Appendix A – Subsidence Predictions and Impact Assessment Report (MSEC, 2021)

SIMEC Mining:

Tahmoor Coal – Longwalls W3 and W4

Subsidence Predictions and Impact Assessments for Natural and Built Features due to the extraction of the proposed Longwalls W3 and W4 in support of the Extraction Plan Application

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
A	Final issue	DJK		Mar-21

Report produced to: Support the Extraction Plan Application to be issued to the Department of Planning, Industry and Environment.

Previous reports: MSEC647 (Revision A) – Longwalls 31 to 37 - Subsidence Predictions and Impact Assessments for Natural and Built Features in Support of the SMP Application (December 2014).

MSEC1019 (Revision B) – Longwalls W1 and W2 - Subsidence Predictions and Impact Assessments for Natural and Built Features in Support of the Extraction Plan Application (July 2019).

Background reports available at *www.minesubsidence.com*[1]:

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)

[1] Direct link: http://www.minesubsidence.com/index_files/page0004.htm

Tahmoor Coal (TC) owns and operates Tahmoor Mine, an existing underground coal mine that is located approximately 80 km south-west of Sydney in the Southern Coalfield of NSW. Tahmoor Coal is a wholly owned entity within the SIMEC Mining Division of the GFG Alliance group.

TC has completed the extraction of Longwall W1 (LW W1) and, at the time of this report, was in the process of mining Longwall W2 (LW W2). The longwalls are being extracted in accordance with the current Development Consent (DA 67/98) and Extraction Plan Approval.

TC previously submitted a Subsidence Management Plan Application (SMP Application) for LWs 31 to 37 in the Bulli Seam in December 2014. Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC647 (Rev. A), which provided subsidence predictions and impact assessments on natural and built features due to the proposed extraction of these longwalls in support of the SMP Application.

TC has reviewed its mine plan based on many factors, including feedback received from the community following submission of the SMP Application in 2014 and additional information gathered from underground conditions, which influenced the orientation of the proposed longwalls.

The modified mine plan included underground mining operations by the extraction of Longwalls W1 and W2 (LW W1-W2) in the Western Domain – an area located northwest of the Main Southern Railway between the townships of Thirlmere and Picton. TC received approval of the Extraction Plan for LW W1-W2 in November 2019. LW W1 commenced extraction on 15 November 2019 and completed extraction on 19 November 2020. Extraction of LW W2 commenced on 7 December 2020.

The proposed LW W3-W4, also situated in the Western Domain, are located to the west of the township of Picton, between Matthews, Cedar and Stonequarry Creeks, the Main Southern Railway and LW W1-W2. The layouts of the completed, active and proposed longwalls at the mine are shown in Drawing No. MSEC1112-01, in Appendix E.

Natural features and items of surface infrastructure have been identified within the vicinity of the proposed longwalls, including creeks, steep slopes, the Main Southern Railway and the Picton-Mittagong Loop Line and associated infrastructure, public roads and associated infrastructure, drainage culverts, potable water infrastructure, sewer infrastructure, gas infrastructure, electrical infrastructure, telecommunications infrastructure, building structures, items of archaeological and heritage significance, farm dams, groundwater bores and survey control marks.

TC is preparing an Extraction Plan Application for LW W3-W4, which will be submitted to the Department of Planning, Industry and Environment (DPIE). MSEC has been commissioned by TC to:

- prepare subsidence predictions for the existing and proposed longwalls;
- identify the natural and built features in the vicinity of the proposed longwalls;
- provide subsidence predictions for each of these surface features;
- prepare impact assessments, in conjunction with other specialist consultants, for each of the natural and built features; and
- recommend management strategies and monitoring.

This report should be read in conjunction with the Extraction Plan being prepared by TC and in conjunction with the reports from specialist consultants engaged by TC for the Extraction Plan.

Chapter 1 provides background information on the study, including mining geometry, surface and seam and overburden lithology.

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

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

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

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

The overall findings of the assessments undertaken by MSEC are that the levels of impact and damage to identified natural features and built infrastructure are manageable and can be controlled by the preparation and implementation of Subsidence Management Plans, many of which have already been developed and are being successfully implemented during mining at Tahmoor Mine.

These management plans are developed in consultation with the owners of infrastructure and relevant government agencies. The findings in this report should be read in conjunction with all other associated consultant reports.

Recommended management measures generally include monitoring of ground movements and the condition of surface features. Some mitigation measures are recommended to mitigate or avoid the risk of serious consequences should impacts occur to some critical surface features.

It is recommended that Tahmoor Mine continues to develop management plans to manage the potential impacts for the surface features within the future mining areas.

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Drawings

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

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MSEC1112-01	General layout	A
MSEC1112-02	Development Consent boundaries	A
MSEC1112-03	Mine Subsidence Districts	A
MSEC1112-04	Urban areas	A
MSEC1112-05	Surface level contours	A
MSEC1112-06	Bulli Seam floor contours	A
MSEC1112-07	Bulli Seam depth of cover contours	A
MSEC1112-08	Geological structures	A
MSEC1112-09	Land drainage	A
MSEC1112-10	Hidden creeks	A
MSEC1112-11	Cliffs and steep slopes	A
MSEC1112-12	Railways	A
MSEC1112-13	Local roads	A
MSEC1112-14	Bridges, tunnels and culverts	A
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MSEC1112-20	Groundwater bores, exploration drill holes and survey marks	A
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MSEC1112-27	Predicted cumulative subsidence contours due to LW W3 & W4	A
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MSEC1112-30	Monitoring plan	A

1.0 INTRODUCTION

1.1. Background

Tahmoor Coal (TC) owns and operates Tahmoor Mine, an existing underground coal mine that is located approximately 80 km south-west of Sydney in the Southern Coalfield of NSW. Tahmoor Coal is a wholly owned entity within the SIMEC Mining Division of the GFG Alliance group.

TC has completed the extraction of Longwall W1 (LW W1) and, at the time of this report, was in the process of mining Longwall W2 (LW W2). The longwalls are being extracted in accordance with the current Development Consent (DA 67/98) and Extraction Plan Approval.

Tahmoor Coal previously submitted an Extraction Plan Application for Longwalls W1 and W2 (LW W1-W2) in the Western Domain – an area located northwest of the Main Southern Railway between the townships of Thirlmere and Picton. The Extraction Plan was approved in November 2019.

The proposed Longwalls W3 and W4 (LW W3-W4) are an extension of LW W1-W2. The longwalls are also situated in the Western Domain, and are located to the west of the township of Picton, between Matthews, Cedar and Stonequarry Creeks, the Main Southern Railway and LW W1-W2. The layouts of the completed, active and proposed longwalls at the mine are shown in Drawing No. MSEC1112-01, in Appendix E. The locations of LW W3-W4 have been overlaid on a 2018 orthophotograph in Fig. 1.1.

Natural features and items of surface infrastructure have been identified within the vicinity of the proposed longwalls, including creeks, steep slopes, the Main Southern Railway and the Picton-Mittagong Loop Line and associated infrastructure, public roads and associated infrastructure, drainage culverts, potable water infrastructure, sewer infrastructure, gas infrastructure, electrical infrastructure, telecommunications infrastructure, building structures, items of archaeological and heritage significance, farm dams, groundwater bores and survey control marks.

TC is preparing an Extraction Plan Application for LW W3-W4, which will be submitted to the Department of Planning, Industry and Environment (DPIE). MSEC has been commissioned by TC to:

- prepare subsidence predictions for the existing and proposed longwalls;
- identify the natural and built features in the vicinity of the proposed longwalls;
- provide subsidence predictions for each of these surface features;
- prepare impact assessments, in conjunction with other specialist consultants, for each of the natural and built features; and
- recommend management strategies and monitoring.

A comparison between the longwalls proposed in the previous 2014 SMP Application and the layout of LW W1-W4 is provided in Fig. 1.2. The key differences are listed below:

- LW W1-W4 do not mine directly beneath Matthews, Cedar and Stonequarry Creeks, whilst the previously proposed LWs 33 to 37 were located directly beneath the creeks. The change in mine plan will substantially reduce the severity and extent of mining-induced impacts on the creeks; and

- LW W1-W4 will progressively extract each longwall from west to east, whilst the previously proposed LWs 33 to 37 were sequenced in the opposite direction.
  From a mine subsidence perspective, the change in direction reduces the impact of transient subsidence effects on houses within the Stonequarry Estate, and also allows TC to track mining-induced movements as the mine extends towards the Picton Railway Tunnel on the Main Southern Railway, which is a substantial and significant item of civil infrastructure.

Chapter 1 provides background information on the study, including the mining geometry, surface and seam and overburden lithology.

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

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

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

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

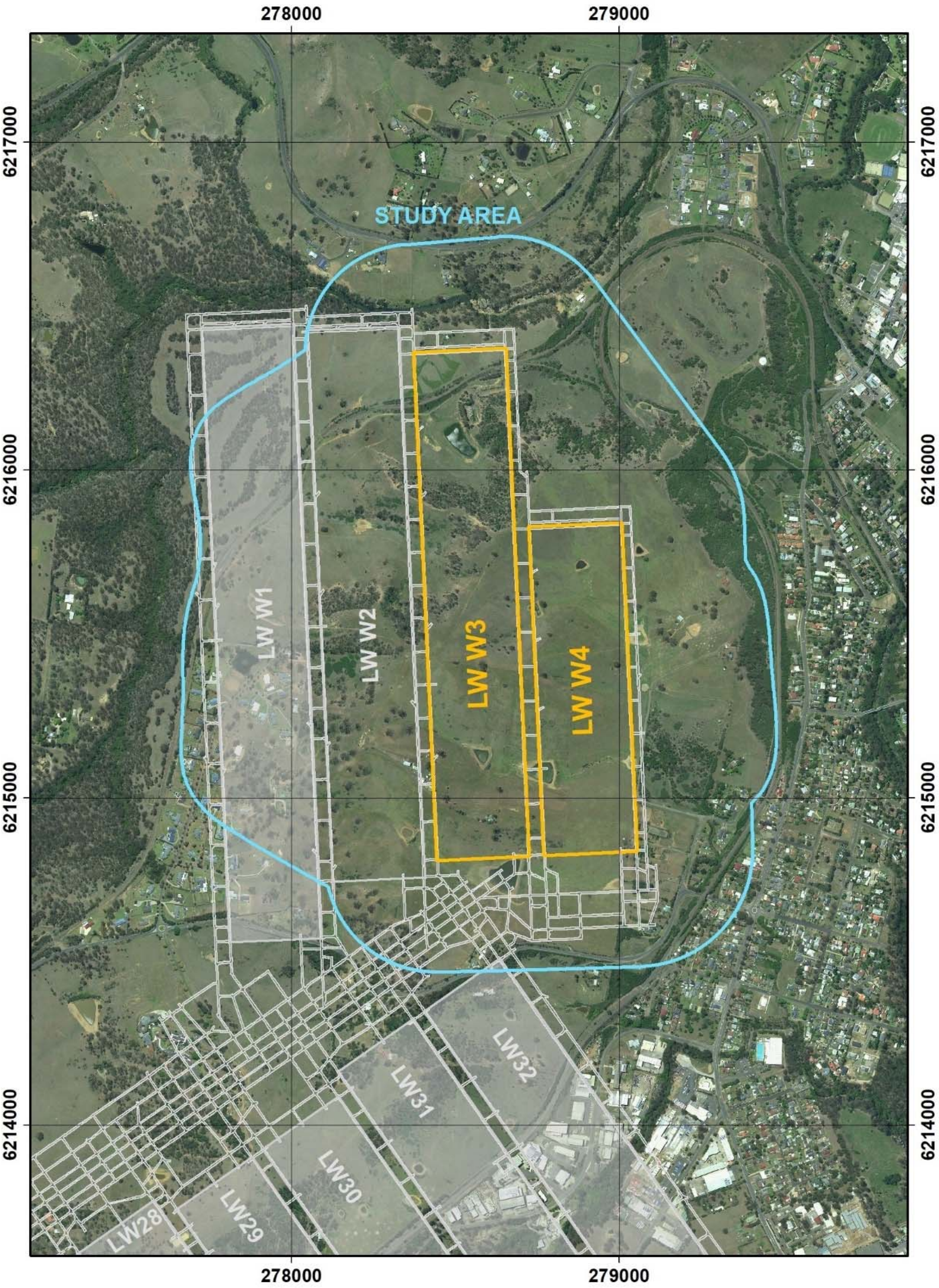

Fig. 1.1 Proposed longwalls and the Study Area

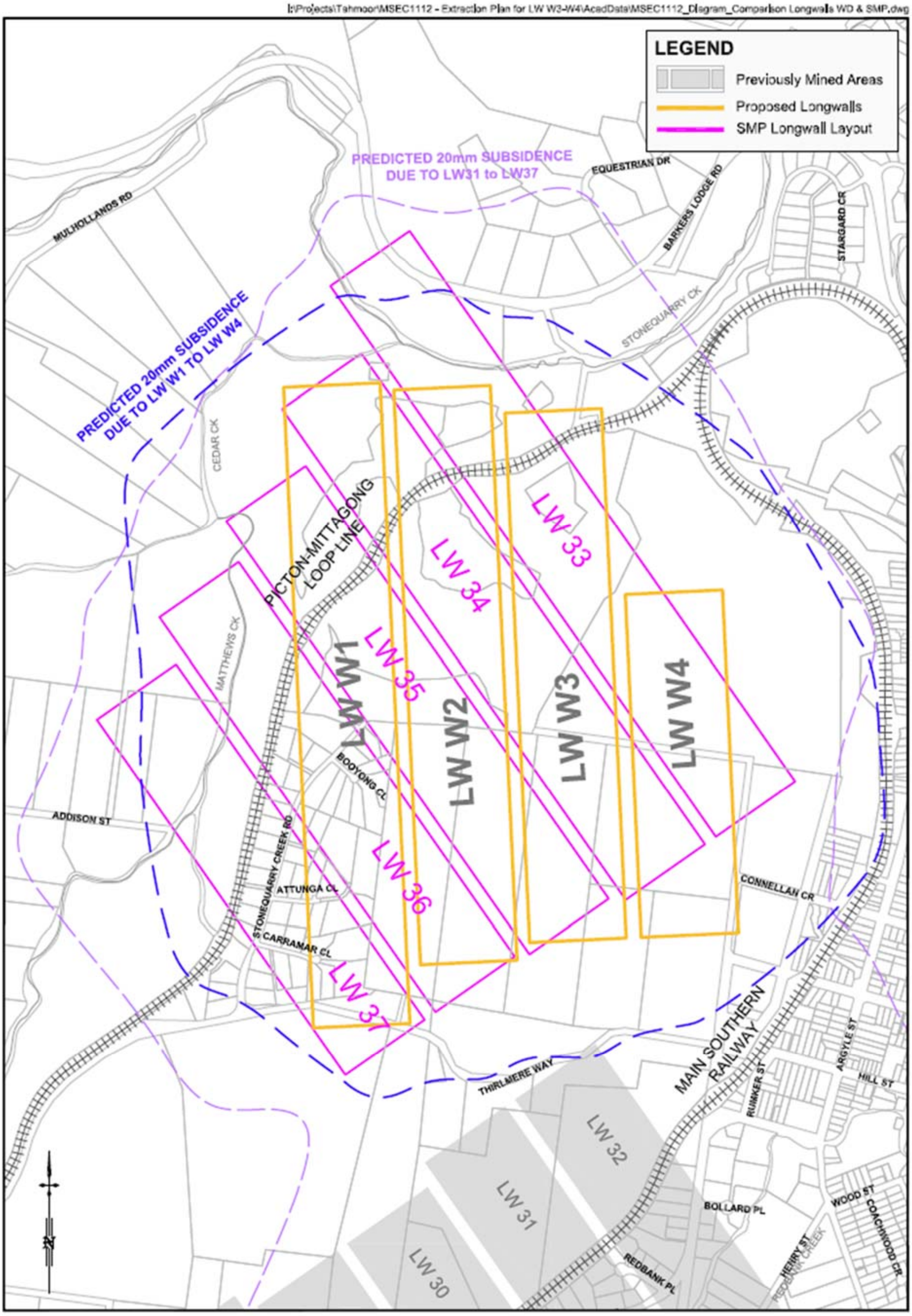

Fig. 1.2 Comparison between mine layouts for LW W1-W4 (2020 Extraction Plan) and LWs 33 to 37 (2014 SMP Application)

1.2. Mining geometry

The layouts of LW W3-W4 are shown in Drawings Nos. MSEC1112-01 and MSEC1112-02. A summary of the dimensions of the longwalls is provided in Table 1.1.

Table 1.1 Geometry of the longwalls

Longwall	Overall void length including installation heading (m)	Overall void width including first workings (m)	Overall tailgate chain pillar width (m)
LW W3	1552	283	39
LW W4	1004	285	44

An additional longwall chock is proposed to be installed for LW W4, increasing the panel width by 2 metres.

The lengths of longwall extraction excluding the installation headings are approximately 9 m less than the overall void lengths provided in Table 1.1. The longwall face width of LW W3 and LW W4, excluding the first workings, are 272 m and 274 m, respectively. The longwalls will be extracted within the Bulli Seam towards the main headings (i.e. from north to south).

1.3. Mining Lease boundaries

The mining lease boundaries are shown in Drawing No. MSEC1112-02.

The proposed longwalls will extract coal within two mining leases, ML 1376 and ML 1539. The Tahmoor North Mining Lease for the rural areas is ML 1376. The Tahmoor North Mining Lease for the urban areas and railways is ML 1539. The original mining lease for Tahmoor Mine is CCL 716.

1.4. Planning Approval boundaries

The planning approval boundaries are shown in Drawing No. MSEC1112-02.

Development consent (DA 57/93) was granted in 1994 for land within ML 1376. Development consent (DA 67/98) was granted in February 1999 for mining beneath certain urban areas and railway land not included within ML 1376, and this area is covered by ML 1539. Development consent was modified in 2006 (Mod 1), 2012 (Mod 2), 2018 (Mod 4) and 2020 (Mod 5).

The predicted limit of subsidence from the extraction of LW W3-W4 lies wholly within the 1994 and 1999 consent boundaries, taking into account Modification 5. It does not encroach into the “two areas shown in black crosshatching in Figure 2” of the 1999 Consent of DA 67/98 (as amended in 2020 and reproduced in blue crosshatching in Drawing No. MSEC1112-02).

It is noted that an additional longwall chock is proposed to be installed for LW W4, increasing the panel width by 2 metres. The decision to widen the panel was proposed in December 2020, after the approval of Modification 5 was made. When compared to the predictions provided in Report No. MSEC1075 in support of the application for Modification 5, the following comments are provided:

- The minor addition in longwall width has the effect of pushing out the location of the predicted 20 mm subsidence contour to the eastern side of LW W4 by approximately 4.5 metres. The predicted contours are shifted further laterally than the panel width due to subtle changes in the predicted subsidence profile due to the slightly wider panel width. The predicted 20 mm subsidence contour line is located close to but does not cross over one of the “areas shown in black crosshatching in Figure 2” near kilometrage 88.40 km on the Main Southern Railway;
- The effect beyond the ends and corners of LW W4 are reduced, such that the location of the predicted 20 mm subsidence contour in these locations are pushed out by less than 1 metre;
- The effect of the widening in all directions is, therefore, well within the accuracy of the prediction model and have a negligible effect on the potential for impacts; and
- The boundary limits of the Modification 5 area were mainly influenced by LW W3, which has not changed in dimensions. The effect of the change within the Modification 5 area is, therefore, negligible.

1.5. Mine Subsidence Districts

The boundaries of the Mine Subsidence Districts (MSDs) are shown in Drawing No. MSEC1112-03. It can be seen from this drawing that the Study Area is wholly within the Picton MSD, with the exception of a small portion of land within the Main Southern Railway loop. The Mushroom Tunnel and an old farm dam are located within this section of land.

The Picton MSD was proclaimed in July 1997. It was extended following a review by Subsidence Advisory NSW (SA NSW) in 2017. SA NSW extended MSDs where future mining was planned to occur. The Picton MSD was extended in 2017 to include most of the land within the Study Area.

1.6. Urban and rural areas

The extent of urban and rural areas, as defined for the purposes of this Study Area, are shown in Drawing No. MSEC1112-04. Urban areas include the urban areas within ML 1539 as defined in the development application (DA 67/98), and the urban areas within ML 1376, which have been defined by current Wollondilly Shire Council zoning boundaries.

1.7. Surface and seam levels

The surface level contours are shown in Drawing No. MSEC1112-05. The longwalls are located beneath a small ridgeline with a high point of approximately 286 metres above Australian Height Datum (m AHD) within the Study Area.

The surface falls toward Matthews, Cedar and Stonequarry Creeks in the north-western part of the mining area and towards Redbank Creek in the south-eastern part of the mining area. The minimum surface level is approximately 162 m AHD at Stonequarry Creek at the most downstream section, in the north-western part of the Study Area.

The longwalls are proposed to extract coal from the Bulli Seam. Tahmoor Coal proposes to extract a constant height of 2.1 m.

The seam floor contours and depth of cover contours are shown in Drawings Nos. MSEC1112-06 and MSEC1112-07, respectively. The Bulli Seam dips towards the north-east with an average gradient of 5 % (i.e. 1 in 20) across the mining area. The depths of cover directly above the proposed longwalls vary between a minimum of 470 m above the commencing end of LW W3 and a maximum of 550 m above the commencing end of LW W4.

The levels of the natural surface and the Bulli Seam are illustrated along Cross-section A and Long-section B in Fig. 1.3 and Fig. 1.4, respectively. The locations of these sections are shown in Drawings Nos. MSEC1112-05 to MSEC1112-07. The definition of the Study Area is provided in Section 2.1.

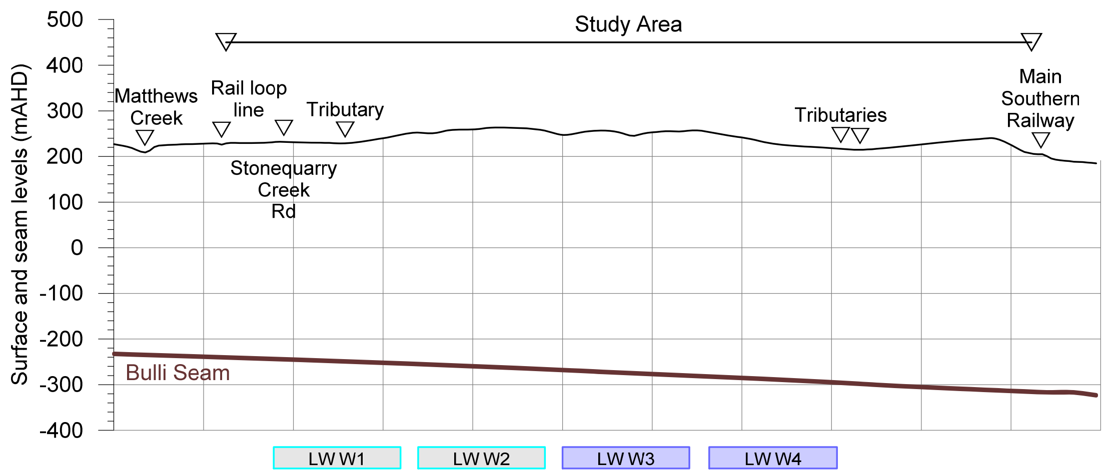

Fig. 1.3 Surface and seam levels along Cross-section A

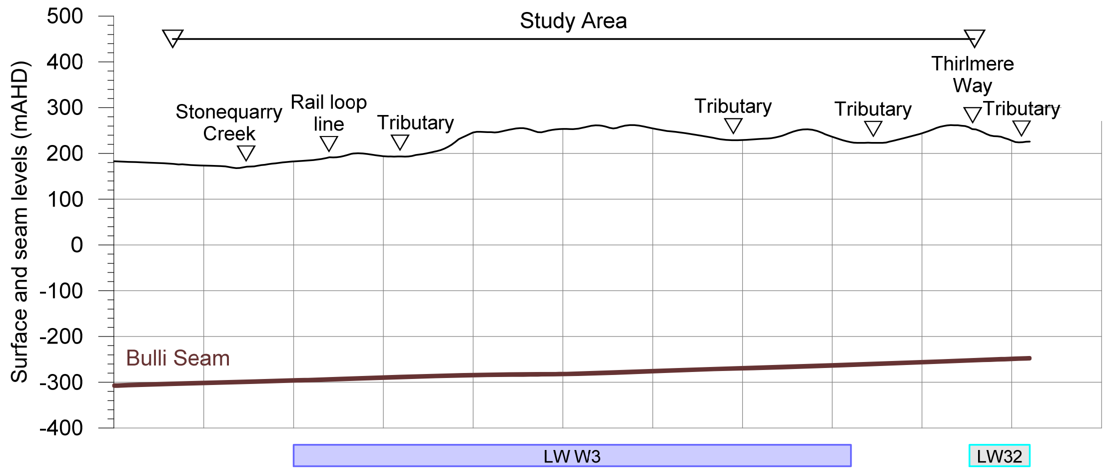

Fig. 1.4 Surface and seam levels along Long-section B

1.8. Geological details

Tahmoor Mine lies in the southern part of the Permo-Triassic Sydney Basin, within which the main coal bearing sequence is the Illawarra Coal Measures, of Late Permian age. The Illawarra Coal Measures contain four workable seams, the uppermost of which is the Bulli Seam, and it is this seam that is proposed to be extracted by LW W3-W4.

A typical stratigraphic section for TC (Borehole TNC30) is shown in Fig. 1.5. Borehole TNC30 is located south of Longwall 31 near Remembrance Drive.

The sediments forming the overburden to the Bulli Seam belong to the Hawkesbury Tectonic Stage that comprise three stratigraphic divisions. The lowest division is the Narrabeen Group, which is subdivided into a series of interbedded sandstone and claystone units. It ranges in age from Lower to Middle Triassic and varies in thickness up to 310 m. Overlying the Narrabeen Group is the Hawkesbury Sandstone, which is a series of bedded sandstone units which dates from the Middle Triassic and has a thickness of up to 185 m. Above the Hawkesbury is the Wianamatta Group, which consists of shales and siltstones and is poorly represented in this region, having a thickness of only a few tens of metres.

The major sandstone units are interbedded with other rocks and, though shales and claystones are quite extensive in places, the sandstone predominates. The major sandstone units are the Scarborough (Narrabeen Group), the Bulgo (Narrabeen Group) and the Hawkesbury Sandstones (Hawkesbury Sandstone) and these units vary in thickness from a few metres to as much as 200 m. The rocks exposed in the river gorges and creek alignments belong to the Hawkesbury Sandstone.

The other rocks generally exist in discrete but thinner beds of less than 15 m thickness or are interbedded as thin bands within the sandstone. The major claystone unit is the Bald Hill Claystone, which lies above the Bulgo Sandstone at the base of the Hawkesbury Sandstone. This claystone varies in thickness and is, in some places, more than 25 m thick. Due to the nature of the clay, which swells when it is wetted, it tends to act as an aquitard.

The geological structures identified at seam level are shown in Drawing No. MSEC1112-07. No significant geological structures have been identified within the Western Domain from underground workings by Tahmoor Mine.

The Nepean Fault is located east of the mining area. TC commissioned an engineering geologist from Strata Control Technology in 2018 (SCT, 2018a and 2018b) to undertake site inspections and mapping of the Nepean Fault. The investigations in 2018 examined a 12 kilometre section of the Nepean Fault Complex and focussed on the commencing end (southeastern end) of Longwall 32. This work has provided detailed information on the nature and location of the Nepean Fault and second order geological structures associated with the fault.

TC commissioned SCT to conduct a second detailed investigation of the Nepean Fault Complex in the vicinity of LW W4, specifically around the Picton Tunnel on the Main Southern Railway. SCT conducted field mapping and inspections in November 2020.

The Nepean Fault is mapped as "*an en-echelon distribution of first order faults with major offsets. Ramps are developed between these en-echelon fault surfaces. Numerous first order north-south faults, each of limited extent, step across the area investigated.*" (SCT, 2018a and SCT, 2020).

SCT further advise that the fault is sub-vertical from surface to seam, based on site investigations and geological information gathered by TC since 2014. A cross-section provided by SCT (2018a) has been reproduced in Fig. 1.6.

In addition to the mapped first order faults, SCT has mapped second order faults, which are described as "*mainly conjugate sets of strike slip faults and splay faults being observed between the en-echelon first order faults*." (SCT, 2018a and SCT, 2020).

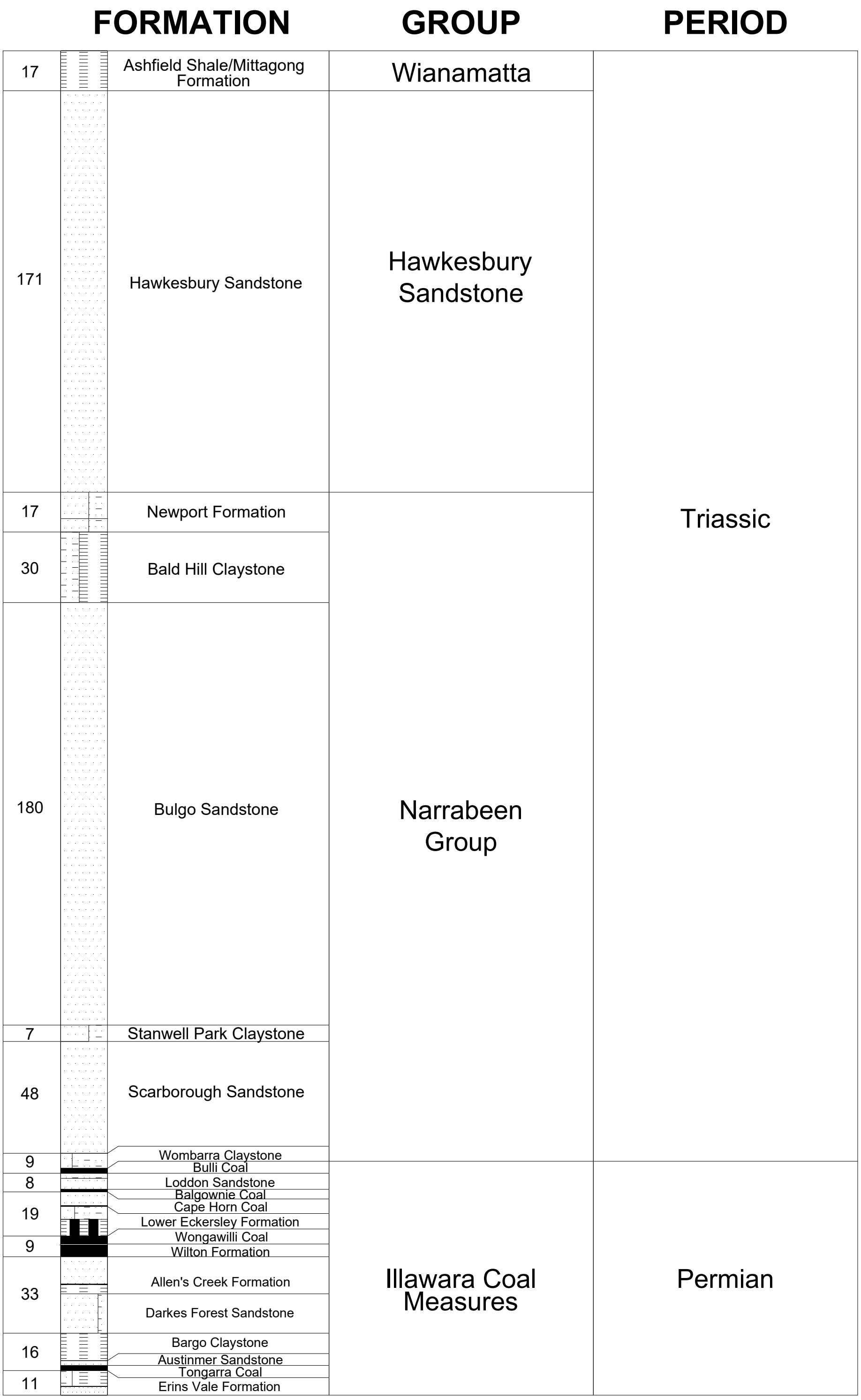

Fig. 1.5 Typical stratigraphic section at Tahmoor Mine (Borehole TNC30)

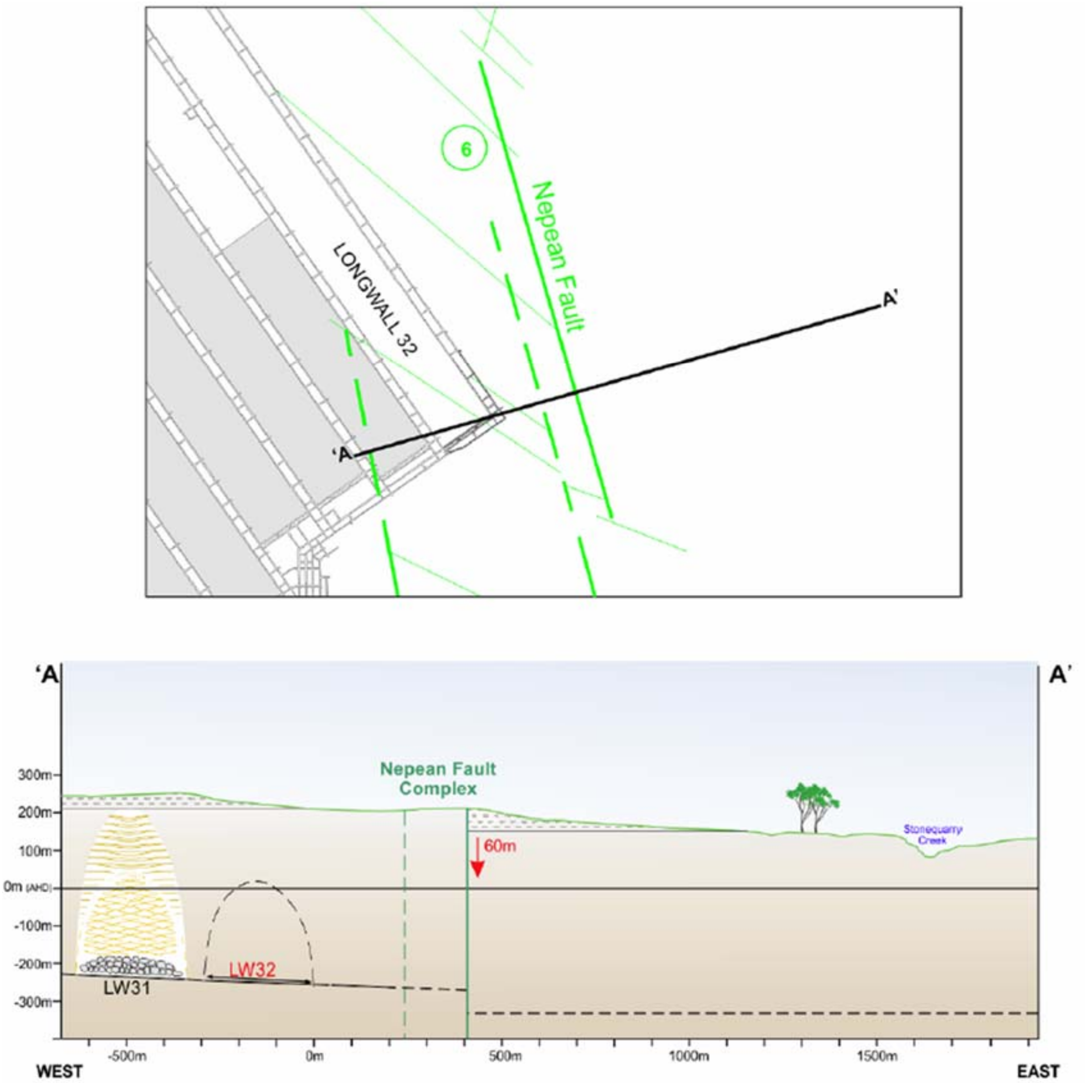

Fig. 1.6 Cross-section of Nepean Fault near Longwall 32 by SCT (2018a)

An updated map of the Nepean Fault Complex has been developed by SCT (2020), which has been reproduced in Fig. 1.7. SCT (2020) has summarised the results of the investigations:

- The Nepean Fault Complex is projected to pass through the Picton Tunnel. The Picton Tunnel area is located within a fault ramp area.
- The structures in this area mainly comprises the terminal ends of the north-south trending fault segments, with minimal offsets distributed among the fault planes that are present. This is supported by visual inspections by an engineering geologist, observations of the terrain around the Picton Tunnel and a review of geotechnical coring investigations that have recently been completed alongside the Tunnel in December 2020.
- Field observations found no indication of disturbance of the strata immediately surrounding the Tunnel. Fault displacements were not readily observed in the area of the Tunnel, which is consistent with an interpretation that the first order faults have transitioned into multiple fault segments that have dispersed the fault displacements.
- The nature of the faulting within the Picton Tunnel area strongly indicates that the Nepean Fault Complex has formed in a tensile, “extensional”, environment.

The geological structures, as mapped by SCT (2020), have been overlaid with built structures within and adjacent to LW W3-W4. These are shown in Drawing No. MSEC1112-08.

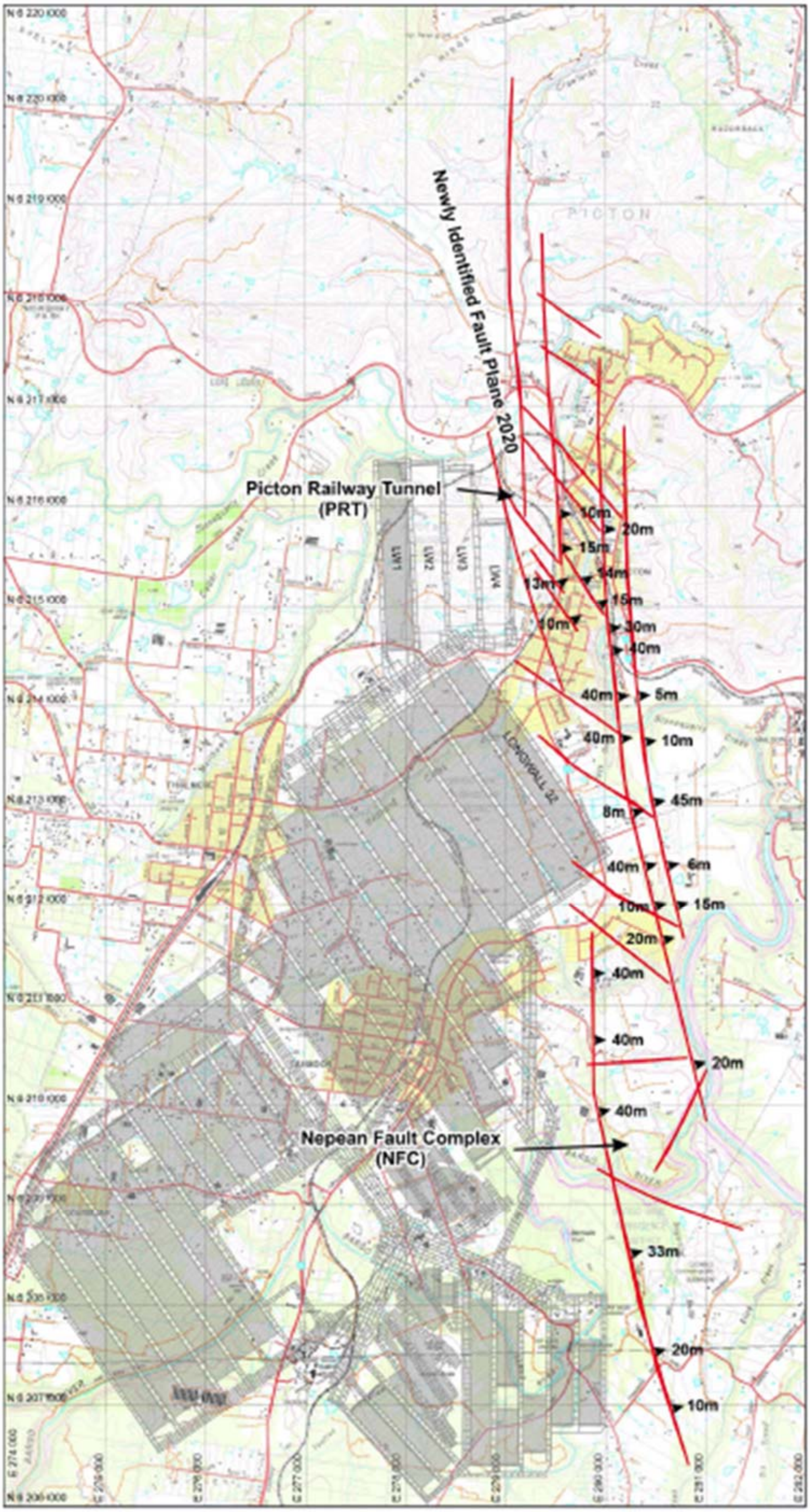

Fig. 1.7 Nepean Fault mapping superimposed on 1:25,000 topographic map (courtesy SCT, 2020)

The surface lithology is illustrated in Fig. 1.8, which shows the proposed longwalls overlaid on Geological Series Sheet 9029, published by NSW Mining, Exploration and Geoscience.

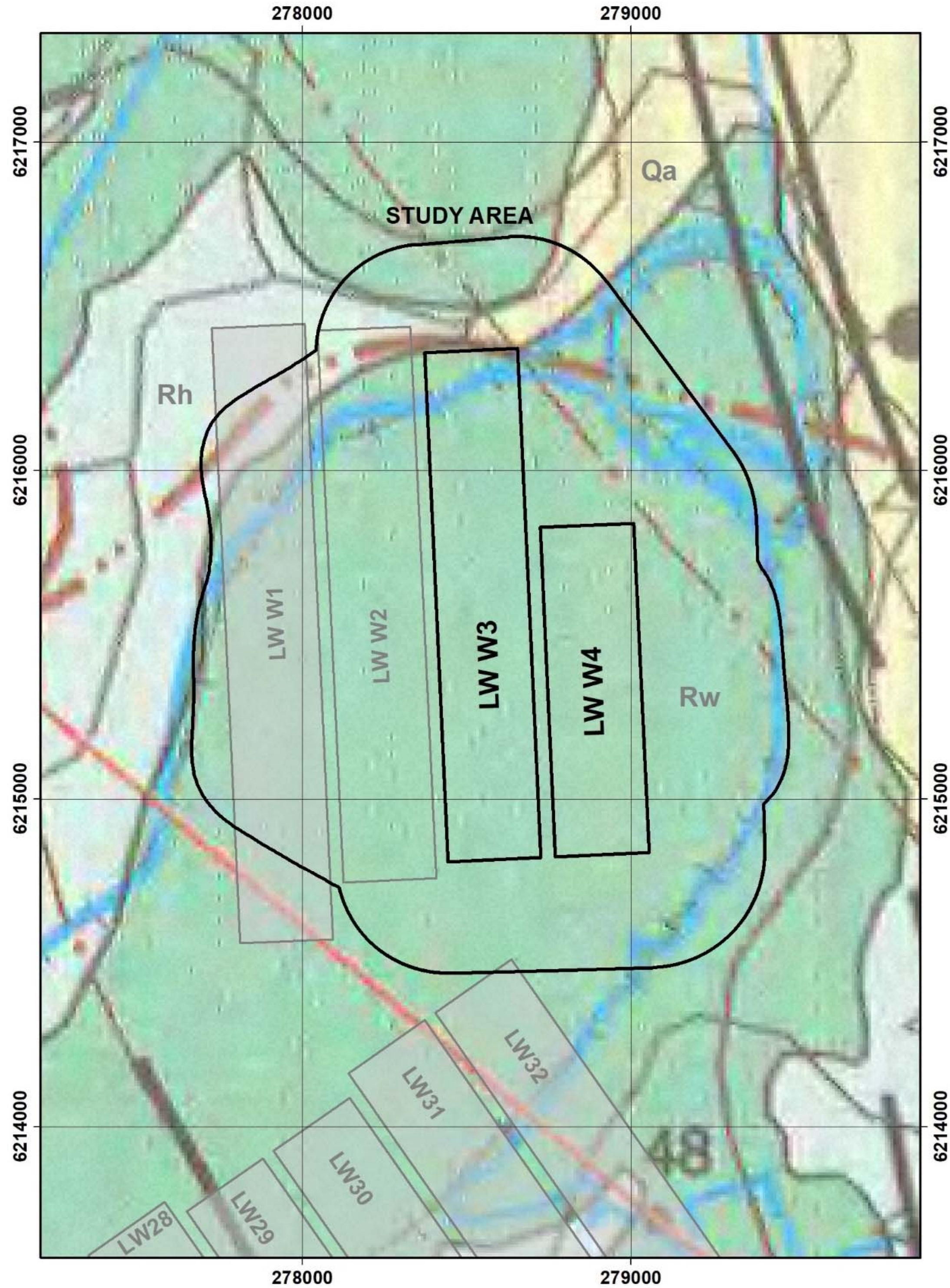

Fig. 1.8 Surface lithology within the Study Area (DPI Geological Series Sheet 9029)

The surface lithology above the proposed longwalls generally comprises the Wianamatta Group (Rw), with the Hawkesbury Sandstone Group (Rh) exposed in Matthews, Cedar and Stonequarry Creeks.

2.1. Definition of the Study Area

The *Study Area* is defined as the surface area that could be affected by the mining of LW W3-W4. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- A 35° angle of draw from the extents of LW W3-W4;
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of LW W3-W4; and
- Features that could experience far-field or valley-related movements and could be sensitive to such movements.

The depths of cover contours for the Bulli Seam are shown in Drawing No. MSEC1112-07. The depths of cover directly above LW W3-W4 vary between 470 m and 550 m. The 35° angle of draw, therefore, has been determined by drawing a line that is a horizontal distance varying between 330 m and 385 m around the extent of the longwall mining area.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour due to the extraction of LW W3-W4, has been determined using the Incremental Profile Method, which is described in Chapter 3. The predicted subsidence contours, including the 20 mm subsidence contour, due to LW W3-W4 are shown in Drawing No. MSEC1112-27. The predicted subsidence contours represent the additional movements due to LW W3-W4 only.

The predicted 20 mm subsidence contour is located outside the 35° angle of draw adjacent to the tailgate of LW W3 and adjacent to the maingate of LW W4. The predicted 20 mm subsidence contour is located within the angle of draw adjacent to the longwall commencing and finishing ends. The Study Area based on the combined 35° angle of draw and the predicted 20 mm subsidence contour is shown in Drawing No. MSEC1112-01.

In addition to the above, investigations have been undertaken within 600 m of the extents of LW W3-W4 within Cedar and Stonequarry Creeks. A minimum of 600 metres from the nearest edge of longwalls was recommended in the independent inquiry report titled "Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield – Strategic Review" (NSW Department of Planning (DoP), 2008).

There are additional features that are located outside the Study Area that could experience either far-field horizontal movements or valley-related movements. The surface features that could be sensitive to such movements have been identified and have also been included in the assessments provided in this report. These features include railway infrastructure, survey control marks and groundwater bores.

2.2. Natural and built features within the Study Area

The major natural and built features within the Study Area can be seen in the 1:25,000 Topographic Map of the area, *Picton 9029-4-S,* published by the Central Mapping Authority (CMA). The longwalls and the Study Area have been overlaid on an extract of the CMA map in Fig. 2.1.

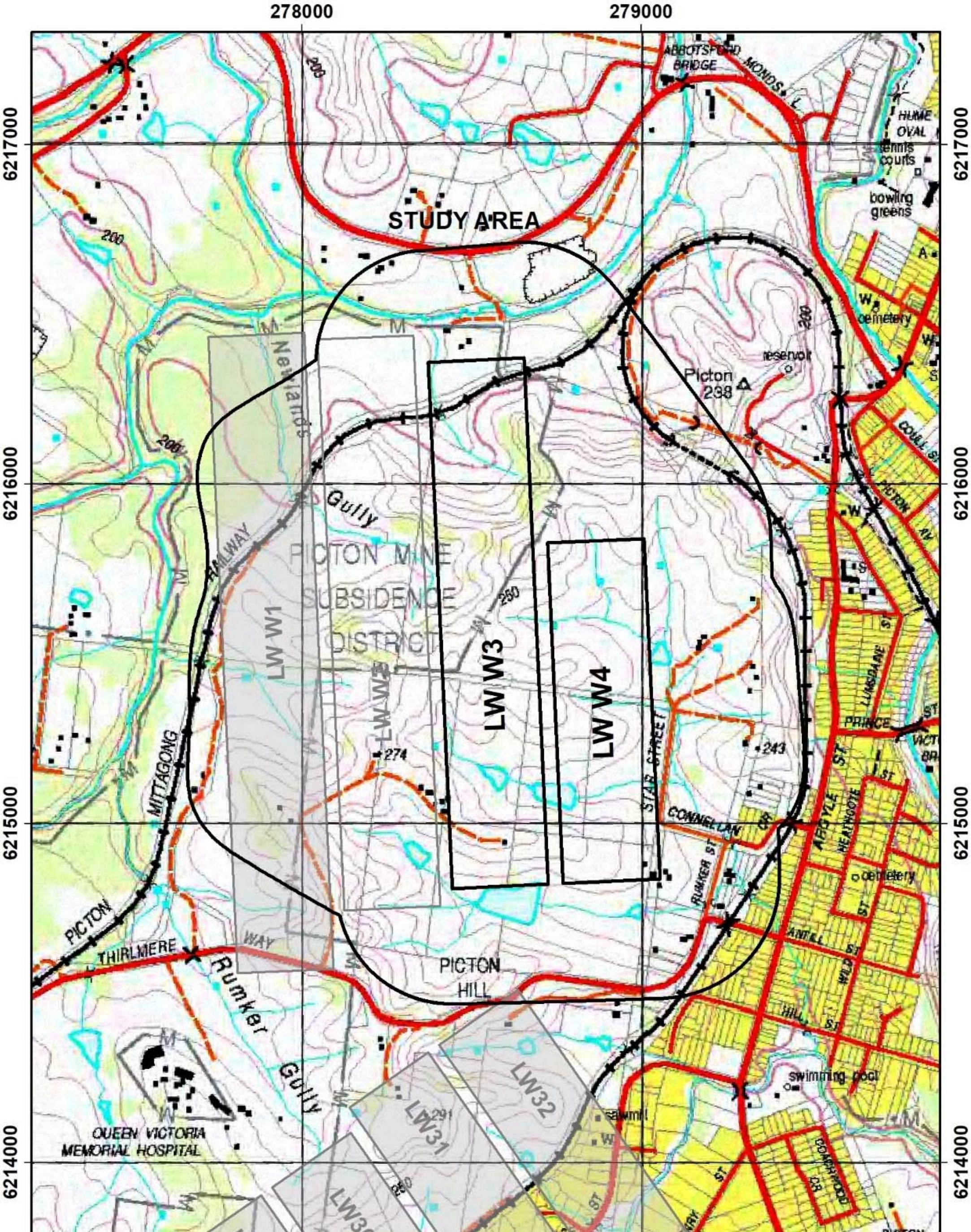

Fig. 2.1 The longwalls and Study Area overlaid on CMA Map *Picton 9029-4-S*

A summary of the natural and built features located within the Study Area is provided in Table 2.1. The locations of these features are shown in Drawing Nos. MSEC1112-09 to MSEC1112-21. Descriptions, predictions and impact assessments for the natural and built features are provided in Chapters 5 and 6. The section number references are provided in Table 2.1.

Table 2.1 Natural and built features within the Study Area

Item	Within Study Area	Section number reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	×	5.1
Rivers or Creeks	✓	5.2 to 5.4
Aquifers or Known Groundwater Resources	✓	5.5
Springs	×	
Sea or Lake	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Pagodas	×	5.6
Steep Slopes	✓	5.7
Escarpments	×	
Land Prone to Flooding or Inundation	×	
Swamps, Wetlands or Water Related Ecosystems	✓	5.10
Threatened or Protected Species	✓	5.11
National Parks	×	
State Forests	×	
State Conservation Areas	×	5.1
Natural Vegetation	✓	5.12
Areas of Significant Geological Interest	×	
Any Other Natural Features Considered Significant	×	
PUBLIC UTILITIES		
Railways	✓	6.1 & 0
Roads (All Types)	✓	6.3
Bridges	✓	6.1 & 6.5
Tunnels	✓	6.6
Culverts	✓	0
Water, Gas or Sewerage Infrastructure	✓	6.7, 6.8 & 6.9
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	✓	6.10
Telecommunication Lines or Associated Plants	✓	6.11
Water Tanks, Water or Sewage Treatment Works	✓	6.15
Dams, Reservoirs or Associated Works	×	
Air Strips	×	
Any Other Public Utilities	×	
PUBLIC AMENITIES		
Hospitals	×	6.12
Places of Worship	×	
Schools	×	
Shopping Centres	×	
Community Centres	×	
Office Buildings	×	
Swimming Pools	×	
Bowling Greens	×	
Ovals or Cricket Grounds	×	
Racecourses	×	
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	×	
Farm Buildings or Sheds	✓	6.14
Tanks	×	
Gas or Fuel Storages	×	
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	✓	6.16
Farm Dams	✓	6.17
Wells or Bores	✓	0
Any Other Farm Features	×	
INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS		
Factories	×	
Workshops	×	
Business or Commercial Establishments or Improvements	✓	6.19
Gas or Fuel Storages or Associated Plants	×	
Waste Storages or Associated Plants	×	
Buildings, Equipment or Operations that are Sensitive to Surface Movements	×	
Surface Mining (Open Cut) Voids or Rehabilitated Areas	×	
Mine Infrastructure Including Tailings Dams or Emplacement Areas	×	
Any Other Industrial, Commercial or Business Features	×	
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓	6.21 & 0
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	✓	6.23
RESIDENTIAL ESTABLISHMENTS		
Houses	✓	6.24
Flats or Units	×	
Caravan Parks	×	
Retirement or Aged Care Villages	✓	6.12
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts	✓	6.25, 6.25.1 & 6.25.2
Any Other Residential Features	✓	6.25
ANY OTHER ITEM OF SIGNIFICANCE	×	
ANY KNOWN FUTURE DEVELOPMENTS	✓	6.27

3.0 OVERVIEW OF MINE SUBSIDENCE AND THE METHODS THAT HAVE BEEN USED TO PREDICT THE MINE SUBSIDENCE PARAMETERS FOR THE LONGWALLS

3.1. Introduction

The following sections provide overviews of conventional and non-conventional mine subsidence parameters and the methods that have been used to predict these movements. Further information is also 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/kilometres* (km^{-1}), but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*;
- **Strain** is the relative differential horizontal movement 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 distances between two points increase and **Compressive strains** occur when the distances between two points decrease. 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; and
- **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), and vice versa.

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

3.3. Far-field movements

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

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

In some cases, higher levels of far-field horizontal movements have been observed where steep slopes or surface incisions exist nearby, as these features influence both the magnitude and the direction of ground movement patterns. Similarly, increased horizontal movements are often observed around sudden changes in geology or where blocks of coal are left between longwalls or near other previously extracted series of longwalls. In these cases, the levels of observed subsidence can be slightly higher than normally predicted, but these increased movements are generally accompanied by very low levels of tilt 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 400 m, such as the case over a large part of the Study Area, the observed subsidence profiles along monitoring lines are generally smooth. Where the depth of cover is less than 100 m, the observed subsidence profiles along monitoring lines are generally irregular. Very irregular subsidence movements are observed with much higher tilts, curvatures 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:

- sudden or abrupt changes in geological conditions;
- steep topography; and
- valley-related mechanisms.

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

3.4.1. Non-conventional subsidence movements due to changes in geological conditions

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

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

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

In this report, non-conventional ground movements are being included statistically in the predictions and impact assessments, by basing these on the frequency of past occurrence of both the conventional and non-conventional ground movements and impacts. The analysis of strains provided in Section 4.4 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 and 6, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

3.4.2. Non-conventional subsidence movements due to steep topography

Non-conventional movements can also result from increased horizontal movements in the downslope direction where longwalls are extracted beneath steep slopes. In these cases, elevated tensile strains develop near the tops of the steep slopes and elevated compressive strains develop near the bases of the steep slopes. The potential impacts resulting from the increased horizontal movements 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 downslope movements for the steep slopes within the Study Area are provided in Section 5.7.

3.4.3. Valley-related movements

The streams within the Study Area will be affected by valley-related movements, which are commonly observed 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.

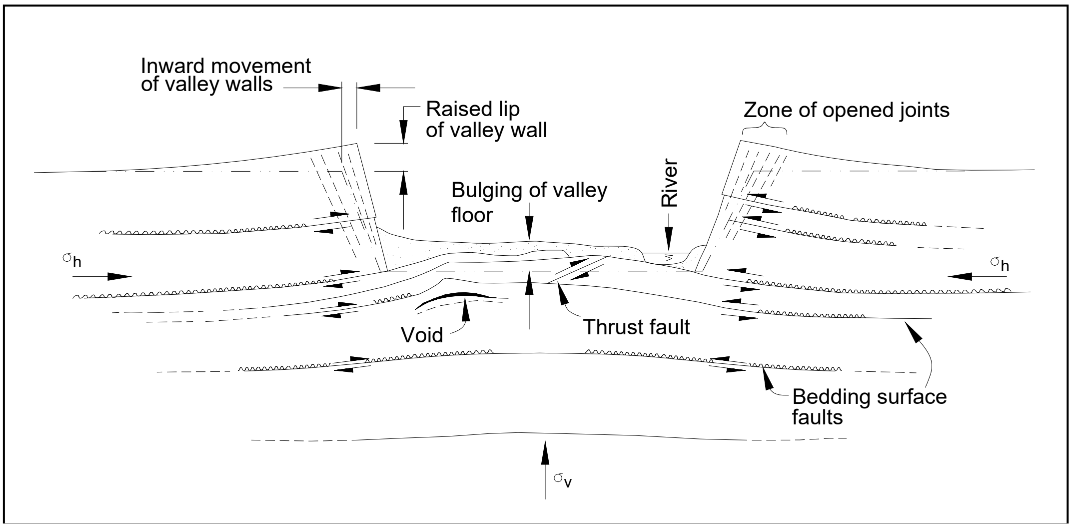

Fig. 3.1 Valley formation in flat-lying sedimentary rocks (after Patton and Hendren 1972)

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 downslope 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 horizontal distance between any two points on the opposing valley sides; and

- **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 for the streams in the vicinity of the mining area have been determined using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002), referred to as the 2002 ACARP method.

More recently, the empirical prediction method has been refined based on further research undertaken as part of ACARP Research Project No. 18015 (Kay and Waddington, 2014), referred to as the 2014 ACARP method. This method only provides predictions for valley closure and not for upsidence.

The predictions based on the 2002 ACARP method can be directly compared with the predictions provided in previous MSEC subsidence reports for TC and with other case studies from the Southern Coalfield. This method has also been more widely used and tested than the more recent 2014 ACARP method. The assessments provided in this report, therefore, have been based on the predictions obtained using the 2002 ACARP method.

The reliability of the predicted valley-related closure movements is discussed in Section 3.10.

The predicted strains resulting from valley-related movements have been determined using the monitoring data for longwalls which have previously mined directly beneath and adjacent to streams in the Southern Coalfield. The predicted valley-related strains are discussed with the impact assessments for the streams provided in Chapter 5.

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*.

3.5. The Incremental Profile Method

The predicted conventional subsidence parameters for the proposed longwalls have been determined using the Incremental Profile Method (IPM), which has been developed by MSEC. 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 NSW.

The database consists of detailed subsidence monitoring data from collieries in NSW including: Angus Place, Appin, Baal Bone, Bellambi, Beltana, Blakefield South, Bulli, Chain Valley, Clarence, Coalcliff, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Fernbrook, Glennies Creek, Gretley, Invincible, John Darling, Kemira, Lambton, Liddell, Mandalong, Metropolitan, Mt. Kembla, 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 IPM use the database of observed incremental subsidence profiles, the longwall geometries, local surface and seam information and geology. The method tends 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 IPM are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

3.6. Review of the IPM

The use of the IPM at the TC has been continually reviewed and refined based on the latest available ground movement monitoring data. The subsidence model has been reviewed after the completion of each longwall as part of the End of Panel reports.

Initially, the subsidence predictions for the longwalls at TC were based on the standard model for the Southern Coalfield. In 2009, the IPM was refined using the extensive monitoring data that had been collected during the extraction of LW22 to LW25 at the mine. The details of this calibration were outlined in Section 3.6 of Report No. MSEC355 (Rev. B).

A detailed review of the IPM was carried out in 2014, based on the monitoring data that had been collected during the extraction of LW22 to LW28. It was found that the calibrated IPM generally provided reliable predictions at TC. However, exceedances occurred in the areas of increased subsidence above LW24A and above the south-eastern ends of LW25 to LW27.

The IPM has again been reviewed based on the latest monitoring data. The following sections review the predictions obtained using the subsidence model based on the monitoring lines located outside the areas of increased subsidence. Discussions on the areas of increased subsidence are provided in Section 3.7.

3.6.1. Comparison of measured and predicted vertical subsidence

Comparisons of the measured and predicted profiles of vertical subsidence are provided along: Bridge Street in Fig. 3.2; Brundah Road in Fig. 3.3; the Main Southern Railway in Fig. 3.4; and Remembrance Drive in Fig. 3.5.

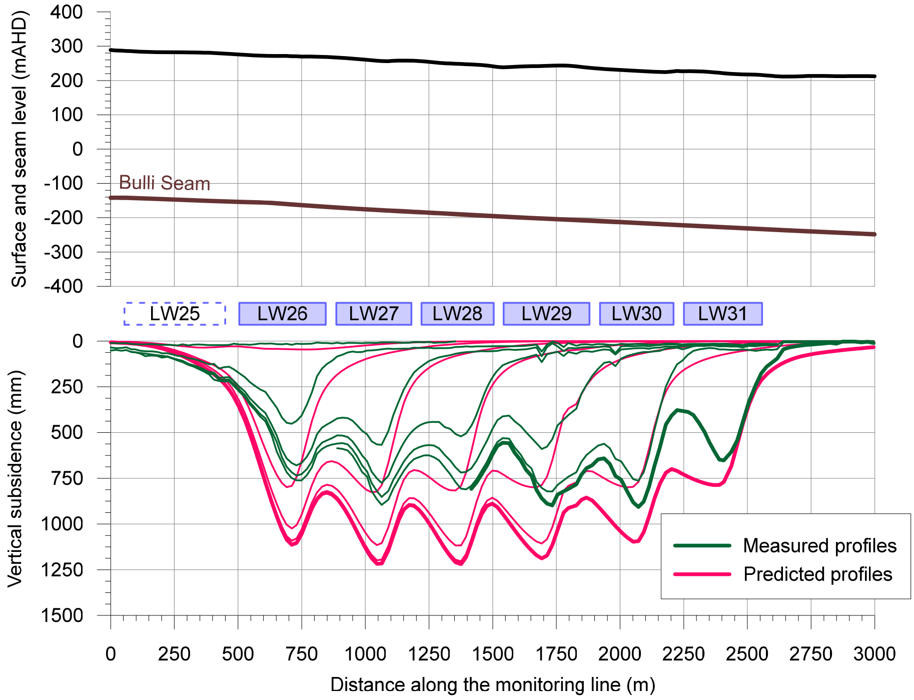

Fig. 3.2 Measured and predicted vertical subsidence along Bridge Street

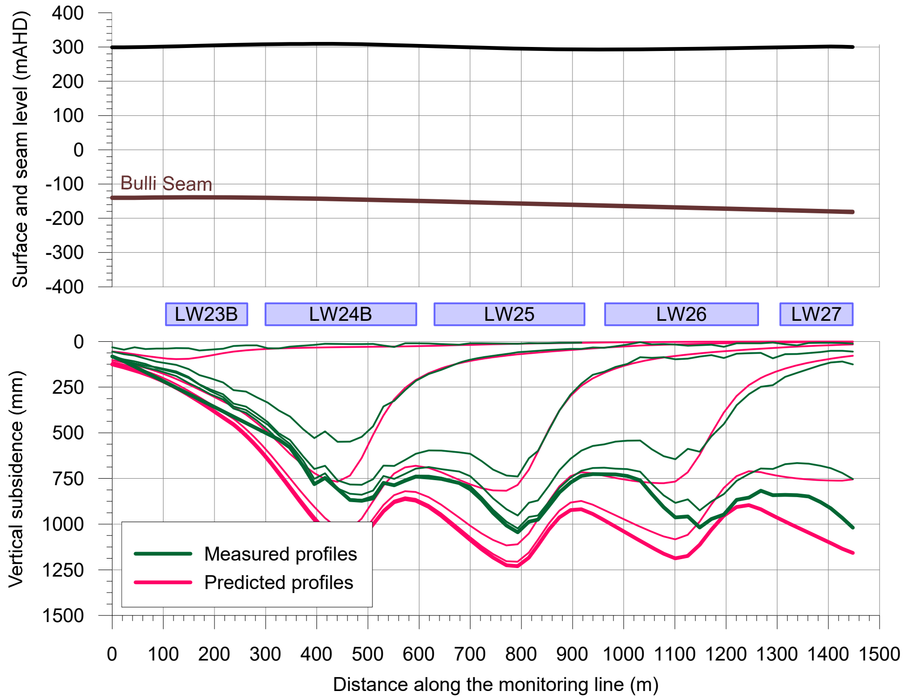

Fig. 3.3 Measured and predicted vertical subsidence along Brundah Road

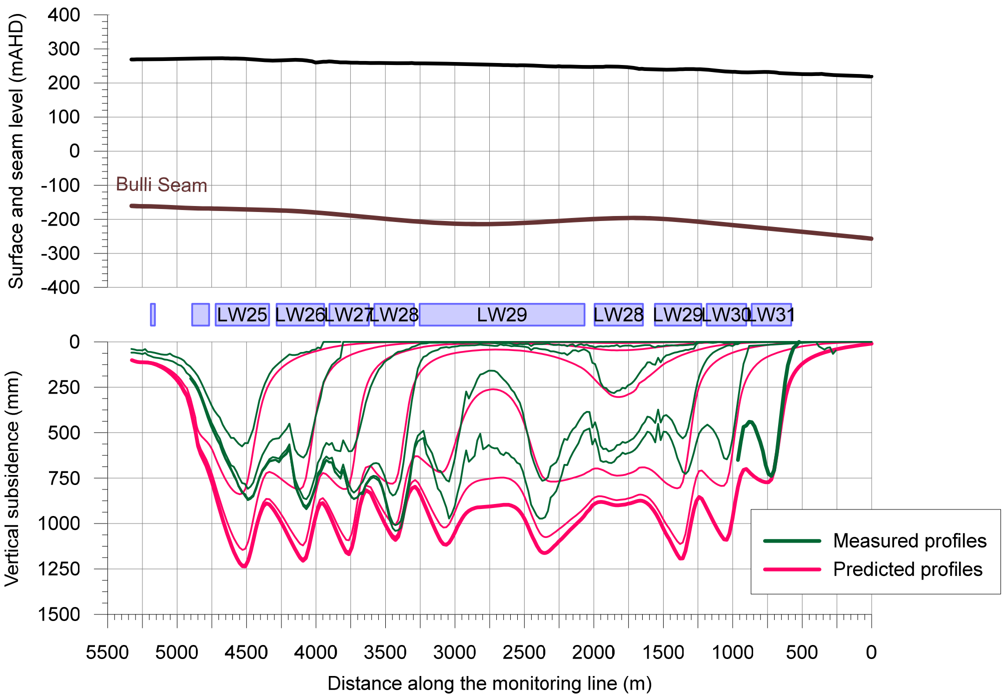

Fig. 3.4 Measured and predicted vertical subsidence along the Main Southern Railway

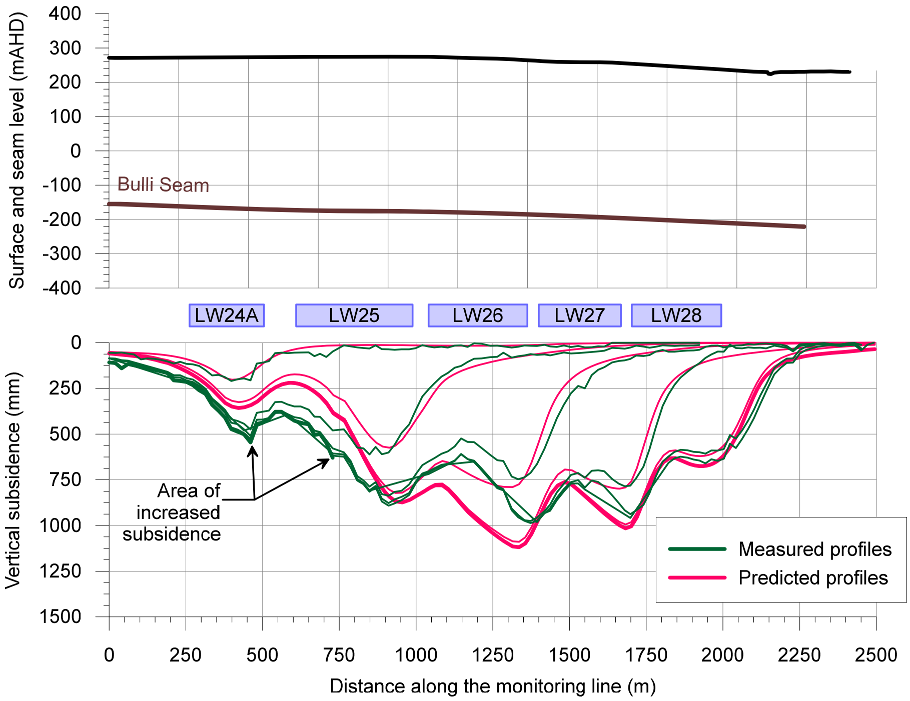

Fig. 3.5 Measured and predicted vertical subsidence along Remembrance Drive

The maximum measured vertical subsidence directly above each of the extracted longwalls was typically less than the maximum values predicted. The measured vertical subsidence was greater than the predicted values above LW24A and above the south-eastern ends of LW25 to LW27. These exceedances occurred in the areas of increased subsidence, such as along the southern end of Remembrance Drive (refer to the left-side of Fig. 3.5). Further discussions on the areas of increased subsidence is provided in Section 3.7.

The measured profiles of vertical subsidence reasonably matched the predicted profiles, although the magnitudes were smaller. In some cases, the low-level subsidence measured outside of the mining area was greater than predictions. However, the exceedances were generally less than 50 mm and these were accompanied by only low levels of tilt, curvature and strain.

There is a lateral shift between the measured and predicted profiles of vertical subsidence along some monitoring lines. This can occur due to the surface slope or seam dip. The impact assessments for point features have been based on the maximum predicted values within 20 mm of their extents to account for the potential lateral shift.

A comparison between the maximum measured and maximum predicted incremental vertical subsidence for the monitoring lines at the mine, due to the extraction of each of LW22 to LW31, is provided in Fig. 3.6. These data exclude the sections of monitoring lines that are located within the areas of increased subsidence, which is discussed separately in Section 3.7. The data also exclude monitoring lines that do not extend across the full width of the active longwall.

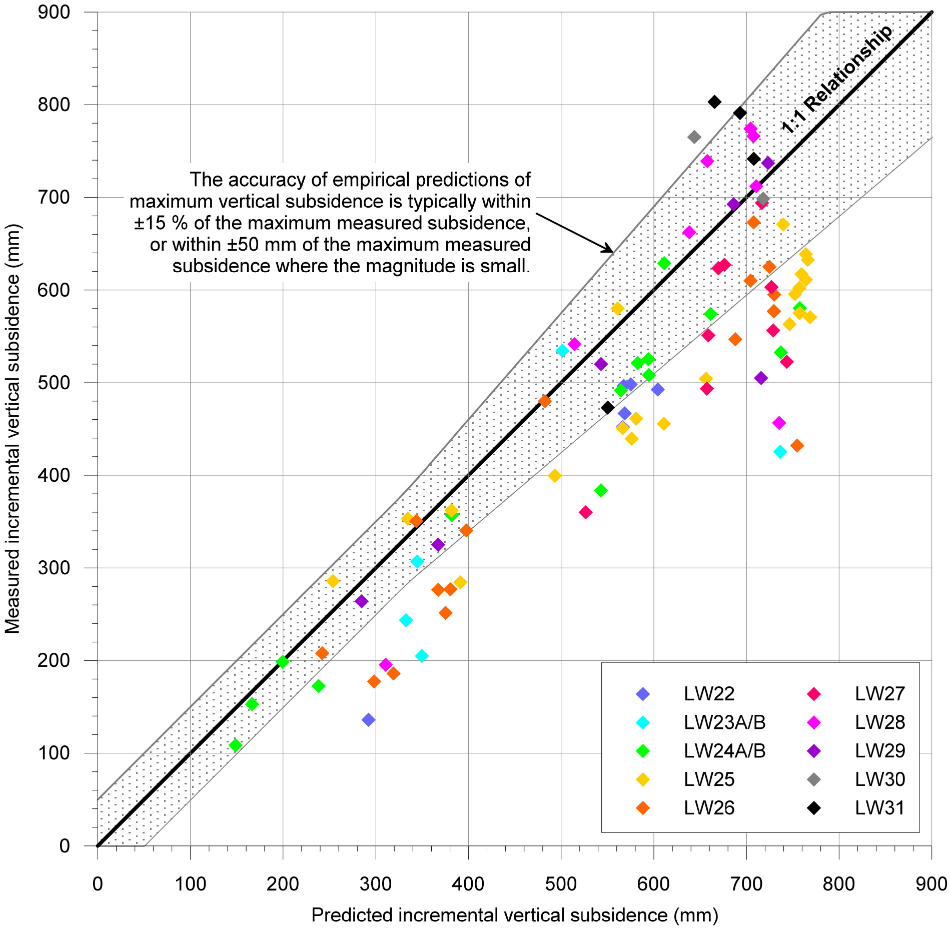

Fig. 3.6 Comparison of maximum measured and maximum predicted incremental vertical subsidence due to LW22 to LW31

The maximum measured incremental vertical subsidence was typically less than the maximum predicted incremental vertical subsidence or was within +15 % or +50 mm of the maximum predicted values. There are two cases where the maximum measured incremental vertical subsidence was greater than +15 % of the maximum predicted values, along the Optical Fibre Line due to LW30 and along Stilton Lane due to LW31.

A comparison between the maximum measured and maximum predicted total vertical subsidence for the monitoring lines at the mine, after the extraction of each of LW22 to LW31, is provided in Fig. 3.7. In all cases, the maximum measured total vertical subsidence was less than the maximum predicted vertical subsidence or was within +15 % or +50 mm of the maximum predicted values.

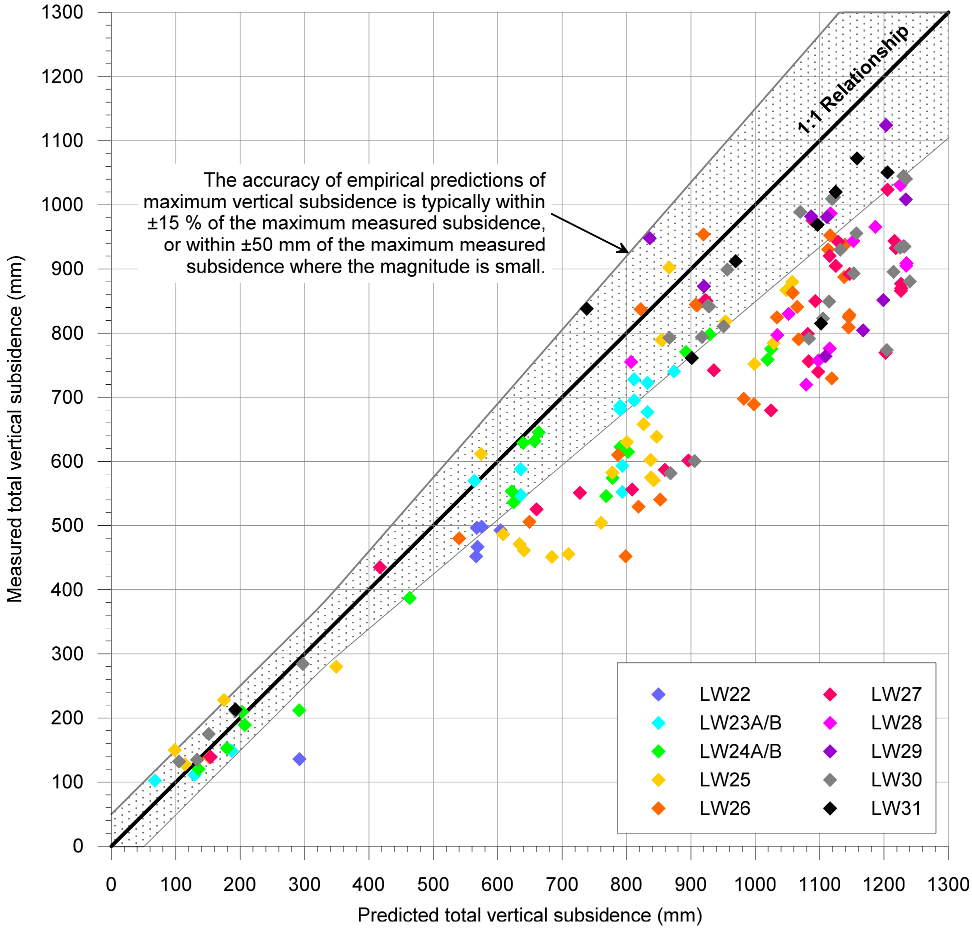

Fig. 3.7 Comparison of maximum measured and maximum predicted total vertical subsidence after each of LW22 to LW31

The distribution of the ratio of the maximum measured to maximum predicted total vertical subsidence for the monitoring lines above LW22 to LW31 is illustrated on the left-side of Fig. 3.8. As per previous, these data exclude the sections of monitoring lines that are located within the areas of increased subsidence and the monitoring lines that do not extend across the full width of the active longwall. A gamma distribution has been fitted to the data and this is shown on the left-side of Fig. 3.8. The probabilities of exceedance based on the fitted gamma distribution are shown in the right-side of this figure.

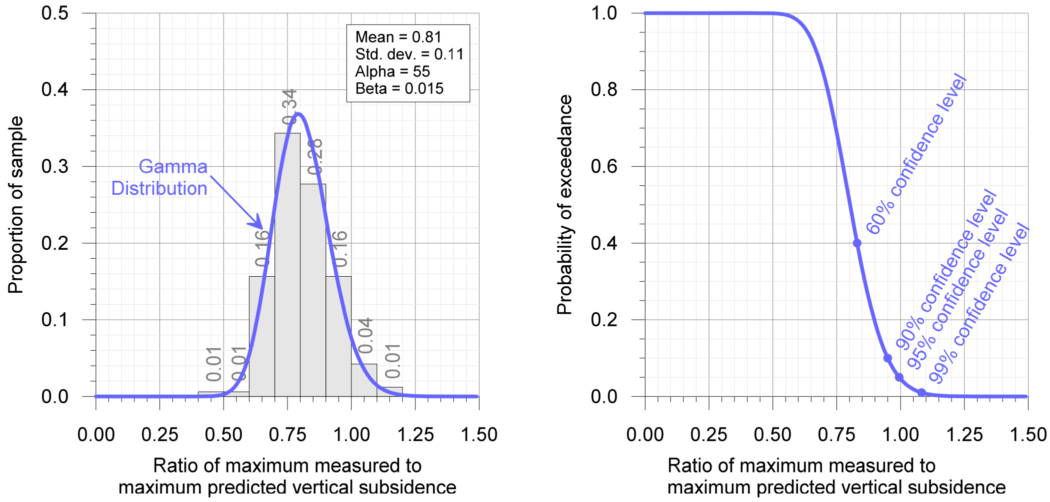

Fig. 3.8 Distribution of the ratio of maximum measured to maximum predicted total vertical subsidence due to LW22 to LW31

The mean ratio of the maximum measured to maximum predicted total vertical subsidence for the monitoring lines is 0.81. That is, the maximum measured vertical subsidence was, on average, 81 % of the maximum predicted values outside the areas of increased subsidence. The maximum measured subsidence was, at most, +10 % greater than the maximum predicted value. Greater subsidence was measured within the areas of increased subsidence, which were excluded from this dataset, and are discussed further in Section 3.7.

The 95 % confidence level approximately represents a ratio of maximum measured to maximum predicted total vertical subsidence of 1.0. That is, there is approximately a 5 % probability that the maximum measured total subsidence exceeds the maximum predicted total value along each of the monitoring lines.

It is considered that the calibrated IPM provides reasonable, if not, slightly conservative predictions of vertical subsidence outside the areas of increased subsidence. LW W3-W4 are, however, located closer to the Nepean Fault. It is therefore possible that increased subsidence may develop directly above these panels. This is discussed in Section 3.7.

3.6.2. Comparison of measured and predicted subsidence for LW W1-W2

LW W1

Observed subsidence above single panels is typically more variable than above subsequent longwall panels in a series. The variations are due to different strengths of the overburden strata above the panel, which is supported on all four sides of the longwall.

A summary of observed maximum subsidence against predictions from the calibrated IPM is provided in Fig. 3.9. Recently extracted LW W1 has been included in the figure.

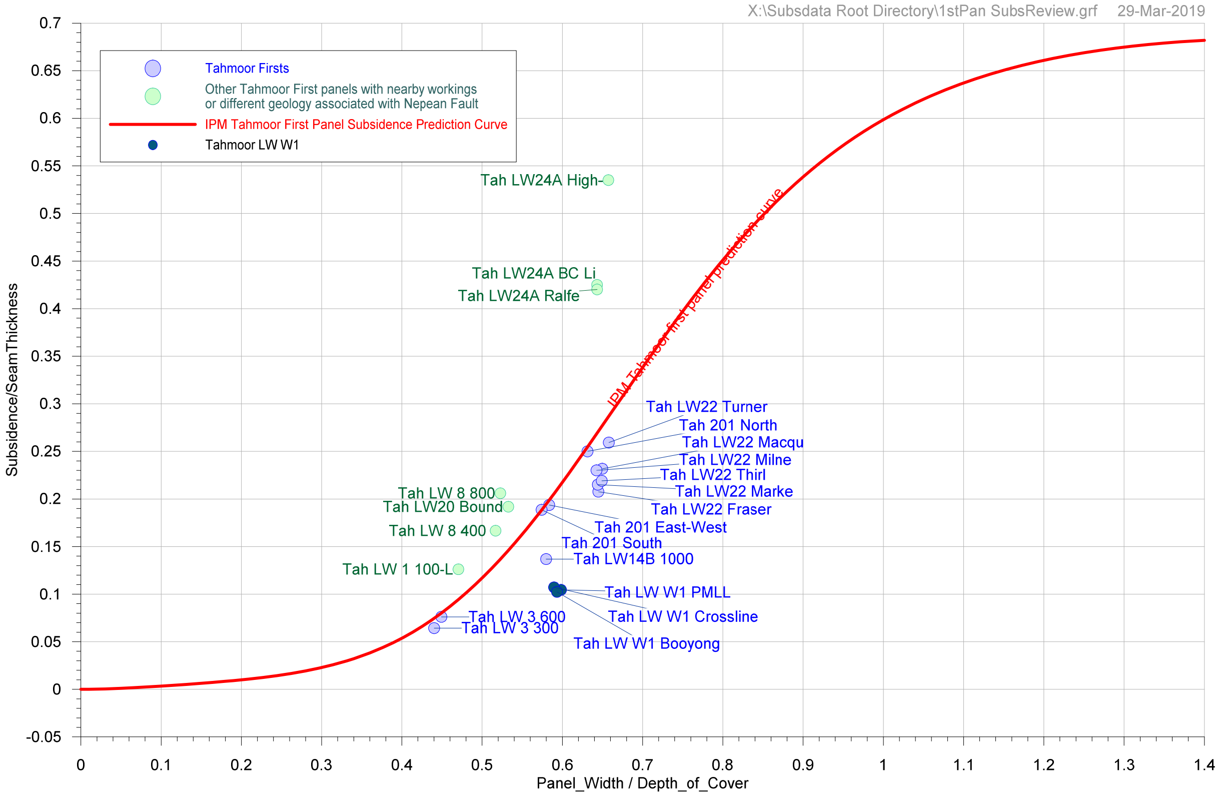

Fig. 3.9 Comparison between observed and predicted maximum subsidence for single panels at Tahmoor

It can be seen from Fig. 3.9 that there has been a reasonable correlation between predicted and observed maximum subsidence for single panels at TC, particularly Longwall 22. Some variations have been observed, however, in other locations. In these cases, highlighted in green in Fig. 3.9, special circumstances exist and these are described below:

- Tahmoor Longwall 1 – This panel is located adjacent to total extraction workings and is not, therefore, an isolated single panel;
- Tahmoor Longwall 8 – This panel is located adjacent to total extraction workings and is not, therefore, an isolated single panel. It is also located near the Nepean Fault, which is discussed further in Section 3.7;
- Tahmoor Longwall 20 – This panel is located adjacent to total extraction workings and is not, therefore, an isolated single panel; and
- Tahmoor Longwall 24A – This panel is located adjacent to total extraction workings and is not, therefore, an isolated single panel. It is also located near the Nepean Fault, which is discussed further in Section 3.7.

Ground surveys during the mining of LW W1 have found that subsidence has been substantially less than predicted (approximately 50%). The experience is new for Tahmoor Mine but it has been previously observed at nearby longwalls at Appin Colliery, including LW901 and the southern section of LW703.

A comparison between measured and predicted profiles of vertical subsidence along the Picton to Mittagong Loop Line are provided in Fig. 3.10 after the mining of LW W1 at TC.

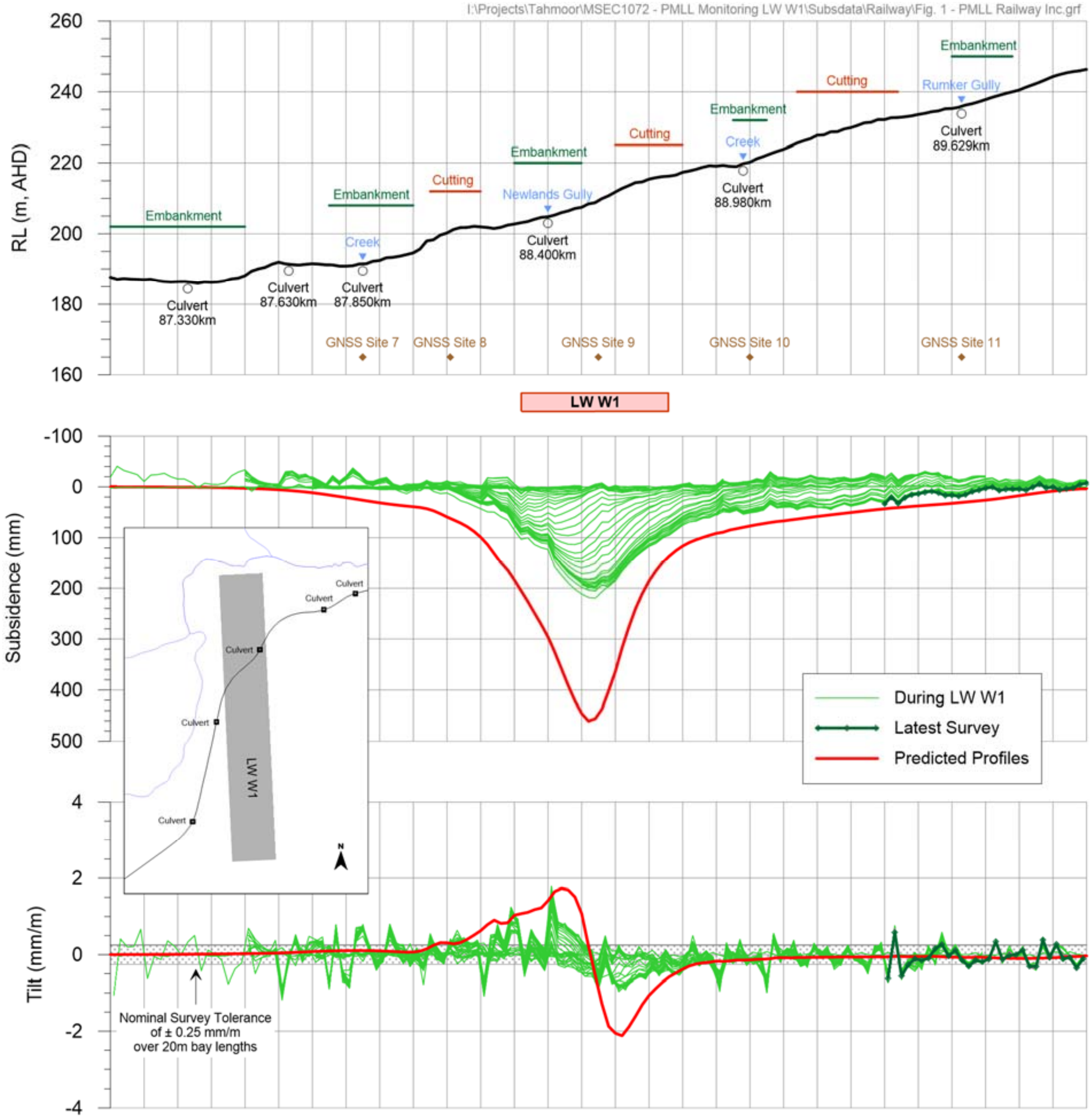

Fig. 3.10 Comparison between measured and predicted subsidence and tilt profiles along Picton to Mittagong Loop Line during the mining of LW W1 at TC

It can also be seen that observed tilts were lower than predicted.

LW W2

As at March 2021, subsidence surveys above LW W2 have measured less subsidence than predicted. Observed subsidence along the centreline of LW W2 is shown in Fig. 3.11.

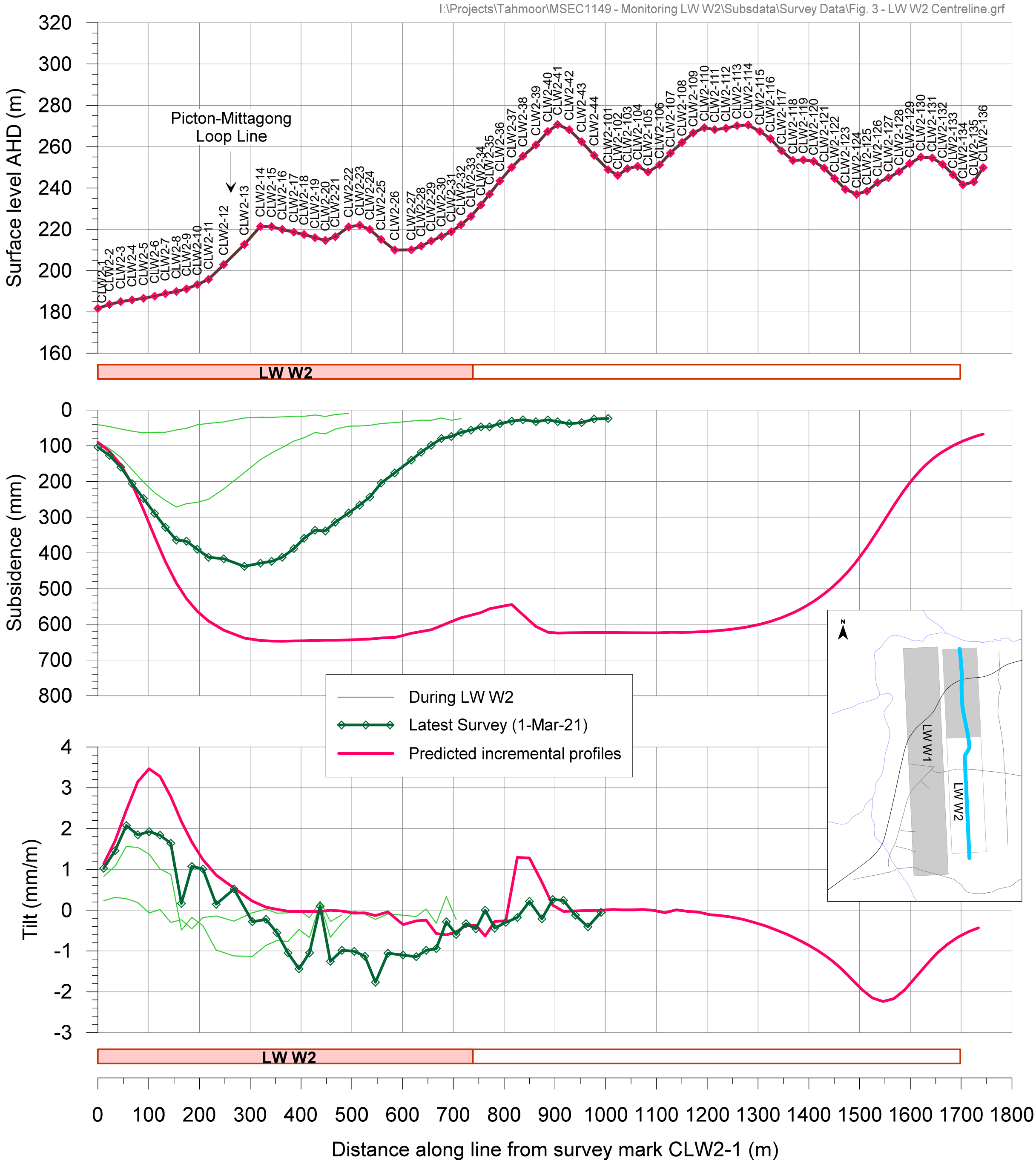

Fig. 3.11 Comparison between measured and predicted subsidence and tilt profiles along LW W2 Centreline during the mining of LW W2 at TC

The length of extraction at the time of survey was approximately 730 metres. As shown in Fig. 3.12, the majority of subsidence above the commencing end of LW W2 is expected to have developed at this length of extraction.

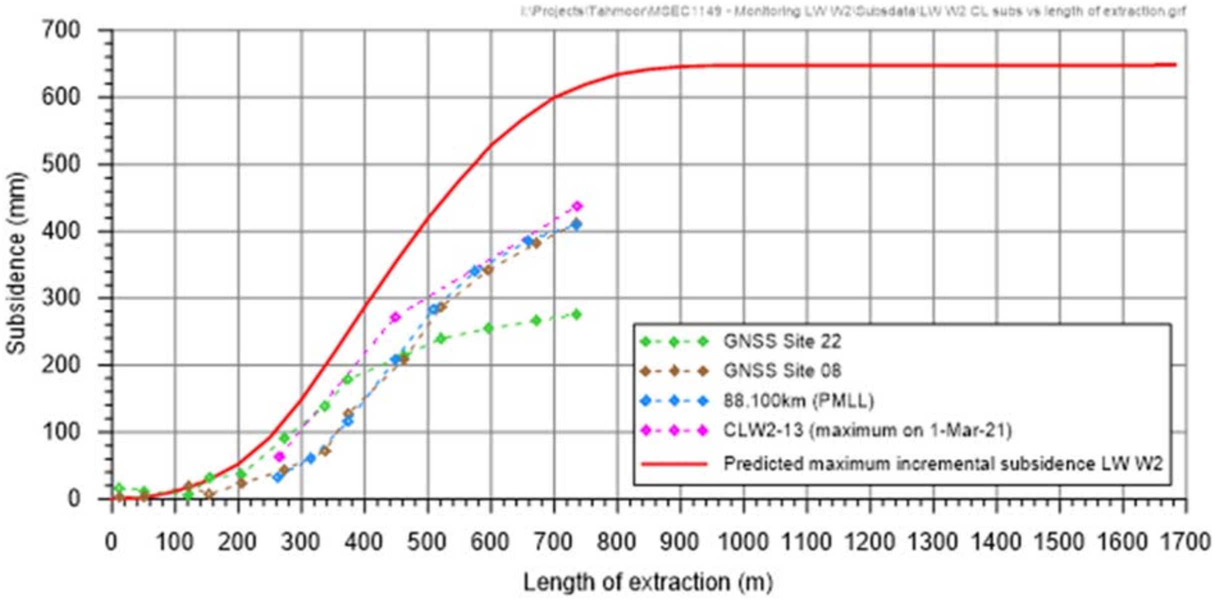

Fig. 3.12 Development of subsidence along centreline of LW W2 relative to length of longwall extraction at TC

Whilst observed subsidence above LW W1 and LW W2 was less than predicted, subsidence due to the extraction of LW W3-W4 may not follow the same pattern and return to normal levels. Subsidence may also be greater than predicted.

It is therefore recommended that monitoring be conducted during the early stages of extraction of LW W3 and LW W4 to compare observations with predictions. TC has extensive experience in successfully managing potential subsidence impacts on surface features, even when actual subsidence is substantially greater than the magnitudes that have been predicted above LW W3-W4. It is recommended that subsidence management plans be developed to manage potential impacts that could occur if greater than predicted subsidence occurs.

3.6.3. Comparison of measured and predicted tilt

The measured and predicted tilts along Bridge Street, Brundah Road, the Main Southern Railway and Remembrance Drive are represented by the slopes of the vertical subsidence profiles shown in Fig. 3.2 to Fig. 3.5. The maximum slopes of the measured profiles of vertical subsidence are reasonably similar to the maximum slopes of the predicted profiles for these monitoring lines. It can then therefore be inferred that the maximum measured and maximum predicted tilts are reasonably similar.

The maximum tilts generally occur adjacent to the maingate of the last extracted longwall in the series. Localised tilts greater than the predictions were measured at stream crossings, due to valley-related effects, and in locations of irregular ground movement.

A comparison between the maximum measured and maximum predicted total tilts for the monitoring lines at the mine, after the extraction of each of LW22 to LW31, is provided in Fig. 3.13. These data exclude the sections of monitoring lines that are located within the areas of increased subsidence, which is discussed separately in Section 3.7. The data also exclude the localised tilts due to valley-related upsidence or irregular ground movements.

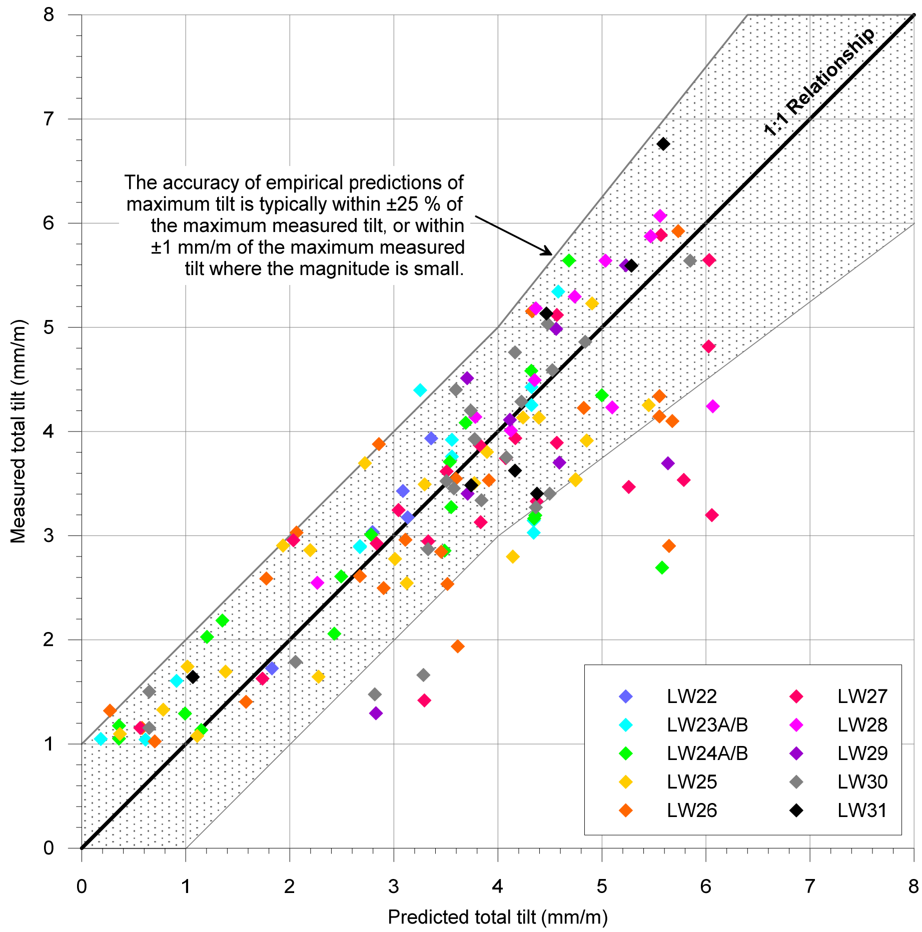

Fig. 3.13 Comparison of maximum measured and maximum predicted total tilts after each of LW22 to LW31

The maximum measured total tilts were typically between ±25 % or ±1 mm/m of the maximum predicted values, or less. It is considered therefore that the calibrated IPM provides reasonable predictions of tilt outside the areas of increased subsidence.

3.6.4. Comparison of measured and predicted curvature

It is more difficult making meaningful comparisons between the measured and predicted curvatures. The reason for this is that survey tolerance can be a large proportion of the measured curvatures and therefore this can result in very irregular profiles. The survey tolerance for relative vertical movements is typically around ±3 mm, which equates to a survey tolerance for curvature of approximately 0.05 km^{-1} over a 20 m bay length. This represents a reasonable proportion of the measured curvatures that are typically in the order of 0.05 km^{-1} to 0.15 km^{-1}.

In order to make meaningful comparisons, the measured curvatures can be derived from smoothed profiles of measured vertical subsidence. The smoothing removes the small deviations that result from survey tolerance, disturbed survey marks and other minor variabilities. The profiles of measured vertical subsidence can be smoothed using Savitzky-Golay or Loess algorithms. These methods remove the localised deviations or variabilities, but they do not reduce the overall maxima. This is illustrated along Brundah Road in Fig. 3.14.

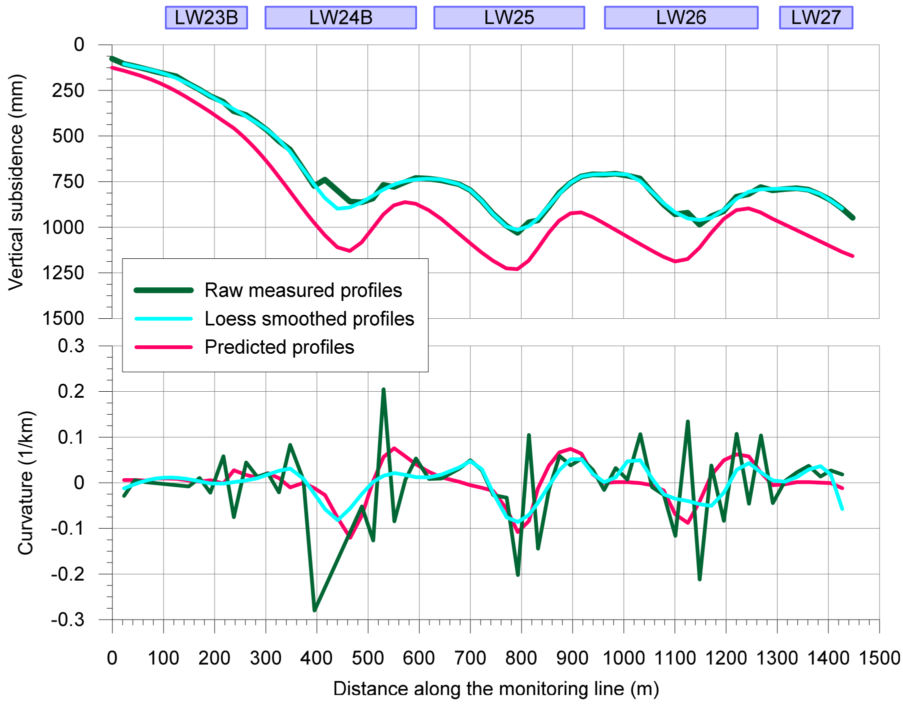

Fig. 3.14 Measured and predicted vertical subsidence and curvature along Brundah Road

The smoothed profile of vertical subsidence, obtained using the Loess algorithm, reasonably matches the raw measured profile of vertical subsidence, but the small deviations have been removed. The smoothed profile has not reduced the maximum values or increased the minimum values.

The profile of raw measured curvature is very irregular due to the small irregularities in the measured vertical subsidence profile resulting from survey tolerance, disturbed survey marks and localised movements. The smoothed profile of curvature derived from the smoothed profile of vertical subsidence more clearly shows the locations of overall hogging curvature and overall sagging curvature, rather than the localised curvatures at each mark.

The profile of predicted curvature reasonably matches the smoothed profile of curvature. The areas of hogging curvature and the areas of sagging curvature reasonably coincide. The maximum predicted curvatures are also similar to the maximum values based on the profile of smoothed curvature. Similar results are obtained for the other monitoring lines.

It is considered therefore that the calibrated IPM provides reasonable predictions of the overall or global curvature along the monitoring lines. Localised irregularities can exceed the predicted values due to survey tolerance, disturbed survey marks and irregular ground movements.

3.7. Areas of increased subsidence compared to predictions

The extraction of longwalls at the mine has generally resulted in mine subsidence movements that were typical of those observed above other collieries in the Southern Coalfield of NSW at comparable depths of cover.

However, several locations where greater subsidence was observed compared to the predicted values were identified:

- over LW24A and the southern parts of LW25 to LW27, and
- over LW8 and along the 800-Line, and over LW13 and along the 900-Line.

It is not a coincidence that there are many faults and dykes at these locations, that they are near the Nepean Fault and they are near major river valleys or gorges. The extents of these zones of increased subsidence are discussed in more detail below.

3.7.1. Zone of increased subsidence near Nepean Fault and the Bargo River Gorge

During the mining of LW24A at Tahmoor Mine, substantially increased subsidence was observed and further increases in observed subsidence compared to the predicted subsidence was observed during LW25.

These increased levels of subsidence were a very unusual event for the Southern Coalfield and immediate investigations were undertaken to identify why it occurred. The conclusions of these studies were published in 2011 in a paper by W. Gale and I. Sheppard, which advised that the increased levels of subsidence were likely to be associated with the proximity of these areas to the Nepean Fault and the Bargo River Gorge and a recognition of the impact of a weathered zone of joints and bedding planes above the water table, which reduced the spanning capacity of the strata below this highly weathered section. This later recognition was determined after extensive computer modelling of factors that may have caused the increased subsidence.

Further subsidence monitoring has occurred over LW26 and LW27 within and around this zone of increased subsidence since 2011. A summary of the monitoring results over LW24A to LW31 is shown in Table 3.1. It can be noted that the zone of increased subsidence extends over LW24A to LW27, though the extent of the increase in subsidence has reduced in magnitude as each longwall was extracted as shown in the table below. It can also be noted that the maximum observed subsidence only slightly exceeded the maximum predicted for LW28 to LW32, with the difference being within the accuracy of the subsidence prediction methods. Increased subsidence was measured over the commencing end of Longwall 32.

Table 3.1 Maximum measured and maximum predicted incremental and total vertical subsidence within the zones of increased subsidence above LW24A to LW32

Longwall	Assumed average seam thickness extracted in zone (m)	Maximum measured incremental vertical subsidence and proportion of seam thickness (mm)	Maximum predicted incremental vertical subsidence and proportion of seam thickness (mm)	Relative increase in incremental vertical subsidence	Maximum measured total vertical subsidence and proportion of seam thickness (mm)	Maximum predicted total vertical subsidence and proportion of seam thickness (mm)	Relative increase in total vertical subsidence
LW24A	2.20	1169 (53%)	500 (23%)	2.34	1262 (57%)	800 (36%)	1.58
LW25	2.20	1216 (55%)	610 (28%)	2.00	1361 (62%)	900 (41%)	1.51
LW26	2.25	893 (40%)	730 (32%)	1.22	1050 (47%)	900 (40%)	1.17
LW27	2.15	823 (38%)	710 (33%)	1.16	896 (42%)	800 (37%)	1.12
LW28	2.10	755 (36%)	710 (34%)	1.06	827 (39%)	785 (37%)	1.05
LW29	2.10	737 (35%)	700 (33%)	1.05	769 (37%)	725 (35%)	1.06
LW30	2.10	765 (36%)	700 (33%)	1.09	783 (37%)	725 (35%)	1.08
LW31	2.10	776 (37%)	700 (33%)	1.11	811 (39%)	725 (35%)	1.12
LW32	2.10	975 (46%)	700 (33%)	1.39	-	-	-

Maximum total subsidence over Longwall 32 has not been reported in Table 3.1 because the peg above the centreline of Longwall 32 was installed after the completion of Longwall 31 and, therefore, only measured the development of incremental subsidence during the mining of Longwall 32.

Further details of the observed zones of increased and normal subsidence over LW24A to LW27 are shown in longitudinal cross sections along LW24A to LW32 as Fig. 3.15 to Fig. 3.23 and a discussion on these details is presented below.

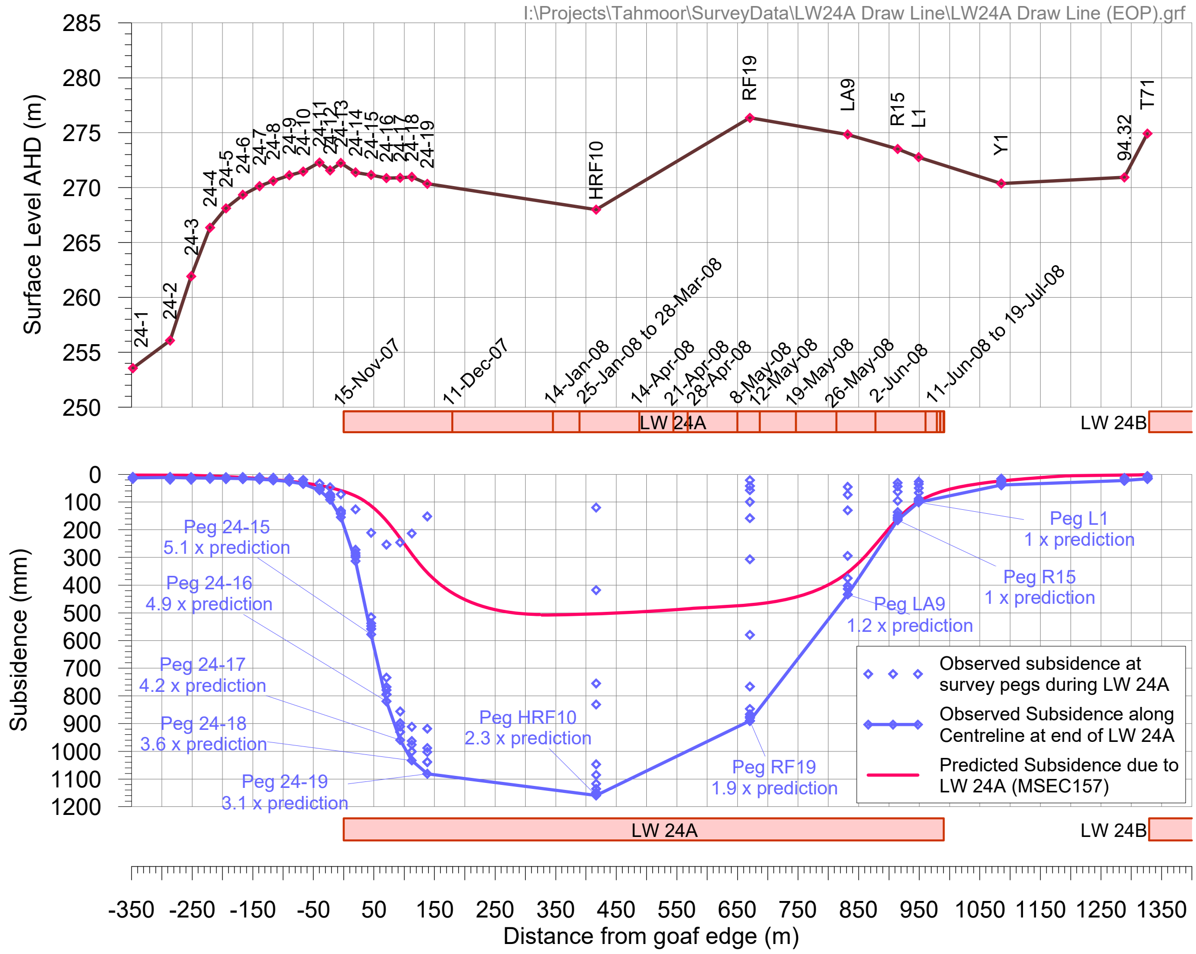

Fig. 3.15 Measured incremental vertical subsidence along the centreline of LW24A

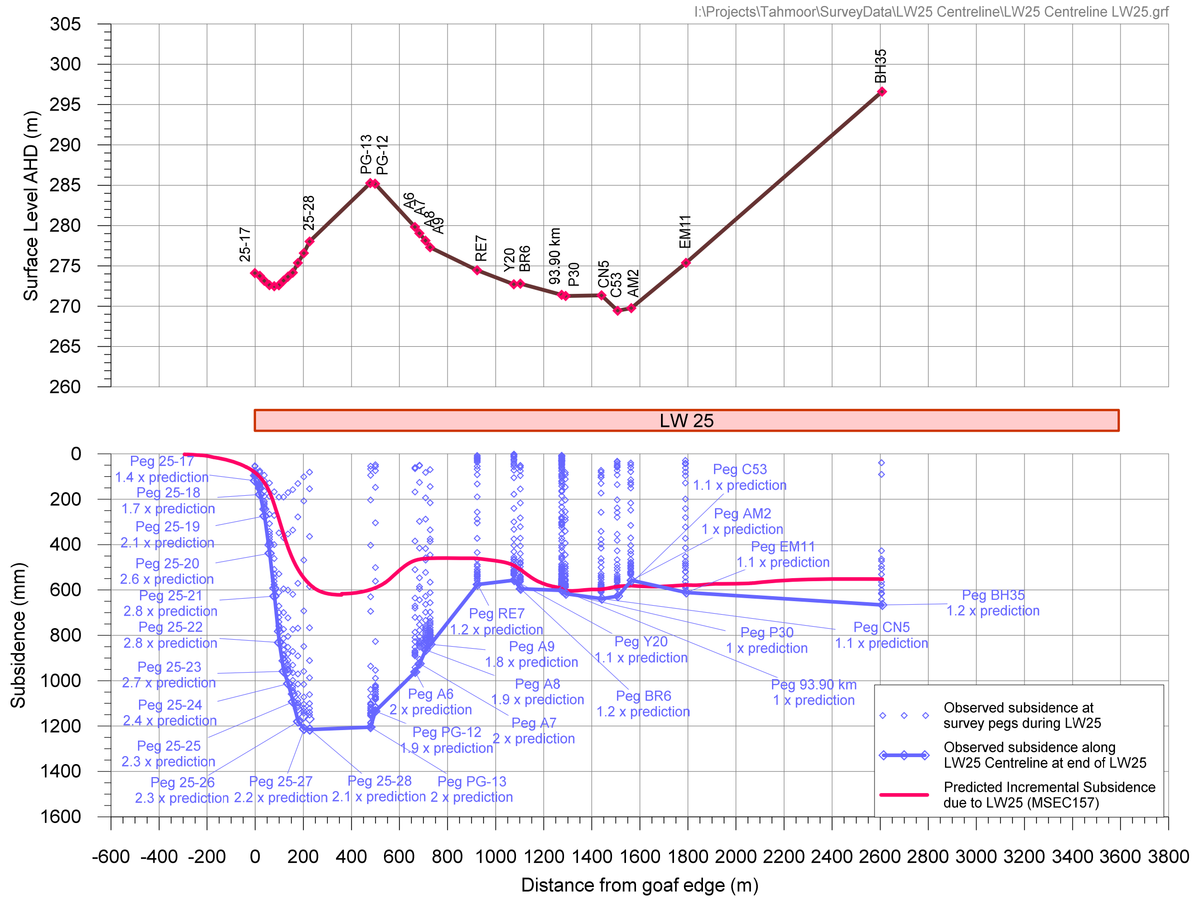

Fig. 3.16 Measured incremental vertical subsidence along the centreline of LW25

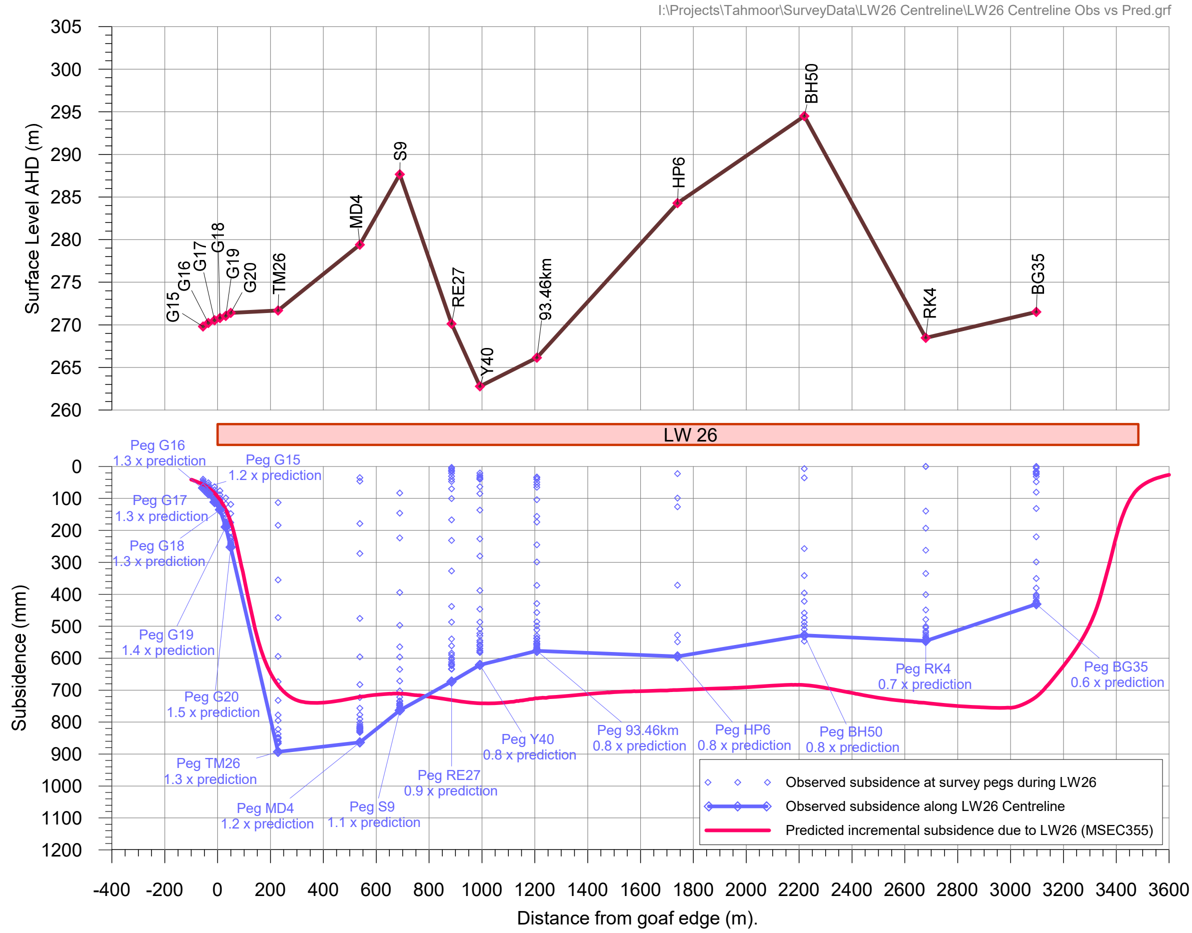

Fig. 3.17 Measured incremental vertical subsidence along the centreline of LW26

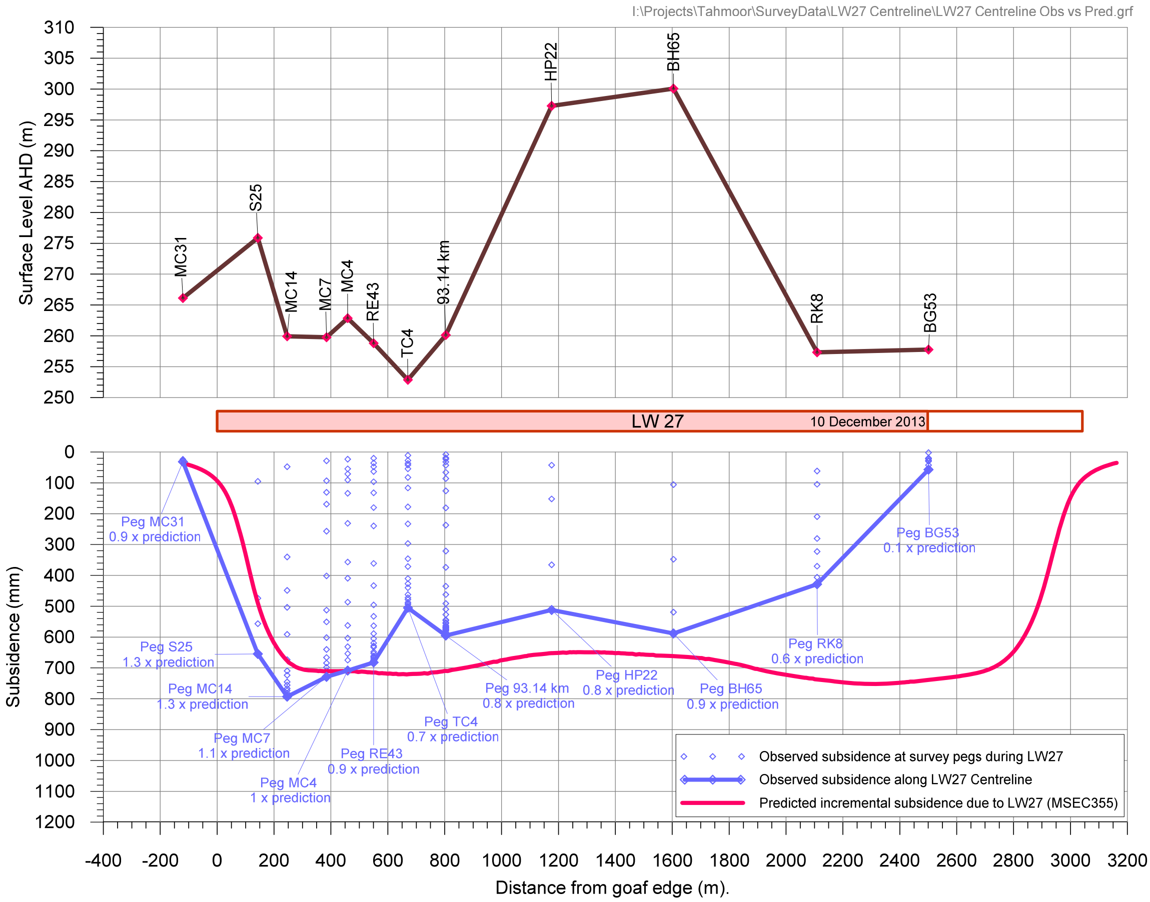

Fig. 3.18 Measured incremental vertical subsidence along the centreline of LW27

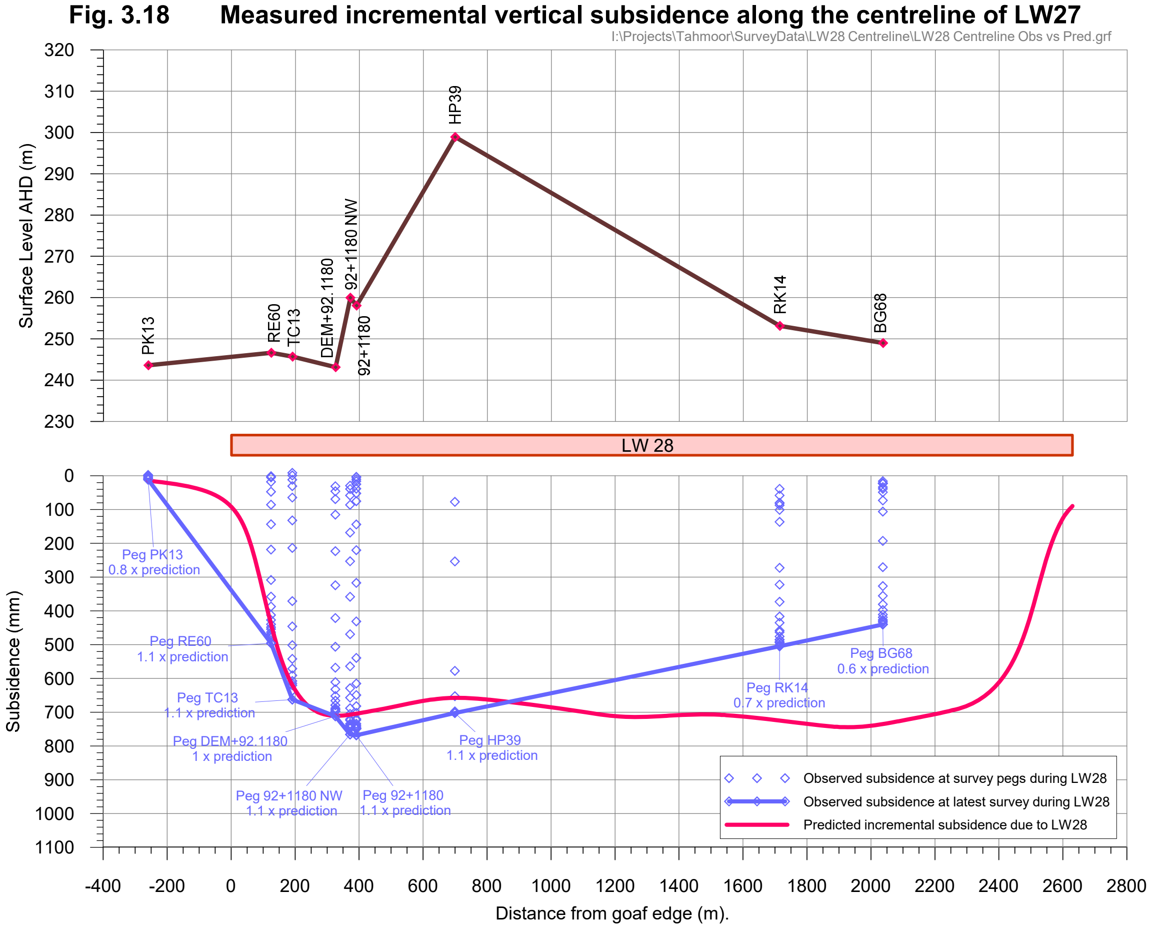

Fig. 3.19 Measured incremental vertical subsidence along the centreline of LW28

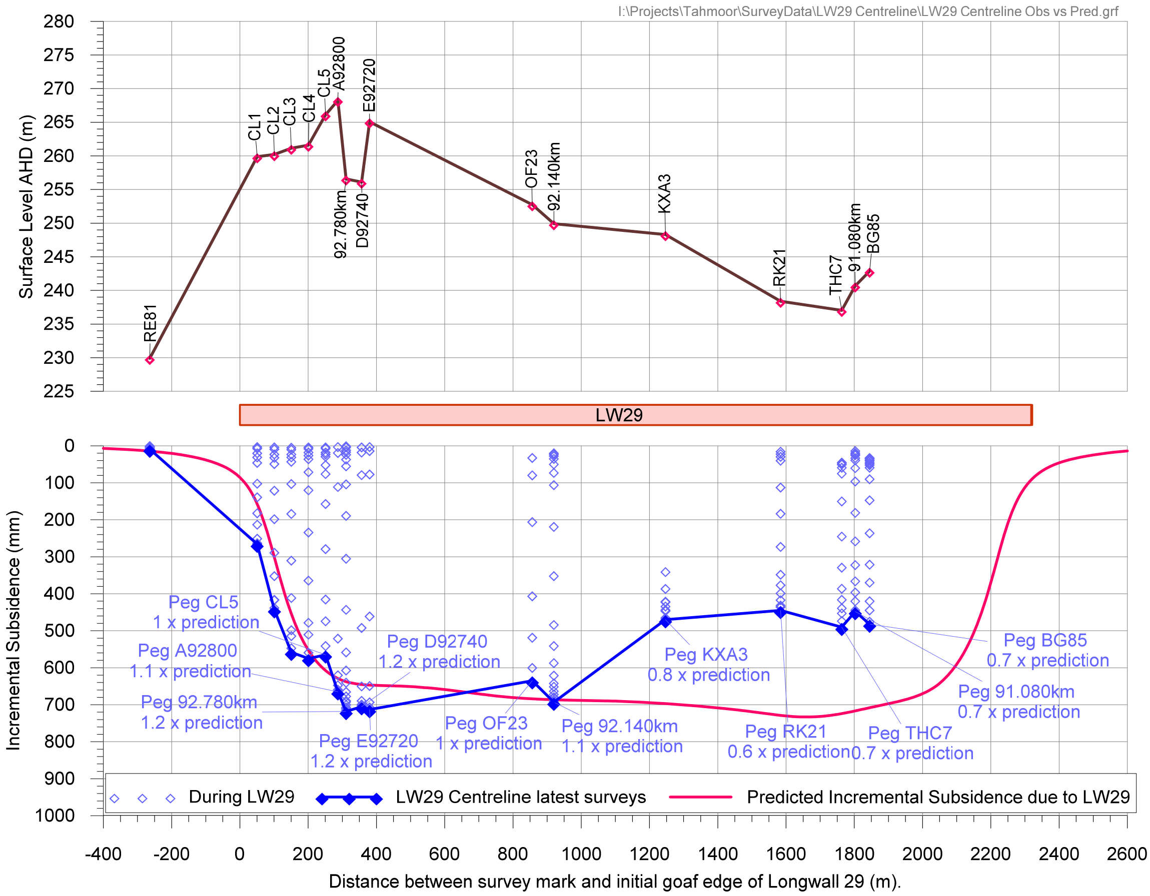

Fig. 3.20 Measured incremental vertical subsidence along the centreline of LW29

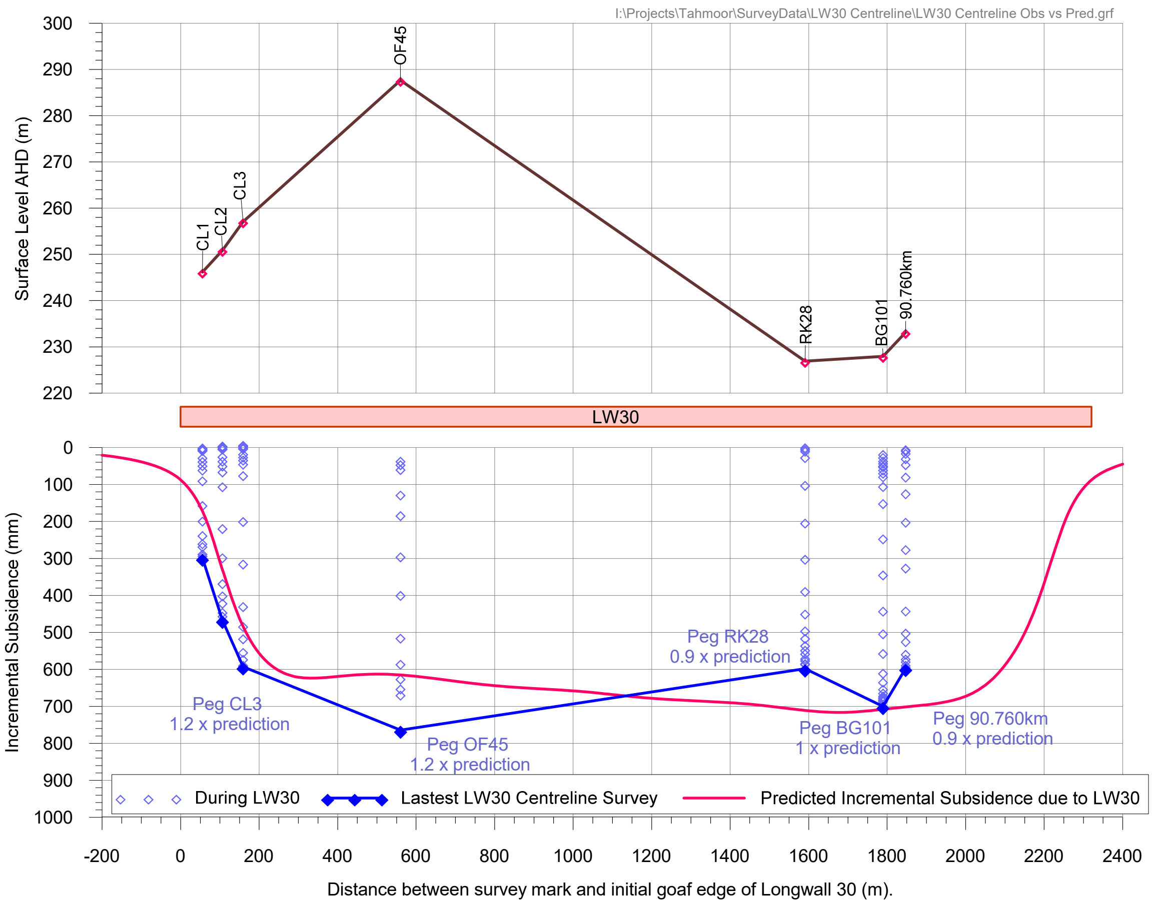

Fig. 3.21 Measured incremental vertical subsidence along the centreline of LW30

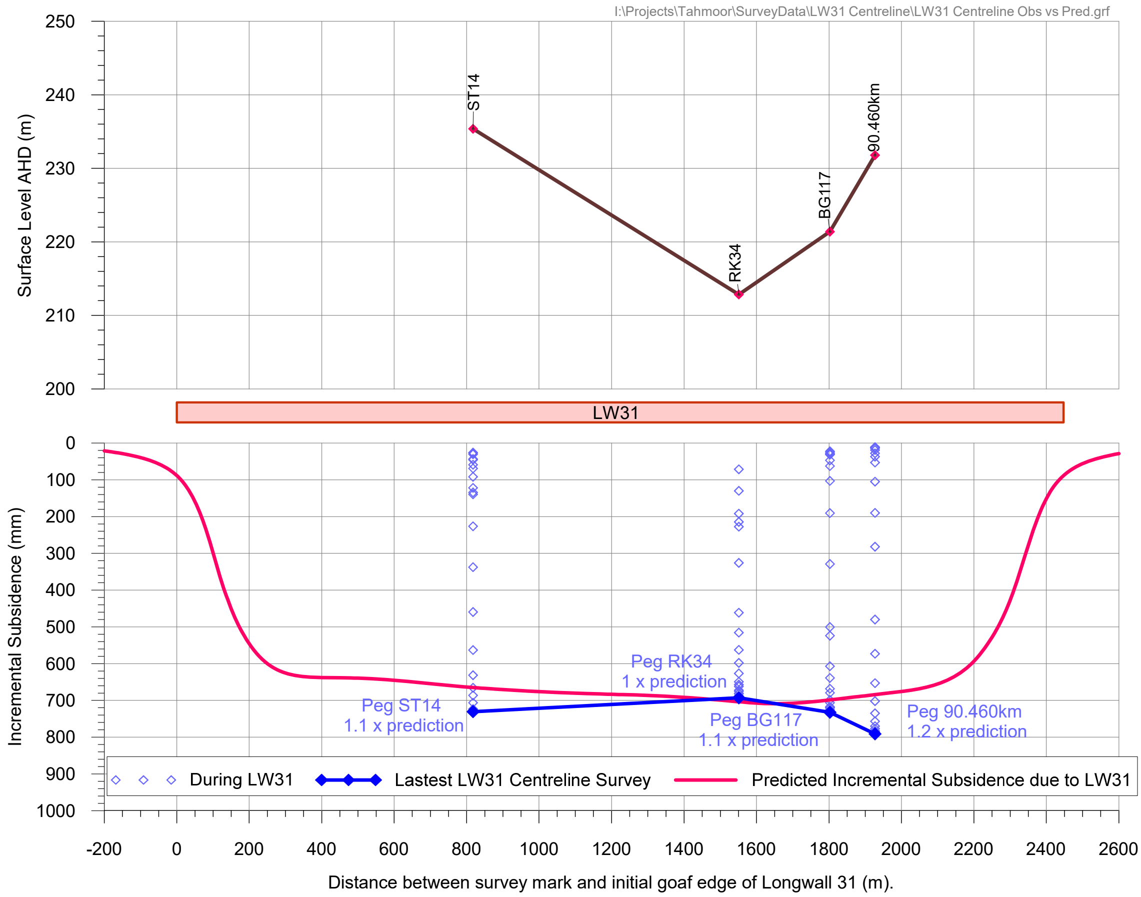

Fig. 3.22 Measured incremental vertical subsidence along the centreline of LW31

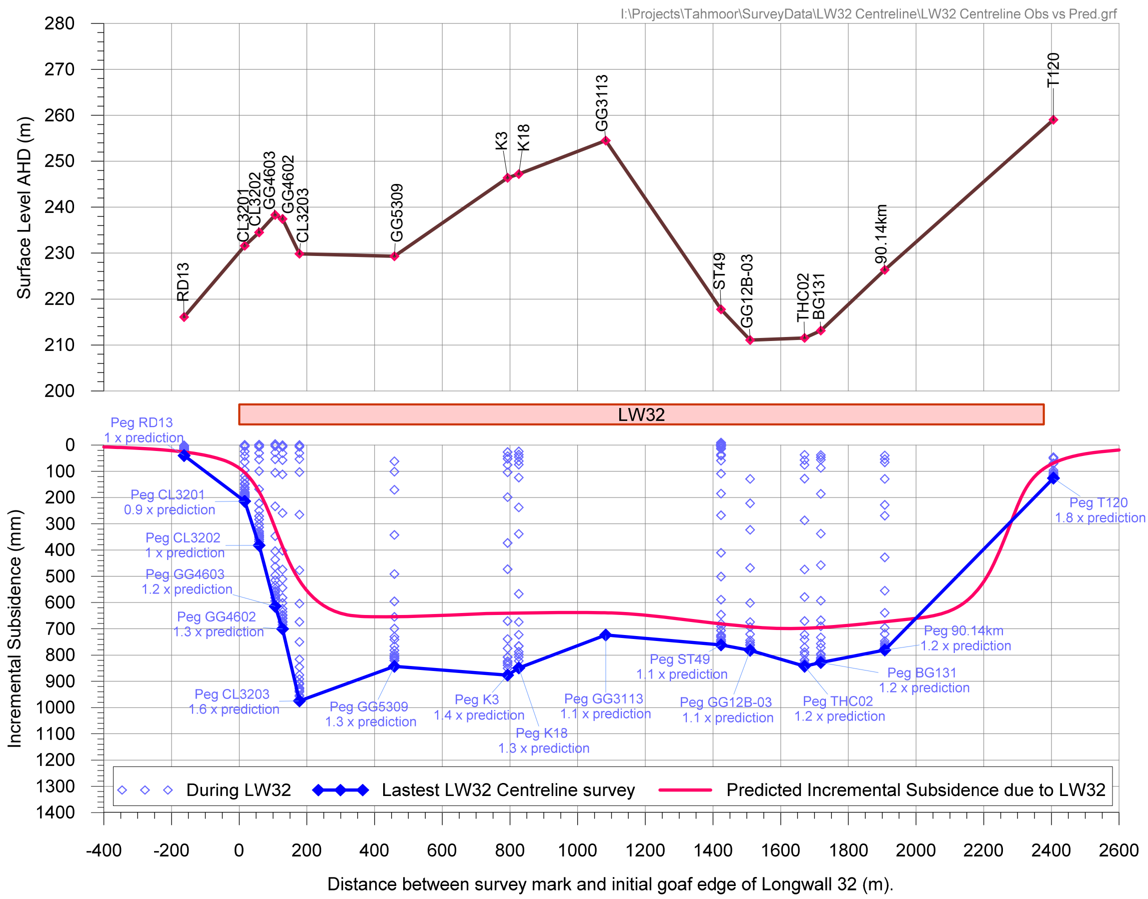

Fig. 3.23 Measured incremental vertical subsidence along the centreline of LW32

Observed increased subsidence during the mining of LW24A

- Fig. 3.15 shows the surface levels, the locations of survey pegs along the centre of LW24A and the observed incremental subsidence profiles at these survey pegs. It can be seen that the greatest increase in observed subsidence was in an area above the southern half of LW24A that is closer to the Bargo River Gorge, closer to the Nepean Fault Zone and within 100 metres of a smaller fault zone that, like several other parallel faults, runs off the Nepean Fault in an en-echelon style and within 140 metres of previous total extraction workings in the 204 panel. The extent of the increased subsidence then gradually reduced in magnitude towards the northern half of the longwall, which was directly beneath the urban area of Tahmoor.
- It can be seen from Fig. 3.15 that the observed subsidence was similar to the predicted levels near Peg R15 on Remembrance Drive. Survey pegs RF19 and LA9 were located within a transition zone where subsidence gradually reduced from areas of maximum increased subsidence to areas of normal subsidence.

Observed increased subsidence during the mining of LW25

- Fig. 3.16 shows the observed incremental subsidence at survey pegs located along the centreline of LW25. It can be seen that the greatest increase in observed subsidence was in an area above the southern half of LW25 that is closer to the Bargo River Gorge and closer to the Nepean Fault Zone.
- The observed incremental subsidence is similar to but only slightly more than was predicted at Peg RE7 and is similar to the prediction at Peg Y20 and at all pegs located further along the panel. Survey pegs A6, A7, A8 and A9 are located within a transition zone where subsidence has gradually reduced from areas of maximum increased subsidence to areas of normal subsidence.

Observed increased subsidence during the mining of LW26

- Fig. 3.17 shows the observed incremental subsidence at survey pegs located along the centreline of LW26. Increased incremental subsidence was observed during the first stages of mining LW26, but at a reduced magnitude compared to the incremental subsidence observed above LW24A and LW25.
- Observed subsidence reduced along the panel until Peg Y40 on York Street, where it was less than prediction. Survey pegs S9 and RE27 are located within a transition zone where subsidence has gradually reduced from areas of maximum increased subsidence between Pegs TM26 and MD4 to areas of normal subsidence at Peg Y40 and beyond.

Observed increased subsidence during the mining of LW27

- Fig. 3.18 shows the observed incremental subsidence at survey pegs located along the centreline of LW27. Increased incremental subsidence was observed during the first stages of mining LW27, but at a reduced magnitude compared to the incremental subsidence observed above LW24A, LW25 and LW26.
- As shown in Fig. 3.18 the observed subsidence reduced along the panel until Peg 93.140 km on the Main Southern Railway. Survey pegs MC4, MC7, RE43 and TC4 are located within a transition zone where subsidence has gradually reduced from areas of maximum increased subsidence between Pegs MC14 and 93.140 km to areas of normal subsidence along the Railway and beyond.

Observed subsidence during the mining of LW28

- Fig. 3.19 shows the observed incremental subsidence at survey pegs located along the centreline of LW28. It can be seen that observed subsidence has returned to normal levels, and within 6 % of subsidence predictions.
- As shown in Fig. 3.19, there is a reasonable correlation between the observed and predicted subsidence profile along the centreline of LW28.

Observed subsidence during the mining of LW29 to LW31

- Tahmoor Coal has completed extraction of LW29 to LW31.
- The experiences observed during this period of time have found that maximum subsidence has continued at a similar level as observed during the mining of LW28.

Observed subsidence during the mining of LW32

- Tahmoor Coal has completed extraction of LW32.
- The experiences observed during this period of time have found that maximum subsidence increased above LW32, close to LW26 levels.
- Fig. 3.23 shows the observed incremental subsidence at survey pegs located along the centreline of Longwall 32. Increased incremental subsidence was observed above the commencing end of

the panel and then reduced slightly towards the finishing end. Subsidence along the centreline is at the higher end of the previously observed range.

3.7.2. Analysis and commentary on the zone of increased subsidence over LW24A to LW27 and LW32

The cause for the increased subsidence was investigated during the extraction of LW25 by SCT on behalf of Tahmoor Mine as discussed in the previously referenced paper by Gale and Sheppard (2011).

These investigations concluded that the areas of increased subsidence were consistent with localised weathering of joint and bedding planes above a depressed water table adjacent to an incised gorge. This conclusion was further confirmed in further recent report by Gale W. of SCT (2013a), who confirms that:

> "*Longwall panels 24A and 25 both show increased maximum subsidence to approximately 1.0-1.2m, where predicted subsidence was in the order of 0.5 - 0.8m. In the study by Gale and Sheppard, (2011), it became apparent that the increased subsidence is likely to be due to reduction in joint friction and stiffness due to the weathering process in the strata above the water table where the water table is considerably lower due to the Bargo Gorge. The intact rock properties were not changed, only the properties of the joints were altered*."

There have been many locations where monitoring near faults has revealed little increase of observed subsidence and there are many locations where monitoring near deep gorges and valleys has revealed little increase in observed subsidence. In summary, it appears that the location of the zones of increased subsidence is linked to both the:

- close proximity and the alignment of the Nepean Fault, which is within 1,000 metres of these zones; and
- close proximity to the Bargo River Gorge, which is approximately 100 metres deep, within 700 metres of these zones. The presence of the Bargo River Gorge has permitted groundwater flows to weather the joint and bedding plane properties of the surrounding strata.

In light of the above conclusions and observations, three areas or zones have been identified from the observed subsidence monitoring above the extracted LW24A to LW27 at the mine:

- Maximum increased subsidence zone – where the observed vertical subsidence is substantially greater than the predicted subsidence;
- Transition zone – where the subsidence behaviour appears to be transitioned between areas of maximum increased subsidence and normal subsidence; and
- Normal subsidence zone – where the observed vertical subsidence is within the normal range and correlates well with predictions.

The locations of the three zones were plotted on a plan using the surveyed pegs that were identified along the centrelines above LW24A to LW31 as a guide. This plan, Fig. 3.24, shows that the transition zone is roughly consistent in width above LW24A, LW25 and LW26 and possibly slightly narrower above LW27. The orientation of the transition zone is also roughly parallel to the Nepean Fault and the magnitude of the increased subsidence above LW26 and LW27 is reduced compared to LW24A and LW25. There was little to no increased subsidence identified above LW28 to LW31.

It can be seen in Fig. 3.24, that as the alignment of the Nepean Fault moved further away from the Bargo River gorge and above LW26 and LW27, the magnitude of increased subsidence reduced, indicating that the cause of the movements is clearly linked to the proximity of the Bargo River. This observation confirms the findings of Gale and Sheppard (2011) that the increased subsidence is linked to localised weathering of joint and bedding planes above a depressed water table adjacent to the incised gorge of the Bargo River and the presence of the major fault.

The interpolated location of the Nepean Fault within the Tahmoor North lease has recently been updated for Tahmoor Mine by SCT (2018). The revised mapping describes the Nepean Fault as comprising a series of en echelon faults, rather than one continuous geological structure.

The change in understanding of the Nepean Fault is significant because the finding could provide an alternative explanation for the observed return to normal subsidence above LW28 to LW30, as the fault linked to increased subsidence above LW24A to LW27 terminated beyond LW29.

Prior to the mining of LW32, it was therefore considered possible that subsidence might return to higher than normal levels during the mining of LW32, even though observed subsidence above previously extracted LW30 and LW31 was close to normal levels.

Observations during the mining of LW32 found that increased subsidence developed above the commencing end of the longwall at levels similar to those observed above LW26. It was also observed that the magnitude of subsidence reduced along the panel as the longwall face progressed.

LW W1-W2 are located further away from the Nepean Fault complex than LWs 24A to 32. The potential for increased subsidence to occur was therefore considered to be low. Observations during the mining of LW W1 have measured substantially less subsidence than predicted and early observations during the mining of LW W1 have measured subsidence less than predicted.

It is possible, however, that increased subsidence could develop above LW W3 and LW W4 as these longwalls are closer to the Nepean Fault. A similar assessment has been provided by SCT (2021).

It is therefore recommended that monitoring be conducted during the early stages of extraction of LW W3-W4 to compare observations with predictions. TC has extensive experience in successfully managing potential subsidence impacts on surface features, even when actual subsidence is substantially greater than the magnitudes that have been predicted above single panel LW W3-W4. It is recommended that subsidence management plans be developed to manage potential impacts that could occur if greater than predicted subsidence occurs.

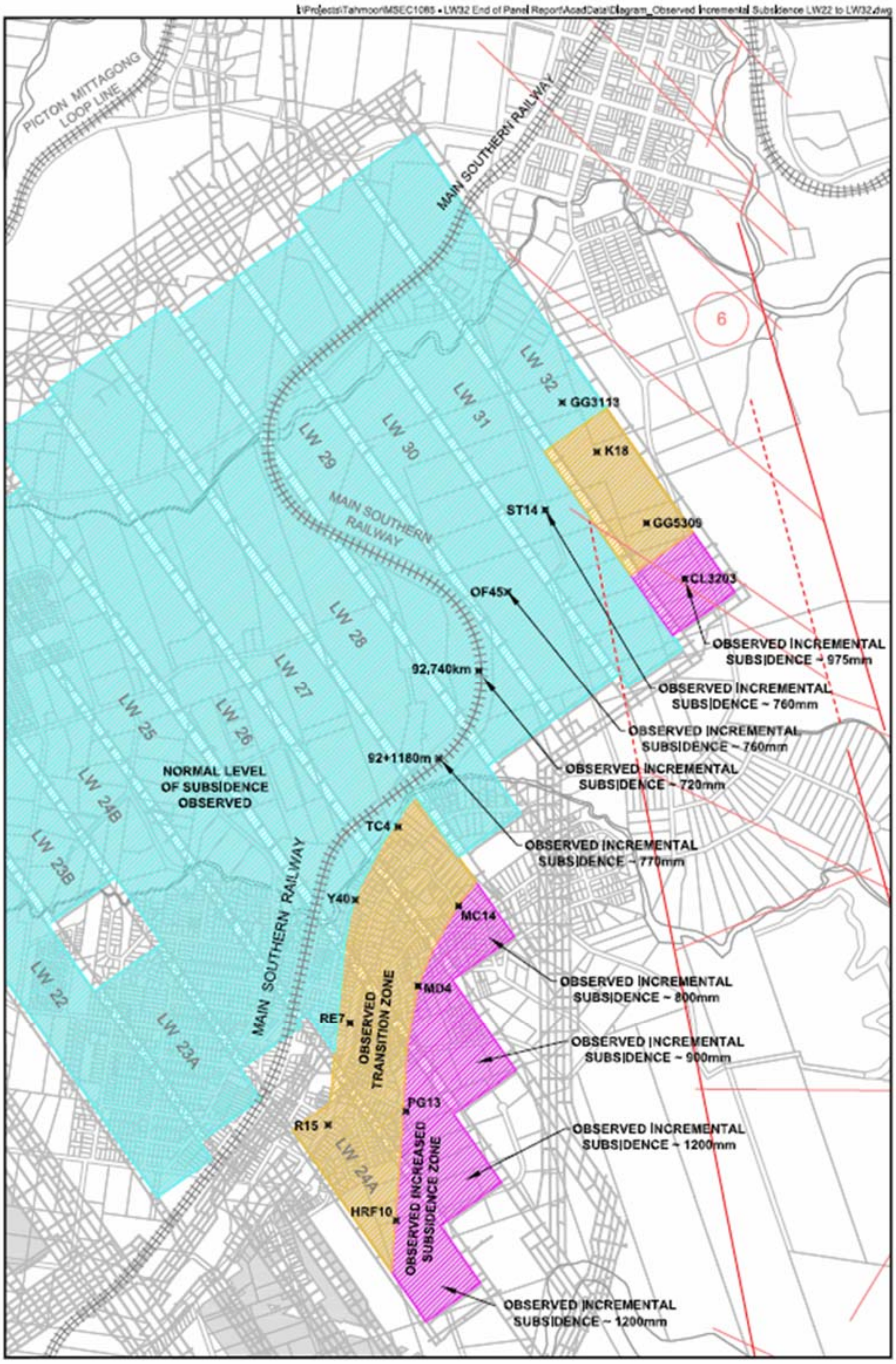

Fig. 3.24 Zones of increased subsidence over LW22 to LW32

3.8. Experience of subsidence movements between previously extracted longwalls and Nepean Fault at Tahmoor Mine

Tahmoor Coal has surveyed subsidence along many streets during the mining of previous Longwalls 24A to 32. Some of these monitoring lines are located over solid, unmined coal, between the extracted longwalls and the Nepean Fault.

The survey lines cross first order faults to the side of Longwall 32 within the Picton Water Recycling Plant. The surveys also cross mapped second order conjugate faults including Stilton Dam Line, Remembrance Drive East Line and the Tahmoor and Picton Rising Mains.

A study has been completed to ascertain whether irregular subsidence have occurred along the survey lines.

The locations of the survey lines relative to the Nepean Fault and associated geological structures is shown in Fig. 3.25.

The monitoring lines examined included:

- LW24 Draw Line, due to the extraction of LWs 24A and 25;
- LW25-XS1 Line, due to the extraction of LWs 25 and 26;
- Greenacre Drive, due to the extraction of LWs 25 and 26;
- Tahmoor Road Line, due to the extraction of LWs 25 to 27;
- Myrtle Creek Avenue, due to the extraction of LWs 25 to 28;
- Moorland Road, due to the extraction of LWs 25 to 28;
- River Road South, due to the extraction of LWs 27 and 28;
- Park Avenue, due to the extraction of LWs 25 to 28;
- River Rd, due to the extraction of LWs 26 to 28;
- Stilton Dam Northern Line, due to the extraction of LWs 29 to 31;
- Remembrance Drive East, due to the extraction of LW31 and 32;
- Nepean Fault Line 1, due to the extraction of LW32 (refer Fig. 3.26);
- Nepean Fault Line 2, due to the extraction of LW32 (refer Fig. 3.27);
- Nepean Fault Line 3, due to the extraction of LW32 (refer Fig. 3.28);
- Picton Water Recycling Plant and Picton Rising Main, due to the extraction of LW32;
- Picton High School cross lines, due to the extraction of LW32;
- Coachwood Crescent, due to the extraction of LW32; and
- Wonga Road, due to the extraction of LW32.

The study found no increased subsidence, tilt or strains were measured along the survey lines that were located over unmined, solid coal areas between the extracted longwalls and the Nepean Fault.

A histogram of the maximum observed tensile and compressive strains measured along the selected survey lines for survey bays located over solid coal between previously extracted longwalls at Tahmoor Mine and the Nepean Fault is provided in Appendix A is provided in Fig. 3.29.

It can be seen from Fig. 3.29 that observed ground strains have been relative minor.

Three survey lines within the Picton Water Recycling Plant were installed to measure subsidence, tilt and strain across the Nepean Fault. As shown in Fig. 3.26 to Fig. 3.28, observed differential movements were relatively minor. No impacts were observed to the Plant structures.

The experiences observed to date have shown no significant differential movements across the Nepean Fault complex. While the possibility for significant differential movement across the Nepean Fault complex to the side of proposed LW W3-W4 cannot be ruled out, the likelihood is considered to be very low based on the experiences observed to date. This is supported by the assessment provided by SCT (2021).

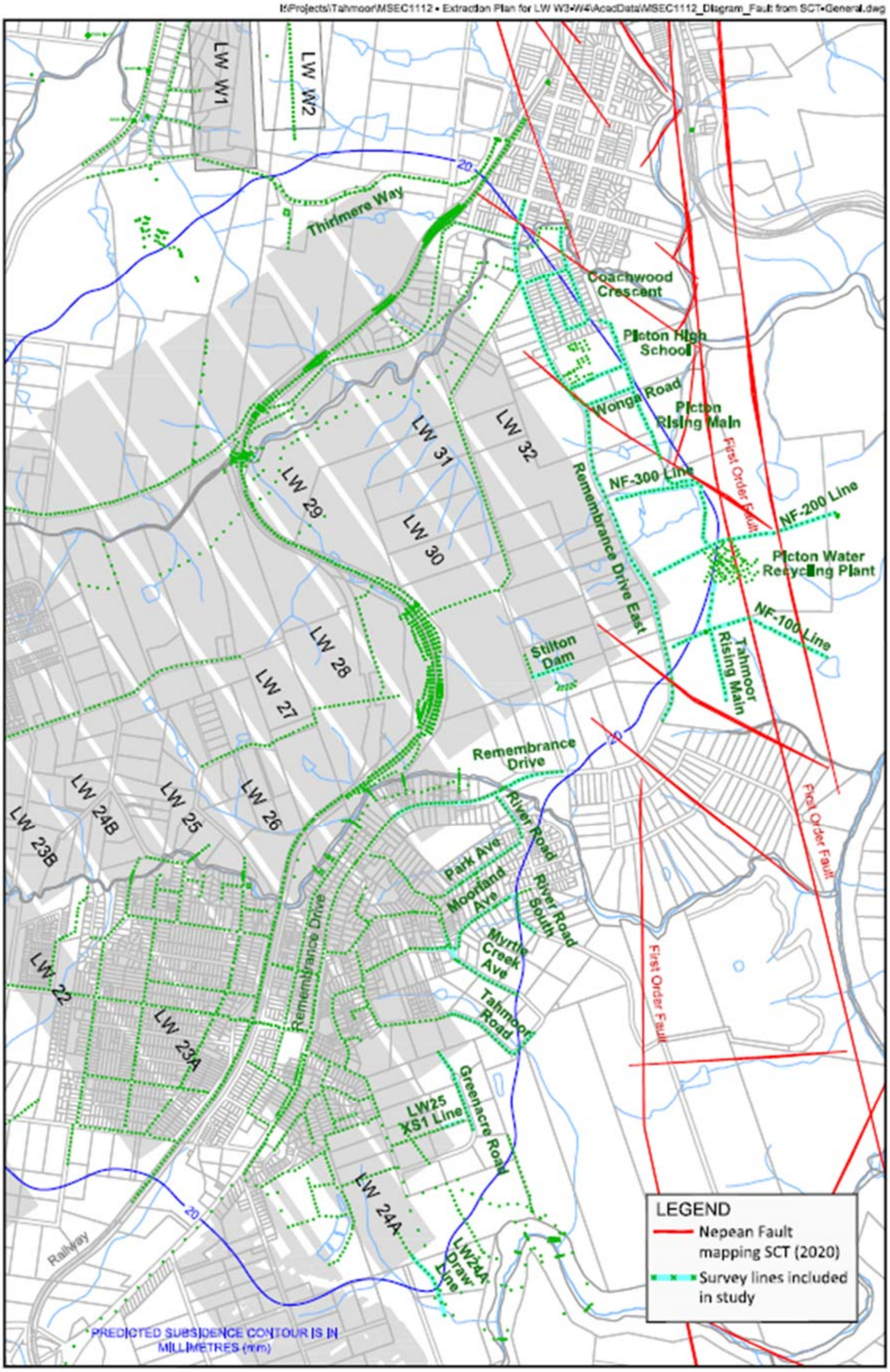

Fig. 3.25 Locations of ground survey lines in relation to the mapped geological structures by SCT (2018a and 2020) and streams

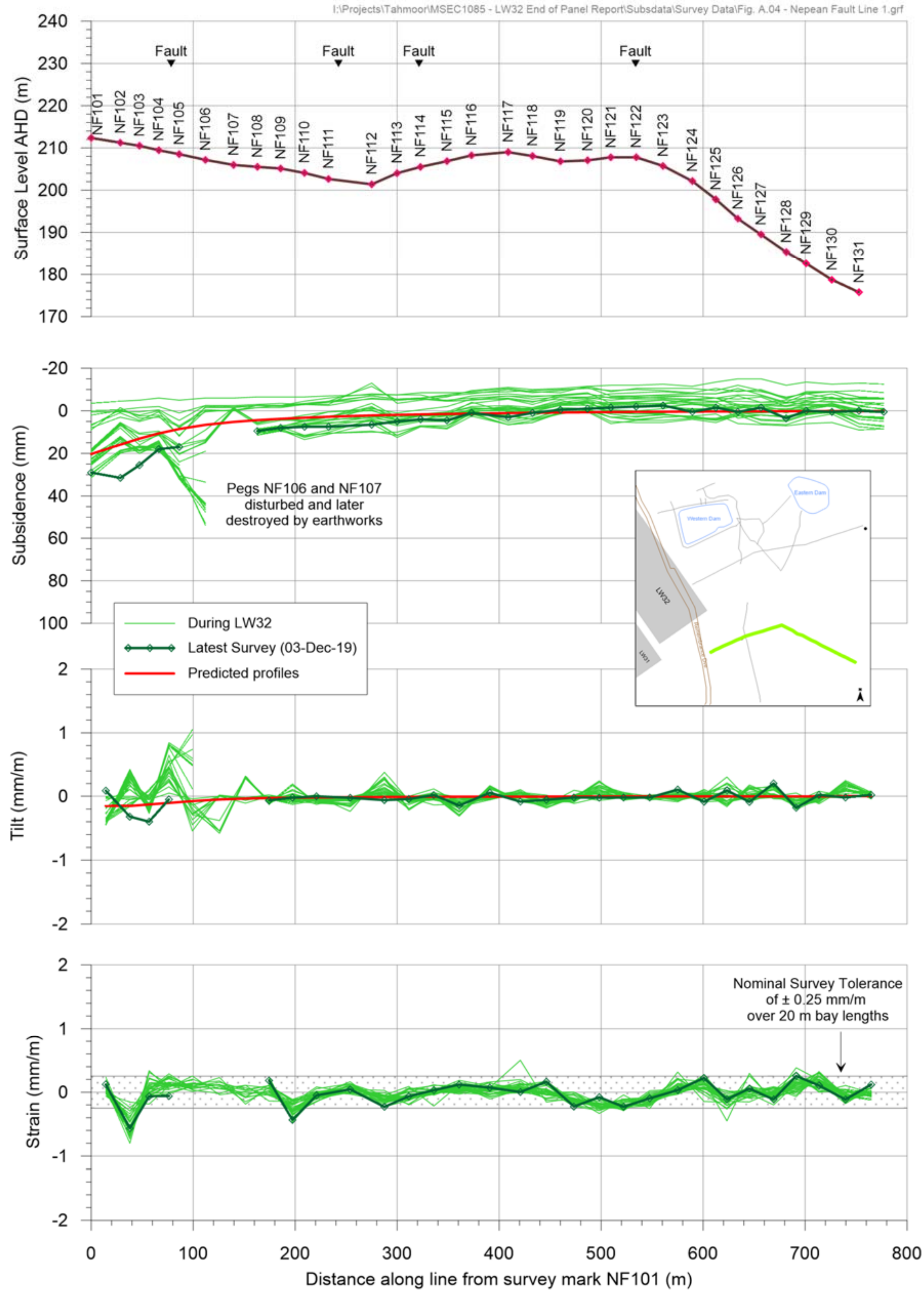

Fig. 3.26 Observed subsidence along the Nepean Fault Line 1 during the mining of LW32

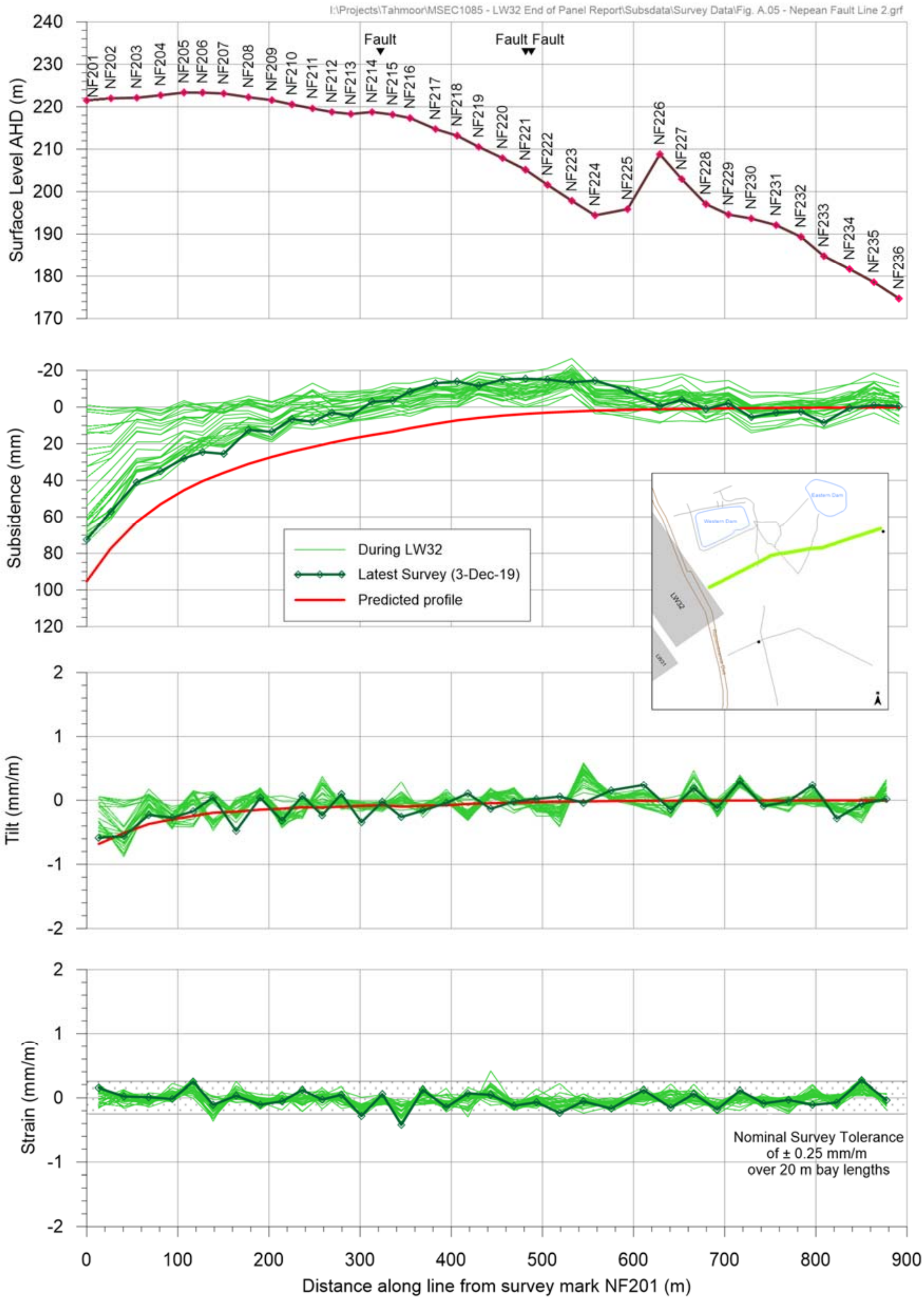

Fig. 3.27 Observed subsidence along the Nepean Fault Line 2 during the mining of LW32

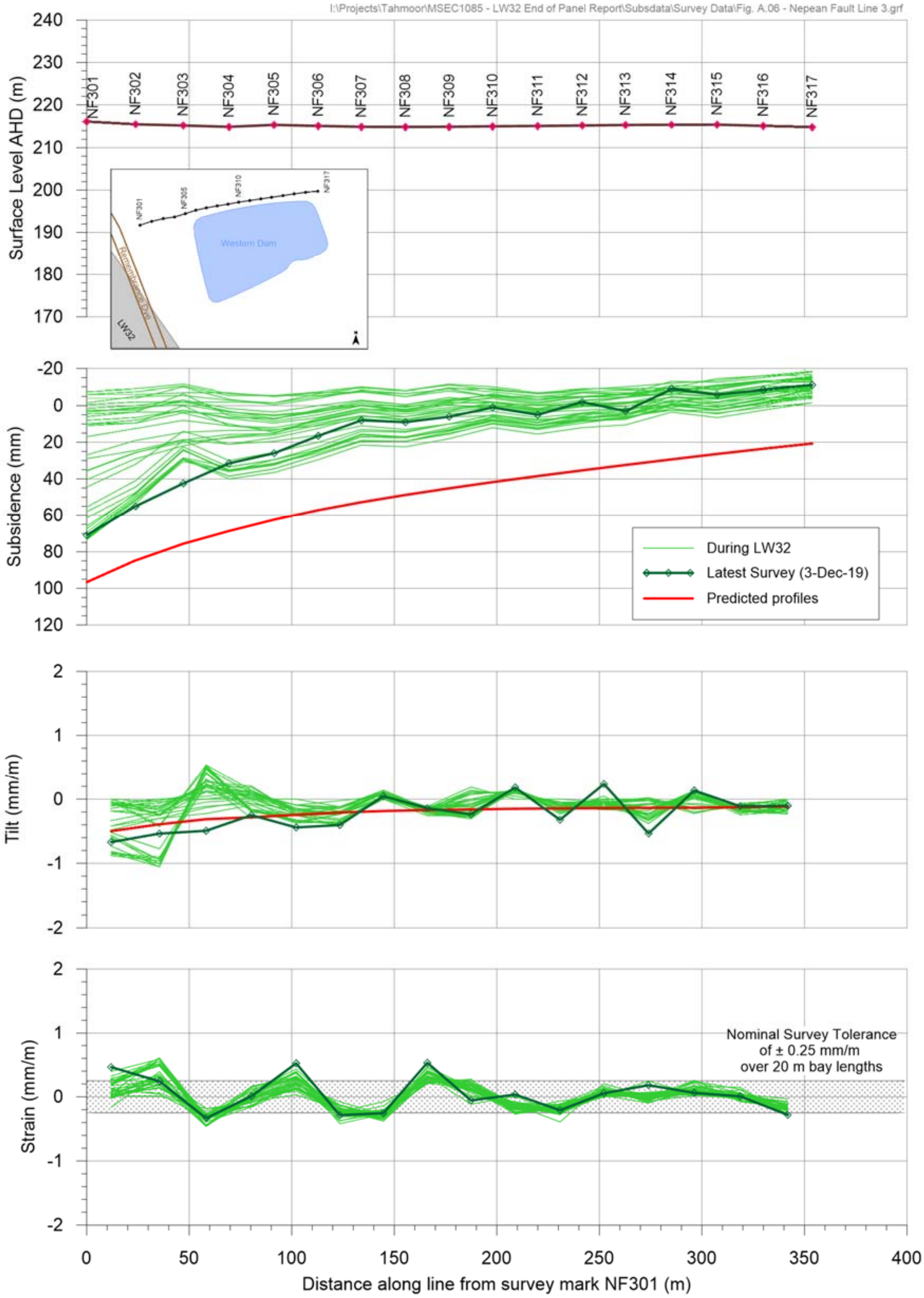

Fig. 3.28 Observed subsidence along the Nepean Fault Line 3 during the mining of LW32

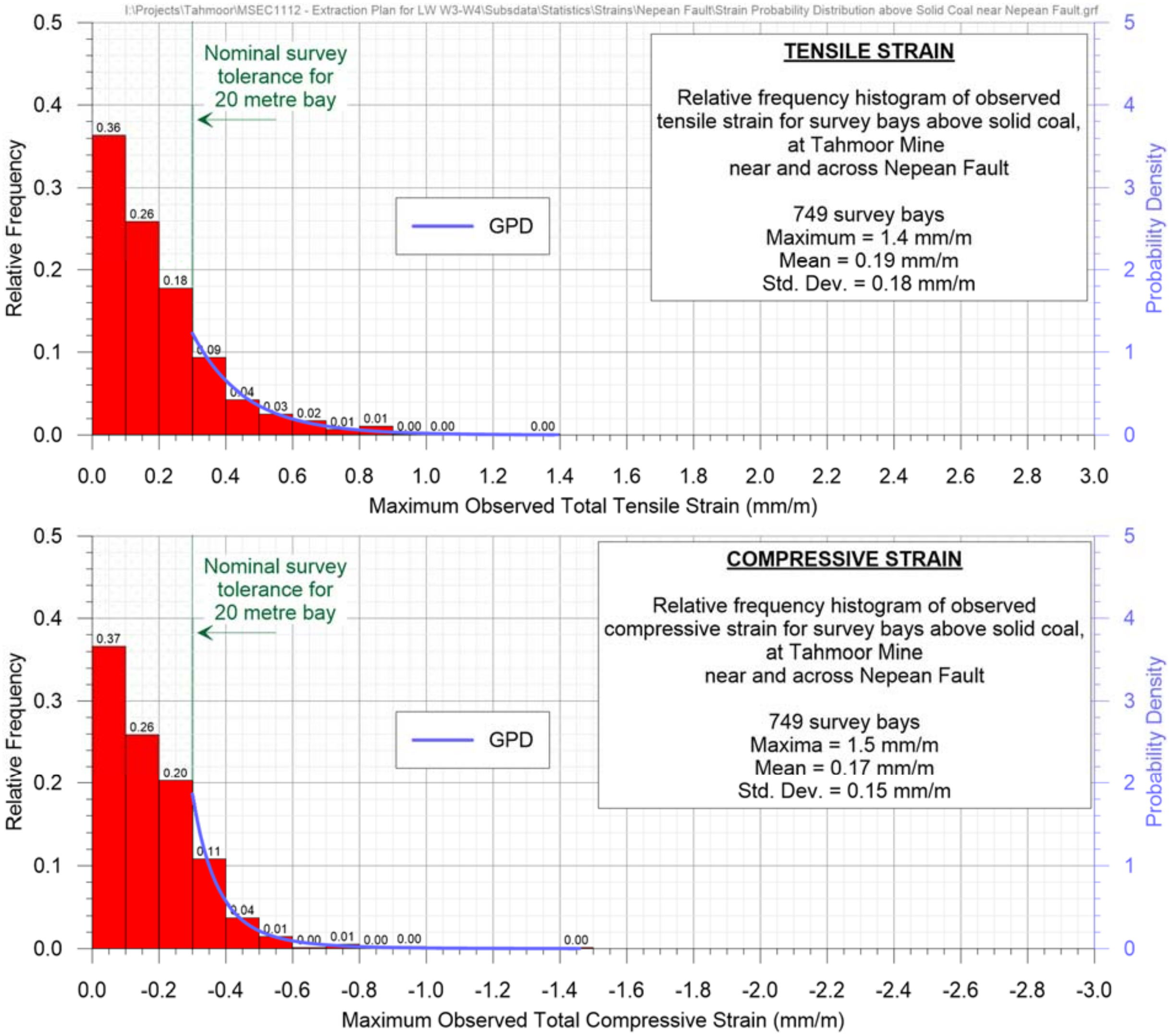

Fig. 3.29 Distributions of the Measured Maximum Tensile and Compressive Strains for Bays Located over Solid Coal at Tahmoor Mine near and across the Nepean Fault

3.9. Numerical model

A numerical model has been developed for the mine using Universal Distinct Element Code (UDEC). This method is a two-dimensional Discrete Element Method (DEM) comprising deformable elements that interact via compliant contacts (Itasca, 2015). The numerical modelling has been undertaken to supplement the predictions obtained using the empirical IPM.

The UDEC model has been derived from the *base model* that was developed for the Southern Coalfield for mining in the Bulli Seam (Barbato, 2017). The numerical model has been updated for the local stratigraphy (refer to Section 1.8) and has been calibrated for the local mining conditions using the available ground monitoring data.

3.9.1. Calibration of the UDEC model

The UDEC model has been calibrated using the available ground monitoring from LW22 to LW31. The void widths of these existing longwalls are 283 m and the solid chain pillar widths vary between 35 m and 40 m. The depths of cover to the Bulli Seam vary between 420 m and 500 m, with an average of 450 m. The width-to-depth ratios for the existing longwalls vary between 0.48 and 0.67, with an average of 0.63. The maximum mining height was 2.1 m.

The element (i.e. block) size adopted in the numerical model has been based on Block Type B1 for the *base model* (refer to Section 6.4.3.1 of Barbato, 2017). Minor adjustments of the element sizes have been made to suit the depths of each stratigraphic unit. The element aspect ratio has been taken as 1.5:1.0 (H:V) as per the *base model*.

The horizontal *in situ* stress has been based on Stress Type S2 for the *base model* (refer to Section 6.4.4 of Barbato, 2017). The stress at the surface is 1.5 MPa and the stress gradient through the overburden strata is 36 kPa/m.

The parametric analysis of the *base model* (refer to Section 6.9 of Barbato, 2017) showed that the appropriate material and joint properties are dependent on the other properties adopted in the numerical model, including the element size and aspect ratio. The appropriate properties are also dependent on the depth of cover and mining height, as these affect the relative contributions of vertical subsidence due to sagging of the overburden strata and pillar compression.

The material and joint properties have been calibrated for the local conditions using the available ground monitoring data. The initial calibration of the numerical model using the ground monitoring data from Areas 3A and 3B at the Mine found that the *base model* (i.e. Material Type M1 and Joint Type J2) underpredicted the vertical subsidence above the longwalls and the chain pillars.

The magnitudes and the profiles of vertical subsidence obtained from the numerical model better matched those measured in Area 3A by adopting joint strength parameters (i.e. cohesion and friction angle) that were 85 % of those used in the *base model*. The bulking ratio in the caving zone was also reduced from 1.03 to 1.01 to account for the seam roof comprising the Wombarra Claystone rather than the Coal Cliff Sandstone.

A comparison between the modelled and measured vertical subsidence are illustrated in Fig. 3.30 based on the Bridge Street monitoring line and in Fig. 3.31 based on the Railway Deviation monitoring line. The monitoring data have been normalised so that the distances are transverse to the longwalls so as to match the UDEC model.

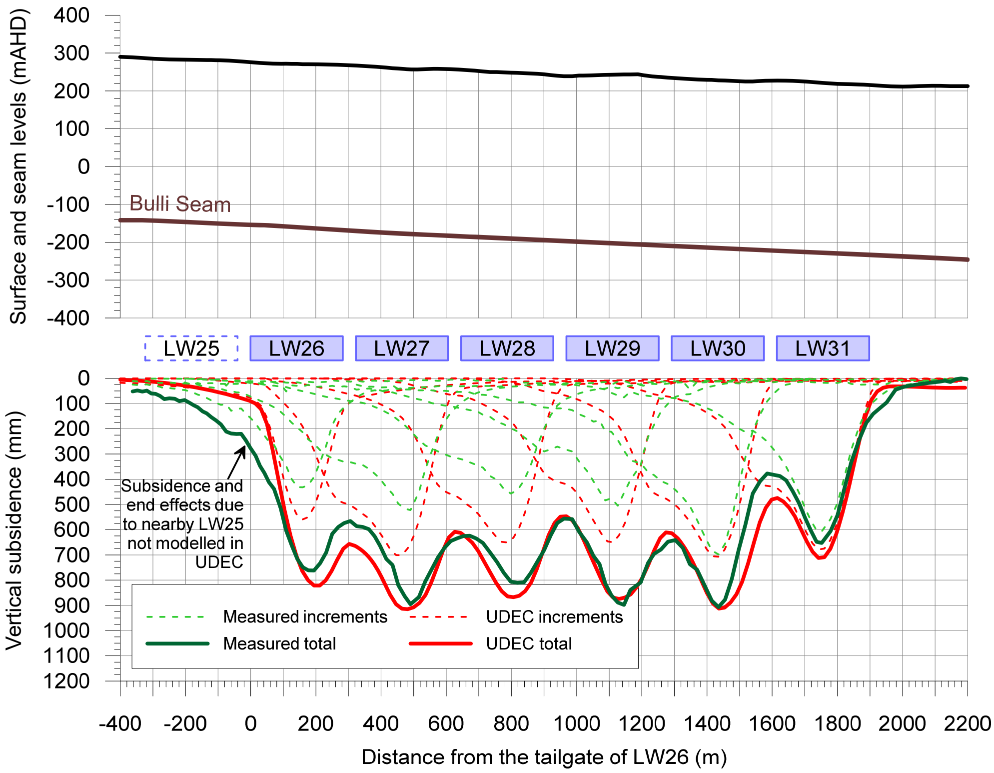

Fig. 3.30 Comparison of modelled and measured vertical subsidence along Bridge Street

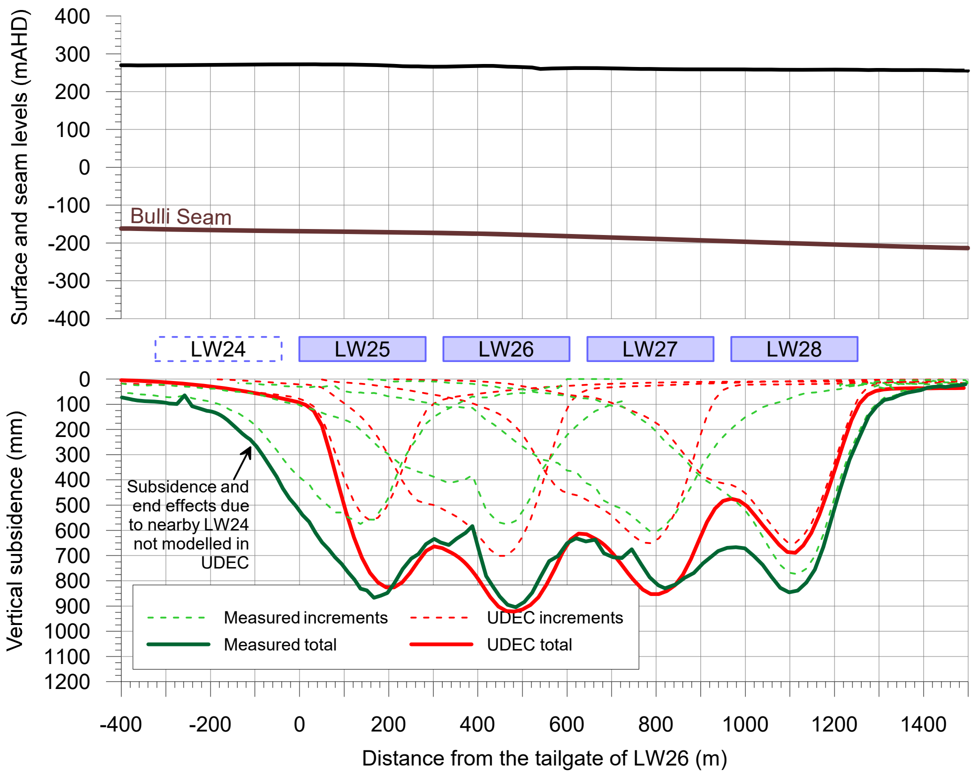

Fig. 3.31 Comparison of modelled and measured vertical subsidence along the Railway Deviation

It is considered that the profiles of vertical subsidence obtained from the UDEC model reasonably match the measured profiles along the Bridge Street and Railway Deviation monitoring lines. The numerical model slightly overpredicts the vertical subsidence adjacent to the tailgate of LW26 along Bridge Street and adjacent to the tailgate of LW25 along the Railway Deviation. However, these exceedances occurred due to subsidence from other adjacent longwalls that were not included in the numerical model.

3.9.2. UDEC model for LW W1-W4

The widths of LW W1-W3 are 283 metres and the width of LW W4 is 285 metres and the solid pillar widths are 39 to 44 metres. The average depth of cover to the Bulli Seam along the centreline of the proposed longwalls is 500 m. The width-to-depth ratio of each of the proposed longwalls therefore is approximately 0.57. It is proposed that the longwalls will extract a constant height of 2.1 m.

A summary of the stratigraphy adopted in the UDEC model is provided in Table 3.2. The element sizes have been based on Block Type B1 of the *base model*, with minor adjustments to suit the depths of each stratigraphic unit.

Table 3.2 Stratigraphy adopted in the UDEC model

Unit	Thickness (m)	Depth to base on unit (m)	Block size (H x V, m x m)
Wianamatta Group	20	20	6.0 x 4.0
Hawkesbury Sandstone	170	190	15.0 x 10.0
Newport/Garie Formations	20	210	7.5 x 5.0
Bald Hill Claystone	30	240	7.5 x 5.0
Bulgo Sandstone	180	420	15.0 x 10.0
Stanwell Park Claystone	10	430	7.5 x 5.0
Scarborough Sandstone	60	490	15.0 x 10.0
Wombarra Claystone	10	500	7.5 x 5.0
Bulli Coal	3	503	1.5 x 1.0
Sub-Bulli	100	603	15.0 x 10.0

Summaries of the material and joint properties adopted in the UDEC model are provided in Table 3.3 and Table 3.4, respectively. The joint normal stiffness and shear stiffness have been taken as 30 GPa/m and 3 GPa/m, respectively. The parameter analysis of the joint stiffness properties found that the numerical model is not sensitive to these two parameters (refer to Section 6.9.4 of Barbato, 2017).

Table 3.3 Material properties adopted in the UDEC model

Unit	Density (kg/m^3)	Bulk modulus (GPa)	Shear modulus (GPa)	Cohesion (MPa)	Friction angle (deg.)	Tensile strength (MPa)
Wianamatta Group	2700	5.00	2.32	6.0	25	0.5
Hawkesbury Sandstone	2400	3.33	2.00	7.0	34	0.5
Newport/Garie Formations	2400	3.45	2.48	4.0	30	0.5
Bald Hill Claystone	2700	5.0	2.31	6.0	25	0.5
Bulgo Sandstone	2500	5.56	4.17	10	30	0.5
Stanwell Park Claystone	2700	6.17	4.07	9.0	30	0.5
Scarborough Sandstone	2500	7.47	5.37	7.0	38	0.5
Wombarra Claystone	2600	6.90	4.96	10	25	0.5
Bulli Coal	1500	1.54	0.97	2.0	25	0.5
Sub-Bulli	2500	8.00	4.80	15	25	0.5

Table 3.4 Joint properties adopted in the UDEC model

Unit	Cohesion (MPa)		Friction angle (deg.)	
	Peak	Residual	Peak	Residual
Wianamatta Group	2.34	1.40	18.0	10.8
Hawkesbury Sandstone	2.13	1.28	21.1	12.7
Newport/Garie Formations	1.91	1.15	20.4	12.2
Bald Hill Claystone	2.34	1.40	18.0	10.8
Bulgo Sandstone	3.83	2.30	20.4	12.2
Stanwell Park Claystone	2.34	1.40	20.4	12.2
Scarborough Sandstone	2.76	1.66	22.1	13.3
Wombarra Claystone	2.55	1.53	18.7	11.2
Sub-Bulli	3.61	2.17	18.7	11.2

The modelled profiles of vertical subsidence obtained from the UDEC model for the proposed LW W1-W4 are illustrated in red in Fig. 3.32. The predicted profiles based on the IPM are shown in blue in this figure for comparison.

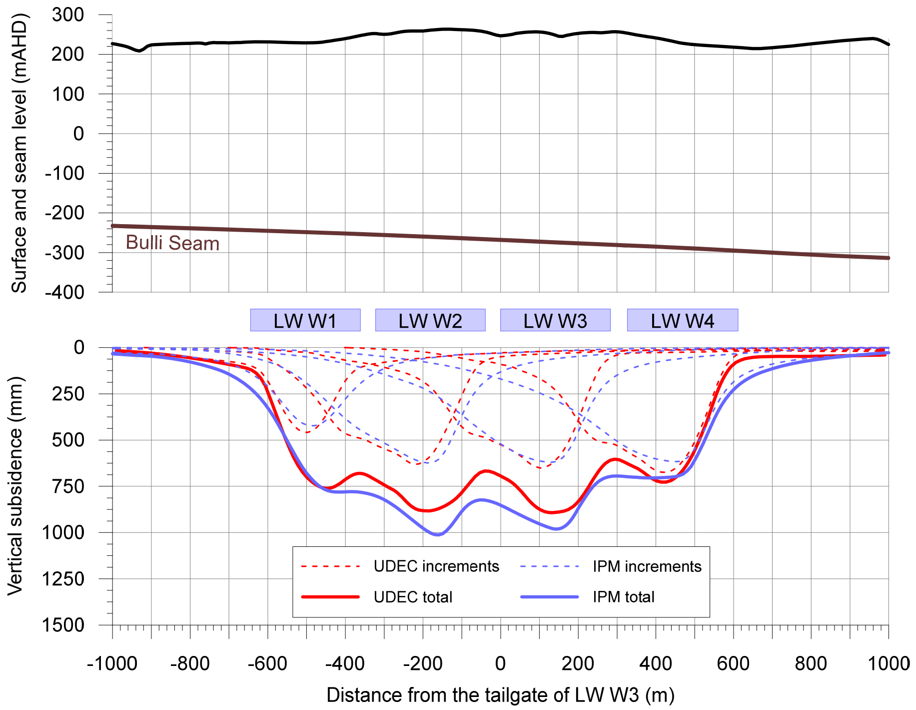

Fig. 3.32 Modelled profiles of vertical subsidence for the proposed LW W1-W4

The profiles of vertical subsidence obtained from the UDEC model reasonably match those predicted using the IPM. The maximum vertical subsidence directly above each of the proposed longwalls is reasonably similar, with the magnitudes being within ±15 %. The numerical model predicts slightly less vertical subsidence above LW W3 and a similar magnitude above LW W4 compared with that obtained from the IPM.

The maximum predicted tilts and curvatures obtained from the UDEC model are similar to the maximum predicted values based on the IPM. The numerical model predicts slightly higher tilt and curvature above the tailgate of LW W1 due to the lower vertical subsidence in this location.

It is considered that the profiles of vertical subsidence obtained from the UDEC model reasonably match those predicted using the IPM. It is not considered necessary, therefore, to further calibrate the IPM based on the outcomes of the numerical model.

The modelled profiles of vertical subsidence and horizontal movement through the overburden strata are illustrated in Fig. 3.33. The profiles have been taken through the centreline of LW W2, midway between the centreline and tailgate (referred to as the quarter point) and at the tailgate of this longwall.

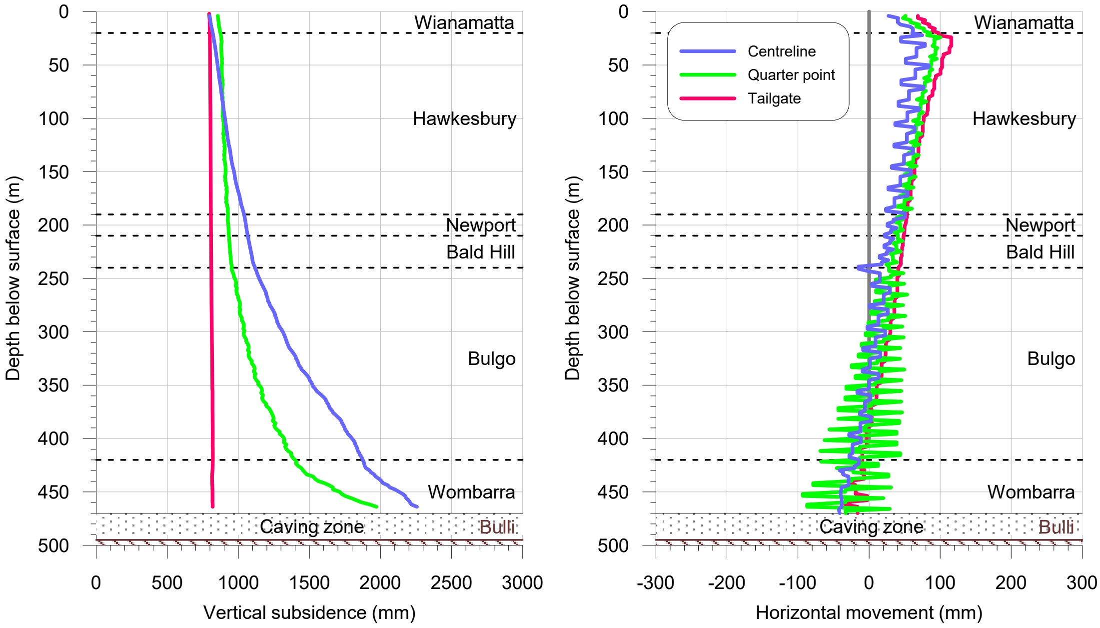

Fig. 3.33 Modelled profiles of vertical subsidence and horizontal movement through the overburden at the centreline, quarter point and tailgate of LW W2

The vertical subsidence at the longwall centreline varies between 35 % of the mining height at the surface through to 100 % of the mining height at the caving zone. The vertical subsidence adjacent to the longwall tailgate is 30 % of the mining height through most of the overburden.

The vertical strain (over a 20 m height) within the Hawkesbury Sandstone varies between approximately 0.5 mm/m at the surface and 2 mm/m at the base of the unit. The maximum vertical strain within the Hawkesbury Sandstone occurs at the longwall centreline with the strains reducing towards the longwall maingate and tailgate.

The vertical strain within the Bulgo Sandstone, at the longwall centreline, varies between approximately 3 mm/m at the top, 6 mm/m near mid-height and 4 mm/m at the base of the unit. The vertical strain at the quarter-points of the longwall vary between approximately 2 mm/m at the top and 12 mm/m at the base of the Bulgo Sandstone.

The vertical strain within the Wombarra Claystone varies between 12 mm/m and 16 mm/m. The maximum vertical strain occurs at the longwall quarter-points with the strains reducing towards the longwall centreline, maingate and tailgate. The vertical strains within the Newport Formation and the Bald Hill Claystone are typically less than 2 mm/m.

The horizontal shear on the bedding plane partings is approximately 20 mm within the Hawkesbury Sandstone and varies between 40 mm and 120 mm within the Bulgo Sandstone. The maximum horizontal shear occurs at the quarter point within the Bulgo Sandstone.

It is noted that the magnitudes of horizontal shear are dependent on their spacings. Hence, fewer but larger horizontal shears, or more but smaller horizontal shears could develop compared with that predicted, depending on their actual spacing.

3.10. Review of the measured and predicted valley-related effects at Tahmoor

The predicted upsidence and closure movements for the longwalls at TC have been obtained using the empirical method outlined in Australian Coal Association Research Program (ACARP) Research Project No. C9067 (Waddington and Kay, 2002), referred to as the 2002 ACARP method. Comparisons between the measured and predicted valley-related effects for the previously extracted longwalls at Tahmoor Mine have been provided in the following sections.

3.10.1. Myrtle Creek and the Skew Culvert

Detailed ground monitoring was undertaken where Myrtle Creek and a tributary to this creek (referred to as the Skew Culvert) crosses beneath the Main Southern Railway above Longwalls 26 and 27. A map showing the monitoring lines in these locations is shown in Fig. 3.34.

Fig. 3.34 Monitoring lines across Myrtle Creek and the Skew Culvert

The development of valley closure at each of the monitoring lines across the Myrtle Creek, during the extraction of Longwalls 24B to 27, are illustrated in Fig. 3.35.

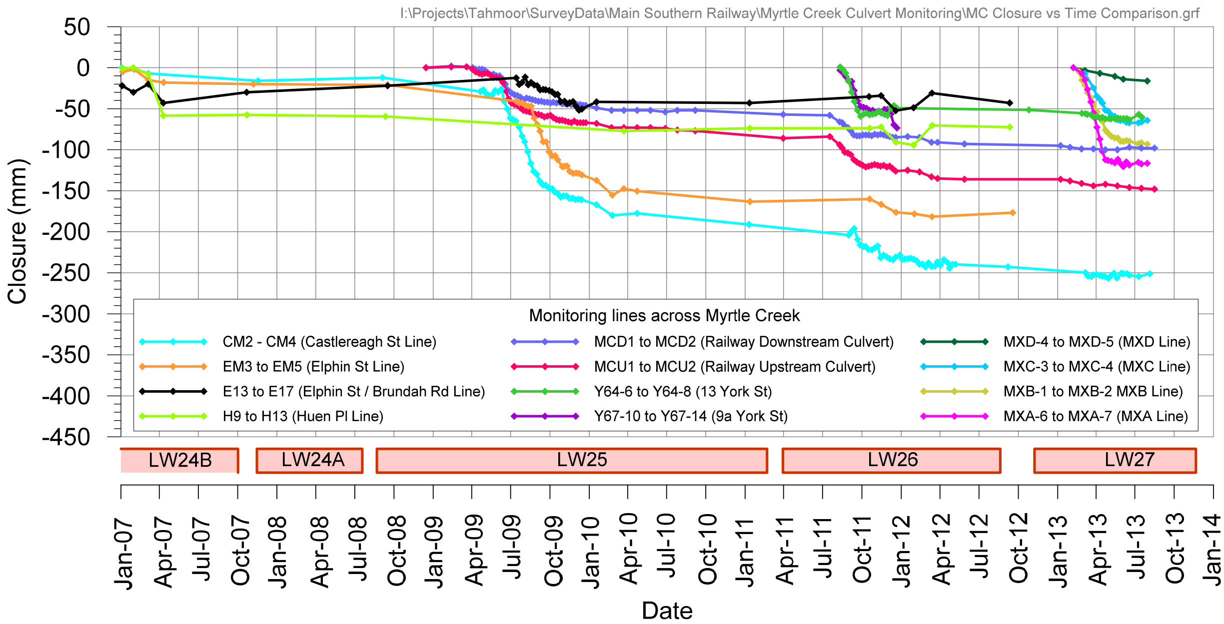

Fig. 3.35 Development of closure across Myrtle Creek during LW24B to LW27

The development of valley closure at each of the monitoring lines across the creek at the Skew Culvert, during the extraction of LW26 and LW27, are shown in Fig. 3.36.

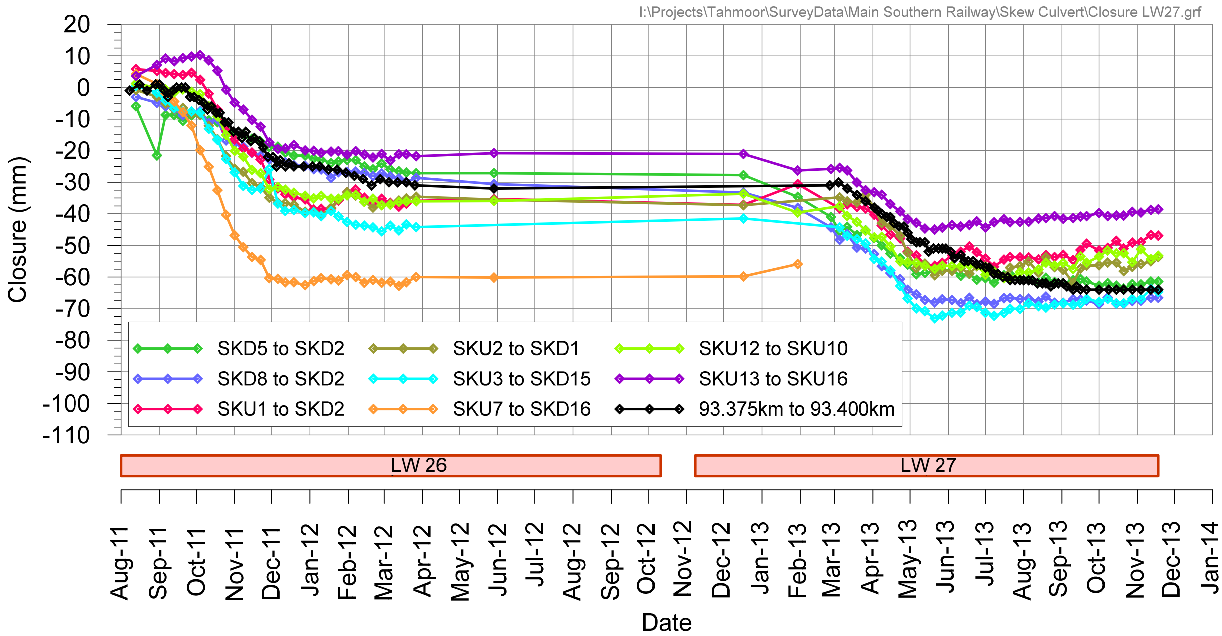

Fig. 3.36 Development of closure across the Skew Culvert during LW26 and LW27

A summary of the predicted and measured incremental closure across Myrtle Creek and the Skew Culvert is provided in Table 3.5. The predictions are consistent with those provided in Report No. MSEC355, which supported the SMP Application for Tahmoor LW27 to LW30.

Table 3.5 Predicted and measured incremental closure at the monitoring lines across Myrtle Creek and the Skew Culvert

Location	Category	Predicted and measured valley closure due to the mining of each longwall (mm)			
		Due to LW24	Due to LW25	Due to LW26	Due to LW27
Castlereagh Street (Pegs CM2 to CM4)	Predicted	30	55	45	25
	Measured	12	179	52	8
Elphin-Myrtle (Pegs EM3 to EM5)	Predicted	60	70	40	-
	Measured	21	142	22	-
Elphin St / Brundah Rd (Pegs E13 to E17)	Predicted	75	75	30	-
	Measured	0	21	6	-
Huen Place (Pegs H9 to H13)	Predicted	60	35	15	-
	Measured	58	15	20	-
Main Southern Railway Upstream (MCU1 to MCU4) Downstream (MCD1 to MCD4)	Predicted	15	30	30	15
	Measured	-	57 (d/s) to 86 (u/s)	36 (d/s) to 50 (u/s)	5 (d/s) to 12 (u/s)
Skew Culvert (8 cross-sections)	Predicted	< 5	10	25	25
	Measured	-	-	21 to 60 (average 36)	8 to 36 (average 21)
13 York Street (Pegs Y64-6 to Y64-8)	Predicted	-	-	65	50
	Measured	-	-	51	9
9a York Street (Pegs Y67-10 to Y67-14)	Predicted	-	-	85	85
	Measured	-	-	73	No access
MXA Line (Pegs MXA-6 to MXA-7)	Predicted	-	-	-	150
	Measured	-	-	-	116
MXB Line (Pegs MXB-1 to MXB-2)	Predicted	-	-	-	170
	Measured	-	-	-	93
MXC Line (Pegs MXC-3 to MXC-4)	Predicted	-	-	-	150
	Measured	-	-	-	64
MXD Line (Pegs MXD-4 to MXD-5)	Predicted	-	-	-	50
	Measured	-	-	-	16

It can be seen from the above table, that the measured valley closure has substantially exceeded predictions at the Castlereagh Street crossing, at the crossing of the Elphin-Myrtle monitoring line and, to a lesser extent, the crossing of the Main Southern Railway during the mining of LW25. It is considered that the reason for the differences in observations may be linked to the change in orientation of Myrtle Creek as the three above-mentioned monitoring lines are located along the same stretch of Myrtle Creek. It is noted, however, that substantially less closure has developed at Castlereagh Street than predicted during the mining of LW27.

The measured valley closure across the creek at the Skew Culvert has also slightly exceeded predictions, where the differences between predicted and measured closure are relatively small for most cross sections.

The measured valley closure across Myrtle Creek where it flows directly above LW27 (MXA to MXC lines) has been less than predicted, but greater in magnitude than that measured across monitoring lines upstream of LW27. This was expected because the valley is deeper compared to sections further upstream.

3.10.2. Redbank Creek

Detailed ground monitoring has been undertaken along Redbank Creek during the extraction of LWs 26 to 31. The ability to survey valley closure across the creek was constrained as access was not provided by some landowners located adjacent to the creek. There was no access to the creek from the northern bank and limited access on the southern bank of the Redbank Creek.

Ground surveys were undertaken in relative 3D from Bridge Street to a monitoring line that is located in cleared pasture land along the top of the valley, as shown in Fig. 3.37. This has provided measurements of total valley closure. Some survey pegs have been installed along a fenceline on the southern side to a point where surveyors can sight a survey peg on Bridge Street. Despite the best efforts of the survey team, the accuracy of the survey is challenged by the lack of cross lines across Redbank Creek. Baseline monitoring indicates that the valley closure measurements were accurate to approximately 20 mm to 30 mm.

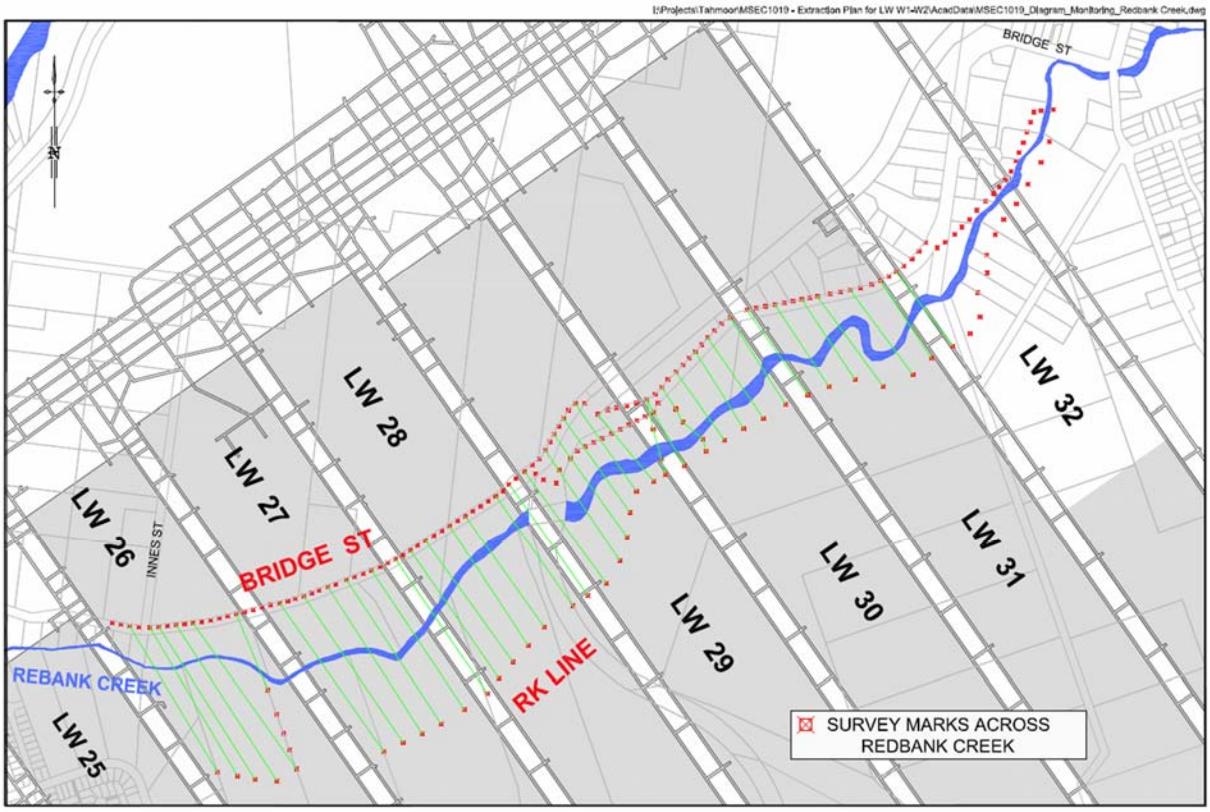

Fig. 3.37 Location of survey marks across Redbank Creek

A comparison between observed and predicted total valley closure along Redbank Creek after the mining of Longwall 31 is shown in Fig. 3.38. A comparison between observed and predicted incremental closure along Redbank Creek is also provided.

The closures are based on calculating changes in horizontal distance between pegs located across the valley in an orientation that is approximately parallel to the longwall panel. This orientation was chosen as Redbank Creek flows approximately at right angles across the panel.

Different results can be derived if the calculations were based on different pairs of pegs, though it is considered that if different pairs were chosen, such calculations would include an additional component of conventional and non-conventional ground shortening that occurs across the panel in both plateau areas or valleys. This is particularly the case if the pegs are located across the width of the longwall panel from each other. When comparing the results against predictions of valley closure, it was considered simpler to choose pegs that are approximately aligned with longwall direction so as not to make allowances for the additional effects of conventional lateral ground closure movements.

A number of observations are made from the monitoring data:

- There has been a reasonable correlation between predicted and observed incremental closure at the completion of Longwall 31. Valley closure was slightly greater for a temporary period of time, when the transient effects of the subsidence travelling wave passed through the valley.
- Observed total closure from the mining of Longwalls 26 to 31 is less than predicted.

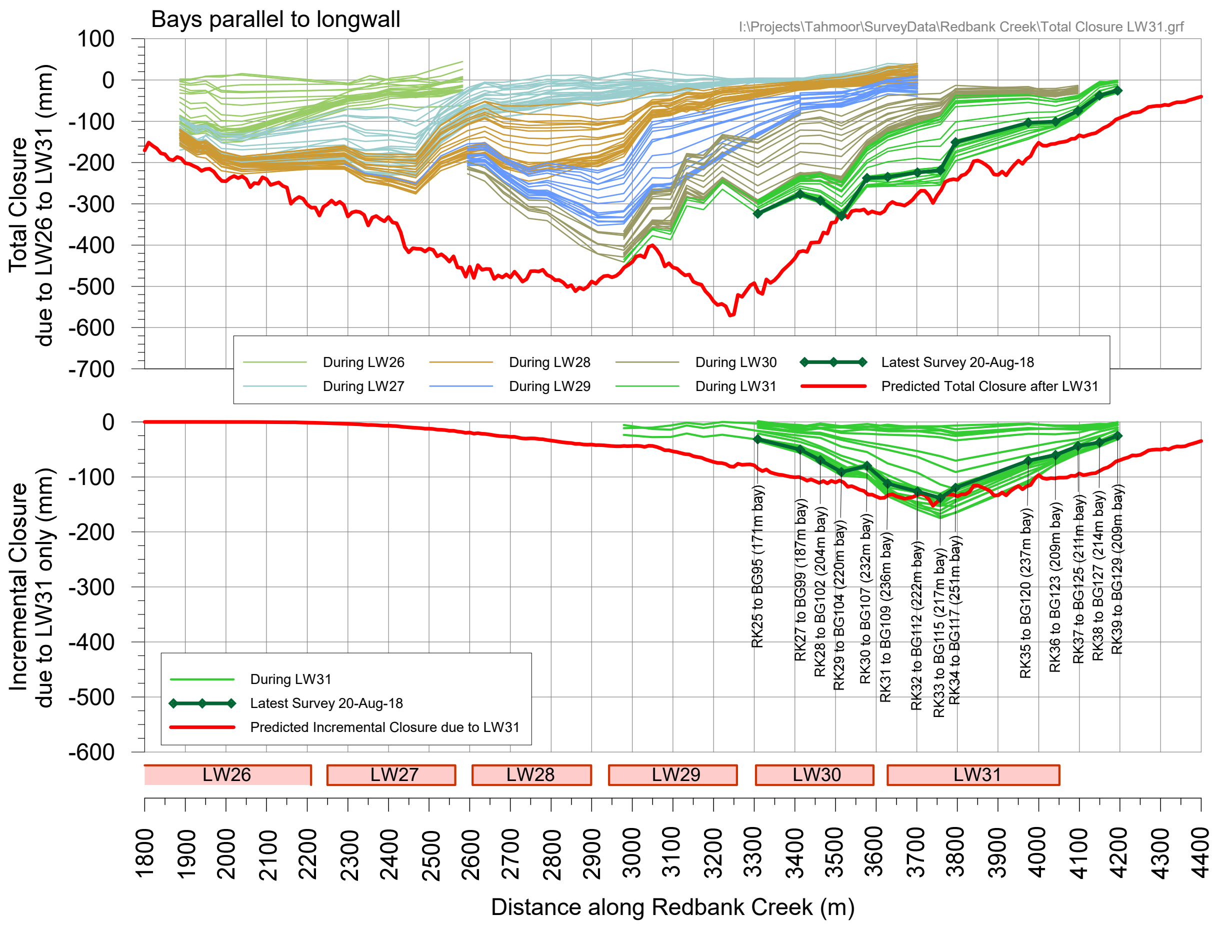

Fig. 3.38 Comparison between observed and predicted valley closure along Redbank Creek

3.10.3. Matthews, Cedar and Stonequarry Creeks

A summary of observed valley closure and upsidence movements across Matthews, Cedar and Stonequarry Creeks is discussed in Section 5.3. Very little to no measurable closure or upsidence was observed during the mining of LW W1. Very minor valley closure has been measured around the confluence of Cedar and Stonequarry Creeks beyond the commencing ends of LW W1-W2 during the mining of LW W2.

3.10.4. Creek crossings above LW W1

Very minor closure of approximately 20 mm was measured across the creek crossing at 88.400 km on the Picton to Mittagong Loop Line during the mining of LW W1, which is less than predicted. Closure is, however, currently developing during the mining of LW W2, with total closure likely to be a similar order of magnitude to the prediction of 125 mm.

Surveys across other creeks above LW W1 have measured very little to no measurable valley closure. As at March 2021, LW W2 has not yet mined directly beneath or adjacent to other creek crossings.

The results show that while the prediction of valley closure is not an exact science, there is a reasonable correlation between measured and predicted subsidence when measured across the width of the valley.

3.10.5. Reliability of the predicted valley-related movements

The review of the observed movements at Myrtle and Redbank Creeks and the observed movements directly above and adjacent to LW W1 indicate that the ACARP Method provides reasonable predictions for valley closure at TC. It is noted, however, the measured closures substantially exceeded those predicted in three locations along Myrtle Creek, due to the extraction of LW25, but these all occurred along the same section of creek. Elsewhere, the measured closures were typically similar to or less than those predicted.

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.

Notwithstanding the abovementioned limitations, the 2002 ACARP method is the most thoroughly used and tested prediction method for upsidence and closure movements in the Southern Coalfield. It is expected in most cases to provide reasonable, if not, slightly conservative predictions of the valley-related movements for the proposed longwalls.

More recently, the empirical prediction method has been refined based on further research undertaken as part of ACARP Research Project No. 18015 (Kay and Waddington, 2014). The 2014 ACARP method only provides predictions for valley closure and not for upsidence.

The predictions based on the 2002 ACARP method can be directly compared with the predictions provided in previous MSEC subsidence reports for TC and with other case studies. This method has also been more widely used and tested than the more recent 2014 ACARP method. The assessments provided in this report, therefore, have been based on the predictions obtained using the 2002 ACARP method.

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of the proposed LW W3-W4. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapters 5 and 6.

The predicted vertical subsidence, tilt and curvature have been obtained using the IPM, which has been calibrated based on the latest monitoring data from Tahmoor Mine, as described in Section 3.6. The predicted strains have been determined by analysing the strains measured at other collieries within the NSW coalfields, where the longwall width-to-depth ratios and extraction heights are similar to those for the proposed longwalls.

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

4.2. Maximum predicted conventional subsidence, tilt and curvature

The predicted incremental vertical subsidence contours resulting from the extraction of the proposed longwalls are shown in Drawings Nos. MSEC1112-25 to MSEC1112-26, in Appendix E A summary of the maximum predicted values of incremental vertical subsidence, tilt and curvature are provided in Table 4.1. The incremental parameters represent the additional movements due to the extraction of each of the proposed longwalls.

Table 4.1 Maximum predicted incremental conventional subsidence, tilt and curvature for the proposed longwalls

Longwall	Maximum predicted incremental vertical subsidence (mm)	Maximum predicted incremental tilt (mm/m)	Maximum predicted incremental hogging curvature (km^{-1})	Maximum predicted incremental sagging curvature (km^{-1})
LW W3	650	4.5	0.05	0.09
LW W4	600	4.5	0.05	0.08

The predicted total vertical subsidence contours resulting from the extraction of the proposed longwalls are shown in Drawings Nos. MSEC1112-27 to MSEC1112-29, in Appendix E. A summary of the maximum predicted values of total vertical subsidence, tilt and curvature is provided in Table 4.2. The predicted total parameters represent the accumulated movements due to the extraction of all proposed longwalls within each of the mining areas.

Table 4.2 Maximum predicted total conventional subsidence, tilt and curvature for the proposed longwalls

Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
LW W3	950	5.0	0.06	0.10
LW W4	1025	5.0	0.06	0.10

The maximum predicted total vertical subsidence of 1025 mm represents 49 % of the proposed mining height of 2.1 m. The maximum predicted total tilt is 5.0 mm/m (i.e. 0.5 %, or 1 in 200) and it occurs adjacent to the maingate of LW W4. The maximum predicted total curvatures are 0.06 km^{-1} hogging and 0.10 km^{-1} sagging, which represent minimum radii of curvature of 17 km and 10 km, respectively.

The predicted conventional subsidence parameters vary across the mining area. To illustrate this variation, the predicted profiles of vertical subsidence, tilt and curvature have been determined along two prediction lines. The predicted profiles of total vertical subsidence, tilt and curvature along Prediction Lines 1 and 2 are shown in Figs. C.01 and C.02, respectively, in Appendix C. The locations of these prediction lines are shown in Drawings Nos. MSEC11112-25 to MSEC1112-29.

4.3. Potential additional settlement above coal barriers between proposed and previous mine workings

The proposed LW W3-W4 will be extracted in a new series from the previous series of LWs 22 to 32, separated by a barrier of unmined coal, except for development headings.

Additional vertical settlement has been observed within the following areas at Tahmoor and Appin Mines that were located above solid intact coal between previously extracted areas, such as:

- Between Longwall 3 and Longwall 22 at Tahmoor Mine;
- Between Longwall 23A and 23B at Tahmoor Mine;
- Between Longwall 24A and the 200 Panels at Tahmoor Mine;
- Between Longwalls 22 to 24B and Longwall 24A and the 200 Panels and Longwall 25 (i.e. mining on three sides of a corridor of intact coal) at Tahmoor Mine;
- Between Longwalls 8-12, Longwall 18 and Longwall 408 at Appin Colliery; and
- Between Longwalls 14-18, 301-302 and 401 at Appin Colliery.

Additional vertical settlement in these areas has generally been between 50 and 150 mm of subsidence above what was predicted using the IPM and generally low levels of tilt and strain were measured within these areas. Increased subsidence has not always been observed in these situations. For example, it was not observed between Longwalls 3-9 and Longwall 20 at Tahmoor Mine.

Whilst observed subsidence may exceed predictions above the coal barrier between proposed LW W3-W4 and previous series of LWs 22 to 32, subsidence monitoring has shown that it is usually accompanied by relatively low conventional tilts, curvature and strains (less than 0.5 mm/m and usually within survey tolerance).

Observations during the mining of LW W1 have not detected additional settlement above the coal barrier. While the result is encouraging, LW W1 is the first longwall in a series and additional settlement may develop during and after the mining of LW W2-W4.

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 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.

The maximum predicted conventional strains resulting from the extraction of proposed longwalls, based on applying a factor of 15 to the maximum predicted curvatures, are 0.9 mm/m tensile and 1.5 mm/m compressive. These strains represent typical values when the ground subsides regularly with no localised or elevated strains due to near-surface geological structures or valley closure effects. The maximum strains can be much greater than these typical values, especially in the locations of near-surface geological structures and in the bases of valleys.

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, rather than providing a single predicted conventional strain.

The range of potential strains above the proposed longwalls has been determined using monitoring data from previously extracted longwalls at the mine. The range of strains measured during the extraction of these longwalls should, therefore, provide a reasonable indication of the range of potential strains for the proposed 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 effects, which are discussed separately in the impact assessments for the natural and built features provided in Chapters 5 and 6. 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 maximum strains measured in 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 previous longwalls at the mine, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls, which has been referred to as "*above goaf*".

A histogram of the maximum total tensile and compressive strains measured in survey bays above goaf is provided in Fig. 4.1. A number of probability distribution functions were fitted to the empirical data. It was found that a *Generalised Pareto Distribution (GPD)* provided a good fit to the raw strain data, which have also been shown in this figure.

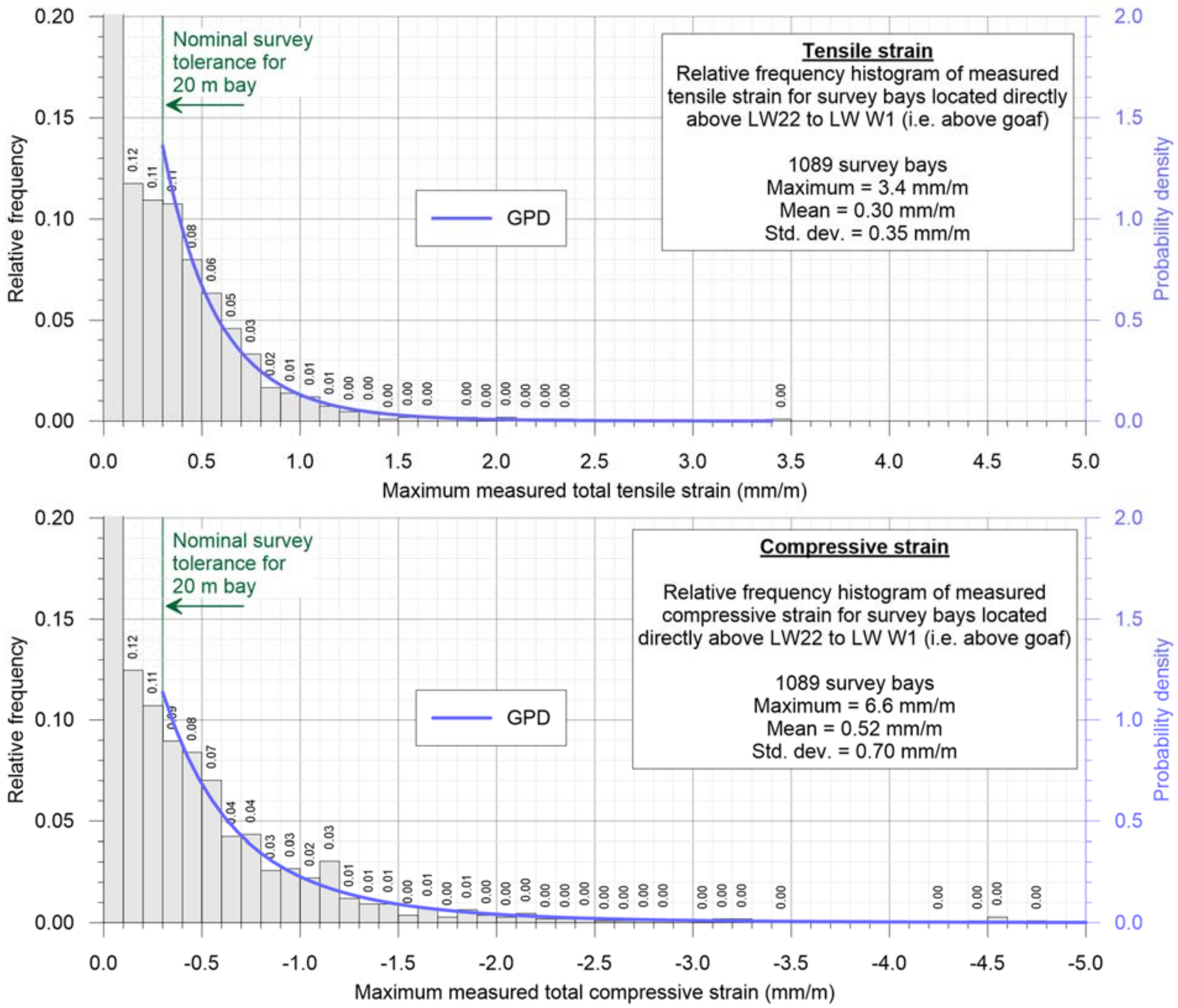

Fig. 4.1 Distributions of the maximum measured tensile and compressive strains during the extraction of previous longwalls at the mine for survey bays located directly above goaf

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during 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 goaf, based on the fitted GPDs, is provided in Table 4.3. The analysis does not include the strains resulting from valley-related effects, which are discussed separately in the impact assessments for the natural and built features provided in Chapters 5 and 6.

Table 4.3 Probabilities of exceedance for strain for survey bays located directly above goaf

	Strain (mm/m)	Probability of exceedance
Compression	-8.0	1 in 1800
	-6.0	1 in 680
	-4.0	1 in 180
	-2.0	1 in 25
	-1.0	1 in 7
	-0.5	1 in 3
	-0.3	1 in 2
Tension	+0.3	1 in 2
	+0.5	1 in 5
	+1.0	1 in 20
	+2.0	1 in 300
	+3.0	1 in 2800

The 95 % confidence levels for the maximum total strains that the individual survey bays above goaf experienced at any time during mining were 1.0 mm/m tensile and 1.7 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 1.5 mm/m tensile and 3.3 mm/m compressive.

The probabilities for survey bays located above goaf are based on the strains measured anywhere above the previously extracted longwalls at the mine. 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.

The distribution of incremental strains measured above previously extracted longwalls in the Southern Coalfield is illustrated in Fig. 4.2 (after Barbato, 2017). 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.

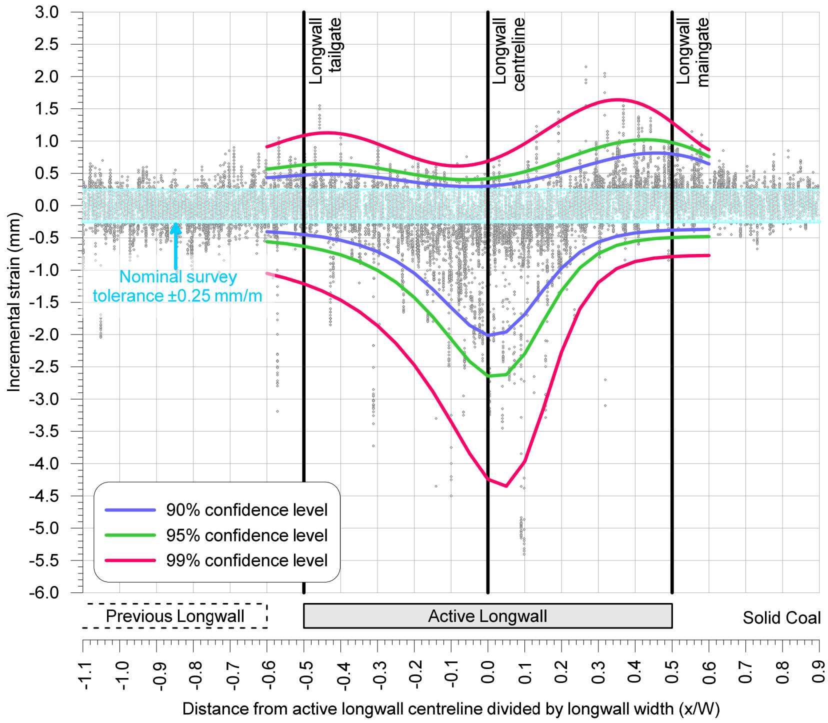

Fig. 4.2 Measured incremental strains versus normalised distance from the longwall maingate for previously extracted longwalls in the Southern Coalfield

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 previous longwalls at the mine, 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*".

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

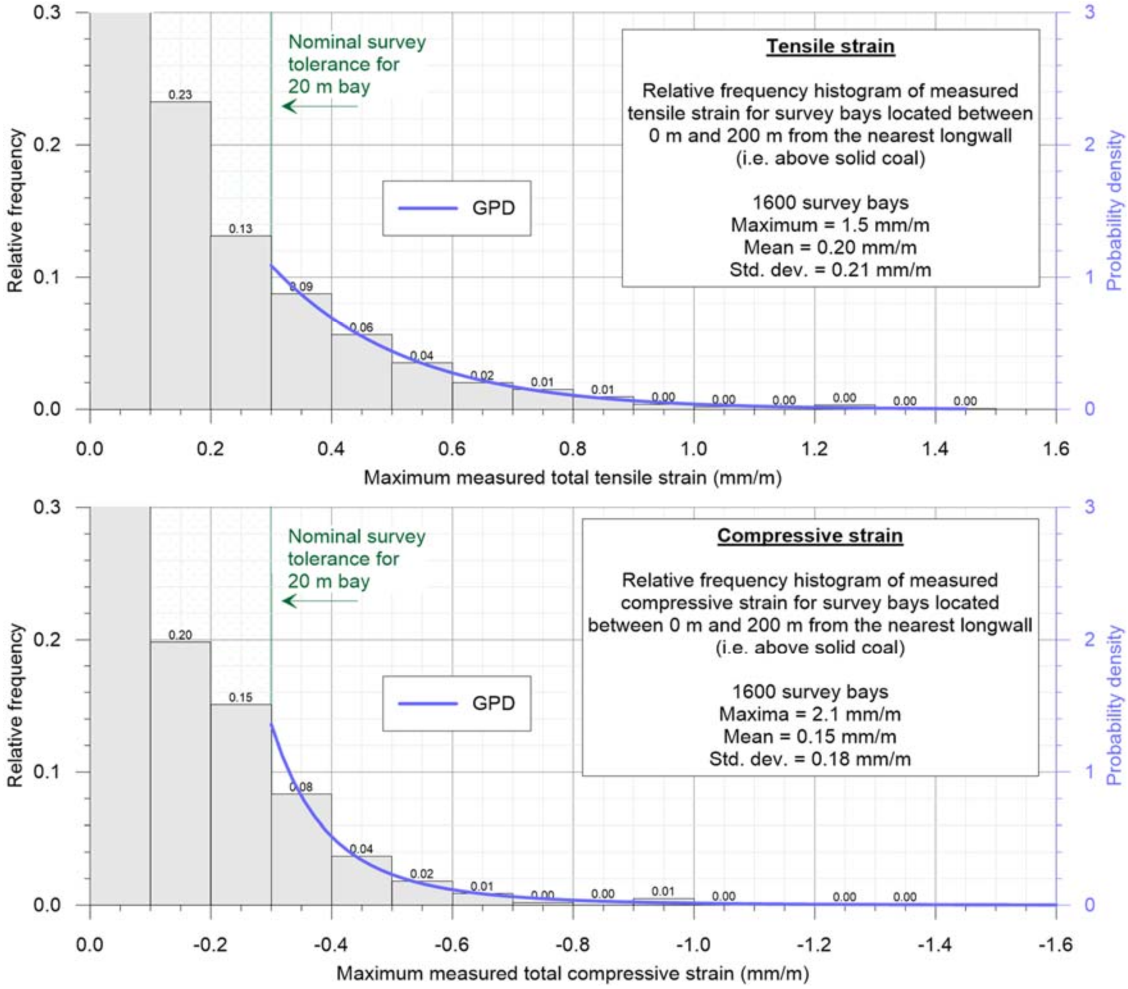

Fig. 4.3 Distributions of the maximum measured tensile and compressive strains during the extraction of previous longwalls at the mine for survey bays located directly above solid coal

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 4.4. The analysis does not include the strains resulting from valley-related movements, which are discussed separately in the impact assessments for the natural and built features provided in Chapters 5 and 6.

Table 4.4 Probabilities of exceedance for strain for survey bays located above solid coal

	Strain (mm/m)	Probability of exceedance
Compression	-2.0	1 in 2100
	-1.5	1 in 800
	-1.0	1 in 210
	-0.5	1 in 25
	-0.3	1 in 6
Tension	+0.3	1 in 4
	+0.5	1 in 10
	+1.0	1 in 130
	+1.5	1 in 2000
	+2.0	1 in 5000

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 1.0 mm/m tensile and 0.8 mm/m compressive.

Observed ground strain during the mining of LW W1 were generally low. The maximum observed tensile strain was 0.60 mm/m, which was measured between Pegs 88.38 km and 88.40 km on the Picton to Mittagong Loop Line. The maximum observed compressive strain was 1.35 mm/m, which was measured between Pegs WX-09 and WX-10 on the LW W1-W2 Crossline.

While the observed strains have generally been low, LW W1 is the first longwall in a series and larger ground strains are expected to develop during and after the mining of LW W2-W4.

4.4.2. Analysis of strains measured along whole monitoring lines

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

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

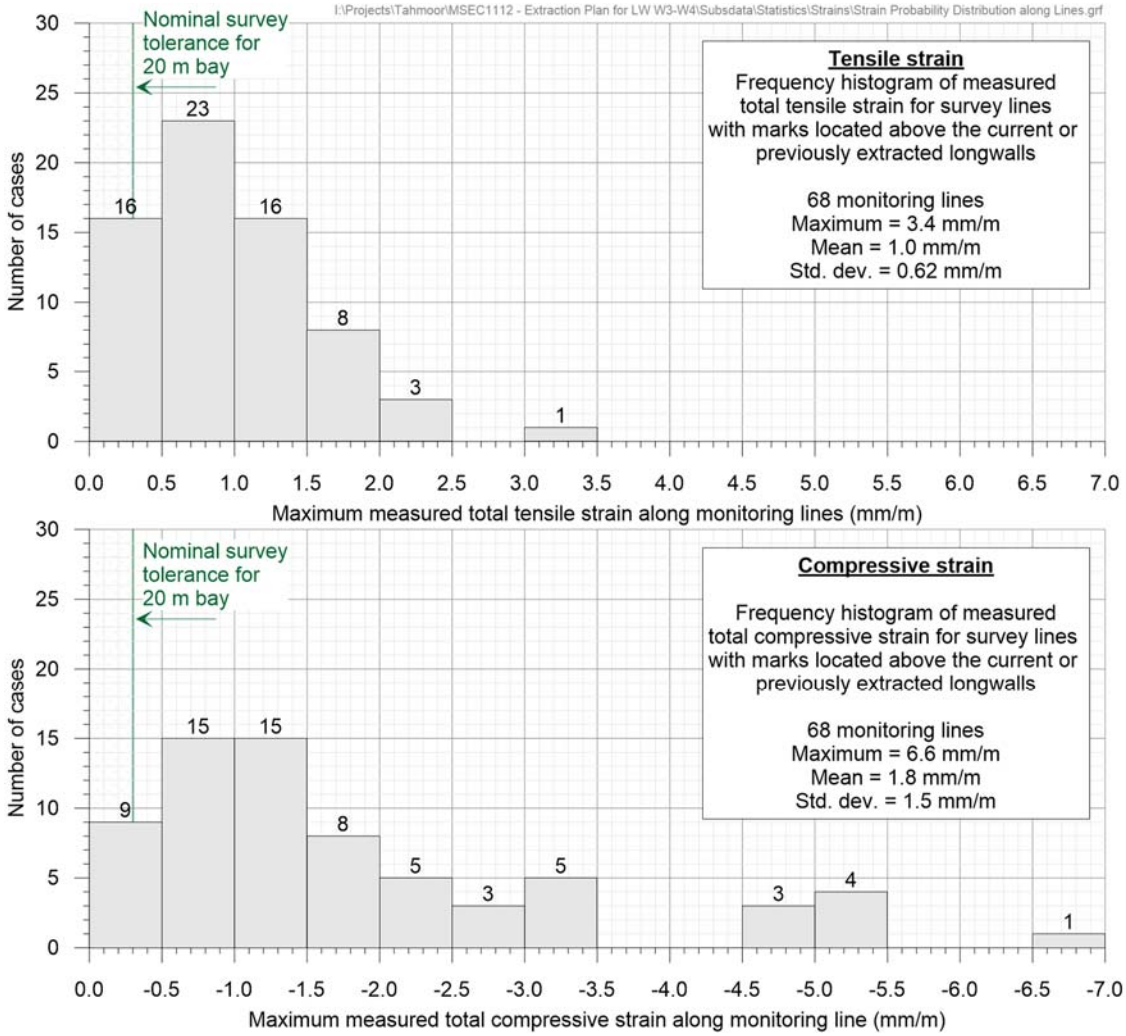

Fig. 4.4 Distributions of maximum measured tensile and compressive strains along the monitoring lines during the extraction of previous longwalls at the mine

It can be seen from the above figure, that 39 of the 68 monitoring lines (i.e. 57 %) had recorded maximum total tensile strains of 1.0 mm/m or less, and that 63 monitoring lines (i.e. 93 %) had recorded maximum total tensile strains of 2.0 mm/m or less. It can also be seen, that 47 of the 68 monitoring lines (i.e. 69 %) had recorded maximum compressive strains of 2.0 mm/m or less, and that 60 of the monitoring lines (i.e. 88 %) had recorded maximum compressive strains of 4.0 mm/m or less.

4.4.3. 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, dependent on the orientation in which they are measured. The maximum normal strains (i.e. 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) 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 marks 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, horizontal mid-ordinate deviation, angular distortion and shear index. In this report, horizontal 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 total horizontal mid-ordinate deviations measured at survey marks above goaf, for previously extracted longwalls in the Southern Coalfield, is provided in Fig. 4.5. As the typical survey bay length was 20 metres, the calculated mid-ordinate deviations were over a chord length of 40 metres. The probability distribution function, based on the fitted GPD, has also been shown in this figure.

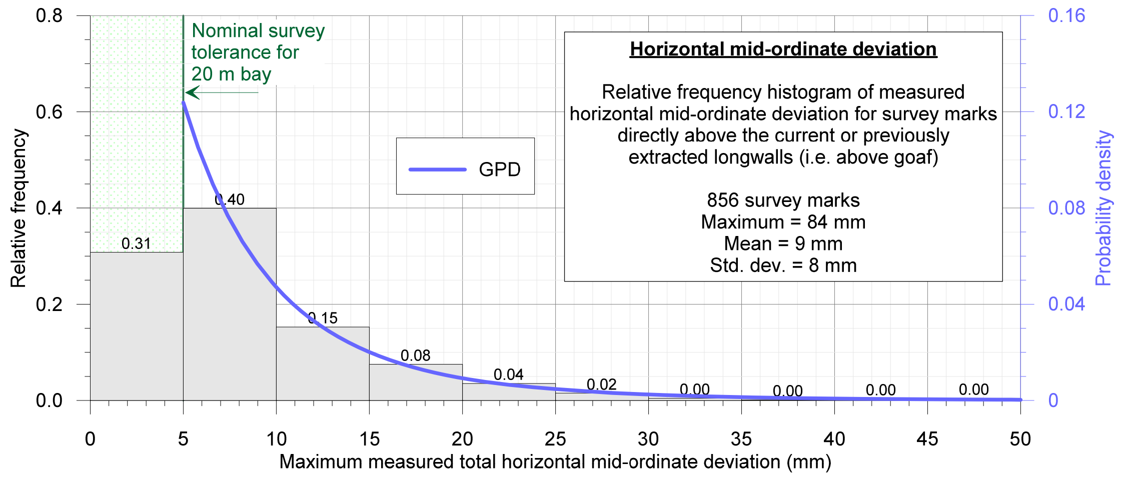

Fig. 4.5 Distribution of maximum measured mid-ordinate deviation during the extraction of previous longwalls in the Southern Coalfield for marks located above goaf

A summary of the probabilities of exceedance for total horizontal mid-ordinate deviation for survey bays located above goaf, based the fitted GPD, is provided in Table 4.5. The analysis does not include the strains resulting from valley-related movements, which are discussed separately in the impact assessments for the natural and built features provided in Chapters 5 and 6.

Table 4.5 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 a 40 m chord length	10	1 in 3
	20	1 in 15
	30	1 in 40
	40	1 in 110
	50	1 in 250
	60	1 in 550
	70	1 in 1,000
	80	1 in 1,900

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 23 mm and 39 mm, respectively.

4.5. Predicted absolute horizontal movements

The predicted conventional horizontal movements over the proposed longwalls are calculated by applying a factor to the predicted conventional tilt values. In the Southern Coalfield a factor of 15 is generally adopted, being the same factor as that used to determine the conventional strains from the conventional curvatures, and this has been found to give a reasonable correlation with measured data. This factor will vary and will be higher at low tilt values and lower at high tilt values. The application of this factor will therefore lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the movements where the tilts are low.

The maximum predicted conventional tilt due to the extraction of LW W1-W4 is 5 mm/m. The maximum predicted conventional horizontal movement, therefore, is approximately 75 mm, i.e. 5 mm/m multiplied by a factor of 15. Greater movements can develop in incised terrain, due to the increased horizontal movements that develops in the downslope direction and due to valley-related effects.

The distribution of the measured horizontal movements for the 3D survey marks located directly above the longwalls at the mine is provided in Fig. 4.6. It can be seen from this figure, that horizontal movements have been measured up to 300 mm at the mine, with an average measured value of approximately 150 mm. The greater horizontal movements have occurred due to topographic and valley-related effects.

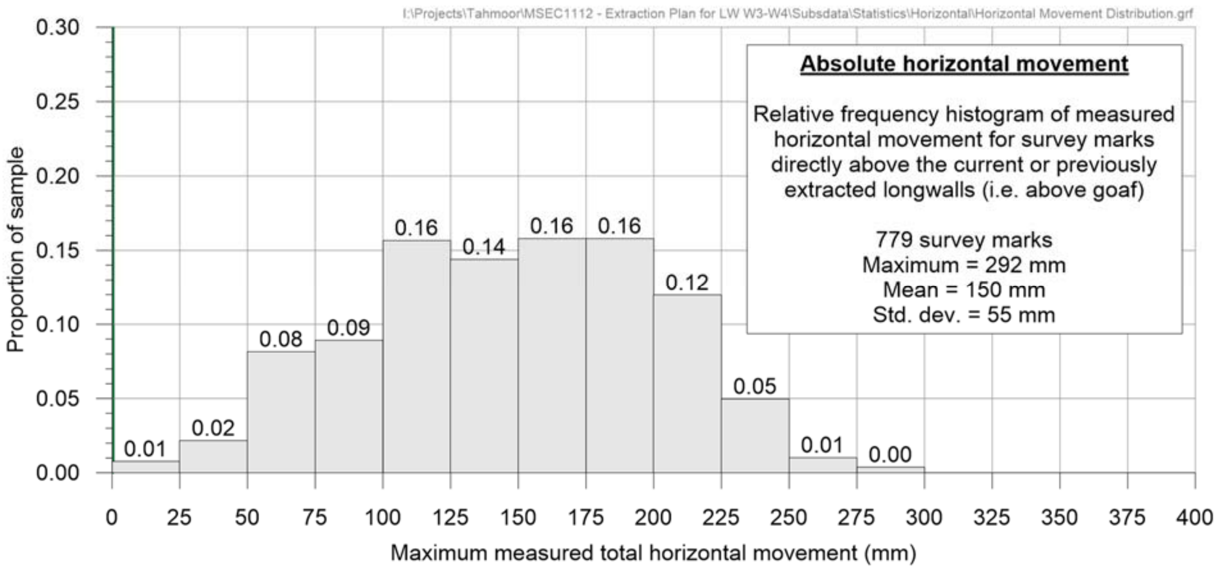

Fig. 4.6 Distribution of measured absolute horizontal movements at the mine

Observed horizontal movements during the mining of LW W1 were generally low. The maximum observed movement was 124 mm, which was measured at Peg 88.58 km on the Picton to Mittagong Loop Line.

While the observed horizontal movements have generally been low, LW W1 is the first longwall in a series and larger horizontal movements are expected to develop directly above the extracted panels during and after the mining of LW W2-W4.

Absolute horizontal movements do not directly impact on natural and built features, rather impacts occur as the result of differential horizontal movements. Strain is the rate of change of horizontal movement. The impacts of strain on the natural features and items of surface infrastructure are addressed in the impact assessments for each feature, which have been provided in Chapters 5 and 6.

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.

The observed incremental far-field horizontal movements resulting from the extraction of each longwall, in any location above goaf (i.e. above the currently mined or previously mined longwalls) or above solid coal (i.e. unmined areas of coal) are provided in Fig. 4.7. The observed incremental far-field horizontal movements above solid coal only, i.e. outside the extents of extracted longwalls, are shown in Fig. 4.8. The confidence levels based on fitted GPDs have also been shown in these figures to illustrate the spread of the data. It can be seen from Fig. 4.7 and Fig. 4.8 that the magnitudes of observed far-field horizontal movements over solid unmined areas of coal are lower and more consistent than the observed far-field horizontal movements over previously extracted longwalls.

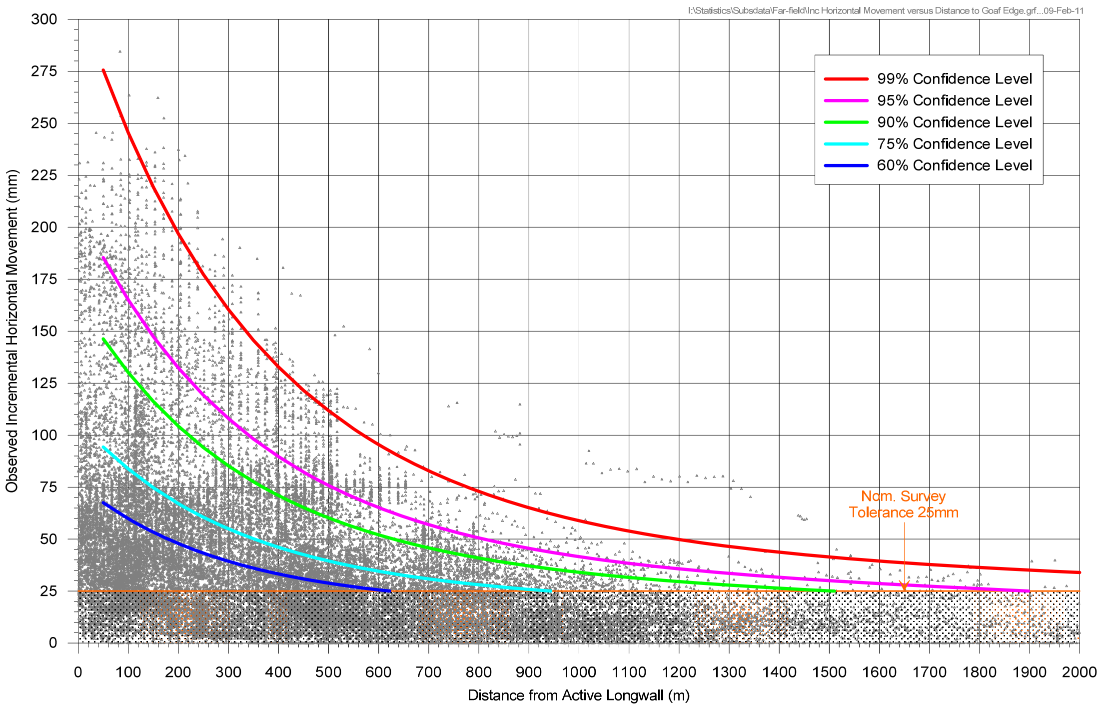

Fig. 4.7 Measured incremental far-field horizontal movements above goaf or solid coal

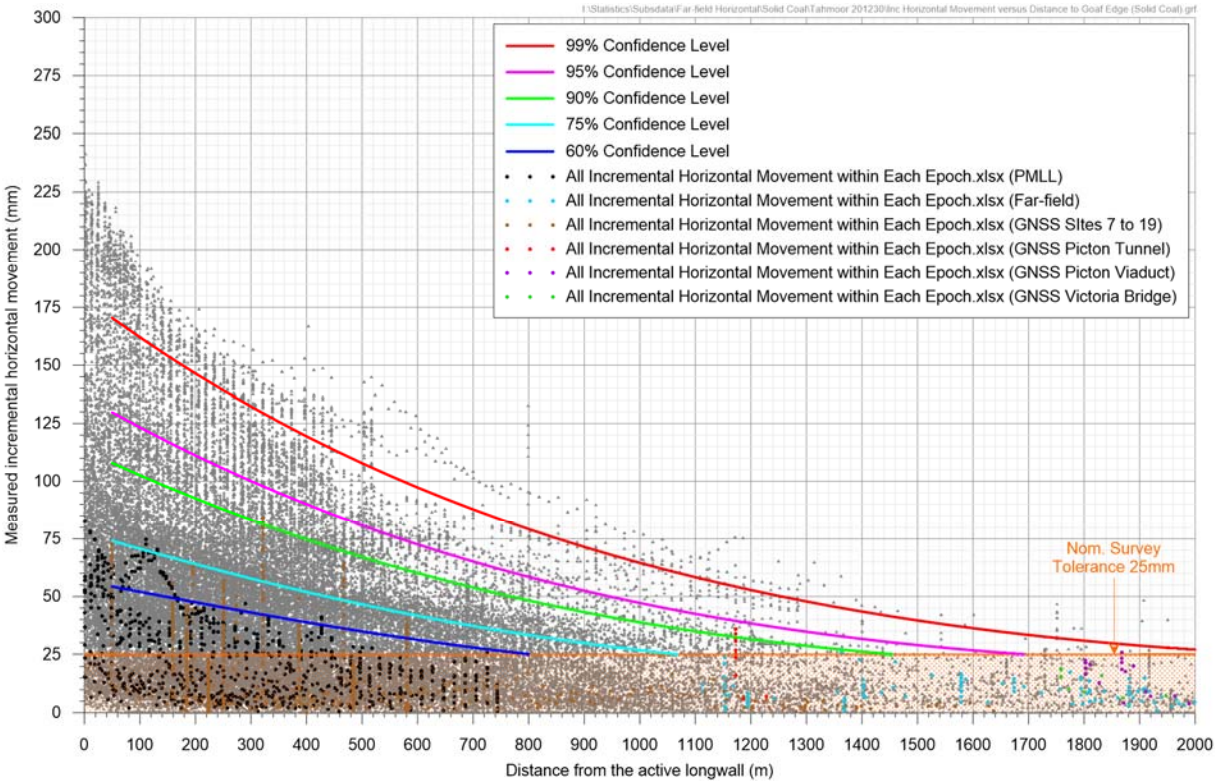

Fig. 4.8 Measured incremental far-field horizontal movements above solid coal only

As successive longwalls within a series of longwalls are mined, the magnitudes of the incremental far-field horizontal movements tend to decrease. The total far-field horizontal movement is not, therefore, the sum of the incremental far-field horizontal movements for the individual longwalls.

Observed horizontal movements measured during the mining of LW W1 beyond solid coal is shown in Fig. 4.8. Observed movements were within the previously observed range. The highest recorded movements were located to the west of LW W1 on the opposite side of Matthews and Cedar Creeks.

Confidence levels have been determined from the empirical horizontal movement data using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum measured horizontal movement was used in the analysis. A summary of incremental horizontal movements within the 95% and 99% confidence levels are shown in Table 4.6.

Table 4.6 Confidence levels for horizontal for mid-ordinate deviation for survey marks above goaf for monitoring lines in the Southern Coalfield

Distance from active longwall (m)	Incremental horizontal movement within 95% confidence level (mm)	Incremental horizontal movement within 99% confidence level (mm)
400	90	120
600	75	100
800	60	80
1000	50	65
1200	40	50
1400	30	45

The predicted far-field horizontal movements resulting from the extraction of the longwalls are very small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain, which are generally less than survey tolerance. The potential impacts of far-field horizontal movements on the natural and built features within the vicinity of the proposed longwalls are not expected to be measurable, with possibly the exception of the larger infrastructure such as the road and railway bridges, which is discussed further below.

The potential for impacts on the larger infrastructure outside the Study Area do not result from absolute far-field horizontal movements, but rather from differential horizontal movements over the lengths of the structures. For example, differential horizontal movements along the alignments of the bridges could potentially affect the widths of the expansion joints or the capacities of the support bearings. Differential horizontal movements across the alignments of concrete bridges could potentially induce eccentricities into the structure or affect the capacities of the support bearings.

The potential for differential horizontal movements at the infrastructure outside the Study Area has been assessed by statistically analysing the available 3D monitoring data from the Southern Coalfield. The observed incremental differential longitudinal movements for survey marks spaced at 20 metres ±10 metres, relative to the distance from the active longwall, is shown in Fig. 4.9. The 95 % confidence levels have also been shown in this figure, which were determined from the empirical data using the fitted *Generalised Pareto Distributions* (GPDs).

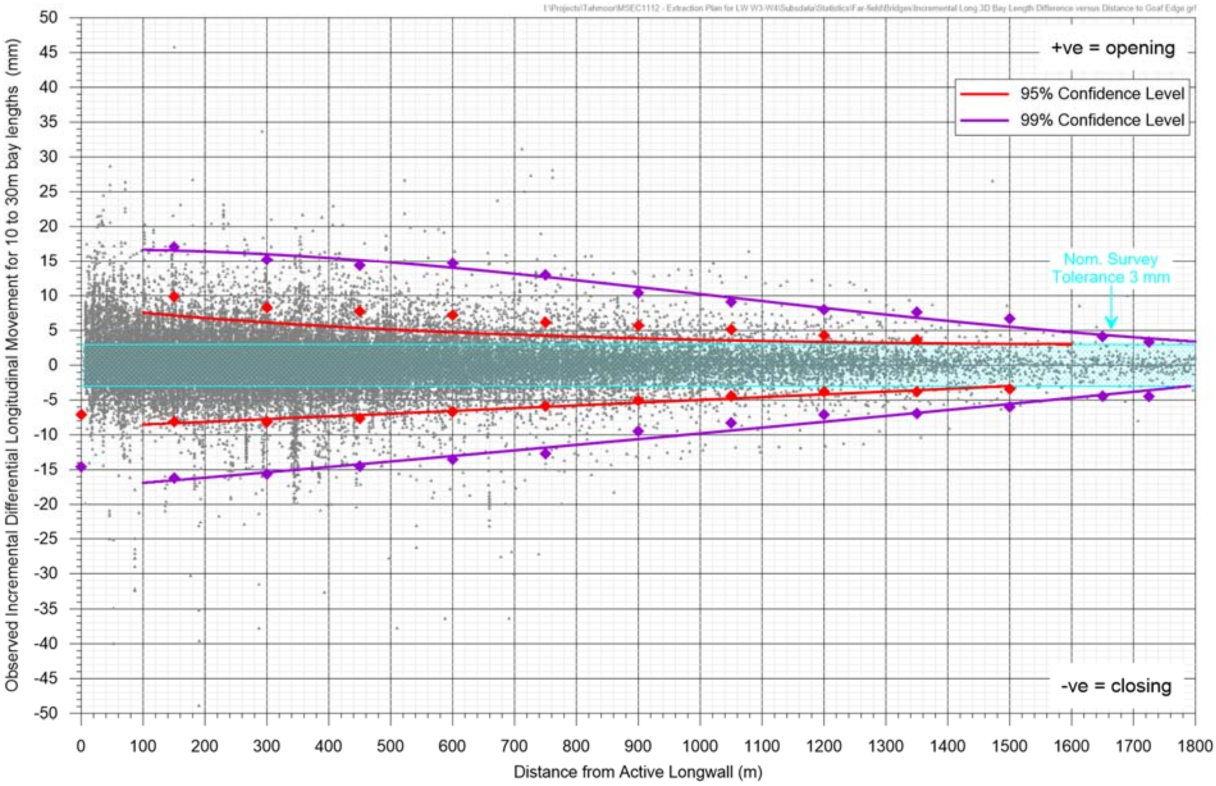

Fig. 4.9 Observed Incremental Differential Horizontal Movements versus Distance from Active Longwall for Marks Spaced at 20 metres ±10 metres

Mid-ordinate deviation is a measure of differential lateral movement, which is the change in perpendicular horizontal distance from a point to a chord formed by joining points on either side. A schematic sketch showing the mid-ordinate deviation of a peg compared to its adjacent survey pegs between two survey epochs is provided in Fig. 4.10.

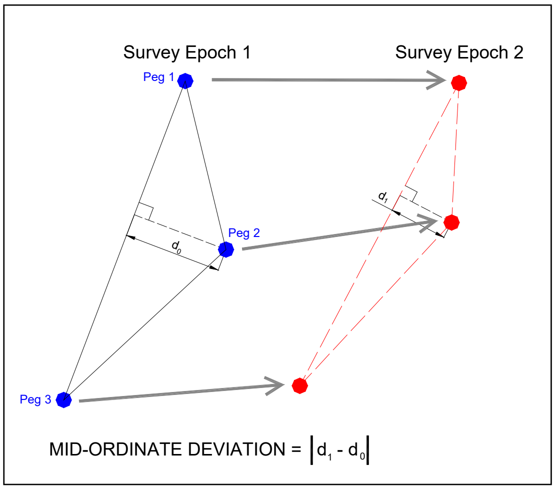

Fig. 4.10 Schematic Representation of Mid-Ordinate Deviation

The distribution of the observed incremental horizontal mid-ordinate deviation for survey marks spaced at 20 metres ±10 metres, relative to the distance from the active longwall, is shown in Fig. 4.11.

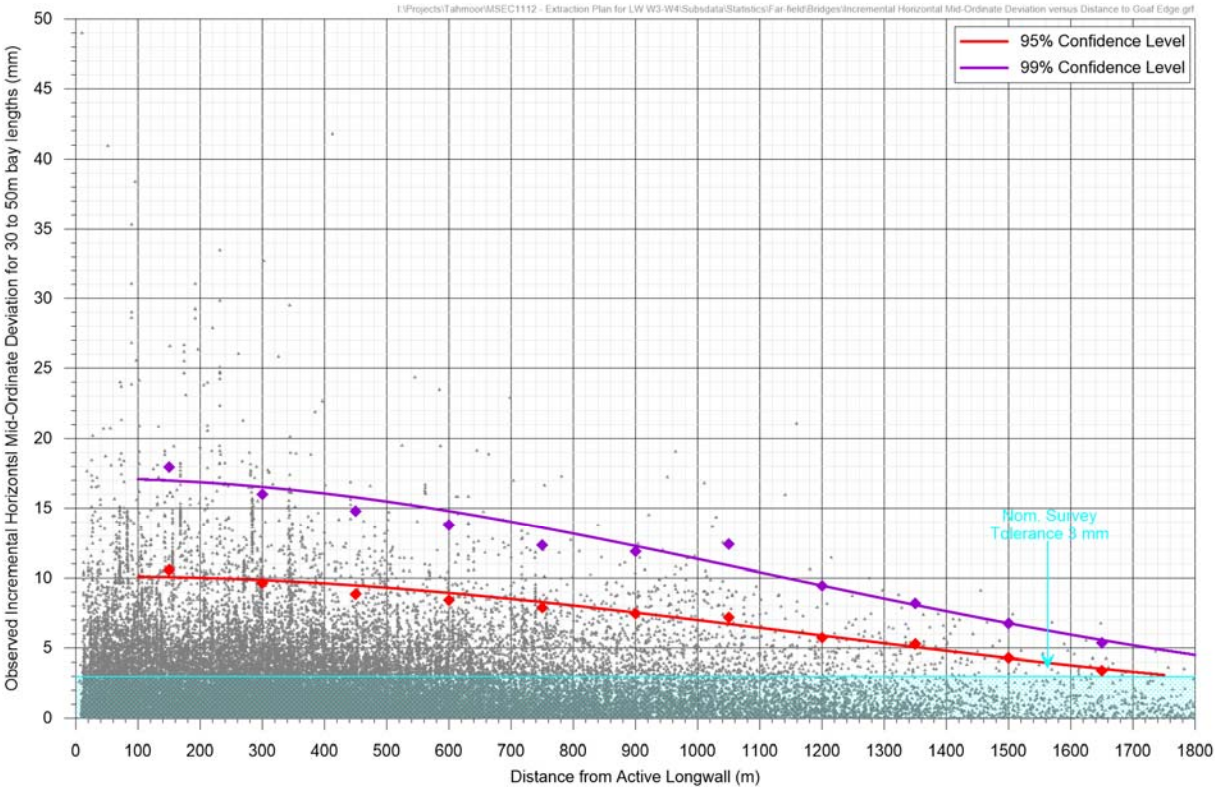

Fig. 4.11 Observed Incremental Horizontal Mid-Ordinate Deviation versus Distance from Active Longwall for Marks Spaced at 20 metres ±10 metres

The predicted far-field differential horizontal movements have been determined from the empirical data using the fitted GPDs based on the 95 % confidence levels. In the cases where survey marks or survey bays were measured multiple times during a longwall extraction, the maximum opening, maximum closing and maximum horizontal mid-ordinate deviation were used in the analysis (i.e. single measurement per survey mark or survey bay).

A summary of the maximum incremental differential longitudinal movements and horizontal mid-ordinate deviation, based on the 95 % confidence levels for the fitted GPDs, is provided in Table 4.7. It is noted, that a large proportion of these measured movements comprise survey tolerance, which is around ±3 mm.

Table 4.7 Maximum Observed Far-field Differential Horizontal Movements based on Monitoring Data from the Southern Coalfield

Distance from the Active Longwall (m)	Observed Differential Movement based on a 95 % Confidence Level		
	Maximum Incremental Longitudinal Opening over a 20 metre Bay Length (mm)	Maximum Incremental Longitudinal Closing over a 20 metre Bay Length (mm)	Maximum Incremental Horizontal Mid-Ordinate Deviation over a 40 metre Bay Length (mm)
200	9	8	10
600	8	7	9
1,200	4	4	6
1,800	3	3	3

The impact assessments for the larger infrastructure located outside the Study Area, due to these far-field horizontal movements, are provided in Chapter 6.

4.7. Non-conventional ground movements

It is likely non-conventional ground movements will occur within the Study Area, as discussed in Section 3.4. These non-conventional movements are often accompanied by elevated tilts and curvatures that 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 and 5.4. 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 5.7.

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 NSW coalfields, 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 features and items of surface infrastructure, which are provided in Chapters 5 and 6, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

Mining beneath urban and semi-rural areas at Tahmoor and Thirlmere by LWs 22 to 32 provides valuable “whole of panel” information. A plan showing the locations of observed non-conventional movements at Tahmoor is shown in Fig. 4.12. The locations were selected based on ground monitoring results or observed impacts that appear to have been caused by non-conventional movement. A total of approximately 59 locations (not including valleys) have been identified over the extracted Longwalls 22 to 32.

The surface area directly above the longwalls is approximately 9.1 km^2. This equates to a frequency of 6 sites per square kilometre or one site for every 16 hectares. The non-conventional movements were mainly characterised by elevated compressive ground strains that varied up to a maximum of approximately 5 mm/m.

The largest known case of non-conventional movement in the Southern Coalfield occurred above Appin Colliery Longwall 408 (Swarbrick *et al*, 2007). 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/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/week.

A recent example occurred at a low angle fault that intersected the Main Southern Railway in the Deviation Cutting at Tahmoor, which was located directly above Longwall 29. The site was monitored extensively during the mining of Longwalls 28 to 31. This included three monitoring lines along the railway cutting, and survey prisms along the railway track.

The results of observed changes in vertical alignment of the pegs along the railway cutting are shown in Fig. 4.13. It can be seen that the most significant changes occurred during the mining of Longwall 29. The changes, however, developed gradually over time, allowing the railway track to be adjusted such that trains could continue to travel through the site.

The observations of the gradual development of differential movements have been consistently observed during the mining of previous longwalls at Tahmoor Mine. While some sites have experienced severe impacts, the subsidence movements developed gradually, allowing time for repair before they became unsafe.

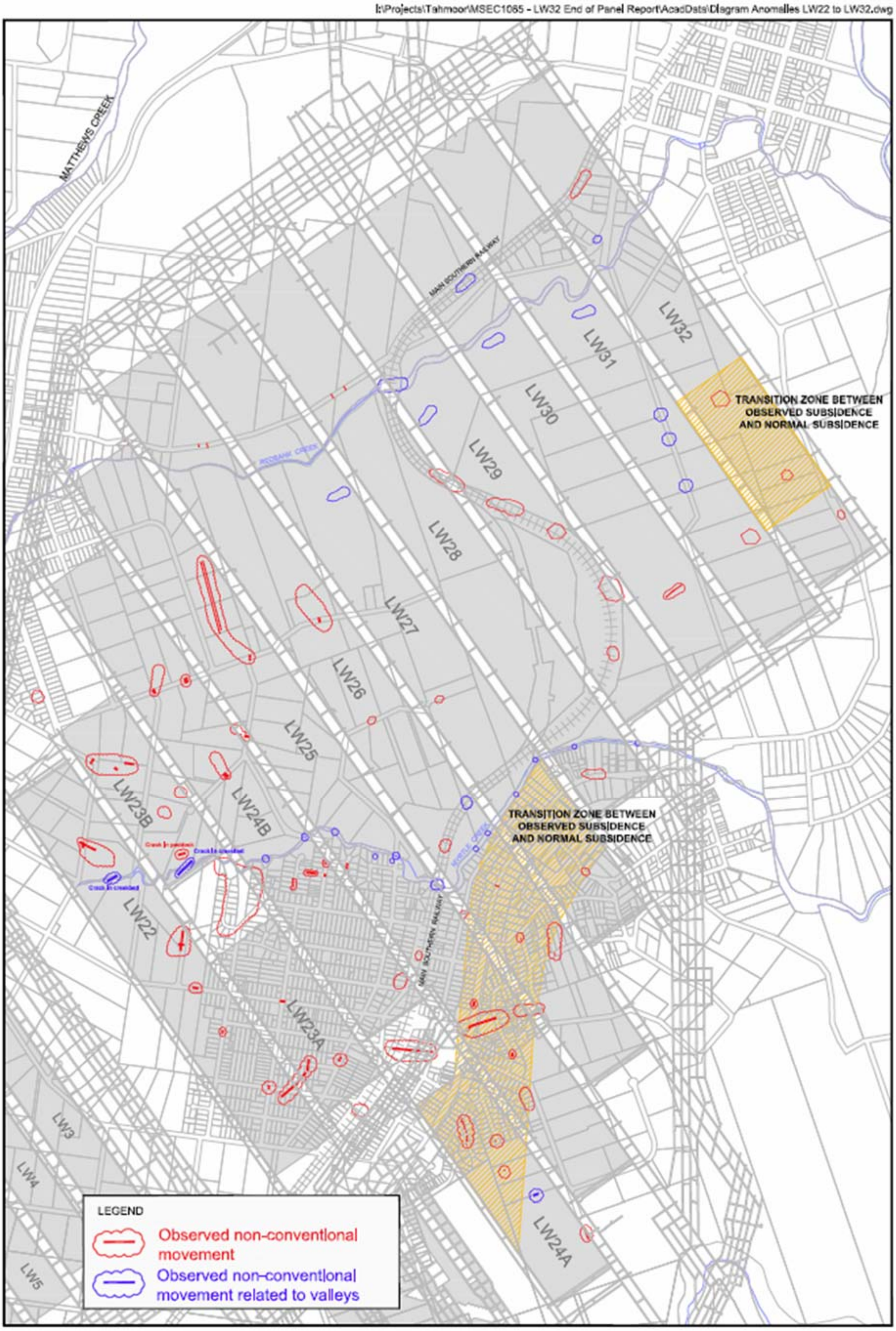

Fig. 4.12 Map of Locations of Potential Non-Conventional Movements above LWs 22 to 32

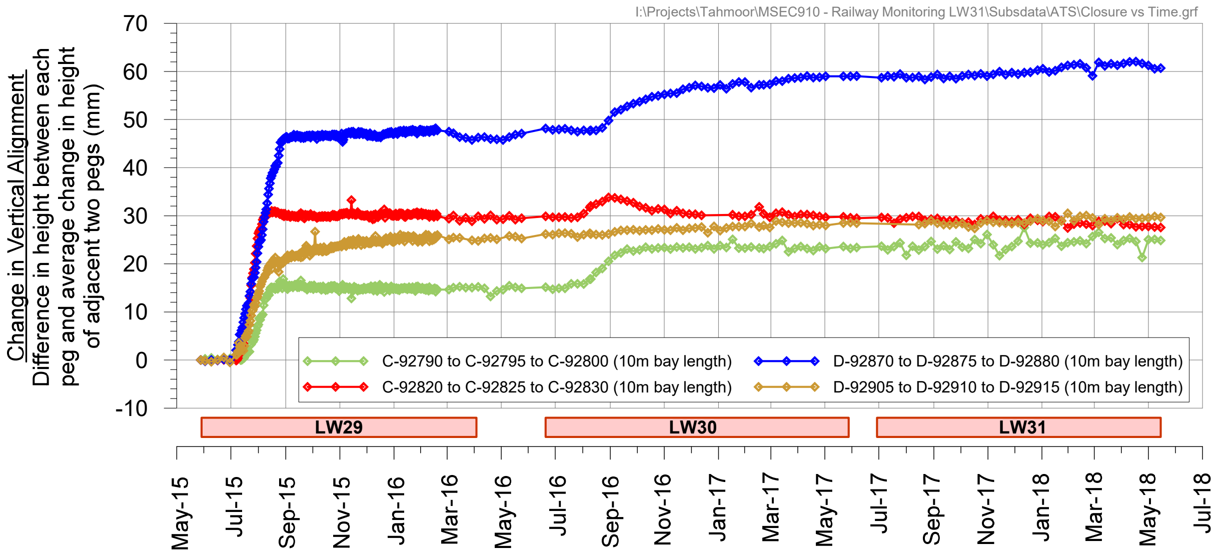

Fig. 4.13 Changes in vertical alignment across a geological fault within a railway cutting during the mining of Longwalls 29 to 31 at Tahmoor Coal

Relatively minor non-conventional movements were observed during the mining of LW W1. The greatest movements were observed across the creek crossing at 88.400 km on the Picton to Mittagong Loop Line. Valley closure movements were also observed across Carramar Close, which was paved over a natural stream.

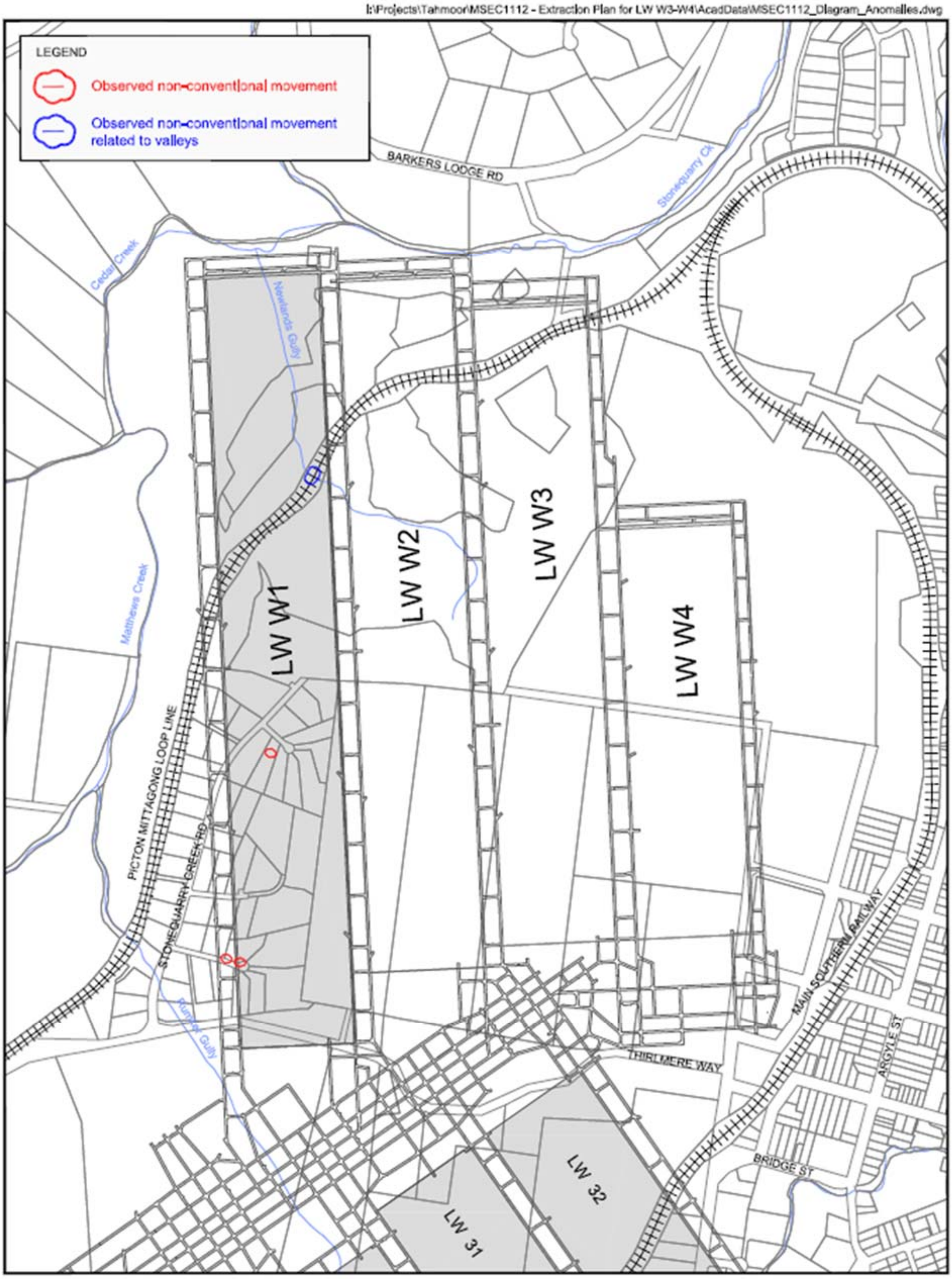

Fig. 4.14 Map of Locations of Potential Non-Conventional Movements above LW W1

4.8. Surface 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 several 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 destressing 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.

The depths of cover within the Study Area are greater than 400 metres. Cracking in the surface soils as the result of conventional subsidence movements are not commonly observed at these depths of cover, in areas away from valleys and steep slopes. Surface cracking that has been observed as the result of conventional subsidence movements has generally been relatively isolated and of a minor nature.

Surface deformations can also develop as the result of downslope movements where longwalls are extracted beneath steep slopes. In these cases, the downslope movements can result in the development of tension cracks at the tops and on the sides of the steep slopes and compression ridges at the bottoms of the steep slopes. The impact assessments for downslope movements are provided in Section 5.7.

Fracturing of bedrock can also occur in the bases of stream valleys due to the compressive strains associated with valley upsidence and closure movements. The impact assessments for valley-related movements are provided in Sections 5.3 and 5.4.

The following sections provide descriptions, predictions and impact assessments for the natural features located within the Study Area. All significant natural features located outside the Study Area, which may be subjected to far-field movements or valley-related movements and may be sensitive to these movements, have also been included as part of this review.

5.1. Catchment Areas and Declared Special Areas

There are no catchment areas or declared special areas within the Study Area. The nearest catchment area is the Warragamba Special Area, and its closest point to the proposed longwalls is at Thirlmere Lakes National Park, which is located approximately 5.1 km southwest of the proposed longwalls.

5.2. Rivers

There are no rivers within the Study Area. The closest river is the Nepean River located more than 3 km southeast of LW W3-W4. At this distance, the Nepean River will not experience measurable movements due to the extraction of the proposed longwalls. Adverse impacts are not anticipated even if the actual ground movements exceed the predictions by a factor of two times.

5.3. Creeks

5.3.1. Descriptions of the creeks

The locations of the named creeks within the Study Area are shown in Drawing No. MSEC1112-09.

The NSW Government's Strategic Review into the Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield (DoP, 2008) recommended that risk management zones (RMZs) be applied to all streams of third order or above, in the Strahler stream classification. The stream orders, as mapped in the Strategic Review, are shown in Drawing No. MSEC1112-09.

The details of the creeks are provided in Table 5.1.

Table 5.1 Creeks located within the Study Area

Location	Strahler stream order within Study Area (incl. 600 m of LW W3-W4)	Total length within Study Area (km)	Total length within 600 m of LW W3-W4 (km)	Minimum distance of the creek thalweg / centreline from LW W3-W4 (m)
Cedar Creek	Fifth order	-	0.37	350 m northwest of the commencing end of LW W3
Stonequarry Creek	Fifth order	0.88	1.67	120 m north of the commencing end of LW W3
Redbank Creek	Fourth order	-	0.22	600 m southeast of finishing end of LW W4

Matthews Creek is located outside the Study Area and is more than 750 metres from LW W3-W4. Subsidence predictions have been provided in this report for Matthews Creek for completeness, as it was within the influence of LW W1-W2.

A cross-section through Stonequarry Creek, where it is located near to LW W3 is provided in Fig. 5.1. The angle between the proposed LW W3 and the thalweg of the creek is also shown in the figure.

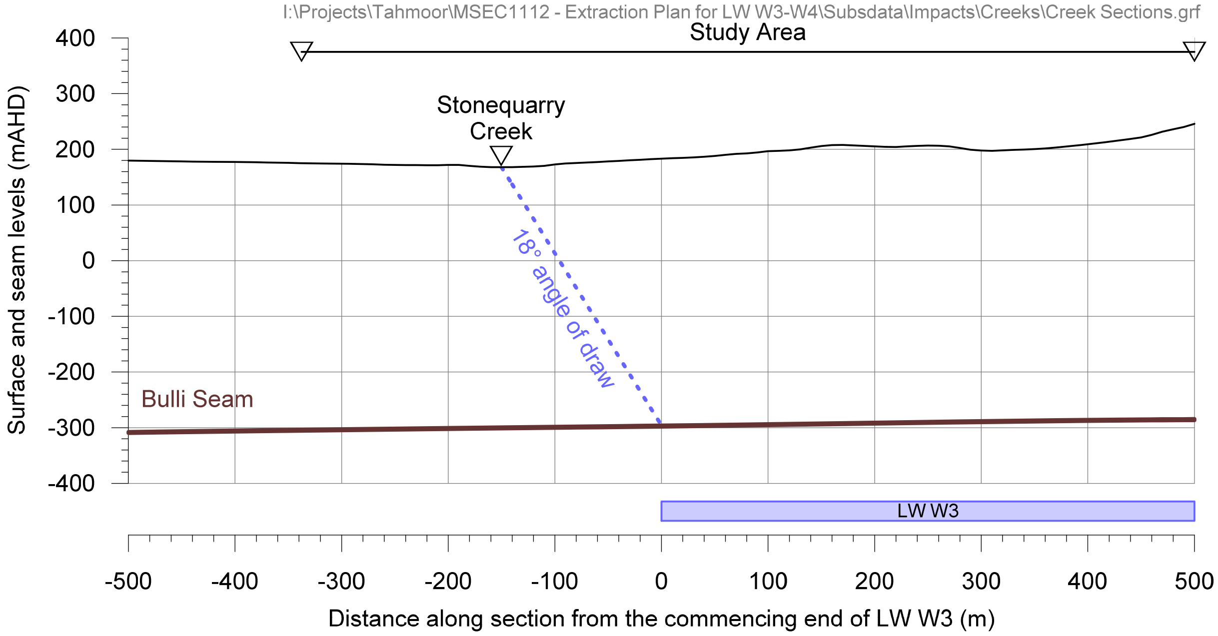

Fig. 5.1 Cross-section through Stonequarry Creek and LW W3

The sections of the creeks located within 600 m of LW W1-W2 have been mapped by the specialist surface water consultant (GeoTerra, 2014) and surface water monitoring and assessments have been conducted by HEC (2020). The pools along the streams have flow controlling features along their alignments that include rockbars, boulders, tree roots and gravel. The locations of pools along these streams were determined by GeoTerra and are shown in Drawing No. MSEC1112-09.

The mapped stream features for Matthews, Cedar and Stonequarry Creeks are provided in Tables D.01, D.02 and D.03, respectively, in Appendix D.

Cedar Creek

Cedar Creek is located to the west and north of LW W3. The catchment of this creek mainly consists of rural properties. This creek flows into Stonequarry Creek adjacent to the commencing end of LW W2. The last 370 metres of the downstream end of Cedar Creek is located within 600 metres of LW W3-W4. The base of Cedar Creek falls 2 m over this section, which is an inferred average gradient of 5.4 mm/m (i.e. 0.5 %, or 1 in 200).

Cedar Creek flows over predominantly Hawkesbury Sandstone bedrock, though it can be seen that sediments are present on the banks of some pools. There are a number of channel constraints including rockbars, boulders and rock shelves, which form standing pools along the alignment of the creek. The downstream end of Cedar Creek has flatter gradients, with water flowing over sand substrate.

Monitoring of Cedar Creek during a period of prolonged drought prior to and during the early stage of mining of LW W1 found that pools at the downstream end of Cedar Creek remained full with a trickle flow observed out of the majority of the pools. The sand substrate along the lower reaches of Cedar Creek near the confluence with Stonequarry Creek had no observable surface flow, though the stream would have been flowing into Stonequarry Creek through the sand. Pools in this section were either dry or at low levels. Surface water flows returned following the significant rain event in February 2020.

Example photographs of the sections of Cedar Creek that are within 600 metres of LW W3-W4 are shown in Fig. 5.2 to Fig. 5.4. The photographs show the pools during and after the prolonged drought period.

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5.3.4. Observed closure across rockbars in creeks during the mining of LW W1

Tahmoor Coal installed survey marks across rockbars in Cedar, Matthews and Stonequarry Creeks, and the long Pool SR17, prior to the commencement of LW W1.

The 47 survey locations are shown in Drawing No. MSEC1112-30. A total of 14 locations have been installed across Stonequarry Creek, 14 locations across Cedar Creek and 19 locations across Matthews Creek.

In some cases, it was only possible to install a pair of survey marks at each end of the rockbar or across the pool. These surveys measure closure across the rockbar or pool and changes in height between the marks.

In other cases in Cedar Creek and Matthews Creek, it was possible to install survey marks across rockbars. In addition to measuring closure, it is also possible to detect whether upsidence has occurred at these rockbars.

A comparison between observed and predicted valley closure along Stonequarry Creek is shown in Fig. 5.26.

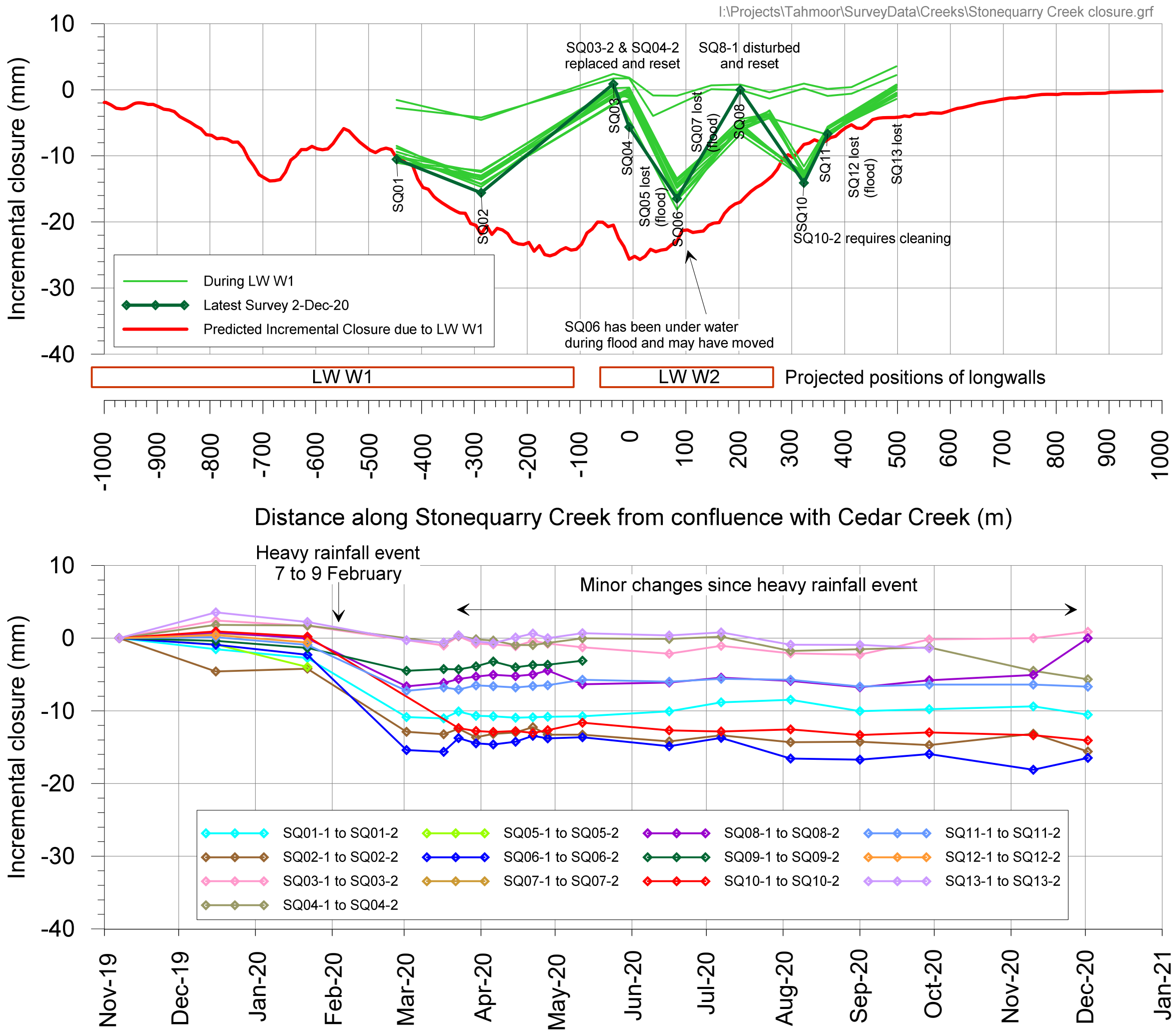

Fig. 5.26 Comparison between observed and predicted valley closure along Stonequarry Creek

An early challenge for the survey program occurred when several pegs were disturbed, damaged or destroyed following heavy rainfall on 7 to 9 February 2020. The length of extraction at this time was approximately 320 metres. The survey marks were reinstated as soon as water levels had fallen and debris had been cleared. The first re-survey after the rain event was on 2 March, which was 40 days after the previous survey on 22 January.

The GNSS units located along Stonequarry Creek were actively moving during this time and some potential closure movements may not have been captured between late January 2020 and mid to late February 2020 where pegs were lost or disturbed.

The survey frequency was therefore increased from monthly to weekly to capture any mining-induced closure that may be developing, and track trends that could indicate how much closure may have occurred when the pegs were lost. As shown in Fig. 5.26, very little change in closure has been observed since the pegs were reinstated. This suggests that very little closure has developed to date across Stonequarry Creek.

A comparison between observed and predicted valley closure along Cedar Creek is shown in Fig. 5.27.

As discussed for the Stonequarry Creek surveys, some survey marks were lost in Cedar Creek following heavy rainfall on 7 to 9 February 2020. The pegs were reinstated on Cedar Creek as soon as water levels had fallen and debris had been cleared. As discussed for Stonequarry Creek, the survey frequency was then increased from monthly to weekly to capture any mining-induced closure that may have been developing, and to track trends that could indicate how much closure may have occurred when the pegs were lost.

As shown in Fig. 5.27, very little change in closure has been observed. This suggests that very little closure has developed to date across Cedar Creek. Very little change was also measured across rockbars in Cedar Creek

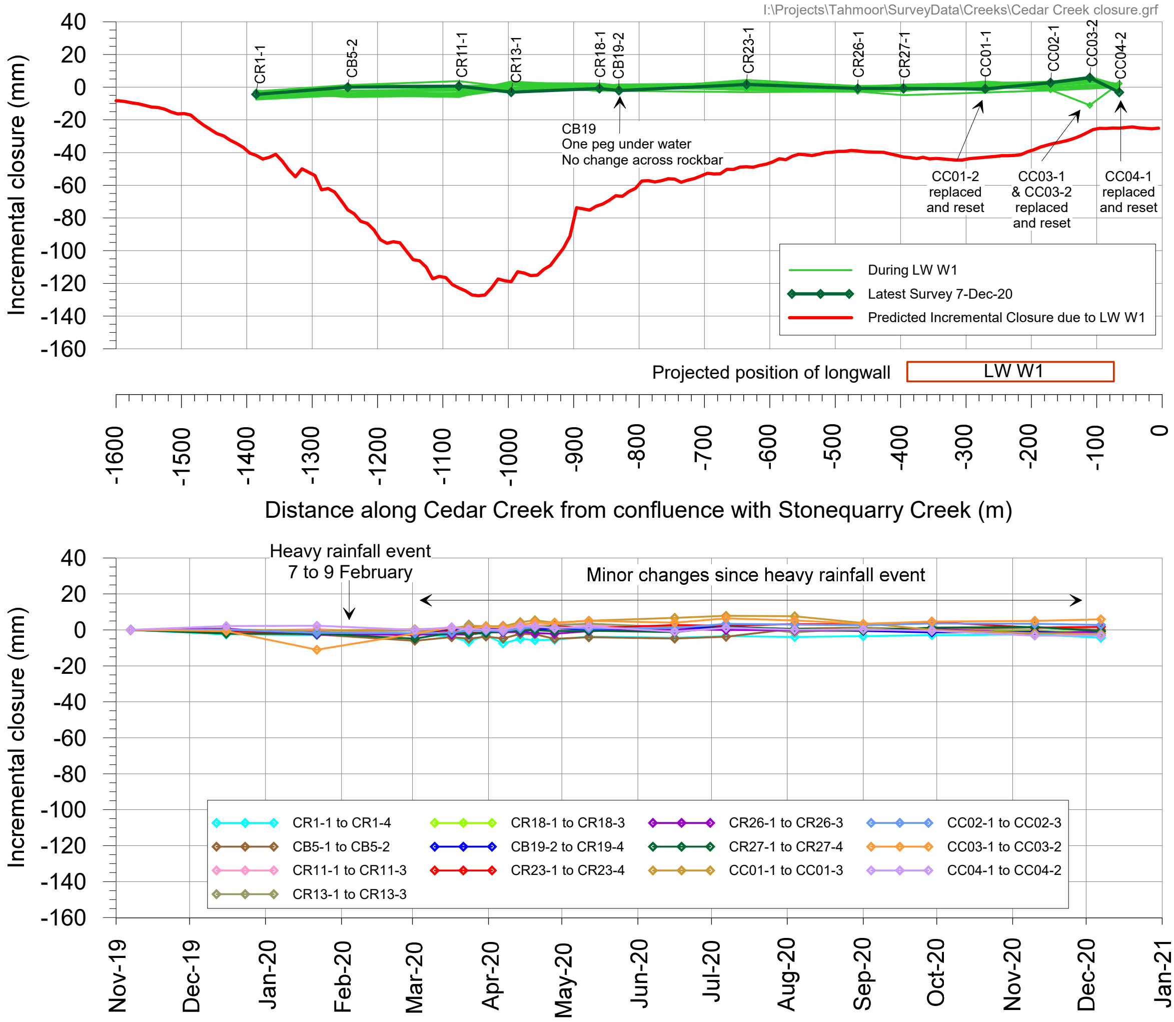

Fig. 5.27 Comparison between observed and predicted valley closure along Cedar Creek

Survey results along three cross lines across Cedar Creek are shown in Fig. 5.28 to Fig. 5.30.

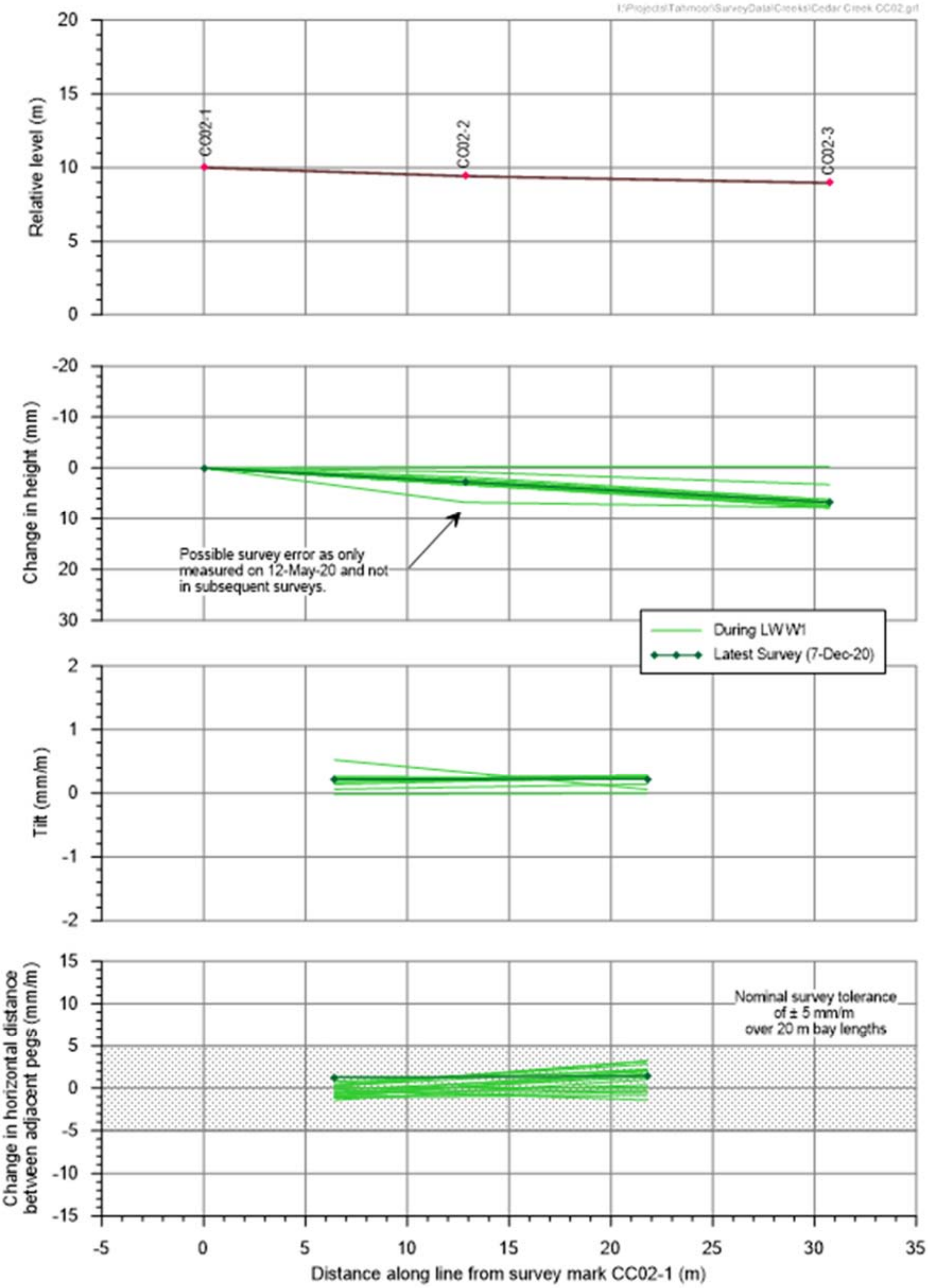

Fig. 5.28 Observed changes in height, tilt and changes in horizontal distances across Cedar Creek at CC02

Survey line CC02 is located approximately 80 metres from the commencing end of LW W1 near the centreline of the panel, as shown in Drawing No. MSEC1112-30. The surveyed heights are measured relative to Peg CC02-1, which is located on the left bank when looking downstream, furthest from LW W1. The survey shows a tilt across the survey line, falling towards LW W1. Measured changes in horizontal distance across the survey line are within survey tolerance.

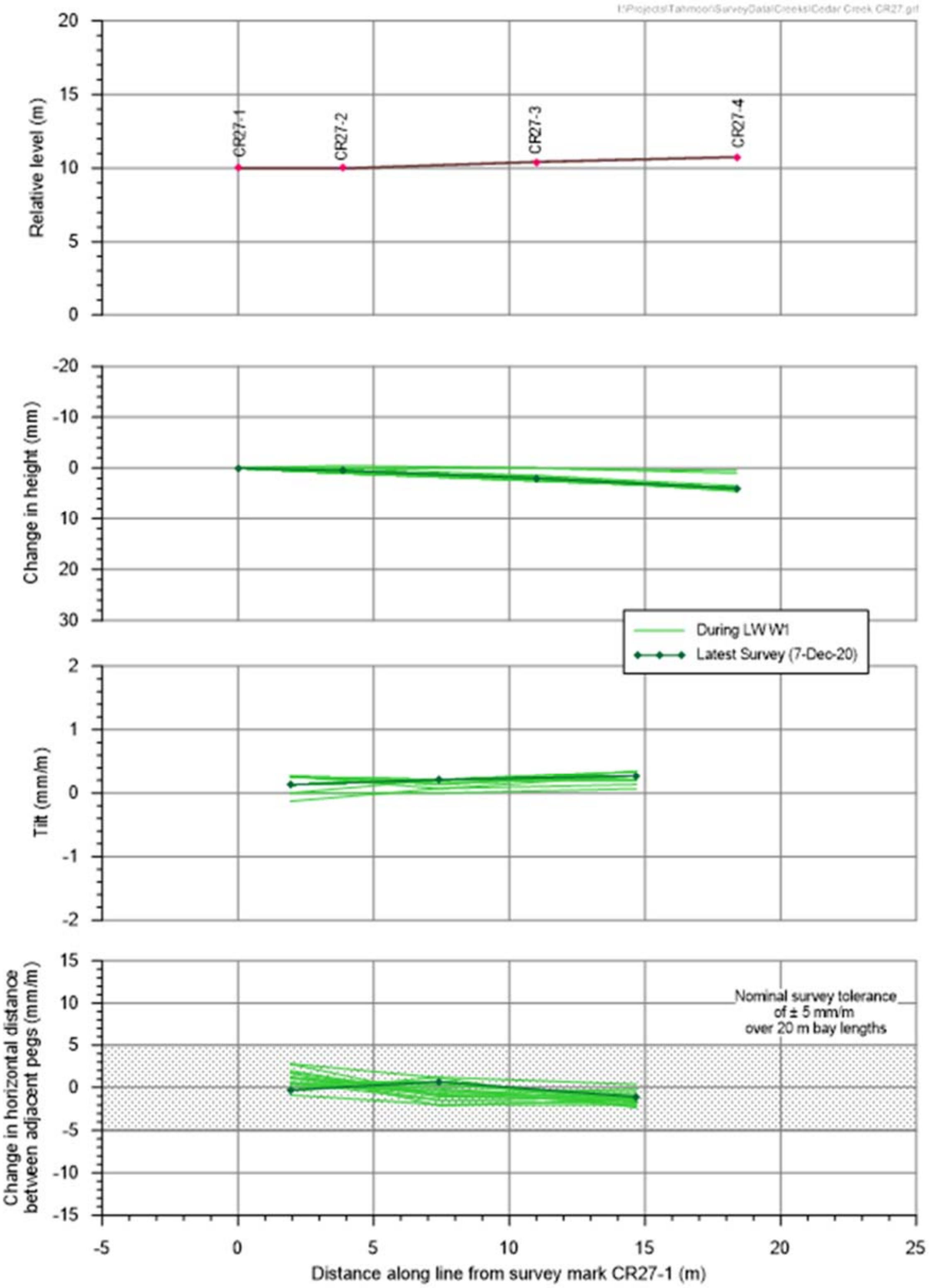

Fig. 5.29 Observed changes in height, tilt and changes in horizontal distances across Cedar Creek at Rockbar CR27

Rockbar CR27 is located approximately 80 metres from the commencing end of LW W1 near the western (tailgate) side of the panel, as shown in Drawing No. MSEC1112-30. The surveyed heights are measured relative to Peg CR27-1, which is located on the left bank when looking downstream, furthest from LW W1. The survey shows a tilt across the survey line, falling towards LW W1. Measured changes in horizontal distance across the survey line are within survey tolerance.

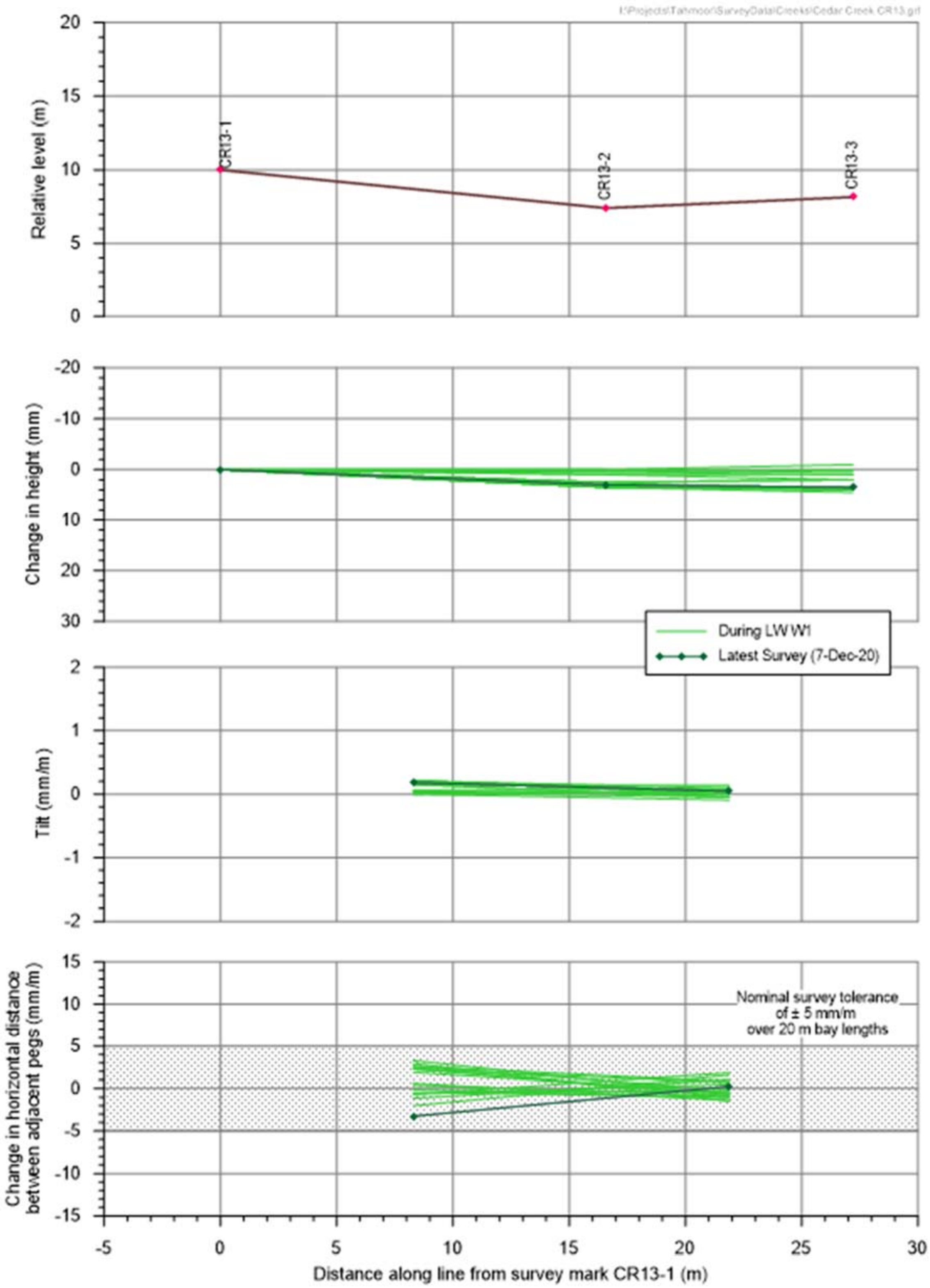

Fig. 5.30 Observed changes in height, tilt and changes in horizontal distances across Cedar Creek at Rockbar CR13

Rockbar CR13 is located approximately 220 metres to the west of LW W1, as shown in Drawing No. MSEC1112-30. The surveyed heights are measured relative to Peg CR13-1, which is located on the left bank when looking downstream, furthest from LW W1. The survey shows a tilt across the survey line, falling towards LW W1. Measured changes in horizontal distance across the survey line are within survey tolerance.

A comparison between observed and predicted valley closure along Matthews Creek is shown in Fig. 5.31. Whilst some marks in Matthews Creek were inaccessible following the large rain event in February 2020, the majority of the marks in Matthews Creek do not appear to have been disturbed.

Minor changes have been observed. Very little change was also observed across rockbars in Matthews Creek. Observed changes in tilt and strain are more variable for pegs spaced closely together, as survey tolerance represents a larger proportion of the measured values.

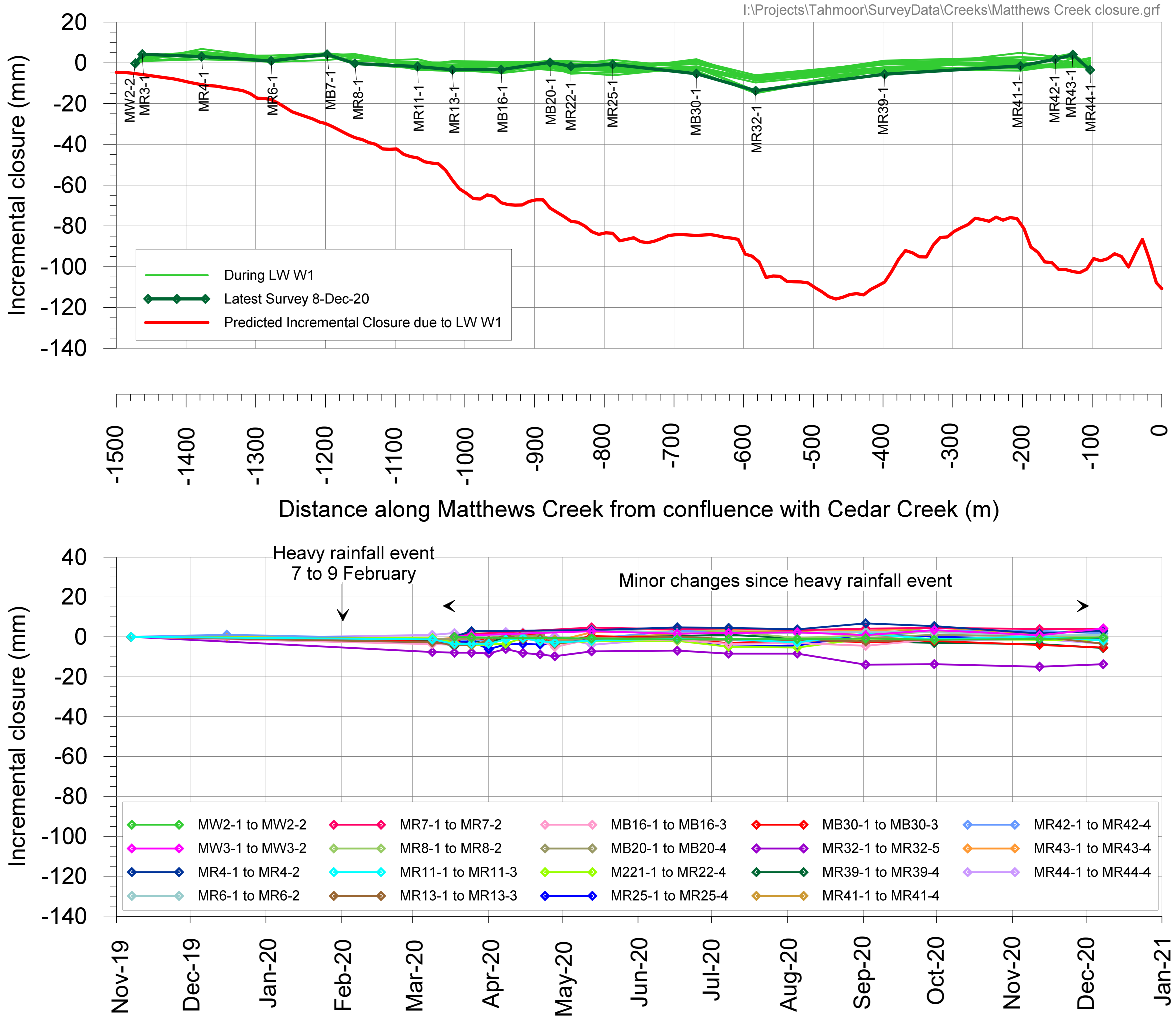

Fig. 5.31 Comparison between observed and predicted valley closure along Matthews Creek

Survey results along four cross lines across Matthews Creek are shown in Fig. 5.32 to Fig. 5.35.

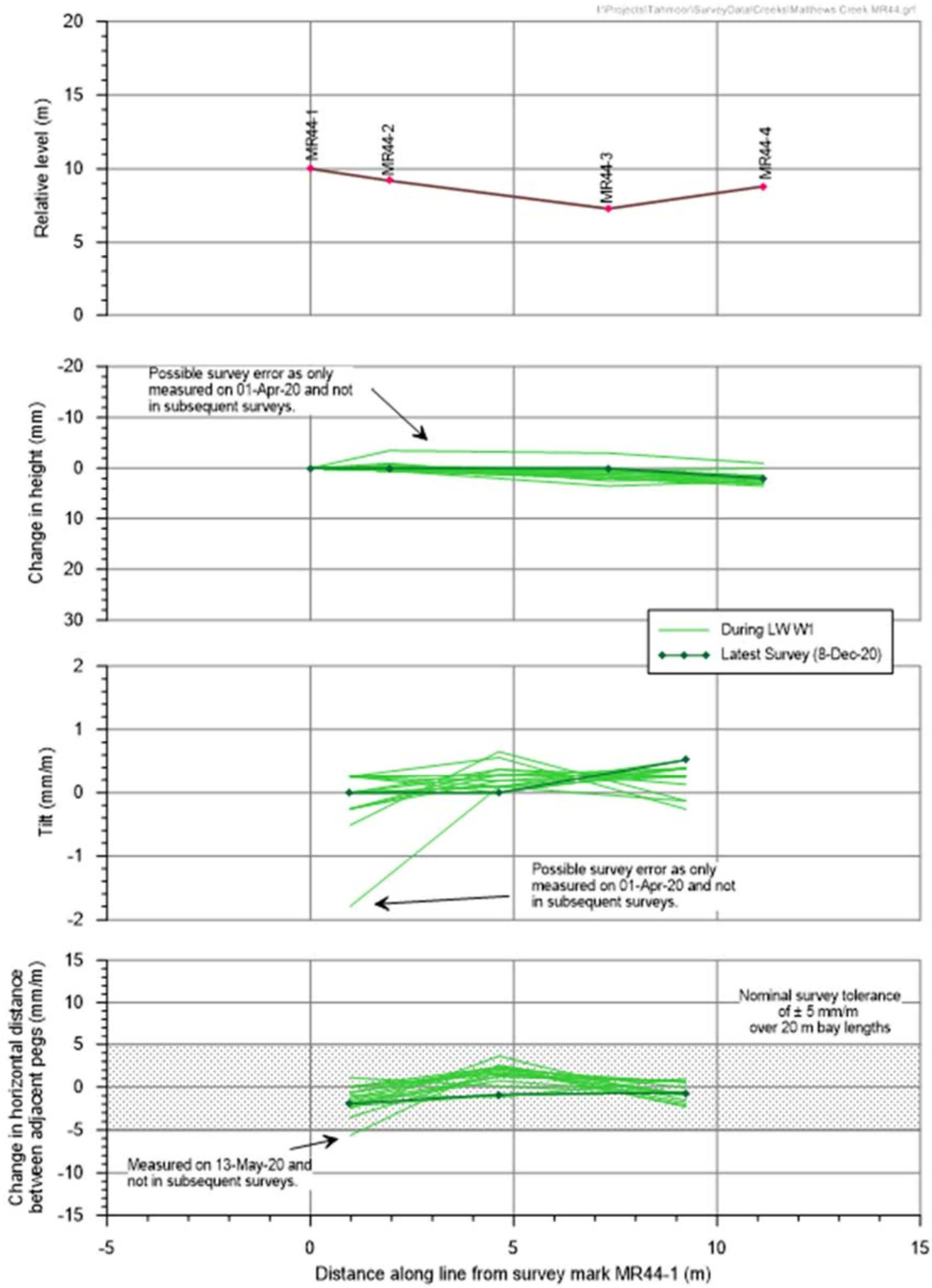

Fig. 5.32 Observed changes in height, tilt and changes in horizontal distances across Matthews Creek at Rockbar MR44

Rockbar MR44 is located approximately 115 metres to the west of LW W1, as shown in Drawing No. MSEC1112-30. The surveyed heights are measured relative to Peg MR44-1, which is located on the left bank when looking downstream, furthest from LW W1. The survey shows very minor tilt across the survey line, falling towards LW W1. Measured changes in horizontal distance across the survey line are within survey tolerance.

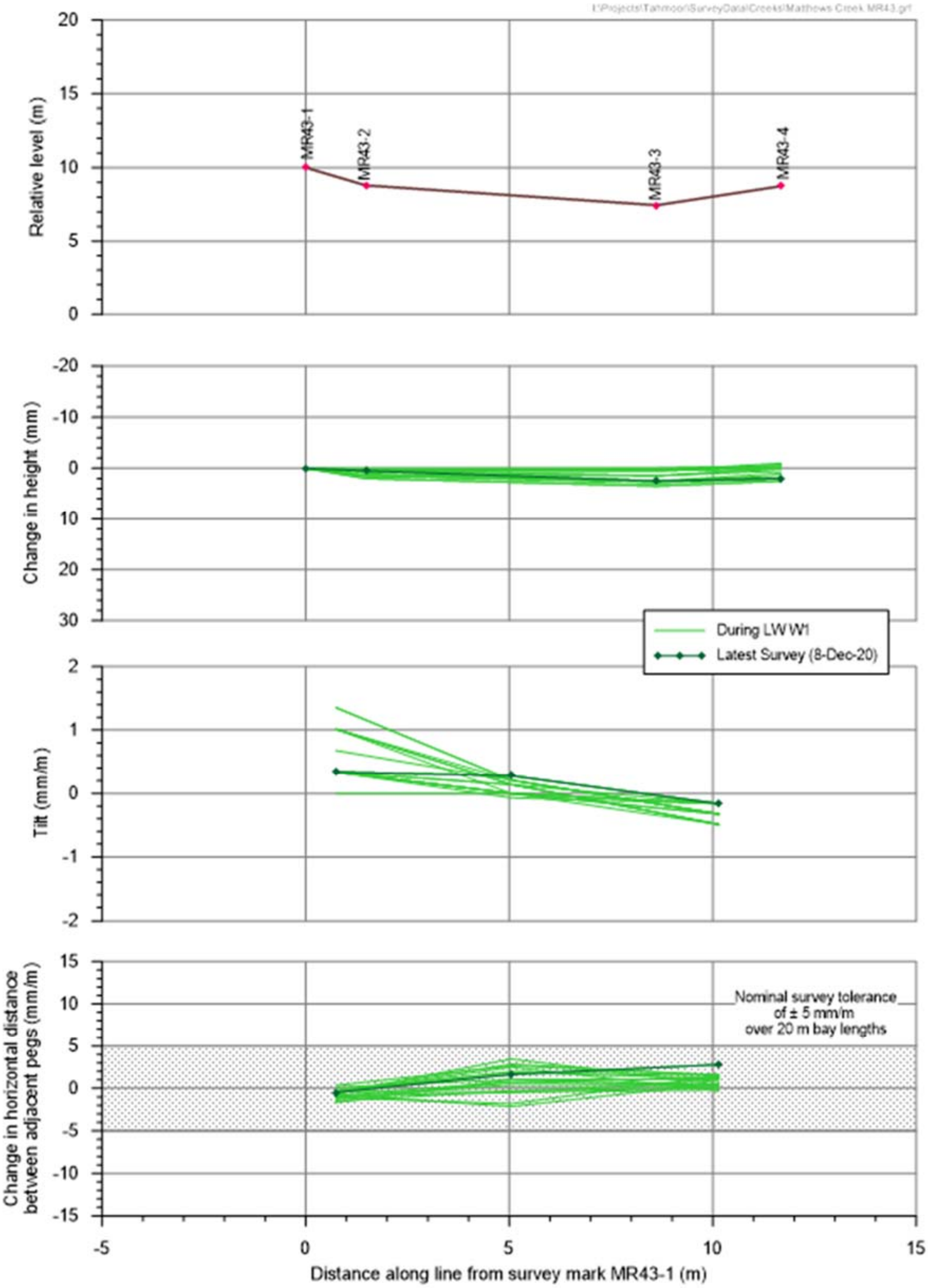

Fig. 5.33 Observed changes in height, tilt and changes in horizontal distances across Matthews Creek at Rockbar MR43

Rockbar MR43 is located approximately 115 metres to the west of LW W1, as shown in Drawing No. MSEC1112-30. The surveyed heights are measured relative to Peg MR43-1, which is located on the left bank when looking downstream, furthest from LW W1. The survey shows very minor tilt across the survey line, falling towards LW W1. Measured changes in horizontal distance across the survey line are within survey tolerance.

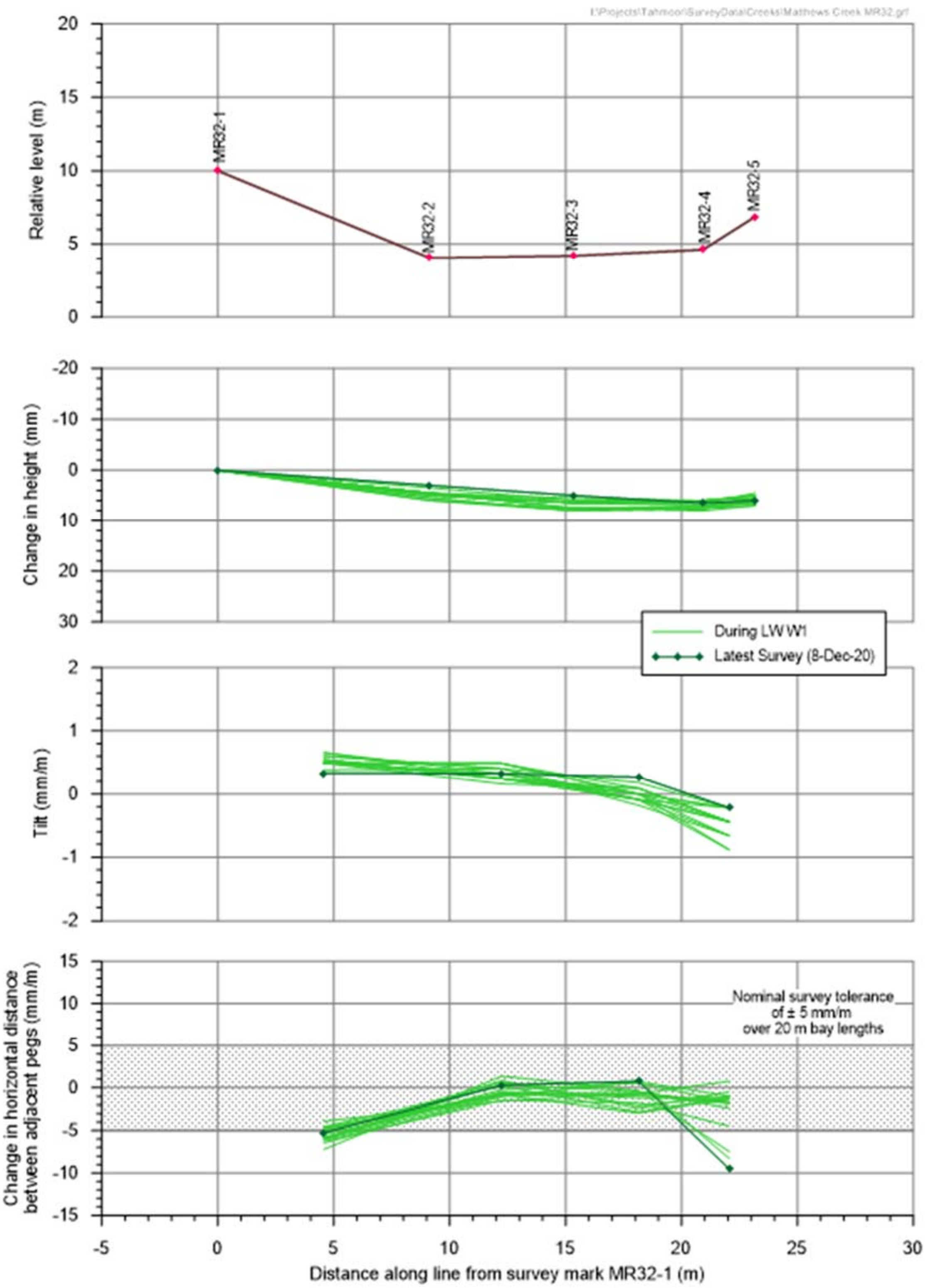

Fig. 5.34 Observed changes in height, tilt and changes in horizontal distances across Matthews Creek at Rockbar MR32

Rockbar MR32 is located approximately 175 metres to the west of LW W1, as shown in Drawing No. MSEC1112-30. The surveyed heights are measured relative to Peg MR32-1, which is located on the left bank when looking downstream, furthest from LW W1. The survey shows a tilt across the survey line, falling towards LW W1.

Closure has been measured between Pegs MR32-1 and MR32-2, and between MR32-3 and MR32-4, which are located at the ends of the rockbar. Measured changes across the central portion of the rockbar are within survey tolerance. No impacts are observed from visual inspections at this rockbar.

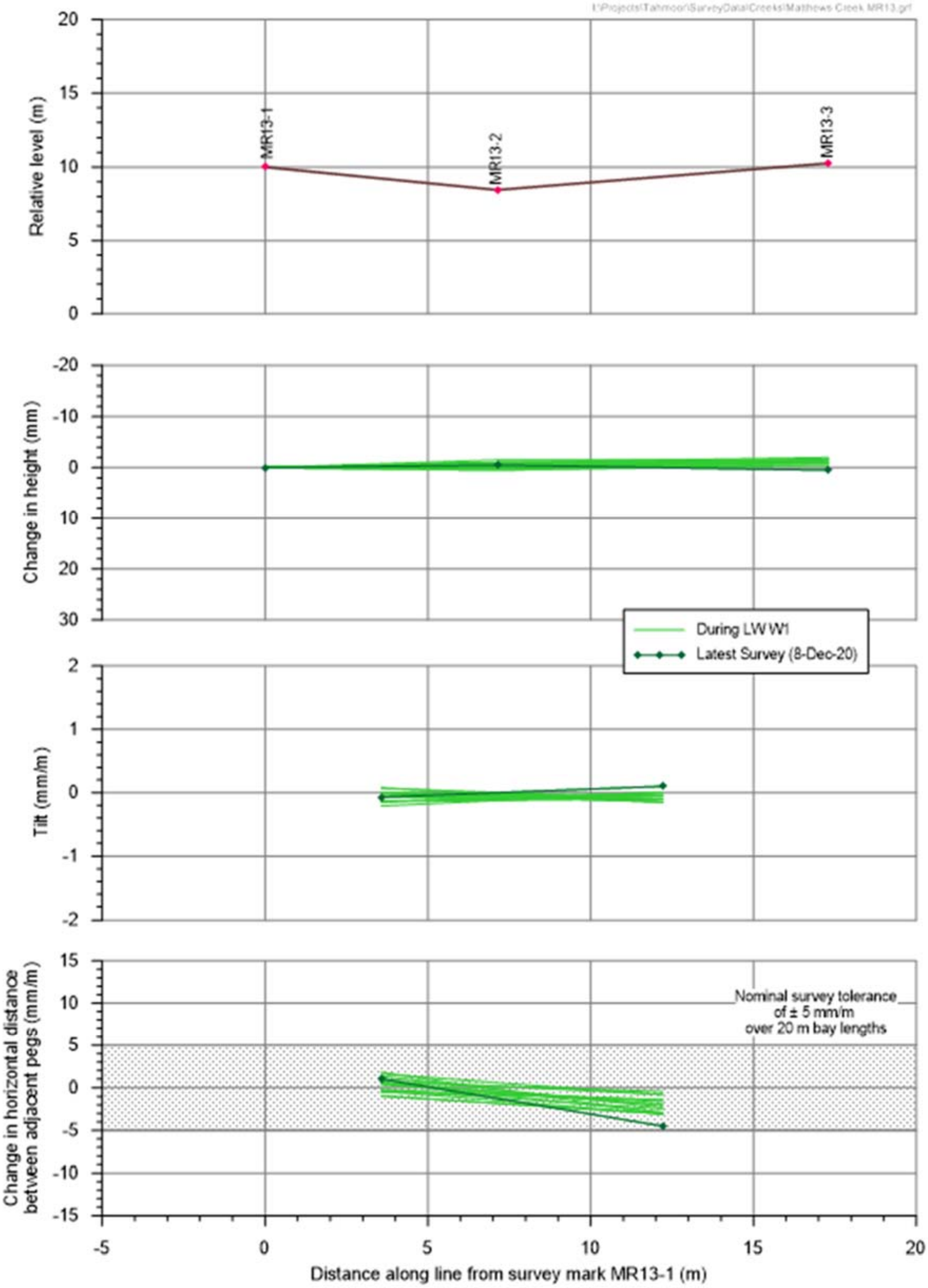

Fig. 5.35 Observed changes in height, tilt and changes in horizontal distances across Matthews Creek at Rockbar MR13

Rockbar MR13 is located approximately 320 metres to the west of LW W1, as shown in Drawing No. MSEC1112-30. The surveyed heights are measured relative to Peg MR13-1, which is located on the left bank when looking downstream, furthest from LW W1. Measured changes in height across the survey line are within survey tolerance. Measured changes in horizontal distance across the survey line are within survey tolerance.

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The upwards movement had first been measured after a heavy rain fall event occurred from 7 to 9 February 2020. Peg RBE15 was inspected by Douglas Partners in April 2020, who confirmed that this peg is located in clay soil while the rest of the pegs are founded in exposed carbonaceous siltstone bedrock or quartz sandstone. The nearby GNSS unit 12 is also located in clay soil and also moved upwards following the rain event. Douglas Partners advise that the measured upward movements of both Peg RBE15 and GNSS unit 12 are likely to be due to swelling of clay soil following the heavy rainfall event on 7 to 9 February 2020.

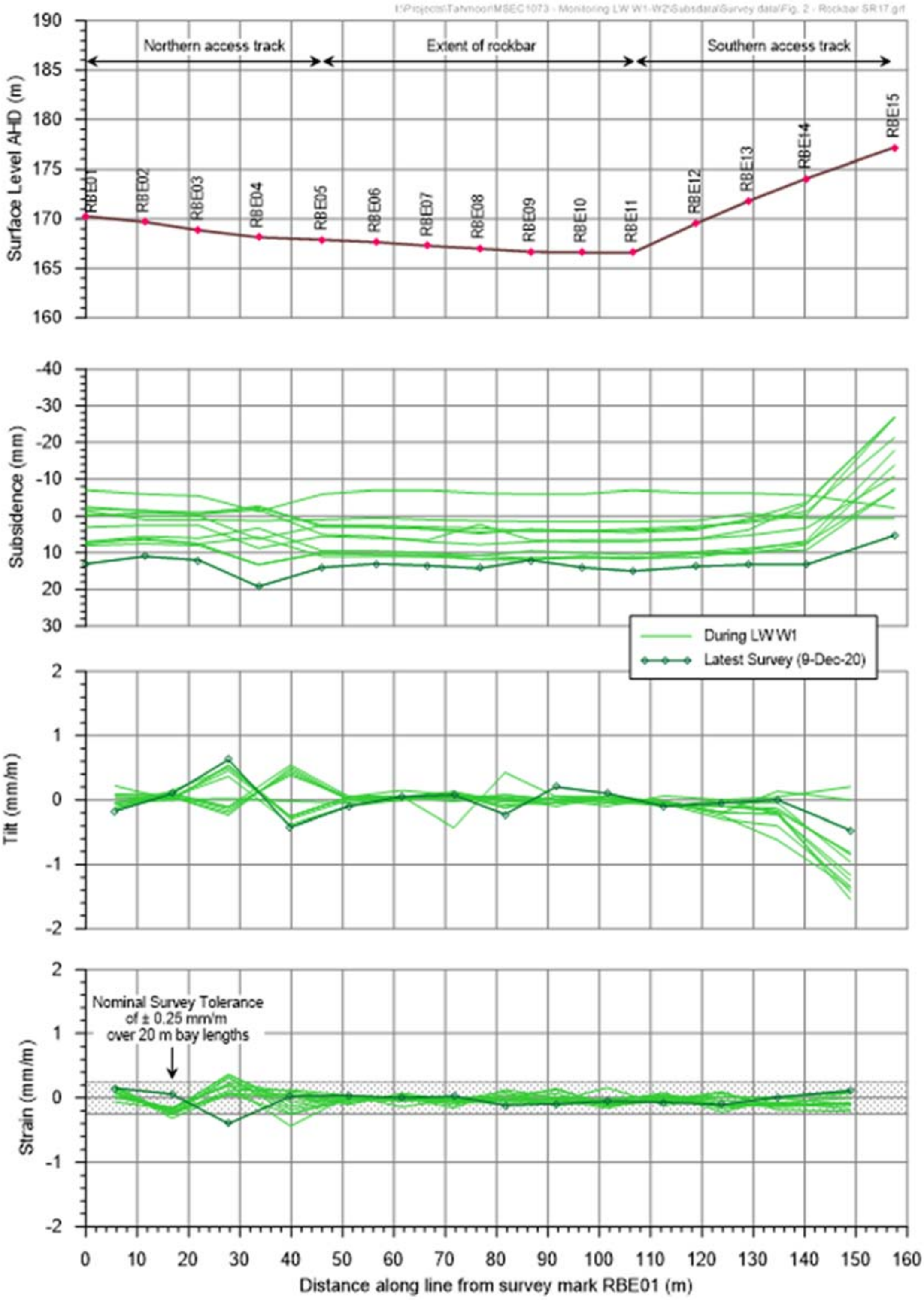

Fig. 5.37 Observed incremental subsidence profiles across Rockbar SR17

Minor changes in horizontal distances were observed both along and across the rockbar, as shown in Fig. 5.38.

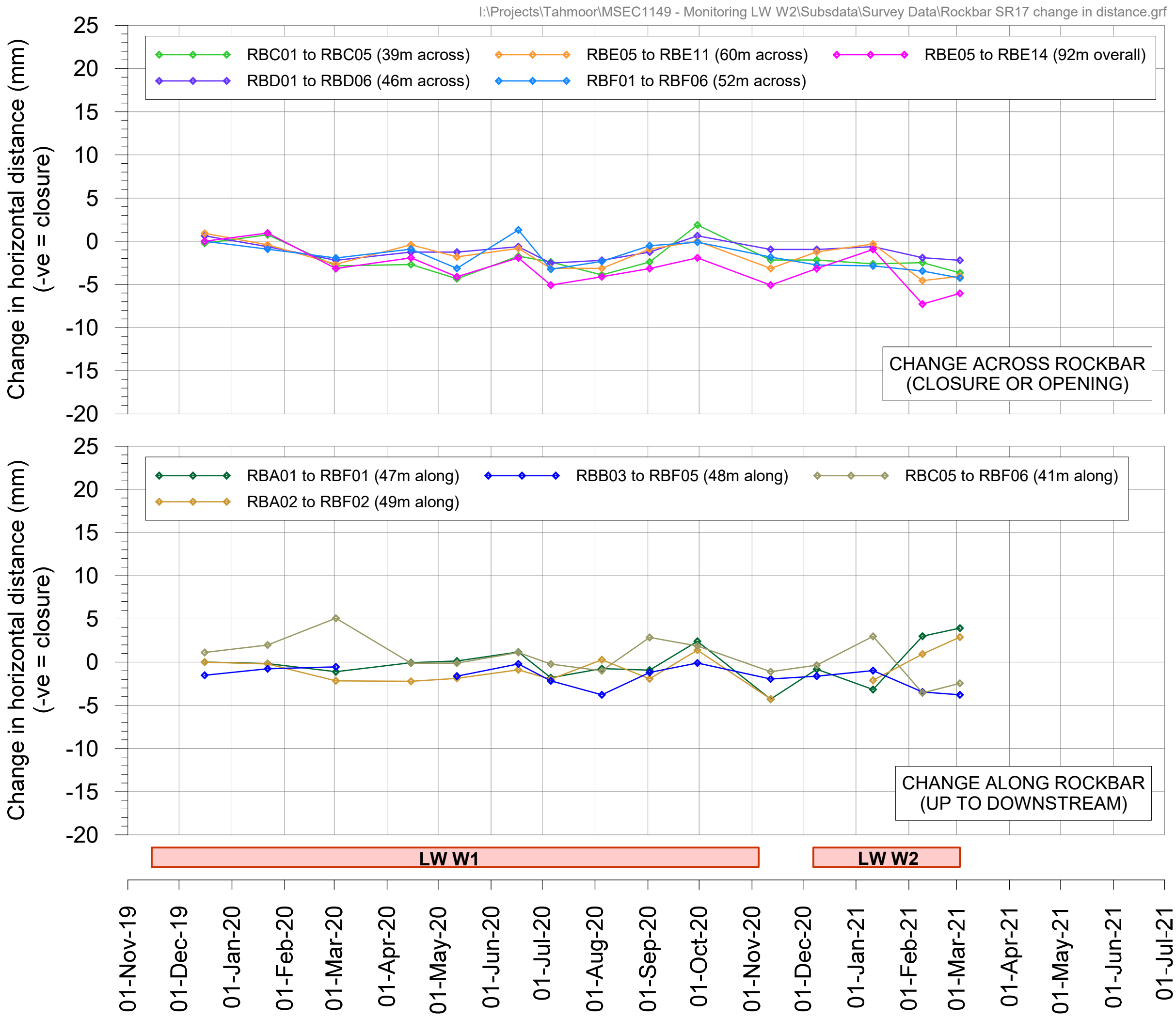

Fig. 5.38 Observed changes in distance across and along Rockbar SR17 during LW W1-W2

5.3.6. Observations from visual inspections during the mining of LW W1

Visual inspections along the streams were conducted by GeoTerra.

Visual inspections prior to the commencement of LW W1 and in December 2019 found that there were no connective overland water flows in Matthews Creek due to the prolonged drought. Most pools were dry with a few pools holding water at low to medium levels. No connective overland water flows were observed in Cedar Creek upstream of the confluence with Matthews Creek due to the prolonged drought. Most pools were dry with a few pools holding water at low to medium levels. Downstream of Matthews Creek, pools in Cedar Creek were full, with a trickle flow observed out of the majority of the pools. There was no flow over the sand substrate at the lower reaches of Cedar Creek near the confluence with Stonequarry Creek. Water levels in the long pool SR17 in Stonequarry Creek fell below the Cease to Flow level in late October 2019.

An inspection was conducted on 22 January 2020 following a series of rain events between 8 and 21 January. Pools that were previously dry were observed to contain water and the overland flow was observed over the previously dry lower reaches of Cedar Creek. An inspection was conducted on 27 February 2020 following a large rain event on 7 to 9 February 2020. Higher volumes of connective flow and flood levels were observed in Matthews, Cedar and Stonequarry Creeks.

Small but reasonably persistent gas bubbles have been observed at 6 sites in Pool MR45 in Matthews Creek. The bubbles were not observed during baseline inspections. Bubbles were observed in Pool MR45 on 24 March, 24 April, 26 May and 25 June 2020. The gas discharge had almost stopped on 25 June. No gas bubbles were detected on 24 July, 24 August, 21 September and 20 October. No reduction in pool water levels were observed.

Sampling and analysis of the gas emissions by Tahmoor Coal indicates that the gas is likely to have been emitted from the shallow Hawkesbury Sandstone and/or shall anoxic muddy alluvium. Whilst there is no survey line across Pool MR45, it is noted that surveys across Rockbar MR44 immediately upstream have measured changes in horizontal distances that are within survey tolerance, as shown in Fig. 5.32. To place the observations in context, gas bubbles were also observed in Stonequarry Creek in Pool SR17 prior to the commencement of mining in June 2019, and bubbles were observed at the same locations in February 2020.

As the bubbles may represent a mining-induced impact, they are considered to have exceeded the Level 3 TARP trigger level in the Water Management Plan. Monitoring of gas bubbling will continue during the mining of LW W2, in accordance with the Water Management Plan.

No subsidence related creek bed cracking or increased iron hydroxide precipitation is evident.

5.3.7. Observations from surface water monitoring during the mining of LW W1

Observations from surface water monitoring are described in the report by HEC (2021). Water flows and pool levels in Matthews Creek, Cedar Creek and Stonequarry Creek were at historically low levels at the commencement of LW W1 in November 2019 due to prolonged drought conditions. Following rainfall events in mid-January to February 2020, the streamflow rates and water levels have increased at the monitoring sites.

No surface water impacts have been observed in Matthews Creek and Stonequarry Creek during the mining of LW W1.

Monthly monitoring and inspections of Cedar Creek during the mining of LW W1 observed rising and falling of water levels consistent with rainfall events until October 2020. An analysis of the data found atypical surface water behaviour from 8 October 2020 to late January 2021 at Pool CR14 (Logger CB) when water flows had reduced after a period of reduced rainfall. Further investigations have identified that changes in water level recession rates are observed in Pools CB3, CB10 and CR14. The effects only persisted at Pool CB10 and Pool CR14.

HEC (2021) report that there has been no visible evidence of cracking, splitting or spalling of the creek rock bar controls and levels of iron oxy-hydroxide precipitation have not exceeded levels observed during the baseline (pre-mining) period.

5.3.8. Observed closure between GNSS units across creeks during the mining of LW W1

Prior to the commencement of LW W1, it had been planned to install GNSS units on both sides of the creeks to measure changes in horizontal distances between them. Despite extensive negotiations with the landholders, access was not permitted to install survey pegs and GNSS units on a large landholding on the southern and eastern sides of Stonequarry Creek, Cedar Creek and Matthews Creek. Formal access to the landholding has now been agreed and Sites 20 to 22 were installed prior to the commencement of LW W2.

GNSS units were also placed across creeks at two locations prior to the commencement of LW W1. Sites 12 and 13 are located across Rockbar SR17 at Stonequarry Creek, and Sites 18 and 19 are located across Matthews Creek near Addison Street. Their locations are shown in Drawing No. MSEC1112-30.

Changes in horizontal distances have been calculated between these GNSS units and the results are shown in Fig. 5.39.

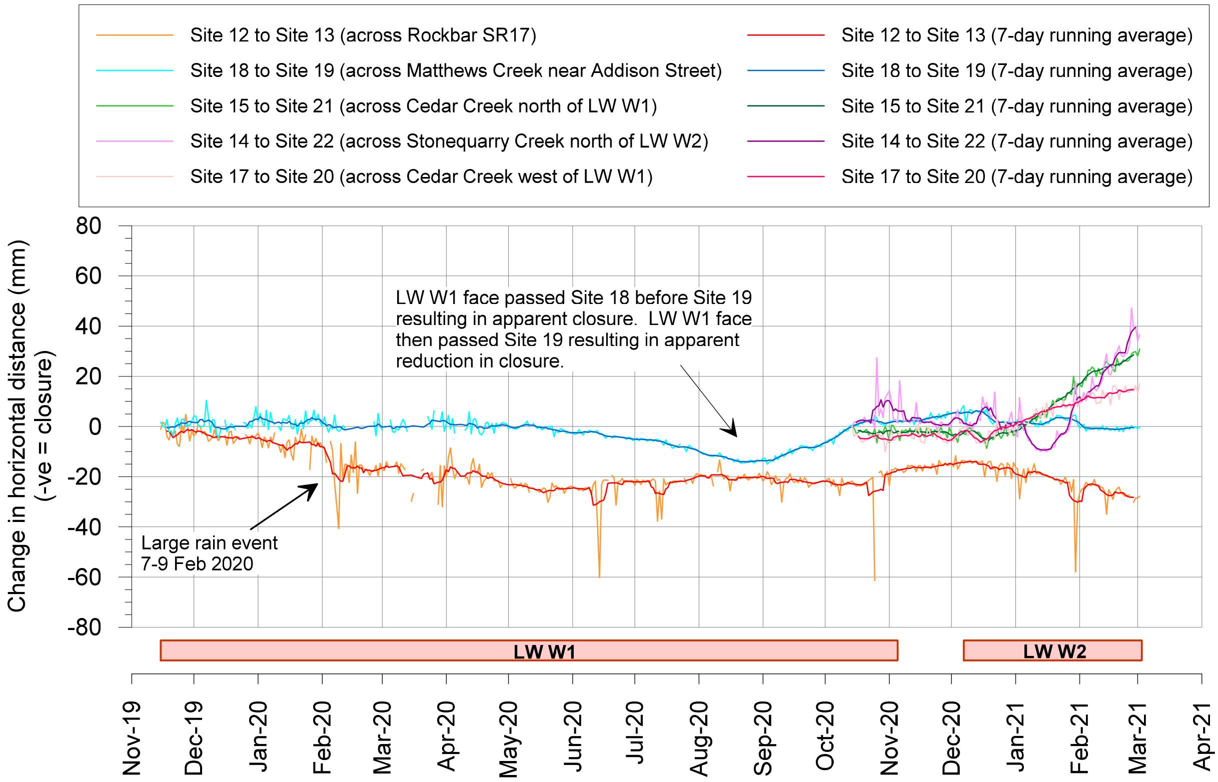

Fig. 5.39 Observed changes in horizontal distances between GNSS units across creeks during the mining of LW W1

Sites 12 and 13 are located across Stonequarry Creek at Rockbar SR17. Site 12 appears to have been affected by the heavy rainfall event between 7 and 9 February 2020, with accelerated movements observed in the week of the event and little change observed in following weeks. Geotechnical engineers Douglas Partners inspected Site 12 and confirmed that this sensor is mounted in clay soil, which may have swelled in response to the wet weather event. If the movements during the week after the wet weather event on 7 and 9 February 2020 are removed from the results, the movements at Site 12 would be similar in magnitude to the movements measured at Site 13.

Very minor closure in the order of 5 mm was measured to develop between November 2019 and late January 2020. The large rain event resulted in a net closure of approximately 20 mm. Site 13 is currently moving south faster than Site 12, resulting in closure of approximately 10 mm since the commencement of LW W2. Very little change is, however, measured across the rockbar itself.

The LW W1 face passed Site 18 in early August 2020 and passed Site 19 in late August 2020. Site 18 therefore moved towards LW W1 earlier than Site 19. This resulted in an apparent closure between the two sites between June and late August 2020, as shown in Fig. 5.39. An apparent reduction in closure was measured as Site 19 commenced moving towards LW W1. The net change in distance returned towards zero in mid-October 2020.

Sites 15 and 21 are located across Cedar Creek to the north of LW W1. Sites 17 and 20 are located across Cedar Creek to the west of LW W1. Both pairs of units are recording similar changes, with minor opening observed across the creek.

Sites 14 and 22 are located across Stonequarry Creek to the north of LW W2. The units moved towards each other by approximately 10 mm during early January, but have since moved apart approximately 50 mm, as the LW W2 face moves away to the south.

5.3.9. Observations during the mining of LW W2

Monitoring has continued during the mining of LW W2. Ground movements as at March 2021 continue to develop and it is too early to draw conclusions.

Ground surveys have measured minor closure (less than 25 mm) beyond the commencing ends of LW W1-W2 around the confluence of Cedar and Stonequarry Creeks. Rates of change have reduced in the last month but it is too early to confirm at this stage. No impacts have been observed to surface water at this stage. No measurable closure or impacts have been measured across Rockbar SR17.

Ground surveys have not measured valley closure across Cedar and Mathews Creeks to the western side of LW W1. Ground extension has been measured across the tops of the valleys by the GNSS units, as discussed in the previous section.

As discussed in Section 5.3.7, water levels measured in Pool CR14 in Cedar Creek were measured to have reduced below previously lowest levels in December 2020 and January 2021 during periods of dry weather. Further investigations have identified that changes in water level recession rates are observed in Pools CB3, CB10 and CR14. The effects only persisted at Pool CB10 and Pool CR14.

The pools were subsequently observed to be full and overflowing in February after a series of rainfall events. No fracturing has been observed in the creeks, noting that the base of the pools cannot be inspected as they contain water and are covered with wet clay and sediment.

Investigations have continued at the site, including installation of additional ground and water monitoring. Further impacts may be observed as mining continues following a period of prolonged dry weather.

5.3.10. Experience of mining adjacent to creeks in the Southern Coalfield

TC has mined directly beneath various streams including Myrtle Creek, Redbank Creek and their tributaries. The impacts experienced along these creeks are not representative of the potential impacts that may occur along Matthews, Cedar and Stonequarry Creeks, as the proposed longwalls do not mine directly beneath these creeks. Longwalls have mined adjacent to but not directly beneath similar streams elsewhere in the Southern Coalfield.

The most appropriate case studies are the Cataract River at Appin Area 3, the Georges River at West Cliff Area 5 and Wongawilli Creek at Dendrobium Areas 3A and 3B. These case studies are described below.

Cataract River in Area 3 at Appin Colliery

Longwalls 301 and 302 in Area 3 at Appin Colliery were mined adjacent to the Cataract River. The river is located adjacent to the tailgate of Longwall 301 and the commencing ends of Longwalls 301 and 302. The locations of the river, longwalls and monitoring lines are shown in Fig. 5.40. The closest distance of the extracted longwalls to the Cataract River was 100 m, near the E-Line.

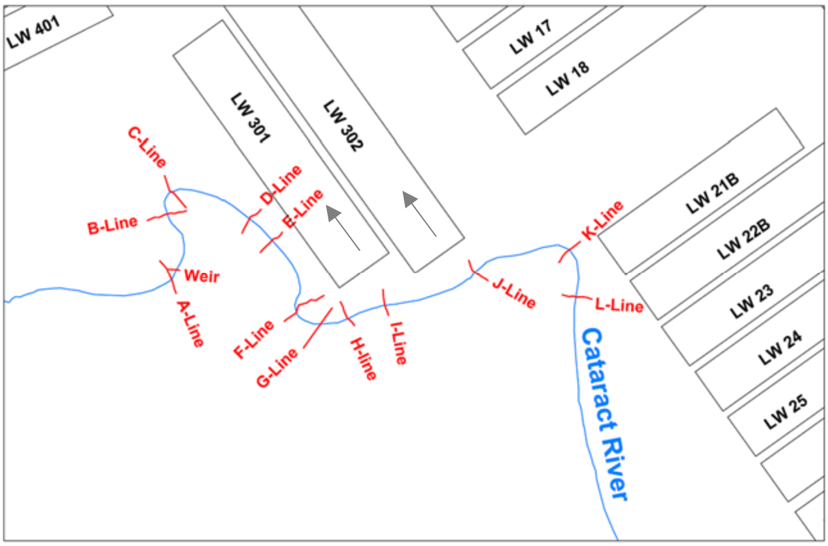

Fig. 5.40 Locations of the Cataract River, longwalls and monitoring lines in Area 3 at Appin Colliery

Longwalls 301 and 302 had overall void widths of 260 m and a solid chain pillar width of 40 m. The longwalls were extracted in the Bulli Seam at depths of cover ranging between 470 m and 520 m. The seam thickness within the extents of the longwalls varied between 2.7 m and 3.1 m. The longwalls were extracted towards the northwest, away from the Cataract River, as shown by the arrows in Fig. 5.40.

The equivalent valley heights of the Cataract River within the mining area vary between 60 m and 70 m. The valley sides of this river, therefore, are higher than those along Matthews, Cedar and Stonequarry Creeks.

The valley closure effects were measured across the Cataract River at a number of monitoring lines, including the Cat X A-Line to L-Line. The measured and predicted closure movements for the Cataract River at the completion of Longwall 302 are illustrated in Fig. 5.41. The maximum measured total closure was 285 mm at the E-Line, adjacent to the tailgate of Longwall 301, and the maximum predicted total closure was 460 mm near the E-Line.

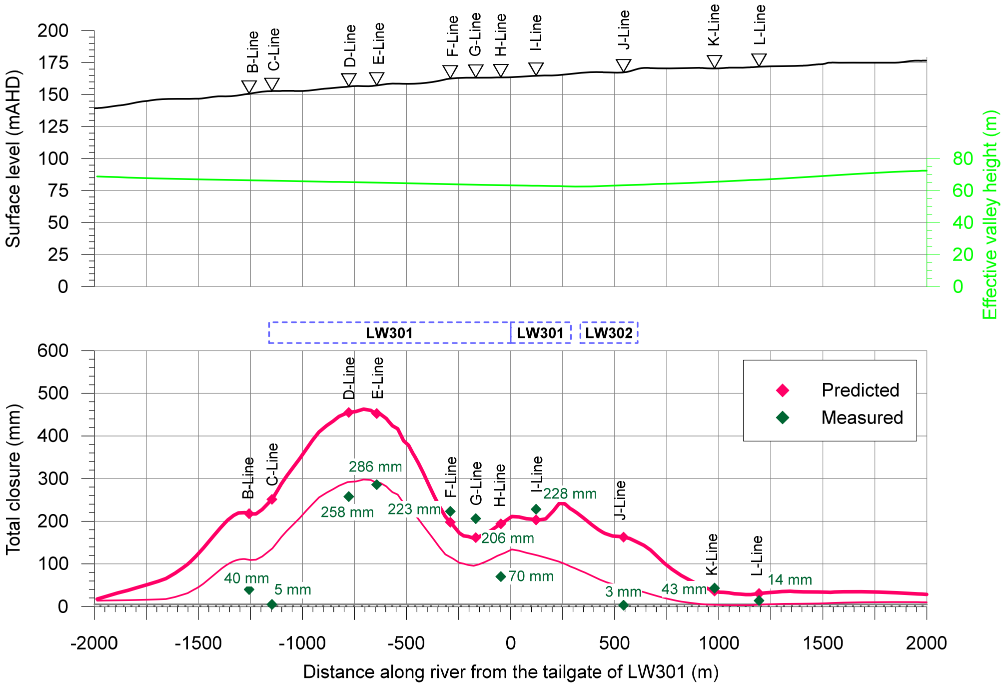

Fig. 5.41 Measured and predicted total closure along the Cataract River due to Longwalls 301 and 302

Fracturing and gas release zones were observed along the section of the Cataract River located adjacent to the tailgate of Longwall 301 and adjacent to the commencing ends of Longwalls 301 and 302. Minor and isolated fracturing were observed up to 400 m from these longwalls. No surface water flow diversions were observed due to the extraction of Longwalls 301 and 302. Water flows were controlled by releases from the Cataract Dam, which were between 35 and 250 ML/day at times.

Georges River in Area 5 at West Cliff Colliery

The longwalls in Area 5 at West Cliff Colliery were initially mined directly beneath the Georges River. However, further downstream, Longwalls 29 to 38 were mined adjacent to but not directly beneath this river. Longwalls 29 to 37 are located on the western side of the Georges River and Longwall 38 is located on the eastern side of the river. The locations of the river, longwalls and monitoring lines are shown in Fig. 5.42.

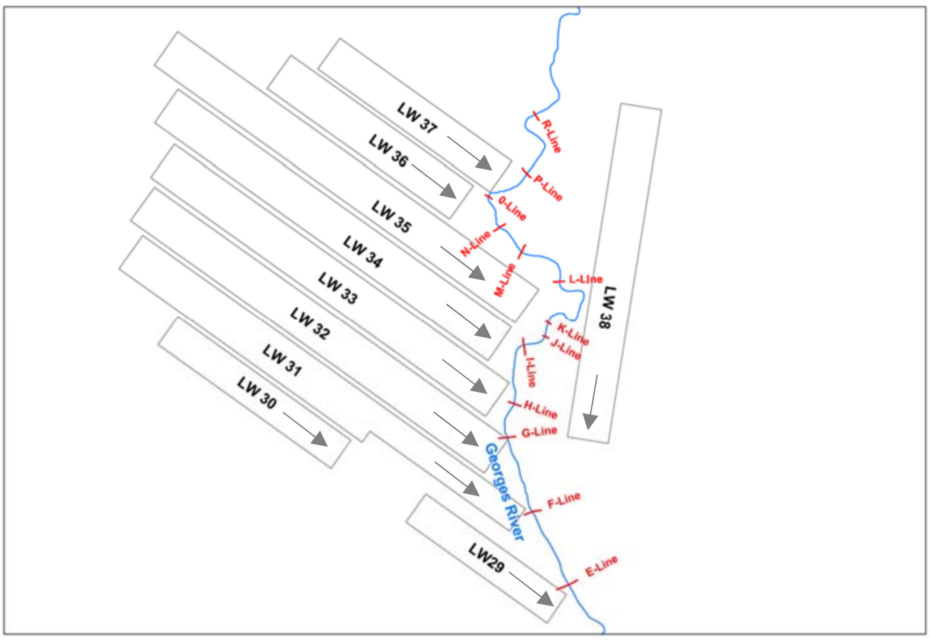

Fig. 5.42 Locations of the Georges River, longwalls and monitoring lines in Area 5 at West Cliff Colliery

The overall voids widths were 255 m for Longwalls 29 and 30, 205 m for the eastern part of Longwall 31, 280 m for Longwall 37 and 305 m for the remaining longwalls, including the western part of Longwall 31. The solid chain pillar widths typically varied between 35 m and 40 m, with a 135 m pillar between

Longwall 29 and the eastern part of Longwall 31. The longwalls were extracted in the Bulli Seam at depths of cover ranging between 470 m and 550 m. The seam thickness within the extents of the longwalls varied between 2.2 m and 2.8 m. The longwalls were extracted towards the southeast, towards the Georges River, as shown by the arrows in Fig. 5.42.

The Georges River is located adjacent to the finishing ends of Longwalls 29, 31 and 32 to 37. Longwalls 32 and 37 were mined up to but not directly beneath the thalweg (i.e. centreline) of the river. The finishing ends of Longwalls 29, 31 and 33 are at minimum distances ranging between 30 m and 50 m from the river thalweg. The finishing ends of Longwalls 34, 35 and 36 are at minimum distances ranging between 130 m and 190 m from the river thalweg.

Sections of the Georges River are also located adjacent to the maingate of Longwall 35 and the tailgate of Longwall 38. The sides of Longwalls 35 and 38 are located at minimum distances of 150 m and 40 m, respectively, from the river thalweg.

The equivalent valley heights of the Georges River within the mining area vary between 15 m and 35 m. The valley sides of this river, therefore, are higher than those along Matthews, Cedar and Stonequarry Creeks.

The valley closure effects were measured across the Georges River at 13 monitoring lines, referred to as the Geo X E-Line to R-Line. The measured and predicted closures for the Georges River at the completion of Longwall 38 are illustrated in Fig. 5.43. The maximum measured total closure was 250 mm at the N-Line and the maximum predicted total closure was 220 mm adjacent to the maingate of Longwall 35.

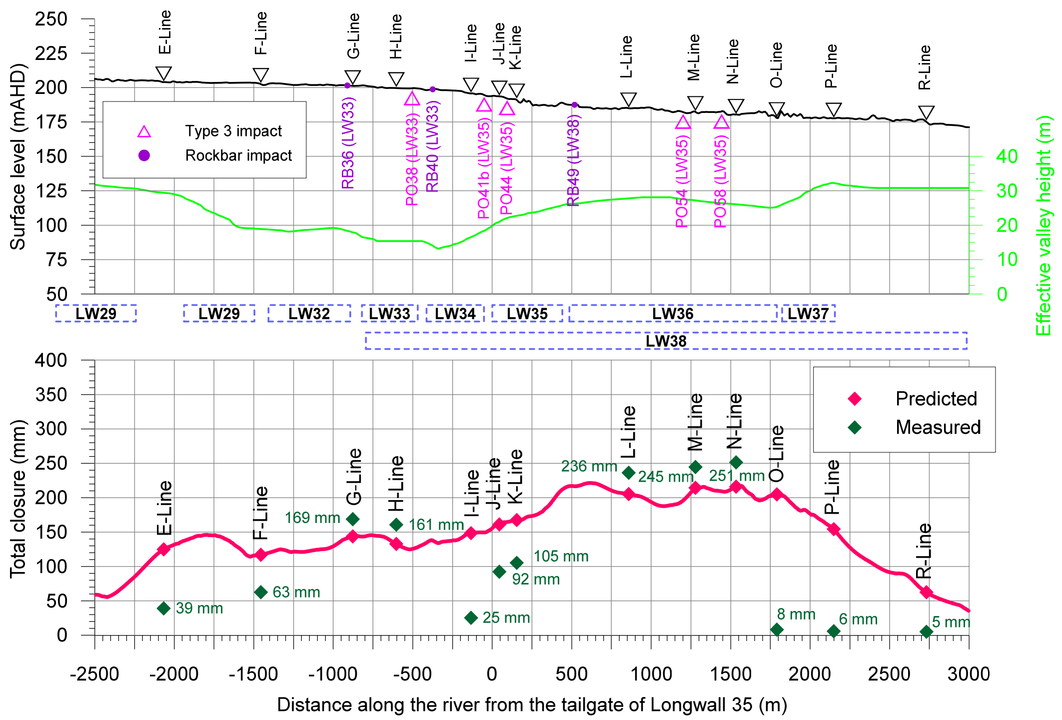

Fig. 5.43 Measured and predicted total closure along the Georges River due to Longwalls 29 to 38

Gas releases and fracturing were observed at discrete locations along the Georges River during the extraction of Longwalls 29 to 38. Pool water levels were observed to fall lower than their baseline levels (referred to as Type 3 impacts) at five locations. Whilst standing water levels were reduced, there were no pools that completely drained. Surface water flow diversions were also identified at three rockbars; however, the upstream pools were not affected.

The surface water flow impacts were observed during the mining of Longwalls 33, 35 and 38. The impacts were located near the finishing ends of Longwalls 33 and 35, along the side of Longwall 35 and at the closest pool to Longwall 38.

The total length of the Georges River located within a distance of 400 m of the as-extracted longwalls is approximately 5.6 km. There is a total of 50 pools that have been mapped over this section of river. The observed rate of Type 3 impacts (i.e. fracturing resulting in the reduction in the pool standing water levels) therefore is 10 %. The observed rate is consistent with that assessed using the rockbar impact model based on a maximum predicted closure of 220 mm, which is discussed in the following Section 5.3.11. Water flows were partially controlled by releases from Brennans Creek Dam, which were typically between 0.5 and 3 ML/day, which are similar flowrates to those observed in Stonequarry Creek within the Study Area.

Wongawilli Creek in Areas 3A and 3B at Dendrobium Mine

Longwalls have been mined on two sides of Wongawilli Creek at Dendrobium Mine. Longwalls 6 to 8 in Area 3A were mined on the eastern side of the creek at a minimum distance of 110 m from the thalweg. Longwalls 9 to 13 were mined on the western side of Wongawilli Creek at a minimum distance of 290 m from the thalweg. The locations of the creek, longwalls and monitoring lines are shown in Fig. 5.44.

The overall voids widths were 250 m for Longwalls 6 and 7 and 305 m for Longwalls 8 to 13. The solid chain pillar widths varied between 40 m and 45 m. The longwalls were extracted in the Wongawilli Seam at depths of cover ranging between 280 m and 390 m in Area 3A and between 320 m and 420 m in Area 3B. The mining height was 3.9 m in Area 3A and varied between 3.9 m and 4.6 m in Area 3B. The longwalls in both series were extracted towards the southeast as shown by the arrows in Fig. 5.44.

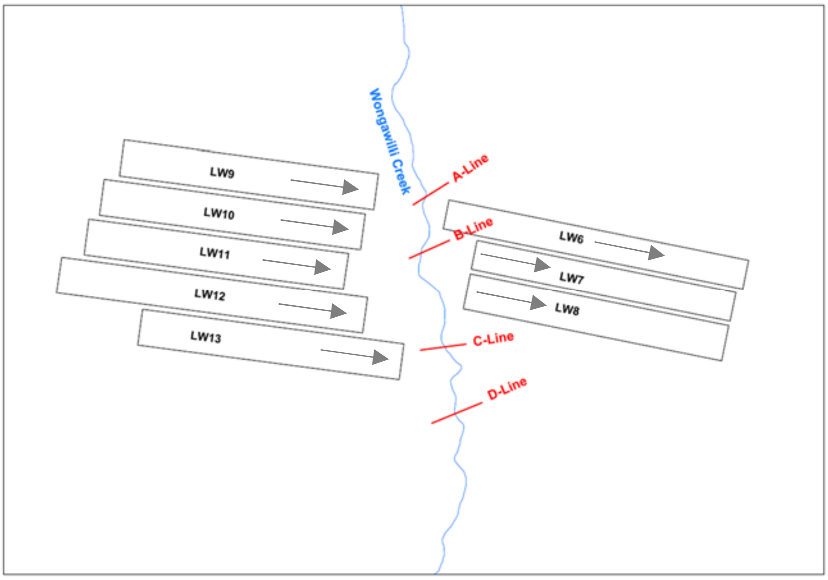

Fig. 5.44 Locations of Wongawilli Creek, the longwalls and monitoring lines in Areas 3A and 3B at Dendrobium Mine

The effective valley heights of Wongawilli Creek within the mining area vary between 50 m and 60 m. The valley sides of this creek, therefore, are higher than those along Matthews, Cedar and Stonequarry Creeks. The valley closure effects were measured across Wongawilli Creek at four monitoring lines. The measured and predicted closure for Wongawilli Creek at the completion of Longwall 13 are illustrated in Fig. 5.45. The maximum measured total closure was 124 mm at the A-Line and the maximum predicted total closure was 210 mm between the A-Line and B-Line.

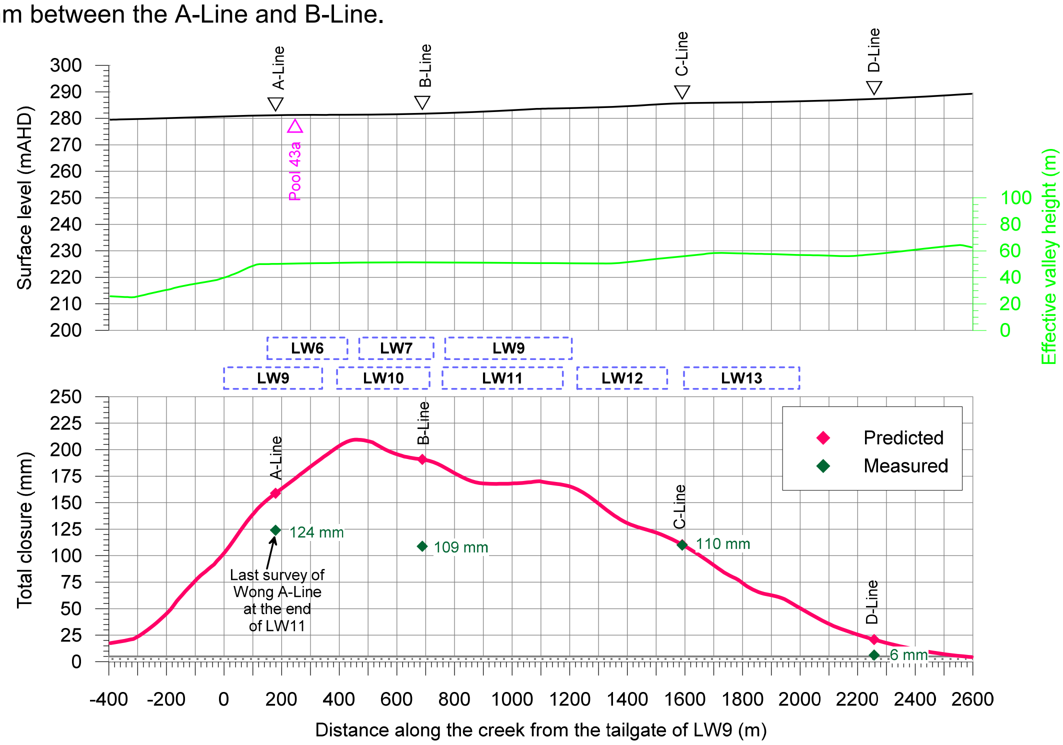

Fig. 5.45 Measured and predicted closure along Wongawilli Creek due to Longwalls 6 to 13

The extraction of Longwalls 6 to 13 has resulted in fracturing and the reduction in the standing water level in Pool 43a. This pool is located 200 m west of Longwall 6 in Area 3A and 410 m east of Longwall 9 in Area 3B. There were no other impacts observed along Wongawilli Creek at the completion of Longwall 13.

The total length of Wongawilli Creek located within a distance of 400 m of the as-extracted longwalls is 2 km. The rate of impacts along Wongawilli Creek due to the mining in Areas 3A and 3B therefore is considered to be very low.

Summary of case studies and application to Matthews, Cedar and Stonequarry Creeks

There are many factors that influence the potential for mining-induced impacts to occur on streams, including but not limited to the mining geometry, direction of mining away from or towards the stream, offset distances between the longwall panels and the streams, valley shape and geology, the nature of the pools and how their water levels are controlled, and the nature of the surface water flows.

Of the three case studies presented, the Cataract River in Area 3 at Appin Colliery would be the most representative in terms of the mining geometry, direction of mining away from the stream and offset distances to the side of the longwall panels. The Georges River in Area 5 at West Cliff Colliery would be the most representative in terms of the depths of the valley and offset distances to the side and end of the longwall panels. Surface water flows are, however, greater in volume and more consistent over time, particularly in the Cataract River, compared to those that are present within Matthews, Cedar and Stonequarry Creeks.

Regardless of these similarities and differences, each of the case studies demonstrate that the outcomes were not impact free, but the severity and extent of impacts on streams were substantially lower compared to examples when longwalls are extracted directly beneath streams.

5.3.11. Impact assessments for the creeks

The proposed extraction of LW W3-W4 is predicted to result in minor additional increases in subsidence, valley closure and upsidence along Matthews and Cedar Creeks. The predicted movements are in addition to movements that will have occurred previously due to the extraction of LW W1 (completed) and LW W2 (currently extracting). As shown in Fig. C.03 and Fig. C.04, the majority of the movements for these creeks are predicted to occur during the mining of LW W1-W2. The predicted maximum additional movements due to the extraction of LW W3-W4 represent approximately 10 to 15% of the total maximum predicted movements due to LW W1-W4.

Impacts were observed to water levels in Cedar Creek to the side of LW W1 near the confluence of Cedar and Matthews Creeks during the extraction of LW W1-W2, taking into account variations due to rainfall and temperature. The impact sites are located where valley closure movements are predicted to be the greatest. It is possible that further impacts will be experienced at these sites during the mining of LW W3.

Surveys across 14 locations in Cedar Creek and 19 locations across Matthews Creek have generally measured changes in horizontal distances that are within survey tolerance, including where the impacts have occurred. Minor valley closure movements (less than 25 mm) have been measured beyond the ends of LW W1-W2 near the confluence of Cedar and Stonequarry Creeks. No impacts have been observed at this location, noting that the movements have occurred across the upper reaches of the long Pool SR17.

The proposed extraction of LW W3-W4 is predicted to result in minor additional increases in subsidence, valley closure and upsidence along Stonequarry Creek. The predicted movements are in addition to movements that will have occurred previously due to the extraction of LW W1 (completed) and LW W2 (currently extracting), noting that LW W3 is setback further from Stonequarry Creek than LW W1-W2 from the streams.

As shown in Fig. C.05, some sections of Stonequarry Creek are predicted to experience greater movements due to the extraction of LW W3 rather than due to LW W1-W2. This occurs along part of Pool SR17, Rockbar SR17 and downstream of Rockbar SR17. These sections of Stonequarry Creek are closest to LW W3. The predicted maximum increase in valley closure of 45 mm due to LW W3-W4 represents approximately two-thirds of the predicted total closure due to LW W1-W4 at this location.

Whilst Stonequarry Creek is predicted experience low levels of vertical subsidence, the creek is not expected to experience measurable conventional tilts, curvatures or strains.

Water levels in Pool SR17 are controlled by the height of Rockbar SR17. As shown in Fig. C05, Rockbar SR17 is predicted to experience roughly the same magnitude of vertical subsidence as the confluence of Cedar Creek and Stonequarry Creek, and approximately 10 mm more subsidence than the upper reaches of Pool SR17 near Rockbar SR16. It is therefore expected that the pool extent and overall pool length will change only slightly due to the extraction of LW W3-W4.

The central portion of Pool SR17 is, however, predicted to subside slightly more than Rockbar SR17. This section of the pool is predicted to become deeper by approximately 40 mm. Water level sensor SC2 is located near the point of maximum predicted subsidence and may, therefore, detect a minor increase in depth.

The average gradient downstream of Rockbar SR17 is approximately 18 mm/m, which is substantially greater than the predicted mining-induced tilts. The mining-induced changes in grade downstream of Rockbar SR17 are predicted to be negligible. It is unlikely, therefore, that this section of creek would experience adverse impacts due to increased levels of ponding, increased levels of scouring of the banks or changes in stream alignment.

The maximum predicted valley-related closure for Matthews, Cedar and Stonequarry Creeks are 200 mm, 200 mm and 80 mm, respectively. The maximum compressive strain measured at similar streams in the Southern Coalfield is 6 mm/m based on the 95 % confidence level.

Fracturing in bedrock has been observed due to previous longwall mining where the tensile strains are greater than 0.5 mm/m or where the compressive strains are greater than 2 mm/m. Fracturing could therefore occur along Stonequarry Creek due to valley-related compressive strains. Fracturing has been observed at distances of up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield.

The potential for Type 3 impacts along Matthews, Cedar and Stonequarry Creeks has been assessed using the rockbar impact model for the Southern Coalfield (Barbato, et al., 2014). A Type 3 impact is defined as *fracturing in a rockbar or upstream pool resulting in reduction in standing water level based on current rainfall and surface water flow*.

The rockbar model relates the likelihood of impact on rockbars with the predicted total valley closure along the stream based on previous longwall mining experience in the Southern Coalfield. The impact model is illustrated in Fig. 5.46. This model was used to determine the longwall setbacks at West Cliff Colliery from the Georges River and at Dendrobium Mine from Wongawilli Creek.

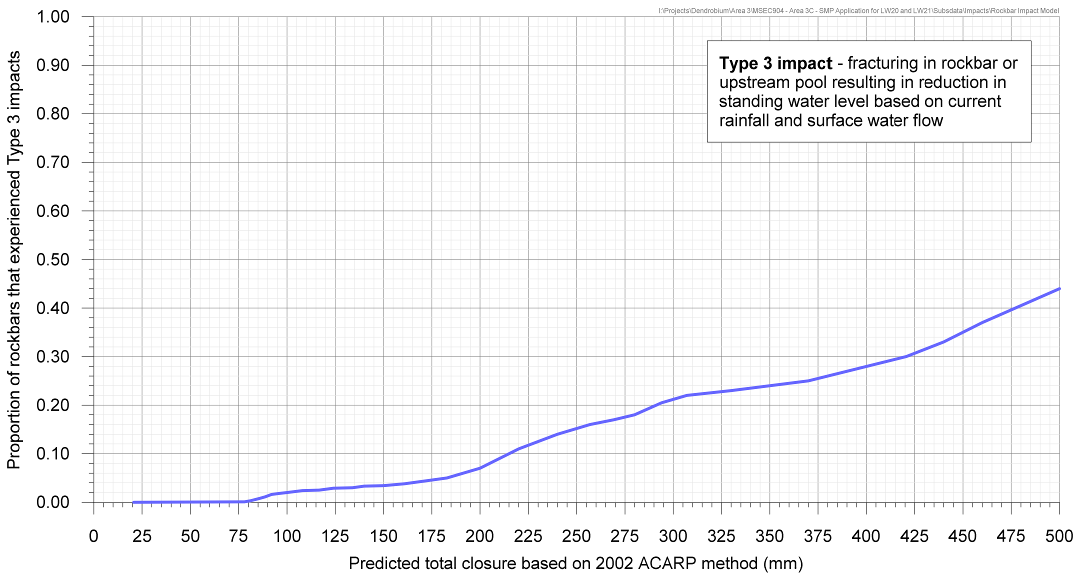

Fig. 5.46 Rockbar impact model for the Southern Coalfield

The maximum predicted total closure for Matthews and Cedar Creeks due to the total extraction of the Longwalls W1-W4 is 200 mm. The predicted rate of impact for the pools along these creeks due to the extraction of the proposed longwalls, therefore, is less than 10 %. As advised in Report No. MSEC1019 in support of the Extraction Plan application for LW W1-W2, impacts are more likely to occur near the commencing ends of LW W1-W3, where Cedar Creek is located closest to these longwalls, and where Cedar and Matthews Creeks are located closest to the tailgate of LW W1. The impacts that have been observed in Cedar Creek during the mining of LW W2 are located where valley closure was predicted to be 200 mm, adjacent to the tailgate of LW W1. The impacts observed to date are, therefore, within expectations.

The likelihoods of fracturing and surface flow diversions reduce with distance away from the proposed longwalls. The furthest distance of an observed fracture from longwall mining was at the base of Broughtons Pass Weir, which was located approximately 415 m from Appin Colliery Longwall 401. Another minor fracture was also recorded in the upper Cataract River, approximately 375 m from the commencing end of Appin Colliery Longwall 301. This fracture occurred in a large rockbar, which was formed in thinly bedded sandstone, which had experienced movements from nearby previously extracted longwalls. These are the furthest-most recorded fractures from longwall mining in the NSW coalfields.

It is possible, therefore, that mining-induced fractures could occur at Rockbar SR17 due to the extraction of LW W3. The rockbar is thinly bedded in places and natural fractures are already present at isolated locations.

If mining-induced fractures occur, it is possible that fracturing could create surface flow diversions within the rockbar if they can connect hydraulically in order for surface water to divert underground and emerge further downstream of Rockbar SR17.

The commencing position of LW W3 was setback 50 metres further from Stonequarry Creek compared to LW W2 to reduce the potential for adverse impacts on Rockbar SR17. The maximum predicted total closure for Stonequarry Creek due to the total extraction of the Longwalls W1-W4 is 80 mm and the predicted total closure at Rockbar SR17 is 60 mm. The predicted rate of impact for Rockbar SR17 due to the extraction of the proposed longwalls, therefore, is assessed to be less than 5 %. While the observed frequency of impacts gradually increases with increasing valley closure, it can be seen from the impact model in Fig. 5.46 that there is little difference in the observed frequency of impacts between 60 mm and 150 mm.

Investigations and assessments have also been conducted by SCT (2021), who advise that valley closure movements are not expected to be large enough to cause significant impacts to the rockbar. Some opening of existing joints and the small fractures may form as minor readjustments occur in the ground around the rockbar in response to the proposed mining.

In the event that impacts occur to Rockbar SR17 or any other rockbars, surface flow diversions can be remediated.

Tahmoor Coal has commenced remediation of pools in Myrtle Creek and Redbank Creek with successful results, in consultation with the Tahmoor community, neighbouring landowners, Wollondilly Council, the NSW DPIE, including the NSW Resources Regulator, and the NSW Department of Primary Industries - Fisheries.

A series of trials in 2019 and 2020 were conducted, building on the results of successful stream remediation projects at other longwall mining sites in the local area. The remediation trial project has successfully restored pool holding capacity by filling mining-induced fracture networks with a hydrophobic polyurethane grout that is suitable for potable water use.

- The grout has been safely used for the same application within the Sydney Water Drinking Catchment. The grout has no particles, a medium viscosity and expands in volume and sets when in contact with water, such that it does not flow in the groundwater system. There is minimal wastage on site.
- Holes can be drilled using drill rigs that can be carried on foot, and shallower holes can be drilled by hand. The drill holes are 38 mm to 74 mm in diameter. The holes are only visible on the surface, which are treated at completion using local sand and colour oxides so there is limited evidence that works have occurred.

In the case of Rockbar SR17, it is noted that no further mining will be conducted near the rockbar after the extraction of LW W3. LW W4 is set back substantially from Stonequarry Creek to reduce the potential for impacts on the Picton Railway Tunnel. In the unlikely event of impacts, remediation could commence based on observations soon after the influence of LW W3. Rockbar SR17 can also be accessed by vehicle.

Gas emissions from the sandstone strata have been previously observed above and adjacent to mining areas in the Southern Coalfield and some gas emissions have also been observed in water bores. Analyses of gas compositions indicate that the Bulli Seam is not the direct and major source of the gas and that the most likely source is the Hawkesbury Sandstone (APCRC, 1997).

Prior to the extraction of LW W1, recorded examples of gas emissions have occurred in collieries located to the east and to the northeast of Tahmoor Mine. No gas emissions or consequential changes in water quality had been reported over Tahmoor Mine in the Bargo River, Redbank Creek or Myrtle Creek.

As at October 2020, gas bubbles were observed in Pool MR45 in Matthews Creek between February and June 2020. If the gas bubbles were discharged due to mine subsidence movements, it is likely that further emissions will occur during the mining of LW W2 and further emissions could possibly occur during the mining of LW W3. Monitoring of gas bubbling will continue in accordance with the Water Management Plan.

Where these gas releases occur into the water column there is insufficient time for any substantial amount of gas to dissolve into the water. The majority of the gas is released into the atmosphere and is unlikely to have an adverse impact on water quality.

It is possible for substantial gas emissions at the surface to cause localised vegetation die-back. This is a rare event and has only been observed to occur previously on one occasion at Tower Colliery, over small areas in the base of the Cataract Gorge that had been directly mined beneath by Longwalls 10 and 14. These impacts were limited to small areas of vegetation, local to the points of emission, and when the gas emissions declined, the affected areas were successfully restored.

Further discussions on the potential impacts of fracturing, changes in surface water flows and water quality, and environmental consequences are provided in the Surface Water Technical Report (HEC, 2020).

5.3.12. Adaptive management of impacts on Stonequarry Creek

Following feedback received in relation to the 2014 SMP Application for Longwalls 31 to 37, Tahmoor Coal has designed the layout of LW W1-W3 to avoid mining directly beneath Matthews, Cedar and Stonequarry Creeks. The purpose of the design is to substantially reduce the severity and extent of impacts on surface water flows within these creeks, compared to impacts that could occur if the longwalls were extracted directly beneath them. LW W1-W2 were setback at least 50 metres from Cedar and Stonequarry Creeks. LW W3 has been set back 100 metres from Rockbar SR17 on Stonequarry Creek to further reduce the potential for impacts at the rockbar, which controls the water level of the long pool and contains grinding grooves that are assessed to be of high significance.

Tahmoor Coal has committed to implementing a detailed monitoring program to measure and record mining-induced ground movements and impacts on the streams during the mining of LW W1-W4. The monitoring program allows Tahmoor Coal to develop and implement an adaptive management strategy where observations can be reviewed during mining, such that the mine layout for future longwalls can be adjusted to reduce the potential for future impacts.

The adaptive management strategy was accepted by DPIE. Condition 6 of the LW W1-W2 Extraction Plan Approval for Tahmoor Longwall W1, dated 8 November 2019, states:

> *"6) At least 2 months prior to commencing extraction of Longwall W2, the Applicant must submit an Adaptive Management report for approval to the Secretary. The report must include a summary of the:*
>
> *(a) Applicant's performance under the Extraction Plan and this Extraction Plan approval;*
> *(b) Implementation of the revised Water Management Plan Trigger Action Response Plan; and*
> *(c) Outcomes of the adaptive management strategy, including any additional setbacks proposed to be implemented for Longwall W2. If no additional setbacks are proposed, detailed justification must be provided with reference to observed and predicted impacts."*

A review of observations was undertaken after the LW W1 face had mined a sufficient distance such that the majority of mining-induced movements had occurred (after approximately 1000 m of extraction). If impacts on Cedar and Stonequarry Creeks near the commencing end of LW W1 had been greater than anticipated, Tahmoor Coal would have considered amending the commencing position of LW W2 to further reduce the potential for impacts on Stonequarry Creek.

The review in July 2020 (MSEC, 2020) found that observations during the mining of LW W1 were consistent with the findings of the subsidence impact assessment that was provided in support of the Extraction Plan for LW W1-W2. The observations did not indicate that subsidence impact performance measures for streams in Condition 1 of the Extraction Plan Approval for LW W1-W2 were likely to be exceeded. Accordingly, it was not recommended to change the start position of LW W2.

DPIE reviewed the findings of the adaptive management report and approved the start position of LW W2, subject to a requirement that Tahmoor Coal conducted higher frequency downloading of stream flow and groundwater level data, and that visual inspections of the gas bubble impact site at Pool MR45 were conducted more frequently.

Observations between July and October 2020 during the remainder of LW W1 were consistent with the findings in the adaptive management report (MSEC, 2020).

A similar review will be undertaken after 800 m extraction of LW W2, prior to confirming the commencing position of future LW W3. The review will concentrate, in particular, on observations at Rockbar SR17 on Stonequarry Creek and observed movements beyond the ends of LW W1-W2.

The review will be undertaken in consultation with DPIE.

5.3.13. Recommendations for the creeks

TC has developed and implemented a Water Management Plan as part of the Extraction Plan for LW W1-W2. The management plan includes ground monitoring, water quality and pool level monitoring and visual inspections. The adaptive management strategy is described in the plan. The plan also commits to remediation of aquatic ecosystems if impacts occur.

It is planned to update the Water Management Plan for LW W3-W4.

5.4. Tributaries

5.4.1. Description of the tributaries

The locations of the tributaries within the Study Area are shown in Drawing No. MSEC1112-09.

Tributary 1 to Redbank Creek is a first to third order stream that runs directly above and to the side of LW W3-W4. The catchment area is located above LW W3-W4 in predominantly grazing land, with stream flow captured by a number of farm dams. The total length of stream within the Study Area is 1.45 km. Approximately 120 metres of the stream within the Study Area is third order. The closest section of third order stream is approximately 250 metres from the finishing end of LW W4.

Photograph courtesy Newcastle Geotech

Fig. 5.47 Tributary 1 to Redbank Creek

The other tributaries within the Study Area are first and second order stream, which flow into Matthews, Cedar and Stonequarry Creeks to the north and west.

5.4.2. Predictions for the tributaries

The predicted profiles of total vertical subsidence, upsidence and closure along Tributary 1 to Redbank Creek are shown in Fig. C.06, in Appendix C. The predicted total profiles after the extraction of each of the proposed longwalls are shown as the blue lines.

A summary of the maximum predicted values of total vertical subsidence, upsidence and closure for Tributary 1 to Redbank Creek is provided in Table 5.7.

Table 5.7 Maximum predicted total vertical subsidence, upsidence and closure for Tributary 1 to Redbank Creek

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Tributary 1 to Redbank Creek	After LW W2	75	60	120
	After LW W3	525	200	325
	After LW W4	850	375	500

The first and second order tributaries are located directly above LW W1-W4. They could, therefore, experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

5.4.3. Impact assessments for the tributaries

The majority of Tributary 1 to Redbank Creek flows to the side of LW W4 and will experience less than 150 mm vertical subsidence, with minor changes in grade that are generally less than 1 mm/m or 0.1%. it is unlikely, therefore, that the lower reaches of Tributary 1 will experience noticeable changes in grade even though some downstream sections of the stream have relatively flat gradients.

The upper reaches of the stream will be directly mined beneath by LW W3 and LW W4. The maximum predicted final tilt for Tributary 1 to Redbank Creek is 3.5 mm/m, which is a change in grade of 0.35%, or 1 in 280).

The predicted mining-induced changes in grade are small when compared with the natural grades of the upper reaches Tributary 1 to Redbank Creek, which exceed 30 mm/m, or 3%. It is unlikely, therefore, that the Tributary 1 to Redbank Creek would experience adverse impacts due to increased levels of ponding, increased levels of scouring of the banks nor changes in stream alignment.

The other tributaries are located directly above LW W1-W4. The maximum predicted tilt for the first and second order tributaries located directly above LW W1-W4 is 5 mm/m (i.e. 0.5 %, or 1 in 200). The natural grades of these tributaries typically vary between 20 mm/m (i.e. 2 %, or 1 in 50) and 150 mm/m (15 %, or 1 in 7), with an average value of approximately 50 mm/m (i.e. 5 %, or 1 in 20).

The predicted mining-induced changes in grade are small when compared with the natural grades of the tributaries. It is unlikely, therefore, that the tributaries would experience adverse impacts due to increased levels of ponding, increased levels of scouring of the banks nor changes in stream alignment.

The first and second order tributaries located directly above LW W1-W4 could experience compressive strains of 10 mm/m, or greater, due to valley closure effects.

Fracturing in bedrock has been observed due to previous longwall mining where the tensile strains are greater than 0.5 mm/m or where the compressive strains are greater than 2 mm/m. Fracturing could therefore develop along the tributaries located within the Study Area. The fracturing will predominately occur where the tributaries are located directly above LW W1-W4, but it can also occur at distances up to approximately 400 m outside the longwalls.

The mining-induced compression due to valley closure effects can also result in dilation and the development of bed separation in the topmost bedrock, as it is less confined. This additional dilation due to valley closure is expected to develop predominately within the top 10 m to 20 m of the bedrock. Compression can also result in buckling of the topmost bedrock resulting in heaving in the overlying surface soils.

Surface water flow diversions could occur along the tributaries that are located directly above LW W1-W4. In times of heavy rainfall, the majority of the runoff would flow over the fractured bedrock and soil beds and would not be diverted into the dilated strata below. In times of low flow, however, surface water flows can be diverted into the dilated strata below the beds. The tributaries are ephemeral and, therefore, surface water flows only occur during and for short periods after rain events.

Further discussions on the environmental consequences for the drainage lines are provided in the Surface Water Technical Report (HEC, 2020).

5.4.4. Recommendations for the tributaries

TC has developed Environmental Management Plans for managing potential impacts to streams during the mining of Longwalls 22 to 32 and LW W1-W2. The management plans include ground monitoring, water quality and pool level monitoring and visual inspections. The plans also commit to remediation of aquatic ecosystems if impacts occur.

TC is required to develop and implement a Water Management Plan as part of the Extraction Plan for LW W3-W4.

5.5. Aquifers and known groundwater resources

The potential for adverse impacts on groundwater and seeps as a result of mine subsidence is provided in Groundwater Technical Report (SLR, 2021) and the Baseline Private Bore Assessment (GeoTerra, 2020).

GeoTerra advise that it is possible that groundwater seepage may discharge in the streams in addition to the non-mining induced springs observed in Redbank Creek, Matthews Creek and Cedar Creek. If an adverse change in stream water quality occurs through development of an isolated new, or change to an existing, ferruginous spring occurs, it is anticipated that due to the ephemeral nature of the streams and the generally low flow volumes in the creeks, the effect will be localised around the point of discharge and will not adversely affect the overall water quality discharging out of the Study Area.

In relation to aquifer / aquitard interconnection, GeoTerra advise that, from past experience in NSW coalfields, it has been assessed that hydraulic connection of surface water or alluvial groundwater systems is not likely at mining depths of cover greater than 150 m.

A temporary lowering of the regional piezometric surface over the subsidence area due to horizontal dilation of strata may occur due to the increase in secondary porosity and permeability. This effect will be more notable directly over the area of greatest subsidence and dilation, and will dissipate laterally out to the edge of the subsidence zone.

Based on observations within the LW22 to LW31 mining area and similar observations in other areas in the Southern Coalfield, GeoTerra advise that groundwater levels may reduce by up to 15 m, and may stay at that reduced level until maximum subsidence develops at a specific location. The duration of the reduced levels depends on the time required to develop maximum subsidence, the time for subsidence effects to migrate away from a location as mining advances to subsequent panels, and the length of time required to recharge the secondary voids.

On the basis that the pre-mining circumstances of rainfall recharge and bore pumping remain the same, and based on observation of groundwater levels over LW22 to LW31, it is anticipated that groundwater levels generally recover over a few months to a year or so as the secondary void space is recharged by rainfall infiltration.

TC has developed an Environmental Management Plan for managing the potential impacts to groundwater bores during the mining of Longwalls 22 to 32 and LW W1-W2. The management plan includes ground monitoring, water quality and pool level monitoring and visual inspections. The plan also commits to remediation of groundwater bores if impacts occur.

TC is required to develop and implement a Water Management Plan as part of the Extraction Plan for LW W3-W4.

5.6. Cliffs, minor cliffs and rock outcrops

5.6.1. Descriptions of the cliffs, minor cliffs and rock outcrops

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

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

Rock outcrops have been defined in this report as a rockface with a minimum slope of 2 to 1 (> 63.4°) irrespective of its length and height.

Cliffs, minor cliffs and rock outcrops have been identified from LiDAR surface level contours and from field investigations. The locations of these rock features relative to the Study Area are shown in Drawing No. MSEC1112-11.

There are no cliffs located within the Study Area or within the Study Area for natural features based on the 600 m boundary. Cliffs located along Matthews and Cedar Creeks are at minimum distances of 740 m and 850 m, respectively, to the west of LW W3.

Minor cliffs and rock outcrops have also been identified along the valleys of Matthews and Cedar Creeks. These features are located outside the extents of LW W3-W4 at a minimum distance of 700 m from the proposed longwalls.

5.7. Steep slopes

5.7.1. Descriptions of the steep slopes

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

The areas identified as having steep slopes are shown in Drawing No. MSEC1112-11.

Natural steep slopes have been identified along the banks of Matthews, Cedar and Stonequarry Creeks, where the near surface lithology is part of the Hawkesbury Sandstone group. Natural steep slopes are also located on the sides of ridges above the proposed longwalls, where the near surface lithology is part of the Wianamatta Shale group.

An analysis of the LiDAR survey has also identified steep slopes that have been constructed, such as dam walls, embankments and cutting faces. In some cases, retaining walls have been cut into the side of a natural slope with a gradient that is less than 1 in 3 but the analysis has identified a "steep slope" due to the presence of the retaining walls. Potential impacts on built features that are located on or near natural steep slopes are addressed in Chapter 6 of this report. A total of 54 structures within the Study Area have been built on or near steep slopes. A summary of these structures is provided in Table 5.8.

Table 5.8 Structures and dams within the Study Area that are located on or near steep slopes

Structure Type	Description	No.
H	Houses	12
P	Pools	1
R	Rural structures	28
PU	Public Utilities	13
	Total	**54**

The structures and dams within the Study Area that are located on or near steep slopes are shown in Drawing No. MSEC1112-11. Driveways that traverse along or near steep slopes are also shown in Drawing No. MSEC1112-11.

5.7.2. Predictions, impact assessments and recommendations for the steep slopes

The steep slopes located directly above LW W3-W4 could experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The maximum predicted tilt for the steep slopes within the Study Area is 5 mm/m (i.e. 0.5 %, or 1 in 200). The predicted changes in grade are very small when compared to the natural surface grades, which are greater than 1 in 3. It is unlikely, therefore, that the mining-induced tilts would result in an adverse impact on the stability of the steep slopes.

The steep slopes are more likely to be affected by curvature and strain, rather than tilt. The potential impacts generally occur from the increased horizontal movements in the downslope direction, resulting in tension cracks appearing at the tops and on the sides of the steep slopes and compression ridges forming at the bottoms of the steep slopes.

There has been extensive experience of mining directly beneath the steep slopes along the banks of Myrtle Creek and Redbank Creek during the extraction of LW22 to LW32. No slope instabilities were observed during this mining. Soil cracking up to 65 mm wide was observed on both the upper banks and flanks of

Myrtle Creek at one location above Longwall 23B. The cracks extended into the soil to depths of approximately 1.5 m to 2.0 m and over a length of approximately 40 m.

No slope instabilities have been observed during the mining of LW W1. This includes the slopes directly above LW W1 adjacent to the houses within the Stonequarry Estate, and steep slopes that are located along the banks of Matthews, Cedar and Stonequarry Creeks.

There is extensive experience of mining beneath steep slopes elsewhere in the Southern Coalfield, including during the mining of Longwalls 14 to 19 at Tahmoor Mine. The majority of the steepest slopes above previous mining within the Southern Coalfield were within the Hawkesbury Sandstone group, along the Cataract, Nepean, Bargo and Georges Rivers, and no slope instabilities have been observed.

There is also some experience of mining beneath slopes in the Wianamatta Shale group at Tahmoor Mine, during the mining of Longwalls 27 and 28 directly beneath the ridge that runs along Tickle Drive. No slope instabilities were observed during mining.

Whist experience indicates that the likelihood of impacts if extremely low, it is possible that some remediation might be required to ensure that any mining-induced cracking does not result in the formation of soil erosion channels. In some cases, erosion protection measures may be needed, such as the planting of additional vegetation in order to stabilise the slopes in the longer term.

While any impacts on slopes are likely to consist of surface cracking, there remains a possibility of slope slippage on the ridges. Localised natural slope slippage has been observed at Tahmoor, such as on Redbank Range and, therefore, it is possible that localised slope slippages could develop along the ridges within the Study Area that may be attributable to either natural causes, mine subsidence, or both.

Experience indicates that the likelihood of slope slippages due to mining is extremely low due to the significant depth of cover beneath the ridges. No large scale mining-induced slope failures have been observed in the Southern Coalfield at depths of cover exceeding 400 m. While the risk is extremely low, some risk remains and attention must therefore be paid to any structures or roads that may be located in the vicinity of steep slopes.

A total of 54 structures have been identified on or near to natural steep slopes within the Study Area. There are also a number of privately owned driveways or tracks that are located on or near these steep slopes.

TC has developed a subsidence management plan for managing potential impacts on steep slopes during the mining of Longwalls 22 to 32 and LW W1-W2. The management plans include:

- identification of structures, dams and roads that lie in close proximity to steep slopes;
- site investigation and landslide risk assessment of structures near slopes by a qualified geotechnical engineer. GHD Geotechnics assessed all structures near steep slopes that may experience subsidence during the mining of Longwalls 22 to 32. Douglas Partners assessed structures near steep slopes that may experience subsidence during the mining of LW W1-W2;
- site investigation and structural assessment of structures where recommended by the geotechnical engineer. This may include recommendations to mitigate against potential impacts;
- monitoring, including ground survey and visual inspections; and
- remediation if cracking or slippage occurs.

While no impacts have been observed on structures or dams due to mining-induced slope instabilities during the mining of Longwalls 22 to 32 and LW W1, it is recommended that TC continue to develop strategies to manage potential impacts on slopes during the mining of the proposed longwalls.

Thirlmere Way runs along the side of a ridge near the southern (i.e. finishing) ends of LW W1-W3. Steep slopes are located above and below the road, as shown in Drawing No. MSEC1019-11. A cross-section through Thirlmere Way and the ridgeline above the finishing end of LW W3 is provided in Fig. 5.48.

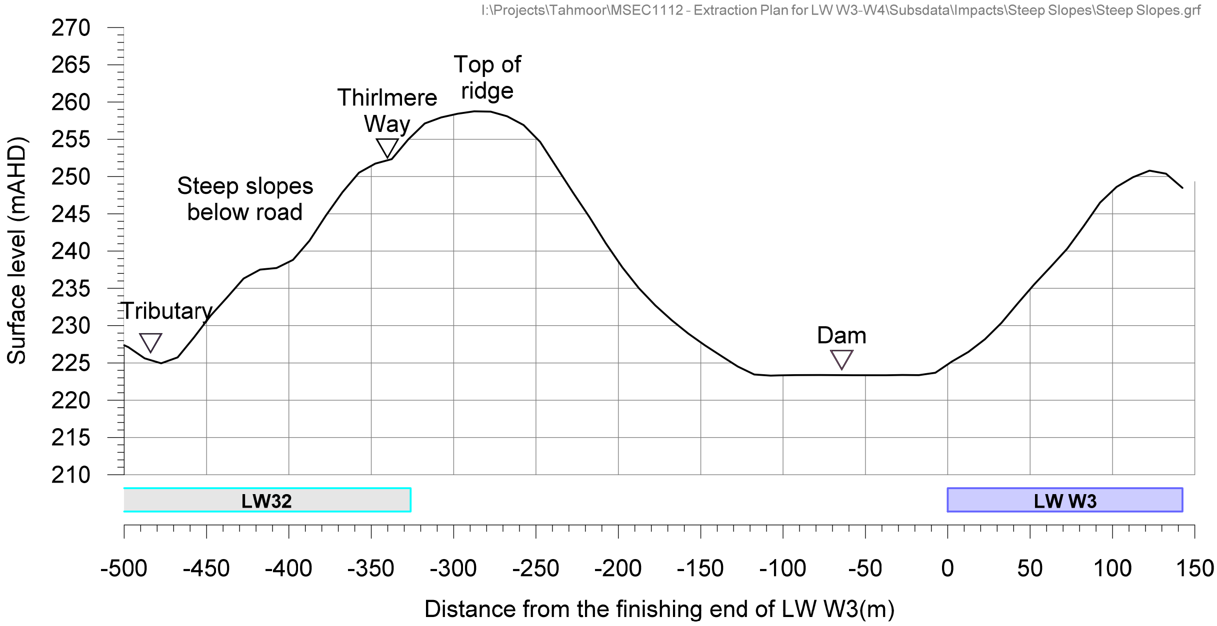

Fig. 5.48 Cross-section through Thirlmere Way and the ridgeline above LW W3

It is possible that surface cracking or slippage could develop on the side of the ridge due to the extraction of LW W3 and that these may intersect with Thirlmere Way. Thirlmere Way narrows in this section, with no shoulders on either side of the pavement, limiting the access for monitoring and undertaking repairs. The traffic along this section of road, therefore, will need to be managed to allow surveys and inspections to be undertaken and to undertake any required remediation works.

Tahmoor Coal engaged geotechnical engineer GHD Geotechnics to undertake a geotechnical assessment of the steep slopes along Thirlmere Way (GHD Geotechnics, 2017). The existing conditions along Thirlmere Way were appraised using RMS methodology (RMS Guide to Slope Risk Management, Version 4), where ARL1 is a high risk, and ARL5 is low;

- A scenario of approximately 20m^3 of rock or soil debris flowing onto the road from the cuttings was assessed as ARL3; and
- A scenario of loss of embankment edge leading to step in the road pavement was assessed as assessed as ARL4.

The assessments were repeated taking into account the potential effects from subsidence. The assessments did not change from the current condition.

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with Wollondilly Shire Council. Prior to the influence of LW 31, Tahmoor Coal installed survey marks along Thirlmere Way where steep slopes are located above and below the road. The survey was extended to monitor changes during the mining of LW32 and extended further during the mining of LW W1.

The survey pegs were surveyed and the road visually inspected on a weekly basis during the mining of LWs 31, 32 and LW W1. Low level subsidence was observed during and after the mining of LWs 31, 32 and LW W1. While some differential movements were measured across the pavement, no impacts have been observed to the slope or pavement.

It is recommended that TC continue to develop strategies to manage potential impacts on Thirlmere Way during the mining of the proposed longwalls, in consultation with Wollondilly Shire Council during the mining of LW W3.

In addition to the above, TC is required to develop and implement a Land Management Plan and a Built Features Management Plan as part of the Extraction Plan for LW W3-W4, and measures to manage potential impacts on steep slopes are included in these plans.

5.8. Escarpments

There are no escarpments located within the Study Area.

5.9. Land prone to flooding and inundation

Flood modelling has been undertaken by WRM based on the existing topography as surveyed by LiDAR and predicted subsidence movements due to the extraction of the proposed longwalls *WRM* (2019).

The study found that flows are generally contained within the channels of Matthews Creek, Cedar Creek and Stonequarry Creek within the Study Area. The crest of Barkers Lodge Road may be overtopped during a Probable Maximum Flood (PMF) event. The subsidence resulting from the mining of the proposed LW W1-W4 results in a negligible change in flood levels, flow velocities and flood extent within the catchment area (WRM, 2019). As discussed in Section 1.2 and Section 1.4, the recent change to the mine plan, where the panel width of LW W4 was extended by 2 metres will result in negligible changes to subsidence predictions around the edges of the panel around LW W4 where the creeks are located. The change will, therefore, result in negligible changes to flood modelling outcomes.

5.10. Water-related ecosystems

Potential impacts on the water-related ecosystems within the Study Area are discussed in the Aquatic Biodiversity Technical Report (*Niche* 2021a).

5.11. Threatened, protected species, other fauna and natural vegetation

Impact assessments for threatened and protected species, other fauna and natural vegetation within the Study Area, are provided in the Terrestrial Biodiversity Technical Report (Niche, 2021b).

5.12. Natural Vegetation

The majority of the natural vegetation in the Study Area has previously been cleared for residential, agricultural and commercial land uses. Remnant natural vegetation has been identified along the alignments of the streams and along the ridges. A survey of the natural vegetation within the Study Area has been undertaken by Niche Environment and Heritage and included in Terrestrial Biodiversity Technical Report (Niche, 2021b).

SIMEC

This information has been retracted

- For more information contact Tahmoor Coal

6.25.4. Fences in urban areas

There are many fences at properties within the Study Area. The fences are constructed in a variety of ways, generally using timber, stone or metal materials. Fences are generally flexible in construction and can usually tolerate mine subsidence movements in the Southern Coalfield.

The maximum predicted tilt resulting from the extraction of the proposed longwalls is 6.0 mm/m (i.e. 0.6 %, or 1 in 165). Fence post tilts of less than 10 mm/m are barely noticeable.

The most vulnerable sections of fences are gates, particularly long gates or those with latches, as they are less tolerant to differential horizontal movements and tilts between the gate posts and the ground. It has also been found that Colorbond fences are particularly susceptible to mine subsidence impacts as there is very little flexibility in their construction.

A total of 73 impacts have been reported to gates and fences within the urban areas during the extraction of Longwalls 22 to 31. These gates and fences are typically Colorbond gates, which have been constructed with small clearances. Gates are often fixed to one side of the house. This form of construction is vulnerable to differential movements that can occur between the fence post and the house.

It is therefore assessed that some fences could experience impacts as a result of the extraction of the proposed longwalls. Some impacts may occur to gates, which may need ongoing repairs as mining occurs. Damaged fences and gates are relatively easy to rectify by re-tensioning of fencing wire, straightening of fence posts, and if necessary, replacing some sections of fencing. Impacts to fences would be repaired or, if required, fences would be replaced in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

As discussed in Section 6.25.1, it is recommended that pool fences are monitored during mining in the interests of public safety.

6.25.5. Management of potential impacts to residential structures

TC has developed and acted in accordance with risk management plans to manage potential impacts to residential structures during the mining of Longwalls 22 to 32 and LW W1-W2. The management plans provides for identification of buildings in poor pre-mining condition that are hazardous or may become hazardous due to mining, and visual kerbside monitoring of structures during active subsidence. Impacts would be repaired or, if required, replaced in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

The management plans are reviewed periodically. It is recommended that TC continue to develop management plans to manage potential impacts during the mining of the proposed longwalls.

6.26. Managing public safety

The primary risk associated with mining beneath structures is public safety. Historically, residents have not been exposed to immediate and sudden safety hazards as a result of impacts that occur due to mine subsidence movements in the NSW Coalfields, where the depths of cover were greater than 350 metres, such as the case above the proposed longwalls. This includes the recent experience at Tahmoor Mine, which has affected more than 2000 houses and civil structures.

Emphasis is placed on the words “immediate and sudden” as in rare cases, some structures have experienced severe impacts, but the impacts did not present an immediate risk to public safety as they developed gradually with ample time to relocate residents.

The existing condition of structures varies above LW W1-W2. This is a function of age, structural design, construction workmanship and maintenance. Pre-mining hazard identification inspections undertaken by Tahmoor Mine have identified elements of structures that did not appear to comply fully with Australian Standards, in regard to design and construction. In a small number of cases, the existing structural condition has been considered potentially unsafe and Tahmoor Mine has undertaken measures to repair the defect.

There is a remote possibility that the comparatively small additional contribution of mine subsidence movements could be sufficient to result in the structures that do not meet Australian Standards to become potentially unstable.

It is recommended that Tahmoor Coal continues its current practice of ensuring that built structures remain safe and serviceable at all times during mining. It is recommended that Tahmoor Mine, in consultation with landowners, study the potential for impacts on the structures and other infrastructure and develop management measures. The study would require input from structural and subsidence engineers. The risk management process includes the following processes:

1. Regular consultation, cooperation and coordination with the community before, during and after mining. This includes letters and door knocking to all residents of structures that will soon be affected by subsidence. The letters offer a free pre-mining inspection and hazard identification inspection by a structural engineer;
2. Site-specific investigations, where they are necessary and appropriate, into the conditions of buildings and associated structures and their surrounding environment (where access is allowed). The site-specific investigations have been and will continue to be undertaken early so that there is adequate time, if required, to arrange additional inspections and/or surveys and implement any mitigation measures before mining-induced impacts are experienced;

   For properties located directly above the first 300 m of the commencing end of a longwall, the investigations are targeted to be undertaken prior to extraction or at the latest, they will be undertaken prior to the first 200 m of extraction of the longwall.

   The site-specific investigations include the following:

   a) Identification of structures from aerial photographs and kerbside inspections;
   b) Front of house risk and visual screening inspections by Tahmoor Coal in company with a structural engineer for all properties that are predicted to experience more than 20 mm of incremental vertical subsidence due to the extraction of each upcoming longwall. The purpose of the inspections is to identify hazards where access has not been granted by the landowner.

      In some cases, particularly in semi-rural and rural areas, it is difficult to inspect a structure that is remote from the street front. Where these cases involve properties that are located directly above a longwall, Tahmoor Coal will request access to conduct a pre-mining inspection and hazard identification inspection by a structural engineer;
   c) Tahmoor Coal will request access to conduct pre-mining geotechnical inspections of structures located on or immediately adjacent to steep slopes that are predicted to experience more than 20 mm of incremental vertical subsidence due to the extraction of each longwall;
   d) Tahmoor Coal will request access to conduct pre-mining hazard identification inspections by a structural engineer (where access is allowed by the landowner) to properties with structures that have been specifically targeted on the basis that may be more sensitive to mine subsidence movements. These include:
      i) Commercial and business establishments, public amenities and public utilities;
      ii) Structures of heritage significance;
      iii) Structures that are located above hidden creeks;
      iv) Structures that are located above mapped geological structures;
      v) Structures that are located on or adjacent to steep slopes or that have been recommended for structural inspection by the geotechnical engineer;
      vi) Structures that have been identified as being potentially unstable or unsafe by landowners (Item 1), or from the front of house inspections (Item 2b);
      vii) Houses and units located outside the declared Mine Subsidence Districts; and
      viii) Houses and units estimated to have been constructed prior to the declaration of the Picton Mine Subsidence District as originally declared in 1997 or if outside the original declared boundary, prior to the declaration of the current boundary in 2017.
3. Implementation of pre-mining mitigation measures following inspections by the geotechnical engineer and the structural engineer, in consultation and agreement with the landowner.
4. Surveys and inspections during mining within the active subsidence area:
   a) detailed visual inspections and vehicle-based inspections along the streets;
   b) ground surveys along the streets;
   c) specific ground surveys for selected properties, where recommended by the geotechnical engineer or structural engineer due to their proximity to steep slopes or pre-existing condition;
   d) visual inspections of residential structures that are either: located on or adjacent to steep slopes, are in poor existing condition (based on the hazard identification inspections), have previously reported impacts, or where recommended by the Structures Response Group;
   e) visual inspections of pool fences and gates; and
   f) visual inspections of commercial, industrial and business establishments, public amenities and public utilities.

Front of house risk and visual screening inspections have been completed by TC in company with a structural engineer for structures within the Study Area. The majority of residents within the Study Area have accepted the offer to conduct a pre-mining inspection and hazard identification inspection by a structural engineer. Two unoccupied house is in a dilapidated condition and it is proposed to erect bunting and warning signs around the structures to discourage access, subject to approval by the landowner.

The structures management plan also provides for additional visual inspections and ground surveys in the event that increased subsidence is observed. This includes pre-mining checks of structures within the affected area, daily visual inspections during active subsidence and weekly ground surveys along streets. TC also consults with Subsidence Advisory NSW to determine whether additional resources are required to assist with undertaking repairs to impacted structures.

6.27. Known future developments

As discussed in Section 6.24, development continues on subdivided lots along Stonequarry Creek Road, Carramar Close, Attunga Close and Booyong Close. A small number of additional buildings are expected to be constructed prior to the extraction of the proposed longwalls.

7.0 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/kilometres (km-1)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*. Curvature can be either **hogging** (i.e. convex) or **sagging** (i.e. concave).
Extracted seam	The thickness of coal that is extracted. The extracted seam thickness is thickness normally given as an average over the area of the panel.
Effective extracted seam thickness (T)	The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel.
Face length	The width of the coalface measured across the longwall panel.
Far-field movements	The measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low-levels of strain.
Goaf	The void created by the extraction of the coal into which the immediate roof layers collapse.
Goaf end factor	A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.
Horizontal displacement	The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.
Inflection point	The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max.
Incremental subsidence	The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.
Panel	The plan area of coal extraction.
Panel length (L)	The longitudinal distance along a panel measured in the direction of mining from the commencing rib to the finishing rib.
Panel width (Wv)	The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.
Panel centre line	An imaginary line drawn down the middle of the panel.
Pillar	A block of coal left unmined.
Pillar width (Wpi)	The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.

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

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APPENDIX B. METHOD OF IMPACT ASSESSMENTS FOR HOUSES

B.1. Introduction

The methods for predicting and assessing impacts on building structures have developed over time as knowledge and experience has grown. MSEC has provided predictions and impact assessments for the building structures within the *Study Area* using the latest methods available at this time.

Longwall mining has occurred directly beneath building structures at a number of collieries in the Southern Coalfield, including Appin, West Cliff, Tower and Tahmoor Collieries. The most extensive data has come from extraction of Tahmoor Mine Longwalls 22 to 29, where approximately 1900 houses have experienced subsidence movements. The experiences gained during the mining of these longwalls, as well as longwalls at other collieries in the Southern and Newcastle Coalfields, have provided substantial additional information that has been used to further develop the methods.

The information was initially collected during the mining of Tahmoor Mine Longwalls 22 to 24A and reviewed in two parallel studies, one as part of a funded ACARP Research Project C12015 (Waddington, 2009), and the other at the request of Industry and Investment NSW (now the Department of Planning and Environment – Resources Regulator).

The outcomes of these studies include:-

- Review of the performance of the previous method,
- Recommendations for improving the method of Impact Classification, and
- Recommendations for improving the method of Impact Assessment.

Additional information was collected in 2016 after the completion of Longwall 29 and impact assessments for the houses in this report have been based on the updated information provided. A summary is provided in the following sections.

B.2. Review of the Performance of the Previous Method

The previous method of impact assessment applied predictions of curvature on the overall length of each house to predict a crack width in the external walls that was classified based primarily in accordance with Table C1 of Australian Standard 2870-1996. This method did not include impacts to other elements, finishes or services.

Extensive data on house impacts has come from extraction of Tahmoor Mine Longwalls 22 to 25 and a comparison between predicted and observed impacts is provided in Table B.1. The comparison is based on pre-mining predictions that were provided in SMP Applications for these longwalls and the observations of impacts using the previous method of impact classification. The comparison is based on information up to 30 November 2008. At that point in time, the length of extraction of Longwall 25 was 611 metres.

A total of 1037 houses and civil structures were affected by subsidence due to the mining of Tahmoor Mine Longwalls 22 to 25 at that time. A total of 175 claims had been received by the MSB, now SA NSW (not including claims that were refused) of which 14 claims did not relate to the main residence or civil structure.

Table B.1 Summary of Comparison between Observed and Predicted Impacts for each Structure

Strain Impact Category	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 0	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 1	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 2	Total
No impact	483	373	20	876
Cat 0	31	70	6	107
Cat 1	8	9	1	18
Cat 2	7	11	2	20
Cat 3	2	2	0	4
Cat 4	3	5	0	8
Cat 5	3	1	0	4
Total	537	471	29	1037
% claim	**10 %**	**21 %**	**31 %**	16 %
% Obs > Pred	**4 %**	**4 %**	**0 %**	-
% Obs <= Pred	**96 %**	**96 %**	**100 %**	-

Note: Predicted impacts due to conventional subsidence only, as described in the SMP Application.

Given that observed impacts are less than or equal to predicted impacts in 96 % of cases, it is considered that the previous methods are generally conservative even though non-conventional movements were not taken into account in the predictions and assessments. However, when compared on a house by house basis, the predictions have been substantially exceeded in a small proportion of cases.

The majority, if not all, of the houses that have experienced Category 3, 4 or 5 impacts are considered to have experienced substantial non-conventional subsidence movements. The consideration is based on nearby ground survey results, where localised bumps are observed in subsidence profiles and high localised strain is observed. The potential for impact from non-conventional movements were discussed generally and not included in the specific impact assessments for each structure.

The inability to specify the number or probability of impacts due to the potential for non-conventional movements is a shortcoming of the previous method. It was considered that there was substantial room for improvement in this area and recommendations are provided to improve the previous method.

The comparison shows a favourable observation that the overall proportion of claims increased for increasing observed ground movements. This suggests that the main parameters currently used to make impact assessments (namely predicted conventional curvature and maximum plan dimension of each structure) are credible. Please note that we have stated predicted conventional curvature rather than strain, as predictions of strain were directly based on predictions of conventional curvature.

A substantial over-prediction is observed at the low end of the spectrum of impacts (Category 0 and 1). A number of causes and/or possible causes for the deviations have been identified:

- Construction methods and standards may mitigate against small differential ground movements.
- The impacts may have occurred but the residents have not made a claim for the following reasons:-
    - All structures contain some existing, pre-mining defects. A pre-mining field investigation of 119 structures showed that it is very rare for all elements of a building to be free of cracks. Cracks up to 3 mm in width are commonly found in buildings. Cracks up to 1 mm in width are very common. There is a higher incidence of cracking in brittle forms of construction such as masonry walls and tiled surfaces.
    - In light of the above, additional very slight Category 0 and 1 impacts may not have been noticed by residents. A forensic investigation of all structures before or after mining may reveal that the number of actual impacts is greater than currently known.
    - Similarly, impacts have been noticed but some residents may consider them to be too trivial to make a claim. While difficult to prove statistically, it is considered that the frequency of claims from tenanted properties is less than the frequency of claims from owner-occupied properties.
- The impacts have been noticed but some residents are yet to make a claim at this stage. It has been observed that there is a noticeable time lag between the moment of impact and the moment of making a claim. At the time of the original study in 2008, more claims were therefore expected to be received in the future within areas that have already been directly mined beneath. This has been confirmed by the findings of the most recent study based on information received in 2016. It has also been found that as assessments and repairs were progressively determined at each house, the level of impacts at each house has generally been greater than was originally reported.
- The predictive method is deliberately conservative in a number of ways.
    - Predicted subsidence movements for each structure are based on the maximum predicted subsidence movements within 20 metres of the structure.
    - An additional 0.2 mm/m of strain was added
    - Maximum strains were applied to the maximum plan dimension, regardless of the maximum predicted strain orientation.
    - The method of impact assessment does not provide for “nil impacts”. The minimum assessed level of impact is Category 0.
    - The impact data was based on double-storey full masonry structures in the UK.

Finally, it is considered that the previous method impact classification has masked the true nature and extent of impacts. It is recommended that an improved method of classification be adopted before embarking on any further analysis. This is discussed in the next chapter of this report.

B.3. Method of Impact Classification

B.3.1. Previous Method

The impacts to structures were previously classified in accordance with Table C1 of Australian Standard 2870-1996, but the table has been extended by the addition of Category 5 and is reproduced below.

Table B.2 Classification of Damage with Reference to Strain

Impact Category	Description of typical damage to walls and required repair	Approximate crack width limit
0	Hairline cracks.	< 0.1 mm
1	Fine cracks which do not need repair.	0.1 mm to 1.0 mm
2	Cracks noticeable but easily filled. Doors and windows stick slightly	1 mm to 5 mm
3	Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weather-tightness often impaired	5 mm to 15 mm, or a number of cracks 3 mm to 5 mm in one group
4	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window or door frames distort. Walls lean or bulge noticeably. Some loss of bearing in beams. Service pipes disrupted.	15 mm to 25 mm but also depends on number of cracks
5	As above but worse, and requiring partial or complete rebuilding. Roof and floor beams lose bearing and need shoring up. Windows broken with distortion. If compressive damage, severe buckling and bulging of the roof and walls.	> 25 mm

Note 1 of Table C1 states that *"Crack width is the main factor by which damage to walls is categorized. The width may be supplemented by other factors, including serviceability, in assessing category of damage.*

Impacts relating to tilt were classified according to matching impacts with the description in Table B.3, not the observed actual tilt. This is because many houses that had experience tilts greater than 5 mm had not made a claim to the MSB (now SA NSW).

Table B.3 Classification of Damage with Reference to Tilt

Impact Category	Tilt (mm/m)	Description
A	< 5	Unlikely that remedial work will be required.
B	5 to 7	Adjustment to roof drainage and wet area floors might be required.
C	7 to 10	Minor structural work might be required to rectify tilt. Adjustments to roof drainage and wet area floors will probably be required and remedial work to surface water drainage and sewerage systems might be necessary.
D	> 10	Considerable structural work might be required to rectify tilt. Jacking to level or rebuilding could be necessary in the worst cases. Remedial work to surface water drainage and sewerage systems might be necessary.

B.3.2. Need for Improvement to the Previous Method of Impact Classification

It is very difficult to design a method of impact classification that covers all possible scenarios and permutations. The application of any method is likely to find some instances that do not quite fit within the classification criteria.

Exposure to a large number of affected structures has allowed the mining industry to appreciate where improvements can be made to all aspects including the identification of areas for improvement in the previous method of impact classification.

A number of difficulties have been experienced with the previous method during the mining period. The difficulty centres on the use of crack width as the main classifying factor, as specified in Table C1 of Australian Standard 2870-1996.

A benefit of using crack width as the main factor is that it provides a clear objective measure by which to classify impact. However, experience has shown that crack width is a poor measure of the overall impact and extent of repair to a structure. The previous method of impact classification may be useful for assessing impact to newly built structures in a non-subsidence environment but further improvement and clarification is recommended before it can be effectively applied to houses impacted by mine subsidence.

The following aspects highlight areas where the previous classification system could be improved.-

- *Slippage on Damp Proof Course*

  Many houses have experienced slippage along the damp proof course in Tahmoor. Slippage on some houses is relatively small (less than 10 mm) though substantial slippage has been observed in a number of cases, such as shown in Fig. B.1 below.

Fig. B.1 Example of slippage on damp proof course

Under the previous classification method, the "crack" width of the slippage may be very small (Category 1) but the distortion in the brickwork is substantial. Moreover, the extent of work required to repair the impact is substantial as it usually involves re-lining the whole external skin of the structure. Such impacts would be considered Category 4 based on extent of repair but only Category 1 or 2 based on maximum crack width.

There is no reference to slippage of damp proof course in the previous method of impact classification. However, if the extent of repair was used instead of using crack width as the main factor, the impact category would be properly classified as either Category 4 or Category 5.

It was recommended that slippage of damp proof courses be added to the previous impact classification table.

- *Cracks to brickwork*

  In some cases, cracks are observed in mortar only. For example, movement joints in some structures have been improperly filled with mortar instead of a flexible sealant, as shown in Fig. B.2. In these situations, the measured crack width may be substantial but the impact is relatively simple to repair regardless of the crack width.

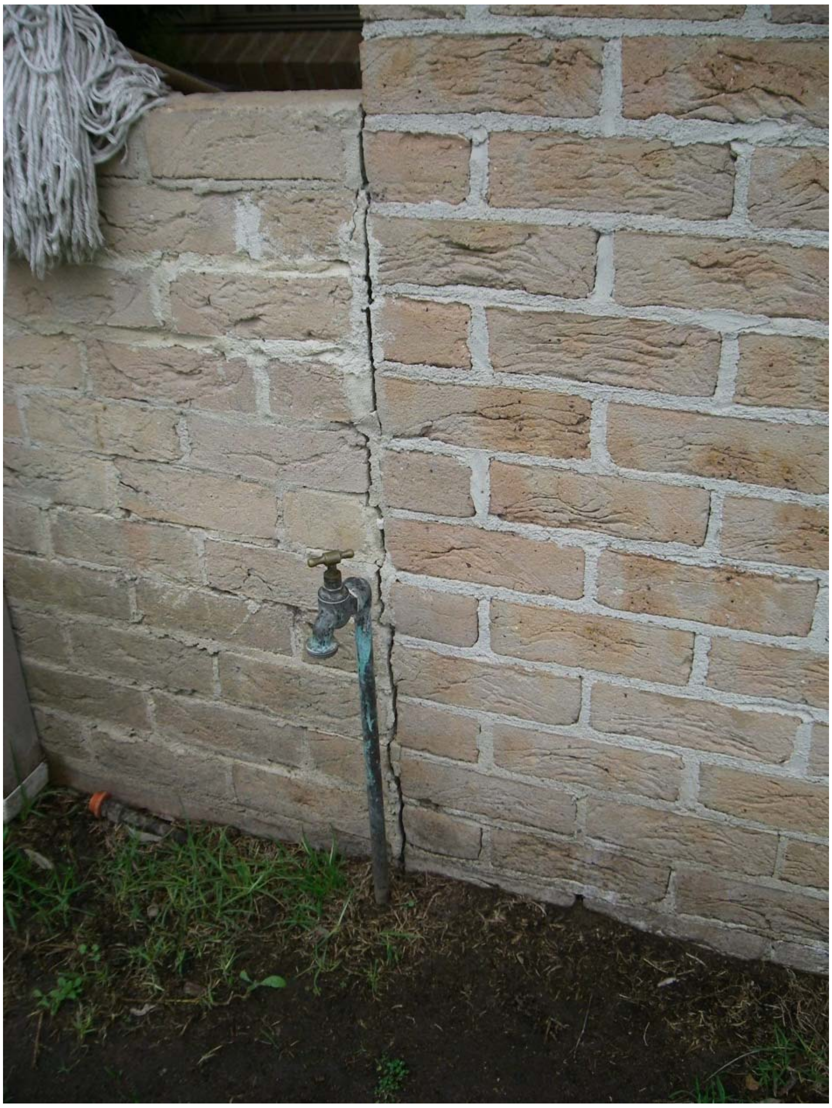


Fig. B.2 Example of crack in mortar only

In other cases, a small number of isolated bricks have been observed to crack or become loose. This is usually straightforward to repair. Under the previous impact classification method, a completely loose brick could be strictly classified as Category 5 as the crack width is infinitely large. This is clearly not the intention of the previous method but clarification is recommended to avoid confusion.

If a panel of brickwork is cracked, the method of repair is the same regardless of the width. While it is considered reasonable to classify large and severe cracks by its width, it is recommended that cracks less than 5 mm in width be treated the same rather than spread across Categories 0, 1 and 2.

If a brick lined structure contains many cracks of width less than 3 mm, the impact would be classified as no more than Category 2 under the previous method of impact classification. The extent of repair may be substantially more than a house that has experienced only one single 5 mm crack. However, it is recognised that it is very difficult to develop a simple method of classifying impacts based on multiple cracks in wall panels. How many cracks are needed to justify an increase in impact category?

- *Structures without masonry walls*

  Timber framed structures with lightweight external linings such weatherboard panels and fibro sheeting are not referenced in the previous classification table. If crack widths were strictly adopted to classify impacts, it may be possible to classify movement in external wall linings beyond Category 3 when in reality the repairs are usually minor.

  It was recommended that the impact classification table be extended to include structures with other types of external linings.

- *Minor impacts such as door swings*

  Experience has shown that one of the earliest signs of impact is the report of a sticking door. In some instances, the only observed impact is one or two sticking doors. It takes less than half an hour to repair a sticking door and impact is considered negligible.

  Such an impact would be rightly classified as Category 0 based on the previous method of impact classification as there is no observed crack. However, the previous classification table suggests that sticking doors and windows occur when Category 2 crack widths develop. It was recommended that the impact classification table be amended in this respect.

B.3.3. Broad Recommendations for Improvement of Previous Method of Impact Classification

It was recommended that crack width no longer be used as the main factor for classifying impacts. This does not mean that the use of crack width should be abandoned altogether. Crack width remains a good indicator of the severity of impacts and should be used to assist classification, particularly for impacts that are moderate or greater.

By focussing on crack width, the previous impact classification table appears to be classifying impacts from a structural stability perspective. It was recommended that a revised impact classification table be more closely aligned with all aspects of a building, including its finishes and services. Residents who are affected by impacts are concerned as much about impacts to internal linings, finishes and services as they are about cracks to their external walls and a revised impact classification method should reflect this.

With crack width no longer used as the main factor, it was recommended that the wording of the descriptions of impact in the classification table be extended to cover impacts to more elements of buildings. In keeping with the previous method of assessment, the level of impact should distinguish between cosmetic, serviceability and stability related impacts:-

- Low impact levels should relate to cosmetic impacts that do affect the structural integrity of the building and are relatively straight-forward to repair,
- Mid-level impact categories should relate to impacts to serviceability and minor structural issues, and
- High level impacts should be reserved for structural stability issues and impacts requiring extensive repairs.

B.3.4. Revised Method of Impact Classification

The following revised method of impact classification has been developed.

Table B.4 Revised Classification based on the Extent of Repairs

Repair Category	Extent of Repairs
Nil	No repairs required
R0 **Adjustment**	One or more of the following, where the damage does not require the removal or replacement of any external or internal claddings or linings:- - **Door** or **window** jams or swings, or - Movement of **cornices**, or - Movement at external or internal **expansion joints**.
R1 **Very Minor Repair**	One or more of the following, where the damage can be repaired by filling, patching or painting without the removal or replacement of any external or internal brickwork, claddings or linings:- - Cracks in **brick mortar** only, or isolated cracked, broken, or loose **bricks** in the external façade, or - Cracks or movement < 5 mm in width in any external or internal wall **claddings**, **linings**, or **finish**, or - Isolated cracked, loose, or drummy floor or wall **tiles**, or - Minor repairs to any **services** or **gutters**.
R2 **Minor Repair**	One or more of the following, where the damage affects a small proportion of external or internal claddings or linings, but does not affect the integrity of external brickwork or structural elements:- - Continuous cracking in **bricks** < 5 mm in width in one or more locations in the total external façade, or - Slippage along the **damp proof course** of 2 to 5 mm anywhere in the total external façade, or - Cracks or movement ≥ 5 mm in width in any external or internal wall **claddings**, **linings**, **finish**, or - Several cracked, loose or drummy floor or wall **tiles**, or - Replacement of any **services**.
R3 **Substantial Repair**	One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or affects the stability of isolated structural elements:- - Continuous cracking in **bricks** of 5 to 15 mm in width in one or more locations in the total external façade, or - Slippage along the **damp proof course** of 5 to 15 mm anywhere in the total external façade, or - Loss of bearing to isolated walls, piers, columns, or other load-bearing elements, or - Loss of stability of isolated structural elements.
R4 **Extensive Repair**	One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or the replacement or repair of several structural elements:- - Continuous cracking in **bricks** > 15 mm in width in one or more locations in the total external façade, or - Slippage along the damp proof course of 15 mm or greater anywhere in the total external façade, or - Relevelling of building, or - Loss of stability of several structural elements.
R5 **Re-build**	Extensive damage to house where the MSB (now SA NSW) and the owner have agreed to rebuild as the cost of repair is greater than the cost of replacement.

As discussed at the start of this chapter, it is very difficult to design a method of impact classification that covers all possible scenarios and permutations. While the method has been floated among some members of the mining industry, it is recommended that this table be reviewed broadly.

The recommended method has attempted to follow the current Australian Standard in terms of the number of impact categories and crack widths for Categories 3 and 4. The method is based on the extent of repairs required to repair the physical damage that has occurred, and does not include additional work that is occasionally required because replacement finishes cannot match existing damaged ones. It is therefore likely that the actual cost of repairs will vary greatly between houses depending on the nature of the existing level and type of finishes used.

The impacts experienced at Tahmoor Mine have been classified in accordance with the revised method of classification with good results. The method allowed clearer trends to be found when undertaking statistical analyses.

A comparison between the previous and revised methods is shown in Fig. B.3.

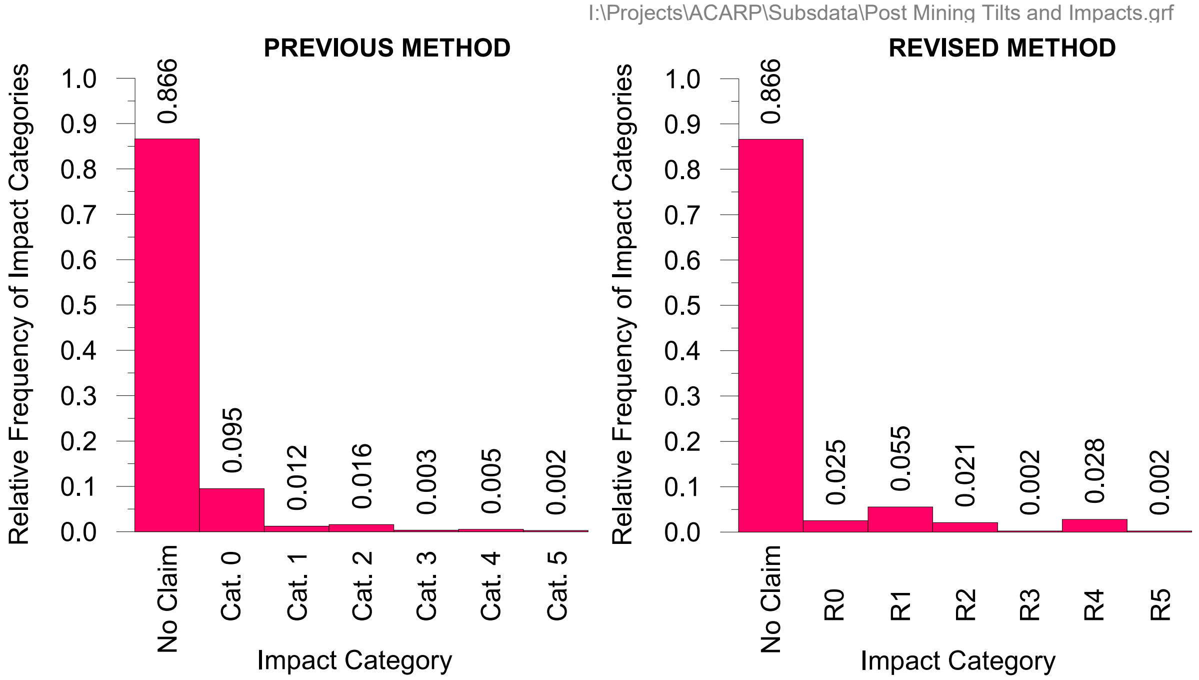


Fig. B.3 Comparison between Previous and Revised Methods of Impact Classification

It can be seen that there was an increased proportion in the higher impact categories using the revised method. This is brought about mainly by the recorded slippage on damp proof courses, which are classified as either Category 3 or Category 4 when they were previously classified as Category 1 or 2.

There was also a noticeable reduction in proportion of Category 0 impacts and noticeable increase in proportion of Category 1 impacts using the revised method. This is because the revised method reserves Category 0 impacts for impacts that did not result in cracking any linings, while the previous method allows hairline cracking to occur.

The consistent low proportion of Category 3 impacts under both the previous and current methods raises questions as to whether this category should be merged with Category 4.

B.4. Method of Impact Assessment

B.4.1. Need for Improvement of the Previous Method

The previous method of impact assessment provided specific quantitative predictions based on predicted conventional subsidence movements and general qualitative statements concerning the potential for impacts due to non-conventional movements. These non-conventional movements are additional to the predicted conventional movements.

This message was quite complex and created the potential for confusion and misunderstanding among members of the community who may easily focus on numbers and letters in a table that deal specifically with their house and misunderstand the message contained in the accompanying words of caution about the low level of reliability concerning predictions of conventional strain and potential for non-conventional movements.

This was unfortunately a necessary shortcoming of the previous method at the time as there was very little statistical information available to quantify the potential for impacts due to non-conventional movement. However, a great deal of statistical information was available following the mining of Tahmoor Mine Longwalls 22 to 24A at the time of the 2009 ACARP study and the method and message to the community could be improved. Additional statistical information was collected in 2016, which was approximately two years after the completion of Longwall 27 and one year after the completion of Longwall 28, which was the last panel to directly mine beneath the urban areas of Tahmoor. The timing of the data is such that it accounts for much of the time lag effect that occurs between the time of impact, when damage is claimed by residents and when the nature and level of the damage requiring repairs is assessed in detail by SA NSW.

While additional statistical information is now available, there remains limited knowledge at this point in time to accurately predict the locations of non-conventional movement. Substantial gains are still to be made in this area.

In the meantime, therefore, a probabilistic method of impact assessment has been developed. The method combines the potential for impacts from both conventional and non-conventional subsidence movement.

B.4.2. Factors that Could be Used to Develop a Probabilistic Method of Prediction

Trend analyses have highlighted a number of factors that could be used to develop a probabilistic method. The trends examined were:-

- *Ground tilt*

  This was found to be an ineffective parameter at Tahmoor Mine as ground tilts have been relatively benign and a low number of claims have been made solely in relation to tilt.

- *Ground strain*

  There appears to be a clear link between ground strain and impacts, particularly compressive strain. The difficulty with adopting ground strain as a predictive factor lies in the ability to accurately predict ground strain at a point.

  Another challenge with using strain to develop a probabilistic method is that there is limited information that links maximum observed strains with observed impacts at a structure. Horizontal strain is a two-dimensional parameter and it has been measured along survey lines that are oriented in one direction only.

  The above issues are less problematic for curvature and the statistical analysis on the relationship between strain and curvature shows that the observed frequency of high strains increased with increasing observed curvature.

- *Ground curvature*

  Curvature appears to be the most effective subsidence parameter to develop a probabilistic method. The trend analysis showed that the frequency of impacts increased with increasing observed curvature.

  It should be noted that we are referring to conventional curvature and not curvatures that have developed as a result of non-conventional subsidence behaviour. This is because conventional curvature can be readily predicted with reasonable correlation with observations. It is also a relatively straight-forward exercise to estimate the observed smoothed or "conventional" mining-induced curvature that has previously been experienced at houses provided some ground monitoring is undertaken across and along extracted longwalls.

  Non-conventional curvature cannot be predicted prior to mining and is accounted for by using a probabilistic method of impact assessment.

  It has also been shown that the observed frequency of high strains increased with increasing observed curvature.

- *Position of structure relative to longwall*

  A clear trend was understandably found that structures located directly above goaf were substantially more likely to experience impact. The calculated probabilities may be applicable for mining conditions that are similar to those experienced at Tahmoor Mine but will be less applicable for other mining conditions. An effective probabilistic method should create a link between the magnitude of differential subsidence movements and impact.

- *Construction type*

  Two trends have been observed. Not surprisingly, structures constructed with lightweight flexible external linings are able to accommodate a far greater range of subsidence movements than brittle inflexible linings such as masonry. The analyses merely quantified what was already well known. The second observation was that houses constructed with strip footings were noticeably more likely to experience impacts than houses constructed with a ground slab, particularly in relation to higher levels of impact. This is because houses with strip footings are more susceptible to slippage along the damp proof course.

- *Structure size*

  Trend analysis showed that larger structures attract a higher likelihood of impact. This is understandable as the chance of impacts increases with increasing footprint area. However, it is noted that the probability of severe impacts was not substantially greater for larger structures even though this would be expected if considering probabilities theoretically rather than empirically. It may be worthwhile including structure size as a factor in the development of a probabilistic method, though it is considered that it is a third order effect behind subsidence movements and construction type.

- *Structure age*

  The trend analysis for structure age did not reveal any noticeable trends.

- *Extensions, variable foundations and building joints*

  There is a clear trend of a higher frequency of impacts for structures that include extensions, variable foundations and building joints. The increased frequency appears to be related mainly to lower impact categories.

- *Urban or rural setting*

  While trends were observed, it is considered that they can be explained by other factors. However, consideration can be made to provide a more conservative estimate of probabilities in rural areas if structure size has not been taken into account.

B.4.3. Revised Method of Impact Assessment

A revised method of impact assessment has been developed, based on information received in 2016 at a time when the extraction of Longwall 29 had been completed. The method is probabilistic and currently includes conventional ground curvature and construction type as input factors.

At the time of the original 2009 ACARP study, the trends in the data were difficult to determine within small ranges of curvature because of the relatively low number of buildings that reported damage at this time. A decision was therefore taken to analyse the data in a limited number of curvature ranges, so that where possible a reasonable sample size would be available in each range. The ranges of curvature originally chosen were 5 to 15 kilometres, 15 to 50 kilometres and greater than 50 kilometres.

Additional information provided in 2016 has demonstrated that the proportion of houses reporting impacts has increased. This has allowed statistical analyses to be conducted using narrower bands of observed curvatures though some inconsistencies remain in some bands due to the sample sizes. The ranges of curvature provided in this report are 2.5 to 15 kilometres, 15 to 50 kilometres and greater than 50 kilometres.

Because the incidence of damage for different construction types showed strong trends and because the sample size was reasonable for each type of structure, the data were analysed to determine the effect of radius of curvature on the incidence of damage for each of the three structure types and for each of the three curvature ranges.

The following probabilities are proposed in Table B.5.

Table B.5 Probabilities of Impact based on Curvature and Construction Type based on the Revised Method of Impact Classification

R (km)	Repair Category			
	No Repair or R0	R1 or R2	R3 or R4	R5
Brick or brick-veneer houses with Slab on Ground				
> 50	90 ~ 95 %	3 ~ 10 %	1 %	< 0.5 %
15 to 50	70 ~ 75 %	20 ~ 25 %	5 ~ 10 %	< 0.5 %
2.5 to 15	45 ~ 65 %	25 ~ 35 %	10 ~ 15 %	1 ~ 3 %
Brick or brick-veneer houses with Strip Footing				
> 50	85 ~ 90 %	5 ~ 15 %	1 ~ 3 %	< 2 %
15 to 50	60 ~ 75 %	20 ~ 30 %	5 ~ 15 %	1 ~ 3 %
2.5 to 15	45 ~ 65 %	25 ~ 30 %	5 ~ 15 %	5 ~ 10 %
Timber-framed houses with flexible external linings of any foundation type				
> 50	90 ~ 95 %	3 ~ 10 %	1 %	< 0.5 %
15 to 50	75 ~ 85 %	10 ~ 20 %	5 ~ 10 %	< 0.5 %
2.5 to 15	70 ~ 80 %	20 ~ 25 %	7 ~ 12 %	< 0.5 %

The results have been expressed as a range of values rather than a single number, recognising that the data had considerable scatter within each curvature range. While structure size and building extensions have not been included in the predictive tables, it is recommended to adopt percentages at the higher end of the range for larger structures or those with building extensions.

The percentages stated in each table are the percentages of building structures of that type that would be likely to be damaged to the level indicated within each curvature range. The levels of damage in the tables are indicated with reference to the repair categories described in the damage classification given in Table B.4.

To place these values in context, Table B.6 shows the actual percentages recorded at Tahmoor Mine for all buildings within the sample.

Table B.6 Observed Frequency of Impacts observed for all buildings at Tahmoor Mine

R (km)	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
> 50	91%	7%	2%	0%
15 to 50	72%	20%	7%	1%
5 to 15	59%	27%	14%	3%

It can be seen that the proposed probabilities for the higher impact categories have been increased compared to those observed to date. These have been deliberately increased, because it has been noticed that some of the claims for damage have been submitted well after the event and it is possible that the numbers damaged in this category could be increased as further claims are received and investigated. These numbers are sensitive to change. In light of the above, it is recommended that the probabilities be revisited in the future as mining progresses.

The ranges provided in Table B.5 have been converted into a set of probability curves to remove artificial discontinuities that are formed by dividing curvatures into three categories. These are shown in Fig. B.4. The probability curves are applicable for all houses and civil structures.

At the time of writing ACARP Research Project C12015 (Waddington, 2009), the observed proportion of houses where the MSB (now SA NSW) and affected landowners had agreed to rebuild rather than repair (Category R5) impacts was less than 0.5 %. Since the publication of the research report, the proportion of houses where a decision has been made to rebuild has increased to approximately 1.1% overall and 3.2% above Longwalls 24A to 27 within the observed zone of increased subsidence. The decision to rebuild rather than repair a house is based on a variety of factors. Whilst acknowledging the significance of a decision to rebuild compared to repair a house, all houses previously impacted at Tahmoor Mine could have been repaired rather than replaced, including those where a decision has been made to rebuild them. This does not diminish the significance of this category from a social and economic impact point of view and it is important to continue recording the number of instances where a decision has been made to rebuild a house.

B.4.4. Review of Observed Probabilities as mining continues

Reviews of observed probabilities are continually undertaken as Tahmoor Mine and other mines continue to extract beneath houses. The provision of additional information on impact on houses in 2016 has improved the level of understanding on the nature and frequency of impacts during the mining of Longwalls 22 to 29 compared to the information that was collected for the previous 2009 ACARP study, which was conducted after the mining of Longwalls 22 to 24A.

Additional statistical information was collected in 2016, which was approximately two years after the completion of Longwall 27 and one year after the completion of Longwall 28, which was the last panel to directly mine beneath the urban areas of Tahmoor.

A finding from the additional information is that the proportion of houses that have experienced impacts has increased over time. The reasons for the increase are due to the time lag effect that occurs between the mining impact, when damage is claimed by residents and when the nature and level of the damage requiring repairs is assessed in detail by SA NSW.

In light of the above, it is recommended that the probabilities be revisited in the future.

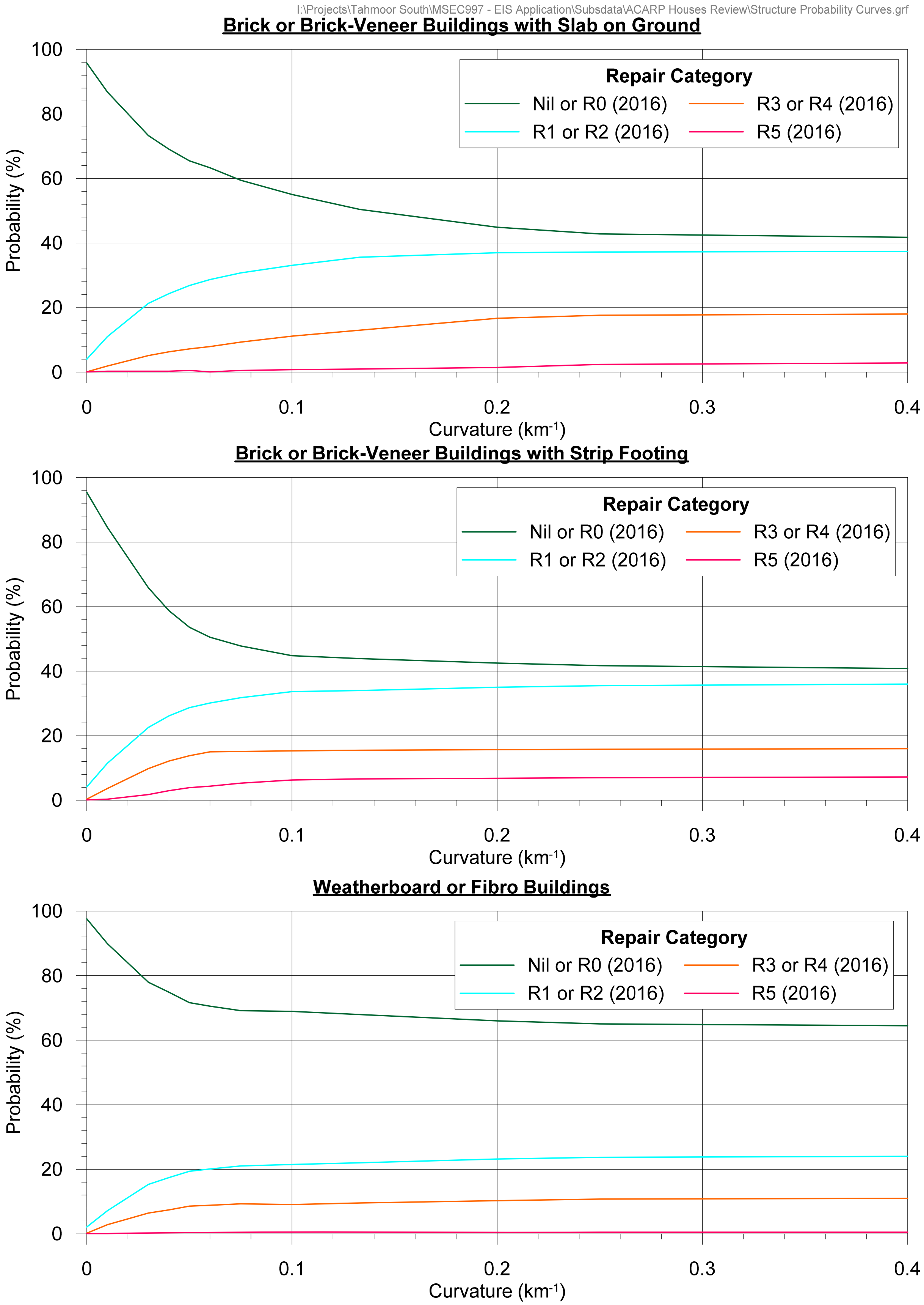
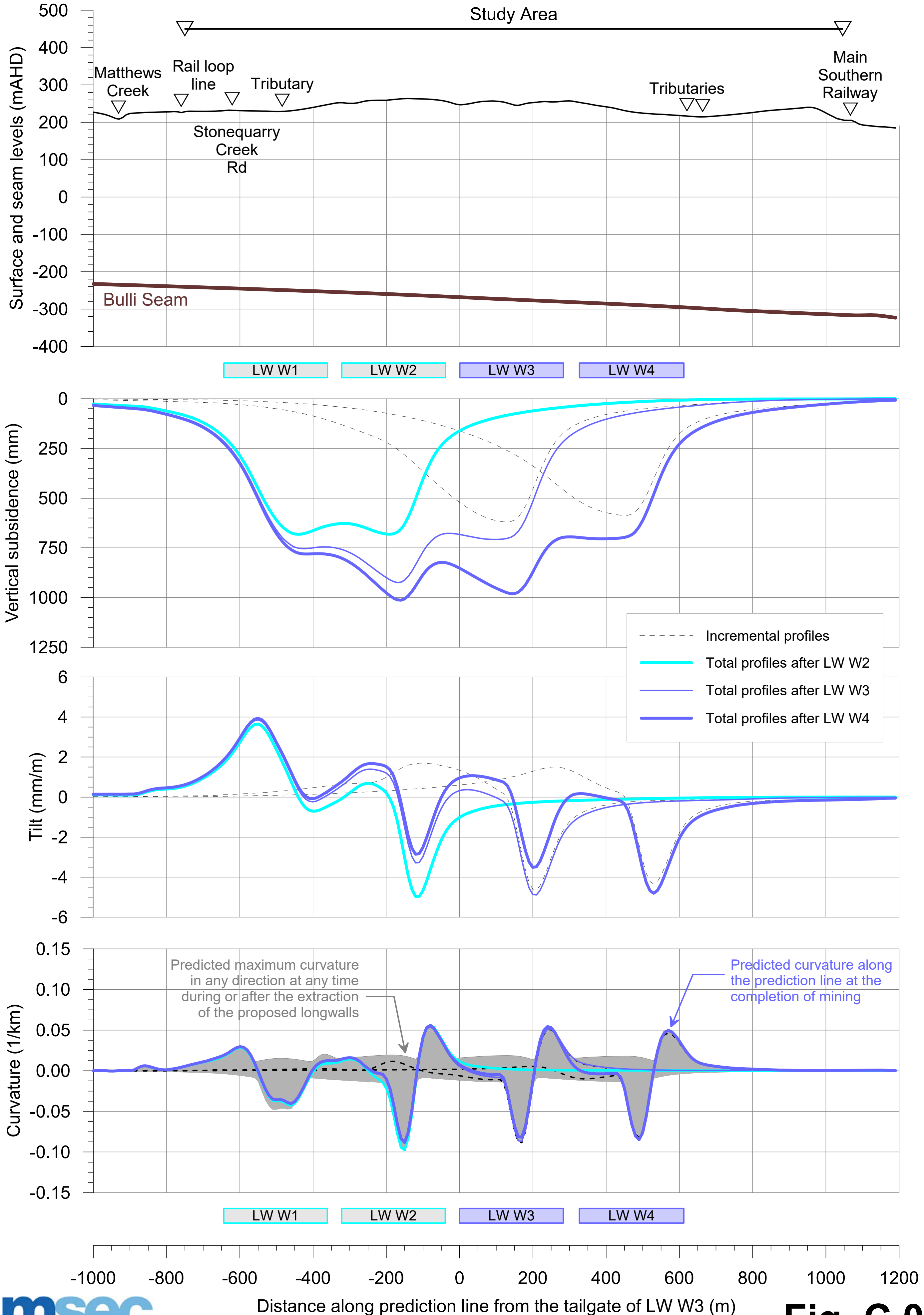


Fig. B.4 Probability Curves for Impacts to Buildings (based on observations up to Longwall 29)

APPENDIX C. FIGURES

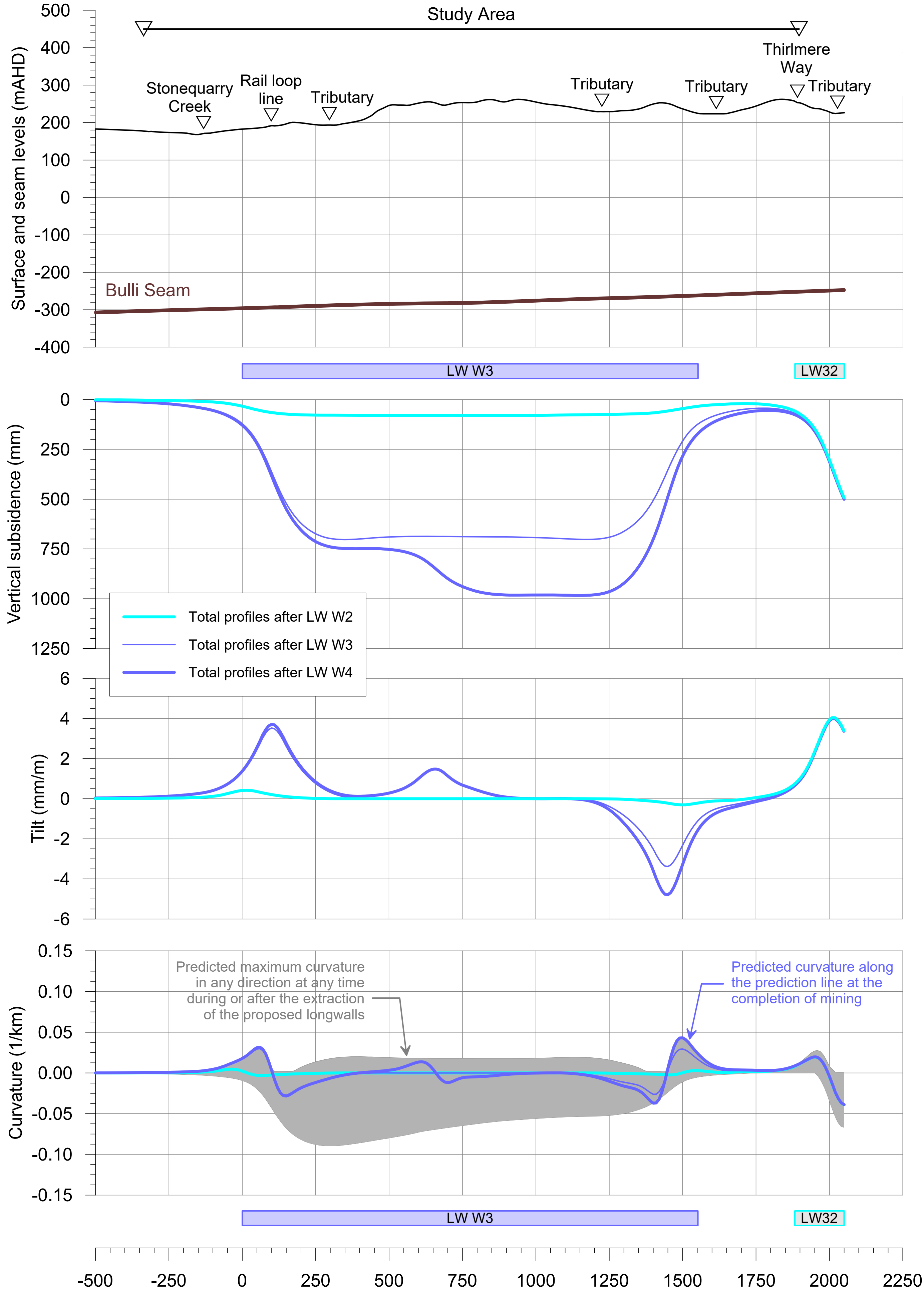
Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 1 due to LW W3-W4



msec

Fig. C.01

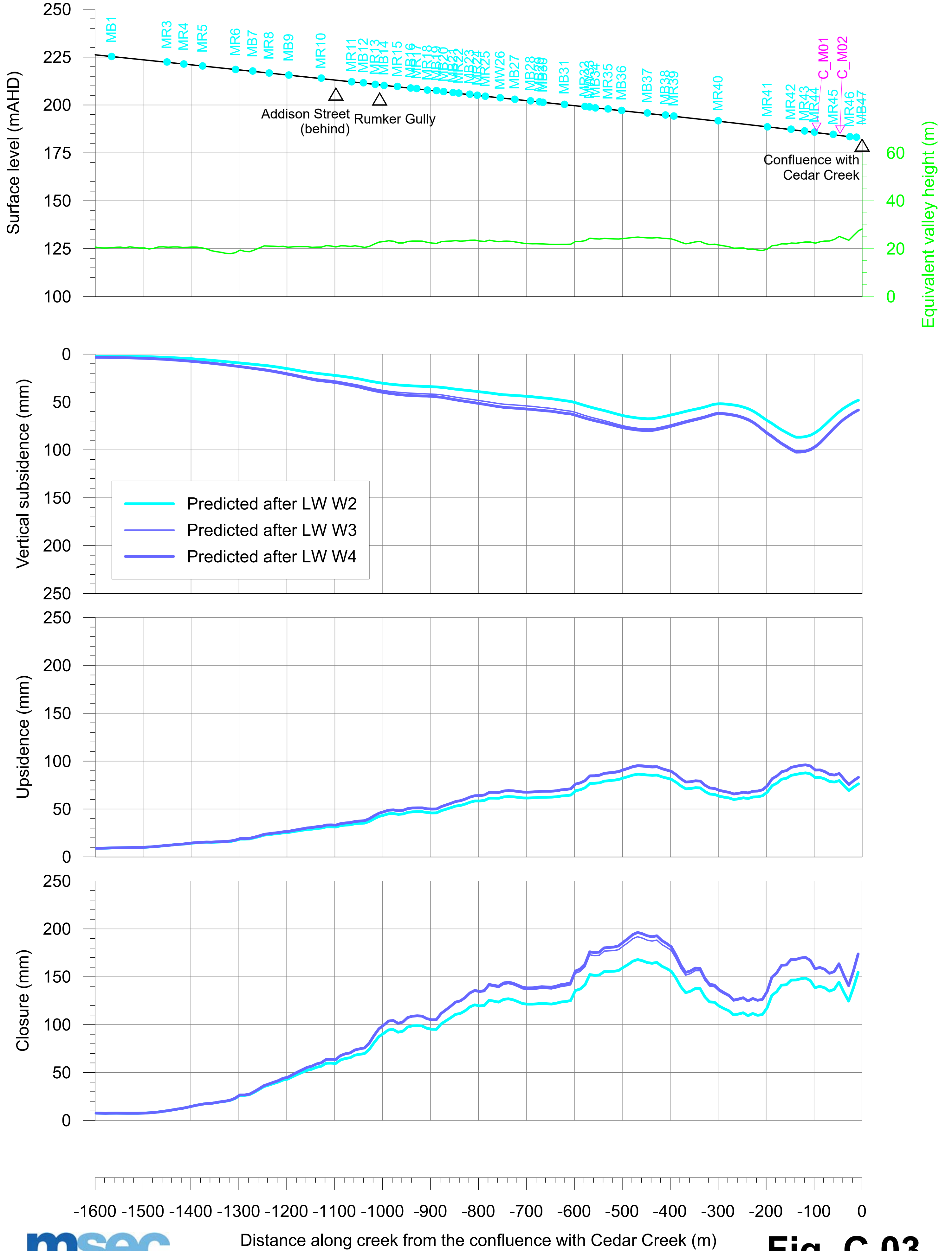
Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 2 due to LW W3-W4



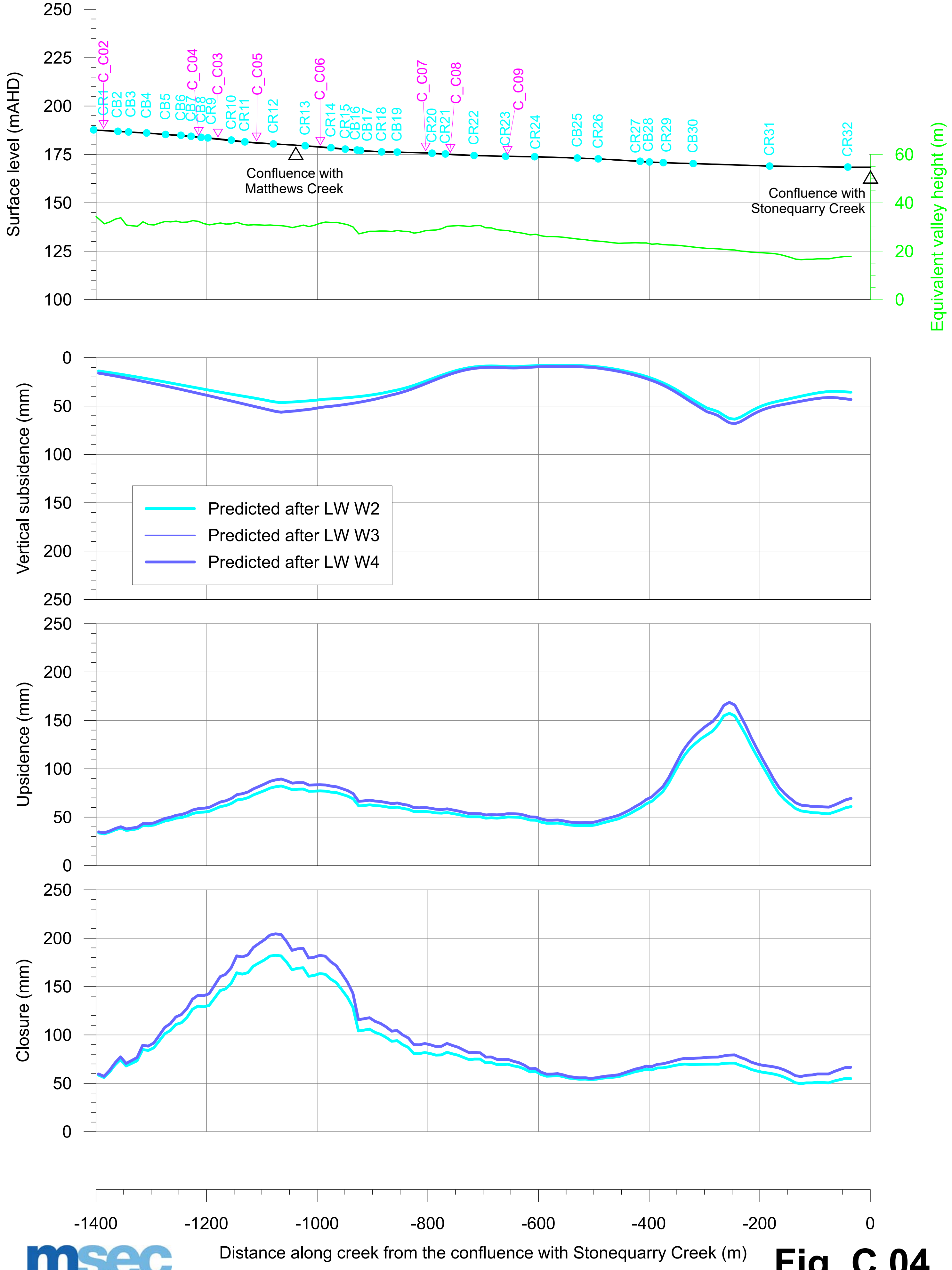
msec

Fig. C.02

Predicted profiles of vertical subsidence, upsidence and closure along Matthews Creek due to the extraction of LW W3-W4



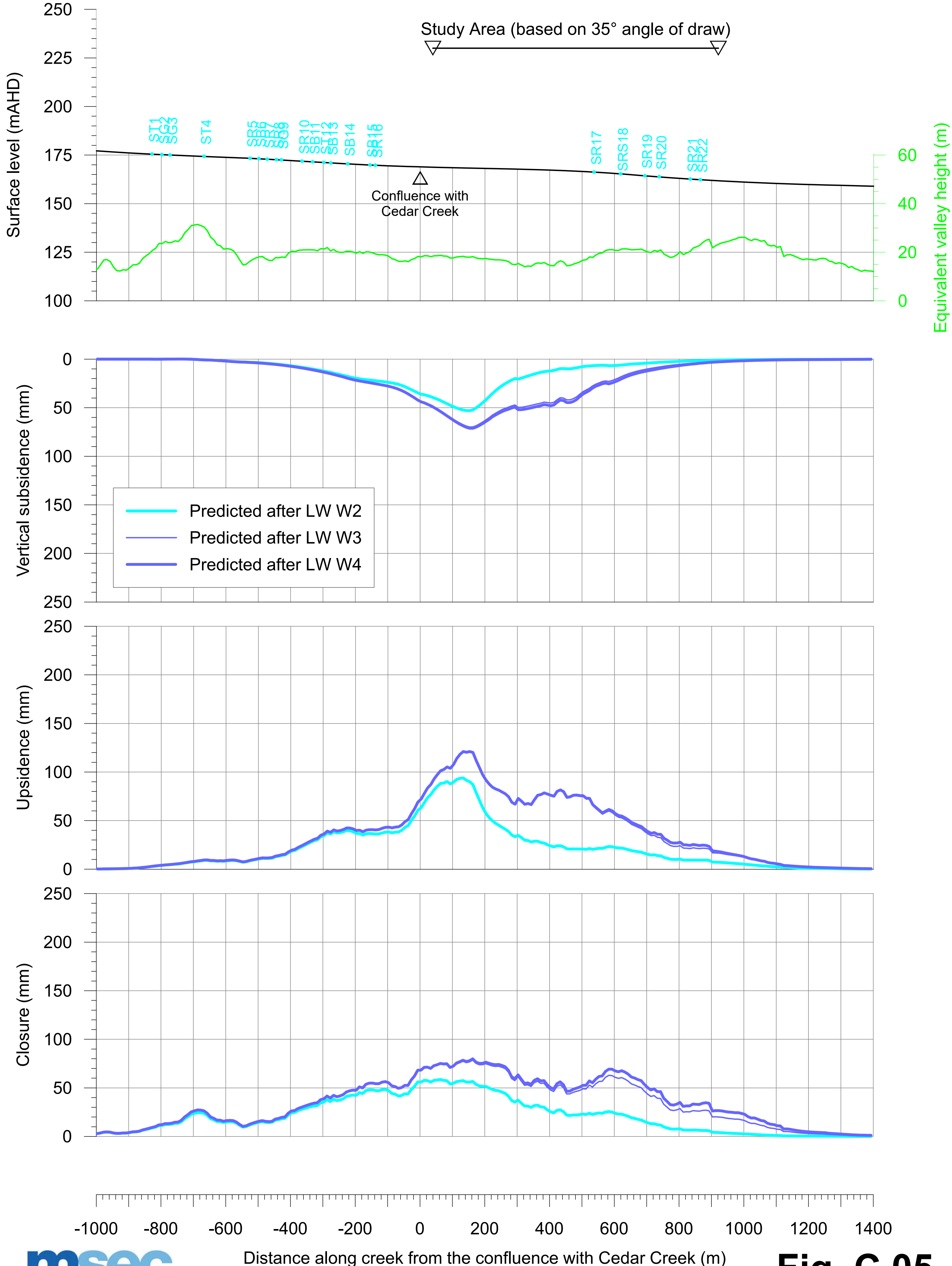
Predicted profiles of vertical subsidence, upsidence and closure along Cedar Creek due to the extraction of LW W3-W4



msec

Fig. C.04

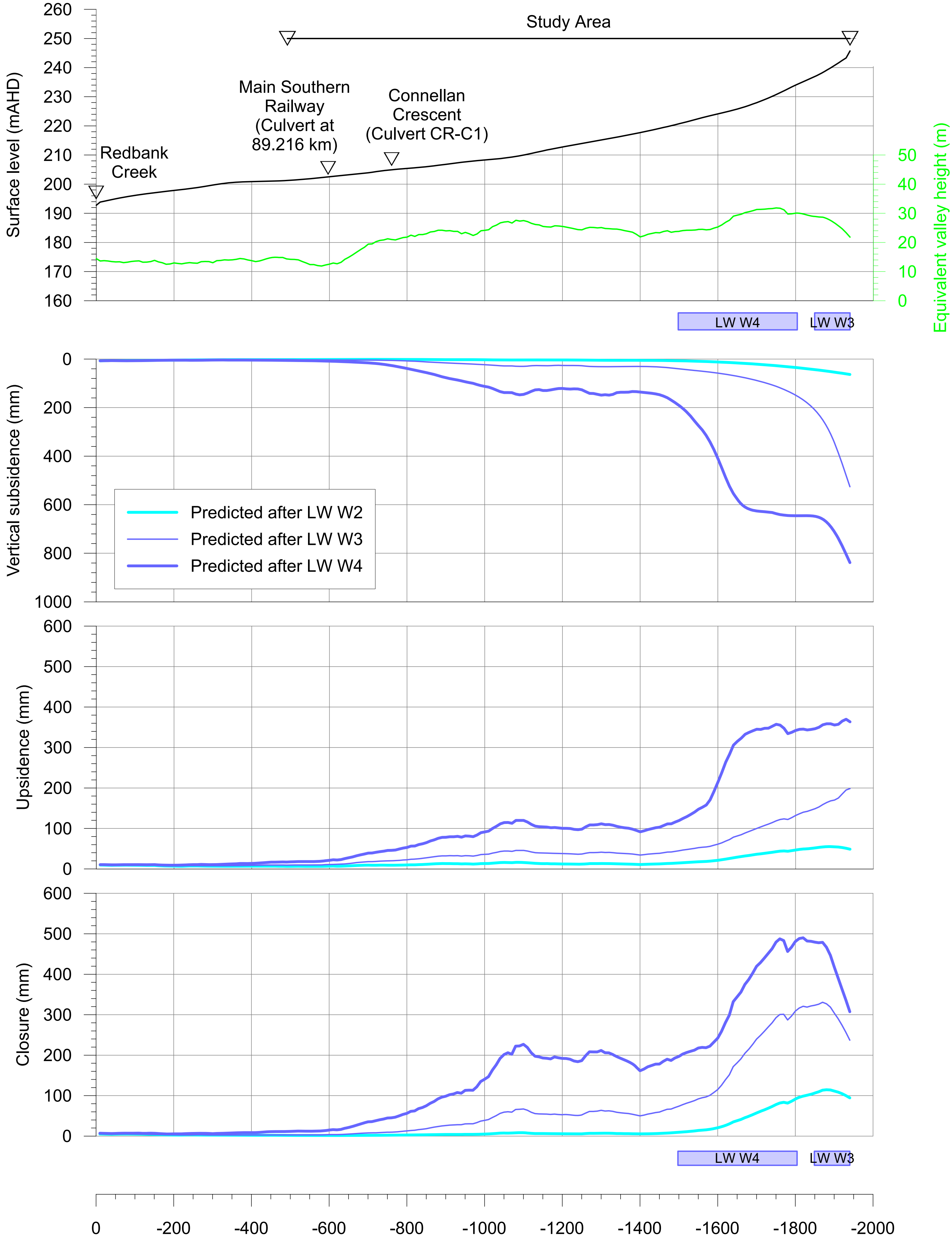
Predicted profiles of vertical subsidence, upsidence and closure along Stonequarry Creek due to the extraction of LW W3-W4



msec

Fig. C.05

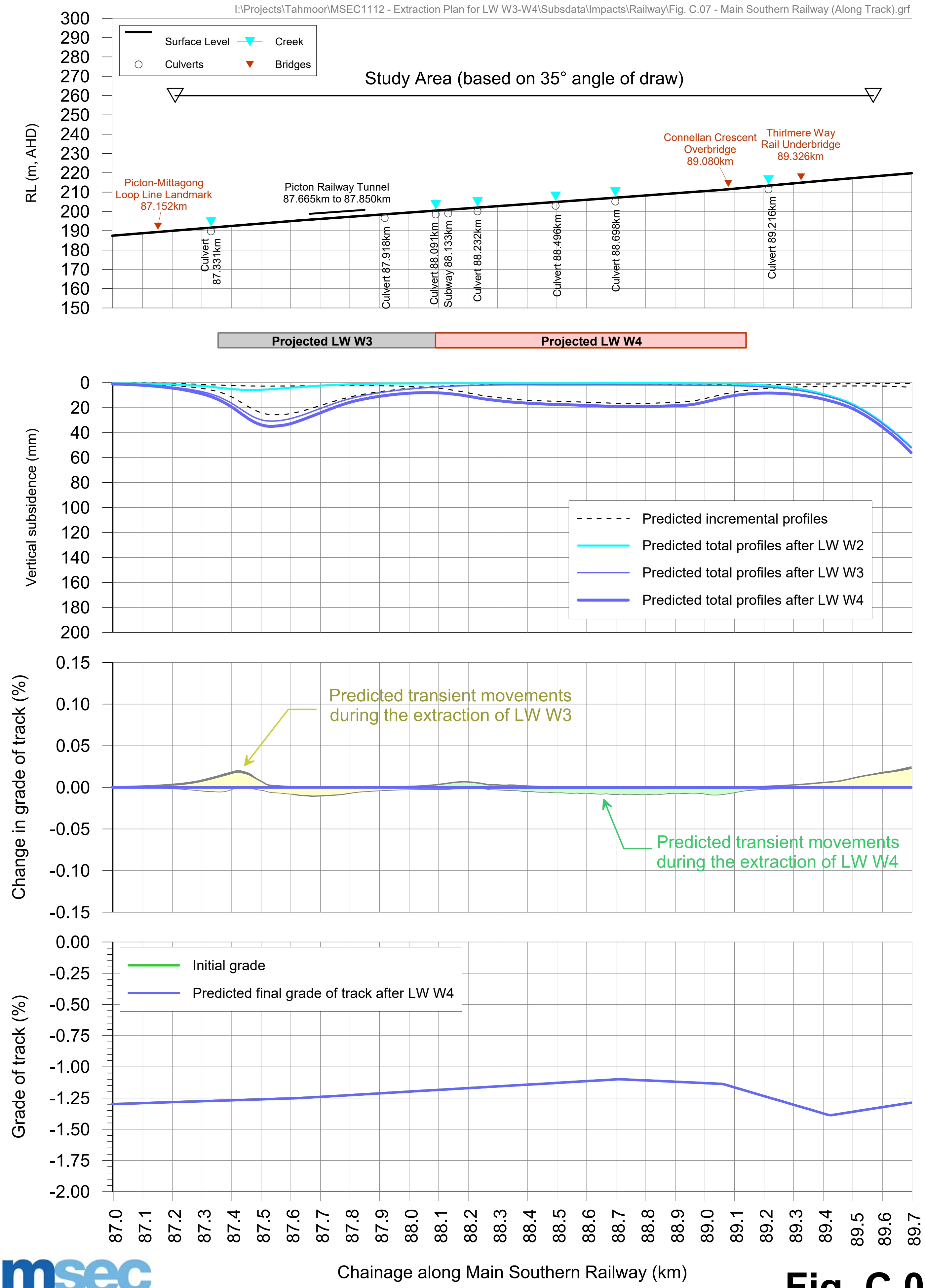
Predicted profiles of vertical subsidence, upsidence and closure along Tributary 1 to Redbank Creek due to the extraction of LW W3-W4



msec

Fig. C.06

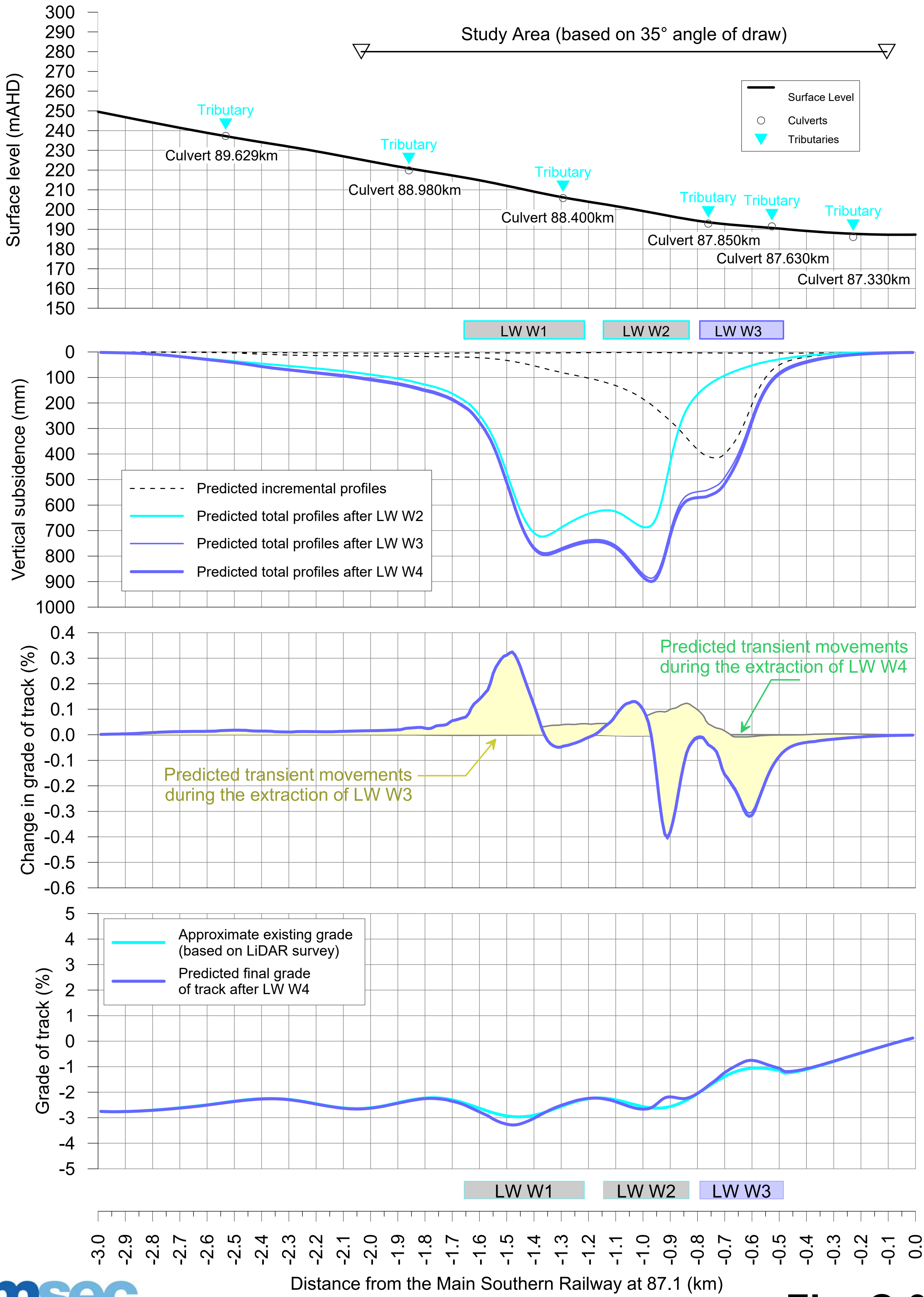
Predicted profilesof vertical subsidence and change in grade along the alignment of the Main Southern Railway duw to LW W3-W4



msec

Fig. C.07

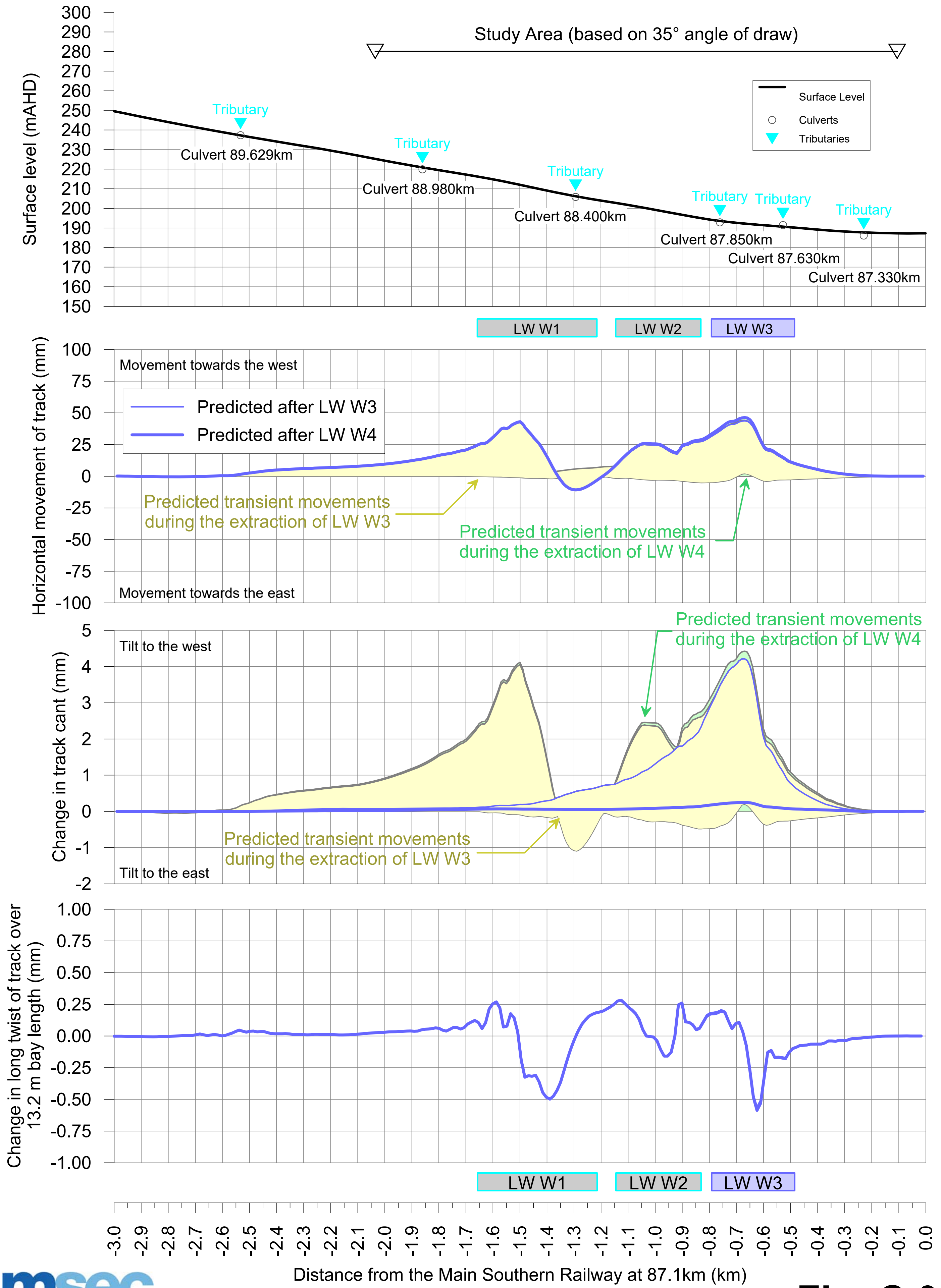
Predicted profiles of vertical subsidence and change in grade along the alignment of the Picton-Mittagong Loop Line due to LW W3-W4



msec

Fig. C.08

Predicted profiles of horizontal movement, change in cant and long twist across the alignment of the Picton-Mittagong Loop Line due to LW W3-W4

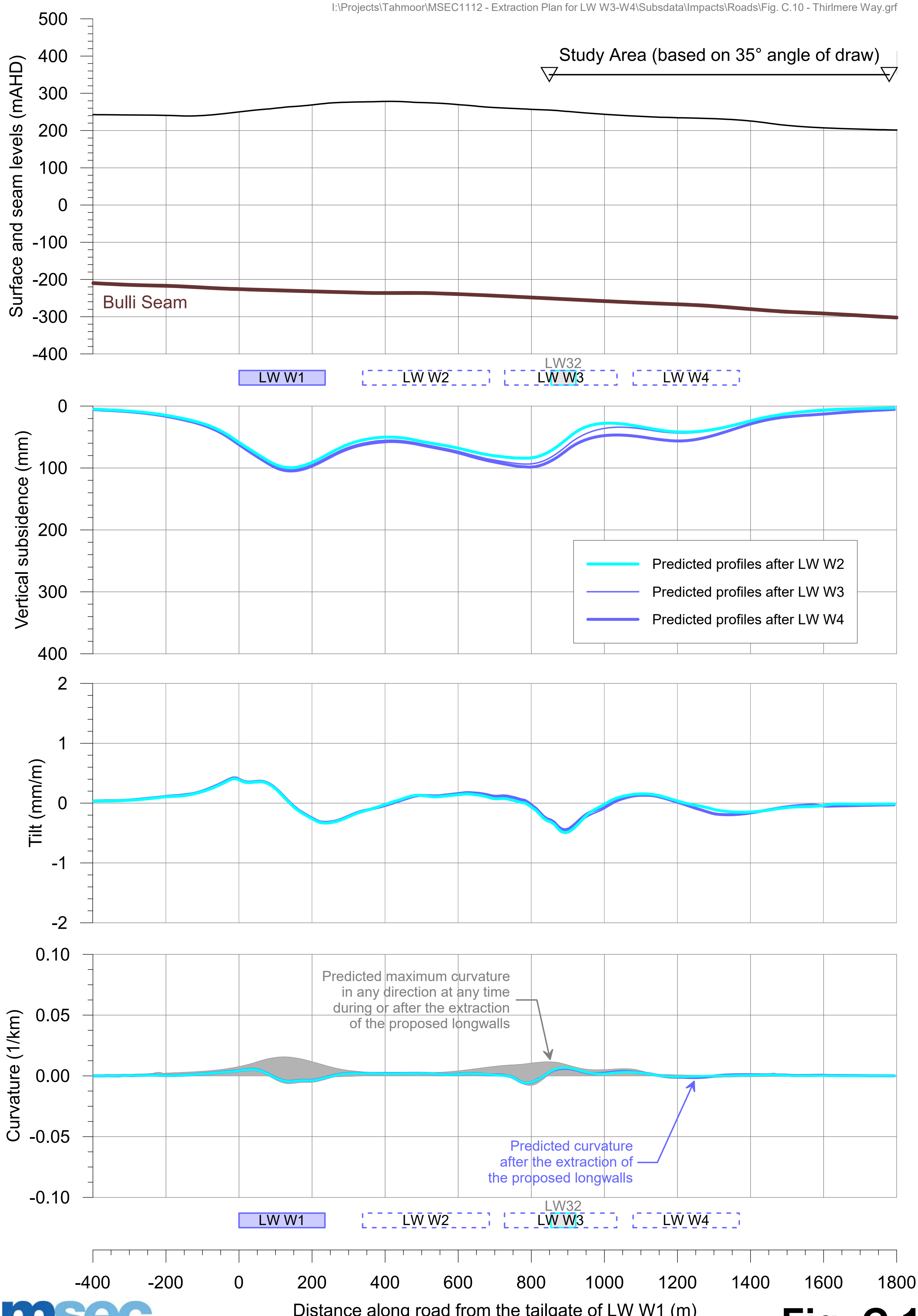


msec

Fig. C.09

Predicted profiles of vertical subsidence, tilt and curvature along Thirlmere Way due to LW W3-W4

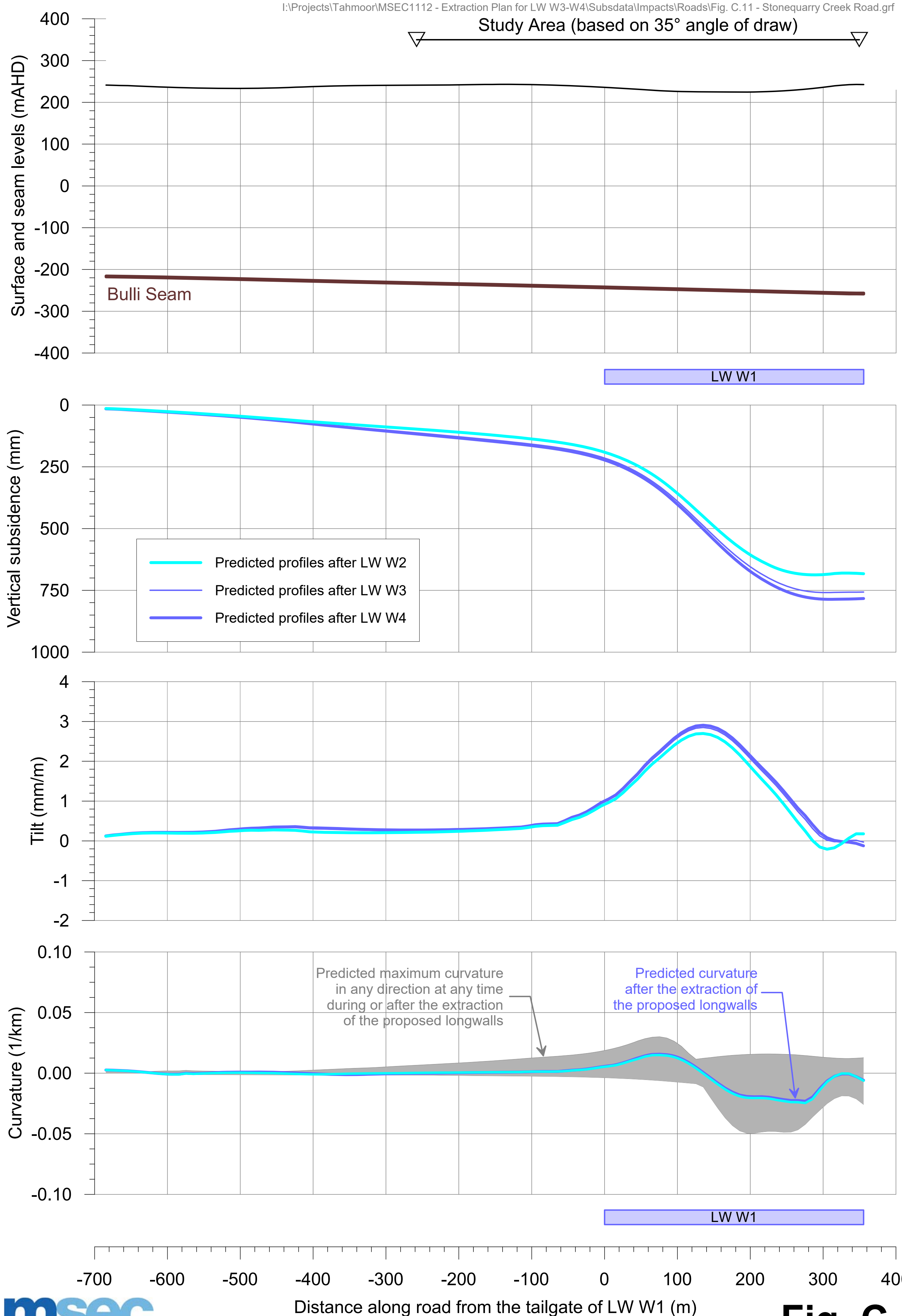
I:\Projects\Tahmoor\MSEC1112 - Extraction Plan for LW W3-W4\Subsdata\Impacts\Roads\Fig. C.10 - Thirlmere Way.grf



msec

Fig. C.10

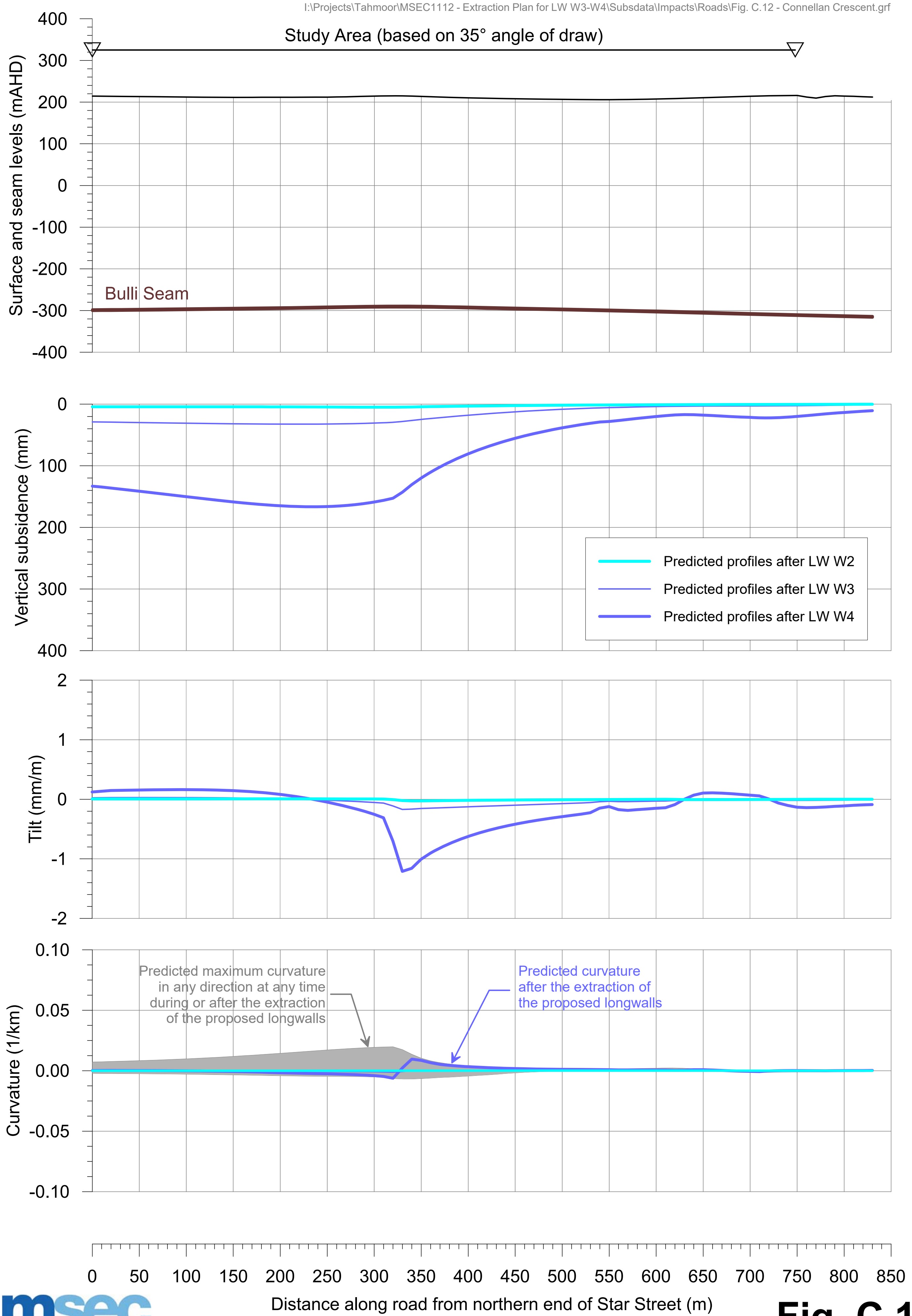
Predicted profiles of vertical subsidence, tilt and curvature along Stonequarry Creek Road due to LW W3-W4



msec

Fig. C.11

Predicted profiles of vertical subsidence, tilt and curvature along Star Street and Connellan Crescent due to LW W3-W4



msec

Fig. C.12

APPENDIX D.   TABLES

Table D.01 - Mapped stream features along Matthews Creek

Label	Description	Approximate distance from LW W3-W4 (m)	Predicted total subsidence after LW W3 (mm)	Predicted total subsidence after LW W4 (mm)	Predicted total upsidence after LW W3 (mm)	Predicted total upsidence after LW W4 (mm)	Predicted total closure after LW W3 (mm)	Predicted total closure after LW W4 (mm)
MB1	Boulder Constrained Pool	1360	< 20	< 20	< 20	< 20	< 20	< 20
MR3	Rockbar Constrained Pool	1310	< 20	< 20	< 20	< 20	< 20	< 20
MR4	Rockbar Constrained Pool	1280	< 20	< 20	< 20	< 20	< 20	< 20
MR5	Rockbar Constrained Pool	1240	< 20	< 20	< 20	< 20	< 20	< 20
MR6	Rockbar Constrained Pool	1175	< 20	< 20	< 20	< 20	30	30
MB7	Boulder Constrained Pool	1150	< 20	< 20	20	20	40	40
MR8	Rockbar Constrained Pool	1125	< 20	< 20	30	30	40	40
MB9	Boulder Constrained Pool	1090	20	20	30	30	50	50
MR10	Rockbar Constrained Pool	1035	30	30	30	30	60	60
MR11	Rockbar Constrained Pool	1005	30	30	40	40	70	70
MB12	Boulder Constrained Pool	990	40	40	40	40	90	90
MR13	Rockbar Constrained Pool	970	40	40	50	50	100	100
MB14	Boulder Constrained Pool	955	40	40	50	50	100	100
MR15	Rockbar Constrained Pool	940	40	40	50	50	110	110
MB16	Boulder Constrained Pool	930	40	40	50	50	110	110
MR17	Rockbar Constrained Pool	930	40	40	50	50	110	110
MR18	Rockbar Constrained Pool	930	40	40	50	50	110	110
MB19	Boulder Constrained Pool	925	40	50	50	50	120	120
MB20	Boulder Constrained Pool	920	40	50	60	60	120	120
MB21	Boulder Constrained Pool	910	50	50	60	60	120	120
MR22	Rockbar Constrained Pool	905	50	50	60	60	130	130
MB23	Boulder Constrained Pool	890	50	50	60	60	130	140
MR24	Rockbar Constrained Pool	880	50	50	60	60	130	140
MR25	Rockbar Constrained Pool	865	50	50	70	70	140	140
MW26	Waterfall Rock Bar Constrained Pool	855	50	60	70	70	140	140
MB27	Boulder Constrained Pool	845	50	60	70	70	140	140
MB28	Boulder Constrained Pool	845	60	60	70	70	140	140
MB29	Boulder Constrained Pool	840	60	60	70	70	140	140
MB30	Boulder Constrained Pool	840	60	60	70	70	140	140
MB31	Boulder Constrained Pool	830	60	60	80	80	150	160
MR32	Rockbar Constrained Pool	820	70	70	80	80	170	180
MW33	Waterfall Rock Bar Constrained Pool	815	70	70	80	90	170	180
MB34	Boulder Constrained Pool	815	70	70	90	90	180	180
MR35	Rockbar Constrained Pool	810	70	80	90	90	180	180
MB36	Boulder Constrained Pool	800	80	80	90	90	190	190
MB37	Boulder Constrained Pool	790	80	80	90	90	190	190
MB38	Boulder Constrained Pool	790	70	80	90	90	180	180
MR39	Rockbar Constrained Pool	800	70	80	90	90	180	180
MR40	Rockbar Constrained Pool	825	60	60	70	70	140	140
MR41	Rockbar Constrained Pool	795	90	90	80	80	150	150
MR42	Rockbar Constrained Pool	760	100	100	100	100	170	170
MR43	Rockbar Constrained Pool	750	100	100	100	100	170	170
MR44	Rockbar Constrained Pool	755	100	100	90	90	160	160
MR45	Rockbar Constrained Pool	790	80	80	90	90	160	160
MR46	Rockbar Constrained Pool	825	60	60	80	80	170	170
MB47	Boulder Constrained Pool	835	60	60	80	80	180	180
		Maximum	**100**	**100**	**100**	**100**	**200**	**200**

Table D.02 - Mapped stream features along Cedar Creek

Label	Description	Approximate distance from LW W3-W4 (m)	Predicted total subsidence after LW W3 (mm)	Predicted total subsidence after LW W4 (mm)	Predicted total upsidence after LW W3 (mm)	Predicted total upsidence after LW W4 (mm)	Predicted total closure after LW W3 (mm)	Predicted total closure after LW W4 (mm)
CR1	Rockbar Constrained Pool	1230	< 20	< 20	40	40	60	60
CB2	Boulder Constrained Pool	1190	20	20	40	40	80	80
CB3	Boulder Constrained Pool	1170	20	20	40	40	80	80
CB4	Boulder Constrained Pool	1135	30	30	50	50	100	100
CB5	Boulder Constrained Pool	1100	30	30	50	50	120	120
CB6	Boulder Constrained Pool	1075	40	40	60	60	140	140
CB7	Boulder Constrained Pool	1055	40	40	60	60	140	140
CB8	Boulder Constrained Pool	1040	40	40	60	60	150	150
CR9	Rockbar Constrained Pool	1025	40	40	70	70	160	160
CR10	Rockbar Constrained Pool	985	50	50	70	70	180	180
CR11	Rockbar Constrained Pool	960	50	50	80	80	190	190
CR12	Rockbar Constrained Pool	910	60	60	90	90	200	200
CR13	Rockbar Constrained Pool	900	50	60	90	90	190	190
CR14	Rockbar Constrained Pool	895	50	50	80	80	180	180
CR15	Rockbar Constrained Pool	895	50	50	80	80	170	170
CB16	Boulder Constrained Pool	895	50	50	80	80	150	150
CB17	Boulder Constrained Pool	895	50	50	80	80	150	150
CR18	Rockbar Constrained Pool	890	40	40	70	70	120	120
CB19	Boulder Constrained Pool	890	40	40	70	70	110	110
CR20	Rockbar Constrained Pool	880	30	30	60	60	90	90
CR21	Rockbar Constrained Pool	880	20	20	60	60	90	90
CR22	Rockbar Constrained Pool	880	< 20	< 20	50	50	80	80
CR23	Rockbar Constrained Pool	850	< 20	< 20	50	50	70	70
CR24	Rockbar Constrained Pool	820	< 20	< 20	50	50	70	70
CB25	Boulder Constrained Pool	790	< 20	< 20	50	50	60	60
CR26	Rockbar Constrained Pool	765	< 20	< 20	50	50	60	60
CR27	Rockbar Constrained Pool	680	20	20	70	70	70	70
CB28	Boulder Constrained Pool	660	30	30	80	80	70	70
CR29	Rockbar Constrained Pool	635	30	30	100	100	70	70
CB30	Boulder Constrained Pool	585	50	50	140	140	80	80
CR31	Rockbar Constrained Pool	490	60	60	120	120	70	70
CR32	Rockbar Constrained Pool	375	40	40	70	70	70	70
		Maximum	**60**	**60**	**150**	**150**	**200**	**200**

Table D.03 - Mapped stream features along Stonequarry Creek

Label	Description	Approximate distance from LW W3-W4 (m)	Predicted total subsidence after LW W3 (mm)	Predicted total subsidence after LW W4 (mm)	Predicted total upsidence after LW W3 (mm)	Predicted total upsidence after LW W4 (mm)	Predicted total closure after LW W3 (mm)	Predicted total closure after LW W4 (mm)
ST1	Tree Plant Roots Constrained Pool	1045	< 20	< 20	< 20	< 20	< 20	< 20
SG2	Gravel Bar Constrained Pool	605	< 20	< 20	< 20	< 20	< 20	< 20
SG3	Gravel Bar Constrained Pool	585	< 20	< 20	< 20	< 20	< 20	< 20
ST4	Tree Plant Roots Constrained Pool	525	< 20	< 20	< 20	< 20	30	30
SR5	Rockbar Constrained Pool	570	< 20	< 20	< 20	< 20	< 20	< 20
SB6	Boulder Constrained Pool	585	< 20	< 20	< 20	< 20	< 20	< 20
SR7	Rockbar Constrained Pool	605	< 20	< 20	< 20	< 20	< 20	< 20
SR8	Rockbar Constrained Pool	595	< 20	< 20	< 20	< 20	< 20	< 20
SG9	Gravel Bar Constrained Pool	585	< 20	< 20	< 20	< 20	20	20
SR10	Rockbar Constrained Pool	555	< 20	< 20	30	30	30	30
SB11	Boulder Constrained Pool	540	< 20	< 20	30	30	30	30
ST12	Tree Plant Roots Constrained Pool	520	< 20	< 20	40	40	40	40
SB13	Boulder Constrained Pool	505	< 20	< 20	40	40	40	40
SB14	Boulder Constrained Pool	480	20	20	40	40	50	50
SB15	Boulder Constrained Pool	430	30	30	40	40	50	50
SR16	Rockbar Constrained Pool	415	30	30	40	40	60	60
SR17	Rockbar Constrained Pool	175	30	30	70	70	60	60
SRS18	Rock Shelf	120	20	20	60	60	60	70
SR19	Rockbar Constrained Pool	150	< 20	< 20	40	50	50	60
SR20	Rockbar Constrained Pool	175	< 20	< 20	30	40	40	50
SR21	Rockbar Constrained Pool	255	< 20	< 20	20	30	30	30
SR22	Rockbar Constrained Pool	285	< 20	< 20	20	30	30	30
		Maximum	**30**	**30**	**70**	**70**	**60**	**70**

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses				House Wall Type			House Roof Type		House Footing Type			Other Structures			
								Single Storey with Length less than 30 metres	Single Storey with Length greater than 30 metres	Double Storey with Length less than 30 metres	Double Storey with Length greater than 30 metres	Brick or Brick Veneer	Weatherboard	Fibro	Tiled	Metal Sheet	Slab on Ground	Suspended on Piered Footings	Suspended on Strip Footings	Rural	Pool	Public Utilities	Commerical
								H1	H2	H3	H4									R	P	PU	C
PAR_078_r01	279280	6214587	Rural	Shed	9.1	80.5														1			
PAR_082_h01	279286	6214600	House		14.0	148.3	1	1				1			1		1						
PAR_088_h01	279312	6214616	House		22.2	314.9	1	1				1			1		1						
PAR_088_p01	279301	6214627	Pool		7.7	26.8															1		
PAR_088_r01	279308	6214623	Rural	Pergola	7.1	38.9														1			
PAR_088_r02	279302	6214621	Rural	Pergola	5.7	20.9														1			
PAR_088_r05	279282	6214617	Rural	Shed	2.3	5.1														1			
PAR_088_t01	279292	6214614	Rural	Tank	2.1	3.3														1			
PAR_090_h01	279354	6214642	House		12.5	115.2	1	1					1			1		1					
PAR_094_r02	279396	6214758	Rural	Garage	6.1	36.5														1			
PAR_096_h01	279401	6214775	House		28.1	391.4	1	1				1				1		1					
PAR_096_p01	279371	6214780	Pool		10.1	35.0															1		
PAR_096_r01	279358	6214794	Rural	Garage	18.2	329.6														1			
PAR_096_r02	279355	6214782	Rural	Shed	7.5	27.5														1			
PAR_096_r03	279379	6214793	Rural	Shed	2.1	3.3														1			
PAR_096_r07	279373	6214786	Rural	Shed	5.5	10.1														1			
PAR_096_t01	279345	6214786	Rural	Tank	3.3	8.3														1			
PAR_096_t02	279349	6214785	Rural	Tank	3.3	8.3														1			
PAR_096_t03	279349	6214800	Rural	Tank	1.7	2.1														1			
PAR_098_c01	279401	6214800	Commercial		54.4	724.6																	1
PAR_100_c04	279404	6214820	Commercial		7.3	32.0																	1
PAR_100_c05	279394	6214823	Commercial		13.9	76.6																	1
PAR_100_c06	279409	6214811	Commercial		23.0	155.7																	1
PAR_102_r02	279412	6214824	Rural	Garage	7.3	54.4														1			
PAR_104_r01	279410	6214847	Rural	Garage	9.7	73.3														1			
PAR_104_r03	279402	6214849	Rural	Tank	2.5	4.9														1			
PAT_001_h01	277728	6214984	House		52.1	689.7	1		1			1				1	1						
PAT_001_r01	277730	6214967	Rural	Garage	9.3	73.1														1			
PAT_001_r02	277735	6214966	Rural	Shed	4.4	12.8														1			
PAT_001_t01	277735	6215023	Rural	Tank	5.9	27.1														1			
PAT_002_h01	277767	6214976	House		27.0	405.9	1	1				1				1	1	1	1				
PAT_003_h01	277799	6214970	House		27.6	508.4	1	1				1				1		1	1				
PAT_003_r01	277817	6214962	Rural	Garage	9.4	83.3														1			
PAT_004_h01	277857	6214964	House		35.9	344.6	2				1		1			1		1	1				
PAT_006_h01	277972	6215004	House		19.6	271.0	1	1					1			1		1	1				
PAT_006_r01	277957	6215033	Rural	Shed	8.4	52.5														1			
PAT_006_r02	277943	6215026	Rural	Shed	5.6	20.8														1			
PAT_006_r03	277943	6215032	Rural	Shed	5.7	14.4														1			

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses: Single Storey with Length less than 30 metres (H1)	Houses: Single Storey with Length greater than 30 metres (H2)	Houses: Double Storey with Length less than 30 metres (H3)	Houses: Double Storey with Length greater than 30 metres (H4)	House Wall Type: Brick or Brick Veneer	House Wall Type: Weatherboard	House Wall Type: Fibro	House Roof Type: Tiled	House Roof Type: Metal Sheet	House Footing Type: Slab on Ground	House Footing Type: Suspended on Piered Footings	House Footing Type: Suspended on Strip Footings	Other Structures: Rural (R)	Other Structures: Pool (P)	Other Structures: Public Utilities (PU)	Other Structures: Commerical (C)
PAT_006_r04	277946	6215032	Rural	Shed	5.7	18.0														1			
PAT_006_r06	277989	6215035	Rural	Shed	3.5	10.4														1			
PAT_006_r07	277986	6215047	Rural	Shed	12.9	99.6														1			
PAT_006_r08	277988	6215054	Rural	Shed	12.0	71.4														1			
PAT_006_r09	277947	6215026	Rural	Shed	5.7	20.4														1			
PAT_006_r10	277932	6215054	Rural	Shed	4.7	11.7														1			
PAT_008_h01	277827	6214897	House		29.5	434.4	1	1				1				1		1	1				
PBG_001_h01	277921	6215362	House		29.1	477.5	1	1					1			1	1						
PBG_001_h02	277933	6215333	House		23.4	224.5	1	1					1			1	1						
PBG_001_r01	277970	6215340	Rural	Shed	2.9	6.9														1			
PBG_002_h01	277972	6215315	House		26.5	418.4	2			1		1				1		1	1				
PBG_002_r01	277999	6215339	Rural	Shed	2.1	4.3														1			
PBG_003_h01	278008	6215271	House		25.2	301.3	1	1				1				1		1	1				
PBG_003_r01	278011	6215301	Rural	Garage	9.6	63.3														1			
PBG_004_h01	277979	6215192	House		29.8	385.7	2			1		1				1		1	1				
PBG_004_p01	277989	6215174	Pool		11.7	37.3															1		
PBG_004_r01	277998	6215151	Rural	Shed	4.9	15.0														1			
PBG_005_h01	277942	6215242	House		35.8	464.6	2				1	1				1	1	1	1				
PBG_005_r01	277937	6215224	Rural	Pergola	4.7	21.1														1			
PBG_006_h01	277908	6215247	House		22.8	378.4	2			1			1			1		1	1				
PBG_007_h01	277888	6215277	House		26.7	446.2	1	1				1				1	1						
PBG_008_h01	277850	6215290	House		30.3	441.9	1		1			1				1	1						
PBL_002_p01	278479	6216590	Pool		7.3	25.6															1		
PBL_013_h01	278472	6216601	House		17.1	156.4	1	1				1				1	1						
PBL_013_r01	278477	6216596	Rural	Pergola	10.1	30.1														1			
PBL_013_r02	278466	6216581	Rural	Garage	13.2	110.6														1			
PBL_013_r03	278471	6216570	Rural	Shed	6.2	24.7														1			
PBL_013_r04	278466	6216569	Rural	Shed	4.3	14.1														1			
PBL_013_r05	278492	6216561	Rural	Shed	6.1	14.3														1			
PBL_013_r06	278470	6216574	Rural	Shed	5.8	13.8														1			
PBL_013_r07	278436	6216625	Rural	Shed	4.8	12.4														1			
PBL_013_t01	278472	6216564	Rural	Tank	2.5	5.1														1			
PBL_013_t02	278472	6216562	Rural	Tank	1.3	1.4														1			
PBL_013_t03	278483	6216602	Rural	Tank	3.2	7.9														1			
PBL_017_h01	278267	6216650	House		12.0	122.2	1	1					1			1		1					
PBL_017_r02	278265	6216642	Rural	Pergola	10.2	33.4														1			
PBL_017_r03	278294	6216607	Rural	Shed	5.3	18.6														1			
PBL_017_r04	278233	6216633	Rural	Shed	7.8	55.4														1			

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses				House Wall Type			House Roof Type		House Footing Type			Other Structures			
								Single Storey with Length less than 30 metres H1	Single Storey with Length greater than 30 metres H2	Double Storey with Length less than 30 metres H3	Double Storey with Length greater than 30 metres H4	Brick or Brick Veneer	Weatherboard	Fibro	Tiled	Metal Sheet	Slab on Ground	Suspended on Piered Footings	Suspended on Strip Footings	Rural R	Pool P	Public Utilities PU	Commerical C
PBL_017_r10	278281	6216638	Rural	Garage	16.7	105.7														1			
PBL_017_t01	278259	6216644	Rural	Tank	2.7	5.7														1			
PBL_017_t02	278259	6216642	Rural	Tank	2.7	5.7														1			
PBL_017_t03	278238	6216630	Rural	Tank	2.7	5.7														1			
PBL_030_r01	278724	6216454	Rural	Shed	11.8	93.4														1			
PBL_030_r02	278723	6216465	Rural	Shed	1.7	1.9														1			
PBL_030_r03	278740	6216466	Rural	Shed	1.7	1.9														1			
PCA_004_r01	277962	6214834	Rural	Shed	14.3	92.2														1			
PCN_001_h01	279322	6214892	House		22.0	233.1	1	1				1			1				1				
PCN_001_p01	279325	6214884	Pool		7.1	21.1															1		
PCN_001_r01	279326	6214888	Rural	Pergola	4.8	20.7														1			
PCN_001_r02	279312	6214873	Rural	Shed	3.1	8.5														1			
PCN_001_r03	279308	6214843	Rural	Shed	8.4	44.8														1			
PCN_001_r04	279311	6214869	Rural	Shed	3.0	7.5														1			
PCN_001_r05	279305	6214836	Rural	Shed	5.7	21.1														1			
PCN_001_t01	279313	6214877	Rural	Tank	2.8	6.2														1			
PCN_001_t02	279314	6214881	Rural	Tank	1.5	1.8														1			
PCN_001_t03	279303	6214840	Rural	Tank	1.5	1.8														1			
PCN_006_h01	279290	6214991	House		18.6	180.0	2			1		1				1			1				
PCN_006_r02	279292	6215014	Rural	Shed	4.4	12.6														1			
PCN_006_t01	279301	6214990	Rural	Tank	1.7	2.3														1			
PCN_008_h01	279312	6214982	House		17.2	221.0	2			1		1			1				1				
PCN_008_r01	279311	6214989	Rural	Pergola	7.8	32.6														1			
PCN_008_r02	279323	6215042	Rural	Shed	3.9	8.4														1			
PCN_010_h01	279329	6214974	House		16.3	227.6	1	1					1			1			1				
PCN_010_p01	279340	6214989	Pool		6.7	23.3															1		
PCN_010_r01	279319	6214962	Rural	Carport	5.9	33.0														1			
PCN_012_h01	279347	6214969	House		22.1	223.7	1	1				1			1		1						
PCN_012_r01	279357	6214961	Rural	Carport	6.9	44.4														1			
PCN_012_r02	279353	6214970	Rural	Pergola	10.0	45.4														1			
PCN_014_h01	279376	6215019	House		19.4	204.6	1	1				1			1				1				
PCN_014_p01	279361	6215029	Pool		7.8	27.1															1		
PCN_014_r01	279379	6215014	Rural	Pergola	9.4	23.0														1			
PCN_014_r02	279370	6215009	Rural	Pergola	6.0	34.8														1			
PCN_014_r03	279369	6215004	Rural	Carport	6.0	26.4														1			
PCN_014_r05	279349	6215017	Rural	Shed	4.7	19.7														1			
PCN_014_r06	279351	6215028	Rural	Shed	6.2	25.2														1			
PCN_021_h01	279347	6215106	House		14.6	198.2	1	1						1		1		1					

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses				House Wall Type			House Roof Type		House Footing Type			Other Structures			
								Single Storey with Length less than 30 metres	Single Storey with Length greater than 30 metres	Double Storey with Length less than 30 metres	Double Storey with Length greater than 30 metres	Brick or Brick Veneer	Weatherboard	Fibro	Tiled	Metal Sheet	Slab on Ground	Suspended on Piered Footings	Suspended on Strip Footings	Rural	Pool	Public Utilities	Commerical
								H1	H2	H3	H4									R	P	PU	C
PCN_021_r01	279315	6215087	Rural	Garage	6.9	40.4														1			
PCN_021_r02	279377	6215122	Rural	Shed	5.8	13.8														1			
PCN_021_r03	279348	6215136	Rural	Shed	3.4	8.1														1			
PCN_021_r04	279362	6215114	Rural	Shed	7.7	26.9														1			
PCN_025_h01	279306	6214895	House		23.7	271.8	1	1					1			1			1				
PCN_025_p01	279302	6214869	Pool		7.6	23.7															1		
PCN_025_t01	279298	6214881	Rural	Tank	2.4	4.6														1			
PHL_091_r01	279220	6214531	Rural	Garage	12.6	103.2														1			
PHL_092_h01	279235	6214560	House		27.2	328.8	1	1				1			1		1						
PHL_092_r01	279234	6214583	Rural	Shed	5.9	32.1														1			
PHL_092_r02	279236	6214574	Rural	Pergola	11.4	35.7														1			
PHL_092_r03	279239	6214556	Rural	Pergola	8.3	24.3														1			
PHL_093_h01	279207	6214561	House		17.7	232.3	1	1				1			1		1						
PHL_093_p01	279218	6214571	Pool		7.0	23.1															1		
PHL_093_r01	279199	6214550	Rural	Carport	5.3	13.5														1			
PHL_093_r02	279193	6214551	Rural	Shed	7.4	29.3														1			
PHL_093_r03	279186	6214553	Rural	Shed	4.9	15.6														1			
PHL_093_r04	279213	6214562	Rural	Pergola	7.2	28.9														1			
PHL_094_h01	279197	6214514	House		14.2	114.8	1	1						1		1		1					
PHL_094_r01	279204	6214529	Rural	Shed	9.1	56.0														1			
PHL_094_r03	279192	6214516	Rural	Pergola	7.1	22.4														1			
PHL_095_h01	279176	6214521	House		25.4	221.0	1	1				1			1				1				
PHL_095_r01	279169	6214523	Rural	Pergola	11.6	66.8														1			
PHL_095_r02	279179	6214536	Rural	Pergola	7.0	42.3														1			
PHL_095_r03	279190	6214547	Rural	Shed	3.4	10.0														1			
PRU_001_h01	279258	6214859	House		13.0	127.7	2			1		1	1		1		1						
PRU_001_p01	279264	6214848	Pool		8.7	34.4															1		
PRU_003_h01	279078	6214840	House		14.5	186.1	1	1					1			1		1					
PRU_003_r01	279072	6214855	Rural	Shed	6.4	24.0														1			
PRU_003_r02	279076	6214854	Rural	Carport	6.4	33.9														1			
PRU_003_r03	279055	6214814	Rural	Shed	11.6	85.6														1			
PRU_003_r04	279049	6214806	Rural	Shed	3.7	13.4														1			
PRU_003_r05	279049	6214791	Rural	Shed	3.5	11.6														1			
PSC_009_h01	277677	6215052	House		16.1	221.1	2			1		1				1	1						
PSC_010_h01	277694	6215100	House		31.5	403.1	1		1			1				1	1						
PSC_010_p01	277672	6215111	Pool		9.7	33.2															1		
PSC_010_r01	277677	6215090	Rural	Garage	9.2	72.2														1			
PSC_010_r02	277687	6215103	Rural	Pergola	12.0	75.8														1			

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses				House Wall Type			House Roof Type		House Footing Type			Other Structures			
								Single Storey with Length less than 30 metres	Single Storey with Length greater than 30 metres	Double Storey with Length less than 30 metres	Double Storey with Length greater than 30 metres	Brick or Brick Veneer	Weatherboard	Fibro	Tiled	Metal Sheet	Slab on Ground	Suspended on Piered Footings	Suspended on Strip Footings	Rural	Pool	Public Utilities	Commerical
								H1	H2	H3	H4									R	P	PU	C
PSC_010_t01	277672	6215094	Rural	Tank	2.2	3.9														1			
PSC_011_h01	277700	6215138	House		24.7	366.3	1	1				1				1		1	1				
PSC_011_p01	277676	6215152	Pool		9.7	47.6															1		
PSC_011_r01	277701	6215146	Rural	Pergola	15.7	56.9														1			
PSC_011_r02	277685	6215154	Rural	Shed	9.0	47.8														1			
PSC_011_r03	277679	6215159	Rural	Awning	6.1	19.3														1			
PSC_012_h01	277709	6215196	House		30.7	475.8	1		1			1				1	1						
PSC_012_p01	277685	6215202	Pool		11.2	38.9															1		
PSC_012_r01	277716	6215174	Rural	Garage	7.1	44.1														1			
PSC_013_h01	277722	6215234	House		28.8	423.4	2			1		1				1		1	1				
PSC_014_h01	277761	6215295	House		28.9	463.3	2			1		1				1		1	1				
PSC_014_r01	277742	6215271	Rural	Garage	10.5	74.7														1			
PSC_014_r02	277738	6215288	Rural	Gazebo	8.8	68.7														1			
PSC_015_h01	277709	6215321	House		40.8	455.3	1		1			1				1	1						
PSC_016_h01	277722	6215386	House		23.3	359.1	1	1					1			1		1	1				
PSC_016_r01	277712	6215370	Rural	Garage	7.2	47.3														1			
PSC_016_r02	277712	6215376	Rural	Awning	5.6	17.3														1			
PSC_016_r03	277718	6215414	Rural	Shed	3.8	6.4														1			
PSC_016_r04	277716	6215424	Rural	Shed	6.7	44.1														1			
PSC_016_r05	277707	6215371	Rural	Shed	5.4	12.3														1			
PSC_017_h01	277770	6215377	House		33.9	423.2	1		1			1			1		1						
PSC_017_r01	277751	6215364	Rural	Garage	18.7	124.4														1			
PSC_018_h01	277816	6215349	House		29.2	703.5	1	1				1				1	1						
PSC_018_p01	277820	6215359	Pool		13.8	67.9															1		
PSC_019_pu01	277753	6215480	Public Utility	Pump station No. 2	5.6	11.9																1	
PSC_019_pu02	277762	6215474	Public Utility	Overflow storage tanks	12.2	77.3																1	
PSC_020_h01	278000	6215430	House		31.0	262.2	1		1				1			1		1	1				
PSC_020_h02	278011	6215439	House		28.0	181.1	1	1					1			1		1	1				
PSC_021_h01	277975	6215371	House		25.9	345.4	1	1				1				1		1	1				
PSC_021_r01	277982	6215354	Rural	Garage	7.9	58.8														1			
PSC_021_r02	277992	6215360	Rural	Shed	5.7	13.1														1			
PSC_022_h01	277778	6215153	House		32.6	462.7	2				1	1				1	1						
PSC_022_t01	277759	6215117	Rural	Tank	5.4	23.2														1			
PSC_023_h01	277835	6215145	House		28.4	518.8	1	1				1				1		1	1				
PSC_023_r01	277820	6215098	Rural	Shed	8.8	76.3														1			
PSC_024_h01	277762	6215064	House		32.8	587.8	1		1				1			1	1						
PSC_024_r01	277776	6215047	Rural	Garage	13.1	95.7														1			
PSC_090_pu01	278547	6216190	Public Utility	Shed	5.2	22.5																1	

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses: Single Storey with Length less than 30 metres	Houses: Single Storey with Length greater than 30 metres	Houses: Double Storey with Length less than 30 metres	Houses: Double Storey with Length greater than 30 metres	House Wall Type: Brick or Brick Veneer	House Wall Type: Weatherboard	House Wall Type: Fibro	House Roof Type: Tiled	House Roof Type: Metal Sheet	House Footing Type: Slab on Ground	House Footing Type: Suspended on Piered Footings	House Footing Type: Suspended on Strip Footings	Other Structures: Rural	Other Structures: Pool	Other Structures: Public Utilities	Other Structures: Commerical
								H1	H2	H3	H4									R	P	PU	C
PSC_090_pu02	278540	6216186	Public Utility	Tank	8.5	57.5																1	
PSC_090_pu03	278542	6216177	Public Utility	Tank	8.5	57.5																1	
PSC_090_pu04	278544	6216168	Public Utility	Tank	8.5	57.5																1	
PSC_090_pu05	278551	6216187	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu06	278547	6216186	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu07	278548	6216182	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu08	278549	6216178	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu09	278550	6216175	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu10	278551	6216171	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu11	278542	6216218	Public Utility	Tank	8.5	57.5																1	
PSC_090_pu12	278535	6216210	Public Utility	Tank	8.5	57.5																1	
PSC_090_pu13	278567	6216240	Public Utility	Shed	3.0	3.6																1	
PSC_091_r01	278472	6216406	Rural	Shed	9.2	84.9														1			
PSC_091_r02	278492	6216419	Rural	Shed	11.5	59.0														1			
PSC_092_h01	278429	6216451	House		13.1	91.5	1	1					1			1		1	1	1			
PSC_092_t01	278423	6216459	Rural	Tank	2.2	4.0														1			
PSG_001_h01	278879	6216530	House		20.3	188.3	1	1				1				1	1						
PSG_001_r01	278884	6216521	Rural	Garage	9.3	59.1														1			
PSG_001_r02	278867	6216494	Rural	Shed	7.1	42.8														1			
PSG_001_t01	278876	6216547	Rural	Tank	2.5	5.1														1			
PSR_001_r01	279303	6215233	Rural	Shed	8.2	57.5														1			
PSR_010_h01	279323	6215660	House		22.8	331.8	1	1				1			1				1				
PSR_010_h02	279340	6215434	House		12.0	140.2	1	1						1		1		1					
PSR_010_r01	279328	6215665	Rural	Pergola	9.0	27.3														1			
PSR_010_r02	279303	6215679	Rural	Shed	10.4	104.1														1			
PSR_010_r03	279184	6215549	Rural	Shed	16.9	222.2														1			
PSR_010_r04	279174	6215533	Rural	Shed	9.4	51.3														1			
PSR_010_r05	279169	6215513	Rural	Shed	3.7	10.0														1			
PSR_010_r06	279325	6215462	Rural	Shed	8.7	50.8														1			
PSR_010_r08	279319	6215394	Rural	Shed	7.9	32.4														1			
PSR_010_r09	279305	6215697	Rural	Shed	3.1	5.9														1			
PSR_010_t01	279298	6215675	Rural	Tank	2.5	4.8														1			
PSR_010_t02	279316	6215666	Rural	Tank	1.6	2.1														1			
PTH_031_r01	278352	6215105	Rural	Shed	18.9	178.8														1			
PTH_031_r02	278374	6215090	Rural	Shed	14.7	180.7														1			
PTH_031_r03	278394	6215056	Rural	Shed	19.0	169.9														1			
PTH_031_r04	278415	6215040	Rural	Shed	3.9	12.6														1			
PTH_031_r05	278422	6215034	Rural	Shed	11.0	53.8														1			

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses: Single Storey with Length less than 30 metres (H1)	Houses: Single Storey with Length greater than 30 metres (H2)	Houses: Double Storey with Length less than 30 metres (H3)	Houses: Double Storey with Length greater than 30 metres (H4)	House Wall Type: Brick or Brick Veneer	House Wall Type: Weatherboard	House Wall Type: Fibro	House Roof Type: Tiled	House Roof Type: Metal Sheet	House Footing Type: Slab on Ground	House Footing Type: Suspended on Piered Footings	House Footing Type: Suspended on Strip Footings	Other Structures: Rural (R)	Other Structures: Pool (P)	Other Structures: Public Utilities (PU)	Other Structures: Commerical (C)
PTH_031_r06	278430	6215072	Rural	Shed	11.6	105.8														1			
PTH_031_r07	278422	6215061	Rural	Shed	11.1	47.5														1			
PTH_031_r08	278412	6215066	Rural	Shed	5.3	24.0														1			
PTH_031_r09	278382	6215087	Rural	Awning	14.7	77.1														1			
PTH_031_t01	278420	6215073	Rural	Tank	5.7	25.4														1			
PTH_031_t02	278404	6215056	Rural	Tank	2.6	5.3														1			
PTH_031_t04	278370	6215103	Rural	Tank	2.6	5.3														1			
PTH_055_h01	278604	6214939	House		22.9	290.9	1	1				1	1			1		1	1				
PTH_055_r01	278577	6214930	Rural	Shed	7.1	49.5														1			
PTH_080_r01	278661	6214817	Rural	Shed	3.1	9.4														1			
PTH_092_r01	279012	6214876	Rural	Shed	7.4	40.2														1			
PTH_092_r02	279006	6214876	Rural	Shed	3.1	9.6														1			
PTH_110_h01	279088	6214598	House		26.8	325.1	2			1		1			1				1				
PTH_110_p01	279068	6214600	Pool		9.6	31.4															1		
PTH_110_r01	279087	6214602	Rural	Pergola	4.9	19.1														1			
PTH_110_r02	279060	6214602	Rural	Shed	4.4	15.0														1			
PTH_112_h01	279142	6214662	House		18.0	262.4	1	1					1			1		1					
PTH_112_r01	279106	6214646	Rural	Shed	13.3	46.7														1			
PTH_112_r02	279114	6214654	Rural	Shed	4.4	12.3														1			
PTH_121_h01	279233	6214754	House		29.0	386.8	1	1				1			1		1						
PTH_121_r01	279252	6214746	Rural	Shed	5.0	15.1														1			
PTH_121_t01	279267	6214779	Rural	Tank	2.3	4.6														1			
PTH_121_t02	279269	6214781	Rural	Tank	2.3	4.6														1			
PTH_126_h01	279322	6214715	House		17.2	189.2	1	1				1			1		1						
PTH_126_p01	279320	6214740	Pool		8.6	35.8															1		
PTH_126_r01	279311	6214715	Rural	Carport	5.9	18.5														1			
PTH_126_r02	279318	6214721	Rural	Pergola	8.2	48.4														1			
PTH_126_r03	279321	6214752	Rural	Shed	6.7	21.9														1			
PTH_126_r04	279333	6214737	Rural	Shed	5.5	20.8														1			
PTH_126_t01	279331	6214727	Rural	Tank	2.1	3.5														1			
PTH_128_h01	279336	6214712	House		17.8	196.8	1	1				1			1		1						
PTH_128_r01	279345	6214706	Rural	Carport	8.2	29.6														1			
PTH_128_r02	279343	6214715	Rural	Pergola	8.8	46.3														1			
PTH_128_r03	279353	6214743	Rural	Shed	9.4	59.7														1			
PTH_128_r04	279344	6214753	Rural	Shed	4.5	13.9														1			
PTH_130_h01	279360	6214707	House		17.6	161.5	1	1					1			1		1					
PTH_130_r01	279363	6214698	Rural	Carport	5.6	30.4														1			
PTH_130_r02	279361	6214739	Rural	Shed	4.7	13.5														1			

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses: Single Storey with Length less than 30 metres (H1)	Houses: Single Storey with Length greater than 30 metres (H2)	Houses: Double Storey with Length less than 30 metres (H3)	Houses: Double Storey with Length greater than 30 metres (H4)	House Wall Type: Brick or Brick Veneer	House Wall Type: Weatherboard	House Wall Type: Fibro	House Roof Type: Tiled	House Roof Type: Metal Sheet	House Footing Type: Slab on Ground	House Footing Type: Suspended on Piered Footings	House Footing Type: Suspended on Strip Footings	Other Structures: Rural (R)	Other Structures: Pool (P)	Other Structures: Public Utilities (PU)	Other Structures: Commerical (C)
PTH_130_r03	279375	6214732	Rural	Shed	3.7	9.6														1			
PTH_132_h01	279378	6214702	House		19.4	294.7	1	1				1			1				1				
PTH_132_r03	279384	6214726	Rural	Shed	5.9	22.1														1			
PTH_132_r04	279379	6214729	Rural	Shed	2.8	7.2														1			
PTH_136_h01	279312	6214653	House		13.3	135.0	1	1				1			1		1						
PTH_136_r01	279321	6214654	Rural	Carport	6.5	22.8														1			
PTH_136_r02	279319	6214647	Rural	Carport	6.1	21.5														1			
PTH_136_r03	279311	6214645	Rural	Pergola	10.3	33.4														1			
PTH_136_r04	279309	6214634	Rural	Shed	14.3	79.0														1			
PTH_136_r05	279321	6214628	Rural	Shed	2.2	4.3														1			
PTH_136_t01	279323	6214628	Rural	Tank	1.6	2.0														1			
PTH_136_t02	279314	6214664	Rural	Tank	2.1	3.3														1			
PTH_138_h01	279287	6214652	House		17.1	201.1	1	1				1			1				1				
PTH_138_r01	279295	6214648	Rural	Carport	15.5	54.9														1			
PTH_138_r02	279282	6214645	Rural	Pergola	11.0	20.6														1			
PTH_138_r03	279272	6214640	Rural	Shed	5.7	15.9														1			
PTH_138_r04	279270	6214635	Rural	Shed	4.4	13.0														1			
PTH_140_h01	279275	6214665	House		14.6	167.1	1	1				1			1		1						
PTH_140_r01	279262	6214660	Rural	Garage	6.3	38.9														1			
PTH_140_r02	279265	6214639	Rural	Shed	6.2	23.3														1			
PTH_142_h01	279226	6214607	House		12.3	98.4	1	1				1				1			1				
PTH_142_h02	279264	6214586	House		10.3	103.9	1	1				1			1		1						
PTH_142_r02	279233	6214593	Rural	Shed	5.1	18.8														1			
PTH_142_r03	279233	6214603	Rural	Carport	8.0	25.0														1			
PTH_142_r04	279240	6214590	Rural	Shed	7.1	40.3														1			
PTH_142_r05	279257	6214586	Rural	Carport	6.4	22.7														1			
V09f	278957	6214492	Rural	Tank	3.0	7.3														1			
V15a	278592	6214524	House		43.1	630.8	1		1			1			1		1						
V15b	278554	6214493	Rural	Shed	23.3	200.1														1			
V15c	278564	6214487	Rural	Shed	19.4	97.1														1			
V15d	278560	6214512	Rural	Tank	7.9	49.2														1			
V15e	278585	6214532	Rural	Carport	8.2	54.8														1			
V15f	278576	6214518	Rural	Pergola	16.9	116.9														1			
V15g	278560	6214523	Rural	Tank	2.6	5.4														1			
							No.	47	9	10	3	49	19	3	22	47	30	29	32	196	16	15	4

Table D.05 - Predicted subsidence effects for the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Structure Type	Predicted total subsidence after LW W3 (mm)	Predicted total subsidence after LW W4 (mm)	Predicted total tilt after LW W3 (mm/m)	Predicted total tilt after LW W4 (mm/m)	Predicted total hogging curvature after LW W3 (1/km)	Predicted total hogging curvature after LW W4 (1/km)	Predicted total sagging curvature after LW W3 (1/km)	Predicted total sagging curvature after LW W4 (1/km)	Predicted mean total tensile strain (mm/m)	Predicted 95% CL for total tensile strain (mm/m)	Predicted mean total comp. strain (mm/m)	Predicted 95% CL for total comp. strain (mm/m)	Predicted Probability of Nil or Category R0 Impact for Houses (%)	Predicted Probability of Category R1 or R2 Impact for Houses (%)	Predicted Probability of Category R3 and R4 Impact for Houses (%)	Predicted Probability of Category R5 Impact for Houses (%)
PAR_078_r01	279279	6214587	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_082_h01	279285	6214601	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.4	4.3	0.2	0.1
PAR_088_h01	279311	6214618	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.5	4.3	0.2	0.1
PAR_088_p01	279300	6214627	Pool	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_088_r01	279308	6214624	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_088_r02	279301	6214621	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_088_r05	279283	6214618	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_088_t01	279292	6214614	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_090_h01	279354	6214643	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	97.3	2.3	0.3	0.1
PAR_094_r02	279396	6214758	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_096_h01	279400	6214775	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	94.9	4.5	0.5	0.1
PAR_096_p01	279370	6214780	Pool	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_096_r01	279356	6214793	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_096_r02	279354	6214782	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_096_r03	279379	6214793	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_096_r07	279373	6214786	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_096_t01	279345	6214786	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_096_t02	279349	6214785	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_096_t03	279349	6214800	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_098_c01	279402	6214801	Commercial	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_100_c04	279404	6214821	Commercial	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_100_c05	279393	6214823	Commercial	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_100_c06	279410	6214812	Commercial	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_102_r02	279411	6214825	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_104_r01	279409	6214848	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAR_104_r03	279402	6214850	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PAT_001_h01	277727	6214985	House	175	175	1.5	1.5	0.01	0.01	< 0.01	< 0.01	0.3	1.0	-0.1	-0.5	84.7	12.6	2.4	0.3
PAT_001_r01	277730	6214968	Rural	150	150	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.3	1.0	-0.1	-0.5	-	-	-	-
PAT_001_r02	277735	6214967	Rural	150	175	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.3	1.0	-0.1	-0.5	-	-	-	-
PAT_001_t01	277735	6215023	Rural	175	175	1.5	1.5	0.01	0.01	< 0.01	< 0.01	0.3	1.0	-0.1	-0.5	-	-	-	-
PAT_002_h01	277767	6214977	House	225	225	2.0	2.0	0.02	0.02	< 0.01	< 0.01	0.4	1.1	-0.1	-0.6	81.3	15.2	3.2	0.3
PAT_003_h01	277798	6214965	House	300	300	2.5	2.5	0.02	0.02	< 0.01	< 0.01	0.4	1.1	-0.2	-0.8	71.0	19.5	8.1	1.4
PAT_003_r01	277817	6214963	Rural	325	325	2.5	3.0	0.02	0.02	< 0.01	< 0.01	0.4	1.1	-0.2	-0.9	-	-	-	-
PAT_004_h01	277861	6214965	House	475	500	3.5	3.5	0.02	0.02	0.02	0.02	0.4	1.1	-0.4	-1.4	81.1	13.2	5.5	0.2
PAT_006_h01	277976	6215004	House	700	725	2.0	2.5	0.01	0.01	0.04	0.04	0.5	1.5	-0.6	-2.3	75.5	17.0	7.2	0.3
PAT_006_r01	277957	6215034	Rural	700	725	2.5	2.5	0.01	0.01	0.04	0.04	0.4	1.3	-0.8	-2.8	-	-	-	-
PAT_006_r02	277943	6215027	Rural	675	700	3.0	3.0	0.01	0.01	0.04	0.04	0.4	1.1	-0.9	-3.1	-	-	-	-
PAT_006_r03	277943	6215032	Rural	675	700	2.5	3.0	0.01	0.01	0.04	0.04	0.4	1.1	-0.9	-3.1	-	-	-	-
PAT_006_r04	277946	6215032	Rural	675	700	2.5	3.0	0.01	0.01	0.04	0.04	0.3	1.2	-0.9	-3.1	-	-	-	-
PAT_006_r06	277989	6215035	Rural	725	750	1.5	1.5	0.01	0.01	0.04	0.04	0.6	1.9	-0.4	-1.5	-	-	-	-
PAT_006_r07	277985	6215048	Rural	725	750	1.5	2.0	0.01	0.01	0.04	0.04	0.6	1.8	-0.4	-1.6	-	-	-	-
PAT_006_r08	277987	6215054	Rural	725	750	1.5	1.5	0.01	0.01	0.04	0.04	0.6	1.9	-0.4	-1.5	-	-	-	-
PAT_006_r09	277946	6215027	Rural	675	700	2.5	2.5	0.01	0.01	0.04	0.04	0.3	1.2	-0.9	-3.1	-	-	-	-
PAT_006_r10	277932	6215055	Rural	675	675	3.0	3.0	0.01	0.01	0.04	0.04	0.4	1.0	-0.9	-3.1	-	-	-	-
PAT_008_h01	277827	6214897	House	350	350	3.0	3.0	0.02	0.02	< 0.01	< 0.01	0.4	1.1	-0.3	-1.0	71.3	19.3	8.0	1.4
PBG_001_h01	277919	6215363	House	725	750	3.5	3.5	0.02	0.02	0.05	0.05	0.4	1.0	-1.0	-3.2	71.7	19.4	8.6	0.4
PBG_001_h02	277931	6215333	House	750	775	3.5	3.5	0.02	0.02	0.05	0.05	0.4	1.1	-0.9	-3.2	71.7	19.3	8.5	0.4
PBG_001_r01	277969	6215340	Rural	750	775	1.5	1.5	0.02	0.02	0.05	0.05	0.6	1.8	-0.4	-1.7	-	-	-	-
PBG_002_h01	277970	6215317	House	750	775	2.0	2.0	0.02	0.02	0.05	0.05	0.6	1.8	-0.4	-1.6	54.2	28.4	13.6	3.8
PBG_002_r01	277999	6215339	Rural	750	775	< 0.5	< 0.5	0.01	0.01	0.04	0.04	0.8	2.4	-0.2	-0.7	-	-	-	-
PBG_003_h01	278008	6215272	House	750	775	< 0.5	0.5	0.02	0.02	0.04	0.04	0.9	2.4	-0.2	-0.6	62.0	24.5	11.1	2.4
PBG_003_r01	278010	6215301	Rural	750	775	< 0.5	< 0.5	0.02	0.02	0.03	0.03	0.9	2.5	-0.2	-0.6	-	-	-	-
PBG_004_h01	277977	6215195	House	750	775	2.0	2.0	0.01	0.01	0.04	0.04	0.6	1.8	-0.4	-1.6	56.5	27.2	12.9	3.4
PBG_004_p01	277989	6215175	Pool	750	775	1.0	1.5	0.01	0.01	0.04	0.04	0.7	2.0	-0.3	-1.2	-	-	-	-
PBG_004_r01	277998	6215151	Rural	750	775	1.0	1.0	0.01	0.01	0.04	0.04	0.7	2.1	-0.3	-1.0	-	-	-	-
PBG_005_h01	277942	6215245	House	750	775	3.0	3.0	0.02	0.02	0.05	0.05	0.3	1.2	-0.9	-3.1	66.4	26.2	7.0	0.5
PBG_005_r01	277936	6215223	Rural	725	750	3.0	3.0	0.01	0.01	0.05	0.05	0.4	1.1	-0.9	-3.2	-	-	-	-
PBG_006_h01	277908	6215244	House	700	725	4.0	4.0	0.02	0.02	0.05	0.05	0.4	1.0	-0.9	-2.9	72.4	18.9	8.3	0.4
PBG_007_h01	277888	6215276	House	650	675	4.0	4.0	0.02	0.02	0.05	0.05	0.3	0.9	-0.7	-2.4	66.0	26.4	7.1	0.5
PBG_008_h01	277849	6215290	House	550	575	4.0	4.0	0.03	0.03	0.03	0.03	0.4	1.0	-0.4	-1.4	72.7	21.8	5.3	0.3
PBL_002_p01	278479	6216590	Pool	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_013_h01	278469	6216601	House	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	94.3	5.2	0.4	0.1

Table D.05 - Predicted subsidence effects for the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Structure Type	Predicted total subsidence after LW W3 (mm)	Predicted total subsidence after LW W4 (mm)	Predicted total tilt after LW W3 (mm/m)	Predicted total tilt after LW W4 (mm/m)	Predicted total hogging curvature after LW W3 (1/km)	Predicted total hogging curvature after LW W4 (1/km)	Predicted total sagging curvature after LW W3 (1/km)	Predicted total sagging curvature after LW W4 (1/km)	Predicted mean total tensile strain (mm/m)	Predicted 95% CL for total tensile strain (mm/m)	Predicted mean total comp. strain (mm/m)	Predicted 95% CL for total comp. strain (mm/m)	Predicted Probability of Nil or Category R0 Impact for Houses (%)	Predicted Probability of Category R1 or R2 Impact for Houses (%)	Predicted Probability of Category R3 and R4 Impact for Houses (%)	Predicted Probability of Category R5 Impact for Houses (%)
PBL_013_r01	278476	6216596	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_013_r02	278465	6216581	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_013_r03	278470	6216570	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_013_r04	278465	6216569	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_013_r05	278492	6216561	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.4	1.1	-0.4	-1.5	-	-	-	-
PBL_013_r06	278469	6216574	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_013_r07	278436	6216625	Rural	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_013_t01	278472	6216564	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_013_t02	278472	6216562	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_013_t03	278483	6216602	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_017_h01	278266	6216651	House	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.4	96.7	2.7	0.5	0.1
PBL_017_r02	278265	6216641	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.4	-	-	-	-
PBL_017_r03	278294	6216607	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PBL_017_r04	278232	6216634	Rural	30	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.2	-0.9	-	-	-	-
PBL_017_r10	278282	6216639	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PBL_017_t01	278259	6216644	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.5	-	-	-	-
PBL_017_t02	278259	6216642	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.5	-	-	-	-
PBL_017_t03	278238	6216630	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.2	-0.8	-	-	-	-
PBL_030_r01	278725	6216455	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.4	-0.1	-0.5	-	-	-	-
PBL_030_r02	278723	6216465	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.4	-0.1	-0.5	-	-	-	-
PBL_030_r03	278740	6216466	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.4	-0.1	-0.6	-	-	-	-
PCA_004_r01	277962	6214836	Rural	550	550	2.5	2.5	0.01	0.01	0.04	0.04	0.4	1.2	-0.8	-2.8	-	-	-	-
PCN_001_h01	279323	6214895	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	92.3	6.3	1.3	0.2
PCN_001_p01	279325	6214884	Pool	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_001_r01	279326	6214888	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_001_r02	279312	6214873	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_001_r03	279307	6214842	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_001_r04	279311	6214869	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_001_r05	279305	6214836	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_001_t01	279313	6214877	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_001_t02	279314	6214881	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_001_t03	279303	6214840	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_006_h01	279289	6214992	House	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	92.8	5.9	1.1	0.2
PCN_006_r02	279292	6215013	Rural	< 20	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_006_t01	279301	6214990	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_008_h01	279311	6214983	House	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	93.1	5.7	1.0	0.2
PCN_008_r01	279311	6214988	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_008_r02	279323	6215042	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_010_h01	279326	6214974	House	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	96.1	3.1	0.7	0.1
PCN_010_p01	279340	6214989	Pool	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_010_r01	279319	6214962	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_012_h01	279347	6214968	House	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	94.2	5.2	0.4	0.1
PCN_012_r01	279357	6214960	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_012_r02	279353	6214971	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_014_h01	279375	6215020	House	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	93.7	5.3	0.9	0.1
PCN_014_p01	279361	6215028	Pool	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_014_r01	279379	6215013	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_014_r02	279370	6215010	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_014_r03	279368	6215004	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_014_r05	279350	6215017	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_014_r06	279351	6215028	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_021_h01	279349	6215108	House	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	96.6	2.7	0.5	0.1
PCN_021_r01	279314	6215088	Rural	< 20	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_021_r02	279376	6215122	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_021_r03	279348	6215136	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_021_r04	279361	6215115	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_025_h01	279307	6214898	House	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.2	3.7	1.0	0.1
PCN_025_p01	279302	6214869	Pool	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PCN_025_t01	279298	6214881	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_091_r01	279221	6214531	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_092_h01	279235	6214558	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.1	4.5	0.2	0.1
PHL_092_r01	279233	6214583	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-

Table D.05 - Predicted subsidence effects for the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Structure Type	Predicted total subsidence after LW W3 (mm)	Predicted total subsidence after LW W4 (mm)	Predicted total tilt after LW W3 (mm/m)	Predicted total tilt after LW W4 (mm/m)	Predicted total hogging curvature after LW W3 (1/km)	Predicted total hogging curvature after LW W4 (1/km)	Predicted total sagging curvature after LW W3 (1/km)	Predicted total sagging curvature after LW W4 (1/km)	Predicted mean total tensile strain (mm/m)	Predicted 95% CL for total tensile strain (mm/m)	Predicted mean total comp. strain (mm/m)	Predicted 95% CL for total comp. strain (mm/m)	Predicted Probability of Nil or Category R0 Impact for Houses (%)	Predicted Probability of Category R1 or R2 Impact for Houses (%)	Predicted Probability of Category R3 and R4 Impact for Houses (%)	Predicted Probability of Category R5 Impact for Houses (%)
PHL_092_r02	279237	6214574	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_092_r03	279239	6214557	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_093_h01	279206	6214562	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	94.9	4.7	0.3	0.1
PHL_093_p01	279218	6214571	Pool	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_093_r01	279199	6214550	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_093_r02	279192	6214552	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_093_r03	279185	6214553	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_093_r04	279213	6214563	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_094_h01	279196	6214513	House	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	96.3	3.0	0.7	0.1
PHL_094_r01	279204	6214530	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_094_r03	279191	6214516	Rural	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_095_h01	279174	6214522	House	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	93.6	5.4	0.9	0.1
PHL_095_r01	279169	6214523	Rural	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_095_r02	279179	6214537	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PHL_095_r03	279190	6214547	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PRU_001_h01	279259	6214860	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	92.8	6.4	0.7	0.2
PRU_001_p01	279263	6214848	Pool	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PRU_003_h01	279077	6214841	House	< 20	50	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.2	91.5	6.1	2.3	0.1
PRU_003_r01	279071	6214855	Rural	< 20	50	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.2	-	-	-	-
PRU_003_r02	279076	6214853	Rural	< 20	50	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.2	-	-	-	-
PRU_003_r03	279055	6214815	Rural	< 20	50	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.2	-	-	-	-
PRU_003_r04	279049	6214806	Rural	< 20	40	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.2	-	-	-	-
PRU_003_r05	279048	6214791	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.2	-	-	-	-
PSC_009_h01	277677	6215051	House	125	125	1.0	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.9	-0.1	-0.4	89.0	9.3	1.5	0.2
PSC_010_h01	277694	6215101	House	125	150	1.0	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.3	0.9	-0.1	-0.4	87.1	10.8	1.9	0.3
PSC_010_p01	277672	6215111	Pool	125	125	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.9	-0.1	-0.4	-	-	-	-
PSC_010_r01	277676	6215090	Rural	125	125	1.0	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.9	-0.1	-0.4	-	-	-	-
PSC_010_r02	277687	6215104	Rural	125	125	1.0	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.3	0.9	-0.1	-0.4	-	-	-	-
PSC_010_t01	277672	6215094	Rural	100	125	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.9	-0.1	-0.4	-	-	-	-
PSC_011_h01	277704	6215139	House	150	150	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.3	1.0	-0.1	-0.4	83.3	12.2	4.0	0.4
PSC_011_p01	277675	6215151	Pool	125	125	1.0	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.3	0.9	-0.1	-0.4	-	-	-	-
PSC_011_r01	277701	6215147	Rural	150	150	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.3	1.0	-0.1	-0.4	-	-	-	-
PSC_011_r02	277685	6215155	Rural	125	125	1.0	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.3	0.9	-0.1	-0.4	-	-	-	-
PSC_011_r03	277678	6215158	Rural	125	125	1.0	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.3	0.9	-0.1	-0.4	-	-	-	-
PSC_012_h01	277705	6215195	House	150	175	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.3	1.0	-0.1	-0.4	84.8	12.5	2.4	0.3
PSC_012_p01	277686	6215201	Pool	125	125	1.0	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.3	0.9	-0.1	-0.4	-	-	-	-
PSC_012_r01	277716	6215174	Rural	150	150	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.3	1.0	-0.1	-0.4	-	-	-	-
PSC_013_h01	277723	6215233	House	175	200	1.5	1.5	0.02	0.02	< 0.01	< 0.01	0.4	1.0	-0.1	-0.4	79.5	14.5	5.3	0.7
PSC_014_h01	277762	6215295	House	250	275	2.0	2.5	0.02	0.02	< 0.01	< 0.01	0.4	1.2	-0.1	-0.6	71.1	19.5	8.1	1.4
PSC_014_r01	277741	6215271	Rural	200	200	1.5	1.5	0.02	0.02	< 0.01	< 0.01	0.4	1.1	-0.1	-0.5	-	-	-	-
PSC_014_r02	277738	6215289	Rural	200	200	1.5	1.5	0.02	0.02	< 0.01	< 0.01	0.4	1.1	-0.1	-0.5	-	-	-	-
PSC_015_h01	277709	6215322	House	175	175	1.5	1.5	0.01	0.02	< 0.01	< 0.01	0.3	1.0	-0.1	-0.4	83.3	13.7	2.7	0.3
PSC_016_h01	277723	6215384	House	200	200	1.5	1.5	0.02	0.02	< 0.01	< 0.01	0.4	1.1	-0.1	-0.4	85.6	10.1	4.1	0.2
PSC_016_r01	277711	6215371	Rural	150	175	1.0	1.5	0.01	0.01	< 0.01	< 0.01	0.4	1.1	-0.1	-0.4	-	-	-	-
PSC_016_r02	277712	6215376	Rural	150	175	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.4	1.1	-0.1	-0.4	-	-	-	-
PSC_016_r03	277718	6215415	Rural	175	175	1.5	1.5	0.01	0.01	< 0.01	< 0.01	0.4	1.1	-0.1	-0.4	-	-	-	-
PSC_016_r04	277715	6215423	Rural	175	175	1.5	1.5	0.01	0.01	< 0.01	< 0.01	0.4	1.1	-0.1	-0.4	-	-	-	-
PSC_016_r05	277707	6215372	Rural	150	150	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.4	1.0	-0.1	-0.4	-	-	-	-
PSC_017_h01	277770	6215374	House	300	300	2.5	2.5	0.03	0.03	< 0.01	< 0.01	0.4	1.2	-0.2	-0.6	74.1	20.7	4.9	0.3
PSC_017_r01	277751	6215363	Rural	225	225	2.0	2.0	0.02	0.02	< 0.01	< 0.01	0.4	1.2	-0.1	-0.5	-	-	-	-
PSC_018_h01	277815	6215345	House	450	450	4.0	4.0	0.03	0.03	< 0.01	< 0.01	0.4	1.1	-0.3	-1.0	73.0	21.5	5.2	0.3
PSC_018_p01	277819	6215359	Pool	425	425	3.5	4.0	0.03	0.03	< 0.01	< 0.01	0.4	1.1	-0.3	-1.0	-	-	-	-
PSC_019_pu01	277753	6215480	Public Utility	225	225	2.0	2.0	0.02	0.02	< 0.01	< 0.01	0.4	1.2	-0.1	-0.6	-	-	-	-
PSC_019_pu02	277761	6215475	Public Utility	250	250	2.0	2.5	0.02	0.02	< 0.01	< 0.01	0.4	1.2	-0.2	-0.6	-	-	-	-
PSC_020_h01	278004	6215429	House	750	800	0.5	1.0	0.02	0.02	0.04	0.04	0.9	2.4	-0.2	-0.6	73.9	18.0	7.8	0.3
PSC_020_h02	278009	6215441	House	750	800	< 0.5	< 0.5	0.02	0.02	0.03	0.03	1.0	2.6	-0.2	-0.5	76.9	16.0	6.7	0.3
PSC_021_h01	277971	6215372	House	750	800	2.0	2.0	0.02	0.02	0.05	0.05	0.6	1.9	-0.4	-1.4	54.0	28.5	13.7	3.8
PSC_021_r01	277982	6215354	Rural	750	800	1.0	1.5	0.02	0.02	0.05	0.05	0.7	2.1	-0.3	-1.1	-	-	-	-
PSC_021_r02	277992	6215359	Rural	750	800	0.5	1.0	0.01	0.01	0.04	0.04	0.8	2.3	-0.2	-0.8	-	-	-	-
PSC_022_h01	277777	6215154	House	275	275	2.5	2.5	0.02	0.02	< 0.01	< 0.01	0.4	1.1	-0.2	-0.7	76.8	18.6	4.3	0.3
PSC_022_t01	277759	6215117	Rural	225	225	1.5	1.5	0.02	0.02	< 0.01	< 0.01	0.4	1.1	-0.1	-0.6	-	-	-	-
PSC_023_h01	277833	6215140	House	450	450	3.5	3.5	0.03	0.03	< 0.01	< 0.01	0.4	1.1	-0.3	-1.2	68.4	21.0	9.0	1.6

Table D.05 - Predicted subsidence effects for the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Structure Type	Predicted total subsidence after LW W3 (mm)	Predicted total subsidence after LW W4 (mm)	Predicted total tilt after LW W3 (mm/m)	Predicted total tilt after LW W4 (mm/m)	Predicted total hogging curvature after LW W3 (1/km)	Predicted total hogging curvature after LW W4 (1/km)	Predicted total sagging curvature after LW W3 (1/km)	Predicted total sagging curvature after LW W4 (1/km)	Predicted mean total tensile strain (mm/m)	Predicted 95% CL for total tensile strain (mm/m)	Predicted mean total comp. strain (mm/m)	Predicted 95% CL for total comp. strain (mm/m)	Predicted Probability of Nil or Category R0 Impact for Houses (%)	Predicted Probability of Category R1 or R2 Impact for Houses (%)	Predicted Probability of Category R3 and R4 Impact for Houses (%)	Predicted Probability of Category R5 Impact for Houses (%)
PSC_023_r01	277820	6215097	Rural	350	375	3.0	3.0	0.03	0.03	< 0.01	< 0.01	0.4	1.1	-0.3	-1.0	-	-	-	-
PSC_024_h01	277765	6215063	House	225	225	2.0	2.0	0.02	0.02	< 0.01	< 0.01	0.4	1.1	-0.1	-0.6	85.1	10.5	4.3	0.2
PSC_024_r01	277775	6215048	Rural	250	250	2.0	2.0	0.02	0.02	< 0.01	< 0.01	0.4	1.1	-0.2	-0.6	-	-	-	-
PSC_090_pu01	278547	6216190	Public Utility	600	625	4.5	4.5	< 0.01	< 0.01	0.08	0.09	0.4	1.3	-0.9	-3.3	-	-	-	-
PSC_090_pu02	278540	6216186	Public Utility	625	650	4.5	4.5	< 0.01	< 0.01	0.08	0.09	0.4	1.2	-1.1	-3.7	-	-	-	-
PSC_090_pu03	278542	6216178	Public Utility	625	650	4.5	4.5	< 0.01	< 0.01	0.09	0.09	0.4	1.2	-1.1	-3.7	-	-	-	-
PSC_090_pu04	278544	6216168	Public Utility	625	675	4.5	5.0	< 0.01	< 0.01	0.09	0.09	0.4	1.3	-1.1	-3.7	-	-	-	-
PSC_090_pu05	278551	6216187	Public Utility	575	625	4.5	4.5	< 0.01	< 0.01	0.08	0.09	0.4	1.4	-0.9	-3.3	-	-	-	-
PSC_090_pu06	278547	6216186	Public Utility	600	625	4.5	4.5	< 0.01	< 0.01	0.08	0.09	0.4	1.3	-0.9	-3.4	-	-	-	-
PSC_090_pu07	278548	6216182	Public Utility	600	625	4.5	4.5	< 0.01	< 0.01	0.08	0.09	0.4	1.3	-1.0	-3.5	-	-	-	-
PSC_090_pu08	278549	6216178	Public Utility	600	625	4.5	5.0	< 0.01	< 0.01	0.08	0.09	0.4	1.3	-1.0	-3.5	-	-	-	-
PSC_090_pu09	278550	6216175	Public Utility	600	650	4.5	5.0	< 0.01	< 0.01	0.08	0.09	0.4	1.4	-0.9	-3.4	-	-	-	-
PSC_090_pu10	278551	6216171	Public Utility	600	650	4.5	5.0	< 0.01	< 0.01	0.08	0.09	0.4	1.4	-0.9	-3.4	-	-	-	-
PSC_090_pu11	278542	6216218	Public Utility	550	575	4.5	4.5	< 0.01	< 0.01	0.08	0.08	0.4	1.2	-0.9	-3.1	-	-	-	-
PSC_090_pu12	278535	6216210	Public Utility	575	600	4.0	4.5	< 0.01	< 0.01	0.08	0.08	0.4	1.2	-1.0	-3.3	-	-	-	-
PSC_090_pu13	278567	6216240	Public Utility	425	450	4.0	4.5	0.03	0.03	0.05	0.05	0.4	1.3	-0.5	-1.8	-	-	-	-
PSC_091_r01	278473	6216407	Rural	100	125	1.0	1.0	0.02	0.02	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_091_r02	278492	6216420	Rural	100	100	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_092_h01	278429	6216451	House	80	80	0.5	0.5	< 0.01	0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	89.8	7.2	2.9	0.1
PSC_092_t01	278423	6216459	Rural	70	70	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSG_001_h01	278878	6216528	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.2	-1.0	95.3	4.4	0.2	0.1
PSG_001_r01	278884	6216520	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.2	-0.9	-	-	-	-
PSG_001_r02	278866	6216494	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.3	0.8	-0.2	-1.2	-	-	-	-
PSG_001_t01	278876	6216547	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.2	-1.0	-	-	-	-
PSR_001_r01	279303	6215232	Rural	< 20	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSR_010_h01	279321	6215660	House	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	94.0	5.1	0.8	0.1
PSR_010_h02	279341	6215435	House	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	96.7	2.7	0.5	0.1
PSR_010_r01	279327	6215665	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSR_010_r02	279303	6215677	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSR_010_r03	279184	6215551	Rural	< 20	90	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.2	-	-	-	-
PSR_010_r04	279173	6215533	Rural	< 20	90	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.2	-	-	-	-
PSR_010_r05	279169	6215514	Rural	20	90	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.2	-	-	-	-
PSR_010_r06	279325	6215463	Rural	< 20	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSR_010_r08	279319	6215394	Rural	< 20	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSR_010_r09	279305	6215697	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSR_010_t01	279298	6215675	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSR_010_t02	279316	6215666	Rural	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_031_r01	278350	6215104	Rural	775	875	3.5	3.0	0.06	0.06	0.01	0.01	1.1	2.9	-0.2	-0.6	-	-	-	-
PTH_031_r02	278373	6215089	Rural	700	825	2.5	2.0	0.06	0.06	0.02	0.02	1.2	2.9	-0.1	-0.4	-	-	-	-
PTH_031_r03	278393	6215056	Rural	650	775	1.5	1.5	0.05	0.06	0.02	0.02	1.1	2.7	-0.1	-0.4	-	-	-	-
PTH_031_r04	278415	6215039	Rural	625	775	1.0	1.5	0.03	0.03	0.02	0.02	0.5	1.2	-0.2	-0.7	-	-	-	-
PTH_031_r05	278421	6215034	Rural	625	775	1.5	2.0	0.03	0.03	0.02	0.02	0.5	1.2	-0.2	-0.8	-	-	-	-
PTH_031_r06	278429	6215072	Rural	650	825	1.0	1.5	0.02	0.02	0.02	0.02	0.5	1.3	-0.2	-0.9	-	-	-	-
PTH_031_r07	278422	6215060	Rural	650	800	1.0	1.5	0.03	0.03	0.02	0.02	0.5	1.3	-0.2	-0.8	-	-	-	-
PTH_031_r08	278412	6215066	Rural	650	800	1.0	1.5	0.04	0.04	0.02	0.02	0.5	1.2	-0.2	-0.8	-	-	-	-
PTH_031_r09	278382	6215086	Rural	675	800	2.0	1.5	0.06	0.06	0.02	0.02	1.1	2.8	-0.1	-0.4	-	-	-	-
PTH_031_t01	278420	6215073	Rural	650	800	1.0	1.5	0.03	0.03	0.02	0.02	0.5	1.3	-0.2	-0.8	-	-	-	-
PTH_031_t02	278404	6215056	Rural	625	775	1.0	1.5	0.04	0.04	0.02	0.02	0.4	1.2	-0.2	-0.7	-	-	-	-
PTH_031_t04	278370	6215103	Rural	700	825	2.5	2.0	0.06	0.06	0.01	0.01	1.2	2.9	-0.1	-0.5	-	-	-	-
PTH_055_h01	278604	6214938	House	500	700	4.0	5.0	0.01	0.02	0.06	0.06	0.4	1.1	-0.7	-2.4	49.7	30.6	15.0	4.6
PTH_055_r01	278577	6214931	Rural	475	650	3.5	5.0	0.01	0.02	0.05	0.05	0.4	1.2	-0.8	-2.5	-	-	-	-
PTH_080_r01	278660	6214816	Rural	100	175	1.5	2.0	0.02	0.03	< 0.01	< 0.01	0.2	0.7	-0.1	-0.6	-	-	-	-
PTH_092_r01	279011	6214877	Rural	< 20	125	< 0.5	2.0	< 0.01	0.02	< 0.01	< 0.01	0.3	0.7	-0.1	-0.2	-	-	-	-
PTH_092_r02	279006	6214876	Rural	< 20	125	< 0.5	2.0	< 0.01	0.02	< 0.01	< 0.01	0.3	0.7	-0.1	-0.3	-	-	-	-
PTH_110_h01	279088	6214599	House	20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	93.7	5.3	0.9	0.1
PTH_110_p01	279068	6214601	Pool	20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_110_r01	279088	6214602	Rural	20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_110_r02	279059	6214602	Rural	20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_112_h01	279140	6214662	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	96.7	2.7	0.5	0.1
PTH_112_r01	279105	6214646	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_112_r02	279114	6214654	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_121_h01	279231	6214754	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.0	4.6	0.3	0.1

Table D.05 - Predicted subsidence effects for the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Structure Type	Predicted total subsidence after LW W3 (mm)	Predicted total subsidence after LW W4 (mm)	Predicted total tilt after LW W3 (mm/m)	Predicted total tilt after LW W4 (mm/m)	Predicted total hogging curvature after LW W3 (1/km)	Predicted total hogging curvature after LW W4 (1/km)	Predicted total sagging curvature after LW W3 (1/km)	Predicted total sagging curvature after LW W4 (1/km)	Predicted mean total tensile strain (mm/m)	Predicted 95% CL for total tensile strain (mm/m)	Predicted mean total comp. strain (mm/m)	Predicted 95% CL for total comp. strain (mm/m)	Predicted Probability of Nil or Category R0 Impact for Houses (%)	Predicted Probability of Category R1 or R2 Impact for Houses (%)	Predicted Probability of Category R3 and R4 Impact for Houses (%)	Predicted Probability of Category R5 Impact for Houses (%)
PTH_121_r01	279251	6214746	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_121_t01	279267	6214779	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_121_t02	279269	6214782	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_126_h01	279321	6214716	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.5	4.3	0.2	0.1
PTH_126_p01	279320	6214740	Pool	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_126_r01	279310	6214715	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_126_r02	279318	6214722	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_126_r03	279322	6214752	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_126_r04	279333	6214736	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_126_t01	279331	6214727	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_128_h01	279337	6214711	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.5	4.2	0.2	0.1
PTH_128_r01	279345	6214707	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_128_r02	279343	6214715	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_128_r03	279352	6214743	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_128_r04	279343	6214752	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_130_h01	279359	6214708	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	97.3	2.3	0.3	0.1
PTH_130_r01	279363	6214698	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_130_r02	279360	6214739	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_130_r03	279375	6214732	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_132_h01	279379	6214700	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.1	4.4	0.4	0.1
PTH_132_r03	279384	6214725	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_132_r04	279379	6214729	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_136_h01	279312	6214656	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.5	4.3	0.2	0.1
PTH_136_r01	279321	6214654	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_136_r02	279319	6214647	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_136_r03	279310	6214645	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_136_r04	279308	6214634	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_136_r05	279321	6214628	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_136_t01	279323	6214628	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_136_t02	279314	6214664	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_138_h01	279288	6214654	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.0	4.4	0.5	0.1
PTH_138_r01	279296	6214649	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_138_r02	279282	6214646	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_138_r03	279271	6214640	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_138_r04	279270	6214635	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_140_h01	279275	6214666	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.4	4.3	0.2	0.1
PTH_140_r01	279262	6214660	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_140_r02	279265	6214640	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_142_h01	279225	6214607	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	94.9	4.5	0.5	0.1
PTH_142_h02	279264	6214587	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.4	4.3	0.2	0.1
PTH_142_r02	279233	6214594	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_142_r03	279232	6214602	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_142_r04	279239	6214589	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_142_r05	279257	6214585	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
V09f	278957	6214492	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.3	0.9	-0.3	-1.2	-	-	-	-
V15a	278592	6214525	House	80	80	1.0	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.4	1.2	-0.4	-1.6	87.1	10.7	1.8	0.3
V15b	278552	6214492	Rural	90	100	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V15c	278563	6214486	Rural	90	100	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V15d	278560	6214512	Rural	80	80	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V15e	278585	6214533	Rural	60	70	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.4	1.1	-0.4	-1.5	-	-	-	-
V15f	278575	6214517	Rural	70	80	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V15g	278560	6214523	Rural	70	70	0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
			Maximum	**775**	**875**	**4.5**	**5.0**	**0.06**	**0.06**	**0.09**	**0.09**	**1.2**	**2.9**	**-1.1**	**-3.7**				

Table D.06 - Predicted subsidence effects for the dams within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Maximum Dimension (m)	Plan Area (m2)	Predicted total subsidence after LW W3 (mm)	Predicted total subsidence after LW W4 (mm)	Predicted total tilt after LW W3 (mm/m)	Predicted total tilt after LW W4 (mm/m)	Predicted total hogging curvature after LW W3 (1/km)	Predicted total hogging curvature after LW W4 (1/km)	Predicted total sagging curvature after LW W3 (1/km)	Predicted total sagging curvature after LW W4 (1/km)	Predicted mean total tensile strain (mm/m)	Predicted 95% CL for total tensile strain (mm/m)	Predicted mean total comp. strain (mm/m)	Predicted 95% CL for total comp. strain (mm/m)	Predicted Change in Freeboard after LW W3 (mm)	Predicted Change in Freeboard after LW W4 (mm)
PBL_030_d01	278629	6216425	9	54	40	50	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-	-	< 50	< 50
PBL_030_d02	278616	6216379	12	51	80	80	1.0	1.0	0.01	0.01	< 0.01	< 0.01	-	-	-	-	< 50	< 50
PRU_003_d01	279171	6214754	11	41	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-	-	< 50	< 50
PRU_003_d02	279148	6214754	9	15	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-	-	< 50	< 50
PRU_003_d03	279126	6214745	14	74	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-	-	< 50	< 50
PSC_019_d01	277857	6215418	80	3669	675	700	4.0	4.0	0.03	0.03	0.05	0.05	0.3	0.8	-0.4	-1.3	150	150
PSC_080_d01	278212	6215831	43	1217	950	975	2.5	2.5	0.02	0.02	0.10	0.10	0.4	1.1	-0.8	-2.7	< 50	< 50
PSC_090_d01	278513	6216093	120	5671	725	775	5.0	5.0	0.02	0.02	0.09	0.10	0.1	0.3	-0.1	-0.2	50	50
PSR_010_d01	279228	6215515	48	1352	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-	-	< 50	< 50
PSR_010_d02	279053	6215498	80	2712	40	250	< 0.5	2.5	< 0.01	0.04	< 0.01	< 0.01	-	-	-	-	< 50	< 50
PSR_010_d03	278740	6215573	53	1479	200	675	1.5	1.5	0.03	0.03	< 0.01	0.02	0.1	0.3	-0.1	-0.2	< 50	< 50
PSR_010_d04	278878	6215709	46	1208	80	500	< 0.5	3.5	< 0.01	0.02	< 0.01	0.06	-	-	-	-	< 50	50
PSR_010_d05	279057	6215756	44	1201	40	100	< 0.5	1.0	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-	-	< 50	< 50
PSR_010_d06	278800	6216274	16	189	60	70	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-	-	< 50	< 50
PST_035_d01	279008	6216345	36	739	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-	-	< 50	< 50
PTH_031_d01	278350	6214905	72	3134	700	750	4.5	5.0	0.05	0.05	0.08	0.08	0.3	0.9	-0.1	-0.4	150	150
PTH_031_d02	278390	6214848	23	127	300	350	3.0	3.5	0.03	0.03	< 0.01	< 0.01	0.3	0.7	-0.1	-0.2	< 50	< 50
PTH_055_d01	278547	6215155	108	3834	700	975	5.0	3.5	0.02	0.02	0.09	0.09	0.1	0.4	-0.1	-0.2	< 50	< 50
PTH_080_d01	278583	6214761	161	15039	150	200	1.5	2.0	0.02	0.03	0.01	0.01	0.1	0.3	-0.1	-0.2	< 50	< 50
PTH_092_d01	278965	6214730	74	1418	< 20	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-	-	< 50	< 50
PTH_105_d01	278720	6215094	139	7279	425	775	4.5	3.5	0.05	0.06	0.01	0.02	0.1	0.3	-0.1	-0.2	100	50
PTH_105_d02	279029	6215114	48	1176	50	375	< 0.5	4.5	< 0.01	0.05	< 0.01	0.01	-	-	-	-	< 50	50
PTH_105_d03	279077	6215337	22	341	40	175	< 0.5	1.5	< 0.01	0.02	< 0.01	< 0.01	-	-	-	-	< 50	< 50
				Maximum	**950**	**975**	**5.0**	**5.0**	**0.05**	**0.06**	**0.10**	**0.10**	**0.4**	**1.1**	**-0.8**	**-2.7**	**150**	**150**

Table D.07 - Predicted subsidence effects for Aboriginal heritage sites within the Study Area

Site Reference	Location	Type	Predicted total subsidence after LW W3 (mm)	Predicted total subsidence after LW W4 (mm)	Predicted total tilt after LW W3 (mm/m)	Predicted total tilt after LW W4 (mm/m)	Predicted total hogging curvature after LW W3 (1/km)	Predicted total hogging curvature after LW W4 (1/km)	Predicted total sagging curvature after LW W3 (1/km)	Predicted total sagging curvature after LW W4 (1/km)	Stream	Predicted total upsidence after LW W4 (mm)	Predicted total closure after LW W4 (mm)
52-2-2068	140 m north of LW W3	Grinding Grooves	30	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Stonequarry Creek	70	70
52-2-2069	Directly above LW W3	Open Site	650	700	3.5	4.0	0.01	0.01	0.09	0.09	-	-	-
52-2-2070	Directly above LW W3	Open Site	250	275	3.5	3.5	0.03	0.04	0.01	0.01	-	-	-
52-2-2071	170 m north of LW W3	Open Site	40	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Stonequarry Creek	70	60
52-2-2072	200 m north of LW W3	Open Site	40	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Stonequarry Creek	70	70
52-2-2073	40 m north of LW W3	Open Site	40	40	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-
52-2-2100	210 m west of LW W3	Modified Tree	875	900	2.0	2.0	0.02	0.02	0.02	0.02	-	-	-
SQC1	110 m north of LW W3	Open Site	60	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Stonequarry Creek	80	60
		Maximum	**875**	**900**	**3.5**	**4.0**	**0.03**	**0.04**	**0.09**	**0.09**		**80**	**70**

APPENDIX E. DRAWINGS

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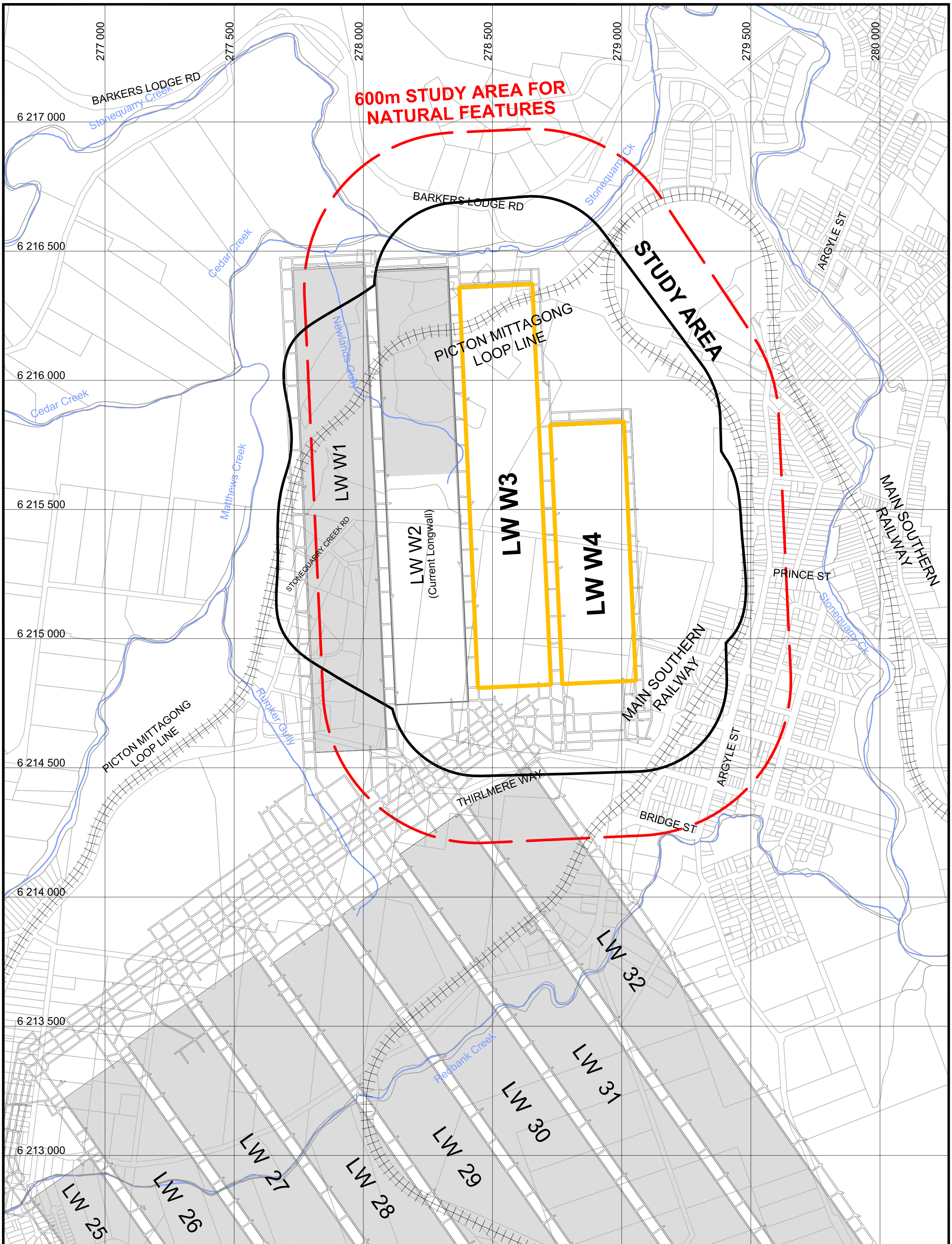

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WESTERN DOMAIN EXTRACTION PLAN LW W3-W4

GENERAL LAYOUT

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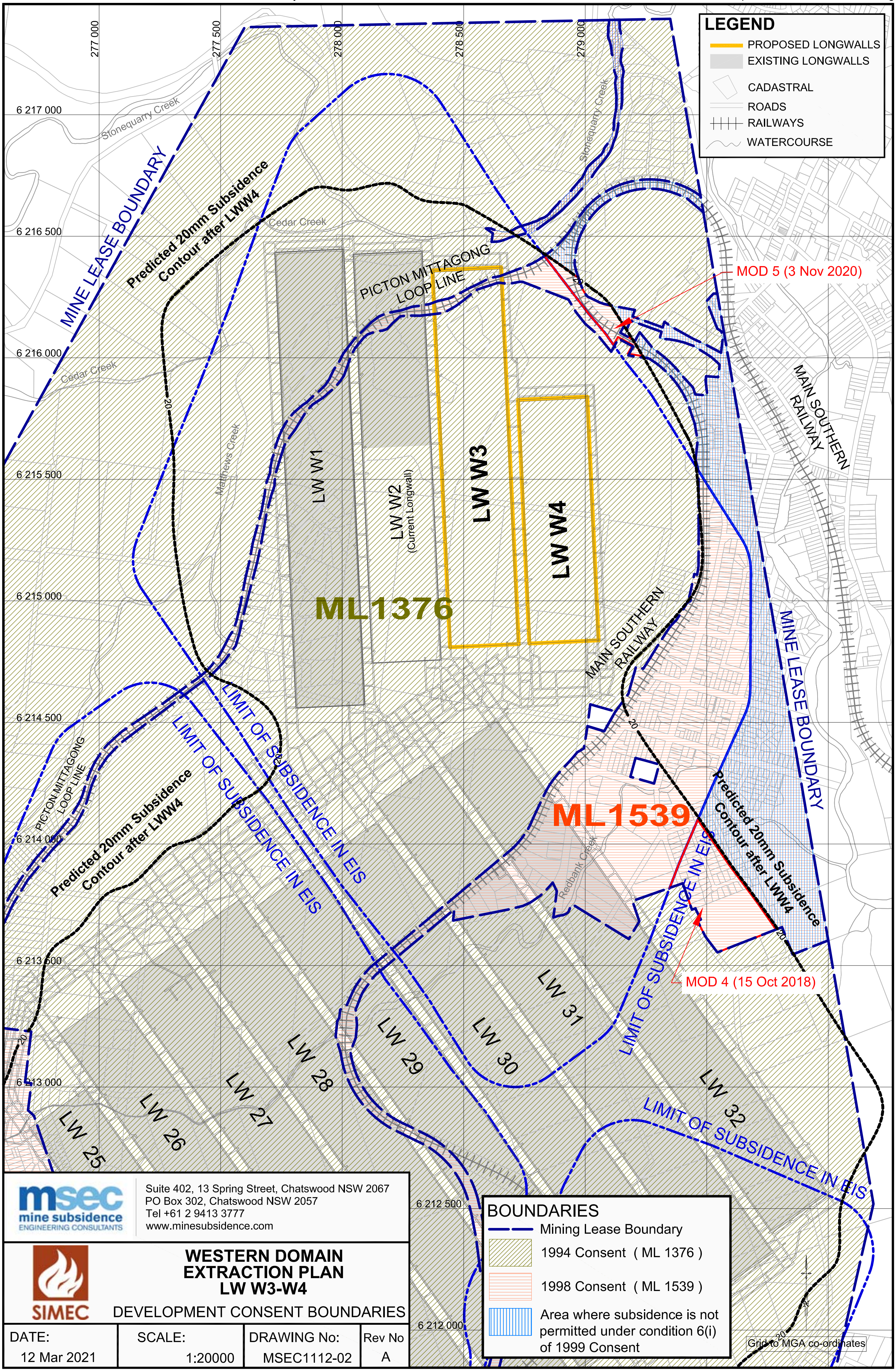

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WESTERN DOMAIN EXTRACTION PLAN LW W3-W4

DEVELOPMENT CONSENT BOUNDARIES

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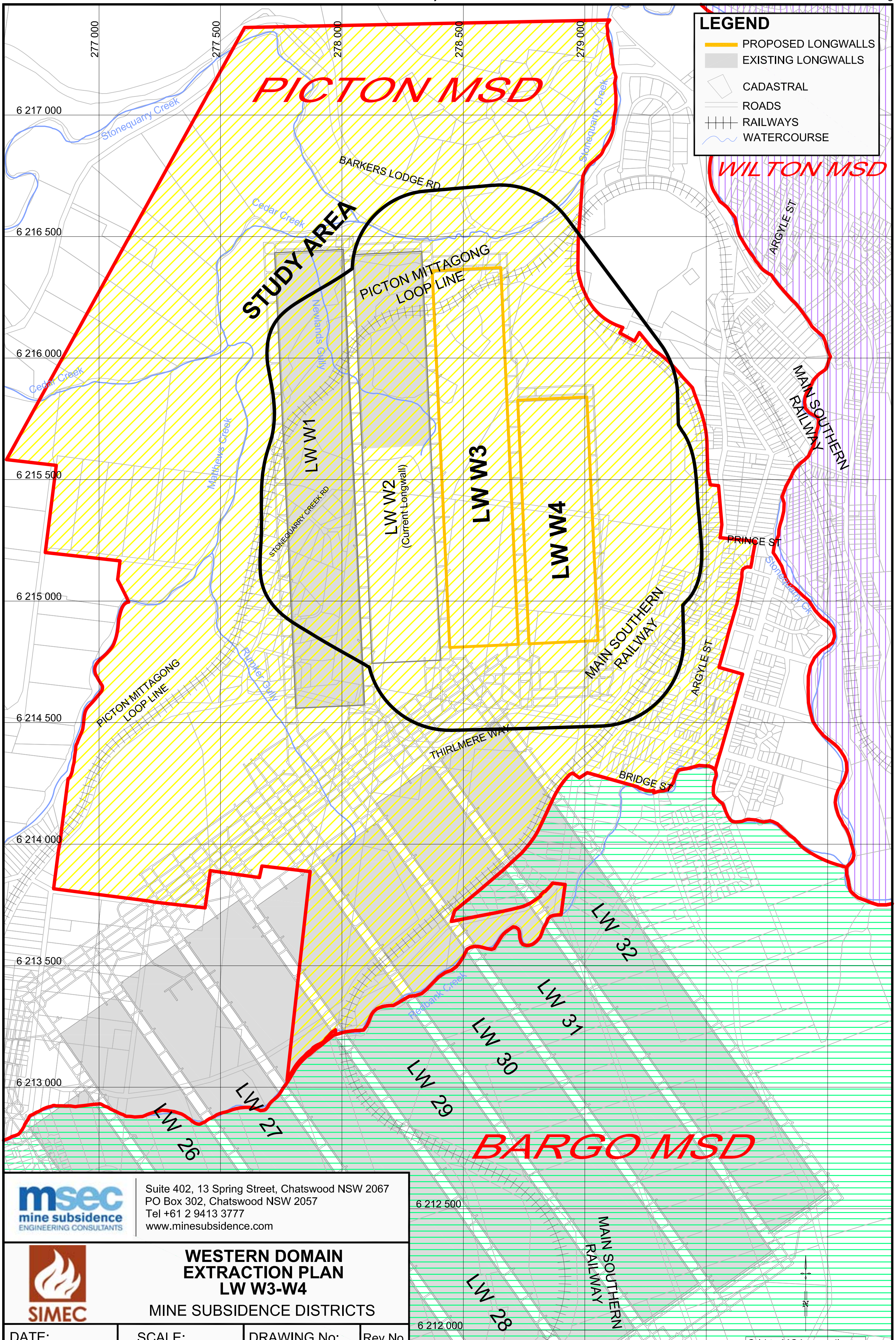

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WESTERN DOMAIN EXTRACTION PLAN LW W3-W4

MINE SUBSIDENCE DISTRICTS

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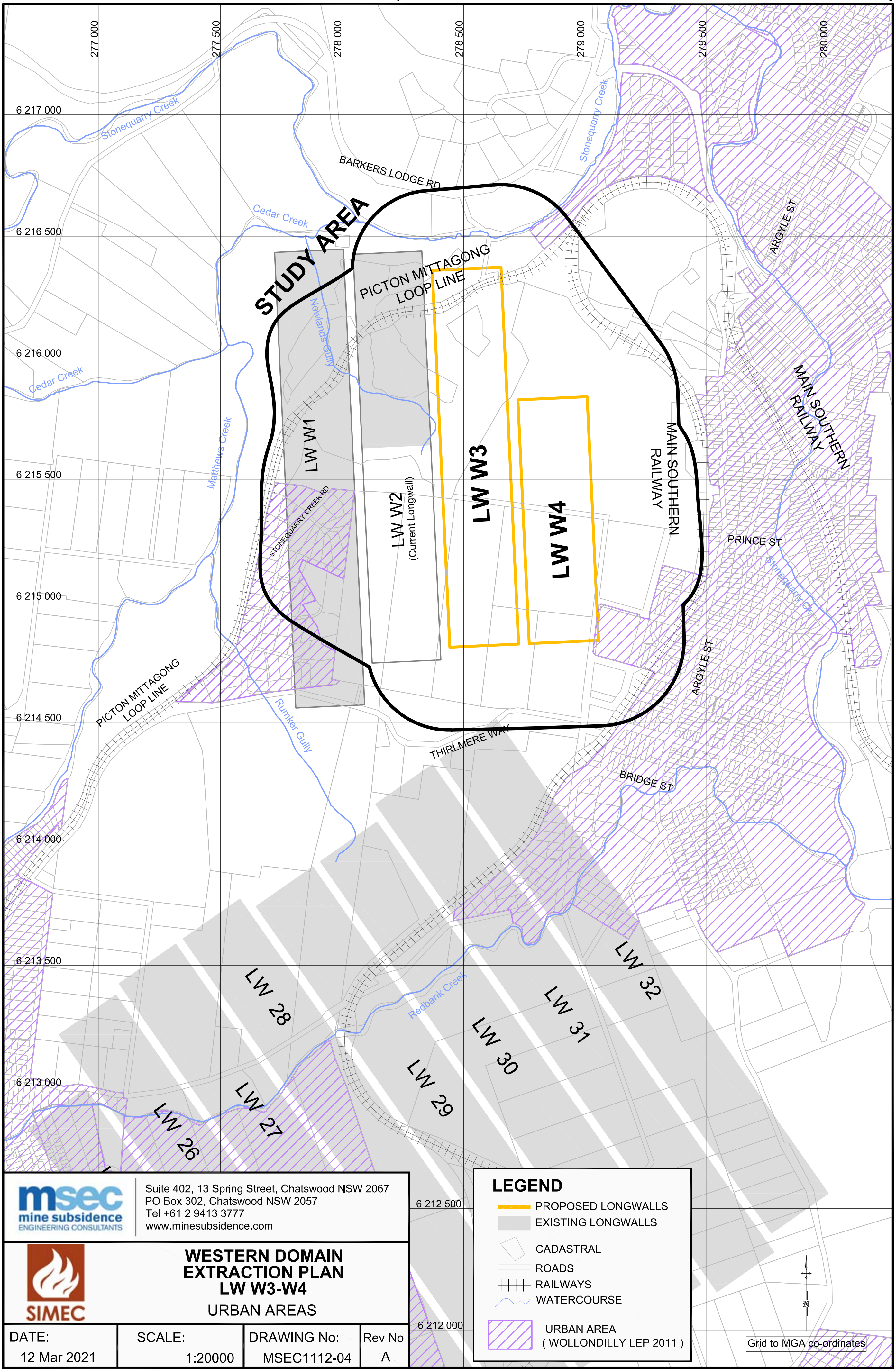

LEGEND

- PROPOSED LONGWALLS
- EXISTING LONGWALLS
- CADASTRAL
- ROADS
- RAILWAYS
- WATERCOURSE
- URBAN AREA (WOLLONDILLY LEP 2011)

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URBAN AREAS

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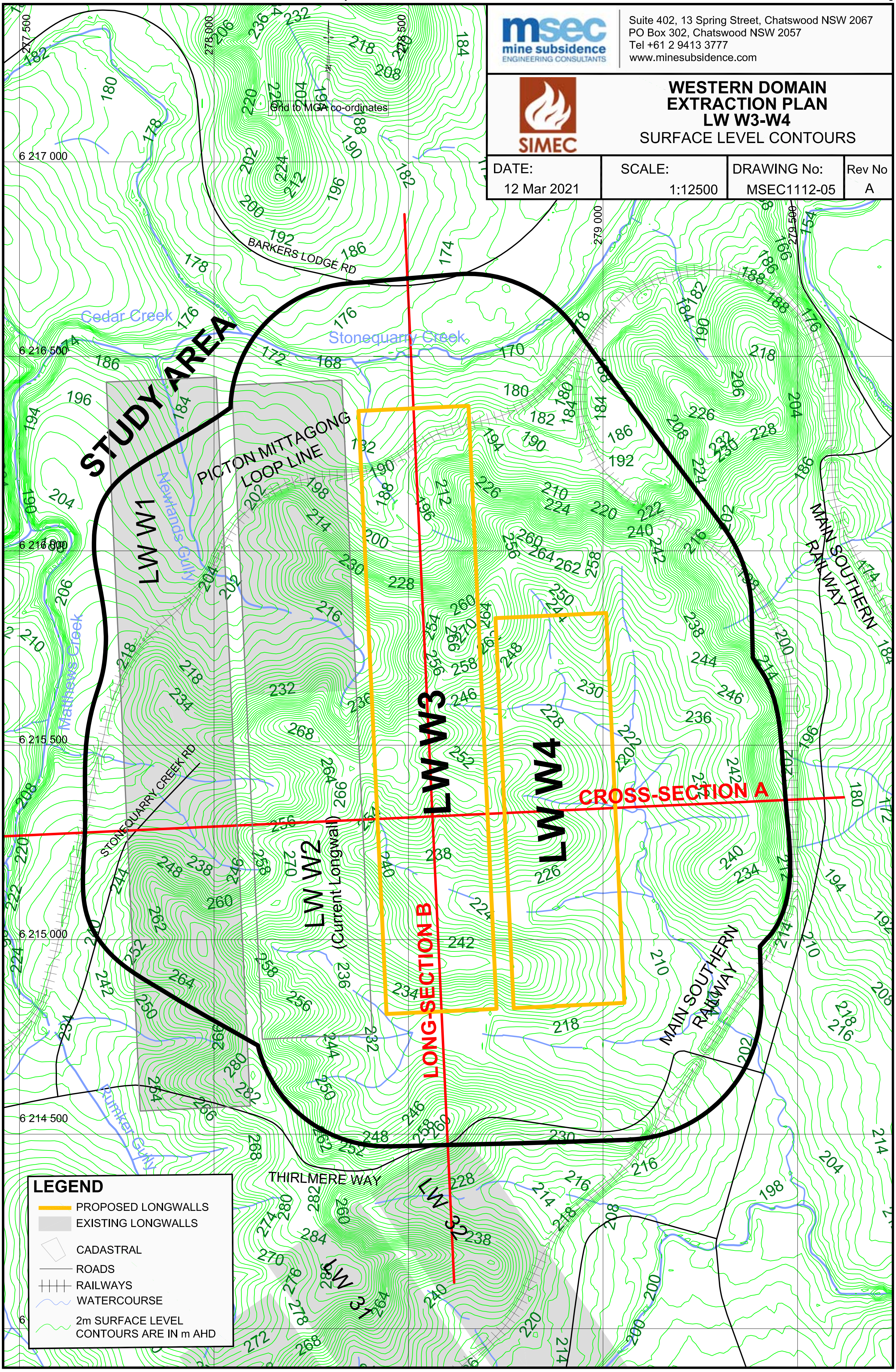

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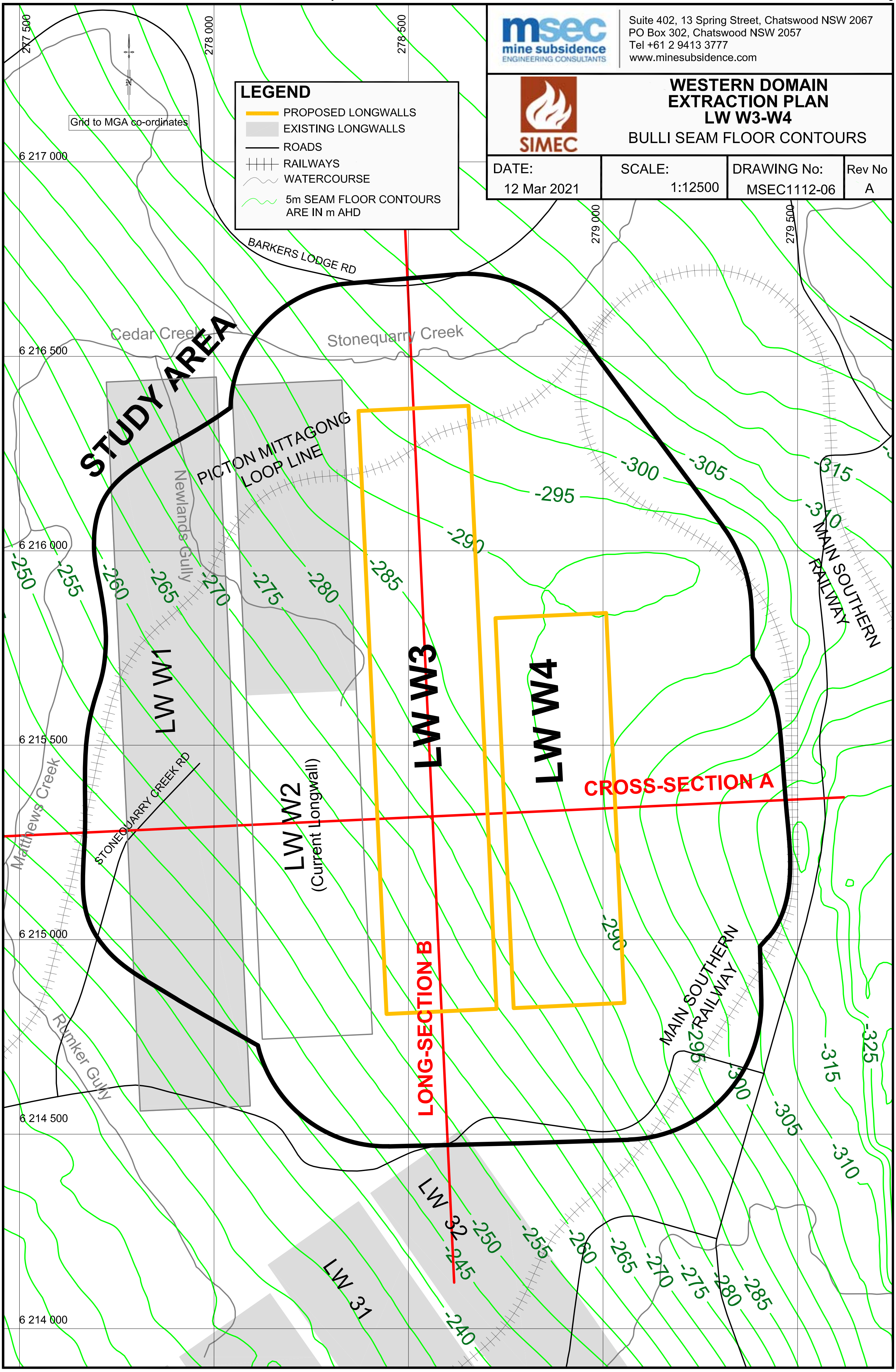

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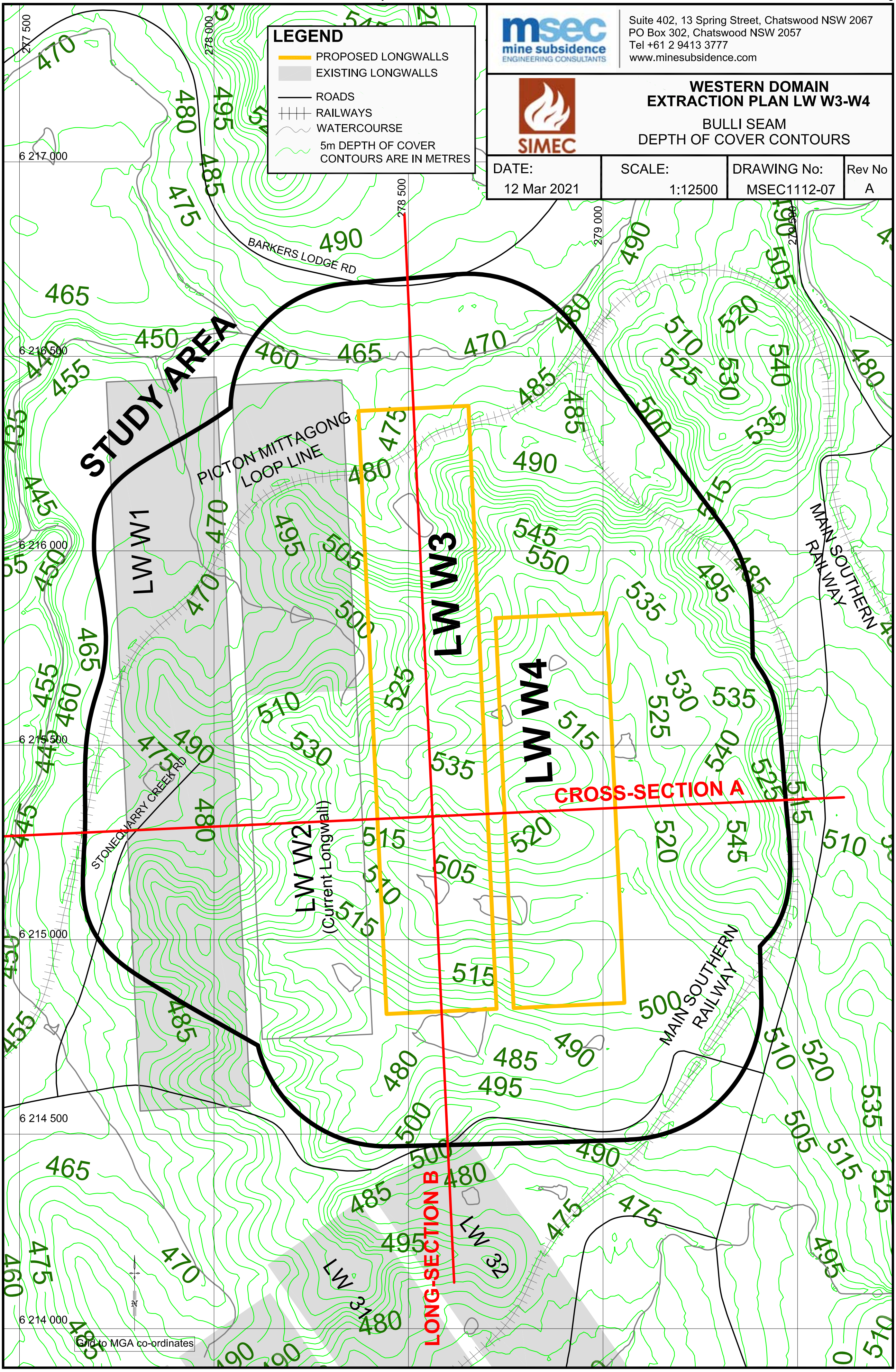

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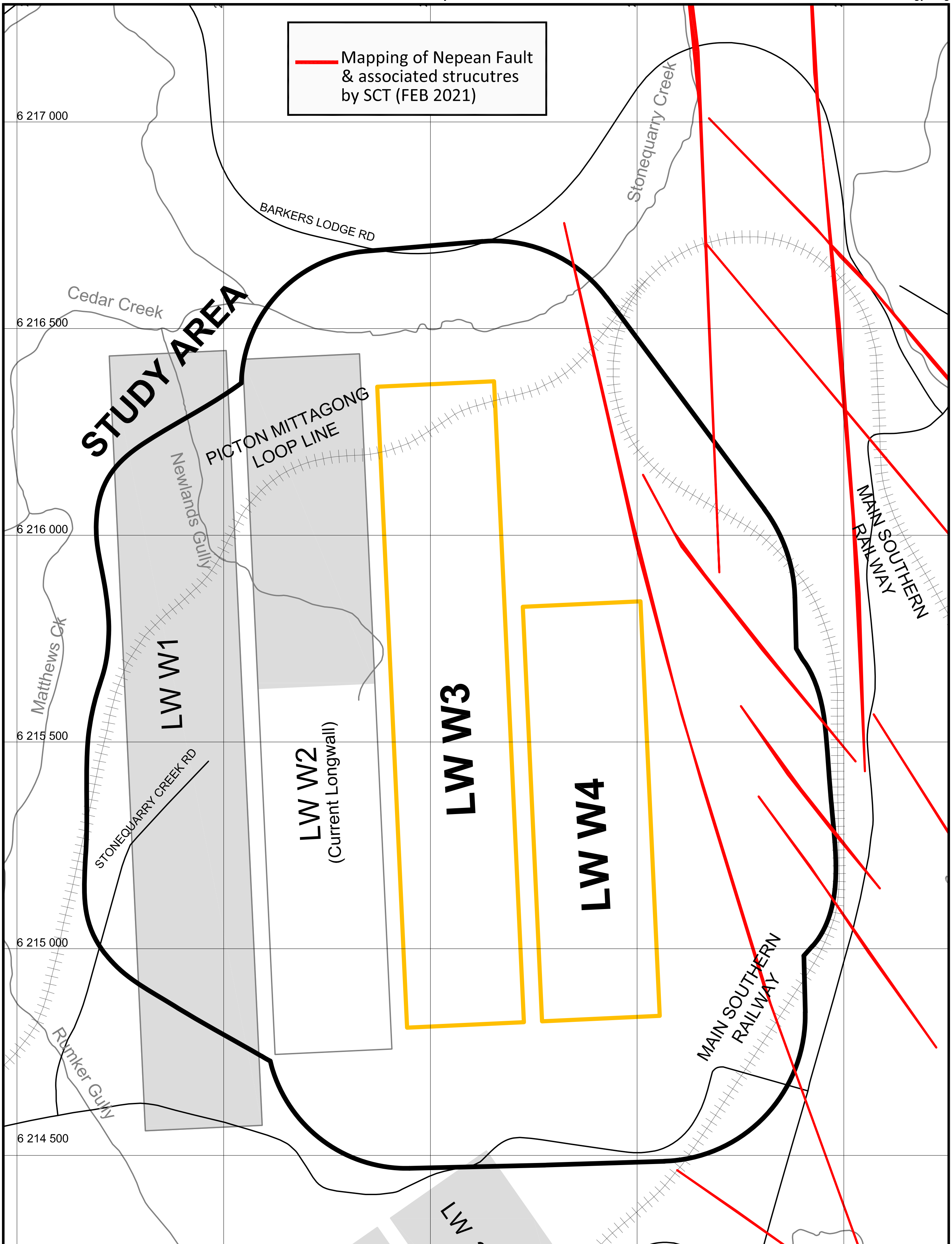

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WESTERN DOMAIN EXTRACTION PLAN LW W3-W4

GEOLOGICAL STRUCUTRES

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12 Mar 2021	1:12500	MSEC1112-08	A

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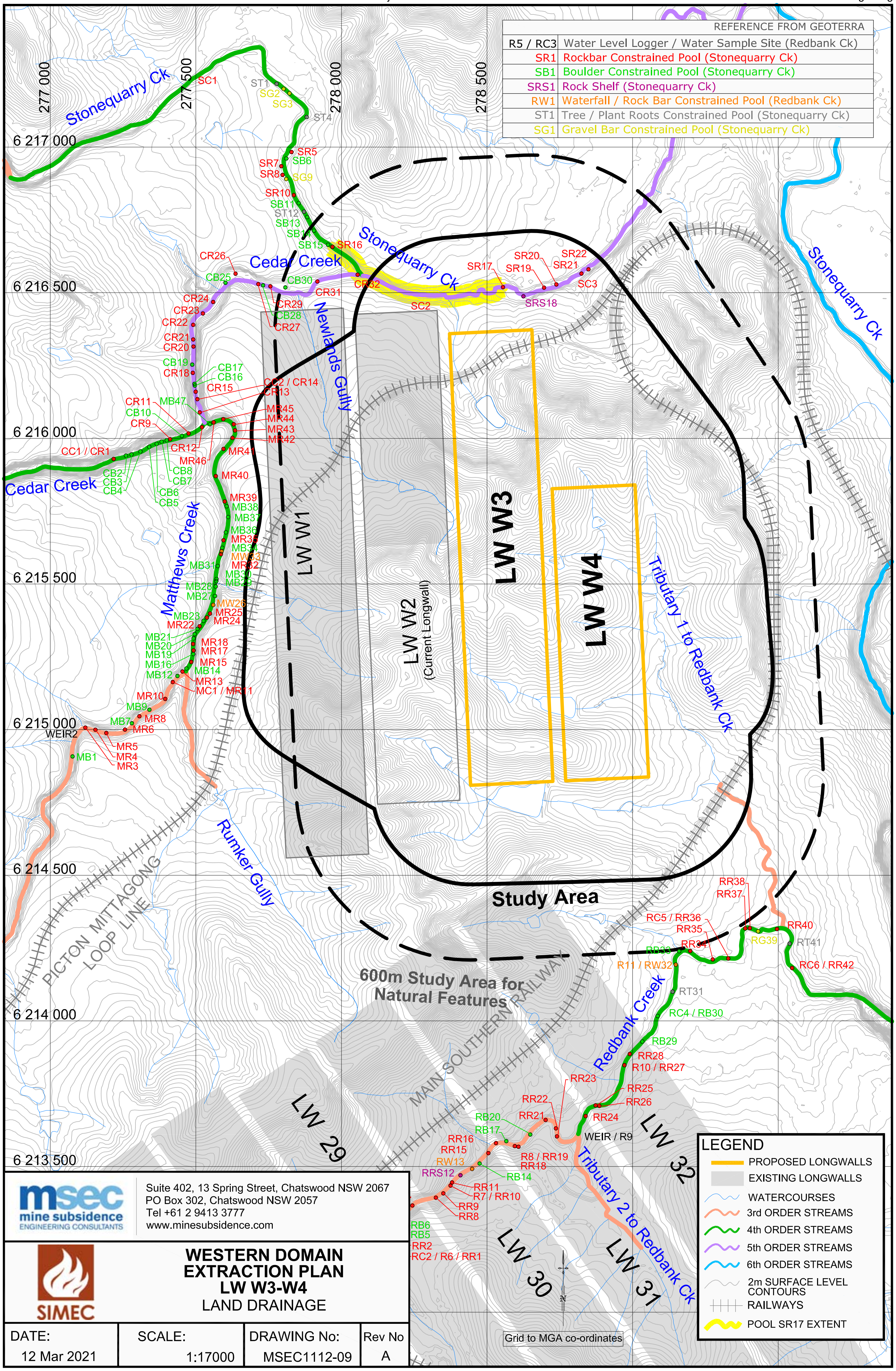

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WESTERN DOMAIN EXTRACTION PLAN LW W3-W4
LAND DRAINAGE

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12 Mar 2021	1:17000	MSEC1112-09	A

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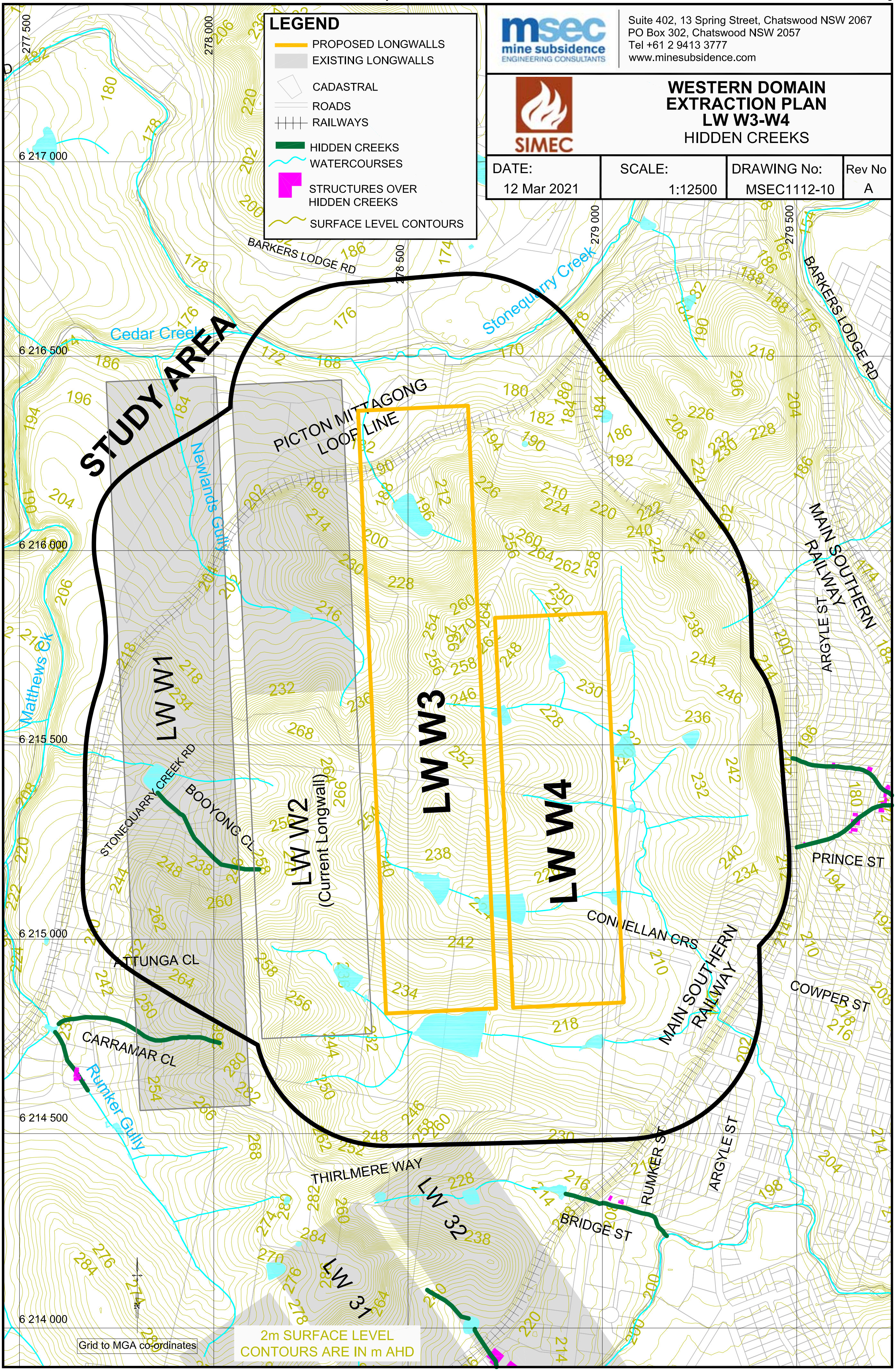

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WESTERN DOMAIN EXTRACTION PLAN LW W3-W4
HIDDEN CREEKS

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12 Mar 2021	1:12500	MSEC1112-10	A

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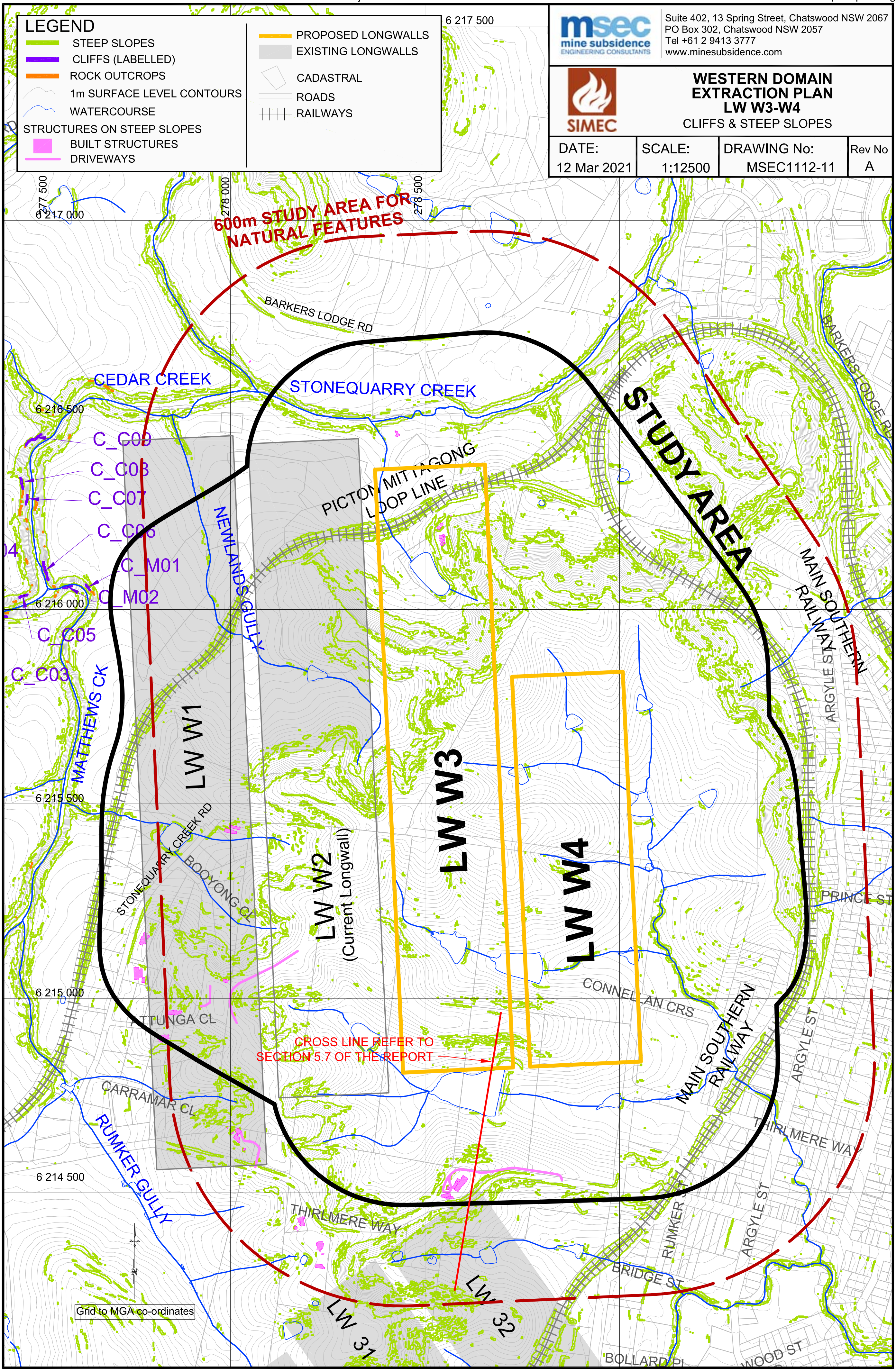

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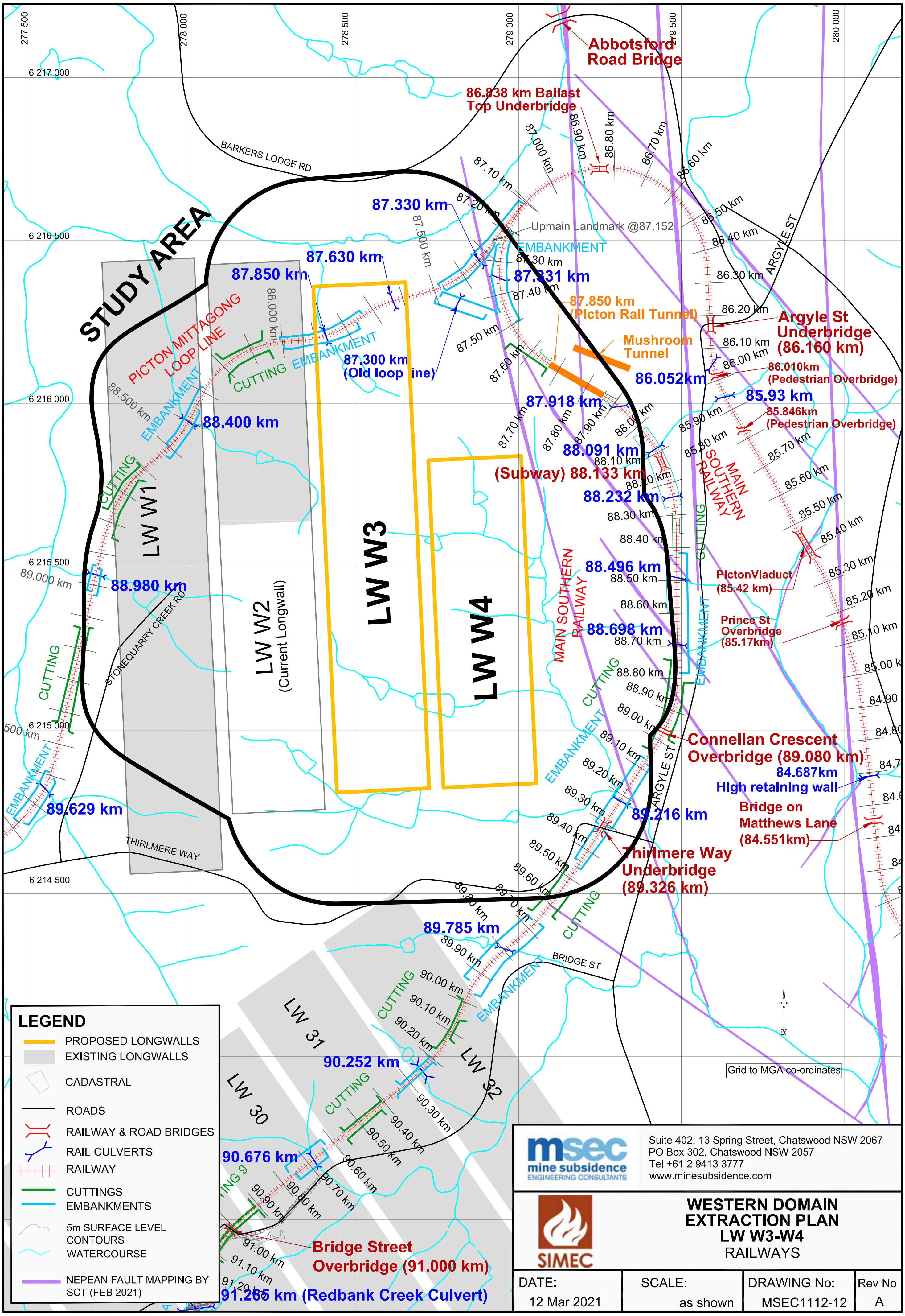

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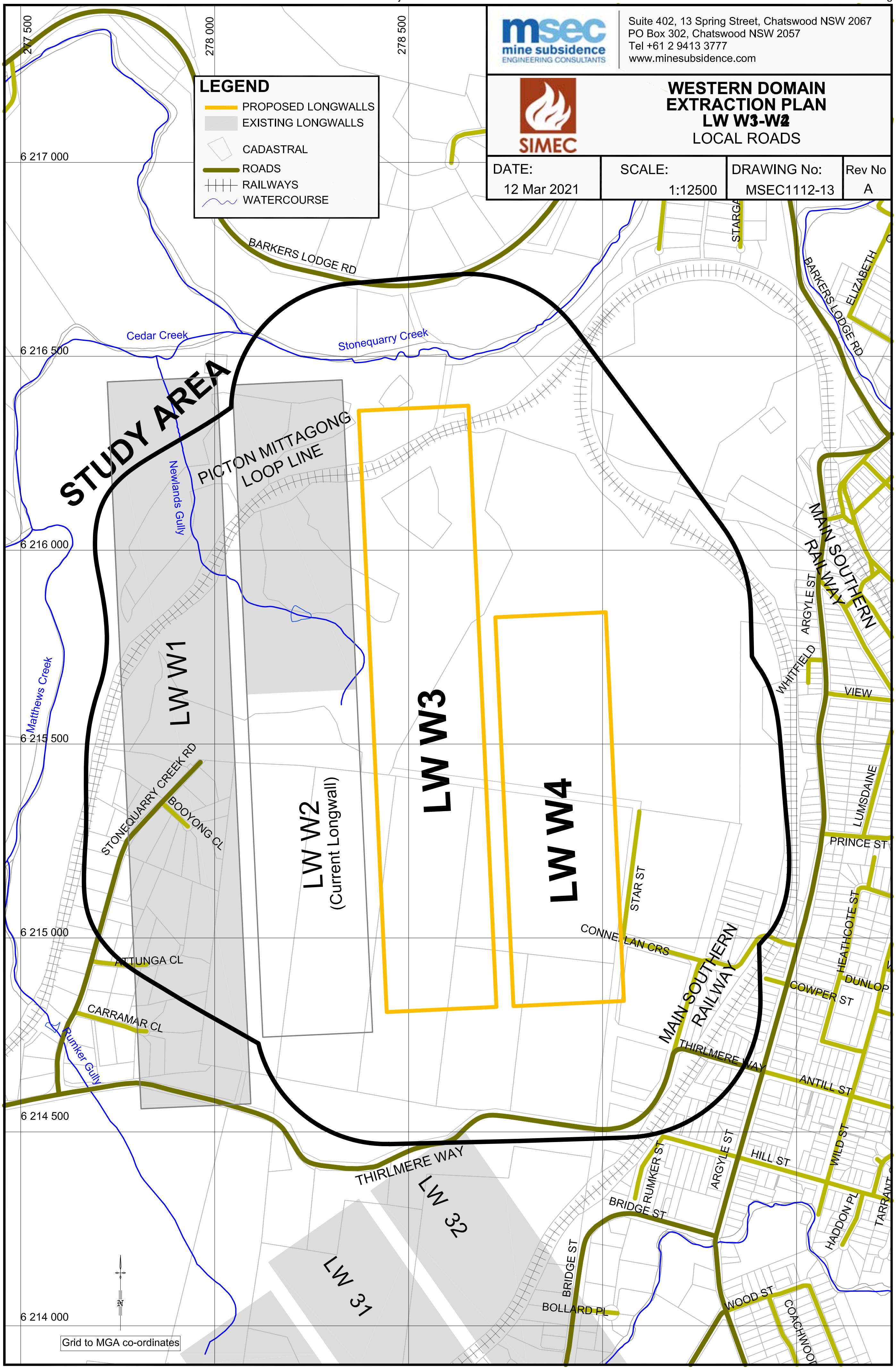

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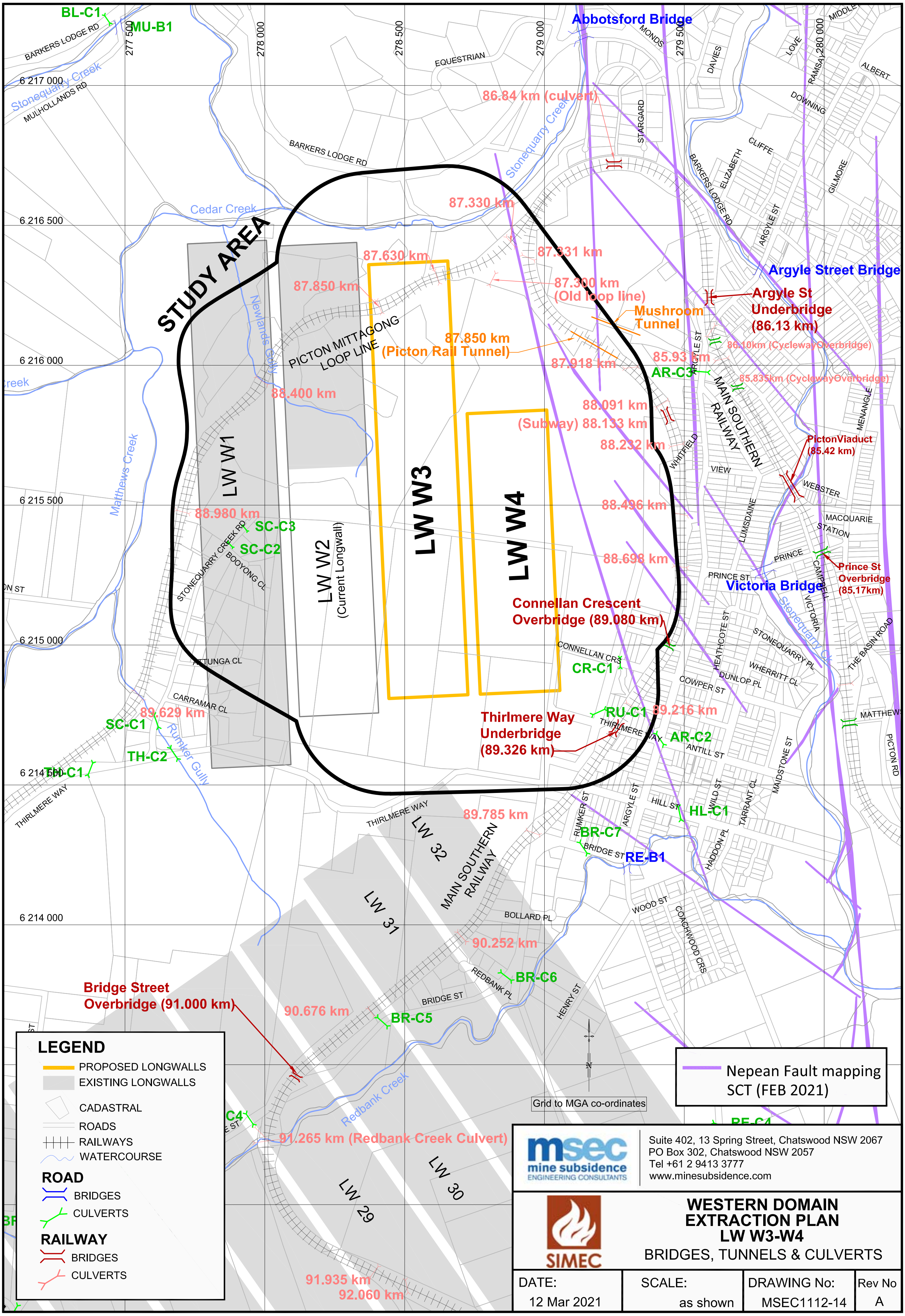

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WESTERN DOMAIN EXTRACTION PLAN LW W3-W4

BRIDGES, TUNNELS & CULVERTS

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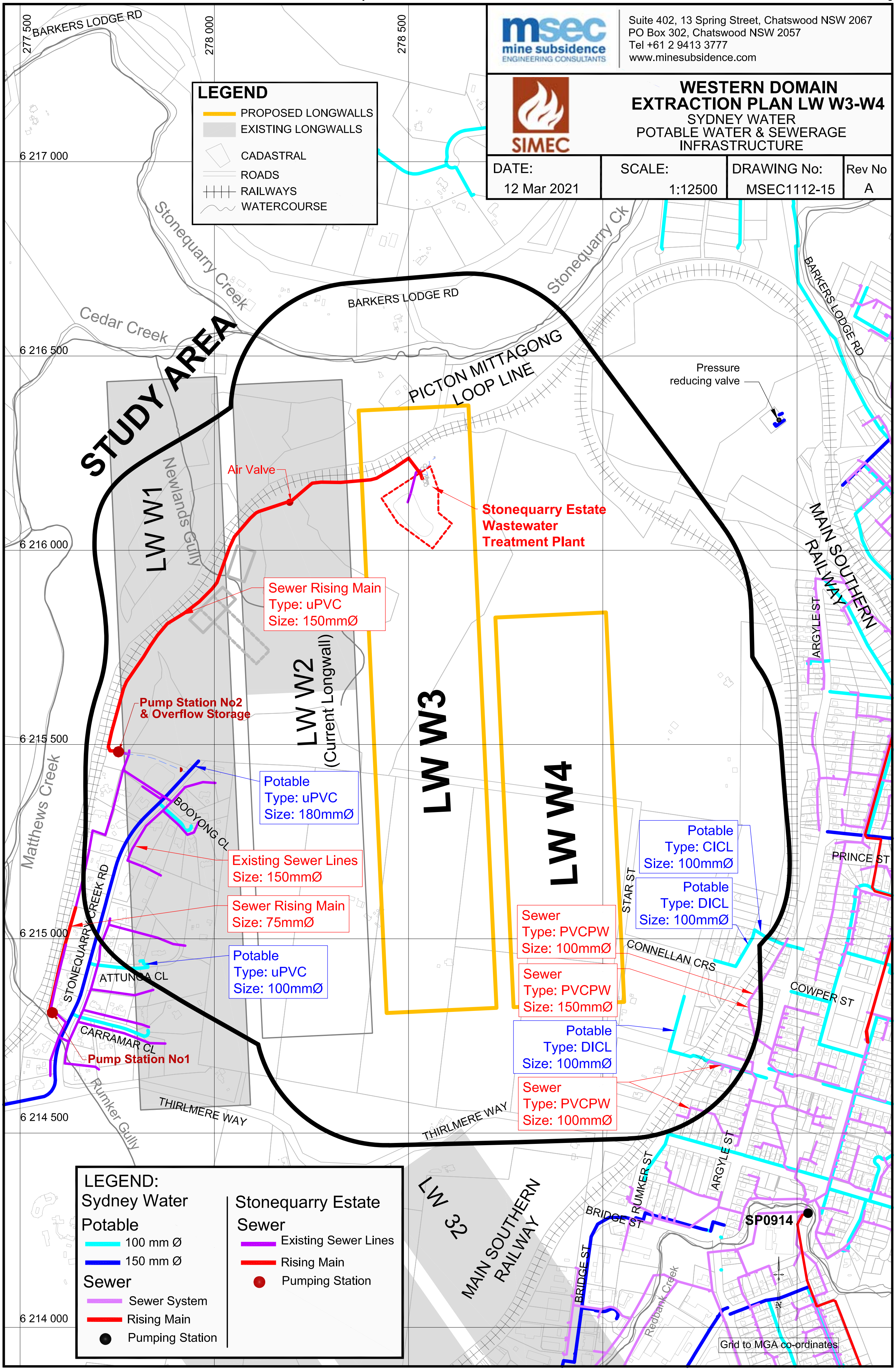

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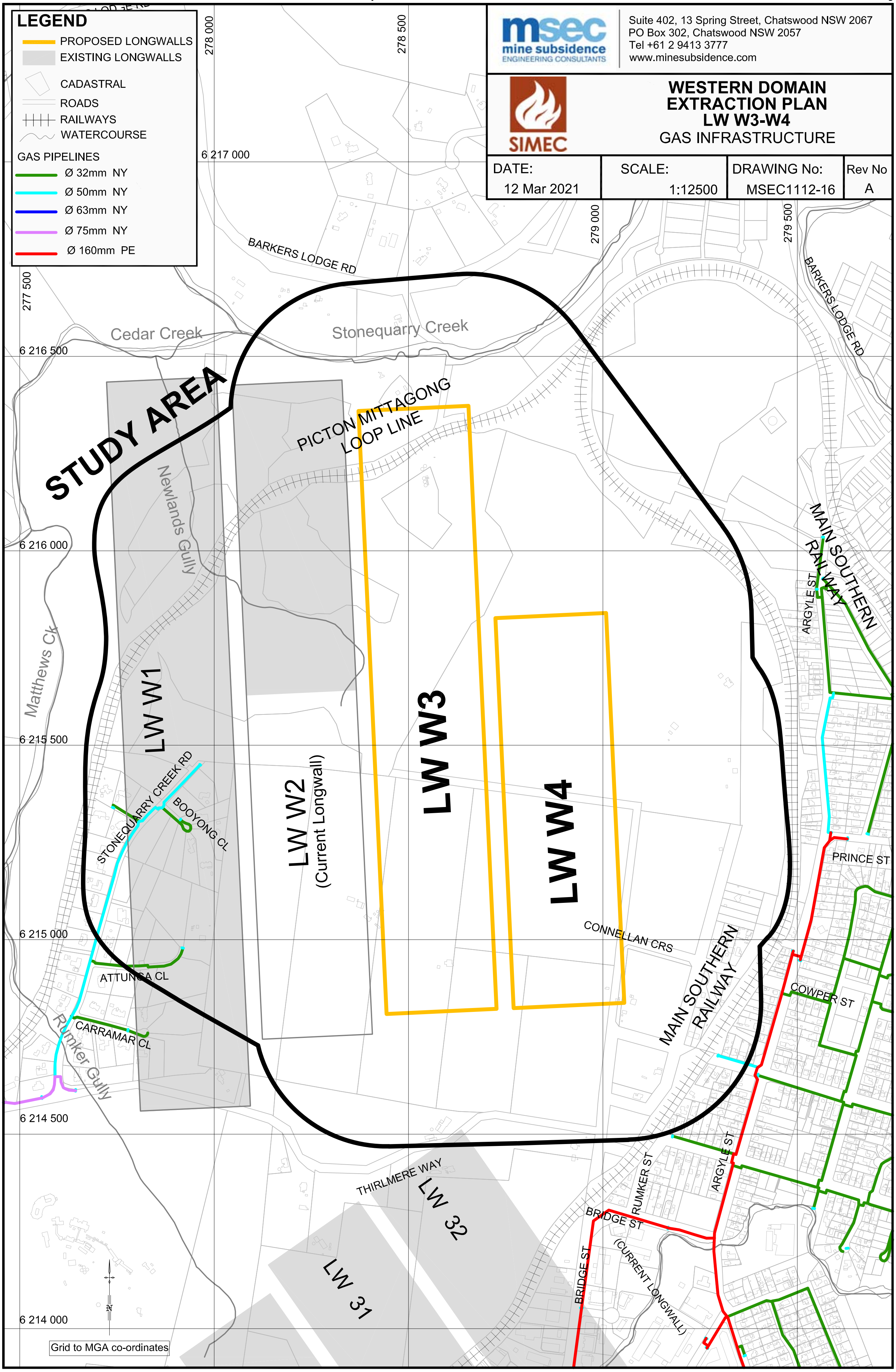

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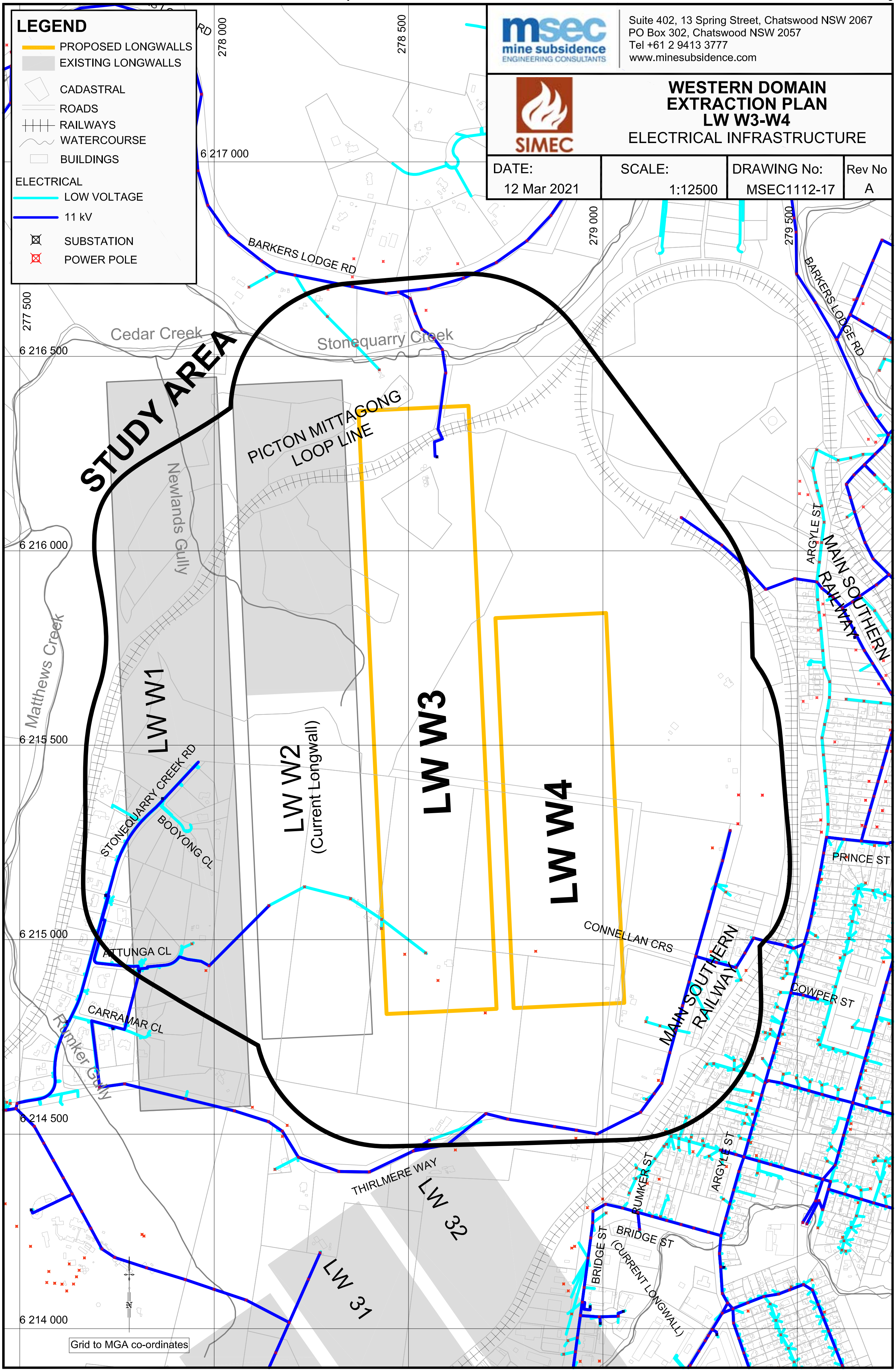

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WESTERN DOMAIN EXTRACTION PLAN LW W3-W4

TELECOMMUNICATIONS INFRASTRUCTURE

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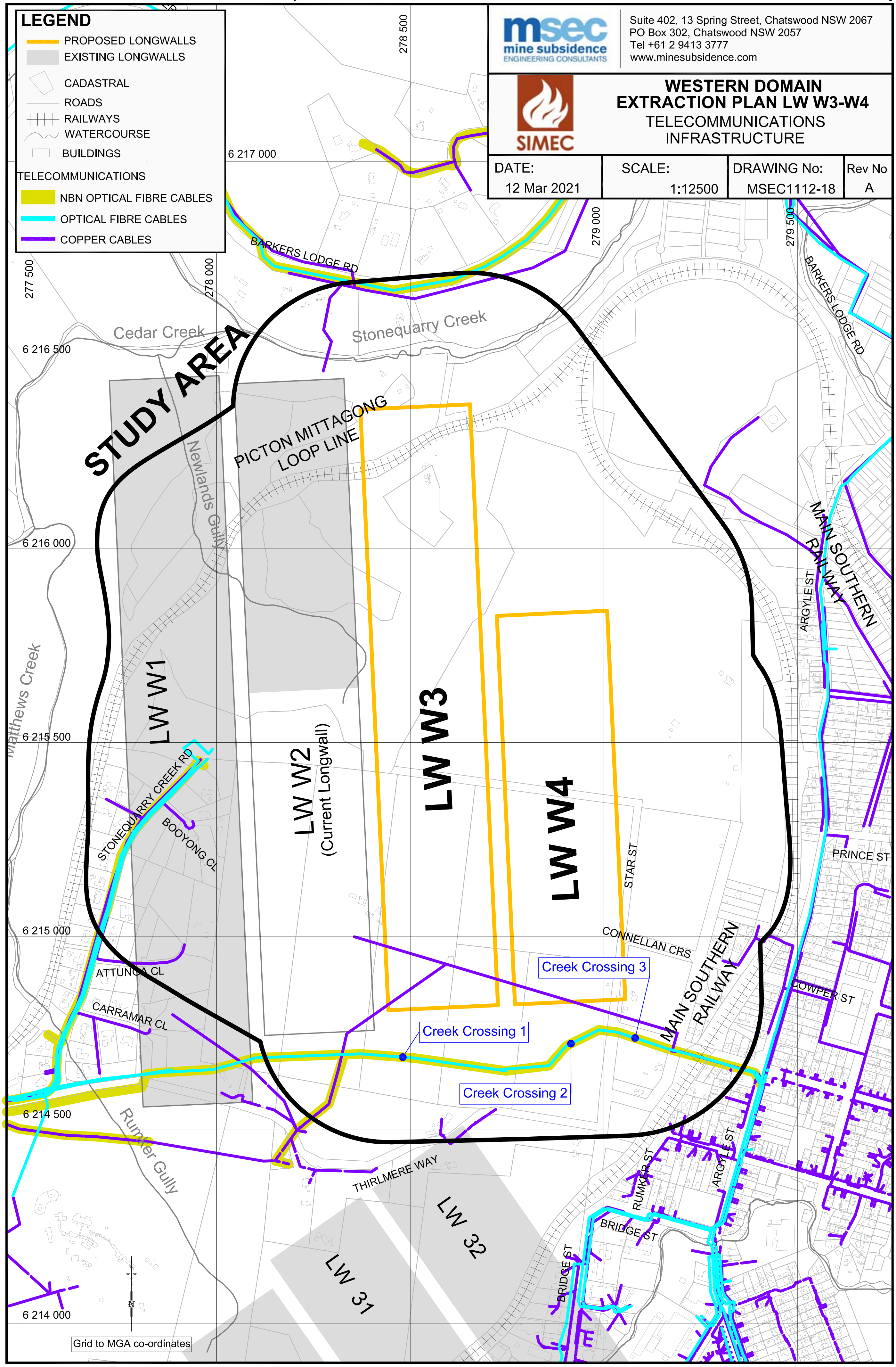

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This information has been retracted

- For more information contact Tahmoor Coal

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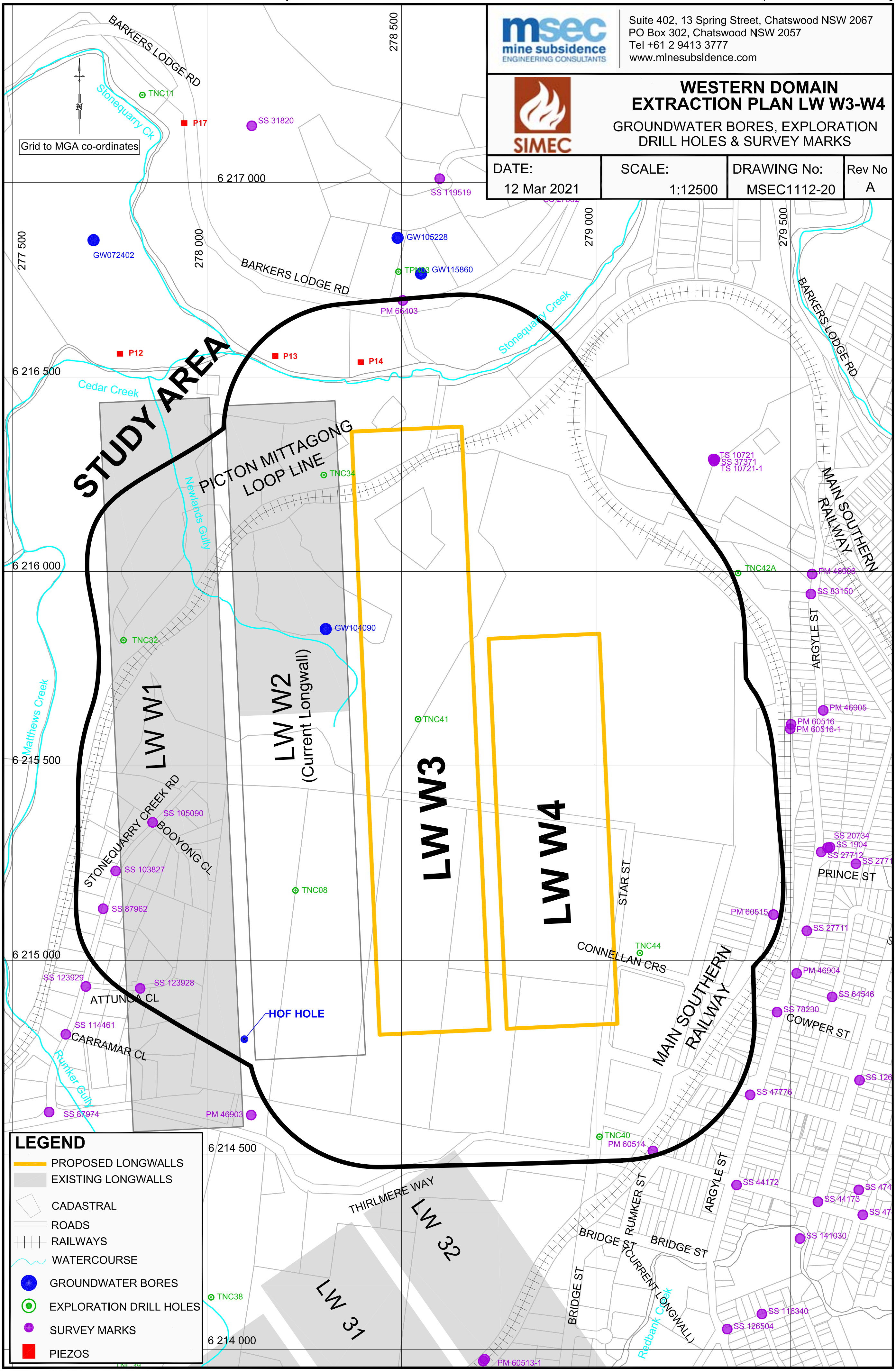

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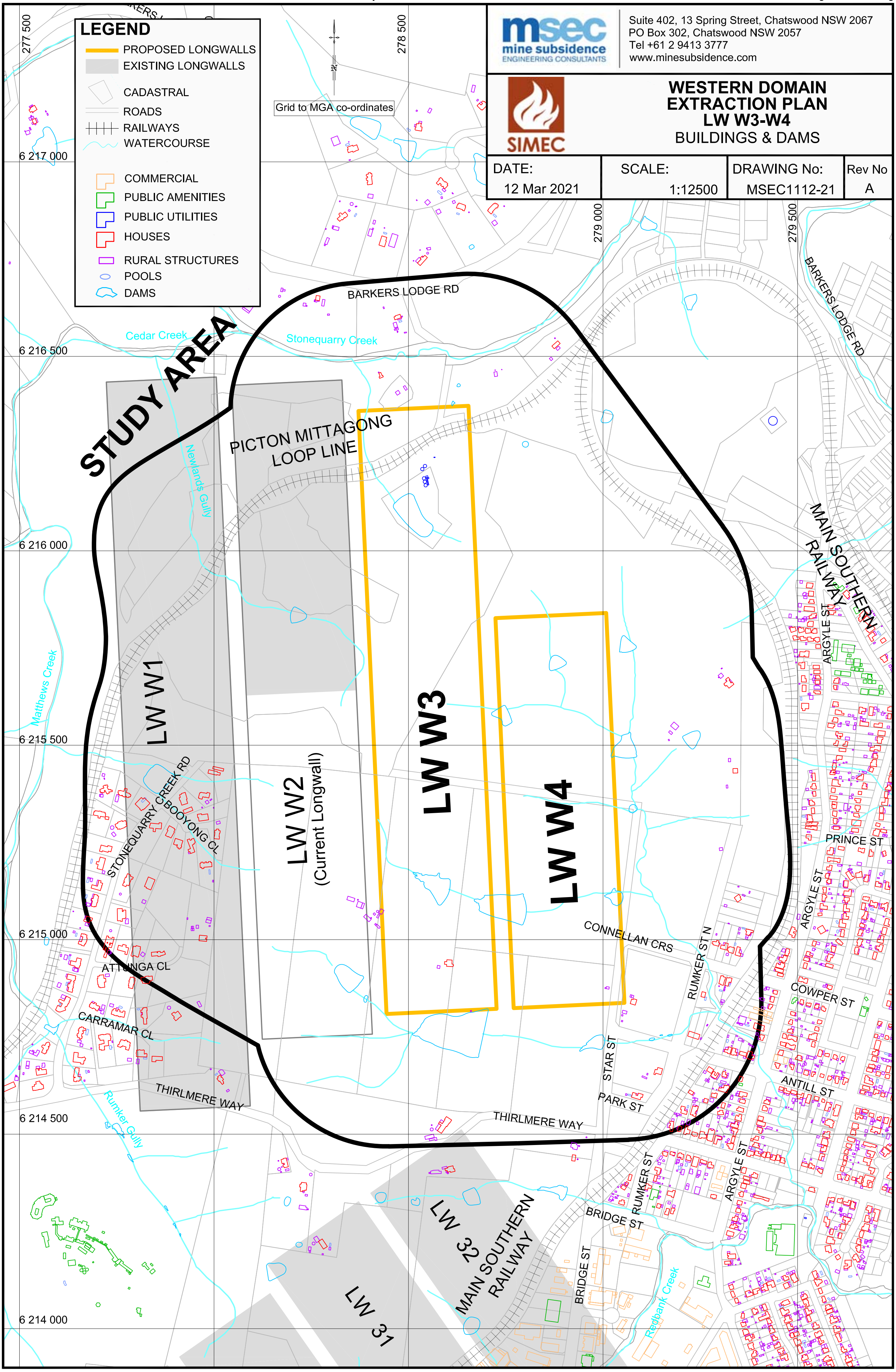

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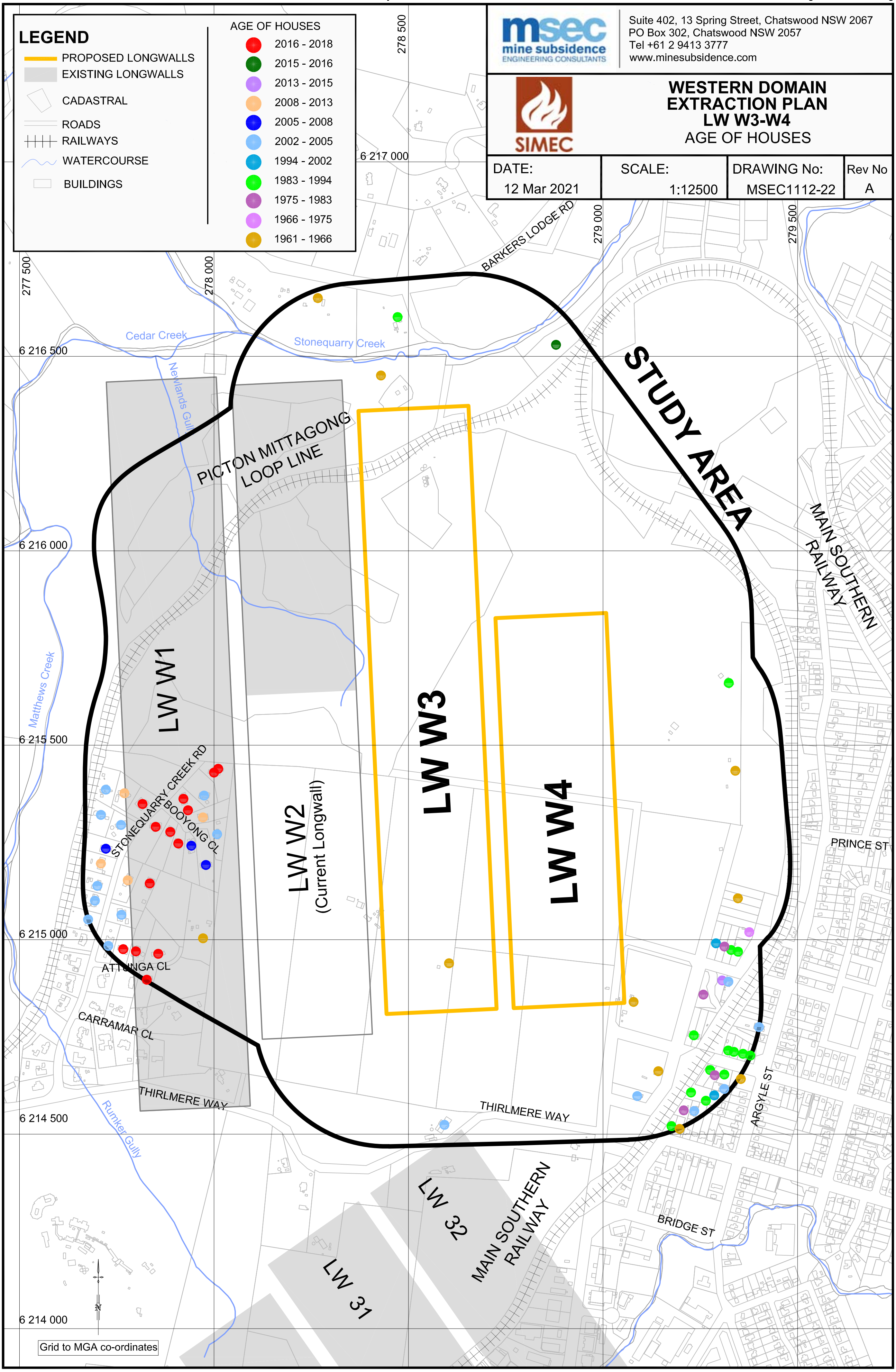

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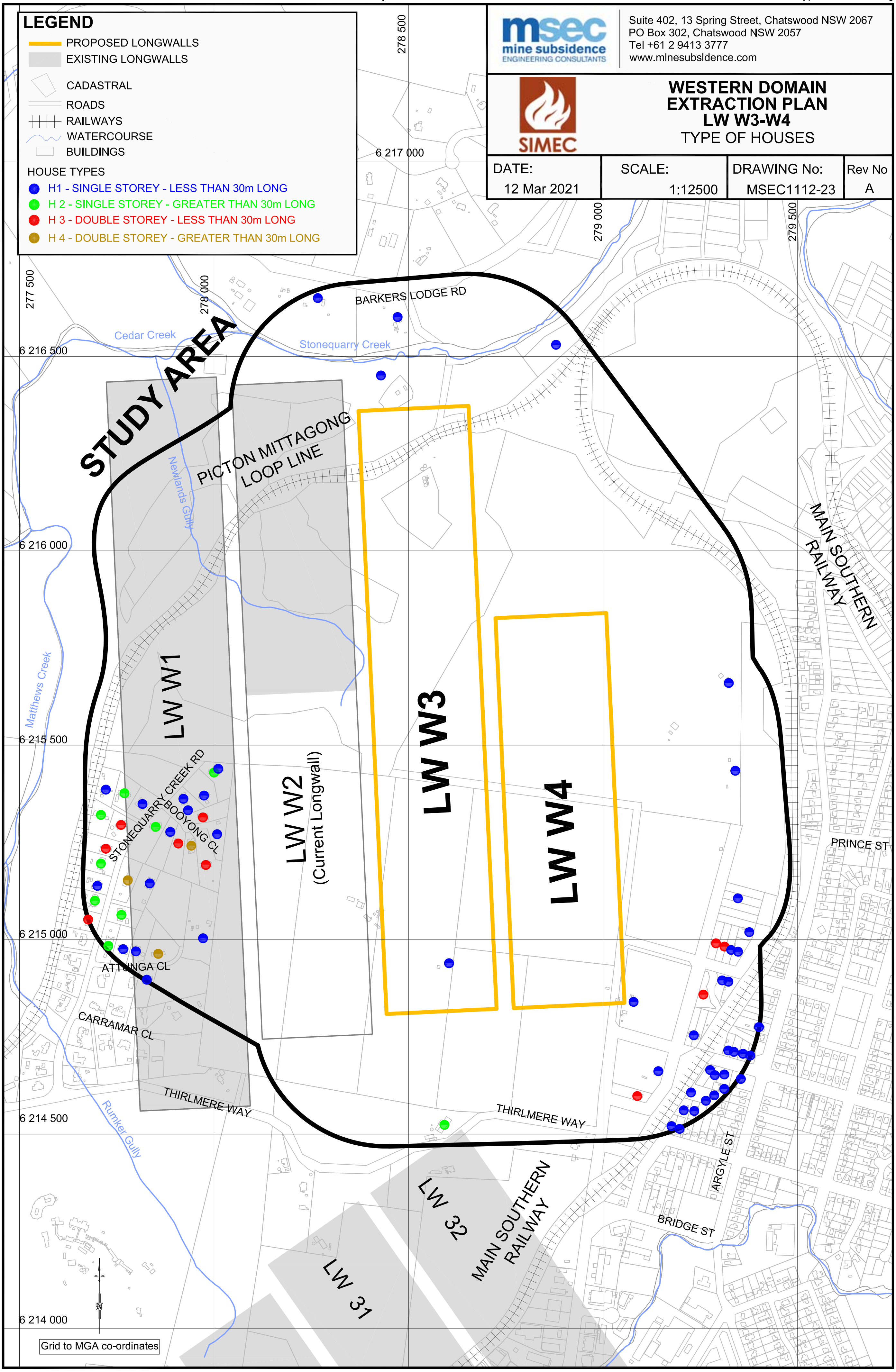

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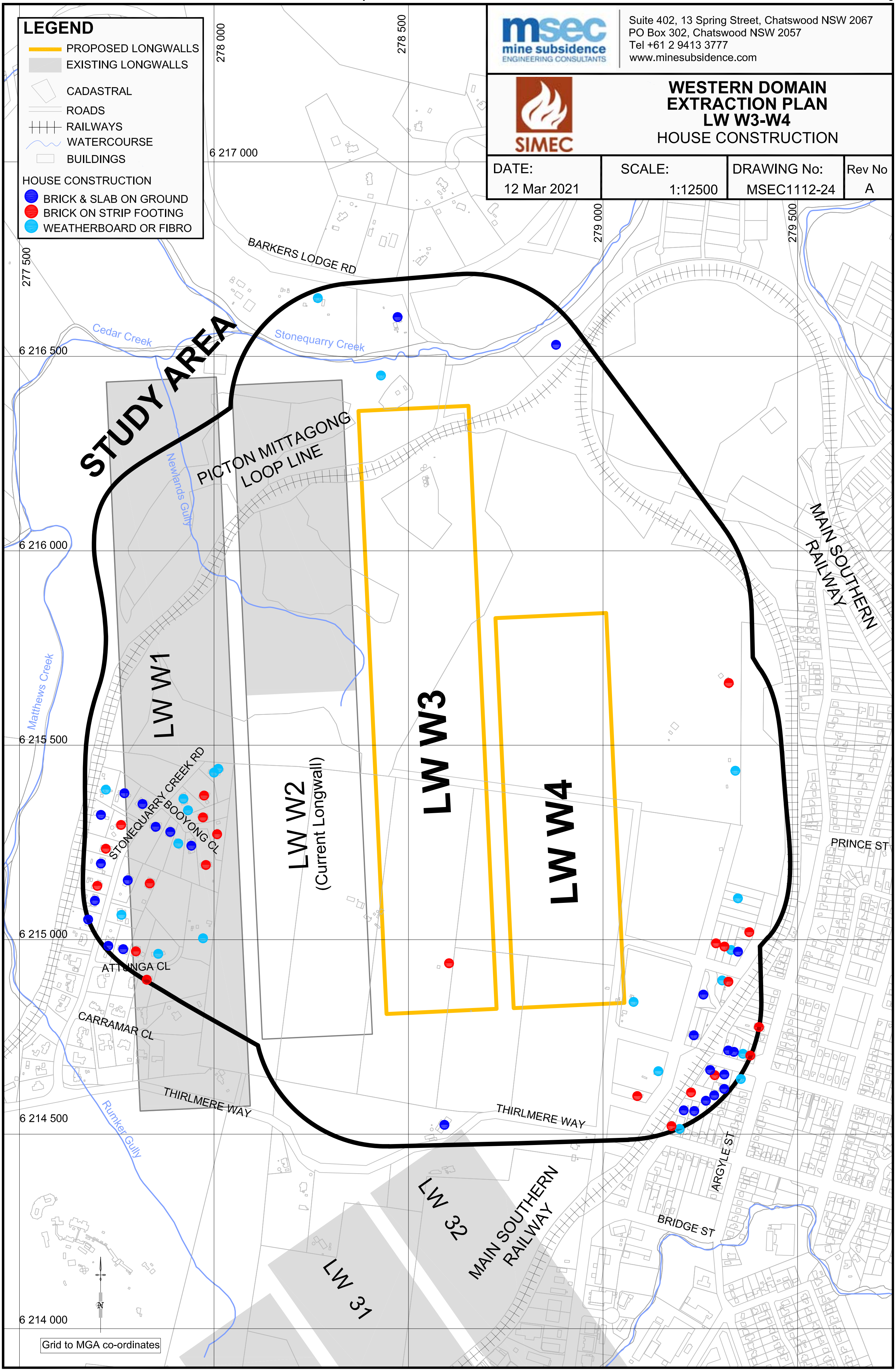

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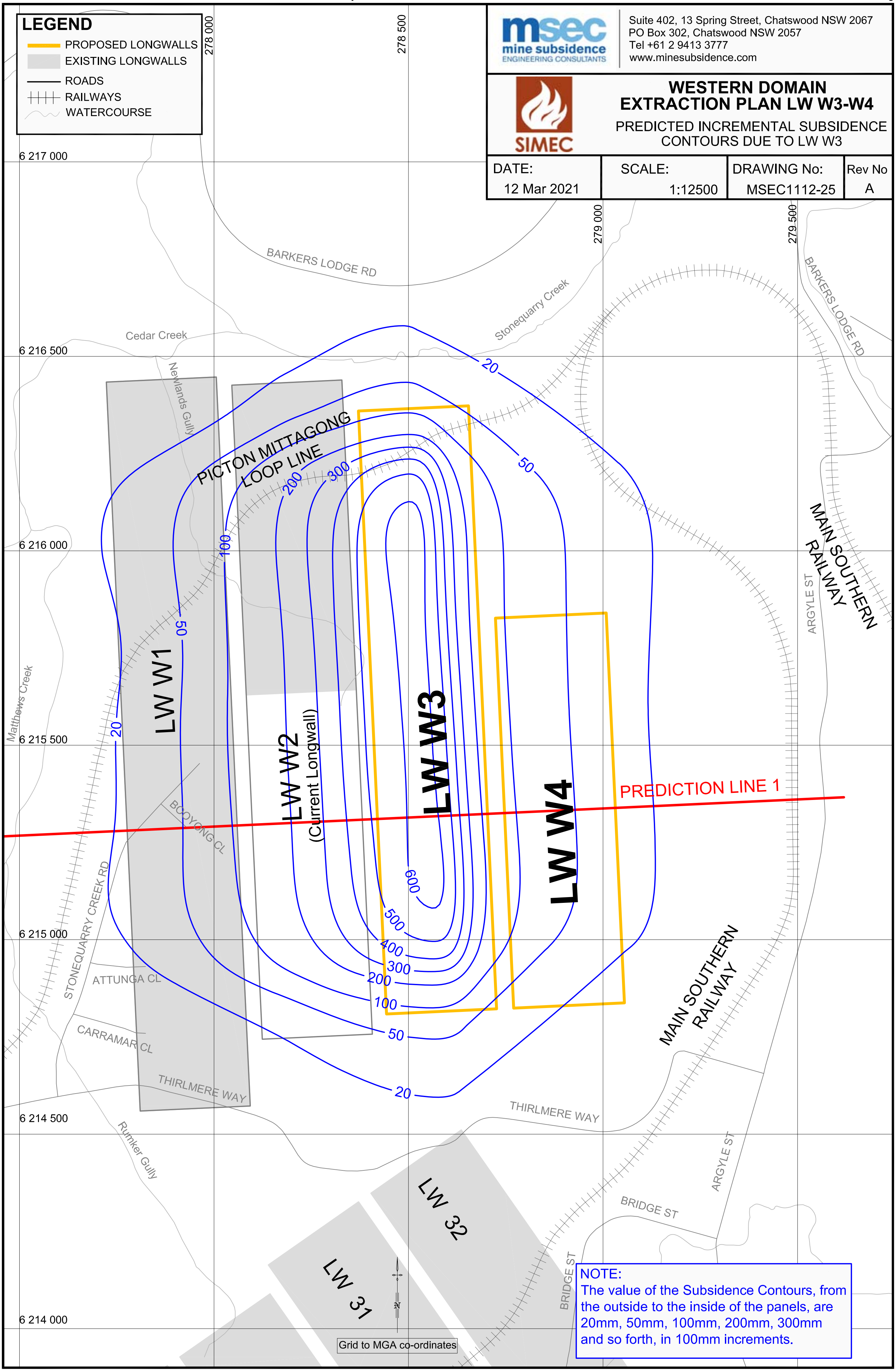

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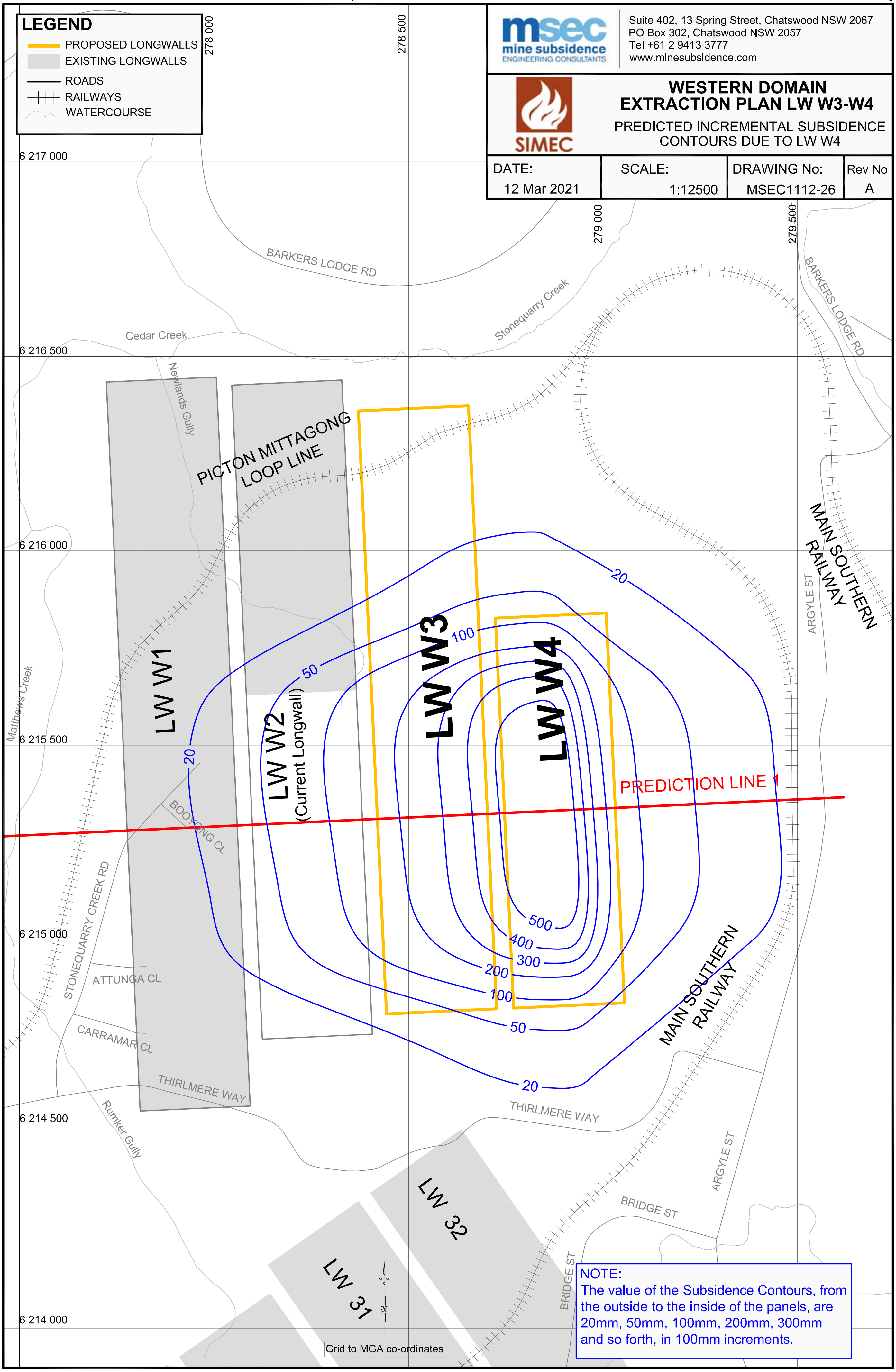

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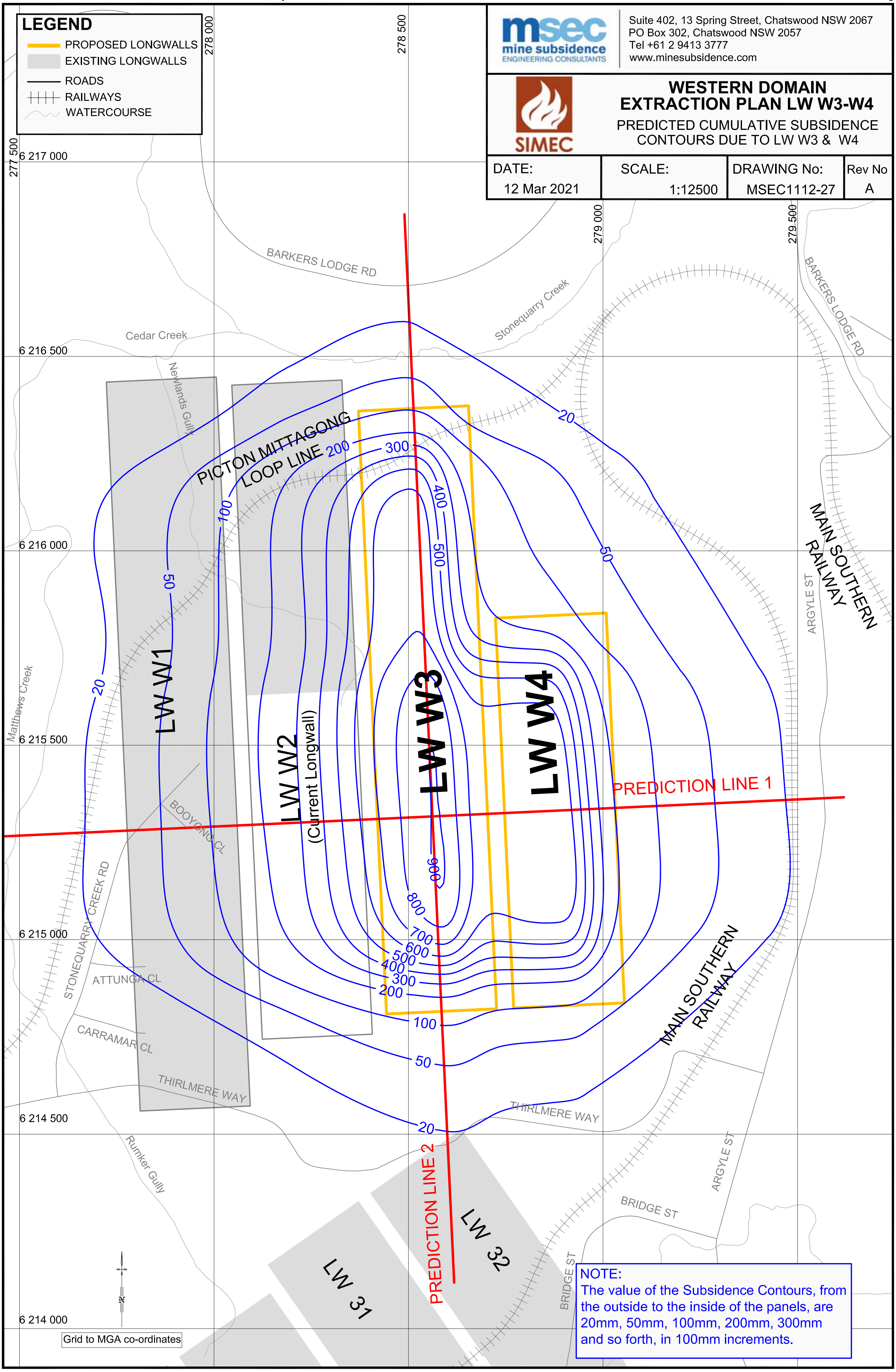

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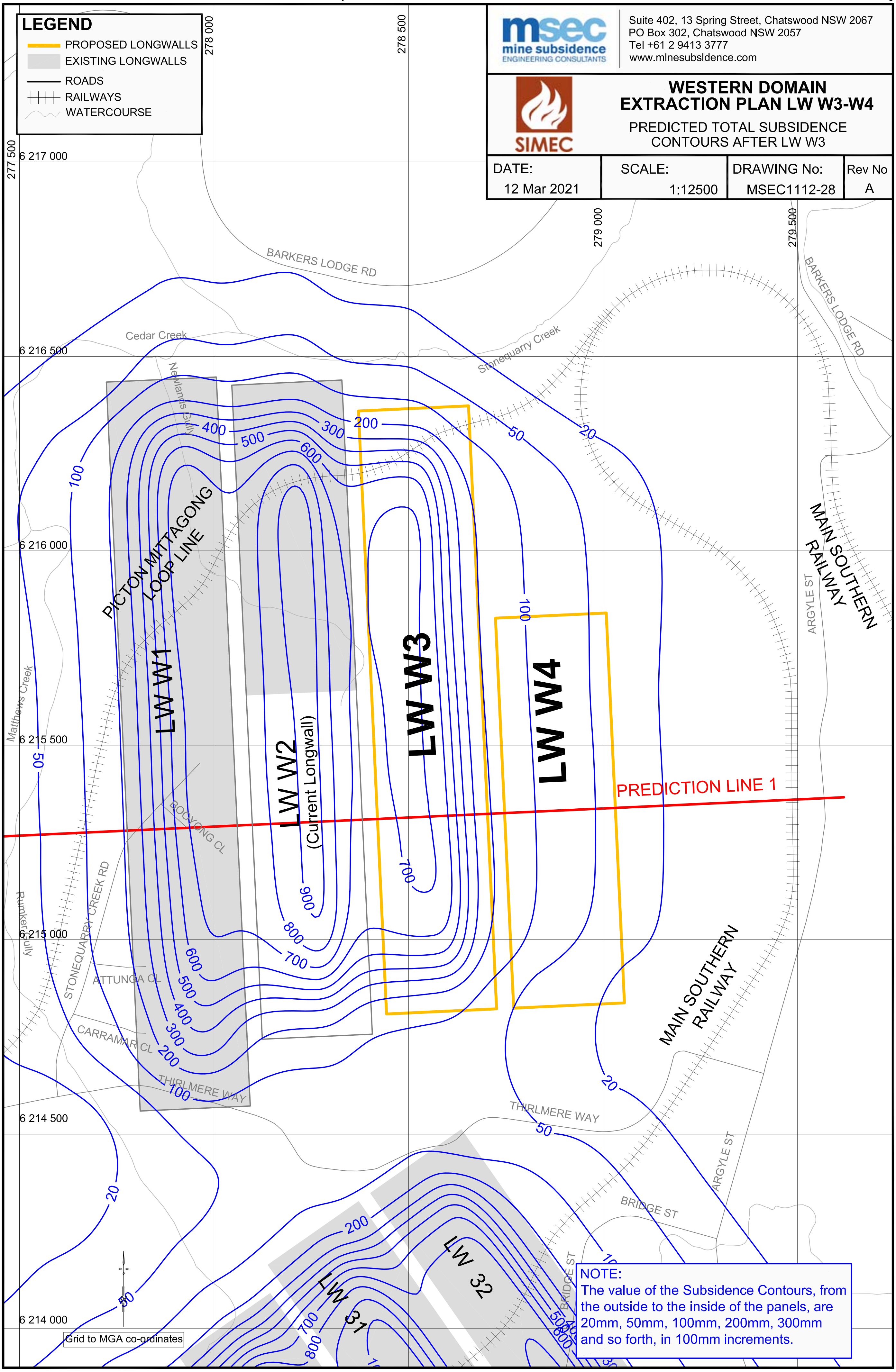

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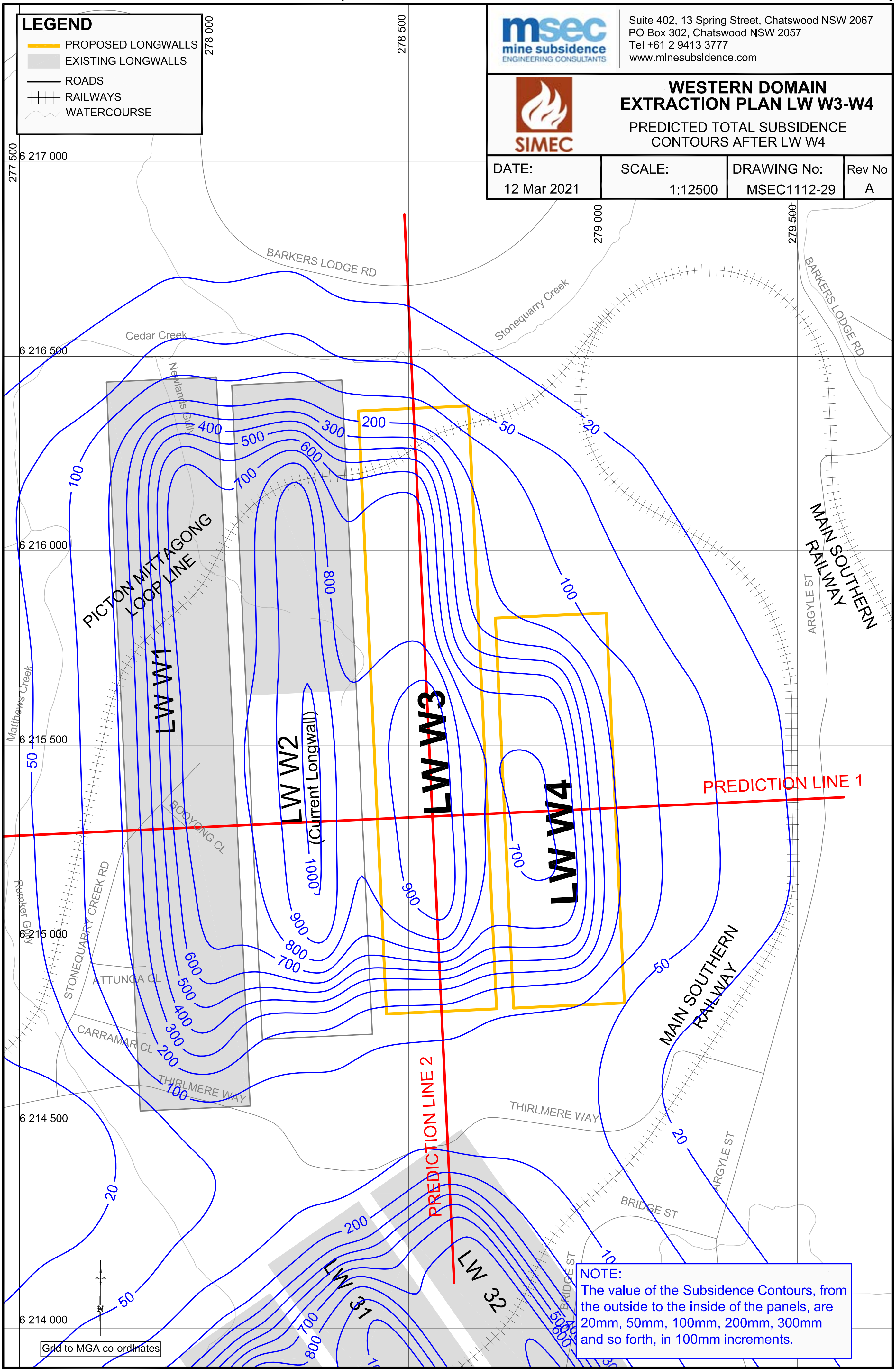

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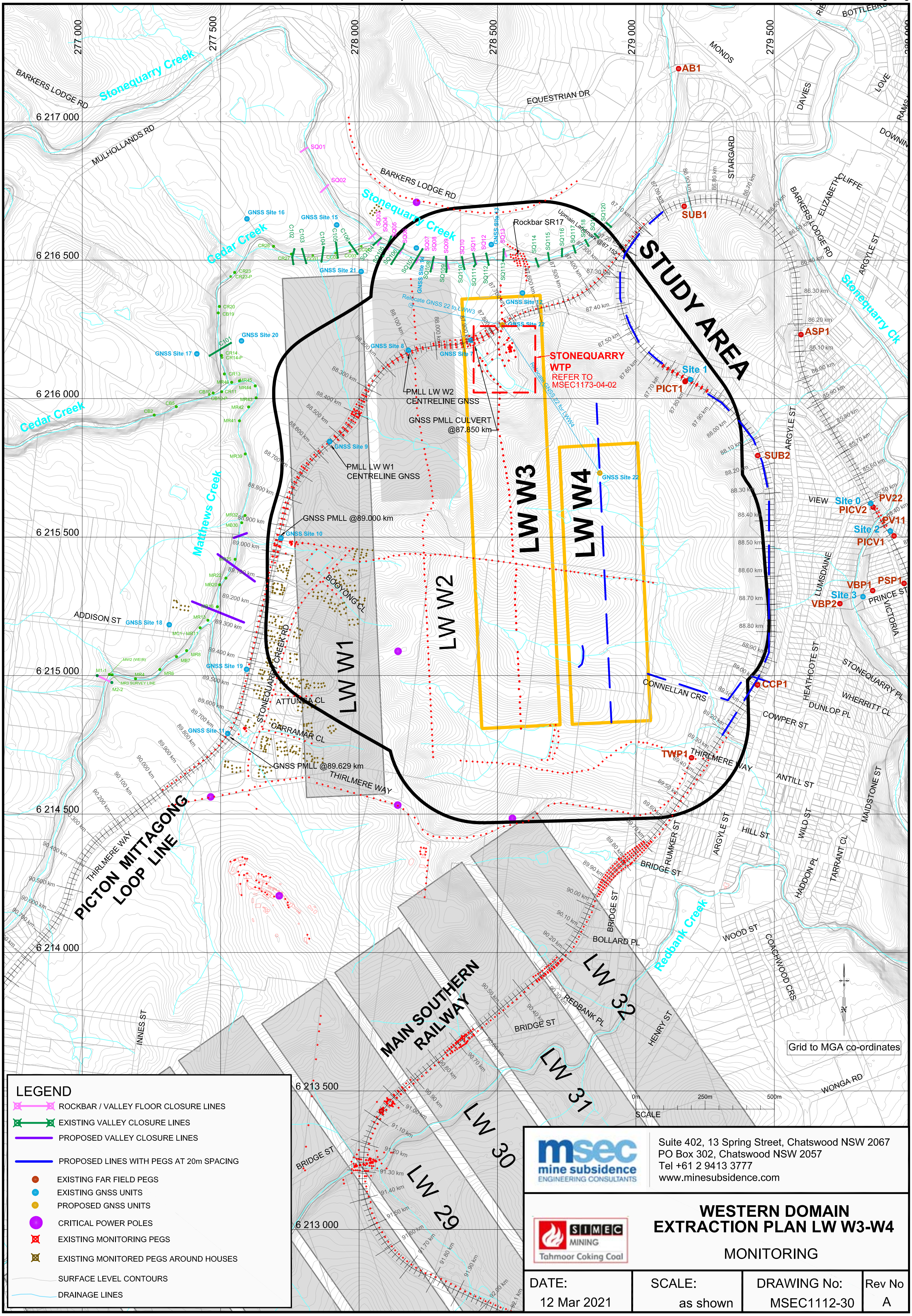

LEGEND

- ROCKBAR / VALLEY FLOOR CLOSURE LINES
- EXISTING VALLEY CLOSURE LINES
- PROPOSED VALLEY CLOSURE LINES
- PROPOSED LINES WITH PEGS AT 20m SPACING
- EXISTING FAR FIELD PEGS
- EXISTING GNSS UNITS
- PROPOSED GNSS UNITS
- CRITICAL POWER POLES
- EXISTING MONITORING PEGS
- EXISTING MONITORED PEGS AROUND HOUSES
- SURFACE LEVEL CONTOURS
- DRAINAGE LINES

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WESTERN DOMAIN EXTRACTION PLAN LW W3-W4

MONITORING

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