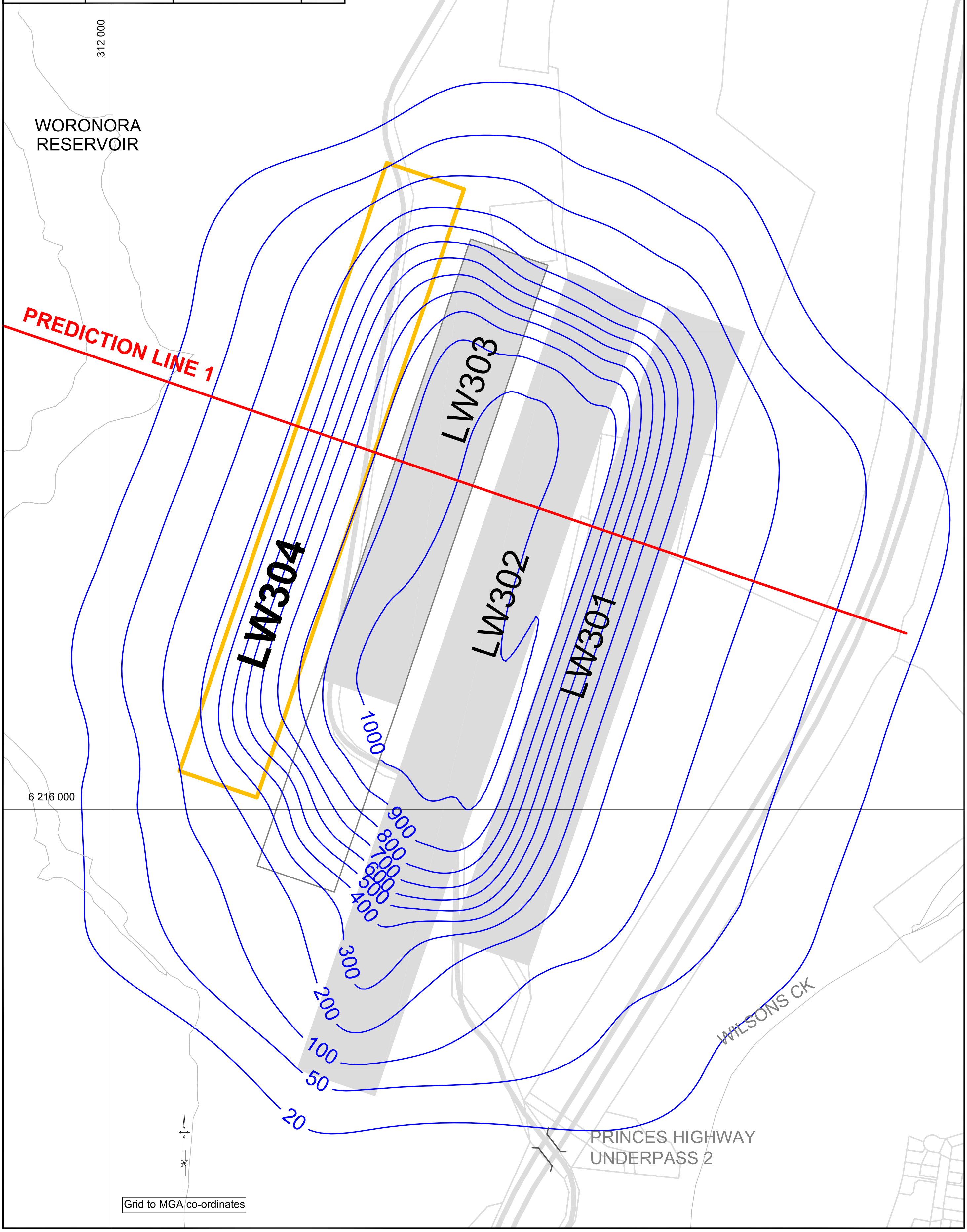


APPENDIX F. ATTACHMENT 1

RE: Subsidence predictions along the Eastern Tributary for Extraction Plan Layout and Alternative Layout, for extraction of Longwalls 304 to 308

Subsidence predictions along the Eastern Tributary for the Extraction Plan Layout and Alternative Layout, for extraction of Longwalls 304 to 308 are provided below.

Table A1 presents the geometry of the longwalls for the Extraction Plan Layout and the Alternative Layout. The overall void width (including first workings) and overall tailgate chain pillar widths are the same for both layouts.

The geometry of Longwalls 303 and 304 for both the Extraction Plan and Alternative Layouts is described in Section 1.1 of the main text of this report. The geometry of Longwalls 305 to 308 for both layouts is consistent, and is based on:

- The finishing end of Longwall 305 shortened by 462 m from the currently approved layout (i.e. rotated Preferred Project Layout approved April 2015).
- The finishing ends of Longwalls 306 to 308 consistent with the currently approved layout (i.e. rotated Preferred Project Layout approved April 2015).

The layouts of Longwalls 305 to 308 will however be subject to review, assessment and approval in future Extraction Plans.

Table A1 Geometry of the Extraction Plan and Alternative Layouts

Longwall	Overall void length including installation heading (m)		Overall void width including first workings (m)	Overall tailgate chain pillar width (m)
	Extraction Plan Layout	Alternative Layout	Extraction Plan and Alternative Layouts	Extraction Plan and Alternative Layouts
LW303	1,325	1,143	163	45
LW304	1,286	1,227	163	45
LW305	1,593	1,593	138	45
LW306	2,634	2,634	138	70
LW307	2,983	2,983	138*/163	70*/45
LW308	3,118	3,118	138*/163	70*/45

* Reduced longwall void width and increased pillar width within 500 m of Woronora Reservoir.

Predicted conventional and valley related effects for the Eastern Tributary for extraction to Longwall 308

The predicted profiles of total vertical subsidence and valley closure for the Eastern Tributary based on longwall extraction to Longwall 308 for the Extraction Plan and Alternative Layouts are shown in the attached Fig. A01 and Fig. A02, respectively. The predicted profiles after the completion of Longwall 27 and after Longwall 302 are shown as grey and light blue lines, respectively. The predicted profiles after the completion of Longwalls 303 to 308 are shown as orange lines.

Plan view summaries of the predicted total closure at rock bars for the Extraction Plan and Alternative Layouts are provided in the attached Fig. A03 and Fig. A04, respectively.

Variations in the magnitude of predicted closure up to approximately 20 mm between layouts is considered to be within the accuracy of the valley closure prediction model.

Predicted profiles of vertical subsidence and valley closure along the Eastern Tributary and the Woronora Reservoir due to LW20 to LW27 and LW301 to LW308 Extraction Plan Layout

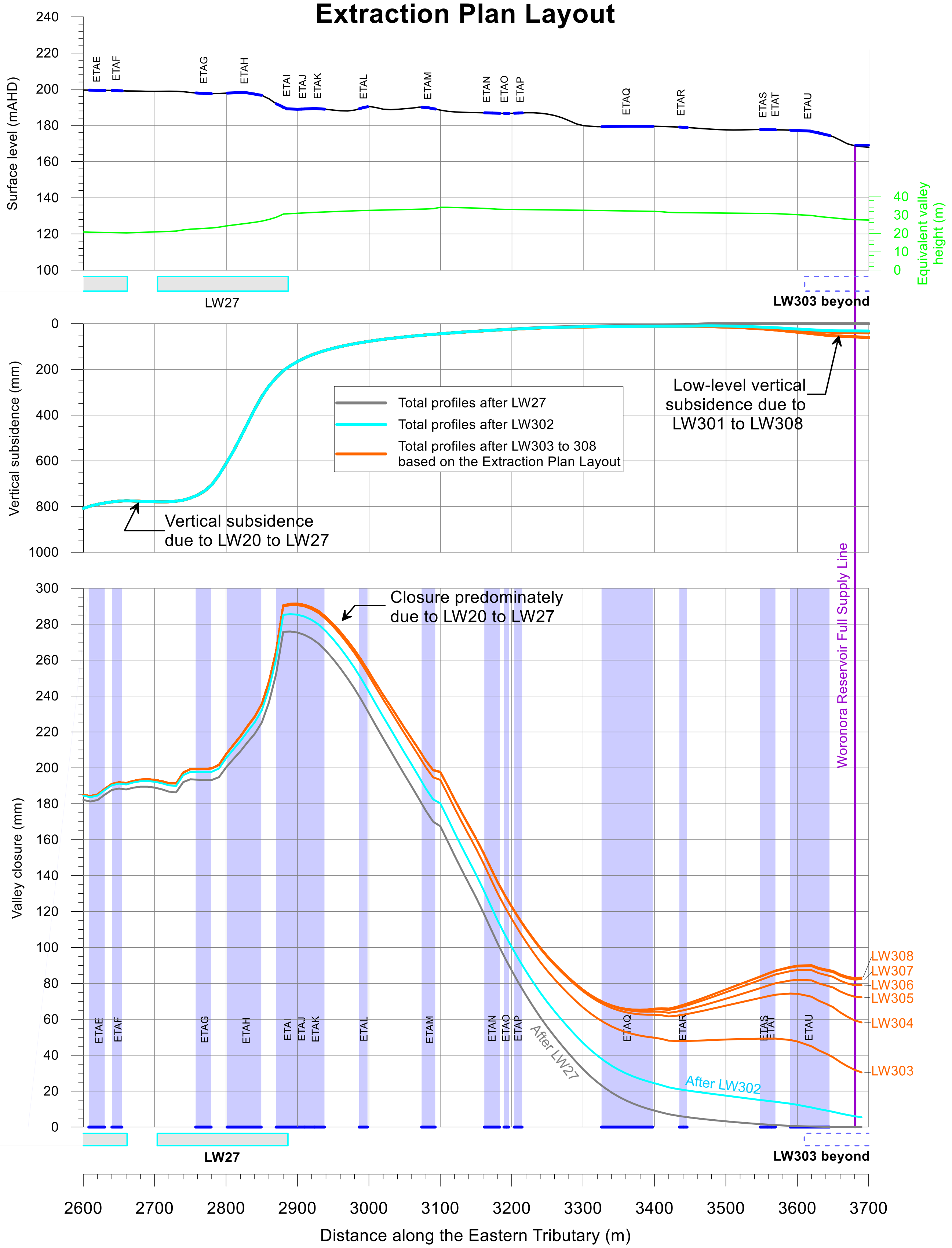


Fig. A.01

Predicted profiles of vertical subsidence and valley closure along the Eastern Tributary and the Woronora Reservoir due to LW20 to LW27 and LW301 to LW308 Alternative Layout

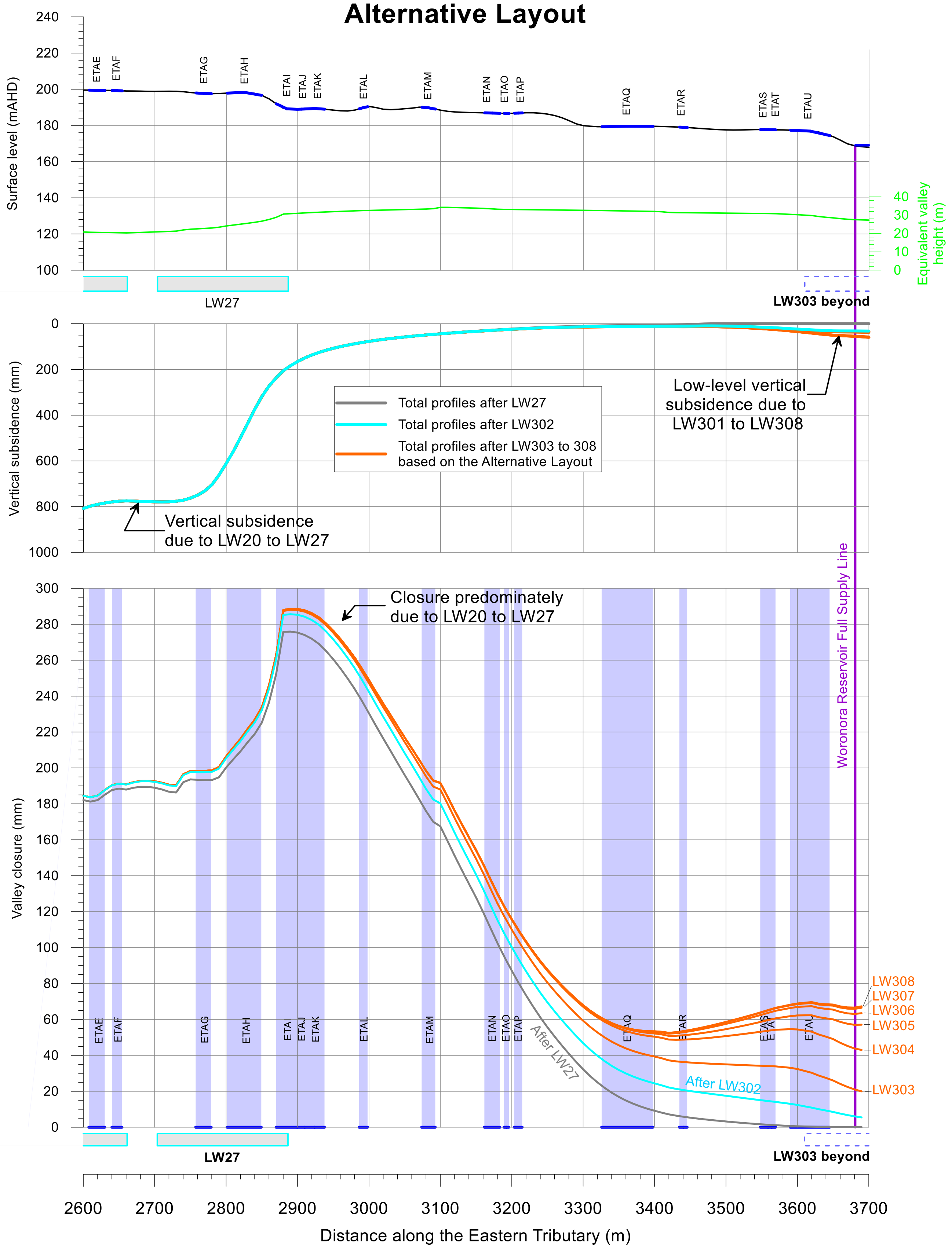


Fig. A.02

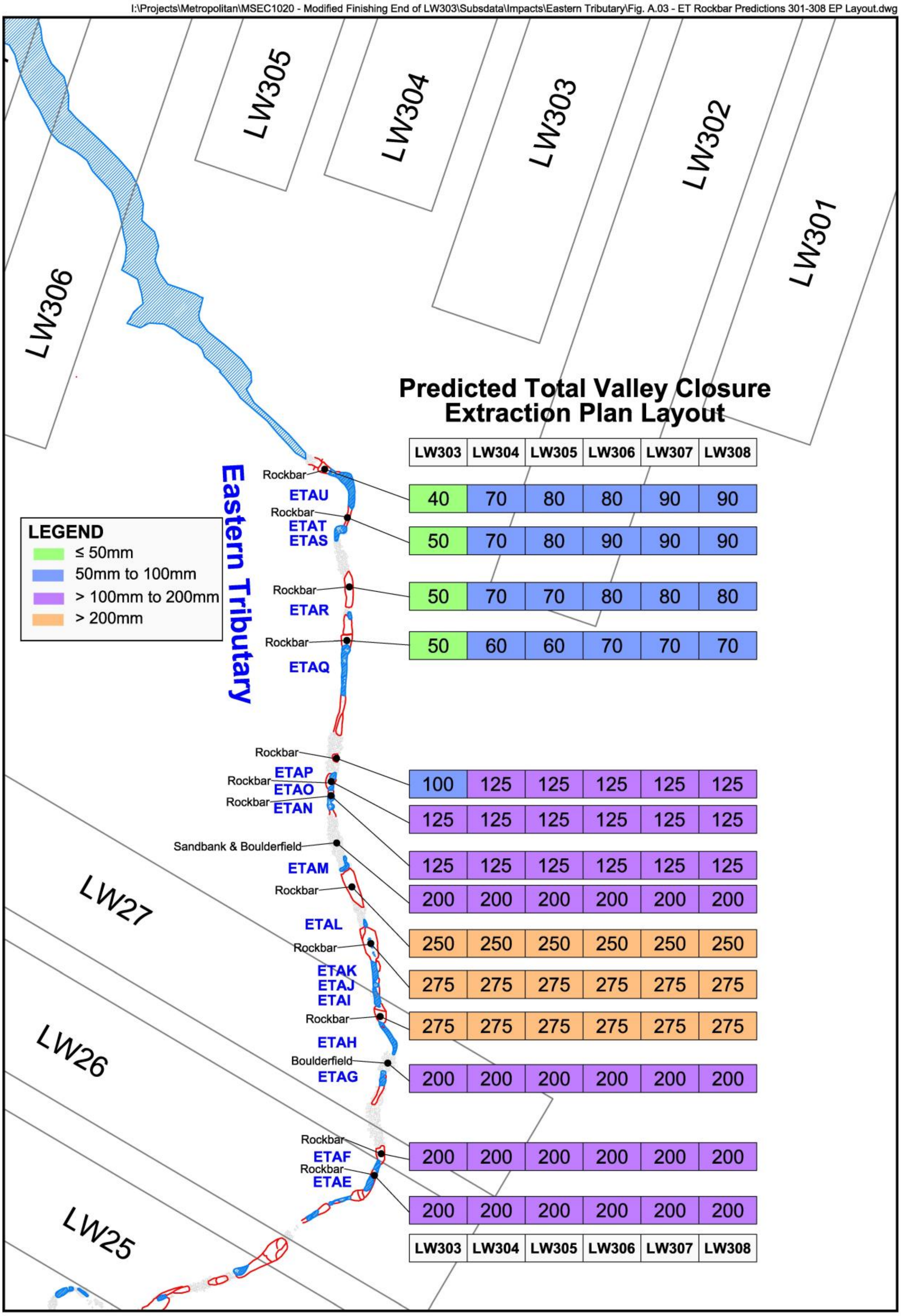
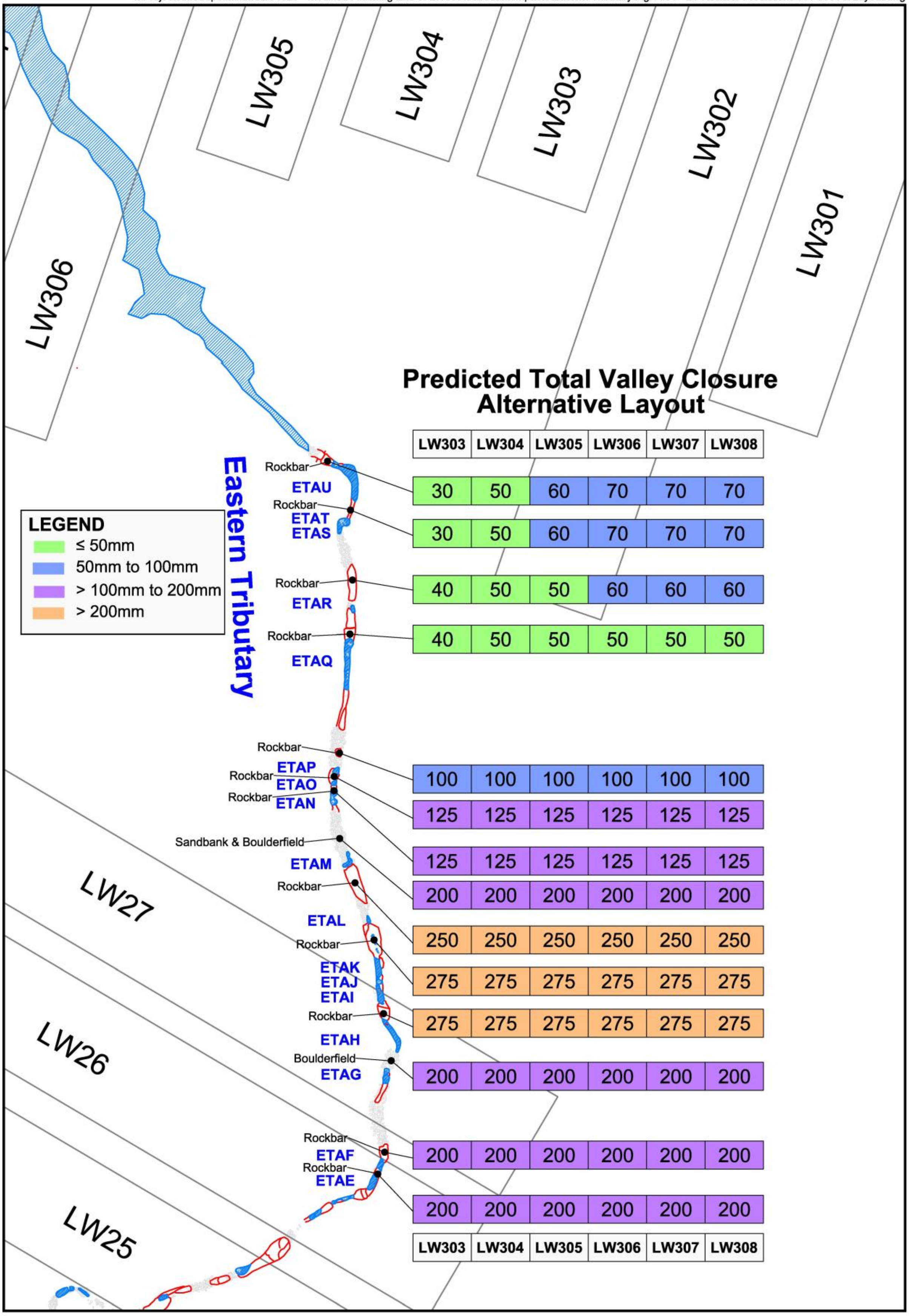


Fig. A.03 Predicted total valley closure after LW303 to 308 at Eastern Tributary rock bars – Extraction Plan Layout



LW303	LW304	LW305	LW306	LW307	LW308
30	50	60	70	70	70
30	50	60	70	70	70
40	50	50	60	60	60
40	50	50	50	50	50
100	100	100	100	100	100
125	125	125	125	125	125
125	125	125	125	125	125
200	200	200	200	200	200
250	250	250	250	250	250
275	275	275	275	275	275
275	275	275	275	275	275
200	200	200	200	200	200
200	200	200	200	200	200
200	200	200	200	200	200
LW303	LW304	LW305	LW306	LW307	LW308

Fig. A.04 Predicted total valley closure after LW303 to 308 at Eastern Tributary rock bars – Alternative Layout