METROPOLITAN COAL LONGWALLS 311-316

SUBSIDENCE REPORT




Peabody

16 October 2024

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Jon Degotardi
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Metropolitan Colliery
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Ref: MSEC1441-100 Revision A

Dear Jon,

RE: Metropolitan Mine – Longwall 312 modified finishing end
Mine Subsidence Overview

Metropolitan Collieries Pty Ltd (Metropolitan Coal) is a wholly owned subsidiary of Peabody Energy Australia Pty Ltd (Peabody) and operates Metropolitan Colliery (Metropolitan Coal Mine), which is located in the Southern Coalfield of New South Wales.

Metropolitan Coal has lodged an extraction plan for the secondary extraction Longwalls 311 to 316 for the approval of the Department of Planning, Housing and Infrastructure. Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC1340 (Rev. A) in support of the Longwalls 311 to 316 Extraction Plan application submitted in March 2024 and Report No. MSEC1441 (Rev. A) in support of the Longwalls 311 to 316 Revised Layout submitted in July 2024, which are provided in Attachment 1 and Attachment 2, respectively. Metropolitan Coal have recently completed extraction of Longwall 310.

Following the submission of the Revised Layout Extraction Plan in July 2024, Metropolitan Coal now proposes to reduce the length of Longwall 312 by 130 m at the finishing (southern) end of the longwall. The finishing end of Longwall 312 as indicated in the Extraction Plan and Revised Layout is referred to as the *Previous Layout* and the proposed shortened extent of this longwall is referred to as the *Modified Layout* in this letter report.

The layout of Longwalls 311 to 316 showing the shortening of Longwall 312 is shown below in Fig. 1. The overall void length (including the installation heading) of Longwall 312 is 1,632 m based on the Previous Layout and 1,502 m based on the Modified Layout. The overall void width and chain pillar widths of this longwall do not change. The depth of cover above the finishing end of Longwall 312 varies from approximately 525 m to 535 m.

A *Study Area* has been defined as the zone where the predicted surface subsidence effects, based on the Modified Layout, are different to those predicted based on the Previous Layout. The Study Area has been based on the combined:

- 35° angle of draw line from the finishing end of Longwall 312, based on both the Previous Layout and the Modified Layout; and
- the limit where the change in the predicted total vertical subsidence, due to the proposed modification to the longwall finishing end, is greater than 20 mm.

The 35° angle of draw and 20mm change in predicted subsidence due to the shortening of Longwall 312 are shown in Fig. 1.

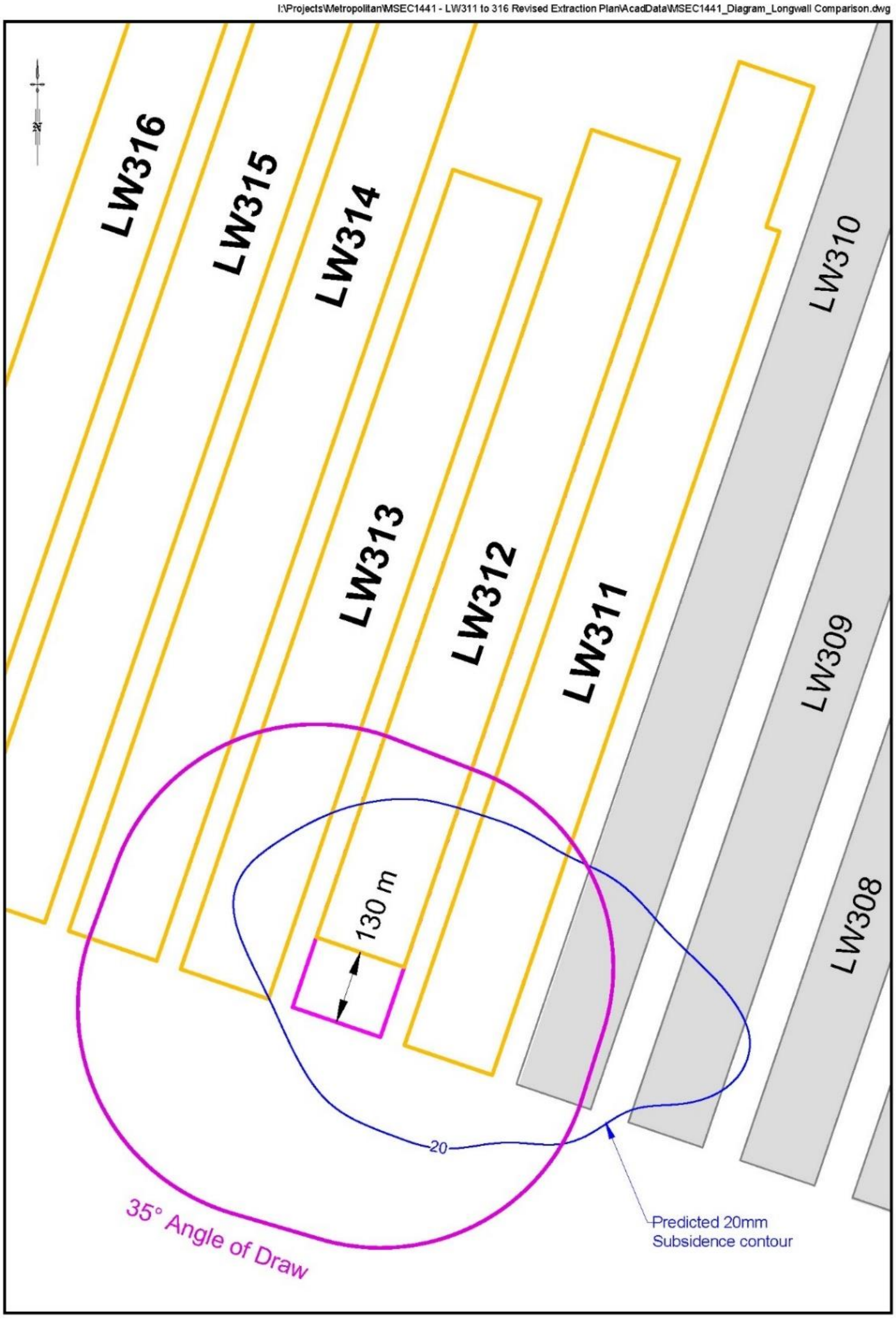


Fig. 1 Shortened Fishing end of Longwall 312 and Study Area

The natural and built features located within the Study Area are shown in Fig. 2 and Fig. 3. Contours showing the reduction in vertical subsidence due to the shortening of Longwall 312 are also shown in Fig. 2 and Fig. 3. The maximum reduction in vertical subsidence is 300 mm, which occurs at the maingate of Longwall 311. The natural and built features located within the Study Area include:

- Tributaries (including Tributary P);
- Woronora Reservoir;
- Tracks and fire roads;
- Steep slopes;
- Swamps S88, S89a, S89b, S90a, S90b, and S92;
- Aboriginal Heritage sites (FRC61, 62, 164, 189 and 193); and
- Exploration bore S288.

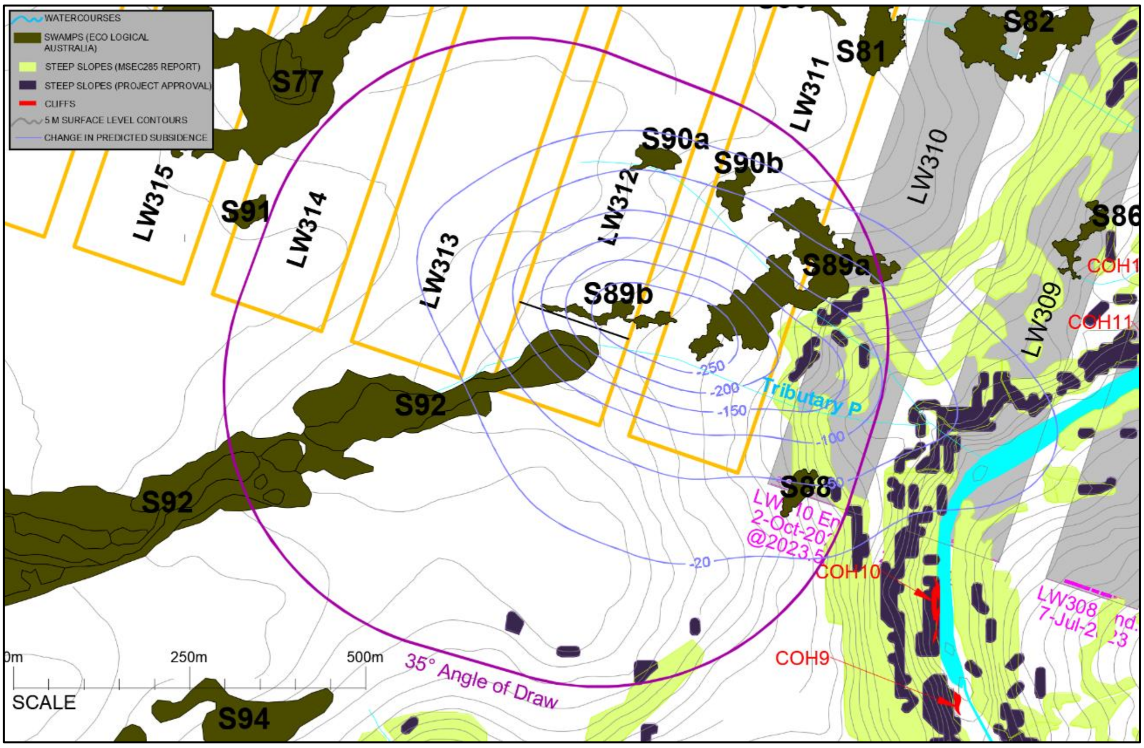


Fig. 2 **Natural features and Study Area for Longwall 312 shortening**

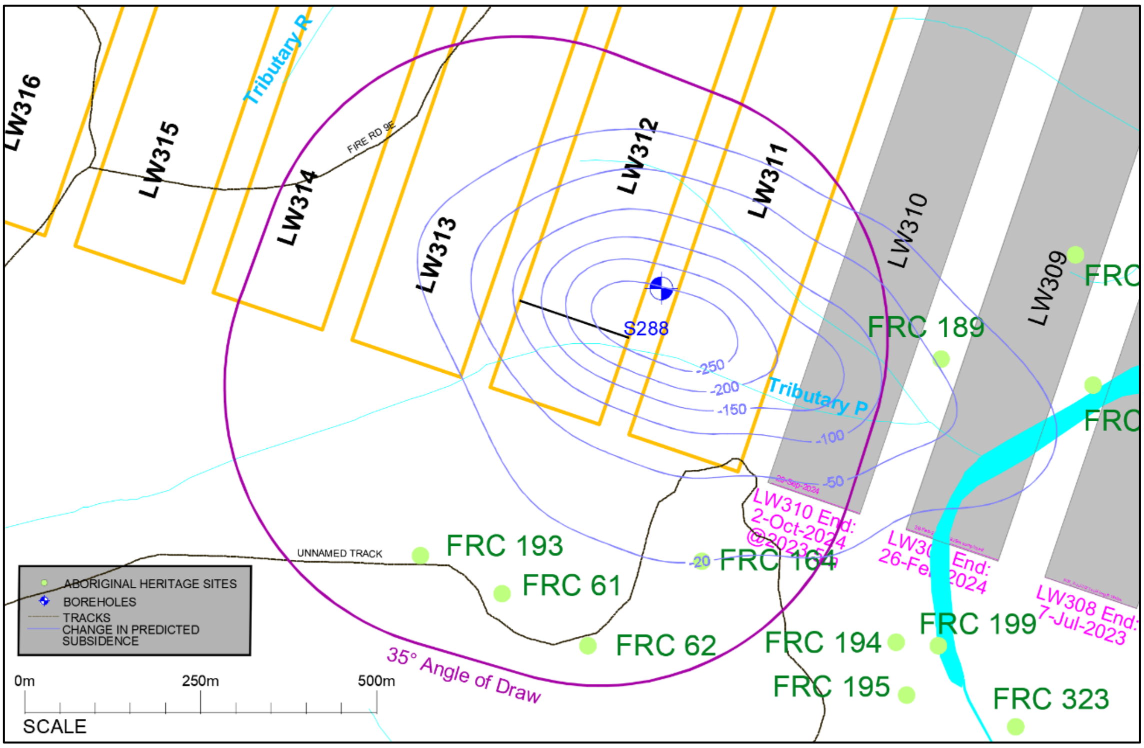


Fig. 3 **Built features and Study Area for Longwall 312 shortening**

The predicted maximum incremental and total vertical subsidence, tilt, curvatures and strains due to the extraction of Longwalls 311 to 316, as presented in Report No. MSEC1441 (Rev. A), do not change with the shortening of Longwall 312.

Whilst the maximum predicted vertical subsidence does not change, the extent of subsidence reduces slightly due to the reduced length of Longwall 312. Similarly, the maximum predicted incremental and total tilt, curvatures and strains do not change due to the Modified Layout, however the location of predicted tilts, curvatures and strains will change as a result of the shortening of Longwall 312. At some locations the predicted tilts, curvatures and strains will reduce slightly and at some locations these parameters will increase slightly.

A discussion of the predicted subsidence parameters and impact assessments for the surface features located within the Study Area is provided below.

Tributaries (including Tributary P)

The changes in predicted subsidence parameters along Tributary P due to the Previous and Modified layouts are shown in shown in Fig. 4. The maximum reduction in vertical subsidence along Tributary P is 280 mm, near the Longwall 311 maingate. The maximum reduction in predicted upsidence and closure are 45 mm and 12 mm respectively, located above Longwall 312. A second, unnamed tributary is located within the Study Area to the north of Tributary P. The predicted subsidence at this tributary reduces by 120mm and reductions in predicted upsidence and closure are minor. The reduced subsidence parameters along the tributaries are minor and do not change the impact assessments outlined in the extraction plan and revised extraction plan subsidence assessments.

Woronora Reservoir

Woronora Reservoir is located approximately 510 m to the east of the Longwall 312 finishing end. The reservoir is located outside the 35° angle of draw line in Fig. 2 but is inside the 20 mm contour. The small section of the reservoir will experience a reduction in predicted vertical subsidence of less than 50 mm. Other predicted subsidence parameters do not change as a result of the shortening of Longwall 312. The reduced length of Longwall 312 does not therefore change the impact assessments outlined in the extraction plan and revised extraction plan subsidence assessments.

Steep slopes

Steep slopes are located to the east of Longwall 311 as shown in Fig. 2, and are within the Study Area and 20mm subsidence contour. The steep slope will experience a reduction in vertical subsidence as indicated by the contour lines in Fig. 2, and will experience a minor reduction in predicted tilt, curvature and strain. The changes in predicted subsidence parameters are minor and do not change the impact assessments outlined in the extraction plan and revised extraction plan subsidence assessments.

Tracks and fire roads

Two fire roads are within the Study Area as shown in Fig. 3, located above Longwall 314 and to south of the longwalls. The fire road above Longwall 314 is located outside the 20mm subsidence contour and will not experience any measurable change in the predicted subsidence parameters. The fire road to the south of the longwalls will experience a reduction in vertical subsidence as indicated by the contour lines in Fig. 3 (less than 75 mm), and will experience a minor reduction in predicted tilt, curvature and strain. The changes in predicted subsidence parameters are minor and do not change the impact assessments outlined in the extraction plan and revised extraction plan subsidence assessments.

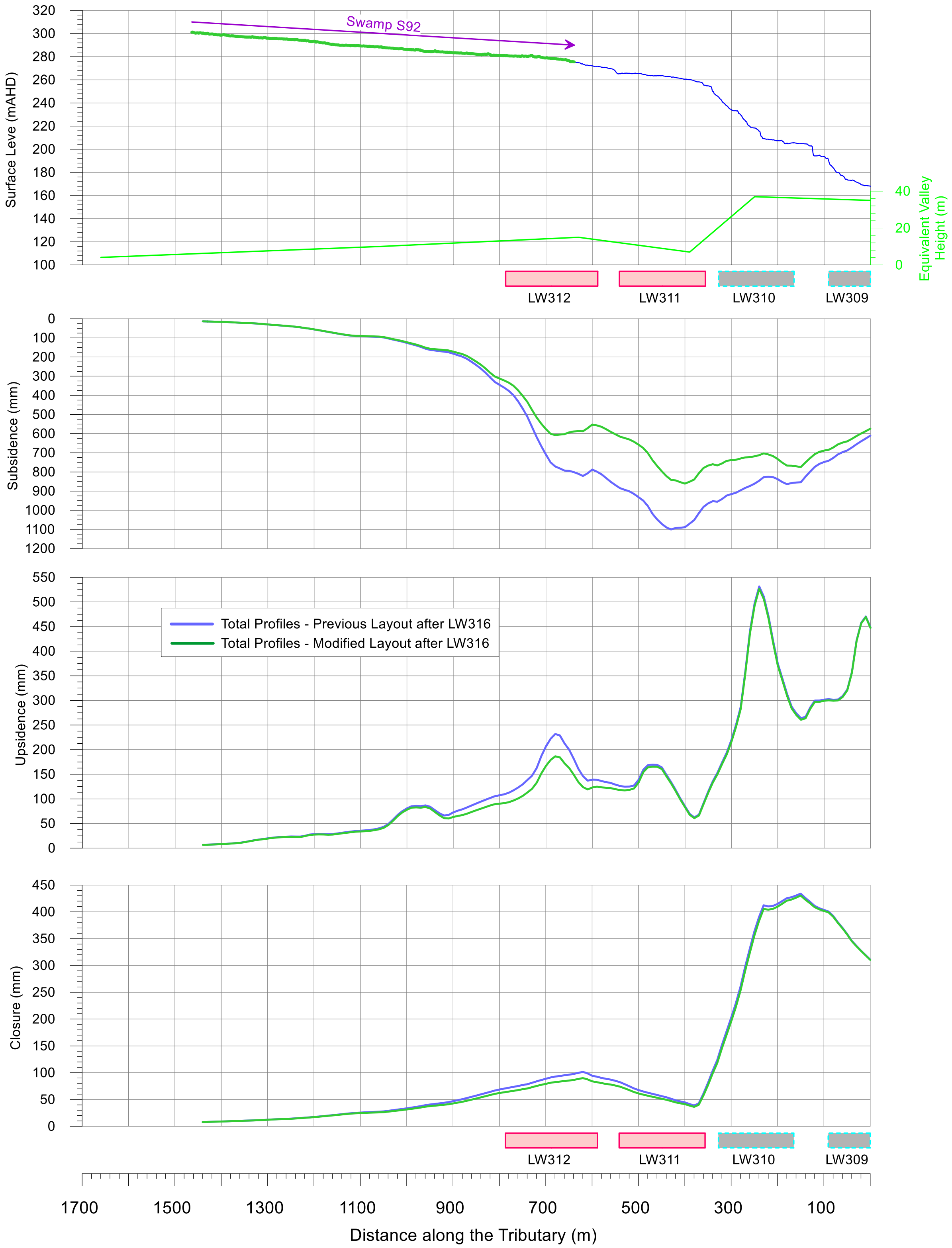


Fig. 4 Tributary P – Predicted total vertical subsident, upsidence and closure due to the Previous Layout and Modified Layout

Swamps

Six swamps (S88, S89a, S89b, S90a, S90b, and S92) are located within the Study Area as shown in Fig. 2. A summary of the predicted subsidence parameters for the six swamps due to the Previous Layout and Modified Layout is provided in Table 1 and Table 2. Table 1 provides a summary of the predicted vertical subsidence, tilt, and hogging and sagging curvature. Table 2 provides a summary of the predicted conventional strains, based on 15 times curvature, and the predicted valley related movements for the swamps located at tributaries.

Table 1 Maximum Predicted Total Subsidence, Tilt and Curvature for Swamps located within the Study Area based on the Previous Layout and Modified Layout

Swamp	Total Subsidence (mm)		Total Tilt (mm/m)		Total Hogging Curvature (km^{-1})		Total Sagging Curvature (km^{-1})	
	Previous Layout	Modified Layout	Previous Layout	Modified Layout	Previous Layout	Modified Layout	Previous Layout	Modified Layout
S88	475	375	5.5	4.5	0.06	0.04	0.02	0.02
S89a	1450	1400	6.5	4.5	0.03	0.03	0.06	0.06
S89b	1200	950	6.5	5.5	0.03	0.04	0.04	0.04
S90a	1500	1500	1.5	2.0	0.04	0.04	0.05	0.05
S90b	1450	1450	1.5	2.0	0.03	0.03	0.05	0.05
S92	975	775	7.0	5.5	0.06	0.05	0.04	0.03

Table 2 Maximum Predicted Conventional Strain and Valley Closure for Swamps located within the Study Area based on the Previous Layout and Modified Layout

Swamp	Total Tensile Strain (mm/m) (based on 15 times curvature)		Total Compressive Strain (mm/m) (based on 15 times curvature)		Total Closure (mm)	
	Previous Layout	Modified Layout	Previous Layout	Modified Layout	Previous Layout	Modified Layout
S88	1.0	1.0	< 0.5	< 0.5	-	-
S89a	< 0.5	< 0.5	1.0	1.0	-	-
S89b	< 0.5	1.0	1.0	1.0	-	-
S90a	1.0	1.0	1.0	1.0	30	20
S90b	< 0.5	< 0.5	1.0	1.0	30	20
S92	1.0	1.0	1.0	< 0.5	100	90

The majority of the predicted subsidence parameters in Table 1 and Table 2 based on the Modified Layout are equal to or less than those based on the Previous Layout. There is a slight increase in some parameters including predicted hogging curvature and tensile strain at Swamp S89b, and predicted tilt at Swamps S90a and S90b. The Modified Layout results in the longwall footprint no longer extracting directly beneath Swamp S92, resulting in a slight reduction in subsidence parameters as shown in Table 2. The changes in predicted subsidence parameters are minor and do not change the overall impact assessments outlined in the extraction plan and revised extraction plan subsidence assessments.

Aboriginal Heritage sites

The Aboriginal Heritage sites located within the Study Area are shown in Fig. 2. There are five Aboriginal Heritage sites (FRC61, 62, 164, 189 and 193) located within the Study Area. Two of the sites are located within the 20mm subsidence contour. A summary of the predicted subsidence parameters for the Aboriginal Heritage Sites based on the Previous Layout and Modified Layout is provided in Table 3.

Table 3 Maximum Predicted Total Subsidence, Tilt and Curvature for Aboriginal Heritage Sites located within the Study Area based on the Previous Layout and Modified Layout

Site ID	Total Subsidence (mm)		Total Tilt (mm)		Total Hogging Curvature (km^{-1})		Total Sagging Curvature (km^{-1})	
	Previous Layout	Modified Layout	Previous Layout	Modified Layout	Previous Layout	Modified Layout	Previous Layout	Modified Layout
FRC 61	50	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
FRC 62	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
FRC 164	125	100	1.0	0.5	< 0.01	< 0.01	< 0.01	< 0.01
FRC 189	925	900	2.5	2.5	0.03	0.03	0.02	0.02
FRC 193	50	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01

The predicted vertical subsidence for the five Aboriginal Heritage Sites based on the Modified Layout is the unchanged or slightly less than that based on the Previous Layout. The predicted tilt and curvatures are unchanged. The changes in predicted subsidence parameters are minor and do not change the impact assessments outlined in the extraction plan and revised extraction plan subsidence assessments.

Exploration bore

Exploration bore S288 is located above the chain pillar between Longwall 311 and 312 as shown in Fig. 2. A summary of the predicted subsidence parameters for the bore based on the Previous Layout and Modified Layout is provided in Table 4.

Table 4 Maximum Predicted Total Subsidence Parameters for Exploration Bore S288 located within the Study Area based on the Previous Layout and Modified Layout

Bore	Total Subsidence (mm)		Total Tilt (mm)		Total Hogging Curvature (km^{-1})		Total Sagging Curvature (km^{-1})	
	Previous Layout	Modified Layout	Previous Layout	Modified Layout	Previous Layout	Modified Layout	Previous Layout	Modified Layout
S288	1250	1050	3.0	4.0	0.03	0.04	0.03	0.02

The predicted vertical subsidence and sagging curvature based on the Modified Layout are less than those based on the Previous Layout. The predicted tilt and hogging curvature based on the Modified Layout are greater than those based on the Previous Layout. The changes in predicted subsidence parameters are minor and do not change the impact assessments outlined in the extraction plan and revised extraction plan subsidence assessments.

The changes to the predicted subsidence parameters for the natural and built features within the Study Area due to the reduced length of Longwall 312 result minor changes in the predicted subsidence parameters. Some features near the ends of the longwalls will experience a reduction in vertical subsidence but an increase in the predicted tilt and curvature, which is discussed above. The increases in predicted tilt and curvature are minor and do not change the impact assessments for the relevant features. The assessed impacts for the features based on the Modified Layout are unchanged from the Previous Layout. The management strategies and required monitoring do not change for the surface features within the Study Area for the Modified Layout. The management strategies include a subsidence monitoring program for the extraction of Longwalls 311 to 316. A plan showing current monitoring, and the proposed subsidence monitoring for the extraction of Longwall 311 to 316 is attached.

I trust that this letter report is of assistance. If you have any questions, please do not hesitate to email or call me on (02) 9413-3777.

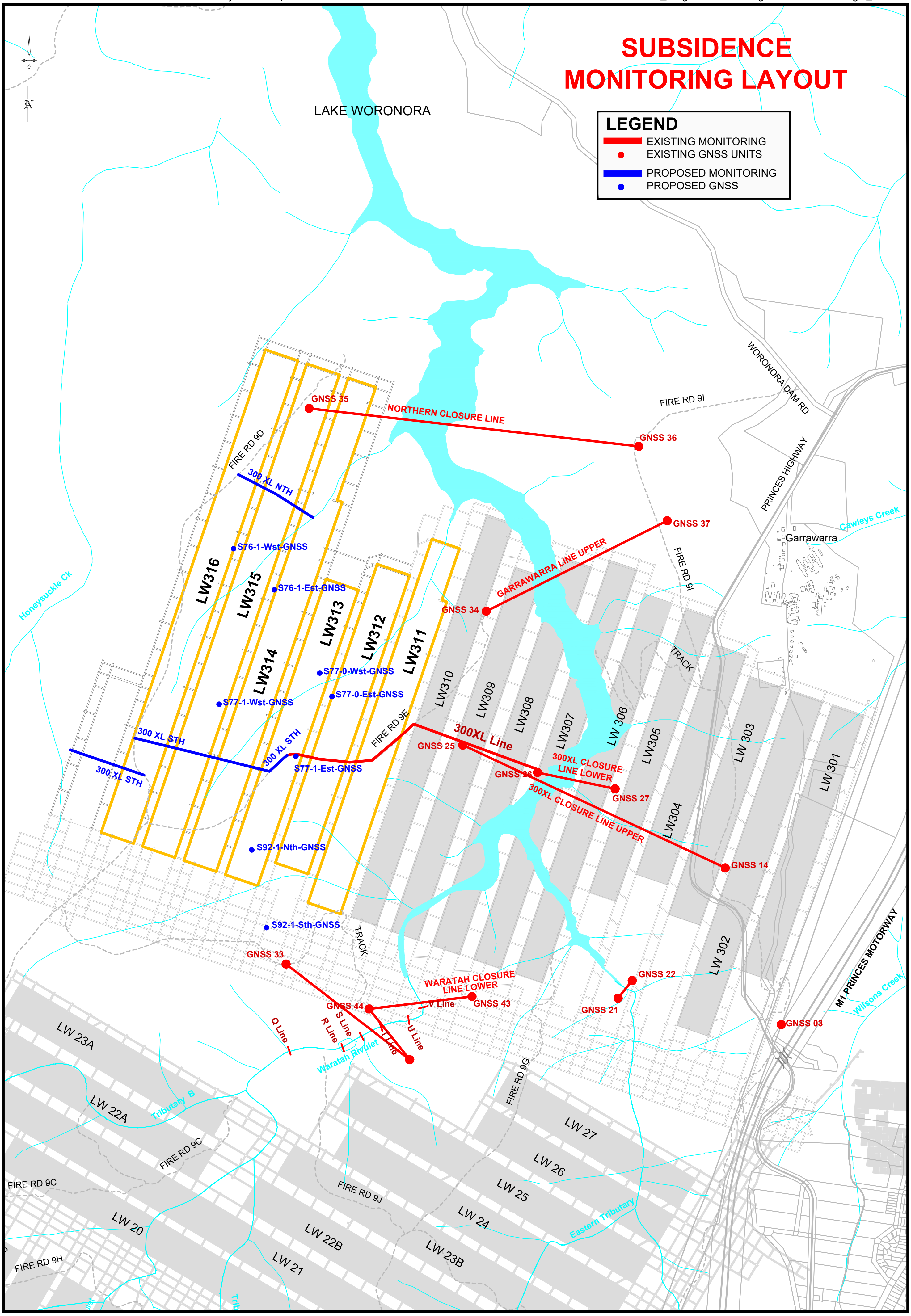
Peter DeBono
Mine Subsidence Engineering Consultants

Attachments:

Subsidence Monitoring Layout for Longwalls 311 to 316.

Attachment 1 – MSEC1348 Metropolitan Coal Mine – Longwalls 311 to 316, Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan Rev A March 2024

Attachment 2 - MSEC1441 Metropolitan Mine – Revised Layout for Longwalls 311 to 316 Mine Subsidence Overview, Rev A 27 June 2024



SUBSIDENCE MONITORING LAYOUT
LEGEND
EXISTING MONITORING
EXISTING GNSS UNITS
PROPOSED MONITORING
PROPOSED GNSS
LAKE WORONORA
N
NORTHERN CLOSURE LINE
GNSS 35
GNSS 36
GNSS 37
GNSS 34
GARRAWARRA LINE UPPER
300 XL NTH
300 XL STH
S76-1-Wst-GNSS
S76-1-Est-GNSS
S77-0-Wst-GNSS
S77-0-Est-GNSS
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S92-1-Nth-GNSS
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LW316
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LW 302
LW 301
300XL Line
GNSS 25
GNSS 26
GNSS 27
GNSS 14
300XL CLOSURE LINE LOWER
300XL CLOSURE LINE UPPER
GNSS 33
GNSS 44
GNSS 43
GNSS 22
GNSS 21
GNSS 03
WARATAH CLOSURE LINE LOWER
V Line
Q Line
R Line
S Line
T Line
U Line
Waratah Rivulet
FIRE RD 9D
FIRE RD 9E
FIRE RD 9I
FIRE RD 9G
FIRE RD 9C
FIRE RD 9J
FIRE RD 9H
TRACK
WORONORA DAM RD
PRINCES HIGHWAY
M1 PRINCES MOTORWAY
Garrawarra
Cawleys Creek
Wilsons Creek
Honeysuckle Ck
Tributary B
Eastern Tributary
LW 23A
LW 22A
LW 20
LW 22B
LW 21
LW 23B
LW 24
LW 25
LW 26
LW 27

ATTACHMENT 1

Metropolitan Mine –Layout for Longwalls 311 to 316 Mine Subsidence Overview
March 2024

METROPOLITAN COAL PROJECT:

Metropolitan Coal Mine – Longwalls 311 to 316

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

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft Issue	PD		Sep 2023
02	Draft Issue	PD		Jan 2024
03	Draft Issue	PD		Feb 2024
A	Final Issue	PD		March 2024

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

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

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

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

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

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

EXECUTIVE SUMMARY

Metropolitan Coal Pty Ltd (Metropolitan Coal) proposes to continue its underground coal mining operations within the Bulli Seam at Metropolitan Colliery (Metropolitan Coal Mine), which is located in the Southern Coalfield of New South Wales. Metropolitan Coal proposes to extract the next longwalls (LW) in the current series, referred to as Longwalls 311 to 316.

Metropolitan Coal was granted Project Approval 08_0149 by the Minister for Planning on the 22nd June 2009. The Project Approval included a layout for Longwalls 301 to 317 referred to as the Preferred Project Layout. Longwalls 311 to 316 based on the *Preferred Project Layout* comprised a 163 m panel width (void) with 45 metres (m) pillars (solid) beyond 500 m from the Woronora Reservoir, and a 138 m panel width (void) with 70 m pillars (solid) within 500 m of the Woronora Reservoir.

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

Mine Subsidence Engineering Consultants (MSEC) has prepared this report to support the Longwalls 311 to 316 Extraction Plan.

The predicted subsidence effects and impact assessments for the natural and built features resulting from extraction of Longwalls 311 to 316 (including the effects of the previous LW301 to LW310), based on the Extraction Plan Layout, have been compared with predicted effects and impact assessments for the Preferred Project Layout for these longwalls at Metropolitan Coal Mine.

The main changes made to the longwalls for the Extraction Plan Layout compared with the Preferred Project Layout include an approximate 6°anti-clockwise rotation, a reduction in the length of Longwalls 311 and 312, and the location of the pillar width increase has been modified based on a 35° angle of draw from the Woronora Reservoir.

An update to the subsidence prediction model was carried out to improve reliability based on observed subsidence movements above the previously extracted longwalls. The calibration for the Incremental Profile Method model results in an increase in vertical subsidence. The predicted tilt based on the Extraction Plan Layout is greater than the Preferred Project Layout near the finishing ends of Longwalls 311 to 316 but is similar to the predicted tilt based on the Preferred Project Layout elsewhere. The magnitudes of predicted curvature do not change significantly.

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

The management and monitoring plans that have been developed for natural and built features have been updated for Longwalls 311 to 316.

Monitoring and management strategies have been revised for the M1 Princes Motorway and bridges as part of the Extraction Plan process for Longwalls 311 to 316, in consideration of the results of additional assessments and consultation with Transport for NSW (TfNSW).

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

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MSEC1340-05	Depth of Cover Contours	A
MSEC1340-06	Geological Structures Identified at Seam Level	A
MSEC1340-07	Natural Features	A
MSEC1340-08	Surface Infrastructure	A
MSEC1340-09	Built Features – Location Plan	A
MSEC1340-10	Predicted Additional Subsidence Contours due to LW311 to LW316	A
MSEC1340-11	Predicted Total Subsidence Contours after Longwall 316	A

1.1. Background

Metropolitan Coal Pty Ltd (Metropolitan Coal) is a wholly owned subsidiary of Peabody Energy Pty Limited (Peabody) and operates Metropolitan Colliery (Metropolitan Coal Mine), which is located in the Southern Coalfield of New South Wales (NSW). Metropolitan Coal has extracted Longwalls (LW) 1 to 27, 301 to 308, at the Metropolitan Coal Mine, and it is currently mining Longwall 309.

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

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

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

MSEC has prepared this report to support the Longwalls 311 to 316 Extraction Plan.

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

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

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of Longwalls 311 to 316 (including the effects of the previous LW301 to LW310) based on the Extraction Plan Layout. Comparisons of these predictions with the maxima based on the Preferred Project Layout are also provided in this chapter.

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

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

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

1.2. Mining Geometry

The layout of Longwalls 311 to 316 is shown in Drawing No. MSEC1340-01 in Appendix E. A summary of the proposed longwall dimensions is provided in Table 1.1.

Table 1.1 Geometry of the Proposed Longwalls 311 to 316 based on the Extraction Plan Layout

Longwall	Void Length Including Installation Heading		Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
	Total (m)	Over Varying Width (m)		
LW311	2,217	1,569 648	163 138	45 70
LW312	2,427	1,569 858	163 138	45 70
LW313	2,997	1,829 1,168	163 138	45 70
LW314	2,997	1,829 1,168	163 138	45 70
LW315	2,997	2,738 258	163 138	45 70
LW316	2,997	2,738 258	163 138	45 70

The overall lengths of the longwalls have been shortened compared with the Preferred Project Layout. The location of the pillar width increase has been adjusted based on a 35° angle of draw from the location of the Woronora Reservoir.

1.3. Surface Topography

The surface level contours in the vicinity of the proposed Longwalls 311 to 316 are shown in Drawing No. MSEC1340-02, which were generated from an airborne laser scan of the area.

Surface levels above Longwalls 311 to 316 vary from approximately 305 metres Australian Height Datum (m AHD) above Longwall 316 to less than 165 m AHD in the base of the Woronora Reservoir. The natural surface slopes down towards the Woronora Reservoir.

1.4. Seam Information

The seam floor contours, seam thickness contours and depth of cover contours for the Bulli Seam are shown in Drawings Nos. MSEC1340-03, MSEC1340-04 and MSEC1340-05, respectively.

The depth of cover to the Bulli Seam within the Study Area varies between a minimum of 405 m, in the south east of the Study Area, to a maximum of 550 m, above the southern end of Longwalls 312 to 316.

The seam floor within the Study Area generally dips from the south west to the north east. The seam thickness within the Longwalls 311 to 316 footprint varies between approximately 2.5 m at the southern end and 2.65 m at the northern end. The proposed longwalls will extract a minimum height of 2.8 m.

The variations in the surface and seam levels across the mining area are illustrated along Cross-section 1 in Fig. 1.2. The location of this section is shown in Drawings No. MSEC1340-05.

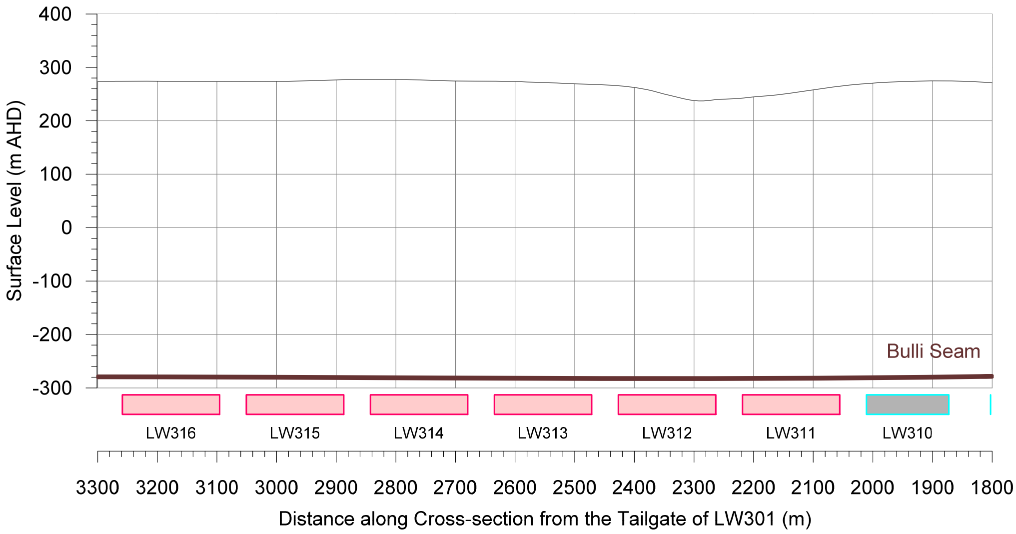

Fig. 1.2 Surface and Seam Levels along Cross-section 1

1.5. Geological Details

The overburden geology mainly comprises sedimentary sandstones, shales and claystones of the Permian and Triassic Periods, which have in some places been intruded by igneous sills. The main geological features mapped at seam level in the area of the longwalls are shown in Drawing No. MSEC1340-06.

Minor discontinuous faulting is located within the Study Area of Longwalls 311 to 316. Mapped structures in the Study Area generally have negligible vertical displacement and are mainly strike, slip features. Two structures in the northern portion of the Study Area, (Fault 0044 and Fault 0046) are known to have vertical displacement of 3 to 5m, with this displacement being laterally discontinuous and reverting to strike slip features over a few hundred metres.

While no significant faulting has been identified within the footprints of Longwalls 311 to 316, the commencing end of Longwall 313 is approximately 1400 m south west from the regional Metropolitan Fault and Waterfall anticline. The Metropolitan Fault has a north west to south east strike and dips to the north east.

A typical stratigraphic section for the Study Area is shown in Fig. 1.3. The sandstone and shale units vary in thickness from a few metres to over 160 m. The major sandstone units are interbedded with other rocks and, though shales and claystones are quite extensive in places, the sandstone predominates.

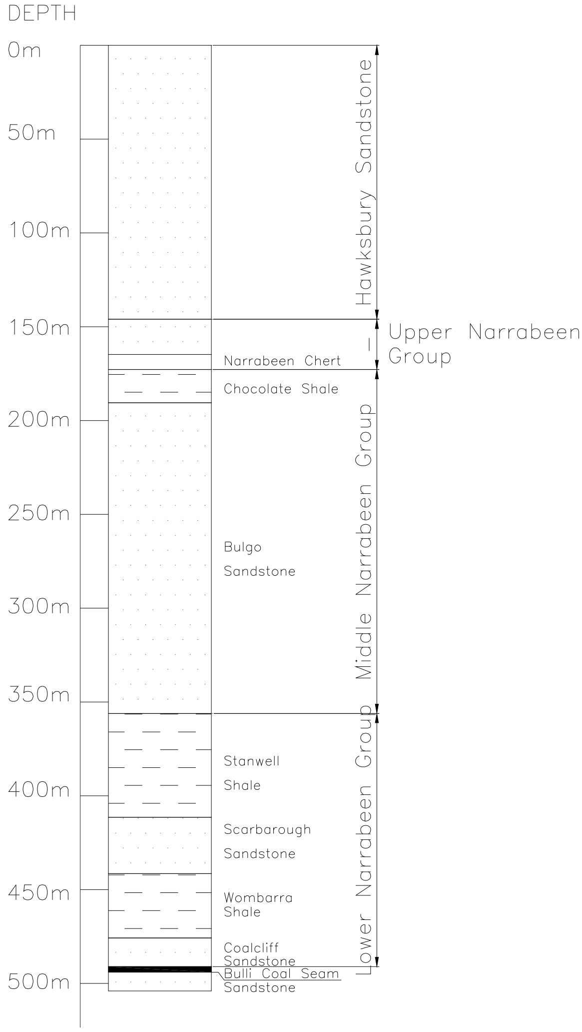

Fig. 1.3 Stratigraphic Section

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

- Hawkesbury Sandstone; and
- the Upper, Middle and Lower Narrabeen Group.

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

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

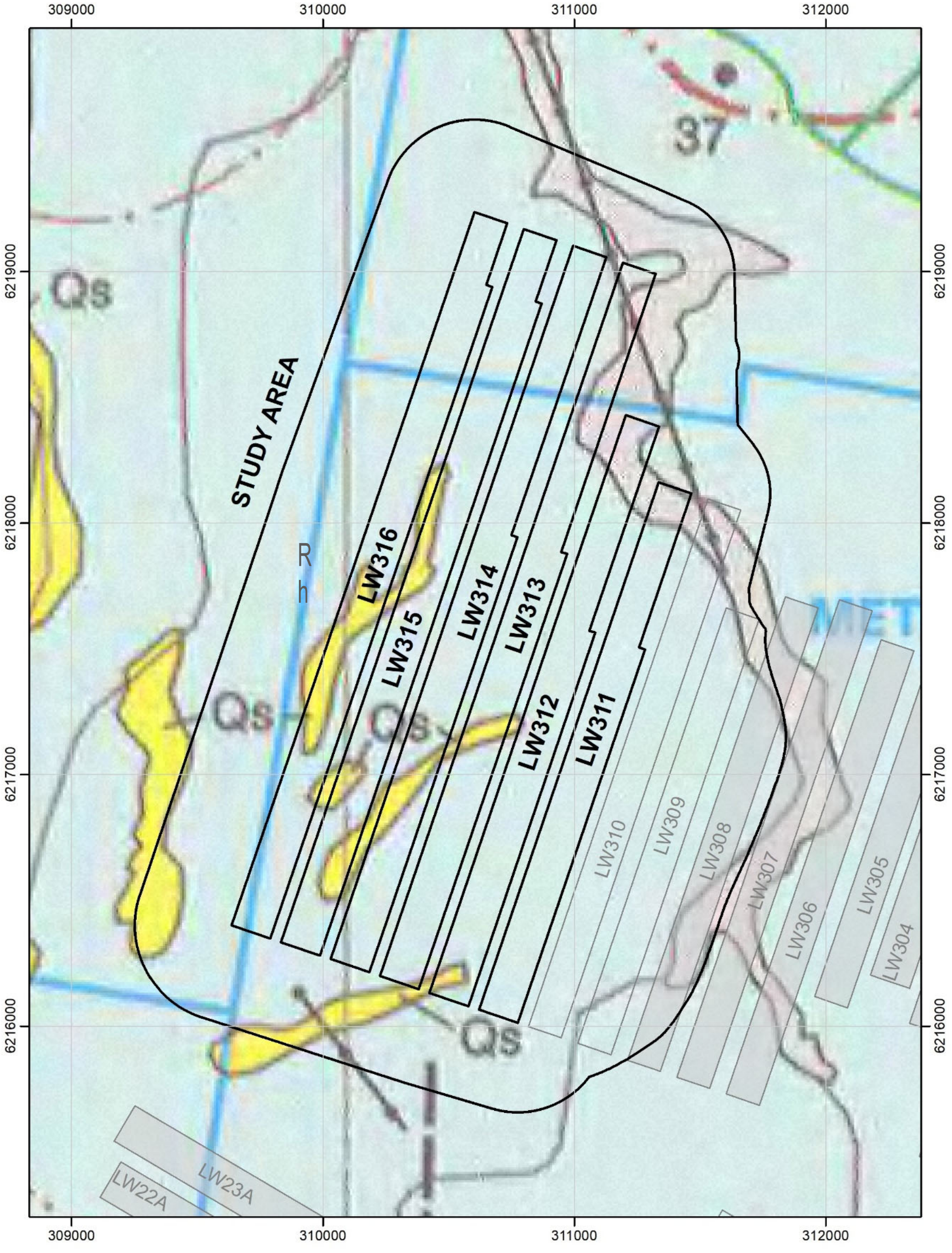

Fig. 1.4 Surface Lithology within the Study Area (DRE Geological Series Sheet 9029-9129)

It can be seen from the above Fig. 1.4 that the surface lithology in the vicinity of the proposed Longwalls 311 to 316 comprises Hawkesbury Sandstone Group (Rh) Quaternary deposits (Qs).

2.1. Definition of the Study Area

The Study Area is defined as the surface area that is likely to be affected by the proposed mining of Longwalls 311 to 316 at the Metropolitan Coal Mine. The surface features included in the Study Area are those features within areas bounded by the following limits:

- A 35° angle of draw line from the proposed extent of Longwalls 311 to 316; and
- The predicted limit of vertical subsidence, taken as the predicted additional 20 millimetre (mm) subsidence contour resulting from the extraction of the proposed Longwalls 311 to 316.

The depth of cover contours are shown in Drawing No. MSEC1340-05. It can be seen from this drawing that the depth of cover directly above the proposed Longwalls 311 to 316 varies between a minimum of 440 m and a maximum of 550 m. The 35° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 308 m and 385 m from Longwalls 311 to 316. The predicted limit of vertical subsidence, taken as the predicted additional 20 mm subsidence contour, has been determined using the calibrated Incremental Profile Method, which is described in Chapter 3.

The line defining the Study Area, based on the further extent of the 35° angle of draw and the predicted additional 20 mm subsidence contour is shown in Drawing No. MSEC1340-01.

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

- Water Infrastructure; and
- Survey control marks.

The natural features within 600 m of the proposed Longwalls 311 to 316 are also considered in this report. Other natural features located outside the 600 m boundary have also been considered where they are predicted to experience far-field or valley related movements and they could be sensitive to these effects.

2.2. Natural and Built Features within the Study Area

Many natural and built features within the Study Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), numbered APPIN 9029-1S. The proposed Longwalls 311 to 316 have been overlaid on an extract of this CMA map in Fig. 2.1.

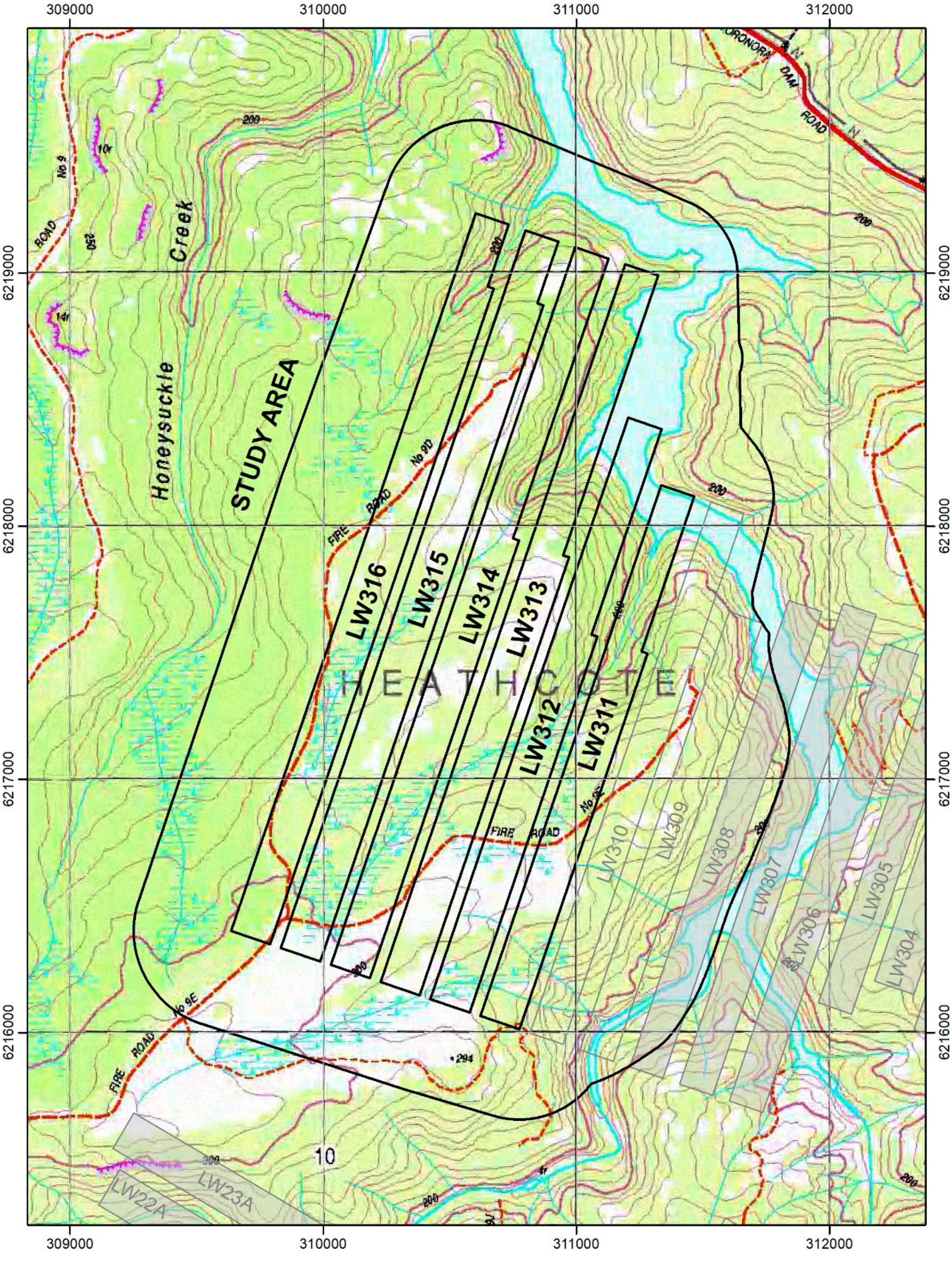

Fig. 2.1 The Proposed Longwalls 311 to 316 Overlaid on CMA Map No. Appin 9029-1S

A summary of the natural and built features within the Study Area is provided in Table 2.1. The locations of these features are shown in Drawings Nos. MSEC1340-07 to MSEC1340-09, in Appendix E.

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

Table 2.1 Natural and Built Features

Item	Within Study Area	Section Number Reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	✓	5.2
Rivers or Creeks	✓	5.3 to 5.6
Aquifers or Known Groundwater Resources	✓	5.7
Springs	×	
Sea or Lake	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Pagodas	✓	5.9 & 5.10
Steep Slopes	✓	5.11
Escarpments	×	
Land Prone to Flooding or Inundation	×	
Swamps, Wetlands or Water Related Ecosystems	✓	5.13
Threatened or Protected Species	✓	5.14
National Parks	×	
State Forests	×	
State Conservation Areas	×	
Natural Vegetation	✓	5.15
Areas of Significant Geological Interest	×	
Any Other Natural Features Considered Significant	×	
PUBLIC UTILITIES		
Railways	×	
Roads (All Types)	✓	6.1 to 6.2
Bridges	×	6.3
Tunnels	×	
Culverts	×	
Water, Gas or Sewerage Infrastructure	✓	6.4
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	×	
Telecommunication Lines or Associated Plants	×	
Water Tanks, Water or Sewage Treatment Works	✓	6.4
Dams, Reservoirs or Associated Works	✓	6.5
Air Strips	×	
Any Other Public Utilities	×	
PUBLIC AMENITIES		
Hospitals	×	
Places of Worship	×	
Schools	×	
Shopping Centres	×	
Community Centres	×	
Office Buildings	×	
Swimming Pools	×	
Bowling Greens	×	
Ovals or Cricket Grounds	×	
Race Courses	×	
Golf Courses	×	
Tennis Courts	×	
Any Other Public Amenities	×	
FARM LAND AND FACILITIES		
Agricultural Utilisation or Agricultural Suitability of Farm Land	×	8.1
Farm Buildings or Sheds	×	
Tanks	×	
Gas or Fuel Storages	×	
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	✓	8.2
Farm Dams	×	
Wells or Bores	×	
Any Other Farm Features	×	
INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS		
Factories	×	
Workshops	×	
Business or Commercial Establishments or Improvements	×	
Gas or Fuel Storages or Associated Plants	×	
Waste Storages or Associated Plants	×	
Buildings, Equipment or Operations that are Sensitive to Surface Movements	×	
Surface Mining (Open Cut) Voids or Rehabilitated Areas	×	
Mine Infrastructure Including Tailings Dams or Emplacement Areas	×	
Any Other Industrial, Commercial or Business Features	×	
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓	10.1 & 10.2
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	×	10.4
RESIDENTIAL ESTABLISHMENTS		
Houses	×	
Flats or Units	×	
Caravan Parks	×	
Retirement or Aged Care Villages	×	
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts	×	
Any Other Residential Features	×	
ANY OTHER ITEM OF SIGNIFICANCE	×	
ANY KNOWN FUTURE DEVELOPMENTS	×	

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

3.1. Introduction

This chapter provides overviews of mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the proposed Longwalls 311 to 316. Further details on longwall mining, the development of subsidence and the methods used to predict mine subsidence movements are provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

3.2. Overview of Conventional Subsidence Parameters

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

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements in some cases, where the subsidence is small beyond the longwall goaf edges, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *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 per cent (%), 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/kilometre* (km^{-1}), but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*.

- **Strain** is the relative differential horizontal movements of the ground. **Normal strain** is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of *millimetres per metre (mm/m)*. **Tensile Strains** occur where the distance between two points increases and **Compressive Strains** occur when the distance between two points decreases. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

  Whilst mining induced normal strains are measured along monitoring lines, ground shearing can also occur both vertically and horizontally across the directions of monitoring lines. Most of the published mine subsidence literature discusses the differential ground movements that are measured along subsidence monitoring lines, however, differential ground movements can also be measured across monitoring lines using 3D survey monitoring techniques.

- **Horizontal shear deformation** across monitoring lines can be described by various parameters including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. It is not possible, however, to determine the horizontal shear strain across a monitoring line using 2D or 3D monitoring techniques.

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

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

3.3. Far-field Movements

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

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

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

Far-field horizontal movements and the method used to predict such movements are described further in Section 0.

3.4. Overview of Non-Conventional Subsidence Movements

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

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

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

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

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

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

It is possible that surface features located above the longwalls could experience localised and elevated strains due to unknown geological structures (i.e. anomalies). Non-conventional or anomalous movements have not been identified during the extraction of Longwalls 301 to 308. It is believed that most non-conventional ground movements are the result of the reaction of near surface strata to increased horizontal compressive stresses due to mining operations. Some of the geological conditions that are believed to influence these irregular subsidence movements are the blocky nature of near surface sedimentary strata layers and the possible presence of unknown faults, dykes or other geological structures, cross bedded strata, thin and brittle near surface strata layers and pre-existing natural joints. The presence of these geological features near the surface can result in a bump in an otherwise smooth subsidence profile and these bumps are usually accompanied by locally increased tilts and strains.

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

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

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

3.4.2. Non-conventional Subsidence Movements due to Steep Topography

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

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

3.4.3. Valley Related Movements

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

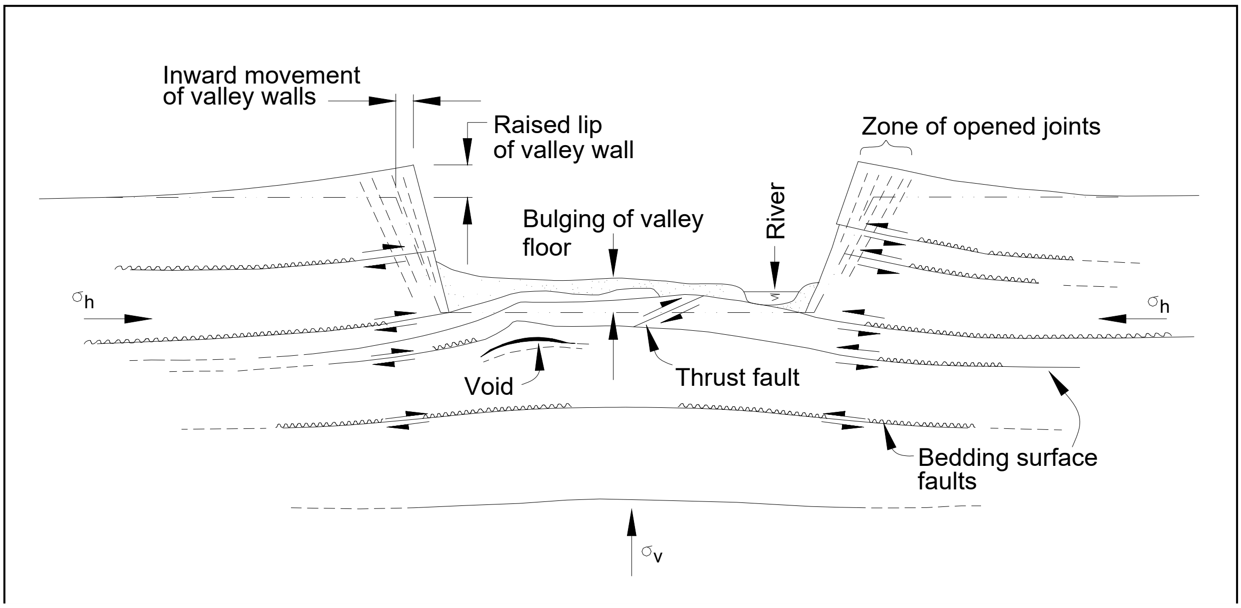

Fig. 3.1 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

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

- **Upsidence** is the reduced subsidence, or the relative uplift within a valley which results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.
- **Closure** is the reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *mm*, is the greatest reduction in distance between any two points on the opposing valley sides.
- **Compressive Strains** occur within the bases of valleys as a result of valley closure and upsidence movements. **Tensile Strains** also occur in the sides and near the tops of the valleys as a result of valley closure movements. The magnitudes of these strains, which are typically expressed in the units of *mm/m*, are calculated as the changes in horizontal distance over a standard bay length, divided by the original bay length.

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

3.5. The Incremental Profile Method

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

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

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

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

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

3.6. Calibration of the Incremental Profile Method

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

With continued longwall extraction in a northerly direction the longwall panel void widths have remained constant from Longwall 11 with a void width of 163m. Recent longwall void widths have reduced to 138 m. Pillar widths have generally increase from 35 m for Longwalls 1 to 18, to 45 m for Longwalls 301 to 305.

Pillar widths for Longwalls 20 to 27 varied from approximately 40 m to 50 m. The average depth of cover above the extracted longwalls has also generally increased to the north from approximately under 450 m above Longwalls 1 to 18, to over 500 above the 300 series longwalls. For each extracted longwall, the magnitude of maximum observed subsidence has generally been less than predicted, however the cumulative maximum subsidence over several panels had increased to be greater than predicted.

In order to assess the greater than predicted subsidence, a review was carried out on the predicted and observed data for the incremental subsidence profiles along the 300XL line. For each extracted longwall the incremental predicted profile was subtracted from the observed profile. The resulting graphs showed areas along the monitoring line where observed incremental subsidence was greater than predicted, as positive values, and areas where observed incremental subsidence was less than predicted, as negative values. The results for Longwall 301 to 307 are shown below in Fig. 3.2 to Fig. 3.5.

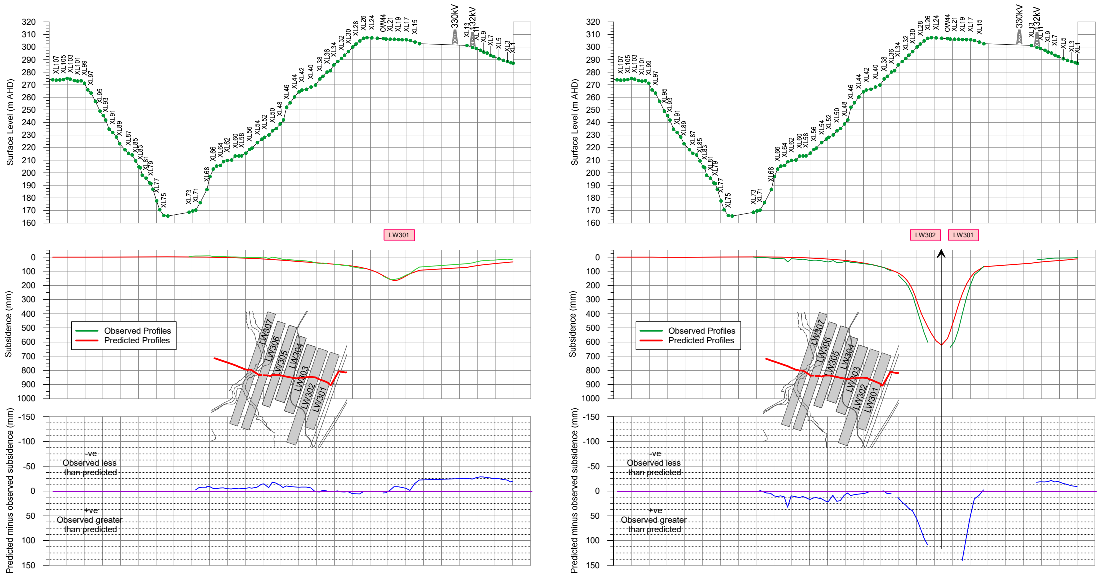

Fig. 3.2 300XL Line incremental subsidence – Longwall 301 and LW302

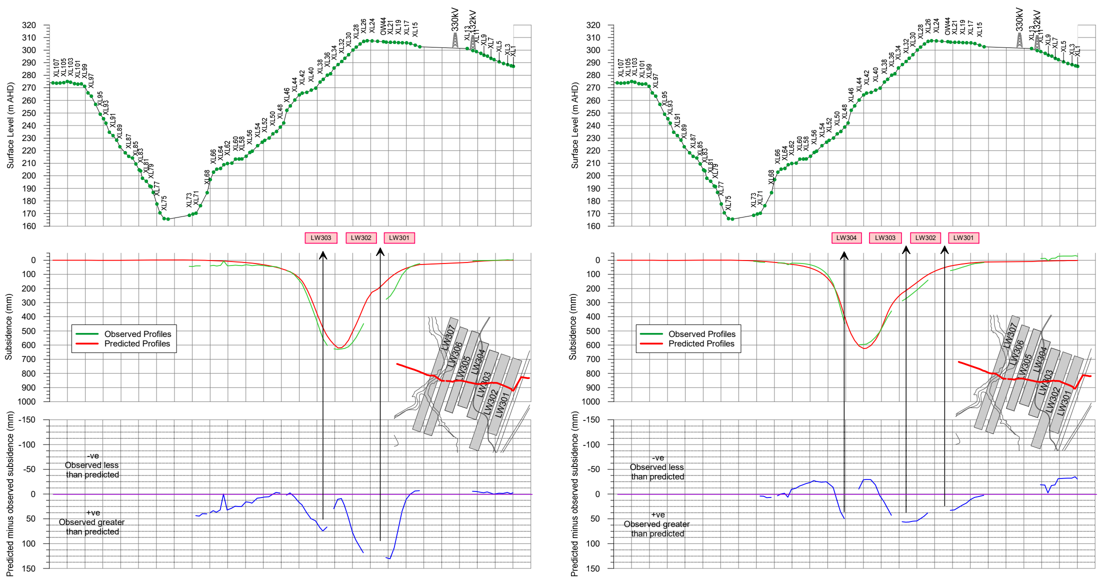

Fig. 3.3 300XL Line incremental subsidence – Longwall 303 and LW304

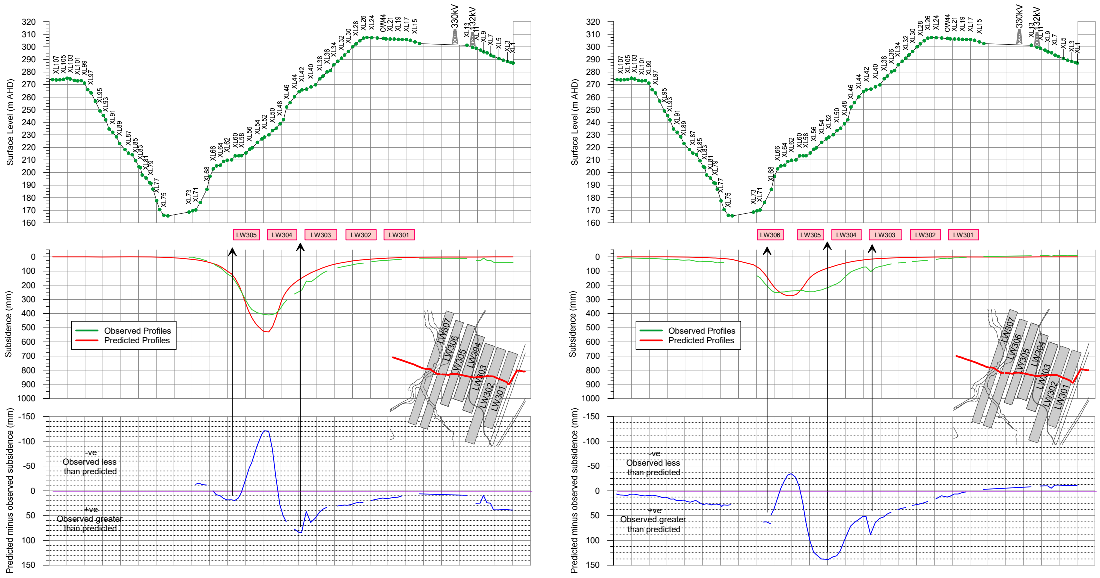

Fig. 3.4 300XL Line incremental subsidence – Longwall 305 and LW306

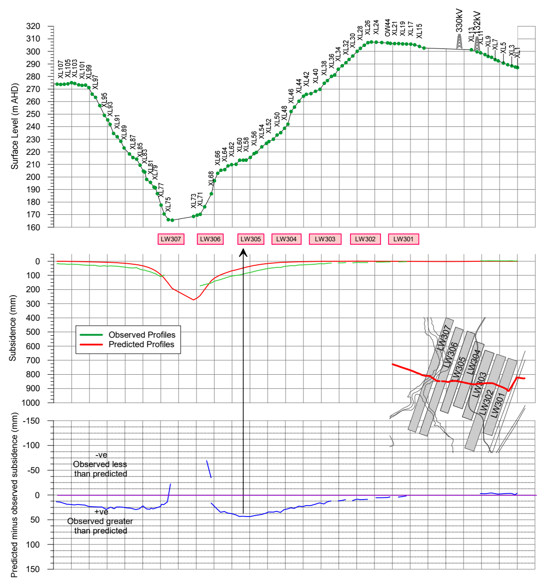

Fig. 3.5 300XL Line incremental subsidence – Longwall 307

The different profiles in Fig. 3.2 to Fig. 3.5 show that typically the maximum incremental observed subsidence is close to or less than predicted with the location of maximum incremental subsidence at the tailgate pillar of the extracted longwall.

Where three or more longwalls have been extracted, observed subsidence is greater than predicted above the tailgate pillar for the previously extracted longwall, with a difference of up to almost 150 mm. In several of the profiles, observed subsidence is slightly greater than predicted directly above the centreline of the extracted longwall, with a difference of up to approximately 50 mm. Greater than predicted subsidence also appears to have occurred with the extraction of Longwall 302, however the survey pegs at the location of maximum subsidence were damaged therefore the profile at this location is not clearly defined.

The assessment of the 300XL line indicated that additional minor subsidence is occurring at the pillars between previously extracted longwalls. The additional subsidence indicates that the coal pillars between previously extracted longwalls are experiencing more pillar squashing than predicted. The additional subsidence above the pillars has resulted in observed maximum total subsidence exceeding predicted maximum subsidence by 17% along this monitoring line. The profiles of predicted vertical subsidence are generally consistent with observed vertical subsidence. With the exception of isolated locations, predicted tilt and curvature are generally consistent with predictions.

An adjustment was made to the Incremental Profile Method prediction model based on the outcomes of the abovementioned 300XL Line assessment. A comparison of the model output is provided below in Fig. 3.6, Fig. 3.7, and Fig. 3.8 for the 300XL Line, Princes Highway Line and Optic Water Line respectively. The comparison is made with observed monitoring data to the end of Longwall 307. In each figure the observed monitoring data is show by a blue line, with the existing subsidence prediction model output in red and the calibrated subsidence prediction model output in green.

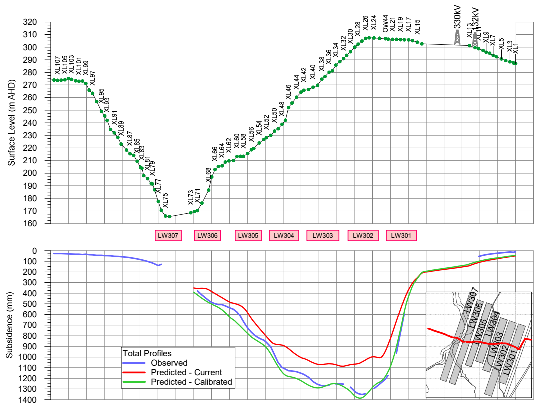

Fig. 3.6 300XL Line – Comparison of observed and predicted subsidence profiles

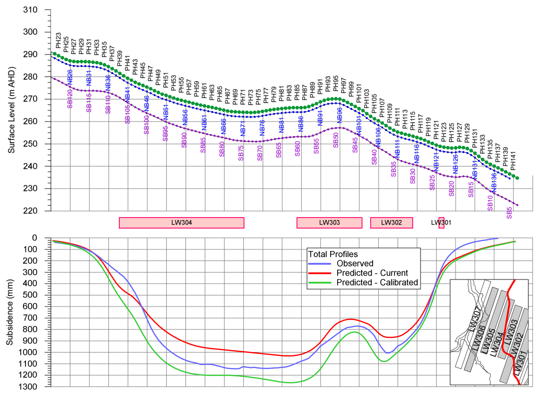

Fig. 3.7 Princes Highway Line – Comparison of observed and predicted subsidence profiles

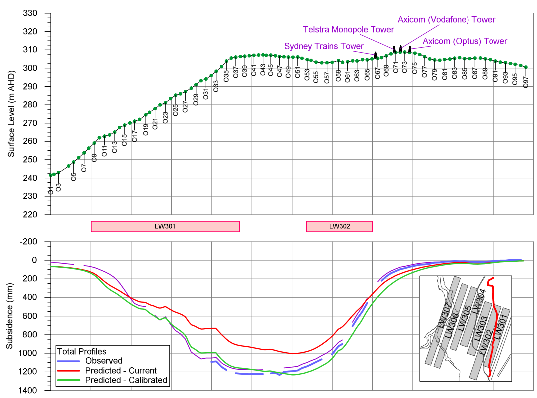

Fig. 3.8 Optic Water Line – Comparison of observed and predicted subsidence profiles

The calibration for the IPM model results in an increase in vertical subsidence, however the magnitudes of predicted tilt and curvature do not change significantly. A comparison of the profiles of predicted total subsidence, tilt and curvature after the extraction of Longwall 316 are shown in Fig. 3.9. The predicted profiles are along Prediction Line 1 which is discussed later in this report. The location of Prediction Line 1 is shown on Drawings Nos. MSEC1340-10 and MSEC1340-11.

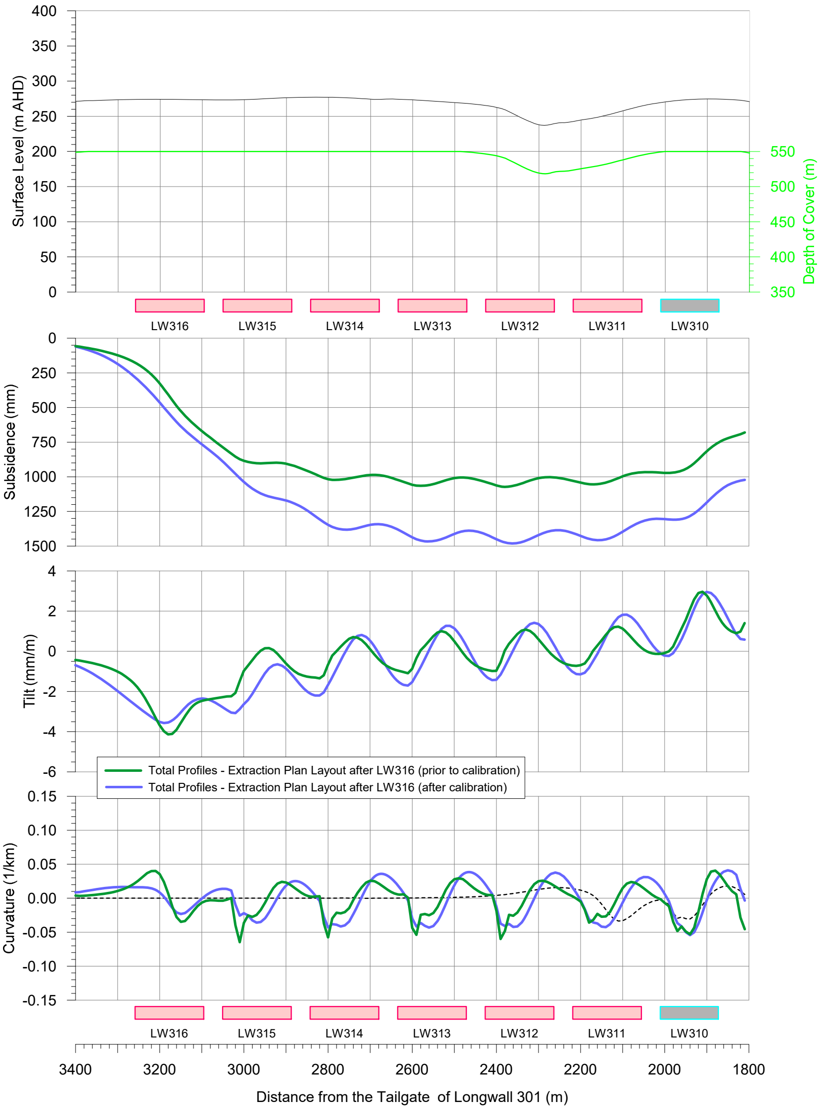

Fig. 3.9 Prediction Line 1 - Comparison of predicted subsidence, tilt and curvature profiles

3.7. Reliability of the Predicted Conventional Subsidence Parameters

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

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

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

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

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

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

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

It is also likely that some localised irregularities will occur in the subsidence profiles due to near surface geological features. The irregular movements are accompanied by elevated tilts, curvatures and strains, which often exceed the conventional predictions. In most cases, it is not possible to predict the locations or magnitudes of these irregular movements. For this reason, the strain predictions provided in this report are based on a statistical analysis of measured strains in the Southern Coalfield, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4. Further discussions on irregular movements are provided in Section 0.

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

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

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

The comparison between the maximum observed total subsidence and the maximum predicted total subsidence for the monitoring lines is illustrated in Fig. 3.10. The results shown in this figure are the maximum observed and predicted subsidence for each monitoring line at the completion of each longwall. The results for Metropolitan Coal Mine have been presented as red data points based on predicted subsidence prior to calibration.

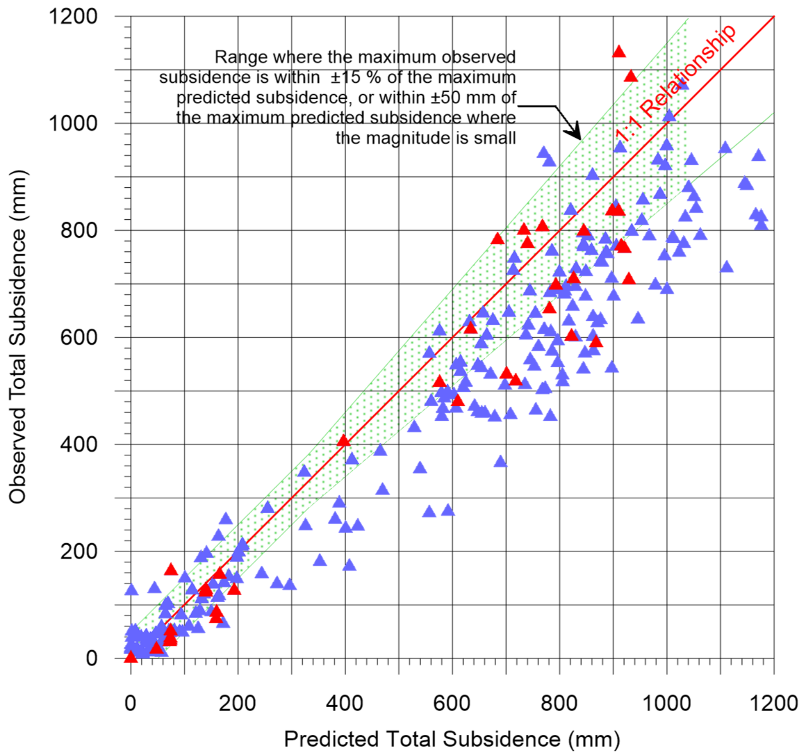

Fig. 3.10 Comparisons between Maximum Observed Incremental Subsidence and Maximum Predicted Incremental Subsidence for the Previously Extracted Longwalls in the Southern Coalfield

It can be seen from the above figure, that in most cases the observed subsidence was typically less than that predicted. The observed subsidence exceeded that predicted in some cases, but was typically less than + 15 % or + 50 mm of the prediction. In the locations where the magnitude of subsidence was small (i.e. beyond the limits of the active longwall), the observed subsidence was typically within ± 100 mm of the prediction. Observed subsidence exceeded + 15 % of the prediction above Longwall 301 at Metropolitan Coal Mine. Following calibration, these predicted values are similar to or less than observed.

The distribution of the ratio of the maximum observed to maximum predicted incremental subsidence for the monitoring lines is illustrated in Fig. 3.11 (left). A gamma distribution has been fitted to the results and is also shown in this figure.

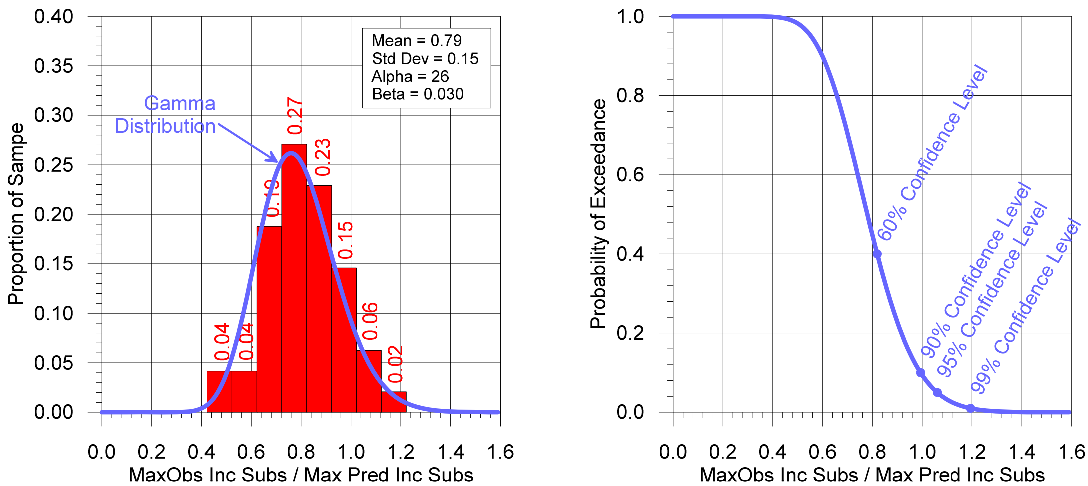

Fig. 3.11 Distribution of the Ratio of the Maximum Observed to Maximum Predicted Incremental Subsidence for Previously Extracted Longwalls in the Southern Coalfield

The probabilities of exceedance have been determined, based on the gamma distribution, which is shown in Fig. 3.11 (right). It can be seen from this figure that, based on the monitoring data from the Southern Coalfield, there is an approximate 90 % confidence level that the maximum observed incremental subsidence will be less than the maximum predicted incremental subsidence using the standard model.

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of Longwalls 311 to 316. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapters 5 to 11.

It should be noted that the predicted conventional subsidence parameters were obtained using the Incremental Profile Model for the Southern Coalfield, which was calibrated to local conditions based on the available monitoring data from Metropolitan Coal Mine.

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report describe and show the conventional movements and do not include the valley related upsidence and closure movements. Such effects have been addressed separately in the impact assessments for each feature provided in Chapters 5 to 11.

4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature

The maximum predicted conventional subsidence parameters resulting from the extraction of Longwalls 311 to 316 were determined using the calibrated Incremental Profile Method, which was described in Chapter 3. A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of Longwall 311 to 316 based on the Extraction Plan Layout, is provided in Table 4.1. The predicted additional subsidence contours resulting from the extraction of Longwalls 311 to 316 are shown in Drawing No. MSEC1340-10.

Table 4.1 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature Resulting from the Extraction of Longwall 311 to 316

Longwall	Maximum Predicted Incremental Conventional Subsidence (mm)	Maximum Predicted Incremental Conventional Tilt (mm/m)	Maximum Predicted Incremental Conventional Hogging Curvature (km^{-1})	Maximum Predicted Incremental Conventional Sagging Curvature (km^{-1})
Due to LW311	600	3.0	0.02	0.04
Due to LW312	600	3.0	0.03	0.05
Due to LW313	600	3.0	0.03	0.05
Due to LW314	600	3.0	0.04	0.05
Due to LW315	600	4.5	0.04	0.08
Due to LW316	600	4.0	0.04	0.06

The predicted total conventional subsidence contours after the extraction of Longwalls 311 to 316 are shown in Drawing No. MSEC1340-11. The predicted total conventional subsidence contours include predictions for all longwalls extracted prior to Longwalls 311 to 316.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature, within the Study Area, after the extraction of Longwalls 310 to 316 based on the Extraction Plan Layout, is provided in Table 4.2. The predicted tilts provided in this table are the maxima after the completion of each longwall. The predicted curvatures are the maxima at any time during or after the extraction of each of the longwalls.

Table 4.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature within the Study Area after the Extraction of Longwalls 310 to 316

Longwalls	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
After LW310	600	3.0	0.05	0.06
After LW311	875	4.0	0.05	0.06
After LW312	1200	5.5	0.05	0.06
After LW313	1350	6.0	0.06	0.06
After LW314	1450	6.5	0.06	0.06
After LW315	1500	6.5	0.06	0.08
After LW316	1500	7.0	0.06	0.09

The maximum predicted total subsidence resulting from the extraction of Longwalls 311 to 316 is 1500 mm, which represents around 54 % of the minimum extraction height of 2.8 m. The maximum predicted total conventional tilt is 7.0 mm/m (i.e. 0.7 %), which represents a change in grade of 1 in 140. The maximum predicted total conventional curvatures are 0.06 km^{-1} hogging and 0.09 km^{-1} sagging, which represent minimum radii of curvature of 17 km and 11 km, respectively.

The predicted conventional subsidence parameters vary across the Study Area as the result of, amongst other factors, variations in the depths of cover and extraction heights. To illustrate this variation, the predicted profiles of conventional subsidence, tilt and curvature have been determined along Prediction Line 1, the location of which is shown in Drawing No. MSEC1340-11.

The predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 1, resulting from the extraction of Longwalls 311 to 316, are shown in Fig. C.01 in Appendix C. The predicted incremental profiles along the prediction line, due to the extraction of Longwalls 311 to 316 for the Extraction Plan Layout, are shown as dashed black lines. The predicted total profiles along the prediction line, after the extraction of Longwalls 311 to 316 for the Extraction Plan Layout, are shown as solid blue lines. The range of predicted curvatures in any direction to the prediction lines, at any time during or after the extraction of the longwalls for the Extraction Plan Layout, are shown by the grey shading. The predicted total profiles based on the Preferred Project Layout are shown as the red lines for comparison.

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

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

The comparison of the maximum predicted subsidence parameters resulting from the extraction of Longwalls 311 to 316 with those based on the Preferred Project Layout for Longwalls 311 to 316 is provided in Table 4.3. The values are the maxima within the Study Area.

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

Layout	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Preferred Project Layout (after LW316) (Report No. MSEC403)	1200	5.0	0.06	0.08
Extraction Plan Layout (Report No. MSEC1340)	1500	7.0	0.06	0.09

In previous MSEC subsidence reports (including MSEC285 report for the Metropolitan Coal Project EA and MSEC403 for the Preferred Project Layout) predictions were provided for strain rather than curvature. The predicted conventional strains were based on the best estimate of the average relationship between curvature and strain. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains and this factor was used for the Preferred Project Layout. In order to provide a suitable comparison of predicted subsidence parameters for the Preferred Project Layout and the currently proposed Longwalls 311 to 316, the predicted curvatures have been derived back from the predicted conventional strains presented in the MSEC403 report using the strain-curvature relationship factor of 15.

It can be seen from Table 4.3, that the maximum predicted total subsidence and tilt based on the Extraction Plan Layout for Longwalls 311 to 316 are greater than the maxima predicted based on the Preferred Project Layout. The increased subsidence is the result of calibration of the model as discussed in Section 3.6. The predicted tilt based on the Extraction Plan Layout is greater than the Preferred Project Layout near the finishing ends of Longwalls 311 to 316 but is similar to the predicted tilt based on the Preferred Project Layout elsewhere. The predicted hogging and sagging curvature based on the Extraction Plan Layout for Longwalls 311 to 316 are similar to the maxima predicted based on the Preferred Project Layout for Longwalls 311 to 316.

There is a significant reduction in predicted subsidence to the north where longwalls lengths have been reduced as shown in Fig. 1.1.

4.4. Predicted Strains

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

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

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

The maximum predicted conventional strains resulting from the extraction of Longwalls 311 to 316 for the Extraction Plan Layout, based on applying a factor of 15 to the maximum predicted total curvatures, are 1.0 mm/m tensile and 1.5 mm/m compressive.

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

The range of potential strains above the proposed Longwalls 311 to 316 has been determined using monitoring data from the previously extracted longwalls in the Southern Coalfield. The monitoring data was used from the nearby Appin, Tower, West Cliff and Tahmoor Collieries, where the overburden geology and depths of cover are reasonably similar to the proposed longwalls. The panel widths at these collieries are greater than those at Metropolitan Coal Mine and, therefore, the statistical analyses should provide a reasonable, if not, conservative indication of the range of potential strains for the proposed longwalls.

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

4.4.1. Analysis of Strains Measured in Survey Bays

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

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

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

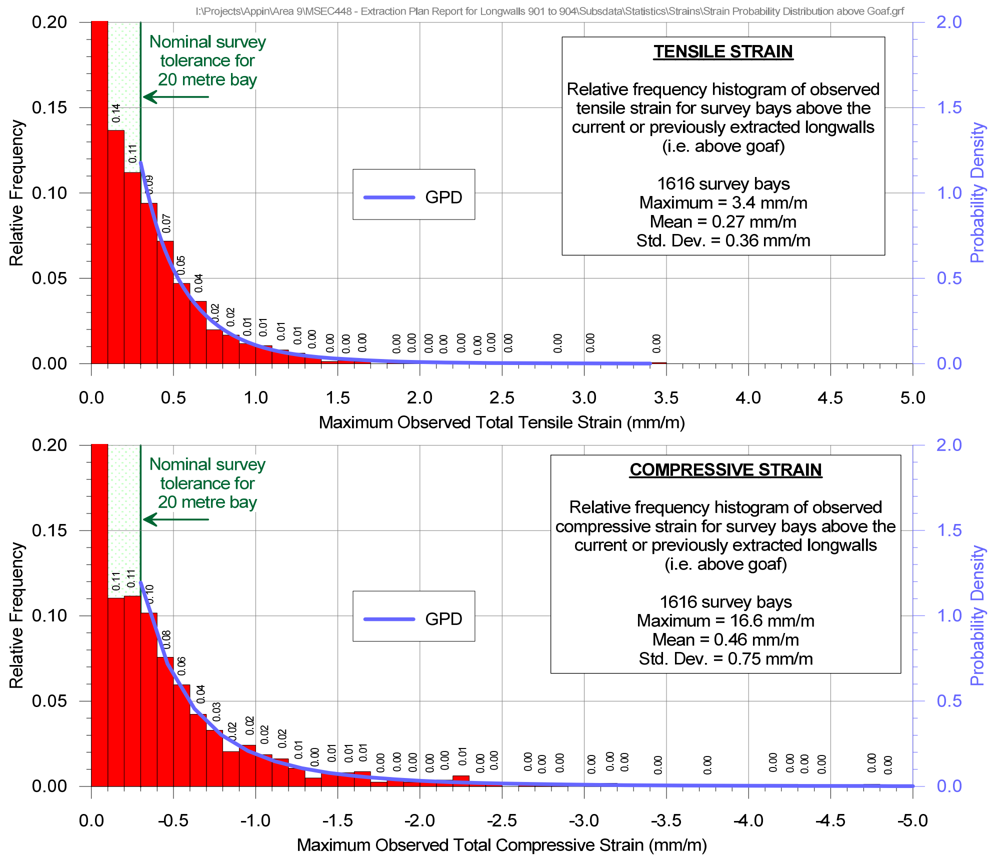

Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield for Bays Located Above Goaf

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

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

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

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

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

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

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

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

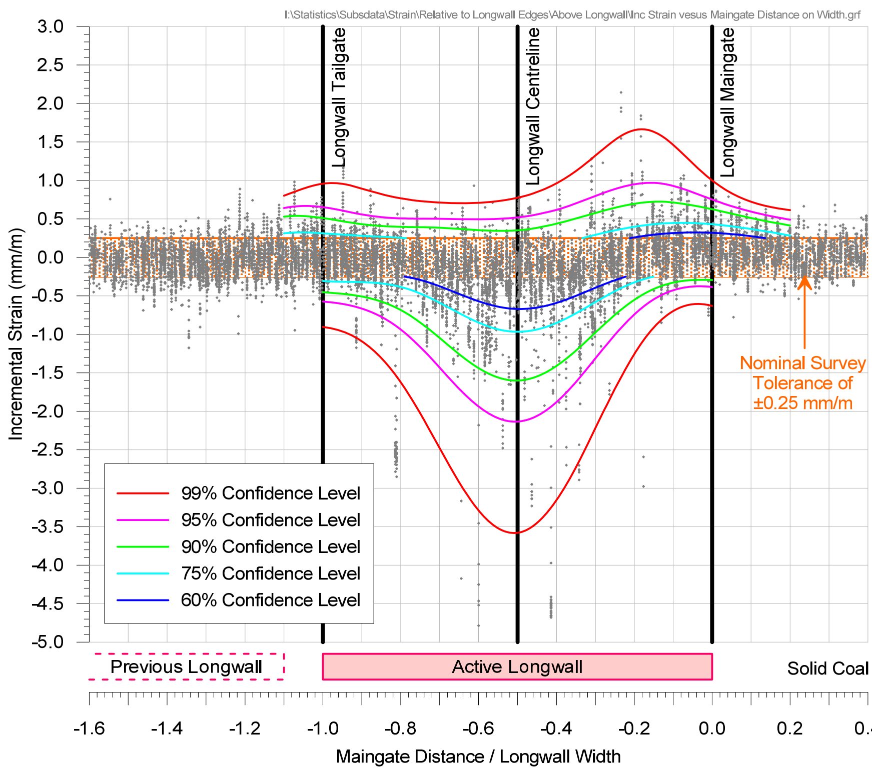

Fig. 4.2 Observed Incremental Strains versus Normalised Distance from the Longwall Maingate for Previously Extracted Longwalls in the Southern Coalfield

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

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

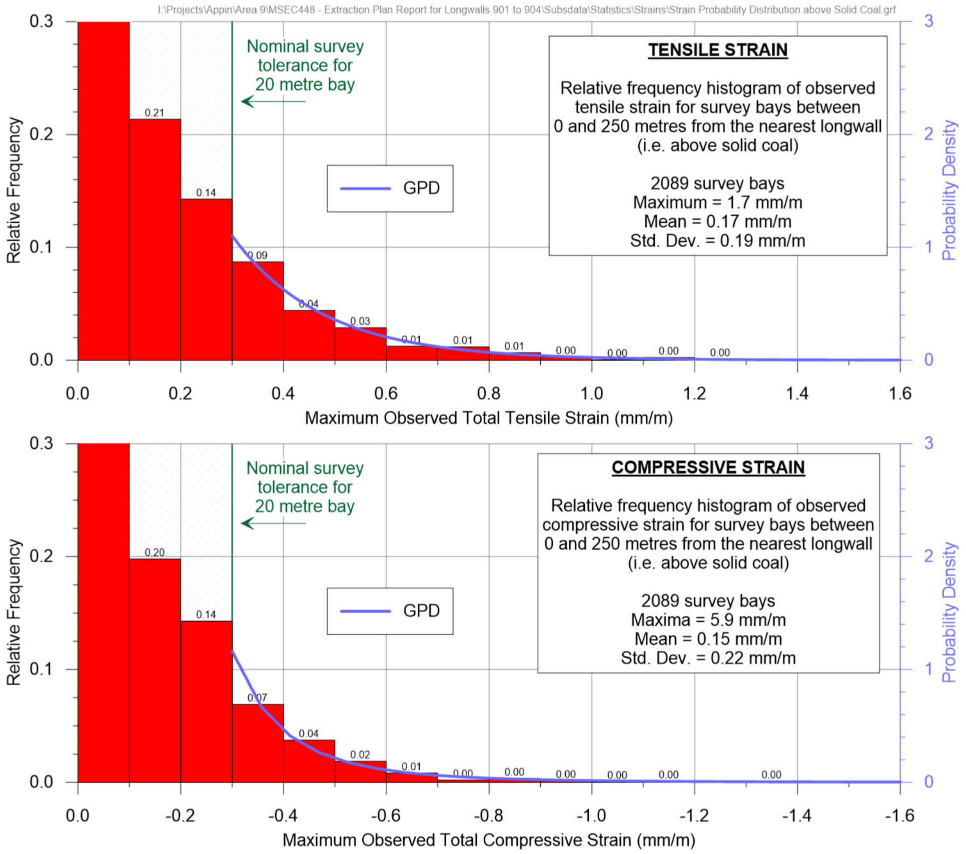

Fig. 4.3 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield for Bays Located Above Solid Coal

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

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

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

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

The 95 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining were 0.6 mm/m tensile and 0.5 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining were 0.9 mm/m tensile and 0.8 mm/m compressive.

4.4.2. Analysis of Strains Measured Along Whole Monitoring Lines

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

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

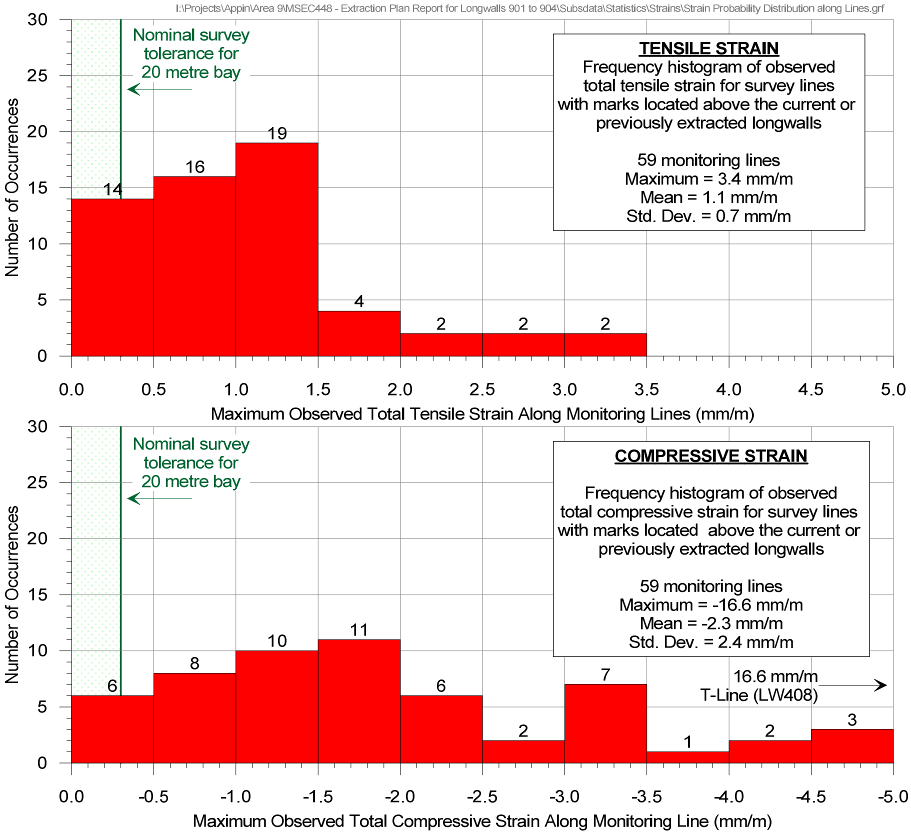

Fig. 4.4 Distributions of Measured Maximum Tensile and Compressive Strains along the Monitoring Lines during the Extraction of Previous Longwalls in the Southern Coalfield

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

4.4.3. Analysis of Strains Resulting from Valley Closure Movements

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

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

The relationship between total closure strain and total closure movement, based on monitoring data for longwalls which have previously mined directly beneath streams in the Southern Coalfield, is provided in Fig. 4.5.

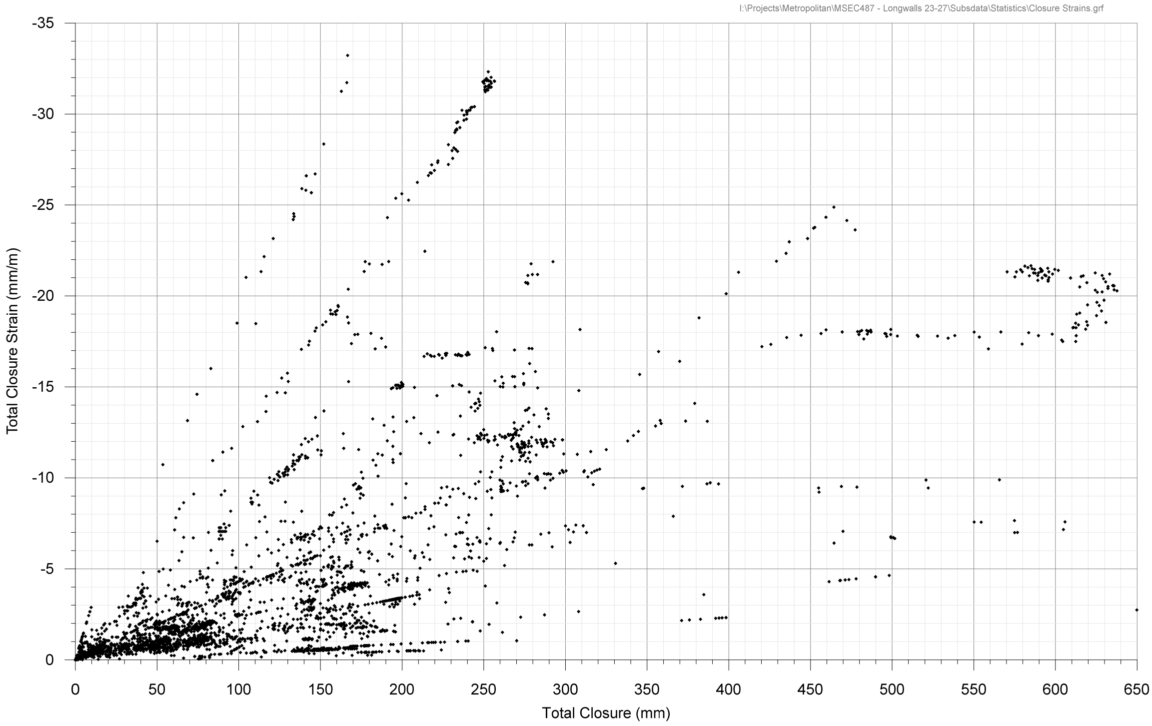

Fig. 4.5 Total Closure Strain versus Total Closure Movement Based on Monitoring Data for Streams Located Directly Above Longwalls in the Southern Coalfield

It can be seen from Fig. 4.5 that total compressive strains up to approximately 20 mm/m to 25 mm/m have been measured for total closures varying between approximately 150 mm to 650 mm. It should be noted, however, that the measured compressive strain is dependent on the length of the survey bay in which the strain was measured. Typical measurements and predictions of conventional strain are based on an approximate survey bay length of 20 m in the Southern Coalfield. Where survey lines are established across streams, for the purposes of measuring valley closure movements, they are often established with survey bay lengths shorter than 20 m in order to provide greater detail and these should not be compared to strain measurements and predictions based on 20 m bay lengths. The bay lengths for the data presented in Fig. 4.5 have been plotted below in a graph of bay length versus total closure (Fig. 4.6) and have been reproduced in Fig. 4.7 to show the distribution of bay lengths.

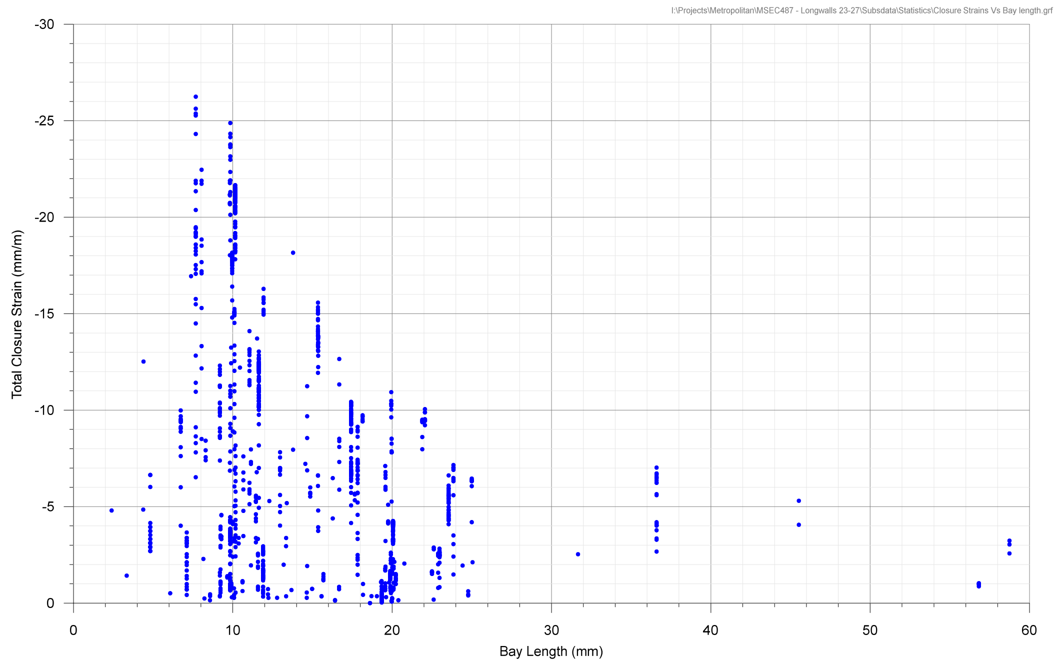

Fig. 4.6 Total Closure Strain versus Bay Length Based on Monitoring Data for Streams Located Directly Above Longwalls in the Southern Coalfield

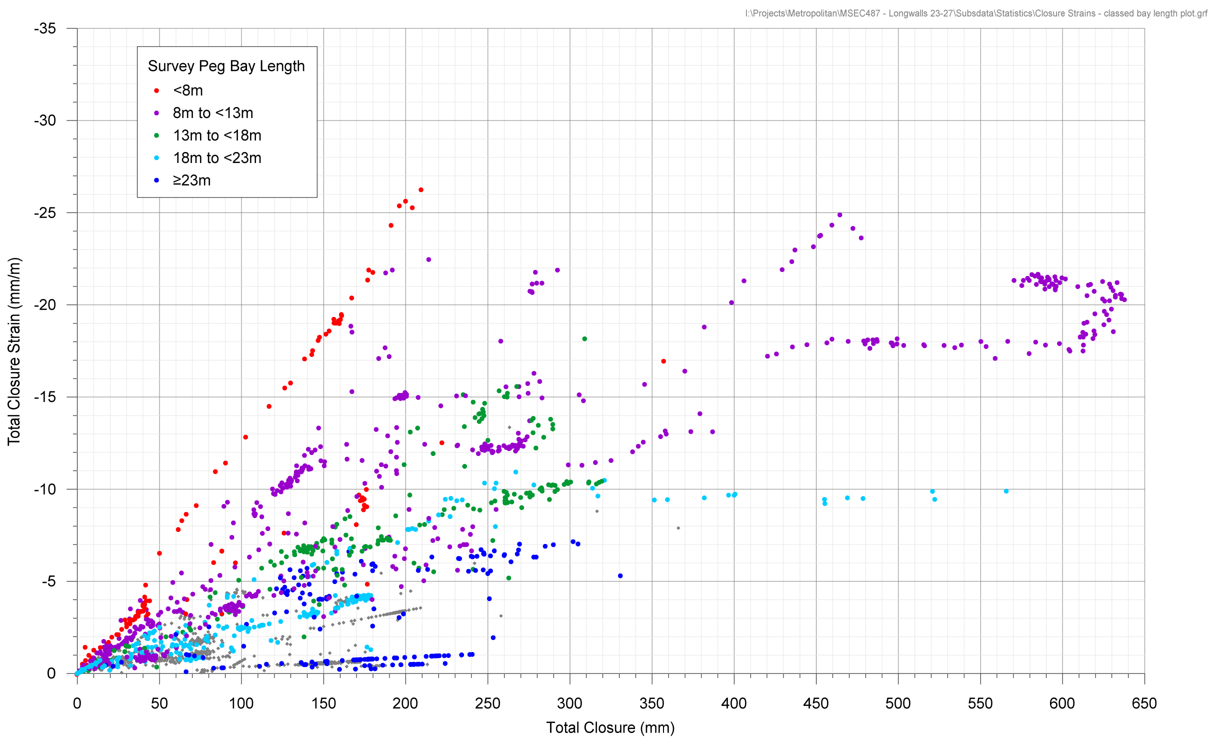

Fig. 4.7 Total Closure Strain versus Total Closure Movement Based on Monitoring Data for Streams Located Directly Above Longwalls in the Southern Coalfield

It can be seen from Fig. 4.6 and Fig. 4.7 that the majority of the data with high compressive strains has been measured over bay lengths much less than 20 m. The maximum measured compressive strain for an approximate 20 m bay length is 11 mm/m as indicated by the cyan coloured points in Fig. 4.7. High compressive strains resulting from valley closure movements often concentrate towards the base of a valley. On this basis, predicted strains have been estimated for a typical 20 m bay length by applying the predicted valley closure over a 20 m length.

4.4.4. Analysis of Shear Strains

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

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

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

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

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

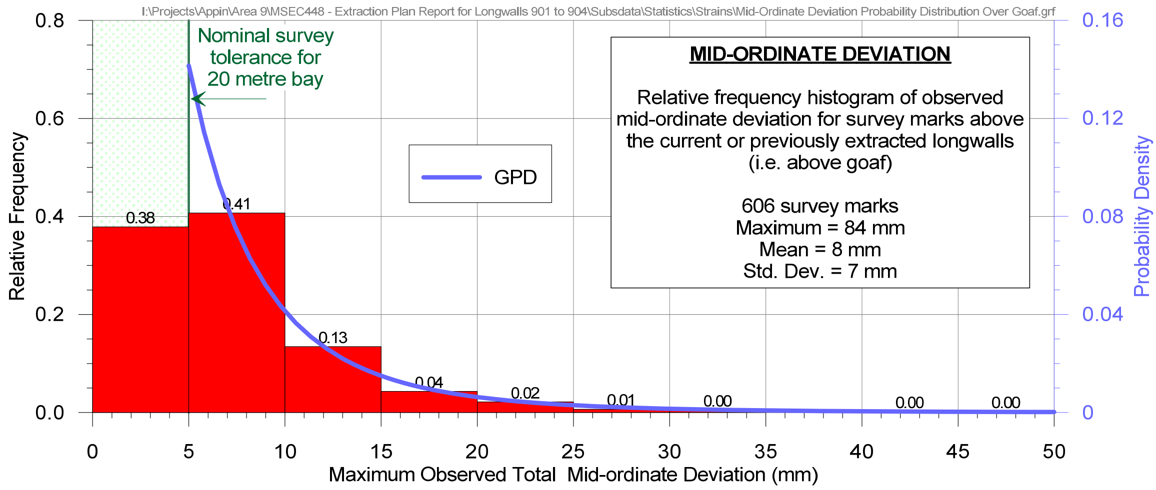

Fig. 4.8 Distribution of Measured Maximum Mid-ordinate Deviation during the Extraction of Previous Longwalls in the Southern Coalfield for Marks Located Above Goaf

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

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

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

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

4.5. Predicted Conventional Horizontal Movements

The predicted conventional horizontal movements over the proposed Longwalls 311 to 316 are calculated by applying a factor to the predicted conventional tilt values. In the Southern Coalfield a factor of 15 is generally adopted, being the same factor as that used to determine conventional strains from curvatures, and this has been found to give a reasonable correlation with measured data. This factor will in fact vary and will be higher at low tilt values and lower at high tilt values. The application of this factor will therefore lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the movements where the tilts are low.

The maximum predicted total conventional tilt within the Study Area, at any time during or after the extraction of the proposed Longwalls 311 to 316, is 7 mm/m. The maximum predicted conventional horizontal movement is, therefore, approximately 105 mm.

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

4.6. Predicted Far-field Horizontal Movements

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

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

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The data is based on survey marks 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). The confidence levels, based on fitted GPDs, have also been shown in this figure to illustrate the spread of the data. Monitoring data from Metropolitan Coal Mine during the extraction of 301 to 308 is also included.

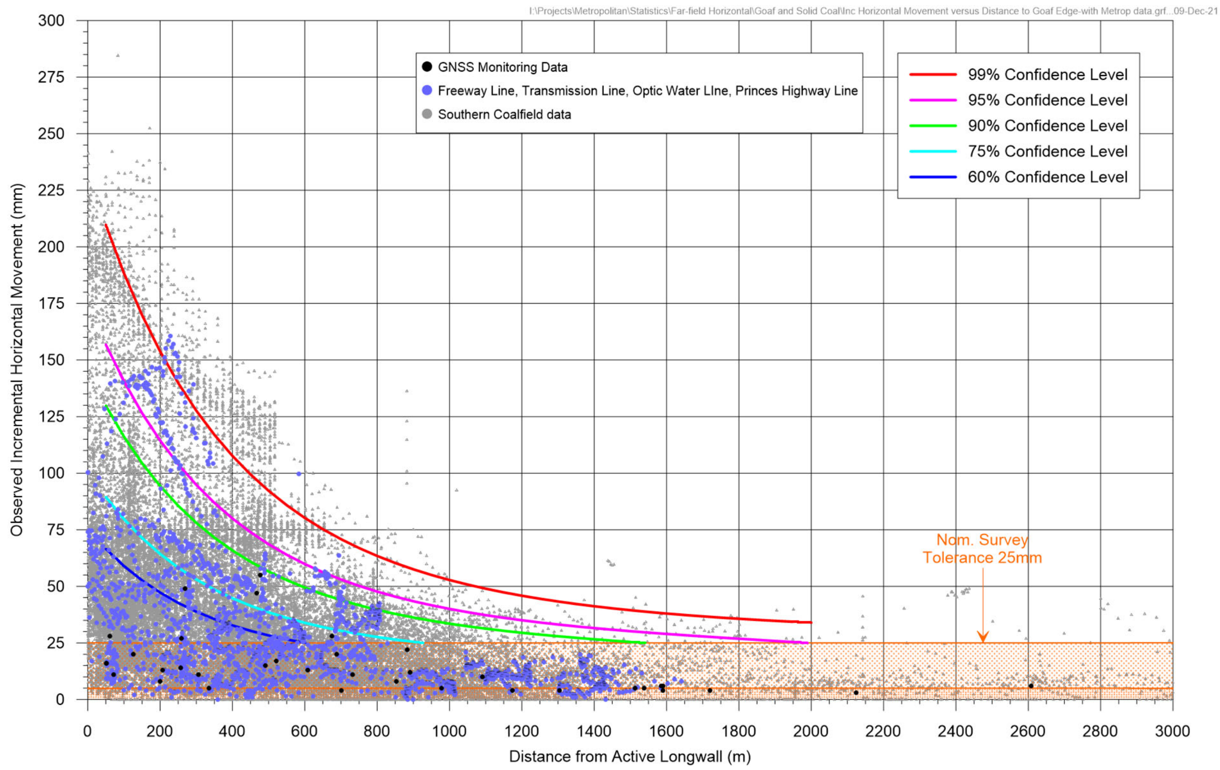

Fig. 4.9 Observed Incremental Far-Field Horizontal Movements from the Southern Coalfield (Solid Coal)

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

The predicted far-field horizontal movements resulting from the extraction of the proposed longwalls tend to be bodily movements towards the extracted goaf area, and are accompanied by very low levels of strain, which are generally less than the order of survey tolerance. While the impacts of far-field horizontal movements on the natural and built features within the vicinity of the Study Area are not expected to be significant, there are structures which are sensitive to small differential movements, including roads and road bridges which are discussed in Section 6.0 .

4.7. Non-Conventional Ground Movements

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

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

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

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

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

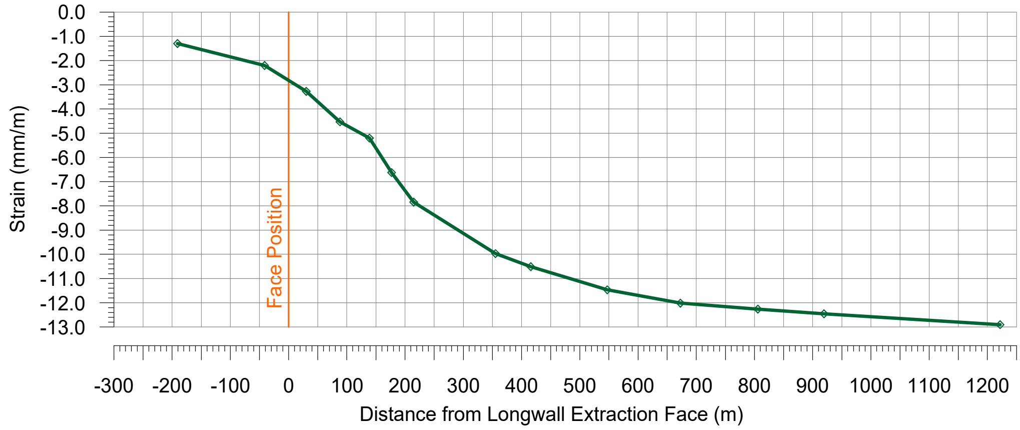

Fig. 4.10 Development of Strain at the Low Angle Thrust Fault Measured along the T-Line during the Extraction of Appin Longwall 408

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

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

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

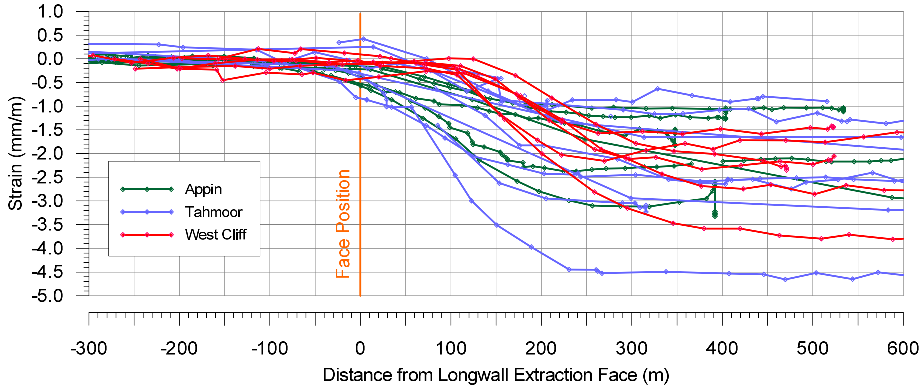

Fig. 4.13 Development of Non-Conventional Anomalous Strains in the Southern Coalfield

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

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

4.8. General Discussion on Mining Induced Ground Deformations

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

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

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

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

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

Fig. 4.14 Surface Compression Buckling Observed in a Pavement

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

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

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

Localised ground buckling and shearing can occur wherever faults, dykes and abrupt changes in geology occur near the ground surface. The identified geological structures at seam level within the Study Area are discussed in Section 1.5. Discussions on irregular ground movements are provided in Section 0.

5.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the natural features located within the Study Area for Longwalls 311 to 316 and selected features located outside the Study Area. The predicted parameters for each of the natural features have been compared to the predicted parameters based on the Preferred Project Layout. Supporting impact assessments for the natural features have also been undertaken by other specialist consultants for the Extraction Plan Layout.

Impact assessments for some natural features have also been provided by the other specialist consultants on the project. The assessments provided in this chapter should be read in conjunction with the assessments provided in all other relevant reports accompanying this application.

5.1. Natural Features

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

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

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

5.2. Catchment Areas and Declared Special Areas

The Study Area lies within the Woronora Special Area, which is controlled by WaterNSW. The Study Area is situated greater than 2km south of the Dams Safety NSW Notification Area for the Woronora Reservoir, which is also known as Lake Woronora.

The Woronora Special Area provides the main water supply for the Sutherland region, via the Woronora Reservoir.

The Woronora Reservoir full supply level occurs within the Study Area and the longwalls will be extracted beneath the main body of the Woronora Reservoir. Subsidence predictions and impact assessments for the Woronora Reservoir full supply level are provided in Section 5.5.

5.3. Waratah Rivulet

5.3.1. Description of the Waratah Rivulet

The Waratah Rivulet flows to the north east and into the Woronora Reservoir (at the Fully Supply Level) approximately 550 m to the south east of Longwalls 311 to 316. The Waratah Rivulet is located outside the Study Area Boundary. The location of the Waratah Rivulet is shown in Drawing No. MSEC1340-07. It is noted that in previous reports, the location of the full supply level was located at the downstream end of the Pool W rock bar. Following continued observation of water covering the Pool W rock bar, a dedicated survey was completed and identified that Pool W and the Pool W rock bar were below the full supply level of the Woronora Reservoir. The full supply level has therefore been defined to the location of Pool W and this pool is not included in the assessments for the Waratah Rivulet below.

5.3.2. Predictions for the Waratah Rivulet

The predicted profiles of vertical subsidence, upsidence and closure along the Waratah Rivulet (to the Woronora Reservoir Full Supply Level), resulting from the extraction of Longwalls 311 to 316 (based on the Extraction Plan Layout), are shown in Fig. C.02, in Appendix C. The predicted incremental profiles along the Waratah Rivulet/Woronora Reservoir Full Supply Level, due to the extraction of Longwalls 311 to 316, are shown as dashed black lines. The predicted total profiles for the Extraction Plan Layout are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as the solid red lines for comparison.

At distances of over 550 m from Longwalls 311 to 316, the Waratah Rivulet is located outside the Study Area and is not expected to experience measurable conventional vertical subsidence, tilts, curvatures, and strains (i.e. no greater than survey accuracy).

A summary of the maximum predicted values of total upsidence and closure for the Waratah Rivulet within the Study Area, resulting from the Extraction Plan Layout, is provided in Table 5.1. The compressive strains due to valley closure effects have also been provided (based on the method outlined in Section 4.4.3).

Table 5.1 Maximum Predicted Total Upsidence, Closure and Compressive Strain for the Waratah Rivulet within the Study Area after the Extraction of Longwalls 310 to 316

Longwall	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Closure Strain based on a 20m Bay Length (mm/m)
After LW310	100	175	7
After LW311	125	175	7
After LW312	125	175	7
After LW313	125	175	7
After LW314	125	175	7
After LW315	125	175	7
After LW316	125	175	7

A summary of the predicted valley closure for the rock bars downstream of Pool P, resulting from the Extraction Plan Layout, is provided in Table 5.3.

Table 5.2 Maximum Predicted Total Closure at Rock bars along the Waratah Rivulet

Longwall	RB-P	RB-Q	RB-R	RB-S	RB-T	RB-V
After LW310	125	125	150	150	150	175
After LW311	150	150	175	175	150	175
After LW312	150	150	175	175	150	175
After LW313	150	150	175	175	150	175
After LW314	150	150	175	175	150	175
After LW315	150	150	175	175	150	175
After LW316	150	150	175	175	150	175

5.3.3. Comparison of the Predictions for the Waratah Rivulet

The comparison of the maximum predicted subsidence parameters for the Waratah Rivulet rock bars, resulting from the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.3.

Table 5.3 Comparison of Maximum Predicted Closure for the Waratah Rivulet Rock Bars based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Closure (mm)					
	RB-P	RB-Q	RB-R	RB-S	RB-T	RB-V
Preferred Project Layout (After LW316) (Report No. MSEC403)	150	150	175	175	200	225
Extraction Plan Layout (Report No. MSEC1340)	150	150	175	175	150	175

The maximum predicted closure for the rock bars downstream of Pools P, Q, R and S based on the Extraction Plan Layout, are the same as the maxima predicted based on the Preferred Project Layout and less than those based on the Preferred Project Layout at the rock bars T and V.

5.3.4. Impact Assessments and Recommendations for the Waratah Rivulet

The maximum predicted subsidence parameters for the Waratah Rivulet, based on the Extraction Plan Layout, are similar to or less than the maxima predicted based on the Preferred Project Layout.

The Waratah Rivulet is located outside the Study Area boundary and 550 m from the nearest longwall (LW311). At this distance, the predicted conventional subsidence parameters due to the extraction of Longwalls 311 to 316 are small and less than expected levels of survey accuracy. Impacts due to conventional subsidence movements, including changes in gradient, flooding, ponding and scouring are not expected to occur.

The performance measure for watercourses as described in the project approval requires negligible environmental consequences along the portion of the '*Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P)'.* This section of the Waratah Rivulet includes Pool P to Rock bar V.

The predictions of total closure for the rock bars/boulderfield downstream of the pools along the Waratah Rivulet, from Pool P to Pool V are summarised in Table 5.2. It can be seen from this table that the predicted total closure resulting from the extraction of Longwalls 311 to 316 increases by a minimum of 25mm at Rock bars P to S, to a maximum of 175 mm at Rock bars R, S and V.

Previous assessments of stream impacts for the Waratah Rivulet, Eastern Tributary and other tributaries at Metropolitan Coal Mine have used a relationship between predicted total closure at rock bars and proportion of impacted pools for streams in the Southern Coalfield. The relationship identified that approximately 10 % of pools were impacted at a predicted total valley closure of up to 200 mm, where the streams are located outside the mining area.

Impacts to some pools along the Eastern Tributary have occurred at predicted values of total valley closure of less than 200 mm resulting in a higher proportion of impacted pools at lower magnitudes of predicted total valley closure. As a result of the impacts to pools along the Eastern Tributary, located above solid coal, the predicted valley closure impact relationship was not adopted and an adaptive management approach was instead used for the lower reaches of the Eastern Tributary.

A predicted total valley closure of 200 mm has been successfully used as a design tool for mining in the vicinity of the Waratah Rivulet from Pool P to Rock bar V during the extraction of Longwalls 20 to 27. Impacts to pools along the Waratah Rivulet have not occurred at predicted total valley closure of less than 200 mm. Impacts that have occurred along the Waratah Rivulet have been the result of mining directly beneath the Waratah Rivulet or in close proximity (< 100 m) to the rock bars with predicted total valley closure greater than 200 mm. Some pools along the Waratah Rivulet have also been mined directly beneath without impact with predicted total closure up to 800 mm.

A geological assessment was carried out by Strata Control (2019) for the Eastern Tributary and Waratah Rivulet, with a particular focus on Pool P to Rock bar V along the Waratah Rivulet and comparisons with Pool ETAM along the Eastern Tributary. The assessment identified a thick unit (approximately 25 m) of thinly bedded sandstone along the Eastern Tributary at the location of Pool ETAM. The thinly bedded sandstone is considered to be of lower strength, and more weathered than adjoining thickly bedded sandstone units and therefore more prone to impact from valley closure movements. In addition, a higher frequency of seam level faults and surface lineaments have been identified in the vicinity of the Eastern Tributary. The thinly bedded units identified along the along Waratah Rivulet were limited to less than 5 m thickness and the frequency of seam level faults and surface lineaments was considerably less. Based on the results of the assessment, the geological features identified along the Eastern Tributary are considered to be unique, compared to the Waratah Rivulet.

The extracted longwalls in the vicinity of Rock bars P to V have been set back from the Waratah Rivulet by distances of 150 m or more. The predicted maximum total closure for these rock bars after the extraction of Longwall 316 is 175 mm and no impacts have occurred along this section of the Waratah Rivulet to date. Longwall 316 is located 550 m from Rock bar V. With the longwalls set back from the Waratah Rivulet there is considered to be a low likelihood of impacts to the pools as a result of valley closure movements.

A monitoring program was developed and is currently being used for monitoring and management during the extraction of Longwalls 308 to 310. Following the completion of these longwalls, it is recommended that a monitoring program be reviewed to assess the need to continued detailed monitoring during the extraction of Longwalls 311 to 316.

5.4. The Eastern Tributary

The Eastern Tributary flows in an approximate south to north direction and flows into the Woronora Reservoir approximately 1.4 km (at the Full Supply Level) to the east of Longwall 311.

At 1.4 km or more, the Eastern Tributary is not predicted to experience measurable valley related movements and conventional subsidence movements during the extraction of Longwalls 311 to 316.

The Eastern Tributary has been managed previously using an adaptive management approach during the extraction of Longwalls 303 to 306 with a comprehensive monitoring program about Rock bar ETAU. The monitoring program was discontinued following the completion of Longwall 307.

5.5. Woronora Reservoir

5.5.1. Description of the Woronora Reservoir

The Woronora Reservoir Full Supply Level is located above the commencing ends of Longwalls 311 to 313. The area of the Full Supply Level immediately downstream of the Waratah Rivulet and Eastern Tributary is referred to as an inundation area. When the Woronora Reservoir is at full capacity, this area is flooded. When the water level is below the Full Supply Level, portions of the inundation area form temporary pools above exposed rock bars that would normally be covered at the Full Supply Level. The inundation area downstream of the Waratah Rivulet is within the Study Area.

5.5.2. Predictions for the Woronora Reservoir

The predicted profiles of vertical subsidence, upsidence and closure for the Woronora Reservoir Full Supply Level, resulting from the extraction of Longwalls 311 to 316 (based on the Extraction Plan Layout), are shown in Fig. C.02 (for the alignment of the Waratah Rivulet) in Appendix C. The predicted incremental profiles due to the extraction of Longwalls 311 to 316 for the Extraction Plan Layout, are shown as dashed black lines. The predicted total profiles for the Extraction Plan Layout are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as the solid red lines for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the Woronora Reservoir Full Supply Level, resulting from the Extraction Plan Layout is provided in Table 5.4. The values are the predicted maxima within the Study Area.

Table 5.4 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Woronora Reservoir Full Supply Level after the Extraction of Longwalls 310 to 316

Longwall	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
After LW310	575	2.5	0.02	0.03
After LW311	625	3.5	0.04	0.03
After LW312	625	4	0.04	0.03
After LW313	650	4	0.04	0.03
After LW314	650	4	0.04	0.03
After LW315	650	4	0.04	0.03
After LW316	650	4	0.04	0.03

The maximum predicted conventional tilt for the Woronora Reservoir Full Supply Level based on the Extraction Plan Layout is 4 mm/m (i.e. 0.4 %, or 1 in 250). The maximum predicted conventional curvatures are 0.04 km^{-1} hogging and 0.03 km^{-1} sagging, which equate to minimum radii of curvature of 25 km and 33 km respectively. The predicted conventional strains for the Woronora Reservoir Full Supply Level based on the Extraction Plan Layout (based on 15 times the curvature) are less than 1.0 mm/m tensile and compressive.

A summary of the maximum predicted values of total upsidence and closure for the Woronora Reservoir Full Supply Level, resulting from the Extraction Plan Layout, is provided in Table 5.5. The compressive strains due to valley closure effects have also been provided (based on Section 4.4.3).

Table 5.5 Maximum Predicted Total Upsidence, Closure and Compressive Strain for the Woronora Reservoir Full Supply Level after the Extraction of Longwalls 310 to 316

Longwall	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Closure Strain based on a 20m Bay Length (mm/m)
After LW310	600	675	> 11
After LW311	625	675	> 11
After LW312	650	675	> 11
After LW313	650	675	> 11
After LW314	650	675	> 11
After LW315	650	675	> 11
After LW316	650	675	> 11

5.5.3. Comparison of the Predictions for the Woronora Reservoir

The comparison of the maximum predicted subsidence parameters for the Woronora Reservoir Full Supply Level, resulting from the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.6. The values are the predicted maxima within the Study Area.

Table 5.6 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Woronora Reservoir Full Supply Level based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Vertical Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Preferred Project Layout (After LW316) (Report No. MSEC403)	475	800	825
Extraction Plan Layout (Report No. MSEC1340)	650	650	675

The maximum predicted vertical subsidence based on the Extraction Plan Layout, is greater than the maximum predicted based on the Preferred Project Layout. The maximum predicted upsidence and closure for the Woronora Reservoir Full Supply Level based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout. The greater predicted vertical subsidence is the result of model calibration which is discussed in Section 3.6.

5.5.4. Impact Assessments and Recommendations for the Woronora Reservoir

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

The potential impacts to the Woronora Reservoir are due to differential movements such as upsidence and closure rather than vertical subsidence. The potential impacts based on the Extraction Plan Layout, therefore, are the same or less than those assessed based on the Preferred Project Layout. The assessments of the potential impacts for the Woronora Reservoir were provided in Section 5.4.2 of Report No. MSEC285, which supported the Metropolitan Coal Project EA and Preferred Project Layout. Where the reservoir level is low, the temporary pools and rock bars that may be exposed within the inundation area would be subject to potential subsidence impacts described for other tributaries in Section 5.6 below.

5.6. Other Tributaries

There are a number of tributaries located within the Study Area and above Longwalls 311 to 316, as shown in Drawing No. MSEC1340-07. These streams consist of shallow drainage lines from the topographical high points, forming tributaries where valley heights increase and drain into the Woronora Reservoir.

The streams are located directly above Longwalls 311 to 316 and could, therefore, experience the full range of predicted subsidence movements, as discussed in Section 4.2.

Three larger tributaries located within the Study Area flow through Swamps S76, S77 and S92, which are listed in Schedule 3, Table 1 (Subsidence Impact Performance Measures) in the project approval. The three tributaries are identified as Tributary P (through Swamp S92), Tributary R (through Swamp S77) and Tributary S (through Swamp S76). Each of the tributaries comprise shallow valley profiles at higher elevations where they flow through the swamps, becoming steeper and more incised as they approach the Woronora Reservoir.

The locations of the Tributaries are shown in Drawing No. MSEC1340-07. Tributary P flows above Longwalls 311 and 312. Tributary R flows above finishing ends of Longwalls 311 to 314. Tributary S flows above Longwalls 313 to 316.

The profiles of predicted Subsidence, Upsidence and Closure for Tributary P, Tributary R and Tributary S are shown in Fig. C.03, Fig. 04 and Fig. 05 respectively.

It can be seen from Fig. C.03, 04 and 05 that the maximum predicted vertical subsidence based on the Extraction Plan Layout is greater than that based on the Preferred Project Layout. The increased subsidence is due mainly to model calibration as discussed in Section 3.6. regarding significant differences between the predicted profiles based on the Extraction Plan Layout and those based on the Preferred Project Layout. The magnitudes of maximum predicted upsidence and closure along Tributary P and S based on the Extraction Plan Layout are generally similar to or less than those based on the Preferred Project Layout. Variation in the magnitudes of the predicted profiles are due to model calibration, and changes to the longwall lengths, widths and orientation. The magnitudes of maximum predicted upsidence and closure along Tributary R based on the Extraction Plan Layout are generally similar to or less than those based on the Preferred Project Layout along the upper reaches where valley heights are shallow.

Along the lower reaches, the maximum predicted upsidence and closure based on the Extraction Plan Layout are greater than those based on the Preferred Project Layout, which is the result of changes to the longwall widths and orientation.

The predicted upsidence and closure at some locations based on the Extraction Plan Layout are greater than those based on the Preferred Project Layout, however the maxima are similar to or less than those elsewhere based on the Preferred Project Layout. The overall potential impacts on the tributaries above Longwalls 311 to 316, based on the Extraction Plan Layout, are therefore similar to those assessed for the Preferred Project Layout. A summary of potential impacts to the tributaries is provided below:

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

5.7. Aquifers and Known Groundwater Resources

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

Descriptions of the aquifers and known groundwater resources within the Study Area are provided in the Metropolitan Coal Longwalls 311 to 316 Water Management Plan.

5.8. Natural Dams

There are no natural dams within the Study Area. There are natural pools in streams and in the upper reaches of the Woronora Reservoir full supply level when reservoir water levels are low, as described in Sections 5.3 to 5.6.

5.9. Cliffs and Overhangs

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

Most of the cliffs and overhangs identified within the Project underground mining area are located along the alignment of the Waratah Rivulet or Waratah Rivulet arm of the Woronora Reservoir. The cliffs and overhangs have formed within the Hawkesbury Sandstone.

The locations of the cliffs and overhangs within the Study Area and surrounds are shown in Drawing No. MSEC1340-07. Six cliffs and overhangs are located within the Study Area (COH10, COH11, COH12, COH13, COH18, COH19) and four cliffs and overhangs (COH5, COH7, COH8, and COH9) are located outside the Study Area but within 600 m of Longwalls 311 to 316. COH18 is located above Longwall 312 and COH19 is located above Longwall 314. COH11, COH12, and COH13 are located above previously extracted Longwalls 307 and 308.

The descriptions, predictions and impact assessments for cliffs are provided in the following sections.

5.9.1. Descriptions of the Cliffs and Overhangs

Details of the cliffs and overhangs within 600 m of Longwalls 311 to 316 are provided in Table 5.7. Several of the cliffs and overhangs listed in Table 5.7 are less than 10 m in height but have been included in the assessment due to the sensitivity of some overhangs to potential movements resulting from mine subsidence.

There are also a number of rock ledges, which are located across the Study Area, generally within the valleys of the drainage lines. Rock ledges are discussed in Section 5.10.

Table 5.7 Details of Cliffs and Overhangs within 600 metres of Longwalls 311 to 316

Cliff and Overhang ID	Approx. Overall Length (m)	Approx. Maximum Height (m)	Approx. Maximum Overhang Depth (m)
COH5	12	2.5	7
COH7	30	6.5	10
	25	6.5	6
	15	5	7
	15	5	5.5
COH8	30	6	6.5
COH9	30	5.5	6
	5	1	2.5
COH10	40	7	5
	35	6.5	2
	25	7	3
COH11	20	16	3
COH12	30	9	4
COH13	40	12	2
COH18	85	10	-*
COH19	60	11	-*

*Depth of overhang to be verified by site survey.

5.9.2. Predictions for the Cliffs and Overhangs

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the cliffs within the Study Area, resulting from the Extraction Plan Layout, is provided in Table 5.8. The predicted tilts provided in this table are the maxima after the completion of Longwalls 311 to 316. The predicted curvatures are the maxima at any time during or after the extraction of Longwalls 311 to 316.

The cliffs located outside of the Longwalls and Study Area and within 600 m of Longwalls 311-316 are not expected to experience any measurable vertical subsidence resulting from the extraction of Longwalls 305-307.

Table 5.8 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the cliffs and overhangs after the Extraction of Longwall 316

ID	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
COH10	150	1.5	0.02	< 0.01
COH11	650	1.0	0.02	0.02
COH12	625	0.5	0.01	0.03
COH13	600	1.0	0.03	0.01
COH18	1450	1.5	0.04	0.03
COH19	1150	2.5	0.04	0.05

The predicted strains for cliffs within the Study Area are provided in Table 5.9. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 5.9 Predicted Strains for cliffs and overhangs based on Conventional and Non-Conventional Anomalous Movements

ID	Type	Conventional based on 15 times Curvature	Non-conventional based on the 95 % Confidence Level	Non-conventional based on the 99 % Confidence Level
COH 11, 12, 13, 18, 19	Tension	< 0.5	0.9	1.6
	Compression	< 0.5	1.6	3.2
COH 10	Tension	< 0.5	0.6	0.9
	Compression	< 0.5	0.5	0.8

COH18 and COH19 are located across Tributaries R and S respectively and will experience valley related closures due to the extraction of Longwalls 311 to 316. The remaining cliffs and overhangs are located along the alignments of the streams and will not experience the predicted valley closures which act across the alignments of the streams. A summary of the maximum predicted upsidence and closure for COH18 and 19, after the extraction of Longwalls 311 to 316 for the Extraction Plan Layout, is provided in Table 5.10. The compressive strains due to valley closure effects have also been provided (based on the discussion in Section 4.4.3).

Table 5.10 Maximum Predicted Total Upsidence, Closure and Valley Related Strain for COH18 and 19 after the Extraction of Longwall 316

Location	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Closure Strain based on a 20m Bay Length (mm/m)
COH18	475	850	11
COH19	325	550	11

5.9.3. Comparison of the Predictions for the Cliffs and Overhangs

The comparison of the maximum predicted subsidence parameters for the cliffs within the Study Area based on the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.11.

Table 5.11 Comparison of Maximum Predicted Conventional Subsidence Parameters for cliffs based on the Extraction Plan Layout and the Preferred Project Layout

ID	Maximum Predicted Total Conventional Subsidence (mm)		Maximum Predicted Total Conventional Tilt (mm/m)		Maximum Predicted Total Conventional Hogging Curvature (km^{-1})		Maximum Predicted Total Conventional Sagging Curvature (km^{-1})	
	Preferred Project Layout	Extraction Plan Layout	Preferred Project Layout	Extraction Plan Layout	Preferred Project Layout	Extraction Plan Layout	Preferred Project Layout	Extraction Plan Layout
COH10	200	150	2.0	1.5	0.02	0.02	0.02	< 0.01
COH11	475	650	< 0.5	1.0	0.01	0.02	0.04	0.02
COH12	475	625	1.0	0.5	0.02	0.01	0.06	0.03
COH13	450	600	0.5	1.0	0.04	0.03	0.02	0.01
COH18	1100	1450	1.5	1.5	0.03	0.04	0.04	0.03
COH19	525	1150	1.0	2.5	0.04	0.04	0.06	0.05

Predicted subsidence based on the Extraction Plan Layout is greater than that for based on the Preferred Project Layout at three sites due primarily to the model calibration discussed in Section 3.6.

The predicted tilts for COH11, COH13. And COH19 based on the Extraction Plan Layout are slightly higher than those based on the Preferred Project Layout. The predicted tilts for COH10, COH12, and COH18 based on the Extraction Plan Layout are the same or slightly lower than those based on the Preferred Project Layout. Hogging and sagging curvatures based on the Extraction Plan Layout are similar to or less than those based on the Preferred Project Layout.

A summary of the maximum predicted vertical subsidence, tilt and curvature for the cliffs is provided in Table 5.12.

Table 5.12 Comparison of Maximum Predicted Conventional Subsidence Parameters for the cliffs based on the Extraction Plan Layout and the Preferred Project Layout

Layout	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Preferred Project Layout (Report No. MSEC403)	1100	2.0	0.04	0.06
Extraction Plan Layout (Report No. MSEC1340)	1450	2.5	0.04	0.05

Predicted subsidence based on the Extraction Plan Layout is greater than that for based on the Preferred Project Layout due to the model calibration discussed in Section 3.6. The maximum predicted tilt and curvatures for the cliffs, based on the Extraction Plan Layout are similar to or less than those based on the Preferred Project Layout.

5.9.4. Impact Assessments for the Cliffs

A discussion of the impact assessments for the cliffs and overhangs is provided in Section 5.6.2 of the MSEC285 Report for the EA Layout. The potential for impacts on the cliffs and overhangs, based on the Extraction Plan Layout, are similar to those based on the Preferred Project Layout. Based on comparisons with other mines in the Southern Coalfield where cliff lines have been undermined, the lengths of potential cliff instabilities are expected to be less than 3 % of the total length of the cliffs and overhangs. The likelihood of impact to COH18 and COH19 is considered to be higher due to the locations above extracted longwalls and alignment oriented across Tributaries R and S.

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

5.10. Rock Ledges

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

The rock ledges will experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence and tilt for the rock ledges, based on the Extraction Plan Layout for Longwalls 311 to 316 are greater than the maxima predicted based on the Preferred Project Layout. The increased subsidence is the result of calibration of the model as discussed in Section 3.6. The predicted tilt based on the Extraction Plan Layout is greater than the Preferred Project Layout near the finishing ends of Longwalls 311 to 316 but is similar to the predicted tilt based on the Preferred Project Layout elsewhere. The predicted hogging and sagging curvature based on the Extraction Plan Layout for Longwalls 311 to 316 are similar to the maxima predicted based on the Preferred Project Layout for Longwalls 311 to 316.

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

5.11. Steep Slopes

The locations of steep slopes are shown on Drawing No. MSEC1340-07. Steep slopes are presented based on the definition used in the subsidence assessment for the Metropolitan Coal Project EA and MSEC285 Report (a natural gradient between 18° and 63°) and also based on the definition in the Project Approval 08_0149 (a natural gradient between 33° and 66°).

There are steep slopes located above Longwalls 311 to 316. The natural gradients for the steep slopes within the Study Area are typically up to 1 in 2, with some isolated areas with natural gradients up to 1 in 1.5.

The steep slopes will experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence and tilt for the steep slopes, based on the Extraction Plan Layout for Longwalls 311 to 316 are greater than the maxima predicted based on the Preferred Project Layout. The increased subsidence is the result of calibration of the model as discussed in Section 3.6. The predicted tilt based on the Extraction Plan Layout is greater than the Preferred Project Layout near the finishing ends of Longwalls 311 to 316 but is similar to the predicted tilt based on the Preferred Project Layout elsewhere. The predicted hogging and sagging curvature based on the Extraction Plan Layout for Longwalls 311 to 316 are similar to the maxima predicted based on the Preferred Project Layout for Longwalls 311 to 316.

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

5.12. Land Prone to Flooding and Inundation

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

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

Fig. 5.1 Woronora Reservoir Inundation Area

The Woronora Reservoir full supply level is shown in Drawing No. MSEC1340-07, which shows the Woronora Reservoir within the Study Area Boundary.

Predictions of subsidence, upsidence and closure for this section of the full supply level for the Extraction Plan Layout are shown Fig. C.02 and C.03, in Appendix C, and are discussed in Section 5.5.

5.13. Swamps, Wetlands and Water Related Ecosystems

5.13.1. Descriptions of the Swamps

The locations of the swamps are shown in Drawing No. MSEC1340-07. The mapped extents of these swamps is based on field inspections and validation by Eco Logical Australia. There are 39 swamps located within the Study Area. There are a further 16 swamps that are located outside the Study Area but within 600 m of Longwalls 311 to 316.

Three swamps are listed in the performance measures in the Project Approval 08_0149 (Swamps S76, S77 and S92). The impact performance measures for these swamps are set through condition 4 which states: *"The Proponent shall not undermine Swamps 76, 77 and 92 without the written approval of the Director General."* Swamp S76 is located above the middle of Longwalls 315 and 316 and follows the alignment of Tributary S. Swamp S77 is located above the southern half of Longwalls 312 to 315 and follows the alignment of Tributary R. Swamp S92 is located above the finishing end of Longwall 312 and follows the alignment of Tributary P. The majority of Swamp S92 is located outside the longwall footprint.

Detailed descriptions of the swamps within the study area are provided in the Metropolitan Coal Longwalls 311 to 316 Biodiversity Management Plan.

5.13.2. Predictions for the Swamps

The maximum predicted subsidence parameters for each of the swamps located within the Study Area are provided in Table. D.01, in Appendix D. The predictions have been provided based on the Extraction Plan Layout and the Preferred Project Layout.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the swamps, resulting from the Extraction Plan Layout, is provided in Table 5.13.

The predicted tilts provided in this table are the maxima after the completion of Longwall 316. The predicted curvatures are the maxima at any time during or after the extraction of Longwalls 311 to 316.

Table 5.13 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Swamps within the Study Area after the Extraction of Longwall 316

Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
S14	< 20	< 0.5	< 0.01	< 0.01
S62	< 20	< 0.5	< 0.01	< 0.01
S74	175	2.0	0.02	< 0.01
S75	750	3.5	0.02	0.02
S76	1300	3.5	0.03	0.04
S77	1450	4.0	0.04	0.04
S78a	1450	2.0	0.04	0.05
S78b	1450	2.0	0.04	0.05
S79	1500	1.5	0.04	0.05
S80	1450	2.0	0.03	0.05
S81	1450	2.0	0.03	0.05
S82	1300	3.0	0.04	0.05
S83	1350	2.0	0.03	0.02
S84	700	1.0	0.01	0.02
S86	925	2.0	0.02	0.05
S88	475	5.5	0.06	0.02
S89a	1450	6.5	0.03	0.06
S89b	1200	6.5	0.03	0.04
S90a	1500	1.5	0.04	0.05
S90b	1450	1.5	0.03	0.05
S91	1050	6.0	0.02	0.04
S92	1350	7.0	0.06	0.04
S93	20	< 0.5	< 0.01	< 0.01
S94	80	1.0	0.01	< 0.01
S102	< 20	< 0.5	< 0.01	< 0.01
S103	< 20	< 0.5	< 0.01	< 0.01
S104	< 20	< 0.5	< 0.01	< 0.01
S105	< 20	< 0.5	< 0.01	< 0.01
S106	50	0.5	< 0.01	< 0.01
S107	150	2.0	0.02	< 0.01
S108	100	1.5	0.01	< 0.01
S109	< 20	< 0.5	< 0.01	< 0.01
S113	175	2.0	0.02	< 0.01
S114	325	3.0	0.02	< 0.01
S115	275	2.5	0.02	< 0.01
S116	< 20	< 0.5	< 0.01	< 0.01
S117	30	< 0.5	< 0.01	< 0.01
S118	< 20	< 0.5	< 0.01	< 0.01
S119	150	1.5	0.02	< 0.01
S120	< 20	< 0.5	< 0.01	< 0.01
S121	< 20	< 0.5	< 0.01	< 0.01
S122	< 20	< 0.5	< 0.01	< 0.01
S123	< 20	< 0.5	< 0.01	< 0.01
S124	< 20	< 0.5	< 0.01	< 0.01
S125	< 20	< 0.5	< 0.01	< 0.01
S126	< 20	< 0.5	< 0.01	< 0.01
S127	< 20	< 0.5	< 0.01	< 0.01
S128	325	3.0	0.02	< 0.01
S129	30	< 0.5	< 0.01	< 0.01
S130	500	3.5	0.02	< 0.01
S131	30	< 0.5	< 0.01	< 0.01
S132	90	1.0	0.01	< 0.01
S135	< 20	< 0.5	< 0.01	< 0.01
S136	< 20	< 0.5	< 0.01	< 0.01
S139	1200	3.0	0.03	0.04

The maximum predicted strains for the swamps located directly above Longwalls 311 to 316 are provided in Table 5.14. The values have been derived for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 5.14 Maximum Predicted Strains for the Swamps Located directly above Longwalls 311 to 316 based on Conventional and Non-Conventional Anomalous Movements

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

A number of the swamps within the Study Area are located along the alignments of tributaries and, therefore, could experience valley related effects. A summary of the maximum predicted upsidence and closure for these swamps, after the extraction of Longwalls 311 to 316 for the Extraction Plan Layout, is provided in Table 5.15. The compressive strains due to valley closure effects have also been provided (based on the discussion in Section 4.4.3).

Table 5.15 Maximum Predicted Total Upsidence, Closure and Valley Related Strain for the Swamps within the Study Area after the Extraction of Longwall 316

Location	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Closure Strain based on a 20m Bay Length (mm/m)
S14	< 20	20	1
S76	150	125	6
S77	325	350	11
S81	70	40	2
S82	250	200	8
S90a	60	30	2
S90b	40	30	2
S92	225	100	5
S93	< 20	< 20	< 1
S106	< 20	< 20	< 1

5.13.3. Comparison of the Predictions for the Swamps

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

The maximum predicted subsidence for the swamps, based on the Extraction Plan Layout for Longwalls 311 to 316 are greater than the maxima predicted based on the Preferred Project Layout at 27 swamps (49%), and equal to or lower at 28 swamps (51%). The greater subsidence above the longwalls is the result of calibration of the model as discussed in Section 3.6. The predicted tilt based on the Extraction Plan Layout is greater than the Preferred Project Layout at 17 swamps (31%) and equal to or lower at 38 swamps (69%). The predicted tilt based on the Extraction Plan Layout is greater than the Preferred Project Layout near the finishing ends of Longwalls 311 to 316 but is similar to the maximum predicted tilt based on the Preferred Project Layout elsewhere. The predicted hogging and sagging curvature based on the Extraction Plan Layout for Longwalls 311 to 316 are low in magnitude and are similar to or less than the maxima predicted based on the Preferred Project Layout for Longwalls 311 to 316.

A summary of the maximum predicted vertical subsidence, tilt and curvature for the swamps within the Study Area is provided in Table 5.16. A summary of the maximum predicted upsidence and closure for the swamps within the Study Area is provided in Table 5.17.

Table 5.16 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Swamps based on the Extraction Plan Layout and the Preferred Project Layout

Layout	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Preferred Project Layout (Report No. MSEC403)	1200	5.0	0.05	0.08
Extraction Plan Layout (Report No. MSEC1340)	1500	7.0	0.06	0.06

Table 5.17 Comparison of Maximum Predicted Upsidence and Closure for the Swamps based on the Extraction Plan Layout and the Preferred Project Layout

Layout	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Preferred Project Layout (After LW307) (Report No. MSEC403)	325	325
Extraction Plan Layout (Report No. MSEC1340)	325	350

It can be seen from Table 5.16, that the maximum predicted conventional subsidence and tilt based on the Extraction Plan Layout, are greater than the maxima based on the Preferred Project Layout after Longwalls 311 to 316. The maximum predicted conventional hogging and sagging curvature based on the Extraction Plan Layout, are similar to the maxima based on the Preferred Project Layout The predicted parameters for the individual swamps increase or decrease, depending on their locations relative to Longwalls 311 to 316. The maximum predicted upsidence and closure in Table 5.17 based on the Extraction Plan Layout, are similar to the maxima predicted based on the Preferred Project Layout after Longwalls 311 to 316.

5.13.4. Impact Assessments and Recommendations for the Swamps

The predicted vertical subsidence increases at some swamps due to calibration of the model as discussed in Section 3.6, and decreases at some swamps due to changes in longwall geometry and orientation. Whilst the predicted tilt and curvatures increase at a small number of swamps, the maximum values are similar to the maxima predicted for other swamps located above the previously extracted longwalls at the Metropolitan Coal Mine. The potential impacts for the swamps, based on the Extraction Plan Layout, therefore, are similar to those assessed based on the Preferred Project Layout.

Cracking of the bedrock within upland swamps is expected to be isolated and of a minor nature, due to the relatively low magnitudes of the predicted curvatures and strains and the relatively high depths of cover. The minor cracking within the swamps would generally not be expected to propagate through swamp soil profiles. An increased risk of cracking may occur due to valley closure along the alignments of tributaries. The cracking risk due to valley closure is greater where the predicted valley closure increases, generally at the downstream ends of the tributaries where valley profiles increase. The majority of predicted valley closure from Table 5.15 is below 100mm. Maximum valley closure at Swamp S82 and S77 is 200mm and 350mm respectively, which occurs at the downstream ends of these swamps, and the risk of cracking in the base of the valley is greater at these locations.

Whilst swamp grades vary naturally, the predicted maximum mining-induced tilts are generally an order of magnitude lower than the existing natural grades within the swamps. At some locations where natural grades are shallow, the predicted tilts may result in more significant changes to grade within the swamps. The predicted tilts would generally not be expected to have a significant effect on the overall gradient of the swamps or the flow of surface water.

Three swamps are listed in the performance measures in the Project Approval 08_0149 (Swamps S76, S77 and S92). The impact performance measures for these swamps are set through condition 4 which states: *"The Proponent shall not undermine Swamps 76, 77 and 92 without the written approval of the Director General."*

Profiles of the surface levels along and across the tributaries through Swamps S76, S77 and S92 are shown below in Fig. 5.2 to Fig. 5.4. The profiles show that grades within the swamps are generally shallow compared to the surrounding topography.

The average grades along each of the long sections and cross sections are show in Fig. 5.5 to Fig. 5.10. The average grades are calculated over an approximate 50m chainage along each of the lines. The pre-mining grades are shown as black lines and post-mining grades are shown as red lines in these figures. The average grades within the swamps shown in Fig. 5.5 to Fig. 5.10 vary from very shallow (close to zero) up to approximately 100mm/m (10%), with the majority below about 40mm/m (4%). The predicted post-mining average grades show that changes are generally small compared to the natural grades, with some locations increasing in grade and some locations decreasing in grade. Where the predicted changes in grade are larger, the post-mining grades are generally within the range of grades at other locations within the swamps.

The recommendations and management strategies for the swamps based on the extraction plan layout are the same as those based on the Preferred Project Layout.

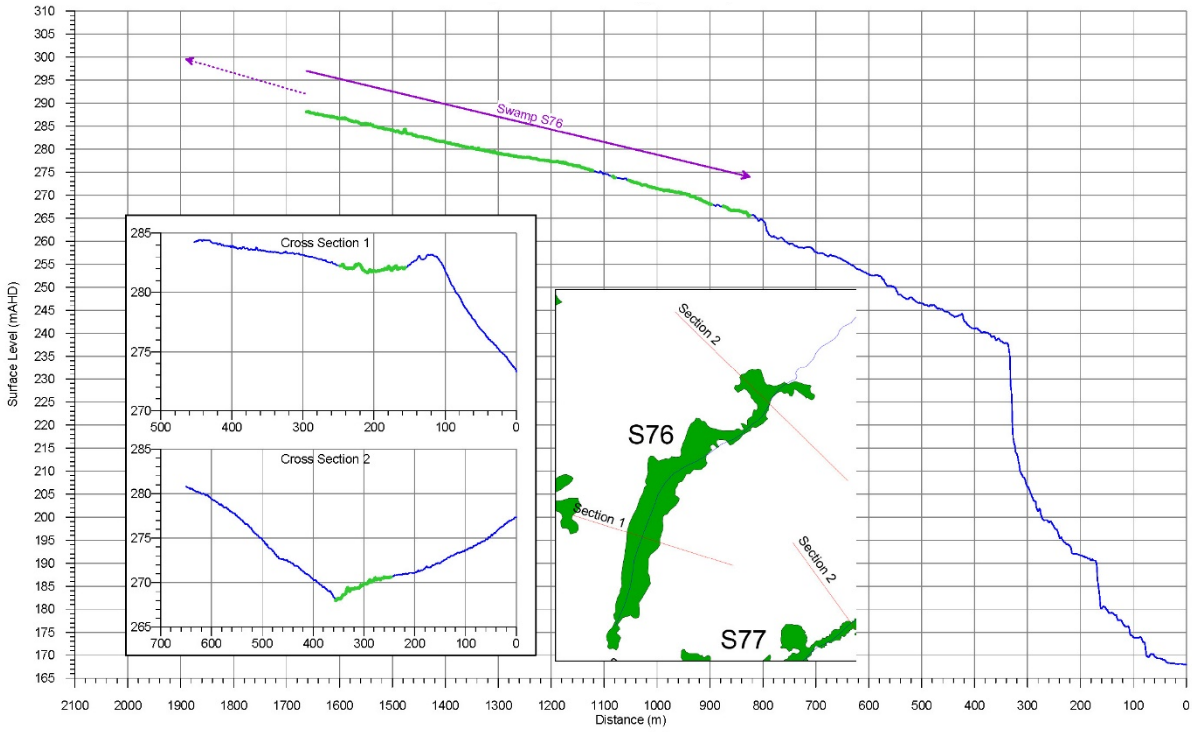

Fig. 5.2 Swamp S76 surface profiles

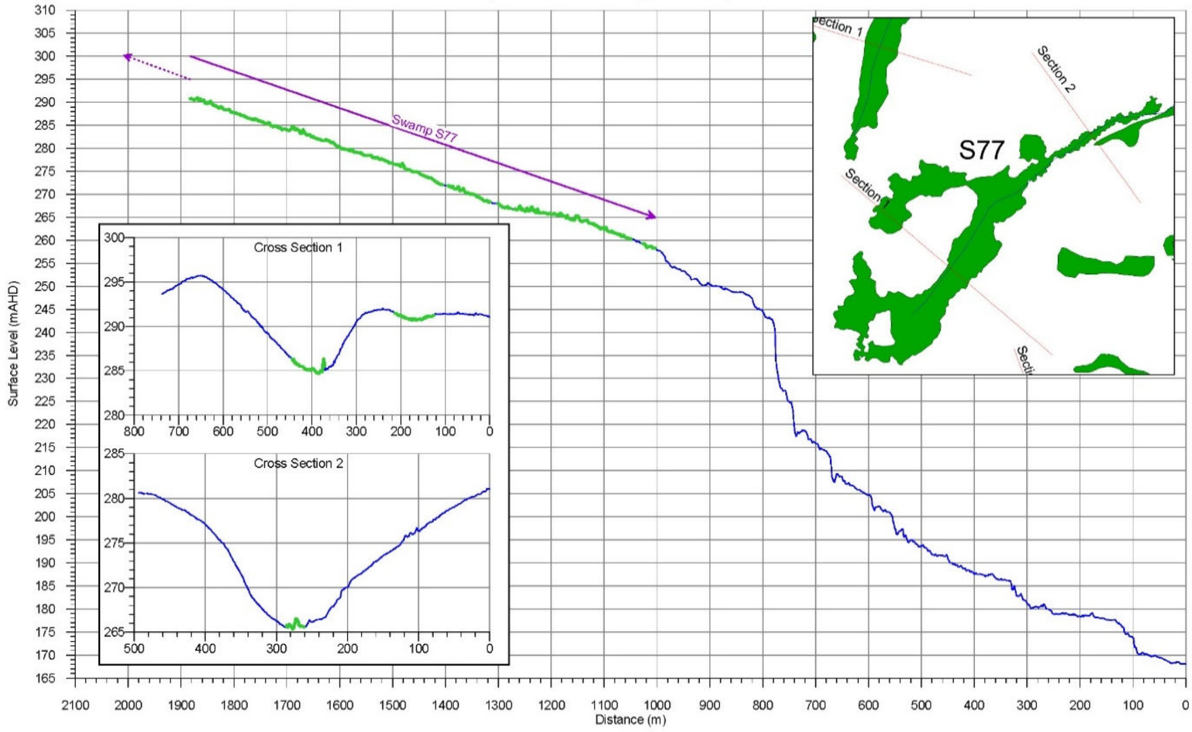

Fig. 5.3 Swamp S77 surface profiles

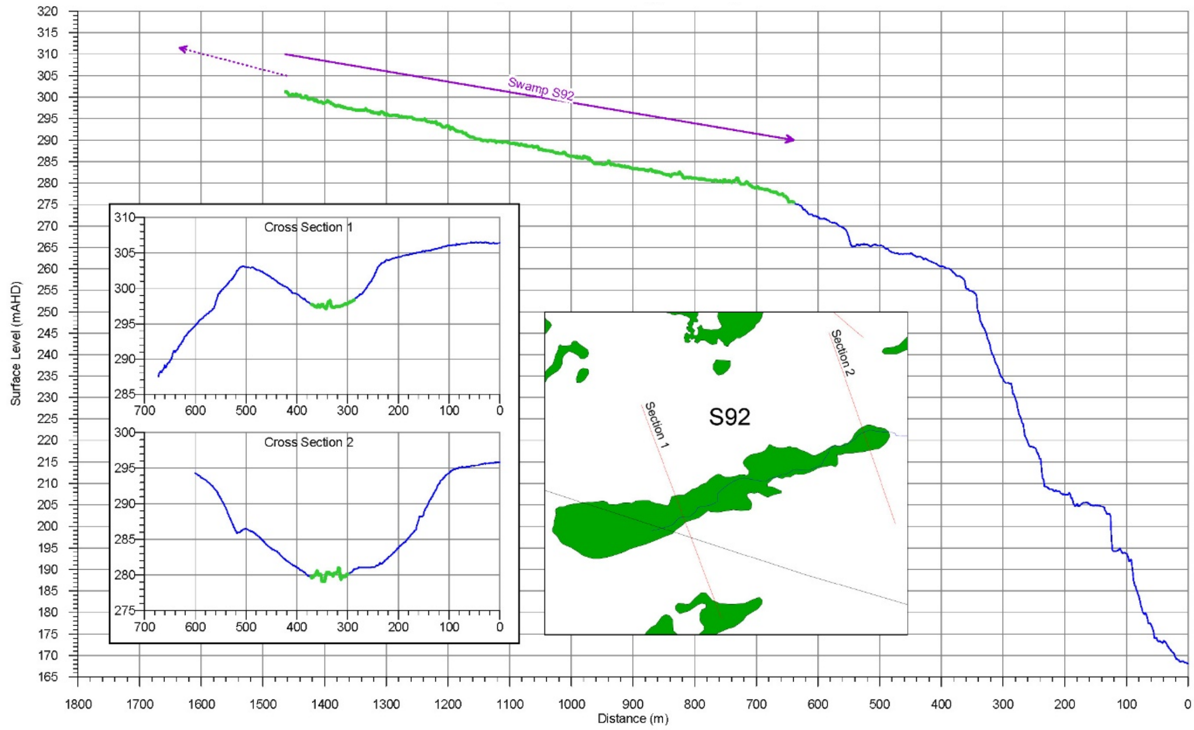

Fig. 5.4 Swamp S92 surface profiles

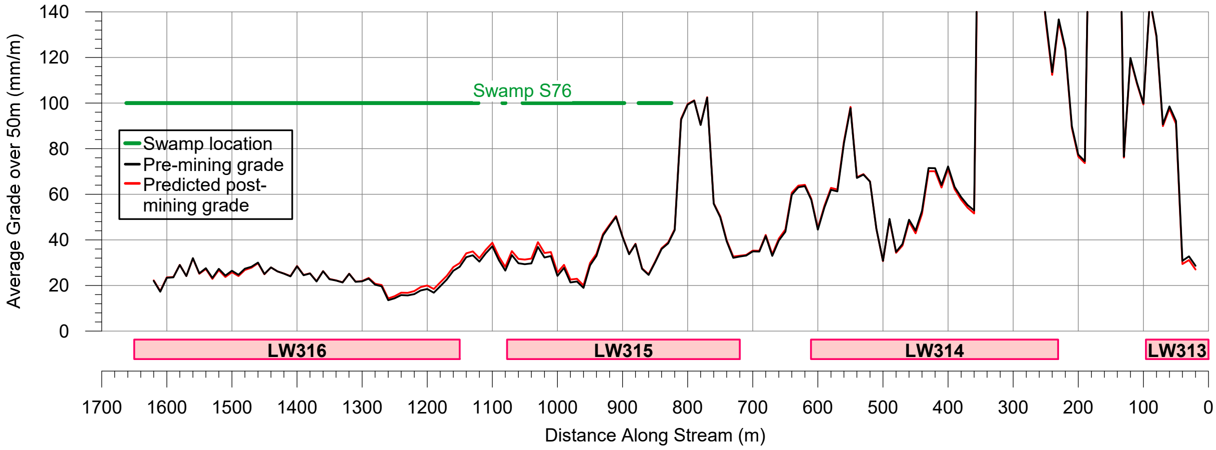

Fig. 5.5 Swamp S76 long section average grades over approximately 50m

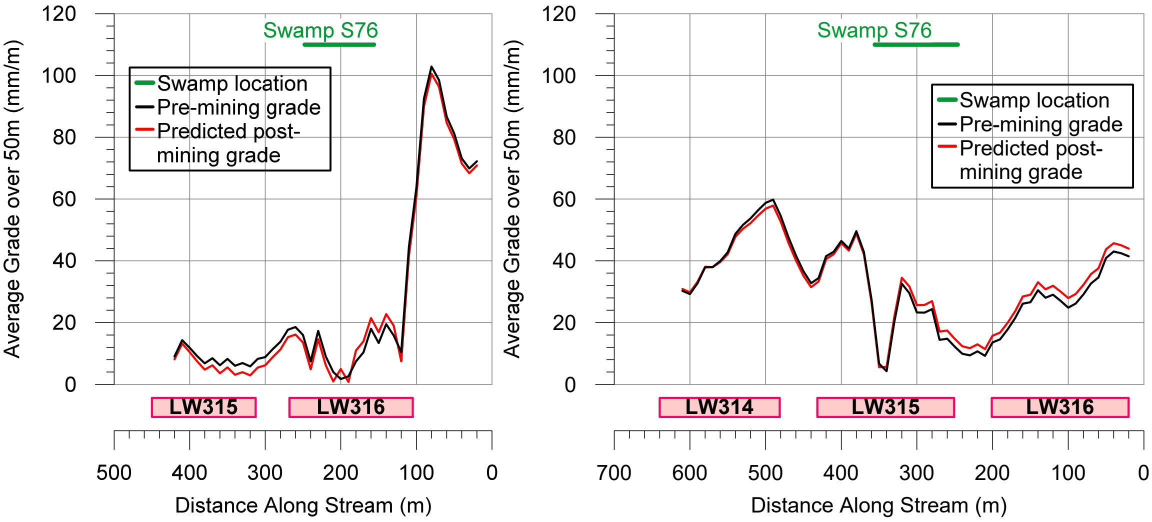

Fig. 5.6 Swamp S76 cross section 1 and 2 average grades over approximately 50m

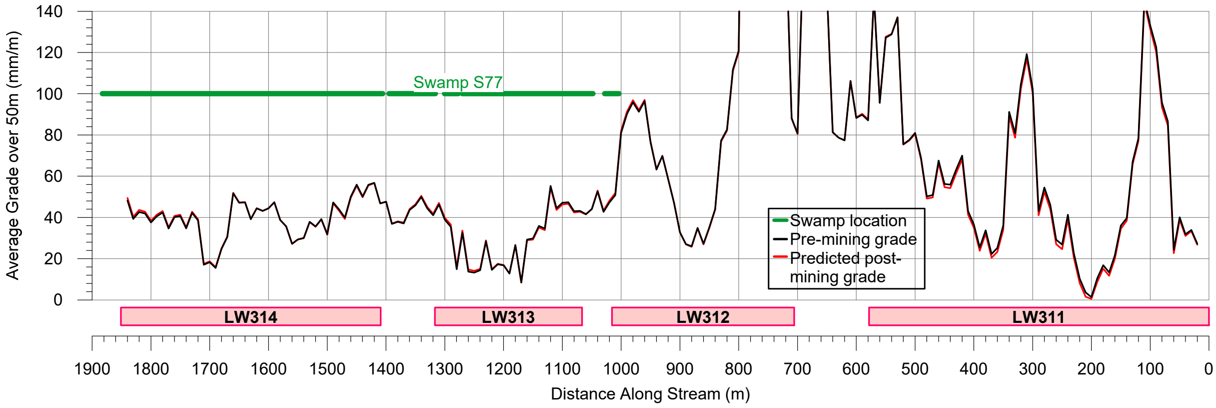

Fig. 5.7 Swamp S77 long section average grades over approximately 50m

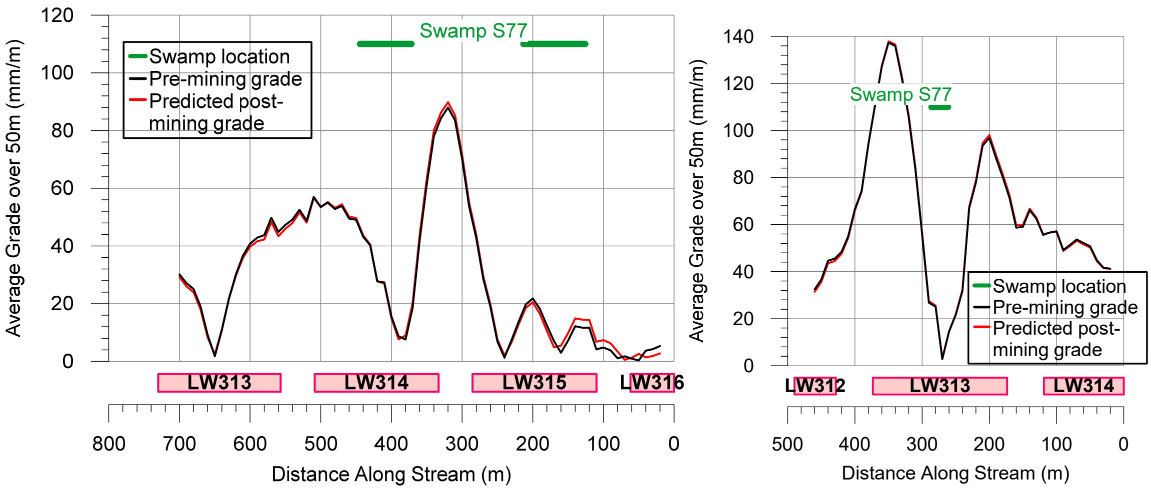

Fig. 5.8 **Swamp S77 cross section 1 and 2 average grades over approximately 50m**

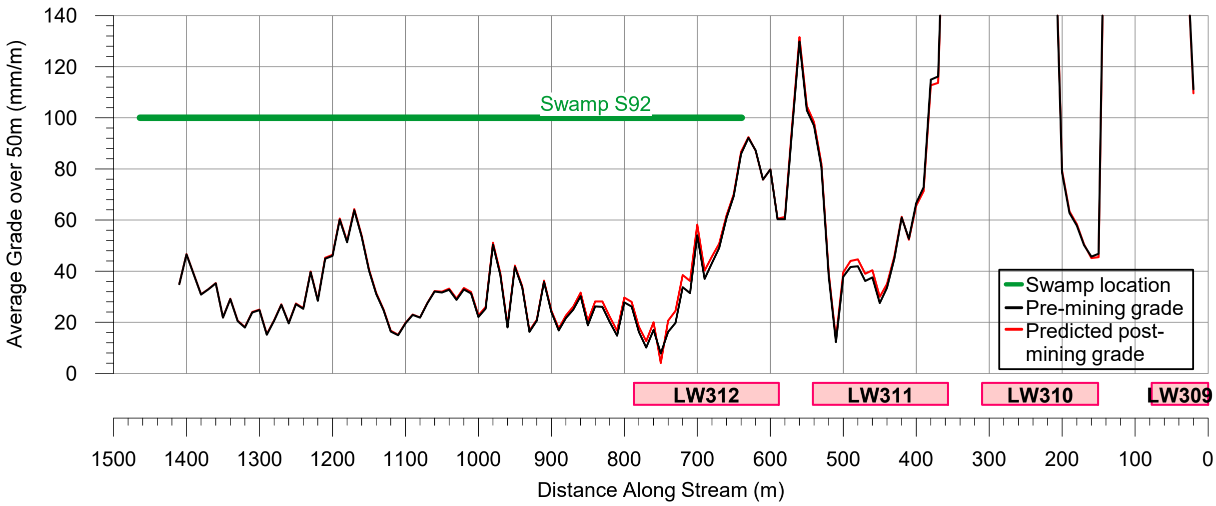

Fig. 5.9 **Swamp S92 long section average grades over approximately 50m**

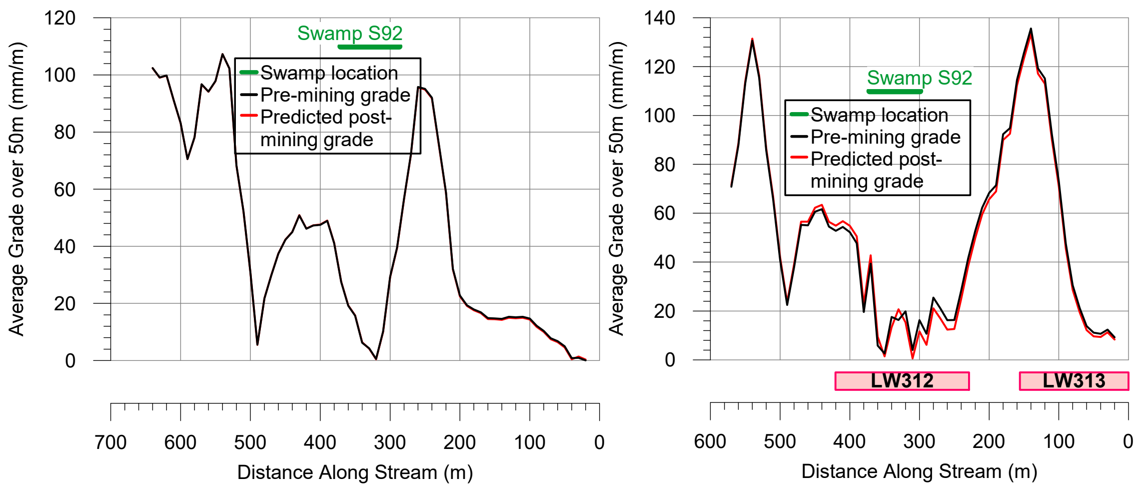

Fig. 5.10 **Swamp S92 cross section 1 and 2 average grades over approximately 50m**

5.14. Threatened, Protected Species or Critical Habitats

There are no lands within the Study Area that have been declared as critical habitat under the *Biodiversity Conservation Act 2016*. However, threatened and protected species and their habitats occur within the Study Area as described in the Longwalls 311 to 316 Biodiversity Management Plan.

5.15. Natural Vegetation

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

Natural vegetation covers the majority of the Study Area. The natural vegetation could, therefore, experience the full range of predicted subsidence movements, as summarised in Table 4.2.

The natural vegetation will experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence and tilt for the natural vegetation, based on the Extraction Plan Layout for Longwalls 311 to 316 are greater than the maxima predicted based on the Preferred Project Layout. The increased subsidence is the result of calibration of the model as discussed in Section 3.6. The predicted tilt based on the Extraction Plan Layout is greater than the Preferred Project Layout near the finishing ends of Longwalls 311 to 316 but is similar to the predicted tilt based on the Preferred Project Layout elsewhere. The predicted hogging and sagging curvature based on the Extraction Plan Layout for Longwalls 311 to 316 are similar to the maxima predicted based on the Preferred Project Layout for Longwalls 311 to 316.

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

5.16. Areas of Significant Geological Interest

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

6.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE PUBLIC UTILITIES

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the public utilities located within the Study Area for Longwalls 311 to 316. The predicted parameters for each of the built features have been compared to the predicted parameters based on the Preferred Project Layout.

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

- Tunnels;
- Roads;
- Bridges;
- Railways;
- Electrical Infrastructure;
- Telecommunications Infrastructure;
- Water Tanks, Water and Sewage Treatment Works;
- Gas pipelines;
- Liquid fuel pipelines;
- Water and sewage treatment works; and
- Air strips.

6.1. Roads

6.1.1. Woronora Dam Road

The Woronora Dam Road is a concrete paved road that connects the Old Princes Highway to Woronora Dam. Woronora Dam Road is located outside the Study Area boundary to the north of Longwalls 311 to 316 and is located over 880 m from Longwall 313 at the nearest point. The location of the Woronora Dam Road is shown in Drawing No. MSEC1340-08. A powerline and Telstra copper cable and optical fibre lines also follow the route of the Woronora Dam Road.

At a distance of 880 m or more from Longwall 311 to 316, the road is located outside the Study Area and is not expected to experience measurable conventional vertical subsidence, tilts, curvatures or strains (i.e. no greater than survey accuracy). The road could however experience low level far-field horizontal movements. The far-field horizontal movements are expected to be similar to those observed for previous longwall mining in the Southern Coalfield.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The maximum absolute horizontal movements measured at distances greater than 880 m from mining are in the order of 40 mm based on the 95 % confidence level. Far-field horizontal movements tend to be bodily movements orientated towards the mining area. The strains associated with these low level horizontal movements are not expected to be measurable.

Whilst the Woronora Dam Road could experience low level far-field horizontal movements, the associated tilts, curvatures or strains are not expected to be measurable. It is unlikely that the Woronora Dam Road and associated infrastructure would experience adverse impacts as a result of Longwalls 311 to 316.

6.1.2. M1 Princes Motorway

The M1 Princes Motorway is located outside the Study Area to the east of Longwalls 311 to 316 as shown on Drawing No. MSEC1340-08. The distance of the M1 Princes Motorway from Longwalls 311 to 316 varies from 2,200 m near the finishing (southern) end to 2,300 m near the commencing (northern) end of Longwall 311.

A series of cuttings and embankments up to a maximum height of approximately 20 m are located along the M1 Princes Motorway. A bridge is located at the crossing of the M1 Princes Motorway with the Old Princes Highway (Bridge 2), and is located approximately 2,200 m from Longwall 311. The next nearest bridge is Cawley Road Overpass, which is located approximately 2,500 km from the commencing end of Longwall 311. A series of culverts cross the M1 Princes Motorway. The culverts comprise pipes of varying diameters from 375 mm to 1800 mm. The pipe materials comprise asbestos cement (pipes up to 600 mm diameter) and steel reinforced concrete (pipes up to 1800 mm diameter). In addition to the culverts, there are also a number of other drainage structures, such as kerbs, gutters, pits and drainage pipes. The largest culvert comprises two 1800 mm pipes located to the north east of the longwalls at Cawley's Creek.

At distances of over 2,200 m from Longwalls 311 to 316, the Transport for NSW (TfNSW) assets are located outside the Study Area at over 4.5 times the depths of cover above Longwalls 311 to 316, and are not expected to experience measurable conventional vertical subsidence, tilts, curvatures or strains (i.e. no greater than survey accuracy). Monitoring to the end of Longwall 308 as identified no significant horizontal movements. It is expected that no measurable horizontal movements would be observed during the extraction of Longwalls 311 to 316.

It is unlikely that the M1 Princes Motorway and associated infrastructure would experience adverse impacts as a result of Longwalls 311 to 316.

6.1.3. Old Princes Highway

The Old Princes Highway (the highway) is a regional road located outside the Study Area boundary, crossing directly above previous Longwalls 301 to 304. The highway is located over 1,200 m from Longwall 311 at the nearest point. The location of the highway is shown in Drawing No. MSEC1340-08.

At a distance of 1,200 m or more from Longwall 311 to 316, the highway is located outside the Study Area and is not expected to experience measurable conventional vertical subsidence, tilts, curvatures or strains (i.e. no greater than survey accuracy). The highway could however experience low level far-field horizontal movements. The far-field horizontal movements are expected to be similar to those observed for previous longwall mining in the Southern Coalfield.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The maximum absolute horizontal movements measured at distances greater than 1,200 m from mining are in the order of 35 mm based on the 95 % confidence level. Observed horizontal movement during the extraction of Longwall 308 were approximately 20 mm, therefore horizontal movement due to the extraction of Longwalls 311 to 316 are likely to be lower than 20 mm. Far-field horizontal movements tend to be bodily movements orientated towards the mining area. The strains associated with these low level horizontal movements are not expected to be measurable.

Whilst the highway could experience low level far-field horizontal movements, the associated tilts, curvatures or strains are not expected to be measurable. It is unlikely that the Old Princes Highway and associated infrastructure would experience adverse impacts as a result of Longwalls 311 to 316.

6.2. Fire Trails and Four Wheel Drive Tracks

The locations of the unsealed four wheel drive tracks and fire roads within and adjacent to the Study Area are shown in Drawings Nos. MSEC1340-08 and MSEC1340-09. Tracks are located directly above Longwalls 311 to 316 and previously extracted longwalls. The tracks would therefore experience the full range of subsidence movements during the extraction of Longwalls 311 to 316, which are provided in Chapter 4.

The maximum predicted subsidence and tilt for the unsealed four wheel drive tracks and fire roads above the longwalls, based on the Extraction Plan Layout for Longwalls 311 to 316 are greater than the maxima predicted based on the Preferred Project Layout. The increased subsidence is the result of calibration of the model as discussed in Section 3.6. The predicted tilt based on the Extraction Plan Layout is greater than the Preferred Project Layout near the finishing ends of Longwalls 311 to 316 but is similar to the predicted tilt based on the Preferred Project Layout elsewhere. The predicted hogging and sagging curvature based on the Extraction Plan Layout for Longwalls 311 to 316 are similar to the maxima predicted based on the Preferred Project Layout for Longwalls 311 to 316.

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

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

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 308 to 310 are updated and continued to manage the potential impacts on the fire trails and four wheel drive tracks. It is expected that the fire trails and four wheel drive tracks can be maintained in safe and serviceable conditions with the implementation of the appropriate monitoring and management strategies.

6.3. Bridges

The nearest bridge to the Extraction Plan Layout is Bridge 2 (RMS reference BN616-southbound and BN617-northbound), which is located approximately 2,200 m from Longwall 311 as shown in Drawing No. MSEC1340-08.

As discussed in Section 6.1, it is unlikely that the M1 Princes Motorway and associated infrastructure would experience adverse impacts as a result of Longwalls 311 to 316.

6.4. Water Infrastructure

The locations of the water infrastructure are shown in Drawing No. MSEC1340-08. No water infrastructure is located within the Study Area. There are two potable water supply pipelines located to the north east of the Study Area. *Water Main 1* comprises a 300 mm diameter Cast Iron Cement Lined (CICL) pipeline and is located 680 m to the east of Longwall 311 at its nearest point. *Water Main 2* comprises a 200 mm diameter CICL pipeline and is located 620 m to the notrth east of Longwall 314.

At distances of 620 m or more from Longwall 311 to 316, the pipelines are located outside the Study Area and are not expected to experience measurable conventional vertical subsidence, tilts, curvatures, strains or valley closure (i.e. no greater than survey accuracy). The pipelines could however experience low level far-field horizontal movements. The far-field horizontal movements are expected to be similar to those observed for previous longwall mining in the Southern Coalfield.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The maximum absolute horizontal movements measured at distances greater than 620 m from mining are in the order of 60 mm based on the 95 % confidence level. The strains associated with these low level horizontal movements are not expected to be measurable.

Whilst the pipelines could experience low level far-field horizontal movements, the associated tilts, curvatures or strains are not expected to be measurable. Metropolitan Coal Mine has mined directly beneath approximately 3.5km of Watermain 1 and 2 (above Longwalls 301 to 305) with no adverse impacts. It is unlikely that the pipelines would experience adverse impacts as a result of Longwalls 311 to 316.

6.5. Dams, Reservoirs or Associated Works

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

The Woronora Dam wall is located approximately 4.5 km from the commencing end of Longwall 316 and the distance from the labyrinth spillway, which is to the south of the dam wall, is approximately 4.1 km.

The dam wall and spillway are located at large distances from Longwalls 311 to 316. It is not expected, therefore, that measurable conventional subsidence movements would occur at the dam wall and spillway.

Far-field horizontal movements have been measured up to distances of approximately 4 km from active longwalls, however, almost all of the measured data beyond approximately 2.5 km is within the order of survey tolerance or accuracy. A discussion of far-field horizontal movements is provided in Section 0.

It is unlikely that far-field movements would be observed at the distances of the dam wall and spillway from Longwalls 311 to 316.

7.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE PUBLIC AMENITIES

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

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

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

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the farm land and facilities located within the Study Area for Longwalls 311 to 316.

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

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

8.1. Agricultural Utilisation

The agricultural land classification types in the vicinity of the proposed Longwalls 311 to 316 are illustrated in Fig. 8.1.

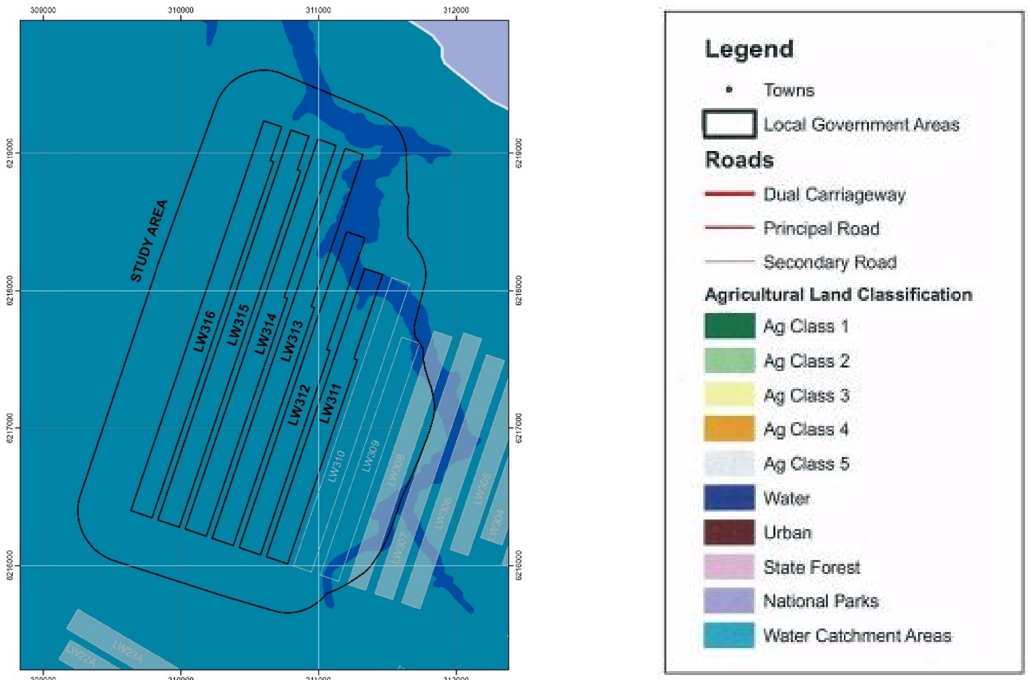

Fig. 8.1 Agricultural Land Classification within the Study Area (NSW DII, 2008)

It can be seen from the above figure, that the land classification within the Study Area is Water Catchment. There are no known agricultural activities within the Study Area.

8.2. Fences

Fences are located within the Study Area associated with the maintenance tracks.

The fences will experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence and tilt for the fences, based on the Extraction Plan Layout for Longwalls 311 to 316 are greater than the maxima predicted based on the Preferred Project Layout. The increased subsidence is the result of calibration of the model as discussed in Section 3.6. The predicted tilt based on the Extraction Plan Layout is greater than the Preferred Project Layout near the finishing ends of Longwalls 311 to 316 but is similar to the predicted tilt based on the Preferred Project Layout elsewhere. The predicted hogging and sagging curvature based on the Extraction Plan Layout for Longwalls 311 to 316 are similar to the maxima predicted based on the Preferred Project Layout for Longwalls 311 to 316.

The potential impacts on the fences, based on the Extraction Plan Layout are the same as those assessed based on the Preferred Project Layout. Fences can be affected by tilting of the fence posts and by changes of tension in the fence wires due to strain as mining occurs. Fences are generally flexible in construction and can usually tolerate significant tilts and strains.

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

It is recommended that management plans be developed to manage potential impacts on fences during the mining of Longwalls 311 to 316.

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

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

- Factories;
- Workshops;
- Business or commercial establishments or improvements;
- Gas or fuel storages and associated plant;
- Waste storages and associated plant;
- Exploration bores;
- Buildings, equipment or operations that are sensitive to surface movements; and
- Surface mining (open cut) voids and rehabilitated areas.

9.1. Any Other Industrial, Commercial or Business Features

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

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

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the archaeological and heritage sites located within the Study Area for Longwalls 311 to 316. The predicted parameters for each of the features have been compared to the predicted parameters based on the Preferred Project Layout.

10.1. Aboriginal Heritage Sites

10.1.1. Descriptions of the Aboriginal Heritage Sites

The detailed descriptions of the Aboriginal heritage sites are provided in the baseline reports prepared by Niche Environment and Heritage. There are 48 Aboriginal heritage sites that have been identified within the Study Area and an additional 3 Aboriginal heritage sites located to the north of the Study Area that have been included in the assessments. The locations of these sites are shown in Drawing No. MSEC1340-09.

The descriptions of the Aboriginal heritage sites within and near the Study Area are provided in Table D.02, in Appendix D. Of the 51 sites, 40 have sandstone overhangs of which 16 have art only, and seven have art and/or artefacts and/or deposits. Nine sites have grinding grooves.

10.1.2. Predictions for the Aboriginal Heritage Sites

The maximum predicted subsidence parameters for each of the Aboriginal heritage sites located within the Study Area is provided in Table D.02, in Appendix D. The predictions have been provided based on the Extraction Plan Layout and Preferred Project Layout.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the sites, resulting from the Extraction Plan Layout, is provided in Table 10.1. The predicted tilts provided in this table are the maxima after the completion of Longwalls 311 to 316. The predicted curvatures are the maxima at any time during or after the extraction of Longwalls 311 to 316.

Table 10.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Aboriginal Heritage Sites within the Study Area after the Extraction of Longwalls 311 to 316

Site Type	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Overhangs	1450	4.5	0.04	0.05
Open Site	1300	4.5	0.04	0.05

The maximum predicted conventional tilt for the sites is 4.5 mm/m (i.e. 0.5 %, or 1 in 220). The maximum predicted conventional curvatures are 0.04 km^{-1} hogging and 0.05 km^{-1} sagging, which equate to minimum radii of curvature of greater than 25 km and 20 km respectively.

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

Table 10.2 Predicted Strains for the Aboriginal heritage sites above solid coal based on conventional and non-conventional anomalous movements

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

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

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

Type	Conventional based on 15 times Curvature (mm/m)	Non-conventional based on the 95 % Confidence Level (mm/m)	Non-conventional based on the 99 % Confidence Level (mm/m)
Tension	1.0	0.9	1.6
Compression	1.0	1.6	3.2

10.1.3. Comparisons of the Predictions for the Aboriginal Heritage Sites

The comparisons of the maximum predicted conventional subsidence parameters for the Aboriginal heritage sites within the Study Area, resulting from the extraction of Longwalls 311 to 316, with those based on the Preferred Project Layout are provided in Table 10.4. A comparison of the maximum predicted subsidence parameters for each of the Aboriginal heritage sites located within the Study Area is provided in Table D.02, in Appendix D.

Table 10.4 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Aboriginal heritage sites based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Preferred Project Layout (Report No. MSEC403)	950	2.5	0.04	0.07
Extraction Plan Layout (Report No. MSEC1340)	1450	4.5	0.04	0.05

The maximum predicted subsidence and tilt for the Aboriginal Heritage sites, based on the Extraction Plan Layout for Longwalls 311 to 316 are greater than the maxima predicted based on the Preferred Project Layout. The increased subsidence is the result of calibration of the model as discussed in Section 3.6. The predicted tilt based on the Extraction Plan Layout is greater than the Preferred Project Layout near the finishing ends of Longwalls 311 to 316 but is similar to the predicted tilt based on the Preferred Project Layout elsewhere. The predicted hogging and sagging curvature based on the Extraction Plan Layout for Longwalls 311 to 316 are similar to or less than the maxima predicted based on the Preferred Project Layout for Longwalls 311 to 316.

It can be seen from Table D.02 in Appendix D that the predicted subsidence reduces at a large number of the Aboriginal Heritage sites. Reduction in the predicted vertical subsidence is the result of longwall length and orientation changes. There is an increase in the predicted vertical subsidence at 30 of the sites and a reduction or no change at 21 sites based on the Extraction Plan Layout when compared to the Preferred Project Layout after Longwall 316. The potential for impacts on these sites does not result from absolute vertical subsidence, but rather the differential movements (i.e. tilt, curvature and strain).

The predicted tilt increases at 24 of the 51 Aboriginal heritage sites based on the Extraction Plan Layout. The hogging curvatures based on the Extraction Plan Layout increase at 13 sites, and sagging curvatures at 7 sites compared to the Preferred Project Layout after Longwall 316.

The predicted tilts increase at approximately 47% of the Aboriginal heritage sites and the predicted hogging and sagging curvature increase at a small number of sites. The maximum tilt and curvatures are similar to or less than the maxima predicted for other Aboriginal heritage sites located above the previously extracted longwalls. The potential impacts for these sites based on the Extraction Plan Layout, therefore, are similar to those assessed based on the Preferred Project Layout.

10.1.4. Impact Assessments and Recommendations for the Aboriginal Heritage Sites

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

The magnitudes of predicted tilt and curvature for the majority of the Aboriginal heritage sites are small due to site locations above narrow geometry and solid coal. Impacts to the sites located above solid coal are considered unlikely. While surface fracturing of the bedrock can occur outside the longwall layouts, as discussed in Section 4.8, such fracturing is minor and isolated and the likelihood of fracturing impacting the Aboriginal Heritage Sites outside the longwall layouts is considered to be low.

Some sites are located close to or at the base of tributaries and could therefore experience valley related movements. The sites most likely to experience valley related movements include NT7, NT8, NT9, NT21, NT27 and NT46. With the exception of NT9 and NT21, the sites are located in very shallow valley profiles and are not expected to experience significant valley closure. NT9 and NT21 are located within deeper and more incised valley profiles and could experience valley closure of up to 300mm and 500mm respectively. Potential impacts resulting from valley closure are discussed in Sections 5.5 and 5.6.

To date, the cumulative percentage of sites affected by subsidence impacts at Metropolitan Coal Mine is less than 2 % (Niche 2019). Impacts have been recorded at 16 sites out of 143 identified sites, with two resulting in impacts to Aboriginal Heritage features, both being cracks through motifs and hand stencils.

The sites located near or above the longwall geometry with narrower panels and wider pillars, compared with previously extracted longwalls (20 to 27 and 301 to 304) results in lower predicted subsidence parameters and associated risk of surface impacts.

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

10.2. European Heritage Sites

There are no European Heritage sites within the Study Area.

10.3. Items of Architectural Significance

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

10.4. Survey Control Marks

There are no survey control marks within the Study Area. The survey control marks near the Study Area are shown in Drawing No. MSEC1340-09. The locations and details of the survey control marks were obtained from the *Land and Property Management Authority* using the *SCIMS Online* website (SCIMS, 2016).

The survey control marks are likely to experience far-field horizontal movements as the longwalls are mined. Far-field horizontal movements have been measured up to distances of approximately 3.9 km from active longwalls, however, almost all of the measured data beyond approximately 2.5 km is within the order of survey tolerance or accuracy. A discussion of far-field horizontal movements is provided in Section 0.

It would be necessary on the completion of Longwalls 311 to 316, when the ground has stabilised, to re-establish the coordinates for marks. The survey control network would be re-established following the completion of mining activities in consultation with Land and Property Information (LPI) NSW, as required by the *Surveyor General's Directions No.11 Preservation of Survey Infrastructure*."

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

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

- Flats or Units;
- Caravan Parks;
- Tennis courts;
- Swimming pools;
- On-site water systems; and
- Any other residential features.

APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

Glossary of Terms and Definitions

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

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

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

APPENDIX B. REFERENCES

References

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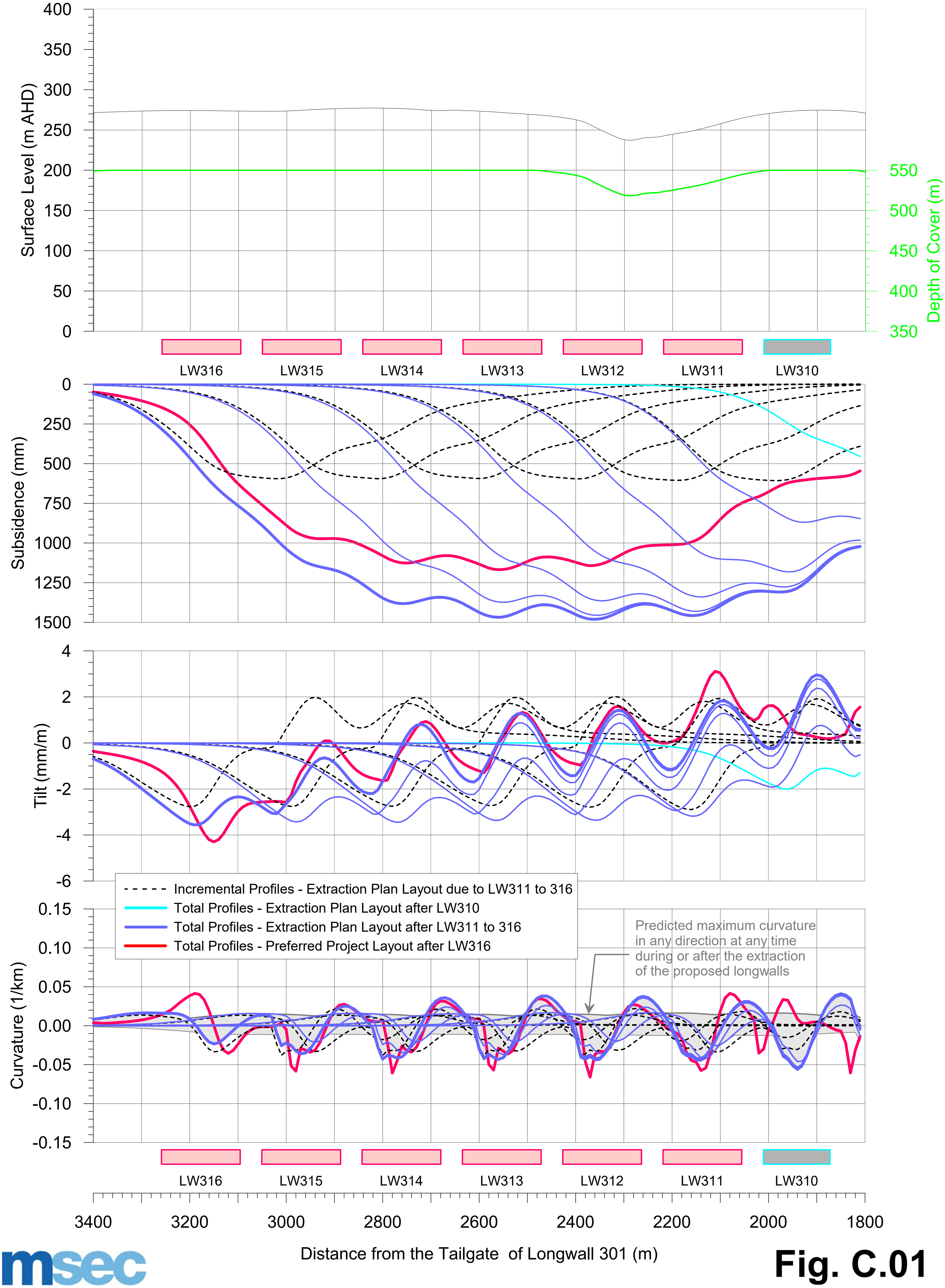
APPENDIX C. FIGURES

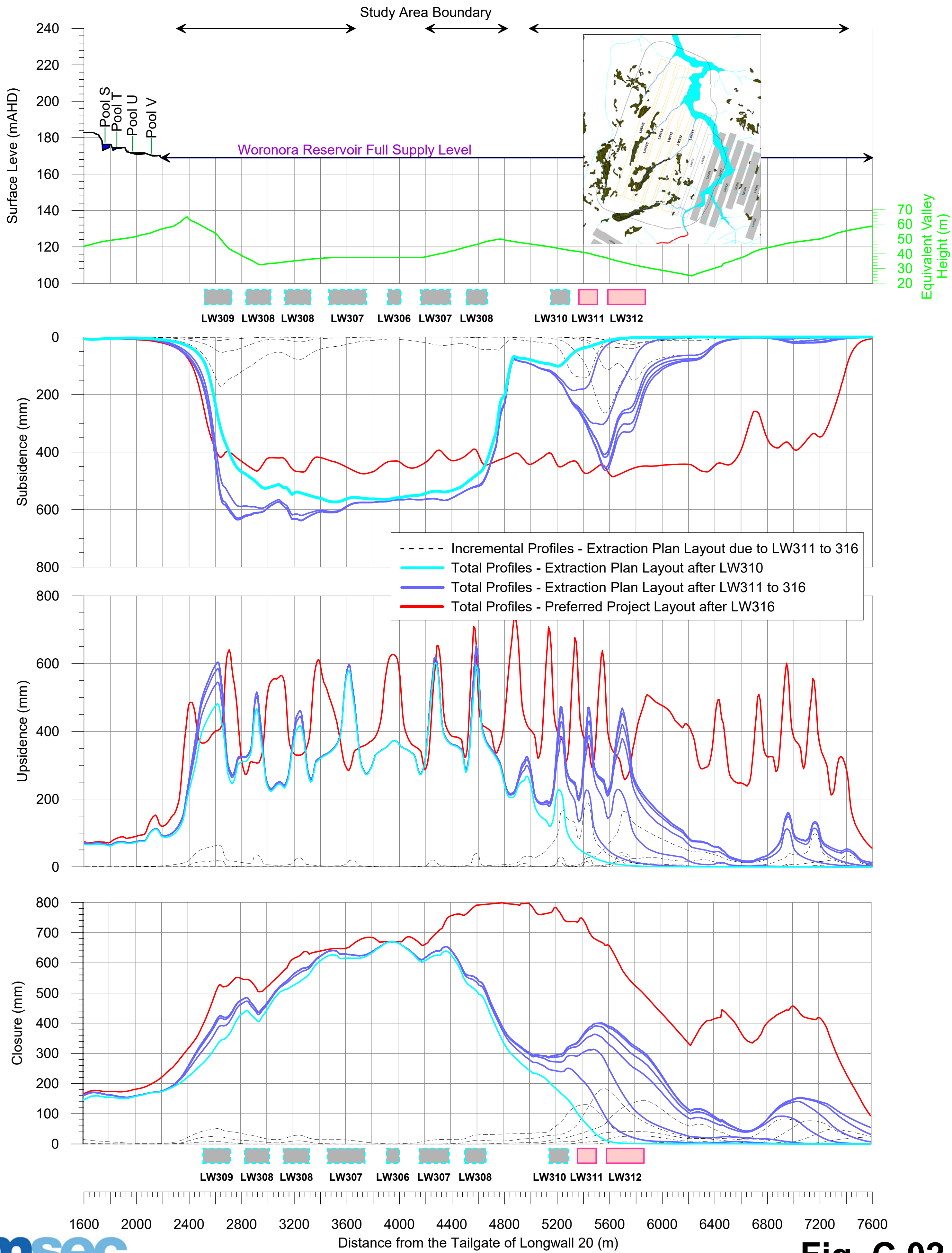
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 due to LW311 to 316



msec

Fig. C.01

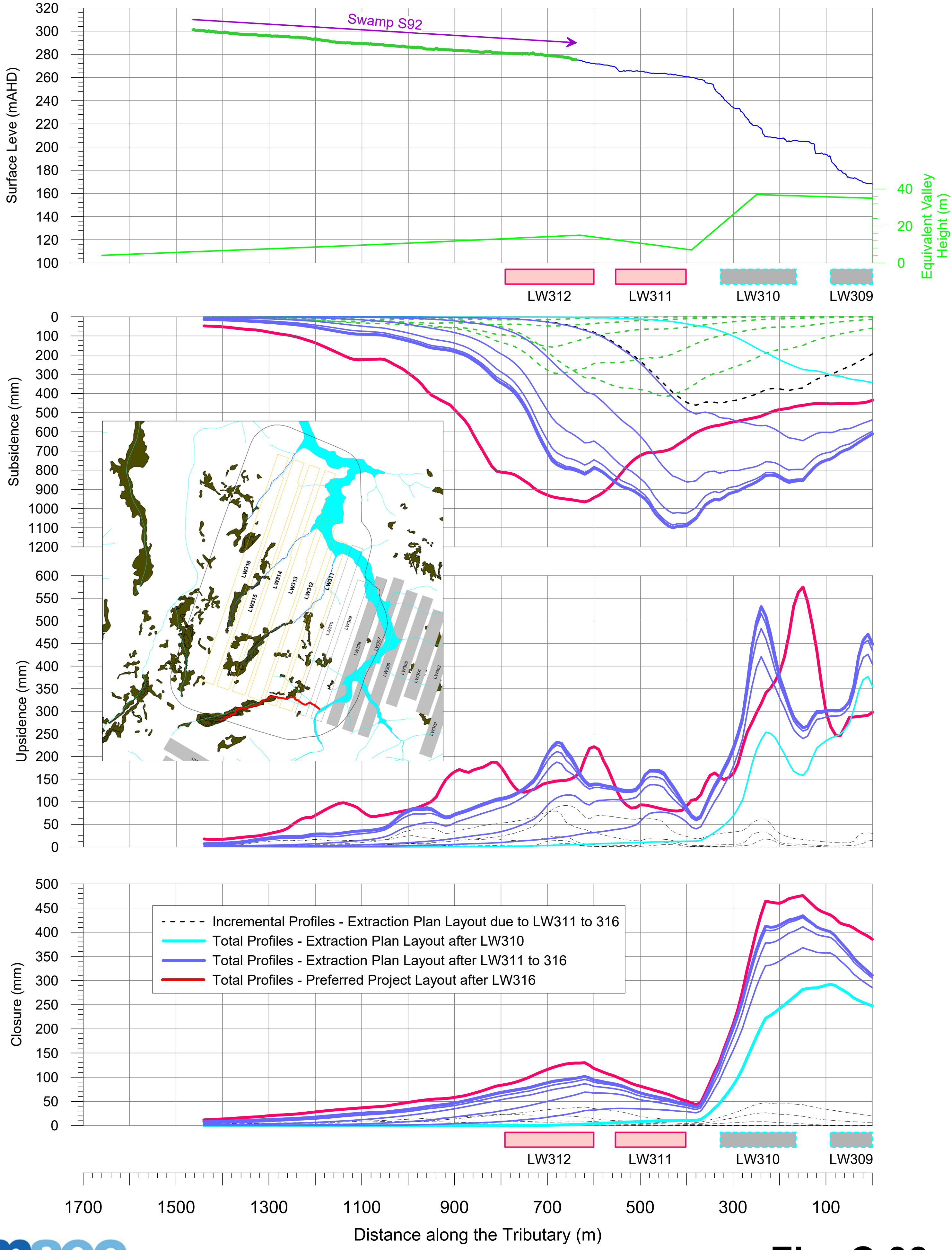
Predicted Profiles of Subsidence, Upsidence and Closure along Waratah Rivulet and Woronora Reservoir due to LW311 to 316



msec

Fig. C.02

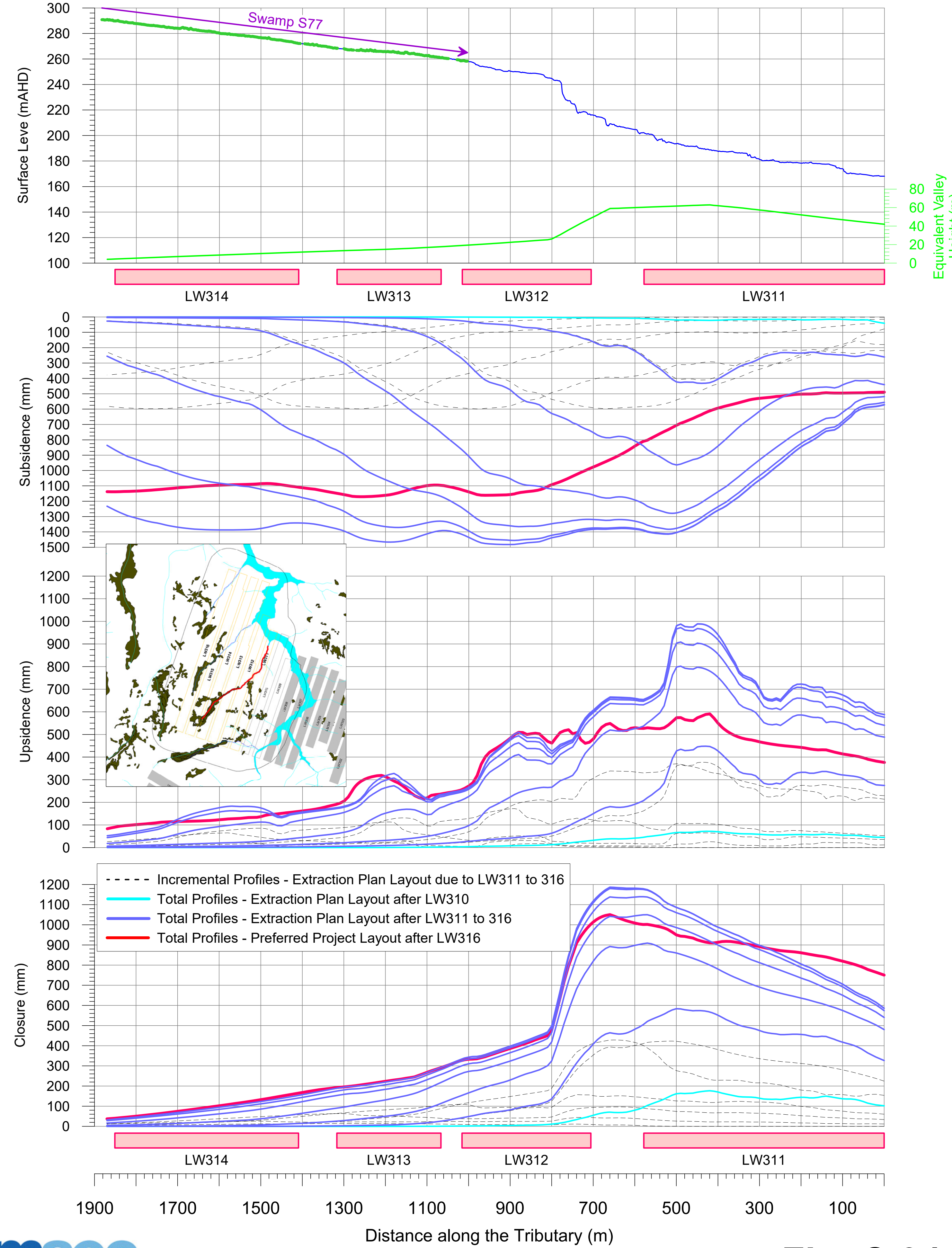
Predicted Profiles of Subsidence, Upsidence and Closure along Tributary P due to LW311 to 316 Extraction Plan Layout



msec

Fig. C.03

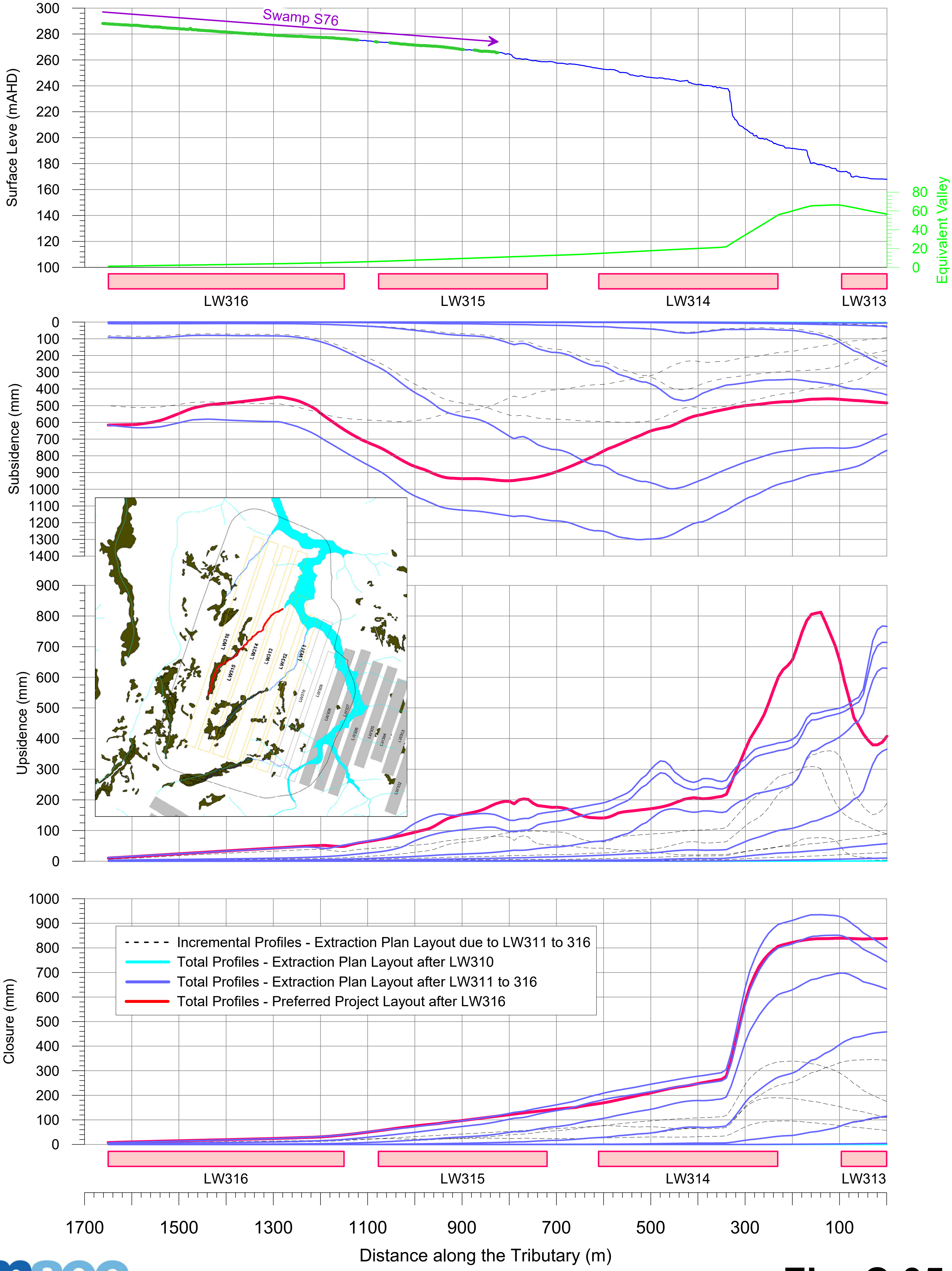
Predicted Profiles of Subsidence, Upsidence and Closure along Tributary R due to LW311 to 316 Extraction Plan Layout



msec

Fig. C.04

Predicted Profiles of Subsidence, Upsidence and Closure along Tributary S due to LW311 to 316 Extraction Plan Layout



msec

Fig. C.05

APPENDIX D. TABLES

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

Swamp	*Maximum Predicted Subsidence based on the Preferred Project Layout after LW316 (mm)*	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW311 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW312 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW313 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW314 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW315 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW316 (mm)	*Maximum Predicted Tilt based on the Preferred Project Layout after LW316 (mm/m)*	Maximum Predicted Tilt based on the Extraction Plan Layout after LW316 (mm/m)	*Maximum Predicted Hogging Curvature based on the Preferred Project Layout after LW316 (1/km)*	Maximum Predicted Hogging Curvature based on the Extraction Plan Layout after LW316 (1/km)	*Maximum Predicted Sagging Curvature based on the Preferred Project Layout after LW316 (1/km)*	Maximum Predicted Sagging Curvature based on the Extraction Plan Layout after LW316 (1/km)
S14	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S62	500	< 20	< 20	< 20	< 20	< 20	< 20	1.0	< 0.5	0.05	< 0.01	0.06	< 0.01
S74	40	< 20	< 20	< 20	< 20	< 20	175	< 0.5	2.0	< 0.01	0.02	< 0.01	< 0.01
S75	175	< 20	< 20	< 20	< 20	150	750	2.0	3.5	0.03	0.02	< 0.01	0.02
S76	975	< 20	< 20	40	300	900	1300	4.5	3.5	0.04	0.03	0.07	0.04
S77	1150	40	400	1000	1350	1450	1450	2.5	4.0	0.04	0.04	0.07	0.04
S78a	1100	650	1100	1350	1450	1450	1450	3.5	2.0	0.05	0.04	0.07	0.05
S78b	1050	550	1050	1350	1450	1450	1450	3.5	2.0	0.05	0.04	0.08	0.05
S79	1150	150	725	1150	1400	1450	1500	1.5	1.5	0.04	0.04	0.07	0.05
S80	1050	600	1100	1350	1450	1450	1450	3.5	2.0	0.05	0.03	0.08	0.05
S81	825	750	1100	1350	1450	1450	1450	2.5	2.0	0.05	0.03	0.06	0.05
S82	600	850	1150	1250	1300	1300	1300	1.5	3.0	0.04	0.04	0.06	0.05
S83	825	775	1150	1300	1350	1350	1350	2.5	2.0	0.05	0.03	0.06	0.02
S84	475	675	700	700	700	700	700	1.0	1.0	0.04	0.01	0.06	0.02
S86	500	800	900	925	925	925	925	1.5	2.0	0.04	0.02	0.06	0.05
S88	450	300	425	450	475	475	475	2.5	5.5	0.02	0.06	0.05	0.02
S89a	825	850	1150	1350	1450	1450	1450	3.0	6.5	0.05	0.03	0.06	0.06
S89b	1050	275	775	1050	1150	1200	1200	3.5	6.5	0.05	0.03	0.08	0.04
S90a	1050	200	775	1200	1400	1500	1500	1.0	1.5	0.03	0.04	0.08	0.05
S90b	1000	475	1050	1350	1450	1450	1450	3.5	1.5	0.05	0.03	0.07	0.05
S91	1100	< 20	< 20	40	300	775	1050	2.0	6.0	0.03	0.02	0.04	0.04
S92	1200	70	425	800	1150	1300	1350	5.0	7.0	0.04	0.06	0.07	0.04
S93	40	20	20	20	20	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S94	60	80	80	80	80	80	80	< 0.5	1.0	< 0.01	0.01	< 0.01	< 0.01
S102	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S103	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S104	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01

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

Swamp	Maximum Predicted Subsidence based on the Preferred Project Layout after LW316 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW311 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW312 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW313 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW314 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW315 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW316 (mm)	Maximum Predicted Tilt based on the Preferred Project Layout after LW316 (mm/m)	Maximum Predicted Tilt based on the Extraction Plan Layout after LW316 (mm/m)	Maximum Predicted Hogging Curvature based on the Preferred Project Layout after LW316 (1/km)	Maximum Predicted Hogging Curvature based on the Extraction Plan Layout after LW316 (1/km)	Maximum Predicted Sagging Curvature based on the Preferred Project Layout after LW316 (1/km)	Maximum Predicted Sagging Curvature based on the Extraction Plan Layout after LW316 (1/km)
S105	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S106	175	< 20	< 20	< 20	< 20	< 20	50	2.0	0.5	0.03	< 0.01	< 0.01	< 0.01
S107	600	< 20	< 20	< 20	< 20	20	150	4.0	2.0	0.04	0.02	0.03	< 0.01
S108	550	< 20	< 20	< 20	< 20	< 20	100	3.5	1.5	< 0.01	0.01	0.03	< 0.01
S109	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S113	225	< 20	< 20	< 20	< 20	< 20	175	2.0	2.0	0.03	0.02	< 0.01	< 0.01
S114	450	< 20	< 20	< 20	< 20	40	325	4.5	3.0	0.05	0.02	< 0.01	< 0.01
S115	300	< 20	< 20	< 20	< 20	30	275	3.5	2.5	0.05	0.02	< 0.01	< 0.01
S116	20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S117	50	< 20	< 20	< 20	< 20	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S118	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S119	125	< 20	< 20	< 20	< 20	< 20	150	1.0	1.5	< 0.01	0.02	< 0.01	< 0.01
S120	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S121	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S122	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S123	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S124	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S125	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S126	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S127	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S128	30	< 20	< 20	< 20	< 20	30	325	< 0.5	3.0	< 0.01	0.02	< 0.01	< 0.01
S129	< 20	< 20	< 20	< 20	< 20	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S130	60	< 20	< 20	< 20	< 20	60	500	0.5	3.5	< 0.01	0.02	< 0.01	< 0.01
S131	< 20	< 20	< 20	< 20	< 20	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S132	< 20	< 20	< 20	< 20	< 20	20	90	< 0.5	1.0	< 0.01	0.01	< 0.01	< 0.01
S135	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S136	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S139	950	< 20	< 20	20	200	800	1200	2.5	3.0	0.04	0.03	0.07	0.04

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

Swamp	*Predicted Conventional Tensile Strain based on the Preferred Project Layout after LW316 (mm/m)*	Predicted Conventional Tensile Strain based on the Extraction Plan Layout after LW316 (mm/m)	*Predicted Conventional Compressive Strain based on the Preferred Project Layout after LW316 (mm/m)*	Predicted Conventional Compressive Strain based on the Extraction Plan Layout after LW316 (mm/m)	*Maximum Predicted Upsidence based on the Preferred Project Layout after LW316 (mm)*	Maximum Predicted Upsidence based on the Extraction Plan Layout after LW316 (mm)	*Maximum Predicted Closure based on the Preferred Project Layout after LW316 (mm)*	Maximum Predicted Closure based on the Extraction Plan Layout after LW316 (mm)
S14	< 0.5	< 0.5	< 0.5	< 0.5	*< 20*	< 20	*20*	20
S62	1.00	< 0.5	1.00	< 0.5	-	-	-	-
S74	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S75	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S76	1.00	< 0.5	1.50	1.00	*200*	150	*125*	125
S77	1.00	0.50	1.50	0.50	*325*	325	*325*	350
S78a	1.00	1.00	1.50	1.00	-	-	-	-
S78b	1.00	1.00	1.50	1.00	-	-	-	-
S79	1.00	1.00	1.50	1.00	-	-	-	-
S80	1.00	< 0.5	1.50	1.00	-	-	-	-
S81	1.00	1.00	1.00	1.00	*50*	70	*40*	40
S82	1.00	1.00	1.00	1.00	*225*	250	*175*	200
S83	1.00	< 0.5	1.00	< 0.5	-	-	-	-
S84	1.00	< 0.5	1.00	< 0.5	-	-	-	-
S86	1.00	< 0.5	1.00	1.00	-	-	-	-
S88	< 0.5	1.00	1.00	< 0.5	-	-	-	-
S89a	1.00	< 0.5	1.00	1.00	-	-	-	-
S89b	1.00	< 0.5	1.50	1.00	-	-	-	-
S90a	< 0.5	1.00	1.50	1.00	*40*	60	*30*	30
S90b	1.00	< 0.5	1.50	1.00	*50*	40	*30*	30
S91	< 0.5	< 0.5	1.00	1.00	-	-	-	-
S92	1.00	1.00	1.50	1.00	*200*	225	*125*	100
S93	< 0.5	< 0.5	< 0.5	< 0.5	*< 20*	< 20	*< 20*	< 20
S94	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S102	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S103	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S104	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-

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

Swamp	*Predicted Conventional Tensile Strain based on the Preferred Project Layout after LW316 (mm/m)*	Predicted Conventional Tensile Strain based on the Extraction Plan Layout after LW316 (mm/m)	*Predicted Conventional Compressive Strain based on the Preferred Project Layout after LW316 (mm/m)*	Predicted Conventional Compressive Strain based on the Extraction Plan Layout after LW316 (mm/m)	*Maximum Predicted Upsidence based on the Preferred Project Layout after LW316 (mm)*	Maximum Predicted Upsidence based on the Extraction Plan Layout after LW316 (mm)	*Maximum Predicted Closure based on the Preferred Project Layout after LW316 (mm)*	Maximum Predicted Closure based on the Extraction Plan Layout after LW316 (mm)
S105	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S106	< 0.5	< 0.5	< 0.5	< 0.5	*< 20*	< 20	*< 20*	< 20
S107	1.00	< 0.5	1.00	< 0.5	-	-	-	-
S108	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S109	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S113	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S114	1.00	< 0.5	< 0.5	< 0.5	-	-	-	-
S115	1.00	< 0.5	< 0.5	< 0.5	-	-	-	-
S116	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S117	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S118	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S119	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S120	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S121	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S122	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S123	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S124	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S125	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S126	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S127	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S128	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S129	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S130	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S131	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S132	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S135	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S136	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S139	1.00	< 0.5	1.50	1.00	-	-	-	-

Note: Predicted conventional strains are based on 15 times curvature

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

Site	Description	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW316 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW311 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW312 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW313 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW314 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW315 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW316 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW316 (mm/m)*	Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW316 (mm/m)
FRC 164	Open site with grinding grooves only	*150*	50	80	100	125	125	125	*1.5*	1.0
FRC 184	Sandstone overhang with artefacts and deposit	*425*	375	375	400	400	400	400	*1.0*	1.5
FRC 185	Sandstone overhang with art, artefacts and deposit	*425*	525	550	550	550	550	550	*< 0.5*	1.5
FRC 186	Sandstone overhang with art and deposit	*450*	650	675	675	675	675	675	*< 0.5*	0.5
FRC 187	Sandstone overhang with art only	*450*	675	700	725	725	725	725	*< 0.5*	1.0
FRC 189	Sandstone overhang with art only	*475*	725	875	925	925	925	925	*< 0.5*	2.5
FRC 191	Sandstone overhang with art only	*500*	775	850	875	875	875	875	*1.5*	2.0
FRC 193	Open site with grinding grooves only	*125*	< 20	< 20	30	40	50	50	*1.0*	< 0.5
FRC 194	Sandstone overhang with art only	*70*	50	60	70	70	70	70	*0.5*	0.5
FRC 195	Sandstone overhang with art only	*40*	30	30	40	40	40	40	*< 0.5*	< 0.5
FRC 198	Sandstone overhang with art only	*450*	650	675	700	700	700	700	*< 0.5*	1.5
FRC 199	Sandstone overhang with art only	*80*	50	60	70	70	70	70	*1.0*	0.5
FRC 314	Sandstone overhang with art and PAD	*475*	< 20	< 20	40	40	40	40	*< 0.5*	< 0.5
FRC 315	Sandstone overhang with PAD only	*475*	< 20	< 20	40	40	40	40	*< 0.5*	< 0.5
FRC 340	Sandstone overhang with art only	*475*	500	525	550	550	550	550	*1.5*	2.0
FRC 344	Sandstone overhang with artefacts and deposit	*525*	825	900	925	925	925	925	*< 0.5*	2.0
FRC 345	Sandstone overhang with artefacts and deposit	*525*	825	925	925	950	950	950	*< 0.5*	1.5
FRC 61	Sandstone overhang with PAD only	*90*	< 20	< 20	30	40	50	50	*0.5*	< 0.5
FRC 62	Sandstone overhang with art and PAD and/or grinding grooves	*60*	< 20	< 20	30	30	30	30	*< 0.5*	< 0.5
FRC 97	Sandstone overhang with art only	*450*	650	650	650	650	650	650	*< 0.5*	< 0.5
NT 10	Sandstone overhang site	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
NT 11	Sandstone overhang with art only	*725*	50	375	950	1300	1400	1400	*1.0*	1.0
NT 12	Open site	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
NT 17	Open site	*30*	< 20	< 20	< 20	< 20	20	250	*< 0.5*	2.5
NT 18	Sandstone overhang site	*125*	< 20	< 20	30	50	200	650	*1.5*	2.0
NT 19	Sandstone overhang with art only	*475*	< 20	< 20	< 20	40	60	60	*1.0*	0.5
NT 21	Open site	*30*	< 20	< 20	< 20	30	60	475	*< 0.5*	4.5
NT 29	Open site	*20*	< 20	< 20	< 20	< 20	40	250	*< 0.5*	2.5

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

Site	Description	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW316 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW311 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW312 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW313 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW314 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW315 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW316 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW316 (mm/m)*	Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW316 (mm/m)
NT 3	Sandstone overhang with art and PAD	*425*	< 20	< 20	50	200	750	1000	*< 0.5*	< 0.5
NT 33	Sandstone overhang with art and PAD	*950*	575	1100	1350	1450	1450	1450	*2.5*	1.5
NT 34	Sandstone overhang - art and PAD and/or grinding grooves	*850*	625	1100	1350	1400	1450	1450	*2.5*	1.5
NT 35	Sandstone overhang with art and PAD and/or grinding grooves	*925*	500	1050	1350	1450	1450	1450	*1.5*	1.0
NT 4	Sandstone overhang site	*40*	< 20	< 20	< 20	< 20	50	450	*< 0.5*	4.0
NT 46	Open site with grinding grooves and engravings	*950*	< 20	< 20	< 20	150	725	1150	*1.0*	1.0
NT 5	Sandstone overhang site	*30*	< 20	< 20	< 20	20	50	425	*< 0.5*	4.5
NT 6	Sandstone overhang with art and PAD	*525*	< 20	< 20	< 20	125	700	1150	*< 0.5*	1.0
NT 7	Open site with grinding grooves only	*775*	< 20	< 20	40	325	925	1300	*< 0.5*	2.0
NT 74	Sandstone overhang site	*60*	< 20	< 20	< 20	< 20	< 20	60	*0.5*	0.5
NT 75	Sandstone overhang site	*70*	< 20	< 20	< 20	< 20	< 20	60	*0.5*	0.5
NT 77	Sandstone overhang with art only	*30*	< 20	< 20	< 20	< 20	< 20	30	*< 0.5*	< 0.5
NT 78	Sandstone overhang with art only	*450*	90	375	500	550	575	600	*0.5*	1.5
NT 79	Sandstone overhang with art only	*450*	100	375	475	500	550	550	*0.5*	2.0
NT 8	Open site with grinding grooves and engravings	*575*	< 20	< 20	70	475	975	1250	*1.0*	2.0
NT 80	Sandstone overhang with PAD only	*475*	< 20	30	175	425	700	850	*1.0*	2.0
NT 81	Sandstone overhang with PAD only	*475*	< 20	< 20	80	350	600	675	*0.5*	1.5
NT 85	Sandstone overhang site	*70*	< 20	< 20	< 20	< 20	< 20	40	*0.5*	< 0.5
NT 9	Sandstone overhang with art and PAD	*525*	< 20	< 20	70	425	875	1100	*1.0*	2.5
NEW-RS-01	Sandstone overhang with art only	*150*	< 20	< 20	< 20	< 20	< 20	30	*2.0*	< 0.5
NEW-RS-02	Shelter with art	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
NEW-ST-01	Potential scarred tree	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
NEW-GG-01	Grinding grooves	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5

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

Site	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW316 (1/km)*	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW316 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW316 (1/km)*	Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW316 (1/km)	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW316 (mm/m)*	Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW316 (mm/m)	*Maximum Predicted Total Compressive Strain based on the Preferred Project Layout after LW316 (mm/m)*	Predicted Total Conventional Comp. Strain based on the Extraction Plan Layout after LW316 (mm/m)
FRC 164	*0.02*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 184	*0.04*	0.02	*0.02*	< 0.01	*1.0*	< 0.5	*< 0.5*	< 0.5
FRC 185	*< 0.01*	0.01	*0.02*	0.02	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 186	*< 0.01*	0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 187	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 189	*0.02*	0.03	*0.02*	0.02	*< 0.5*	1.0	*< 0.5*	< 0.5
FRC 191	*0.03*	0.02	*0.06*	0.05	*< 0.5*	< 0.5	*1.0*	1.0
FRC 193	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 194	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 195	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 198	*0.01*	0.03	*0.02*	0.02	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 199	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 314	*0.01*	< 0.01	*0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 315	*0.01*	< 0.01	*0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 340	*0.02*	0.02	*0.07*	0.01	*< 0.5*	< 0.5	*1.5*	< 0.5
FRC 344	*0.01*	0.01	*< 0.01*	0.02	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 345	*< 0.01*	0.01	*0.02*	0.02	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 61	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 62	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 97	*< 0.01*	< 0.01	*0.02*	0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 10	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 11	*0.03*	0.01	*0.05*	0.05	*< 0.5*	< 0.5	*1.0*	1.0
NT 12	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 17	*< 0.01*	0.02	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 18	*0.03*	0.03	*< 0.01*	0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 19	*0.02*	< 0.01	*0.05*	< 0.01	*< 0.5*	< 0.5	*1.0*	< 0.5
NT 21	*< 0.01*	0.04	*< 0.01*	0.02	*< 0.5*	1.0	*< 0.5*	< 0.5
NT 29	*< 0.01*	0.03	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5

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

Site	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW316 (1/km)*	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW316 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW316 (1/km)*	Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW316 (1/km)	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW316 (mm/m)*	Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW316 (mm/m)	*Maximum Predicted Total Compressive Strain based on the Preferred Project Layout after LW316 (mm/m)*	Predicted Total Conventional Comp. Strain based on the Extraction Plan Layout after LW316 (mm/m)
NT 3	*0.03*	0.02	*0.04*	0.03	*< 0.5*	< 0.5	*1.0*	< 0.5
NT 33	*0.01*	0.02	*0.06*	0.04	*< 0.5*	< 0.5	*1.0*	1.0
NT 34	*0.03*	0.02	*0.05*	0.04	*< 0.5*	< 0.5	*1.0*	1.0
NT 35	*0.03*	0.02	*0.03*	0.04	*< 0.5*	< 0.5	*1.0*	1.0
NT 4	*< 0.01*	0.03	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 46	*0.03*	0.02	*0.04*	0.02	*< 0.5*	< 0.5	*1.0*	< 0.5
NT 5	*< 0.01*	0.04	*< 0.01*	< 0.01	*< 0.5*	1.0	*< 0.5*	< 0.5
NT 6	*0.03*	0.02	*0.02*	0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 7	*0.03*	0.02	*0.02*	0.02	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 74	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 75	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 77	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 78	*0.04*	0.02	*0.02*	0.03	*1.0*	< 0.5	*< 0.5*	< 0.5
NT 79	*0.04*	0.01	*0.02*	0.04	*1.0*	< 0.5	*< 0.5*	1.0
NT 8	*0.03*	0.01	*0.05*	0.05	*< 0.5*	< 0.5	*1.0*	1.0
NT 80	*0.04*	0.02	*0.02*	0.04	*1.0*	< 0.5	*< 0.5*	1.0
NT 81	*0.01*	0.02	*0.01*	0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 85	*0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 9	*0.03*	0.04	*0.03*	0.02	*1.0*	1.0	*< 0.5*	< 0.5
NEW-RS-01	*0.03*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NEW-RS-02	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NEW-ST-01	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NEW-GG-01	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5

APPENDIX E. DRAWINGS

I:\Projects\Metropolitan\MSEC1340 - LW311 to 316 Extraction Plan\AcadData\MSEC1340-01 General Layout.dwg

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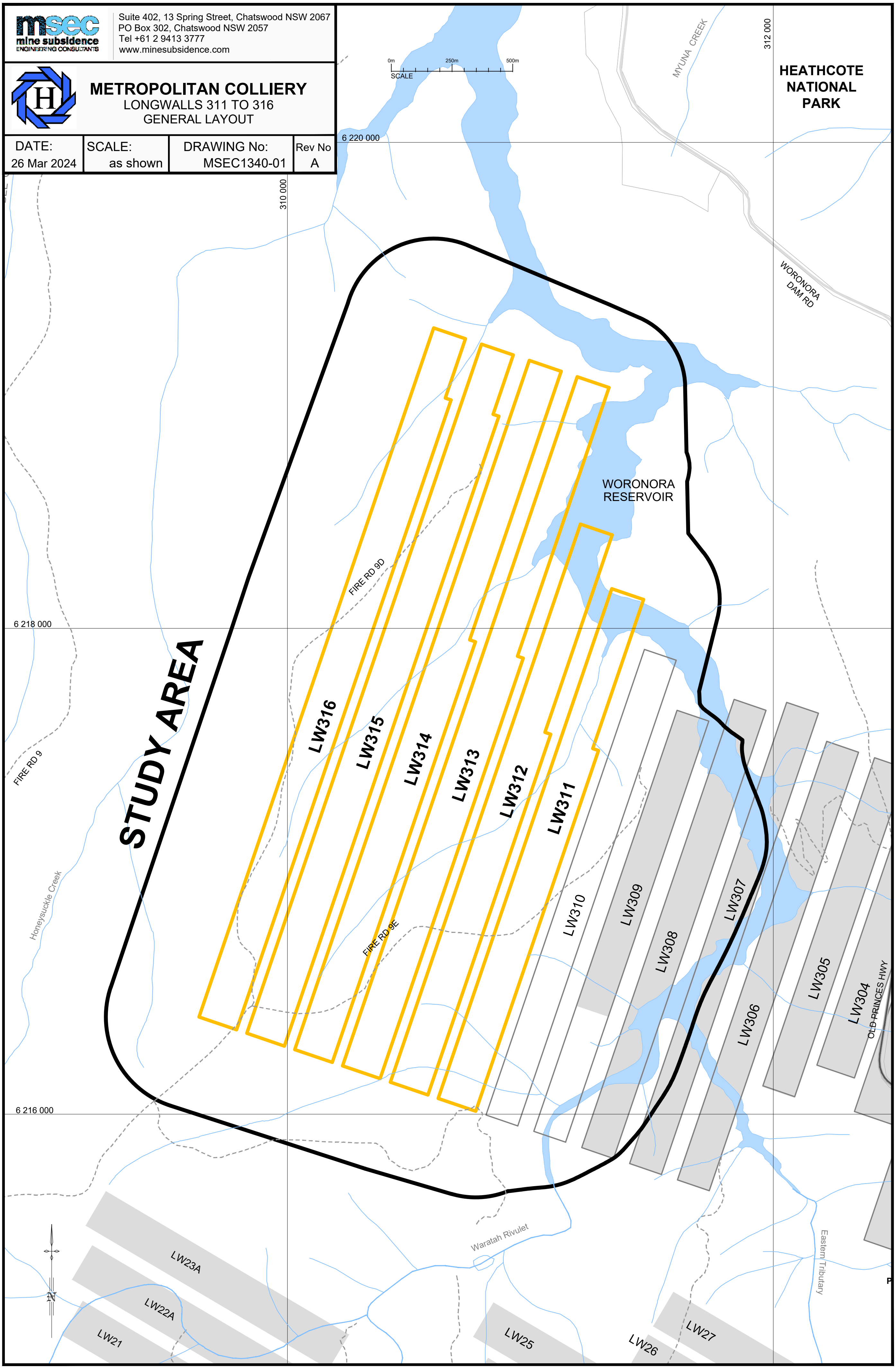
METROPOLITAN COLLIERY
LONGWALLS 311 TO 316
GENERAL LAYOUT

DATE:	SCALE:	DRAWING No:	Rev No
26 Mar 2024	as shown	MSEC1340-01	A



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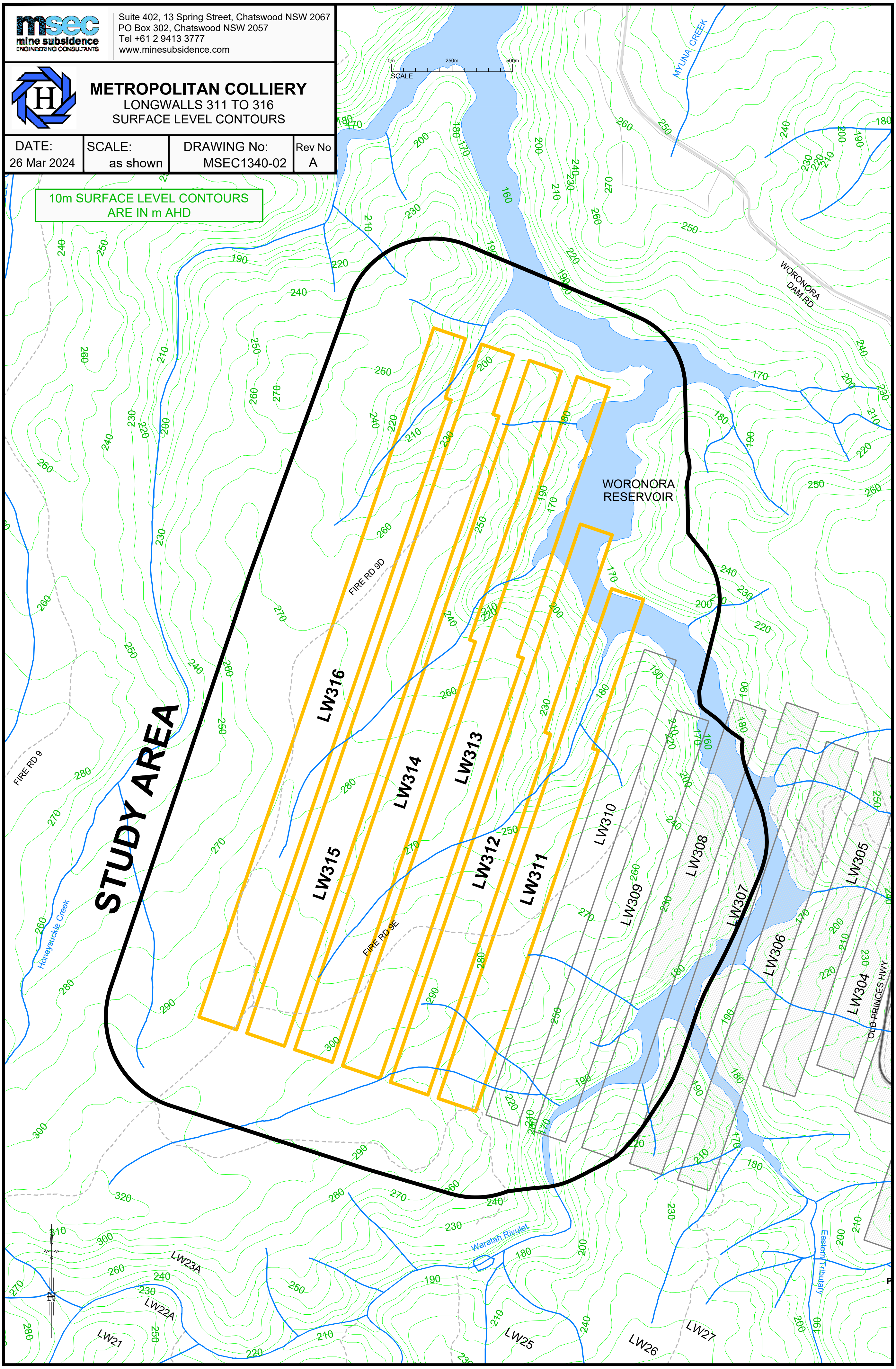
METROPOLITAN COLLIERY
LONGWALLS 311 TO 316
SURFACE LEVEL CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
26 Mar 2024	as shown	MSEC1340-02	A

10m SURFACE LEVEL CONTOURS ARE IN m AHD



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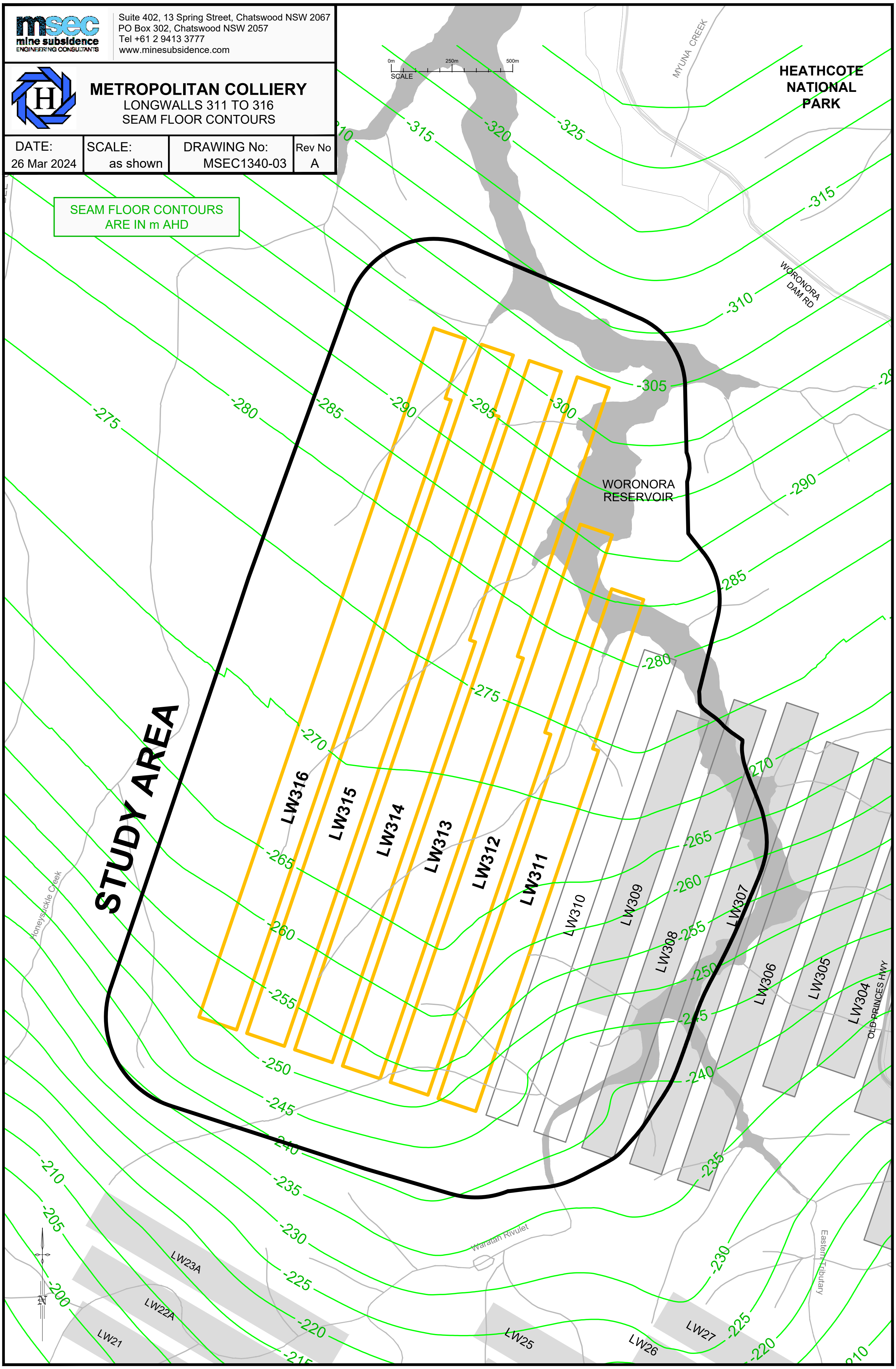

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METROPOLITAN COLLIERY
LONGWALLS 311 TO 316
SEAM THICKNESS CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
26 Mar 2024	as shown	MSEC1340-04	A

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LONGWALLS 311 TO 316
DEPTH OF COVER CONTOURS

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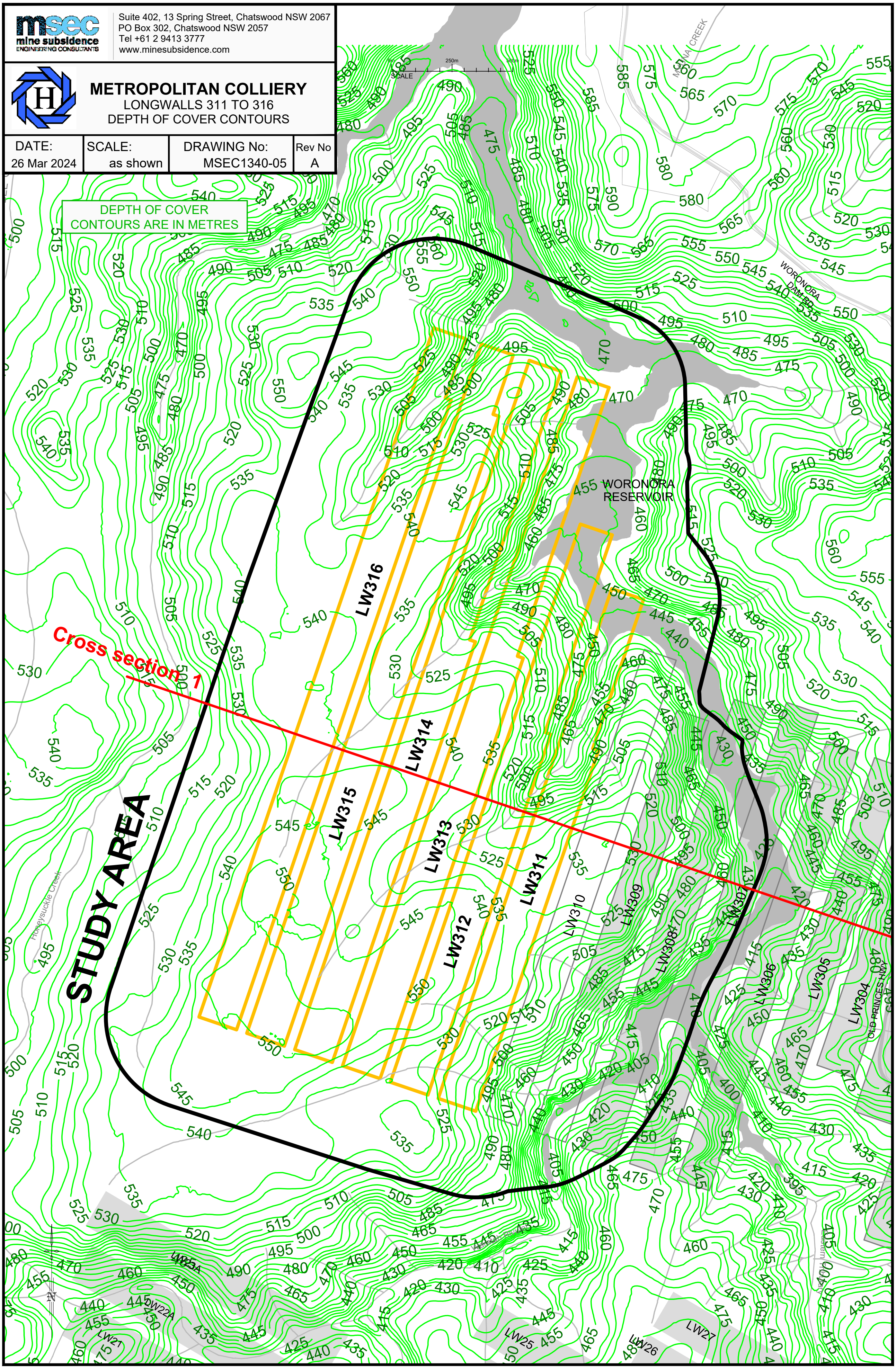
26 Mar 2024	as shown	MSEC1340-05	A



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LONGWALLS 311 TO 316
GEOLOGICAL STRUCTURES

DATE:	SCALE:	DRAWING No:	Rev No
26 Mar 2024	as shown	MSEC1340-06	A

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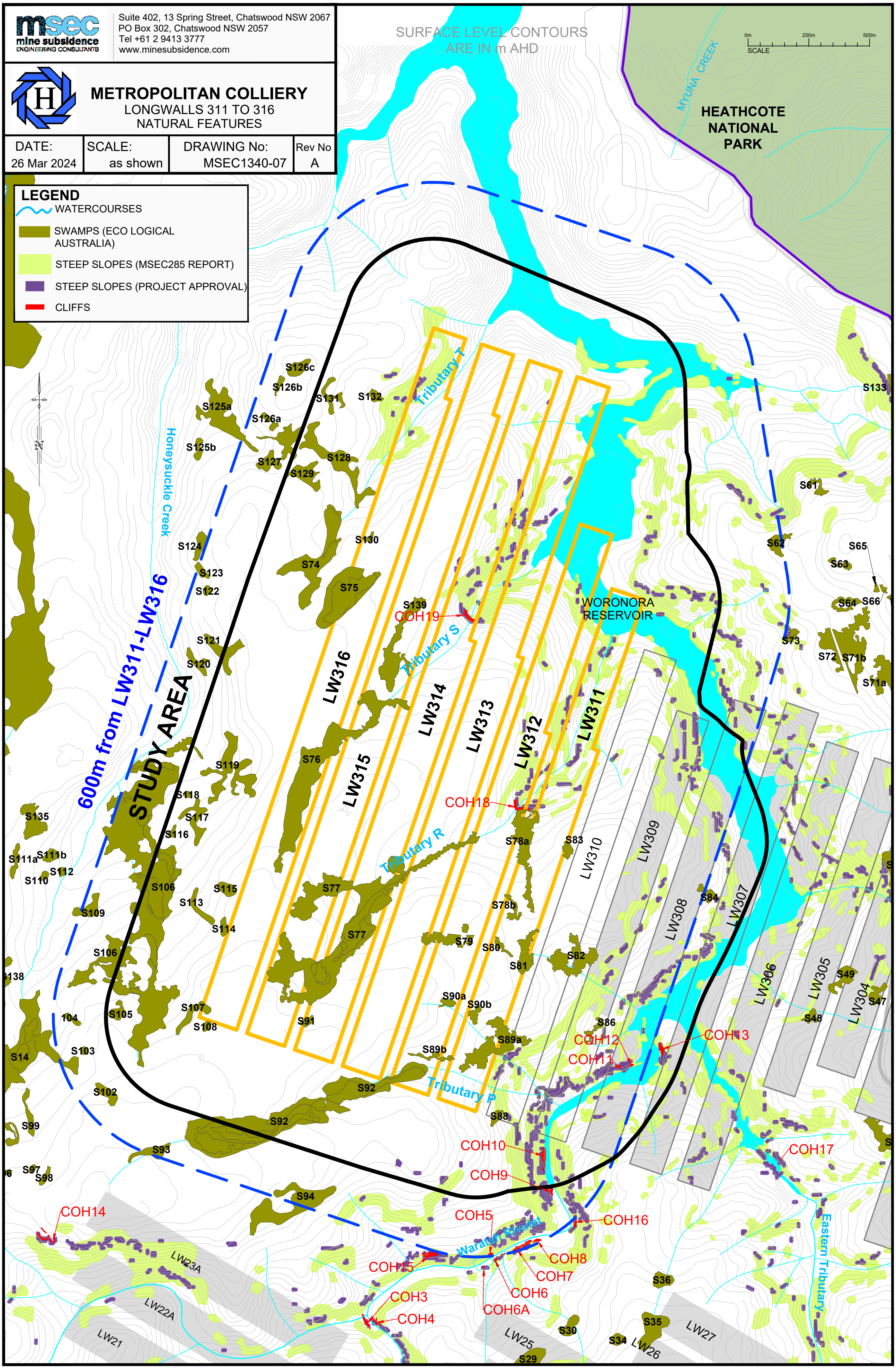

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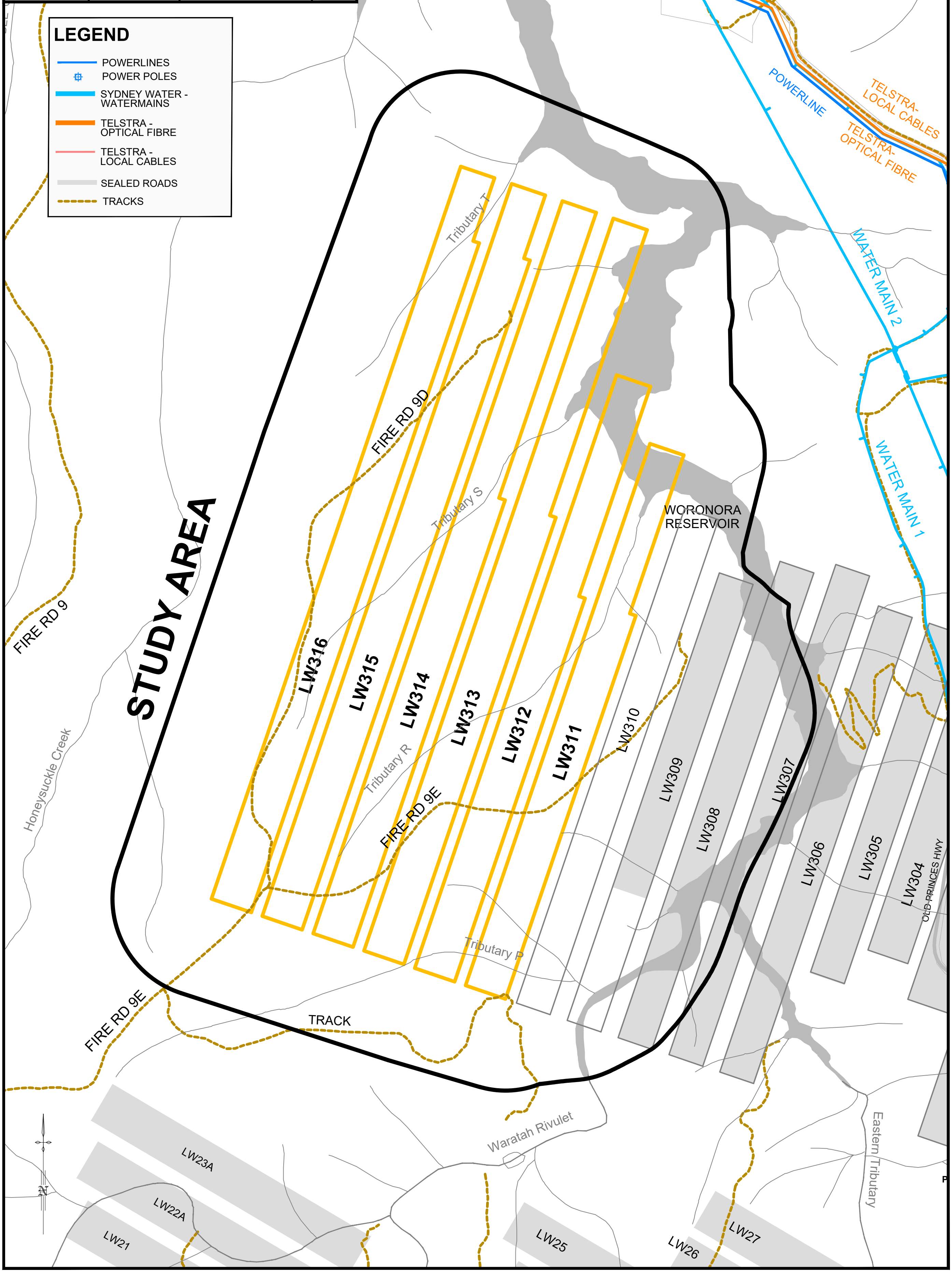
METROPOLITAN COLLIERY
LONGWALLS 311 TO 316
SURFACE INFRASTRUCTURE

DATE:	SCALE:	DRAWING No:	Rev No
26 Mar 2024	as shown	MSEC1340-08	A



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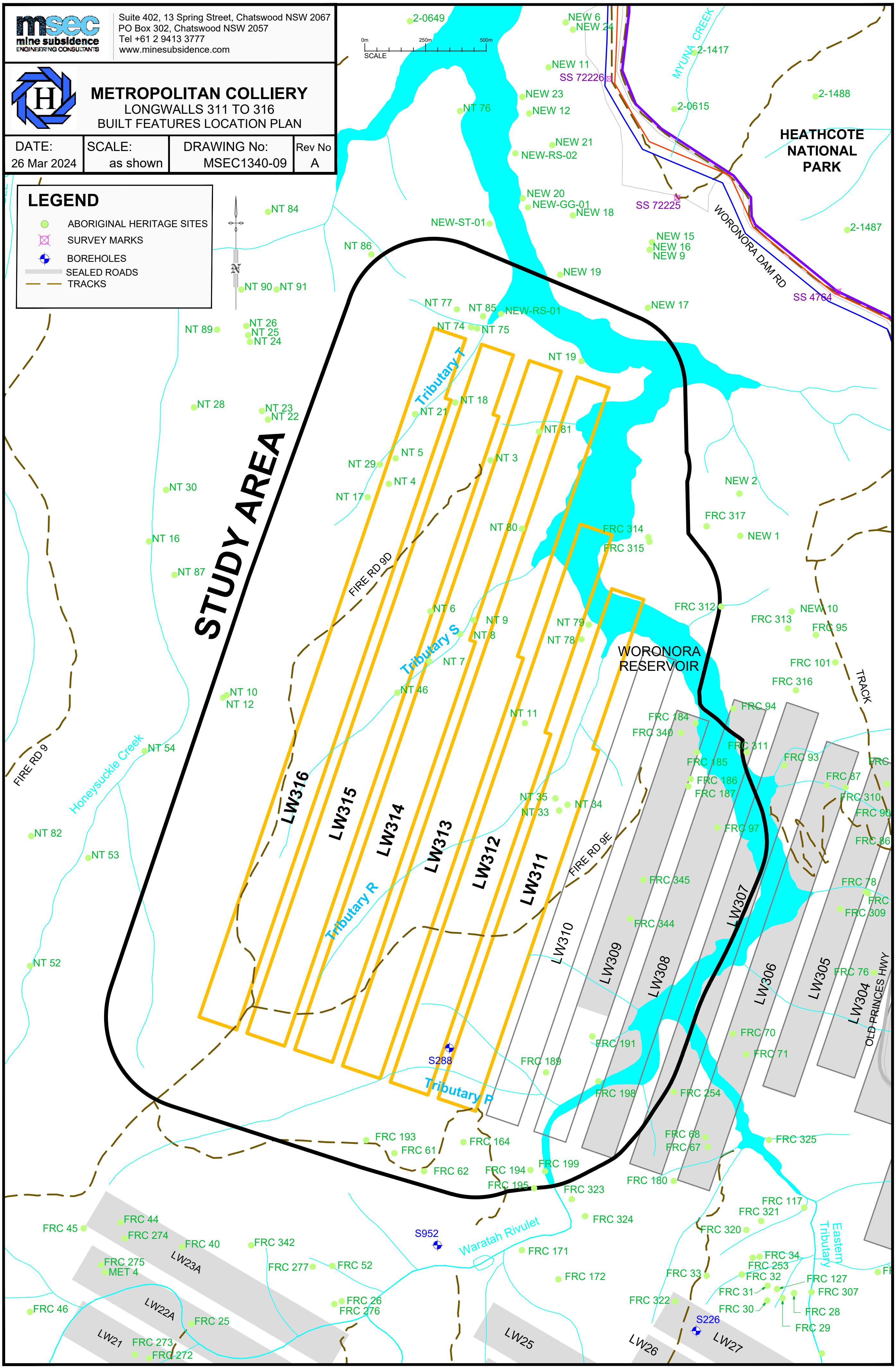

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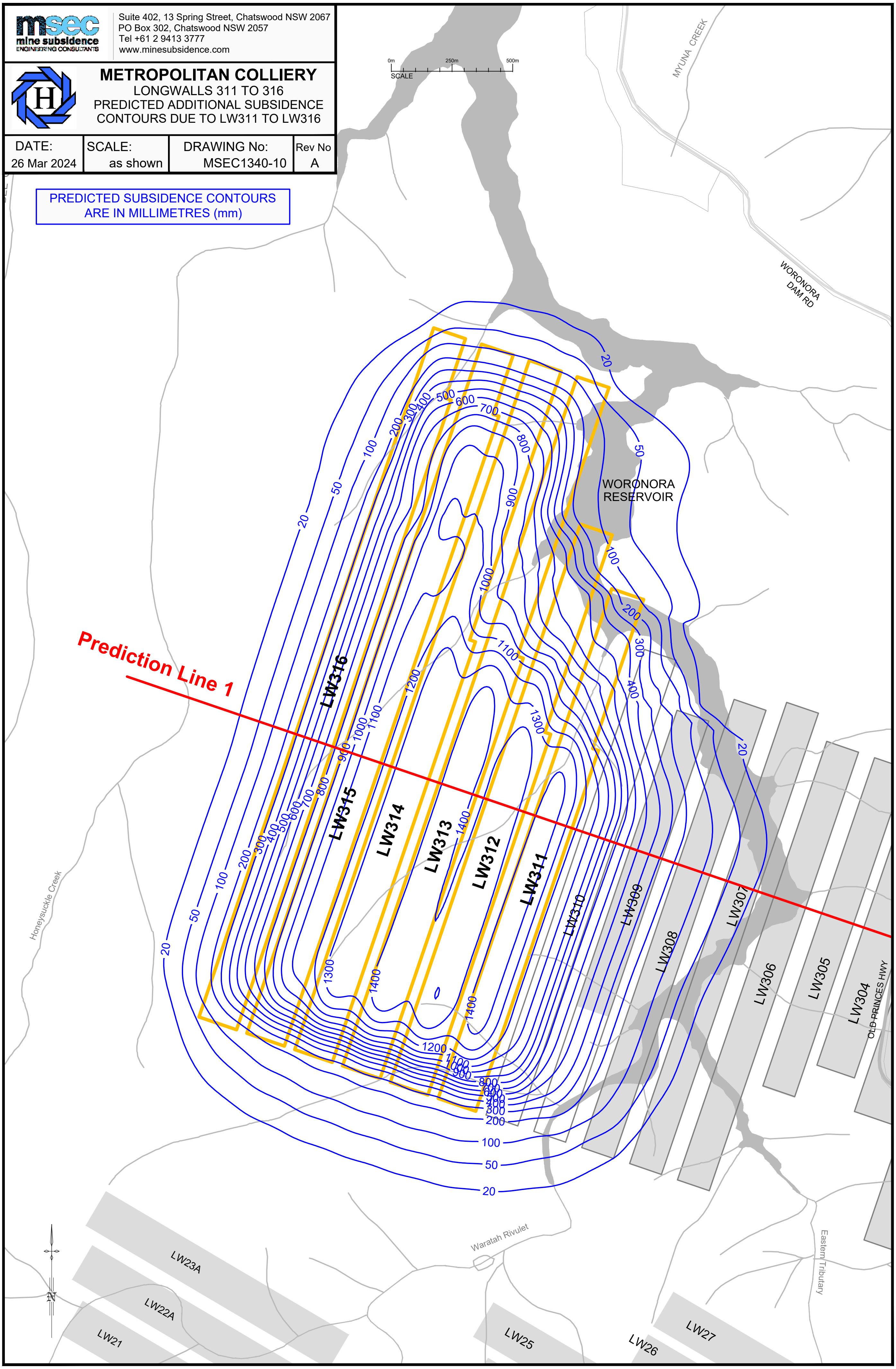
METROPOLITAN COLLIERY
LONGWALLS 311 TO 316
PREDICTED ADDITIONAL SUBSIDENCE CONTOURS DUE TO LW311 TO LW316

DATE:	SCALE:	DRAWING No:	Rev No
26 Mar 2024	as shown	MSEC1340-10	A

PREDICTED SUBSIDENCE CONTOURS ARE IN MILLIMETRES (mm)



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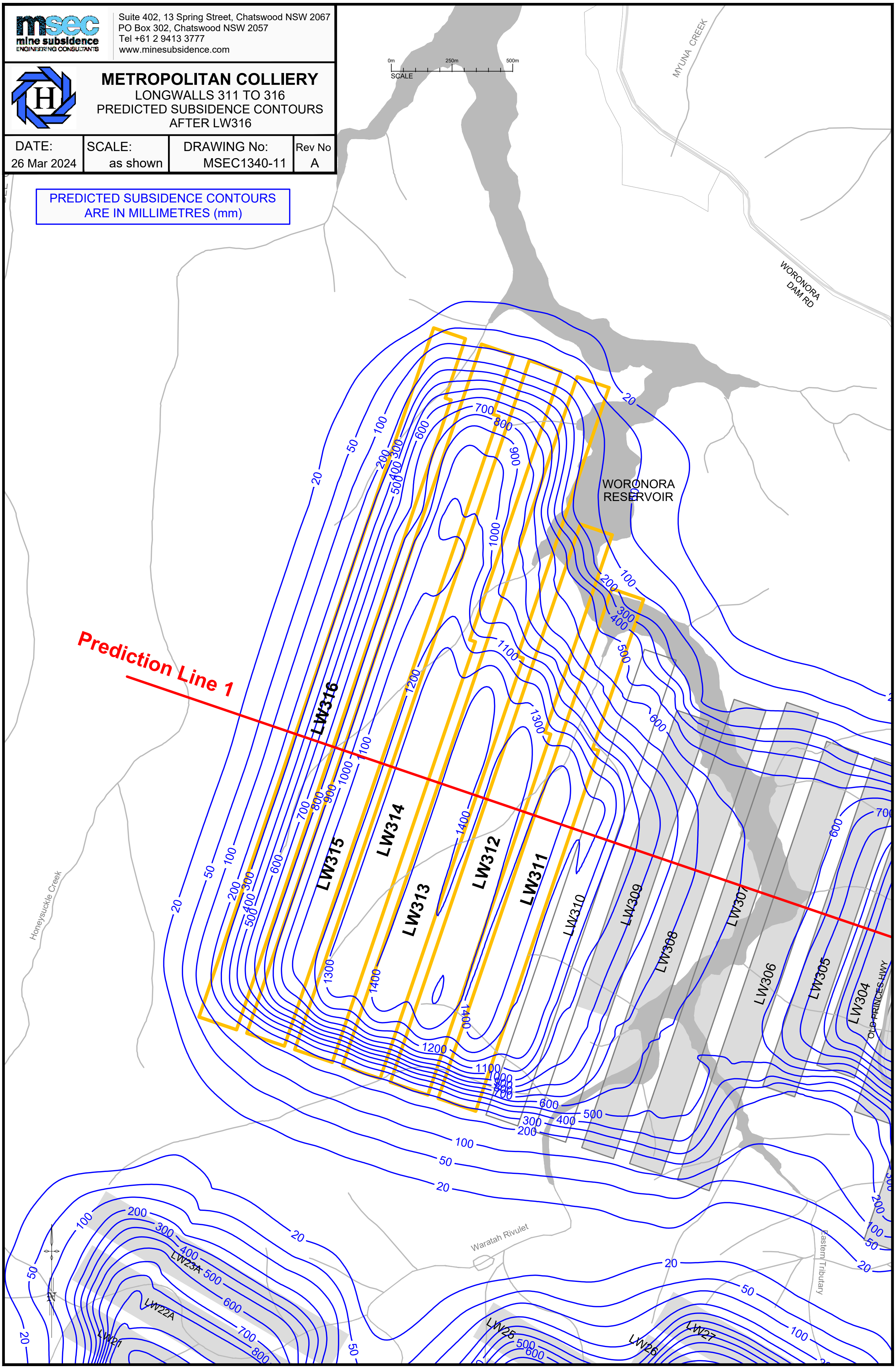
METROPOLITAN COLLIERY
LONGWALLS 311 TO 316
PREDICTED SUBSIDENCE CONTOURS
AFTER LW316

DATE:	SCALE:	DRAWING No:	Rev No
26 Mar 2024	as shown	MSEC1340-11	A

PREDICTED SUBSIDENCE CONTOURS ARE IN MILLIMETRES (mm)



ATTACHMENT 2

Metropolitan Mine – Revised Layout for Longwalls 311 to 316 Mine Subsidence Overview
July 2024

27 June 2024

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mine subsidence
ENGINEERING CONSULTANTS

Jon Degotardi
Helensburgh Coal Pty Ltd
Metropolitan Colliery
PO Box 402
Helensburgh NSW 2508

Ref: MSEC1441 Revision A

Dear Jon,

RE: Metropolitan Mine – Revised Layout for Longwalls 311 to 316
Mine Subsidence Overview

Metropolitan Coal is a wholly owned subsidiary of Peabody Energy Pty Limited (Peabody) and operates Metropolitan Colliery, which is located in the Southern Coalfield of New South Wales.

Metropolitan Coal have submitted and extraction plan for the extraction Longwalls 311 to 316. Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC1340 (Rev. A) in support of the Extraction Plan application for Longwalls 311 to 316. Metropolitan Coal are currently extracting Longwall 310.

Metropolitan Coal proposes to shorten the length of each of the Longwalls 311 to 316 from the northern ends (commencing ends). The extent of Longwalls 311 to 316 indicated in the Extraction Plan is referred to as the *Previous Layout* and the proposed reduced extent is referred to as the *Revised Layout* in this letter report. A summary of the lengths of the Previous Layout and Revised Layout are provided in Table 1. The total combined length of reduction is 4,404 m. The layout of Longwalls 311 to 316 for the Previous Layout and Revised Layout is shown in the attached Drawing No. MSEC1441-01. The overall pillar widths of the longwalls do not change, however the lengths of the varying widths change as shown in Table 1.

Table 1 Geometry of Longwalls 311 to 316 based on the Previous Layout and Revised Layout

Longwall	Void Length Including Installation Heading					Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
	Total for Previous Layout (m)	Total for Revised Layout (m)	Reduction in Total Length (m)	Over Varying Width for Previous Layout (m)	Over Varying Width for Revised Layout (m)		
LW311	2,217	1,829	388	1,569 648	1,569 260	163 138	45 70
LW312	2,427	1,632	795	1,569 858	1,632 0	163 138	45 70
LW313	2,997	1,486	1511	1,829 1,168	1,486 0	163 138	45 70
LW314	2,997	2,427	570	1,829 1,168	1,858 569	163 138	45 70
LW315	2,997	2,427	570	2,738 258	2,427 0	163 138	45 70
LW316	2,997	2,427	570	2,738 258	2,427 0	163 138	45 70

A Revised *Study Area* has been defined for the Revised Layout based on the greater of the following:

- 35° angle of draw line from the Revised Layout; and
- The predicted 20mm subsidence contour for the Revised Layout.

The natural and built features located within the Study Area are shown in Drawings Nos. MSEC1411-07 to 09. The natural and built features within the Study Area for the previous layout that are located outside the Study Area for the Revised Layout include:

- Aboriginal Heritage sites (FRC314, FRC315, NT19, NT74, NT75, NT77, NT88, NEW-RS-01);
- Tributaries;
- Woronora Reservoir; and
- Steep slopes.

A comparison summary of the incremental and total predicted subsidence parameters based on the Previous Layout and Revised Layout are provided in Table 2 and 3 below.

Table 2 Maximum Predicted Incremental subsidence Parameters based on the Previous Layout and Revised Layout

Longwall	Incremental Subsidence (mm)		Incremental Tilt (mm/m)		Incremental Hogging Curvature (km^{-1})		Incremental Sagging Curvature (km^{-1})	
	Previous Layout	Revised Layout	Previous Layout	Revised Layout	Previous Layout	Revised Layout	Previous Layout	Revised Layout
LW311	600	600	3.0	3.0	0.02	0.02	0.04	0.04
LW312	600	600	3.0	3.0	0.03	0.02	0.05	0.04
LW313	600	600	3.0	3.0	0.03	0.02	0.05	0.04
LW314	600	600	3.0	4.5	0.04	0.05	0.05	0.08
LW315	600	600	4.5	4.5	0.04	0.05	0.08	0.08
LW316	600	600	4.0	4.5	0.04	0.04	0.06	0.08

Table 3 Maximum Predicted Total subsidence Parameters based on the Previous Layout and Revised Layout

Longwall	Total Subsidence (mm)		Total Tilt (mm)		Total Hogging Curvature (km^{-1})		Total Sagging Curvature (km^{-1})	
	Previous Layout	Revised Layout	Previous Layout	Revised Layout	Previous Layout	Revised Layout	Previous Layout	Revised Layout
LW311	875	875	4.0	4.0	0.05	0.05	0.06	0.06
LW312	1200	1200	5.5	5.5	0.05	0.06	0.06	0.06
LW313	1350	1350	6.0	6.0	0.06	0.06	0.06	0.06
LW314	1450	1450	6.5	6.5	0.06	0.06	0.06	0.08
LW315	1500	1500	6.5	6.5	0.06	0.07	0.08	0.08
LW316	1500	1500	7.0	7.0	0.06	0.08	0.09	0.09

The maximum predicted incremental and total vertical subsidence due to the extraction of the Previous Layout does not change due to the Revised Layout. Whilst the maximum predicted vertical subsidence does not change, the extent of subsidence reduces significantly due to the reduced lengths at the northern ends of the longwalls.

The predicted 20 mm contour based on the Previous Layout is shown in Drawings Nos. MSEC1411-10 and 11. It can be seen from these drawings that the predicted 20 mm vertical subsidence contour reduces significantly as a result of the reduced longwall lengths. The predicted vertical subsidence for the natural and built features between the Study Area and the Previous Study Area are less than those based on the Previous Layout.

Similarly, the maximum predicted total tilt does not change due to the Revised Layout. The maximum predicted total hogging and sagging curvatures vary slightly between the Previous Layout and Revised Layout however the magnitudes of curvature are small and changes are negligible. The maximum predicted incremental tilt and curvatures also vary slightly between the Previous Layout and Revised Layout.

The changes in predicted subsidence parameters are shown in the attached Fig. 01 to Fig. 11. The attached Fig. 01 to Fig. 04 show a comparison of the predicted profiles of vertical subsidence, upsidence and closure along Waratah Rivulet/Woronora Reservoir, Tributaries R, Tributary S, and Tributary P. Fig. 05 provides a comparison of profiles across the longwall layouts. Fig. 06 to Fig. 11 provide a comparison of the predicted profiles of vertical subsidence, tilt and curvature along longitudinal lines through each of the longwalls 311 to 316 based on the Previous Layout and Revised Layout.

While the changes in tilt and curvature are minor, the locations of the longitudinal components of these parameters (i.e. orientated along the main longwall axis) move towards the south with the corresponding change in location of the commencing end. This is illustrated in the attached Fig. 01 to Fig. 11.

The predicted total tilts, curvatures and strains for the natural and built features within the Study Area based on the Revised Layout would decrease for some features and increase for other features. It can be seen in Fig. 06 to 11 that predicted maximum tilts at the commencing ends of the longwalls based on the Revised Layout are greater than the predicted tilts at the commencing ends of the Previous Layout for most of the longwalls and are shifted due to the change in position of the commencing end. The increases in tilt are due to the different widths and position of adjacent longwalls at the commencing ends of the two layouts. The predicted curvatures also increase at the commencing ends. While the predicted tilts and curvatures increase at the commencing ends of the Revised Layout compared to the Previous Layout, the magnitudes are similar to or less than the maxima elsewhere above the longwalls.

The predicted tilt and curvature for the surface features will generally reduce where features are located to the north of the Revised Layout. The increases in predicted tilt and curvature are more likely to occur at features located above the northern ends of the Revised Layout, including Fire Road 9D, Tributary R, Tributary S, Cliff COH19 and Aboriginal Heritage sites NT4, 8, 9 and 11. The increases for these features are likely to be similar to or less than the predicted values elsewhere above the mining area and will not change the impact assessments for the features.

A comparison of the predicted subsidence parameters for the Swamps and Aboriginal Heritage sites is provided in attached Table A.01 and Table A.02 respectively.

The predicted vertical subsidence based on the Revised Layout is the same or less than that based on the Previous Layout for all Swamps and Aboriginal Heritage sites.

Of the 55 swamps within 600m of the Previous Layout, the predicted total tilt increases at 3 swamps (S75, S130 and S139) and reduces at 2 sites (S74 and S132), predicted total hogging curvature increases at 5 swamps (S75, S76, S128, S130, and S139) and reduces at 1 site (S132), and predicted total sagging curvature increases at 3 swamps (S75, S130, and S139). The predicted parameters for the remaining sites are unchanged due to the Revised Layout. The predicted valley closure reduces slightly at swamp S77 and does not change for the remainder of the swamps due to the Revised Layout.

Of the 51 Aboriginal Heritage sites within the Study Area for the Previous Layout, the predicted total tilt increases at 7 sites and reduces at 15 sites, predicted total hogging curvature increases at 5 sites and reduces at 13 sites, and predicted total sagging curvature increases at 3 sites and reduces at 10 sites. The predicted parameters for the remaining sites are unchanged due to the Revised Layout.

Cliff COH19 is located near the tailgate of Longwall 314. The predicted total tilt and hogging curvature increase at the cliff due to the Revised Layout. The predicted total subsidence reduces and sagging curvature remains unchanged. COH19 is located along Tributary S and is expected to experience valley closure. The predicted total valley closure at COH19 reduces from 550 mm based on the Previous Layout to 50 mm based on the Revised Layout.

The changes to the predicted subsidence parameters for the natural and built features within the Study Area due to the reduced lengths of Longwalls 311 to 316 result a reduction in the predicted parameters for features located to the north of the Revised Layout. Some features near the commencing ends of the longwalls will experience a reduction in vertical subsidence but an increase in the predicted tilt and curvature, as discussed above. The increases in predicted tilt and curvature do not change the impact assessments for the relevant features. The assessed impacts for the features based on the Revised Layout are therefore unchanged or less than those based on the Previous Layout. The management strategies and required monitoring do not change for the majority of the surface features and could be reduced for features located outside and to the north of the Study Area for the Revised Layout.

I trust that this letter report is of assistance. If you have any questions, please do not hesitate to email or call me on (02) 9413-3777.

Peter DeBono
Mine Subsidence Engineering Consultants

Attachments:

Fig. 01 Predicted profiles of subsidence, upsidence and closure along Waratah Rivulet and Woronora Reservoir due to LW311 to 316 – Revised Layout

Fig. 02 Predicted profiles of subsidence, upsidence and closure along Tributary R due to LW311 to 316 – Revised Layout

Fig. 03 Predicted profiles of subsidence, upsidence and closure along Tributary S due to LW311 to 316 – Revised Layout

Fig. 04 Predicted profiles of subsidence, upsidence and closure along Tributary P due to LW311 to 316 – Revised Layout

Fig. 05 Predicted profiles of conventional subsidence, tilt and curvature along Prediction Line R1 due to LW311 to 316 – Revised Layout

Fig. 06 Predicted profiles of conventional subsidence, tilt and curvature along LW311 Longitudinal Line

Fig. 07 Predicted profiles of conventional subsidence, tilt and curvature along LW312 Longitudinal Line

Fig. 08 Predicted profiles of conventional subsidence, tilt and curvature along LW313 Longitudinal Line

Fig. 09 Predicted profiles of conventional subsidence, tilt and curvature along LW314 Longitudinal Line

Fig. 10 Predicted profiles of conventional subsidence, tilt and curvature along LW315 Longitudinal Line

Fig. 11 Predicted profiles of conventional subsidence, tilt and curvature along LW316 Longitudinal Line

Table A.01 Maximum Predicted Subsidence Parameters for the Swamps.

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

Drawing No. MSEC1441-01 Rev. 01 - General Layout

Drawing No. MSEC1441-02 Rev. 01 – Surface Level Contours

Drawing No. MSEC1441-03 Rev. 01 – Seam Floor Contours

Drawing No. MSEC1441-04 Rev. 01 – Seam Thickness Contours

Drawing No. MSEC1441-05 Rev. 01 – Depth of Cover Contours

Drawing No. MSEC1441-06 Rev. 01 – Geological Structures

Drawing No. MSEC1441-07 Rev. 01 – Natural Features

Drawing No. MSEC1441-08 Rev. 01 – Surface Infrastructure

Drawing No. MSEC1441-09 Rev. 01 – Built Features Location Plan

Drawing No. MSEC1441-10 Rev. 01 – Predicted Additional Subsidence Contours Due to LW311 to 316

Drawing No. MSEC1441-11 Rev. 01 – Predicted Subsidence Contours after LW20-LW27 and LW301-316

Predicted Profiles of Subsidence, Upsidence and Closure along Waratah Rivulet and Woronora Reservoir due to LW311 to 316 Revised Layout

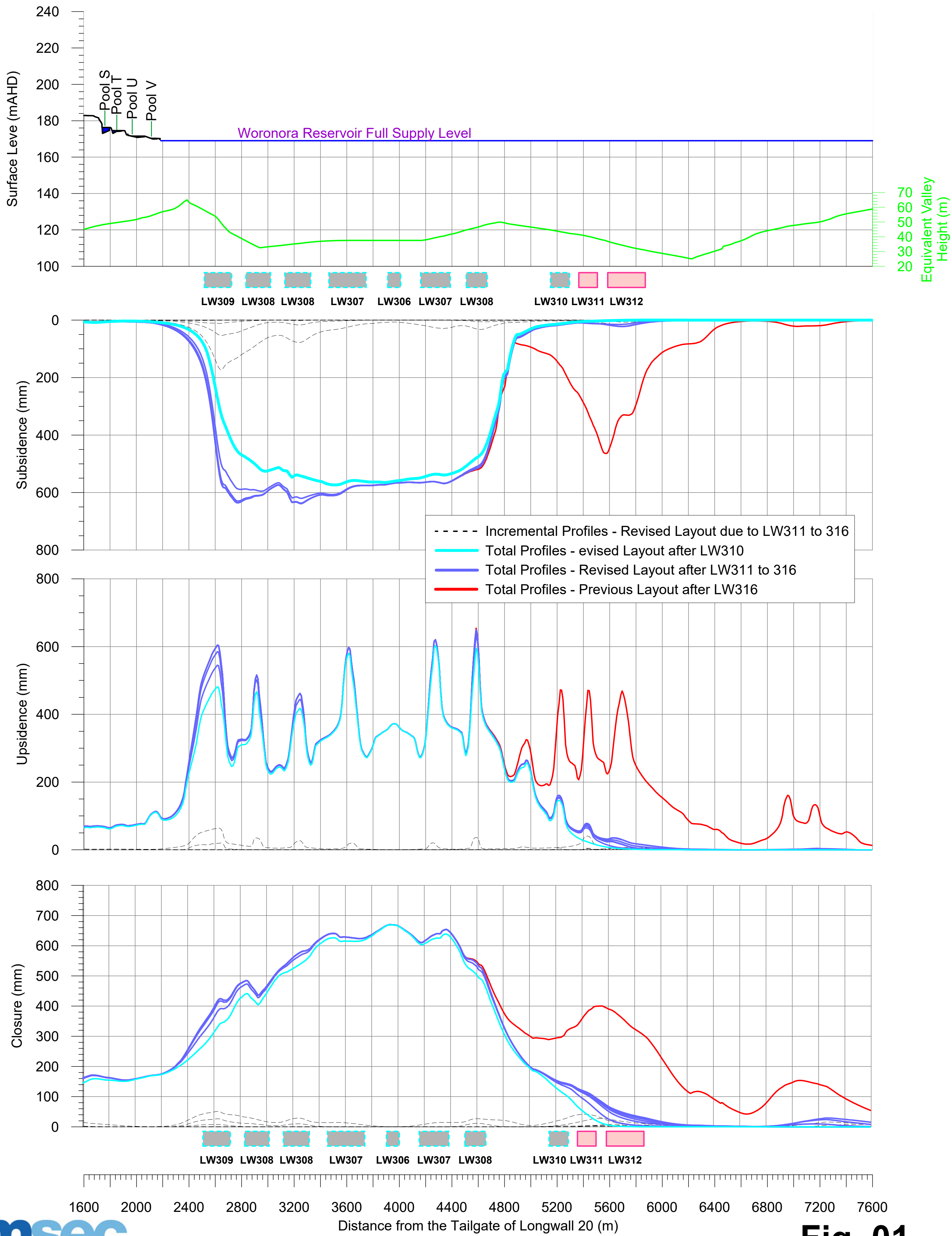

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Fig. 01

Predicted Profiles of Subsidence, Upsidence and Closure along Tributary R due to LW311 to 316 Revised Layout

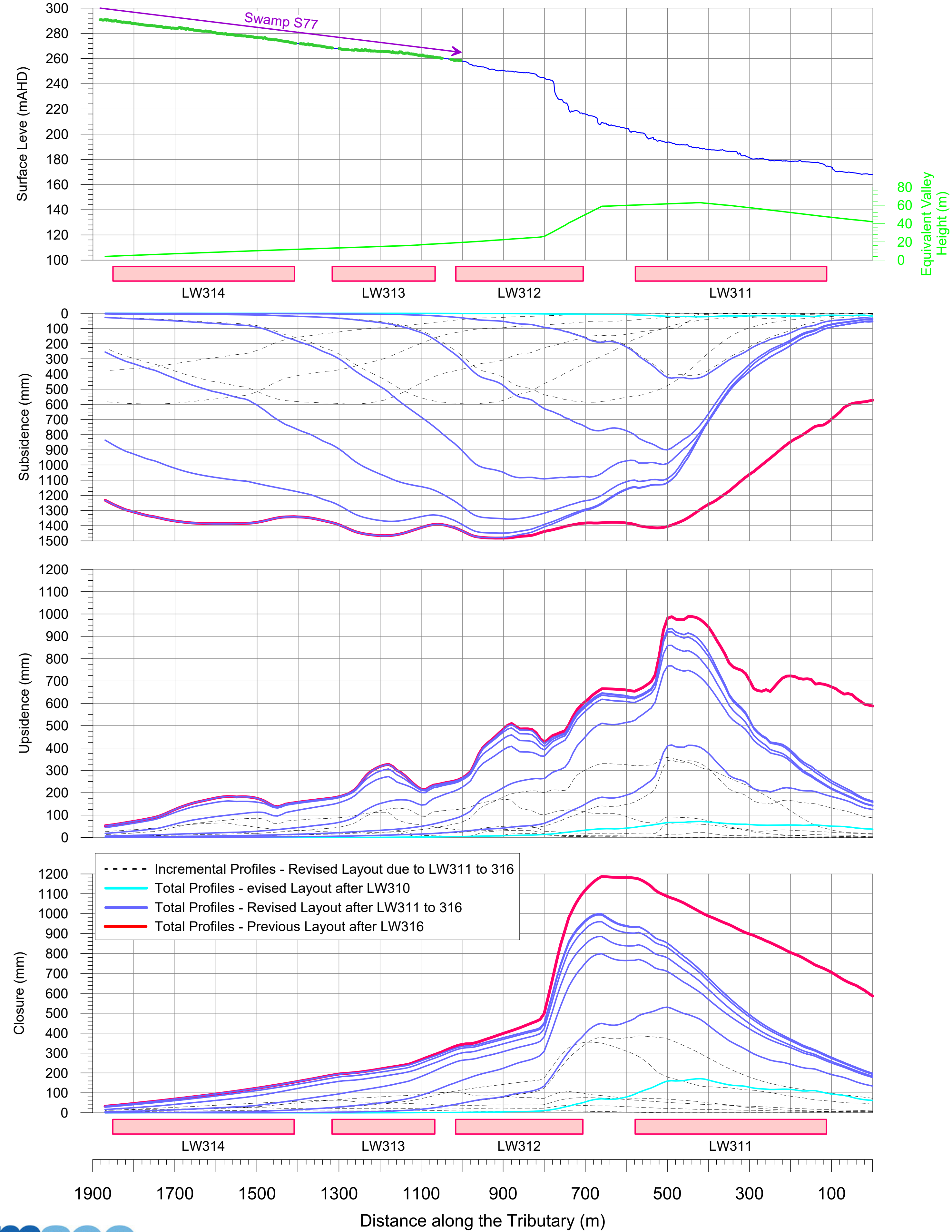

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Fig. 02

Predicted Profiles of Subsidence, Upsidence and Closure along Tributary S due to LW311 to 316 Revised Layout

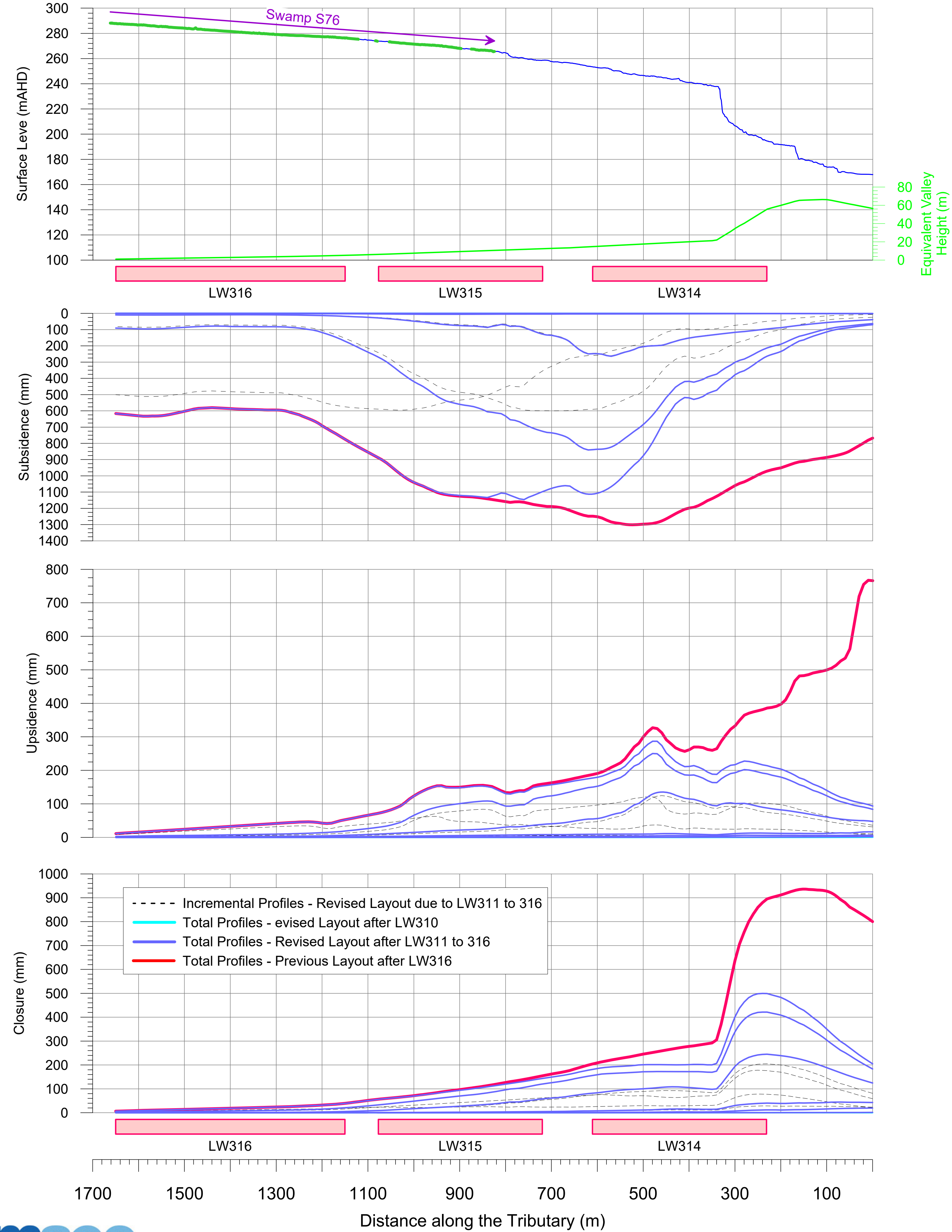

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Fig. 03

Predicted Profiles of Subsidence, Upsidence and Closure along Tributary P due to LW311 to 316 Revised Layout

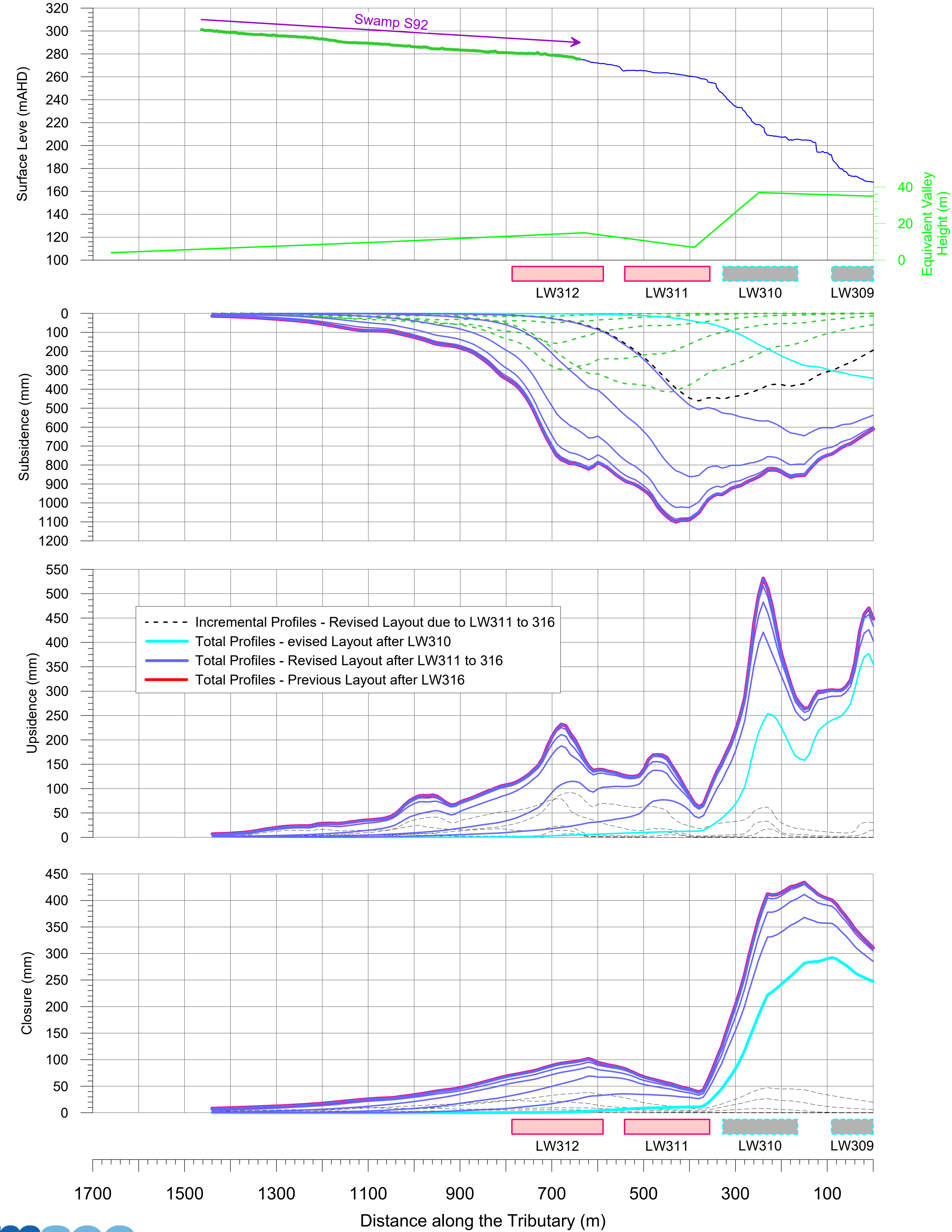

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Fig. C.04

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line R1 due to LW311 to 316 Revised Layout

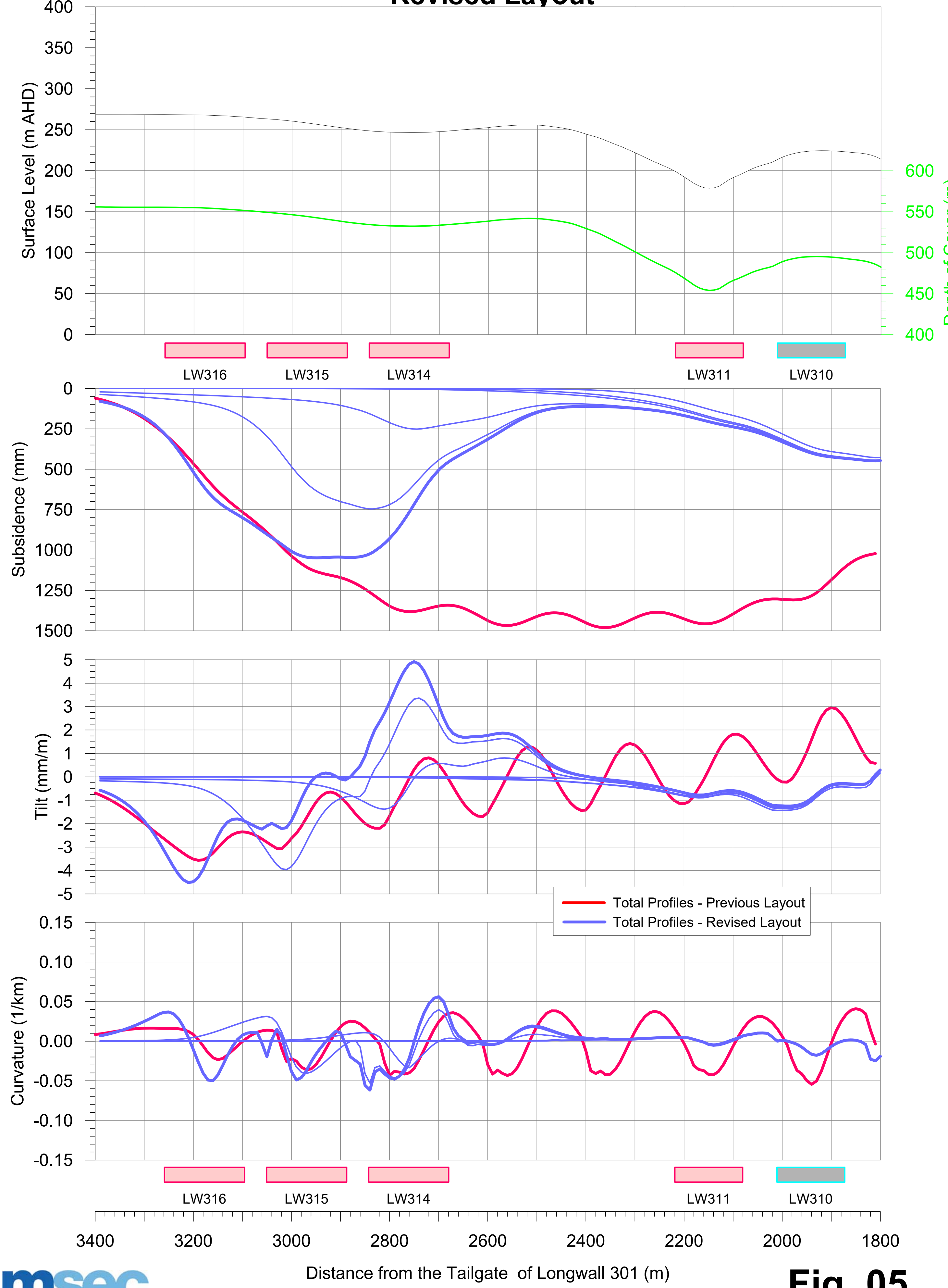

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Fig. 05

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along LW311 Longitudinal Line

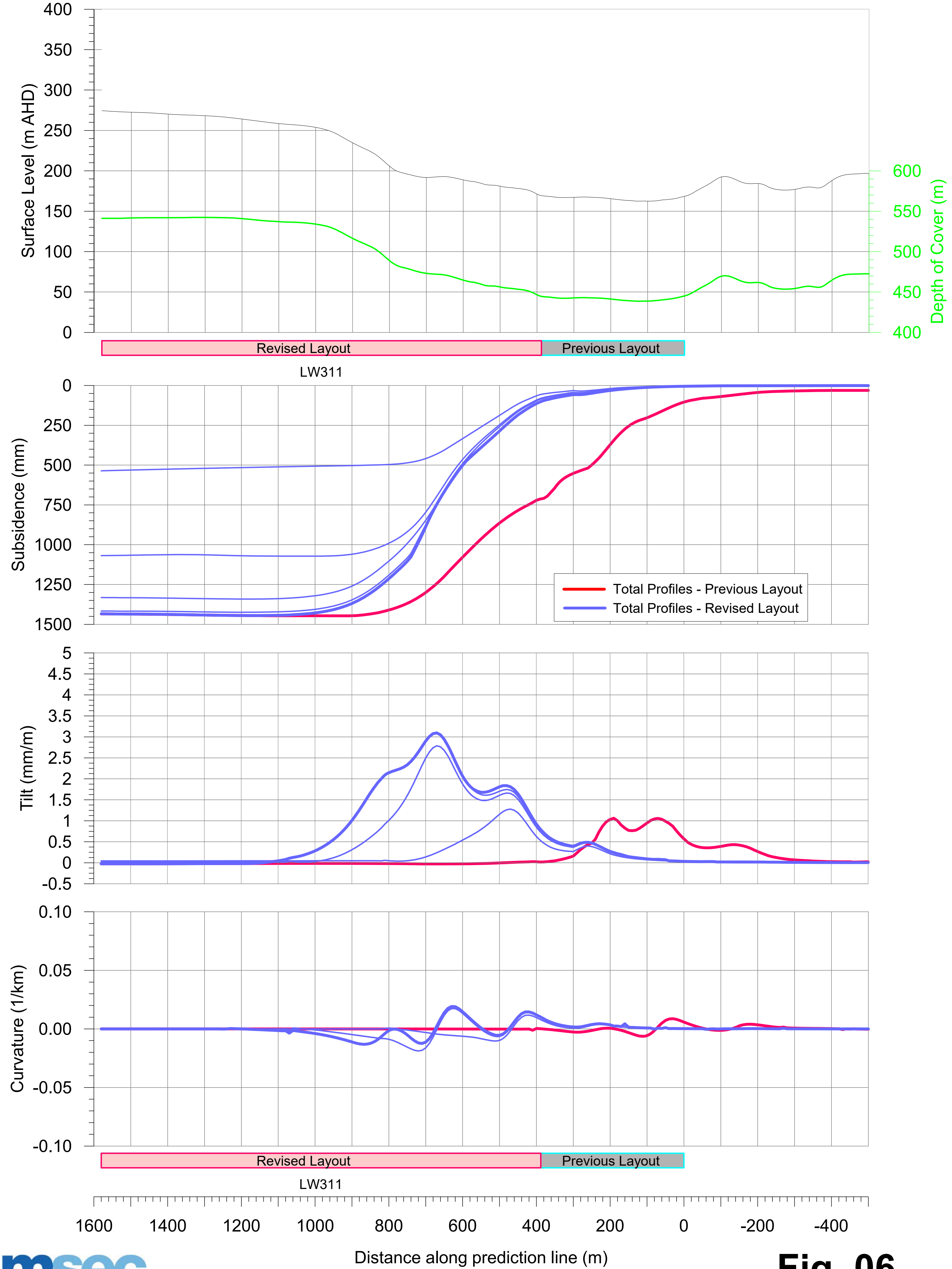

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Fig. 06

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along LW312 Longitudinal Line

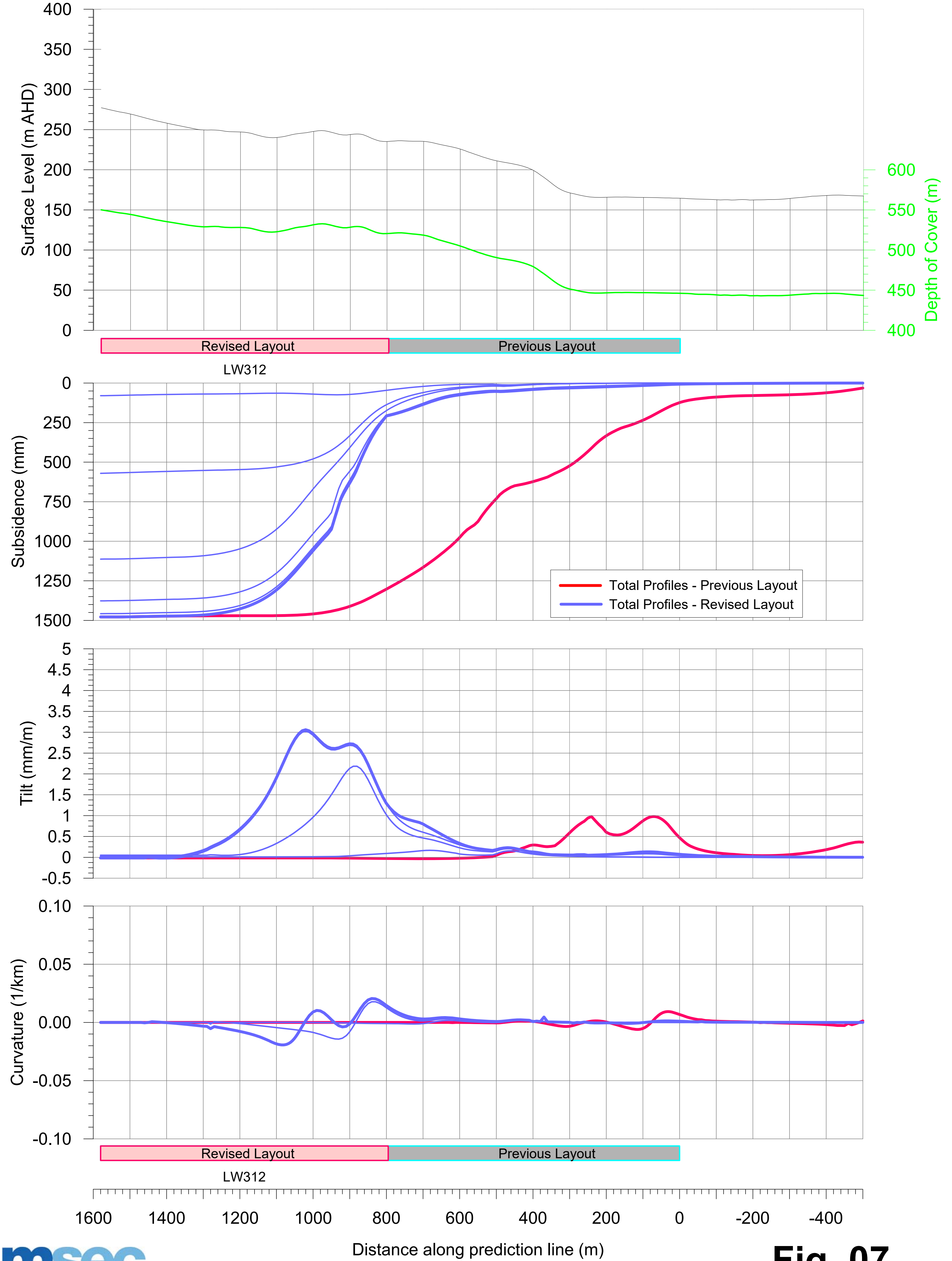

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Fig. 07

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along LW313 Longitudinal Line

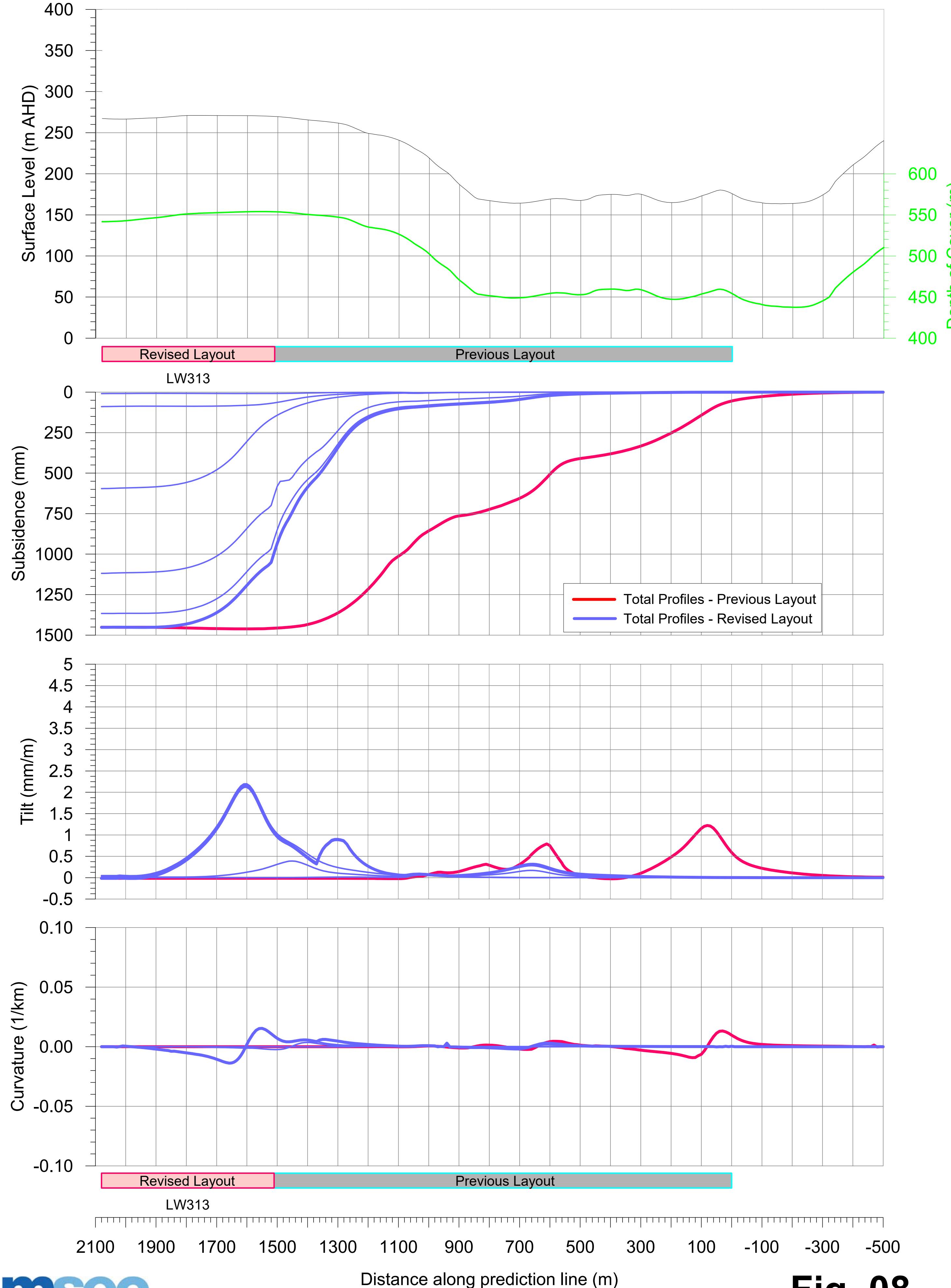

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Fig. 08

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along LW314 Longitudinal Line

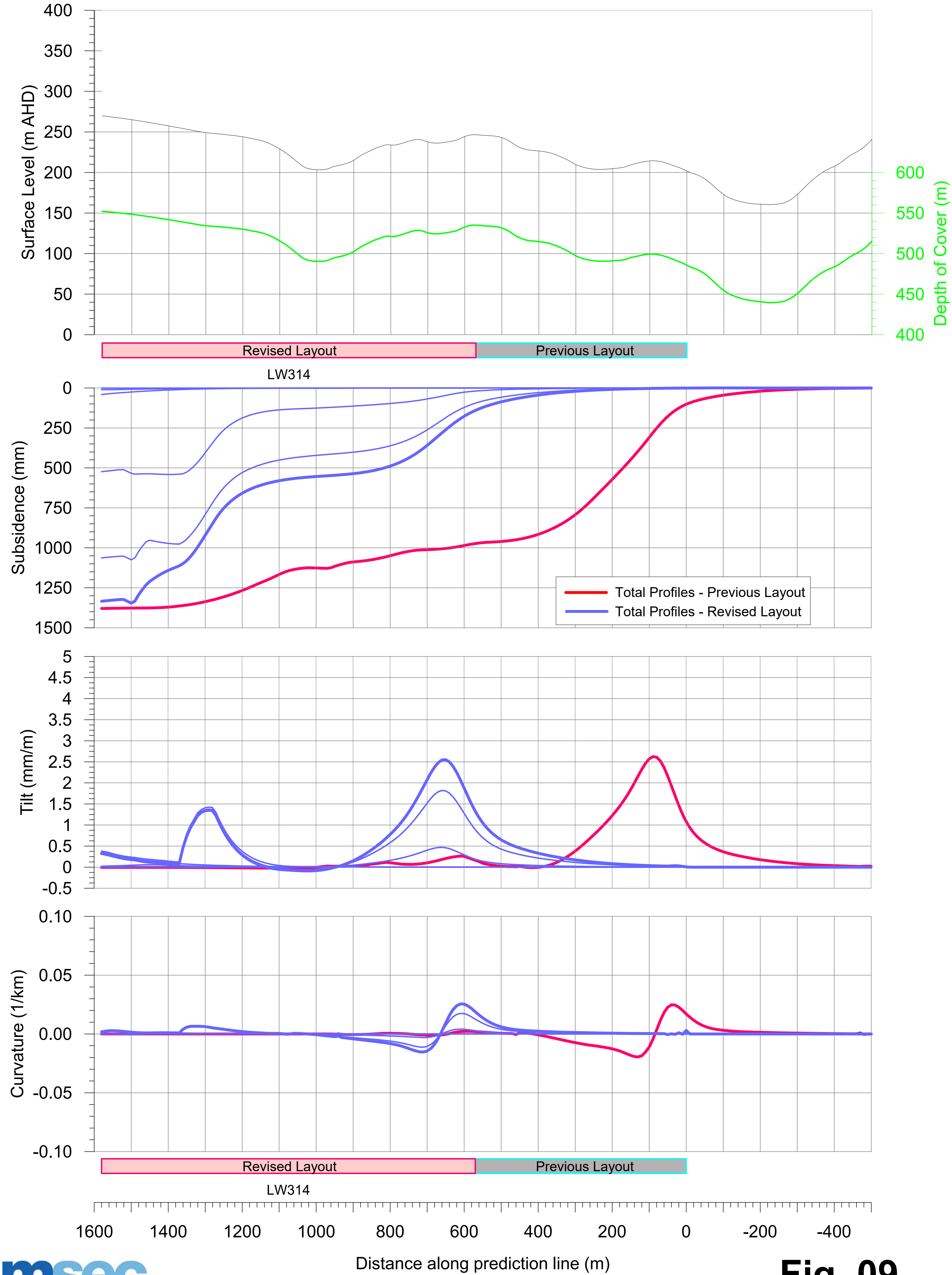

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Fig. 09

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along LW315 Longitudinal Line

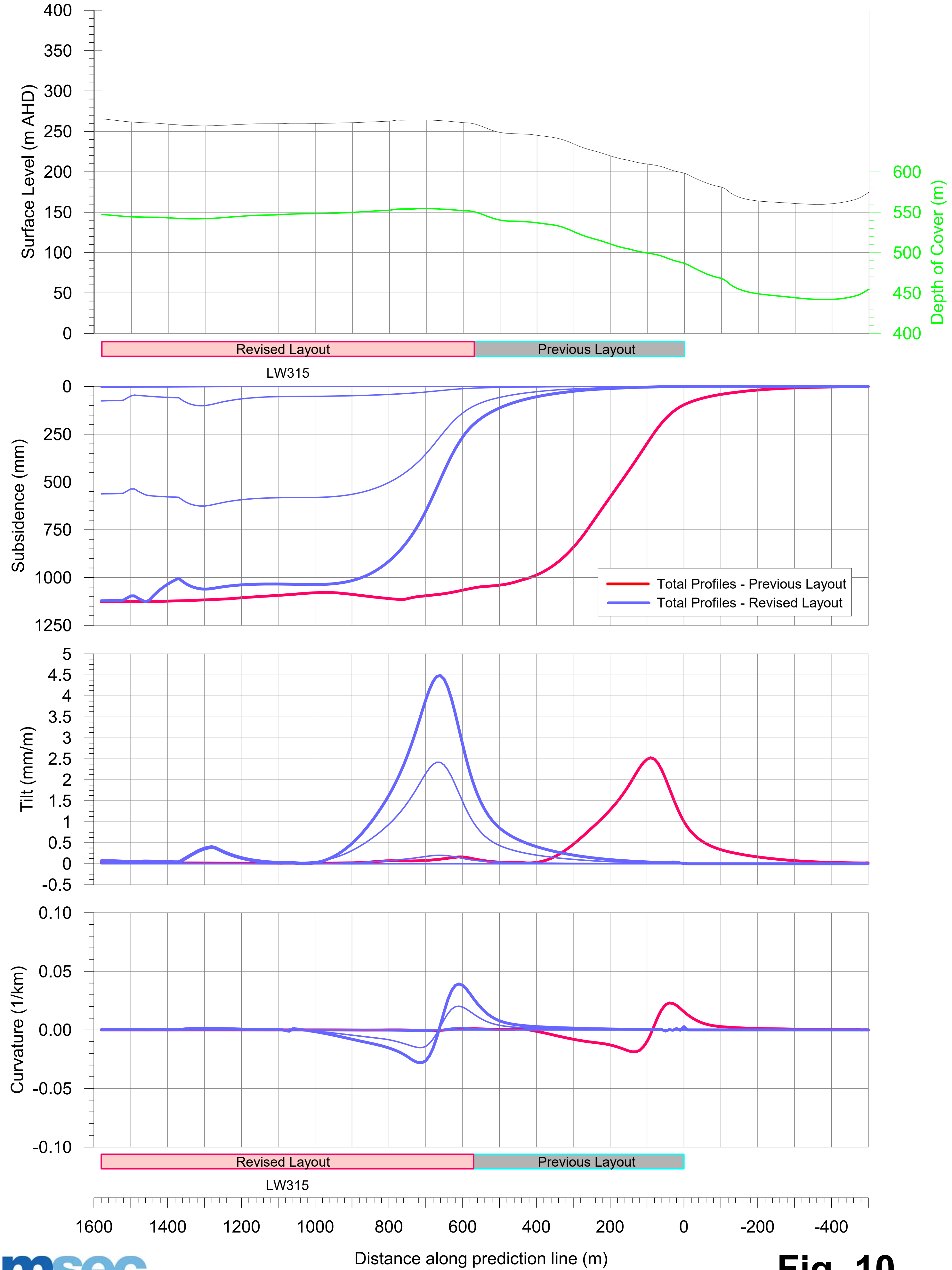

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Fig. 10

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along LW316 Longitudinal Line

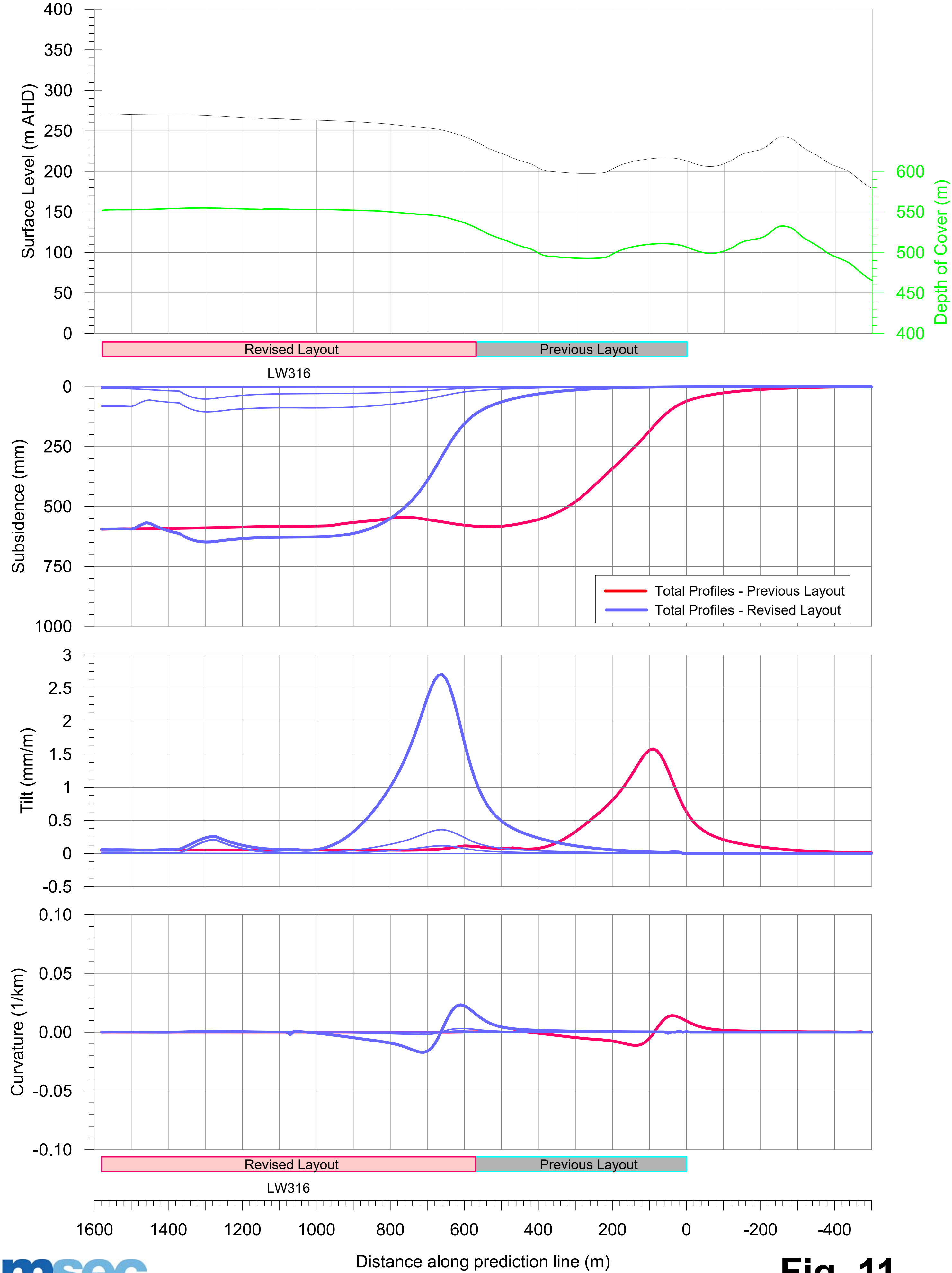

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Fig. 11

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

Swamp	*Maximum Predicted Subsidence based on the Previous Layout after LW316 (mm)*	Maximum Predicted Subsidence based on the Revised Layout after LW311 (mm)	Maximum Predicted Subsidence based on the Revised Layout after LW312 (mm)	Maximum Predicted Subsidence based on the Revised Layout after LW313 (mm)	Maximum Predicted Subsidence based on the Revised Layout after LW314 (mm)	Maximum Predicted Subsidence based on the Revised Layout after LW315 (mm)	Maximum Predicted Subsidence based on the Revised Layout after LW316 (mm)	*Maximum Predicted Tilt based on the Previous Layout after LW316 (mm/m)*	Maximum Predicted Tilt based on the Revised Layout after LW316 (mm/m)	*Maximum Predicted Hogging Curvature based on the Previous Layout after LW316 (1/km)*	Maximum Predicted Hogging Curvature based on the Revised Layout after LW316 (1/km)	*Maximum Predicted Sagging Curvature based on the Previous Layout after LW316 (1/km)*	Maximum Predicted Sagging Curvature based on the Revised Layout after LW316 (1/km)
S14	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5	*< 0.01*	< 0.01	*< 0.01*	< 0.01
S62	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5	*< 0.01*	< 0.01	*< 0.01*	< 0.01
S74	*175*	< 20	< 20	< 20	30	40	150	*2.0*	1.5	*0.02*	0.02	*< 0.01*	< 0.01
S75	*750*	< 20	< 20	< 20	40	150	750	*3.5*	4.5	*0.02*	0.04	*0.02*	0.04
S76	*1300*	< 20	< 20	< 20	275	875	1250	*3.5*	3.5	*0.03*	0.04	*0.04*	0.04
S77	*1450*	40	400	1000	1350	1450	1450	*4.0*	4.0	*0.04*	0.04	*0.04*	0.04
S78a	*1450*	650	1100	1350	1450	1450	1450	*2.0*	2.0	*0.04*	0.04	*0.05*	0.05
S78b	*1450*	550	1050	1350	1450	1450	1450	*2.0*	2.0	*0.04*	0.04	*0.05*	0.05
S79	*1500*	150	725	1150	1400	1450	1500	*1.5*	1.5	*0.04*	0.04	*0.05*	0.05
S80	*1450*	600	1100	1350	1450	1450	1450	*2.0*	2.0	*0.03*	0.03	*0.05*	0.05
S81	*1450*	750	1100	1350	1450	1450	1450	*2.0*	2.0	*0.03*	0.03	*0.05*	0.05
S82	*1300*	850	1150	1250	1300	1300	1300	*3.0*	3.0	*0.04*	0.04	*0.05*	0.05
S83	*1350*	775	1150	1300	1350	1350	1350	*2.0*	2.0	*0.03*	0.03	*0.02*	0.02
S84	*700*	675	700	700	700	700	700	*1.0*	1.0	*0.01*	0.01	*0.02*	0.02
S86	*925*	800	900	925	925	925	925	*2.0*	2.0	*0.02*	0.02	*0.05*	0.05
S88	*475*	300	425	450	475	475	475	*5.5*	5.5	*0.06*	0.06	*0.02*	0.02
S89a	*1450*	850	1150	1350	1450	1450	1450	*6.5*	6.5	*0.03*	0.03	*0.06*	0.06
S89b	*1200*	275	775	1050	1150	1200	1200	*6.5*	6.5	*0.03*	0.03	*0.04*	0.04
S90a	*1500*	200	775	1200	1400	1500	1500	*1.5*	1.5	*0.04*	0.04	*0.05*	0.05
S90b	*1450*	475	1050	1350	1450	1450	1450	*1.5*	1.5	*0.03*	0.03	*0.05*	0.05
S91	*1050*	< 20	< 20	40	300	775	1050	*6.0*	6.0	*0.02*	0.02	*0.04*	0.04
S92	*975*	80	425	750	900	950	975	*7.0*	7.0	*0.06*	0.06	*0.04*	0.04
S93	*20*	20	20	20	20	20	20	*< 0.5*	< 0.5	*< 0.01*	< 0.01	*< 0.01*	< 0.01
S94	*80*	80	80	80	80	80	80	*1.0*	1.0	*0.01*	0.01	*< 0.01*	< 0.01
S102	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5	*< 0.01*	< 0.01	*< 0.01*	< 0.01
S103	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5	*< 0.01*	< 0.01	*< 0.01*	< 0.01
S104	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5	*< 0.01*	< 0.01	*< 0.01*	< 0.01

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

Swamp	*Maximum Predicted Subsidence based on the Previous Layout after LW316 (mm)*	Maximum Predicted Subsidence based on the Revised Layout after LW311 (mm)	Maximum Predicted Subsidence based on the Revised Layout after LW312 (mm)	Maximum Predicted Subsidence based on the Revised Layout after LW313 (mm)	Maximum Predicted Subsidence based on the Revised Layout after LW314 (mm)	Maximum Predicted Subsidence based on the Revised Layout after LW315 (mm)	Maximum Predicted Subsidence based on the Revised Layout after LW316 (mm)	*Maximum Predicted Tilt based on the Previous Layout after LW316 (mm/m)*	Maximum Predicted Tilt based on the Revised Layout after LW316 (mm/m)	*Maximum Predicted Hogging Curvature based on the Previous Layout after LW316 (1/km)*	Maximum Predicted Hogging Curvature based on the Revised Layout after LW316 (1/km)	*Maximum Predicted Sagging Curvature based on the Previous Layout after LW316 (1/km)*	Maximum Predicted Sagging Curvature based on the Revised Layout after LW316 (1/km)
S105	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S106	50	< 20	< 20	< 20	< 20	< 20	50	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01
S107	150	< 20	< 20	< 20	< 20	20	150	2.0	2.0	0.02	0.02	< 0.01	< 0.01
S108	100	< 20	< 20	< 20	< 20	< 20	100	1.5	1.5	0.01	0.01	< 0.01	< 0.01
S109	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S113	175	< 20	< 20	< 20	< 20	< 20	175	2.0	2.0	0.02	0.02	< 0.01	< 0.01
S114	325	< 20	< 20	< 20	< 20	40	325	3.0	3.0	0.02	0.02	< 0.01	< 0.01
S115	275	< 20	< 20	< 20	< 20	30	275	2.5	2.5	0.02	0.02	< 0.01	< 0.01
S116	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S117	30	< 20	< 20	< 20	< 20	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S118	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S119	150	< 20	< 20	< 20	< 20	< 20	150	1.5	1.5	0.02	0.02	< 0.01	< 0.01
S120	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S121	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S122	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S123	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S124	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S125	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S126	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S127	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S128	325	< 20	< 20	< 20	< 20	40	250	3.0	3.0	0.02	0.03	< 0.01	< 0.01
S129	40	< 20	< 20	< 20	< 20	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S130	525	< 20	< 20	< 20	30	80	525	3.5	4.0	0.02	0.03	< 0.01	0.03
S131	30	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S132	90	< 20	< 20	< 20	< 20	< 20	< 20	1.0	< 0.5	0.01	< 0.01	< 0.01	< 0.01
S135	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S136	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
S139	1200	< 20	< 20	< 20	175	750	1150	3.0	4.0	0.03	0.04	0.04	0.08

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

Swamp	*Predicted Conventional Tensile Strain based on the Previous Layout after LW316 (mm/m)*	Predicted Conventional Tensile Strain based on the Revised Layout after LW316 (mm/m)	*Predicted Conventional Compressive Strain based on the Previous Layout after LW316 (mm/m)*	Predicted Conventional Compressive Strain based on the Revised Layout after LW316 (mm/m)	*Maximum Predicted Upsidence based on the Previous Layout after LW316 (mm)*	Maximum Predicted Upsidence based on the Revised Layout after LW316 (mm)	*Maximum Predicted Closure based on the Previous Layout after LW316 (mm)*	Maximum Predicted Closure based on the Revised Layout after LW316 (mm)
S14	< 0.5	< 0.5	< 0.5	< 0.5	*< 20*	< 20	*20*	20
S62	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S74	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S75	< 0.5	1.00	< 0.5	1.00	-	-	-	-
S76	< 0.5	1.00	1.00	1.00	*150*	150	*125*	125
S77	1.00	0.50	1.00	0.50	*325*	325	*350*	325
S78a	1.00	1.00	1.00	1.00	-	-	-	-
S78b	1.00	1.00	1.00	1.00	-	-	-	-
S79	1.00	1.00	1.00	1.00	-	-	-	-
S80	< 0.5	< 0.5	1.00	1.00	-	-	-	-
S81	1.00	1.00	1.00	1.00	*70*	70	*40*	40
S82	1.00	1.00	1.00	1.00	*250*	250	*200*	200
S83	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S84	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S86	< 0.5	< 0.5	1.00	1.00	-	-	-	-
S88	1.00	1.00	< 0.5	< 0.5	-	-	-	-
S89a	< 0.5	< 0.5	1.00	1.00	-	-	-	-
S89b	< 0.5	< 0.5	1.00	1.00	-	-	-	-
S90a	1.00	1.00	1.00	1.00	*60*	60	*30*	30
S90b	< 0.5	< 0.5	1.00	1.00	*40*	40	*30*	30
S91	< 0.5	< 0.5	1.00	1.00	-	-	-	-
S92	1.00	1.00	1.00	1.00	*225*	225	*100*	100
S93	< 0.5	< 0.5	< 0.5	< 0.5	*< 20*	< 20	*< 20*	< 20
S94	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S102	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S103	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S104	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-

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

Swamp	*Predicted Conventional Tensile Strain based on the Previous Layout after LW316 (mm/m)*	Predicted Conventional Tensile Strain based on the Revised Layout after LW316 (mm/m)	*Predicted Conventional Compressive Strain based on the Previous Layout after LW316 (mm/m)*	Predicted Conventional Compressive Strain based on the Revised Layout after LW316 (mm/m)	*Maximum Predicted Upsidence based on the Previous Layout after LW316 (mm)*	Maximum Predicted Upsidence based on the Revised Layout after LW316 (mm)	*Maximum Predicted Closure based on the Previous Layout after LW316 (mm)*	Maximum Predicted Closure based on the Revised Layout after LW316 (mm)
S105	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S106	< 0.5	< 0.5	< 0.5	< 0.5	*< 20*	< 20	*< 20*	< 20
S107	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S108	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S109	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S113	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S114	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S115	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S116	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S117	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S118	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S119	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S120	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S121	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S122	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S123	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S124	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S125	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S126	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S127	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S128	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S129	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S130	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S131	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S132	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S135	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S136	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
S139	< 0.5	1.00	1.00	1.50	-	-	-	-

Note: Predicted conventional strains are based on 15 times curvature

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

Site	Description	*Maximum Predicted Total Subsidence based on the Previous Layout after LW316 (mm)*	Maximum Predicted Total Subsidence based on the Revised Layout after LW311 (mm)	Maximum Predicted Total Subsidence based on the Revised Layout after LW312 (mm)	Maximum Predicted Total Subsidence based on the Revised Layout after LW313 (mm)	Maximum Predicted Total Subsidence based on the Revised Layout after LW314 (mm)	Maximum Predicted Total Subsidence based on the Revised Layout after LW315 (mm)	Maximum Predicted Total Subsidence based on the Revised Layout after LW316 (mm)	*Maximum Predicted Total Tilt based on the Previous Layout after LW316 (mm/m)*	Maximum Predicted Total Tilt based on the Revised Layout after LW316 (mm/m)
FRC 164	Open site with grinding grooves only	*125*	50	80	100	125	125	125	*1.0*	1.0
FRC 184	Sandstone overhang with artefacts and deposit	*400*	325	325	325	325	325	325	*1.5*	2.0
FRC 185	Sandstone overhang with art, artefacts and deposit	*550*	525	525	525	525	525	525	*1.5*	1.5
FRC 186	Sandstone overhang with art and deposit	*675*	650	675	675	675	675	675	*0.5*	1.0
FRC 187	Sandstone overhang with art only	*725*	675	700	700	700	700	700	*1.0*	1.0
FRC 189	Sandstone overhang with art only	*925*	725	875	925	925	925	925	*2.5*	2.5
FRC 191	Sandstone overhang with art only	*875*	775	850	875	875	875	875	*2.0*	2.0
FRC 193	Open site with grinding grooves only	*50*	< 20	< 20	30	40	50	50	*< 0.5*	< 0.5
FRC 194	Sandstone overhang with art only	*70*	50	60	70	70	70	70	*0.5*	0.5
FRC 195	Sandstone overhang with art only	*40*	30	30	40	40	40	40	*< 0.5*	< 0.5
FRC 198	Sandstone overhang with art only	*700*	650	675	700	700	700	700	*1.5*	1.5
FRC 199	Sandstone overhang with art only	*70*	50	60	70	70	70	70	*0.5*	0.5
FRC 314	Sandstone overhang with art and PAD	*40*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
FRC 315	Sandstone overhang with PAD only	*40*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
FRC 340	Sandstone overhang with art only	*550*	450	475	475	475	475	475	*2.0*	2.0
FRC 344	Sandstone overhang with artefacts and deposit	*925*	825	900	925	925	925	925	*2.0*	2.0
FRC 345	Sandstone overhang with artefacts and deposit	*950*	825	925	925	950	950	950	*1.5*	1.5
FRC 61	Sandstone overhang with PAD only	*50*	< 20	< 20	30	40	50	50	*< 0.5*	< 0.5
FRC 62	Sandstone overhang with art and PAD and/or grinding grooves	*30*	< 20	< 20	30	30	30	30	*< 0.5*	< 0.5
FRC 97	Sandstone overhang with art only	*650*	650	650	650	650	650	650	*< 0.5*	< 0.5
NT 10	Sandstone overhang site	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
NT 11	Sandstone overhang with art only	*1400*	50	200	275	425	450	475	*1.0*	2.0
NT 12	Open site	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
NT 17	Open site	*250*	< 20	< 20	< 20	< 20	40	200	*2.5*	2.5
NT 18	Sandstone overhang site	*650*	< 20	< 20	< 20	< 20	< 20	< 20	*2.0*	< 0.5
NT 19	Sandstone overhang with art only	*60*	< 20	< 20	< 20	< 20	< 20	< 20	*0.5*	< 0.5
NT 21	Open site	*475*	< 20	< 20	< 20	< 20	< 20	20	*4.5*	< 0.5
NT 29	Open site	*250*	< 20	< 20	< 20	< 20	< 20	80	*2.5*	1.5
NT 3	Sandstone overhang with art and PAD	*1000*	< 20	< 20	< 20	< 20	50	80	*< 0.5*	0.5

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

Site	Description	*Maximum Predicted Total Subsidence based on the Previous Layout after LW316 (mm)*	Maximum Predicted Total Subsidence based on the Revised Layout after LW311 (mm)	Maximum Predicted Total Subsidence based on the Revised Layout after LW312 (mm)	Maximum Predicted Total Subsidence based on the Revised Layout after LW313 (mm)	Maximum Predicted Total Subsidence based on the Revised Layout after LW314 (mm)	Maximum Predicted Total Subsidence based on the Revised Layout after LW315 (mm)	Maximum Predicted Total Subsidence based on the Revised Layout after LW316 (mm)	*Maximum Predicted Total Tilt based on the Previous Layout after LW316 (mm/m)*	Maximum Predicted Total Tilt based on the Revised Layout after LW316 (mm/m)
NT 33	Sandstone overhang with art and PAD	*1450*	575	1100	1300	1400	1400	1400	*1.5*	1.5
NT 34	Sandstone overhang - art and PAD and/or grinding grooves	*1450*	625	1100	1250	1350	1350	1350	*1.5*	1.5
NT 35	Sandstone overhang with art and PAD and/or grinding grooves	*1450*	500	1050	1250	1350	1400	1400	*1.0*	2.0
NT 4	Sandstone overhang site	*450*	< 20	< 20	< 20	< 20	40	275	*4.0*	3.0
NT 46	Open site with grinding grooves and engravings	*1150*	< 20	< 20	< 20	100	700	1150	*1.0*	< 0.5
NT 5	Sandstone overhang site	*425*	< 20	< 20	< 20	< 20	< 20	90	*4.5*	1.0
NT 6	Sandstone overhang with art and PAD	*1150*	< 20	< 20	< 20	80	675	1000	*1.0*	< 0.5
NT 7	Open site with grinding grooves only	*1300*	< 20	< 20	< 20	300	850	1100	*2.0*	1.5
NT 74	Sandstone overhang site	*60*	< 20	< 20	< 20	< 20	< 20	< 20	*0.5*	< 0.5
NT 75	Sandstone overhang site	*60*	< 20	< 20	< 20	< 20	< 20	< 20	*0.5*	< 0.5
NT 77	Sandstone overhang with art only	*30*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
NT 78	Sandstone overhang with art only	*600*	< 20	20	30	40	50	50	*1.5*	< 0.5
NT 79	Sandstone overhang with art only	*550*	< 20	< 20	< 20	30	30	30	*2.0*	< 0.5
NT 8	Open site with grinding grooves and engravings	*1250*	< 20	< 20	< 20	175	550	700	*2.0*	6.0
NT 80	Sandstone overhang with PAD only	*850*	< 20	< 20	< 20	30	60	80	*2.0*	1.0
NT 81	Sandstone overhang with PAD only	*675*	< 20	< 20	< 20	< 20	< 20	< 20	*1.5*	< 0.5
NT 85	Sandstone overhang site	*40*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
NT 9	Sandstone overhang with art and PAD	*1100*	< 20	< 20	< 20	125	350	450	*2.5*	5.5
NEW-RS-01	Sandstone overhang with art only	*30*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
NEW-RS-02	Shelter with art	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
NEW-ST-01	Potential scarred tree	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5
NEW-GG-01	Grinding grooves	*< 20*	< 20	< 20	< 20	< 20	< 20	< 20	*< 0.5*	< 0.5

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

Site	*Maximum Predicted Total Hogging Curvature based on the Previous Layout after LW316 (1/km)*	Maximum Predicted Total Hogging Curvature based on the Revised Layout after LW316 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Previous Layout after LW316 (1/km)*	Maximum Predicted Total Sagging Curvature based on the Revised Layout after LW316 (1/km)	*Maximum Predicted Total Tensile Strain based on the Previous Layout after LW316 (mm/m)*	Predicted Total Conventional Tensile Strain based on the Revised Layout after LW316 (mm/m)	*Maximum Predicted Total Compressive Strain based on the Previous Layout after LW316 (mm/m)*	Predicted Total Conventional Comp. Strain based on the Revised Layout after LW316 (mm/m)
FRC 164	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 184	*0.02*	0.02	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 185	*0.01*	< 0.01	*0.02*	0.02	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 186	*0.01*	0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 187	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 189	*0.03*	0.03	*0.02*	0.02	*1.0*	1.0	*< 0.5*	< 0.5
FRC 191	*0.02*	0.02	*0.05*	0.05	*< 0.5*	< 0.5	*1.0*	1.0
FRC 193	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 194	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 195	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 198	*0.03*	0.03	*0.02*	0.02	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 199	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 314	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 315	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 340	*0.02*	0.01	*0.01*	0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 344	*0.01*	0.01	*0.02*	0.02	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 345	*0.01*	0.01	*0.02*	0.02	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 61	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 62	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
FRC 97	*< 0.01*	< 0.01	*0.01*	0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 10	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 11	*0.01*	0.02	*0.05*	< 0.01	*< 0.5*	< 0.5	*1.0*	< 0.5
NT 12	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 17	*0.02*	0.03	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 18	*0.03*	< 0.01	*0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 19	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 21	*0.04*	< 0.01	*0.02*	< 0.01	*1.0*	< 0.5	*< 0.5*	< 0.5
NT 29	*0.03*	0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 3	*0.02*	< 0.01	*0.03*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5

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

Site	*Maximum Predicted Total Hogging Curvature based on the Previous Layout after LW316 (1/km)*	Maximum Predicted Total Hogging Curvature based on the Revised Layout after LW316 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Previous Layout after LW316 (1/km)*	Maximum Predicted Total Sagging Curvature based on the Revised Layout after LW316 (1/km)	*Maximum Predicted Total Tensile Strain based on the Previous Layout after LW316 (mm/m)*	Predicted Total Conventional Tensile Strain based on the Revised Layout after LW316 (mm/m)	*Maximum Predicted Total Compressive Strain based on the Previous Layout after LW316 (mm/m)*	Predicted Total Conventional Comp. Strain based on the Revised Layout after LW316 (mm/m)
NT 33	*0.02*	0.01	*0.04*	0.04	*< 0.5*	< 0.5	*1.0*	1.0
NT 34	*0.02*	0.02	*0.04*	0.04	*< 0.5*	< 0.5	*1.0*	1.0
NT 35	*0.02*	0.01	*0.04*	0.04	*< 0.5*	< 0.5	*1.0*	1.0
NT 4	*0.03*	0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 46	*0.02*	0.03	*0.02*	0.05	*< 0.5*	< 0.5	*< 0.5*	1.0
NT 5	*0.04*	0.01	*< 0.01*	< 0.01	*1.0*	< 0.5	*< 0.5*	< 0.5
NT 6	*0.02*	0.02	*0.01*	0.03	*< 0.5*	< 0.5	*< 0.5*	1.0
NT 7	*0.02*	0.02	*0.02*	0.06	*< 0.5*	< 0.5	*< 0.5*	1.0
NT 74	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 75	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 77	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 78	*0.02*	< 0.01	*0.03*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 79	*0.01*	< 0.01	*0.04*	< 0.01	*< 0.5*	< 0.5	*1.0*	< 0.5
NT 8	*0.01*	0.05	*0.05*	0.03	*< 0.5*	1.0	*1.0*	< 0.5
NT 80	*0.02*	0.02	*0.04*	< 0.01	*< 0.5*	< 0.5	*1.0*	< 0.5
NT 81	*0.02*	< 0.01	*0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 85	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NT 9	*0.04*	0.07	*0.02*	< 0.01	*1.0*	1.5	*< 0.5*	< 0.5
NEW-RS-01	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NEW-RS-02	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NEW-ST-01	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5
NEW-GG-01	*< 0.01*	< 0.01	*< 0.01*	< 0.01	*< 0.5*	< 0.5	*< 0.5*	< 0.5

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METROPOLITAN COLLIERY
LONGWALLS 311 TO 316 REVISED
GENERAL LAYOUT

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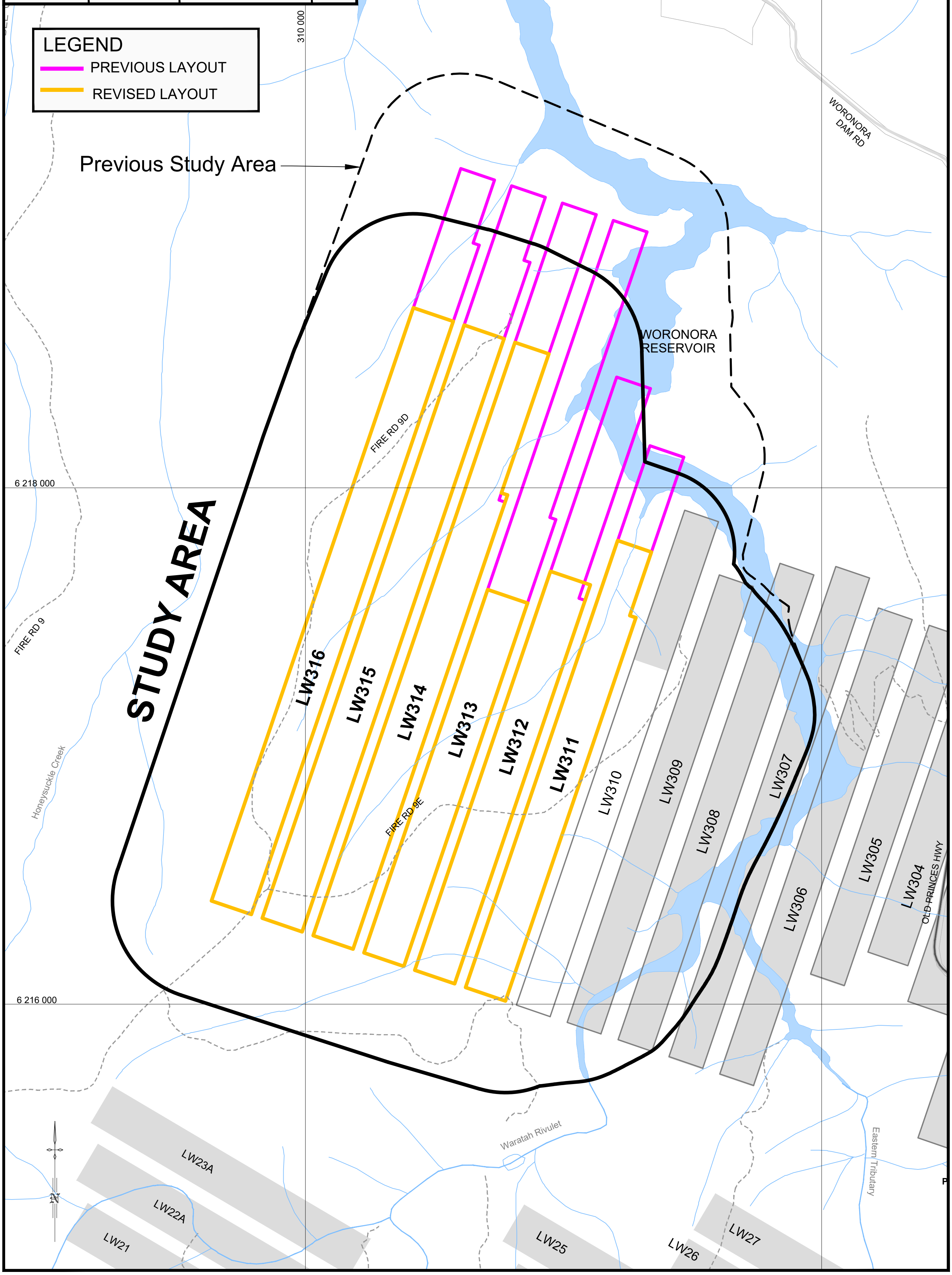

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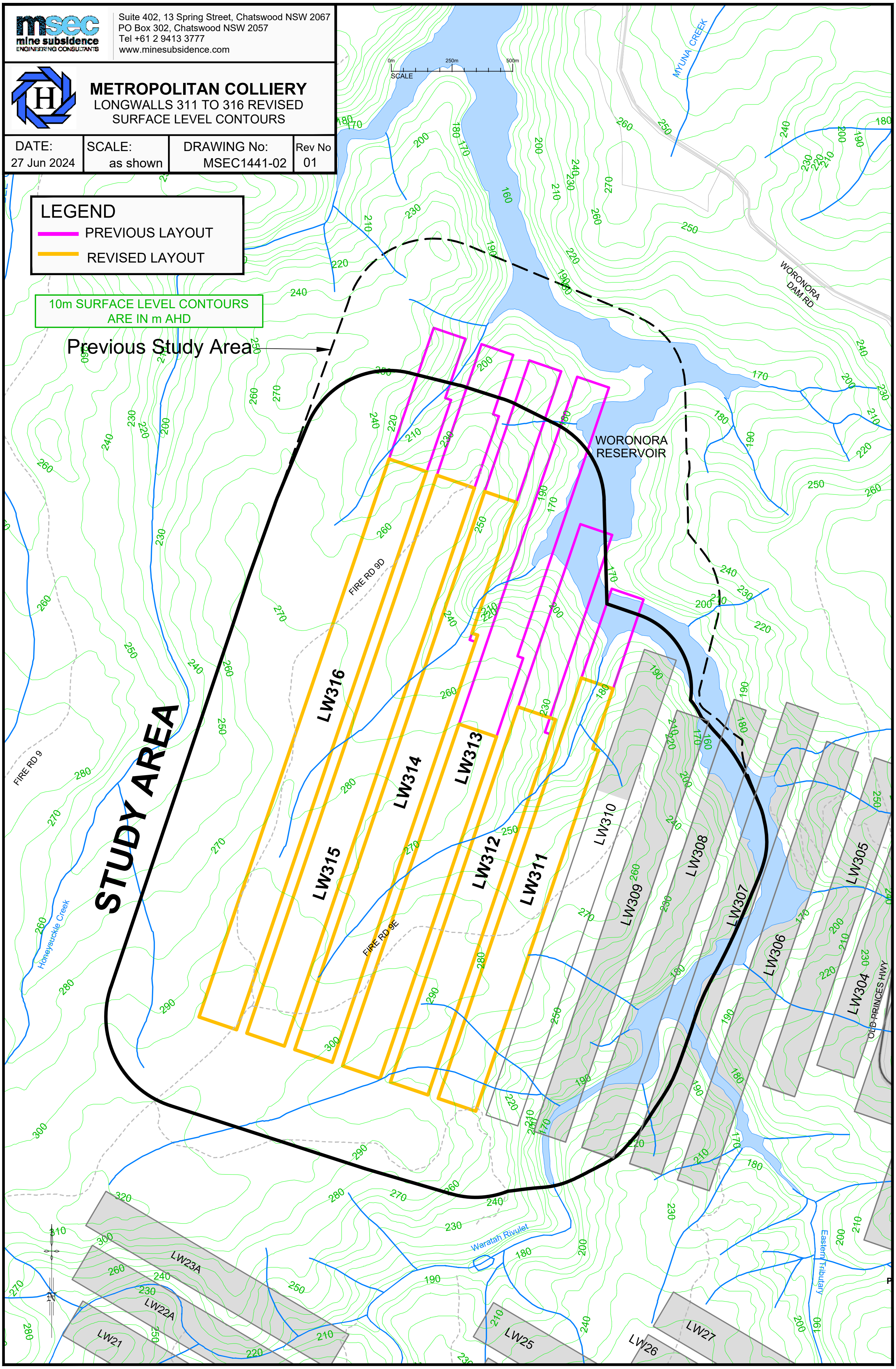

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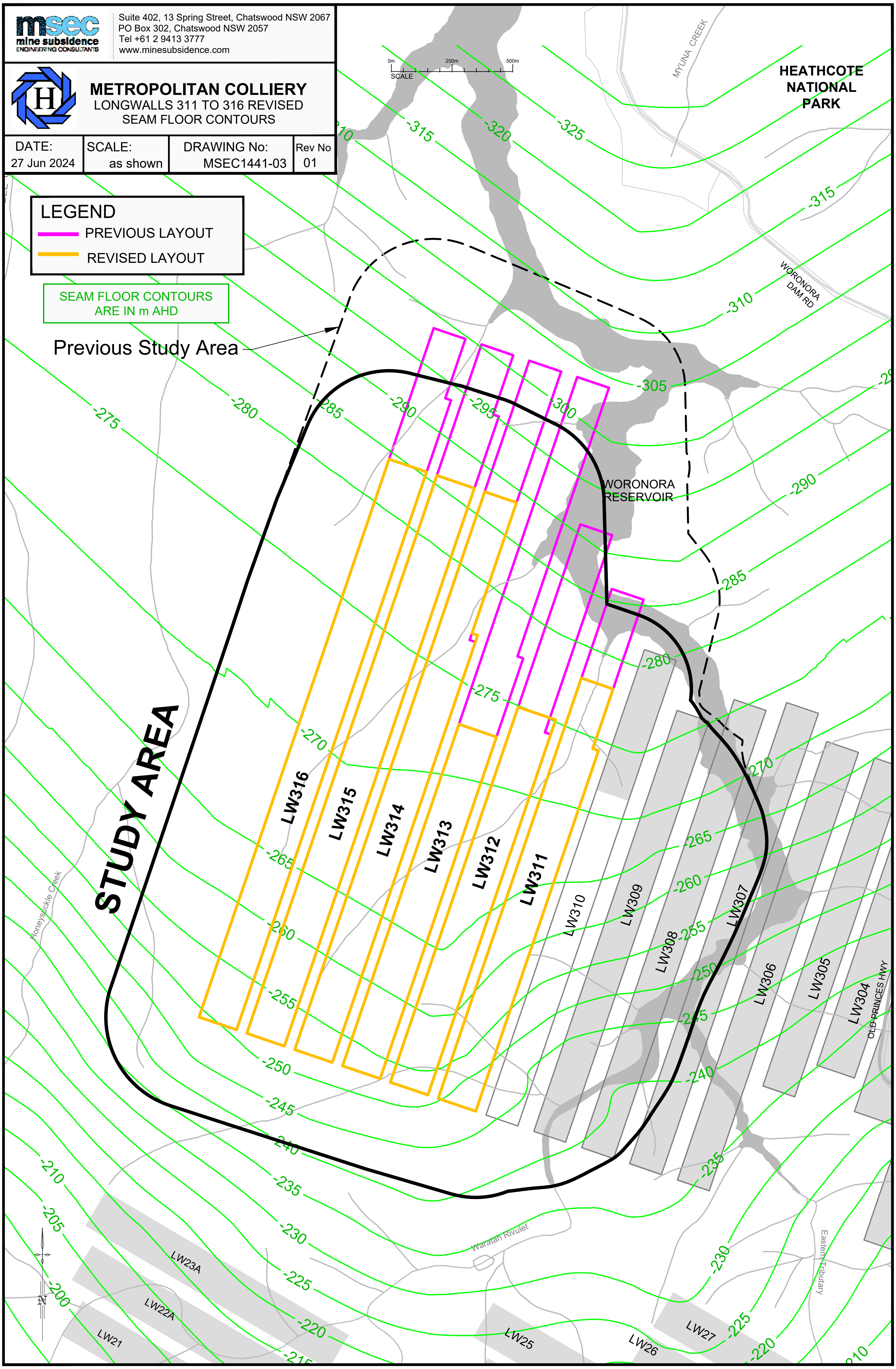

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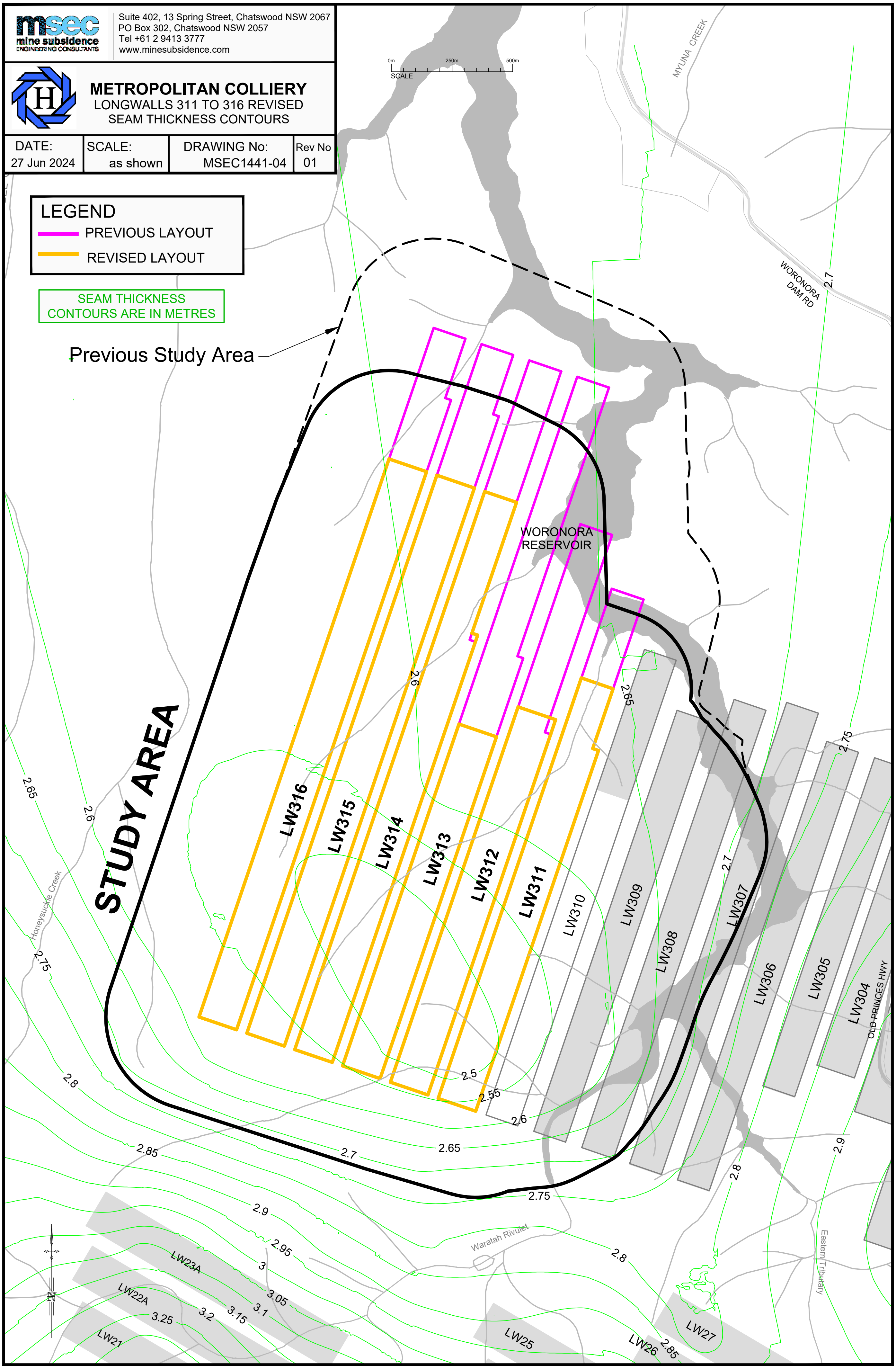

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LONGWALLS 311 TO 316 REVISED
DEPTH OF COVER CONTOURS

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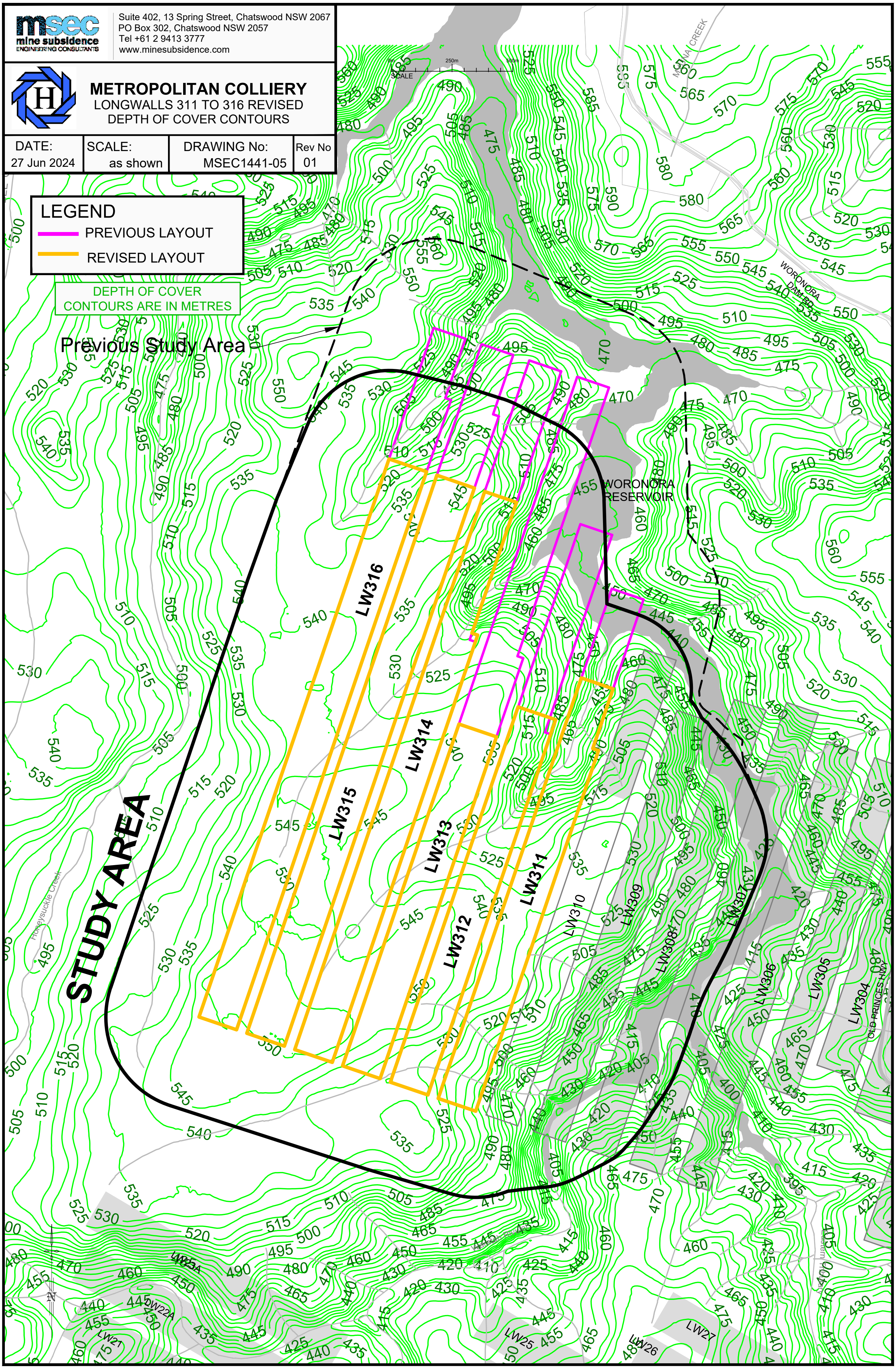

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LONGWALLS 311 TO 316 REVISED
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GEOLOGICAL STRUCTURES

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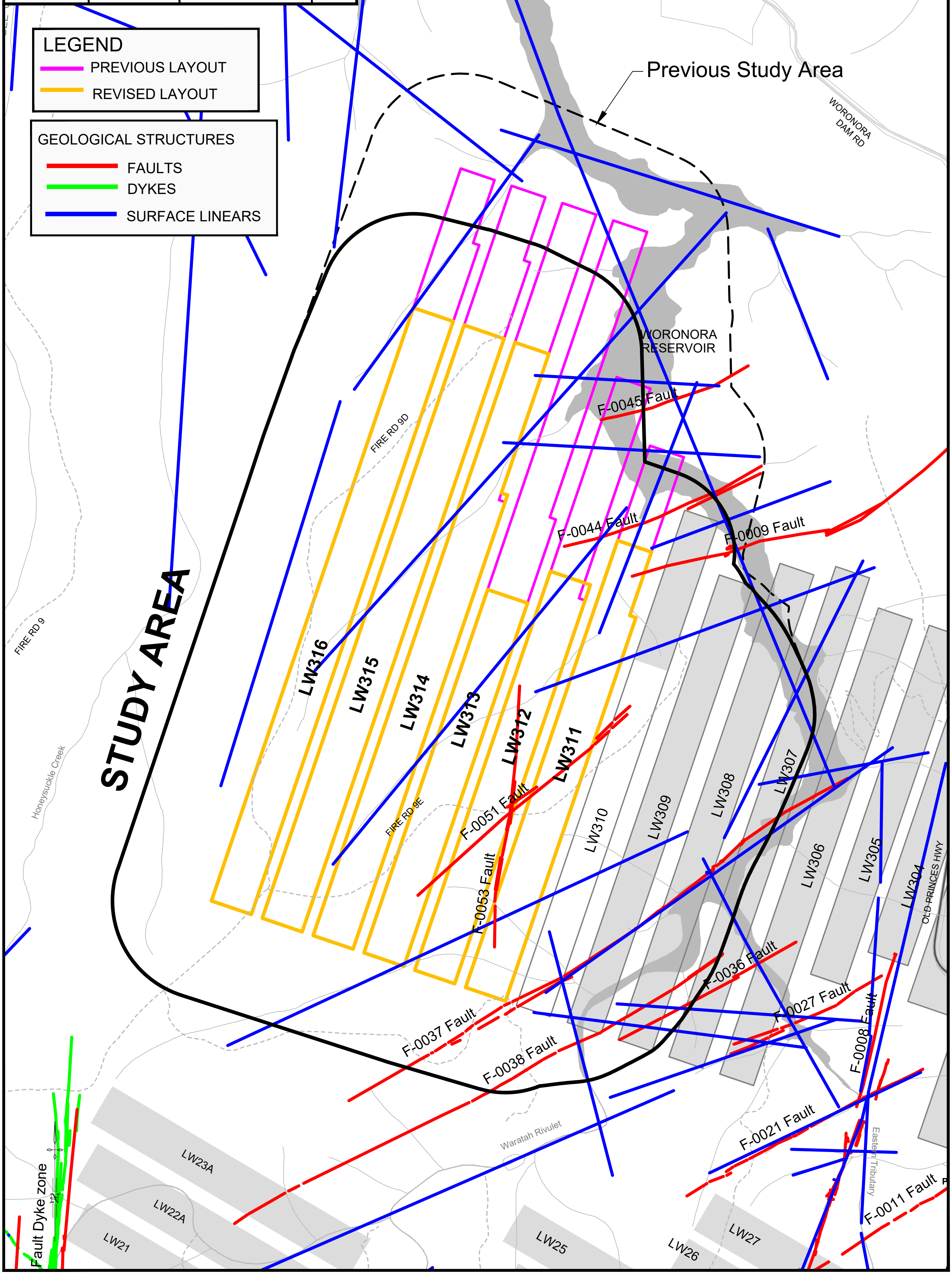

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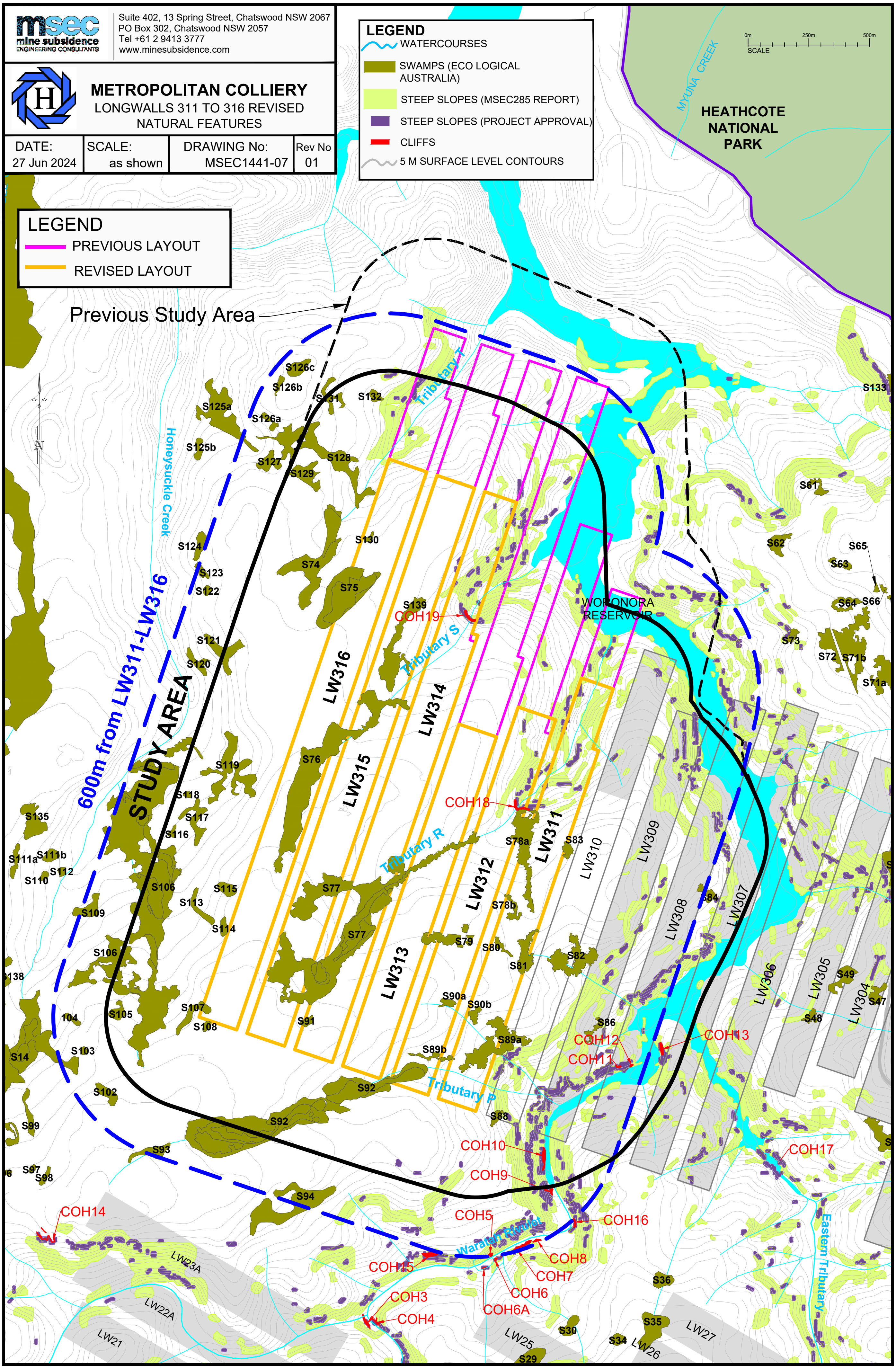

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LONGWALLS 311 TO 316 REVISED
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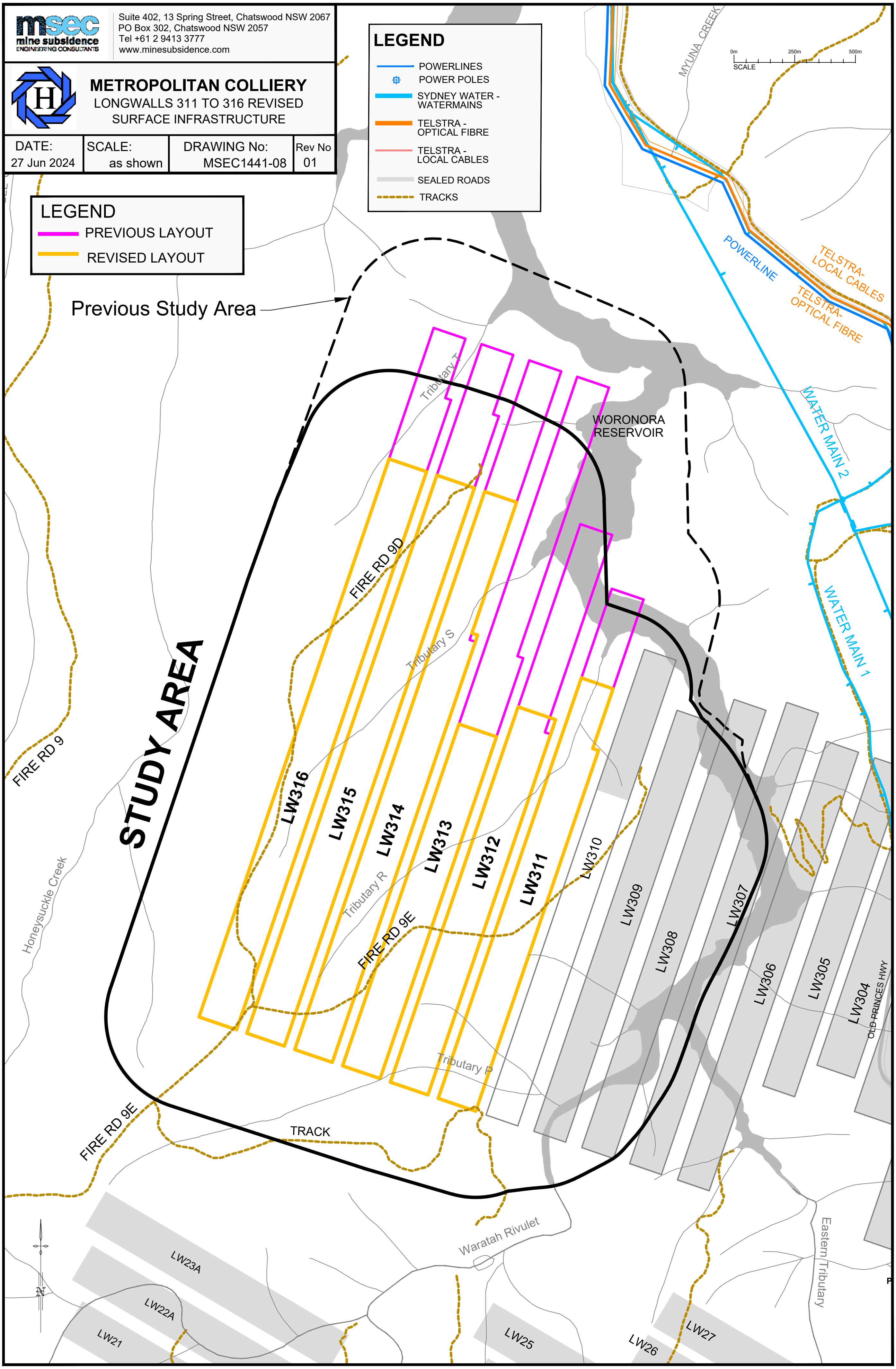

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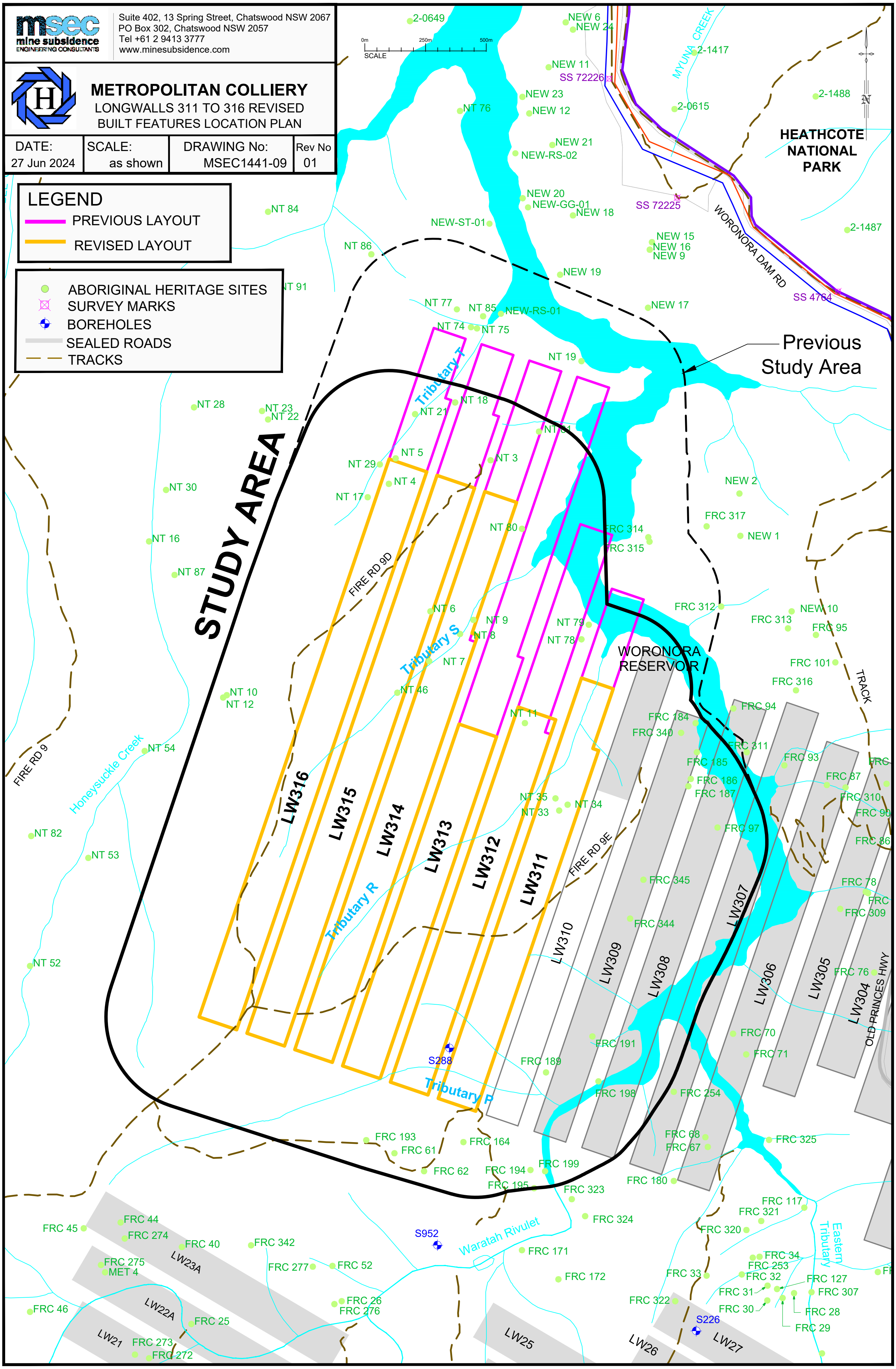

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LONGWALLS 311 TO 316 REVISED
PREDICTED ADDITIONAL SUBSIDENCE
CONTOURS DUE TO LW311 TO LW316

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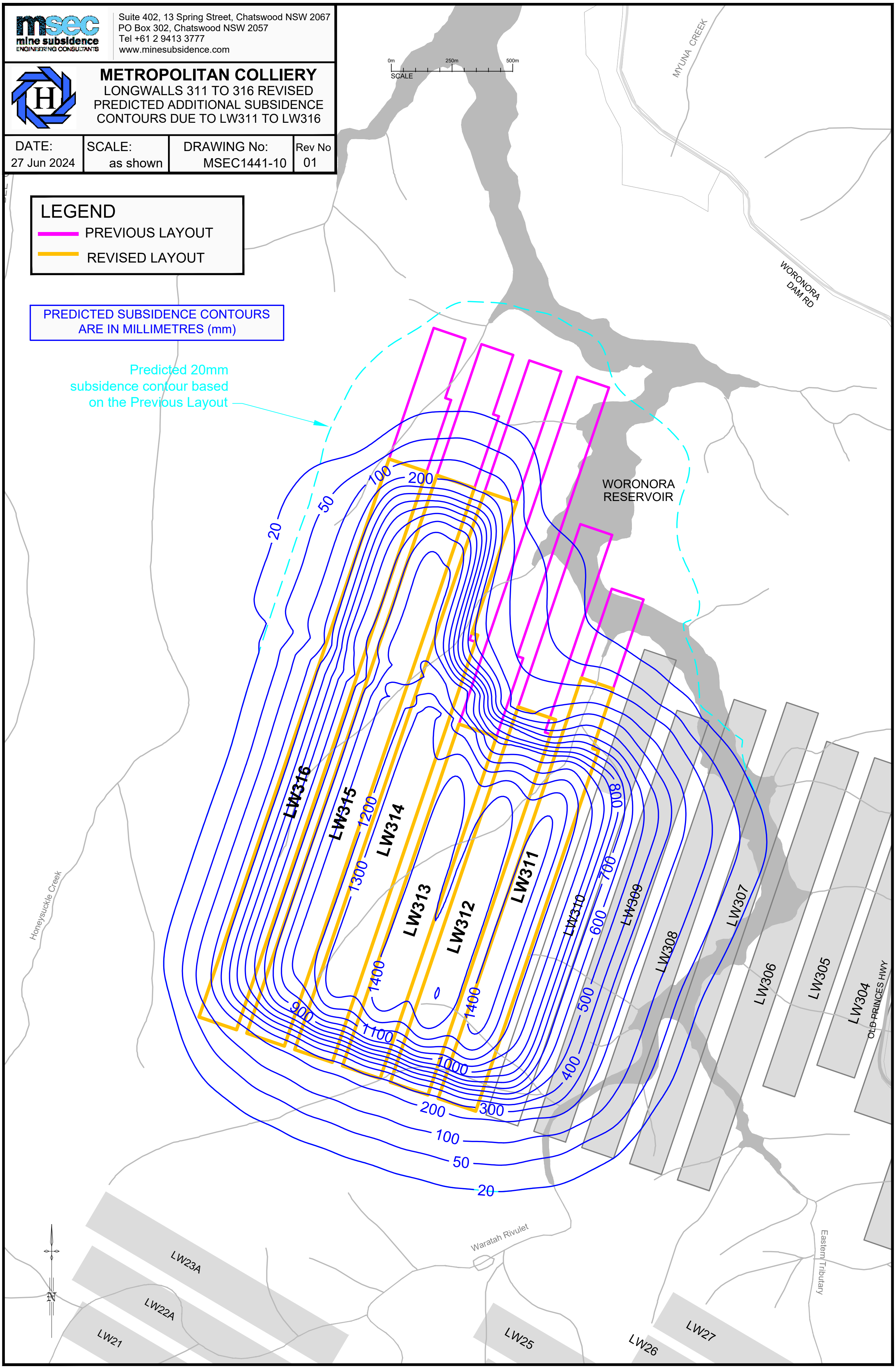

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LONGWALLS 311 TO 316 REVISED PREDICTED SUBSIDENCE CONTOURS AFTER LW20-LW27 AND LW301- LW316

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